BIO-SYSTEMS AS SELF-ORGANIZING QUANTUM SYSTEMS

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Preface

This book belongs to a series of online books summarizing the recent state Topological Geometrodynamics (TGD) and its applications. TGD can be regarded as a unified theory of fundamental interactions but is not the kind of unified theory as so called GUTs constructed by graduate students at seventies and eighties using detailed recipes for how to reduce everything to group theory. Nowadays this activity has been completely computerized and it probably takes only a few hours to print out the predictions of this kind of unified theory as an article in the desired format. TGD is something different and I am not ashamed to confess that I have devoted the last 32 years of my life to this enterprise and am still unable to write The Rules.

I got the basic idea of Topological Geometrodynamics (TGD) during autumn 1978, perhaps it was October. What I realized was that the representability of physical space-times as 4-dimensional surfaces of some higher-dimensional space-time obtained by replacing the points of Minkowski space with some very small compact internal space could resolve the conceptual difficulties of general relativity related to the definition of the notion of energy. This belief was too optimistic and only with the advent of what I call zero energy ontology the understanding of the notion of Poincare invariance has become satisfactory.

It soon became clear that the approach leads to a generalization of the notion of space-time with particles being represented by space-time surfaces with finite size so that TGD could be also seen as a generalization of the string model. Much later it became clear that this generalization is consistent with conformal invariance only if space-time is 4-dimensional and the Minkowski space factor of imbedding space is 4-dimensional.

It took some time to discover that also the geometrization of also gauge interactions and elementary particle quantum numbers could be possible in this framework: it took two years to find the unique internal space providing this geometrization involving also the realization that family replication phenomenon for fermions has a natural topological explanation in TGD framework and that the symmetries of the standard model symmetries are much more profound than pragmatic TOE builders have believed them to be. If TGD is correct, main stream particle physics chose the wrong track leading to the recent deep crisis when people decided that quarks and leptons belong to same multiplet of the gauge group implying instability of proton.

There have been also longstanding problems.

- Gravitational energy is well-defined in cosmological models but is not conserved. Hence the conservation of the inertial energy does not seem to be consistent with the Equivalence Principle. Furthermore, the imbeddings of Robertson-Walker cosmologies turned out to be vacuum extremals with respect to the inertial energy. About 25 years was needed to realize that the sign of the inertial energy can be also negative and in cosmological scales the density of inertial energy vanishes: physically acceptable universes are creatable from vacuum. Eventually this led to the notion of zero energy ontology which deviates dramatically from the standard ontology being however consistent with the crossing symmetry of quantum field theories. In this framework the quantum numbers are assigned with zero energy states located at the boundaries of so called causal diamonds defined as intersections of future and past directed light-cones. The notion of energy-momentum becomes length scale dependent since one has a scale hierarchy for causal diamonds. This allows to understand the non-conservation of energy as apparent. Equivalence Principle generalizes and has a formulation in terms of coset representations of Super-Virasoro algebras providing also a justification for p-adic thermodynamics.

- From the beginning it was clear that the theory predicts the presence of long ranged classical electro-weak and color gauge fields and that these fields necessarily accompany classical electromagnetic fields. It took about 26 years to gain the maturity to admit the obvious: these fields are classical correlates for long range color and weak interactions assignable to dark matter. The only possible conclusion is that TGD physics is a fractal consisting of an entire hierarchy of fractal copies of standard model physics. Also the understanding of electro-weak massivation and screening of weak charges has been a long standing problem, and 32 years was needed to discover that what I call weak form of electric-magnetic duality gives a satisfactory solution of the problem and provides also surprisingly powerful insights to the mathematical structure of quantum TGD.

I started the serious attempts to construct quantum TGD after my thesis around 1982. The original optimistic hope was that path integral formalism or canonical quantization might be enough to construct the quantum theory but the first discovery made already during first year of TGD was that these formalisms might be useless due to the extreme non-linearity and enormous vacuum degeneracy of the theory. This turned out to be the case.

- It took some years to discover that the only working approach is based on the generalization of Einstein's program. Quantum physics involves the geometrization of the infinite-dimensional "world of classical worlds" (WCW) identified as 3-dimensional surfaces. Still few years had to pass before I understood that general coordinate invariance leads to a more or less unique solution of the problem and implies that space-time surfaces are analogous to Bohr orbits. Still a coupled of years and I discovered that quantum states of the Universe can be identified as classical spinor fields in WCW. Only quantum jump remains the genuinely quantal aspect of quantum physics.

- During these years TGD led to a rather profound generalization of the space-time concept. Quite general properties of the theory led to the notion of many-sheeted space-time with sheets representing physical subsystems of various sizes. At the beginning of 90s I became dimly aware of the importance of p-adic number fields and soon ended up with the idea that p-adic thermodynamics for a conformally invariant system allows to understand elementary particle massivation with amazingly few input assumptions. The attempts to understand p-adicity from basic principles led gradually to the vision about physics as a generalized number theory as an approach complementary to the physics as an infinite-dimensional spinor geometry of WCW approach. One of its elements was a generalization of the number concept obtained by fusing real numbers and various p-adic numbers along common rationals. The number theoretical trinity involves besides p-adic number fields also quaternions and octonions and the notion of infinite prime.

- TGD inspired theory of consciousness entered the scheme after 1995 as I started to write a book about consciousness. Gradually it became difficult to say where physics ends and consciousness theory begins since consciousness theory could be seen as a generalization of quantum measurement theory by identifying quantum jump as a moment of consciousness and by replacing the observer with the notion of self identified as a system which is conscious as long as it can avoid entanglement with environment. "Everything is conscious and consciousness can be only lost" summarizes the basic philosophy neatly. The idea about p-adic physics as physics of cognition and intentionality emerged also rather naturally and implies perhaps the most dramatic generalization of the space-time concept in which most points of p-adic space-time sheets are infinite in real sense and the projection to the real imbedding space consists of discrete set of points. One of the most fascinating outcomes was the observation that the entropy based on p-adic norm can be negative. This observation led to the vision that life can be regarded as something in the intersection of real and p-adic worlds. Negentropic entanglement has interpretation as a correlate for various positively colored aspects of conscious experience and means also the possibility of strongly correlated states stable under state function reduction and different from the conventional bound states and perhaps playing key role in the energy metabolism of living matter.

- One of the latest threads in the evolution of ideas is only slightly more than six years old. Learning about the paper of Laurent Nottale about the possibility to identify planetary orbits as Bohr orbits with a gigantic value of gravitational Planck constant made once again possible to see the obvious. Dynamical quantized Planck constant is strongly suggested by quantum classical correspondence and the fact that space-time sheets identifiable as quantum coherence regions can have arbitrarily large sizes. During summer 2010 several new insights about the mathematical structure and interpretation of TGD emerged. One of these insights was the realization that the postulated hierarchy of Planck constants might follow from the basic structure of quantum TGD. The point is that due to the extreme non-linearity of the classical action principle the correspondence between canonical momentum densities and time derivatives of the imbedding space coordinates is one-to-many and the natural description of the situation is in terms of local singular covering spaces of the imbedding space. One could speak about effective value of Planck constant coming as a multiple of its minimal value. The implications of the hierarchy of Planck constants are extremely far reaching so that the significance of the reduction of this hierarchy to the basic mathematical structure distinguishing between TGD and competing theories cannot be under-estimated.

From the point of view of particle physics the ultimate goal is of course a practical construction recipe for the S-matrix of the theory. I have myself regarded this dream as quite too ambitious taking into account how far reaching re-structuring and generalization of the basic mathematical structure of quantum physics is required. It has indeed turned out that the dream about explicit formula is unrealistic before one has understood what happens in quantum jump. Symmetries and general physical principles have turned out to be the proper guide line here. To give some impressions about what is required some highlights are in order.

- With the emergence of zero energy ontology the notion of S-matrix was replaced with M-matrix which can be interpreted as a complex square root of density matrix representable as a diagonal and positive square root of density matrix and unitary S-matrix so that quantum theory in zero energy ontology can be said to define a square root of thermodynamics at least formally.

- A decisive step was the strengthening of the General Coordinate Invariance to the requirement that the formulations of the theory in terms of light-like 3-surfaces identified as 3-surfaces at which the induced metric of space-time surfaces changes its signature and in terms of space-like 3-surfaces are equivalent. This means effective 2-dimensionality in the sense that partonic 2-surfaces defined as intersections of these two kinds of surfaces plus 4-D tangent space data at partonic 2-surfaces code for the physics. Quantum classical correspondence requires the coding of the quantum numbers characterizing quantum states assigned to the partonic 2-surfaces to the geometry of space-time surface. This is achieved by adding to the modified Dirac action a measurement interaction term assigned with light-like 3-surfaces.

- The replacement of strings with light-like 3-surfaces equivalent to space-like 3-surfaces means enormous generalization of the super conformal symmetries of string models. A further generalization of these symmetries to non-local Yangian symmetries generalizing the recently discovered Yangian symmetry of $\mathcal{N}=4$ supersymmetric Yang-Mills theories is highly suggestive. Here the replacement of point like particles with partonic 2-surfaces means the replacement of conformal symmetry of Minkowski space with infinite-dimensional super-conformal algebras. Yangian symmetry provides also a further refinement to the notion of conserved quantum numbers allowing to define them for bound states using non-local energy conserved currents.

- A further attractive idea is that quantum TGD reduces to almost topological quantum field theory. This is possible if the Kähler action for the preferred extremals defining WCW Kähler function reduces to a 3-D boundary term. This takes place if the conserved currents are so called Beltrami fields with the defining property that the coordinates associated with flow lines extend to single global coordinate variable. This ansatz together with the weak form of electric-magnetic duality reduces the Kähler action to Chern-Simons term with the condition that the 3-surfaces are extremals of Chern-Simons action subject to the constraint force defined by the weak form of electric magnetic duality. It is the latter constraint which prevents the trivialization of the theory to a topological quantum field theory. Also the identification of the Kähler function of WCW as Dirac determinant finds support as well as the description of the scattering amplitudes in terms of braids with interpretation in terms of finite measurement resolution coded to the basic structure of the solutions of field equations.

- In standard QFT Feynman diagrams provide the description of scattering amplitudes. The beauty of Feynman diagrams is that they realize unitarity automatically via the so called Cutkosky rules. In contrast to Feynman's original beliefs, Feynman diagrams and virtual particles are taken only as a convenient mathematical tool in quantum field theories. QFT approach is however plagued by UV and IR divergences and one must keep mind open for the possibility that a genuine progress might mean opening of the black box of the virtual particle.

  In TGD framework this generalization of Feynman diagrams indeed emerges unavoidably. Light-like 3-surfaces replace the lines of Feynman diagrams and vertices are replaced by 2-D partonic

2-surfaces. Zero energy ontology and the interpretation of parton orbits as light-like "wormhole throats" suggests that virtual particle do not differ from on mass shell particles only in that the four- and three- momenta of wormhole throats fail to be parallel. The two throats of the wormhole defining virtual particle would contact carry on mass shell quantum numbers but for virtual particles the four-momenta need not be parallel and can also have opposite signs of energy. Modified Dirac equation suggests a number theoretical quantization of the masses of the virtual particles. The kinematic constraints on the virtual momenta are extremely restrictive and reduce the dimension of the sub-space of virtual momenta and if massless particles are not allowed (IR cutoff provided by zero energy ontology naturally), the number of Feynman diagrams contributing to a particular kind of scattering amplitude is finite and manifestly UV and IR finite and satisfies unitarity constraint in terms of Cutkosky rules. What is remarkable that fermionic propagatos are massless propagators but for on mass shell four-momenta. This gives a connection with the twistor approach and inspires the generalization of the Yangian symmetry to infinite-dimensional super-conformal algebras.

What I have said above is strongly biased view about the recent situation in quantum TGD and I have left all about applications to the introductions of the books whose purpose is to provide a bird's eye of view about TGD as it is now. This vision is single man's view and doomed to contain unrealistic elements as I know from experience. My dream is that young critical readers could take this vision seriously enough to try to demonstrate that some of its basic premises are wrong or to develop an alternative based on these or better premises. I must be however honest and tell that 32 years of TGD is a really vast bundle of thoughts and quite a challenge for anyone who is not able to cheat himself by taking the attitude of a blind believer or a light-hearted debunker trusting on the power of easy rhetoric tricks.

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Hanko,
September 15, 2010

Acknowledgements

Neither TGD nor these books would exist without the help and encouragement of many people. The friendship with Heikki and Raija Haila and their family have been kept me in contact with the everyday world and without this friendship I would not have survived through these lonely 32 years most of which I have remained unemployed as a scientific dissident. I am happy that my children have understood my difficult position and like my friends have believed that what I am doing is something valuable although I have not received any official recognition for it.

During last decade Tapio Tammi has helped me quite concretely by providing the necessary computer facilities and being one of the few persons in Finland with whom to discuss about my work. I have had also stimulating discussions with Samuli Penttinen who has also helped to get through the economical situations in which there seemed to be no hope. The continual updating of fifteen online books means quite a heavy bureaucracy at the level of bits and without a systemization one ends up with endless copying and pasting and internal consistency is soon lost. Pekka Rapinoja has offered his help in this respect and I am especially grateful for him for my Python skills. Also Matti Vallinkoski has helped me in computer related problems.

The collaboration with Lian Sidorov was extremely fruitful and she also helped me to survive economically through the hardest years. The participation to CASYS conferences in Liege has been an important window to the academic world and I am grateful for Daniel Dubois and Peter Marcer for making this participation possible. The discussions and collaboration with Eduardo de Luna and Istvan Dienes stimulated the hope that the communication of new vision might not be a mission impossible after all. Also blog discussions have been very useful. During these years I have received innumerable email contacts from people around the world. In particualr, I am grateful for Mark McWilliams and Ulla Matfolk for providing links to possibly interesting web sites and articles. These contacts have helped me to avoid the depressive feeling of being some kind of Don Quixote of Science and helped me to widen my views: I am grateful for all these people.

In the situation in which the conventional scientific communication channels are strictly closed it is important to have some loop hole through which the information about the work done can at

least in principle leak to the publicity through the iron wall of the academic censorship. Without any exaggeration I can say that without the world wide web I would not have survived as a scientist nor as individual. Homepage and blog are however not enough since only the formally published result is a result in recent day science. Publishing is however impossible without a direct support from power holders- even in archives like arXiv.org.

Situation changed for five years ago as Andrew Adamatsky proposed the writing of a book about TGD when I had already got used to the thought that my work would not be published during my life time. The Prespacetime Journal and two other journals related to quantum biology and consciousness - all of them founded by Huping Hu - have provided this kind of loop holes. In particular, Dainis Zeps, Phil Gibbs, and Arkadiusz Jadczyk deserve my gratitude for their kind help in the preparation of an article series about TGD catalyzing a considerable progress in the understanding of quantum TGD. Also the viXra archive founded by Phil Gibbs and its predecessor Archive Freedom have been of great help: Victor Christianto deserves special thanks for doing the hard work needed to run Archive Freedom. Also the Neuroquantology Journal founded by Sultan Tarlaci deserves a special mention for its publication policy. And last but not least: there are people who experience as a fascinating intellectual challenge to spoil the practical working conditions of a person working with something which might be called unified theory: I am grateful for the people who have helped me to survive through the virus attacks, an activity which has taken roughly one month per year during the last half decade and given a strong hue of grey to my hair.

For a person approaching his sixty year birthday it is somewhat easier to overcome the hard feelings due to the loss of academic human rights than for an inpatient youngster. Unfortunately the economic situation has become increasingly difficult during the twenty years after the economic depression in Finland which in practice meant that Finland ceased to be a constitutional state in the strong sense of the word. It became possible to depose people like me from the society without fear about public reactions and the classification as dropout became a convenient tool of ridicule to circumvent the ethical issues. During last few years when the right wing has held the political power this trend has been steadily strengthening. In this kind of situation the concrete help from individuals has been and will be of utmost importance. Against this background it becomes obvious that this kind of work is not possible without the support from outside and I apologize for not being able to mention all the people who have helped me during these years.

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Hanko,
September 15, 2010

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Chapter 1

Introduction

1.1 Basic Ideas of TGD

The basic physical picture behind TGD was formed as a fusion of two rather disparate approaches: namely TGD is as a Poincare invariant theory of gravitation and TGD as a generalization of the old-fashioned string model.

1.1.1 Background

T(opological) G(eometro)D(ynamics) is one of the many attempts to find a unified description of basic interactions. The development of the basic ideas of TGD to a relatively stable form took time of about half decade [K1]. The great challenge is to construct a mathematical theory around these physically very attractive ideas and I have devoted the last twenty-three years for the realization of this dream and this has resulted in seven online books about TGD and eight online books about TGD inspired theory of consciousness and of quantum biology.

Quantum T(opological) G(eometro)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness and of quantum biology have been for last decade of the second millenium the basic three strongly interacting threads in the tapestry of quantum TGD.

For few years ago the discussions with Tony Smith initiated a fourth thread which deserves the name 'TGD as a generalized number theory'. The basic observation was that classical number fields might allow a deeper formulation of quantum TGD. The work with Riemann hypothesis made time ripe for realization that the notion of infinite primes could provide, not only a reformulation, but a deep generalization of quantum TGD. This led to a thorough and extremely fruitful revision of the basic views about what the final form and physical content of quantum TGD might be. Together with the vision about the fusion of p-adic and real physics to a larger coherent structure these sub-threads fused to the "physics as generalized number theory" th

A further thread emerged from the realization that by quantum classical correspondence TGD predicts an infinite hierarchy of macroscopic quantum systems with increasing sizes, that it is not at all clear whether standard quantum mechanics can accommodate this hierarchy, and that a dynamical quantized Planck constant might be necessary and certainly possible in TGD framework. The identification of hierarchy of Planck constants whose values TGD "predicts" in terms of dark matter hierarchy would be natural. This also led to a solution of a long standing puzzle: what is the proper interpretation of the predicted fractal hierarchy of long ranged classical electro-weak and color gauge fields. Quantum classical correspondences allows only single answer: there is infinite hierarchy of p-adically scaled up variants of standard model physics and for each of them also dark hierarchy. Thus TGD Universe would be fractal in very abstract and deep sense.

Every updating of the books makes me frustrated as I see how badly the structure of the representation reflects my bird's eye of view as it is at the moment of updating. At this time I realized that the chronology based identification of the threads is quite natural but not logical and it is much more logical to see p-adic physics, the ideas related to classical number fields, and infinite primes as sub-threads of a thread which might be called "physics as a generalized number theory". In the following I adopt this view. This reduces the number of threads to four! I am not even sure about the number of threads! Be patient!

TGD forces the generalization of physics to a quantum theory of consciousness, and represent TGD as a generalized number theory vision leads naturally to the emergence of p-adic physics as physics of cognitive representations. The seven online books [K82, K63, K51, K49, K64, K72, K70] about TGD and eight online books about TGD inspired theory of consciousness and of quantum biology [K75, K11, K58, K9, K30, K40, K44, K69] are warmly recommended to the interested reader.

1.1.2 TGD as a Poincare invariant theory of gravitation

The first approach was born as an attempt to construct a Poincare invariant theory of gravitation. Space-time, rather than being an abstract manifold endowed with a pseudo-Riemannian structure, is regarded as a surface in the 8-dimensional space $H = M^4_\times CP_2$, where M^4 denotes Minkowski space and $CP_2 = SU(3)/U(2)$ is the complex projective space of two complex dimensions [A25, A13, A22, A11].

The identification of the space-time as a submanifold [A9, A24] of $M^4 \times CP_2$ leads to an exact Poincare invariance and solves the conceptual difficulties related to the definition of the energy-momentum in General Relativity.

It soon however turned out that submanifold geometry, being considerably richer in structure than the abstract manifold geometry, leads to a geometrization of all basic interactions. First, the geometrization of the elementary particle quantum numbers is achieved. The geometry of CP_2 explains electro-weak and color quantum numbers. The different H-chiralities of H-spinors correspond to the conserved baryon and lepton numbers. Secondly, the geometrization of the field concept results. The projections of the CP_2 spinor connection, Killing vector fields of CP_2 and of H-metric to four-surface define classical electro-weak, color gauge fields and metric in X^4.

1.1.3 TGD as a generalization of the hadronic string model

The second approach was based on the generalization of the mesonic string model describing mesons as strings with quarks attached to the ends of the string. In the 3-dimensional generalization 3-surfaces correspond to free particles and the boundaries of the 3- surface correspond to partons in the sense that the quantum numbers of the elementary particles reside on the boundaries. Various boundary topologies (number of handles) correspond to various fermion families so that one obtains an explanation for the known elementary particle quantum numbers. This approach leads also to a natural topological description of the particle reactions as topology changes: for instance, two-particle decay corresponds to a decay of a 3-surface to two disjoint 3-surfaces.

This decay vertex does not however correspond to a direct generalization of trouser vertex of string models. Indeed, the important difference between TGD and string models is that the analogs of string world sheet diagrams do not describe particle decays but the propagation of particles via different routes. Particle reactions are described by generalized Feynman diagrams for which 3-D light-like surface describing particle propagating join along their ends at vertices. As 4-manifolds the space-time surfaces are therefore singular like Feynman diagrams as 1-manifolds.

1.1.4 Fusion of the two approaches via a generalization of the space-time concept

The problem is that the two approaches to TGD seem to be mutually exclusive since the orbit of a particle like 3-surface defines 4-dimensional surface, which differs drastically from the topologically trivial macroscopic space-time of General Relativity. The unification of these approaches forces a considerable generalization of the conventional space-time concept. First, the topologically trivial 3-space of General Relativity is replaced with a "topological condensate" containing matter as particle like 3-surfaces "glued" to the topologically trivial background 3-space by connected sum operation. Secondly, the assumption about connectedness of the 3-space is given up. Besides the "topological condensate" there could be "vapor phase" that is a "gas" of particle like 3-surfaces (counterpart of the "baby universies" of GRT) and the nonconservation of energy in GRT corresponds to the transfer of energy between the topological condensate and vapor phase.

What one obtains is what I have christened as many-sheeted space-time. One particular aspect is topological field quantization meaning that various classical fields assignable to a physical system correspond to space-time sheets representing the classical fields to that particular system. One can speak of the field body of a particular physical system. Field body consists of topological light rays, and electric and magnetic flux quanta. In Maxwell's theory system does not possess this kind of field identity. The notion of magnetic body is one of the key players in TGD inspired theory of consciousness and quantum biology.

This picture became more detailed with the advent of zero energy ontology (ZEO). The basic notion of ZEO is causal diamond (CD) identified as the Cartesian product of CP_2 and of the intersection of future and past directed light-cones and having scale coming as an integer multiple of CP_2 size is fundamental. CDs form a fractal hierarchy and zero energy states decompose to products of positive and negative energy parts assignable to the opposite boundaries of CD defining the ends of the space-time surface. The counterpart of zero energy state in positive energy ontology is in terms of initial and final states of a physical event, say particle reaction.

General Coordinate Invariance allows to identify the basic dynamical objects as space-like 3-surfaces at the ends of space-time surface at boundaries of CD: this means that space-time surface is analogous to Bohr orbit. An alternative identification is as light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian and interpreted as lines of generalized Feynman diagrams. Also the Euclidian 4-D regions would have similar interpretation. The requirement that the two interpretations are equivalent, leads to a strong form of General Coordinate Invariance. The outcome is effective 2-dimensionality stating that the partonic 2-surfaces identified as intersections of the space-like ends of space-time surface and light-like wormhole throats are the fundamental objects. That only effective 2-dimensionality is in question is due to the effects caused by the failure of strict determinism of Kähler action. In finite length scale resolution these effects can be neglected below UV cutoff and above IR cutoff. One can also speak about strong form of holography.

There is a further generalization of the space-time concept inspired by p-adic physics forcing a generalization of the number concept through the fusion of real numbers and various p-adic number fields. Also the hierarchy of Planck constants forces a generalization of the notion of space-time.

A very concise manner to express how TGD differs from Special and General Relativities could be following. Relativity Principle (Poincare Invariance), General Coordinate Invariance, and Equivalence Principle remain true. What is new is the notion of sub-manifold geometry: this allows to realize Poincare Invariance and geometrize gravitation simultaneously. This notion also allows a geometrization of known fundamental interactions and is an essential element of all applications of TGD ranging from Planck length to cosmological scales. Sub-manifold geometry is also crucial in the applications of TGD to biology and consciousness theory.

The worst objection against TGD is the observation that all classical gauge fields are expressible in terms of four imbedding space coordinates only- essentially CP_2 coordinates. The linear superposition of classical gauge fields taking place independently for all gauge fields is lost. This would be a catastrophe without many-sheeted space-time. Instead of gauge fields, only the effects such as gauge forces are superposed. Particle topologically condenses to several space-time sheets simultaneously and experiences the sum of gauge forces. This transforms the weakness to extreme economy: in a typical unified theory the number of primary field variables is countered in hundreds if not thousands, now it is just four.

1.2 The threads in the development of quantum TGD

The development of TGD has involved several strongly interacting threads: physics as infinite-dimensional geometry; TGD as a generalized number theory, the hierarchy of Planck constants interpreted in terms of dark matter hierarchy, and TGD inspired theory of consciousness. In the following these threads are briefly described.

1.2.1 Quantum TGD as spinor geometry of World of Classical Worlds

A turning point in the attempts to formulate a mathematical theory was reached after seven years from the birth of TGD. The great insight was "Do not quantize". The basic ingredients to the new approach have served as the basic philosophy for the attempt to construct Quantum TGD since then and have been the following ones:

1. Quantum theory for extended particles is free(!), classical(!) field theory for a generalized Schrödinger amplitude in the configuration space CH consisting of all possible 3-surfaces in H. "All possible" means that surfaces with arbitrary many disjoint components and with arbitrary internal topology and also singular surfaces topologically intermediate between two different manifold topologies are included. Particle reactions are identified as topology changes [A20, A26, A28]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \rightarrow B+C$. Classically this corresponds to a path of configuration space leading from 1-particle sector to 2-particle sector. At quantum level this corresponds to the dispersion of the generalized Schrödinger amplitude localized to 1-particle sector to two-particle sector. All coupling constants should result as predictions of the theory since no nonlinearities are introduced.

2. During years this naive and very rough vision has of course developed a lot and is not anymore quite equivalent with the original insight. In particular, the space-time correlates of Feynman graphs have emerged from theory as Euclidian space-time regions and the strong form of General Coordinate Invariance has led to a rather detailed and in many respects un-expected visions. This picture forces to give up the idea about smooth space-time surfaces and replace space-time surface with a generalization of Feynman diagram in which vertices represent the failure of manifold property. I have also startd introduced the word "world of classical worlds" (WCW) instead of rather formal "configuration space". I hope that "WCW" does not induce despair in the reader having tendency to think about the technicalities involved!

3. WCW is endowed with metric and spinor structure so that one can define various metric related differential operators, say Dirac operator, appearing in the field equations of the theory. The most ambitious dream is that zero energy states correspond to a complete solution basis for the Dirac operator of WCW so that this classical free field theory would dictate M-matrices which form orthonormal rows of what I call U-matrix. Given M-matrix in turn would decompose to a product of a hermitian density matrix and unitary S-matrix.

   M-matrix would define time-like entanglement coefficients between positive and negative energy parts of zero energy states (all net quantum numbers vanish for them) and can be regarded as a hermitian quare root of density matrix multiplied by a unitary S-matrix. Quantum theory would be in well-defined sense a square root of thermodynamics. The orthogonality and hermiticity of the complex square roots of density matrices commuting with S-matrix means that they span infinite-dimensional Lie algebra acting as symmetries of the S-matrix. Therefore quantum TGD would reduce to group theory in well-defined sense: its own symmetries would define the symmetries of the theory. In fact the Lie algebra of Hermitian M-matrices extends to Kac-Moody type algebra obtained by multiplying hermitian square roots of density matrices with powers of the S-matrix. Also the analog of Yangian algebra involving only non-negative powers of S-matrix is possible.

4. By quantum classical correspondence the construction of WCW spinor structure reduces to the second quantization of the induced spinor fields at space-time surface. The basic action is so called modified Dirac action in which gamma matrices are replaced with the modified gamma matrices defined as contractions of the canonical momentum currents with the imbedding space gamma matrices. In this manner one achieves super-conformal symmetry and conservation of fermionic currents among other things and consistent Dirac equation. This modified gamma matrices define as anticommutators effective metric, which might provide geometrization for some basic observables of condensed matter physics. The conjecture is that Dirac determinant for the modified Dirac action gives the exponent of Kähler action for a preferred extremal as vacuum functional so that one might talk about bosonic emergence in accordance with the prediction that the gauge bosons and graviton are expressible in terms of bound states of fermion and antifermion.

The evolution of these basic ideas has been rather slow but has gradually led to a rather beautiful vision. One of the key problems has been the definition of Kähler function. Kähler function is Kähler action for a preferred extremal assignable to a given 3-surface but what this preferred extremal is? The obvious first guess was as absolute minimum of Kähler action but could not be proven to be right or wrong. One big step in the progress was boosted by the idea that TGD should reduce to almost topological QFT in which braids wold replace 3-surfaces in finite measurement resolution, which could be inherent property of the theory itself and imply discretization at partonic 2-surfaces with discrete points carrying fermion number.

1. TGD as almost topological QFT vision suggests that Kähler action for preferred extremals reduces to Chern-Simons term assigned with space-like 3-surfaces at the ends of space-time (recall the notion of causal diamond (CD)) and with the light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian. Minkowskian and Euclidian regions would give at wormhole throats the same contribution apart from coefficients and in Minkowskian regions the $\sqrt{g_4}$ factor would be imaginary so that one would obtain sum of real term identifiable as Kähler function and imaginary term identifiable as the ordinary action giving rise to interference effects and stationary phase approximation central in both classical and quantum field theory. Imaginary contribution - the presence of which I realized only after 33 years of TGD - could also havetopological interpretation as a Morse function. On physical side the emergence of Euclidian space-time regions is something completely new and leads to a dramatic modification of the ideas about black hole interior.

2. The manner to achieve the reduction to Chern-Simons terms is simple. The vanishing of Coulombic contribution to Kähler action is required and is true for all known extremals if one makes a general ansatz about the form of classical conserved currents. The so called weak form of electric-magnetic duality defines a boundary condition reducing the resulting 3-D terms to Chern-Simons terms. In this manner almost topological QFT results. But only "almost" since the Lagrange multiplier term forcing electric-magnetic duality implies that Chern-Simons action for preferred extremals depends on metric.

3. A further quite recent hypothesis inspired by effective 2-dimensionality is that Chern-Simons terms reduce to a sum of two 2-dimensional terms. An imaginary term proportional to the total area of Minkowskian string world sheets and a real tem proportional to the total area of partonic 2-surfaces or equivalently strings world sheets in Euclidian space-time regions. Also the equality of the total areas of strings world sheets and partonic 2-surfaces is highly suggestive and would realize a duality between these two kinds of objects. String world sheets indeed emerge naturally for the proposed ansatz defining preferred extremals. Therefore Kähler action would have very stringy character apart from effects due to the failure of the strict determinism meaning that radiative corrections break the effective 2-dimensionality.

1.2.2 TGD as a generalized number theory

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness, have been for last ten years the basic three strongly interacting threads in the tapestry of quantum TGD. The fourth thread deserves the name 'TGD as a generalized number theory'. It involves three separate threads: the fusion of real and various p-adic physics to a single coherent whole by requiring number theoretic universality discussed already, the formulation of quantum TGD in terms of hyper-counterparts of classical number fields identified as sub-spaces of complexified classical number fields with Minkowskian signature of the metric defined by the complexified inner product, and the notion of infinite prime.

p-Adic TGD and fusion of real and p-adic physics to single coherent whole

The p-adic thread emerged for roughly ten years ago as a dim hunch that p-adic numbers might be important for TGD. Experimentation with p-adic numbers led to the notion of canonical identification mapping reals to p-adics and vice versa. The breakthrough came with the successful p-adic mass calculations using p-adic thermodynamics for Super-Virasoro representations with the super-Kac-Moody algebra associated with a Lie-group containing standard model gauge group. Although the details of the calculations have varied from year to year, it was clear that p-adic physics reduces not only the ratio of proton and Planck mass, the great mystery number of physics, but all elementary particle mass scales, to number theory if one assumes that primes near prime powers of two are in a physically favored position. Why this is the case, became one of the key puzzless and led to a number of arguments with a common gist: evolution is present already at the elementary particle level and the primes allowed by the p-adic length scale hypothesis are the fittest ones.

It became very soon clear that p-adic topology is not something emerging in Planck length scale as often believed, but that there is an infinite hierarchy of p-adic physics characterized by p-adic length scales varying to even cosmological length scales. The idea about the connection of p-adics with cognition motivated already the first attempts to understand the role of the p-adics and inspired 'Universe as Computer' vision but time was not ripe to develop this idea to anything concrete (p-adic numbers are however in a central role in TGD inspired theory of consciousness). It became however obvious that the p-adic length scale hierarchy somehow corresponds to a hierarchy of intelligences and that p-adic prime serves as a kind of intelligence quotient. Ironically, the almost obvious idea about p-adic regions as cognitive regions of space-time providing cognitive representations for real regions had to wait for almost a decade for the access into my consciousness.

There were many interpretational and technical questions crying for a definite answer.

1. What is the relationship of p-adic non-determinism to the classical non-determinism of the basic field equations of TGD? Are the p-adic space-time region genuinely p-adic or does p-adic topology only serve as an effective topology? If p-adic physics is direct image of real physics, how the mapping relating them is constructed so that it respects various symmetries? Is the basic physics p-adic or real (also real TGD seems to be free of divergences) or both? If it is both, how should one glue the physics in different number field together to get *The Physics*? Should one perform p-adicization also at the level of the configuration space of 3-surfaces? Certainly the p-adicization at the level of super-conformal representation is necessary for the p-adic mass calculations.

2. Perhaps the most basic and most irritating technical problem was how to precisely define p-adic definite integral which is a crucial element of any variational principle based formulation of the field equations. Here the frustration was not due to the lack of solution but due to the too large number of solutions to the problem, a clear symptom for the sad fact that clever inventions rather than real discoveries might be in question. Quite recently I however learned that the problem of making sense about p-adic integration has been for decades central problem in the frontier of mathematics and a lot of profound work has been done along same intuitive lines as I have proceeded in TGD framework. The basic idea is certainly the notion of algebraic continuation from the world of rationals belonging to the intersection of real world and various p-adic worlds.

Despite these frustrating uncertainties, the number of the applications of the poorly defined p-adic physics growed steadily and the applications turned out to be relatively stable so that it was clear that the solution to these problems must exist. It became only gradually clear that the solution of the problems might require going down to a deeper level than that represented by reals and p-adics.

The key challenge is to fuse various p-adic physics and real physics to single larger structures. This has inspired a proposal for a generalization of the notion of number field by fusing real numbers and various p-adic number fields and their extensions along rationals and possible common algebraic numbers. This leads to a generalization of the notions of imbedding space and space-time concept and one can speak about real and p-adic space-time sheets. The quantum dynamics should be such that it allows quantum transitions transforming space-time sheets belonging to different number fields to each other. The space-time sheets in the intersection of real and p-adic worlds are of special interest and the hypothesis is that living matter resides in this intersection. This leads to surprisingly detailed predictions and far reaching conjectures. For instance, the number theoretic generalization of entropy concept allows negentropic entanglement central for the applications to living matter.

The basic principle is number theoretic universality stating roughly that the physics in various number fields can be obtained as completion of rational number based physics to various number fields. Rational number based physics would in turn describe physics in finite measurement resolution and cognitive resolution. The notion of finite measurement resolution has become one of the basic principles of quantum TGD and leads to the notions of braids as representatives of 3-surfaces and inclusions of hyper-finite factors as a representation for finite measurement resolution.

The role of classical number fields

The vision about the physical role of the classical number fields relies on the notion of number theoretic compactifiction stating that space-time surfaces can be regarded as surfaces of either M^8 or $M^4 \times CP_2$. As surfaces of M^8 identifiable as space of hyper-octonions they are hyper-quaternionic or co-hyper-quaternionic- and thus maximally associative or co-associative. This means that their tangent space is either hyper-quaternionic plane of M^8 or an orthogonal complement of such a plane. These surface can be mapped in natural manner to surfaces in $M^4 \times CP_2$ [K74] provided one can assign to each point of tangent space a hyper-complex plane $M^2(x) \subset M^4$. One can also speak about $M^8 - H$ duality.

This vision has very strong predictive power. It predicts that the extremals of Kähler action correspond to either hyper-quaternionic or co-hyper-quaternionic surfaces such that one can assign to tangent space at each point of space-time surface a hyper-complex plane $M^2(x) \subset M^4$. As a consequence, the M^4 projection of space-time surface at each point contains $M^2(x)$ and its orthogonal complement. These distributions are integrable implying that space-time surface allows dual slicings defined by string world sheets Y^2 and partonic 2-surfaces X^2. The existence of this kind of slicing was earlier deduced from the study of extremals of Kähler action and christened as Hamilton-Jacobi structure. The physical interpretation of $M^2(x)$ is as the space of non-physical polarizations and the plane of local 4-momentum.

One can fairly say, that number theoretical compactification is responsible for most of the understanding of quantum TGD that has emerged during last years. This includes the realization of Equivalence Principle at space-time level, dual formulations of TGD as Minkowskian and Euclidian string model type theories, the precise identification of preferred extremals of Kähler action as extremals for which second variation vanishes (at least for deformations representing dynamical symmetries) and thus providing space-time correlate for quantum criticality, the notion of number theoretic braid implied by the basic dynamics of Kähler action and crucial for precise construction of quantum TGD as almost-topological QFT, the construction of configuration space metric and spinor structure in terms of second quantized induced spinor fields with modified Dirac action defined by Kähler action realizing automatically the notion of finite measurement resolution and a connection with inclusions of hyper-finite factors of type II_1 about which Clifford algebra of configuration space represents an example.

The two most important number theoretic conjectures relate to the preferred extremals of Kähler action. The general idea is that classical dynamics for the preferred extremals of Kähler action should reduce to number theory: space-time surfaces should be either associative or co-associative in some sense.

1. The first meaning for associativity (co-associativity) would be that tangent (normal) spaces of space-time surfaces are quaternionic in some sense and thus associative. This can be formulated in terms of octonionic representation of the imbedding space gamma matrices possible in dimension $D = 8$ and states that induced gamma matrices generate quaternionic sub-algebra at each space-time point. It seems that induced rather than modified gamma matrices must be in question.

2. Second meaning for associative (co-associativity) would be following. In the case of complex numbers the vanishing of the real part of real-analytic function defines a 1-D curve. In octnionic case one can decompose octonion to sum of quaternion and quaternion multiplied by an octonionic imaginary unit. Quaternionicity could mean that space-time surfaces correspond to the vanishing of the imaginary part of the octonion real-analytic function. Co-quaternionicity would be defined in an obvious manner. Octonionic real analytic functions form a function field closed also with respect to the composition of functions. Space-time surfaces would form the analog of function field with the composition of functions with all operations realized as algebraic operations for space-time surfaces. Co-associaty could be perhaps seen as an additional feature making the algebra in question also co-algebra.

3. The third conjecture is that these conjectures are equivalent.

Infinite primes

The discovery of the hierarchy of infinite primes and their correspondence with a hierarchy defined by a repeatedly second quantized arithmetic quantum field theory gave a further boost for the speculations about TGD as a generalized number theory. The work with Riemann hypothesis led to further ideas.

After the realization that infinite primes can be mapped to polynomials representable as surfaces geometrically, it was clear how TGD might be formulated as a generalized number theory with infinite primes forming the bridge between classical and quantum such that real numbers, p-adic numbers, and various generalizations of p-adics emerge dynamically from algebraic physics as various completions of the algebraic extensions of rational (hyper-)quaternions and (hyper-)octonions. Complete algebraic, topological and dimensional democracy would characterize the theory.

What is especially satisfying is that p-adic and real regions of the space-time surface could emerge automatically as solutions of the field equations. In the space-time regions where the solutions of field equations give rise to in-admissible complex values of the imbedding space coordinates, p-adic solution can exist for some values of the p-adic prime. The characteristic non-determinism of the p-adic differential equations suggests strongly that p-adic regions correspond to 'mind stuff', the regions of space-time where cognitive representations reside. This interpretation implies that p-adic physics is physics of cognition. Since Nature is probably an extremely brilliant simulator of Nature, the natural idea is to study the p-adic physics of the cognitive representations to derive information about the real physics. This view encouraged by TGD inspired theory of consciousness clarifies difficult interpretational issues and provides a clear interpretation for the predictions of p-adic physics.

1.2.3 Hierarchy of Planck constants and dark matter hierarchy

By quantum classical correspondence space-time sheets can be identified as quantum coherence regions. Hence the fact that they have all possible size scales more or less unavoidably implies that Planck constant must be quantized and have arbitrarily large values. If one accepts this then also the idea about dark matter as a macroscopic quantum phase characterized by an arbitrarily large value of Planck constant emerges naturally as does also the interpretation for the long ranged classical electro-weak and color fields predicted by TGD. Rather seldom the evolution of ideas follows simple linear logic, and this was the case also now. In any case, this vision represents the fifth, relatively new thread in the evolution of TGD and the ideas involved are still evolving.

Dark matter as large $\hbar$ phase

D. Da Rocha and Laurent Nottale [E7] have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [K67] .

TGD predicts correctly the value of the parameter v_0 assuming that cosmic strings and their decay remnants are responsible for the dark matter. The harmonics of v_0 can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes n^2-fold: much like the replacement of a closed orbit with an orbit closing only after n turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes. Also a model for the formation of planetary system as a condensation of ordinary matter around quantum coherent dark matter emerges [K67] .

The values of Planck constants postulated by Nottale are gigantic and it is natural to assign them to the space-time sheets mediating gravitational interaction and identifiable as magnetic flux tubes (quanta). The magnetic energy of these flux quanta would correspond to dark energy and magnetic tension would give rise to negative "pressure" forcing accelerate cosmological expansion. This leads to a rather detailed vision about the evolution of stars and galaxies identified as bubbles of ordinary and dark matter inside magnetic flux tubes identifiable as dark energy.

Hierarchy of Planck constants from the anomalies of neuroscience biology

The quantal effects of ELF em fields on vertebrate brain have been known since seventies. ELF em fields at frequencies identifiable as cyclotron frequencies in magnetic field whose intensity is about 2/5 times that of Earth for biologically important ions have physiological effects and affect also behavior. What is intriguing that the effects are found only in vertebrates (to my best knowledge). The energies for the photons of ELF em fields are extremely low - about 10^{-10} times lower than thermal energy at physiological temperatures- so that quantal effects are impossible in the framework of standard quantum theory. The values of Planck constant would be in these situations large but not gigantic.

This inspired the hypothesis that these photons correspond to so large value of Planck constant that the energy of photons is above the thermal energy. The proposed interpretation was as dark photons and the general hypothesis was that dark matter corresponds to ordinary matter with non-standard value of Planck constant. If only particles with the same value of Planck constant can appear in the same vertex of Feynman diagram, the phases with different value of Planck constant are dark relative to each other. The phase transitions changing Planck constant can however make possible interactions between phases with different Planck constant but these interactions do not manifest themselves in particle physics. Also the interactions mediated by classical fields should be possible. Dark matter would not be so dark as we have used to believe.

Also the anomalies of biology support the view that dark matter might be a key player in living matter.

Does the hierarchy of Planck constants reduce to the vacuum degeneracy of Kähler action?

This starting point led gradually to the recent picture in which the hierarchy of Planck constants is postulated to come as integer multiples of the standard value of Planck constant. Given integer multiple $\hbar = n\hbar_0$ of the ordinary Planck constant $\hbar_0$ is assigned with a multiple singular covering of the imbedding space [K25]. One ends up to an identification of dark matter as phases with non-standard value of Planck constant having geometric interpretation in terms of these coverings providing generalized imbedding space with a book like structure with pages labelled by Planck constants or integers characterizing Planck constant. The phase transitions changing the value of Planck constant would correspond to leakage between different sectors of the extended imbedding space. The question is whether these coverings must be postulated separately or whether they are only a convenient auxiliary tool.

The simplest option is that the hierarchy of coverings of imbedding space is only effective. Many-sheeted coverings of the imbedding space indeed emerge naturally in TGD framework. The huge vacuum degeneracy of Kähler action implies that the relationship between gradients of the imbedding space coordinates and canonical momentum currents is many-to-one: this was the very fact forcing to give up all the standard quantization recipes and leading to the idea about physics as geometry of the "world of classical worlds". If one allows space-time surfaces for which all sheets corresponding to the same values of the canonical momentum currents are present, one obtains effectively many-sheeted covering of the imbedding space and the contributions from sheets to the Kähler action are identical. If all sheets are treated effectively as one and the same sheet, the value of Planck constant is an integer multiple of the ordinary one. A natural boundary condition would be that at the ends of space-time at future and past boundaries of causal diamond containing the space-time surface, various branches co-incide. This would raise the ends of space-time surface in special physical role.

Dark matter as a source of long ranged weak and color fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. Also scaled up variants of ordinary electro-weak particle spectra are possible. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics. A possible solution of the matter antimatter asymmetry is based on the identification of also antimatter as dark matter.

1.2.4 TGD as a generalization of physics to a theory consciousness

General coordinate invariance forces the identification of quantum jump as quantum jump between entire deterministic quantum histories rather than time=constant snapshots of single history. The new view about quantum jump forces a generalization of quantum measurement theory such that observer becomes part of the physical system. Thus a general theory of consciousness is unavoidable outcome. This theory is developed in detail in the books [K75, K11, K58, K9, K30, K40, K44, K69] .

Quantum jump as a moment of consciousness

The identification of quantum jump between deterministic quantum histories (configuration space spinor fields) as a moment of consciousness defines microscopic theory of consciousness. Quantum jump involves the steps

$$\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_f \quad ,$$

where U is informational "time development" operator, which is unitary like the S-matrix characterizing the unitary time evolution of quantum mechanics. U is however only formally analogous to Schrödinger time evolution of infinite duration although there is *no* real time evolution involved. It is not however clear whether one should regard U-matrix and S-matrix as two different things or not: U-matrix is a completely universal object characterizing the dynamics of evolution by self-organization whereas S-matrix is a highly context dependent concept in wave mechanics and in quantum field theories where it at least formally represents unitary time translation operator at the limit of an infinitely long interaction time. The S-matrix understood in the spirit of superstring models is however something very different and could correspond to U-matrix.

The requirement that quantum jump corresponds to a measurement in the sense of quantum field theories implies that each quantum jump involves localization in zero modes which parameterize also the possible choices of the quantization axes. Thus the selection of the quantization axes performed by the Cartesian outsider becomes now a part of quantum theory. Together these requirements imply that the final states of quantum jump correspond to quantum superpositions of space-time surfaces which are macroscopically equivalent. Hence the world of conscious experience looks classical. At least formally quantum jump can be interpreted also as a quantum computation in which matrix U represents unitary quantum computation which is however not identifiable as unitary translation in time direction and cannot be 'engineered'.

Can one say anything about the unitary process? Zero energy states correspond in positive energy ontology to physical events and break time reversal invariance. This because either the positive or negative energy part of the state is prepared whereas the second end of CD corresponds to a superposition of (negative/positive energy) states with varying particle numbers and single particle quantum numbers just as in ordinary particle physics experiment. State function reduction must change the roles of the ends of CDs. Therefore U-matrix should correspond to the unitary matrix relating zero energy state basis prepared at different ends of CD and state function reduction would be equivalent with state preparation.

The basic objection is that the arrow of geometric time alternates at imbedding space level but we know that arrow of time is universal. What one can say about the arrow of time at space-time level? Quantum classical correspondence requires that quantum mechanical irreversibility corresponds to irreversibility at space-time level. If the observer is analogous to an inhabitant of Flatland gaining information only about space-time surface, he or she is not able to discover that the arrow of time alternates at the level of imbedding space. The inhabitant of a folded bath towel is not able to observer the folding of the towel! Only by observing systems for which the imbedding space arrow of time is opposite, observer can discover the alternation. Living systems indeed behave as if they would contain space-time sheets with opposite arrow of geometric time (self-organization). Phase conjugate light beam is second example of this.

The notion of self

The concept of self is absolutely essential for the understanding of the macroscopic and macro-temporal aspects of consciousness. Self corresponds to a subsystem able to remain un-entangled under the sequential informational 'time evolutions' U. Exactly vanishing entanglement is practically impossible in ordinary quantum mechanics and it might be that 'vanishing entanglement' in the condition for self-property should be replaced with 'subcritical entanglement'. On the other hand, if space-time decomposes into p-adic and real regions, and if entanglement between regions representing physics in different number fields vanishes, space-time indeed decomposes into selves in a natural manner.

It is assumed that the experiences of the self after the last 'wake-up' sum up to single average experience. This means that subjective memory is identifiable as conscious, immediate short term memory. Selves form an infinite hierarchy with the entire Universe at the top. Self can be also interpreted as mental images: our mental images are selves having mental images and also we represent mental images of a higher level self. A natural hypothesis is that self S experiences the experiences of its subselves as kind of abstracted experience: the experiences of subselves S_i are not experienced as such but represent kind of averages $\langle S_{ij} \rangle$ of sub-subselves S_{ij}. Entanglement between selves, most naturally realized by the formation of join along boundaries bonds between cognitive or material space-time sheets, provides a possible a mechanism for the fusion of selves to larger selves (for instance, the fusion of the mental images representing separate right and left visual fields to single visual field) and forms wholes from parts at the level of mental images.

An attractive possibility suggested by zero energy ontology is that the notions of self and quantum jump reduce to each other and that a fractal hierarchy of quantum jumps within quantum jumps is enough. CDs would serve as imbedding space correlates of selves and quantum jumps would be followed by cascades of state function reductions beginning from given CD and proceeding downwards to the smaller scales (smaller CDs). State function reduction cascades could also take place in parallel branches of the quantum state. One ends up with concrete ideas about how the arrow of geometric time is induced from that of subjective time defined by the experiences induced by the sequences of quantum jumps for sub-selves of self. One ends also ends up with concrete ideas about how the localization of the contents of sensory experience and cognition to the upper boundaries of CD could take place.

Relationship to quantum measurement theory

The third basic element relates TGD inspired theory of consciousness to quantum measurement theory. The assumption that localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It also implies the state function reduction of the standard quantum measurement theory as the following arguments demonstrate (it took incredibly long time to realize this almost obvious fact!).

1. The standard quantum measurement theory a la von Neumann involves the interaction of brain with the measurement apparatus. If this interaction corresponds to entanglement between microscopic degrees of freedom m with the macroscopic effectively classical degrees of freedom M characterizing the reading of the measurement apparatus coded to brain state, then the reduction of this entanglement in quantum jump reproduces standard quantum measurement theory provide the unitary time evolution operator U acts as flow in zero mode degrees of freedom and correlates completely some orthonormal basis of configuration space spinor fields in non-zero modes with the values of the zero modes. The flow property guarantees that the localization is consistent with unitarity: it also means 1-1 mapping of quantum state basis to classical variables (say, spin direction of the electron to its orbit in the external magnetic field).

2. Since zero modes represent classical information about the geometry of space-time surface (shape, size, classical Kähler field,...), they have interpretation as effectively classical degrees of freedom and are the TGD counterpart of the degrees of freedom M representing the reading of the measurement apparatus. The entanglement between quantum fluctuating non-zero modes and zero modes is the TGD counterpart for the $m-M$ entanglement. Therefore the localization in zero modes is equivalent with a quantum jump leading to a final state where the measurement apparatus gives a definite reading.

This simple prediction is of utmost theoretical importance since the black box of the quantum measurement theory is reduced to a fundamental quantum theory. This reduction is implied by the replacement of the notion of a point like particle with particle as a 3-surface. Also the infinite-dimensionality of the zero mode sector of the configuration space of 3-surfaces is absolutely essential. Therefore the reduction is a triumph for quantum TGD and favors TGD against string models.

Standard quantum measurement theory involves also the notion of state preparation which reduces to the notion of self measurement. Each localization in zero modes is followed by a cascade of self measurements leading to a product state. This process is obviously equivalent with the state preparation process. Self measurement is governed by the so called Negentropy Maximization Principle (NMP) stating that the information content of conscious experience is maximized. In the self measurement the density matrix of some subsystem of a given self localized in zero modes (after ordinary quantum measurement) is measured. The self measurement takes place for that subsystem of self for which the reduction of the entanglement entropy is maximal in the measurement. In p-adic context NMP can be regarded as the variational principle defining the dynamics of cognition. In real context self measurement could be seen as a repair mechanism allowing the system to fight against quantum thermalization by reducing the entanglement for the subsystem for which it is largest (fill the largest hole first in a leaking boat).

Selves self-organize

The fourth basic element is quantum theory of self-organization based on the identification of quantum jump as the basic step of self-organization [K65] . Quantum entanglement gives rise to the generation of long range order and the emergence of longer p-adic length scales corresponds to the emergence of larger and larger coherent dynamical units and generation of a slaving hierarchy. Energy (and quantum entanglement) feed implying entropy feed is a necessary prerequisite for quantum self-organization. Zero modes represent fundamental order parameters and localization in zero modes implies that the sequence of quantum jumps can be regarded as hopping in the zero modes so that Haken's classical theory of self organization applies almost as such. Spin glass analogy is a further important element: self-organization of self leads to some characteristic pattern selected by dissipation as some valley of the "energy" landscape.

Dissipation can be regarded as the ultimate Darwinian selector of both memes and genes. The mathematically ugly irreversible dissipative dynamics obtained by adding phenomenological dissipation terms to the reversible fundamental dynamical equations derivable from an action principle can be understood as a phenomenological description replacing in a well defined sense the series of reversible quantum histories with its envelope.

Classical non-determinism of Kähler action

The fifth basic element are the concepts of association sequence and cognitive space-time sheet. The huge vacuum degeneracy of the Kähler action suggests strongly that the absolute minimum space-time is not always unique. For instance, a sequence of bifurcations can occur so that a given space-time branch can be fixed only by selecting a finite number of 3-surfaces with time like(!) separations on the orbit of 3-surface. Quantum classical correspondence suggest an alternative formulation. Space-time surface decomposes into maximal deterministic regions and their temporal sequences have interpretation a space-time correlate for a sequence of quantum states defined by the initial (or final) states of quantum jumps. This is consistent with the fact that the variational principle selects preferred extremals of Kähler action as generalized Bohr orbits.

In the case that non-determinism is located to a finite time interval and is microscopic, this sequence of 3-surfaces has interpretation as a simulation of a classical history, a geometric correlate for contents of consciousness. When non-determinism has long lasting and macroscopic effect one can identify it as volitional non-determinism associated with our choices. Association sequences relate closely with the cognitive space-time sheets defined as space-time sheets having finite time duration and psychological time can be identified as a temporal center of mass coordinate of the cognitive space-time sheet. The gradual drift of the cognitive space-time sheets to the direction of future force by the geometry of the future light cone explains the arrow of psychological time.

p-Adic physics as physics of cognition and intentionality

The sixth basic element adds a physical theory of cognition to this vision. TGD space-time decomposes into regions obeying real and p-adic topologies labelled by primes $p = 2, 3, 5, ...$ p-Adic regions obey the same field equations as the real regions but are characterized by p-adic non-determinism since the functions having vanishing p-adic derivative are pseudo constants which are piecewise constant functions. Pseudo constants depend on a finite number of positive pinary digits of arguments just like numerical predictions of any theory always involve decimal cutoff. This means that p-adic space-time regions are obtained by gluing together regions for which integration constants are genuine constants. The natural interpretation of the p-adic regions is as cognitive representations of real physics. The freedom of imagination is due to the p-adic non-determinism. p-Adic regions perform mimicry and make possible for the Universe to form cognitive representations about itself. p-Adic physics space-time sheets serve also as correlates for intentional action.

A more more precise formulation of this vision requires a generalization of the number concept obtained by fusing reals and p-adic number fields along common rationals (in the case of algebraic extensions among common algebraic numbers). This picture is discussed in [K73] . The application this notion at the level of the imbedding space implies that imbedding space has a book like structure with various variants of the imbedding space glued together along common rationals (algebraics). The implication is that genuinely p-adic numbers (non-rationals) are strictly infinite as real numbers so that most points of p-adic space-time sheets are at real infinity, outside the cosmos, and that the projection to the real imbedding space is discrete set of rationals (algebraics). Hence cognition and intentionality are almost completely outside the real cosmos and touch it at a discrete set of points only.

This view implies also that purely local p-adic physics codes for the p-adic fractality characterizing long range real physics and provides an explanation for p-adic length scale hypothesis stating that the primes $p \simeq 2^k$, k integer are especially interesting. It also explains the long range correlations and short term chaos characterizing intentional behavior and explains why the physical realizations of cognition are always discrete (say in the case of numerical computations). Furthermore, a concrete quantum model for how intentions are transformed to actions emerges.

The discrete real projections of p-adic space-time sheets serve also space-time correlate for a logical thought. It is very natural to assign to p-adic pinary digits a p-valued logic but as such this kind of logic does not have any reasonable identification. p-Adic length scale hypothesis suggest that the $p = 2^k - n$ pinary digits represent a Boolean logic B^k with k elementary statements (the points of the k-element set in the set theoretic realization) with n taboos which are constrained to be identically true.

p-Adic and dark matter hierarchies and hierarchy of moments of consciousness

Dark matter hierarchy assigned to a spectrum of Planck constant having arbitrarily large values brings additional elements to the TGD inspired theory of consciousness.

1. Macroscopic quantum coherence can be understood since a particle with a given mass can in principle appear as arbitrarily large scaled up copies (Compton length scales as $\hbar$). The phase transition to this kind of phase implies that space-time sheets of particles overlap and this makes possible macroscopic quantum coherence.

2. The space-time sheets with large Planck constant can be in thermal equilibrium with ordinary ones without the loss of quantum coherence. For instance, the cyclotron energy scale associated with EEG turns out to be above thermal energy at room temperature for the level of dark matter hierarchy corresponding to magnetic flux quanta of the Earth's magnetic field with the size scale of Earth and a successful quantitative model for EEG results [K21] .

Dark matter hierarchy leads to detailed quantitative view about quantum biology with several testable predictions [K21] . The general prediction is that Universe is a kind of inverted Mandelbrot fractal for which each bird's eye of view reveals new structures in long length and time scales representing scaled down copies of standard physics and their dark variants. These structures would correspond to higher levels in self hierarchy. This prediction is consistent with the belief that 75 per cent of matter in the universe is dark.

1. Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [K21] . Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [K42, K21] . A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [K21] .

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

2. Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [K20, K21] . The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \hbar$ of the quantum jump.

Quantum jumps form also a hierarchy with respect to p-adic and dark hierarchies and the geometric durations of quantum jumps scale like $\hbar$. Dark matter hierarchy suggests also a slight modification of the notion of self. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. The quantum parallel dissipation at the lower levels would give rise to the experience of flow of time. For instance, hadron as a macro-temporal quantum system in the characteristic time scale of hadron is a dissipating system at quark and gluon level corresponding to shorter p-adic time scales. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

3. The time span of long term memories as signature for the level of dark matter hierarchy

The basic question is what time scale can one assign to the geometric duration of quantum jump measured naturally as the size scale of the space-time region about which quantum jump gives conscious information. This scale is naturally the size scale in which the non-determinism of quantum jump is localized. During years I have made several guesses about this time scales but zero energy ontology and the vision about fractal hierarchy of quantum jumps within quantum jumps leads to a unique identification.

Causal diamond as an imbedding space correlate of self defines the time scale τ for the space-time region about which the consciousness experience is about. The temporal distances between the tips of CD as come as integer multiples of CP_2 length scales and for prime multiples correspond to what I have christened as secondary p-adic time scales. A reasonable guess is that secondary p-adic time scales are selected during evolution and the primes near powers of two are especially favored. For electron, which corresponds to Mersenne prime $M_{127} = 2^{127} - 1$ this scale corresponds to .1 seconds defining the fundamental time scale of living matter via 10 Hz biorhythm (alpha rhythm). The unexpected prediction is that all elementary particles correspond to time scales possibly relevant to living matter.

Dark matter hierarchy brings additional finesse. For the higher levels of dark matter hierarchy τ is scaled up by $\hbar/\hbar_0$. One could understand evolutionary leaps as the emergence of higher levels at the level of individual organism making possible intentionality and memory in the time scale defined τ.

Higher levels of dark matter hierarchy provide a neat quantitative view about self hierarchy and its evolution. Various levels of dark matter hierarchy would naturally correspond to higher levels in the hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question. The level would determine also the time span of long term memories as discussed in [K21] . The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [K42, K21]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

1.3 Bird's eye of view about the topics of the book

The quantum theory of self organization represents a rather old layer of TGD inspired theory of consciousness. There are several new elements as distinguishing TGD based view from the more conventional approaches to self-organization.

1. Self organization is a non-deterministic process and corresponds to the evolution of conscious entities - selves - to asymptotic self-organization patters via quantum jumps. This requires obviously macroscopic quantum coherence.

2. Space-time surfaces are analogous to Bohr orbits and the failure of the classical non-determinism in the conventional sense of the word makes it possible to interpret space-time surfaces as representations of not only quantum states but also of sequences of quantum states assignable to the sequences of quantum jumps. The huge vacuum degeneracy of Kähler action suggests strongly spin glass degeneracy in 4-dimensional sense. Spin glass degeneracy would provide maximal resources for a system to represent information about external world by mapping its states to its own internal states. Space-time sheets can be seen also as four-dimensional statues gradually carved by a sequence of quantum jump to a shape representing asymptotic self-organization pattern possibly mimicking a corresponding pattern of external world.

3. Magnetic body is the intentional agent controlling the biological body. Dark matter hierarchy and p-adic length scale hierarchy bring additional important elements into this vision but are not discussed in detail in this book. The fractal hierarchy of copies of standard model physics involving in particular a hierarchy of electro-weak bosons and gluons with increasingly longer weak/confinement length scale is an essential piece of the story. For instance, charged topological light rays (W MEs) could take care of motor control and neutral MEs for communication of sensory data to the magnetic body. The concrete quantum model for how intentions are transformed to actions provides additional insights to quantum self-organization.

4. The new view about time and energy giving justification for the time mirror mechanism involving sending of negative energy phase conjugate photons to geometric past is crucial for the models of long term memory, intentional action, and remote metabolism.

5. The model of self organization involves two kinds of radiations used as communication and control tools: cyclotron radiation from the cyclotron transitions assignable with the Bose-Einstein condensates of charged bosons at the magnetic bodies and Josephson radiation from Josephson junctions assignable to the cell membrane and also other layer like structures (electrets).

It must be added that this book reflects the TGD inspired vision about quantum biology as it was roughly one decade before the notion of zero energy ontology and the idea about dark matter hierarchy with levels labeled by the value of Planck constant emerged. The implications of the dark matter hierarchy are manifold.

1. The hierarchy justifies the crucial assumption about the presence of macroscopic quantum phases and leads to a concrete model for catalyst action and for how DNA and cell membrane could act as a topological quantum computer.

2. A generalization of the notion of genome emerges. Super genome would code for coherent gene expression at the level of organs and hyper genome at the level of population. Magnetic flux sheets containing sequences of genomes like pages of book contain text lines would make this notion almost unavoidable in TGD framework and the success of the resulting model of EEG and nerve pulse supports this vision.

3. Evolutionary leaps could be understood as an emergence of a new level into the "personal" hierarchy of Planck constants associated with the magnetic body having onion like structure thus implying that the time scales of long term memory and planned action increase.

4. One begins to understand the collective aspects of self-organization at the level of say human society. Both Blackmore's notion of meme and Sheldrake's idea about learning at the level of species finds a concrete realization at the genetic level. The miraculous feats of ant and bee communities consisting or rather simple individuals can be assigned to intelligence of the magnetic bodies controlling the behavior of these societies.

The topics of the book are roughly following. In the first chapters the vision about biological self organization in TGD framework is discussed. There is also a chapter devoted to the possible implications of p-adic length scale hypothesis. The last chapters of the book are devoted to how quantum control and coordination could be realized in TGD Universe.

The seven online books about TGD [K82, K63, K64, K72, K51, K49, K70] and eight online books about TGD inspired theory of consciousness and quantum biology [K75, K11, K58, K9, K30, K40, K44, K69] are warmly recommended for the reader willing to get overall view about what is involved.

1.4 The contents of the book

1.4.1 Quantum Theory of Self-Organization

Quantum theory of self-organization based on the idea that quantum jump serves as the basic step of self-organization, is represented. The notion of self and the identification of self as the fundamental statistical ensemble gives totally new meaning for the concept of self-organization as a generation of hierarchies of selves.

Zero modes of the configuration space geometry, whose existence derives from the generalization of point like particle to 3-surface, provide universal, nonlocal order parameters and the emergence of the new level of self-organization occurs through phase transition like process as also in Haken's theory. The fact that quantum jumps involve localization in zero modes means that the sequence of quantum jumps means hopping in zero modes characterizing the classical aspects of the spacetime geometry.

The recent view about quantum TGD involves several incredients which allow to considerably sharpen and enrich the original view about self-organization. In zero energy ontology all space-time sheets are "mind-like" space time sheets assigned with cognition. Number theoretical Shannon entropy having also negative values and making sense for rational or at most algebraic entanglement probabilities allows negentropic entanglement so that Negentropy Maximization Principle in this case favors formations of larger coherent structures. One could say that intelligent life resides in the intersection of real and various p-adic worlds much like rationals represent islands of order in the sea of chaos defined by generic real or p-adic numbers. Dark matter hierarchy with levels partially labelled by the value of Planck constant brings in dark matter playing a key role in biological self organization.

The quantum version of Haken's theory of self-organization is proposed. Spin glass analogy means that "energy" landscape has fractal valleys inside valleys structure: this structure is important for understanding long term memories. A crucially important aspect of the quantum self-organization is the Darwinian selection of very few asymptotic self-organization pattterns by dissipation which explains the selection of both genes and memes: this selection provides royal road to the understanding of various miraculous feats performed by living matter.

The comparison with Rupert Sheldrake's concepts of morphic field and morphic resonance leads to interesting ideas about how learning at the level of species could occur quantum-mechanically. For instance, the phenomenon of biofeedback suggests that self could quite generally effectively act on its subselves. In zero energy ontology all quantum states have properties allowing to interpret them as memes or quanta of morphic fields and the challenge is to find their biological counterparts. DNA as topological quantum computer hypothesis suggest the identification of the biological memes as topological quantum computer programs assignable to the intronic portion of the genome and coded also by nerve pulse patterns. The notion of magnetic body as intentional agent leads to a concrete model for the morphic resonance as a transfer of topological quantum computation programs between separate brains with the mediary of the personal magnetic bodies and the magnetic body of Mother Gaia using EEG like communications. The model explains also 'alike likes alike' rule.

1.4.2 Possible Role of p-Adic Numbers in Bio-Systems

In this chapter a general view about p-adic physics is discussed. The proposal is that the living matter in very general sense corresponds to the intersection of real and p-adic worlds. The identification of some p-adic length scales predicted by the p-adic length scale hypothesis as biologically relevant length scales is suggested. Also the possibility of small-p p-adicity is discussed. p-Adic ultrametricity, the non-determinism of the p-adic differential equations, the special features of the p-adic dynamical flows, the delicacies of the p-adic probabity concept and the special features of p-adic entanglement are also discussed briefly and possible implications for biosystems are pointed out. Also ideas, which are only marginally consistent with the interpretation of p-adic physics as physics of cognition, are discussed.

1.4.3 Biological Realization of Self Hierarchy

Self-hierarchy is the basic prediction of the TGD inspired theory of consciousness and the biological realization of the self-hierarchy is the basic theme of this chapter. Space-time sheets, in particular mind like space-time sheets having finite temporal duration and providing cognitive representation of the material world, are geometrical correlates of selves and biological self hierarchy reduces geometrically and topologically to the hierarchy of space-time sheets. Crucially involved is the notion of the topological field quantization, which among other things implies that photons have as their classical geometrical correlates so called topological field quanta. One interpretation for the topological field quanta of em field is as classical/quantal coherence regions of classical/quantum em field and electromagnetic (em) fields and their topological field quanta are expected to be especially important in bio-systems. One can assign vacuum quantum numbers to topological field quanta and these quantum numbers are expected to be carriers of a biologically relevant information.

In principle the self hierarchy starts already at elementary particle level but the atomic length scale serves as a natural length scale for length scale at which biological relevant part of the self-hierarchy starts.

a) The assumption that various bio-molecules are selves allows to understand the miraculous abilities of living systems as outcome of quantum self-organization process in which dissipation selects very limited repertoire of self-organization patterns identifiable as survivors in Darwinian selection. For instance, one can understand protein folding and DNA replication as self-organization processes.

b) The fact that bio-systems are liquid crystals, makes them ideal for the realization of the self hierarchy. The reason is that liquid crystals have ability to self-organize to very complicated structures and are ideal for communication purposes: for instance, mechanical signals can be coded to electric signals and vice versa. Liquid crystals are also electrets: the presence of electric fields is indeed an important prerequisite of cognition in TGD as discussed in the chapter "Information and consciousness". In fact, one could identify various bio-structures such as micro-tubuli, cell organelles and cells as generic outcomes of the self-organization of the liquid crystals. An especially important level of the self hierarchy is provided by collagen networks which could give rise to what might be called 'body consciousness'. Central nervous system is only one, although very important level in the self hierarchy, and TGD approach allows to understand why this is the case.

c) p-Adic length scale hypothesis allows quantitative grasp to the structure of the self hierarchy and one can build general picture about how various p-adic length scales emerged during the evolution. In particular, one can identify various p-adic length scales associated with the brain.

d) One level of the self hierarchy corresponds to the topological field quanta of ELF em fields associated with EEG. ELF (extremely low frequency) em fields are known to have dramatic effects on living matter and brain and the origin of these effects is poorly understood. A simple argument based on Uncertainty Principle leads to the conclusion that ELF photons in 10 Hz frequency range correspond to topological field quanta of size of entire Earth. This leads to a rather dramatic conclusion that our biological body is only a dip of an iceberg and we are much more than our neurons. The most important levels in our personal self hierarchy contains levels are of size of Earth! Support for this picture come from the quantitative success of the scenario: one can immediately understand various important neuro time scales in terms of the cyclotron frequencies of various charged particles in Earth's magnetic field.

e) Each bio-structure is accompanied by a topologically quantized magnetic field defining corresponding magnetic body and these magnetic bodies form a hierarchy. Magnetic bodies could serve as intentional agents, as templates for the formation of various biological control circuits crucial for homeostasis and biological information processing, define the basic structure making possible metabolism with universal metabolic energy currencies, and could even define what might be called Nature's own bio-laboratory.

f) The magnetic flux structures associated with body could be of crucial importance for understanding human consciousness. For instance, eyes generate magnetic fields. Also brain, in particular pineal gland (the 'third eye' of mystics and the seat of soul for Descartes), contains magnetic materials. Corresponding magnetic transition frequencies correspond to time scales relevant for the self narrative in human time scales. Perhaps these higher levels of magnetic self hierarchy could relate with NDE experiences and represent structures surviving in physical death.

1.4.4 Quantum Control and Coordination in Bio-Systems: Part I

The basic dynamical aspects of the biological system relate to coordination and control. Coordination is involved with almost automatic and predictable activities involving no volition whereas control involves volition and non-predictability. A basic examples of coordination and control are EEG and nerve pulse respectively. Various motor activities are good examples of a control involving macroscopic changes of the shape of the organ. The great challenge is to identify the quantum correlates of coordination and control.

The vision about living matter as consisting of a fractal hierarchy of MEs controlling a fractal hierarchy super-conducting magnetic flux tube structures in turn controlling ordinary matter at atomic space-time sheets via many-sheeted ionic flow equilibrium provides a very promising approach for modelling living matter. MEs interact with magnetic superconductors via magnetic induction by inducing supra-currents, by acting as Josephson junctions between magnetic flux tubes, and by inducing magnetic transitions.

The fact that TGD predicts infinite hierarchy of dark matters defining scaled down copies of color and electro-weak physics generalizes this picture dramatically and means that dark matter becomes the quintessential component of living systems. The predicted spectrum for the values of Planck constant conforms with quantum criticality since Kähler function does not depend on $\hbar$ and long range fluctuations at quantum criticality can be also interpreted as fluctuations in the value of $\hbar$ appearing only in the construction of quantum states and making possible macroscopic quantum coherence.

TGD suggests strongly that the formation of join the along boundaries bonds between the space-time sheets possibly representing different levels of the self hierarchy could be the basic mechanism of control and coordination. The interpretation as a prerequisite for bio-feedback, understood in very general sense, is very suggestive. The presence of join along boundaries bonds makes possible transfer of various charge particles between space-time sheets in question and the resulting system is very similar to two weakly coupled super conductors connected by Josephson junctions. This suggests that that super currents and Josephson currents between the space-time sheets are crucial for the coordination, which could be identified as deterministic quantum time development without quantum jumps.

Any harmonic perturbation with some magnetic transition frequency can induce magnetic quantum transitions and even magnetic quantum phase transitions. An attractive identification for this process is as basic tool of quantum control tool so that the resonance frequency appears as control parameter 'waking up' subself at its critical value. Critical frequencies correspond to the magnetic and Z^0

magnetic cyclotron frequencies in the model of super conductor relying on the presence of weak magnetic or Z^0 magnetic field (magnetic field guarantees effective one-dimensionality of the super conductor and implies finite gap energy in TGD framework). Cyclotron frequency hypothesis has had rather dramatic success and leads to a rather detailed picture about brain as a macroscopic quantum system.

This general picture is applied at various levels. A general model for weakly coupled super conductors is constructed and simple models for various control tools like comparison circuits, biological clocks and alarm clocks, feature detectors and novelty detectors are sketched. This model of quantum control is applied in some particular cases.

1.4.5 Quantum Control and Coordination in Bio-Systems: Part II

The topics of this chapter are related to the implications of absolute minimization of Kähler action for the understanding of bio-systems, to the TGD counterparts of scalar waves of Tesla and the realization of the time mirror mechanism mechanism, to 1/f noise as a signature of quantum criticality, and to the role of ELF fields in living systems.

1. Absolute minimization of Kähler action

Absolute minimization of Kähler action yields a non-deterministic dynamics mimicking the dissipative dynamics of the quantum jump sequence. This dynamics leads to asymptotic field patterns for which dissipation represented by a non-vanishing Lorentz 4-force is absent. The vanishing is guaranteed by the topologization of the Kähler current so that it becomes proportional to instanton current. When Kähler electric field is absent, magnetic field reduces to what is known as Beltrami field. Beltrami fields are known to be extremely complex but highly organized structures. The natural conjecture is that topologically quantized many-sheeted magnetic and Z^0 magnetic Beltrami fields and their generalizations serve as templates for the helical molecules populating living matter, and explain both chirality selection, the complex linking and knotting of DNA and protein molecules, and even the extremely complex and self-organized dynamics of biological systems at the molecular level.

2. Tesla's scale waves and time mirror mechanism

TGD allows scalar wave pulses represented as space-time sheets propagating with velocity of light and carrying longitudinal electric field. These solutions exist certainly as vacuum extremals and, as it seems, also as solutions of field equation which do not represent asymptotic self-organization patterns but kind of transits analogous to longitudinal virtual photons.

Many-sheeted space-time makes possible many-sheeted lasers since cold space-time sheets can contain Bose-Einstein condensates of ions and their Cooper pairs. If the system contains population inverted many-sheeted laser for which the increment of zero point kinetic energy corresponds to the energy of photons associated with negative energy MEs, the absorption of negative energy photons gives rise to a phase transition like dropping of particles to larger space-time sheet by the induced emission mechanism, and the control signal represented by negative energy MEs can be amplified if a critical number of particles drops to the larger space-time sheet. This control mechanism allows an instantaneous motor control in which intention is transformed to a desire represented by negative energy MEs and generates in geometric past a reaction representing the desired response, say neuronal activity giving rise to motor action. This process probably involves entire hierarchy of magnetic selves realizing their intentions as desires communicated to lower level magnetic selves and the lowest level corresponds to the regions of brain responsible for liberating metabolic energy.

3. Quantum criticality and $1/f$ noise

Criticality is one prerequisite of control: the controlled system must be initial value sensitive, that is critical, in some degrees of freedom. TGD universe is indeed quantum critical and the universality of $1/f$ noise serves as an empirical support for this. It is indeed known that $1/f$ noise is related to criticality but the problem is that critical systems are by definition unstable. This has led to the paradigm of self-organized criticality in which system is assumed to self-organize into a critical state. Since TGD Universe is quantum critical, this questionable assumption is not needed. The only coupling parameter of TGD is analogous to critical temperature and as a fundamental coupling constant is not subject to external perturbations.

4. The role of ELF fields in bio-control

Some evidence for the hypothesis that higher levels of the biological self hierarchy control biological body using fields at ELF frequencies (EEG frequencies are in ELF range) is discussed. The basic inputs are topological field quantization, the idea of memetic code and the observations about the effects of ELF em fields to brain suggesting that the higher levels of our self hierarchy correspond to em selves with sizes of order wavelength of photons generated by EEG currents and thus realized as topological field quanta having size of order of Earth.

Chapter 2

Quantum Theory of Self-Organization

2.1 Introduction

Self-organization [B13] seems to be closely related to the generation of fractal patterns and the book of Barnsley [A3] about fractals gives rather convincing arguments supporting the belief that a very general class of fractals can be regarded as fixed points of iteration. The space in which fixed point exists is rather abstract: typically it belongs to the set of subsets of some space, say, 3-dimensional Euclidian space. This fixed point can be a landscape, biosystem, ecological population, hydrodynamical flow,... For instance, the success of this receipe in reproducing even a virtual photo of a forest is amazing. Even evolution could be regarded as resulting from this kind of iterative process leading gradually to a fixed point.

One can even consider the possibility that iteration, if understood in a sufficiently general sense, could be the basic element of self-organization. There is no obvious manner how this iteration could result from the equations of the classical physics. For instance, Haken has been ready to consider the possibility that subsystems, even electron, are actually certain kind of computers, cellular automata and that the basic computational step would provide the required fundamental iteration step. Zero energy ontology assigns to electron fundamental time scale of .1 seconds, which is also a fundamental bio-rhythm so that this idea need not be so crazy as it looks first.

TGD suggests that the quantum jump between quantum histories could be the fundamental iteration step in very general sense of the world. Self-organization would have a completely new meaning as the evolution of the hierarchical structures formed by conscious entities - selves. The iteration step could be seen reaction of self to its state created in previous quantum jump involving also the interaction with external world essential for self-organization.

In TGD subjective time evolution corresponds to the sequence of quantum jumps $\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_f$, where U was originally thought to be the TGD counterpart of the unitary time evolution operator $U(-t,t)$, $t \rightarrow \infty$, associated with the scattering solutions of Schrödinger equation. It seems however uncessary and probably also impossible to assign any real Scrödinger time evolution with U. In zero energy ontology this is indeed the case. Zero energy states states correspond to pairs of positive and negative energy states having opposite quantum numbers and located at the opposite light-like boundaries of causal diamonds (CDs) defined as intersections of future and past directed light-cones (actually their cartesian products with CP_2). In zero energy ontology U defines a unitary matrix between zero energy states and is naturally assignable to intentional actions whereas the ordinary S-matrix telling what happens in particle physics experiment (for instance) generalizes to M-matrix defining time-like entanglement between positive and negative energy parts of zero energy states. One might say that U process creates a quantum superposition of possibilities and the remaining steps generalizing state function reduction select between them.

The basic challenge is to understand psychological time and its arrow and why the contents of sensory experience are localized in a narrow time interval. I have developed several proposals during years. The recent view [K4] relies on several new notions but zero energy ontology has had the strongest impact on the recent view. Single quantum jump corresponds to an average increment of psychological time identifiable as the temporal distance between the tips of CD coming as octaves of CP_2 time scale about 10^4 Planck times. Also the notions of quantum jump and self are unified as one and same thing since zero energy state itself can be seen as a physical event.

Quantum jump decomposes to quantum jumps performed by separate selves with self being defined as subsystem able to remain unentangled during sequential quantum jumps. State function reduction part of quantum jump corresponds to the measurement of density matrix for some subsystem of self (or equivalently, for its complement inside self). If each quantum jump involves localization in zero modes representing classical degrees of freedom entangled with quantal degrees of freedom within accuracy defined by the measurement resolution, the final states of quantum jumps are superpositions of macroscopically equivalent space-time surfaces. This would explain the classicality of the world of the subjective experience.

Negentropy Maximization Principle (NMP) states that in a given quantum state only one of the most quantum entangled subsystems can perform the quantum jump. The reduction of the entanglement entropy in the quantum jump is as large as possible: presumably the interpretation of entanglement entropy as some kind of information gain makes sense [K15] . Quantum jumps inside self imply dissipation crucial for self organization and quantum jump could be regarded as the basic step of iteration process. If self consists of a large number of nearly identical subselves, quantum statistical determinism implies that quantum jump can be interpreted as iterated map from the point of view of self. From the point of view of entire Universe this is certainly the case. NMP predicts that self organization and hence presumably also fractalization can occur inside selves. The existence of number theoretic counterparts of Shannon entropy in the case that entanglement probabilities are rational or algebraic numbers implies the possibility of negentropic entanglement so that NMP would force generation of entanglement. This notion is highly attractive since it could allow to understand how quantum selforganization generates larger coherent structures.

With respect to geometric time the contents of conscious experiences is naturally determined by the space-time region inside CD in zero energy ontology. This geometro-temporal integration should have subjecto-temporal counterpart. The experiences of self are determined by the mental images assignable to subselves (having sub-CDs as imbedding space correlates) and the quantum jump sequences associated with sub-selves define a sequence of mental images. The hypothesis is that self experiences these sequences of mental images as a continuous time flow. In absence of mental images self would have experience of "timelessness" in accordance with the reports of practitioners of various spiritual practices. Self would lose consciousness in quantum jump generating entropic entangelement and experience enlightment if the resulting entanglement is negentropic. The assumption that the integration of experiences of self involves a kind of averaging over sub-selves of sub-selves guarantees that the sensory experiences are reliable despite the fact that quantum nondeterminism is involved with each quantum jump.

Thus the measurement of density matrix defined by the $MM^\dagger$, where M is the M-matrix between positive and negative energy parts of the zero energy state would correspond to the passive aspects of consciousness such as sensory experiencing. U would represent at the fundamental level volition as a creation of a quantum superposition of possibilities. What follows it would be a selection between them. The choice between different maxima of Kähler function could be basically responsible for the active aspect of consciousness. The fundamental perception-reaction feedback loop of biosystems would result from the combination of the active and passive aspects of consciousness represented by U and M.

TGD indeed gives good hopes for understanding self-organization using quantum level concepts.

1. Quantum criticality of TGD suggests the existence of macroscopic quantum systems in all length scales so that quantum theory of self-organization might apply also in the description of the hydrodynamical self-organization. The proposed interpretation of dark matter in terms of a hierarchy of Planck constants requiring a generalization of the notion of imbedding space to a book like structure with pages characterized partially by the value of Planck constant leads to a similar prediction [K25] . On basis of some intriguing findings about planetary orbits the space-time sheets mediating gravitational interation are proposed to have gigantic values of Planck constant : the mysterious dark energy would corresponds to macroscopic quantum systems in astrophysical and even cosmic length and time scales [K67] .

2. Both p-adic length scale hierarchy and hierarchy of Planck constants suggest that evolution can be seen as a dispersion or migration like process in the world of classical worlds whose

sectors correspond CDs characterized by the positions of their tips, by the p-adic length scales characterizing the light-like 3-surfaces and also by the sizes of corresponding CDs as well as the page of the Big Book labelled by the value of Planck constant. Since the number of primes larger than given prime is infinite, one expects that p must increase in the long run. This would mean that the p-adic primes characterizing given light-like 3-surfaces tend to increase meaning also the increase of the size of the surface. A possible interpretation is in terms of cosmic expansion. Also NMP favours the increase of p and implies evolution and second law of thermodynamics since maximum entanglement entropy equal to maximum negentropy gain in quantum jump increases with p. The phase transitions increasing the value of Planck constant involve tunneling between the pages of the book like structure defined by the imbedding space, and generate quantum coherent space-time regions with increasing size. They would give rise to similar evolution. A possible interpretation is as a counterpart of quantum counterpart of cosmic evolution reduced to a sequence of phase transitions. These periods would correspond to accelerated cosmic expansion difficult to understand in standard cosmology. The model of EEG would be one concrete application of this vision. An open question is whether the two expansion like evolutions are independent or whether there is some connection between them.

3. The replacement of the point like particle with 3-surface brings in an infinite number of zero modes characterizing the shape and size of and the classical Kähler field (projection of CP_2 Kähler form) associated with the space-time surface $X^4(X^3)$ assignable to a given 3-surface X^3 having components at the boundaries of CD and its sub-CDs. Even macroscopic 3-surfaces behave like elementary particles in these degrees of freedom. These zero modes serve as fundamental order parameters, which in the ordinary theories of self-organization must be introduced in an ad hoc manner. As already noticed, localization in the zero modes within measurement resolution implies that the world of conscious experience looks classical and that time evolution in zero modes can be regarded as hopping like motion.

4. Long range quantum correlations are crucial for quantum self-organization. Quantum criticality is indeed basic aspect of quantum TGD. The preferred extremals of Kähler action having interpretation as generalized Bohr orbits are critical in the sense that there exist deformations of the space-time surface -actually infinite number of them- for which the second variation of Kähler action vanishes [K26] . The hierarchy of Planck constants implies the criticality against phase transitions changing the value of Planck constant and realized as a tunneling between the pages of the "Big Book" [K25] . This has many implications. Quantum criticality is characterized by long range quantum correlations and implies also fractality. The universality of $1/f$ noise, which is a direct consequence of criticality, is difficult to understand in standard physics context since critical systems are by definition unstable. Therefore the universality of $1/f$ noise could be seen as a direct support for quantum criticality of the entire Universe. From the real point of view self itself is a critical phenomenon. The exact vanishing of entanglement with external world is extremely unprobable and must be replaced with the vanishing of entanglement modulo finite measurement resolution. If one accepts the notion of number theoretic Shannon entropy, entanglement can be negentropic and instead of a loss of consciousness leads to enlightment experience. Also in this case the criticality is present since entanglement probabilities are not in general rational nor even algebraic.

5. Arbitrarily large join along boundaries condensates of 3-surfaces are possible by quantum criticality and this suggests the possibility of arbitrarily large macroscopic quantum subsystems. Especially interesting biological examples of join along boundaries bonds are chemical bonds, the MAPs connecting microtubules and gap junctions connecting cells. Join along boundaries bonds can also join mindlike space-time sheets.

6. The manysheeted space-time concept having hierarchical structure provides the realization of a fundamental slaving hierarchy at the level of the space-time geometry. p-Adic length scale hierarchy and the hierarchy of Planck constant make this hypothesis quantitative.

7. Spin glass analogy leads to an infinite-dimensional generalization of Thom's catastrophe theory and the maxima of Kähler function play the role of the minima of the potential function in Haken's theory of self-organization. Vacuum functional of TGD in turn is in the role of the generalized partition function appearing in Haken's theory.

8. Dissipation can be understood as caused by quantum jumps and occurs only inside selves. Dissipation leads to Darwinian selection of the asymptotic self-organization patterns and the selection of both genes and memes, in particular stable mental images, can be understood as resulting from quantum self-organization. Note that dissipation can be regarded as a direct signature of consciousness.

This picture allows to generalize Haken's classical theory of self-organization to quantum context. The sequence of quantum jumps can be regarded as hopping in zero modes and hence the situation is very classical, in fact much like in Brownian motion. In particular, the classical theory of the feature detection generalizes to quantum context. One can also generalize Haken's theory to describe how biosystem acts to external world; in this theory the active quantum jumps play the key role.

Rupert Sheldrake [I30] postulates the concept of morphic fields and morphic resonance making possible learning and memory at the level of species. The comparison with Rupert Sheldrake's concepts of morphic field and morphic resonance leads to interesting ideas about how learning at the level of species could occur quantum-mechanically. For instance, the phenomenon of biofeedback suggests that self could quite generally effectively act on its subselves. In zero energy ontology all quantum states have properties allowing to interpret them as memes or quanta of morphic fields and the challenge is to find their biological counterparts. DNA as topological quantum computer hypothesis suggest the identification of the biological memes as topological quantum computer programs assignable to the intronic portion of the genome and coded also by nerve pulse patterns. The notion of magnetic body as intentional agent leads to a concrete model for the morphic resonance as a transfer of topological quantum computation programs between separate brains with the mediary of the personal magnetic bodies and the magnetic body of Mother Gaia using EEG like communications. The model explains also 'alike likes alike' rule.

2.2 Quantum theory of self-organization

In the following basic ideas about self-organization and its quantum counterpart are introduced.

2.2.1 Basic characteristics of self-organization

Self organizing system corresponds typically to a system dissipating the energy feeded into it. Dissipation leads to typical self-organization patterns decomposing into more or less autonomous subsystems. Subsystems perceive the state of the external world and reacts to it. Human society is a typical example in which individuals or groups of them perceive and react. Self-organization is also critical phenomenon in the sense that new self-organization patterns are formed in phase transition like manner at the critical values of the parameters characterizing the interaction of the system with external world. Co-operatitivity, long range correlations and fractality, typical characteristics of critical phenomena, are involved with the emergence of new self-organization patterns. Also spontaneous symmetry breaking associated with the phase transitions changing self-organization pattern is a characteristic of self-organization process.

Iteration, understood in a very general sense, seems to be the basic element of self-organization. A good example is provided by cellular automata (game of life is the best known example). Automaton consists of cells, which perceive their surroundings and perform a decision to change their state according to some rule. Rule need not be deterministic but the dynamics dictated by it is irreversible. This is what makes it so difficult to understand how iteration might result from the reversible equations of physics and suggests that thermodynamics or some deeper principle behind thermodynamics is important.

Second example is camera, which monitors tv screen to which the picture taken by the camera is the feedback. This system exhibits typical self-organization patterns obtained by varying the direction angle of the camera with respect to the TV screen. Iteration is rather abstract process now: camera perceives the state of tv and reacts by sending a new picture to the TV screen.

Benard convection is a third standard example of self-organization. When liquid is heated evenly from below, a temperature gradient develops and at some critical value of temperature gradient, convection sets on. A flow pattern consisting of liquid cells is formed. The size and shape of cell as well as the pattern of liquid motion in cell depends on the parameters characterizing the situation (size and shape of the liquid vessel, the temperature difference,...). As temperature difference increases, more complicated flow patterns emerge: what happens is essentially that patterns of larger scale coherent motions emerge by the organization of the Benard cells to larger units.

Biosystems provide more complicated examples of self-organization. In this case self-organization has many hierarchical levels. First DNA and proteins together with genetic code are formed by self-organization at molecular level, then come monocellulars, multicellulars,..., individuals, families, social organizations,... Clearly, subsystems of previous level form combine to form larger coherent subsystems at the higher levels of self-organization. Here the basic interaction step is response to a response.

Iteration is clearly a 'social' process: subsystem perceives consciously the external world and reacts to it. Subsystem can in principle be any subsystem of the entire system so that the scenario is considerably more general than cellular automaton. The process can also create a subsystem such as Benard cell in Benard convection or a cell in biological evolution.

2.2.2 Self-organization as organization of self-hierarchies

TGD suggests that the quantum jump between quantum histories could be the fundamental iteration step of self-organinization with M-matrix related to the perception and U-process to the volitional act resulting as a reaction to the perception. Even more, self-organization has a completely new meaning in TGD. Self-organization can be identified as the evolution of hierarchical structures formed by conscious selves. Zero energy ontology, p-adic length scale hierarchy, and the hierarchy of Planck constants bring in additional refinements to the picture.

Quantum jump as the basic iterative step of self-organization

In TGD subjective time evolution corresponds to the sequence of quantum jumps

$$\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_f \ ,$$

where U represents unitary quantum mechanical "time evolution".

Quantum jump corresponds to the measurement of density matrix for some subsystem of self (or equivalently, for its complement inside self). In quantum jump a localization in zero modes (possibly modulo measurement resolution) takes place and the final states of quantum jumps are superpositions of space-time surfaces indistuingishable in the measurement resolution used This would explain the classicality of the world of the subjective experience. Quantum jump occurs also between two classical histories, say between solutions of reversible equations of hydrodynamics in Benard convection.

In zero energy ontology the view about quantum state as quantum history finds a more precise quantitative characterization through the notion causal diamond (CD).

Autonomous subsystems of self-organized system as selves

A crucial concept is that of self being defined as a subsystem able to remain unentangled during sequential quantum jumps. Self would lose consciousness when it entangles. What this statement really means is far from obvious and I have proposed several interpretations.

1. The idea that even slightest entanglement leads to a loss of consciousness does not sound realistic. This suggests that entanglement should be defined only modulo finite measurement resolution. System would be conscious only provided that its entanglement entropy with the external world is below the value defined by the measurement resolution. For hyper-finite factors of type II_1 the notion of finite measurement resolution is unvoidable. The concrete interpretation at space-time level would be that space-time sheets (subselves) topologically condensed at larger space-time sheets (selves) can be connected by flux tubes to form an entangled state. The selves represented by the larger space-time sheets would remain unentangled in the resolution applying to the systems themselves (flux tubes would be invisible in this resolution). This invisible entanglement would however give rise to a sharing and fusion of mental images implying what might be called stereo consciousness.

2. How the notion measurement resolution should be defined is far from obvious. p-Adication approach suggests that finite measurement resolution boils down to a pinary cutoff for the p-adic entanglement entropy represented as a series in powers of p. This pinary cutoff should have

also space-time correlate. For hyper-finite factors of type II_1 and type III_1 emerging naturally in quantum TGD entanglement entropy is always defined only modulo finite measurement resolution, which can be characterized in terms of inclusions of hyper-finite factors [K84] . The included factor defines the measurement resolution in the sense that its action creates states not distinguishable from the original in the resolution used. There should exist a connection between the two approaches.

3. A further complication is due to the fact that also the p-adic variants of Shannon entropy obtained by replacing the logarithm of probability with the logarithm of the p-adic norm of probability make sense if entanglement probabilities are rational or have values in some algebraic extension of rationals. The fact that number theoretic entanglement entropy can be negative it especially attractive from the point of view of consciousness theory and also quantum computation since entanglement indeed carries information. There is also a temptation to identify evolution as the emergence of increasingly complex systems having negative entanglement entropy. The generation of negative entanglement entropy could correspond to a kind of enlightment experience-fusion to a sea of consciousness- instead of a loss of consciousness.

4. This forces to reconsider the original vision that everything is conscious but consciousness can be lost as the system entangles in U process. U process generates highly entangled states and the sub-sequent state function reduction (possibly modulo measurement resolution) repeatedly decomposes the Universe (or CD) into unentangled pairs of subsystems. The process stops for any subsystem for which all subsystem pairs have either bound state entanglement or negentropic entanglement. If the bound state entanglement is entropic, the entangled subsystems lose consciousness. If the entanglement beween the subsystems in negentropic the process stops but subsystems remain conscious. Mystics might associate the entropic entanglement to what they calls attachment and negentropic entanglement to a relationship which they might characterize as love.

5. Zero energy ontology brings in additional aspects. Zero energy states correspond to entangled pairs of positive and negative energy states located at the opposite light-like boundaries of a given causal diamond (CD) defined as the intersection of future and past directed light-cones. Strictly speaking a Cartesian product of CD with CP_2 is in question. CDs form a fractal hierarchy. In the ordinary ontology zero energy state corresponds to a physical event. The time-like entanglement between positive and negative energy states defines M-matrix generalizing the notion of S-matrix. Time-like entanglement must be fundamental also from the point of view of consciousness as a reduction of quantum state to a state with well defined values of observables for the initial (positive energy) and final (negative energy) states.

The identification of the space-time correlates of selves is not so obvious as one might think. One can imagine three options. The space-time correlates of selves are space-time sheets or CDs or somehow combinations of these two.

1. If space-time sheets serve as correlates for selves, the space-time correlate for the entanglement is the presence of join along boundaries bonds connecting the space-time sheets serving as correlates for selves. The entanglement which corresponds to join along boundaries bonds associated with subselves (smaller space-time sheets topologically condensed at the space-time sheet representing self) is below the measurement resolution assignable to self. In this kind of situation selves remain conscious whereas subselves loose consciousness for positive entanglement entropy and fuse to form single stereo mental image of self. For negative entanglement entropy subselves would remain conscious.

2. In zero energy ontology [K18] one is forced to ask whether the notion of self should be defined at the level of imbedding space rather that at the level of space-time sheets so that a given CD would serve as a correlate for self. This identification leads to a beautiful argument for how the arrow of subjective time, the flow of subjective time, and the localization of the contents of conscious experience around a narrow time interval takes place [K4] . There is no reason for why CDs should not be allowed to overlap and this overlap would be a natural correlate for the sharing and fusion of mental images. Both of these identifications look natural and one can argue that the geometric correlates of self exist at both imbedding space and space-time level.

3. If both space-time sheets and CDs serve as correlates for selves, the join along boundaries bonds would connect space-time sheets associated with the two CDs and would belong to their intersection. One can also require that the CDs are at the same p-adic level of hierarchy. In other words, CDs correspond to the same value of p-adic prime near a power of two meaning that the temporal distance between the tips of CDs is same octave of CP_2 time for the standard value of Planck constant. The hierarchy of Planck constants [K25] means an additional complication in this picture but does not bring in anything essentially new.

One should also understand how the experience about the flow of subjective time emerges.

1. It seems obvious that quantum jumps must somehow integrate to self: quantum jump would be the elementary particle of consciousness and self the many particle state -possibly bound state (one can of course wonder what the notion of bound state means in case of zero energy states: can one say that positive and negative energy parts of the state form a bound state?) This analogy and the identification of zero energy states as events suggests that the notion of self could be reduced to that of quantum jumps so that self hierarchy would correspond to a hierarchy of quantum jumps within quantum jumps and also to the hierarchy of CDs within CDs.

2. The state function for the zero energy state should create the fundamental experience about time flow. The value of the time increment associated with the quantum jump would be determined by the temporal distance between the tips of CD and determine the interval about which the contents of consciousness is about. Note that for quantum states identified as time equal to constant snapshots quantum jump cannot give rise to an experience about flow of time since information about two values of geometric time is not present. Before zero energy ontology the proposed way out of this problem was the failure of classical determinism in the standard sense and zero energy ontology could be seen as a manner to formalize this failure.

3. The fractality of zero energy ontology implies that zero energy states are analogous to self-organization patterns and that a sequence of quantum jumps leads to an asymptotic self-organization pattern in 4-D sense. The M-matrix defining the generalization of S-matrix is indeed a "complex square root" of the density matrix so that statistical and thermodynamical aspects are present already at the fundamental level.

Since self behaves effectively like a separate autonomous universe, an attractive hypothesis is that the typical decomposition of self-organized system to almost autonomous subsystems corresponds to the decomposition of universe to selves. This means very close connection between self-organization theory and theory of consciousness.

1. The hierarchy of selves corresponds geometrically to the hierarchies of space-time sheets and CDs and defines obvious counterpart for the nested slaving hierarchies of self-organized systems with the property that the system at given level of hierarchy serves as a master for the lower level systems inside it. Zero energy ontology implies that physical state itself corresponds to a physical event is more like a process than state so that self-organization is basically evolution of temporal rather than spatial patterns. In neuroscience this has dramatic implications for the model of long term memories and also for the models of sensory perception and motor action.

2. Although active quantum jump itself is nondeterministic, quantum statistical determinism implies that the time evolution by quantum jumps is predictable at the limit of large self having large number of subselves. In this quantum evolution is a genuinely iterative process in the space of distribution functions for various types of selves with iteraction step defined by state function reduction for zero energy state (perception) following by the volitional act representing the reaction creating a superposition of possibilities (U-process). At the level of the large sub-selves there is always non-predictability involved. This feature could make it possible to understand the special features of biological self-organization. A good example is the behavior of group of people who meet for the first time: self-organization leads rapidly to an adoption of simple social roles. In this kind of self organization both active and passive quantum jumps play important role.

3. If the notion of number theoretic entropies is accepted, the generation of larger quantum coherent structures by the generation of rational or algebraic entanglement is favored by NMP. This feature distinguishes quantum TGD from other quantum theoretic approaches to self-organization and could allow to understand the miracle like phenomena occurring in the evolution of the living matter. One can ask whether this process is always involved in the phase transitions generating larger coherent structures (also the increase of Planck constant and p-adic length scale could be involved).

2.2.3 Dissipation and quantum jumps between histories concept

The phenomenon of dissipation is paradoxical from the point of view of standard physics. It is generally accepted that fundamental laws of physics are reversible but everyday reality is manifestly irreversible. Thus the situation is rather schizophrenic. Two worlds, the reversible and extremely beautiful world of fundamental physics and the irreversible and mathematically rather ugly 'real' world, seem to exist simultaneously. The description of dissipation is highly phenomenological: one introduces mathematical monsters like non-Hermitian Hamiltonians; in particle physics particle decay widths are introduced by making energies complex; in macroscopic length scales one introduces parameters like friction coefficients, viscosity, diffusion constants, etc.. The mathematical beauty of the reversible world is lost and dissipation becomes an unavoidable nuisance of physics, which perhaps explains why so little conscious thought is devoted in the attempts to understand why these two worlds seem to co-exist.

This schizophrenic world picture is of course logically inconsistent. Something in the implicit assumptions underlying this paradoxical world view must be wrong. Quantum jump between quantum histories concept indeed resolves the paradox and explains the apparent existence of two worlds as resulting from a wrong view about psychological time. Without quantum jumps there would be single reversible reality behaving determistically and there would be neither dissipation nor consciousness. Quantum jumps between the reversible realities however cause dissipation, which can be more correctly seen as a self organization via quantum jumps and as a necessary prequisite for evolution and consciousness. The source of all the ugly mathematics related to the description of dissipation is the failure to realize that there are two time developments: subjective time development proceeding via quantum jumps and geometric time development described by the dynamical equations without dissipation. The ugly dissipative terms in dynamical equations result, when the sequence of quantum jumps between time developments is replaced with single dissipative time development. One can very loosely say that the dissipative world is envelope for the classical worlds, one classical world per CP_2 time. Or more concretely, dissipative space-time surface is the space-time surface going through a sequence of 3-surfaces defined by the values of psychological time measured using CP_2 time as unit.

Dissipation can be seen as a phenomenological description for the tendency of the self-organizing development by quantum jumps to lead to fixed points, limit cycles, limiting tori, strange attractors, etc.. in the space of quantum histories. In this description irreversible time development is 'almost' envelope for the family of reversible time developments defined by quantum jumps: various parameters characterizing dissipation describe the deviation from the exact 'envelopeness'. Hence the study of chaotic dissipative systems could be also seen as a study of the phenomenological descriptions for the asymptotic behaviors yielded by the time development by quantum jumps. It is not of course clear whether this kind of effective description really works always or whether one should replace it by a genuine quantum description under some circumstances.

Consider as an example the description of a self organizing system using Haken's theory of self-organization relying on the hypothesis that system's states correspond to the minima of free energy function. Free energy depends on external parameters. When the value of some external parameter becomes critical, large fluctuations in long length scales occur and new level of self-organization with new length scale emerges or disappears in a phase transition like manner. For instance, potential well can split into two potential wells and system selects either well. This suggests that near the critical values of the external parameters quantum statistical determinism and hence also effective description fails at macroscopic length scales. The catastrophic changes in system's behavior could correspond to macroscopic quantum jumps. Biosystems obviously provide excellent candidates for critical systems. Since TGD Universe is quantum critical, any subsystem is basically critical system: only the time scale of the critical fluctuations determines whether given system looks critical from human point of view. In particular, selves are critical systems since the increase of the real entanglement above critical value means disappearance of self. Since time development corresponds to hopping in zero modes which are the fundamental order parameters in TGD framework, the picture of Haken applies almost as such as far as development in zero modes is considered. An interesting question is whether the criticality in zero modes actually corresponds to criticality for the disappearance or occurrence of new self.

Dissipation can be seen as an extremely concrete proof for the hypothesis that quantum jumps between quantum histories occur all the time. However, to possibly convince colleagues about this, very delicate experiments must be invented (say tribar effect testing the new concept of psychological time described in [K45] ! The crucial demonstration is however at the level of mere logic: 0 and 1 are the numbers needed, no experiments testing 10:th decimal for some quantitative prediction are needed.

Dissipation can be seen also as direct signature for consciousness and existence of selves Any system, which has ability to dissipate, to grow older, must have moments of consciousness in some length scales. Living systems are not the only systems growing old. Buildings and cars and computers grow old. Hydrodynamic flow without external energy feeded gets older by gradually losing its velocity- (and Z^0 magnetic-) vortices. The rate of the energy loss by dissipation could be even seen as a rough measure for the level of consciousness.

The crucial question is however in which length scales quantum jumps occur: does all the dissipation occur in atomic length scales as standard physics strongly suggests or are all length scales involved as quantum criticality of TGD and new TGD based space-time concept suggest. Hydrodynamic flow is especially interesting example in this respect. The TGD based model for turbulent flow [K38] . with external energy feed assumes that dissipation occurs in all length scales: the decay of vortices of given radius to smaller vortices should therefore involve primitive consciousness in the length scale of the vortices. In turbulent flow with external energy feed there is stationary energy flow between space-time sheets of various sizes and this means that the level of consciousness, if indeed measured by energy dissipation, is same at various p-adic length scales involved. In this picture life as we know it, is a result of continual quantum self-organization of the sea water: indeed, we are 70 per cent of sea water.

One can represent an objection against above line of reasoning. The dissipative parameters of classical dynamics certainly make it ugly but this description is very practical. Should one really give it up at the fundamental level? This need not be the case. The above argument mentions nothing about quantum classical correspondence, which in its strongest from requires that also quantum jumps sequences and therefore also dissipation should have space-time correlates. The failure of the classical detgerminism in the standard sense of the word for Kähler action caused by its immense vacuum degeneracy forces to replace space-like 3-surfaces with unions of space-like 3-surfaces with time-like separations so that there are good reasons to hope that these space-time correlates exist. In this framework zero energy ontology based on the notion of causal diamond is very natural. In zero energy ontology unitary S-matrix is replaced by a "complex square root" of the density matrix decomposing to a product of diagonal density matrix and unitary S-matrix and defining the time-like entanglement coefficients between the positive and negative energy parts of the zero energy state. Therefore thermodynamics becomes a part of quantum theory. Quantum classical correspondence in turn requires t that thermodynamical parameters have space-time correlates so that the ugly formulation of the dissipative dynamics at space-time level might allow a replacement by something more elegant. This seems to be possible. The quantum numbers characterizing zero energy states couple directly to space-time geometry via the measurement interaction term of the modified Dirac action [K26] and thermodynamics would naturally couple to the space-time geometry via the thermodynamical or quantum averages of the quantum numbers.

2.2.4 Co-operativity, long range correlations, zero modes and quantum entanglement

The generation of the long range order is one of the basic characteristics of the self-organized systems (the formation of Benard cells in Benard convection, the formation of Taylor's vortex belts in the rotation of a cylinder containing fluid, concentration patterns in Belounow-Zabotinsky reaction). In Benard convection the long range order corresponds to the formation of the Benard cells, whose size and shape depend on the temperature difference and the size and the shape of the vessel. In TGD Universe long range order can be generated in two manners.

The generation of long range order seems to be in contradiction with the fact that the increase of the energy feed should destroy macroscopic quantum bound states. For instance, in the case of Benard convection one could ask why one should not regard the stationary initial state as the state with maximal long range order. A possible way out of the dilemma is the fractal structure of the spin glass energy landscape. The external energy feed drives the system from the bottom of the energy valley which corresponds to a product of uncorrelated valleys, and it sooner or later ends down to the bottom of a deeper energy valley corresponding to a more stable state for which there are long range correlations between the degrees of freedom associated with the values of the initial valleys.

Entropic quantum entanglement between two selves destroys them as separate selves and creates higher level self, which behaves like single system. In the case of negentropic entanglements selves do not lose consciousness but its expansion. At the level of conscious experience this means a formation of a 'whole' form its parts. An interesting question relates to the importance of quantum entanglement in self-organization and how closely it corresponds to the formation of long range correlations. 'Ontogeny recapitulates phylogeny' metaphor suggests that quantum entanglement is geometrically realized as the formation of join along boundaries contact and this would suggest that generation of quantum entanglement requires a direct contact interaction in four-dimensional sense (particle exchange for Feynman graphs). In biosystems the quantum entanglement between cells could be generated during the replication of cell or via the mediation of magnetic flux tubes which are in key role in the model of DNA as topological quantum computer [K24] . For instance, in Benard convection heating could lead to decay of fluid particles and create quantum entanglement between the degrees of freedom associated with distant fluid particles. Also the formation of join along boundaries contact condensates of large size (recall quantum criticality) could be involved in the formation of hydrodynamical quantum entanglement.

Zero modes are the fundamental order parameters in TGD framework.

1. Zero modes characterize the size, the shape, and the classical Kähler field of the space-time surface, and are purely classical variables in the sense that a complete localization for them is in principle possible in each quantum jump.

2. It is not quite clear to me whether the nonexistence of metric based volument element in zero modes forces the wave functions in zero modes to have a discrete locus. There certainly exists a symplectic measure defined by the symplectic form in zero modes. It does not however allow a complexification to Kähler form as it does in quantum fluctuating degreees of freedom. This symplectic from could define a hierarchy of integration measures coming as restrictions of $J \wedge J ... \wedge J$ with n factors to $2n$-dimensional sub-manifolds. Under some additional conditions- maybe the homological non-triviality of J and the orientability of the sub-manifold are enough, this measure would define a positive definite inner product and one would have a hierarchy finite-dimensional sub-spaces of zero modes. The maxima of Kähler function with respect to zero modes replace naturally the continuum with a discrete set of points and define the counterpart of the spin glass energy landscape consisting of the minima of free energy. Effective finite-dimensionality and even effective discreteness would be achieved.

3. Zero modes give rise to long range correlations in purely classical sense. This means that even macroscopic 3-surfaces can behave like elementary particles in zero modes: tornado is a good example of a locally chaotic particle like object.

Neural plasticity can be regarded as a self-organization. Sperry observed that when one splits the optical nerve of a frog, the nerve ends fuse again and frog begins to see [B2] . It seemed obvious that nerve ends recombine randomly and a genuine self-organization was in question. This hypothesis can be tested by rotating the eye of the frog by 180 degrees and looking what happens. If frog begins to see normally, genuine neural plasticity and self-organization is in question. If the field of vision is reverted then self-organization is not in question and nerve ends must somehow recognize each other, perhaps chemically. It was found that the frog begins to see things upside-down! A bad blow for self-organization paradigm at that time! Later it was however found that neural plasticity is a real self-organization phenomenon.

An interesting possibility (having at least entertainment value) to explain the disappointing result about frog's eye without losing the faith to self-organization in this particular case. Quantum entanglement might correlate the ends of the split nerve to form single coherent unit and to find each other after splitting. Biotelepathy would be in question. If this were the case, the paradoxical results of these experiments could be regarded as a direct support for biosystems as macroscopic quantum systems. In the same spirit one could also consider the possibility that the fundamental reason for why replication (and also pairing) occurs in biosystems is that replication and pairing creates quantum entangled systems just like the annihilation of photon creates quantum entangled pair of charged particles. In fact, it has turned out that the most elegant model for brain functioning results when one assumes that primary sensory qualia are experienced at a sub-cortical level, presumably at the level of the sensory organs. Quantum entanglement between brain and sensory organs and the TGD based view about long term memory allow to circumvent various objections against this view.

The model for DNA as topological quantum computer relies on the assumption DNA and lipids of nuclear and cell membranes are connected by magnetic flux tubes carrying dark matter. These magnetic flux tubes would appear quite generally and explain the miraculous looking phenomena like bio-catalysis, DNA replication, translation, and transcription based on the ability of biomolecules to find each other in a dense soup of bio-molecules. The basic mechanism would be the contraction *resp.* expansion of the flux tube induced by the reduction *resp.* increase of Planck constant. The phase transitions of gel phase would be based on this process and on the reconnection of magnetic flux tubes changing the topology of the web formed by the flux tubes.

2.2.5 Self organization requires external energy feed

Essential for the self-organization is external energy feed (Benard convection and even the general intuition about biosystems as systems living in the boundary between chaos and order). This can be understood on basis of Negentropy Maximization Principle [K46] . Only bound state entanglement is stable against the self measurement cascade giving rise to a state preparation during quantum jump. When the system is subject to energy feed the bound states formed by the fused subselves decay and thus the number of selves increases and the system become more complex. Each self defines a self-organization pattern. At the level of very large energy feed system becomes chaotic.

The same principle applies in the case of brain and the level of metabolism determines whether brain is in a deep meditative state empty of mental images or in a chaotic state of high arousal. In [K66] a model of cognition based on the generation of hierarchical self cascades is proposed. Metabolism gives rise to the energy feed generating subselves. During meditation the energy feed is minimal and sub-selves bound state entangle to for very few sub-selves and a state of "one-ness" results. The fusion gives rise to a stereo consciousness (analogous to stereo vision resulting when left and right visual fields fuse).

In zero energy ontology zero energy state is quantum superposition over states with different energies of the positive energy state. Also super-position of states having different fermion numbers for positive energy state is possible as in case of coherent state of Cooper pairs. Thermal equilibria define square roots of special kind of zero energy states. In this framework the energy feed to the system means that the quantum superposition changes in such a manner that the average energy of the positive energy state increases. This excites new degrees of freedom and makes the system more complex. The dissipation caused by quantum jumps reducing entanglement entropy tends to reduce the average energy and this tendency is compensated by the energy feed selecting also the most stable self-organization pattern as a flow equilibrium.

2.2.6 Many-sheeted space-time concept and self-organization

TGD replaces ordinary space-time concept with a hierarchical structure of space-time sheets. For instance, in a proper TGD based description of Benard convection, there is hydrodynamics at each space-time sheet. The sheets of 3-space, which can be regarded basic units of flow (say vortices) at a given p-adic length scale appear as particles at larger space-time sheets. Space-time sheets form in a natural manner master-slave hierarchy: we must in general adopt our behavior to the slow dynamics of external world. This picture has counterpart at the level of CDs.

The original formulation of quantum TGD led to the conclusion that there are two kinds of space-time sheets: material space-time sheets and mindlike space-time sheets so that one can say that Matter Mind duality is realized in geometrical sense: of course, Mind is understood in the sense of cognitive representations only. What one means with mind like space sheets is however not at all obvious.

1. The original proposal was that mind like space-time sheets have a finite temporal extension. In zero energy ontology this holds true for all space-time sheets so that all space-time sheets are mindlike if this criterion makes sense. This could make perfect sense. For instance, the fermionic part of zero energy state can be regarded as a logical rule $A \to B$ with the instances of A and B represented as positive and negative energy fermion states in Fock basis: the Fock basis for many-fermion states indeed defines a representation of Boolean logic.

2. Mind like space-time sheets could be also interpreted as p-adic space-time sheets responsible for cognition whereas real space-time sheets would be matter like in the sense that they define the space-time correlates of sensory experience. The intersection of p-adic and real worlds is along rational and common algebraic points of the imbedding space and is discrete (note that this statement assumes the identification of preferred imbedding space coordinates). p-Adic space-time sheets could serve as natural correlates of cognition and intentionality and their interaction with real space-time sheets could give rise to effective p-adic topology crucial for the interpretation of p-adic mass calculations. p-Adic space-time sheets have infinite size in real topology so that cognition and intentionality could not be localized in brain. Only the cognitive representations defined by the intersections of real and p-adic space-time sheets allow this localization.

3. p-Adic space-time sheets can be mapped to real space-time sheets via a generalization of the canonical identification map which is continuous and maps rationals m/n,$m,n < p^k$, $k > 0$. to rationals. The explicit form of the map is $m/n \to I_k(m)/I_k(n)$, with $I_k(m)$ defined as

$$x = \sum x_n p^{nk} \to \sum x_n p^{-nk} \quad .$$

   This map could define the effective p-adic topology for real space-time sheets in finite measurement resolution reducing to discretized real topology above distances defined by the p-adic length scale corresponding to p^k. Below the resolution length scale the impossibility to well-order p-adic numbers would correspond to the impossibility to order space-time points by physical measurements. What makes this map attractive is that it commutes with the discrete counterparts of various space-time symmetries in the resolution defined by p^k and is also continuous.

NMP tells that the subsystem with maximum quantum entanglement can perform quantum jump and in this quantum jump previous flow is replaced with a new one. In positive energy ontology one could argue that hydrodynamical equations alone can *never* give rise to the self-organized pattern of the Benard flow as asymptotic solution. In zero energy ontology relying on the failure of standard form of the classical determinism one can imagine the possibility that also the sequence of quantum jumps representing the self-organization process leading to the final pattern has space-time surface as a representative. The space-time sheets associated with the temporal sequences of sub-CDs could represent various steps in the self-organization process whereas the CD itself would represent the outcome of self-organization but in longer length and time scale (the sizes of CDs would come as powers of two). Larger CD could also code the asymptotic self-organization pattern in terms of external parameters such as energy feed dictating it and represented as long range classical fields.

TGD suggests a model of nerve pulse and EEG based on Josephson junction defined by cell membrane. More generally, the hierarchical structures formed by weakly coupled super conductors of various types seem to provide a very elegant general realization of conscious quantum control. Josephson junction networks are known to be self-organizing systems. The coherent light created by linear bio-structures, such as microtubules and possibly also DNA, is also a school example of self-organization [B13] . A gradual generation of phase coherence could in this case make possible the coherent oscillations of entanglement making possible self-organizing quantum jumps.

2.2.7 Infinite primes and self-organization

p-Adic length scale hypothesis stating that the typical size of 3-surface is of order $L_p \simeq l\sqrt{p}$, l about CP_2 size, suggests that the p-adic prime associated with the 3-surface representing entire infinite universe is infinite. The construction of infinite primes [K35] suggests that the decomposition of infinite primes to finite primes corresponds to the decomposition of space-time surface or at least light-like 3-surfaces to regions obeying effective p-adic topology characterized by an finite prime.

This would mean that the effective p-adic topology in a particular sector of configuration space corresponds to infinite prime P coding in very well defined sense the decomposition of $X^4(Y^3)$ to p-adic regions obeying finite-p p-adic topology and also providing the effective topology of $X^4(Y^3)$ in asymptotic regions of it: this would explain the success of physics based on real numbers.

The often stated intuitive belief is that real topology corresponds to the limit of p-adic topology as p approaches infinity. I must admit that I have not really understood this statement although it certainly makes sense if one considers solutions of polynomial equations with integer coefficients interpreted as equations in p-adic number field. In any case, this raises the question whether infinite primes could define p-adic topologies as such in the same manner as finite primes do. One can also consider the formulation of perturbation theory in powers of infinite prime p and thus containing only two non-vanishing orders. If one modifies the canonical identication to $I_k(m/n) = I_k(m)/I_k(n)$ defined previously, finite rationals are mapped to themselves already for $k = 1$ and infinite-p p-adic topology is more or less equivalent with the restriction of the real topology in the field of rationals.

Infinite-p p-adic space-time surfaces and real space-time surfaces would have rational points of imbedding space in common and the topology would be the same real topology in the set of rational points. This applies also at the level of configuration space where point corresponds to 3-D light-like 3-surfaces. The number theoretic anatomy of the infinite prime would however code for the p-adic effective topologies of the light-like 3-surfaces characterizing the space-time surface via quantum holography: this decomposition corresponds to the structure of a particular point of the world of classical worlds.

There is entire hierarchy of infinite primes and infinite prime in general decomposes to infinite primes belonging to the lower level of infinity and at the bottom of this decompositional hierarchy are finite primes.

1. Infinite primes form a hierarchy such that infinite primes p_N at level N decompose in a well defined manner to infinite primes p_{N-1} at level $N-1$, which in turn.... decompose into infinite primes at the lowest level, which in turn decompose into finite primes.

2. The infinite primes of level $N-1$ label single boson and single fermion states of a supersymmetric theory. Therefore each infinite prime at level N corresponds formally to a many-particle state consisting of bosons and fermions. Those primes of level $N-1$ for which fermionic or bosonic occupation number are non-vanishing, define the entire system. 'Ontology recapitulates phylogeny' metaphor suggests that the occupied infinite primes correspond to space-time regions appearing in the decomposition of the space-time surface to regions with different effective p-adic topologies. Thus the effective topology of D_P and the spectrum of p-adic topologies for the space-time surfaces in D_P correspond to each other in one-to-one manner.

3. The occupied fermion states of level $N-1$ are analogous to a subsystem of the manyparticle state formed by fermions and bosons. By b), this subsystem corresponds to a union of p-adic regions of the entire space-time surface. A very tempting identification of this region is as the sub-universe to which NMP applies in the quantum jump. The sub-system of this sub-universe winning negentropy gain maximization race makes the quantum jump.

4. Actually space-time sheets identified in this manner form an entire hierarchy since similar decomposition occurs for each infinite prime at level $N-1$. The lowest level corresponds to infinite primes having decomposition to finite primes.

p-Adic evolution means that the infinite prime associated with the space-time surfaces appearing in final states of quantum jump increases in the long run. The increase of the p-adic primes associated with finite space-time regions in the long run and implies also the increase of infinite prime. This means that evolution at global level is implied by local evolution.

2.2.8 Illness as a failure to self-organize properly

One can consider two definitions of illness.

1. Structural illness: Illness as a loss of quantum coherence at some level. For instance, some group of neurons fails to form a quantum coherent system.

2. Functional illness: Illness as the failure to self organize effectively. For instance, cancer cells fail to organize to larger coherent units and behave in a selfish manner. Here Negentropy Maximization Principle relying on number theoretic variants of Shannon entropy suggests a manner to understand illness.

Actually, 1) might reduce to 2) since biosystems are not static systems but more like vortices in a stream with fluid particles being replaced with new ones all the time: self-organization creates various subsystems again and again. In zero energy ontology the equivalence of the two definitions would be even more natural.

It seems indeed possible to understand the illness qualitatively in TGD based theory of self-organization. In TGD framework one can envision living system as a dynamical hierarchy of selves. For instance, cognitive acts corresponds to self cascades, our thoughts correspond to subselves as also do various components of sensory experience. In this picture illness is pathology resulting from the inability of some subselves to remain conscious so that higher level self are not able to form mental images crucial for the survival. Some subsystems lose consciousness, and the system could be said to be ill.

The mathematical correlate for the loss of consciousness would be entropic entanglement with the external world. Subsystem can remain conscious by keeping the entanglement entropy below the maximum value defined by the measurement resolution or by generating negentropic entanglement. A superposition of states with both negentropic and entropic entanglement is generated in U-process and the subsequent process involves many selections.

1. One of them is state function reduction for M-matrix reducing as a special case to what is known as state preparation (reduction) for the positive (negative) energy part of the state. Since quantum numbers of the positive energy part of the zero energy state couple directly to the space-time geometry [K26] , quantum numbers are mapped to classical variables (zero modes) in state function reduction in accordance with the basic hypothesis of the standard quantum measurement theory.

2. The selection of quantization axes is a further choice and means a localization to a particular sector of WCW for which the geometry of causal diamonds codes for the preferred measurement axis. A selection of single CD from quantum superposition of CDs would mean localization of the lower and upper times of CD. This does not seem to be consistent with the assumption that energy momentum eigenstates are in question and only approximate localization is expected to be possible. A further selection is selection of the page of the Big Book defined by the generalized imbedding space meaning also a selection of the value of Planck constant.

3. An example about a more abstract choice could be the selection between entropic and negentropic entanglement. If this choice, which essentially means selection of rationals from the continuum of reals or p-adics, is possible it could serve as the physical correlate for the choice between good and evil. One might argue that this selection is made possible at space-time level by the intersection of real and p-adic variants of the imbedding space. At configuration space level it could correspond to a more abstract intersection with the counterpart of rationals identified as light-like 3-surfaces represented by rational functions with rational coefficients identifiable as common to real and p-adic worlds. State function reduction to the intersection of p-adic and real worlds would induce also the rationality of entanglement probalities since they must make sense both p-adically and in real sense. One might say that the enlightment means living in both real and p-adic world simultaneously.

4. These two interpretations for the intersection of real and p-adic worlds need not be independent. The absence of definite integral in p-adic number fields suggests that the transition amplitudes between p-adic and real sectors must be expressible using only the data associated with rational and common algebraic points (in the algebraic extension of p-adic numbers used) of imbedding space. This intersection is discrete and could even consist of a finite number of points. For instance, Fermat's last theorem tells that the surface $x^n + y^n = z^n$ contains only origin as rational point for $n = 3, 4, ...$ whereas for $n = 2$ it contains all rational multiples of integer valued points defining Pythagorean triangles: this is due to the homogenity of the polynomial in question. Therefore p-adic-to real transition amplitudes would have a purely number theoretical

interpretation. One could speak of number theoretical field theory as an analogy for topological field theory.

Why selves would then tend to chose the evil? Perhaps the reason is that this choice almost decouples the system from the external world and provides maximum freedom for action wheras strong negentropic entanglement reduces the number of degrees of freedom. The freedom is nice as long as the system is able to keep the entanglement entropy below the critical value and therefore avoids death as the prize of the sin. Note that even if the system identified at a given level of hierarchy behaves a saint, it probably happens that some of its subsystems are sinners. This conforms with the interpretation that meditative states involve minimum number of mental images so that there are not many sub-systems performing tge wrong choices. One can of course claim that the sinners are needed since they lead to the re-organization and evolution of the system by destroying existing structures based on negentropic entanglement. Eternal life would be a catastrophe since it would not allow any evolution at all.

One could say that a healthy system consists of maximally alert subsystems able to stay wake-up by generating negentropic entanglement. This raises the question what 'getting tired' means.

1. Getting tired could mean death of mental images: the entanglement of sub-selves with the external world becomes entropic and nearly critical leading eventually to the death of mental images and the system becomes drowsy. If also the system itself generates entropic entanglement it falls into sleep identified as a loss of consciousness. The interaction with the external generates mental images and these subselves in turn tend to generate also entropic entanglement since only few of them are saints. This would mean that the dying of mental images is equivalent with getting tired.

2. In principle it would be possible to remain conscious by generating negentropic entanglement instead of sleep and perhaps meditative practices allow to achieve this. The question is why ordinary people are not able to achieve this by just getting tired. The first thing to notice is that meditators tend to get rid of their mental images. The sensory input and also thoughts are systematically eliminated. If entanglement entropy for the system is sum of the entanglement entropies of the various levels in the hierarchy assignable to the system (hierarchy of CDs and space-time sheets) then englightment is facilitated by enlightment at lower levels and getting tired by entropic entanglement of mental images tends to lead to a loss of consciousness at the higher levels. Meditative practices indeed emphasize whole body consciousness achieved by exercises involving directed attention to all body parts. If all levels of the self hierarchy below given level contribute to the entanglement entropy then all length scales below the given length scale are relevant for the ability of the system generate negative entanglement entropy. Unless highly negentropic entanglement is possible in longer length scales (say at dark space-time sheets) the evolution of consciousness must proc

3. The proposed interpretation means that sleep identified as a loss of consciousness is in a well-defined sense regression. One can of course ask whether sleep really means a loss of consciousness: could it be that only memories are lacking from this period? Even if a loss of consciousness is in question as the arguments above suggest sleep could have many vital functions. For instance, the resting state would mean absence of sensory input at various levels and the absences of mental images would make easier for the subsystems to generate negentropic entanglement by meditating. Note that one can even consider the possibility that conciousness always means negentropic entanglement.

From the energetic point of view metabolism means the transfer of the metabolic energy from the nutrients to the system. This energy is ordered energy so that the energy feed can be seen as a feed of negentropy. One could perhaps say that biosystem 'eats' negentropic entanglement or the ability to generate it.

1. The chopping of the nutrient molecules to their basic building bricks and the reconstruction of proteins and other bio-molecules from them would detach from the nutrient molecules the negentropic entanglement and leave only the waste having entropic entanglement with the external world. This raises some questions. How the interaction of the biomolecules of the body

with the molecules of the nutrient leads to the transfer of the negentropic entanglement? Is the negentropic entanglement assignable to particular parts of the nutrient molecule transferred to the receiving system? How the fundamental ADP→ATP Karma's cycle relates to the transfer of entropic entanglement? Is phosporus ion perhaps a standardized negentropic entangler?

2. If magnetic flux tubes carrying dark matter serve as correlates for entanglement and also directed attention as assumed in the model of DNA as topological quantum computer [K24] then the transfer of negentropic entanglement would correspond toa re-connection of the magnetic flux tubes having direct information theoretic interpretation since the flux tubes serve as a correlate for the program of topological quantum computer. The end of a dark magnetic flux tube would be transferred from the nutrient molecule to a molecule of the living system providing it with negentropic entanglement. This would also provide a deeper level explanation for why the nutrients must be organic molecules.

From above one can conclude that illness as a failure to self-organize in normal manner is basically a failure to generate normal patterns of self-hierarchy. Some part of biosystem does not receive the needed entanglement negentropy feed. 'Metabolism does not work properly' would be a more familiar manner to state the same thing. The mysterious ability (from classical physics point of view) of a self-organizing system to repair itself (get cured) can be understood as a consequence of the fact that system ends up with some self-organization pattern (fixed point of iteration) automatically. The new element would the presence of choices between good and evil at every level of the hierarchy.

Some examples are useful in the attempt to concretize these ideas.

1. Healthy heart is sufficiently chaotic, not ordered. Quite generally, living systems seem to reside at the border between chaos and order. Suppose that "chaotic" really means chaotic rather than just complex. The border between chaos and order could be seen as a compromise in which the external energy feed creates a large enough number of patterns allowing to form representations about external world but does not yet lead to a total loss of negentropic entanglement at various levels of hierarchy. This borderline would naturally correspond to quantum criticality which can have several interpretations. One of them is as criticality with respect to the phase transitions changing the value of Planck constant.

2. According to TGD based model of nerve pulse and EEG [K60, K21] , EEG is directly related to the oscillations of various Bose-Einstein condensates associated with neurons and possibly also glial cells. Large group of neurons could have simultaneously negentropic entanglement during coherent oscillations and synchronous firing could serve as a correlate for this collective behavior. Nerve pulse patterns could reflect a temporal loss of this coherence as individual neurons generate entropic entanglement and start to behave as individuals. The interpretation of spike patterns as communications indeed requires that neurons behave as separate selves. If the coherence of EEG is lost, neuron group ceases to behave like a coherent unit firing synchronically. The spatial coherence of EEG in brain could serve as a measure for the quantum coherence of brain. The spatial coherence EEG is indeed known to reflect psychic disorders. Similar loss of coherence could explain the behavior of cancer cell population and an interesting possibility is that some EEG type collective oscillation is missing from cancer cell population. If magnetic flux tubes serve as correlates of negentropic entanglement, decoherence could reduce to a disorder of the magnetic body.

3. Both rising and lowering of the body temperature leads to the lowering and even loss of consciousness. The development of organisms able to control their body temperature and thus stay conscious in wide range of external temperatures is regarded as one the great evolutionary steps. A natural interpretation for the narrow range of physiological temperatures is in terms of quantum criticality vital for the possibility to self-organize to a large number of widely differing patterns making possible to react to the changing environment and form sensory and cognitive representations about it. For instance, the lipid layers of cell membranes are in liquid crystal phase only in narrow range of temperatures. Too low temperature means that the lipids are frozen. If the magnetic flux tubes connecting nucleotides of DNA to lipid layers define the braids involved with quantum computation, freezing makes quantum computations impossible [K24] . Too high temperatures in turn make the motion of lipids too chaotic. Also the quantum entanglement between the ends of flux tube can become entropic. Hallucinations associated with

the fever could perhaps be regarded as a pathological state in which the feedback from brain generating virtual sensory input to sensory organs begins to dominate.

2.3 Haken's theory of self organization

Haken's classical theory of self-organization and the related model of pattern recognition (see the book "Information and Self-Organization" [B13]) is rather attractive in its simplicity and generality. Of course, the model cannot tell how the conscious experience associated with the pattern recognition is created but the concept of quantum jump might provide this lacking piece. The model generalizes also to a description of how biosystem acts on external world.

The potential wells representing attractors of the classical dynamics of the order parameter are replaced by the maxima of the Kähler function with respect to non-zero modes in quantum TGD based model. The zero modes of the configuration space geometry serve as control parameters and maximum depends on them. There are several maxima for given values of zero modes so that a typical catastrophe theoretic situation results and non-equilibrium phase transitions become possible.

2.3.1 Haken's theory of non-equilibrium phase transitions

The basic elements of Haken's theory [B13] are the concepts of order parameter and Slaving Hierarchy, Langevin and Focker Planck equations, maximum entropy principle and non-equilibrium phase transitions associated with the fluctuations of the order parameter at criticality.

Dynamical variables

Order parameters, denote them by q, are the fundamental dynamical variables in Haken's theory. They could be chemical concentrations, densities, some parameter specifying the geometrical conformation of system, etc. The basic element in Haken's theory is master-slave hierarchy. Slave possesses swift dynamics which follows the much slower dynamics of the master. Master typically appears as an external slowly varying parameter in the dynamics of the slave. In TGD larger space-time sheet, external world, typically serves as a master of the smaller space-time sheet, perceiver, in sensory perception. Situation could be also reversed: the reaction to the sensory experience is good example of this! p-Adic length scale hierarchy is a good example of master-slave hierarchy.

Dynamics

The dynamics of the order parameter is determined by a dissipative force proportional to the time derivative dq/dt of the order parameter, conservative force field defined as a gradient of a potential function $V(q)$ and random fluctuating force $F(t)$. In equilibrium the velocity is determined from the requirement that acceleration vanishes and this condition is known as Langevin equation. Potential function contains as external parameters the slowly varying order parameter of the master.

Fokker-Planck equation describes the devopment for the probability distribution $f(q,t)$ associated with the order parameter (an ensemble of identical systems is assumed: for instance, cells could form this kind of ensemble). Fokker-Planck equation is just the continuity equation for the probability density and the associated probability current containing convective term $\nabla_q V f$ proportional to the gradient of the potential $V(q)$ and a diffusive term proportional to the gradient $\nabla_q f(q,t)$ of the probability density.

Equilibria and maximum entropy principle

In non-equilibrium thermodynamics the requirement that entropy is maximal implies that in equilibrium situation the probability density $f(q)$ is proportional to the exponential of the potential function $V(q)$ and is hence analogous to Boltzmann weight:

$$f_{eq}(q) = Nexp(-\frac{V(q)}{K}) \ .$$

K is analogous to temperature. V determines single particle correlation functions $\langle q_i \rangle$, two-particle correlation functions $\langle q_i q_j \rangle$ and also higher correlation functions for the components of the order parameter and this gives means of deducing the function V from experimental data. Typically a Gaussian modified with a fourth-order interaction terms is in question. There is a direct analogy with Higgs potential and non-equilibrium phase transitions have interpretation as symmetry breaking/restoration.

Non-equilibrium phase transitions

Non-equilibrium phase transitions are induced by a change in some parameter of the potential, typically the coefficient b of the quadratic term in

$$V = bq^2 - aq^4 \ ,$$

which represents master type order parameter itself. For instance, single potential well ($b < 0$) becomes unstable when b becomes positive ($b > 0$) and order parameter moves to either well of the double well potential. In a deformed potential Langevin equation leads rapidly to a new attractor corresponding to the free energy minimum of the potential: order parameter is captured by the nearest attractor. In Focker Planck equation spontaneous symmetry breaking with a selection of second potential well occurs.

2.3.2 Pattern recognition in Haken's theory

1. Perception gives rise to order parameter describing information about the external world. Visual field of the eye is a good example.

2. Each attractor of the order parameter dynamics corresponds to a characteristic pattern, feature. Grandma, apple, etc..

3. Pattern recognition is essentially feature detection and completion of the pattern to one of the characteristic patterns. Features are preferred patterns of q, which correspond to the minima of the free energy associated with the order parameter in question. Formally, features correspond to the eigenvectors of the quadratic part of the free energy determined by the inverse of the quadratic form defined by the correlation functions of the components of the order parameter.

4. Perception creates a pattern of the order parameter q. If the system is above criticality (there is minimum feed of metabolic energy to guarantee that one has $b > 0$ in the potential function) this leads to a rapid dynamics (Langevin equation) leading from the pattern near an attractor to the attractor, the feature. The dynamics clearly creates caricatures.

2.4 Non-equilibrium thermodynamics and quantum TGD

Quantum TGD suggests the replacement of Haken's theory with a quantum description based on the generalization of the Thom's catastrophe theory to configuration space context ("world of classical worlds", briefly WCW) and the introduction of spin glass analogy and p-adic fractality at the fundamental level.

1. If the space of 3-surfaces with fixed values of zero modes is infinite-dimensional symmetric space [K16, K16] , one can expect that there is a single maximum of Kähler function in quantum fluctuating degrees of freedom and that one can effectively consider only the maximum just as in the case of integrable quantum systems.

2. Zero modes correspond to non-quantum fluctuating degrees of freedom and define a natural quantum counterpart of control variables. As already explained, under rather general assumptions it is possible to have have a hierarchy of wave functions with 2n-dimensional locus in zero modes and reducing effectively to the exponent of Kähler function. Therefore the maxima of Kähler function with respect to zero modes define an effective discretization of zero modes and give rise to the counterpart of spin glass energy landscape.

3. The discretization of the partonic 2-surfaces X^2 by replacing them with the discrete set of the loci of fermions at X^2 is the counterpart for the finite measurement resolution. This means the replacement of light-like 3-surfaces with braids and a connection with topological quantum field theories. At space-time level one has 2-dimensional string world sheets connecting the braid strands belonging to separate light-like 3-surfaces and a connection with string model based description emerges. If stringy effects can be neglected, discretization effectively replaces WCW with a finite cartesian power of imbedding space. Note that the induced Kähler form of CP_2 associated with space-time sheet defines important class of zero modes and this information is lost in this approximation. In any case, in these approximations TGD based theory would be finite-dimensional and would in many respects resemble Haken's theory.

There are also several profound differences.

1. p-Adic length scale hypothesis is an essential part of TGD based approach and makes possible quantitative predictions based on simple scaling arguments. A more speculative hypothesis is that infinite primes characterize the p-adic length scale assignable to a light-like 3-surface so that a given sector of WCW would be characterized by infinite prime. The latter assumption does not have practical implications.

2. The hierarchy of Planck constant implying the generalization of the notion of imbedding space plays a key role in biological applications. Magnetic flux tubes would serve as correlates for entanglement and directed attention. The contraction and lengthening of magnetic tubes induced by the phase transitions changing Planck constant and their reconnection could define the basic mechanisms of bio-catalysis. Magnetic flux tubes would also serve as braids and make possible topological quantum computations.

3. Quantum criticality means that space-time surfaces are critical in the sense that there is an infinite number of deformations of the space-time surface with a vanishing second variation of Kähler action [K26] . In the framework of catastrophe theory this means that the system resides at the critical manifold for which several (now infinite number of) branches defined by the extrema of potential function co-incide so that the rank of the matrix defined by the second derivatives of the potential function is reduced and even some higher derivatives can vanish (as in the tip of the cusp catastrophe). These critical manifolds define an inclusion hierarchy just as in Thom's theory and to this hierarchy one can speculatively assign inclusion hierarchy of super-conformal algebras and of hyper-finite factors of type II_1, which play a key role in the formulation of quantum TGD.

4. One cannot avoid bringing in also quantum theory of consciousness. Zero energy ontology replaces classical state with zero energy state analogous to a physical event or process, and S-matrix is replaced with the pair defined by U-matrix and M-matrix. U-matrix characterizes quantum jumps between zero energy states and makes possible volitional action. M-matrix characterizes zero energy states and is assigned with perception. Quantum jump corresponds to perception-reaction pair and defines the counterpart for the basic iterative step of self organization (note that state function reduction and state preparation combine to a single state function reduction in zero energy ontology). NMP defines the variational principle of consciousness theory. The notion of number theoretical Shannon entropy brings in the choice between quantum jumps generating positive *resp.* negative entanglement entropy. This choice between co-operation and maximal independence could be a correlate for a conscious choice between good and evil. This aspect should allow a statistical description in terms of a probability of being sinner or saint.

2.4.1 Spin glass analogy

At the level of the configuration space geometry spin glass analogy is well understood. The configuration space CH consisting of 3-surfaces in H has fiber space structure. Fiber corresponds to nonzero modes of configuration space metric contributing to the line element of metric and base corresponds to zero modes in which line element vanishes. Spin-glass analogy implies large degeneracy of the absolute minima of Kähler action. In the approximation that classical gravitation can be neglected all extremals of Kähler action are degenerate and CP_2 canonical transformations are $U(1)$ gauge symmetries in fiber degrees of freedom: actually however $U(1)$ gauge symmetry is broken and the gauge-related space-time surfaces are not gauge-equivalent configurations so that spin-glass analogy results. The functional integration around maxima of Kähler function as function of fiber coordinates gives well define results since Gaussian determinant and metric determinant cancel each other.

The localization in zero modes around single maximum of Kähler function in quantum jump could mean that they are equivalent with measurement resolution. Symmetric space property in turn suggest that the integration over fiber degrees of freedom reduces to an integral around single maximum of Kähler function. This would mean huge simplification in the construction of the theory since very close resemblance with the formalism of quantum field theory would results as a consequence. The physical picture of quantum field theories certainly suggests this strongly.

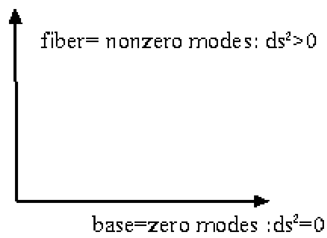

Figure 2.1: Configuration space has fiber space structure. Fiber corresponds to coordinates appearing in the line element and base to zero modes, which do not appear in the line element.

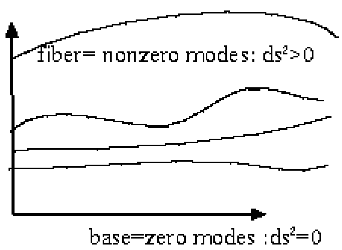

Figure 2.2: The reduced configuration space CH(red) has many-sheeted structure with each sheet parameterized by zero modes.

2.4.2 Maxima of the Kähler function as reduced configuration space CH_{red}

When one calculates the probability amplitude for a given quantum jump, given as the inner product between configuration space spinor fields, one obtains an integral of the fermionic Fock space inner product as a functional of 3-surface X^3 over fiber degrees of freedom around maxima of Kähler function as function of fiber coordinates: if the most optimistic expectations are realized, only single maximum contributes. This integral can be calculated approximately by performing Gaussian perturbation theory. Thus the *maxima* of the Kähler function, which are completely analogous to the free energy minima of spin glass, can be identified as the reduced configuration space CH_{red}. The ill defined Gaussian and metric determinants cancel each other and the non-locality of Kähler function as a functional of 3-surfaces implies that the standard divergences of the local quantum field theory are absent.

The number of maxima for given values of zero modes can be large: this is in fact expected since only classical gravitational action differentiates between canonical transforms of a given absolute minimum space-time surfaces. In particular, the presence of mindlike space-time sheets is expected to give rise to huge degeneracy. Thus CH_{red} has many-sheeted structure which each sheet parameterized by zero modes and a generalization of catastrophe theory to infinite-dimensional context is needed to describe the situation mathematically. This degeneracy corresponds in the simplest case to the degeneracy of state associated with cusp catastrophe and phase transition like quantum jumps corresponds to selection of one of the various allowed branches.

Figure 2.3: Cusp catastrophe. In this case CH_{red} has two sheets (intermediate sheet is not maximum of Kähler function).

The simplest manner to understand the expected decomposition of the reduced configuration space to different regions D_P characterized by a collection of p-adic primes is to assume that $exp[K_{max}]$ is p-adic fractal as a function of the zero modes. p-Adic fractality is suggested both by criticality and by spin glass analogy. p-Adic fractality implies automatically ultrametric hierarchy at the level of configuration space allowing the decomposition of CH_{red} to a tree like structure. This kind of hierarchy is suggested by Parisi [B20] to be fundamental for the biological information processing, especially for the formation of concepts and classification into categories.

2.4.3 The concept of quantum average effective space-time

If the most optimistic expectations hold true, functional integration in fiber degrees of freedom reduces to integration around some maximum X^3_{max} of Kähler function with respect to fiber coordinates. It is convenient to identify the space-time surface $X^4(X^3_{max})$ as 'quantum average effective space-time'. Since configuration space integration occurs over the sector D_p associated with the final state of the quantum jump, effective quantum average space-time characterizes final state and can be regarded as a representative example from the set of space-time surfaces appearing in the final state, which all have same macroscopic characteristics.

One can associate this space-time surface only with the final state of the quantum jump and the sequence of quantum jumps defines a sequence of space-time surfaces of this type. As already explained, dissipative time evolution could be interpreted as kind of envelope for this sequence of reversible time evolutions. TGD however allows to code for thermal parameters to space-time geometry via the coupling of the modified Dirac action to average values of the quantum numbers for the positive energy part of the state. Classical Langevin dynamics for order parameters can be identified as the counterpart of the hopping in zero modes and in degrees of freedom characterizing various degenerate absolute minima associated with the maxima X^3_{max} of Kähler function.

2.4.4 Haken, Thom, Penrose and Hameroff

The picture leads to a generalization of Haken's theory of non-equilibrium phase transitions to a Penrose-Hameroff type picture [J23] . Any quantum jump corresponds to a selection of space-time surfaces as the relevant maximum of Kähler function and the fundamental order parameters are the zero modes characterziing the space of these 3-surfaces. Non-equilibrium phase transitions correspond to quantum jumps leading to a selection of one maximum, from a quantum superposition of several ones appearing in the state $U\Psi_i$. The classical theories of Haken and Thom correspond to the hopping motion in zero modes. The sequence of quantum jumps leads to the regions of configuration space at which vacuum functional is maximum and when Kähler function has several maxima this leads with great probability to hopping from one sheet of the catastrophe surface to another. For volitional quantum jumps selecting between maxima of Kähler function in fiber degrees of freedom, one ends up with the quantum versions of these theories in which genuine phase-transition like quantum jump selecting between the sheets of the catastrophe surfaces occurs near the 'Maxwell line': the Penrose-Hameroff proposal [J23] for the orchestrated reduction of state function is analogous to this kind of selections.

2.4.5 Classical gravitation and quantum self-organization

The symplectic transformations of CP_2 acting as local $U(1)$ gauge transformations leave zero modes invariant since they do not affect the induced Kähler form of CP_2. The classical gravitational interaction breaks local $U(1)$ invariance as a gauge symmetry of the Kähler action and means that the action of a symplectic transformation spoils the preferred extremum property in general: gauge degeneracy transforms to spin glass degeneracy in 4-D sense. This means that symplectic transformation become dynamical symmetries acting as symplectic transformations only at the partonic 2-surfaces defined by the intersections of wormhole throats with the boundaries of causal diamonds. In the interior of space-time sheet their action is not symplectic anymore and Kähler action is affected: this is necessary for having a non-trivial Kähler metric in WCW. The symmetric space property for the preferred extremals suggests that there is single maximum of Kähler function at the orbit of the symplectic group defined by the symplectic deformations of the partonic 2-surface.

The value of the Kähler action depends only very weakly on the symplectic degrees of freedom. Hence one expects a large number of space-time sheets with almost identical value of Kähler function. Only the contribution of the induced metric proportional to R^2 (R denotes CP_2 radius) distinguishes between almost degenerate extremals in the lowest approximation. Since space-time surfaces code for the four-momenta of partons [K26] , one expects that the contribution is expressible in terms of quantities GM_i/L, where M_i are mass parameters and L a length scale naturally defined by the size of CD. This kind of expression indeed follows from general arguments for the form of the measurement interaction term. For $L >> 2GM$, (Schwartschild radius) one has $GM/L << 1$. This situation corresponds to a nonperturbative situation in the sense that a very large number of preferred extremals gives a sizable contribution to the vacuum functional.

Non-perturbative phase seems to emerge also in different manner above Planck mass scale. The coupling constant parameter $GM_1M_2/\hbar$ is analogous to gauge coupling strength $\alpha = g^2/4\pi\hbar$ appearing in perturbation theory. It becomes large above Planck length scale and one can argue that perturbation theory fails. On basis of the experience with hydrogen atom one can also argue that also the nonperturbative quantum description of gravitationally bound states in terms of Schröndinger equation fails. The proposal is that the hierarchy of Planck constants saves the situation [K67, K54] : a phase transition increasing $\hbar$ and guaranteing the smallness of $GM_1M_2/\hbar$ takes place. Equivalence Principle fixes the form of $\hbar_{gr}$ to $\hbar_{gr} = GM_1M_2/v_0$, where $v_0 < 1$ corresponds physically to a velocity. Planck length redefined as $\sqrt{G\hbar_{gr}}$ is transformed to $GM/\sqrt{v_0}$ and is of the order of Schwartsild radius. Above this length scale non-perturbative phase prevails if the previous argument is accepted. The implication would be macroscopic quantum coherence at astrophysical scales with a gigantic value of Planck constant at the space-time sheets mediating gravitational interaction [K67, K54] .

For condensed matter densities Planck mass corresponds to the length scale of 100 μm defining the size scale of a large neuron. These observations suggest that macroscopic quantum phases at the space-time sheets mediating gravitational interaction are fundamental in TGD and also in TGD inspired quantum biology. The almost degenerate preferred extremals could define the TGD counterpart for the gravitationally degenerate microtubule conformations of Penrose and Hameroff [J23] . In Penrose-

Hameroff theory gravitons are believed to play important role. The vacuum Einstein tensor associated with the preferred extremals (say massless extremals) is indeed expected to generate a coherent state of gravitons characterized by large value of Planck constant so that $E = hf$ relationship implies that very low frequency gravitons are energetic. An interesting possibility is that these coherent states of gravitons give rise to the sense of proprioception.

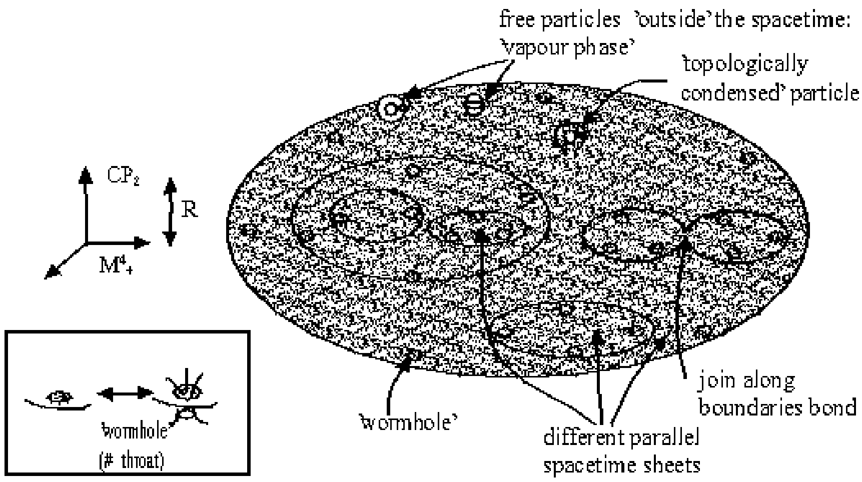

Figure 2.4: Topological condensate and vapor phase: two-dimensional visualization.

2.4.6 Quantum model for perception and reaction

All quantum jumps involve both active and passive aspects of consciousness and it is interesting to look for a general model for active and passive aspects of consciousness based on the generalization of Haken's theory. Before continuin one must notice that the meaning of the active-passive dichotomy depends on one's tastes. One could argue that the genuinely active aspect corresponds to the U process generating the quantum superposition of possibilities and that the subsequent selections correspond to the passive aspect. Also volition as a selection between given options would be a passive aspect. Second interpretation is that only that part of the selection process which has a clear identification in terms of volitional acts corresponds to the active aspect whereas perception would correspond to the passive aspect. It is however known that sensory perception is to some extent a process involving also a selection between alternative sensory percepts (binocular rivalry).

Consider first the general picture.

1. In TGD the fundamental order parameters correspond to the zero modes of WCW. Modified Dirac action containing a measurement interaction term couples various conserved quantum numbers to the dynamics of the space-time surface so that standard quantum measurement theory results. Since partonic 2-surfaces carry the quantum numbers the coupling is to the zero modes characterizing the induced Kähler in the interior of the space-time surface.

2. In positive energy ontology volitional acts would select between initial values defining initial value sensitive dynamical developments of the 3-surface. In zero energy ontology the selection is between entire time developments, which are not deterministic in the standard sense of the world. This means a hierarchy selections at various time scales associated with the hierarchy of CDs. Quantum criticality is a more natural notion than initial value sensitivity in this framework. The fractal hierarchy of criticalities means that critical manifolds contain catastrophe surfaces which in turn have critical surfaces.

3. The outcome of the selection process is 4-D dynamical pattern rather than time=constant snapshot. This interpretation is especially natural in living matter where spatio-temporal EEG patterns characterize the state of brain.

4. Besides state function reduction in geometric degrees of freedom there are selections in spin degrees of freedom of WCW spinor field. Zero energy configuration space spinor fields allow interpretation as superpositions of Boolean statements and the natural interpretation would be that state function reduction in these degrees of freedom gives rise to Boolean cognition and configuration space spinor fields represents rules of type $A \rightarrow B$ as superposition of all instances. Boolean cognition would be analogous to sensory perception.

In TGD framework the dynamics for order parameters corresponds basically to hopping in the space of order parameters. Therefore the statistical description of hopping as a continuous motion is expected to be an excellent approximation. The motion is much like Brownian motion in presence of drift term. Langevin dynamics for order parameters can be regarded as a model for the hopping in the space of order parameters. Focker-Planck dynamics applies, when the number of nearly identical space-time sheets each characterized by zero modes is large so that one can apply quantum statistical determinism. One can also introduce probability distribution also for single space time sheet to describe the distribution of zero modes defined by quantum jumps during some macroscopic time scale.

The hopping in the space of order parameters must lead to the region of order parameter space in which the modulus squared of the configuration space spinor field has maximum. The simplest situation is that the maxima correspond to the maxima of vacuum functional as function of order parameters. Since vacuum functional is exponential of Kähler function, this means that Kähler action for space-time sheet representing subsystem containing zero modes as external parameters takes the role of the potential function in Haken's theory.

If sensory experience is determined by the localization in zero modes then feature detection must correspond to Langevin type dynamics leading to some minimum of potential function and in TGD it corresponds to a hopping motion leading to attractors defined by several maxima of the Kähler function as a function of zero modes. For instance, in the case of cusp catastrophe quantum jumps lead rapidly from the stable sheet of catastrophe to another in the vicinity of Maxwell line. Conscious feature detection would require that there is sub-self defining mental image whose sensory experience is dictated by the localization in zero modes characterizing feature. It seems that this requires macroscopic quantum phases whose order parameters in ground state are determined by the values of zero modes. The essentially quantal element of the feature detection is the wake-up of the subself whose subsequent self-organization gives rise to a mental image depending only weakly on initial conditions. A general model for this wake-up mechanism is based on the quantum jumps induced by Josephson currents running between two superconductors representing master and slave. These quantum jumps are induced resonantly in slaved superconductor, when the frequency of the Josephson current corresponds to the energy difference for the states of the slaved superconductor [K55, K56] .

The recognition of phonemes takes place in definite places in the linguistic regions of brain. This suggests that the same input comes into each of these detectors and gives rise to yes-no response so that cusp catastrophe would be in question. The assumption that various phoneme detectors receive same input data is in accordance with the ideas about hologram like data representation in brain.

Generalizing, it seems that some parts brain could be to some extent act as a collection of simple yes-no feature detectors receiving essentially the same input.

2.4.7 Are proteins quantum spin glass type systems?

The entire universe should be quantum spin glass type system if TGD is correct. There is indeed some evidence for the spin glass nature of biosystems at protein level [I7, I7] . A long standing problem of molecular biology is to understand why proteins [I9] fold to very few preferred spatial conformations only [I28, I4] . I have discussed a TGD inspired model for protein foldinc [K3] , which is completely unrelated to the following discussion.

A naive expectation, assuming *random* amino-acid sequences, is that folding should occur randomly. It would however would however require the age of the Universe for the protein to fold in this manner [I4] . According to the article [I7, I7] , Ken Dill has simulated proteins using a simplified computer model in which the 20 amino-acids are replaced with 2 model aminoacids: 'hydrophobic' or 'hydrophilic'. It has turned out that only few per cent of these virtual proteins are good folders. The lesson seems to be that random sequences of aminoacids are not sufficiently protein like and that good folders have some specific property allowing them to arrive at a unique shape.

Could protein spin glass energy landscape have single deep valley

According to the same article, Peter Wolynes suggests that proteins are spin glass type systems characterized by a fractal like energy landscape containing very many nearly degenerate energy minima. This means that system has difficult time in finding low energy arrangements and it can end up to any one of the very many energy minima with almost degenerate energies. Therefore *typical* spin glass like system is not a good folder. Wolynes suggest that, as a consequence of natural selection, real proteins differ from random proteins in that they have one deep energy minimum besides shallow minima still present. The energy landscape is still rugged but now there is one preferred configuration at the bottom of a deep energy valley. Also the states near this state are assumed to have energy below the average energy. This funnel like structure in energy landscape is proposed to be a solution to the folding paradox. One can understand the correct folding to result from external perturbations: if protein is put in hot liquid, thermal perturbations take care that it is not left in any local energy valley during cooling but ends up to the deep energy minimum. Minimization of free energy could also selet good folders during evolution starting from a soup of random aminoacid sequences.

If protein is in self state, quantum jumps inside it occur and imply quantum self-organization leading toa preferred final state pattern selected by dissipation. This pattern represents protein folding depending on the external parameters like pH, ionic concentrations and temperatures whereas the dependence on the initial state is very weak. Thus the phenomenon of protein folding gives direct support for the self-hierarchy and consciousness in even protein length scales.

One can also try to estimate the time scales involved. According to [I9] the time times for protein folding vary in the reange $10^{-1}-10^3$ seconds both in vivo and vitro. According to Wikipedia article [I4] the times for small proteins with lengths up to hundreed residues fold in single step and the time scale is 1 millisecond and the shortest time scales are in microsecond range. The question is whether these time scales could be understood without making any dynamical assumptions by using only p-adic length scale hypothesis.

1. The naive application of p-adic length scale hypothesis before zero energy ontology would suggest that the duration of the protein self is of order $T_p = L_p/c = L(k)/c$ for $p \simeq 2^k$. For the p-adic length scale $L(151) \simeq 10^{-8}$ meters (cell membrane thickness) this gives $T_p \sim 10^{-15}$ seconds. This time scale is quite too short.

2. One might argue that in zero energy ontology the secondary p-adic time scale $T_{2,p} = \sqrt{p}L_p$ of the CD, where the p-adic length scale L_p characterizes the protein or the folding mechanism is relevant. One can consider several identifications of L_p. What comes first in mind are the length of the protein, the size scale of the folded protein, and the thickness of the amino-acid sequence. Also the p-adic length scale of electron or proton inducing catalytically crucial steps in the folding of short proteins could determine $T_{2,p}$. For $k = 151$ (cell membrane thickness) this would give a time scale of order 10^5 seconds, roughly 50 hours. $k = 145$, which corresponds to

nanometer length scale and thickness of the protein, would give a time scale of one hour, which corresponds to the experimental upper bound according to [I9] .

$k = 127$ corresponding to electron would give a secondary time scale of .1 seconds, which is the lower bound according to [I9] . The interpretation could be that single electron initiates the folding process catalytically. Millisecond would correspond to $L(k = 120) \sim 10^{-13}$ m . This could correspond to the p-adic scale for quarks with mass about 5 MeV. Quarks and antiquarks indeed appear at the ends of (wormhole) magnetic flux tubes in the model of DNA as topological quantum computer. If the interpretation is correct the two fundamental time scales of living matter would correspond to elementary particles. The fastests time sale of order microsecond could correspond to the p-adic length scale of proton giving a time scale of order 10^{-7} s: this could make sense if proton is essential for the catalytic step involved. I have indeed proposed that the dropping of electrons and protons between space-time sheets defines key element of bio-catalysis [K3] .

3. The appearence of .1 second time scale characterizing electron and defining a fundamental bio-rhythm is intriguing as is also the appearance of the millisecond time scale defining the time scale of nerve pulses. The hierarchy of Planck constants brings in additional scaling of the time scale by the ratio $r = \hbar/\hbar_0$. If dark protons are involved one could understand all three time scale ranges if r is in the range $10^3 - 10^4$. The TGD based model of EEG [K21] assumes that the preferred values of Planck constant come in powers of 2^{11}, which happens to be near to the proton-electron mass ratio. If the secondary p-adic time scales correspond to those of electron , quarks, and proton inducing basic catalytic steps of the folding then the variation of r in the range $1-10^4$ would predict time scale ranges $10^{-7}-10^{-3}$ s for proton induced folding, $10^{-3}-10$ s and $.1 - 10^3$ s for electron induced folding.

These very naive arguments suggest that the general order of magnitude for the folding time might have something to do with the p-adic length scale hypothesis in zero energy ontology.

Should one replace thermal spin glass with 4-D quantum spin glass?

Wolynes models protein as a thermal spin glass. TGD suggests that the entire universe is quantum spin glass. The partition function of spin glass (or rather the average over the partition functions with different coupling strengths between spins) is replaced with vacuum functional, which is exponent of Kähler function. The averaging over the coupling constant strengths corresponds in TGD to the average over so called 'zero modes' of the Kähler function: using QFT terms, these degrees of freedom do not couple to the inverse of the propagator defined by the Kähler function. Zero modes characterize the shape and size of the 3-surface and also the classical induced Kähler field on it (classical em field is very closely related to Kähler field) and can be identified as fundamental order parameters in TGD inspired quantum theory of self-organization. In each quantum jump localization in zero modes occurs so that averaging is indeed genuine statistical averaging: quantum states representing the final states of quantum jumps are not delocalized in zero modes.

Evolution at quantum level has selected those proteins for which the rugged 'energy landscape' defined by the negative of Kähler function contains only few deep minima. One can criticize the assumption about the selection of the spin glass energy landscape as too strong. There are always deep minima and depending on the initial conditions self-organization leads to some minimum. On the other hand, selection certainly occurs also in the sense that proteins and corresponding spin glass energy landscapes are selected by evolution.

The proposed mechanism might be a general mechanism of evolution. In the generalization of Haken's self-organization theory to quantum TGD context the maxima of the Kähler function correspond to those configurations to which self-organizing system rapidly moves if perturbed. For instance, pattern perception could be described as a dynamical evolution leading to one of few maxima identifiable as 'features', which are caricature like patterns providing idealization of the actual sensory stimulus. 'Features' would correspond to configurations with one deep minimum of the negative of the Kähler function selected during evolution. Also preferred behavioral modes developed during evolution, 'phylogenetic invariants', could have similar identification.

As a matter fact, quantum self-organization should occur even in elementary particle length scales. The duration of elementary particle selves can be estimated from the p-adic length scale hypothesis to be of the order of Compton time determined by the particle mass. Self-organization could explain the selection of preferred p-adic primes characterizing elementary particles and also macroscopic space-time sheets.

Could zero energy ontology and conscious choice be significant factors in the protein folding?

The proposed view about selection of protein conformations is quantal and involves the notion of 4-D spin glass but does not involve zero energy ontology and hierarchy of Planck constants. It was already noticed that the introduction of hierarchy of Planck constants might allow to understand the rough time scales of folding in terms of the secondary p-adic time scales assignable to electron and proton without detailed assumptions about dynamics.

1. In zero energy ontology state function reduction selects one particular folding process rather than a particular folding. The folding process is a sequence of quantum jumps selecting a folding process and then acting on it by U-matrix. The entire folding process including the initial folding is affected in the folding process. The final state is asymptotic self-organization pattern. The asymptotic classical folding process should always lead to the same preferred folding and also begin from the same folding.

2. Fractals are indeed typically fixed sets of iteration and quantum jump sequence is analogous to iteration so that this principle might apply quite generally. By quantum classical correspondence the classical folding should reflect this fractality. The folding process is predicted to have a modular structure with a hierarchy of length and time scales defined by CDs involved. The choice of the folding process would proceed simultaneously in all scales and presumably the fixed point would be reached first in shorter scales so that the folding process would proceed from short to long scales.

3. If the asymptotic classical folding is invariant under the classical folding dynamics, the sequence of quantum jumps leads naturally to a fixed point of the classical folding dynamics in various scales defined by the hierarchy of CDs. Therefore the change of the geometric past and future in quantum jump would be crucial for the understanding of the folding process.

One is also forced to ask whether protein can be treated as a dead matter and whether intentional action preferring the generation of macroscopic quantum coherence (number theoretic negentropy) at various scales could play a role in the folding process. This question whether living matter might behave like living matter might look somewhat strange after few decades but at this moment the historical ballast forces to represent it very cautiously.

2.4.8 Cognitive evolution as self-organization of association sequences

Before the emergence of zero energy ontology cognitive evolution was regarded as a self-organization of association sequences. Association sequences can develop not only the ordinary space-like quantum entanglement but also combine to form longer association sequences having quantum entanglement in time direction. The emergence of association sequences characterized by increasingly larger value of p-adic prime corresponds to the development of larger coherent cognitive units. The formation of association sequences of association sequences corresponds to the formation of cognitive slaving hierarchies. The replication of association sequences provides a geometric realization for the idea of ideas as living organisms.

In zero energy ontology association sequences are replaced with space-time sheets with CDs and the fractal hierarchy of CDs codes for the non-determinism of association sequences. In zero energy property the replication of these states is expected to be easier than in positive energy ontology. This encourages the interpretation in terms of memes. One can assign to these states representations of logic rules in accordance with the idea that physical world forms a cognitive representation for the laws of physics.

2.4.9 Brain as a self-organizing quantum spin glass

The plasticity of brain is consistent with the identification of brain as quantum spin glass. In this picture the evolution of subselves/mental images is a dissipative self-organization process leading to some asymptotic self-organization patterns which correspond to the valleys of the spin glass energy landscape of brain. One can understand development of memories, habits, skills and even fix idees as a quantum self-organization based on Darwinian selection of subselves having nerve pulse patterns and synaptic strengths as neural correlates.

The crucial element of the self-organization is external energy feed making possible interesting self-organization patterns. Nerve pulse pattern is analous to an external energy feed and the propagation of nerve pulse could indeed induce energy transfer inducing self-organization in the cytoplasma just below axonal membrane. The gel-sol phase transition accompanying nerve pulse conduction could define the self-organization pattern induced by the conduction of the nerve pulse along axon. Nerve pulses affect the postsynaptic cell: typically excitation or inhibition is in question. The interpretation is again that the incoming nerve pulses push and pull the postsynaptic cell in different directions in spin glass energy landscape and in this manner cause frustrations typical for spin glass like systems. Also frequency and time codings and the lack of a precise neuronal code are consistent with this.

A flow of cytoplasma and of lipids of cell membrane is induced by the conduction of nerve pulse. If DNA as topological computer model makes sense in the case of axons, this would induce a braiding of the magnetic flux tubes assumed to connect DNA to cell membrane and thus quantum computation and memory representation for the conduction of nerve pulse pattern.

In TGD framework nerve pulse patterns provide a symbolic representation of the sensory experience whereas sensory qualia are located at sensory receptors. The back projection from brain is essential in building the sensory percepts as asymptotic self-organization patterns via the dialog between brain and sensory receptors. Neural pathways would give rise to characteristic self-organization patterns providing symbolic representations for the sensory input. Quantum spin glass paradigm combined with the notion of the geometric memory leads to a general model of long term memories circumventing the basic difficulty of the neural net models of long term memory related to the fact that long term memories identified as synaptic strengths tend to be destroyed by the learning of new memories. This view about memory also resolves the objections against the idea that sensory receptors are loci of sensory qualia.

2.4.10 About the notion of quantum criticality in TGD framework

Quantum criticality is a fundamental physical principle of TGD dictating the classical and also quantum dynamics so that it deserves a separate discussion from the "modern" viewpoint inspired by what has happened in TGD during more than decade after writing the text above "classical" view. According to the "classical" view, the value of Kähler coupling strength - the only parameter of theory - is fixed as the analog of critical temperature. In order to characterize the critical degrees of freedom one must say something about the Kähler metric of WCW [K76].

1. The matrix defined by the second order derivatives of Kähler function with respect to WCW coordinates is degenerate as is also the WCW Kähler metric defined by a subset of these derivatives ($G_{K\overline{L}} = \partial_K \partial_{\overline{L}} K$ is the defining formula of Kähler metric in complex coordinates in terms of Kähler function K).

   The reason for the degeneracy is that WCW metric depends on real zero mode coordinates, which do not appear as differentials in the line-element. These coordinate directions of WCW correspond to non-quantum fluctuating classical degrees of freedom not contributing to WCW Kähler metric. The proposed generalization of quantum measurement theory assumes that zero modes are analogous to classical variables defining say the position of a pointer of a measurement instrument and that they are in 1-1 correspondence with the outcomes of quantum measurements in quantum fluctuating degrees of freedom and give rise to quantum classical correspondence.

2. Quantum criticality would corresponds to a situation in which maximum of Kähler function (defining most probable space-time surface in their quantum superpososition) corresponds to a Kähler metric for which some elements of Kähler metric approach zero so that the rank for the matrix defined by the non-vanishing components of the Kähler metric is reduced. The resulting degrees of freedom would be effectively zero modes inside the critical manifold but not elsewhere.

The criticalities would define an infinite hierarchy analogous to the finite hierarchy of criticalities for finite dimensional catastrophes Thom's catastrophe theory [A31]: cusp catastrophe is the simplest non-trivial example.

3. At the level of conformal symmetry algebras [K63] defining the infinite-dimensional symmetries of TGD Universe - call them with generic name A - this hierarchy could have very elegant representation. The elements of conformal algebra are labeled by integer plus other quantum numbers so that one can write the element of algebra $a_{n,\alpha}$. Critical sub-manifolds woud correspond to sub-spaces of WCW for which the elements $a_{nk,\alpha}$ of sub-algebra A_n (k is integer) annihilate the states or creates zero norm f states from them. Here n is a non-negative integer characterizing the critical manifold. Critical manifolds would be in 1-1 correspondence with non-negative integers n. If n_1 divides n_2, the critical manifold Cr_{n_2} belongs to Cr_{n_1}.

4. In the phase transitions between different critical manifolds some quantum fluctuating degrees of freedom become local zero modes in the sense that their contribution to WCW metric at a given point of WCW vanishes at criticality. Also the reverse transformation can take place.

The progress that has occurred since 2005 raises some interesting questions.

1. Criticalities form a number theoretic hierarchy and primes define "prime criticalities". Does this mean that the primes dividing integer n define the possible p-adic topologies assignable to criticality defined by n?

2. The hierarchy of effective Planck constants is labelled by integers and giving integer n corresponds to n-furcation made possible by the failure of strict determinism for Kähler action. Could this integer correspond to the integer defining the criticality? Criticality is indeed accompanied by non-determinism realized as long range fluctuations.

3. Causal diamonds have size scales coming as integer multiples of CP_2 scale. Does this integer relate to the integer defining criticality?

4. The condition that the n characterizes finite measurement resolution in the sense A_n annihilates the physical states everywhere would delocalize the critical states outside the critical manifold. Does this mean that also finite measurement resolution is characterized by integer.

5. How the 4-D spin glass degeneracy due to the huge vacuum degeneracy of Kähler action implying breaking of strict determinism relates to quantum criticality?

These suggestive connections suggest that integer arithmetics are coded directly to the hierarchy of criticalities and also be a basic characteristic of consciousness. This would give additional piece of support for the vision about physics as a generalized number theory [K72].

2.5 Could TGD provide justification for the ideas of Rupert Sheldrake?

Rupert Sheldrake [I30] has developed a theory of learning and memory based on the concepts of morphic fields and morphic resonance. In the following I describe briefly the theory of Sheldrake and consider a TGD variant of of the theory.

2.5.1 Sheldrake's theory

The following summarizes very briefly the basic ideas of Sheldrake's theory.

1. The basic hypothesis is that learning occurs also at the level of species. If some individuals of the species have learned some habit then it becomes easier for the remaining individuals of the species to learn the same habit. The individuals who learned the habit first need not even live anymore or can live in a distant part of the world. Collective learning is claimed to occur in a morphic resonance analogous to a phase transition leading from a small seed of invididuals with new habit to a population having the same habit. Morphic field provides a representation for a

habit and resemble the concept of meme in this respect. Sheldrake states the basic assumptions of his theory in the following manner:

The idea is that there is a kind of memory in nature. Each kind of thing has a collective memory. So, take a squirrel living in New York now. That squirrel is being influenced by all past squirrels. And how that influence moves across time, the collective squirrel-memory both for form and for instincts, is given by the process I call morphic resonance. It's a theory of collective memory throughout nature. What the memory is expressed through are the morphic fields, the fields within and around each organism. The memory processes are due to morphic resonance.

2. Sheldrake defines morphic fields in the following manner:

   Basically, morphic fields are fields of habit, and they've been set up through habits of thought, through habits of activity, and through habits of speech. Most of our culture is habitual, I mean most of our personal life, and most of our cultural life is habitual. "We don't invent the English language. We inherit the whole English language with all its habits, its turns of phrase, its usage of words, its structure, its grammar.

3. 'Alike likes alike' rule states that learning induces learning only in the members of *same* species. This suggests that the morphic fields correlate strongly with genome.

4. Sheldrake represents the learning of language as a good example of morphic resonance.

   Occasionally people invent new words, but basically, once we've assimilated it, it happens automatically. I don't have to think when I'm speaking, reaching for the next word. It just happens, and the same is true about physical skills, like riding a bicycle, or swimming, or skiing if you can ski, these kinds of things. So I think the more often these things happen the easier they become for people to learn. Things like learning language have happened over- well, we don't know how long human language has been around, at least 50,000 years, so there's a tremendously well-established morphic field for language-speaking. Each particular language has its own field which is usually established over centuries at least.

5. Sheldrake notices also that morphic resonance and morphic fields are not all what is needed to understand evolution.

   The whole idea of morphic resonance is evolutionary, but morphic resonance only gives the repetitions. It doesn't give the creativity. So evolution must involve an interplay of creativity and repetition. Creativity gives new forms, new patterns, new ideas, new art forms. And we don't know where creativity comes from. Is it inspired from above? Welling up from below? Picked up from the air? What? Creativity is a mystery wherever you encounter it, in the human realm, or in the realm of biological evolution, or of cosmic evolution. We know creativity happens. And then what happens is a kind of Darwinian natural selection. Not every good idea survives. Not every new form of art is repeated. Not every new potential instinct is successful. Only the successful ones get repeated. By natural selection and then through repetition they become probable, more habitual.

2.5.2 TGD based interpretation of morphic fields and collective memory

I have proposed for more than decade ago a TGD based formulation justifying the basic ideas of Sheldrake to some degree. The recent formulation involves several new elements. Zero energy ontology implying that WCW ("world of classical worlds") spinor fields allow an interpretation as memes or morphic fields, the model for living matter in which the notion of magnetic body plays a key role, and the model of DNA as topological quantum computer allowing to identify the morphic quanta relevant for living matter.

WCW spinor fields

In TGD framework zero energy states correspond to the modes of completely classical WCW spinor fields with fermionic second quantization at space-time level having purely geometric interpretation at the level of WCW. The analysis of the degrees of freedom involved demonstrates that WCW spinor fields are analogous to ordinary quantum fields but hav infinite number of components.

1. WCW decomposes to a sub-WCWs association with unions of causal diamonds (CDs). Individual CD is partially characterized by the moduli defined by the positions of its upper and lower tips. The proposal is that the temporal distances between the tips are quantized in octaves of CP_2 time scale and thus coming in good approximation as secondary p-adic time scales for primes very neary to power of two. The most general proposal is that also the position of the upper tip at proper time = constant hyperboloid of future lightcone M^4_+ is quantized for positive energy states. For negative energy states this happens to the lower tip. This disrete set would provide a discretized quantum version of Robertson-Walker cosmology with discretized lattice like structure replacing the continuum. The interpretation would be that lower tip corresponds to the usual Minkowski space-time of special relativity and the discretized position of upper tip to the space-time of cosmology. This implies very strong predictions such as the quantization of cosmic redshifts which is indeed observed [K68] . Similar quantization would take place in CP_2 degrees of freedom for either tip. WCW spinor fields for single CD would depend on these moduli and for positive (negative) states one would have wave functions in the space formed by sub-WCWs with wave function basis consisting of products of plane waves in M^4 with a wave function in the discrete subset of $M^4_\pm$. These degrees of freedom generalize those of a quantum field in Minkowski space.

2. The notion of generalized imbdding space forces to assign to a given CD a selection of quantization axis of energy and spin which in the case of M^4 boils down to a choice of a preferred plane $M^2 \subset M^4$ plus a choice of time direction (rest system). In the case of CP_2 the choice of quantization axes of color isospin and hypercharge means a choice of a homologically trivial geodesic sphere of CP_2 plus preferred isospin quantization axes. The space for possible choices of quantization axis defines additional moduli. The selection of quantization axes in state function reduction means a localization in these degrees of freedom. The space characterizing the selections of color quantization axis represents an example of so called flag manifold. It has already earlier appeared in TGD inspired biology with a motivation coming from the observation of topologists Barbara Shipman that the mathematical model for honeybee dance leads naturally to the introduction of this space. Shipman speculated that quarks have some role in biology [A23] . Dark matter hierarchy indeed makes indeed possible scaled up copies of QCD type theory in biological length scales.

3. WCW spinor fields restricted to a CD with fixed moduli have infinite number of bosonic and fermionic degrees of freedom. Spin-like degrees of freedom for these fields correspond to WCW spinors, which describe many-fermion states consisting of quarks and leptons and bosons defined as their bound states. This Fock state is assigned to each 3-surface and the dependence on 3-surface defines purely bosonic ('orbital') degrees of freedom, which can be coded by using a state basis whose elements have well-defined spin and color quantum numbers. The bosonic and fermionic degrees of freedom are super-symmetrically related.

WCW spinor fields as morphic fields

The interpretation of the WCW spinor fields as memes or morphic fields is encouraged by two observations.

1. Zero energy states have an interpretation as Boolean rules $A \to B$ as well as self-organization patterns. Fermion number 1 and 0 for a given fermion mode represents values of one particular Boolean statement in positive *resp.* negative part of the state. The instances of A are assigned to the positive energy (initial) state and those of B to the negative energy (final) state and the quantum superposition of the paired instances defines the rule. Since time-like entanglement coefficients define M-matrix, the interpretation as a law of physics coded to the structure of the physical state itself is possible. Fermionic degrees of freedom correspond to the spin indices of WCW spinor fields. Besides this there are "orbital" degrees of freedom in the moduli space for CDs and in the space of deformations of light-like 3-surfaces. It is natural to assign these degrees of freedom to sensory perception.

2. The p-adic description of cognition and intentional action involves a generalization of the notions of number and of imbedding space. The hierarchy of Planck constants means a further

generalization of the notion of imbedding space by replacing it with a book like structure. It seems that the discrete intersection of real and p-adic space-time surfaces consisting of rational points (possibly also algebraic points) is crucial from the point of view of consciousness theory. This is true also for the intersection of real and p-adic variants of WCW identified as 3-surfaces whose mathematical representation makes sense in both real and p-adic number fieldsin preferred coordinate fixed by symmetries.

The first intersection is expected to be relevant at quantum field theory limit, which involves the replacement of the partonic 2-surfaces with a discrete subset of points carrying quantum numbers. The second intersection is relevant in the full quantum theory. The notion of number theoretic Shannon entropy having negative values makes sense in both intersections since entanglement probabilities must make sense in both number fields so that they are rational or belong to an algebraic extension of rationals. In these intersections of realities and various p-adicities the evolution of memes is expected to take place.

One manner to understand the special role of rationals and algebraics relies on the observation that rationals represent islands of order in the sea of chaos defined by reals since their pinary expansion is predictable and analogous to a periodic orbit of a dynamical system whereas for a generic real number there is no manner to predict the pinary expansion.

Morphic fields relevant to living matter

All zero energy states have interpretation as memes or quanta of morphic fields in TGD framework. One can however ask what zero energy states are relevant for biological systems.

1. The memes relevant to living matter must have a very concrete connection to biology. DNA as topological quantum computer hypothesis states the magnetic flux tubes connecting nucleotides to lipids of nuclear and cell membranes define braid strands needed to realize topological quantum computations. Nerve pulse patterns induce fluid flows of cytoplasma and of lipids in turn inducing timelike braidings defining running topological quantum computation programs and their memory representations as space-like braidings in the final state. These programs living (in very literal sense) in the brains of geometric future and past define a 4-D population of memes. The intronic part of the genome is specialized to topological quantum computations and the time scale in this case can be and must be faster than for the chemical gene expression. The repetitive character of many intronic DNA sequences regarded as evidence for their junk character does not mean any restriction for topological quantum computation.

2. The notion of magnetic body has a central role in TGD inspired biology. Magnetic body has an onionl ike fractal structure and astrophysical size with wavelength of EEG wave defining the size scale of the magnetic body with which it is associated. Magnetic body acts as as an intentional agent using biological body as a motor instrument and sensory receptor. Magnetic body receives sensory and other information from biological body through EEG and its fractal counterparts and controls biological body via EEG type signals sent to the genome, where they induce chemical or electromagnetic gene expression. This allows to imagine also a mechanism of collective learning. The spatio-temporal nerve pulse patterns defining topological quantum computations are mediated via EEG and its fractal counterparts to the magnetic body of organism and from it to the magnetic body of another organism. The magnetic body of Earth - magnetic Mother Gaia- could serve as a relay station and Schumann resonances and alpha band could allow broadcasting of the nerve pulse pattern to a large number of magnetic bodies of organisms. From the latter magnetic body the field representation of nerve pulse pattern would induce via EEG type signal from magnetic body to the receiver genome the original nerve pulse pattern in the brain of the receiver. Nerve pulse patterns would be quite generally induced by magnetic bodies via appropriate part of the intronic genome as electromagnetic gene expression. This mechanism could be also involved with telepathy and remote mental interactions.

3. Morphic resonance and alike likes alike rule can be understood from the condition that the intronic parts of genomes must be similar enough to allow the realization of the topological quantum computation. Also neuronal pathways involved must resemble each other in order that spatial nerve pulse patterns can be re-produced faithfully enough. Also the evolutionary levels

must be more or less the same in order that the topological quantum computation has same meaning for the receiver and sender. Therefore the collective memory might be restricted to the level of species. This might be however too strong an assumption. For instance, shamanism could represent an example of interspecies memory. The TGD based view about memory allows also the possibility to use the memories of the already deceased members of species which can in principle continue to exist in the geometric past.

4. The general vision about evolution as recreation of the quantum Universe implies that creativity is in very literal sense a basic aspect of TGD Universe. The U process represents the creative aspect of consciousness generating quantum super-position of Universes from which generalized state function reduction process selects the outcome. Both volitional actions and sensory perception involves the selection but quantum statistical determinism implies that sensory percepts are usually predictable.

Collective memory, geometric memory and self hierarchy

The notion of species memory is rather radical departure from the teachings of standard neuroscience so that TGD based view about memory deserves a separate discussion.

TGD predicts infinite hierarchy of selves and if this hierarchy has levels between living systems and entire universe, the idea about collective memory makes sense and generalizes to an entire hierachy of them.

Geometric memory provides a promising candidate for the mechanism of a long term memory. Geometric memory is made possible by the fact that self can have multitime experiences such that the space-time sheets associated with various values of the geometric time give contributions to the experiences and past contributions are experienced as memories. In zero energy ontology these space-time sheets are associated with sub-CDs of CD associated with self. Both time-like entanglement betweeen sub-CDs of recent and past implying sharing and fusion of mental images an classical communications between these CDs are possible and give rise to episodal memories (direct re-experiences) and symbolic memories.

Since both geometric past and future change in each quantum jump these memories are not stable: long term memories are certainly unreliable. The memory formation mechanism of brain however tends to stabilize these memories. There is in principle no upper bound for the span of the geometric memories and one can consider the possibility of racial memory and even species memory. Under suitable conditions organism could be able to have the space-time sheets of the geometric past as its subselves and experiences these memories. Thus geometric memory is consistent with Sheldrake's claims and to some degree supports them.

Language learning and morphic resonance

The easiness of children to learn language could have explanation in terms of morphic resonance. The strong quantum entanglement between the child and parents, especially mother, could make the morphic resonance possible in the proposed sense. One can even imagine that mother's magnetic body directly induces nerve pulse sequences representing linguistic memes in the brain of child.

One can of course wonder why it is so difficult for the older people to learn language. Do we force us to learn the language at reflective level although it could occur at proto-level also. Older people learn rules but find difficult to apply them whereas child learns to apply the rules without learning the rules themselves. Are older people so far from quantum criticality that the large fluctuations leading to the generation of the new level of self-organization are not possible anymore? The reason could also relate to the degeneration of the magnetic flux tubes circuits due to ageing so that new topological quantum computation programs are not establishes so easily anymore.

Self hierarchy, bio-feedback and sociofeedback

Magnetic bodies act as intentional agents in the proposed model. They form also a hierarchy analogous to master-slave hierarchy. The proposed mechanism of collective learning involves the magnetic body of Earth in an essential manner. Also magnetic bodies of larger structures could be involved: there is indeed evidence that remote cognition involves galactic magnetic fields [K61] , [J40] .

The phenomenon of bio-feedback provides direct evidence for this phenomenon in a length scale familiar to us. By monitoring the behavior of say single neuron, it is possible to learn to affect the behavior of neuron volitionally. No knowledge about how this happens is needed: the volition is enough. The explanation would be that the information provided by the monitoring goes to the magnetic body of the person which reacts by sending control signals to the brain. The already existing magnetic flux tube connections guarantee that the volitional act affects the neuron. The possibility of biofeedback suggests the possibility of socio-feedback and feedback even at the level of species and entire biosphere.

An interesting test for the idea that people very close to each other could directly affect the brain function of each other would be biofeedback in which subject person tries to affect the behavior of a neuron of a close friend or relative. Mother and child might be an optimal choice in this respect.

2.6 Sheldrake's morphic fields and TGD view about quantum biology

I received two books of Rubert Sheldrake as a gift from Marc McWilliams, who has for years helped me by reporting about problems at my homepage and sending links to interesting articles. The titles of the books of Sheldrake are "*A new Science of Life: the Hypothesis of Formative Causation* [I30] and "*The Presence of the Past: Morphic Resonance and Habits of Nature*" [I31]. The titles reveal the two basic notions underlying the vision of Sheldrake.

What makes the study of the books so rewarding is that Sheldrake starts from problems of the existing paradigm, analyzes them thoroughly, and proposes solutions in the framework provided by his vision. There is no need to accept Sheldrake's views, just the reading of his arguments teaches a lot about the fundamental ideas and dogmas underlying recent day biology and forces the reader to realize how little we really know - not only about biology but even about so called established areas of physics such as condensed matter physics. These books are precious gems for anyone trying to build overall view.

The discussion of the previous section is several years older than the discussion of this section and I have not checked whether the two views are consistent and whether I am repeating same statements. This is not solely due to my laziness: the me of year 2004 is not the me of year 2011 and I feel that it is useful to allow the two prophets to express themselves freely: the reader can use both inputs besides Sheldrake's own excellent representations to form her own views. The reader should take these sections as jazz improvizations using the same theme rather than expressions of last will.

2.6.1 Habits of Nature

The idea that Nature would have habits just as we do is probably one of those aspects which generate most irritation in physicalists believing that Nature is governed by deterministic laws with classical determinism replaced with quantum statistical determinism. Sheldrake is one of those very few scientists able to see the reality rather than only the model of reality. Morphic resonance would make possible to establish the habits of Nature and the past would determine to high extent the present but on organic manner and in totally different sense as in the world of physicalist.

Some problems of biology

It is instructive to consider as an example the first chapter of the book about formative causation discussing the basic problems of biology. Shelrake's proposal is that something more than organic chemistry is needed to understand living systems. He assigns to this something the notions of formative causation, morphic fields, and morphic resonance. In the following brief summary I refer also to some TGD inspired proposals for the needed new notions as remarks.

1. First Sheldrake discusses first the standard mechanistic view which does not accept any "vital factors" or goal directedness but just the blind chemistry based on random change and choice but implicitly brings in these factors as genetic programs. In neuroscience one introduces computer paradigm without realizing that computers by definition are systems whose goal is to solve a problem mechanically. The goal is of course not posed by the computer but by its builder.

One important aspect of the vision is the idea about chemically operated switches (they could be non-coding DNA sequences) switching genes on and off. Morphogenesis could be seen as differentiation in which genes are switched on and off to produce a particular body part. A fairy tale in which the hero receives a key to open the next door to receive a new key to open... is very attractive metaphor for morphogenesis as a chemical process. This idea is very powerful but might not be all that is needed. The question popping up automatically is "Who turns the switches on and off?".

Note that assigning the information about organism to its genome is very near to the idea about organism as hologram. More generally, the idea about germ cell as a hologram representing some essential aspects about the organism is very attractive. There would no need to assign this information to genes or DNA alone. This would be more refined form of the naive idea that there is some kind of miniature representation of the fully developed organism realized in germ cells level.

2. Sheldrake discusses four problems of morphogenesis.

   (a) The first problem of morphogenesis is its stability - one speaks about regulation. In some experiments second cell of two-celled embryo is destroyed but the embryo still develops to a full organism albeit with abnormally small size. One can also fuse several embryos and they develop to single abnormally large organism. This suggests goal directedness. In the fairy tale the hero must overcome all kinds of misfortunes while trying to find the door to which the newest key fits.

   Development as a self-organization process depending only weakly on initial conditions might help to understand goal directedness as something only apparent. The basic aspect of self-organization indeed is the weak dependence on initial values: the reason is that dissipation in presence of external energy feed leads to a highly unique outcome. In absence of energy feed all motion ceases! Note however that the notion of self-organization should be also defined precisely. Should we adopt a purely classical view about self-organization based on non-equilibrium thermodynamics or about its quantum counterpart?

   (b) Second problem is how completely new structures (eyes, heart, brain, body parts,...) emerge during morphogenesis. It is very difficult to understand this in terms of genetic code alone. Genes seem to be too rigid structures. In the vision of Sheldrake's (and TGD vision) genes are only the hardware. Also software is needed. The fairy tale about hero with the keys comes in mind. Maybe the keys would be represented by the genes serving as switches activating or de-activating genes? This could mean a highly flexible chemical program since each reaction could proceed only when the preceding reactions have proceeded.

   But is morphogenesis only a realization of an existing plan or a genuinely creative process? What happens when something genuine new emerges in the genuine evolutionary process leading to full grown organism? Could non-equilibrium thermodynamics help to conceptualize the situation? In non-equilibrium thermodynamics one has several flow equilibria and the emergence of something genuinely might be seen as emergence of a new flow equilibrium. But is non-equilibrium thermodynamics enough? Is quantum coherence in biological length scales necessary in order to understand the creative aspects of morphogenesis.

   (c) Regeneration is the third problem. Full grown organism is able to regenerate large damaged parts of the organism. Also small pieces of organism can develop to a full organism. The brain of salamander can be split into pieces and these pieces can be shuffled randomly: yet the development leads to a salamander with a healthy brain. Could one regard organisms as hologram like structures with pieces of organisms representing in a good approximation the entire organism?

   The recent discoveries showing that the amount of DNA does not correlate much with the evolutionary level force to conclude that DNA alone cannot code for the entire organism. So called homeobox genes thought originally to code the phenotype of the organism are essentially same for all organisms so that something else is definitely involved. Could genetic code combined with self-organization and hologram paradigms be enough? The answer depends much about what we mean with self-organization and with hologram. Or should one interpret DNA as hardware and assume software as something unknown to the recent day physics?

(d) Reproduction is the fourth problem. It is also clear that a kind of fractal pattern is involved in the sense that the reproduction is scaled up variant of DNA replication and induced by the replication. The idea that everything reduces to DNA replication is attractive but do we really understand DNA replication at the level of first principles? Could it be that replication in some sense reduces to some fundamental process of Nature not yet identified in what we are used to call fundamental physics? Sheldrake suggests that morphic resonance favors the formation of almost copies and therefore replication. Morphic resonance is analogous to the tuning of radio but why this tuning should take place spontaneously? What principle could imply it?

Remark: In TGD framework the notion of generalized Feynman diagram leads to the idea that replication is indeed a key aspect of quantum physics. The 1-D lines of ordinary Feynman diagrams are replaced by 3-D light-like surfaces identifiable as orbits of partonic 2-surfaces. These 2-surfaces can have arbitrarily large sizes and one could assign them even to cell membrane. By strong form of holography these 2-surfaces are very much like holograms representing 4-D physics almost faithfully (the precise characterization of "almost" would require a more technical language telling not much for a non-mathematician). In the vertices of generalized Feynman diagrams the ends of the light-like 3-surfaces are glued together along partonic 2-surfaces. The simplest $1 \rightarrow 2$ vertex representing particle decay or emission has interpretation as a replication of partonic 2-surface. The quantum states associated with the resulting partonic 2-surfaces are not identical but geometrically replication is in question.

Could one identify this process as the fundamental replication process? If so, then replication in living matter would be only special case of a universal process present already in particle physics and distinguished from it only by the enormous complexity involved. This would be of course only the fundamental mechanism of replication. One must also explain why replication occurs.

The idea about self-tuning is highly attractive as a partial explanation for why replication takes place. What tuning makes possible is information transfer and in TGD framework there is temptation to explain tuning in terms of Negentropy Maximization Principle (NMP) [K46].

3. The understanding of morphogenesis is difficult but should be child's play as compared to the understanding of behavior. Inherited behavioral patterns - instincts- define the first hard problem. Information is transferred between generations and saying that genes -that is organic chemistry- code this information does not help much. Second problem is the goal directnedness of the animal behavior: animals can modify their behavior when something prevents the achievement of the goal. Behavior can be also intelligent: animals can learn new behavioral patterns. This is not in accordance with the idea that behavior is hardwired in the genome.

Remark: Physicist might see behavioral patterns as 4-dimensional patterns resulting in self-organization: characteristic time evolutions. But does this kind of notion make sense? Does it assume additional time? Usually it is thought that self-organization corresponds to an evolution of a 3-D pattern rather than 4-D one. Perhaps TGD based view about time is needed. The experienced/subjective time is assigned to conscious experience identified as a sequence of quantum jumps defining the basic building brick of conscious existence. Subjective time is not identified with the geometric time although they relate closely to each other- at least in standard wake-up consciousness [K4].

Each quantum jump replaces 4-dimensional pattern with a new one and the self-organization patterns in this 4-D sense could correspond to behavioral patterns whereas approximately static 4-D patterns reducing to 3-D patterns would represent morphologies. There are quantum jumps within quantum jumps so that the outcome is a fractal pattern having also interpretation as a self hierarchy. This gives one possible meaning for the "presence of the past" in the title of the second book of Sheldrake. Living matter would be essentially 4-dimensional and the goal directed behavior based on memory would reflect this 4-dimensionality: goal in general case 4-D pattern. In zero energy ontology the arrow of geometric time need not be always the same and signals propagating to geometric past are key element of TGD based view about memory, intentional action, and metabolism [K4]. This would represent a new element distinguishing TGD view from Sheldrake's view.

4. The notion of evolution is also problematic. Can microevolution within species explain the evolution of species itself? Or do sudden discontinuous jumps take place? Could evolution involve a genuinely creative aspect? Is there any hope that a choice among random mutations could explain the emergence of a new highly organized morphological or behavioral pattern? Note that exactly the same problem was encountered at the level of morphogenesis and development of individual. Only the time scale is different.

   Also adaptive convergence looks mysterious: same structure emerges at different sides of Earth simultaneously. For instance, the emergence of large primates leading to humans took place at widely separated places. This forces to ask whether morphic fields are involved and make entire species an organism so that the evolution is non-local process. This also relates to the idea about bio-system as a hologram. In Sheldrake's vision the simultaneous emergence of new species would reflect the holistic evolution of the entire biosphere.

   Remark: In TGD framework the emergence of a completely new structure could involve a phase transition introducing a new level to the hierarchy of Planck constants assignable to a given species. Since the value of Planck constant serves as a measure for evolutionary level, something genuinely new would emerge in the process. The maximal value of Planck constant could allow to characterize the evolutionary level of cell or neuron, organ, organism, population, and even species. The understanding of dark matter would become a prerequisite for the understanding of the living matter.

5. Sheldrake discusses also the origin of minds and parapsychology in this chapter. Morphic fields could obviously relate to mind and make also possible remote mental interactions.

   Remark: In TGD framework the theory of living matter involves quantum theory of consciousness as an essential part and the notion of magnetic body carrying dark matter - in particular dark photons- is a good candidate for the counterpart for the morphic fields.

The notion of morphic field

The notions of morphic field, morphic resonance and formative causation are very interesting and there is considerable support for Sheldrake's vision. The initial motivation for the notion of morphic field was that the same skill discovered by populations located in different parts of the world. Theory leads to idea about learning and memory at the level of species and also to an idea about gene expression at level of species in which remote activation of genome takes place using morphic signals from past. Genome would be the hardware and morphic fields the software.

Shelrake uses TV as an analogy.

1. Morphic fields would be analogous to radio waves carrying information (say in terms of amplitude or frequency modulation) and could code genetic information and genetic programs. Genes act as antennas and the details of gene expression depend on the value of the tunable antenna frequency. When the antenna frequency changes, the received signal changes and gene expression changes too. Adaptation could correspond to a change of antenna frequency in turn modifying gene expression as a response to a modified morphic signal. Also epigenetic inheritance could relate to the activation of genes acting as switches for genes. Mutations would correspond to changes in the genome analogous to the changes in the hardware of TV.

2. The tuning to some frequency would be the basic process in brain and is known as entrainment. In fact, even mechanical systems such as clocks are known to entrain to a common rhythm. The physical mechanism for this is not well-understood. Perhaps the entrainment is a fundamental physical process having explanation in terms of NMP (Negentropy Maximization Principle [K46]. If so, the idea about tuning would be a generalization of what we already know to take place.

3. The idea about morphic signals from past affecting the gene expression in the genomes of the same species would explain many strange findings discussed by Sheldrake. Morphic signals could silence or activate genes. If there are genes inducing modifications of DNA, then morphic signals could even modify the genome. Species would be kind of hologram: each member would be a representation for the species and genetic expression would be collectively determined.

4. What kind of morphic field patterns are possible? A natural proposal is that DNA sequences can be coded to the spatiotemporal patterns of morphic fields. TGD based realization of morphic fields is one possible realization of his condition. In this case frequency which for a fixed photon energy is coded by the value of Planck constant matters as also the connection defined by magnetic flux tube between molecules involved.

   Modern radio-communications code the data to bit sequences represented as temporal patters of the radio wave. Could the temporal patterns of morphic fields be important and could one imagine some codes? Among other words this would make possible selective communications using passwords. For resonance common antenna frequency would be enough and the experience from computer communications suggests the possibility of a coding based on the representation of bits as pulses but many other codes can be imagined.

   Remark: If certain carrier frequencies carry information, NMP would explain why self-tuning occurs.

Sheldrake proposes speculative but fascinating applications of morphic resonance in somewhat unexpected contexts.

1. The fact is that even the formation of simplest crystals is poorly understood for the simple reason that the calculations needed are extremely complex. Simplified models represent larger numbers of crystal structures and it is difficult to understand why only very few crystal forms are realized in Nature. The standard professional folklore among chemists is that once some new chemical compound has been been crystallized for the first time its crystallization becomes gradually easier and easier. The obvious looking explanation for this is not however obvious. Could morphic fields select one of the many possible crystal forms? Could crystallization to a specific crystal form be a habit of Nature?

2. Protein folding is second mysterious phenomenon. The mysterious aspect of the process are its deterministic character and its rapidity. The number of possible foldings is astrophysical and one can expect a huge number of local minima of free energy and therefore a huge number of thermodynamically stable foldings. Sheldrake suggests that the interaction with the morphic fields of the environment is part of the process and makes the folding a learned habit.

Inheritance and morphic fields

Sheldrake discusses inheritance and suggests that besides genetic inheritance and epigenetic inheritance also morphic fields could give rise to a new kind of heritance. The basic question is whether the acquired characteristics resulting from adaptation could be inherited in some manner. This is usually known as Lamarkcian inheritance of acquired characteristics. One can also ask whether adaptations perhaps allowing interpretation as mutations of morphic fields- software- could be transformed to mutations - modifications of the hardware.

1. Epigenetics [I1] is the study of the mechanisms inducing changes in gene expression without change in DNA itself. Differentiation of cells is the most obvious example of this kind of process. The suppression of gene expression without altering the DNA sequence of altered genes by DNA methylation or histone deacetylation is one mechanism of epigenesis. Epigenetic changes are preserved in cell division.

   Also epigenetic inheritance is possible. This requires that the modification of genes -say methylation of DNA - takes place also at the level of eggs and sperm. For instance, it has been discovered that the effects of famine and diseases can echo to the next generations. The mechanism making this possible is not well-understood and one can ask whether morphic resonance is involved and affects also the eggs and sperm. If so, one could speak about inheritance of acquired characteristics.

2. The notions of dominating and recessive gene are familiar for everyone from school days but very few of us has asked what makes the gene dominant or recessive. Or whether both genes (alleles) could affect the phenotype (say color of the flower) to some degree. Usually the chromosomes appear as non-identical pairs and the members contain corresponding genes (alleles) coming from the parents. These genes are not identical so that they can code different trait for the same

phenotype. The question is what chooses which allele is expressed. The usual answer is that the "normal" gene is expressed. But what makes the gene "normal"?

The proposal of Sheldrake is that morphic signals from past force the expression of the normal gene. The normal gene is the one expressed also in the past and for these reason the signal from past supporting the expression of this gene dominates. Gene expression is to some degree like a habit due to majority democratic decision of a 4-D society. It is also possible that both alleles determine the trait. Sheldrake's interpretation would be that in this case both morphic signals can be realized and the outcome is a mixture of traits. Different cells have in this case different habits.

3. Sheldrake discusses also what is known as genetic assimilation discovered by Waddington in his study of fruit files. Fruit flies are subjected to external stimuli and as a result develop abnormal phenotypes. What happens that when external stimuli are absent the abnormal phenotype still appears. One can consider several explanations.

   (a) Waddington explains this in terms of canalized pathways of development which he calls chreodes. Abnormal chreodes would be so stable that the the absence of stimulus originally inducing them would not affect the situation.

   Remark: In TGD framework chreods could correspond to 4-D self-organization patterns depending only weakly on the initial conditions.

   (b) Epigenetic inheritance could explain the phenonenon.

   (c) Also morphic resonance could explain the finding. The morphic signals from previous generations are present and the net signal would favor the continuation of abnormal gene expression. Indeed, Mae-Wan Ho demonstrated that a strain of flies not subjected to the treatment at all also exhibited the abnormal phenotype in absence of the stimuli. Gradually however the normal phenotype wins. Morphic resonance explains this finding whereas epigenetic inheritance fails to do it.

4. Adaptation to an external stimulus (such as X-rays, come chemical, unusual temperature ....) can produce similar effects on phenotype as a genuine homeotic mutation (say the replacement of antenna of fruit fly with wing). Why mutations can produce effects similar to those produced by adaptation? Is it possible that adaptive changes are transformed to mutations by some mechanism?

   (a) Epigenesis is a possible explanation for the change of the phenotype. Epigenetic inheritance does not however explain whyt mutations and adaptations look so similar.

   (b) Morphic resonance would modify only the software but not hardware and could thus explain adaptation. The modification of the antenna frequencies of genes could have profound effects on gene expression in the case that the antenna frequencies of the switch genes are modified. Morphic signal could be even turned off or on.

   Neither explanation for adaptation is able to explain why mutation and adaptation produce similar modifications of the phenotype nor provide a mechanism transforming long term adaptation transform to a mutation. In the case of adaptation the same effect would be produced by using suitable genetic program. Does the finding of the correct genetic modification - addition of a new gene in the simplest case- require trial and error process? How the system knows what mutation produces the same effect as the more complex genetic pathway induced by adaptation? How the activation of this pathway could favor the selection of mutated genes producing the same effect? The Darwinian answer to the question would be of course "survival of the fittest" but is this process too slow?

   Remark: Later a TGD inspired mechanism for the transformation of adaptation to mutation will be discussed.

2.6.2 TGD inspired quantum biology

TGD inspired quantum biology leads to a picture which has quite a lot in common with Sheldrake's vision. The hypothesis are following.

1. There is a hierarchy of conscious entities and therefore also what can be called hierarchy of collective levels of consciousness. One can speak about species as a living and conscious organism. This suggests among other things coherent collective gene expression and one ends up with the notions of super genome assignable to organs and hyper genomes assignable to organisms, populations and even species. Entire biosphere can be seen as conscious living organism.

2. TGD is an attempt to unify real number based physics and p-adic physics for various p-adic number fields interpreted as physical correlates of cognition. One can assign to each p-adic prime a number theoretic entropy making sense when probabilities are rational or even algebraic numbers. The number theoretic entropy can have negative sign and in this case represents genuine information. In the case of negentropic entanglement the interpretation is that entanglement represents information. This information is not about the state of individual subsystem but about the state of the entire entangled system. A kind of abstraction representing a rule with paired states in the superposition representing the instances of the rule.

   The proposal is that living systems reside in well-defined sense in the intersection of real and p-adic worlds: in the intersection of matter and cognition. Combined with negentropy maximization principle (NMP) stating the information contents of conscious experience is maximal [K46] this leads to a more general view about quantum jump and state function reduction: state function reduction need not anymore be a random process. NMP could explain why morphic resonance identified as tuning to particular frequencies takes place spontaneously.

3. Non-locality is essential. TGD provides a new view about fields and the relationship between experienced and physicist's time. One outcome is possibility of macroscopic quantum entanglement and also time-like entanglement in macro-temporal scales of order of memory span and time scale of planned action. One can say that any physical system is four-dimensional and for the understanding of living system this four-dimensionality is essential.

4. The identification of dark matter (the dominant portion of matter) as ordinary matter but with (effective) Planck constant equal to integer multiple of and hence larger than ordinary Planck constant, is essential. For large values of Planck constant macroscopic quantum phases are possible even in the scales of order Earth size and would be a crucial element of living matter making among other things quantum entanglement in the scale of species possible. One can indeed imagine the possibility of collective gene expression. Also phase transitions changing the value of Planck constant would play a key role in bio-chemistry. Dark matter indeed plays a key role in the TGD inspired model for living systems.

5. So called topological quantization of classical fields is essential. In particular, magnetic fields correspond to flux quanta which have concrete geometric representations as flux tubes and sheets identifiable as non-trivial topology of space-time in macro scales.

   (a) The notion of magnetic body is in a key role. One can say that magnetic body uses biological body as a motor instrument and sensory receptor. A fractal hierarchy of EEG like radiation patterns makes possible control by magnetic body and communication to it from biological body. Topological field quanta- in particular magnetic body carrying dark matter- plus ordinary inanimate matter make together living matter.

   (b) Also classical electric fields are predicted to be important: living matter is indeed full of electrets. One can consider two kinds of electric fields. In the first case one can have strong electromagnetic (electro-weak) fields although space-time sheet is almost vacuum extremal. In the second case one has far from vacuum extremal and electromagnetic field and color gauge field are proportional to each other. Both situations are expected to be important in biology [K29, K21].

   (c) So called topological light rays ("massless extremals") attached to magnetic flux tubes are in central role [K53]. Topologically condensed dark photons propagate along them and they can be regarded as analogs of laser beams making possible precisely target communications without dispersion and with maximal signal velocity.

6. Morphic fields might allow identification as dark photon signals propagating with light velocity: this implies effective simultaneity. Also genuine simultaneity is possible by quantum entanglement in macroscopic scales. I have proposed a model for remote DNA replication and remote

gene expression and even remote modification of genome becomes possible if there are genes specialized to this.

DNA and also other biomolecules act as quantum antennas receiving and sending "dark" photons. Two molecules communicate and are able to interact when they have same antenna frequency. This is key part of also bio-catalysis and quantum antenna resonance makes it possible for biomolecules to find each other in the dense soup of biomolecules.

7. Genetic code generalizes and has several realizations. One can say that DNA sequences provide names for polar molecules and one can imagine a mechanism which assigns to this kind of molecule a DNA sequence which codes for a protein attaching to this polar molecule. This might be the basic mechanism allowing the immune system to modify itself rapidly as a response to external stimuli such as invader molecules.

The TGD counterparts of morphic fields

Sheldrake does not speak about quantum effects but is well aware that new physics is needed to understand morphic fields. It is indeed clear that one cannot understand morphic fields in standard physics framework. Even standard quantum theory might not be enough since it allows quantum coherence only in atomic and molecular length scales and already now it is known that quantum coherence prevails in longer length scales in living matter.

1. Quite generally, the ordinary classical gauge fields allowing geometrization in TGD framework and their quanta would define could candidates for the counterparts of morphic fields. This would include both electro-weak and color gauge fields and for large values of Planck constants both weak and color gauge fields could have interaction range relevant for living matter. Biomolecules would act as quantum antennas and morphic resonance would correspond to antenna resonance.

2. Magnetic flux tubes carrying dark photons would replace morphic fields. The braiding of magnetic flux tubes would make possible coding of topological quantum computer programs and flux tubes could connect various molecules with same resonance frequencies making them quantum antennas. The changes of Planck constant for the flux tubes would change their lengths and the contraction of the flux tube could bring distant molecules near to each other so that they would participate in common reaction. This would be the basic mechanism of DNA replication, DNA-mRNA transcription, mRNA-aminoacid transcription and other similar processes. One can also imagine remote replication of DNA and remote version of gene expression. Here TGD based view about dark matter predicting that the states of dark nucleons are in 1-1 correspondence with DNA, RNA, tRNA, and amino-acids is of crucial importance since it makes possible for water to realize genetic code so that biological realization would emerge from this more fundamental realization.

3. The fractal hierarchy of magnetic bodies makes possible collective quantum coherent gene expression and perhaps even collective modifications of genome explaining the convergent evolution. One can imagine that the flux sheets traversing through DNA arrange it to flux sheets organizing the DNAs of organs to single coherent whole. Same would apply in the case of organism and perhaps even in the case of group of organisms and of population. I have introduced the notions of super - and hyper genome to describe this idea [K31].

It must be emphasized that the TGD counterpart for morphic fields and morphic resonance would not explain the creative aspects of evolution. Also the TGD based view about quantum jump, zero energy ontology, hierarchy of Planck constants, NMP, and other new notions are needed.

Self-organization and morphic resonance

Consider next the general TGD inspired view about self-organization by the analog of morphic resonance.

1. In TGD Universe one could see morphologies as 3-D static self-organization patterns and behavioral patterns as 4-D self-organization patterns. The signals defined by morphic fields should select these self-organization patterns. Since self-organization patters typically depend only

weakly on their initial values (now basically 4-D self-organization patterns replaced by new ones in quantum jumps), morphic fields must select initial values properly. In 4-D situation about which static 3-D situation is special case, frequencies and wave lengths would represent simplest information about the asymptotic self-organization pattern. They would correspond to higher level slowly varying fields serving as effectively external parameters determining the self-organization patterns in shorter time and length scales in accordance with the Slaving Principle of Haken.

2. One can also imagine the morphic resonance mechanism in which molecules act as quantum antennas tuning to each other and forming interacting groups of molecules. The ability of biomolecules to find each other in a dense soup of biomolecules could be based on pre-existing flux tube connections between them. Morphic resonance could be seen as spontaneous self tuning. Organisms would be like radio receivers spontaneously tuning to frequencies at which the previous generations send information. After this tuning the self-organization would proceed rapidly. In terms of consciousness theory one might say that self at the higher level of hierarchy would turn its subselves like we tune radio to a particular wavelength.

   But why this tuning would take place spontaneously? One can argue that tuning generates negentropy and in TGD framework the basic distinction between living and inanimate is negentropy. Could the NMP - in some sufficiently strong form- explain why this tuning takes place? What the maximization of the information content of conscious experience [K46] can mean is however not clear. NMP could also relate to how the arrow of geometric time emerges and in sufficiently general form could even explain why the contents of sensory experience is about rather narrow time interval (with duration of about .1 seconds for human sensory perception) [K4].

   Tuning to the frequencies or morphic fields realized as antenna frequencies would be the manner to determine in a given scale the initial conditions leading to unique final outcome very rapidly. The hierarchy of Planck constants assignable to flux tubes mediating dark photons signals would allow the dark photons to have same energy -say at visible range- but different wave-length to which flux tube would be proportional to. Kind of Indra's web would serve as space-time correlate for the morphic fields.

   Tuning to a particular frequency to maximize conscious information suggests that this particular frequency defines a carrier wave for information transfer. Frequency and amplitude modulations and bit sequences represented as temporal patterns is what comes first in mind as concrete representations of this information. TGD based view about hearing [K29, K59] suggests two basic representations of information corresponding to temporal patterns and frequencies (the inspiration comes from the 'left brain talks, right brain sings' metaphor).

3. The explanation of Sheldrake for dominating/recessive genes in terms of morphic resonance implying that normal gene expression is a genetic habit based on majority decision of members of species in the past is very elegant but need not be correct of course!

   If the antenna frequency of the corresponding genes (alleles) in the chromosome pair are same and corresponds to the antenna frequency of either parent, the gene corresponding to this frequency is expressed. Suppose that this frequency corresponds to the same dark photon energy so that the frequencies are inversely proportional to Planck constant so that higher Planck constant would correspond to a lower frequency. Could the lower frequency defined the common antenna frequency for chromosomes so that the parent with larger value of Planck constant would dominate? This option would explain the dominance differently and normal would correspond to the larger value of Planck constant. The mutations favoring the increase the value of Planck constant would be favored. NMP - understood in sufficiently strong sense- would favor the increase of Planck constant quite generally. One must of course be however very cautious in order to avoid systematic use of NMP to fill the holes in the theory.

4. What is the role of magnetic body and of topological quantum computer programs coded by braidings? Certainly this level should be very closely related to morphic fields. The function of introns is not well-understood and the obvious question is whether the flux tubes emerging from introns could be responsible for quantum computer like activities defining the real software [K24, K79]. Is the magnetic body itself genetically coded and does temporal self-organization patterns - behavior - correspond to this coding?

It is known that the distribution of codons in intronic portion mimic distribution of letters in natural languages. Could the intronic part of the genome code for the magnetic body, in particular its braiding? What is the effect of external perturbations inducing flow of lipids at lipid layers of cell membrane to the braiding. Zipf law stating that the frequency of the word of natural language is proportional to its rank defined according to the ordering defined by its frequency of occurrence holds also for artificial words identified as sequences of subsequent intronic DNA nucleotides of fixed length. Does this mean that intronic DNA defines some kind of language.

5. A reasonable guess is that adaptation affects the genetic programs identified as topological quantum computer programs but not DNA and only rarely even genome (as in case of methylation). In mutation the hardware- genome- is affected and the question concerns the mechanism for the transformation of adaptation to mutation. Dark nuclei define representation of the genetic code and the following proposal is a suggestion for how this could happen.

Dark nucleons, genetic code, and its modifications

Dark nucleons represent genetic code in TGD Universe. What could be their role in the gene expression and in the evolution of genome? Cold dark nucleons define a kind of R&D laboratory allowing to test various kinds of DNA sequences.

1. The basic idea is that any polar molecular is covered by an "ice layer" consisting of ordered water. Assume that this layer determines the magnetic body of the molecule. External perturbation such as the feed of energy cuts the hydrogen bonds connecting the molecule to this layer and molecule can temporarily loose its magnetic body. Assume that this process generates sequences of dark nucleons (dark nuclei consisting of dark protons) which correspond to RNA, DNA, tRNA or amino-acid sequences. In this manner polar molecule would get name coded by the dark nuclei. If transcription of this sequence to DNA or RNA exists, it is possible to assign to this sequence DNA sequence serving as a gene coding for a protein which interacts resonantly with the polar polar molecule via the antenna frequencies defined by the cyclotron frequencies of its magnetic body. This would allow to generate a gene coding for gene attaching to the invader molecule.

2. At least in the case of immune system one might think that system is able to perform genetic engineering as a response to molecules invading to the system and I have proposed a mechanism for this. The transcription of dark genes represented as dark nuclei to DNA or RNA could provide a completely new mechanism of modifying the genome of egg and sperm cells since dark nuclei could penetrate cell membrane without difficulty.

3. Could the mechanism assigning to polar molecule a protein attaching to it allow the transformation of adaptation to mutation? If some protein defines a bottleneck step in adaptation, one could imagine that the transcription of the dark nucleon assigned with this protein to a piece of RNA reverse transcribed to DNA could transform the adaptation to mutation. More generally, if some proteins appear as basic steps in adaptive production of the change of phenotype then this process applied to them could produce the desired mutation of DNA.

4. Also collective genetic modifications can be imagined if there are genes inducing standard genetic modifications. Hardware would modify itself. Species could modify itself by using remote or collective expression of this kind of genes. Recall that retroviruses consist of RNA and reverse transcriptase catalyzing the reverse transcription of RNA to DNA in turn yielding the copies of retrovirus via transcription to mRNA and RNA. If RNA era continues in cell nucleus one can ask whether genome is continuously modified by the attachments of reversely transcribed DNAs from pieces of RNA. Reverse transcription has a high error rate.

To sum up, TGD approach would allow physical interpretation for morphic fields making possible remote gene expression and perhaps even remote genetic engineering. The past of species would affect the recent species. Both spatial and temporal non-locality would be key elements of life making possible memory and planned action.

2.7 Some considerations relating to the dynamics of quasicrystals

The dynamics of quasicrystals [L4] looks to me very interesting because it shares several features of the dynamics of Kähler action defining the basic variational principle of classical TGD and defining the dynamics of space-time surfaces. In the following I will compare the basic features of the dynamics of quasicrystals to the dynamics of preferred extremals of Kähler action [K8].

Magnetic body carrying dark matter is the fundamental intentional agent in TGD inspired quantum biology and the cautious proposal is that magnetic flux sheets could define the grid of 3-planes (or more general 3-surfaces) defining quasi-periodic background fields favoring 4-D quasicrystals or more general structures in TGD Universe. Also 3-D quasicrystal like structures defined by grids of planes can be considered and 4-D quasicrystal structure could represent their time evolution.

Quite recently it has been reported that grids consisting of 2-D curved orthogonal surfaces characterize the architecture of neural wiring so that this hypothesis might make sense. This structure would be analogous to 2-D quasicrystal and its time evolution to 3-D quasicrystal.

2.7.1 The non-determinism for the dynamics of quasicrystals contra non-determinism of Kähler action

The dynamics of quasicrystals is non-deterministic in the sense that one cannot construct a unique quasicrystal by starting from a finite portion or even D-1-dimensional section of D-dimension quasicrystal thickened to a slice. Four-dimensional quasicrystals would therefore define a non-deterministic dynamics. This dynamics could serve as a geometric correlate for a full non-deterministic quantum dynamics involving also state function reductions. This requires that quantum classical correspondence is generalized so that also non-deterministic aspects of quantum dynamics are required to have geometric space-time correlates. The global empires of the 4-D quasicrystal could be interpreted as self-organization patterns whereas global empires would represent long range correlations.

This is very much analogous to 4-D spin glass degeneracy in TGD framework.

1. In TGD framework the preferred extremals of so called Kähler action define the dynamics of space-time surfaces. Kähler action [K34] is Maxwell action for the gauge field induced from the Kähler form of CP_2. Symplectic transformations of CP_2 act as abelian gauge transformations and therefore leave the induced Kähler form invariant. They do not however leave the induced metric invariant so that the action changes by a contribution assignable to classical gravitation. For vacuum extremals however the symplectic transformations act as symmetries.

2. This implies huge vacuum degeneracy. Every space-time surface for which CP_2 projection is Lagrangian manifold and thus having at most 2-D CP_2 projection has vanishing induced Kähler form and is therefore vacuum extremal: there is infinite number of 6-D vacuum sectors labelled by Lagrangian sub-manifolds of CP_2 transformed to each other by symplectic transformations. These vacuum extremals behave non-deterministically which means an analogy with quasicrystal dynamics and suggests that quasicrystals might define a simplified model for quantal self-organization.

3. Small deformations of these define non-vacuum extremals and It is very conceivable that part of the vacuum degeneracy remains and is manifested as multi-furcations. The number n of branches for a multi-furcation has interpretation in terms of effective Planck constant $\hbar_{eff} = n\hbar$ to which dark matter is assigned in TGD framework. This degeneracy is very much analogous to a 4-dimensional spin glass degeneracy meaning that space-time decomposes to deterministically behaving regions just like spin glass decomposes to magnetized regions with varying direction of magnetization.

4. The interpretation for the situation in TGD framework is in terms of quantum classical correspondence: not only quantum states correspond to space-time geometries as analogs of Bohr orbits but also quantum jump sequences - which according to TGD inspired theory of consciousness define the contents of consciousness - have non-deterministic space-time geometries as geometric correlates. Space-time geometry and topology are like written text providing information about contents of consciousness.

5. Also p-adic topology as effective topology of space-time surfaces and natural topology for the landscape of extrema of Kähler function of WCW definings its Kähler geometry emerges naturally from this degeneracy. In physics obeying effective p-adic topology the counterpart would be short range chaos with long range correlations in the sense that one would have periodicity in the sense that physical states at time time at and $t + kp^n$, $k = 0, 1, ...p - 1$, $n \geq\geq 1$, would be very near to each other. The interpretation in terms of intentional action would be natural.

   One could also imagine of defining the analogs of empires as connected deterministic regions of space-time surface and the analogs of empires would be unions of disconnected components perhaps understandable in terms of p-adicity. Self-organization patterns would naturally correspond to these regions. Many-sheeted space-time would imply fractal hierarchy of self-organization patterns within self-organization patterns.

2.7.2 The dynamics of quasicrystals as a model for fundamental dynamics or high level symbolic dynamics?

Stephen Wolfram has suggested that cellular automatons could define the fundamental dynamics. It is not difficult to invent grave objections against this view. One of the objections is that this kind of dynamics is based on simple and rather ad hoc rules and applies to a society rather than to elementary particles. It is difficult to circumvent this counter argument.

One can however ask in what scale the symbolic dynamics does emerge? For few years ago my answer would have been "in biological length scales" (genetic code as symbolic dynamics). TGD Universe is however fractal, and this forces to ask whether this symbolic dynamics emerges already above CP_2 scale in some rudimentary form. In any case, even in this case the dynamics of self-organization would not be identifiable as the fundamental dynamics but as analogous to the rules of behavior in society.

The dynamics of quasicrystals brings indeed strongly in mind the dynamics of self-organization patterns prevailing at relatively high level of dynamical hierarchy. Symbolic dynamics prevailing at the level of biomolecules (genetic code) and at higher levels could be in question. This dynamics is dynamics for a society of conscious entities, which can decide whether to follow the rules or not. Rules as such do not matter too much: what is important that they make possible to predict the behavior of individuals and therefore make possible co-operation and formation of coherent and synchronous large scale structures making possible collective consciousness. In human society moral rules, laws, traffic rules, grammatical rules of language, etc... are examples about symbolic dynamics having very little to do with the laws of physics at fundamental level.

A natural question is whether the rules for building quasicrystals could provide a simplified model for this "social" dynamics - or perhaps even semi-realistic description - at the molecular level? Either quasicrystals or their building bricks - the arguments to be discussed later suggest that finite-sized quasicrystals - could be seen as a kind of society. The refusal to obey the rules guaranteeing the formation of larger quasicrystals would stop the quasicrystal growth and isolate the individual quasicrystal from the society. It could also lead to metabolic starvation: metabolic energy feed is indeed crucial element in living systems.

Quasicrystals could be seen as idealized structures having maximal complexity and therefore ability to represent information. Critical systems - also quantum critical ones - have a universal dynamics so that there is a large number of models making the same predictions for a given system. In practice this can be used to find the simplest possible model to simplify the mathematical description (say by finding the simplest conformal field theory to describe a 2-D critical system). From this point of view quasicrystals could be seen as an especially simple model possibly able to catch the universal properties of a real world system.

Does this self-organization dynamics then emerge only at and above bio-molecular scales or in all scales?

1. In TGD framework the classical dynamics at the fundamental level would be the geometrodynamics of space-time surfaces [K63]. Quantum Dynamics would be dictated by Dirac equation for WCW ("world of classical worlds") spinor fields and reduce to the modified Dirac equation for second quantized induced spinor fields at space-time surfaces.

   The fractality of the TGD Universe suggests that self-organization occurs in all length scales above CP_2 scale, which is about 10^4 times Planck scale. If so, structures analogous to finite pieces quasicrystals could appear in all scales down to CP_2 scale.

2. I have proposed a method for constructing preferred extremals of Kähler action [K86] and this recipe leads to an iteration procedure. Quite generally, iteration is known to lead to fractals as fixed sets of iteration. Therefore space-time surfaces could be seen as space-time correlates of self-organization patterns and fractals.

3. Fractality would mean that even inanimate matter should share some aspects assigned to living matter and that also systems like species and biosphere could behave like living organisms in some respects. Sheldrake has proposed is famous for his notion of memory at the level of entire species. He has also proposed that even inanimate systems could have "habits". For instance, minerals would have adopted the habit to crystallize to a particular crystal form. In this framework living matter would differ from mineral kingdom in that its habits would be much more flexible. I have discussed the implementation of Sheldrake's ideas in TGD framework [L3].

2.7.3 Could ordered water layers around biomolecules be modelled as quasicrystal like structure?

Water forms multilayered quasi-lattices (to be distinguished from quasicrystals!). These quasi-lattices around molecules are like ice coverings. These quasilattices have water molecule as a basic tedrahedral building blocks giving rise to icosahedral blocks (as suggested in discussions): the 4 electron pairs of water molecule are indeed located at the vertices of tedrahedron and for lattice like structures a regular tedrahedron is in question. Perhaps these quasi-lattices could be modelled as deformed quasicrystals.

This molecular ice would form a quasicrystal, which could somehow store information about environment via its structural degeneracy. If the information is conscious, it should be stored in the negentropic entanglement between the states of finite-sized quasi-lattices surrounding two separate molecules, and would have magnetic flux sheets connecting them as a space-time correlate. For 3-D quasicrystal like structure the lattice points would be in the intersections of 3 2-planes (or thin locally planar flux sheets) and define points of a lattice at which the analogs of coordinate planes meet.

Making these structures dynamical one would obtain 4-D quasicrystal like structures. In this case the intersections of 2 3-planes (or thin locally planar 3-D flux sheets) would give rise to 1-dimensional word lines of 3-D quasicrystal points whereas the intersections of 3 3-planes would correspond to points of 4-D lattice. What special could happens at these dynamically special points of space-time?

Zero energy ontology and TGD inspired theory of consciousness allows to consider a possible answer: the points of 4-D lattice correspond to CDs (causal diamonds) serving as space-time correlates for sub-selves identifiable as mental images. Quite generally quasi-periodically appearing mental images might be assigned to the points of quasi-lattice like structure.

Note that also cubic crystals can be constructed using grid consisting now of 3 orthogonal planes and the distances between grid planes serve as geometrical parametersm which magnetic body could vary. The constant deformation of the magnetic body would now however force rather large deformations of crystal structure probably impossible energetically. One can however ask whether phonons could be induced by the local deformations of the flux sheets of the grid inducing small oscillations of the lattice points. If the magnetic body indeed serves as the intentional agent using biological body, this connection might allow to understand the very special role of acoustic oscillations in hearing, speech, internal speech, and thought. For instance, could the reaction of magnetic flux sheets to sound give rise to hearing? And could the reaction of the quasilattice units to the oscillations of the flux sheets give rise to internal speech or induce even speech in sound organs? It has been argued that the structure of the intronic portion of DNA resembles that of language and this has led to proposal that acoustic waves propagating along DNA could code for language. If DNA is indeed accompanied by flux tubes and flux sheets, this idea would look rather natural in the recent context.

One of the basic findings of biology is that protein molecules are most of the time in a resting state in a folded configuration with globular form and surrounded by ordered water defining kind of ice covering. This state could represent conscious information realized as a negentropic entanglement between different molecules: kind of a molecular meditative state would be in question. In the presence of energy feed inducing "molecular summer" the molecular ice would melt, globular proteins would open and self-organize to form molecular aggregates as a reaction to the energy feed. After the energy feed stops, molecules would fold back to the globular form but the memory from the "molecular summer" would be stored to the negentropic entanglement between molecules.

The Indra's net formed by the magnetic flux tubes and sheets has become a standard part of TGD based view about living matter. The model for DNA as quantum computer [K24] involves flux sheets traversing through DNA strand and flux tubes connecting nucleotides to lipids of the cell membrane as well as flux sheets with the shape of cell membrane. This suggests that one actually has also in the case of DNA-cell membrane system three orthogonal grids of flux sheets at some scale and flux tubes condensed at the sheets of grids. These structure would organized the living matter to a well-organized geometric structure.

One of the first really crazy ideas related to the magnetic was the proposal that the magnetic bodies associated with living organisms could have shape reflecting the shape of the organism and its parts - even in the length scale of Earth [K41]. If one takes the flux sheets grids seriously, and replaces planes with closed surfaces obtained by scaling outer surfaces for parts of the organism, something like this is indeed expected.

2.7.4 What could be the variational principle behind self-organization?

Quasicrystals (say Penrose tilings) have a huge ground state degeneracy: given region of quasicrystal can be completed to infinite number of quasicrystals. For crystals the situation is different: local empire is the entire infinite crystal. Quasicrystals are clearly analogous to spin glass systems also possessing also large ground state degeneracy.

TGD Universe is a 4-D spin glass, and this degeneracy would imply non-determinism analogous to the non-determinism of quasi-crystal dynamics in 4-D 4-D Minkowski space) with local empires interpreted as self-organization patterns and global empires reflecting the long range correlations due to intentional action and obedience for social rules. In human society the ability to predict what person probably does next year in given day only by knowing his profession, would represent example about this kind of long range correlation caused basically by social forces.

Why Negentropy Maximization Principle should favor quasicrystals?

In TGD inspired theory of consciousness Negentropy Maximization Principle (NMP) [K46] is the basic variational principle. NMP states that the information contents of conscious experience is maximal. Therefore entanglement negentropy is expected to be the fundamental quantity.

1. Since conscious entities forming larger coherent structures (societies) are in question, it seems that one should characterize the quasi-lattice by a negentropy, which should be maximized (purely mathematically negentropy is very similar to entropy which is maximized for a closed system). This negentropy would *not* correspond to the negative of the ordinary thermodynamical entropy, which characterizes ensemble of particles rather than single coherent unit.

2. In TGD Universe this negentropy would naturally be the number theoretic negentropy characterizing negentropic entanglement identified as a measure for conscious information. This information measure is assigned with the magnetic flux tubes connecting biomolecules and other units of living organism and even living organisms to larger coherent structures. In the case of quasicrystals flux tubes or flux sheets give rise to the long range constraints binding the units of quasi-crystal to each other.

3. The maximization of negentropy characterizing information content of conscious experience should be equivalent with the maximization of complexity as the number of almost degenerate ground states of quasicrystal. It is intuitively clear why quasicrystals would be favored over crystals. But how quasicrystals could maximize entanglement negentropy? Why the entanglement negentropy would be large for quasicrystals? Why the large number of quasicrystals configurations would favor large entangelment negentropy.

   If the entanglement is between two different quasicrystals, it means formation of quantum superposition of pairs of quasicrystal configurations and the higher the quasicrystal degeneracy, the larger the maximal entanglement negentropy. This conforms with the fact that quasicrystals are necessary of finite size. Most naturally the negentropic entanglement would be between the degenerate ground states of two finite-sized quasicrystals.

4. If degrees of freedom associated with the space-time geometry are entangled, the quantum dynamics at the level of "world of classical worlds" would be involved and by definition would not be describable by QFT in a fixed background space-time. One could speak about genuine quantum gravity: The Orch-OR proposal of Penrose and Hameroff is also a conjecture of similar character. One can also consider entanglement between states of some particle and quasicrystal but the negentropy content would be now much smaller due to the small number of particle states.

Maximal capacity to represent information with minimal metabolic energy costs as a basic variational principle?

The interpretation as a symbolic dynamics assignable to conscious entities would suggest that the maximization of the capacity to represent information (perhaps with minimal metabolic costs) could be the variational principle behind this dynamics. The number of different quasicrystals formed using the given rules should be maximal. This would give rise to very large number of states with nearly same energy allowing to represent the states of the external world (primitive sensory system). The larger the size of quasicrystal, the larger the number of degenerate configurations. Here of course physical constraints would pose an upper limit of the size.

But can one really assume rigid rules of construction giving rise to only quasicrystals? If the basic dynamical units are conscious entities they refuse to obey strict rules although they can decide to do so under "social pressures" (absence of metabolic energy feed can transform a sinner a saint!). Should these rules be an outcome of the variational principle alone? Or are they forced by some minimization principle - say minimization of metabolic energy feed - in presence of quasi-periodic background field configuration regarded as an external field favoring quasicrystals?

It seems that all configurations of the basic units must be accepted a priori: in principle even random spatial configurations of the basic units. For random configurations complexity would be maximal but co-operation minimal, long range correlations would be absent, and the ability to represent information would be minimal. For crystals long range correlations and co-operation would be maximal but crystal would have minimal capacity to represent and mimic. The natural manner to achieve long range correlations is to assume slowly varying quasi-periodic fields configurations representing the "social forces". In TGD framework these fields would naturally correspond to magnetic flux quanta serving as basic building bricks of magnetic bodies controlling biological body.

Note that by previous argument, the capacity to store conscious information is equivalent with ability to generate negentropic entanglement.

A possible realization for 4-D dynamics favoring quasicrystal like structures

Can one imagine a physical realization of 4-D quasicrystal dynamics in TGD framework? The basic problem is to understand how the rules for the formation of quasicrystals are forced. Certainly the hyper-plane grids associated with the basic polytope defining the quasicrystal force the long range correlations. But how to realize these grids physically?

1. In TGD Universe magnetic body acts as an intentional agent using biological body as a motor organ and sensory receptor. This suggests that the plane grids parallel to the faces of - say - icosahedron in the case of 3-D quasicrystal could in TGD Universe be realized as thin (and thus effectively 2-D) magnetic flux sheets forming the magnetic body around which the ordinary matter would self-organize to form a quasicrystal as a configuration sustainable by using minimum metabolic energy feed. These grids would be part of the magnetic body responsible for the "social forces".

   Rather remarkably, quite recent findings strongly suggest that brain involves an orthogonal grid of curved planes. Maybe this grid correspond to a quasi-lattice associated with a cubic basic unit serving as a basic information processing unit. Exact cubic crystal does not guarantee the needed ground state degeneracy and the deviation from it could be crucial in guaranteing large degeneracy of the basic structures.

2. Maybe the basic variational principle could be minimization of the metabolic energy feed in presence of fixed grid structure formed by flux sheets representing the slow dynamics to which the molecular dynamics would rapidly adapt. The intersections of the grid hyper-planes are good

candidates for the equilibrium points and going outside them would require metabolic energy. The minimum of the magnetic energy $\mu \cdot B$ of magnetic dipole is reduced in the intersections of flux sheets if the effects of the magnetic fields sum up at the intersection. For the crossing of n orthogonal sheets there is an enhancement by $\sqrt{n}$ factor. The motor activities of the magnetic body itself would deform the quasicrystals: the flux sheets could be deformed and the distances between the flux sheets could also vary. This would lead to new quasicrystal configurations with high negentropic content.

From the point of view of individual quasicrystal regarded as conscious entity fight for survival would be fighting for metabolic resources and fusion with a bigger quasicrystal could be one manner to guarantee the availability of metabolic energy.

3. Phason dynamics seems to allow both short range description in terms of permutations of basic units and long range hydrodynamical description. Two dynamics seem to be present: slow *resp.* fast dynamics in short *resp.* long scales. Maybe these paradoxical properties of phasons could be understood in this framework if the microscopic fast dynamics forced by the slow long length scale dynamics of flux sheets.

4. Also other than quasicrystal configurations would be possible but would require higher metabolic energy feed to preserve entanglement negentropy (amount of conscious information). In 4-D case one would have similar grids of thin and effectively 3-D magnetic flux sheets associated with the 3-D faces (maybe icosahedrons) of 4-D building brick of quasicrystals. Magnetic flux sheets would carry dark matter and give rise to negentropic entanglement between the units of the quasicrystal.

5. The negentropic entanglement between two different quasi-crystal like structures means quantum superposition of different space-time surfaces since the grids formed by the flux sheets would have different geometric parameters such as the distance between the flux sheets of the grid. Hence genuine quantum gravitational effects would be in question having no description in QFT framework and requiring description at the level of WCW.

Summary

The essential element of picture would be spin glass degeneracy giving a large number of ground states making possible highly negentropic entanglement betweemn separate spin glasses. Quasicrystals are not the only manner to satisfy this condition and 4-D quasi-lattices for which grid could contain also more general 3-surfaces than hyperplanes, can be considered. Grids of thin 3-surfaces would represent the rules forcing the quasi-lattice like configurations through localization to the wordlines defined by intersections of two 3-surfaces. TGD inspired quantum model for biology suggests concrete models for the grids of flux sheets involving also flux tubes topologically condensed on them as a manner to generate negentropic entanglement. Also fractal structures consisting of flux quanta inside flux quanta are highly suggestive.

The basic variational principle of quasicrystal dynamics (and its generalization to quasi-lattices) could be minimization of metabolic energy feed in presence of fixed configuration of the magnetic body obeying a relatively slow dynamics. The time scale of EEG is in the range .01-.1 seconds gives a first guess for the time scale of the dynamics of the magnetic body in scale of Earth. This time scale is to be compared to the time scale of 10^{-10} seconds of conformational dynamics bio-molecules. Quasi-crystallization - or more generally, formation quasi-latticices - would be due to the existence of grids of thin 3-sheets parallel to the basic units of the 3-faces of 4-D basic unit of quasicrystal.

To show that this picture makes or does not make sense, one should be able to estimate reliably the metabolic energy feed needed to preserve a given negentropic entanglement entropy for a given configuration of the basic units (say clusters of water molecules) and to show that it is minimized for quasicrystal configurations in presence of the grid structure formed by flux sheets. This is probably relatively easy since the first guess for the equilibrium configurations corresponds to the highly symmetric crossing lines of for two 3-planes. One might also try to demonstrate the presence of negentropic entanglement between molecules, which are in resting state. This would be a direct demonstration for the notion of WCW and for non-trivial quantum gravity effects in living matter.

2.7.5 Could quasi-lattices and quasi-crystals emerge from the notion of p-adic manifold?

This section is inspired by the considerations of the new chapter "What p-adic icosahedron could mean? And what about p-adic manifold?" [K87]. The original purpose was to understand what the notion of p-adic icosahedron could mean but soon it turned out that the key challenge is to understand what p-adic manifold means. Also in TGD framework this is one of the basic challenges posed by the condition of number theoretical universality and the idea about algebraic continuation of physics between different number fields.

The basic problem is that p-adic topology is totally disconnected meaning that p-adic balls are either disjoint or nested so that the usual construction of manifold structure fails. The basic criticism against the notion of p-adic icosahedron, and more generally, the notion of p-adic manifold, is the technical complexity of the existing constructions by mathematicians.

TGD however suggests much simpler construction. The construction relies on a simple modification of the notion of manifold inspired by the interpretation of p-adic preferred extremals defining counterparts of real preferred extremals as cognitive representations of the latter. This requires a mapping from p-adic preferred extremals to real ones and vice versa. In manifold theory chart maps are the analogs of these maps and the only difference is that they are between different number fields.

What I have christened as canonical identification $I_{k,l}^Q$ mapping rationals $p^{rk}m/n$ with $|m|_p > p^{-k}$, $|n|_p > p^{-k}$, as $I_{k,l}^Q(p^{rk}(m/n)) = p^{-rk}I_{k,l}(m)/I_{k,l}(n)$, where $I_{k,l}(m = \sum m_n p^{nk}) = \sum_{n<l} m_n p^{-nk}$ defines canonical identification for p-adic numbers m, n satisfying the above conditions in their pinary expansion with two cutoffs k and l. $I_{k,l}^Q$ is ill defined for irrational p-adic numbers since for them the representation as rational is not unique. A generalization to algebraic extensions is straightforward.

$I_{k,l}^Q$ is a compromise between the direct identification along common rationals favored by algebra and symmetries but being totally discontinuous without the cutoff $n < l$. This cutoff breaks symmetries slightly but guarantees continuity in finite measurement resolution defined by the pinary cutoff l. Symmetry breaking can be made arbitrarily small and has interpretation in terms of finite measurement resolution. Due to the pinary cutoff the chart map applied to various p-adic coordinates takes discrete set of rationals to discrete set of rationals and preferred extremal property can be used to make a completion to a real space-time surface. Uniqueness is achieved only in finite measurement resolution and is indeed just what is needed. Also general coordinate invariance is broken in finite measurement resolution. In TGD framework it is however possible to find preferred coordinates in order to minimize this symmetry breaking.

TGD based view about p-adic manifolds

The construction of p-adic manifold topology somehow overcoming the difficulty posed by the fact that p-adic balls are either disjoint or nested is necessary. It should also allow a close relationship between p-adic and real preferred extremals. It will be found that TGD leads naturally to a proposal of p-adic manifold topology [K87] based on canonical identification used to map the predictions of p-adic mass calculations to real numbers. This map would define coordinate charts for p-adic space-time surfaces - not as p-adic chart leafs as in the standard approach - but as real chart leafs. The real topology induced from real map leafs to the p-adic realm would be path-connected as required.

In TGD framework one must also require finite measurement resolution meaning that the canonical identification is characterized by pinary cutoff takes a discrete subset of rational points of p-adic preferred extremal to its real counterpart: for a subset of this subset rationals are mapped to themselves. One can complete this point set to a real preferred extremal in finite measurement resolution. This construction allows also to define p-adic integrals and differential forms in terms of their real counterparts by algebraic continuation. Therefore geometric notions like distance and volume make sense and there is a very close correspondence between real space-time geometries and their p-adic counterpart in the situations when they exist.

Can one consider a p-adic generalization of Penrose tiling and quasicrystals?

The mathematically rigorous generalization of Penrose Tilings and quasicrystals to p-adic context might be possible but is bound to be rather technical. The p-adic icosahedron as it is defined in the article does not seem very promising notion. The point is that it is defined in terms of fixed point set for subgroups of icosahedral group acting on Riemann sphere: the action in Euclidian 3-space is now more natural and certainly makes sense and actually simplifies the situation since Q_p^3 sd analog of E^3 is simplest possible 3-D p-adic manifold. It does not however allow Bruhat-Tits tree since the points of Q_p^n are not in 1-1 correspondence with the lattices of Q_p^n. The possibility to construct Bruhat-Tits tree is a special feature of projective spaces.

TGD based view about p-adic E^3 and S^2 as its sub-manifold allows to define also the counterpart of Penrose tiling and QCs in an elegant manner with a close relationship between real and p-adic variants of QC.

1. If one considers lattices in n-dimensional p-adic space Q_p^n replacing E^n, a more natural definition would be in terms of this space than in terms of sphere. For the counterpart of E^3 one can define the action of the subgroup A_5 of rotation group $SO(3)$ by introducing an algebraic extension of the p-adic numbers containing $cos(2\pi/5)$, $sin(2\pi/5)$ and $cos(2\pi/3)$, $sin(2\pi/3)$ and their products. What is interesting is that algebraic extension is forced automatically in p-adic context! In cut and project method [A7] the QC structure requires also this since the imbedded space has an algebraic dimension over integers equal to the dimension of the imbedding space over reals.

   Could it be that p-adic variants of QCs might provide number theoretic insights about QCs? Subspace would define algebraic extension of p-adic numbers and this extension would be such that it allows the representation of the isometry group of the Platonic solid possibly assignable to the QC.

2. One can also now define the icosahedron or any Platonic solid in terms of fixed points also now. Only discrete subgroups of the rotation group can be represented p-adically since algebraic extension is required. This brings in mind the notion of finite measurement resolution leading to a discretization of p-adically representable rotations and more general symmetries. For instance, without algebraic extension only rotations for which the rotation matrices are rational numbers are representable. It seems that finite subgroups of this kind are generated by rotations with rotation angle $\pi/2$ around various coordinate axes. Pythagorean triangles correspond to rationals values of cosine and sine and rotations for which rotation angle corresponds to Pythagorean angle define rational rotation matrices: these groups are discrete but contain infinite number of elements.

   Altogether this suggests a hierarchy of p-adic extensions leading to higher algebraic dimensions and larger discrete symmetries. This conforms with the general number theoretic vision about TGD.

3. Lattices in Q_p^n with integer coefficients make also sense and are characterized by n linearly independent (over p-adic integers) basic vectors $(a_1, ..., a_n)$. Most points of lattice would correspond to values of p-adic integers n_i in $\sum_i n_i a_i$ infinite as real numbers.

   Consider first a non-realistic option in which p-adic integers are mapped to p-adic integers as such. Note also that most of p-adic lattice points would map to real infinity. This kind of correspondence makes sense also for rationals but would give a totally discontinuous correpondence between reals and p-adics.

   p-Adic manifold topology defined in terms of the canonical identification I_{kl} allows to interpret the p-adic lattice as a cognitive representation of the real one. The presence of pinary cutoffs k and l having interpretation in terms of finite cognitive resolution has two implications. Integers $n_i < p^k$ are mapped to themselves so that this portion of lattice is mapped to itself faitfully. The integers $k \leq n < l$ are not mapped to integers and the length of the image is bounded below. The real image of the p-adic lattice under I_{kl} is necessary compressed to a finite volume of E^3. This kind of compression and cutoff is natural for cognitive representations for which numerics with finite cutoff provides one particular analogy.

4. Could the notion of p-adic QC and Penrose tiling make sense if one considers p-adic counterparts of Euclidian space and a n-D cubic lattice with integer valued coefficients and spanned by unit vectors? Could the cut and project method generalize [A7]?

   This is not clear since projection would lead from a lattice in Q_p^n to a QC in lower-dimensional space which is associated with algebraic extension of Q_p but having algebraic dimension equal to n. If this space is K^m, K an algebraic extension of Q_p, one has $n = dim(K) \times m$. For prime values of n this would mean that $m = 1$ and one has n-D algebraic extension.

Projection should be generalized to a map mapping points of n-D space to m-dimensional subspace K^m associated with algebraic extension of Q_p. Maybe it is better to formally extend Q_p^n to K^n and restrict the lattice to integer lattice in $Q_p^n \subset K^n$. In this manner the projection becomes well-defined as map from $Q_p^n \subset K^n$ to a subspace K^m of K^n. The basic condition could be that the points of the subspace K^m in K^n with algebraic dimension $n \times dim(K)$ define and m-dimensional subspace over K and n-dimensional subspace of Z_p.

The "irrational angles" associated with the lower-dimensional subspace defining quasilattice defining algebraic extension of Q_p should be such that it allows the representation of the isometry group of the p-adic Platonic solid possibly assignable to the QC in question.

Cut and project construction of quasicrystals from TGD point of view

Cut and project [**?**] method is used to construct quasicrystals (QCs) in sub-spaces of a higher-dimensional linear space containing an ordinary space filling lattice, say cubic lattice. For instance, 2-D Penrose tiling is obtained as a projection of part of 5-D cubic lattice - known as Voronyi cell - around 2-D sub-space imbedded in five-dimensional space. The orientation of the 2-D sub-space must be chosen properly to get Penrose tiling. The nice feature of the construction is that it gives the entire 2-D QC. Using local matching rules the construction typically stops.

1. Sub-manifold gravity and generalization of cut and project method

The representation of space-time surfaces as sub-manifolds of 8-D $H = M^4 \times CP_2$ can be seen as a generalization of cut and project method.

1. The space-time surface is not anymore a linear 4-D sub-space as it would be in cut and project method but becomes curved and can have arbitrary topology. The imbedding space ceases to be linear $M^8 = M^4 \times E^4$ since E^4 is compactified to CP_2. Space-time surface is not a lattice but continuum.

2. The induction procedure geometrizing metric and gauge fields is nothing but projection for H metric and spinor connection at the continuum limit. Killing vectors for CP_2 isometries can be identified as classical gluon fields. The projections of the gamma matrices of H define induced gamma matrices at space-time surface. The spinors of H contain additional components allowing interpretation in terms of electroweak spin and hyper-charge.

2. Finite measurement resolution and construction of p-adic counterparts of preferred extremals forces "cut and project" via discretization

In finite measurement resolution realized as discretization by finite pinary cutoff one can expect to obtain the analog of cut and project since 8-D imbedding space is replaced with a lattice structure.

1. The p-adic/real manifold structure for space-time is induced from that for H so that the construction of p-adic manifold reduces to that for H.

2. The definition of the manifold structure for H in number theoretically universal manner requires for H discretization in terms of rational points in some finite region of M^4. Pinary cutoffs- two of them - imply that the manifold structures are parametrized by these cutoffs charactering measurement resolution. Second cutoff means that the lattice structure is piece of an infinite lattice. First cutoff means that only part of this piece is a direct imagine of real/p-adic lattice on p-adic/real side obtained by identifying common rationals (now integers) of real and p-adic number fields. The mapping of this kind lattice from real/p-adic side to p-adic/real side defines the discrete coordinate chart and the completion of this discrete structure to a preferred extremal gives a smooth space-time surface also in p-adic side if it is known on real side (and vice versa).

3. Cubic lattice structures with integer points are of course the simplest ones for the purposes of discretization and the most natural choice for M^4. For CP_2 the lattice is completely analogous to the finite lattices at sphere defined by orbits of discrete subgroups of rotation group and the

analogs of Platonic solids emerge. Probably some mathematician has listed the Platonic solids in CP_2.

4. The important point is that this lattice like structure is defined at the level of the 8-D imbedding space rather than in space-time and the lattice structure at space-time level contains those points of the 8-D lattice like structure, which belong to the space-time surface. Finite measurement resolution suggests that all points of lattice, whose distance from space-time surface is below the measurement resolution for distance are projected to the space-time surface. Since space-time surface is curved, the lattice like structure at space-time level obtained by projection is more general than QC.

The lattice like structure results as a manifestation of finite measurement resolution both at real and p-adic sides and can be formally interpreted in terms of a generalization of cut and project but for a curved space-time surface rather than 4-D linear space, and for H rather than 8-D Minkowski space. It is of course far from clear whether one can obtain anything looking like say 3-D or 4-D version of Penrose tiling.

1. The size scale of CP_2 is so small (10^4 Planck lengths) that space-time surfaces with 4-D M^4 projection look like M^4 in an excellent first approximation and using M^4 coordinates the projected lattice looks like cubic lattice in M^4 except that the distances between points are not quite the M^4 distances but scaled by an amount determined by the difference between induced metric and M^4 metric. The effect is however very small if one believes on the general relativistic intuition.

   In TGD framework one however can have so called warped imbeddings of M^4 for which the component of the induced metric in some direction is scaled but curvature tensor and thus gravitational field vanishes. In time direction this scaling would imply anomalous time dilation in absence of gravitational fields. This would however cause only a the compression or expansion of M^4 lattice in some direction.

2. For Euclidian regions of space-time surface having interpretation as lines of generalized Feynman diagrams M^4 projection is 3-dimensional and at elementary particle level the scale associated with M^4 degrees of freedom is roughly the same as CP_2 scale. If CP_2 coordinates are used (very natural) one obtains deformation of a finite lattice-like structure in CP_2 analogous to a deformation of Platonic solid regarded as point set at sphere. Whether this lattice like structure could be seen as a subset of infinite lattice is not clear.

3. One can consider also string like objects $X^2 \times Y^2 \subset M^4 \times CP_2$ with 2-D M^4 projection and their deformations. In this case the projection of M^4 lattice to X^2 - having subset of two M^4 coordinates as coordinates - can differ considerably from a regular lattice since X^2 can be locally tilted with respect to M^4 lattice. This cannot however give rise to Penrose tiling requiring 5-D flat imbedding space. This argument applies also to 2-D string world sheets carrying spinor modes. In the idealized situation that string world sheet is plane in M^4 one might obtain an analog of Penrose tiling but with 4-D imbedding space.

The above quasi lattice like structures (QLs) are defined by a gravitational deformation of the cubic lattice of M^4. Is there any hope about the 4-D QLs in M^4 so that gravitation would give rise to the analogs of phason waves deforming them? Could cut and project method be generalized to give QL in M^4 as projection of 8-D cubic lattice in M^8?

3. $M^8 - H$ duality

Before considering an explicit proposal I try to describe what I call $M^8 - H$ duality ($H = M^4 \times CP_2$).

1. What I have christened $M^8 - H$ duality is a conjecture stating that TGD can be equivalently defined in M^8 or $M^4 \times CP_2$. This is the number theoretic counterpart of spontaneous compactification of string models but has nothing to do with dynamics: only two equivalent representations of dynamics would be in question.

2. Space-time surfaces (preferred extremals) in M^8 are postulated to be quaternionic sub-manifolds of M^8 possessing a fixed $M^2 \subset M^4 \subset M^8$ as sub-space of tangent space. "Quaternionic" means that the tangent space of M^4 is quaternionic and thus associative. Associativity conditions would thus determine classical dynamics. More generally, these subspaces $M^2 \subset M^8$ can form integrable distribution and they define tangent spaces of a 2-D sub-manifold of M^4. If this duality really holds true, space-time surfaces would define a lattice like structure projected from a cubic M^8 lattice. This of course does not guarantee anything: $M^8 - H$ duality itself suggests that these lattice like structures differ from regular M^4 crystals only by small gravitational effects.

3. The crucial point is that quaternionic sub-spaces are parametrized by CP_2. Quaternionic 4-surfaces of $M^8 = M^4 \times CP_2$ containing the fixed $M^2 \subset M^8$ can be mapped to those of $M^4 \times CP_2$ by defining M^4 coordinates as projections to preferred $M^4 \subset M^8$ and CP_2 coordinates as those specifying the tangent space of 4-surface at given point.

4. A second crucial point is that the preferred subspace $M^4 \subset M^8$ can be chosen in very many manners. This imbedding is a complete analog of the imbedding of lower-D subspace to higher-D one in cut and project method. M^4 can be identified as any 4-D subspace imbedded in M^4 and the group $SO(1,7)$ of 8-D Lorentz transformations defines different imbeddings of M^4 to M^8. The moduli space of different imbeddings of M^4 is the Grassmannian $SO(1,7)/SO(1,3) \times SO(4)$ and has dimension $D = 28 - 6 - 6 = 16$.

   When one fixes two coordinate axes as the real and one imaginary direction (physical interpretation is as an identification of rest system and spin quantization axes), one obtains $SO(1,7)/SO(2) \times SO(4)$ with higher dimension $D = 28 - 1 - 6 = 21$. When one requires also quaternionic structure one obtains the space $SO(1,7)/SU(1) \times SU(2)$ with dimension $D = 28 - 4 = 24$. Amusingly, this happens to be the number of physical degrees of freedom in bosonic string model.

4. How to obtain quasilattices and quasi-crystals in M^4?

Can one obtain quasi-lattice like structures (QLs) at space-time level in this framework? Consider first the space-time QLs possibly associated with the standard cubic lattice L^4_{st} of M^4 resulting as projections of the cubic lattice structure L^8_{st} of M^8.

1. Suppose that one fixes a cubic crystal lattice in M^8, call it L^8_{st}. Standard M^4 cubic lattice L^4_{st} is obtained as a projection to some M^4 sub-space of M^8 by simply putting 4 Euclidian coordinates for lattice points o constant. These sub-spaces are analogous to 2-D coordinate planes of E^3 in fixed Cartesian coordinates. There are $7!/3!4! = 35$ choices of this kind.

   One can consider also E_8 lattice is an interesting identification for the lattice of M^8 since E_8 is self-dual and defines the root lattice of the exceptional group E_8. E_8 is union of Z^8 and $(Z + 1/2)^8$ with the condition that the sum of all coordinates is an even integer. Therefore all lattice coordinates are either integers or half-integers. E_8 is a sub-lattice of 8-D cubic lattice with 8 generating vectors $e_i/2$, with e_i unit vector. Integral octonions are obtained from E_8 by scaling with factor 2. For this option one can imbed L^4_{st} as a sub-lattice to Z^8 or $(Z + 1/2)^8$.

2. Although $SO(1,3)$ leaves the imbedded 4-plane M^4 invariant, it transforms the 4-D crystal lattice non-trivially so that all 4-D Lorentz transforms are obtained and define different discretizations of M^4. These are however cubic lattices in the Lorentz transformed M^4 coordinates so that this brings nothing new. The QLs at space-time surface should be obtained as gravitational deformations of cubic lattice in M^4.

3. L^4_{st} indeed defines 4-D lattice at space-time surface apart from small gravitational effects in Minkowskian space-time regions. Elementary particles are identified in TGD a Euclidian space-time regions - deformed CP_2 type vacuum extremals. Also black-hole interiors are replaced with Euclidian regions: black-hole is like a line of a generalized Feynman diagram, elementary particle in some sense in the size scale of the black-hole. More generally, all physical objects, even in everyday scales, could possess a space-time sheet with Euclidian metric signature characterizing their size (AdS^5/CFT correspondence could inspire this idea). At these Euclidian space-time

sheets gravitational fields are strong since even the signature of the induced metric is changed at their light-like boundary. Could it be that in this kind of situation lattice like structures, even QCs, could be formed purely gravitationally? Probably not: an interpretation as lattice vibrations for these deformations would be more natural.

It seems that QLs are needed *already at the level of* M^4. M^8-H duality indeed provides a natural manner to obtain them.

1. The point is that the projections of L^8_{str} to sub-spaces M^4 defined as the $SO(1,7)$ Lorentz transforms of L^4_{st} define generalized QLs parametrized by 16-D moduli space $SO(1,7)/SO(1,3)\times SO(4)$. These QLs include also QCs. Presumably QC is a QL possessing a non-trivial point group just like Penrose tiling has the isometry group of dodecagon as point group and 3-D analog of Penrose tiling has the isometries of icosahedron as point group.

   This would allow to conclude that the discretization at the level of M^8 required by the definition of p-adic variants of preferred extremals as cognitive representations of their real counterparts would make possible 4-D QCs. M^8 formulation of TGD would explain naturally the QL lattices as discretizations forced by finite measurement resolution and cognitive resolution.

   A strong number theoretical constraint on these discretizations come from the condition that the 4-D lattice like structure corresponds to an algebraic extension of rationals. Even more, if this algebraic extension is 8-D (perhaps un-necessarily strong condition), there are extremely strong constraints on the 22-parameters of the imbedding. Note that in p-adic context the algebraic extension dictates the maximal isometry group identified as subgroup of $SO(1,7)$ assignable to the imbedding as the discussion of p-adic icosahedron demonstrates.

2. What about the physical interpretation of these QLs/QCs? As such QLs define only natural discretizations rather than physical lattices. It is of course quite possible to have also physical QLs/QCs such that the points - rather time like edge paths - of the discretization contain real particles. What about a "particle" localized to a point of 4-D lattice? In positive energy ontology there is no obvious answer to the question. In zero energy ontology the lattice point could correspond to a small causal diamond containing a zero energy state. In QFT context one would speak of quantum fluctuation. In p-adic context it would correspond to "though bubble" lasting for a finite time.

3. It is also possible to identify physical particles as edge paths of the 4-D QC, and one can consider time= constant snapshots as candidates for 3-D QCs. It is quite conceivable that the non-trivial point group of QCs favors them as physical QLs.

5. Expanding hyperbolic tesselations and quasi-tesselations obtained by imbedding $H^3\subset M^4$ *to* $H^7\subset M^8$

M^8-$M^4\times CP_2$ duality and the discretization required by the notion of p-adic manifold relates in an interesting manner to expanding hyperbolic tesselations and quasi tesselations in $H^7\subset M^8$, and possible expanding quasi-tesselations in obtained by imbedding $H^3\subset M^4$ to $H^7\subset M^8$

1. Euclidian lattices E_8, E_7, E_6

   I have already considered E_8 lattice in M^8. The background space has however Minkowskian rather than Euclidian metric natural for the carrier space of the E_8 lattice. If one assigns some discrete subgroup of isometries to it, it is naturally subgroup of $SO(8)$ rather than $SO(1,7)$. Both these groups have $SO(7)$ as a subgroup meaning that preferred time direction is chosen as that associated with the real unit and considers a lattice formed from imaginary octonions.

   E_8 lattice scaled up by a factor 2 to integer lattice allows octonionic integer multiplication besides sums of points so that the automorphism group of octions: discreted subgroups of $G_2\subset SO(7)$ would be the natural candidates for point groups crystals or lattice like structures.

   If one assumes also fixed spatial direction identified as a preferred imaginary unit, G_2 reduces to $SU(3)\subset SO(6)=SU(4)$ identifiable physically as color group in TGD framework. From this one ends up with the idea about $M^8-M^4\times CP_2$ duality. Different imbeddings of $M^4\subset M^8$ are quaternionic sub-spaces containing fixed M^2 are labelled by points of CP_2.

All this suggests that E_7 lattice in time=constant section of even E^6 lattice is a more natural object lattice to consider. Kind of symmetry breaking scenario $E_8 \rightarrow E_7 \rightarrow E_6 \rightarrow G_2 \rightarrow SU(3)$ is suggestive. This Euclidian lattice would be completely analous to a slicing of 4-D space-time by 3-D lattices labelled by the value of time coordinate and is of course just what physical considerations suggest.

2. Hyperbolic tesselations

Besides crystals defined by a cubic lattice or associated with E_6 or E_7, one obtains an infinite number of hyperbolic tesselations in the case of M^8. These are much more natural in Minkowskian signature and could be also cosmologically very interesting. Quite generally, one can say that hyperbolic space is ideal for space-filling packings defined by hyperbolic manifolds H^n/Γ: they are completely analogous to space-filling packings of E^3 defined by discrete subgroups of translation group producing packings of E^3 by rhombohedra. One only replaces discrete translations with discrete Lorentz transformations. This is what makes these highly interesting from the point of view of quantum gravity.

   (a) In M^{n+1} one has tesselations of n-dimensional hyperboloid H^n defined by $t^2-x1^2-...-x_n^2 = a^2 > 0$, where a defines Lorentz invariant which for $n=4$ has interpretation as cosmic time in TGD framework. Any discrete subgroup Γ of the Lorentz group $SO(1,n)$ of M^{n+1} with suitable additional conditions (finite number of generators at least) allows a tesselation of H^n by basic unit H^n/Γ. These tesselations come as 1-parameter families labelled by the cosmic time parameter a. These 3-D tesselations participate cosmic expansion. Of course, also ordinary crystals are crystals only in spatial directions. One can of course discretize the values of a or some function of a in integer multiples of basic unit and assign to each copy of H^n/Γ a "center point" to obtain discretization of M^{n+1} needed for p-adicization.

   (b) For $n=3$ one has M^4 and H^3, and this is very relevant in TGD cosmology. The parameter a defines a Lorentz invariant cosmic time for the imbeddings of Robertson-Walker cosmologies to $M^4 \times CP_2$. The tesselations realized as physical lattices would have natural interpretation as expanding 3-D lattice like structures in cosmic scales. What is new is that discrete translations are replaced by discrete Lorentz boosts, which correspond to discrete velocities and observationally to discrete red shifts for distant objecst. Interestingly, it has been found that red shift is quantized along straight lines [E5]: "God's fingers" is the term used. I proposed for roughly two decades ago an explanation based on closed orbits of photons around cosmic strings [K19]. but explanation in terms of tesselations would also give rise to periodicity. A fascinating possibility is that these tesselation have defined macroscopically quantum coherent structures during the very early cosmology the the size scale of H^3/Γ was very small. One can also ask whether the macroscopic quantum coherence could still be there.

   Hyperbolic manifold property has purely local signatures such as angle surplus: the very fact that there are infinite number of hyperbolic tesselations is in conflict with the the fact that we have Euclidian 3-geometry in every day length scales. In fact, for critical cosmologies, which allow a one-parameter family of imbeddings to $M^4 \times CP_2$ (parameter characterizes the duration of the cosmology) one obtains flat 3-space in cosmological scales. Also overcritical cosmologies for which $a = constant$ section is 3-sphere are possible but only with a finite duration. Many-sheeted space-time picture also leads to the view that astrophysical objects co-move but do not co-expand so that the geometry of time=constant snapshot is Euclidian in a good approximation.

3. Does the notion of hyperbolic quasi-tesselation make sense?

Can one construct something deserving to be called quasi tesselations (QTs)? For QCs translational invariance is broken but in some sense very weakly: given lattice point has still an infinite number of translated copies. In the recent case translations are replaced by Lorentz transformations and discrete Lorentz invariance should be broken in similar weak manner.

If cut and project generalizes, QTs would be obtained using suitably chosen non-standard imbedding $M^4 \subset M^8$. Depending on what one wants to assume, M^4 is now image of M^4_{st} by an element of $SO(1,7)$, $SO(7), SO(6)$ or G_2. The projection - call it P - must take place to M^4 sliced by scaled copies of H^3 from M^8_{st} sliced by scaled copies of H^7/Γ tesselation. The natural option is that P is directly from H^7 to $H^3 \subset H^7$ and is defined by a projecting along geodesic lines orthogonal to H^3. One can choose always the coordinates of M^4 and M^8 in such a manner that the coordinates of points of M^4 are $(t,x,y,z,0,0,0,0)$ with $t^2 - r^2 = a_4^2$ whereas for a general point of H^7 the coordinates are $(t,x,y,z,x_4,...x_7)$ with $t^2 - r^2 - r_4^2 = a_8^2$ for $H^3 \subset H^7$. The projection is in this case simply $(t,x,y,z,x_4,...,x_7) \rightarrow (t,x,y,z,0,...,0)$. The projection is non-empty only if one has $a_4^2 - a_8^2 \geq 0$ and the 3-sphere S^3 with radius $r_4 = \sqrt{a_4^2 - a_8^2}$ is projected to single point. The images of points from different copies of H^7/Γ are identical if S^3 intersects both copies. For r_4 much larger than the size of the projection $P(H^7/\Gamma)$ of single copy overlaps certainly occurs. This brings strongly in mind the overlaps of the dodecagons of Penrose tiling and icosahedrons of 3-D icosahedral QC. The point group of tesselation would be Γ.

4. Does one obtain ordinary H^3 tesselations as limits of quasi tesselations?

   Could one construct expanding 3-D hyperbolic tesselations H_3/Γ_3 from expanding 7-D hyperbolic tesselations having H^7/Γ_7 as a basic building brick? This seems indeed to be the outcome at at the limit $r_4 \rightarrow 0$. The only projected points are the points of H^3 itself in this case. The counterpart of the group $\Gamma_7 \subset SO(1,7)$ is the group obtained as the intersection $\Gamma_3 = \Gamma_7 \cap SO(1,3)$: this tells that the allowed discrete symmetries do not lead out from H^3. This seems to mean that the 3-D hyperbolic manifold is H^3/Γ_3, and one obtains a space-filling 3-tesselation in complete analogy for what one obtains by projecting cubic lattice of E^7 to E^3 imbedded in standard manner. Note that $\Gamma_3 = \Gamma_7 \cap SO(1,3)$, where $SO(1,3) \subset SO(1,7)$, depends on imbedding so that one obtains an infinite family of tesselations also from different imbeddings parametrized by the coset space $SO(1,7)/SO(1,3)$. Note that if Γ_3 contains only unit element $H^3 \subset H^7/\Gamma_7$ holds true and tesselation trivializes.

Do Penrose tilings correspond to edge paths of Bruhat-Tits tree for projective sphere $P^1(Q_p)$?

Perhaps it deservers to be mentioned that there is an amusing co-incidence with Penrose tilings (see the book "In search of the Rieman zeros" [A17] by Lapidus, page 200) and between the representation of 2-adic numbers. This representation is in terms of a a tree containing only 3-vertices. Incoming edge represents n:th binary digit in the expansions $x = \sum x_n 2^n$, $x_n = 0,1$ and the two outgoing edges corresponds to the two values of the $n+1$:th binary digit. Each 2-adic number corresponds to a one particular edge path in this semi-infinite tree. This structure is very much analogous to Bruhat-Tits tree for p-adic projective line $P^1(Q_p)$ [A6] discussed in [K87].

A given Penrose tiling corresponds to semi-infinite bit string having only non-negative pinary digits and could be seen as a 2-adic integer. Two bit sequences describe same tiling if they differ from each other for a finite number bits only. Could the ends for the analog of Bruhat-Tits tree for p-adic integers (half-infinite paths beginning from some bit) be in one-one correspondence with Penrose tilings! Could one really describe 2-D Penrose tilings 2-adically? What about more general Penrose tilings and QCs? Maybe this conjecture is trivially true since Lapidus, who mentions this description of Penrose tilings, has written his book about p-adic strings [A17].

Unfortunately, I do not understand the arguments leading to the representation of Penrose tilings using bit sequences and whether this co-incidence has some deeper meaning.

Acknowledgements: I want to thank the quantum gravity research group of Topanga, CA, for a generous support Klee Irwin, Fang Fang, Julio Kovacs, Carlos Castro, Tony Smith for highly interesting discussions concerning quasicrystals.

Chapter 3

Possible Role of p-Adic Numbers in Bio-Systems

3.1 Introduction

In this chapter p-adic physics, p-adic length scale hypothesis, and the special features of p-adic numbers are discussed from the point of view of biosystems. The identification of p-adic physics as physics of cognition tentatively identified as a cognitive simulation of real physics is the basic philosophical quide line. Second key idea is that living matter in very general sense lives in the intersection of real and p-adic worlds making among other things possible negentropic entanglement so that Negentropy Maximization Principle drives the formation of increasingly larger structures with negentropic entanglement.

The justification of the p-adic length scale hypothesis in zero energy ontology is discussed and the application of the hypothesis is discussed: both primary p-adic length scales and secondary p-adic length scales emerging naturally in zero energy ontology are discussed and it is found that the secondary p-adic scales assignable to elementary particles are in general macroscopic so that a connection between elementary particle physics and macroscopic physics suggests itself. Small-p p-adicity is also highly attractive idea and it is demonstrated that dark matter hierarchy characterized by hierarchy of Planck constants provides a first principle realization of this idea.

The characteristic features of p-adic physics are due to p-adic ultrametricity, p-adic non-determinism, and to some exotic properties of p-adic probability and are expected to characterize also cognition. It is however too early to take too strong views concerning the interpretation of p-adics. Therefore also speculative ideas about the role of p-adic numbers in biology, which are only marginally consistent with the cognitive interpretation, are discussed in the sequel.

Also some speculations about possible role of so called exotic representations of super-conformal algebra are included. These speculations rely heavily on the assumption that canonical correspondence between p-adic and real masses holds true in full generality. The prediction is the existence of a hierarchy of p-adic states for which p-adic masses have extremely small real counterparts whereas the corresponding real states have super-astronomical masses. These strange states have huge degeneracies and the original speculation was that they are crucial for the understanding of biological life. Later however came the realization that the states of the super-symplectic representations associated with the lightlike boundaries of massless extremals (MEs) have also gigantic almost-degeneracies. In particular, there is no need to assume the highly questionable p-adic–real correspondence at the level of masses for them. Therefore the cautious conclusion is that biology can do without the exotic super-conformal representations.

3.2 General vision about fusion of real and and p-adic physics

3.2.1 p-Adic mass calculations as original motivation for p-adic physics

The basic motivation for p-adic physics was provided by successful p-adic mass calculations based on p-adic thermodynamics which is thermodynamics for conformal weight to which p-adic mass squared is proportional. The p-adic mass squared is mapped to a real number by canonical identification.

p-adic thermodynamics is justified by the randomness of the motion of partonic 2-surfaces restricted only by light-likeness of the orbit. It is essential that the conformal symmetries associated with the light-like coordinates of parton and light-cone boundary are not gauge symmetries but dynamical symmetries.

In p-adic thermodynamics scaling generator L_0 having conformal weights as its eigen values replaces energy and Boltzmann weight $exp(H/T)$ is replaced by p^{L_0/T_p}. The quantization $T_p = 1/n$ of conformal temperature and thus quantization of mass squared scale is implied by number theoretical existence of Boltzmann weights. p-Adic length scale hypothesis states that primes $p \simeq 2^k$, k integer. A stronger hypothesis is that k is prime (in particular Mersenne prime or Gaussian Mersenne) makes the model very predictive and fine tuning is not possible.

The basic mystery number of elementary particle physics defined by the ratio of Planck mass and proton mass follows thus from number theory once CP_2 radius is fixed to about 10^4 Planck lengths. Mass scale becomes additional discrete variable of particle physics so that there is not more need to force top quark and neutrinos with mass scales differing by 12 orders of magnitude to the same multiplet of gauge group. Electron, muon, and τ correspond to Mersenne prime $k = 127$ (the largest non-super-astrophysical Mersenne), and Mersenne primes $k = 113, 107$. Intermediate gauge bosons and photon correspond to Mersenne M_{89}, and graviton to M_{127}.

The value of k for quark can depend on hadronic environment [K47] and this would produce precise mass formulas for low energy hadrons. This kind of dependence conforms also with the indications that neutrino mass scale depends on environment [C1]. Amazingly, the biologically most relevant length scale range between 10 nm and 4 μm contains four Gaussian Mersennes $(1 + i)^n - 1$, $n = 151, 157, 163, 167$ and scaled copies of standard model physics in cell length scale could be an essential aspect of macroscopic quantum coherence prevailing in cell length scale.

3.2.2 Questions raised by the success of p-adic thermodynamics

p-Adic mass calculations raise several technical questions which in turn help to imagine the interpretation of p-adic physics.

1. Is the canonical identification I: $\sum x_n p^n \rightarrow \sum x_n p^{-n}$- the only possible manner to map p-adic mass squared values to real numbers or can one consider also more general mappings? Can one require that p-adic mass calculations are equivalent with their real counterparts with the quantization for the counterpart of the p-adic temperature forced by this equivalence? This requires that a p-adic rational m/n defined as a ratio of finite p-adic integers is mapped to a ratio $I(m)/I(n)$ of the images of these integers under the canonical identification rather than mapping the infinite p-adic power series of the rational to a real number. This would affect p-adic mass calculations but would have no dramatic effects in the case that the lowest contribution to mass squared is integer valued as it indeed is.

2. It is also possible to generalize canonical identification by expanding p-adic numbers in powers of p^k with coefficients being non-negative integers $n < p^k$. This form of canonical identification applied to the numerator and denominator of rational m/n to give $I_k(m)/I_k(n)$is especially suitable when the p-adic temperature is $T = 1/k$. Could one interpret the hierarchy of canonical identifications I_k defined in this manner in terms of a measurement resolution for mass squared (IR cutoff) defined as the p-adic length scale corresponding to p^k? p-Adic integer points $n < p^k$ correspond indeed as such to real integers as also do the rationals formed from this kind of integers. Quite generally, for $T = 1/k$ the mass scale of particles is $p^{-k/2}$ and very small.

These questions inspire further questions.

1. Canonical correspondence between p-adics and reals and its possible generalizations apply to probabilities. Could similar correspondence relate also p-adic and real space-time sheets? Could symmetries allow to identify preferred coordinates of the imbedding space so that the general coordinate invariance would not be lost. Could it be enough for the generalized canonical identification to respect the fundamental space-time symmetries in the IR resolution identified in terms of the pinary cutoff defined by p-adic length scale associated with p^k?

2. If both real and p-adic space-time physics makes sense what is the correspondence between them? Is it via common rational points of imbedding space plus common algebraic points in preferred coordinates of the imbedding space. This correspondence would be extremely discontinuous and the intersection of the p-adic and real worlds would be discrete. Or should one apply canonical correspondence or some of its generalizations to the coordinates of the points in the preferred coordinate system forced by symmetries.

   Could real physics in finite length and time scale resolution allow an elegant description in terms of p-adic physics in the sense that the lack of the well-ordering of p-adic numbers would be allowed below the resolution scale? Could one apply identification I_k applied to rational valued points in preferred coordinates so that one would have correspondence via common rationals below IR resolution scale and continuous map above this scale: this would mean a compromize between continuity requirement and space-time symmetries. These maps map arbitrarily distant common rational points of real and p-adic space-time sheets arbitrarily near to each other if their differ by a large power of p. Does this mean that canonical identification maps have interpretation in terms of holography?

3. What could be the interpretation of p-adic physics if it is a genuine part of physics at the space-time level? Could p-adic physics relate to cognition and intentionality, which are characteristics of living matter? If so, could living matter in some sense correspond to the intersection of p-adic and real worlds?

3.2.3 Zero energy ontology and p-adic length scale hypothesis

Zero energy ontology classically

In TGD inspired cosmology [K68] the imbeddings of Robertson-Walker cosmologies are vacuum extremals. Same applies to the imbeddings of Reissner-Nordström solution [K78] and in practice to all solutions of Einstein's equations imbeddable as extremals of Kähler action. Since four-momentum currents define a collection of vector fields rather than a tensor in TGD, both positive and negative signs for energy corresponding to two possible assignments of the arrow of the geometric time to a given space-time surface are possible. This leads to the view that all physical states have vanishing net energy classically and that physically acceptable universes are creatable from vacuum.

The result is highly desirable since one can avoid unpleasant questions such as "What are the net values of conserved quantities like rest mass, baryon number, lepton number, and electric charge for the entire universe?", "What were the initial conditions in the big bang?", "If only single solution of field equations is selected, isn't the notion of physical theory meaningless since in principle it is not possible to compare solutions of the theory?". This picture fits also nicely with the view that entire universe understood as quantum counterpart 4-D space-time is recreated in each quantum jump and allows to understand evolution as a process of continual re-creation.

Zero energy ontology at quantum level

Also the construction of S-matrix [K17] leads to the conclusion that all physical states possess vanishing conserved quantum numbers. Furthermore, the entanglement coefficients between positive and negative energy components of the state define an M-matrix which can be seen as a "complex" square root of density matrix decomposable to a square root of diagonal positive definite density matrix and a unitary S-matrix. S-matrix thus becomes a property of the zero energy state and physical states code by their structure what is usually identified as quantum dynamics. The square root of the density matrix means taking square root of thermodynamics which thus becomes genuine part of quantum theory with thermodynamical ensembles realized at single particle level rather than being a useful fiction of theoretician. Also the transitions between zero energy states are possible and described by U matrix which would have natural identification as characterized of intentional action.

At space-time level this would mean that positive energy component and negative energy component are at a temporal distance characterized by an appropriate p-adic time scale and the integer characterizing the value of Planck constant for the state in question. The scale in question would also characterize the geometric duration of quantum jump and the size scale of space-time region contributing to the contents of conscious experience. The interpretation in terms of a mini bang followed by a mini crunch suggests itself also.

How do p-adic coupling constant evolution and p-adic length scale hypothesis emerge from zero energy ontology?

Zero energy ontology in which zero energy states have as imbedding space correlates causal diamonds for which the distance between the tips of future and past directed light-cones are power of 2 multiples of fundamental time scale ($T_n = 2^n T_0$) implies in a natural manner coupling constant evolution. A weaker condition would be $T_p = pT_0$, p prime, and would assign all p-adic time scales to the size scale hierarchy of CDs.

Could the coupling constant evolution in powers of 2 implying time scale hierarchy $T_n = 2^n T_0$ induce p-adic coupling constant evolution and explain why p-adic length scales correspond to $L_p \propto \sqrt{p}R$, $p \simeq 2^k$, R CP_2 length scale? This looks attractive but there is a problem. p-Adic length scales come as powers of $\sqrt{2}$ rather than 2 and the strongly favored values of k are primes and thus odd so that $n = k/2$ would be half odd integer. This problem can be solved.

1. The observation that the distance traveled by a Brownian particle during time t satisfies $r^2 = Dt$ suggests a solution to the problem. p-Adic thermodynamics applies because the partonic 3-surfaces X^2 are as 2-D dynamical systems random apart from light-likeness of their orbit. For CP_2 type vacuum extremals the situation reduces to that for a one-dimensional random light-like curve in M^4. The orbits of Brownian particle would now correspond to light-like geodesics γ_3 at X^3. The projection of γ_3 to a time=constant section $X^2 \subset X^3$ would define the 2-D path γ_2 of the Brownian particle. The M^4 distance r between the end points of γ_2 would be given $r^2 = Dt$. The favored values of t would correspond to $T_n = 2^n T_0$ (the full light-like geodesic). p-Adic length scales would result as $L^2(k) = DT(k) = D2^k T_0$ for $D = R^2/T_0$. Since only CP_2 scale is available as a fundamental scale, one would have $T_0 = R$ and $D = R$ and $L^2(k) = T(k)R$.

2. p-Adic primes near powers of 2 would be in preferred position. p-Adic time scale would not relate to the p-adic length scale via $T_p = L_p/c$ as assumed implicitly earlier but via $T_p = L_p^2/R_0 = \sqrt{p}L_p$, which corresponds to secondary p-adic length scale. For instance, in the case of electron with $p = M_{127}$ one would have $T_{127} = .1$ second which defines a fundamental biological rhythm. Neutrinos with mass around .1 eV would correspond to $L(169) \simeq 5$ μm (size of a small cell) and $T(169) \simeq 1. \times 10^4$ years. A deep connection between elementary particle physics and biology becomes highly suggestive.

3. In the proposed picture the p-adic prime $p \simeq 2^k$ would characterize the thermodynamics of the random motion of light-like geodesics of X^3 so that p-adic prime p would indeed be an inherent property of X^3. For $T_p = pT_0$ the above argument is not enough for p-adic length scale hypothesis and p-adic length scale hypothesis might be seen as an outcome of a process analogous to natural selection. Resonance like effect favoring octaves of a fundamental frequency might be in question. In this case, p would a property of CD and all light-like 3-surfaces inside it and also that corresponding sector of configuration space.

3.2.4 How to fuse p-adic and real physics?

Generalization of number concept and fusion of real and p-adic physics

The unification of real physics of material work and p-adic physics of cognition and intentionality leads to the generalization of the notion of number field. Reals and various p-adic number fields are glued along their common rationals (and common algebraic numbers too) to form a fractal book like structure. Allowing all possible finite-dimensional extensions of p-adic numbers brings additional pages to this "Big Book".

This generalization leads to a generalization of the notion of manifold as a collection of a real manifold and its p-adic variants glued together along common rationals. The precise formulation involves of course several technical problems. For instance, should one glue along common algebraic numbers and Should one glue along common transcendentals such as e^p? Are algebraic extensions of p-adic number fields glued together along the algebraics too?

This notion of manifold implies a generalization of the notion of imbedding space. p-Adic transcendentals can be regarded as infinite numbers in the real sense and thus most points of the p-adic space-time sheets would be at infinite distance and real and p-adic space-time sheets would intersect in a discrete set consisting of rational points. This view in which cognition and intentionality would be literally cosmic phenomena is in a sharp contrast with the often held belief that p-adic topology emerges below Planck length scale.

What number theoretical universality might mean?

Number theoretic universality has been one of the basic guide lines in the construction of quantum TGD. There are two forms of the principle.

1. The strong form of number theoretical universality states that physics for any system should effectively reduce to a physics in algebraic extension of rational numbers at the level of M-matrix so that an interpretation in both real and p-adic sense (allowing a suitable algebraic extension of p-adics) is possible. One can however worry whether this principle only means that physics is algebraic so that there would be no need to talk about real and p-adic physics at the level of M-matrix elements. It is not possible to get rid of real and p-adic numbers at the level of classical physics since calculus is a prerequisite for the basic variational principles used to formulate the theory. For this option the possibility of completion is what poses conditions on M-matrix.

2. The weak form of principle requires only that both real and p-adic variants of physics make sense and that the intersection of these physics consist of physics associated with various algebraic extensions of rational numbers. In this rational physics would be like rational numbers allowing infinite number of algebraic extensions and real numbers and p-adic number fields as its completions. Real and p-adic physics would be completions of rational physics. In this framework criticality with respect to phase transitions changing number field becomes a viable concept. This form of principle allows also purely p-adic phenomena such as p-adic pseudo non-determinism assigned to imagination and cognition. Genuinely p-adic physics does not however allow definition of notions like conserved quantities since the notion of definite integral is lacking and only the purely local form of real physics allows p-adic counterpart.

Experience has taught that it is better to avoid too strong statements and perhaps the weak form of the principle is enough. It is however clear that number theoretical criticality could provide important insights to quantum TGD. p-Adic thermodynamics is excellent example of this. In consciousness theory the transitions transforming intentions to actions and actions to cognitions would be key applications. Needless to say, zero energy ontology is absolutely essential: otherwise this kind of transitions would not make sense. In the original version of this chapter number theoretical universality was identified as number theoretical criticality and this leads to so strong conditions that they might not be possible to satisfy.

p-Adicization by algebraic continuation

The basic challenges of the p-adicization program are following.

1. The first problem -the conceptual one- is the identification of preferred coordinates in which functions are algebraic and for which algebraic values of coordinates are in preferred position. This problem is encountered both at the level of space-time, imbedding space, and configuration space. Here the group theoretical considerations play decisive role and the selection of preferred coordinates relates closely to the selection of quantization axes. This selection has direct physical correlates at the level of imbedding space and the hierarchy of Planck constants has interpretation as a correlate for the selection of quantization axes [K25] .

   Algebraization does not necessarily mean discretization at space-time level: for instance, the coordinates characterizing partonic 2-surface can be algebraic so that algebraic point of the configuration space results and surface is not discretized. If this kind of function spaces are finite-dimensional, it is possible to fix X^2 completely data for a finite number of points only.

2. Local physics generalizes as such to p-adic context (field equations, etc...). The basic stumbling block of this program is integration already at space-time (Kähler action etc..). The problem becomes really horrible looking at configuration space level (functional integral). Algebraic continuation could allow to circumvent this difficulty. Needless to say, the requirement that the continuation exists must pose immensely tight constraints on the physics. For instance, at

configuration space level radiative corrections to the functional integral should vanish and the resulting perturbation theory using propagators and vertices could make sense p-adically.

One general idea which results as an outcome of the generalized notion of number is the idea of a universal function continuable from a function mapping rationals to rationals or to a finite extension of rationals to a function in any number field. This algebraic continuation is analogous to the analytical continuation of a real analytic function to the complex plane.

1. Rational functions with rational coefficients are obviously functions satisfying this constraint. Algebraic functions with rational coefficients satisfy this requirement if appropriate finite-dimensional algebraic extensions of p-adic numbers are allowed. Exponent function is such a function.

2. For instance, residue calculus essential in the construction of N-point functions of conformal field theory might be generalized so that the value of an integral along the real axis could be calculated by continuing it instead of the complex plane to any number field via its values in the subset of rational numbers forming the rim of the book like structure having number fields as its pages. If the poles of the continued function in the finitely extended number field allow interpretation as real numbers it might be possible to generalize the residue formula. One can also imagine of extending residue calculus to any algebraic extension. An interesting situation arises when the poles correspond to extended p-adic rationals common to different pages of the "great book". Could this mean that the integral could be calculated at any page having the pole common. In particular, could a p-adic residue integral be calculated in the ordinary complex plane by utilizing the fact that in this case numerical approach makes sense.

3. Algebraic continuation is the basic tool of p-adicization program. Entire physics of the TGD Universe should be algebraically continuable to various number fields. Real number based physics would define the physics of matter and p-adic physics would describe correlates of cognition and intentionality.

4. For instance, the idea that number theoretically critical partonic 2-surfaces are expressible in terms of rational functions with rational or algebraic coefficients so that also p-adic variants of these surfaces make sense, is very attractive.

5. Finite sums and products respect algebraic number property and the condition of finiteness is coded naturally by the notion of finite measurement resolution in terms of the notion of (number theoretic) braid. This simplifies dramatically the algebraic continuation since configuration space reduces to a finite-dimensional space and the space of configuration space spinor fields reduces to finite-dimensional function space.

The real configuration space can well contain sectors for which p-adicization does not make sense. For instance, if the exponent of Kähler function and Kähler are not expressible in terms of algebraic functions with rational or at most algebraic functions or more general functions making sense p-adically, the continuation is not possible. p-Adic non-determinism in p-adic sectors makes also impossible the continuation to real sector. All this is consistent with vision about rational and algebraic physics as as analog of rational and algebraic numbers allowing completion to various continuous number fields.

Due to the fact that real and p-adic topologies are fundamentally different, ultraviolet and infrared cutoffs in the set of rationals are unavoidable notions and correspond to a hierarchy of different physical phases on one hand and different levels of cognition on the other hand. For instance, most points p-adic space-time sheets reside at infinity in real sense and p-adically infinitesimal is infinite in real sense. Two types of cutoffs are predictedp-adic length scale cutoff and a cutoff due to phase resolution related to the hierarchy of Planck constants. Zero energy ontology provides natural realization for the p-adic length scale cutoff. The latter cutoff seems to correspond naturally to the hierarchy of algebraic extensions of p-adic numbers and quantum phases $exp(i2\pi/n)$, $n \geq 3$, coming as roots of unity and defining extensions of rationals and p-adics allowing to define p-adically sensible trigonometric functions These phases relate closely to the hierarchy of quantum groups, braid groups, and II_1 factors of von Neumann algebra.

3.2.5 p-Adic physics and consciousness

p-Adic physics, cognition, and intentionality

p-Adic physics as physics of cognition and intentionality provides one of the key elements of TGD inspired theory of consciousness. At the fundamental level light-like 3-surfaces are basic dynamical objects in TGD Universe and have interpretation as orbits of partonic 2-surfaces. The generalization of the notion of number concept by fusing real numbers and various p-adic numbers to a more general structure makes possible to assign to real parton a p-adic prime p and corresponding p-adic partonic 3-surface obeying same algebraic equations. The almost topological QFT property of quantum TGD is an essential prerequisite for this. The intersection of real and p-adic 3-surfaces would consists of a discrete set of points with coordinates which are algebraic numbers. p-Adic partons would relate to both intentionality and cognition.

The transformation of p-adic variant of the partonic 3-surface with bosonic quantum numbers to its real counterpart in quantum jump would represent a transformation of intention to action and the unitary matrix U would govern this process. The larger the number of algebraic points in the intersection, the more precise the realization of intention as action would be.

Real fermion and its p-adic counterpart forming a pair would represent matter and its cognitive representation being analogous to a fermion-hole pair resulting when fermion is kicked out from Dirac sea. The larger the number of points in the intersection of real and p-adic surfaces, the better the resolution of the cognitive representation would be. This would explain why cognitive representations in the real world are always discrete (discreteness of numerical calculations represent the basic example about this fundamental limitation).

All transcendental p-adic integers are infinite as real numbers and one can say that most points of p-adic space-time sheets are at spatial and temporal infinity in the real sense so that intentionality and cognition would be literally cosmic phenomena. If the intersection of real and p-adic space-time sheet contains large number of points, the continuity and smoothness of p-adic physics should directly reflect itself as long range correlations of real physics realized as p-adic fractality. It would be possible to measure the correlates of cognition and intention and in the framework of zero energy ontology [K17] the success of p-adic mass calculations can be seen as a direct evidence for the role of intentionality and cognition even at elementary particle level: all matter would be basically created by intentional action as zero energy states.

Generalization of the notion of information

TGD inspired theory of consciousness, in particular the formulation of Negentropy Maximization Principle (NMP) in p-adic context, has forced to rethink the notion of the information concept. In TGD state preparation process is realized as a sequence of self measurements. Each self measurement means a decomposition of the sub-system involved to two unentangled parts. The decomposition is fixed highly uniquely from the requirement that the reduction of the entanglement entropy is maximal.

The additional assumption is that bound state entanglement is stable against self measurement. This assumption is somewhat ad hoc and it would be nice to get rid of it. The only manner to achieve this seems to be a generalized definition of entanglement entropy allowing to assign a negative value of entanglement entropy to the bound state entanglement, so that bound state entanglement would actually carry information, in fact conscious information (experience of understanding). This would be very natural since macro-temporal quantum coherence corresponds to a generation of bound state entanglement, and is indeed crucial for ability to have long lasting non-entropic mental images.

The generalization of the notion of number concept leads immediately to the basic problem. How to generalize the notion of entanglement entropy that it makes sense for a genuinely p-adic entanglement? What about the number-theoretically universal entanglement with entanglement probabilities, which correspond to finite extension of rational numbers? One can also ask whether the generalized notion of information could make sense at the level of the space-time as suggested by quantum-classical correspondence.

In the real context Shannon entropy is defined for an ensemble with probabilities p_n as

$$S = -\sum_n p_n log(p_n) \ . \tag{3.2.1}$$

As far as theory of consciousness is considered, the basic problem is that Shannon entropy is always non-negative so that as such it does not define a genuine information measure. One could define information as a change of Shannon entropy and this definition is indeed attractive in the sense that quantum jump is the basic element of conscious experience and involves a change. One can however argue that the mere ability to transfer entropy to environment (say by aggressive behavior) is not all that is involved with conscious information, and even less so with the experience of understanding or moment of heureka. One should somehow generalize the Shannon entropy without losing the fundamental additivity property.

p-Adic entropies

The key observation is that in the p-adic context the logarithm function $log(x)$ appearing in the Shannon entropy is not defined if the argument of logarithm has p-adic norm different from 1. Situation changes if one uses an extension of p-adic numbers containing $log(p)$: the conjecture is that this extension is finite-dimensional. One might however argue that Shannon entropy should be well defined even without the extension.

p-Adic thermodynamics inspires a manner to achieve this. One can replace $log(x)$ with the logarithm $log_p(|x|_p)$ of the p-adic norm of x, where log_p denotes p-based logarithm. This logarithm is integer valued ($log_p(p^n) = n$), and is interpreted as a p-adic integer. The resulting p-adic entropy

$$\begin{aligned} S_p &= \sum_n p_n k(p_n) \ , \\ k(p_n) &= -log_p(|p_n|) \ . \end{aligned} \tag{3.2.2}$$

is additive: that is the entropy for two non-interacting systems is the sum of the entropies of composites. Note that this definition differs from Shannon's entropy by the factor $log(p)$. This entropy vanishes identically in the case that the p-adic norms of the probabilities are equal to one. This means that it is possible to have non-entropic entanglement for this entropy.

One can consider a modification of S_p using p-adic logarithm if the extension of the p-adic numbers contains $log(p)$. In this case the entropy is formally identical with the Shannon entropy:

$$S_p = -\sum_n p_n log(p_n) = -\sum_n p_n \left[-k(p_n)log(p) + p^{k_n} log(p_n/p^{k_n}\right] \ . \tag{3.2.3}$$

It seems that this entropy cannot vanish.

One must map the p-adic value entropy to a real number and here canonical identification can be used:

$$\begin{aligned} S_{p,R} &= (S_p)_R \times log(p)) \ , \\ (\sum_n x_n p^n)_R &= \sum_n x_n p^{-n} \ . \end{aligned} \tag{3.2.4}$$

The real counterpart of the p-adic entropy is non-negative.

Number theoretic entropies and bound states

In the case that the probabilities are rational or belong to a finite-dimensional extension of rationals, it is possible to regard them as real numbers or p-adic numbers in some extension of p-adic numbers for any p. The visions that rationals and their finite extensions correspond to islands of order in the seas of chaos of real and p-adic transcendentals suggests that states having entanglement coefficients in finite-dimensional extensions of rational numbers are somehow very special. This is indeed the case. The p-adic entropy entropy $S_p = -\sum_n p_n log_p(|p_n|)log(p)$ can be interpreted in this case as an ordinary rational number in an extension containing $log(p)$.

What makes this entropy so interesting is that it can have also negative values in which case the interpretation as an information measure is natural. In the real context one can fix the value of the value of the prime p by requiring that S_p is maximally negative, so that the information content of the ensemble could be defined as

$$I \equiv Max\{-S_p, \ p \ \text{prime}\} \ . \tag{3.2.5}$$

This information measure is positive when the entanglement probabilities belong to a finite-dimensional extension of rational numbers. Thus kind of entanglement is stable against NMP, and has a natural interpretation as bound state entanglement. The prediction would be that the bound states of real systems form a number theoretical hierarchy according to the prime p and and dimension of algebraic extension characterizing the entanglement.

Number theoretically state function reduction and state preparation could be seen as information generating processes projecting the physical states from either real or p-adic sectors of the state space to their intersection. Later an argument that these processes have a purely number theoretical interpretation will be developed based on the generalized notion of unitarity allowing the U-matrix to have matrix elements between the sectors of the state space corresponding to different number fields.

Does living matter reside in the intersection of real and p-adic worlds?

Number theoretic entanglement entropies make sense only if entanglement probabilities are real or algebraic numbers in the extension of p-adic numbers considered. This is implied by number theoretic universality in the intersection of real and p-adic variants of the imbedding space which at QFT limit of TGD correspond to discrete points of partonic 2-surfaces carrying elementary particle numbers. Their motion along light-like 3-surfaces gives rise to number theoretic braids [K17] .

At configuration space level the intersection of real and p-adic worlds would correspond to a more abstract intersection with the counterpart of rationals identified as light-like 3-surfaces represented by rational functions with rational coefficients identifiable as common to real and p-adic worlds. State function reduction to the intersection of p-adic and real worlds would induce also the rationality (or algebraic number property) of the entanglement probalities since they must make sense both p-adically and in the real sense. One might say that the enlightment means living in both real and p-adic world simultaneously.

One manner to understand the special role of rationals and algebraics relies on the observation that rationals represent islands of order in the sea of chaos defined by reals since their pinary expansion is predictable and analogous to a periodic orbit of a dynamical system whereas for a generic real number there is no manner to predict the pinary expansion.

The phase transitions transforming p-adic space-time sheets to real ones could be understood as a tunneling through the intersection of the p-adic and real worlds: here zero energy ontology is absolutely essential in order to avoid the problems caused by the impossibility to compare directly real and p-adic quantum numbers and by the non-existence of p-adic conserved charges caused by the lack of definite integral (field equations however make sense). This would provide one candidate for the formation of cognitive representation on one hand and for the transformation of intention to action on the other hand. Only living matter could carry negentropic entanglement and evolution would take place in the intersection of p-adic and real worlds. This has rather far reaching implications also for understanding the evolution of consciousness if one accepts Negentropy Maximization Principle as the basic variational principle of consciousness. These implications are discussed in [K65] .

3.2.6 p-Adic length scale hypothesis and biosystems

In the following a brief summary about biologically relevant p-adic length scales is given.

p-Adic coupling constant evolution

Could the time scale hierarchy $T_n = 2^n T_0$ defining hierarchy of measurement resolutions in time variable induce p-adic coupling constant evolution and explain why p-adic length scales correspond to $L_p \propto \sqrt{p}R$, $p \simeq 2^k$, R CP_2 length scale? This looks attractive but there is a problem. p-Adic length scales come as powers of $\sqrt{2}$ rather than 2 and the strongly favored values of k are primes and thus odd so that $n = k/2$ would be half odd integer. This problem can be solved.

1. The observation that the distance traveled by a Brownian particle during time t satisfies $r^2 = Dt$ suggests a solution to the problem. p-Adic thermodynamics applies because the partonic 3-surfaces X^2 are as 2-D dynamical systems random apart from light-likeness of their orbit. For

CP_2 type vacuum extremals the situation reduces to that for a one-dimensional random light-like curve in M^4. The orbits of Brownian particle would now correspond to light-like geodesics γ_3 at X^3. The projection of γ_3 to a time=constant section $X^2 \subset X^3$ would define the 2-D path γ_2 of the Brownian particle. The M^4 distance r between the end points of γ_2 would be given $r^2 = Dt$. The favored values of t would correspond to $T_n = 2^n T_0$ (the full light-like geodesic). p-Adic length scales would result as $L^2(k) = DT(k) = D2^k T_0$ for $D = R^2/T_0$. Since only CP_2 scale is available as a fundamental scale, one would have $T_0 = R$ and $D = R$ and $L^2(k) = T(k)R$.

2. p-Adic primes near powers of 2 would be in preferred position. p-Adic time scale would not relate to the p-adic length scale via $T_p = L_p/c$ as assumed implicitly earlier but via $T_p = L_p^2/R_0 = \sqrt{p}L_p$, which corresponds to secondary p-adic length scale. For instance, in the case of electron with $p = M_{127}$ one would have $T_{127} = .1$ second which defines a fundamental biological rhythm. Neutrinos with mass around .1 eV would correspond to $L(169) \simeq 5\ \mu$m (size of a small cell) and $T(169) \simeq 1. \times 10^4$ years. A deep connection between elementary particle physics and biology becomes highly suggestive.

3. In the proposed picture the p-adic prime $p \simeq 2^k$ would characterize the thermodynamics of the random motion of light-like geodesics of X^3 so that p-adic prime p would indeed be an inherent property of X^3.

4. The fundamental role of 2-adicity suggests that the fundamental coupling constant evolution and p-adic mass calculations could be formulated also in terms of 2-adic thermodynamics. With a suitable definition of the canonical identification used to map 2-adic mass squared values to real numbers this is possible, and the differences between 2-adic and p-adic thermodynamics are extremely small for large values of for $p \simeq 2^k$. 2-adic temperature must be chosen to be $T_2 = 1/k$ whereas p-adic temperature is $T_p = 1$ for fermions. If the canonical identification is defined as

$$\sum_{n\geq 0} b_n 2^n \rightarrow \sum_{m\geq 1} 2^{-m+1} \sum_{(k-1)m\leq n<km} b_n 2^n \ .$$

It maps all 2-adic integers $n < 2^k$ to themselves and the predictions are essentially same as for p-adic thermodynamics. For large values of $p \simeq 2^k$ 2-adic real thermodynamics with $T_R = 1/k$ gives essentially the same results as the 2-adic one in the lowest order so that the interpretation in terms of effective 2-adic/p-adic topology is possible.

Biologically relevant primary p-adic length scales

The following table lists the p-adic length scales L_p, p near prime power of 2, which might be interesting as far as biosystems are considered. Some overall scaling factor r of order one is present in the definition of the length scale and it is interesting to look whether with a suitable choice of r it is possible to identify p-adic length scales as biologically important length scales. The requirement that $L(151)$ corresponds to the thickness of the cell membrane about 10^{-8} meters gives $r \simeq 1.2$.

k	127	131	137	139	149
$L_p/10^{-10}m$	.025	.1	.8	1.6	50
k	151	157	163	167	169
$L_p/10^{-8}m$	1	8	64	256	512
k	173	179	181	191	193
$L_p/10^{-4}m$	.2	1.6	3.2	100	200
k	197	199	211	223	227
L_p/m	.08	.16	10	640	2560

Table 1. p-Adic length scales $L_p = 2^{k-151}L_{151}$, $p \simeq 2^k$, k prime, possibly relevant to bio physics. The last 3 scales are included in order to show that twin pairs are very frequent in the biologically interesting range of length scales. The length scale $L(151)$ is take to be thickness of cell scale, which is 10^{-8} meters in good approximation.

The study of the table supports the idea that p-adic length scale hypothesis might have explanatory power in biology. What is remarkable is the frequent occurrence of twin length scales related by a factor 2 in the range of biologically interesting p-adic length scales: only 3 of 15 primes in the range do not belong to a twin pair! The fact that these length scales seem to correspond to biologically interesting length scales suggests that twins might be related to replication phenomenon and to the possible 2-adicity in biology: for a given twin pair the smaller length scale would define basic 2-adic length scale. In the following the scales denoted by $\hat{L}(n)$ are related by a factor $r = 1.2$ to the lengthscales $L(n)$ appearing in the table above.

1. $\hat{L}(137) \simeq 7.84E - 11\ m$, $\hat{L}(139) \simeq 1.57E - 10m$ form a twin pair. This length scales might be associated with atoms and small molecules.

2. The secondary p-adic length scale $L(\hat{71}, 2) \simeq .44\ nm$ corresponds to the thickness of the DNA strand which is about .5 nm. Both DNA strand and double helix must correspond to this length scale. The secondary p-adic length scale $L(\hat{73}, 2) \simeq 1.77\ nm$ is longer than the thickness of DNA double strand which is roughly 1.1 nm. Whether one could interpret this length scale as that associated with DNA double strand remains an open question. Alpha helix, the basic building block of proteins provides evidence for has radius 1.81 $nm \sim \hat{L}(139)$ and the height of single step in the helix is .544 nm.

3. $\hat{L}(149) \simeq .5.0\ nm$ and $\hat{L}(151) \simeq 10.0\ nm$ form also a twin pair. The thickness of cell membrane of order $10^{-8}\ m \sim \hat{L}(151)$. Cell membrane consists of two separate membranes and the thickness of single membrane therefore corresponds to $\hat{L}(149)$. Microtubules, which are basic structural units of the cytoskeleton, are hollow cylindrical surfaces having thickness $d \sim 11\ nm$, which is not too far from the length scale $\hat{L}(151)$. It has been suggested that microtubules might play key role in the understanding of biosystem as macroscopic quantum system [J31, J1] .

4. If neutrinos have masses of order one eV as suggested by recent experiments then the primary condensation level of neutrinos could correspond to $k_Z = 167$ or $k_Z = 13^2 = 169$ and would be the level at which nuclei feed their Z^0 gauge charges. This level is many particle quantum system in p-adic sense and p-adic effects are expected to important at this condensation level. Chirality selection should take place via the breaking of neutrino superconductivity at this level and involve the generation of Z^0 magnetic fields at some level $k < k_Z$, too. $k = 151$ is a good candidate for the level in question.

5. In the previous version of this chapter it was stated that $\hat{L}(167) = 2.73\ \mu m$, $\hat{L}(169 = 13^2) = 5.49\ \mu m$ form a twin pair and correspond to typical length scales associated with cellular structures. Neutrino mass calculations give best predictions for $k = 169$ and this suggests that the generalization of 'k = prime' to 'k = power of prime' should be considered: generalization would allow also $k = 169$ as basic length scale. Also blackhole elementary particle analogy suggests the generalization of the length scale hypothesis. Furthermore, only $k = 169$ would appear as a new length scale between electron length scale and astrophysical length scales ($k = 3^5, 2^8, 17^2$)! This suggests that the length scales $L(167)$ and $L(169)$ might form effective twin pair. That this could be the case is suggested by the fact that so called epithelial sheets appearing in skin, glands, etc., consisting of two layers of cells play in biosystems same role as cell membranes and are generally regarded as a step of bioevolution analogous to the formation of cell membrane.

6. $\hat{L}(173) = 2.20 \cdot 10^{-5}\ m$ might correspond to a size of some basic cellular structure (A structure consisting of 64 cell layers?). $\hat{L}(179) = 1.75 \cdot 10^{-5}\ m$ and $\hat{L}(181) = 3.52 \cdot 10^{-4}\ m$ form a twin pair. Later it will be found that the pair $k = 179, 181$ might correspond to basic structures associated with cortex.

7. Length scales $\hat{L}(191) = 1.12\ cm, \hat{L}(193) = 2.24\ cm$ and $\hat{L}(197) = 9.0\ cm$. $\hat{L}(199) = 18.0\ cm$ are again twins.

Secondary p-adic time scales and biology

The basic implication of zero energy ontology is the formula $T(k) \simeq 2^{k/2}L(k)/c = L(2,k)/c$. This would be the analog of $E = hf$ in quantum mechanics and together hierarchy of Planck constants would imply direct connection between elementary particle physics and macroscopic physics. Especially important this connection would be in macroscopic quantum systems, say for Bose Einstein condensates of Cooper pairs, whose signature the rhythms with $T(k)$ as period would be. The presence of this kind of rhythms might even allow to deduce the existence of Bose-Einstein condensates of hitherto unknown particles.

1. For electron one has $T(k) = .1$ seconds which defines the fundamental $f_e = 10$ Hz bio-rhythm appearing as a peak frequency in alpha band. This could be seen as a direct evidence for a Bose-Einstein condensate of Cooper pairs of high T_c super-conductivity. That transition to "creative" states of mind involving transition to resonance in alpha band might be seen as evidence for formation of large BE condensates of electron Cooper pairs.

2. TGD based model for atomic nucleus [L2] , [L2] predicts that nucleons are connected by flux tubes having at their ends light quarks and anti-quarks with masses not too far from electron mass. The corresponding p-adic frequencies $f_q = 2^k f_e$ could serve as a biological signature of exotic quarks connecting nucleons to nuclear strings . $k_q = 118$ suggested by nuclear string model would give $f_q = 2^{18} f_e = 26.2$ Hz. Schumann resonances are around 7.8, 14.3, 20.8, 27.3 and 33.8 Hz and f_q is not too far from 27.3 Hz Schumann resonance and the cyclotron frequency $f_c(^{11}B^+) = 27.3$ Hz for $B = .2$ Gauss explaining the effects of ELF em fields on vertebrate brain.

3. For a given $T(k)$ the harmonics of the fundamental frequency $f = 1/T(k)$ are predicted as special time scales. Also resonance like phenomena might present. In the case of cyclotron frequencies they would favor values of magnetic field for which the resonance condition is achieved. The magnetic field which in case of electron gives cyclotron frequency equal to 10 Hz is $B_e \simeq 3.03$ nT. For ion with charge Z and mass number A the magnetic field would be $B_I = \frac{A}{Z}(m_p/m_e)B_e$. The $B = .2$ Gauss magnetic field explaining the findings about effects of ELF em fields on vertebrate brain is near to B_I for ions with f_c alpha band. Hence the value of B could be understood in terms of resonance with electronic B-E condensate.

4. The hierarchy of Planck constants predicts additional time scales $T(k)$. The prediction depends on the strength of the additional assumptions made. One could have scales of form $nT(k)/m$ with m labeling the levels of hierarchy. $m = 1$ would give integers multiples of $T(k)$. Integers n could correspond to ruler and compass integers expressible as products of first powers of Fermat primes and power of 2. There are only four known Fermat primes so that one has $n = 2^n \prod_i F_i$, $F_i \in \{3, 5, 17, 257, 2^{16} + 1\}$. In the first approximation only 3- and 5- and 17-multiples of 2-adic length scales would result besides 2-adic length scales. In more general case products $m_1 m_2$ and ratios m_1/m_2 of ruler and compass integers and their inverses $1/m_1 m_2$ and $m_2 m_1$ are possible.

5. Mersenne primes are expected to define the most important fundamental p-adic time scales. The list of real and Gaussian (complex) Mersennes M_n possibly relevant for biology is given by n=89, 107, 113*, 127, 151*,157*, 163*, 167* ('*' tells that Gaussian Mersenne $(1 + i)^k - 1$ is in question). The folowing table gives also the corresponding the secondary p-adic frequencies or time scales.

n	89	107	113	127
f/Hz	2.7×10^{12}	1.0×10^7	1.6×10^5	10
n	151	157	163	167
T	$19.4\ d$	$3.40\ y$	$218.0\ y$	$3.49 \times 10^3\ y$

(3.2.6)

3.3 p-Adic ultrametricy and biosystems

Ultrametrcity is what distuinguishes p-adic notion of distance and topology from the real one and makes the latter coarser than the real topology.

3.3.1 Spin glasses and ultrametricity

Spin glasses [B20, B17, B6] are spin systems with the property that the couplings J_{kl} between neighboring spins σ_k and σ_l are random variables although the characteristic scale of time variation of J_{kl} is very long as compared to the corresponding time scale associated with the dynamics of the spins. The characteristic property of spin glasses is their infinite ground state degeneracy. More precisely, the dynamics of the spin glasses is nonergodic and there is infinite number of pure states, which correspond to the local minima of free energy. For the purposes of comparison it should be recalled that for ferromagnet above critical temperature only one pure state exists and below the critical temperature there are two pure states corresponding to two possible directions of magnetization.

The space of pure states possesses a very general property called ultrametricity, which means that one can define in this space distance function $d(x,y)$ with the property

$$d(x,z) \leq max\{d(x,y),d(y,z)\} \ . \tag{3.3.1}$$

The properties of the distance function make it possible to decompose the space into a union of disjoint sets using the criterion that x and y belong to same class if the distance between x and y satisfies the condition

$$d(x,y) \leq D \ . \tag{3.3.2}$$

This division of the metric space into classes has following properties:

1. Distances between the members of two different classes X and Y do not depend on the choice of points x and y inside classes. One can therefore speak about distance function between classes.
2. Distances of points x and y inside single class are smaller than distances between different classes.
3. Classes form a hierarchical tree.

These properties of ultrametric spaces suggest several biological applications.

1. Parisi [B20] has suggested that ultrametricity might be used in taxonomy. Individuals of various species correspond to points of the ultrametric space and ultrametric distance gives mathematical description for the classicification criterion: in practice ultrametric distance might correspond to some genetic measure for the difference between individuals.
2. The representation of biological information seems to take place using a hierarchy of categories. Lowest and most important categories are very rough (friend/ enemy?, black/white?, etc...). Higher levels correspond more refined classifications (what kind of enemy?, does enemy move or not?,....). This kind of representation has obvious value in the struggle for survival. The hypothesis that biosystems save information into variables, which define points of ultrametric space, leads automatically to a hierarchical structure of information storage. The simplest model assumes that states of brain or at least memories correspond to free energy minima of a spin glass like statistical system [B17] .
3. Statistical models of memory and learning process, which share with spin glasses the property that the minima of free energy form ultrametric space are proposed [B17] , the main idea being that memories correspond to the minima of free energy. Learning takes place in these models via a slow change (slow as compared to the time scale of the dynamics associated with the spin variables) of the field J_{kl} associated with bond connecting k:th and l:th cell.

3.3.2 p-Adic ultrametricity

p-Adic numbers [A4] are a natural candidate for a basic tool in the description of higher dimensional critical systems since the distance function defined by p-adic norm is ultrametric. The verification of the ultrametricity is elementary task using the definition of the p-adic norm [A4]

$$|x|_p = |\sum_{k\geq k_0} x_k p^k| = p^{-k_0} \quad . \tag{3.3.3}$$

Since p-adic norm possesses discrete set of values, the values of the parameter D in the classification criterion $|x-y|_p \leq D$ can be chosen to be belong to the set $\{D_k = p^{-k}\}$, k integer. p-Adic numbers belonging to same class have same k:th pinary digit p-adic cutoff

$$\begin{aligned} x &= x_0 + x_1 \ , \\ x_0 &= \sum_{k_1<m<k} x_m p^m \ , \\ x_1 &= \sum_{m\geq k} x_m p^m \ , \end{aligned} \tag{3.3.4}$$

so that the set of classes corresponds to p-adic numbers with cutoff in k:th pinary digit. In this picture the p-adic power expansion of any p-adic observable defines a tree. The levels of the tree correspond to various pinary digits of p-adic number and each branching point gives rise to p branches. In p-adic case one can regard the root of the either as the highest cutoff pinary digit or lowest non-vanishing pinary digit of the p-adic number. In the first case, the tree is infinite: in the latter case the tree is always finite.

For x, y with same p-adic norm (same class) and z with different p-adic norm as x, y (different class) the distance function satisfies the condition

$$\begin{aligned} d_p(x,y) &\leq d_p(x,z) \ , p > 2 \ , \\ d_2(x,y) &< d_2(x,z) \ , \end{aligned} \tag{3.3.5}$$

so that there is important difference between $p = 2$ and $p > 2$ cases. Ultrametricity (or non-Archimedean property as it is called in p-adic context) holds also true for the algebraic extensions of p-adic numbers with distance defined by the canonical norm [A4] .

It has become clear that p-adicity emerges in TGD at the level of space-time topology and that one can identify p-adic space-time regions as cognitive representations of matter regions. Thus p-adic dynamics is predicted to be the dynamics of cognition and thus p-adic ultrametricity, the exotic features of p-adic probability concept, and non-determinism of p-adic differential equations are predicted to characterize the physics of cognition.

There is however also a second manner how p-adic ultrametricity might emerge in the description of biological systems. TGD Universe is quantum critical and critical systems [B21] are characterized typically by a large degeneracy of metastable states and resemble in this respect spin glasses. The vacuum degeneracy of the Kähler action defining the Kähler function in the configuration space of 3-surfaces is highly analogous to the ground state degeneracy of the spin glasses in [**?**, K8] . One cannot therefore exclude the possibility that p-adicity, in particular, small-p p-adicity for which there is also evidence, could emerge at the level of energy landscape of spin glass. According to the arguments of quantum TGD the reduced configuration space CH_{red}, consisting of the maxima of Kähler function as a function of zero modes characterizing the shape, size and induced Kähler fields on 3-surface, can be regarded as a spin glass energy landscape. Hence one can define ultrametric distance function, and it is possible that this distance function could be regarded as being induced from p-adic norm.

3.3.3 p-Adic ultrametricity and information processing in biosystems

This picture suggest a general model for the information processing in biosystems. Observations made by biosystem correlate with the variables characterizing the possibly conscious knowledge of the system about itself. The p-adic expansions of these variables give intrinsically hierarchical coding of the information associated with the observation. The lowest pinary digit is the most significant pinary digit and gives the roughest description for the observation. Higher pinary digits add details to the observation. The number of pinary digits in the p-adic representation of the observation measures the amount of information associated with it. The time order in which the information is stored or retrieved is from lowest to highest pinary digit. The Slaving Hierarchy associated with the topological condensation might have counterpart at the level of biosystems: this would mean the existence of a hierarchy $p_1 < p_2 < ..p_n < ..$ of p-adic dynamics each with its own characteristic time scale satisfying $T_1 < T_2 < .... < T_n < ...$ and the relationship between two consecutive dynamics is that of master and slave. The higher the level p_n in the p-adic Slaving Hierarchy the higher is the intelligence associated with that level as measured in the number of possible conceptual categories.

A highly nontrivial prediction is that the number of conceptual categories is same at all levels and equal to prime p. This means that $p = 2$ case provides most primitive (but much used!) classification of type black/white. A well known mystery of cognitive science is the so called 7 ± 2 rule [B19] : human mind tends to classify observations into $p = 7$ categories and the classification using more categories than this is difficult. One possibility to test applicability of the p-adic ideas to biosystems is to check whether biossystems obey small-p p-adic rather than ordinary statistics. The nondeterminism and fractality of biosystems might be in better accordance with p-adic rather than ordinary statistics.

The analogy with spin glass models of learning suggests a microscopic TGD inspired physical model for learning. Short term learning is believed to correspond to slow changes in synaptic connections between neighboring cells. Long term learning probably involves the formation of new contacts between neighoring cells and according to suggestion of [K38] topological storage of information. In TGD inspired model for brain it was suggested that cells correspond to 'topological field quanta', 3-surfaces possessing outer boundary and having size of cell One mechanism for the formation of macroscopic quantum systems is as a formation of bonds connecting boundaries of neighbouring 'topological field quanta' (now 3-surfaces associated with cells). A possible identification for the counterpart of the spin glass coupling parameter J_{kl} is as Kähler electric interaction energy between neighbouring topological field quanta associated with this kind of bond. Therefore it would be the Kähler electric fluxes through the bonds, which change primarily in the short term learning. This change can be partially nondeterministic process since p-adic dynamics allows partial non-determinism and this nondeterminism is related to freedom to choose the low pinary digits of the dynamical variables arbitrarily.

3.4 p-Adic non-determinism and biosystems

The non-determinism of quantum jump, the classical non-determinism associated with the maximization of Kähler action, and p-adic non-determinism form a trinity of independent non-determinisms. Classical non-determinism of Kähler action can be assigned with volition whereas p-adic non-determinism is naturally the geometric correlate of imagination.

3.4.1 Could p-adic differential equations simulate quantum jump sequence?

In practical applications one must idealize the biosystem with a system of differential or partial differential equations. Since cognition is basic aspect of living systems one might expect that the general properties of p-adic differential equations might be useful for modelling not only cognition but also the behavior of living matter.

1. The non-determinism associated with p-adic differential and partial differential equations is due to the presence of arbitrary functions depending on finite number of pinary digits of p-adic coordinates, which are in the role of the integration constants. p-Adic integration constants are actual constants below some p-adic time scale. Solution of field equations typically consists of regions which are deterministic in the ordinary sense of the world glued to each other. Various conserved quantities are pseudo constants. This means that p-adic reality is somewhat like the reality of dreams consisting of fragments which could be realized also in everyday reality.

2. p-Adic space-time sheets could provide a simulation for the time development occurring via quantum jumps. p-Adic space-time surface would consist of fragments for which p-adic integration constants are ordinary constants. These pieces would represent the conscious information obtained about various real space-time surfaces in the sequence of quantum jumps (the space-time surfaces appearing in the quantum superpositions defined by the final states of quantum jumps are macroscopically equivalent). The lack of well-orderedness of the p-adic topology could reflect the fact that the arrow of time associated with t is only statistical.

3. p-Adic realization of the Slaving Hierarchy [B12] roughly means that there is a hierarchy .. < $p_1 < p_2 <$ ... of p-adic dynamics and that the integration constants at level p_1 (slave) obey some dynamic equations at some higher p-adic level $p_2 > p_1$ (master) and are actual constants below length scale $L_{p_2} > L_{p_1}$ for each pair in the sequence. This hierarchy of dynamics need not be completely deterministic. If Kähler action allows nonunique classical histories, the p-adic integration constants can be chosen to some degree freely at each level of the Slaving Hierarchy. The free choice of p-adic integration constants has interpretation as a plan of an intelligent system for its future behavior. At p- adic length and time scales (macroscopic!) it is possible to "break physical laws": Universe learns engineering skills and begins to plan its own future!

4. The real counterparts for the solutions of p-adic differential equations have characteristic large jumps followed by small scale zig-zag type behavior. This zig-zag behavior is observed also for analytic solutions containing only ordinary integration constants, say for $x = At^2, y = Bt$ at values $t = 2^n$. Since p-adic integration constants are actual constants only for time scales smaller than $\Delta t = 2^{-n}$, the nondeterminism appears also as sudden jumps concentrated at multiples of Δt: Δt defines clearly a natural unit of time and therefore biological clock. In [B19] the generality of this zig-zag motion in all length scales was emphasized as one of the characteristics of biosystems and the sudden jumps were identified as jumps from strange attractor to another and small scale motion as motion along attractor. A good example of this kind of motion is the motion of eye [B19] . The fractal property of solutions of p-adic differential equations implies an infinite number of time scales corresponding to $\Delta_m = p^{-m}$, $m \leq n$. This in turn implies characteristic $1/f$ spectrum for the Fourier transform of orbit, which is quite general feature of biosystems [B19] .

5. An important property of p-adic differential equations suggested by the iteration of simpls p-adic maps (say $Z \to Z^2$) in algebraic extensions of R_p is that critical orbits form a set ($|Z| = 1$), which possesses same dimension as the configuration space so that critical metastable orbits are therefore not rare occurrences like in ordinary dynamics based on real topology. The small scale zig-zag motion between large jumps in the motion desribed by p-adic differential equations could correspond to motion near metastable orbit and be analogous to the motion along strange attractor in the strange attractor model of information processing proposed in [B19] .

3.4.2 Information filtering and p-adics

Intelligent systems are extremely effective information filters. Only an extremely small amount of information is absorbed from the incoming information. As far as visual observations are considered it is the angles and boundaries, which receive most attention [B19] . An interesting possibility is that intelligent system concentrates its attention to p-adic super-conformal invariants such as angles. This would apply quite generally: any observation correspond to an orbit in some internal configuration space simulating the observed system. The correspondence between the observation and simulation is determined only modulo p-adic super-conformal transformations of the configuration space.

One can even consider a simple model for the coupling between internal configuration space and outer world using 'Newton's equations' assuming that acceleration corresponds to the sensory experience:

$$\frac{d^2x^k}{dt^2} = F^k(t) - k\frac{dx^k}{dt} \quad . \tag{3.4.1}$$

$F^k(t)$ describes observation as an external force acting on system. In the absence of $F^k(t)$ motion is linear (no angles!) and only when $F^k(t)$ is non-vanishing the direction of motion changes direction (angle). The friction term guarantees that constant stimulus leads to no sensory experience situation (adaptation). Idealized case corresponds to delta pulses causing zig-zag type motion. Note that p-adic indeterminacy brings in certain degree of 'subjectivity' and could provide a phenomenological model for the quantum nondeterminacy.

This kind of model could serve as a model of language analogous to that considered in [B19] . Individual phonemes correspond to linear part on the orbit in some configuration space and the duration of phonem doesn't matter. The change of phoneme to another one corresponds to angle on the orbit (external force) and different angles correspond to different phonem pairs. The hierarchy of structures (phonemes, hyphens, worlds, sentences,..) might correspond to p-adic slaving hierarchy (say, $p = 2, 3, 7, 127..$) associated with the differential equations governing the orbit in internal configuration space.

3.5 p-Adic probabilities and biosystems

p-Adic probabilities can be defined in a manner analogous to that used to define ordinary probabilities [A16] . One can consider sufficiently large number of observations N chosen by some criterion since conditional probabilities are considered in practice and observe possible mutually exclusive outcomes N_i labeled by integer i. The relative frequencies N_i/N are estimates for p-adic probabilities. Probability conservation corresponds to the condition $\sum_i N_i = N$. The feature, which differentiates between ordinary and p-adic probabilities is related to the large N limit, which must exist in p-adic rather than ordinary sense. This means that the values of N, which differ by large powers of p are p-adically near to each other. For example, N and $N+1$ are in general not near each other p-adically! For large values of p say $p = M_{127} \simeq 10^{38}$ the value of N rarely exceeds the critical value p and there is no practical difference between p-adic and ordinary probabilities. For small values of p the situation changes.

3.5.1 Does p-adic probability apply only to cognition?

p-Adic probality concept is expected to apply in quantum statistical models of cognition. If p-adic space-time sheets indeed model sequences of quantum jumps by replacing consciously observed pieces of real space-time appearing in the sequence of quantum jumps by finite space-time regions glued to each other in p-adically continuous manner, then p-adic statistics might apply as a model of self-organization resulting from a dissipative time development by quantum jumps.

p-Adic probalities might be natural in the statistical description of fractal structures resulting in the self-organization, and which by definition can contain same structural detail with all possible sizes.

1. Consider counting of conformally invariant structural details of a p-adic fractal. A simple biologically interesting example is the solution curve of p-adic differential equations in some configuration space associated with biosystem (say the space of average chemical concentrations). The angles associated with the kinks of the curve measured with some finite precision are the structural details in question.

2. One can count how many times i:th structural detail appears in a finite region of the fractal structure: although this number is infinite as real number it might possess (and probably does so!) finite norm as p-adic number and provides a useful p-adic invariant of the fractal. One can calculate also the total number of structural details defined as $N = \sum_i N_i$ and also define p-adic probability for the appearance of i:th structural detail as relative frequency $p_i = N_i/N$. The real, 'renormalized' counterparts of N_i and P_i obtained via the canonical correspondence define real valued invariants of the fractal structure.

3. The evaluation of the p-adic probalities of occurrence can be done by evaluating the required numbers N_i and N in a given resolution. Better estimate is obtained by increasing resolution and counting the numbers of the hitherto unobserved structural details. The increase in the resolution greatly increases the number of observations in case of p-adic fractal and the fluctuations in the values of N_i and N increase with resolution so that N_i/N has no well defined limit as real number although one can define the probabilities of occurrence as resolution dependence concept. In p-adic sense the increase in the values of N_i and fluctuations is small and the procedure should converge rapidly so that reliable estimates should result with quite a reasonable resolution.

3.5.2 Is small-p p-adic statistics possible?

There is a distinct possibility that p-adic statistics with small p might be a unique testable signature of intelligent systems! The replication property of biosystems suggests that the lowest level in topological condensate of biosystem has $p = 2$. The quantization of the number of observations in biological experiment could be understood in the following manner. A natural choice for N in biosystem corresponds to all individuals that have existed or exist in the biosystem during some time interval. For an ideally replicating biosystem this number develops during time in the following manner. $N = 1$ for zeroth generation, $N = 1 + 2 = 3$ for the second generation,$N = 1 + 2 + ...2^k = 2^{k+1} - 1$ for $k + 1$:th generation. The expression for the relative frequency is

$$P = \frac{\sum_k N_k}{\sum_k 2^k} \ . \tag{3.5.1}$$

The dominating contribution to p-adic probability comes from the lowest generations. For p-adic probability to make sense the behavior of the system must be sufficiently deterministic during the earliest stages of the development. Non-determinism becomes possible for large of N. The development of the embryo during the first cell divisions is indeed highly deterministic process.

An interesting feature of the ideally replicating biosystem is that $N = 2^{k+1} - 1$ is Mersenne prime for certain values of the generation number $k + 1$. If the topological condensate associated with biosystem contains also higher levels p then these values of N might mean the emergence of something new since the value of N exceeds the critical value $p = M_{k+1}$, when the number generations becomes $k + 1$ and p-adic probability concept begins to apply at p:th level. This suggests that the values of the total cell number $N_{cell} = 2^{k-1}$ associated with the Mersenne primes M_k are critical cell numbers. Some of the lowest critical generation numbers are $k = 2$: $N_{cell} = 2$, $k = 3$: $N_{cell} = 4$,$k = 7$: $N_{cell} = 64$,...

3.5.3 The concept of monitoring

In p-adic quantum theory expected to provide a model for cognition one must somehow associate real probabilities to p-adic probabilities. This problem has been already discussed and leads to the conclusion that the transition probabilities of p-adic quantum system depend on how it is monitored. p-Adic sum of transition probabilities corresponds to the experimental situation, when one does not monitor individual transitions but using some common experimental signature only looks whether the transition leads to this set of finals states or not. When one looks each transition separately or effectively performs different experiment by considering only one transition channel in each experiment one must use the sum of real probabilities. More precisely, the choice of experimental signatures divides the set U of the final states to disjoint union $U = \cup_i U_i$ and one must define the real counterparts for transition probabilities P_{iU_k} as

$$\begin{aligned} P_{iU_k} &= \sum_{j\in U_k} P_{ij} \ , \\ P_{iU_k} &\rightarrow (P_{iU_k})_R \ , \\ (P_{iU_k})_R &\rightarrow \frac{(P_{iU_k})_R}{\sum_l (P_{iU_l})_R} \equiv P^R_{iU_k} \ . \end{aligned} \tag{3.5.2}$$

Similar resolution can be defined also for initial states by decomposing them into a union disjoint subsets. The assumption means deep difference with respect to the ordinary probability theory.

p-Adic probability conservation implies that the lowest order terms for p-adic probabilities satisfy the condition $\sum_j P^0_{ij} = 1 + O(p)$. The general solution to the condition is $P^0_{ij} = n_{ij}$. If the number of the final states is much smaller than p this alternative implies that real transition rates are enormous: typically of order p! Therefore it seems that one must assume

$$P^0_{ij} = \delta(i, j) \ . \tag{3.5.3}$$

As a consequence the probability for anything to happen (no monitoring of different events) is given by

$$\sum_j (P_{ij} - \delta(i,j)) = 0 \ , \tag{3.5.4}$$

and vanishes identically! This is not so peculiar as it looks first since there must be some signature for anything to happen in order that it can be measured and signature always distinguishes between two different events at least: it is difficult to imagine what the statement 'anything did not happen' might mean! Of course, in real context this philosophy would imply the triviality of S-matrix.

If biosystems are indeed quantum systems and p-adic probabilities apply to their description then the unavoidable prediction is that the behavior of biosystems depends on how it is monitored (remembering all anecdotes about experimentation with living matter, one might somewhat light-heartedly argue that this is just the case!). For small values of p, in particular for $p = 2$, the deviations from the standard probability theory are especially large. In particular, the resolution of the monitoring is essential factor. It must be stressed that this peculiar behavior seems not to be related with the predictions of standard quantum measurement theory and this supports the view that p-adic probabilities apply only to the statistical modelling of cognition.

3.6 Is small-p p-adicity possible?

A longstanding problem of TGD inspired theory of consciousness and p-adic TGD in general has been whether small-p p-adicity is present in macroscopic length scales. The basic form of p-adic length scale hypothesis suggests that small-p p-adicity should be present only in length scales near CP_2 size about 10^4 Planck lengths, which defines the fundamental p-adic length scale. On the other hand, p-adic fractality suggests that also the scaled up versions of entire p-adic length scale hierarchy might be possible in the sense that CP_2 size is effectively replaced with p-adic length scale L_p for any prime p and most probably for primes $p \simeq 2^k$, k power of prime. In particular, the realization of genetic code, which corresponds to p-adic prime $p = 127$, at the level of DNA molecules suggests, that small-p p-adicity is realized in Nature and involves transmutation of the fundamental p-adic length scale to atomic length scale. This expectation conforms also with the idea that Universe is infinite-sized self-organizing quantum computer emulating itself in all possible scales and building scaled up simulations of the lower levels. Even science could be regarded as one such emulation.

There are two manners to achieve this transmutation. Either there is some mechanism making this transmutation possible dynamically or the scaled up variants of the p-adic length scales are present from the beginning. I constructed long ago an argument suggesting that the first option might be possible. If one accepts the hierarchy of Planck constants, this hierarchy is present from the beginning at the level of dark matter but manifesting itself also in the behavior of the visible matter since dark matter and visible matter interact in TGD framework via the standard interactions such as classical em fields and photon exchange. What darkness means that particles at different pages of the Big Book realizing dark matter hierarchy cannot appear in the same local interaction vertex of Feynman diagram so that in particle physics laboratory these interactions cannot be observed.

3.6.1 Hierarchy of Planck constants and small-p p-adicity

The hierarchy of Planck constants [K67, K67, K54, K25] realizes small-p p-adicity in a very natural manner.

1. p-Adic length scale hypothesis states that the hierarchy of primary p-adic length scales $L_p = \sqrt{p}R$, where R is CP_2 size is fundamental. The primes near power of 2 are favored so that the primary p-adic length and time scales would come as half octaves. The justification for the hypothesis came originally from p-adic mass calculations and Uncertainty Principle.

2. The secondary p-adic time (and length) scales $T_{p,2}$ associated with primes $p \simeq 2^k$ coming as octaves of CP_2 scale define the proper time temporal distances between the tips of CDs (and their spatial sizes). The secondary p-adic length scales are analogous to the horizon sizes in cosmology. p-Adic length scale hypothesis follows from a simple argument using the light-like randomness of 3-surfaces implying that primary p-adic length scale is proportional to a square root of the temporal distance between the tips of CD.

3. The basic prediction of the generalization of quantum theory by allowing a hierarchy of Planck constants is that for $r = \hbar/\hbar_0$ the primary p-adic length scale L_p is scaled to $\sqrt{r}L_p$ and secondary p-adic time scale to $rL_{p,2}$. In principle all rational values of r are possible but certain rationals such as ratios and products and inverses of products of ruler-and-compass integers are favored. These integers are expressible as products of a power of two and product of different Fermat primes $F_k = 2^{2^k}+1$. Only $k = 1,2,3,4$ are known to give rise to prime.

4. Second interesting hierarchy of values of r are ratios, products and inverses of products of primes. The reason is that the quantum phases $exp(i2pi/p)$ behave as primes under multiplication in the sense that more general phases can be expressed as products of powers of these prime phases. This would give as a special case small prime multiples of the secondary p-adic length scales.

3.6.2 Hierarchy of Planck constants and small-p p-adicity in gravitational sector

The hierarchy of Planck constants [K67, K67, K54, K25] realizes small-p p-adicity in a very natural manner. The basic prediction is that for $r = \hbar/\hbar_0$ p-adic length scale L_p is scaled to $\sqrt{r}L_p$. In principle all rational values of r are possible but certain rationals such as ratios and products and inverses of products of ruler-and-compass integers are favored. These integers are expressible as products of a power of two and product of different Fermat primes $F_k = 2^{2^k}+1$. Only $k = 1,2,3,4$ are known to give rise to prime.

Gravitational Planck constant expressible as $\hbar_{gr} = GM_1M_2/v_0$, wehere $v_0/c < 1$ is not too far from unity, is extremely large. Using $L_p = \sqrt{p}R$, and $R = k10^4\sqrt{G/\hbar}$ one obtains that for the scaled up p-adic length scale the expression

$$L_p \rightarrow \sqrt{\frac{GM_1M_2}{v_0}}L_p = \sqrt{\frac{p}{v_0}G\sqrt{M_1M_2}} \ .$$

For $M_1 = M_2 = M$ which makes sense if one consider self-gravitation one has

$$L_p \rightarrow \sqrt{\frac{GM^2}{v_0}}L_p = \frac{1}{2}\sqrt{\frac{p}{v_0(S)}}r_S \ .$$

where $r_S = 2GM$ is Schwartschild radius. One can ask whether the well-known Titius-Bode law [E4] stating an approximate quantization of orbital radii via formula $r = r_0 + r_1 2^k$ might relate to the p-adic length scale hypothesis for small primes. The powers 2^k, $k = 1,2,...,8$ correspond to primes $p = 2^k + \epsilon$ for either sign of k. The radii of Bohr orbits come as $n^2 r_S/v_0$ and produce for $v_0 \simeq 2^{-11}$ reasonable fit for the orbital radii of the inner planets for $n = 3,4,5$. For outer planets the scaling $v_0 \rightarrow v_0/5$ is required. This would give the approximate formula

$$p(n) \simeq log(\frac{4n^4 v_0(S))}{v_0^2})$$

for the inner planets and

$$p(n) \simeq log(\frac{100n^4 v_0(S))}{v_0^2})$$

for the outer planets. The corresponding time scales would come as approximate octaves of the same basic time scale and would be of order few minutes.

Since electron corresponds to a huge prime $p = 2^{127} - 1$, one can consider the possibility that relatively small p-adic primes in this scale give rise to biological time scales and that the periodicities which appear in living matter as prime multiples of year might be understood in terms of dark matter at space-time sheets mediating gravitational interaction.

For Earth the Schwartschild radius is $r_S \simeq .9$ cm so that for $v_0(E) = 2^{-11}$ one would have the basic scale of .4 m and p-adic length scale hypothesis for small values of p would give half octaves of this scale. These scales need not have anything to do with biology.

3.6.3 Small-p p-adicity and hydrodynamics

Hydrodynamic turbulence in the atmosphere involves generation of coherent macroscopic structures which are typically structures appearing in excitable media. One example are spiral waves which represent spiral like convective roll pattern such that the radius of the rolling vortex increases exponentially when one moves away from the apex of the spiral wave. Tornadoes and hurricanes are also well known self-sustaining structures. The generation of these structures is difficult to understand in ordinary hydrodynamics and Indian meteorologists Mary Selvam [H11] takes as her challenge to understand the microscopic mechanism leading to the generation of these structures. TGD suggests quite generally the reduction of the hydrodynamical turbulence and chaos in excitable media to magnetic or Z^0 magnetic turbulence. The work of Selvam related to the turbulent atmospheric flows inspires also additional very interesting insight to p-adic length scale hypothesis and suggests that n-ary p-adic length scales $L(n,k)$ corresponding to very large values of n are realized in hydrodynamical turbulence, and that hydrodynamical vortices could be regarded as elementary particle like objects on the space-time sheets at which they are condensed topologically.

Spiral waves and magnetic turbulence

Self-sustaining spiral waves are known to be characteristic for all excitable media [A2] and typical results of self-organization. The growth of plants leads quite generally to the generation of logarithmic spirals; spiral Ca_{++} waves are known to be crucial for intracellular communications [A19] ; spiral waves appear also in heart [A30] [A30, A10] .

1. Logarithmic spiral and Penrose tilings

Spiral waves (say roll-vortices with vortex core along spiral) are waves for which the the center of the wave defined by logarithmic spiral

$$\frac{R}{r} = exp(b\theta) \ .$$

The values of R/r are Fibonacci numbers $F(n+1) = F(n) + F(n-1)$ for certain values of the angular variable θ. At the limit of large Fibonacci numbers one has $F_n \simeq \tau^n$ and substituting to the equation one obtains $\theta \simeq n\theta_0$, $\theta_0 = log(\tau)/b$, $\tau = \frac{1+\sqrt{5}}{2}$.

Logarithmic spirals form a one-parameter family and especially interesting is the logarithmic spiral for which the line connecting the points $r = F_n$ and $r = F(n+1)$ has length F_n. In this case

$$\theta_0 = \frac{2\pi}{10} = 36 \ \text{degrees} \ .$$

This particular logarithmic spiral leads to a generation of Penrose tiling [A21] : this occurs in both 2- and 3-dimensional case. This particular logarithmic spiral is very general in botany. Rather interestingly, the angle of 36 degrees happens to be the angle between two subsequent DNA nucleotides in DNA helix, which encourages to consider the possibility that the helical structure of DNA rather concretely codes is in some sense fractal growth defined by the logarithmic spiral with this value of b. Note that this kind of growth preserves shape and this is probably one reason for why logarithmic spirals appear so often in botany. In fact, the notion of manysheeted DNA [K42] suggests that genes in DNA helix in some sense represent contracted versions of the organism preserving 1-dimensional homology: perhaps the contraction preserves also spiral structure. A further interesting point to notice is that the shortest sequence of DNA:s for which the net winding angle along helix is multiple of 2π and which codes for an entire protein consisting of 30 DNA nucleotides, has thickness of cell membrane as already found.

2. Reduction of chaos to magnetic turbulence?

TGD suggests that quite generally spiral waves are accompanied by the underlying magnetic and Z^0 magnetic flux tube structures. Spiral wave would correspond to Z^0 flux tube around which ordinary matter rotates so that rolling vortex results. At the apex magnetic flux tube apparently ends. The conservation of (Z^0) magnetic flux requires that flux tube leaves the space-time sheet at the apex and continues at the second space-time sheet. This suggests the fascinating possibility that macroscopic structures in hydrodynamic turbulence could correspond to wormhole magnetic fields [K85] associated with pairs of space-time sheets and be generated by rotating wormholes at the boundaries of the structure. If time orientation is negative at second space-time sheet, this space-time sheet carries negative energy density which can be very small if only the energy of Z^0 magnetic field is in question. If wormhole magnetic fields (besides MEs) represent mindlike space-time sheets of finite time duration, one could perhaps (rather loosely) speak about interaction of matter and mind. The same mechanism might be at work also at cell level.

3. Magnetic turbulence and loss of macroscopic quantum coherence

For superconductors quantization conditions imply that the increment of the phase of the complex order parameter of the supra phase around the circuit along boundary of the flux tube equals to the magnetic flux through the tube. Thus magnetic turbulence implies turbulence of superconductor and probably destruction of the supraphase. If ionic superconductors are responsible for biocontrol, then magnetic turbulence would be reflected as chaotic functioning of organ. This loss of quantum coherence would be caused by the leakage oft he supra currents from flux tubes via join along boundaries bonds. This in turn would imply dissipation at the non-superconducting space-time sheets by particle collisions. This leakage would be forced by the inertia when the local curvature of the flux tube becomes too large: this is indeed expected to occur in a chaotic situation when flux tubes have very Brownian shapes.

Heart failure, known to involve the generation of decaying spiral waves modellable using Hodkin-Huxley equations or their variants [A30, A10] , might be one example of this mechanism. The reduction of this model to quantum level is required by internal consistency if one takes seriously TGD based model of nerve pulse activity in terms of ionic and electronic superconductors relying crucially on Josephson junctions associated with axons [K60] . In case of heart, normal situation would in ideal case correspond to spatially constant phase wave of Josephson current oscillating in time with basic frequency (there is precise analogy with a rotating mathematical pendulum) so that the Josephson currents associated with all heart cells oscillate in unisono, perhaps at the the rhytm of heart beat. During heart failure magnetic turbulence destroys this coherence. Interestingly, the time period of fibrillation is .1 seconds, the time scale of the memetic code [A30] .

4. Atmosphere as cortex of Mother Gaia?

In TGD framework self-organization means the presence of conscious selves and suggests that even atmosphere is in some sense part of Mother Gaia. Perhaps it is of some significance that the ratio of the thickness of atmosphere (10 km) to the radius of Earth radius is of order 1/100 and is same as the ratio of cell membrane thickness to cell size. Fractality indeed suggests this ratio if atmosphere is regarded as scaled-up version of the cell membrane. Note however that the thickness of flora is about 10 m: in case of cell membrane this would suggest a layer of thickness of order 10^{-11} meters, which happens to correspond to the p-adic length scale $L_{M_{127}}$ associated with electron. The p-adic prime associated with the memetic code pops up again and one could wonder whether the MEs with length of $L_2(127)$ could have thickness equal to $L(127)$ and form structure analogous to biosphere at surface of Earth. The fact, that the frequency distribution of so called sferics, em perturbations induced by lightnings resemles at low frequencies delta band in EEG [J2] , suggests that these exotic levels of life might be there and interact with animal brains.

Selvam's model and claims

Selvam studies a model for hydrodynamical spiral waves by assuming that these waves are vortices with core at logarithmic spiral

$$z \equiv \frac{R}{r} = b \times exp(b\theta) \ .$$

Selvam assumes also that the radius ρ of rolling convective vortex grows with z and that also this growth obeys similar law: that is $\rho = exp(b\theta)$. Selvam assumes that the parameter θ_0 corresponds to the angle of 36 degree associated with equilateral Fibonacci triangle having short sides F_n and long side $F(n+1)$ at the limit $n \to \infty$. As noticed, this logarithmic spiral gives rise to Penrose tiling.

Selvam does not specify precisely this growth law: for instance, whether there is phase lag between R characterizing position of growing vortex and r characterizing its size. Selvam does not either clearly specify how R develops with time: for instance, whether growth occurs linearly in which case θ would grow logarithmically. One possible manner to obtain the proposed growth is to assume that the growth is analogous to biological growth such that turbulent eddies are in the role of cells and replicate. If the growing vortex decomposes of radius $\rho(n)$ to an inner cylinder of thickness $\rho(n-2)$ and outer annulus of thickness $r(n-1)$ such that outer annulus replicates to annulus of same thickness at $n+1$:th step of growth process one indeed obtains $\rho(n+1) = \rho(n)+\rho(n-1)$ giving rise to Fibonacci sequence asymptotically.

Selvam claims that the dominating temporal periodicities T_n of flow are Fibonacci numbers in suitable units:

$$T_n = F(n) \simeq \tau^n \quad , \quad \tau = \frac{1+\sqrt{5}}{2} \quad .$$

This claim can be understood if vortex structures with radius F_n form special structures and if there are standing waves moving with constant velocity v along these structures: this gives

$$T_n = \frac{F_n r}{v}$$

for the periodicities of these waves. Selvam argues that Fibonacci numbers reflect also the periodicities of prime number distribution but I find it difficult to understand the motivations for this claim.

Selvam also studies the distribution for the ratio $z = R/r$ of large vortex radius R to smallest vortex radius r, and, as far as I have understood correctly, claims that this distribution is the same as the distribution of primes in region of rather small primes. This could be understood if vortex radii are prime multiples of r

$$R = kr \quad , \quad k \ \text{ prime} \quad ,$$

and if each prime appears with the same probability. This assumption can be actually loosened: one can also interpret r as the p-adic length scale associated with minimum size vortex interpreted as space-time sheet. Even the assumption that vortices sizes are given by primes might be too strong: only one-one correspondence with the distribution of primes is needed. Selvam also argues that vortex dynamics has quantal features and that vortices could in some aspects be regarded as quantum objects: this is certainly what TGD approach strongly suggests.

It must be emphasized that the arguments of Selvam do not satisfy the requirement of mathematical rigour and it is only my personal feeling that something deep is involved and I just take Selvam's claims as inspiration for studying whether small-p p-adicity suggested strongly by fractality might be realized in hydrodynamical flows. Certainly, TGD predicts p-adic evolution and this evolution should reflect itself directly in biological growth and perhaps even in hydrodynamical self-organization. Also Matthew Watkins has proposed a connection between evolution and prime numbers [A1] .

p-Adic evolution and quantum classical correspondence (classical dynamics should provide a Bohr orbit type representation for quantum dynamics) suggests that growth processes quite generally corresponds to p-adic evolution. First pop-up structures with $p = 2$, then structures with $p = 3$, and so on. In hydrodynamics case these structures correspond to stable vortices with prime-valued radius $R/r = p$. If the growth of spiral wave is linear in time then vortices with prime valued radio pop-up for the first time at time values which are prime multiples of basic time unit. If the emergence of these vortices reflects itself as somekind of distinguishable feature in the temporal behavior of dynamical quantities, as one might expect, the Fourier spectrum should reflect the properties of the spectrum of prime numbers. This is clearly a strong and testable prediction.

Why vortices with prime radii are stable?

The first question to be answered is why vortices with radii which are prime valued are stable. Suppose that there is fundamental length scale r identifiable as the radius of turbulent eddy. This radius would result from the quantization of Z^0 magnetic flux if one assumes that there is a preferred value for the strength of the Z^0 magnetic field. Flux quantization would imply that the radii of the vortices are quantized as $r \propto \sqrt{n}$, n integer. The problem is to understand why n is square of prime rather than arbitrary integer.

One could however correspond the possibility that prime valued radii correspond to secondary p-adic lengths scales with a scaled-up fundamental p-adic length scale defined by the Z^0 magnetic flux quantization (a possible mechanism leading to transmutation of the fundamental p-adic length scale will be discussed later). This implies that all vortices (cylindrical and annular) have radius which is integer multiple of this length scale: $z = n$. Vortices consists of turbulent eddies or tend to decay to vortices $z = 1 < m < n$. The wavelengths of the radial perturbations tending to induce the decay of the vortices to smaller ones, are integer multiples of r. One has effectively aperiodic lattice, Penrose tiling known to be associated with logarithmic spirals [A21] . Also in the periodic lattice only integer multiples of the basic wave vector propagate. Turbulent eddy defines the equivalent of fundamental lattice cell.

As a consequence, only vortices with prime-valued radii are stable. For instance, $n = p_1 \times p_2$, p_1 and p_2 primes, the vortex can decompose to p_1 cylindrical or annular vortices with radius p_2 or vice versa by a perturbation with wavelength $\lambda = p_1 r$ $(p_2 r)$. The impossibility to generate radial periodic perturbations with wavelength which is nontrivial multiple of the fundamental length, explains why prime vortices are stable against decay. Note that in [K66] precisely the same argument was used to explain why some retarded persons are able to 'see' factorization of 8-digit numbers into prime factors (see the book 'The man who mistook his wife for hat' of Oliver Sacks [J38]). Mental images representing number n, is represented by some structure, perhaps vortex(!), and if n is not prime it has tendency to decay to some number of identical smaller structures! Thus non-primeness is directly visible property: perhaps higher levels selves spend their time by monitoring the factorization of very large integers.

How the transmutation of a fundamental p-adic length scale to macroscopic length scale could occur?

What might be the mechanism effectively leading to the transmutation of the fundamental p-adic length scale $l \simeq 10^4$ Planck lengths to a macroscopic length scale? Hierarchy of Planck constants represents one solution to the problem. A possible p-adic explanation for these length scales would be as secondary p-adic length scales for Planck constants, which correspond to a prime multiples of the ordinary Planck constant: $r = \hbar/\hbar_0 = p$. Since electron corresponds to a secondary p-adic length scale of order Earth's radius the primes in question must be smaller than M_{127}. Some examples are in order.

1. $k = 113$, which corresponds to nuclear p-adic length scale and Gaussian Mersenne, would correspond to a secondary p-adic length scale 1.831 km. Prime multiples of this scale identified in terms of hierarchy of Planck constants might have something do with the radii of vortices reported by Selvam.

2. The p-adic length scale defined by M_{107} assignable to the hadronic space-time sheets would correspond to a secondary p-adic length scale of 28.6 meters. The secondary p-adic length scale assignable to M_{89} characterizing intermediate gauge bosons would be .1 millimeters defining the size scale of a large neuron and also the size of water blob having Planck mass. The mapping of elementary particle p-adic length scales to secondary p-adic length scales defining size scales of CDs would mean a correlation between elementary particle physics and macroscopic physics in human length and time scales, which has remained hidden.

3. The primary p-adic length scale $k = 137$ assignable to atom corresponds to the secondary p-adic time scale of 102.4 seconds. The corresponding length scale, which is 2^{10} times the circumference of Earth, is $r = 61$ Gm. The distance of Earth from Sun is $AU = 149$ Gm and about 5/2 times this distance.

3.6.4 2-adic psychophysics?

Music metaphor has turned out to be of crucial importance for the theory of qualia. The most natural explanation for this is that music metaphor reflects underlying 2-adicity of our sensory experience. Perhaps at least some aspects of our experience result from a mimickry of the lowest level of the p-adic self-hierarchy. Taking 2-adicity seriously, one is forced to ask for the possible consequences of 2-adicity. For instance, could it be that at the level of primary qualia the intensity of sensation as function of stimulus depends on the 2-adic norm of the 2-adic counterpart of the stimulus and is thus a piecewise constant function if sensory input?

An observation supporting this speculation is following. When over-learning occurs in tasks involving temporal discrimination, the intensity of sensation as a function of stimulus deviates from smooth logarithmic form in small scales by becoming piecewise continuous function [J20] such that the plateaus where response remains constant are octaves of each other. This observation suggests a generalization inspired by 2-adic version of music metaphor. Primary quale has multiple of cyclotron frequency as its correlate and, being integer valued, is essentially 2-based logarithm of the 2-adic norm for the 2-adic counterpart of the intensity of the sensory input. Hence the increase of intensity of the sensory input by octave correspond to a jump-wise replacement of the n:th harmonic by n+1:th one and should be seen in EEG. Our experience usually corresponds to the average over a large number of this kind of primary experiences so that underlying 2-adicity is smoothed out. In case of over-learning or neurons involved act unisono and the underlying 2-adicity is not masked anymore. At the level of ELF selves this would mean generation of higher harmonic when the number of nerve pulses per unit of time achieves threshold value allowing the amplification of corresponding frequency by the mechanism discussed already earlier.

3.6.5 Small-p p-adicity in biosystems and psychophysics

There are several hints for small-p p-adicity in macroscopic length and time scales from biology and psychophysics besides this decisive result of Selvam.

1. 2-Adicity of music experience suggests that 2-adicity present in macro-temporal scales [K66] . Also the general form of the p-adic length scale hypothesis and the concrete appearance of 2-adic fractals [K50] suggests that 2-adicity is realized also in macroscopic length scales. The topological model for thoughts as association sequences suggests strongly small-p p-adicity and this idea was in fact one of the first ones relating p-adic numbers with consciousness. The 2-adicity of music experience is relatively easy to understand if any p-adic time scale can serve as effective fundamental time scale for 2-adicity of music experience. Note however that by p-adic length scale hypothesis the fundamental time scales come as powers of 2. The apparently complete freedom to choose the fundamental time scale can be understood if practically any p-adic time scale L_p replacing l can serve as effective fundamental time scale.

2. Genetic code corresponds to $p = 127 = 2^7 - 1$ in TGD inspired model of abstraction process predicting infinite hierarchy of 'genetic codes' [K31] . It should be however realized in macrotemporal scales rather than near CP_2 time scale and if the proposed mechanism scales l to p-adic length scale of order atomic length scale this is indeed realized.

3. Memetic code corresponds to $p = 2^{127} - 1$ and to a unique p-adic time scale of .1 seconds [K31] . Codeword has 126 bits and single bit corresponds to the time scale of nerve pulse. What is disturbing that this would make time scale of human brain unique. Situation changes if any p-adic time scale can take the role of fundamental p-adic time scale so that .1 seconds would become lower limit for time duration of memetic code word. Hence brain would represents the first step in the evolution creating memetic codes in longer time scales. In light of p-adic fractality the idea that the time scale associated with M_{127} is the only possible duration of memetic codon, does not sound plausible. One can indeed imagine a hierarchy of scaled-up versions of M_{127} code. This would suggest that M_{127} could be also realized at time scales $k \times T_2(127)$, k prime, $T_2(127) = .1$ s. $T_2(127)$ would be the smallest p-adic time scale, where memetic code is possible and the distribution of longer time scales would obey distribution of primes. This distribution should reflect itself in the EEG spectrum at very low frequencies.

3.7 L_0 mod $p^m = 0$ excitations of Super Virasoro algebra as higher forms of life?

Topological field quanta can have all possible sizes. Uncertainty Principle suggests that the size of the topological field quantum corresponds to the p-adic length scale of the corresponding 3-surface. This would mean that the vibrational excitations of even macroscopic 3-surfaces could correspond to Super Virasoro representations. Indeed, the states of real super-symplectic representations associated with the lightlike boundaries of MEs have gigantic almost-degeneracies and provide excellent candidates for representing biological information [K53] . These representations realize the idea of quantum hologram in the sense of quantum gravity and quantum information theory concretely and emerge naturally also in the TGD based theory of qualia [K29] .

Besides this there are also what might be called exotic p-adic representations of super-conformal Super Virasoro algebra for which the real counterparts of the p-adic masses are extremely small although the masses of the corresponding real states are super-astronomical. These states have enormous quaternion-conformal (rather than only super-symplectic degeneracies) degeneracies and this raises the question about the possible biological relevance of these states. Thus it seems (at least now when I am writing this!) that the exotic states are not relevant for the understanding of biosystems. Despite this, and also because I ended up with super-symplectic representations via exotic p-adic representations, I do not have heart to throw away the discussion of the properties and possible biological significance of these representations. The reader can however safely skip this section if she wishes.

3.7.1 Exotic p-adic super-conformal representations

The eigenvalues of Super Virasoro generator L_0 are non-negative integers n. In p-adic context one can naturally decompose these eigenvalues into classes such that in class m eigen-values are of form $n = kp^m$, $k = 1, 2, ...$, $k \ mod \ p \neq 0$. In class m the real counterpart of the mass squared is of order $1/p^m$ and hence extremely small for large values of m. Does this predict the existence of light excitations for all particles, even fermions?

1. The answer 'No' suggested by the fact that p-adic representations of super-conformal algebras should describe the physics of cognition rather than real physics so that these exotic states need not correspond to real physics states.

2. One might argue that p-adic and real states correspond to each other in case that the states can be transformed to each other by a p-adic–real phase transition respecting conservation laws. This is achieved if the exotic states appear in pairs having opposite quantum numbers: this is the case if the otherwise identical states of the pair are associated with space-time sheets having opposite time orientations. The exotic p-adic states would represent vacuum polaron realized as a pair of real states with superastronomical energies which however cancel each other exactly. Obviously the gigantic masses of the real space-time sheets would make virtually impossible to separate them from each other. It is of course questionable if the real counterparts of these vacuum polarization states can have any significance. p-Adic counterparts might however have relevance for the physics of cognition.

3. One might of course argue that every every p-adic state (imaginable state!) must have a real counterpart with essentially the same real physics properties. In recent case the real counterparts of the p-adic masses obtained by canonical identification are extremely small whereas the masses of the corresponding real states are superastronomical if the value of the string tension is formally the same and of order $O(p^0)$. String tension is however a dynamical quantity and one can consider the possibility that the real counterpart of the p-adic string tension for the super-conformal representations is such that the real and p-adic mass scales are mutually consistent. Admittedly, this argument does not satisfy the requirement of mathematical elegance.

3.7.2 Elementary particles cannot correspond to exotic super-conformal states

If the real counterparts of the exotic states are created in pairs with vanishing total quantum numbers and having super-astronomical real masses, they certainly cannot have any relevance for elementary particle physics. If one assumes that string tension for real states is such that real masses of exotic states are of same order as p-adic mass situation can change. For instance, intermediate gauge bosons would have also excitations with mass $1/\sqrt{p}$ and one can wonder whether these excitations could correspond to the observed intermediate gauge bosons. One could even consider the possibility of understanding the entire elementary particle mass spectrum in terms of these $n = 0$ and $n = p$ excitations assuming that the vacuum weight of the Super Virasoro representations is vanishing. There are quite a number of consistency conditions, which definitely exclude this possibility.

1. Photon, graviton and gluon correspond to a ground state created by vanishing conformal weight. This happens to be the case. By a suitable choice for the coefficient of modular contribution and with a suitable choice of mass scale one might be able to reproduce charged lepton mass ratios correctly.

2. All states with non-vanishing ground state vacuum weight should correspond to $n = p$ states and would have same non-vanishing mass equal to $1/\sqrt{p}$ in natural units for given p. For quarks no mass splitting would result in first order approximation and the experience with CKM matrix suggests very strongly that it is not possible to achieve correct CKM matrix for mass degenerate u and d quarks.

3. A strong counter argument against the scenario is the huge ground state degeneracy of the states expected. As well known the degeneracy of states with eigenvalue n of L_0 increases exponentially as a function of n. For instance, huge number of color, electro-weak and spin excitations would have same mass and this does not seem to make sense. Thus it seems that p-adic thermodynamics giving extremely small probability for all large n excitations must be correct for elementary particles at least. Again there is however loophole involved. Low energy hadron physics corresponds to non-perturbative QCD like theory and one might wonder whether these exotic states of Super Virasoro algebra could become important at low hadron momentum transfers and whether some kind of phase transition from the dominance of the ordinary Super Virasoro representations to that of exotic Super Virasoro representations might take place. Amazingly, this hypothesis predicts the mass of pion and Regge slope correctly as fundamental constants of Nature [K49] .

3.7.3 Could exotic p-adic counterparts of elementary particles be relevant for living systems?

Previous arguments do not exclude the appearance of $n\ mod\ p^k = 0$ p-adic states. Also their zero energy pairs could appear as real states. If the couplings of these excitations obey the conservation of L_0 charge (conformal weight), the states in class m couple only to the states in same class or to $n = 0$ massless states and therefore these particles could probably emit and absorb ordinary $n = 0$ elementary particles. The possibility of pair creation seems to be excluded (it would require that antiparticles have negative spectrum of L_0, which looks peculiar). If this is true then $m = 1$ states are not be created in ordinary elementary particle reactions. It must be emphasized that the matrix elements for emission of exotic states could be small for other reasons: for instance, because the conformal weights of states involved differ so much.

An interesting possibility is that $m > 1$ excitations of known elementary particles could be present in macroscopic length scales.

1. For hadrons $m = 2$ excitations correspond by Uncertainty Principle to the length scale $L(k = 2 \times 107) \sim .4$ meters whereas for electron one has length scale $L(k = 2 \times 127) \sim 10^7$ meters. The corresponding time scale is .1 seconds, which is the fundamental time scale of brain consciousness defining the duration of psychological moment. This time scale is crucial in the TGD based model of memetic code. The model derives from a model of abstraction process leading to a hierarchy of 'genetic codes' labelled by Mersenne numbers: $M(n) = M_{M(n-1)}$. $M_7 = 127$ corresponds to genetic code and M_{127}, which is the next level of the hierarchy, corresponds to the memetic code.

2. For $m = 2$ excitations of Z^0 and W (also other states could be present) the corresponding length scale is $L(k = 2 \times 89 = 178) \sim 10^{-4}$ meters, which is $2^{4.5}$ times larger than the p-adic length scale $L(k = 169)$ associated with neutrinos. Is this a pure accident or could it be that there are exotic Z^0 bosons in cell length scale and that this explains the primary condensation level of neutrinos? In this picture it would be perhaps easier to understand also why classical Z^0 fields appear dominantly above cell length scale as required by the arguments based on the smallness of parity breaking effects. It should be mentioned that $k = 178$ corresponds to the size of the largest neurons.

The super astronomical degeneracy $D \sim exp(p)$, $p = M_{89}$ (!) associated with these excitations plus Negentropy Maximization Principle could make biosystems with size larger that the critical size of 10^{-4} meters something quite special, to put it very mildly! The same argument applies to the $p = M_{127}$ associated with the memetic code. The p-adic length scale nearest to $L(178)$ corresponds to the secondary condensation level for the $m = 2$ particles. It is $k = 179$ and in fact forms twin prime with $k = 181$. As a rule, twin primes in bio-systems seem to be associated with two-layered structures and this particular twin prime corresponds to ocular dominance columns, the largest known two-layered structure in the cortex (in fact this twin prime is the first one in the series of three twin primes $(179, 181)$, $(191, 193)$, $(197, 199)$!).

This raises the question whether the physics based explanation for the huge qualitative and quantitative differences in the behavior of higher primates and more primitive life forms could be based on the huge entanglement entropy resources provided by these exotic particles? It seems that this question becomes more or less obsolete with the realization that the immense super-symplectic almost-degeneracies for the massless states of super-conformal representations explain very naturally the huge information resources of biosystems without need to introduce exotic representations.

One can end up to the similar speculations via a different route by starting from the TGD based reduction of the notion of potential energy to space-time topology (potential energy unlike kinetic energy does not allow any visualization in standard physics and thus remains a fictive concept).

1. In TGD framework the sign of energy depends on the time orientation of the space-time sheet and can be negative. Topological field quanta of negative energy represent negative energy virtual particles. The generation of negative potential energy corresponds to the emission of negative energy virtual bosons condensing on larger space-time sheets and in this manner one can understand potential energy as the total energy emitted by particle in form of low energy topological field quanta condensed on larger space-time sheets. In particular, the huge energy densities in strong gravitational fields of early cosmology result via the emission of negative energy virtual gravitons: only in this manner one can understand in TGD framework how conservation of energy can be consistent with gravitational interaction. For instance, gravitational redshift, which in GRT means nonconservation of energy, results in TGD framework from the absorption of negative energy virtual gravitons.

2. An objection against this interpretation is provided by long range classical Z^0 fields: attractive classical Z^0 potential energy should also correspond to topological field quanta of negative energy at larger space-time sheets. This is certainly possible. These topological field quanta cannot however correspond to the ordinary quanta of Z^0 field which are extremely massive and propagate only over range of order 10^{-17} meters. Thus the correspondence *quanta↔topological quanta* seems to fail.

3. There is however a loophole allowed by p-adic mathematics. As already noticed, the secondary almost massless excitations $n \ mod \ p = 0$ of Super Virasoro algebra have mass of order $m(CP_2)/p$ and possess huge exponential degeneracy of states characteristic for the Super Virasoro algebra. For $p = M_{89} = 2^{89} - 1$ the mass of these excitations is of order $m \sim m_W 2^{-89/2} \sim 10^{-2}$ eV, which happens to be rather near to the thermal energy associated with the room temperature, which is the critical temperature for the higher forms of biological life. The corresponding length scale is by Uncertainty Principle 10^{-4} meters and would represent the range of the Z^0 forces based on the exchange of the secondary quanta. Thus the exchange of these quanta between nuclei and neutrinos could be an essential element of what it is to be biosystem. These excitations having huge ground state degeneracy could also provide a quantum level description for the huge degeneracy of states certainly characteristic for biosystems. This degeneracy might also explain dynamically why neutrinos topologically condense on cell length scale.

4. A further objection is that classical Z^0 force seems to be not restricted to biological length scales but is present also in the planetary length scales. This objection can be circumvented too. Higher secondary excitations of Super Virasoro algebra satisfying $n \ mod \ p^3 = 0$ with mass of order $m(CP_2)/p^{3/2}$ should be also present. This mass would correspond to $m \sim 2^{-89} m_W$ and to the length scale of 2×10^9 meters characterizing solar system. The corresponding time scale is 8 seconds, which is also an important length scale in biosystems as is also the time scale of .1 seconds associated with the second power of $p = M_{127}$, which is the p-adic length scale of electron and characterizes memetic code. This hypothesis is consistent with the idea that ELF em and Z^0 fields give rise to a new form of life, 'culture', living in symbiosis with biological life.

5. This would suggest a hierarchy of lifeforms whose intelligence quotient is roughly characterized by the degeneracy of the Super Virasoro states involved and thus by the power and value of the p-adic prime p to which they correspond. Since Mersenne primes are fundamental for elementary particle physics, one expects that the powers of the Mersenne primes M_{89}, M_{107} and $M127$ should label the most important higher lifeforms. M_{89} would give rise to two higher levels already discussed whereas M_{127} gives rise to the menetic code. The $n\ mod\ p^2 = 0$ excitations associated with M_{107}, the Mersenne prime characterizing hadrons, would correspond to the length scale of about 25 meters and time scale of order 10^{-7} seconds. $n\ mod\ p^3 = 0$ excitations associated with M_{107} would in turn correspond to the time scale of 10^9 seconds, or 30 years in more natural units: this is of the same order as human life span!

6. A further observation of possible relevance is that if Super Algebra representation has vanishing conformal vacuum weight, the subalgebra consisting of generators having conformal weights n proportional to p^m forms sub-algebra of entire Super algebra. Thus the exotic states correspond to sub-algebra of Super Virasoro and become therefore even more interesting in light of fractality suggesting strongly hierarchical breaking of supersymmetry to subalgebras of Super Virasoro algebra isomorphic with the entire algebra.

Because of their physical properties MEs provide excellent candidate for a model of mindlike space-time sheets and one can assign to the lightlike boundaries of MEs super-symplectic representations defining quantum holograms. Thus MEs could carry also exotic p-adic Super Virasoro representations but as already noticed, they are not needed in order to understand the information sources associated with living matter.

Chapter 4

Biological Realization of Self Hierarchy

4.1 Introduction

The understanding of the biological systems from the first principles seems to be an almost insurmountable task. These systems are both structurally and functionally extremely complicated and the existing basic physics doesn't offer very many obvious clues as how one might understand the generation of the spatial and temporal structures from the first principles. In fact, it is not at all obvious whether the first principles are even known. The standard reductionistic and materialistic world view combined with the notion of linear time is extremely restrictive framework and might simply not allow life and consciousness. TGD and TGD inspired theory of consciousness has indeed led to a general conceptual framework, which differs radically from that of the standard physics. The highly nontrivial implication is that TGD inspired theory of consciousness provides, not only general insights, but very detailed ideas as regards to the structure and functioning of the living systems. In this chapter the emphasis is more on structure whereas the next chapters entitled "Quantum Control and Coordination in Bio-Systems: part I/II" [K55, K56] concentrate on the functional aspects.

4.1.1 The notions of self and self hierarchies

The breakthrough idea in TGD inspired theory of consciousness was the notion of self defined as a subsystem able to remain unentangled during the unitary quantum "time evolutions" U associated with quantum jumps $\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_f$. The notion of self leads to the concept of self hierarchy and the interpretation of quantum self-organization as evolution of selves [K65] . Zero energy ontology implies that quantum states correspond to physical events in standard ontology. This means that self has extension in time direction and has causal diamonds (CDs) defined as intersections of future and past directed light-cones as imbedding space-time correlates and space-time sheets within CDs as space-time correlates. Self corresponds therefore to a finite-sized object in both spatial and temporal directions and can be seen as a classical self-organization pattern at space-time level. Quantum jumps replace this pattern gradually with an asymptotic self-organization pattern.

The infinite size of the universe forces to introduce the notion of infinite primes and corresponding p-adic topologies. Infinite primes have decomposition into finite primes labelling space-time sheets possessing p-adic topology. The notion of infinite prime allows to understand continuous evolution of physical systems as increase of the finite p-adic prime associated with them as also discontinuous processes in which entirely new p-adic space-time sheets emerge. The gradual increase of the cell size during evolution and emergence of multicellular structures provide examples of the two aspects of the evolution. The increase of the finite prime corresponds to gradual refinement of the corresponding p-adic topology in the sense that the notion of nearness as it is realized at the level of conscious experience becomes more and more refined. Also the maximum information content of conscious experiences increases with p-adic prime. Thus a measure for the complexity of a conscious system is in question.

The observation that Shannon entropy allows an infinite number of number theoretic variants for which the entropy can be negative in the case that probabilities are algebraic numbers leads to the idea that living matter in a well-defined sense corresponds to the intersection of real and p-adic worlds. This would mean that the mathematical expressions for the space-time surfaces (or at least 3-surfaces or partonic 2-surfaces and their 4-D tangent planes) make sense in both real and p-adic sense for some primes p. Same would apply to the expressions defining quantum states. In particular, entangelement probabilities would be rationals or algebraic numbers so that entanglement can be negentropic and the formation of bound states in the intersection of real and p-adic worlds generates information and is thus favored by NMP. The proposal is that the generation of negentropic bound state entanglement does not lead to a loss of consciousness unlike the generation of negentropic bound state entanglement can do. The need to remain conscious and even expand consciousness would favor co-operation and sharing instead of selfish fight for survival. Dissipation would still serve as the Darwinian selector.

4.1.2 Selves self-organize

A system possessing self (possibly having sub-selves) performs quantum jumps and dissipates. This leads to quantum self organization leading to asymptotic patterns selected by dissipation, which thus acts as a Darwinian selector of both memes and genes. Actually, there is no deep difference between genes and memes (understood here rather metaphorically) since selves are always conscious systems and consciousness is present already at elementary particle level. Furthermore, the zero energy states themselves have meme like properties. For instance, the many fermion states associated with positive and negative energy parts of the states have interpretation in terms of elements of Boolean algebra so that states define logical rules $A \rightarrow B$ with various instances of A and B appearing as pairs of positive and negative energy fermion stats in the quantum superposition. In light of this the notion of the self hierarchy should be of crucial importance for the understanding of living systems and the purpose of this chapter is to demonstrate this and also to propose a general view about how biological self hierarchy is realized.

4.1.3 Massless extremals

Space-time sheets having their ends at the opposite light-like boundaries of CDs have finite temporal duration in zero energy ontology and provide representations of the material world. They serve as geometrical correlates of selves and biological self hierarchy reduces geometrically and topologically to a hierarchy of space-time sheets related to the hierarchy of CDs. within CDs. Crucially involved is the notion of topological field quantization, which implies that also photons have as their geometrical correlates so called topological field quanta.

Electromagnetic (em) fields and their topological field quanta are expected to be especially important in bio-systems. One possible interpretation for the topological field quanta of em field is as classical/quantal coherence regions of classical/quantum em field. ELF (extremely low frequency) em fields are known to have dramatic effects on living matter and brain and the origin of these effects is poorly understood. A simple argument based on Uncertainty Principle leads to the conclusion that ELF photons in 10 Hz frequency range correspond to topological field quanta of size of entire Earth! This leads to a rather dramatic conclusion that our biological body is only a dip of an iceberg and we are much more than our neurons. The most important levels in our personal self hierarchy contains levels are of size of Earth!

The so called massless extremals (MEs) are excellent candidates for the topological field quanta of radiation fields. They allow at their light like boundaries representations of super-conformal and super-symplectic algebras with gigantic state degeneracies broken only by gravitation. These states are genuinely quantum gravitational states in the space of 3-surfaces ('world of worlds') and thus in a well-defined sense correspond to a higher level of abstraction. By general coordinate invariance these states define quantum holograms and are excellent candidates for coding biological information. The properties of MEs make them also ideal for holographic quantum teleportation. Also the quantum model of qualia relies on the quantum phase transitions for super-symplectic representations [K29, K62]
.

4.1.4 Hierarchy of super-conducting magnetic flux tube and electret structures

All magnetic flux structures associated with body could be of crucial importance for understanding human consciousness. For instance, eyes generate magnetic fields. Also brain, in particular pineal gland (the 'third eye' of mystics and the seat of soul for Descartes), contains magnetic materials. Corresponding magnetic transition frequencies correspond to time scales relevant for the self narrative in human time scales. Perhaps these higher levels of magnetic self hierarchy could relate with NDE experiences and represent structures surviving in physical death. It took some time to realize that magnetic flux tubes have the flux quanta of electric field as dual solutions of the field equations. Bio-system is indeed populated by various electret structures, mention only micro-tubuli and cell membrane as examples.

4.1.5 Living matter as symbiosis of MEs, super-conducting magnetic flux tube structures, electrets and ordinary matter

This picture leads to a view about living matter as a symbiosis of the fractal hierarchies of MEs and super-conducting magnetic flux tube structures and electrets with ordinary bio-matter at atomic space-time sheets. Bio-control is based on many-sheeted ionic flow equilibrium and magnetic quantum phase transitions allowing very effective control of biochemistry. The interactions between MEs and super-conducting ions are standard interactions between em fields and super-conductors (magnetic induction, induction of Josephson currents, magnetic phase transitions).

In the following the most recent (and still developing) TGD inspired view about biological self hierarchy is described and the possible consequences are considered at various length scales. For the reader willing to learn about the general ideas relating to self and self hierarchy, the references [K45, K66] of [K75] are recommended.

4.1.6 TGD based view about dark matter

TGD suggests an explanation of dark matter as a macroscopically quantum coherent phase residing at larger space-time sheets [K20] .

1. TGD suggests that $\hbar$ is dynamical and possesses a spectrum expressible in terms of generalized Beraha numbers $B_r = 4cos^2(\pi/r)$, where $r > 3$ is a rational number [K84, K20] . Just above $r = 3$ arbitrarily large values of $\hbar$ and thus also macroscopic quantum phases are possible. The criterion for transition to large $\hbar$ phase is the failure of perturbative expansion so that Mother Nature takes care of the problems of theoretician. A good guess is that the criticality condition reads as $Q_1Q_2\alpha \simeq 1$ where Q_i are gauge charges and α gauge coupling strength. This leads to universal properties of the large $\hbar$ phase. For instance, $\hbar$ is scaled in the transition to dark phase by a harmonic or subharmonic of parameter $1/v_0 \simeq 2^{11}$ which is essentially the ratio of CP_2 length scale and Planck length [K67, K20] . The criticality condition can be applied also to dark matter itself and entire hierarchy of dark matters is predicted corresponding to the spectrum of values of $\hbar$.

2. An infinite hierarchy of dark matters is predicted [K28] . The hierarchy of dark matter levels is labeled by the values of Planck constant having quantized but arbitrarily large values. For the most general option the values of $\hbar$ are products and ratios of two integers [K25] . The products of distinct Fermat primes and power of two are number theoretically favored values for these integers. p-Adic length scale hypothesis favors powers of two. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T \propto \hbar$ of the quantum jump. Second hierarchy corresponds to particles labelled by selected integers characterizing the p-adic length scales of particles with which the particle interacts. Direct interactions occur only between the particles characterized by integers having common p-adic prime factors characterizing the p-adic length scales of bosons exchanged in the interaction. The algebraic extensions of p-adic numbers define an additional hierarchy. Also the notion of darkness must be refined by attributes partial and relative.

3. The classical scattering cross sections are not changed in the scaling of Planck constant but changes of the geometric sizes of dark quarks, hadrons, and nuclei take place. The original hypothesis that ordinary valence quarks are dark whereas sea quarks correspond to ordinary value of $\hbar$ is taken as a starting point. In accordance with the earlier model, nucleons in atomic nuclei are assumed to be accompanied by color bonds connecting exotic quark and anti-quark characterized p-adic length scale $L(127)$ with ordinary value of $\hbar$ and having thus scaled down mass of order MeV. The strong binding would be due the color bonds having exotic quark and anti-quark at their ends.

4. Quantum classical correspondence suggests that classical long ranged electro-weak gauge fields serve as classical space-time correlates for dark electro-weak gauge bosons, which are massless below the appropriate weak length scale L_w. This hypothesis could explain the special properties of bio-matter, in particular the chiral selection as resulting from the coupling to dark Z^0 quanta. Long range weak forces present in TGD counterpart of Higgs=0 phase should allow to understand the differences between biochemistry and the chemistry of dead matter.

5. For ordinary condensed matter quarks and leptons Z^0 charge are screened in electro-weak length scale whereas in dark matter $k = 89$ electro-weak space-time sheet have suffered a phase transition to a p-adic topology with a larger value of k. Gaussian Mersennes, in particular those associated with $k = 113, 151, 157, 163, 167$ are excellent candidates in this respect. The particles of this exotic phase of matter would have complex conformal weights closely related to the zeros of Riemann Zeta. The simplest possibility is that they correspond to a single non-trivial zero of Zeta and there is infinite hierarchy of particles of this kind.

   In dark matter phase weak gauge fluxes could be feeded to say $k = k_Z = 169$ space-time sheet corresponding to neutrino Compton length and having size of cell. For this scenario to make sense it is essential that p-adic thermodynamics predicts for dark quarks and leptons essentially the same masses as for their ordinary counterparts [K43] .

4.2 Many-sheeted space-time concept and living systems

4.2.1 Topological field quantization

Topological field quantization is a concept whose central importance in TGD has become only gradually clear. In the following some aspects of the topological field quantization are discussed. Superconducting magnetic flux tubes and massless extremals (MEs) are especially important topological field quanta as far as quantum control is considered. MEs allow at their light like boundaries representations of super-conformal and super-symplectic algebras providing quantum hologram type representation of biological information with enormous state degeneracies. Since these representations have interpretation as genuinely quantum gravitational state functionals in the 'world of worlds', they should correspond to higher level consciousness than the super-conducting BE condensates at magnetic flux tubes.

Topological field quantization as geometric counterpart of quantization

Topological field quantization [K38] implies that various notions of quantum field theory have rather precise classical analogies. Topological field quantization provides the correspondence between the abstract Fock space description of elementary particles and the description of the elementary particles as concrete geometric objects detected in the laboratory. In standard quantum field theory this kind of correspondence is lacking since classical fields are regarded as a phenomenological concept only. Topological field quanta define regions of coherence for the classical fields and classical coherence is the prerequisite of the quantum coherence.

The energies and other classical charges of the topological field quanta are quantized as preferred extremals of Kähler action making classical space-time surfaces the counterparts of the Bohr orbits. Feynmann diagrams become classical space-time surfaces with lines thickened to 4-manifolds. For instance, "massless extremals" representing topologically quantized classical radiation fields are the classical counterparts of gravitinos and photons. Topologically quantized non-radiative nearby fields give rise to various geometric structures such as magnetic and electric flux tubes.

The virtual particles of quantum field theory have also classical counterparts. In particular, the virtual particles of quantum field theory can have negative energies: this is true also for the TGD counterparts of the virtual particles. The fundamental difference between TGD and GRT is that in TGD the sign of energy depends on the time orientation of the space-time sheet: this is due to the fact that in TGD energy current is vector field rather than part of tensor field. Therefore space-time sheets with negative energies are possible.

This could have quite dramatic technological consequences: consider only the possibility of generating energy from vacuum and classical signalling backwards in time along negative energy space-time sheets [K77, K23] . Also bio-systems might have invented negative energy space-time sheets: in fact, so called "massless extremals" (MEs) provide an ideal manner to generate coherent motions as recoil effects caused by the creation of negative energy massless extremals [K55, K56] . An interesting possibility is that quantum entanglement has the formation of the join along boundaries bonds as its geometric correlate.

The crucial question is of course 'How to make this idea quantitative?'. An attractive possibility is that topological field quanta identified as material or mind like space-time sheets could be regarded as counterparts of oscillator operators of free fields in quantum field theory. This would mean that one could make order of magnitude estimates for the probabilities for the presence of various numbers of both material and mind like space-time sheets using quantum field theoretical intuition. The coefficient of a particular state in the expansion of the creation operators of the outgoing interacting quantum fields in terms of the creation and annihilation operators of free quantum fields could provide an estimate for the probability that a particular configuration containing topological field quanta with positive and negative energies results in quantum jump between quantum histories. Since mind like space-time sheets are correlates for virtual particles, this would also mean a deep connection between quantum field theory and cognition.

Topological field quanta, in particular flux tubes of magnetic fields, could serve as templates for the formation of the bio-structures. Thus topologically quantized classical electromagnetic fields could be equally important for the functioning of the living systems as the structures formed by the visible bio-matter and the visible part of bio-system might represent only a tip of an ice berg.

Topological field quantization and classical de-coherence

The fact that topological field quanta correspond to coherence regions of classical field suggests that there must be a deep connection between classical de-coherence and space-time topology. This connection indeed exists. An innocent question of Claude Rifat concerning macroscopic classical coherence led me to realize that the nebulous phenomenon of de-coherence can be regarded as a direct evidence for the many-sheetedness of the space-time! In principle, the counting the number of noncoherent components of various fields gives an experimental method to deduce the number of space-time sheets present. The nature of de-coherence gives also information about the sizes of the space-time sheets and their durations! Thus everyday physics provides direct demonstration for the notion of the many-sheeted space-time: for some reason I had not realized this earlier. The detailed argument goes as follows.

1. Everything is classically coherent at basic level

Topological field quanta can be said to be coherence regions of classical fields, say em field. Typically frequency determines the size of the coherence region by Uncertainty Principle and topological field quanta of ELF em fields are huge: 10 Hz corresponds to the circumference of Earth. One can also say that everything is coherent at the level of the microscopic description. In TGD framework the loss of coherence is only a phenomenological manner to describe certain experimental facts in Maxwell's theory.

2. 'Loss of coherence' provides direct evidence for topological field quantization!

In standard physics one has topologically trivial space-time containing classical fields: fields propagating to a given region just superpose. The predicted interference effects of two interfering classical fields are *not* always observed: this is called loss of coherence. As if superposed components would live in their own space-times so that interference is not possible so that energy and momentum densities are sums over the energy densities associated with these space-times. *This indeed the case in TGD! When two classical field sum noncoherently this means that they live on different space-time sheets and correspond to different topological field quanta* Classical coherence is also more or less equivalent with quantum coherence. The belief that physics does not allow macroscopic quantum coherence is illusion created by wrong space-time concept.

4. Phenomenological description of many-sheetedness as a loss of coherence

In Maxwell theory one describes the observed lack of interference effects due to many-sheetedness phenomenologically. The very definition of de-coherence is extremely problematic: one is forced to assume that measured quantities correspond to an ensemble or temporal averages and that the phases for the superposed fields vary randomly. This need not to be the case actually. Only when one builds effective description by replacing the entire many-sheeted space-time with ordinary space-time, one is forced to introduce linear superposition of various fields associated with various space-time sheet plus the nebulous notion of non-coherent superposition. At the level of many-sheeted space-time everything

5. Classical de-coherence is the counterpart for the loss of quantum coherence

By 'Ontogeny Recapitulates Phylogeny Principle' (analogous to the corresponding biological principle), the loss of classical coherence is classical counterpart for the loss of quantum coherence occurring in quantum jumps. What this concretely means is that the initial quantum state, which is in general Fock state associated with single topological field quantum containing fermions and bosons, develops in time to a quantum superposition of states in which each fermion and boson resides at its own topological field quantum. This occurs already at the level of single quantum history. The occurrence of quantum jumps makes it possible to observe this since the sequence of quantum jumps increases the value of the psychological time of observer: sooner or later the final 'de-cohered' state consisting of topological field quanta representing elementary particles is observed. It should be emphasized that quantum jump selecting one space-time surface from the superposition of space-time surfaces representing final state many particle configurations is a genuine element of this process: quantum jump cannot be reduced to classical physics.

4.2.2 Bio-system as a topological condensate with several important space-time sheets

Topological condensate has hierarchical structure consisting of 3-surfaces with various sizes condensed on each other. In case of a bio-system several space-time sheet are expected to be important and to form a hierarchical information processing structure. Organic molecules belong to the lowest level of the hierarchy and correspond to 3-surfaces with outer boundary so that the association of the geometric form to molecules becomes much more than a convenient phenomenological modelling tool and leads to a new view concerning the understanding, say, the action of the organic catalysts. The topological condensation of the polymers to larger surfaces in turn gives rise to the formation of the cells, the topological condensation of the cells gives rise to the formation of the higher organs. In general, the vacuum quantum numbers tend to increase with the size of the structure.

p-Adic length scale hypothesis provides a precise quantitative formulation of the length scale hierarchy and predicts correctly several important biological length scales. In particular, the thicknesses for both the cell membrane consisting of two lipid layers and for the lipid layer appear in this hierarchy.

4.2.3 Topological field quantization and dark matter hierarchy

The realization that the unavoidable hierarchy of long ranged classical color and electro-weak gauge fields at various space-time sheets is a space-time correlate for an infinite dark matter hierarchy and a hierarchy of color and electro-weak physics characterized by a p-adic hierarchy of weak and confinement length scales [K6, K5, K28, K71, K22, K20] means that ordinary elementary particles are only a tip of an iceberg. For instance, the scope of the term "supra current" in TGD context becomes much wider than originally believed to be.

One might illustrate TGD Universe as being analogous to a Mandelbrot fractal. Just as each zooming in of Mandelbrot fractal reveals new worlds, each zooming out of TGD Universe reveals new universes for which the elementary particles of scaled down physics are lighter than at previous level and remain easily invisible for the previous level because the energies involved are so tiny. From the point of view of life and consciousness these subtle higher levels however represent the most essential aspects and we experience them directly.

Topological field quanta correspond to space-time correlates of particles at various levels of hierarchy. Wormhole contacts (# contacts) discussed in [K28] and join along boundaries bonds ($\#_B$ bonds) connecting boundaries of holes at different space-time sheets mediate interactions between space-time sheets. # contacts can be modelled as CP_2 type extremals with an Euclidian signature of induce metric glued to the two space-time sheets with Minkowskian signature of induced metric. Wormhole contacts are thus accompanied by two light-like causal horizons having identification a partons. Thus # contacts represent an instance of an exotic dark matter residing simultaneously at two space-time sheets: this form of matter should be present in all length scales and could play decisive role in living matter [K85] . If the time orientations of two space-time sheets are opposite, these particles can have vanishing inertial energies. The splitting of # contacts gives rise to dark particles at the two space-time sheets involved.

The finding that the dark matter component of even astrophysical systems could be macroscopically quantum coherent and determine the properties of the visible matter to a high degree [K20] forces to seriously consider the possibility that living matter is much more than what is catched by eye. In particular, the notion of field body as a key concept in the attempts to understand of living systems finds additional support. The grand vision is that it is the presence of macroscopically quantum coherent dark matter hierarchy which makes "dead" matter living. The first attempt to deduce implications of this vision can be found in [K20] and a more detailed view is discussed in [K22] .

4.2.4 Topological field quantization and vacuum quantum numbers

Topological field quantization provides a TGD based first principle explanation for the emergence of the spatial structures. The size of the bio-structure depends on the vacuum quantum numbers [K38] and is dictated by the stability criteria implied by the minimization principle allowing to assign unique space-time surface to a given 3-surface, which is in general union of space-like 3-surfaces with time-like separations since the classical determinism in standard sense fails.

The hypothesis that bio-systems are super conductors in some sense implies that supra currents are a basic tool of the bio-control. The density of the charge carriers dictates the stable size and form of the organ and also the nontrivial phase information carried by the order parameter is expected to be important. There are handful of vacuum quantum numbers arising from the time and spatial behavior of the phase angles ϕ_i associated with the two complex CP_2 coordinates [K38] . One can express the dependence of these phase angles on space-time coordinates as a sum of Fourier expansion plus zero mode term linear in some coordinates and not allowing Fourier expansion. In linear Minkowski coordinates the vacuum quantum numbers behave like components of four-momentum. In spherical coordinates vacuum quantum numbers correspond to frequency, momentum in given direction plus integer analogous to the component of the angular momentum in the direction of momentum.

The set of vacuum quantum numbers associated with the two phase factors depends on the choice of the coordinates for M^4_+ and CP_2 and involves a selection of maximal number of mutually commuting observables in the Lie-algebras of Poincare group and color group. This is consistent with the fact that topological field quantization indeed is the classical counterpart of quantization. The construction of quantum TGD and understanding of the p-adic aspects of quantum TGD involves in an absolutely essential manner the choice of these quantization axes.

To fix the notation, the quantum numbers associated with the spherical coordinates will be denoted by (ω_i, k_i, n_i), $i = 1, 2$. detailed definitions of vacuum quantum numbers reader should consult the appendix of this book and [K38] . The first consequence is that given space-time sheet is characterized by two frequencies. A good guess is that the frequency difference associated with two space-time sheets connected by Josephson junctions corresponds directly to the voltage difference over Josephson junction: $\Delta\omega_1 = ZeV$.

4.2.5 Vacuum quantum numbers as carriers of biological information

The supra currents flowing in a closed loop of an organic polymer or of the brain nerve circuit depends linearly on the vacuum quantum numbers n_i, $i = 1, 2$ corresponding to the phase angles of the two complex CP_2 coordinates. The values of n_i for closed loops provide a manner to store biological information and a model for the memory. The change of n_i in a closed loop is achieved by a phase slippage process creating a kink, that is a localized change of Φ or Ψ by an integer multiple of 4π or 2π respectively, propagating in the loop. Associated with the kink is a localized supra current depending linearly on the integer n_1. Kink like supra currents provide a a possible mechanism of the information processing at the bio-molecular level and at the level of the nerve cell, too. TGD based model of nerve pulse and EEG, to be described later, identifies nerve pulse as this kind of kink. The flux quanta are carriers of magnetic and Z^0 magnetic fields and these fields provide a candidate for memory storage and information processing mechanism.

4.2.6 Super-symplectic representations and quantum holograms

Peter Marcer [I15, I14] has strongly advocated the idea that quantum holograms are crucial for the information processing in bio-systems. TGD leads to a similar vision. An almost universal manner to satify field equations at the boundaries of space-time sheets is to assume that boundaries are light like 3-surfaces. For massless extremals (MEs) this condition can be always satisfied [K53] and in this case also the M^4_+ projections X^3 of MEs are light like. X^3 is completely analogous with the boundary of the future light cone and thus metrically two-dimensional. Therefore the cosmological super-conformal and super-symplectic symmetries generalize. Fractality, the classical non-determinism of Kähler action, and quantum holography suggest that the construction of the configuration space geometry and quantum TGD can be in good approximation reduced to that in the sub-configuration spaces $CH(X^3)$ consisting of 3-surfaces in spaces $X^3 \times CP_2$ using super-conformal and super-symplectic symmetries.

The boundaries of MEs are in many respects like moments of big bang and by general coordinate invariance the states restricted to the boundaries contain all relevant information about the physical state in the 'subcosmology' defined by 4-surfaces for which the M^4_+ projection is ME. This is nothing but quantum hologram property. The classical lighlike vacuum currents which are non-deterministic at given point of ME correspond to classical aspects of quantum communication and actually define dynamical hologram in the classical sense. super-symplectic transformations do not commute with Poincare transformations but the non-commutativity is expected to be small and only due to gravitational interactions. Thus gigantic multiplets of super-symplectic states with almost degenerate masses are predicted and are obviously ideal for representative purposes. Genuine quantum gravitational states in the space of 3-surfaces ('world of worlds') are in question and these states clearly represent higher abstraction level than ordinary physical states. Thus TGD seems to realize Marcer's vision in the sense that MEs would correspond to the highest and most abstract level of consciousness and intelligence in the self hierarchy. Genetic code would be analogous to read-only-memory burnt into the hardware and that most interesting and dominating information correspond to quantum holograms associated with MEs.

4.2.7 Many-sheeted space-time concept and living matter

The notion of many-sheeted space-time has several nontrivial implications. Many-sheeted space-time concept makes possible the transfer of particles between various space-time sheets. Since non-atomic space-time sheet are almost empty and couple weakly to atomic space-time sheets, this effect is expected to make possible effects like high T_c super-conductivity. The transfer of particles between two space-time sheets could along via possibly temporary join along boundaries bonds connecting the boundaries of the space-time sheets possibly belonging to different levels of the (self) hierarchy. The quantum dynamical counterpart of this process are supra-currents and Josephson currents running along join along boundaries bonds serving as Josephson junctions.

1. The first implication is the possibility of many-sheeted ionic flow equilibrium for a circuitry involving both atomic (non-super-conducting) and super-conducting space-time sheets (magnetic flux tubes). In ionic flow equilibrium extremely small densities of super-conducting ions and magnetic space-time sheets can be amplified to much larger ion densities at atomic space-time sheets. The magnetic induction interaction between magnetic fields of MEs and ions in magnetic flux tubes (analogous to interaction of the weak magnetic fields of brain with SQUIDs) allows MEs to control the magnetic quantum numbers characterizing supra-currents and thus also the ion densities at the atomic space-time sheets. Ohmic currents on atomic space-time sheets require weak but coherent em fields and this provides a reason why for why bio-matter must be liquid crystal and electret. The DC circuitry discovered already by Becker [J4] can be identified as the part of control circuitry associated with the atomic space-time sheets.

2. Josephson current serves effectively as a harmonic perturbation for the system formed by weakly coupled super conductors. If Josephson frequency corresponds to a difference for the energies associated with two states localized in either super conductor quantum jumps occurs leading to 'wake-up' of sub-self occur. Also magnetic interaction with ME at magnetic transition frequency

can induce magnetic transitions. Parallel supra currents running in the weakly coupled super conductors could induce the resonant ion transfer. For instance, if the phases of the supra currents in the two super conductors are identical, constructive interference of Josephson currents associated with various junctions occurs. Josephson currents and resonant ion currents generated at critical Josephson frequencies might provide the royal road to the understanding of the quantum level coordination and control in the living systems [K55, K56] .

3. p-Adic physics as physics of cognition suggests that real–p-adic phase transitions for space-time sheets give rise to the transformation of thoughts to actions and of sensory input to thoughts. The phase transition must conserve quantum numbers and this suggests that net quantum numbers must vanish for the space-time sheets created in these transitions: this is indeed possible. In TGD energy density is vector field rather than tensor. The time orientation of the space-time sheet need not always be the standard one. For a negative time orientation classical energy density is negative. Pairs of MEs or magnetic flux tubes (wormhole magnetic fields) of opposite time orientation and with vanishing net energy and momentum could transform between p-adic and real states.

4. Pairs of MEs make also possible "buy now, pay later" type energy production by generating negative energy space-time sheets. In the similar manner, effective generation of momentum becomes possible and the MEs with negative energy are optimal in this respect. Therefore the fundamental mechanism realizing "matter mind interaction" at the level of the space-time geometry could be in question. Bio-systems could also feed some fraction of their own gravitational flux to "nonstandard" space-time sheets and also channel part of the gravitational flux of Earth to "nonstandard" space-time sheets. This ability might make bio-systems antigravity machines. At negative energy space-time sheets classical fields could propagate backwards in time. Together with the vision about entire space-time surface as a community of mind like space-time sheets, one ends up with the idea that communication from geometric future to past is possible (and that we are just now discovering it!).

Obviously the notion of many-sheeted space-time would have fantastic explanatory power in biology. Thus it is especially gratifying that the strange findings challenging the association of ionic channels and pumps to cell membrane [I27] provide strong empirical support for the notion of many-sheeted space-time and for ionic super-conductivity at non-atomic space-time sheets. These findings will be discussed in [K13] .

4.2.8 Self-referentiality and space-time topology

The notion of self-referentiality is one of the deepest and most fascinating notions of mathematics but for some reason it has not catched the full attention of physicists. I encountered the mystic variant of this notion during my 'great experience' (the idea about living system as a computer sitting at its own terminal) and a more mathematical variant of the idea for a year or two later while reading the book "Gödel, Escher, Bach" of Douglas Hofstadter. It took however more than fifteen years before I managed to identify a possible concrete realization of the notion in TGD based physics.

Does physical system provide a representation for a theory about physical system?

MEs and magnetic mirrors play a key role in TGD based model of living matter. The connection with standard chemistry has been however lacking. It seems that some deep principle is needed to build this connection. The hints about the big principle come from the following observations related to the topological field quantization implying what might be called Bohr orbitology for the classical fields.

1. TGD predicts the existence of negative energy space-time sheets, in particular MEs. The prediction is based solely on the assumption that the space-time is representable as a 4-surface.

2. One could understand gravitational binding energy only if negative energy MEs represent this energy. This suggests that binding energy of a system has a very concrete representation as a negative energy MEs.

3. Quantum entanglement has as a geometric correlate join along boundaries bonds, in particular MEs and possibly also magnetic mirrors. Only the entanglement associated with the bound states is stable against the state preparation process leading to a maximally unentangled state in each quantum jump.

4. Classical superposition for em fields could mimic quantum superposition for states. The multiples of the fundamental frequency for ME could represent the BE condensate of bosons with energy defined by the fundamental frequency $f = c/L$.

5. The phase increments of the CP_2 coordinates around closed loops could represent phase increments of spinor fields and super-conducting order parameters around them as suggested in [K38] .

6. Join along boundaries bonds could represent even half-odd integer spin topologically. The join along boundaries bonds connecting 3-surface to a larger 3-surface get entangled in 2π rotation but in 4π rotation no entanglement results : this is due to the fact that the bonds provide a representation for the homotopy group of 3-dimensional rotation group. A good manner to visualize the situation is to think of a cube inside a larger cube with threads connecting the correesponding vertices of the cubes. An interesting question is whether also spin and statistics connection could be represented classically somehow.

These observations suggests a far-reaching generalization. Perhaps many-sheeted space-time allows the system to represent in its own structure the theory about itself. All theoretical concepts usually thought to have rather ethereal existence would have a concrete topological representation. These representations would exist already at the elementary particle level. Not only bio-molecules, but even hadrons, would be accompanied by a topological representation about their theory analogous to a written language. p-Adic-to-real transition would actualize this theory. Thus not only cognition but also symbolic representations of thoughts would be present in all length scales.

This idea of self-referentiality is actually an essential part of the basic philosophy of TGD. TGD inspired theory of consciousness implies that the Cartesian division to a world and theory about it is an illusion. Quantum histories, which are TGD counterparts for the solutions of field equations *are* the reality, there is no need to postulate any 'real' reality behind them since conscious experience is associated between quantum jumps between quantum histories rather than the 'real' reality. 'Ontogeny recapitulates phylogeny' principle states that quantum histories have geometric and topological correlates at space-time level. This is just what the idea about topological representation of a theory about the system as a part of the system itself means. System could consist of a hierarchy of levels such that $N+1$:th level represents N:th level. Or perhaps more precisely, what results in the interaction of N:th level systems.

In atomic and molecular physics the basic implications would be following.

1. Atoms and bio-molecules would carry a representation about their own theory based on MEs. Since MEs carry light like four-momentum, they should appear as pairs of parallel MEs with opposite momenta and with frequency corresponding to one half of the binding energy: $f = E_B/2$. The frequencies associated with ME come as multiplies of its fundamental frequency $f = c/L$, L the length of ME. This dictates to a high degree the lengths of the MEs associated with a given binding energy. The most natural length corresponds to the wavelength defined by one half of the binding energy. In the spirit of Bohr orbitology justified by quantum criticality allowing only preferred extremals of Kähler action with the property that there exists infinite number of deformations with a vanishing second variation, one can also require that ME pair has a classical energy equal to the binding energy: this requirement correlates the field strength and the thickness of the negative energy MEs.

2. Atomic binding energies would correspond to MEs with wavelengths in UV region. The binding energies of typical covalent bonds would give rise to MEs with lengths in wavelength region which corresponds to UV and visible light. The binding energies of hydrogen bonds in turn would give rise to MEs with lengths which correspond to wavelengths in the near infrared, cell size would be the typical length scale.

3. In the case of a potential well, such as the one associated with a harmonic oscillator or constant magnetic field, a natural representation would be in terms of positive energy ME allowing various harmonics. Vibrational and rotational frequencies would correspond to infrared and microwave region and magnetic energies to ELF region. The idea that these frequencies correspond to high level representations for the system is of course already now a basic element of TGD inspired theory of consciousness and conforms fully with the idea about topological self reference.

Possible biological implications of topological self reference

The notion of topological self-referentiality, if correct, means the possibility to combine enormous amount of knowledge from biochemistry to build a concrete view about em bodies of molecules and about how living matter represents itself in its own structure. One could also try to identify the chemical counterparts for the special frequencies predicted by the p-adic length scale hypothesis. One might even hope that one could at some level understand how such very high level phenomena like written language emerge from the topological self-referentiality. What is so interesting is that the hypothesis connects various length scales. For instance, the binding energies of atoms with nuclear charges $Z \sim 10$ are in keV range and correspond to MEs with size of order nanometer. Perhaps even the structure of condensed matter is partly coded into the representation of the binding energies of atoms.

Some examples of the possible consequences in biological length scales deserve to be mentioned.

1. The many-sheeted structure associated with a molecule would provide a representation for the molecule identifiable as its electromagnetic signature introduced in the theories of homeopathy and water memory [K32] . And not only this: this structure would also serve as a 4-D dynamical hologram serving as a photograph-like template for the self-organization of matter around the molecule. This would mean effective reductionism, but obviously only effective.

2. Genetic code would be a highly developed form of this representation. It would involve the negative energy MEs associated with various atomic and molecular binding energies. Especially important negative energy MEs would be in the visible region and associated with the covalent bonds and in the near infrared associated with the hydrogen bonds connecting DNA nucleotides together. Also the MEs associated with rotational and vibrational degrees of freedom are expected to be very important and for them liquid crystal blocks of water could serve as mimickers and amplifiers. The transparency of water to visible frequencies (covalent bonds have energies 4.7 eV in UV region) means that water is an ideal medium in the visible region for communications by MEs since coherent visible light can propagate long distances with attenuation caused only by the absorption by bio-molecules.

This picture gives a justification for the suggestion of Peter Gariaev that DNA is accompanied by laser mirror pairs [I14] . The negative energy ME pairs associated with various binding energies would correspond to the laser mirror pairs. This picture differs slightly from the earlier proposal for the realization of genetic code involving orthogonal pairs of MEs associated with each nucleotide giving rise to 4 different pairs of polarizations and suggests a simpler realization in which the four polarization pairs associated with a pair of parallel MEs would realize the genetic code in a given length scale.

Topological self-referentiality allows also to understand what happens in overunity energy production and these insights might be also crucial for the understanding of how life has evolved as a parallel development of macroscopic quantum bound states and the ability to metabolize. The components of the system can bind mutually or with the environment and negative energy space-time sheets represent binding energy. Bound state energy is liberated as a usable energy. The resulting bound states have entanglement irreducible under state function preparation process: this makes possible fusion of sub-selves to larger sub-selves. The bound states correspond to space-time sheets having typical sizes given by the p-adic length scale hypothesis and the process means basically space-time engineering. The typical wavelength of the radiation emitted in the process gives estimate for the electromagnetic or gravitational size of the bound state. In ELF frequency range the electromagnetic size is of order Earth size. Electrolytic processes are especially interesting from the point of view of over unity energy production.

For instance, the production of hydrogen molecules in the electrolysis of water might be accompanied by the formation of large bound states of water molecules and the liberation of the binding energy as a usable energy. The signature for the process is simple: the energy liberated is larger than the energy deduced from the binding energies of water and hydrogen molecules. Rather interestingly, the hydrogen bond energy deduced from the evaporation energy per water molecule is .485 eV and is very near to the photon energy $E(167) = .4844$ eV corresponding to p-adic length scale $L(167) = 256L(151)$ for $L(151) = 10$ nm: $k = 167$ is one of the four subsequent p-adic length scales $k = 151, 157, 163, 167$ which correspond to Gaussian Mersennes. Perhaps cold fusion involves both the nuclear fusion by Trojan horse mechanism and the formation of large scale bound states. Biology provides an important area of applications and the model of bio-photons developed in [K32] leads to a concrete model for the generation of pairs of positive and negative energy MEs at DNA level. Bio-molecules and cells are are indeed bound states of macroscopic size.

The first form of life evolved under conditions in which electrolytic processes occurred: perhaps bound state formation led to the generation of bio-molecules and cells. What is nice that the development of long range order (negative energy MEs) would have been automatically accompanied by the development of metabolism (positive energy MEs!). Sol-gel transition crucial for the cellular locomotion is a particular example of this process. Thus a natural path to follow in the attempts to build new energy technologies is to try to mimic what living nature has already achieved. This kind of energy production would be also wasteless and support evolution. Quantum spin glass analogy means that Kähler action has an enormous almost ground state degeneracy and only classical gravitational energy differentiates between different ground states. Thus the classical gravitational binding and also the generation of coherent gravitons by MEs might have a role to play in the quantum physics of living matter. A rough order of magnitude estimate for the gravitational binding energy for a blob of water having size $L(k)$ is

$$E_{gr} \sim \frac{GM^2}{L(k)} = G\rho^2 L(k)^5 \sim \frac{Gm_p^2}{L(137)} \frac{L(k)}{L(137)^5} \simeq 2^{-127} 2^{5/2(k-137)} \frac{1}{L(137)} \ .$$

Gravitational binding energy is larger than the p-adic energy $\pi/L(k)$ for $L(k = 179) \simeq .169$ mm. In the range $L(163) = 640$ nm and $L(167) = 2.56\ \mu m$ gravitational binding frequency varies between 1 Hz and 1 kHz, that is over EEG range up to the maximal frequency of nerve pulses. For $k = 157$ and $k = 151$ the gravitational binding frequency corresponds to a time scale of 9 hours and 100 years respectively so that the time scales relevant for life are spanned by the Gaussian Mersennes. Perhaps gravitonic MEs carrying vanishing em fields accompany the basic building blocks of the cell. Neither the connection with EEG is excluded.

4.3 Realization of the lower levels of biological self hierarchy

Am important question concerns about actual biological realization of the self hierarchy predicted to begin already at elementary particle level and continuing indefinitely. TGD indeed leads to rather concrete ideas about how this hierarchy is possibly realized. In the following the lowest levels of the hierarchy are discussed.

4.3.1 General ideas about biological self hierarchy

Neurons are only one level of selves in the biological self hierarchy starting from the level of body and sensory organs (or possibly from much higher level) and ending up to the level of 64 basic DNA triplets via neurons and micro-tubuli and all between (or probably continuing even further downwards as suggested by the estimate for the duration of self as p-adic time scale associated with the system).

Buddhists classify fundamental experiences to 64 basic types in I Chin. One can (with tongue slightly in cheek) wonder whether they have achieved in meditation the level of DNA selves and recognized its presence clearly? In [K31] a very simple model of abstraction process reproducing the basic numbers of genetic code is discussed and in this framework DNA:s might provide a physical realization for selves representing basic mutually consistent statements of simple formal system.

The model for the abstraction process also predicts higher levels of the hierarchy and the identification of the next level as the 'memetic code' leads to correct predictions for the duration of psychological moment and for the time scale of nerve pulse duration. It turns out that these levels could involve also electromagnetic selves and bodies with size of entire Earth: the conclusion follows using only Uncertainty Principle and topological field quantization.

4.3.2 Criteria for being biologically significant self

The biologically relevant selves might be distinguished as selves able to stay awake for sufficiently many quantum jumps. Possible additional criteria are following.

1. Self corresponds geometrically to a system with a well defined inside and outside. In standard physics context this requirement looks too strong. For instance, it is questionable whether DNA satisfies this requirement in standard physics framework. In TGD framework inside-outside decomposition is satisfied if system corresponds to a separate space-time sheet. Presumably DNA and proteins satisfy this criterion.

2. The effect of anesthetics on self candidate must affect also our consciousness. In TGD framework loss of sub-selves at any level affects the experience at the higher levels so that this criterion is sensible.

3. The behavior of self candidates should show responsiveness and adaptivity. Selves should demonstrate the ability to control their own structure or the structure or behavior of the structure to which they belong. These abilities would follow from the ability of self to quantum self-organize. For instance, in case of proteins the allowed protein foldings could be regarded as fixed states of self-organization by quantum jumps.

4. The exponent of the Kähler action provides measure for the cognitive level of the subsystem measured as the number of degenerate space-time surfaces associated with given 3-surface. Thus the presence of strong Kähler electric fields fields is a good signature for the presence of cognition. Polar molecules (say proteins) are thus good candidates for systems containing selves.

5. Self candidates should be able to communicate. One possible means of communication is proton conduction in ordered water associated with the structure. Second means of communication are dipole oscillations: this requires that structures in question are polar. Wormhole BE condensate and coherent photons provide TGD based means of communication. Also electrons 'dropped' on larger space-time sheets provide make possible this kind of communication.

6. There exist irreducible selves containing no sub-selves. Irreducible selves are thus "elementary particles" of consciousness. This slightly "romantic" criterion is motivated more by my particle physicist background and should be only taken as an attractive candidate for a rule of game.

4.3.3 Possible interpretation for the system formed by DNA and proteins

In [K15] it was proposed that DNA and proteins could form a physical representation for so called formal systems [D5] formalizing arithmetic systems to a set of symbols and rules for manipulating them. DNA sequences represent possible special cases of theorems represented by amino acid sequences and genetic code is mapping determined which are the special cases corresponding to given theorem. The larger structure formed from proteins correspond to statements about statements. This suggests that proteins and higher level structures formed from them forming self hierarchy give meaning to the theorems represented by amino-acid sequences.

The modelling of DNA and protein interactions is based on chemical kinematics which is basically a statistical model for the time development by quantum jumps occurring at the level of individual chemical compounds.

This requires that DNA and proteins participating the chemical reaction form entangled subsystems of some self and that quantum jumps leads to states in which reaction products become are unentangled subsystems, possibly selves which stay awake for some time. This argument only requires that some larger system containing DNA and proteins is in self state. This system could be some cell organelle, nucleus for DNA replication to mRNA and ribosome for the translation of mRNA to to proteins. In this picture the magical looking processes of biochemistry (replication of DNA, translation of DNA sequences to protein molecules) could be understood as fixed points of quantum self-organization resulting from a sequence of quantum jumps. For a wake-up time of order 10^{-10} seconds this would mean 10^{30} quantum jumps during single wave-up period of self. Therefore the precise determinism of DNA replication and translation could be perhaps understood as processes completely analogous to the formation of convective pattern in Benard flow. Final state would only depend on the macroscopic parameters the self containing the reactants (pH, temperature, electric fields).

This picture allows a realization of self hierarchy in which the fraction of time (quantum jumps) spent in self state increases with the size of the self. Natural guess is that this time scales as the size of the system. Wake-up time of 10^{-10} second in protein length scale would give time of order second in the length scale of meter which look rather sensible result. In the following a first guess for self hierarchy based on some general criteria is proposed.

4.3.4 Proteins as selves and protein folding

Proteins are good candidates for building blocks of self-hierarchy for several reasons.

1. Proteins are known to react sensitively to what happens in the surrounding world by changing their conformation.

2. Individual proteins are characterized by a huge number of enfoldings and one of the mysteries of biophysics is to understand what determines the few allowed configurations that are actually realized (self-organization by quantum jumps and spin glass analogy might help to solve protein enfolding problem as suggested in [K65] .

3. Proteins are polar molecules and form electrets. This is in accordance with the fact that electric field serve as a measure for cognitive resources. Already Fröhlich suggested that electret property is crucial for life. Proteins contain both hydrophilic polar parts and hydrophobic residues. The enfolding of proteins creates “dry” pockets in which hydrophobic residues of the proteins point inward so that one can speak of inside-outside distinction. It is not however clear whether one cannot regard protein pockets as selves having sufficiently long lifetime. Protein folding seems to however require that protein cannot be irreducible self but decomposes in quantum jumps to subsystem and its complement. How long times subsystems created in this manner can spend in self state is an open question.

4. There are speculations that these pockets could form the ”brain” of protein. The states of this tiny brain would corresponds to the conformations of hydrophobic residues inside pocket. The motivation is that anaesthetics seem to act on the electrons associated with the pockets and reduce their motility.

   In TGD framework one could understand the ability of protein to control its conformation as resulting from the interaction between the electrons in the pockets with the wormhole BE condensate associated with the boundaries of the protein. In quantum jumps electrons could entangled with the conformations of proteins and quantum jump would select one conformation. The loss of electron mobility by interaction with anestetics leads to the loss of protein self or at least the ability to protein to control its motions by quantum jumps. It seems however unnecessary to assume that electron or hydrophobic pockets behaves as a self.

5. Proteins are typically surrounded by ordered water and proton conduction makes possible communication. The dipole oscillations associated with the polar bonds of proteins provide a second communication mechanism. Wormhole BE condensate and coherent photons provide additional purely TGD based communication mechanisms. Also electrons dropped to non-atomic space-time sheet could provide a new conduction mechanism.

Protein folding is one of the mysteries of biology and provides direct justification for the hypothesis that proteins has self. The duration of the self of average protein having length of order 10^{-7} meters is about 10^{-15} seconds: this time scale corresponds to the wavelength of visible light. The assumption that protein can be in self state resolves the mystery of protein folding [K65] . The self-organization occurring inside protein self leads unavoidably to a bottom of some deep valley in the energy landscape of the protein representing the values of Kähler function for various protein conformations. Dissipation associated with self-organization by quantum jumps selects the final pattern of self-organization determined by external parameters like pH and temperature and with very slight dependence on initial conformation.

4.3.5 Larger selves formed by proteins

The larger structures formed by proteins give rise to the next level of the self hierarchy. The basic hydrophobic-hydrophilic splitting of the protein personality implies that proteins dissolved in water form very rich structures. Typically bi-layered structures, micelles, for which hydrophobic residues point inwards, are formed. Hollow cylinders, spheres and disks are possible. Micelles self-organize further to form liquid crystal phases. The end result of self-assembly depends on the pH, ionic concentrations and temperature of as well as electric fields in the the surrounding water. Rather general belief is that the dipole oscillations of proteins could be the Bose-Eistein condensate relevant for bio-consciousness. TGD framework suggest that the Bose-Einstein condensate of charged wormholes located on boundaries of tubulin dimers is one relevant BE condensate: the charge density of the wormholes is in fact equal to the normal component of electric field on boundary. The completely new element is the presence of phase of the wormhole order parameter mathematically analogous to order parameter of super-conductor. One can say that wormholes are the square root of the dipole condensate of Fröchlich.

Micro-tubuli

Protein molecules arrange into several, typically linear structures. The cytoskeleton is formed by micro-tubuli [J30, J32] . They consist of hollow cylinders formed as a lattice like structure of tubulin dimers. Tubulin dimer consists of two tubulin isomers, α- and β-tubulin. Second tubulin isomer contains attached Ca^{++} ion and second isomer contains two electrons, the other one being in the region intermediate to the isomers. Therefore tubulins are polarized. The region, where the tubulins of individual tubulin dimer join together, contains an electron. Tubuline dimers have at least two basic conformations and give rise to two different polarization states. Quantum jumps of the electron in the hydrophobic pocket are believed to induce jumps between the two conformations. anesthetics are known induce aneasthesia by affecting the mobility of these electrons. The relevant interaction is presumably van-der-Waals interaction since even noble gases are known to act as anesthetics [J32] .

An important question is whether the tubulin isomers are sub-selves of micro-tubule or not. The crucial question is whether tubulin isomers have mutual join along boundaries contacts. Join along boundaries contacts carry magnetic or electric fluxes and this would require magnetic or electric polarization of tubulins joined by the join along boundaries bond. Tubulins have only van der-Waals type interactions induced by the induced dipole-moments. This suggests that join along boundaries bonds are not present. The important conclusion is that tubulins are excellent candidates for selves and the mental life of micro-tubule can be very obviously very rich. The two conformations corresponding to two different polarization states of the tubulin would give a rough characterization for the mental state of single tubulin.

The lattice formed by polarized tubulins dimers can be regarded as a spin lattice like structure. The first phase corresponds to randomly oriented dipoles. This phase is ideal for communication since arbitrary message can be conveyed. Second case corresponds to spin glass like phase with groups of neighboring dipoles are in same orientation. This phase is ideal for computational activities since the configurations are temporally stable and memory storage becomes possible. The third case correspond to ferro-electret phase with all dipoles having same orientation.

If tubulin isomers are selves, they are rather simple selves having perhaps only two basic mental states corresponding to two different tubulin conformations. The mental state of micro-tubule self is "sum" of the tubulin selves and experienced by the micro-tubule as separate mental images. This if entanglement between tubulins is absent. In this manner the mental state of the micro-tubule could perhaps be interpreted as representing a binary sequence. Even the interpretation as a conscious computer could be considered. The mental states of the micro-tubule self would correspond to time developments of the tubulin conformations starting from the last moment of wake-up. Conformational waves propagating along micro-tubule, suggested also in [J30] to correspond to fundamental mental images, would give rise to very rich repertoire of micro-tubular experiences. Thus anesthetics reducing the mobility of electrons in hydrophobic pockets should have a dramatic effect also on "our" consciousness.

Cell membranes

Cell membranes are basic example of a structure formed by two lipid layers such that the hydrophobic residues point inwards. The region between the lipid layers could perhaps be regarded as forming "cell membrane self". The hydrophobic tails of lipids point inwards. Unless the lipids contain hydrophobic pockets, there are no candidates for sufficiently long lived lower-level selves. Thus cell membranes could perhaps in good approximation be regarded "irreducible selves" having no mental images.

Cell is full of endoplasma membranes and contains also cell organelles like nucleus surrounded by similar membranes. All these membranes are good candidates for material counterparts of selves if the proposed criteria are accepted. One possibly relevant macroscopic quantum phase is now the BE condensate of wormholes [K85] .

Larger structures

1. Protein collagen is the main component of the connective tissue in living systems. According to observations of Mae-Wan Ho [I20] , collagen forms liquid crystalline mesophases extending through the entire body. This encourages the conjecture that collagen fibres, which could be regarded as a scaled up version of cytoskeleton formed by micro-tubuli, could form one level in the self hierarchy. Mae-Wan Ho has indeed suggested that this structure is the seat of body-consciousness [I20] .

2. Entire cells, having clear inside-outside separation, are good candidates for selves and the superpositions of mental images of micro-tubuli would be part of the content of conscious experience of "cell self". The binary structure of micro-tubuli indeed makes possible very large number of different mental states even in the case that the contents of the cellular conscious experience reduces to the conformational dynamics of tubulins.

3. The two cell layers in epithelial sheets form a structure, which is much like a scaled up version of the cell membrane. Bio-systems are full of these structures: both skin, organs and the nuclei of brain are surrounded by epithelial sheets. In TGD based model for bio-consciousness "our" consciousness is assigned with the structures formed by epithelial sheets.

4. Brain contains also larger bi-layered structures, which seem to correspond to twin integers k and $k+2$ such that $p \simeq 2^k$, k power of prime is p-adic prime. These structures could give rise to even higher levels of consciousness. One possibility is that the hierarchy sensory-emotional-cognitive corresponds to p-adic length scale hierarchy, perhaps $k = 169, 173, 179$. Also the level $k = 181$ could be present and correspond to highest levels cognition. Cell layers forming ocular dominance columns correspond to $k = 179$ whereas $k = 181$ corresponds the combination of visual fields to stereo vision. This suggests that $k = 181$ combines the experiences of left and half brain to single experience.

4.3.6 Identifying our sensory sub-selves in p-adic length scale hierarchy

The synchronous firing of neurons would mean the 'waking up' of quantum critical neuronal selves in a cascade like manner (think of fox perceived by a crowd of hens sleeping initially!). The receival of a nerve pulse would wake up neuron. Perhaps neurons inside synchronously firing neuron groups of both hemispheres have small real entanglement slightly above the critical value for wake-up so that small perturbation is needed for wake-up. In this case neuronal self creation would not involve any quantum jump.

The nature of cognitive act depends on the type of the quantum entanglement involved as well as on the nature of wake-up process. The richness of structure associated with dark matter hierarchy implies that very many combinations are possible for cognitive cascades possessing several levels and at this stage one can only speculate. A rather speculative TGD based model for thoughts is based on "cognitive neutrino pairs" consisting of dark neutrinos as giving realization for Boolean algebra. The density of dark neutrinos is predicted to be very low in p-adic length scales much larger than $L(169) \simeq 5\ \mu$m (two times cell size roughly). The defects of dark neutrino super conductor could define representations of thoughts and in the simplest model the macroscopic quantum phases formed by Z^0

magnetized antineutrons at the cell membrane space-time sheet give rise to symbolic representations of thoughts.

If the levels of self hierarchy correspond to p-adic space-time sheets and dark neutrinos are present at all levels, thoughts cannot involve too many hierarchy levels. In the model of cell membranes as defects of dark neutrino super conductor, the relevant p-adic length scales correspond to $k = 169$ and $k = 151$. If dark neutrino super conductor can however form defects also at levels $k = 167, 163, 157$, then hierarchies with four levels are possible (sentences, words, syllables, phonemes?).

Direct support for the idea that the components of our conscious experience correspond to sub-selves comes from the phenomenon of after mental images. For instance, by looking at bright light source and closing eyes, one can experience periodically emerging after images changing their color. Phenomenon is actually much more general: all our mental images tend to occur periodically. A natural explanation is in terms of a periodic wake-up of the sub-selves representing these mental images. Even we are periodically occurring mental images of some high level self if the hierarchy of selves exists: there would be no deep difference between thinker and thought!

One could wonder how many cognitive sub-selves (mental images) we typically have. 7 ± 2 rule of psychology states that we can typically classify things into this number of different categories unless we use auxiliary tools. For instance, the number of digits in phone number is typically 7 for this reason. During intense concentration the number of categories is smaller and can reduce to only one. This would suggest that the number of cognitive sub-selves is typically 7 ± 2: of course, also other kinds of selves, such as bodily self, can exist simultaneously.

Good candidates for *our* sub-selves are structures bounded by epithelial sheets bounding various structures. Our body is full of these structures: skin, various organs and various brain nuclei, especially hypothalamus, hippocampus and reticular formation [J32] are examples of these structures. The seats of the primary sensory experiences should contain primary sensory organs. Hippocampus is crucial for laying down of the long term memories and this suggests that hippocampus can quantum entangle with higher level selves having long range memories as subjective memories. Limbic brain and hypothalamus are often regarded as the seat of emotions and the simplest hypothesis is that limbic brain is the seat of emotional consciousness which involves the comparison of the geometric memories with subjective memories. The damage of the reticular formation, which is the oldest and the most primitive part of the brain, implies unconscious state (at least using the generally accepted criteria for consciousness). Since reticular formation is not active during dreams, also the other parts of brain must have the ability to perform quantum jumps so that the sometimes heard claim that reticular formation is the seat of consciousness is incorrect. Various sensory homunculi in brain are good candidates for sub-selves performing higher level processing of the sensory information (pattern recognition, novelty detection,...).

An interesting question is what subconscious activity as opposed to unconscious activity might mean: one might think that this kind of activity is conscious activity of some self at the same level of self hierarchy as 'our self'. Perhaps Zombi within us type phenomena such as blind sight correspond to activities of this kind of parallel self perhaps identifiable as body with sensory organs acting as primary sensory experiencers. Could drives correspond to the desires of limbic brain or higher level selves? Could association cortex or even society correspond to the desires of 'superego'? Could the splitting of the personality correspond to the presence of a too large number of parallel 'our-selves' and having conflicting desires and plans? Or is poor communication between 'our-selves' the problem. It has indeed been found that the hemispheres of the split brain subjects are separately conscious [J32] . The 'collective unconscious' of Jung, on the contrary, might correspond to larger self, say, the whole society or even bio-system.

4.3.7 Hardware for body consciousness

The great challenge is to identify the hardware for the self hierarchy. The ideas of Mae-Wan Ho and her colleagues [I20, I22, I23, I24] seem to be on right track in this respect. Mae-Wan Ho has suggested that collagen network of body gives rise to body-consciousness understood to be something different from brain consciousness under usual conditions. This hypothesis indeed seems natural also from TGD point of view.

Liquid crystals

Liquid crystals (for excellent introduction see [D2] containing online text book about liquid crystals) can be regarded as mesophases: phases which are intermediate between solid crystal phase and liquid phase. Large class of crystals indeed appears in narrow temperature range between crystallization and melting.

The molecules able to form liquid crystals must be nonsymmetric under rotations. Typically rod like or disc like molecules are in question. The detailed structure of the molecule does not matter: typically only length-to-thickness ratio is what characterizes liquid crystals. Liquid crystal molecules contain also rigid polarizable part. Permanent dipole moment does not seem to be essential for liquid crystallinity.

Liquid crystals allow two basic phases. In nematic phases there is long range orientational order but translational order is lost. In smectic phases translational order is present in single direction and liquid crystal behaves like liquid orthogonal directions and has layer-like structure. Each layer behaves like two dimensional liquid. Molecules in each layer have definite average direction which can vary from layer to layer. If liquid molecules are chiral, the orientation of the molecules in layers can rotate helically.

The liquid crystals formed by collagen forms are lyotropic liquid crystals. Lyotropic liquid crystals are formed by amphiphilic molecules, surfactants, in polar solvent, say water. Amphiphilic molecules have hydrophilic and hydrophobic parts. Above critical concentration surfactant molecules form micelles, which are hollow spherical, cylindrical or disk like structures such that the hydrophobic residues point in interior and hydrophilic residues form hydrogen bonds with surrounding water. The liquid crystals in question can be electrets. In smectic phase, the direction of spontaneously generated electric field is parallel to the layer formed by micelles. Micelles themselves can have spontaneous polarization. Cell membrane is biologically important example of a polarized spherical micelle formed by lipids of cell membrane in which hydrophobic lipid tails point inwards.

Micelles, rather than molecules are building blocks of nematic and smectic phases which are formed when concentration is further increased. The formation of micelles and nematic and smectic phases occurs via self-assembly and could be regarded in TGD framework as quantum self-organization process. The result of self-assembly is sensitive to pH and ionic concentrations of water, to temperature and hydration of water and to external electric fields.

Both micro-tubuli and collagen can be regarded as examples of liquid crystals. There are many kinds of collagens. All share a general repeating sequence of the tri-peptide (X-Y-glycine), where X and Y are usually proline or hydroxyproline. They also have in common a molecular structure in which three polypeptide chains are wound around one another in a triple helix [I22] . In case of collagen liquid crystal micelles are long cylindrical structures, fibrils and these in turn organized to fibers with thickness of 1-20 micrometers [I22] . Cells can be regarded as micelles and therefore the layered structures formed by cells could also be regarded as liquid crystals. Epithelial sheets could perhaps be regarded as higher level micelle.

Living organisms as liquid crystals?

The book "The Rainbow and the Worm" of Mae-Wan Ho [I20] represents empirical support for the concept of body consciousness. The lecture talk of Mae-Wan Ho [I22] gives brief summary and references to the work by her and her colleagues. There are very simple observations supporting the notion of body consciousness.

1. Oscillations in olfactory bulb and in brain are in in phase with the movement of lungs. Also the coordinated movement of four limbs in locomotion is accompanied by patters of activity in motor centres of brain which are in phase with locomotion. It is very difficult to understand how this could be possible if brain would be only a central unit organizing these movements. Lags of order one second would be expected. Rather, it seems that brain and body work as a coherent unit.

2. Hydra and sea anemone, which have no nervous system, contract very rapidly when one of tentacles is touched. This suggests that consciousness is not a property of only nervous system but present already at the cell and body level.

Mae-Wan Ho [I20, I22] suggests the identification of the hardware of body consciousness as collagenous liquid crystalline mesophase [I24] associated with the connective tissue present everywhere in the body. Collagen is the most common protein of body and gives rise to a mechano-electrical network making possible for the parts of body to act as a coherent whole.

1. Collagen is a good conductor of electricity. The conduction mechanism is proton jump conduction in the ordered water associated with the collagen. Proton jump conduction is much faster than nerve conduction. The conductivity increases by addition of water when the amount of absorbed water is 10-30 per cent of total weight. The maximum increase occurs at body temperature.

2. Collagen forms mechanical network having connection with intracellular matrices through proteins located on cell membranes. Collagenous network, being liquid crystal, is characterized by the local orientation of the fibrous structures. For instance, in skin the alignment is due to stresses and strains during growth. Similar oriented fibrous structures are present in bones and cartilages. The hydrogen bonded water associated with the collagenous fibres makes this network also a electrical network having connections with the intracellular structures. These properties make collagen network an electro-mechanical network making possible intercommunication and responsiveness.

3. Proteins in liquid crystals have coherent motions constrained strongly by the fibrillar structure. These mechanical motions involve vibrational deformations of protein bonds accompanied by polarization waves coupling to proton conduction. Very weak, mechanical, electrical and thermal signals are amplified and propagate as modulation of proton currents or coherent polarization waves. Metabolic pumping of energy is probably involved.

4. Acupuncture system is known to have rather interesting manifestations. For instance, the stimulation of an acupoint in little toe leads to a similar activity in visual cortex as flash of light [J16] . This cannot be explained in terms of standard neuroscience. Stimulation of acupuncture points can produced local anesthesia. Thus acupuncture points and meridians might be closely related to body-consciousness.

5. Becker discovered the so-called body DC electric fields [J4, J15] are of central importance for consciousness. Becker found that general anesthetics attenuate the DC field completely. Sleep state can be induced by manipulating these fields using external currents. Becker also observed that during a perceptive event local changes in body the DC field can be measured half as second before the arrival of the sensory signals in the brain. There is also evidence that anesthetics act by replacing and releasing bound water from proteins and membrane interfaces. It is known that patients under general anaesthesia can regain brain consciousness with accompanying experience of pain. On the other hand, local anesthesia by acupuncture has been applied to patients who are fully awake. Acupuncture points are known to exhibit low electrical resistances as compared to the surrounding skin and could be juncture points of this network.

   Mae-Wan Ho suggests that collagen network, body DC fields and acupuncture system are closely related. Conduction channels could be associated with the fibrous structures formed by collagen, most probably the bound water in collagen fibres would serve as electric conductor.

6. One of the basic mysteries of living systems is their ability to move coherently. Some miraculous mechanism making it possible to transform energy to coherent energy must be in use. Otherwise the energy of metabolism would go to an disordered molecular motion and no macroscopic motion would be possible. Mae-Wan Ho also introduces the concept of coherent energy [I22] , which is the counterpart of "qi" in ancient Chinese medicine. For instance, coherent energy could correspond to collective motion in which momenta of particles are in same direction. Bio-systems seem to have ability to store fraction of incoming energy flux as coherent energy. This is not in contradiction with the second law of thermodynamics if the necessary dissipation occurs outside the bio-system or in some part of special part it. What is difficult to understand in the framework of standard physics is how bio-systems could so cleverly circumvent second law of thermodynamics.

TGD based view about living systems as liquid crystals

Protein molecules able to form micelles and crystals seem to be ideal candidate for realizing self hierarchy physically.

1. Liquid crystals are in a well defined sense critical phenomenon. This is in concordance with the idea that bio-systems are quantum critical systems.

2. The independence of the properties of the liquid crystal on the detailed shape of molecule is in accordance with idea that liquid crystal phase must be assigned to some non-atomic space-time sheet at which molecule is represented by the distribution of the wormhole contacts on the boundary of the molecule. Lyotropic liquid crystals are simple in the sense that micelles are basic building blocks with very simple geometry. Note that collagen proteins, micelles formed by them and liquid crystals formed in turn by them form naturally a hierarchy, perhaps identifiable as self hierarchy.

3. Liquid crystal assembly are sensitive to external electric fields, pH and ionic strengths. Also this supports the picture based on interaction between charged wormholes a proper description for the interaction between basic units of liquid crystal. For pure water pH determines the density of the water molecules on the boundary of 3-surface containing water molecules ($pH = -log(H_+), pH + POH = 14$). This is in accordance with the interaction between proteins occurs indeed via the classical em fields associated with wormholes on the boundaries of proteins. Note that as proteins contain peptide bonds which are polar. These polar bonds could involve wormhole contacts making possible amplification of the electric field in the direction of bond. There must be a compensating electric field on the larger space-time sheet.

4. Lyotropic liquid crystals seem to be ideal as far as consciousness is considered.

   (a) The hierarchy formed by proteins, micelles formed by them, and liquid crystals formed in turn by the micelles, could be interpreted as par of the physical realization of self hierarchy. At the lowest level are hydrophobic pockets of proteins and at the highest level collagen structures and organs formed by the cell layers.

   (b) If one believes on the hypothesis that Kähler action provides an entropy type measure for cognitive resources, then the presence of electric fields and spontaneous polarization can be regarded as advantageous from the point of view of cognitive consciousness.

1. First vision about liquid crystals and consciousness

The proposals of Mae-Wan Ho are restricted to the framework of the classical physics and, even if of crucial importance, might not be enough to allow understanding of body as a macroscopic quantum system. TGD suggest a more radical views about the role of collagen network, DC fields and acupuncture system in making possible body consciousness. The first vision developed for few years ago (this particular "now" corresponds to year 2001) is following.

1. In TGD one can understand the coherence of bio-system in terms of the classical coherence resulting from connectedness of appropriate 3-surfaces made possible by join along boundaries contacts ("massless extremals") in turn implying quantum coherence. Classical connectedness is quantum correlate for quantum coherence making possible subsystems to quantum entangle. Note that the concept of 3-surface is something totally new from point of view of standard physics were the modelling of the macroscopic structures is based on completely ad hoc assumption about their existence.

2. Liquid crystals look in short length scales like ordinary crystals behaving like single macroscopic unit. This behavior is something totally different of that of ordinary dissipating systems. A possible interpretation is that these units are irreducible selves and, being in a state of whole-body consciousness, do not dissipate in the usual manner. Thus body would consists of parts spending considerable fraction of time in a state of whole-body consciousness. If these regions belong to same level of self-hierarchy, they do not know about each other. "Brain self" knows nothing about "heart self".

3. The observations of Becker [J4] about the role of the electric fields in consciousness fit nicely with the TGD based hypothesis that the negative of Kähler function measures gives entropy type measure for the cognitive resources of the 3-surface. Exponent of Kahler action gives essentially the number of absolute minima of Kähler action going through given 3-surface. The generation of Kähler electric fields is a basic manner to increase cognitive resources. In light of this one can understand why cell membranes carry huge electric fields and why body DC fields, perhaps associated with the epithelial sheets consisting of two cell layers, are fundamental for our consciousness.

4. p-Adic fractality and many-sheeted space-time concept lead to the idea that epithelial sheets consisting of two cell layers could give rise to a scaled up version of nervous system. The basic phenomena would be periodic collective oscillations and propagating solitons in the Josephson junctions formed by the cell layers of the epithelial sheets. The electro-chemical shadows of these phenomena could be different from those in case of ordinary nerve pulse and EEG. Liquid crystals [D2] are typically electrets consisting of layered structures having electric fields in the transversal direction of the symmetry axis. DC fields could correspond to longitudinal electric fields associated with collagenous fibres and in direction of the fibres.

5. TGD suggests new physics mechanism realizing the notion of coherent energy purely classically. An interesting possibility is that the generation of "massless extremals" with net momentum basically generates the volitional macroscopic coherent motion in living systems. The properties of the collagen network might make it possible to "buy now and pay later" and also provide guarantee for the payment. Payment would mean that the negative energy massless extremal is absorbed by living system itself or surrounding world. Most naturally this absorption occurs when the motion of part of organism ceases. At this moment organism must be able pay back the energy gain. Thus metabolism would be needed to stop the motion rather than to initiate it! The only sensible interpretation is that stopping occurs automatically and is forced by the classical field equations.

An interesting question is whether non-volitional phenomena like heart beat involve emission of the negative energy massless extremals. The emission could indeed be purely classical process. Of course, heartbeat could be non-volitional only from the point of view point of "brain self". There could be "heart self" making decision about each heart beat!

2. Second vision about liquid crystals and consciousness

The first reason why for liquid crystals involves rather general arguments. The notion of many-sheeted ionic flow equilibrium allows much more precise argument catching what seems to be quintessential for bio-control. Liquid crystals allow weak but coherent electric fields making possible ohmic currents at atomic space-time sheets which together with the magnetic super current circuitry could form many-sheeted quantum control circuitry which in ionic flow equilibrium amplifies very small densities of ions at super-conducting magnetic flux tubes to much higher densities of ions at the atomic space-time sheets. MEs could induce various quantum transitions of ions (perhaps also molecules like enzymes) at magnetic flux tubes in quantum coherent manner and even amplify them to quantum phase transitions. This would make possible very effective biochemical control. Body consciousness could be assigned with the magnetic flux tube circuitry and magnetic quantum phase transitions whereas higher level consciousness would correspond to quantum transitions of super-symplectic representations assignable to the boundaries of MEs. The difference would be that magnetic states reduce to states defined in 3-surface whereas super-symplectic states are genuine quantum gravitational states defined in the space of 3-surfaces: thus body consciousness and 'our' consciousness would correspond to totally different abstraction levels (quantum field theory and quantum TGD as a matter of fact!).

If one accepts the idea that living matter resides in the intersection of real and p-adic worlds it becomes easy to accept the hypothesis that evolution corresponds to p-adic evolution. This hypothesis is testable. The reason is that p-adic length scale hypothesis selects very few physically interesting primes in the range of biologically interesting length scales and makes the notion of p-adic evolution very predictive. The hierarchy of the p-adic primes should also correspond to the hierarchical structure of consciousness.

p-Adic length scale hypothesis can be actually applied at two levels. p-Adic length scale hypothesis follows if the proper time distance between the tips of CD come as octaves of CP_2 time scale. An argument based on light-like randomness implies p-adic length scale hypothesis stating that primary p-adic length scales L_p are proportional to $\sqrt{p}$, $p \simeq 2^k$, whereas the the temporal and spatial size of CD is proportional to $2^k \simeq p$ and corresponds to $L_{p,2} = \sqrt{p}L_p$. This implies that elementary particles are accompanied by macroscopic time and length scales [K52] meaning a hidden connection between elementary particle physics and macroscopic physics. For instance, electron corresponds to the time scale .1 second defining the fundamental biorhythm.

The emergence of space-time sheets having size given by the primary p-adic length scale $L(k)$ and accompanied by secondary p-adic length scales should have been a dramatic breakthrough in evolution since new level of space-time sheet hierarchy emerged. In the following this hypothesis will be tested. The consideration is however restricted to the primary p-adic length scale hypothesis.

4.3.8 How to apply p-adic length scale hypothesis?

The p-adic length scale $L(k)$ can be expressed in terms of the p-adic length scale $L(151)$, which corresponds to cell membrane length scale about $L(151) \simeq 10^{-8}$ meters as

$$L(k) = 2^{(k-151)/2}L(151) \ .$$

The problem is to find whether there is some precise geometric criterion fixing the p-adic prime of the structure and what this criterion is. It must be emphasized that the upper bound for the size of a structure with given k might be dynamically determined. At least, join along boundaries condensates formed from basic objects with size of order $L(k)$ seem to be possible. In [K22] this kind of criteria were discussed and the conclusion was that join along boundaries condensate might have size which is hundred times larger than the size of the basic building block (say atom).

Even if the criterion determining the p-adic prime of basic structure is purely geometric, one has still the problem of deciding what the precise form of the criterion is. In case of most layered structures there seem to be no special problems (note however the problem with epithelial sheets!).

1. The lower limit for the thickness of the structure should corresponds to $L(k)$. This criterion indeed works nicely for all layered structures. In case of spherical and cylindrical structures the criterion is not so obvious. Should one interpret p-adic length scale as the minimum radius or diameter? It seems that the identification of the p-adic length scale as a lower limit for the radius of the structure is the correct one.

2. One should have also criterion giving lower bound for k in case that the structure is irreducible in the sense that it is not join along boundaries condensate of nearly identical basic units. A possible criterion is that if the irreducible structure contains cube of side $L(k)$ then the p-adic prime must be at least k. This would mean that $L(k)$ is the p-adic length scale of a spherical structure up to diameter $d = \sqrt{3}L(k)$,

The problem becomes especially acute in case of cell and epthelials sheets consisting of two cell layers. The twin pair $(167, 169)$ is especially natural looking in this respect and would suggest that the p-adic length scale of cell is $L(167)$. $L(169)$ would in turn be the p-adic length scale associated with the epithelial sheets formed from two cell layers abundant in living system (skin and cavities surrounding organs, sensory organs, nuclei of brain).

This looks nice. It is however known that the sizes of cells vary in wide limits. The cells of bacteria have size about one micrometer, the lower bound for neuron size is 5 micrometers, red blood cells have size of 8 micrometers. Some sources mention the size of 20 microns as the size of a typical cell! Egg has macroscopic size. Also neurons can have gigantic sizes. Thus it looks very questionable to assign $k = 167$ with these cell sizes. and would be in conflict with the spirit of p-adic evolution hypothesis. The solution of the dilemma is simple. Cell differentiation means also p-adic evolution of the cell so that the p-adic prime of cell can grow during the development. Of course, the p-adic prime characterizing mature cell grows also in the course of evolution. Thus the p-adic prime of cell would give a measure for its level of evolution. Egg is certainly much more evolved system than bacterium.

The criterion $d < \sqrt{3}L(k)$ for the size of cells corresponding to $L(k)$, implies that cells with diameters in the range $(2.2, 9)$ micrometers should correspond to $k = 167$. Accepting this criteria bacteria would have $k = 163$ and smallest neurons with diameters in the range $5 - 9$ micrometers and red blood cells would have $k = 167$. Cells with size of 20 microns (typically neurons) correspond to $L(169)$. One can however quite well consider the possibility that the length scales characterizing bacteria, blood cells and neurons correspond to $k = 167, 169$ and 173.

It seems that there are epithelial sheets consisting of two cell layers which are considerably more thicker than 5 microns suggested by the simplest guess. Rather it seems that 5 micron serve only as a lower bound for the thickness of the epithelial sheets and it is this prediction which is testable. The natural explanation is based on evolution leading to the increase of the mature cells but leaving the topology unchanged. 'Ontogeny recapitulates phylogeny' principle suggests that the evolution is repeated during the development of individual organism. Epithelial sheet is a join along boundaries condensate of more or less identical cells. Join along boundaries bonds are gap junctions now. At some stage of the growth join along boundaries condensate must have had critical thickness of order $L(169)$. At this stage a phase transition leading to generation of new $k = 169$ space-time sheet occurred and led to the separation of the structure as separate geometric space-time sheet. After than cell growth continued and the p-adic prime of cells could grow in a phase transition manner to $k = 169$ at some later stage. Of course, also larger p-adic primes are possible. Note that the p-adic prime of cells and of the epithelial sheet can be also same.

To make things even more complicated, biologists tend to determine the size of cell by dividing the area spanned by cells by their number so that the size of the cell is actually determined as the area occupied by the cell! Therefore one must be very cautious with the numbers claimed to give "cell size".

k	127	131	137	139	149
$L_p/10^{-10}m$	.025	.1	.8	1.6	50
k	151	157	163	167	169
$L_p/10^{-8}m$	1	8	64	256	512
k	173	179	181	191	193
$L_p/10^{-4}m$	.2	1.6	3.2	100	200
k	197	199	211	223	227
L_p/m	.08	.16	10	640	2560

Table 1. p-Adic length scales $L_p = 2^{k-151}L_{151}$, $p \simeq 2^k$, k prime, possibly relevant to biophysics. The last 3 scales are included in order to show that twin pairs are very frequent in the biologically interesting range of length scales. The length scale $L(151)$ is take to be thickness of cell scale, which is 10^{-8} meters in good approximation.

4.3.9 Are also Gaussian primes and Eisenstein primes important?

Besides ordinary primes also Gaussian and Eisenstein primes exists and it seems that one define the notion of G-adic and E-adic number fields. This makes these primes very interesting from the point of view of bio-systems.

Gaussian primes

Gaussian primes consist of complex integers $e_i \in \{\pm 1, \pm i+\}$, ordinary primes $p \ mod \ 4 = 3$ multiplied by the units e_i to give four different primes, and complex Gaussian primes $r \pm is$ multiplied by the units e_i to give 8 primes with the same modulus squared equal to prime $p \ mod \ 4 = 1$. Every prime $p \ mod \ 4 = 1$ gives rise to 8 non-degenerate Gaussian primes. Pythagorean phases correspond to the phases of the squares of complex Gaussian integers $m + in$ expressible as products of even powers of Gaussian primes $G_p = r + is$:

$$G_p = r + is \ , \quad G\overline{G} = r^2 + s^2 = p \ , \quad p \ \text{prime} \ \& \ p \ mod \ 4 = 1 \ . \tag{4.3.1}$$

The general expression of a Pythagorean phase expressible as a product of even number of Gaussian primes is

$$U = \frac{r^2 - s^2 + i2rs}{r^2 + s^2} \ . \tag{4.3.2}$$

By multiplying this expression by a Gaussian prime i, one obtains second type of Pythagorean phase

$$U = \frac{2rs + i(r^2 - s^2)}{r^2 + s^2} \quad . \tag{4.3.3}$$

Eisenstein primes

Whereas Gaussian primes rely on modulo 4 arithmetics for primes, Eisenstein primes rely on modulo 3 arithmetics. Let $w = exp(i\phi)$, $\phi = \pm 2\pi/3$, denote a nontrivial third root of unity. The number 1-w and its associates obtained by multiplying this number by ± 1 and $\pm i$; the rational primes $p \; mod \; 3 = 2$ and its associates; and the factors $r + sw$ of primes $p \; mod \; 3 = 1$ together with their associates, are Eisenstein primes. One can write Eisenstein prime in the form

$$\begin{aligned} E_p(r,s) &= r - \frac{s}{2} + is(r - \frac{s}{2})\sqrt{3} \ , \\ r^2 + s^2 - rs &= p \ . \end{aligned} \tag{4.3.4}$$

What might be called Eisenstein triangles correspond to the products of powers of the squares of Eisenstein primes and have integer-valued long side. The sides of the orthogonal triangle associated with a square of Eisenstein prime $E_p(r,s)$ have lengths

$$(r^2 - rs - \frac{s^2}{2} \ , \ s(r-s)\frac{\sqrt{3}}{2} \ , \ p = r^2 + s^2 - rs) \ .$$

Eisenstein primes clearly span the ring of the complex numbers having the general form $z = (r + i\sqrt{3}s)/2$, r and s integers.

Of course, there exists infinite number of extensions of rational numbers and each of them allows the notion of prime number in appropriate sense.

G-adic and E-adic number fields

It seems possible to generalize the notion of p-adicity so that could speak about G-adic and E-adic number fields. The properties of the Gaussian and Eisenstein primes indeed strongly suggest a generalization for the notion of p-adic numbers to include what might be called G-adic or E-adic numbers.

1. Consider for definiteness Gaussian primes. The basic point is that the decomposition into a product of prime factors is unique. For a given Gaussian prime one could consider the representation of the algebraic extension involved (complex integers in case of Gaussian primes) as a ring formed by the formal power series

$$G = \sum_n z_n G_p^n \quad . \tag{4.3.5}$$

   Here z_n is Gaussian integer with norm smaller than $|G_p|$, which equals to p for $p \; mod \; 4 = 3$ and $\sqrt{p}$ for $p \; mod \; 4 = 1$.

2. If any Gaussian integer z has a unique expansion in powers of G_p such that coefficients have norm squared smaller than p, modulo G arithmetics makes sense and one can construct the inverse of G and number field results. For $p \; mod \; 4 = 1$ the extension of the p-adic numbers by introducing $\sqrt{-1}$ as a unit is not possible since $\sqrt{-1}$ exists as a p-adic number: the proposed structure might perhaps provide the counterpart of the p-adic complex numbers in case $p \; mod \; 4 = 1$.

   Thus the question is whether one could regard Gaussian p-adic numbers as a natural complexification of p-adics for $p \; mod \; 4 = 1$, perhaps some kind of square root of R_p, and if they indeed form a number field, do they reduce to some known algebraic extension of R_p?

3. In case of Eisenstein numbers one can identify the coefficients z_n in the formal power series $E = \sum z_n E_p^n$ as Eisenstein numbers having modulus square smaller than p associated with E_p and similar argument works also in this case.

4. What is interesting from the physics point of view is that for $p \ mod \ 4 = 1$ the points G_p^n and E_p^n are on the logarithmic spiral $z_n = p^{n/2}exp(in\phi_0/2)$, where ϕ is the Pythagorean (Eisenstein) phase associated with G_p^2 (E_p^2). The logarithmic spiral can be written also as $\rho = exp(nlog(p)\phi/\phi_0)$. This reminds strongly of the logarithmic spirals, which are fractal structures frequently encountered in self-organizing systems: perhaps G- and E-adics might provide the mathematics for the modelling of these structures.

5. p-Adic length scale hypothesis should hold true also for Gaussian primes, in particular, Gaussian Mersennes of form $(1 \pm i)^k - 1$ should be especially interesting from TGD point of view.

   i) The integers k associated with the lowest Gaussian Mersennes are following: $2, 3, 5, 7, 11, 19, 29, 47, 73, 79, 11$ $k = 113$ corresponds to the p-adic length scale associated with the atomic nucleus and muon. Thus all known charged leptons, rather than only e and τ, as well as nuclear physics length scale, correspond to Mersenne primes in the generalized sense.

   ii) The primes $k = 151, 157, 163, 167$ define perhaps the most fundamental biological length scales: $k = 151$ corresponds to the thickness of the cell membrane of about ten nanometers and $k = 167$ to cell size about 2.56 μm. This strongly suggests that cellular organisms have evolved to their present form through four basic stages.

   iii) $k = 239, 241, 283, 353, 367, 379, 457$ associated with the next Gaussian Mersennes define astronomical length scales. $k = 239$ and $k = 241$ correspond to the p-adic time scales .55 ms and 1.1 ms: basic time scales associated with nerve pulse transmission are in question.

   $k = 283$ corresponds to the time scale of 38.6 min. An interesting question is whether this period could define a fundamental biological rhythm. The length scale $L(353)$ corresponds to about 2.6×10^6 light years, roughly the size scale of galaxies. The length scale $L(367) \simeq \times 3.3 \times 10^8$ light years is of same order of magnitude as the size scale of the large voids containing galaxies on their boundaries (note the analogy with cells). $T(379) \simeq 2.1 \times 10^{10}$ years corresponds to the lower bound for the order of the age of the Universe. $T(457) \sim 10^{22}$ years defines a completely super-astronomical time and length scale.

6. Eisenstein integers form a hexagonal lattice equivalent with the root lattice of the color group $SU(3)$. Micro-tubular surface defines a hexagonal lattice on the surface of a cylinder which suggests an interpretation in terms of E-adicity. Also the patterns of neural activity form often hexagonal lattices.

Do Gaussian Mersennes define 'miracle frequencies' in living matter?

Ordinary and Gaussian Mersenne primes are of special importance in elementary particle length scales. All charged leptons, atomic nuclei, hadrons and intermediate gauge bosons correspond to ordinary or Gaussian Mersennes. The number theoretical, and there are reasons to assume that also biological, miracle is that there are four subsequent Gaussian Mersennes in the biologically most interesting length scale range. The values of k for these length scales L_p, $p \simeq 2^k$, k prime, are $k = 151, 157, 163, 167$ and correspond to the p-adic length scales 10 nm, 80 nm, 640 nm, and 2560 nm. The next p-adic length scale is also very special and corresponds to $k = 13^2 = 169$ which is not prime but a power of prime and very rare as such. It is quite possible that neutrinos could metastably topologically condense at these length scales so that one would have four metastable neutrino physics besides the stable one corresponding to $k = 169$ (this on basis of the data about neutrino mass squared differences [K43] .

The photon energies corresponding to these length scales are $E(151) = 124.0$ eV (UV), $E(157) = 15.5$ eV (UV), $E(163) = 1.9375$ eV (red light) and $E(167) = .4844$ eV (near infrared). The energy corresponding to $k = 169$ is $E(169) = .2422$ eV. One must notice that there is few per cent uncertainty related to an overall scaling of length scales and energies. These energies indeed seem to correspond to biologically important photon energies.

1. $E(163) = 1.9375$ eV corresponds to wavelength of 640 nm which is with .6 per cent accuracy equal to the wave length 644 nm of the photon absorbed in photosynthesis associated with

chlorophyll b). For chlorophyll a) the wavelength is 680 nm and deviation is 6 per cent. This suggests that photosynthesis leads to a generation of positive energy ME representing the stored energy and having length of near to $L(167)$.

2. From the yield of 48 kJ/mole of energy in ADP-to-ATP transformation, .4976 eV corresponds to the energy liberated when ATP decays to phosphor atom and ADP and is few per cent higher than $E(167) = .4844$ eV. In the spirit of the topological self-referentiality, one might play with the thought that also the stored energy, rather than only binding energy, is represented topologically. If so, this energy might be simply stored as positive energy ME carrying this energy disappearing when ATP gives up its energy. It is unclear whether the vibration energy quantum .52 eV of water hydrogen bond could relate to $E(167)$.

   In [K13] a model for ATP as a universal 'energy currency' is developed. The model is based on the hypothesis that $E(167)$ MEs, rather than theoretically and empirically questionable high energy phosphate bonds, serve as the energy currency. This leads also to a model for the coherent locomotion relying on the assumption that the hydrogen ion current accompanying the phosphorylation of ADP molecules to ATP molecules is generated by the leakage of the protonic supra currents from the flux tubes of Earth's magnetic field to the atomic space-time sheets. The macroscopic quantum coherence of the protonic supra currents allows to understand the coherency of the locomotion, which is miracle in the framework of the standard biochemistry.

3. $k = 169$ corresponds to energy $E(169) = .2422$ eV and belongs to the region of hydrogen bond energies, which depend on which kind of molecules hydrogen bond connects with each other. The range of weak hydrogen bond energies is $.13-.3$ eV and in the near infrared. Also strong hydrogen bonds with energies extending up to 1.6 eV are possible but the hydrogen bonds associated with the biological molecules such as those connecting the DNA nucleotides are weak. The maximum binding energy for water hydrogen bond equals to $E(169)$ with one per cent accuracy. Notice however that hydrogen bond energy depends on its environment: typically the energy of the first bond in DNA is largest which gives rise to what might be called zipper effect. Negative energy MEs with this frequency should be very important and allow better understanding of the collective properties of water. Sol-gel transition involves the generation of hydrogen bonds and thus $k = 169$ MEs might be involved with this transition. Hence it would be interesting to look for the effects of coherent light with this frequency on water and to the sol-gel phase transition and its reversal. Also irradiation of DNA by photons with energy $E(167)$ might yield interesting effects. It deserves to be noticed that $E(169)$ which correspond rather nearly to the hydrogen bond energy is liberated together with the corresponding momentum when only the second member of $k = 167$ ME pair liberates its energy.

4. What about the miracle frequencies in ultraviolet? A not very plausible possibility is that these frequencies are associated with atomic transitions. They could also correspond to energies associated with structures with corresponding lengths. For $k = 151$ MEs parallel to lipids of cell membrane are a possible candidate and it is known that the charging of the mitochondrial energy batteries occurs at its membrane. $k = 163$ and $k = 167$ seem to be related to metabolism and one can wonder whether the same could hold true for all the miracle length scales.

   (a) Perhaps the simplest possibility is that MEs with length of $L(167)$ are in question but em field corresponds to $n = 2^8 = 256$ harmonic serving as a topological correlate for a Bose-Einstein condensate of 256 photons with energy $E(167)$. During the discharging of the mitochondrial energy battery the value of n would gradually decrease. During the charging process, which perhaps involves p-adic-to-real phase transition representing the transformation of intention to action, the reversal of this process would occur. It is also possible that the notion of momentum battery makes sense. During discharging coherent momentum would be given to the bio-molecules involved. This could make possible coherent locomotion at the cellular level.

   (b) If one assumes that also 124.0 eV and 15.5 eV correspond to minimum length MEs representing energy packets, one ends up to an alternative idea about how metabolism might work. 124 eV bunches of energy with length equal the cell membrane thickness could be first divided to 8 bunches of 15.5 eV at the membrane of the mitochondria, then these bunches could be divided to .19 eV bunches and finally .48 eV bunches would result. This would be like wares coming to a market store in big packets containing smaller packets containing... Now however every sub-packet of the energy packet have larger size that the packet by uncertainty principle. The problem here is that rather complex topological processes are needed to liberate the energy in this case.

To sum up, the study of the effect of the 'miracle frequencies' in living matter might be very revealing concerning the understanding of the bio-control and demonstrate unexpected effects.

4.3.10 p-Adic length scale hypothesis and molecular evolution

As far as DNA determines the structure of living systems, the evolution of living systems reduces to molecular evolution at the level of DNA. The p-adic primes relevant to molecular evolution span essentially the same range of the length scales as the p-adic primes related to the body since, at least in human, total length of DNA in single chromosome is of order centimeter.

The pair $k = 137, 139$: atoms and simple molecules

The scales associated with $k = 137, 139$ form a twin pair related by a factor two. These length scales are given by $.75 \times 10^{-10}$ meters and 1.5×10^{-10} meters if $L(151)$ is taken to be 10^{-8} meters.

It is interesting to look what the p-adic length scales of typical simple bio-molecules are when the their size is defined as their diameter. Using Angström as unit the diameters are $d(Mg) = 1.44$, $d(Na) = 1.96$, $d(Ca) = 2.0$, $r(Ca) = 2.74$, $r(H_2O) = 2.74$. The criterion $d > \sqrt{3}L(k)$ gives an upper bound for the p-adic length scale for the object of diameter d. Applied to $k = 139$ this gives $d > 2.7$ Angstrom for objects having $k = 139$. Only Ca and H_2O satisfy this criterion and thus they represent $k = 139$ level of molecular evolution.

One can say that light atoms belong to the lowest level of evolution defined to start from $k = 137$ objects. Calcium represents second level of atomic evolution. Interesting possibility proposed already earlier is that outer electrons of Calcium drop on non-atomic space-time sheet $k = 139$ and this indeed makes Ca object involved object consisting of two space-time sheets. H_2O represents the second level of evolution of molecules. It is rather remarkable that Ca and H_2O molecules are indeed in central role in control and coordination protein conformations. For instance, gel-sol phase transition, which seems to be basic process at intracellular level, involves Ca^{++} ions in essential manner.

Tubulins, which are the basic building blocks of micro-tubule, have diameter of 4 nm, which is below the critical diameter of $d = \sqrt{3} \times L(149) \simeq 8.75$ nm. Also the size of tubulin dimer about 8 nm seems to be slightly below the critical size.

The building blocks of DNA strand and double strand have radii of order 1 Angstrom and single strand corresponds to $k = 137$, whereas molecule pair in double strand corresponds to $k = 139$ respectively. For $L(151) = 10^{-8}$ meters, DNA molecule in double helix corresponds to a length of $3.4\ A \simeq 1.13 \times 2 \times L(139)$ of the double helix. This is quite near to $4 \times L(137)$. This suggests that one could perhaps fix the over all normalization of p-adic length scale by requiring that DNA triplet corresponds precisely to $4 \times L(137)$. This gives

$$L(151) = 108.8 \times 10^{-8} \text{ meters} .$$

That single DNA would correspond so precisely to a multiple of p-adic length scale would not probably be an accident.

Since DNA and protein molecules are obviously at quite high level of evolution it seems that the length of the molecule is what determines the value of the corresponding p-adic prime. Thus the evolution maps to the evolution of the p-adic length for DNA molecules! Thus the molecular length of $L(149) = 5$ nanometers should have been the first breakthrough in the molecular evolution (lipid layer of the cell membrane by the assembly of micelles of the liquid crystal!), which was followed rapidly by additional breakthroughs. It is obvious that the evolution reduces in well defined sense to the evolution of DNA sequences. This aspect of evolution will be discussed separately later.

p-Adic evolution of DNA

p-Adic evolution should involve two aspects.

1. The increase of the p-adic length scale characterizing the basic DNA modules. This suggest the classification of the basic building blocks of the genome by the p-adic length scale associated with the corresponding DNA sequences.

2. The fractal evolution involving emergence of longer p-adic length scales characterizing the size of the space-time sheets to which basic DNA sequences had # contacts. Thus the lengths of introns and exons are not expected to correlate with the p-adic scale of the space-time sheet to which they possibly have # contacts. Rather, same gene can have # contacts to arbitrarily large space-time sheets.

Consider first the critical lengths of the basic program modules. The lengths $L(149), L(151), L(157), ...$ of gene or DNA sequence might mean the emergence of something genuinely new in the evolution. This length scale hierarchy expressed in terms of $L(137)$ comes in powers of 2 as $N_{137} = 1, 2, 64, 128, 2^{10}, 2^{13}, 2^{15}, ...$

Single nucleotide pair corresponds to in double helix to distance of .34 nanometers which is larger than the length scale of $L(139)$. The structure of the double helix is such that there is a periodicity of 3.4 nanometers: this means that basic period corresponds to 10 nucleotides. This implies that 5 DNA triplets correspond to a length of 5.05 nanometers, which equals to p-adic length scale $L(149)$ if $L(151)$ is defined to be $L(151) = 10.2$ nm. $L(149)$ corresponds to the thickness of the lipid layer of cell membrane and $L(151)$ corresponds to 10 DNA triplets, to the thickness of the cell membrane and the basic period of DNA sequence when DNA triplet is regarded as a basic unit. Perhaps this periodicity is not accident but has deeper meaning possibly related to the periodicity of phase variable associated with DNA. The lengths of DNA sequences corresponding to p-adic length scale $L(k)$, $p \simeq k$, k power of prime are $N(DNA) = 2^{k-149} \times 5$ DNA triplets.

This means that the critical numbers of DNA triplets possible leading to the emergence of qualitatively new properties of organism are given by

$$\begin{aligned} N(DNA) &= 2^{(k-149)/2} \times 5 \ , \\ k &\in \{149, 151, 157, 163, 167, 169, 174, 179, 181, 191, 193, ..\} \end{aligned} \tag{4.3.6}$$

The few lowest critical values of DNA triplets in gene are

$$N(DNA) = n \times 5 \ ,$$
$$n = 1, 2, 2^4 = 16, 2^7 = 128, 2^9 = 512, 2^{10} = 1024, 2^{12}, 2^{15}, 2^{16}, \cdots$$

The steps of this hierarchy resembles bring in mind the evolution for the length of the basic memory unit of computer memory! One must however notice that 5 DNA triplets seems to serve as a basic unit.

The emergence of new p-adic length scales could have meant emergence of new levels of modularization in the genetic program and it is interesting to look these numbers from this point of view.

1. One could think that short sequences of precursors of DNA, mRNA and tRNA molecules were generated spontaneously by self-assembly. This implied automatically the generation of amino-acids by the more primitive counterparts of transcription and translation processes. The lengths of DNA molecules began gradually grow and at the critical lengths of DNA corresponding to p-adic length scales dramatic new effects emerged. Also new space-time sheets emerged in the genome and the first guess is that this occurred for the critical sizes of the organism given by p-adic length scales.

2. Formation of lipid layers might have been the revolution occurring at this stage and since lipids should have had size of order $L(149)$. This revolution should have occurred when the length of the genome became longer than 5 DNA triplets and meant formation of lipid layers by self organization process known to occur in all liquid crystals: these layers were perhaps formed in the surface of water such that hydrophobic ends of proteins would have pointed out of water. Self organization presumably led simultaneously to the formation of double membranes having thickness $L(151)$ such that the hydrophobic ends of proteins pointed in the interior of the double membrane. Second revolution became possible when the number of DNA triplets became larger

than 10 triplets so that proteins connecting cell interior of the double membrane to its exterior became possible and the control of ion concentrations became in principle possible. Transfer RNA (tRNA) has length of at most 27 triplets. Third revolution should have occurred $L(157)$, which corresponds to 80 triplets.

3. Smallest viruses possessing single strand of DNA have lengths between 15-100 nanometers and this suggest that genome correspond to p-adic length scales $L(149)$, $L(151)$ and $L(157)$. These length scales could characterize largest space-time sheets also present in genome. The building blocks of the envelope of viruses are genetically coded separately and self-assemble spontaneously so that only building blocks need to be coded. Therefore p-adic prime associated with the genome of virus could be smaller than that determined by the size of the virus. Viruses with two DNA strands have sizes between $250 - 1000$ nanometers. This suggest that the emergence of $k = 163$ length scale in the genome of virus was accompanied by the emergence of double stranded DNA. $k = 163$ is perhaps the largest p-adic length scale associated with virus genome.

4. Bacteria have typically sizes of $1 - 10$ micrometers. This suggests that $k = 163, 167, 169$ are the possible space-time sheets associated with the bacterial genome. The emergence of $k = 169$ could have meant the emergence of multicellulars and generation of epithelial sheet like structures consisting of two cell layers as well as emergence of introns and DNA cognition.

Consider now the typical lengths for the structures of the eukaryotic genome.

1. The presence of introns means that the length of a gene coding given protein plus introns is much longer than the DNA coding only the protein. The higher the evolutionary level of the species, the larger the fraction of the introns. For human genome the fraction of the exons is roughly 1 per cent. The typical length of hnRNA in nucleus is 6.000-8.000 np (nucleotide pairs) which corresponds to 18 micrometers and length scale $L(163)$ and $L(167)$. Even genes with length 20.000 np are possible and correspond to $L(169)$. The lengths of mRNA vary between 500-3.000 nucleotides corresponding to interval 1.7×10^{-7}-10^{-6} meters and length scales $L(157)$ and $L(163)$. RNA sequences coding typical protein consisting of roughly 300 amino acids are about 3×10^{-7} meters and correspond to $L(159)$.

2. Most of the highly repetitive DNA has rather short length between $5 - 300$ nucleotides. Introns having typically lengths between $10 - 1000$ nucleotide pairs. The length of ribosomal DNA is not longer than 10^3 nucleotides. These examples suggests that the basic program modules correspond to p-adic length scales between $L(139)$ and $L(157)$ and that introns and genes are built as fractal versions of the basic program modules possibly present in all plants and animals. The basic programs are chemically identical. They could however have wormhole contacts to increasingly larger space-time sheets so that organism possesses fractal like structural hierarchy. Alternatively, the contacts are on the space-time sheets with same p in all animals but the sizes of the join along boundaries condensates formed by fundamental expression domains depend on organism. The frequent occurrence of Hox genes in the genetic code of body parts of various sizes in the entire animal kingdom is consistent with both options.

Cell membrane and cytoskeleton

$k = 149, 151$ is the twin pair related to the lipid layers of cell membrane and cell membrane itself. Micro-tubuli having radius of 25 nanometers correspond to $k = 151$ structure. Also chromosomes have radius of order 25 nanometers.

The length scale associated with $k = 157$ is 80 nanometers. Cell cytoskeleton contains as its basic structural element the cylindrical structures formed by the triplets of micro-tubuli on a cylindrical surface having doublet of micro-tubuli at center. The size of this structure corresponds to $L(157)$. For viruses the diameter of the membrane envelope is between $80 - 120$ nanometers. Cell organelles contain smaller membrane bounded structures (christae, thylakoids,...), which could correspond to the p-adic length scale $L(157)$.

It must be emphasized that DNA evolution occurs also in different direction and corresponds to the emergence of new space-time sheets to many-sheeted DNA. The number of these space-time sheets might serve as more important measure for the evolutionary level of organ than the length of the gene and distinguish between humans and dinosauri.

4.3.11 Evolution of the cellular structures

Cells can be classified into prokaryotic cells having no cell organelles enclosed by membranes and eukaryotic cells containing this kind of cell organelles, which in turn contain further sub-cell organelles surrounded by membranes. The second distinction is division into plant and animal cells. Nanno-bacteria are still further potential but not yet established life form. Besides cell like life there are viruses enclosed by envelope like structure. Viruses are not however able to metabolize.

$k = 163$ and bacteria (prokaryotes)

The length scale associated with $k = 163$ is .64 micrometers. Bacteria have typically cell size of 1 micrometer and would thus have radius of order $L(163)$. Also substructures of collagen fibres in connective tissue have radius about $.5 - 10$ micrometers and might correspond to $L(163)$ and possibly larger p-adic length scales. Of course, evolution of these structures means that their p-adic prime has possibly increased. Also cell organelles like mitocondria, chloroplasts and nucleus could correspond to $k = 163$ length scale. The diameter of mitochondria is indeed of order 1 micrometer.

Evolution of the eukaryotic cellular structures

It is tempting to regard the evolution of cellular structures as gradual increase of p-adic prime and to classify primitive cellular life forms by their p-adic prime. The key observation is that various cell organelles are surrounded by membrane and cell organelles contains smaller organelles surrounded by membrane. There is thus 3-fold hierarchy of membrane like structures present. For instance, nucleus, mitochondria and cloroplast basic cell organelles inside plant cell and mitochondria and chloroplast contain smaller structures like cristae and thylakoids. This Russian dolls inside Russian dolls structure suggests strongly interpretation in terms of space-time sheets labelled by p-adic primes. Evolution of cell has proceeded in steps. When new space-time sheet emerged some population of structures of the previous level remained confined inside the new space-time sheet. Some structures left out and remained possibly living fossils.

1. The first step would correspond to the generation of $k = 157$ structures enclosed by cell membrane (say cristae and thylakoids) with size not smaller than $L(157) = 80$ nanometers. The general model predicts that bacteria are preceded by a more primitive form of life corresponding to $k = 157$. Besides viruses and [I2, I10] correspond to this form of life: in fact, the sizes of nannobacteria are reported to be in the range $.2 - .6$ micrometers and thus correspond to p-adic length scale $k = 157$.

2. At the next step emerged the $k = 163$ structures (nucleus, mitochondria and chloroplasts) enclosed by cell membrane and containing structures. $L(163) = .64$ micrometers corresponds to the lower limit for the size of prokaryotes (bacteria) so that bacteria are living fossils from this period of evolution. The fact that bacteria lack membrane bound compartments is consistent with the assumption that they correspond to $k = 163$. The absence of internal membrane bound structures however suggests that they have evolved from $k = 157$ form of life by a gradual growth of cell size.

3. The next step was the emergence of $k = 167$ structures, eukaryotes, closed by a further cell membrane. These structures are the predecessors of animal and plant cells. No larger structures surrounded by cell membrane emerged anymore.

4. The emergence of $k = 169$ space-time sheets must have meant a dramatic breakthrough in the evolution since double cell layers emerged as new structures condensed at $k = 169$ space-time sheet. The emergence of $k = 169$ space-time sheet makes possible the generation of epithelial sheets as autonomous selves and must have led to a proliferation of structures. The explanation for the difference between plants and animals is that this evolutionary step did not occur in case of plants. The reason is trivial: plant cells are surrounded by a wall hindering the formation of join along boundaries contacts between plant cells.

It must be emphasized that these structures, once created continue to evolve and typically sizes can be considerably larger than the p-adic length scale of the simplest structure. Indeed typical cell size seems to vary between $10-100$ micrometers. The basic topological structure however reflects the evolution of these structures.

4.3.12 p-Adic length scale hypothesis and neural evolution

It is tempting to try to identify the components of sensory experience in terms of the p-adic length scales involved. Both the identification for the quantum correlates of the sensory qualia and emotions and the model for cognition [K29, K31] relies on the hierarchy of p-adic space-time sheets representing selves and forming a master-slave hierarchy of weakly coupled super-conductors. Sensory experiences are parameterized by various magnetic transition frequencies serving as resonance frequencies for which Josephson currents induce 'wake-up' of the sub-selves representing sensory mental images. A partial characterization for a component of conscious experience is in terms of p-adic length scales involved with the group of sub-selves, which are 'awake' during a particular conscious experience.

The general rule helping to understand the general evolution of neural consciousness seems to be that the more emotional the experience is, the lower is the corresponding magnetic transition frequency. This is understandable if emotions are byproducts of sensory experiences resulting from the automatic comparison of subjective (real) memories and geometric memories (expectations, simulations). Thus the typical timescale of the experience measures how emotional the experience is: emotions are indeed long-lasting whereas the characteristic time scale of sensory experiencing is below .1 seconds.

p-Adic length scale hierarchy and components of conscious experience

The p-adic primes relevant above bacterium length scale are twin pair $k = 167, 169 = 13^2$, $k = 173$, twin pair $k = 179, 181$, twin pair $191, 193$, and twin pair $k = 197, 199$. Note that with single exception all length scales in this range relevant to the functioning of human brain have twin partner! The density of primes and twin primes (note however that $k = 169 = 13^2$ is power of prime rather than prime) is exceptionally large in this region. This implies that the number of p-adic hierarchy levels per length unit is exceptionally large. Already this observation sheds some understanding to the question why human brain is so miraculously structured system.

After $k = 199$ there is a huge gap in the distribution of twin primes: next pair $(227, 229)$ corresponds corresponds to length scale of 3 kilometers!

1. In TGD framework cognition is based on cognitive neutrino pairs associated with $k = 151$ defects of $k = 169$ neutrino super-conductor. Cognition making possible to assign names to experiences and thinking as internal speech involves the pair formed by the cellular space-time sheet ($k = 169$) and cell membrane space-time sheet ($k = 151$). Despite the short length scale involved, linguistic thought, being a critical phenomenon, is a latecomer in evolution. The model for many-sheeted DNA suggests that genes at chromosome space-time sheet, which also has $k = 151$, could represent our conscious beliefs [K42] and represent one form of Boolean mind realized in terms of cognitive neutrinos. The dramatic difference between eukaryotes and prokaryotes can be explained as the emergence of $k = 169$ space-time sheet and exon-intron degree of freedom making possible Boolean cognition and genetic representation of beliefs. Thus introns seen as 'junk DNA' by hard-nosed materialists is absolutely crucial for consciousness in TGD framework!

2. Primary sensory experiencing corresponds to $k = 169$ at which Earth's magnetic field resides. Sensory modalities which are simple in the sense that they involve very few sub-modalities (vision, taste, tactile sense) can be parameterized in terms of magnetic transition frequencies of ions in Earth's magnetic field.

3. $k = 173$ space-time sheet is identified as a carrier of Earth's Z^0 magnetic field with strength roughly $g_Z B_Z \sim eB/16$ The emergence of this space-time sheet meant the emergence of olfaction with a rich repertoire of sub-modalities having as quantum-correlates the Z^0 magnetic transition frequencies of various particles (atoms, ions and even molecules). Geometric cognition based on the formation of geometric representations for the objects of perceptive field by generating mind like space-time sheets is related with the emergence of $k = 173$ and longer p-adic length scales. The long time scale (low magnetic transition frequency) associated with olfaction explains why olfaction is so emotional experience.

4. $k = 179$ and $k = 181$ form twin pairs and correspond to sizes of ocular dominance columns and double layered sheets formed by them. $k = 179$ would correspond to higher level geometric cognition implying decomposition of the perceptive field into objects.

5. $k = 181$ could integrate left and right cognition to stereo cognition. Stereovision is excellent example of this integration. Usually the right and left visual fields combine to single field and it is impossible to experience them as separate ones. Visual self is in a state of whole body consciousness. This requires entanglement of the left and right visual field. For instance, if person has been drinking too much, the situation changes. Visual field splits into two separate fields. The interpretation is that visual self contains two sub-selves and is not anymore in a state of whole-body consciousness.

Summation hypothesis for conscious experiences explains at least partially the existence of sensory homunculi in brain. Various sensory homunculi would provide maps sensory experience of self at given level to experience of self at the next hierarchy level. This kind of mapping would be necessary since given self forms average about the experiences of its sub-sub-selves. For instance, all experiences from the points of skin would average to single experience without this map at 2 levels above the primary sensory experience.

The stages at which the sizes of subunits of brain have reached critical size given by some p-adic length scale must have been meant dramatic boosts in the rate of the evolution.

Twin pair $(167, 169)$ and bi-layered epithelial sheets

Already bacteria form colonies but one can regard this as join along boundaries condensates having no internal structures. The size $L(167) = 2.22$ micrometers must have meant a decisive critical size in the evolution of cell. When this size of achieved, the formation of bi-layered epithelial sheets as double sheeted structures condensed on newly emerged $k = 169$ space-time sheet became possible and evolution of genuine multi-cellulars became possible. Cells continued still their own evolution and size of order 9 micrometers must have been landmark in the evolution of cell. It would be interesting to know whether there is some neurophysiological identification for this step.

In order to avoid confusion it must be emphasized that the sizes of many cells are much larger than $L(167)$, egg is extreme example of this. This can be understood as a result of evolution of cells which in their primitive form had size given by $L(167)$ leading to a larger p-adic prime characterizing the cell. In case of neurons the complexity of neuron indeed correlates with its size. Thus the proper interpretation of $L(167)$ is as minimal possible size of cell. Also other p-adic length scales should be interpreted in the same spirit.

$k = 173$, Cambrian explosion and field axis orientation columns of cortex

The proposed model for the hierarchy of consciousness predicts that the size $L(173)$ for basic unit of primitive brain could have been a threshold for the emergence of emotions (of course, also other interpretations are possible). The lower bound for neuron radius is $L(167)$ and and sphere with radius $L(173) \simeq 2 \times 10^{-5}$ meters contains roughly $N = 512$ neurons. Actually the number is smaller since neurons are not tightly packed.

The Orch OR model of Penrose and Hameroff [J22] predicts that Cambrian explosion occured, when critical neuron number about 300 (nematode worms! TGD in turn suggests that it was the emergence of $k = 173$ neuronal space-time sheets that led to Cambrian explosion. According to TGD, the emergence of micro-tubuli meant the emergence of vision making possible formation of cell societies. Of course, it is possible that primitive eye had the critical number of $N = 256$ neurons. Cambrian explosion meant the emergence of arthropods and several phyla which do not exist anymore [I17] .

The obvious place for the identification of this kind of structures is cortex. The relatively small thickness of the cortex (about 1 mm) implies that curvature effects do not mask the local cylindrical symmetry. Cortex is indeed known to possess columnar organization. There are in fact several columnar structures. The first columnar structure [J37] in the visual cortex corresponds to the so called field axis orientation columns consisting of locally stripe like regions of cells, which preferentially react to the orientation of a bar of light in the visual field. The width of the stripes with fixed orientation is about $20 - 50$ μm [J37] . The condensation level in question might correspond to $k = 173$ since the lower bound for thickness is $L(173) \simeq 20$ μm.

Twin pair (179, 181) and ocular dominance columns of visual cortex

$k = 179, 181$ forms also a twin pair of length scales. The emergence of brain substructures with size larger than $L(179) \simeq .16$ millimeters must have also meant an explosive stage in evolution. The emergence of $k = 181$ level must have boosted the this explosion further. Note that $k = 179$ cube contains 8^3 structures of size $k = 173$. Thus it can be regarded as a three-dimensional chess-board or 8-move simulation for ordinary chess. Perhaps it is not accident that chess-board has 8×8 squares! It would be interesting to find at what is the level of evolution at which single structural unit reached the size $L(179)$. The first possibility is that the emergence of $k = 179$ space-time sheets meant the emergence of insects. Insects are basically sensory experiences having more sense than we do but not too much brain. Perhaps the emergence $k = 181$ space-time sheets was related to the emergence of vertebrates and stereo-cognition. This evolution step meant that brain size began to grow rapidly.

Also this twin pair of p-adic length scales seems to be realized in brain. Besides orientation columns visual cortex contains also so called ocular dominance columns. Also other parts of cortex contain similar columnar structures. The thickness for ocular dominance columns seems to correspond to $k = 179$ whereas the thickness for a pairs formed by them corresponds to $k = 181$. Ocular dominance columns consist of cells reacting appreciabely to the stimulus from the second eye only and form columnar structures [J37] with complicated cross section and become visible via a continued stimulation of one eye only. The typical width of the stripe in the region is about $.2 - .5$ mm.

The levels $k = 179$ and $k = 181$ forming a pair with $L(179) \simeq .16$ mm might be the relevant p-adic levels now. The ocular dominance columns associated with right and left eye alternate and the regions formed by right-left pairs of ocular dominance colums is natural candidate for the double layered structure at level 179 and corresponds to $k = 181$. Also the hypothesis that $k = 181$ space-time sheet is the level at which right and left cognition integrate to stereo cognition is suggestive.

Larger structures

Hypercolumns as Rubik cube type structures?

Visual cortex contains also larger structures, "hypercolumns" [J37] , which form basic units for the processing of visual information (and sensory information in general). These structures have roughly the size of order 1 mm, the thickness of cortex, and contain few thousand neurons. This length scale does not correspond to directly to any p-adic length scale. A possible interpretation is as a Rubik cube type structures formed from $3^3 = 27$ $k = 181$ cubes. Structures consisting of 3 basic units are rather abundant in brain (for instance, structures consisting of 3 cell layers).

What is the interpretation of the pair (191, 193)*?*

Next structures correspond to the twin pair $k = 191, 193$. $L(191)$ corresponds to cube with size of 1 cm and $k = 193$ to a cube of 2 cm. Pituitary gland seems to be a structure allowing interpretation as pair of structures with size about 1 cm. It however seems that human cortex does not contain these kind of structures as moduli: the reason is simple: the thickness of cortex (grey matter) is only 1 millimeter.

Pair (197, 199) *and brain lobes*

$k = 197$ and 199 form again a twin pair of length scales related by a scaling factor of two. Structures would have size of order $L(197) = 8$ cm and $L(199) = 16$ cm. Could one identify brain lobes as a binary structure related to this pair of p-adic length scales? After this twin prime there is a huge gap in the spectrum of twin primes which suggests that the length scale range covering biological important length scales is indeed exceptional.

4.4 Higher levels in biological self hierarchy

TGD not only predicts infinite hierarchy of selves but also strongly suggests that "me" as an intentional agent should be identified as my field body, or perhaps better to say, my magnetic body having an astrophysical size. Magnetic body would also serve as an intentional agent and controlling biological body by time mirror mechanism. An entire hierarchy of magnetic bodies is predicted since the flux quanta of each body part define corresponding magnetic body. Also the magnetic body of Earth should define a conscious unit, kind of Magnetic Mother Gaia perhaps responsible for some third person aspects of our consciousness. The role of the magnetic body would be like that of a manual of an electronic instrument, that is it would provide a higher level representation for the body and its environment. Magnetic body would also serve as template for the formation of bio-structures. Magnetic body would share the mental images produced by brain as symbolic representations of the sensory input. The basic theoretical arguments supporting the notion of magnetic body derive from p-adic physics as physics of intention and cognition. Also time mirror mechanism of long term memories and Uncertainty Principle applied to EEG provide support for the notion. Some experimental findings supporting the notion of field body are Libet's findings, the role of Schumann resonance frequency for consciousness about time delays of consciousness, and the effects em radiation on brain and living matter at cyclotron frequencies.

This section was written much before the emergence of the zero energy ontology. A first principle justification for the notion of magnetic body is provided by zero energy ontology predicting that primary p-adic length scales are accompanied by secondary p-adic length scales (as well as time scales). For instance, in case of electron the secondary time scale is .1 seconds and correspond to a length scale of order Earth's circumference. It is natural to assign this time scale to the flux tubes of the magnetic body. This aspect will not be discussed explicitly in the sequel but should be kept in mind.

4.4.1 Support for the notion magnetic body

Theoretical support

1. EEG and Uncertainty Principle

There are good reasons to expect that EEG is accompanied by radiation, which in TGD framework has topological light rays as space-time correlates. Typical EEG frequencies correspond to wavelengths $\lambda = c/f$ which for which natural length scale unit is Earth size. Thus Uncertainty Principle suggests that structures of at least this size are involved with the self hierarchy associated with the brain.

2. p-Adic physics as physics of cognition and intentionality

p-Adic physics as physics of intentionality and cognition is a fundamental key idea of TGD inspired theory of consciousness. p-Adic space-time sheets as correlates for intentions and p-adic-to-real transformations of them as correlates for the transformation of intentions to actions allow deeper understanding of also psychological time as a front of p-adic-to-real transition propagating to the direction of the geometric future. Negative energy MEs are absolutely essential for the understanding of how precisely targeted intentionality is realized.

Intentional behavior means that there is unpredictability in short time scales but predictability in long time scales because system can realize its long term plans and use its partially free will to cope with the changing challenges of the everyday life.

p-Adic topology differs radically from real topology in the sense that p-adically infinitesimal is infinite in real sense.

1. The rational values of real and p-adic imbedding space coordinates correspond to the same points of the generalized imbedding space (essentially union of real and p-adic imbedding spaces for various values of p with rational points common to all number fields and also points, in particular points with algebraic number valued coordinates, shared by different number fields in a pair-wise manner identified).

2. The points, which are p-adically close to each other can have arbitrarily long real distance since the points x and $x + kp^n$, $k \in \{0, p-1\}$, become arbitrarily near to each other p-adically and arbitrarily far way in real sense as n increases for the p-adic topology characterized by prime p.

This means that intentionality and cognition are literally cosmic phenomena and evolution of cognition and intentionality proceeds from long p-adic length scales to short ones in real sense (but from short to long scales in p-adic sense). The carving of a statue by starting from a rough sketch and adding details gradually is a good metaphor for what is involved. Development of any motor skill, say piano playing, is an excellent example of what happens.

Intentions are transformed to action in a phase transition changing p-adic space-time sheet to a real one. This process is most probable when real and p-adic space-time sheets have maximal number of common rational points. Hence one expects that intentions can be transformed to large space-time sheets and topological field quanta are best candidates for these space-time sheets. Pairs of positive and negative energy topological light rays and negative energy topological light rays generated in the dropping of particles to larger space-time sheets, provide an example realizations of intentions. Also wormhole magnetic fields consisting of pair of space-time sheets carrying magnetic fields of equal intensity and having opposite time orientations could be generated intentionally.

3. Time mirror mechanism of long term memories

TGD based model of long term memory requires no storage of memories of past to the brain of the geometric now. The memories are in the geometric past as dynamical self organization patterns and subject to changes.

1. In the case of active memory recall the desire to remember is communicated to the geometric past by sharing and fusion of mental images made possible by entanglement. In the case of episodal memories also the memory recall would result in this manner. For non-episodal memories the memory would be communicated from the geometric past using classical communications.

2. In the case of episodal memories active precisely targeted memory recall might be difficult since the entanglement with a correct mental image seems to require good luck. In principle it is possible to select the distance T to the geometric past where the memory comes from by selecting the fundamental frequency of ME.

3. The most natural manner to realize the time mirror mechanism is to regard magnetic body as the system communicating with the brain of the geometric past serving as mirror. The fundamental frequency $f = c/L$ of associated with a topological light ray of length L would naturally code for the time span of the long term memory as $T = L/c$ in the sense that only these memories would be communicated resonantly. Thus the distance from brain along magnetic flux tubes would code the time span of the memory. Long term memories with a span of order lifetime however require that the size of the magnetic body involved is measured in light decades.

Experimental support for the notion of magnetic body

The work of Blackman and other pioneers of bio-electromagnetism concerning the effects of ELF (extremely low frequency) em fields on brain [J43] discussed in [K21] , provides dramatic support for this idea and also a concrete view about how brain manages to act as macroscopic quantum system. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of size of Earth having natural coupling to the magnetic flux tubes.

The lowest Schumann frequency is roughly $c/2\pi R$, R radius of Earth, and equal to $\omega \simeq 8$ Hz. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies 8, 14, 21 ,... Hz [F1] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere. The higher EEG frequencies seem to correlate with higher Schumann resonance frequencies: in particular, the frequencies 13 and 39 Hz which are also cyclotron resonance frequencies of Na_+, are very near to Schumann frequencies. Schumann frequencies vary in time and it has been found that also the variations of EEG frequencies correlate with this variation.

Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and cortical instabilities such micro-seizures and epilepsies [J34, J36]. The photons generated by Josephson currents associated with macroscopic ionic BE condensates have wavelengths of order Earth size and the topological field quanta representing classically the radiation field have size of Earth.

The explanation of the effects related to water memory [I13, I32] suggests that similar magnetic effects appear at much wider frequency range than ELF frequencies which would mean that the superconducting magnetic flux tube circuitries form a fractal hierarchy. The findings challenging the notions of ionic pumps and channels [I27] provide additional strong support for the notion of many-sheeted space-time and hierarchy of super-conducting of magnetic flux tubes. The evidence for the fractal hierarchy of magnetic flux tubes is discussed in [K12, K13] .

These observations support the view that our "physical" body is only a dip of an iceberg and formed by the topological condensation of the bio-matter around electromagnetic topological field quanta serving as templates for the bio-structures.

4.4.2 Some functions of magnetic body

The magnetic bodies associated with various body parts, including cellular and even molecular magnetic bodies, could have several functions besides defining a hierarchy of intentional agents (for this aspect see [K81]).

Topologically quantized classical fields as templates for the formation of bio-structures?

Magnetic bodies could serve as templates of bio-structures. For instance, blood circulation and central nervous system could have magnetic circuitries as templates. The web like structure formed by topological field quanta representing classical fields, in particular em fields, is reminiscent of structures formed by micro-tubuli and collagens forming the connective tissue of living systems. It has been already earlier suggested that magnetic flux tubes and other topological field quanta serve as templates for various bio-structures in the sense that ordinary matter is topologically condensed on the flux tube like structures. This would mean that living systems would be only part of much larger web formed by Earth's classical em field forming one particular sub-self (mental image!) of Mother Gaia.

The thickness for the flux tubes of Earth's magnetic field is about $2/\sqrt{eB} \simeq 4 \times 10^{-6}$ meters. There is direct evidence for the hypothesis that ions in a magnetic field $B_{end} = 2B_E/5 = .2$ Gauss, where $B_E = .5$ Gauss is the nominal value of the Earth's magnetic field, form quantum states with the characteristic energies of order 10^{-14} eV and size of the orbit being of order $2/\sqrt{eB}$, that is cell size. It must be emphasized that B_{end} is not equal to B_E as I erratically believed for a long time. The model for dark matter as macroscopic quantum phases with Planck constant equal to an integer multiple of the ordinary Planck constant [K25] leads to the working hypothesis that B_{end} corresponds to the dark counterpart of B_E [K21] .

For $B_{end} = 2/5B_E = .2$ Gauss interpreted as a dark magnetic field with $\hbar = 5\hbar_0$ carrying 2 units of flux (the unit is $h_5 = 5h_0$) and corresponding also to the p-adic length scale $L(169)$, the radius is 25 μm, the size of a large neuron. This possibly relates to the fact that the effects of ELF em fields are observed for vertebrates (for details see [K21]).

The coupling of the neuronal layers of cortex and perhaps all cells with the flux tubes of Earth's magnetic field could make possible entanglement between brain and Mother Gaia. If magnetic flux tubes of the dark counterpart of B_E have direct geometric coupling with brain one could perhaps understand the miraculous ability of birds and bees to navigate using Earth's magnetic field. The proteins navigating along micro-tubuli, cells navigating along collagen fibres and birds navigating along Earth's magnetic field lines would all be guided by higher level selves.

One could see also humans and the societies formed by them as continually self-organizing organs in the body of electromagnetic Mother Gaia. In this picture the narrow wave cavity of radius 80 km between Earth's surface and ionosphere could be like brain of Earth, which is very sensitive to the conditions of ionosphere and biosphere and has "biofeedback" coupling with living systems. The effect of oscillatory phenomena (sound, radiations and magnetic fields) at frequencies Schumann resonances on brain to be discussed below supports also the direct interaction of our brain with Mother Gaia via Earth's electromagnetic field.

It is interesting to notice that the ratio of the thickness of solar corona (10^6 m) to the radius of Sun (5×10^8 m), the height of the wave cavity of Earth (80 km) to Earth radius (7×10^6 m), the ratio of the thickness of grey matter of cortex (1 mm)to the size of human brain lobe (10 cm) as well as the the ratio of the thickness of the cell membrane (10^{-8} m) to the radius of neuron (2.5×10^{-6}) have roughly the same value of order 10^{-2}. Could this mean that cell membrane, cortex, electromagnetic cavity of Earth and solar corona might have similar role in the self hierarchy? The general ideas about self-organization indeed support this view: boundary regions are subject to the most intense external energy feed and thus self-organize most effectively.

The web formed by topological field quanta of the classical em and Z^0 fields continues to arbitrary long length scales. For instance, the flux tube structure of solar magnetic field provides an explanation for the anomalously high temperature of solar corona and a model for solar spot cycle [K67] . Perhaps also Sun is a conscious self forming part of "Indra's net" representing electromagnetic and other classical fields of cosmos. Since the four CP_2 coordinates are the primary dynamical variables, one must consider the possibility that topologically quantized classical gauge fields and classical gravitational field could form rather independent sub-selves.

Dark magnetic fields and living matter

A considerable sharpening of the above discussed speculative picture came with the development of TGD inspired vision about dark matter as macroscopic quantum phases with quantized value of Planck constant having arbitrarily large values coming as integer multiples of the ordinary Planck constant [K25] .

As often occurs, also the spotting of errors leads to important new insights. For years I erratically believed that the magnitude of the magnetic field assignable to the biological body is $B_E = .5$ Gauss, the nominal value of the Earth's magnetic field. Probably I had made the calculational error at very early stage when taking Ca^{++} cyclotron frequency as a standard. I am grateful for Bulgarian physicist Rossen Kolarov for pointing to me that the precise magnitude of the magnetic field implying the observed 15 Hz cyclotron frequency for Ca^{++} is .2 Gauss and thus slightly smaller than the minimum value .3 Gauss of B_E. This value must be assigned to the magnetic body carrying dark matter rather than to the flux quanta of the Earth's magnetic field. This field value corresponds roughly to the magnitude of B_E at distance 1.4R, R the radius of Earth.

Dark matter hierarchy leads to a detailed quantitative view about quantum biology with several testable predictions [K21] . The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of dark matter levels is labeled by the values of Planck constant having quantized but arbitrarily large values. For the most general option the values of $\hbar$ are products and ratios of two integers. The products of distinct Fermat primes and power of two are number theoretically favored values for these integers. p-Adic length scale hypothesis favors powers of two. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T \propto \hbar$ of the quantum jump.

Each p-adic length scale corresponds to this kind of hierarchy. Number theoretical arguments suggest that the values of n for which quantum phase $q = exp(i2\pi/n)$ is expressible using only iterated square root operation are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales. The unit of magnetic flux scales up as $h_0 \rightarrow h = nh_0$ in the transition increasing Planck constant: this is achieved by scalings $L(k) \rightarrow nL(k)$ and $B \rightarrow B/n$.

$B = .2$ Gauss would corresponds to a flux tube radius $L = \sqrt{5/2} \times L(169) \simeq 1.58L(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 18$ μm, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth's magnetic field. Furthermore, the model for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5. Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4cos^2(\pi/n)$ equal to Golden Mean [K83] .

An natural working hypothesis is that B_{end} defines the dark counterpart of the ordinary magnetosphere and that the relationship $B_{end} = 2B_E/5$ holds as a time average in the entire magnetosphere. The flux quanta of B_{end} would carry dark matter and would be responsible for the quantum control of the living matter.

Magnetic flux tubes and metabolism

Magnetic flux tubes could define super-conducting circuitry making possible a many-sheeted control of homeostasis: this aspect is discussed in [K37] . The hierarchy of magnetic flux tubes could also define many-sheeted lasers, and the dropping of particles to the larger space-time sheets would define a hierarchy of metabolic energy currencies as zero point kinetic energies liberated in the process. Process would also generate radiation at the harmonics of cyclotron frequencies at the larger space-time sheet . These frequencies could define a considerable part of EEG. Also fractally scaled up versions of EEG having similar band structure are predicted. The findings of Peter [?] [I16] are consistent with this prediction [K10] . The dropping of particles to larger space-time sheets for population inverted lasers would be also ideal for the realization of bio-control by time mirror mechanism and make possible remote metabolism and remote motor control.

Magnetic flux tubes as Nature's own bio-laboratory

Magnetic flux tubes could be ideal structures for the isolation and purification of various bio-molecules, and make also possible precise targeting of the reactants to reaction volumes defined by the nodes of the magnetic flux tube circuitry. Purification is made possible by the weight of the molecule if quantum-classical correspondence holds true in the sense that a magnetic flux tube carrying super-conducting bosons of mass m deforms so that it runs along a classical orbit of the particle with radius proportional to m. This would make sense for a many-sheeted magnetic field for which the fluxes associated with the magnetic flux tubes along which particles move return along much larger space-time sheets and define the average magnetic field in which the particles move. This kind of Nature's own bio-laboratory might explain the miraculous selection of bio-molecules essential for the pre-biotic evolution. In accordance with the p-adic vision about the evolution of cognition, the evolution would have been proceeded from and guided by the magnetic flux tube structures of the Earth's magnetic field to the bio-chemical level [K27] .

4.4.3 The magnetic fields associated with body parts and higher levels of consciousness

The basic vision is that magnetic flux tubes containing ionic super-conductors, MEs carrying exotic representations of p-adic Super Virasoro algebra, and biological organisms live in a fractal symbiosis. MEs can induce cyclotron transitions amplified to quantum phase transitions inside magnetic flux tubes provided they have length above the wavelength defined by the cyclotron frequency. The exotic p-adic Super Virasoro representations with MEs have wavelength determined by the fundamental frequency which is of same order as the cyclotron frequency. The interaction of MEs and magnetic flux tubes by SQUID mechanism requires that magnetic flux of ME generates a current inside a circuit formed by magnetic flux tubes. Magnetic flux tubes to have arbitrary size scales below the size scale of ME.

Some body parts are carriers of static magnetic fields. The value of the static magnetic field associated with eye is slightly below 10^{-11} Tesla whereas the strength of Earth's magnetic field is about $.5 \times 10^{-4}$ Tesla. Also pineal gland ('third eye' also in a rather literal sense, see [K29]) contains magnetic material. Unfortunately I do know the value of the corresponding dipole strength: for a dipole having size of order micrometer the maximal dipole strength would be very roughly 10^{-9} times corresponding dipole strength for Earth's magnetic field which would mean field of order 10^{-13} T. Also head and entire body could act as static magnetic dipoles.

For purely sensory consciousness .1 seconds is the characteristic time scale and EEG is closely related with this form of consciousness. In case of B_e the magnetic cyclotron frequencies are in the range obtained by scaling the range of cyclotron frequencies in Earth's magnetic field by a factor about 2×10^{-7}. This means that the periods of the ionic cyclotron frequencies are roughly in the range 12 hours-1.6 years for ionic cyclotron frequencies corresponding to the range of frequencies $90 - 0.1$ Hz in Earth's magnetic field. These time scales are typical for the contents of higher level self consciousness involving self narrative. Notice however that these fields are perhaps not sufficiently weak for a self narrative in the time scale of several years.

The minimal thickness of the flux tubes for ULF selves associated with B_e would be roughly of the order of few millimeters, as one finds by scaling the radius for the flux tube of Earth's magnetic field which is about 5 microns.

Also bodily magnetic fields B_b could be involved. By scaling one obtains for the head's magnetic field an estimate $(mm/headsize)^2 B_e \sim 10^{-4} B_e$, which gives fT which is slightly above the thermal noise produced by body. The flux tube would have minimal thickness about 10 cm, the size scale of the head. The cyclotron frequency range would be scaled by a further factor of 10^4 factor meaning that the time scale range would be between 10 years and 10^4 years!

Could the flux tubes of bodily magnetic fields correlate with more abstract levels of self consciousness?

The previous observations combined with the general speculative vision about Indra's web of consciousness stimulate several questions and ideas relating to the role of various magnetic fields associated with body.

1. Could it be that the ULF selves associated with the ionic super-conductors residing at the flux tubes of the bodily magnetic fields B_e and B_b (notice also the static magnetic fields of pineal gland and of other organs) belong to the self hierarchy and represent higher level selves contributing to our non-sensory consciousness under ordinary circumstances? This translates to the question whether the flux tubes of the corresponding topological quantized magnetic fields are closed in a relatively small volume as in case of an ideal dipole field or whether part of flux tubes have astrophysical lengths.

2. The above arguments do not pose restrictions on the strengths of the magnetic fields. In case of Earth's magnetic field the magnetic flux tubes have sizes of order of the wavelength associated with a typical cyclotron frequency. Could it be that the interacting MEs and magnetic flux tubes have sizes comparable to the wavelength defined by cyclotron frequency? If this is the case for B_e and B_b, the sizes of flux tubes would be astronomical with light day serving as lower bound. One could see the flux tubes of B_e and B_b as kind of umbilical cords connecting human bodies with magnetic structures of astronomical size and perhaps also with other organisms. Could one assign the more abstract levels of human consciousness and long term memories with the ULF selves associated with both the flux tubes of B_e and B_b and with MEs? In this view biological organisms would be like sensory-motor organs of this magnetic super organism.

3. Could one possibly test this hypothesis in case of B_e by studying the interaction of ULF em fields with frequencies above the time scale defined by day? Is the daily rhythm somehow relevant at the level of these em fields? For instance, could the natural 24 hour period certainly associated with ULF em fields of eye define the analog of alpha peak in EEG? Could the strength of the magnetic fields of eye be seen as a result of adaptation to the daily rhythm or is it dictated by the size of eye and flux quantization (there is roughly unit flux over an area of order millimeter squared)?

Objection

The bodily magnetic field change with time if the location orientation of the magnetic dipoles are fixed with body. Already the rotation of Earth induces periodic rotation of the magnetic flux tubes B_e and B_b. The volitional motion during wake-up period induces further effects.

There are several manners to circumvent this objection.

1. The most convincing manner to avoid the objection is that the flux tubes relevant for ULF consciousness have size at least of order of the wavelength defined by the cyclotron frequency and thus of the same order of magnitude as the size of the corresponding MEs. In this scale the rotating motion for the end of the magnetic flux tube of B_e or B_b would have absolutely no significance and magnetic flux tubes would be somewhat like magnetic umbilic cords (like the tunnel involved with the NDE experiences connecting patient to the deceased relatives!).

2. If the magnetic flux tubes in question have sizes comparable or smaller than Earth size, the situation changes. Only in the very special case that the flux tubes rotate around Earth in the direction of equator, B_e and B_b could remain stationary and it makes sense to speak about stationary states.

3. One could also consider the possibility that magnetic flux quanta are layer like structures around Earth rather than rotating tubular structures, and have rotational symmetry with respect to the rotations around Earth axis so that it is body which is rotating with respect to these structures rather that these structures rotating with body. In this case it would make sense to assign cyclotron frequencies to the super-conducting ions in question since local magnetic states are certainly possible. In super-conductors of type I near critical temperature complicated layer like

flux structures are indeed possible and in [K12, K13] it has been suggested that epithelial sheets formed by cell membrane inside cells correspond to this kind of flux structures.

The obvious question is how the rotation of Earth affects localized stationary states of the superconducting ions inside co-rotating magnetic flux tubes with sizes smaller than Earth size. Does the description of the system in terms of cyclotron states make sense anymore? Quantum mechanically the ion in a stationary magnetic magnetic field is in radial degrees of freedom like a harmonic oscillator.

1. A simple analog system would be a harmonic oscillator rotating with an Earth and having an oscillation period which is longer than 12 hours. By separating center of mass degrees of freedom one finds that the particle in the rotating oscillator well feels besides the ordinary harmonic force a harmonic force $m\omega^2\overline{r}_{cm}$ which means that the complete solution to the equations of motion is superposition of the harmonic oscillator motion plus a periodic oscillatory term with the frequency of the external force. The average motion is therefore just the rotating harmonic oscillator motion.

2. In quantum case one has harmonic oscillator coupled to an external harmonic force having a frequency much larger than the oscillator frequency. Time dependent perturbation theory allows transitions only between the states whose energy difference $n\omega_0$ equals to the forcing frequency and transitions thus possible only if one has $\omega = n\omega_0$. Thus no quantum jumps would occur in the generic case.

3. The guess motivated by these considerations is that the magnetic state in a rotating magnetic field is in a good approximation obtained by applying time dependent rotation to the ordinary magnetic state and that in the time scale defined by the cyclotron frequency the average effects to the state cancel also now. Thus effective adiabaticity holds true.

Further questions related to vision

One can make several interesting questions related to vision and the magnetic fields of eye.

1. What is the role of the rapid eye movements during REM sleep, in particular during dreams? Could it be that the communication of long term memories from ULF level is involved with dreams and that the rhythmic eye movements are essential for establishing this communication?

2. The motor control associated with eyes is decoupled from the motor control of the remaining body. Therefore persons who are totally paralyzed can still move their eyes and can even communicate in this manner. Could the special role of the eye-motorics relate to the remaining ability to stay in contact with ULF selves associated with eyes?

3. What is the interpretation of the rays of light characterizing the visual perception of intense light. Perhaps there is some natural explanation for this but since I do not know about it, I can entertain myself with the idea that these rays could directly correspond to MEs representing rays of light and connecting me with the objects of the external world. The correspondence between sensory experience and reality would be amazingly simple, if this is true.

NDE experiences and magnetic consciousness

NDE experiences [J9, J28] involve vision in an essential manner. This suggests that the dominating component of NDE consciousness could correspond to ULF selves associated with B_e and or B_b and give rise to the typical bird's eye of view about own body involved with the OBE and NDE experiences. The cyclotron frequency time scale associated with B_b would indeed fit with the life review experienced in NDE experiences. Body would be seen by ULF selves in bird's eye of view through the magnetic flux tubes of B_e and B_b. There would be a strange resiprocity resembling to the resiprocity encountered in the techniques of radio communications where the antennae sending messages can also serve as receiving antennae. NDE experiences involve also meeting of the dead relatives. Magnetic flux tubes can connect patient also to other organisms. and it would not be too surprising if magnetic flux tubes starting from the body could serve as an umbilic cord connecting the patient with living relatives or magnetic structures representing deceased relatives.

NDE experiences involve also the experience of travelling through a tunnel. The tunnel is experienced also during epilepsy and migraine, during meditation and relaxed state of mind, and with certain drugs like LSD, philocybin and mescaline.

I have also personal 'tunnel experiences' every-daily: when I close my eyes in a half-meditative state achieved by writing at computer terminal, I can see a dim flow consisting of points. Typically this flow enters to or emergences from a tunnel. It can be rotating spiral like flow or simple sink or source. Source or sink can be also linear structure. The experience is not stable and tends to fade away all the time, and after few minutes I am not anymore able to achieve it. During my great experiences this flow was much more complicated and completely visible and formed a stable background of the ordinary visual experience and of hallucinatory visual images.

There is however no experience of entering into the tunnel in this case so that the tunnel need not be the same as encountered in NDEs. I have pondered quite a many times about the possible interpretation of this background flow. The basic observation was that it resembles liquid flow to a very high extent. Liquid flows are usually incompressible in an excellent approximation and this means that the velocity field is divergence free. This is the basic property of also magnetic fields and means that magnetic flux through a circuit moving along magnetic flux lines is conserved. This has stimulated the obvious guess that the background flow indeed represents magnetic field. The question which I have not made is whether this magnetic field resides inside my brain or outside it. In light of the above considerations the most natural answer to the question is that the magnetic field visualized by the flow is precisely where it seems to be. The flow would represent nothing but the magnetic field associated with my own eyes or more probably head, or rather how the self associated with the flux tubes of this magnetic field experiences the world.

The thickness of the flux tubes of B_b would be roughly the size of the head and this fits with idea that the tunnel experience represents directly the magnetic flow without any scaling factors involved. The fractality of TGD Universe suggests that these magnetic fields contain flux tubes of stronger magnetic fields inside them, so that the tunnel experience would represent the flux tubes of these magnetic fields experienced as sub-selves by the ULF self contributing to my visual consciousness in this altered state of consciousness. Of course, it might well be that also during the ordinary consciousness the experiencer is this magnetic ULF self and that sensory input dominates the content of the conscious experience and creates the illusion about body as self. In the absence of a sensory input the contents of consciousness of a clinically dead person is determined by these magnetic field and bird's eye of view about body results.

What remains after the physical death could therefore be determined by the magnetic fields involved with body. Magnetic flux conservation allows configurations of the closed magnetic flux loops containing ionic super-conductors as the counterpart of soul continuing existence after death. Wormhole magnetic fields and p-adic variants of these magnetic fields would also make it possible to store information about the magnetic fields originally associated with body. The overall view suggesting itself that our bodies are like sensors and motor organs of a gigantic electromagnetic organisms of astrophysical size and represent its sub-selves (mental images). This interpretation conforms with the fact that in EMDR method rhythmic eye movements induce experiences involving the meeting of deceased relatives [J11] .

The experimental study of what happens to the magnetic fields associated with eyes, head and other body parts after the physical death would obviously provide interesting information in this respect, perhaps one can someday even develop refined methods of communication with the deceased.

What about magnetic fields of heart?

The magnetic fields associated with eyes are not the only bodily magnetic fields with peak intensities higher than the non-static magnetic fields generated by brain. Heart generates a periodically oscillating magnetic field B_h of order $.5\times 10^{-10}$ Tesla which is almost ten times higher than the static magnetic field generated by eyes. I do not know whether B_h contains a static component and if so, what is its strength. In any case, the absence of the static component means that the possibly super-conducting ions inside flux tubes of heart's magnetic field are in a periodically oscillating dipole field (most probably with respect to the geometric time!).

Also here my 'great experience', which has turned out to be an extremely valuable repertoire of altered states of consciousness, provides an illustrative example. During the second great experience which lasted only one night, I experienced what might be called 'heart consciousness'. In the beginning of the experience my whole consciousness was filled by the rhythmic '..aqua-aqua-aqua..'. It took some time to recognize that this rhythm was the rhythm of my own heart. Involved was also the mystical experience about the fundamental importance of water for life (said jokingly, heart is an organ specialized to deal with liquid!) and the precognition of the notion of infinite primes. Could it be that the MEs associated with heart dominated the contents of my consciousness during this experience.

Chapter 5

Quantum Control and Coordination in Bio-Systems: Part I

5.1 Introduction

The purpose of this and next chapter is to discuss a model of quantum control and coordination at general level and consider also some examples. Before dwelling down to the details, it is useful to briefly describe the basic philosophy in its present form. A more detailed view about about background can be found from the previous chapters [K65, K52, K14] .

5.1.1 Quantum criticality as a prerequisite for quantum control

Hierarchies involve masters and slaves. Master-slave hierarchy, defined in the spirit of Haken's theory of self-organization, is indeed a natural dynamical correlate of the self hierarchy. Quantum control is possible only if the system is initial value sensitive, that is critical. TGD universe is indeed quantum critical: this also predicts the existence of macroscopic quantum phases in all length scales. Quantum criticality implies initial value sensitivity. There is very beautiful connection with information theoretic aspects: quantum critical universe is in a well defined sense the most intelligent and interesting universe that can exist in TGD framework. Quantum criticality fixes the value of the Kähler coupling strength as a parameter analogous to critical temperature and makes TGD a unique theory (as a matter fact, entire hierarchy of values corresponding to p-adic length scale hierarchy appears).

Quantum criticality should have also space-time correlate. The modified Dirac equation allows to reduce the construction of the geometry of the world of classical worlds (WCW) to the fermionic level needed to construct gamma matrices of WCW. The preferred extremals defining the analogs of Bohr orbits must be critical in the sense of having an infinite number of deformations for which the second variation of Kähler action vanishes. The criticality of Kähler action would thus the basic dynamical principle of space-time dynamics. Purely number theoretic conditions in turn lead to the conclusion that space-time surfaces must be hyper-quaternionic in the sense that the modified gamma matrices span hyper-quaternionic (asociative) or co-hyper-quaternionic (co-associative) plane at each point of the spacce-time surface. "Co-" means that the orthogonal complement of this plane is hyper-quaternionic (associative). Whether criticality and associativity (co-associativity) are consistent is not clear.

$1/f$ noise, which seems to be universal phenomenon popping up in all kinds of contexts, provides direct evidence for quantum criticality. The standard explanation as self-organized criticality is subject to severe criticism since criticality by the definition is something unstable. Situation changes if the fundamental constant of Nature is analogous to critical temperature: there exists simply no perturbations external to the entire universe changing the value of a fundamental constant.

Spin glass analogy could be regarded as one aspect of quantum criticality and states the TGD universe can be regarded as quantum spin glass. Quantum spin glass is phenomenologically characterized by its fractal energy landscape containing valleys inside valleys inside valleys giving rise to extremely complicated system. Quantum self-organization can be described as motion in this kind of energy landscape. p-Adicity can be regarded as one aspect of the quantum spin glassiness. Bio-system as a self-organizing quantum critical spin glass together with the notion of many-sheeted space-time provides rather restrictive general guide line for attempts to construct a general theory of bio-control and -coordination.

5.1.2 p-Adic evolution

Number theoretic entanglement entropies served as the key to a deeper understanding of what distinguishes living matter from dead matter. These entropies can be negative but make sense only if entanglement probabilities are real or algebraic numbers in the extension of p-adic numbers considered. This is implied by number theoretic universality in the intersection of real and p-adic variants of the imbedding space which at QFT limit of TGD correspond to discrete points of partonic 2-surfaces carrying elementary particle numbers. Their motion along light-like 3-surfaces gives rise to number theoretic braids [K17] .

At configuration space level the intersection of real and p-adic worlds would correspond to a more abstract intersection with the counterpart of rationals identified as light-like 3-surfaces represented by rational functions with rational coefficients identifiable as common to real and p-adic worlds. State function reduction to the intersection of p-adic and real worlds would induce also the rationality (or algebraic number property) of the entanglement probalities since they must make sense both p-adically and in the real sense. One might say that the enlightment means living in both real and p-adic world simultaneously.

One manner to understand the special role of rationals and algebraics relies on the observation that rationals represent islands of order in the sea of chaos defined by reals since their pinary expansion is predictable and analogous to a periodic orbit of a dynamical system whereas for a generic real number there is no manner to predict the pinary expansion.

The phase transitions transforming p-adic space-time sheets to real ones could be understood as a tunneling through the intersection of the p-adic and real worlds: here zero energy ontology is absolutely essential in order to avoid the problems caused by the impossibility to compare directly real and p-adic quantum numbers and by the non-existence of p-adic conserved charges caused by the lack of definite integral (field equations however make sense). This would provide one candidate for the formation of cognitive representation on one hand and for the transformation of intention to action on the other hand. Only living matter could carry negentropic entanglement and evolution would take place in the intersection of p-adic and real worlds.

If one accepts the idea that living matter resides in the intersection of real and p-adic worlds it becomes easy to accept effective p-adic topology of real space-time sheets in turn justifying the hypothesis that evolution corresponds to p-adic evolution. Evolution could be seen as diffusion in the discrete space defined by primes and since the number of primes larger than given prime is infinite, evolution as the gradual increase of typical p-adic prime is unavoidable. This hypothesis is testable. The reason is that p-adic length scale hypothesis selects very few physically interesting primes in the range of biologically interesting length scales and makes the notion of p-adic evolution very predictive. The hierarchy of the p-adic primes should also correspond to the hierarchical structure of consciousness.

The infinite size of the universe forces to introduce the notion of infinite primes and corresponding p-adic topologies. Infinite primes have decomposition into finite primes labelling space-time sheets possessing p-adic topology. The notion of infinite prime allows to understand the evolution as two kinds of processes. First process is continuous and corresponds to a gradual increase of the finite p-adic prime associated with the existing physical system. Second process is discontinuous and involves the emergence of entirely new p-adic space-time sheets. The gradual increase of the cell size during evolution and the sudden emergence of multicellular structures provide examples of these two aspects of the evolution. The increase of the finite prime corresponds to a gradual refinement of the corresponding p-adic topology in the sense that the notion of nearness as it is realized at the level of conscious experience, becomes more and more refined. Also the maximum information content of conscious experiences increases with p-adic prime. Thus a measure for the complexity of a conscious system is in question. Identification of p-adic physics as physics of cognitive representations adds considerable concreteness to this vision and one ends up with rather concrete ideas about how thought is transformed to actions and sensory input is transformed to thought.

5.1.3 Self-hierarchy, quantum self-organization, and dissipation as a Darwinian selector

The breakthrough idea in TGD inspired theory of consciousness was the notion of self defined as a subsystem able to remain unentangled during the unitary quantum "time evolutions" U associated with quantum jumps $\Psi_i \to U\Psi_i \to \Psi_f$. The notion of self leads to the concept of self hierarchy and the interpretation of quantum self-organization as evolution of selves [K65] . Zero energy ontology implies that quantum states correspond to physical events in standard ontology. This means that self has extension in time direction and has causal diamonds (CDs) defined as intersections of future and past directed light-cones as imbedding space-time correlates and space-time sheets within CDs as space-time correlates. Self corresponds therefore to a finite-sized object in both spatial and temporal directions and can be seen as a classical self-organization pattern at space-time level. Quantum jumps replace this pattern gradually with an asymptotic self-organization pattern.

Nengentropy Maximization Principle combined with the possibility of positive entangelement negentropy favors the formation of entangled states in the interection of real and p-adic worlds identified as living matter. If consciousness is not lost in quantum jump leading to negentropic bound state entanglement but expands instead, co-operation becomes a manner to survive so that the selection of the fittest would mean also selection of the most un-selfish one. Unselfish genes would be the survivors.

A system possessing self (possibly having sub-selves) performs quantum jumps and dissipates. This leads to quantum self-organization leading to asymptotic patterns selected by dissipation, which thus acts as a Darwinian selector of both memes and genes. Actually, there is no deep difference between genes and memes (understood here rather metaphorically) since selves are always conscious systems and consciousness is present already at elementary particle level. In light of this, the notion of the self hierarchy should be of crucial importance for the understanding of living systems and the purpose of this chapter is to demonstrate this and also to propose a general view about how biological self hierarchy is realized dynamically.

One of the important consequences of the quantum self-organization is that it provides justification for the use of cybernetic notions in the description of bio-systems. Many neuroscientists (and even physicists!) who claim that it is possible to understand brain in terms of classical notions fail to realize that the notions used are very far from classical. For instance, Hodkin-Huxley equations for nerve pulse involve in an absolutely essential manner dissipation. It is the very presence of self which makes dissipation possible! Actually any description involving kinetic equations and irreversibility instead of classical field equations implicitly assumes that system is part of self! In particular, the notions of feedback, neural circuits, excitation, inhibition, signalling,... are all notions, which are not possible in the context of classical physics. The basic signature of self is that it seems the world look like classical in the eyes of neuroscientist!

5.1.4 The prerequisites for macro-temporal quantum coherence

Macroscopic and macro-temporal quantum coherence is an essential element of quantum consciousness theories: for instance, quantum coherence is necessary prerequisite for quantum bio-computation. The basic objection against these theories is that the de-coherence time, which tells in which time scale Schrödinger equation applies, is quite too short to allow macroscopic coherence in the required time scales which could be even of order .1 seconds [J42] .

These arguments are however based on a theory, which contains an inherent logical contradiction (nondeterminism of quantum jump contra determinism of Schrödinger equation) and rely on standard physics. In TGD the mentioned contradiction disappears, and standard physics is replaced with a physics in many-sheeted space-time. In particular, zero modes and quantum spin glass degeneracy emerge as completely new elements absent from quantum quantum field theories, and these elements together with quantum criticality help to understand how macro-temporal quantum coherence is generated. A close relation with the ideas of Penrose and Hameroff results because spin glass degeneracy is due to the presence of a large number of space-time sheets differing only by their classical gravitational energy. Spin glass degeneracy is mathematically identical with a broken $U(1)$ gauge symmetry since CP_2 canonical transformations leaving induced Kähler form invariant and acting as approximate symmetries act like $U(1)$ gauge transformations.

The original belief was that one could do without further elements. This belief was wrong.

1. Zero energy ontology favors formation of macroscopic quantum phases. The notion of causal diamond (CD) explains p-adic length scale hypothesis assigning to elementary particles primary p-adic length scale of order Compton length. The size scale of CD itself corresponds to secondary p-adic length scale which is typically macroscopic even in the case of elementary particles. For electron the time scale in question is .1 second which corresponds to a length scale slightly below Earth's circumference. CDs define naturally macroscopic quantum systems and magnetic body is the natural candidate for this system. The time scale of CD defines the geometric time scale of memory and planned action and also the time scale naturally of quantum computation like processes assignable to self during quantum jump (unitary process U followed by a sequence of state function reductions leaving only bound state entanglement or negentropic entanglement).

2. Various anomalies related to living matter hower - in particular, the strange effects of ELF em fields on vertebrate brain, lead to a generalization of quantum theory by introducing a hierarchy of Planck constants. The mathematical formulation requires a generalization of the notion of imbedding space by replacing it with a book like structure with pages characterized partially by the values of Planck constant which can have arbitrary large values. In particular, the Planck constant associated with the space-time sheets mediating gravitational interactions has a gigantic value this means that all quantum scales are scaled up and macroscopic quantum coherence becomes possible even in cosmological time scales.

The model of DNA as topological quantum computer relies on the notion of magnetic body, CD, and the hierarchy of Planck constants [K24] . This hierarchy provides also the basic mechanisms of catalytic action and of the phase transitions characterizing gel phase. The reconnection of magnetic flux tubes is the first mechanism of this kind. Shorterining or lengthening of the magnetic flux tubes in a phase transition changing the value of Planck constant is second key mechanism.

The fact that oxidative metabolism is anomalously low during a neuronal synchrony supports the view that neuronal synchrony might give rise to negentropic bound-state entangled multineuron states in 'state of oneness'(the liberated binding energy would be usable energy). The quantum computations performed by the neuronal groups might last the typical duration of 'feature', which is about .1 seconds, typical time scale of alpha rhythm. This also suggests that Cooper pairs of electrons are in crucial role. Also the breaking of second law of thermodynamics is predicted in time scale of the negentropic bound state. p-Adic length scale hypothesis actually suggests an entire hierarchy of breakings of second law occurring below p-adic time scale.

5.1.5 TGD based view about dark matter

TGD suggests an explanation of dark matter as a macroscopically quantum coherent phase residing at larger space-time sheets [K20] .

1. TGD suggests that $\hbar$ is dynamical and possesses a spectrum expressible in terms of generalized Beraha numbers $B_r = 4cos^2(\pi/r)$, where $r > 3$ is a rational number [K84, K20] . Just above $r = 3$ arbitrarily large values of $\hbar$ and thus also macroscopic quantum phases are possible. The criterion for transition to large $\hbar$ phase is the failure of perturbative expansion so that Mother Nature takes care of the problems of theoretician. A good guess is that the criticality condition reads as $Q_1Q_2\alpha \simeq 1$ where Q_i are gauge charges and α gauge coupling strength. This leads to universal properties of the large $\hbar$ phase. For instance, $\hbar$ is scaled in the transition to dark phase by a harmonic or subharmonic of parameter $1/v_0 \simeq 2^{11}$ which is essentially the ratio of CP_2 length scale and Planck length [K67, K20] . The criticality condition can be applied also to dark matter itself and entire hierarchy of dark matters is predicted corresponding to the spectrum of values of $\hbar$.

2. An infinite hierarchy of dark matters is predicted [K28] . The basic hierarchy corresponds to the values of $\hbar$ coming as $\lambda^m\hbar(1,m)$, $\lambda = v_0/n$, $v_0 \simeq 2^{11}$. $\hbar(1,m)$ corresponds to the values of $\hbar$ labelled by Beraha numbers B_m. Second hierarchy corresponds to particles labelled by selected integers characterizing the p-adic length scales of particles with which the particle interacts. Direct interactions occur only between the particles characterized by integers having common p-adic prime factors characterizing the p-adic length scales of bosons exchanged in the interaction. The algebraic extensions of p-adic numbers define an additional hierarchy. Also the notion of darkness must be refined by attributes partial and relative.

3. From the point of view of nuclear physics application of this hypothesis is to QCD. The prediction is that the electromagnetic Compton sizes of dark quarks are scaled from $L(107)$ to about $2^{11}L(107) = L(129) = 2L(127)$, which is larger than the p-adic electromagnetic size of electron! The classical scattering cross sections are not changed but changes the geometric sizes of dark quarks, hadrons, and nuclei. The original hypothesis that ordinary valence quarks are dark whereas sea quarks correspond to ordinary value of $\hbar$ is taken as a starting point. In accordance with the earlier model, nucleons in atomic nuclei are assumed to be accompanied by color bonds connecting exotic quark and anti-quark characterized p-adic length scale $L(127)$ with ordinary value of $\hbar$ and having thus scaled down mass of order MeV. The strong binding would be due the color bonds having exotic quark and anti-quark at their ends.

4. Quantum classical correspondence suggests that classical long ranged electro-weak gauge fields serve as classical space-time correlates for dark electro-weak gauge bosons, which are massless below the appropriate weak length scale L_w. This hypothesis could explain the special properties of bio-matter, in particular the chiral selection as resulting from the coupling to dark Z^0 quanta. Long range weak forces present in TGD counterpart of Higgs=0 phase should allow to understand the differences between biochemistry and the chemistry of dead matter.

5. For ordinary condensed matter quarks and leptons Z^0 charge are screened in electro-weak length scale whereas in dark matter $k = 89$ electro-weak space-time sheet have suffered a phase transition to a p-adic topology with a larger value of k. Gaussian Mersennes, in particular those associated with $k = 113, 151, 157, 163, 167$ are excellent candidates in this respect. The particles of this exotic phase of matter would have complex conformal weights closely related to the zeros of Riemann Zeta. The simplest possibility is that they correspond to a single non-trivial zero of Zeta and there is infinite hierarchy of particles of this kind.

   In dark matter phase weak gauge fluxes could be feeded to say $k = k_Z = 169$ space-time sheet corresponding to neutrino Compton length and having size of cell. For this scenario to make sense it is essential that p-adic thermodynamics predicts for dark quarks and leptons essentially the same masses as for their ordinary counterparts [K43] .

5.1.6 Topological field quantization

Topological field quantization assigns to various quantum concepts rather precise geometrical correlates. Absolute minimization of Kähler action implies that the space-time surface associated with given 3-surface satisfies generalized Bohr rules so that something generalizing Bohr model of atom to the level of classical fields results as an exact part of the quantum theory. Also virtual and real particles of quantum field theories have classical correlates. In particular, virtual particles corresponds to cognitive space-time sheets representing geometric correlates for selves. Furthermore, topological field quanta are characterized by vacuum quantum numbers very much analogous to ordinary quantum numbers and topological field quantum defines a unique selection of quantization axes for spin and color quantum numbers.

The p-adic hierarchy of the space-time sheets indeed provides a geometrical and topological realization for the self hierarchy already discussed in detail in the previous chapter. The real power of the notion of topological field quantization came apparent, when it became clear that the topological field quanta associated with ELF em fields with frequencies in EEG frequency range must be correlates of our sub-selves (mental images). This means a radical reconsideration of the basic assumptions of neuroscience. What makes this radical rethinking unavoidable is that one can indeed understand the important frequencies of the EEG and one ends up with a precise quantitative model for cognition and sensory experience. In particular, a general quantum model of coordination and control emerges.

The most important topological field quanta are magnetic flux tubes which are identified as carries of super-conducting ionic BE condensates. They form a fractal hierarchy. Massless extremals (MEs) are second extremely important class of topological field quanta and are for radiation fields what Bohr orbits are for the atom. There is also a close connection with the geometric optics. MEs are ideal for communication purposes both at classical and quantum level. The light like boundaries of MEs are carriers of super-conformal and super-symplectic representations having gigantic almost-degeneracies broken only by the non-commutativity of Poincare transformations and super-symplectic transformations. The boundaries of MEs are quantum holograms in the sense of quantum gravity.

The light like vacuum currents associated with MEs in turn define dynamical classical holograms and there are good reasons to expect that MEs make possible quantum teleportation of electromagnetic states. super-symplectic states are genuinely quantum gravitational states defined in the space of 3-surfaces whereas magnetic states (actually all states predicted by quantum field theories) can be effectively reduced to states associated with single 3-surface. This means that MEs are definitely above the super-conducting magnetic flux tubes in the hierarchy of consciousness and should control what happens at magnetic flux tubes. Perhaps our consciousness is associated with MEs whereas 'body consciousness' would be associated with magnetic super-conductors.

The hypothesis that the topological field quanta associated with a material system provide a representation for the system's quantum properties provides a strong interpretational tool. For instance, electromagnetic transition frequencies should correspond to MEs having lengths equal to the transition wavelengths and binding energies should correspond to negative energy MEs with length determined by the binding energy. This topological self reference leads to the notion of field body. Any system has a field body which serves as a kind of manual providing a symbolic representation about the system: this representation is not possible in Maxwell's theory. In the case of DNA the field body provides a higher level representation of the genetic information. In the case of human body the field body provides among other things a representation for the state of brain: EEG MEs have lengths measured using Earth size as unit but also ULF MEs necessary for the realization of the long term memory and having lengths measured in light years are present. This picture inspires also the hypothesis that sensory representations are realized at the magnetic sensory canvas provided by the flux tubes or shell like topological field quanta of Earth's magnetic field. The magnetic mirrors formed by the magnetic flux tubes emanating from the body and parallel MEs serve as projectors to the magnetic sensory canvas.

5.1.7 Important empirical inputs and overall view

The development of the ideas about quantum control has occurred in jumpwise manner with jumps being induced by some crucial empirical inputs. My own meager knowledge about biology has certainly been one important factor hindering systematic development of the ideas.

Ironically, the needed empirical data providing direct evidence for the importance of the ionic super-conductors has existed already at seventies [J43] and I encountered them almost accidentally (at least it looks so)! Thanks for this are due to Gene Johnson from whom I learned a lot about brain as seen by neuroscientist. These data convincingly demonstrate that cyclotron resonance frequencies of various ions in Earth's magnetic field are very special. Electromagnetic fields at these frequencies or modulated by these frequencies have unexpected and poorly understood effects on living matter and brain. Even more, important EEG frequencies correspond to multiples of the cyclotron frequencies of the basic ions involved with the nerve pulse generation. Most importantly, the data provide the long sought-for direct evidence for bio-systems as macroscopic quantum systems! This empirical input made it possible integrate the bundle of ideas about bio-systems as macroscopic quantum systems to a general model of how coordination and control are realized in living systems.

A second decisive input where the observation that the frequencies of the BE condensed photons associated with the massless extremals (MEs) correspond in EEG frequency range to important EEG resonance frequencies if one assumes that p-adic length scales define preferred lengths for MEs [K62] . Together with the inspiration coming from the vision of Peter Marcer about bio-systems as quantum holograms [I15] , and the realization that the light like boundaries of MEs can be regarded as seats for so called super-symplectic representations providing huge information resources, this observation led to the realization that the fractal hierarchy of MEs must represent the highest control level in bio-system.

The third crucially important empirical input were the empirical findings challenging the notions of ionic channels and pumps [I27] . The explanation of these data led to a rather concrete model for homeostasis as a many-sheeted ionic flow equilibrium. This picture allows to understand how extremely low densities of super-conducting ions at super-conducting magnetic flux tube structures can control much higher ionic densities at atomic, non-super-conducting space-time sheets: the basic formula relates the ratio of densities of ions at atomic and super-conducting space-time sheet to the inverse of the corresponding flow velocities.

Coherent electric fields at atomic space-time sheets are required in order to have non-vanishing ohmic currents and this explains why bio-matter is liquid crystal having as a consequence also the electret property. In this picture one can understand also the role of DC current circuitry discovered already by Becker [J4] . Also the ideas of Mae Wan-Ho about control current circuitry formed by collagen network fits nicely with vision about many-sheeted ionic flow circuitry. A further support for this vision is provided by the empirical evidence for water memory and various effects involved with it [I5, I12, I13, I32] . Many-sheeted ionic flow equilibrium suggests an elegant mechanism of homeopathy: the extremely low densities of homeopathic remedies are at the controlling super-conducting space-time sheets where the control is. Thus homeopathy can be seen as a high precision medicine minimizing the amount of the remedy needed [K12, K13, K32] rather than some kind of magic treatment.

5.1.8 Quantum coordination and control and the hierarchy of MEs, magnetic super conductors, electrets and bio-matter

Basic dynamical aspects of a biological system relate to coordination and control. Coordination is involved with almost automatic and predictable activities involving no volition whereas control involves volition and non-predictability. Basic examples are coordination and control are EEG and nerve pulse respectively. Various motor activities are good examples of control involving macroscopic changes of the shape of the organ.

The basic question, to be addressed in this chapter, concerns about the dynamical realization of the coordination and control. The TGD inspired vision about bio-system is as a symbiosis of the fractal hierarchies of MEs and magnetic super-conductors, with bio-matter. MEs represent the highest hierarchy level controlling magnetic super-conductors which in turn control and coordinate the behavior of the non-super-conducting matter at atom space-time sheets by ionic flow equilibrium. Atoms of condensed matter can possess anomalous Z^0 charge vacuum screened in atomic length scale [K71, K22] . Also Z^0 super-conductivity is in principle possible: thus the control of also neutral atomic and molecular densities is possible. The control operations presumably involve momentary loss of flow equilibrium: the simplest control mechanism is 'let it go for a moment'.

The great challenge is to identify the basic mechanisms of quantum control and coordination.

1. TGD suggests strongly that the formation of join the along boundaries bonds between the space-time sheets possibly representing different levels of the self hierarchy could be one of the basic mechanism of control and coordination. The interpretation as a prerequisite of bio-feedback, understood in very general sense, is very suggestive. The presence of the join along boundaries bonds makes possible transfer of various particles between space-time sheets in question (for instance, atomic and super-conducting space-time sheets).

2. Space-time sheets connected by join along boundaries bonds form a system very similar to two (weakly) coupled super conductors connected by Josephson junctions. This suggests that that Josephson currents between the space-time sheets are crucial for the coordination. The Josephson currents would act effectively as an interaction Hamiltonian representing harmonic perturbation coupling to each other single particle state basis localized in either super conductor and having overlap only in the Josephson junctions. If the frequency of the Josephson current acting as a harmonic perturbation of super conductors, equals to the energy difference for single particle states of either super conductor, the standard rules of quantum mechanics predict the possibility of quantum jumps between these states. When the frequency of the Josephson current is not equal to energy difference, quantum jumps do not occur at the limit of an infinitely long interaction time. This suggests that harmonic perturbations provide a general mechanism of quantum coordination and control: by tuning the frequency of the Josephson current quantum master can 'wake-up' the quantum slave. Large Josephson currents can induce failure of flow equilibrium and lead to non-equilibrium processes crucial for control.

3. Join along boundaries contacts can and must allow also the flow direct supra currents or Ohmic currents above critical velocity. SQUID type circuit is a good analog for the situation. A very natural interaction mechanism between MEs and super-conducting circuits is magnetic induction ($\Phi = LI$ modulo flux quantum), which induces supra-current guaranteing the quantization of magnetic flux in the circuit. The em fields associated with MEs can also induce magnetic quantum transitions possibly amplified to quantum phase transitions. Of course, also other than magnetic quantum transitions might be amplified by the quantum coherence of the BE condensate. These transitions could very effectively modulate the chemical properties of, say

enzymes. The super-conducting electrons at space-time sheets associated with the molecular space-time sheets could be in electronic flow equilibrium with atomic space-time sheets and control the conformation of the molecule very effectively. MEs in turn could control the supra-currents by magnetic interaction and thus the conformations of molecules. Thus the super-conducting magnetic flux tubes are tailor-made for biochemical control.

4. There is also a feedback loop from the magnetic super-conductors to MEs since quantum phase transitions induce emission of photons which can Bose-Einstein condense to MEs carrying collinear BE condensates of photons (and also gravitons). For instance, endogenous NMR spectroscopy and its generalizations could be possible in this manner if magnetic flux tubes have varying thickness! This NMR might be basically responsible for chemical senses.

5. It took quite a long time to fully realize the obvious. Bio-systems are full of electrets and TGD indeed predicts the flux quanta of electric fields as basic solutions of field equations dual to the magnetic flux tubes. Also TGD counterparts of Tesla's scalar waves are predicted as special case of these solutions.

6. The newest and perhaps the most fundamental element of bio-control is time mirror mechanism. Many-sheeted space-time makes possible many-sheeted lasers since cold space-time sheets can contain Bose-Einstein condensates of ions and their Cooper pairs. If the system contains population inverted many-sheeted laser for which the increment of zero point kinetic energy corresponds to the energy of photons associated with negative energy MEs, the absorption of negative energy photons gives rise to a phase transition like dropping of particles to larger space-time sheet by the induced emission mechanism, and the control signal represented by negative energy MEs can be amplified if a critical number of particles drops to the larger space-time sheet. This control mechanism allows an instantaneous motor control in which intention is transformed to desired represented by negative energy MEs and generates in geometric past a reaction representing the desired response, say neuronal activity giving rise to motor action. This process probably involves entire hierarchy of magnetic selves realizing their intentions as desires communicated to lower level magnetic selves and the lowest level corresponds to the regions of brain responsible for liberating metabolic energy.

In this and next chapter my aim is to describe the general view about how quantum coordination and control in bio-systems is realized. In this chapter main emphasis is on super conductivity and many-sheeted ionic flow equilibrium. Next chapter is devoted to field aspect, to the time mirror mechanism as a means to transform intentions to actions, and to the role of classical Z^0 fields in living matter. Reader can find more details about various macroscopic quantum phases involved from subsequent chapters of the book. It must be emphasized that the picture is still evolving and I have not simply had time to integrate various elements in the big and complex picture to single coherent whole.

5.2 Bio-systems as macroscopic quantum systems

Bio-systems contain quantum sub-systems, which can have macroscopic size. For example, organic polymers, nerve cell, muscle fiber and brain could be systems of this kind. The formation of the larger quantum systems from smaller ones is achieved by the join along boundaries bond. At molecular level this corresponds to the formation of a chemical bond [I33] so that macromolecules result. At cell level this means that the lipids and/or proteins of the layers of the cell membrane are joined together by chemical bonds. At the level of organ, say brain, a good candidate for the join along boundaries bond is gap junction [J37] joining neighboring cells together. These gap junction connected structures are very general in bio-system. For instance, sensory organs are gap junction connected structures of neurons and also brain contains these structures.

5.2.1 # contacts as a macroscopic quantum system?

The original wrong belief was that wormhole contacts represent something genuine new. First it became clear that the light-like throats of wormhole contacts are natural carries of fermionic quantum numbers. Later came the realization that bosons and their super-partners have a natural identification as wormhole contacts whereas fermions and their superpartners correspond to wormhole throats assignable to topologically condensed CP_2 type extremals. This implies the notion of bosonic emerges meaning that gauge bosons and their super-partners are not fundamental entities: this has powerful implications for quantum TGD [K57] . This result does not mean that all wormhole contacts allow interpretation in terms of elementary particles and there are good reasons to expect that in living matter wormhole contacts define an entire spectroscopy of elementary particle like entities having masses determined by the appropriate p-adic length scale. A possible interpretation is as scaled variants of quarks, leptons and gluons defining a hierarchy of copies of say QCD type physics.

An excellent candidate for a macroscopic quantum system is provided by # contacts (or wormhole contacts). # contacts must have small inertial mass, which by a dimensional argument must be of order $1/L(n)$, where $L(n)$ is the lower bound for the size of a typical 3-surface at a given condensation level. The presence of the energy gap, given by the rest mass of the # throat, suggests that they can form Bose Einstein condensates located on the boundaries of the 3-surface.

Charged # contacts are especially interesting in this respect. They couple extremely weakly to radiation fields, which explains why they have not been observed and also implies that the BE condensate of # contacts is thermally isolated from the ordinary matter. The coupling to the difference of the classical gauge potentials associated with the two space-time sheets connected by them can give rise to a relatively strong, purely classical interaction. Therefore charged # contacts behave very much like Cooper pairs and the concepts of Josephson current and Josephson junction generalize. # contacts are located near the boundaries of the smaller 3-surface and appear in all length scales. These properties make # contacts an ideal tool of bio-control at quantum level and it might well be that they appear in all the relevant scales associated with the bio-systems.

contacts couple to the difference of the gauge potentials serving as order parameters for the coherent photons topologically condensed on the two space-time sheets connected by # contact and this suggests that the coupling of # contacts to coherent light might serve as a important biological function. Indeed, this kind of coupling provides an explanation for the so called Comorosan effect involving an interaction between laser light and organic molecules, which is not understood in the standard physics context [I8, I29] .

The so called wormhole magnetic fields are two-sheeted structures with finite spatial size containing magnetic fields of same magnitude but opposite direction at the two space-time sheets involved. The magnetic fields are created by wormhole currents residing at the boundaries of the structure. Wormhole magnetic might also have a key role also in bio-systems in providing simplest possible almost vacuum space-time surface of finite spatial size serving as a concrete model for association sequence. For instance, axons and various other linear structures could correspond to the concentrations of ordinary matter around the flux tubes of magnetic or even wormhole magnetic fields. Wormhole magnetic fields provide cognitive representations and the simplest representation is direct mimicry. Thus mind like space-time sheets could carry classical fields of same intensity as material space-time sheets but having as their sources currents of wormhole contacts: this kind of mechanism could provide explanation for some exotic effects like homeopathy [K85] .

5.2.2 Do micro-tubuli act as quantum antennae?

Micro-tubuli are believed to play key role in the information processing of the cell and there are lots of speculations about the possibility that micro-tubuli are mesoscopic quantum systems. In TGD context there is indeed a very general mechanism leading to the generation of the coherent photons and gravitons. The point is that the classical induced gauge fields need can give rise to non-vanishing vacuum currents generating coherent states of photons or gravitons. The many-sheeted nature of space-time suggests the presence of almost vacuum space-time sheets and the so called massless extremals studied in [K53] provide an excellent candidate for an almost vacuum space-time leading to the generation of coherent photons and gravitons. The simplest massless extremals are cylindrical structures and the vacuum gauge currents run along the cylinder with light velocity. Also the Einstein tensor is light like. The frequencies of the coherent photons come as multiples of π/L, where L is the length of the structure. These cylindrical structures clearly act as quantum antennae both sending and receiving coherent photons.

Micro-tubuli represent an important example of a linear bio-structure and an attractive possibility that they are accompanied by a space-time sheet, which is in a good approximation massless extremal having weak coupling to the ordinary space-time sheets containing the bio-matter and thus providing a representation for some aspects of the exterior world in the properties of the vacuum current. Of course, also DNA and other linear structures could act as quantum antennae and quantum antenna mechanism might be completely generic and length scale independent mechanism in the bio-systems.

5.2.3 Classical Z^0 force, neutrinos and chiral selection

The arguments related to the smallness of the parity breaking effects in nuclear, atomic and molecular length scales led to the assumption that elementary particles feed their Z^0 gauge charges to the condensate levels having $L(k) \geq L(k_Z) \geq \xi \simeq 4 \times 10^{-6}\ m$: this length scale corresponds to the cell length scale and also to the Compton length for neutrinos having mass of order one eV. The simplest assumption is that all Z^0 charge is fed at this level. Classical Z^0 force is screened by the neutrinos and a model for the destruction of the super fluidity by Z^0 magnetic vortices leads to the rough estimate $\epsilon_Z \in (10^{20} - 20^{22})$ for the parameter ϵ_Z describing screening ($1/\sqrt{\epsilon_Z}$ is the ratio of unscreened Z^0 charge density to the nuclear Z^0 charge density).

The appearance of the classical Z^0 force suggests an explanation for the chirality selection of the organic molecules taking place in vivo. Very roughly the idea is as follows: the axial part of Z^0 field couples to the spin of neutrinos. Parity breaking effects are small unless there is a net magnetization of neutrinos and this magnetization could be caused by the classical Z^0 magnetic fields inside the cell. These magnetic fields can be strong since they are caused by the moving nuclear Z^0 charge (neutrinos probably do not follow the motion of matter). The tritium beta decay anomaly [K71] provides direct evidence for the presence of classical Z^0 force in condensed matter systems. The magnetized regions in turn could have interpretation as "thinking regions" of space-time in accordance with the interpretation of fermionic state basis as Boolean algebra.

5.2.4 Are bio-systems super-conductors?

The interpretation of the state basis (2^N states) of the fermionic Fock space generated by N creation operators as a Boolean algebra of statements about N basic statements suggests that quantum jumps in the fermionic sector might have something to do with Boolean and quantitative aspects of consciousness. Quantification is here understood as an ability to associate to sensory experience an integer represented as a bit sequence such that bit is represented as the value of fermion number or as the direction of fermion spin. This conforms with the earlier speculations about the fundamental role of defects in type I neutrino super conductors if one identifies defects as "thinking" regions, where Fock basis is natural whereas in super-conducting phase basic particles are bosons. As suggested already earlier, one could also interpret the almost topological vacuum quantum numbers characterizing the magnetic flux associated with the defects as a biologically relevant information. Cell membranes and endoplasma membranes having local stripe like structure indeed resemble defects in type I superconductors. A tentative guess is that bio-systems can be both electronic and neutrino super conductors and that there exist magnetic and/or Z^0 magnetic fields in these regions leading to ordinary and/or Z^0 magnetization.

Atomic space-time sheets are not expected to be electronic super-conductors for obvious reasons but the space-time sheets with larger size contain very small charge densities and super conductivity at these space-time sheets might be possible. A mechanism leading to the presence of electrons at 'non-atomic' space-time sheets would be the 'dropping' of the atomic electrons to the larger space-time sheets so that "exotic atoms" are formed. 'Dropping' could take place via a temporary formation of join along boundaries bonds connecting the space-time sheets in question: in this case exotic phases are probably near the boundaries of the larger space-time sheet. If valence electrons are in question, this phenomenon leads to 'electronic alchemy'. The formation of the exotic atoms is necessarily accompanied by a destruction or a formation of charged # contacts or their flow between space-time sheets joined together by join along boundaries bonds since the net charge of the atomic space-time sheet changes.

A possible mechanism leading to the formation of the Cooper pairs is analogous to the ordinary mechanism based on the phonon exchange. The Coulombic and magnetic interaction of electrons with the # contacts generating the excitations of the # contact BE condensate is analogous to the induction of phonon exchange by the electron-nucleus classical electromagnetic interaction and could give rise to an attractive force between electrons. Since the space-time sheets in question are almost empty, the Cooper pairs could be even thermally shielded. The large value of the gap energy could also make the super conductor in question stable.

Also ionic superconductivity relying on the dropping of ions to cellular space-time sheets is possible and supported by empirical findings. The first observations about the special effects of ELF em fields on brain at cyclotron frequencies of ions Na_+, Cl^-, K_+, Ca_{++} and electron in Earth's magnetic field to brain were made already at seventies [J43] . These experiments suggest strongly that these ions/their Cooper pairs are confined in the magnetic field of Earth and form bound states with macroscopic size of order cell size and extremely small binding energy corresponding to frequency of order 10 Hz. This is certainly not possible in the standard physics framework but can be understood as resulting from the dropping of ions and electrons from the atomic space-time sheet to the space-time sheet of the cell where the density of the matter is very low. There is very cold, dry and silent at the cellular space-time sheets and this makes possible macroscopic quantum phases formed by Cooper pairs of ions Na_+, Cl^-, K_+ and electron as well as well as Ca_{++} ions. Also other ions are possible but these ions are especially important for EEG.

Besides magnetic cyclotron frequencies Z^0 magnetic cyclotron frequencies and even wormhole cyclotron frequencies make sense: Z^0 currents for ions indeed induce automatically also ionic currents. One can quite well consider the possibility that neutral atoms and their Cooper pairs give rise to Z^0 superconductors, or equivalently, super fluids.

The effects related to water memory and claimed effects of homeopathy [I32] suggest that not only ions but only molecules (such as proteins) could form BE condensates at the magnetic flux tubes: these effects are discussed in detail in [K12, K13] . This would obviously open fantastic possibilities as far as quantum level bio-control is considered. A strong support for the notion of many-sheeted space-time and super-conductivity at non-atomic space-time sheets comes from the findings challenging the notions of ionic channels and pumps [I27] (see [K12, K13]).

In case of neutrinos, the interaction with the atomic nuclei via classical Z^0 magnetic fields induces phonon exchange mechanism essentially identical to the ordinary mechanism of superconductivity and the effective absence of Z^0 quanta makes the situation ideal for super conductivity. The breaking of neutrino super-conductivity could be caused in the cell membrane length scale by nuclear Z^0 magnetization leading to the generation of strong Z^0 magnetic fields: the same mechanism would also explain the chirality selection in living matter. According to quark model estimates, also proton has large anomalous Z^0 magnetic moment, so that ordinary magnetization could be accompanied by Z^0 magnetization.

5.2.5 Are all magnetic transition frequencies important for the understanding of conscious experience?

The empirical observations relating to the effects of ELF em fields suggest that multiples of cyclotron frequencies are important for living matter. In fact, also more general magnetic transition frequencies are expected to be important since ions can also have spin and this means that they interact with magnetic and Z^0 magnetic fields. This suggests that magnetic transition frequencies expressible could play a key role in the quantitative understanding of the physical correlates of conscious experience. In fact, one might hope of being able to characterize conscious experiences in terms of various quantum number changes occurred in the quantum jumps so that the idea that quantum jump between initial and final quantum histories determines the contents of consciousness would be realized in a precise quantitative manner. Consider next the generalization implied by taking into account spin.

1. The charge carries of various ionic superconductors can indeed have net spin. The Cooper pairs of electronic high T_c super conductors are in $J = 2$ state which means that the spins of the Cooper pairs for spin 1 state if orbital momentum is 1. This suggest that also the Cooper pairs of bio-super-conductors could have spin $J > 0$. In case of ionic super-conductors the spin can be $J = 2$ even in relative S state. The situation for proton and neuron Cooper pairs is same as for electrons. The magnetic interaction energy $E = \mu \cdot B$ splits the energies of spin degenerate states and spins are parallel to magnetic field in ground state. Thus Earth's magnetic field is expected to cause spontaneous magnetization. It turns out that the spin flip transitions of cognitive antineutrinos in the Z^0 magnetic field of axons are fundamental for the understanding cognition and hearing in TGD framework.

2. Larmor frequency which characterizes the nuclear contribution of this interaction to energy, is related to cyclotron frequency of singly ionized atom by

$$\omega_L = g\frac{S_z}{2}\omega_c \ ,$$

where S_z is the projection of spin in the direction of magnetic field and g is Lande factor, which equals to $g = 1$ in the ideal classical case for which spin corresponds to angular momentum. For elementary fermions $g = 2$ holds true. Nuclear contribution is the dominant contribution for ions Na_+, K_+, Cl_- since electron shell is full for the ions in question. For Ca_{++} spin and magnetic moment vanishes.

3. Since Earth's magnetic field is very weak and Larmor frequencies are of same order of magnitude as cyclotron frequencies, Josephson currents might serve as harmonic perturbations inducing transitions between different spin states. The energies associated with the magnetic transitions are even multiples of Larmor frequency so that transitions changing the direction of spin of Cooper pair are induced by frequencies

$$f = (2n+1)f_c + 2\frac{\Delta S_z}{S}f_L = (2n+1+g\frac{\Delta S_z}{2})f_c \ .$$

Odd multiples of cyclotron frequency are possible in the first order perturbation theory whereas even multiples are possible only in the second order of perturbation theory. For electron $g = 2$ in excellent approximation and the Larmor frequency is very nearly identical with cyclotron frequency. The deviation $\Delta g/g = \alpha/2\pi$ in lowest order of perturbation theory ($\alpha \simeq 1/137$) and thus the frequency for $n = -1$ transition changing the direction of the spins of the Cooper pair is $f \simeq 902$ Hz, which corresponds to the time scale of nerve pulse and of memetic codon [K31] . Since electron corresponds to Mersenne prime M_{127} associated also with the memetic code, the identification or the duration of single bit of memetic codon as $1/f$ is attractive.

4. Josephson currents which can induce cyclotron resonance could also induce more general quantum jumps changing the spin direction but inducing no change in orbital degrees of freedom at Josephson frequencies not far from cyclotron frequency. Note that these transitions are possible also for neutrons since they possess magnetic moment. For proton and neutron the Lande factors are $g(p) = 5.58$ and $g(n) = -3.82$ so that the corresponding Larmor frequencies in Earth's magnetic field would be 838 Hz for proton and 570 Hz for neuron.

5. Also the total spins ($J = 0, 1, 2, 3$) associated with the Cooper pairs of Na_+, Cl_- and K_+ ions having $J = 3/2$, can flip. The corresponding frequency scale is by a factor of order A (atomic number) higher than cyclotron frequency scale since the magnetic moment of nucleus is determined essentially by the magnetic moments of nucleons with unpaired spins.

5.2.6 Dark counterpart of the Earth's magnetic field as carrier of ionic Bose-Einstein condensates

The original model for the effects of ELF em fields on vertebrate brain was based on the hypothesis that the ELF frequencies in question correspond to the harmonics of cyclotron frequencies of ions in the Earth's magnetic field B_E. The development of the vision about dark matter [K21] led to the realization that the macroscopic quantum phases in question are dark matter identifiable as phases with an abnormally large value of Planck constant.

TGD predicts the spectrum of Planck constant(s) (one for M^4 and one for CP_2 type quantum numbers) as integer multiples of the ordinary Planck constant. There is also a spectrum of number theoretically preferred values of Planck constant [K25] which seems to be highly relevant for the understanding of the physics of living matter [K21] . The flux quanta of magnetic field carrying dark matter as macroscopic quantum phases controlling living matter would be responsible for bio-control. The natural question whether this dark magnetic field can be identified as the magnetic field of Earth. The answer to the question came via a detection of a calculational error as progress often comes.

For years I erratically believed that the magnitude of the magnetic field assignable to the biological body is $B_E = .5$ Gauss, the nominal value of the Earth's magnetic field. Probably I had made the calculational error at very early stage when taking Ca^{++} cyclotron frequency as a standard. I am grateful for Bulgarian physicist Rossen Kolarov for pointing to me that the precise magnitude of the magnetic field implying the observed 15 Hz cyclotron frequency for Ca^{++} is .2 Gauss and thus slightly smaller than the minimum value .3 Gauss of B_E. This value must be assigned to the magnetic body carrying dark matter rather than to the flux quanta of the Earth's magnetic field. This field value corresponds roughly to the magnitude of B_E at distance 1.4R, R the radius of Earth.

Dark matter hierarchy leads to a detailed quantitative view about quantum biology with several testable predictions [K21] . The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of Planck constants coming as $\hbar(k) = \lambda^k(p)\hbar_0$, $\lambda \simeq 2^{11}$ for $p = 2^{127-1}$, $k = 0, 1, 2, ...$ [K21] . Also integer valued sub-harmonics and integer valued sub-harmonics of λ might be possible. Each p-adic length scale corresponds to this kind of hierarchy. Number theoretical arguments suggest a general formula for the allowed values of λ [K25] as $\lambda = n$ where n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [K84] . The values of n for which quantum phase is expressible in terms of squared roots are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. $n = 2^{11}$ obviously satisfies this condition. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales. The unit of magnetic flux scales up as $h_0 \rightarrow h = nh_0$ in the transition increasing Planck constant: this is achieved by scalings $L(k) \rightarrow nL(k)$ and $B \rightarrow B/n$.

$B = .2$ Gauss would corresponds to a flux tube radius $L = \sqrt{5/2} \times L(169) \simeq 1.58L(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 18$ μm, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth's magnetic field. Furthermore, the model for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5. Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4cos^2(\pi/n)$ equal to Golden Mean [K83] .

The natural working hypothesis is that $B_{end} = 2B_E/5$ holds true as a time average and that B_{end} defines the dark counterpart of the Earth's magnetosphere.

5.2.7 Massless extremals

The so called 'massless extremals' (MEs) are basic solutions of field equations associated with Kähler action [K53] . MEs describe propagation of one-dimensional nondispersive wave with light velocity and are accompanied by light like vacuum current generating coherent photons and gravitons. Since the vacuum current behaves in a non-deterministic manner at given point of ME, it is ideal for the coding of classical information. MEs can appear also as pairs of space-time sheets such that the two space-time sheets have opposite time orientations and hence also energies so that the net energy of ME pair vanishes. MEs define a fractal hierarchy starting from elementary particle length scales and extending up to cosmic length scales. MEs have light like boundaries carrying super-symplectic

One can assign to the light like boundaries of MEs representations of super-conformal and super-symplectic algebras. Super-symplectic symmetry is thus transformed from a cosmological symmetry to an ordinary macroscopic symmetry. Apart from small gravitational effects, super-symplectic degrees of freedom commute with the translational degrees of freedom. Physical states associated with MEs correspond to Bose-Einstein condensates of collinear photons and gravitons (these degrees of freedom correspond to quaternion conformal degrees of freedom explaining elementary particle quantum numbers) having an additional super-symplectic degeneracy. super-symplectic states can be interpreted as quantum holograms storing quantum information to the light like boundary of ME, which is thus analogous to the moment of big bang at the cosmological level.

The energies of BE condensed photons and gravitons come as multiples of $E = \pi/L$, where L is the length L of ME. p-Adic length scales $L_p(n) = p^{n/2}L_p$ for $p \simeq 2^k$, k power of prime, define a preferred set of lengths for MEs, and this means quantization of the fundamental transition frequencies involved with the transitions of photonic and gravitonic BE condensates as multiples of $f(p, n) = \pi/L_p(n)$. Rather amazingly, in ELF range these frequencies correspond to resonant EEG frequencies!

The super-symplectic degrees of freedom commute with Poincare algebra apart from gravitational effects which means a gigantic almost-degeneracy of states. This means that super-symplectic states can provide huge entanglement negentropy resources crucial for quantum computation and communication type operations as well as for cognitive representations. Thus super-symplectic representations can be interpreted as quantum level articulation for the statement that TGD Universe is quantum critical quantum spin glass. Super-symplectic representations clearly provide an excellent candidate for an infinite hierarchy of life forms. These life forms are labelled by three integers (k, m, n): physically interesting primes correspond to $p \simeq 2^{k^m}$, whereas k prime and m and n are integers. Perhaps it is these life forms which make mind like space-time sheets living creatures and these life forms emerge already in elementary particle length scales and become increasingly complex when the p-adic length scale increases. If so, life could be regarded as a symbiosis of these life forms with lower level life forms associated with super-conducting magnetic flux tubes.

These life forms ('mind') interact with each other, super-conducting magnetic flux tubes and ordinary matter via coherent light and gravitons and the classical gauge fields associated with MEs. MEs indeed act as receiving and sending quantum antennae and the light like classical vacuum currents associated with MEs allow to understand the classical aspects of dynamical quantum holograms and of quantum communications made possible by MEs.

MEs can also serve as Josephson junctions between magnetic flux tubes. MEs interact with super-conducting magnetic flux tube circuitry also by magnetic induction analogous to the interaction of brain's magnetic fields with SQUIDs. MEs can induce also magnetic quantum transitions. These interaction mechanisms could explain the observed intensity windows in the interaction of ELF em fields with bio-matter [J7]. Also

The natural identification of MEs as building blocks of cognitive structures leads to rather concrete model for long term memory and forces the hypothesis that MEs define an infinite hierarchy of electromagnetic life forms living in symbiosis with each other and bio-matter. The model allows to understand EEG as a direct physical correlate of mind like space-times sheets (MEs) associated with ELF selves and provides a general vision about the electromagnetic organization of brain as sensory and motor organ of higher level self. Also so called RF (radio frequency) and MW (microwave) MEs representing our mental images are crucial for the model. MEs are also crucial in the model of qualia. MEs are present also below cellular length scales and even at molecular level.

The model of qualia leads to rather detailed view about the sizes of the hierarchy of various MEs defining what might be called our electromagnetic body. It took long time to answer the question whether we should identify ourselves with the self associated with brain; with the entire body; with ELF ME having size at least of order Earth circumference; with ULF ME having size of order order light years from the fact that we have long term memories in time scale of lifetime; or with self having literally infinite size. The last two options seem to be more plausible than the first three: the illusion that we are nothing but our physical bodies is created by the fact that during wake-up state sensory input is about the region surrounding our body.

5.3 Many-sheeted space-time concept and topological aspects of quantum control

Many-sheeted space-time concept is crucial for TGD inspired theory of consciousness and should allow to understand the topological aspects of quantum control. Topological field quantization is perhaps the most essential aspect involved and together with the absolute minimization of Kähler action it implies rather precise correspondence between quantum and classical, including generalized Bohr rules for classical field configurations. Unfortunately, the extreme complexity of the dynamics does not allow to say much at detailed quantitative level. Quantum self-organization however comes in rescue and tells that physically interesting configurations corresponds to the asymptotic self-organization patterns selected by dissipation. This means that it should be possible to engineer asymptotic configurations by gluing together space-time sheets representing simple, highly symmetric solutions of the field equations associated with Kähler action.

5.3.1 How bio-systems might apply the many-sheeted space-time concept?

Many-sheeted space-time concept makes possible several exotic new physics effects. The first ideas which come into mind are antigravity machines, energy production with apparent efficiency larger than one by generation of negative energy space-time sheets, coherent motion via generation of negative energy space-time sheets having large momentum and even communication backwards in geometric time seem to be in principle possible in TGD Universe. Many-sheeted space-time makes combined with super-conductivity makes also possible mechanisms of bio-control relying on many-sheeted flow equilibrium and the strange findings challenging the notions of ionic pumps and channels [I27] provide support for this notion. The application of these mechanisms might make living systems what they are.

Possible new physics effects related to the TGD space-time concept

TGD based concept of space-time predicts several new effects.

1. One of the basic predictions of TGD is the possibility of classical Z^0 fields having Z^0 charges as their sources. Rotating macroscopic objects should generate Z^0 magnetic fields and this suggests that the behavior of rotating objects should exhibit anomalies. A special signature of effects of this kind is parity breaking caused by the parity breaking couplings of classical Z^0 field.

2. The mere rotation of a 3-surface carrying magnetic or Z^0 magnetic fields should induce electric or Z^0 electric fields whose divergence gives rise to vacuum charge density. Charge conservation suggests that this gauge flux must flow to a second space-time sheet carrying opposite net charge.

3. In TGD the time orientation of given space-time sheet need not be the standard one and this allows the possibility of negative classical energies. If this kind of space-time sheets are created, energy production with apparent efficiency greater than unity becomes possible. At the space-time sheets with negative time orientations classical fields should propagate from future to past making in principle possible to see to the geometric future of, say, astrophysical objects.

4. A further TGD based element is related to the fact that 3-surface can be regarded as a generalization of a point like particle. This means that 3-surface behaves like single coherent whole: in particular, classical fields oscillating coherently in arbitrary long length scales are possible and can give rise to an apparent propagation of effects with infinite velocity. The notion of pair creation from vacuum generalizes. For instance, pairs of space-time sheets with vanishing total classical energy can be created from vacuum. This kind of mechanism leads to a concrete idea about how bio-systems might generate energy ("buy now, pay later").

5. In TGD classical gauge fields and gravitational fields at a given space-time sheet are extremely tightly correlated since all these fields are expressible in terms of CP_2 coordinates and their gradients. Therefore the generation of magnetic and electric fields could induce perturbations of the classical gravitational fields having amplitudes gigantic as compared to those possible in General Relativity. In this kind of situation imbeddability requirement could force the system to feed part of its gravitational flux to some other space-time sheets. These effect might make possible antigravity effects in which the gravitational flux of Earth or test body is partially channelled to some other space-time sheet. An interesting possibility is that bio-systems could apply this kind of effects.

Some anomalies explained by TGD based space-time picture

It has gradually become clear that there is extensive literature about anomalies possibly having TGD based explanation [K7] .

1. There are several TGD based mechanisms which could contribute to the effective gravity modification effects reported by Podkletnov [H9] and Schnurer [H10] and Z^0 force might be involved with the effect.

2. Allais [E2, E6] observed that the oscillation plane of Foucault pendulum changes during solar eclipse. NASA performed the same experiment during 1999 eclipse but the processing of the data is still going on. Z^0 MEs emitted by Sun provide a model explaining basic qualitative facts.

3. There are anomalies related to the behavior of rotating gyroscopes [H5] , [J29] suggesting that rotating gyroscope can lose part of its weight. TGD based mechanism is following: gyroscope channels part of its gravitational fluxes to some other space-time sheets than the one where it resides and, in the case that the receiving space-time sheet contains only very weak gravitational

fields, gyroscope effectively loses part of its weight. Also the re-channelling of Z^0 fluxes might be involved.

4. There are quite puzzling observations related to the behavior of rotating stars [H7] . These observations are in a dramatic conflict with the standard wisdom about finite propagation velocity of signals and with the idea that classical fields propagate in future direction only. The possibility of space-time sheets with negative time orientation, and classical fields propagating from geometric future to geometric past and the possibility that 3-surfaces of even astrophysical size can behave like particle like objects, could explain these mysterious effects.

5. There are a claims about energy production with apparent efficiency larger than unity [H1, H4] by machines which contain rotating magnets. TGD requires generation or existence of space-time sheet carrying charge opposite to the vacuum charge induced by the rotation. If this space-time sheet has negative time orientation, it has negative classical energy and the energy of the material space-time sheet must increase by the requirement of energy conservation.

6. Biefeld-Brown effect is one of the oldest poorly understood anomalous effects [H2, H3] . What happens is that charged capacitor gains center of mass momentum in the direction orthogonal to the plane of the capacitor plates. It seems that the change of the effective gravitational weight of the capacitor based on redistribution of the gravitational and Z^0 fluxes cannot explain the entire effect. Rather, also the generation of a negative energy space-time sheet with net momentum associated with classical gauge fields could be involved. So called "massless extremals" are optimal candidates for this purpose. This mechanism might be applied by bio-systems to generate coherent motions.

Basic new physics mechanisms possibly applied by bio-systems

There are several candidates for new physics mechanisms applied by bio-systems.

How bio-systems are able to move coherently?

The ability of bio-systems (70 per cent of water!) to generate coherent motions is complete mystery from the point of view of standard physics describing bio-system as a soup of randomly moving atoms and molecules. The generation of negative energy space-time sheets with large net momentum compensated by opposite momentum of material space-time sheet provides a candidate for a mechanism making coherent motion possible. Negative energy space-time sheets could actually correspond to mind like space-time sheets: perhaps those representing the thought "I want to move to that direction"! If this were the case, then this mechanism could be, somewhat loosely, said to provide the basic geometric counterpart for the interaction between matter and mind.

As will be found in the chapter [K53] , the generation of so called "massless extremals" provides an optimal mechanism for coherent motion. The reason is that massless extremals have maximal possible classical momentum ($E = P$ holds true) so that the generation of space-time sheet corresponding to massless extremal gives large momentum to the material space-time sheet.

Negative energies are not absolutely essential for generating coherent motions. However, if massless extremals have positive energies, the efficiency of energy usage is however very low, approximately $\beta/2$, where β is the velocity generated: something like 10^{-8} if velocity is of order one meter per second. It could quite well be that massless extremal is created only for the period of time that motion lasts: this in accordance with the idea that classical counterparts of virtual particles are in question. Since the surplus energy generated on the material space-time sheet is partially dissipated during this time interval, this mechanism requires that metabolism feeds energy to the system to compensate this loss. Thus there is no contradiction with the general wisdom about the necessity of metabolic energy feed.

Generation of metabolic energy from vacuum?

If bio-systems can generate negative energy massless extremals, a very efficient generation of metabolic energy from vacuum becomes possible in principle. This principle could be called "buy now, pay later" principle since the lifetime of negative energy space-time sheets is expected to be finite. This suggests that generation of negative energy space-time sheets is rare process and that lifetimes of negative energy space-time sheets are finite. There is a lot of anecdotal evidence about the ability of yogis and mystics to survive without eating [J44] . The explanation often proposed by yogis themselves [J44] is that the energy of light replaces the usual sources of the metabolic energy. Standard science sceptics of course "know" and ridicule all this but, against the background of new physics predicted by TGD, I cannot avoid asking myself whether there might be some seed of truth behind these claims.

Communication backwards in time?

Negative energy space-time sheets have negative time orientation. This suggests that classical fields could propagate backwards in time. Combining this with the TGD view about universe as four-dimensional society with mind like space-time sheets dispersed around entire many-sheeted space-time, one ends up with the idea that communication backwards in geometric time could be possible and be based on generation of propagating classical fields. We could send messages to future along positive energy space-time sheets and receive answers to our messages (probably mostly questions!) along negative energy space-time sheets. An interesting possibility is that this kind of communication in short time scales is actually basic aspect of living systems making for them possible to predict what would happen in future if no quantum jumps between histories would occur. This kind of communication could provide an alternative explanation for the causal anomalies observed by Radin and Biermann [K80, K81] . Note however that quantum jumps between quantum histories picture provides an alternative TGD based explanation for these effects. In any case, if communication backwards in time is really possible, human kind would be at the verge of an evolutionary step whose consequences are impossible to imagine.

Of course, it might be that genuine communication requires quanta, say photons. It seems that the coherent photons generated by negative energy massless extremals should possess negative energies so that the roles of the creation and annihilation type operators would be changed for photons glued to negative energy space-time sheets. If this were the case, one could also consider the possibility of communication based on negative energy photons wandering along negative energy space-time sheets.

Bio-systems as antigravity machines?

In [K77] it is found that TGD provides several mechanisms making possible what look like anti-gravity effects. Bio-system could get rid of part of its effective gravitational mass by feeding part of its gravitational flux to an almost empty space-time sheet different from that at which the gravitational field of Earth resides. Alternatively, bio-systems could reduce the effective strength of Earth's gravitational force by channelling part of the gravitational flux of Earth to some other space-time sheet. Also classical Z^0 fields could contribute to the effective gravitational mass and gravitational force. This is suggested by the explanation of the acceleration anomaly of spacecrafts in outer space [K67] . It this is the case then similar mechanisms could be work for Z^0 electric flux too.

5.3.2 Particle transfer and re-distribution of gauge fluxes between space-time sheets as a control tool in bio-systems?

The basic mechanisms

Particle transfer between space-time sheets is the most straight-forward control mechanism. A more refined mechanism involves redistribution of various # contacts feeding gravitational and gauge fluxes to various space-time sheets from the space-time sheet of the particle.

1. In the transfer of particle between different space-time sheets topological sum contacts, "# throats", connecting the particle to space-time sheet are split and are possibly regenerated between particle and some other space-time sheet. All that it essential that particle disappears from a given space-time sheet. As a special case one has topological evaporation defined as a transfer of particles from a given space-time sheet to "vapor phase". This transfer process can be either classical or occur by quantum jump. The transfer of macroscopic particles by topological evaporation seems however very implausible. One reason for this is that the corresponding space-time sheet has large number wormhole contacts to a large number of space-time sheets and it is extremely improbable that these contacts can split simultaneously. Also the fact that the gravitational mass of particle in vapor phase vanishes, suggests strongly that evaporation process is possible only in elementary particle length scales.

2. It is also possible that temporary join along boundaries bonds between two space-time sheets, say atomic and cellular space-time sheets, are formed and particles flow from space-time sheet to another one along the join along boundaries bond. Join along boundary bonds could be formed both non-dissipatively (Josephson currents) or by quantum jumps giving rise to dissipative currents. For this process, which simply corresponds to the formation of direct geometric contact between physical objects, there is clear evidence from everyday life and the model for bio-control and -coordination relies on Josephson currents flowing between the space-time sheets. Josephson currents could give also rise to the 'dropping' of electrons and ions from the atomic space-time sheet to larger space-time sheets. It seems that this mechanism might be the one which is realized in living matter. Also transfer of entire structures topologically condensed on given space-time sheet to a second space-time sheet is possibly along temporary join along boundaries bond formed between the two space-time sheets. This seems to happen all the time in everyday world: particle of even macroscopic size can diffuse from macroscopic objects to another one.

3. An interesting mechanism is the one in which # contacts of particle to a given space-time sheet glide to some other space-time sheet along join along boundaries bond. In this manner it would be possible to redistribute its own gravitational flux and gauge fluxes from original space-time sheet to some new space-time sheets. This would make possible for particle to reduce its effective gravitational mass. Also the gravitational force experienced by the particle would change as a result of this process: even levitation could become possible by transferring the # contacts to some nonstandard space-time sheet containing only very weak gravitational fields. This process is certainly possible: it requires only the formation of join along boundaries contact between the space-time sheet X at which particle usually feeds most of its gravitational flux and some other space-time sheet Y such that the contact can glide to Y without leaving particle space-time sheet.

Possible examples of particle transfer

Nondeterministic particle transfer between space-time sheets suggests a general mechanism for voluntary bio-control. For instance, particles could flow from atomic to cellular space-time sheets along join along boundaries bonds and particle transfer would be realized as dissipative em currents between the space-time sheets.

1. The transfer of individual electrons and Cooper pairs might provide an effective tool for the control of the electronic configuration of the cells and smaller structures. The concept of exotic atom involves dropping (presumably transfer along temporary join along boundaries bonds) of electrons from atomic space-time sheet to a larger space-time sheet and the electrons at almost empty space-time sheets could be in superconducting state. In these larger space-time sheets a very effective electronic charge transfer by supra currents could be possible since dissipative effects are minimized. One could even consider the possibility of a simultaneous coherent transfer of Cooper pairs at a given level of topological condensate. The transfer of particles along join along boundaries contacts formed between space-time sheets is the most plausible mechanism of a coherent transfer. The constructive interference of Josephson currents between space-time sheets could indeed induce large transfer of particles.

2. Ions and neutral atoms could 'drop' from atomic to larger space-time sheets and form em of Z^0 superconductors at these space-time sheets. The macroscopic quantum phases formed by ions or their Cooper pairs are indeed in key role in TGD based models EEG and of sensory qualia.

3. The transfer of chemical reactants between space-times sheets provides a possible bio-chemical control mechanism. Again also the possibility of synchronous transfer induced by Josephson currents could be considered. One can consider the possibility that the transfer of most important organic molecules such as DNA sequences between space-time sheets is possible. This process provides an effective mechanism for controlling chemical reactions. For example, molecule could avoid Coulomb walls by moving on different space-time sheet and in case of a catalytic reactant this provides an effective control over the reaction. A new type of catalyst action becomes possible since catalyst molecule could overcome the purely geometric obstructions by moving on different space-time sheet ("Houdini effect") [K71] . The transfer of a molecule might be

induced from $k = k_Z$ level. The motion of Z^0 # contacts in Z^0 fields at $k = k_Z$ level induces the motion of nuclei and therefore of molecule condensed on electromagnetic level $k_1 < k_Z$. If molecule enters the boundary of the condensate block k_1, it might suffer the transfer to a larger space-time sheet along join along boundaries bond.

Control mechanisms of motion

The transfer of particles between various space-time sheets suggests several mechanism for the control of locomotion.

1. As noticed, also macroscopic particles could flow between different space time sheets along join along boundaries bonds. The transfer of a substructure of cell size or even size of order 10^{-4} m could change the equilibrium configuration of the organ in external gravitational field. This kind of mechanism could provide a control tool for the motion of the organism.

2. Redistribution of the gravitational flux is made possible by the transfer of the ends of wormhole contacts along the join along boundaries bonds from standard space-time sheet to nonstandard ones. This makes it possible to change both the particle's effective gravitational mass and the effective gravitational field and could be involved with locomotion. This mechanism could explain the observed surprisingly large fluctuations in the value of the gravitational constant in Cavendish experiments [E1] .

3. Much more tricky control mechanisms can be imagined. For instance, resonant current of Ca_{++} ions between atomic and cellular space-time sheets could induce oscillatory sol-gel transition in cytoplasm and this in turn would make possible amoeba like locomotion of a monocellular organism in which organism becomes liquid in some direction and flows that direction and then solidifies. The frequency with which sol-gel transition occurs is few ten Hz and the transfer of Ca_{++} ions is known to be involved with its control. This suggests that resonant Ca_{++} ion currents with an odd multiple of Ca_{++} cyclotron frequency in Earth's magnetic field (15 Hz) are involved with the control of sol-gel transition.

Bio-matter forms liquid crystals and sol-gel transition basically changes the liquid crystal characteristics such as the resistivity and the intensities of the spontaneously generated weak but coherent electric fields. In many-sheeted ionic flow equilibrium various (to be discussed in more detail in the sequel) ion densities at atomic space-time sheets are determined by the many-sheeted ionic flow equilibrium and are proportional k_{ion}/E, where k_{ion} denotes the ionic friction coefficient and E denotes the local electric field. It is quite possible that the transition to sol state is 'let it go' type transition in which the electric drift velocity of the ion becomes so low that a stable control by super-conducting space-time sheets is not possible anymore.

Metabolism in the many-sheeted space-time and the real role of ATP

The dropping of ions from atomic space-time sheets to a much larger space-time sheet, say magnetic flux tubes of Earth's magnetic field or endogenous magnetic fields, liberates the large zero point kinetic energy associated with the particle at the atomic space-time sheet. p-Adic length scale hypothesis allows to estimate the precise value of the zero point energy. The assumption that the transformation of a single ATP molecule to ADP actually involves the dropping of a hydrogen ion from the atomic space-time sheet liberating .49 eV of zero point kinetic energy, allows to get rid of the questionable notion of high energy phosphate bond. ATP bound to magnesium atom couples the water cluster around ATP complex to the magnetic flux tubes and has thus control function rather than serving as a universal energy currency.

The dropping of ions to high n magnetic cyclotron state decaying by the emission of ELF radiation at multiples of cyclotron frequencies provides a mechanism producing EEG. It is even possible to understand the value of the neuronal resting potential in terms of this mechanism. These applications are described in [K37] .

The same mechanism explains also the scaling law of homeopathy stating that the imprinted frequencies in water appear in pairs of high and low frequencies implicating the presence of each other such that the ratio of the frequencies is $f_h/f_l = 2 \times 10^{11}$. This ratio can be identified as the ratio of the zero point kinetic energy of singly ionized ion at atomic space-time sheet to its cyclotron energy in Earth's magnetic field [K32] .

5.3.3 Motor control performed by field body

As briefly described in the introduction, the notion of field body leads to the notion of magnetic sensory canvas [K41, K39] . Sensory representations are realized at the topological field quanta of Earth's magnetic field (flux tubes or shell like field quanta) and the magnetic flux tubes emanating from brain and body accompanied by parallel MEs serve as projectors to the magnetic sensory canvas. The distance of the object of perceptive field is coded by the thickness of the flux tube emanating from the brain in turn coding for the local cyclotron frequency scale.

This picture inspires questions about how the highest level motor control exercised by the field body is realized. Is motor control practiced directly from the magnetic sensory canvas or possibly from a separate Z^0 magnetic motor canvas? Second question relates to the mechanism of the motor control. In [K37] a mechanism of motor control based on Z^0 MEs converging to brain is discussed. The classical Z^0 fields could be transformed to endogenous sounds if the living matter acts as Z^0-piezoelectric. This is in principle possible since atomic nuclei can possess anomalous Z^0 charge and an entire hierarchy of scaled down weak physics possible corresponding to Gaussian Mersennes $(1+i)^k-1$, $k = 151, 157, 163, 167$ [K22] is possible. The control should be very high level control leaving a lot of freedom for brain to decide about the details. Perhaps internal speech is one manifestation of this control.

An important aspect of motor control is the generation of quantum entanglement: the geometric correlate for this is ME bridge. Only bound state entanglement is stable against the state preparation process associated with the quantum jump so that motor control is accompanied by the liberation of a binding energy as a usable energy. This obviously facilitates motor control. There is some evidence for the occurrence of the quantum metabolism. The regions of high neural activity in brain are not seats of high oxidative metabolism as one might expect and this has led to the puzzle about where the brain gets the energy it is believed to need [K37] . One possibility is that quantum metabolism provides the energy. Since thermal noise is expected to destroy the bound state entanglement sooner or later, one can say that thermal energy is utilized by buy now-pay later mechanism (there is definite analogy with thermal ratchets). During synesthesia left brain contains highly synchronous regions and the oxidative metabolism is 18 per cent lower than normally: in case of a normal person this would mean death [K66] . Perhaps quantum metabolism explains also this anomaly.

5.3.4 Scaling law of homeopathy and the role of microwaves in homeostasis

Plasmoids consisting of closed magnetic flux tube structures carrying supra currents plus atomic space-time sheets associated with them, are good candidates for primitive electromagnetic life forms. Ordinary bio-matter is assumed to self-organize around these structures and nerve circuit represents a good example of a structure resulting in this manner.

Also the magnetic life forms need energy feed to self-organize and stay awake. The basic metabolic mechanism would be the same as in the case of living matter [K37] . Energetic super-conducting ions must be somehow driven from the magnetic flux tubes to the atomic space-time sheets, where they collide with atoms, ionize them, and generate visible light in the atomic transitions giving thus rise to the observed luminous phenomena interpreted as UFOs. The ions would eventually 'drop' back to the super-conducting space-time sheet and liberate the zero point kinetic energy as a quantum of metabolic energy defining what is often referred to as a universal energy currency. Essentially identical energetic cycle of Karma would be realized also in living matter but involve a complex molecular organization and many-sheeted current circuitry responsible for the control of homeostasis. For the proton the quantum is predicted to be of order .5 eV liberated also when a single molecule of ATP is used [K37] .

The realization of this primitive metabolic cycle requires the breaking of super-conductivity: some mechanism must generate join along boundaries bonds serving as bridges connecting magnetic flux tubes with atomic space-time sheets along their boundaries so that supra current leakage becomes possible. The gap energy of super-conductors, typically measured in 10^{-4} eV as a unit (corresponding to temperature measured in Kelvins), would naturally correspond to the energy needed to build up this bond (note that the temperature at the magnetic flux tubes would be much lower).

This suggests that microwave photons could induce these bridges, break super-conductivity, and induce energy feed and self-organization. A similar breaking of super-conductivity might be also involved with the driving of the super-conducting ions to the atomic space-time sheets in the living matter. Proteins could generate the needed microwave photons by coherently occurring conformational transitions. Also rotational transitions of clusters of water molecules could emit microwaves and perhaps mimic and amplify the microwaves generated by proteins.

The clusters of water molecules forming liquid crystals can mimic the conformational and rotational spectrum of various molecules, and that the ability to reproduce the rotational frequency spectrum of the medicine molecule is an essential element of homeopathic healing. The level of self-organization of water would thus be measured by how complex mimicry it is able to perform.

Why rotational microwave energy spectrum is so important for healing, could be understood as follows. The many-sheeted current circuitry, involving atomic space-time sheets and magnetic flux tubes and also other space-time sheets, is extremely complex control structure. The continual regeneration of bridges between, say, atomic space-time sheets and magnetic flux tubes by microwaves emitted by proteins is necessary to sustain this circuitry. An important category of diseases is due to the failure to generate the bridges between super-conducting and atomic space-time sheets so that this control circuitry suffers shortcuts. Perhaps the genetic expression of some proteins responsible for the microwaves generating particular bridges fails. The medicine or its homeopathic counterpart would help to generate (or even re-establish the generation of) the microwave spectrum responsible for the generation of the lacking bridges in the circuitry.

A further piece to the puzzle comes from the scaling law of homeopathy. The law states that high and low frequencies accompany each other, the frequency ratio being $f_{high}/f_{low} \simeq 2 \times 10^{11}$ in the simplest situation (the ratio can actually vary). The TGD based interpretation is that ELF MEs are responsible for quantum entanglement in macroscopic, even astrophysical, length scales. Microwave MEs propagating effectively as mass-less particles along ELF MEs in turn induce self-organization by serving effectively as 'food' of the plasmonic life forms at the receiving end. This mechanism could be behind both the endo- and exogenous realizations of intentions as actions, that is ordinary motor actions and phenomena like remote healing and psychokinesis. Also sensory representations at the personal magnetic canvas and magnetosphere rely on this mechanism, and in this case life forms are mental images getting at least partially their metabolic energy from brain.

As a matter fact, also other than microwaves photons, for instance IR and visible photons are predicted to be important for the self-organization of living matter but it seems that microwave photons are of special importance.

5.3.5 Bio-systems as conscious holograms

The idea that brains, bio-systems, and perhaps the entire Universe are some kind of holograms has long history. TGD Universe is indeed quantum gravitational hologram in a well-defined sense but this does not yet allow development of a detailed model of bio-system as a hologram. What seems to be needed is the generalization of ordinary hologram to that of a conscious hologram.

A sequence of small steps of progress in the understanding the endogenous and exogenous realizations of intentionality finally led to a concrete vision about what conscious holograms might be. Ironically, the crucial ideas came from the modelling of homeopathy, Fatima miracle, UFOs, crop circles, and other anomalous phenomena rather than from orthodox science accepted by skeptics (see the relevant chapters of [K40]). Topological light rays (MEs), the role of microwaves in the breaking of super-conductivity in many-sheeted space-time, and scaling law of homeopathy stating that important biological frequencies appear in pairs of low and high frequencies, play key roles in the realization. The vision about living system as a conscious hologram looks roughly like follows [K32] .

1. The points of the hologram correspond to space-time sheets representing some structural units of bio-system with size of considerably smaller than the wavelength associated with high frequency MEs (from the requirement of effective point likeness). Several low frequency MEs from external world converge to these points like light rays. Low frequency MEs can connect also different points of the hologram and one could also speak of 'self-hologram'. Brain and body are basic examples about self hologram. Low frequency MEs serve as quantum entanglers and guarantee both classical coherence and macroscopic and macro-temporal quantum coherence.

2. High frequency (microwaves, IR, and visible light) MEs propagating like massless particles inside low frequency MEs (ELF and radio waves) fuse at the points of the hologram, and the classical fields associated with high frequency MEs interfere in these regions. The resulting classical field induces the leakage of supra currents from magnetic flux tubes to the atomic space-time sheets, and this stimulates self-organization and metabolic cycle and generates mental image. This the counterpart for the generation of ordinary hologram. The scaling law of homeopathy relates the high and low frequencies and makes the model quantitative.

3. The points of hologram correspond to more or less identical structural basic units such as genome, cells, and basic information processing units of cortex having size of order one millimeter. At the level of magnetospheric consciousness different organisms of the same species and even body parts can correspond to points of conscious holograms. The reason why bio-systems consist of similar basic units is that this makes possible conscious holograms and stereo consciousness.

4. Ordinary hologram gives rise to 3-D image. In case of a conscious hologram the fusion of mental images by quantum entanglement gives rise to the formation of what might be called stereo-consciousness and has classical and quantum coherence and the formation of ordinary many-sheeted hologram as physical correlates.

5. The notion of conscious hologram unifies a large number of separate ideas by providing a model for homeostasis and hardwave of consciousness. Also the models for a plethora of anomalous phenomena like homeopathy, remote mental interactions, UFOs, crop circles, and several anomalies related to free energy, can be understood in this general framework. The picture is consistent with the basic empirical facts usually taken as a support for the localization of consciousness in brain and localization of mental functions to various parts of brain. The units of conscious hologram receiving information from external world behave effectively as functional units although the conscious experience is shared by the units of hologram connected by MEs to these units.

In particular, if some part of conscious hologram is stimulated strongly, the experience associated with the entire hologram is determined by this part of the hologram. Neurons can have complex experiences differing from our own experiences only in that stereo aspect is absent. Emotions are experienced by all cells of body: whereas primary sensory organs feed conscious information to sensory cortex, limbic brain acts as a primary emotional organ feeding conscious information to body, where emotions are not only expressed but also felt. Also the hypothesis about the realization of sensory representations at magnetic magnetic body and magnetosphere fits nicely with this picture: the new element is that microwave MEs propagating along EEG MEs induce self-organization at the magnetic body and magnetosphere.

The findings about bio-holograms [I18] give support for the notion of concious hologram. The pairs of frequencies involved corresponds low frequency of about kHz and high frequencies which in visible region. What happens is that simultaneous electrical stimulation of the inner ear affects the Kirlian image taken from the finger tip, and one can even deduce hologrammic image of the inner ear from the Kirlian image.

5.4 Quantum tools for bio-control and -coordination

Coordination and control are the two fundamental aspects in the functioning of the living matter. TGD suggests that at quantum level deterministic unitary time evolution of Dirac equation corresponds to coordination whereas time evolution by quantum jumps giving rise to self-organization corresponds to quantum control. The fractal hierarchies of MEs and super-conducting magnetic flux tubes and bio-matter at atomic space-time sheets would be the basic building blocks of the control system. The basic control structure would be many-sheeted ionic current circuitry: the currents would flow as supercurrents at magnetic flux tubes and as ohmic currents at atomic space-time sheets. MEs would interact with the super currents via magnetic induction and by forming Josephson junctions between magnetic flux tubes. An important mechanism of control would be 'let it go' mechanism in which the control of atomic space-time sheets would fail for a moment: this would be like opening the faucet for a moment.

Supracurrents and non-dissipative Josephson currents associated with weakly coupled superconductors would be the key element in coordination whereas oscillating super currents and Josephson currents at resonance frequencies inducing quantum jumps and thus 'waking-up' sub-selves and initiating quantum self-organization, would be crucial for control.

This view allows to consider more detailed mechanisms. What is certainly needed in the coordination of the grown-up organism are biological clocks, which are oscillators coupled to the biological activity of the organ. Good examples are the clocks coordinating the brain activity, respiration and heart beat [I33] . For example, in the heart beat the muscle contractions in various parts of heart occur in synchronized manner with a well defined phase differences. Various functional disorders, say heart fibrillation, result from the loss of this spatial coherence. For a control also biological alarm clocks are needed. An alarm clock is needed to tell when the time is ripe for the cell to replicate during morphogenesis. Some signal must tell that is time to begin differentiation to substructures during morphogenesis: for example, in case of the verterbrates the generation of somites is a very regular process starting at certain phase of development and proceeding with a clockwise precision.

5.4.1 Many-sheeted ionic flow equilibrium as a fundamental control mechanism

Many-sheeted ionic flow equilibrium in which supra currents at magnetic flux tubes flow to atomic space-time sheets where they run as ohmic currents, and back, is very attractive quantum control mechanism and the empirical facts discussed in the [K12, K13] provide strong support for this mechanism.

1. The mechanism requires the presence of coherent electric fields at atomic space-time sheets, which can however be very weak. The liquid crystal property implying electret property guarantees this. Current conservation relates the ionic densities in super-conducting magnetic flux tube circuitry and non-super-conducting atomic parts of the circuitry. For the simplest circuit one has in equilibrium $I_{super} = n_{super}v_{super} = I_{atom} = n_{atom}v_{atom}$, which gives

   $$n_{atom} = n_{super} \times \frac{v_{super}}{v_{atom}} \quad .$$

   The atomic drift velocity v_{atom} relates to the electric field E at the atomic space-time sheet and to the coefficient k_{ion} characterizing the proportionality of the ionic friction force to velocity

   $$v_{atom} = \frac{E}{k_{ion}} \quad .$$

   The weaker the electric field and the stronger the ionic friction, the stronger the amplification of the super-conducting ionic density to the ionic density at atomic space-time sheet is. Therefore very weak super-conducting ion densities can perform effective control.

2. v_{super} is typically proportional to the magnetic quantum number characterizing super current and the interaction of the current circuits with the external magnetic fields, in particular those associated with MEs, can change the value of the super-conducting ionic velocity v_{super} (magnetic flux is related to current via $\Phi = LI$ modulo elementary flux quantum). This means that MEs can control the densities of the ions at atomic space-time sheets. If the electric field and friction coefficient remain constant paramaters, the values of the ion densities at atomic space-time sheets are quantized by the quantization of the magnetic quantum number, typically integer. This might provide an empirical test for the mechanism.

3. The rates for the quantum transitions for Bose-Einstein condensates of super-conducting ions are proportional to N^2, where N is the number of ions. This means coherence and amplification. This could in fact lead to quantum phase transitions in which all ions experience the same quantum transition. In particular, magnetic quantum phase transitions suggest itself and they could make possible what might be called endogenous nuclear magnetic resonance (NMR) spectroscopy: the generated coherent light would Bose-Einstein condense on MEs and generate conscious experience and give rise to chemical qualia. Perhaps even other than magnetic quantum phase transitions could occur. One cannot exclude the possibility that even DNA and proteins could form super-conducting BE condensates (although the large number of internal almost degenerate states perhaps hinders this) and MEs could thus control their conformations by

inducing conformation changing transitions. This would make possible very effective bio-control by controlling the conformations of enzyme molecules determining their catalytic properties.

4. By their small mass implying high mobility, electrons play an important role in the control of the conformations of bio-molecules. Electronic flow equilibrium between molecular and atomic space-time sheets could be responsible for the quantum control of the molecular conformations. The electronic supra-currents associated with DNA and protein space-time sheets could be directly controlled by the interaction with MEs; the supra-currents (depending on magnetic quantum numbers) would in control the distribution of electrons at the atomic space-time sheets, which in turn would determine the conformation of the bio-molecule. MEs could thus induce collective phase transitions between various molecular conformations. This mechanism seems more plausible than the partipancy of large bio-molecules to the many-sheeted ionic flow.

   Immune system would guarantee that the frequencies associated with the transitions inducing changes of all protein and DNA conformations so near to each other so that MEs can induce these collective phase transitions efficiently. For not quite identical invader protens these frequencies are too different and they cannot participate to the coherent phase transitions. The recognition of the invader proteins could be based on the very fact that they do not respond to the same frequencies as the own proteins of the organism.

5.4.2 Self-hierarchy and hierarchy of weakly coupled superconductors

The realization that bio-systems are full of macroscopic quantum phases led to the general idea about the dynamical realization of the self-hierarchy as a master-slave hierarchy formed by weakly coupled superconductors. The formation of join along boundaries bonds between the space-time sheets at different levels of the self hierarchy makes it possible for a higher level self, not only to experience what it is to be the lower level self, but also to perform quantum control. Join along boundaries bonds give rise to Josephson junctions carrying Josephson current characterized by Josephson frequency.

The first proposal for the mechanism of bio-control was based on the idea was that when Josephson frequency equals to the energy difference of the quantum states of the charge carriers localized in either superconductor, resonant transfer of ions between superconductors occurs. If the localized states in question result from magnetic confinement, energy difference corresponds to a multiple of the cyclotron frequency of the charge carrier. Also supra currents and ohmic currents (above critical flow velocity) could flow through the join along boundaries contacts and are expected to be also important in bio-control. The later work did not lead to any detailed realization of this model and led to proposal for a model of quantum bio-control which makes sense only in the full conceptual framework provided by TGD.

The observed effects of various ELF fields on brain can be indeed understood if cyclotron frequencies in an endogenous magnetic field $B_{end} = .2$ Gauss are in question. This magnetic field is not equal to the magnetic field of Earth as I erratically believed for a long time but relates to the nominal value $B_E = .5$ Gauss of the Earth's magnetic field by the scaling $B_{end} = 2B_E/5$. The interpretation of B_{end} as a dark counterpart of the Earth's magnetic field carrying dark ionic Bose-Einstein condensates turns out to be natural in TGD framework.

This leads to a beautiful general realization of quantum control. Destructive interference of supra currents leads to a large net Josephson current and various biological clocks could rely on this mechanism. When reference supra current representing the expected sensory input and a current representing real sensory input and flowing in parallel manner in weakly coupled superconductors, are sufficiently near to each other, constructive interference of the Josephson currents occurs and can give rise to a synchronous firing. This makes possible conscious comparison circuits. Conscious novelty detectors can be build easily from comparison circuits using inhibitory and excitatory synaptic connections.

Simple model for weakly coupled super conductors

Several kinds of Josephson currents between cell interior and exterior are possible. Soliton sequences are the simplest solutions of Sine-Gordon equation for the Josephson junctions associated with a linear structure such as axon idealized as an infinitely long and thin cylindrical surface and are mathematically equivalent with a rotating gravitational pendulum.

The most general formulation starts from the Klein-Gordon equation for the order parameters Ψ_i, $i = 1,2$ for the super-conductors coupled linearly to each other in the junction

$$
\begin{aligned}
D\Psi_1 &= m^2\Psi_1 + m_{12}^2\Psi_2 \ , \\
D\Psi_2 &= m^2\Psi_2 + m_{12}^2\Psi_1 \ , \\
D &= (\partial_\mu + iZeA_\mu)(\partial_\mu - iZeA_\mu)
\end{aligned}
\tag{5.4.1}
$$

Here m denotes the charge of the super-conducting particle (say Cooper pair) and m_{12}^2 is real parameter characterizing the coupling between the superconductors. A_μ denotes electromagnetic vector potential associated with the superconductors.

Weakly coupled superconductors are assumed to possess cylindrical symmetry and can regarded as inner and out cylinder with Josephson junctions idealized with smooth distribution of them. If ME acts as Josephson junctions this asumption is exact. Weak coupling means that that the densities of charge carriers are same at the two sides of the junction in a good approximation:

$$
\Psi_i = \sqrt{n}exp(i\Phi_i) \ , \ i = 1,2 \ . \tag{5.4.2}
$$

Under these assumptions one obtains for the phase difference $\Phi \equiv \Phi_1 - \Phi_2$ the Sine-Gordon equation with a coupling to the vector potential

$$
\partial^\mu \left[\partial_\mu \Phi - q\Delta A_\mu\right] = m_{12}^2 sin(\Phi) \tag{5.4.3}
$$

ΔA_μ denotes the difference of the vector potential over the junction. q denotes the charge of the super-conducting charge carrier.

Note that Lorentz gauge condition

$$
\partial_\mu A^\mu = 0 \tag{5.4.4}
$$

does not trivialize the coupling to the vector potential since the equation holds true only in 3-dimensional surface defining the junction and the contribution from the direction of the normal is not present.

Josephson current J_J can be identified as the divergence of the 4-current $j_\mu = Ze\rho = Ze\Psi^*(\partial_\mu^{\rightarrow} - \partial_\mu^{\leftarrow})\Psi$ at the either side of the junction.

$$
J_J = \partial_\mu J^\mu = Ze \times \frac{n}{m} \times m_{12}^2 sin(\Phi) \ . \tag{5.4.5}
$$

The Josephson current per unit length of axonal membrane of radius R and thickness d is given by

$$
J = Ze \times \frac{n2\pi Rd}{m} \times m_{12}^2 sin(\Phi) \ . \tag{5.4.6}
$$

The parameter m_{12}^2 is analogous to the inverse of the magnetic penetration length squared ($\hbar = c = 1$) for the super-conductors involved.

$$
m_{12}^2 = \frac{1}{\Lambda^2} \ . \tag{5.4.7}
$$

If one can regard the Josephson junction region as a defect in a super-conductor, Λ is apart from a numerical constant of order unity equal to the thickness of the Josephson junction. In the case of the cell membrane this would mean that the small oscillations associated with the Josephson junction have frequencies of order 10^{16} Hz and correspond to quanta with energies of order 100 eV.

The covariant constancy conditions

$$\begin{aligned}\partial_t\Phi &= ZeV(t,z) \ , \\ \partial_z\Phi &= ZeA_z(t,z) \ . \end{aligned} \tag{5.4.8}$$

are mutually consistent only if the electric field in the axial direction vanishes. They are not however consistent with the right hand side of the equation and only one of the conditions can be satisfied. The condition effectively reduces the equation to an ordinary differential equation. Of course, one cannot assume the condition for general solutions.

For a constant potential difference V_0 the Josephson current is sinusoidal for $\partial_t\Phi = ZeV_0$ ansatz with the basic frequency given by $\omega = eV_0$. An exact treatment replaces the sinusoidal time dependence of Φ with the time dependence of the angle coordinate of gravitational pendulum so that higher harmonics are involved. In case of cell membrane $V(t)$ is typically a sum of constant part and time dependent part giving rise to frequency modulation of the basic Josephson current:

$$\omega(t) = eV = eV_0 + eV_1(t) \ .$$

Entire hierarchy of frequency modulations is possible since also eV_1 can be frequency modulated by Josephson currents.

Josephson junctions and interaction with coherent photons

Josephson junctions between two electronic super conductors make possible the coupling of super conductors to coherent photons, which in TGD based biology are emitted by various linear structures (in case that these structures contain space-time sheet representing massless extremals). The macroscopic description of Josephson junction is based on the current-voltage relation [D8, D6]

$$\begin{aligned} I &= I_0 sin(\phi) + C_j\frac{dV}{dt} + \frac{V}{R_j} \ , \\ \phi &= \int 2eVdt \ . \end{aligned} \tag{5.4.9}$$

Critical current I_0, the shunt resistance R_j and the capacitance C_j are macroscopic parameters in the description of the Josephson junction. Note that C_j is essentially kinematical parameter determined by the geometry of the Josephson junction. ϕ is equal to phase difference between the weakly coupled superconductors and $I_0 sin(\phi)$ is the Josephson current giving rise to the typical stepwise current-voltage characteristic. I_0 can be related to the microscopic properties of the Josephson junction.

A good candidate for a Josephson junction is cell membrane. In this case Josephson current corresponds to a protein connecting the lipid layers of the cell membrane. If Cooper pairs tunnel, I_0 is proportional to density of Cooper pairs at space-time sheet involved and to the rate for the tunnelling of single Cooper pair. If single electron tunnelling is in question, I_0 is proportional to the rate of single electron tunnelling and the density of the unpaired electrons. It is in principle quite possible to estimate I_0 for, say, proteins connecting cell membrane.

In case that there are several parallel Josephson junctions the current contains sum over various Josephson currents and destructive interference between the Josephson currents becomes possible. Quantum criticality suggests that destructive interference might serve as a biological alarm clock based on the interference of some reference current and a current describing input to system and representing perhaps sensory data. Dissipation would lead to the reduction of the reference current but the ringing of the clock induced in this manner would regenerate the reference current automatically. Second possibility is a comparison circuit based on parallel supra currents of equal magnitude flowing in weakly coupled super conductors. If the currents are in the same phase, constructive interference of Josephson currents associated with various Josephson junctions occurs and can in turn lead to large effects, such as neural firing.

Josephson junctions can be realized as join along boundaries bonds and the potential difference between the coupled superconductors characterizes the link as far as the electromagnetic coupling is considered: the energies of photons emitted by the Josephson current are multiples of the potential difference eV: $E = neV$ [D8, D6] . For cell membrane eV is about $eV \simeq .05$ eV.

Simplest solutions of Sine-Gordon equation

Free Sine-Gordon equation resulting, when the coupling to the em field can be neglected, gives a good view about the solutions of full equation. In cylindrical geometry Sine-Gordon equation becomes effectively 2-dimensional under rather natural conditions. This is rather nice since two-dimensional Sine-Gordon equation is completely integrable and thus allows an infinite number of conserved charges [B8] .

Sine-Gordon equation allows two kinds of vacua. The vacua of first type correspond to $\Phi = 2n\pi$ ground state configuration and vacua second type to $\Phi = (2n+1)\pi$. The small perturbations around these vacua correspond to massive 1+2 dimensional free field theory with field equations

$$\begin{aligned} D\Phi &= \epsilon\frac{1}{\Lambda^2}\Phi \ ; \\ D &= \partial_t^2 - \nabla^2 \ , \\ \epsilon &= -1 \ \text{for} \ \Phi = n2\pi \ , \\ \epsilon &= 1 \ \text{for} \ \Phi = (2n+1)\pi \ . \end{aligned} \tag{5.4.10}$$

In the language of quantum field theory, the small perturbations around $\Phi = n2\pi$ describe particle with mass squared $m^2 = \frac{1}{\Lambda^2}$ whereas the small perturbations of the $\Phi = (2n+1)\pi$ vacuum describe tachyons with negative mass squared $m^2 = -\frac{1}{\Lambda^2}$. Therefore these vacua will be referred to as time like and space like respectively.

One might argue that the space like vacua are unstable in the case that the continuous sheet of the Josephson junctions consists actually of discrete Josephson junctions, whose dynamics is given by the differential equation

$$\frac{d^2\Phi}{dt^2} = -\frac{sin(\Phi)}{\Lambda^2}$$

allowing only $\Phi = n2\pi$ as stable ground state. For MEs acting as Josephson junction the situation is different. On the other hand, the ground state at which soliton generation is possible should be quantum critical and hence very sensitive to external perturbations. Note that time like and space like sectors in axonal portion of neuron are permuted by a duality transformation $z \leftrightarrow vt$ (v=c=1), $\Phi \rightarrow \Phi + \pi$, which is exact symmetry of the 1+1-dimensional Sine-Gordon equation.

The propagating waves are of form $sin(u)$, where one has

$$\begin{aligned} u &= \gamma_P(t - \frac{v_P z}{v^2}) \ , \ \text{time like case} \\ u &= \gamma_P(z - v_P t) \ , \ \text{space like case} \\ \gamma_P &= \sqrt{\frac{1}{1-(\frac{v_P}{v})^2}} \ . \end{aligned} \tag{5.4.11}$$

Here v_P is the velocity parameter characterizing the boost. The frequency of these small propagating oscillations (planewaves) is in two cases given by

$$\begin{aligned} \Omega &= \frac{\gamma_P v}{\Lambda} \ , \ \text{time like case} \ , \\ \Omega &= \frac{\gamma_P v_P}{\Lambda} \ , \ \text{space like case} \ . \end{aligned} \tag{5.4.12}$$

The frequency is very high for time like waves, of order 10^{10} Hz and therefore a typical time scale for the conformational dynamics of proteins. In space like case the phase velocity of the propagating waves is $v_P < v$ and frequencies are small and one could consider the possibility of identifying these oscillations as propagating EEG waves. For the time like excitations phase velocity is $v_p = v^2/v_P > v$ and larger than light velocity. For ordinary elementary particles the situation is same but since phase velocity is in question, there are no interpretational problems.

One-dimensional solutions of the Sine-Gordon equation give quite satisfactory picture about the situation as far as the physical interpretation is considered. The simplest solutions of this type correspond to solutions depending on time or spatial coordinates only. For time like vacua one-dimensional solutions depend on time only: note that these solutions are possible for arbitrary geometry of the Josephson junction. For space like like vacua one-dimensional solutions are possible in the axonal portions of the neuron: the simplest one-dimensional solutions depend on the axonal coordinate z only.

Field equations reduce to the equations of motion for gravitational pendulum:

$$\frac{d^2\Phi}{du^2} = -\frac{1}{\Lambda^2}sin(\Phi) \ . \tag{5.4.13}$$

$u = vt$ holds true in time like case ($v = c \equiv 1$ is good approximation). $u = z$ holds true in space like case (in this case equation makes sense for axonal portions only). Energy conservation for the gravitational pendulum gives

$$\frac{1}{2}v^2(\frac{d\Phi}{du})^2 + \frac{v^2}{\Lambda^2}\left[1 - cos(\Phi)\right] = K\frac{2v^2}{\Lambda^2} \ , \tag{5.4.14}$$

where K is dimensionless constant analogous to energy. There are two kinds of solutions: oscillating solutions ($K < 1$) and rotating solutions ($K > 1$): single soliton solution corresponds to $K = 1$.

One can integrate the conservation law for energy to give the time/spatial period of oscillation or rotation (T/λ). For oscillating solutions one has

$$T = \frac{\lambda}{v} = \frac{\Lambda}{v}\int_{-\Phi_0}^{+\Phi_0} d\Phi \frac{1}{\sqrt{2\left[-cos(\Phi_0) + cos(\Phi)\right]}} \ . \tag{5.4.15}$$

Here Φ_0 is maximum value of the phase angle for oscillating solution. For the rotation period one obtains

$$T = \frac{\lambda}{v} = \frac{\Lambda}{v}\int_{0}^{2\pi} d\Phi \frac{1}{\sqrt{(\frac{d\Phi}{dt})^2(\Phi = \pi) + 2\left[1 - cos(\Phi)\right]}} \ . \tag{5.4.16}$$

By Lorentz-boosting space like axonal solutions to move with velocity v_p one obtains propagating soliton sequences.

Sine-Gordon equation is completely integrable and thus allows an infinite number of conserved charges. In quantum theory the eigenvalues of mutually commuting charges characterize the quantum state and these charges are basic quantum observables. Does it make sense to quantize Sine-Gordon and could one characterize the state of the axonal membrane in terms of these charges? Here one must point out the similarity to the ideas of [J30] [J30] , who speculates with the possibility that certain 2-dimensional conformal field theory characterizes the state of micro-tubule and the infinite number of conserve charges characterize the information content of the micro-tubule. It is perhaps also worth of mentioning that the quantum group $SU(2)$ appears in the quantization of the Sine-Gordon equation [B15] : could quantum groups have important applications in biology?

Modulation hierarchy of Josephson currents

The modulation of the Josephson current is induced by the oscillatory time varying part of the potential difference superposed to constant part. The oscillatory time dependent part can be generated by an oscillatory em current through the cell membrane or running from cellular space-time sheet to some other space-time sheet via join along boundaries bonds. Also currents which run between different levels of the p-adic lengths scale hierarchy and could flow along join along boundaries bonds connecting space-time sheets at different levels of the hierarchy.

One can consider also frequency modulations of frequency modulations of .... forming a hierarchical structure analogous to the abstraction hierarchy and giving rise to abstraction hierarchy of senses. This would explain the effects of various frequency modulated signals to brain. The effects of external em field to bio-system are expected to be largest when the frequency modulated signal is as nearly as possible equal to the modulating part of the membrane potential. Modulation hierarchy can be realized if the em current yielding modulation at given level is itself Josephson current so that entire hierarchy of Josephson junctions is implied. In this case modulating current cannot be between cell interior and exterior however but between cell interior or interior and some other space-time sheet at same or different p-adic hierarchy level. Josephson currents induce oscillatory changes of total charges of space-time sheets involved and these in turn induce oscillatory modulations of the potential differences between various Josephson junctions.

The hypothesis that modulation hierarchy corresponds to the p-adic hierarchy of space-time sheets suggests that Josephson currents in question are between space-time sheet representing different hierarchy levels. Josephson current flow along the join along boundary contacts connecting these space-time sheets ('biofeedback'). The current would change the density of charged particles at cellular space-time sheet and induce change of the membrane potential proportional to the Josephson current in question. An essential point is that the two space-time sheets in question ought to be superconducting.

5.4.3 General mechanism making possible biological clocks and alarm clocks, comparison circuits and novelty detectors

Weakly coupled superconductors and quantum self-organization make possible very general models of biological clocks and alarm clocks as well as comparison circuits and novelty detectors.

The Josephson junction between two super-conductors provides a manner to realize a biological clock. Josephson current can be written in the form [D8]

$$\begin{aligned} J &= J_0 sin(\Delta\Phi) = J_0 sin(\Omega t) \ , \\ \Omega &= ZeV \ , \end{aligned} \tag{5.4.17}$$

where Ω is proportional to the potential difference over the Josephson junction. Josephson current flows without dissipation.

In BCS theory of super-conductivity the value of the current J_0 can be expressed in terms of the energy gap Δ of the superconductor and the ordinary conductivity of the junction. When the temperature is much smaller than critical temperature, the current density for a junction is given by the expression [D8]

$$J_0 = \frac{\pi}{2e}\frac{\sigma_s \Delta}{d} \ . \tag{5.4.18}$$

Here σ_s is the conductivity of the junction in the normal state assuming that all conduction electrons can become carriers of the supra current. d is the distance between the superconductors. The current in turn implies a position independent(!) oscillation of the Cooper pair density inside the two superconductors. By the previous arguments the density of the Cooper pairs is an ideal tool of bio-control and a rhythmic change in biological activity expected to result in general. Josephson junctions are therefore good candidates for pacemakers not only in brain but also in heart and in respiratory system.

In the presence of several parallel Josephson junctions quantum interference effects become possible if supra currents flow in the super conductors. Supra current is proportional to the gradient of the phase angle associated with the order parameter, so that the phase angle Φ is not same for the Josephson junctions anymore and the total Josephson current reads as

$$J = \sum_n J_0(n) sin(\Omega t + \Delta\Phi(n)) \ . \tag{5.4.19}$$

It is clear that destructive interference takes place. The degree of the destructive interference depends on the magnitude of the supra currents and on the number of Josephson junctions.

There are several options depending on whether both superconductors carry parallel supra currents or whether only second superconductor carries supra current.

1. If both superconductors carry supra currents of same magnitude but different velocity, the phases associated with the currents have different spatial dependence and destructive interference occurs unless the currents propagate with similar velocity. This mechanism makes possible comparison circuit serving as a feature detector. What is needed is to represent the feature to be detected by a fixed supra current in the second superconductor and the input as supra current with same charge density but difference velocity. The problem is how the system is able to generate and preserve the reference current. If case that feature detector 'wakes-up' into self state when feature detection occurs, the subsequent quantum self-organization should lead to the generation of the reference current representing the feature to be detected.

2. If only second superconductor carries supra current and of this supra current for some reason decreases or becomes zero, constructive interference occurs for individual Josephson currents and net Josephson current increases: current causes large gradients of Cooper pair density and can lead to the in-stability of the structure. When the supra current in the circuit dissipates below a critical value, in-stability emerges. This provides a general mechanism of biological alarm clock.

   Assume that the second superconductor carriers a supra current. As the time passes the reference current dissipates by phase slippages [D4, D8] . If the reference current is large enough, the dissipation takes place with a constant rate. This in turn means that the Josephson current increases in the course of time. When the amplitude of the Josephson current becomes large enough, the density gradients of the charge carriers implied by it lead to an instability of the controlled system: the clock rings. Since the dissipation of (a sufficiently large) Josephson current takes place at constant rate this alarm clock can be quite accurate. It will be found that a variant of this mechanism might be at work even in the replication of DNA. The in-stability itself can regenerate the reference current to the clock. If the alarm clock actually 'wakes-up' the alarm clock to self state, self-organization by quantum jumps must lead to an asymptotic self-organization pattern in which the supra current in the circuit is the original one. Actually this should occur since asymptotic self-organization pattern depends only weakly on the initial values.

3. Novelty detector can be build by feeding the outputs of the feature detectors to an alarm clock circuit. In alarm clock circuit only the second superconductor carries supra current, which represents the sum of the outputs of the feature detectors. Since the output of a feature detector is non-vanishing only provided the input corresponds to the feature to be detected, the Josephson current in additional circuit becomes large only when the input does not correspond to any familiar pattern.

5.4.4 Biological quantum control circuits

Various macroscopic quantum phases such as the BE condensate of # contacts, electronic and ionic Cooper pairs, ions and even neutrino Cooper pairs and atomic Cooper pairs forming Z^0 super conductors provide a rich repertoire of possible realizations for comparison circuits, biological clock and alarm clocks as well as feature- and novelty detectors. Note that # contacts are expected to appear in all biologically relevant length scales.

1. Biological clock consists of parallel Josephson junctions between two subsystems, which could be organs or organelles or even bio-molecules. There is a sinusoidally varying Josephson current between the two super-conductors in question. Note that also propagating waves are possible. For the ordinary electronic superconductor, the current for a single junction is given by $J \propto (\Delta\sigma/\Omega)sin(\Omega t)$. The value of the conductivity σ depends on the properties of the Josephson junction. It is rather remarkable, that for low frequencies Ω the current increases: this could correlate with the fact that low frequency EEG amplitudes are larger than high frequency amplitudes if EEG frequencies indeed correspond to Josephson frequencies for ionic Josephson currents.

2. Possible biological applications are feature- and novelty detection in brain: very complicated logical circuits waking up some sub-self under given conditions are possible and can give rise to complicated program like behaviors in which wake-up leads to self-organization process. Simpler

applications are clocks and alarm clocks with brain (EEG and wake-up cycle) and heart beat and respiratory system. The additional bonus of the Josephson clock is that the nerve pulses generating the muscle contraction in the heart beat and respiration cycle can be generated at the second half of the clock period only so that very sharp control is achieved. These examples suggests that Ω is very small in general. There exist direct evidence for the Josephson clock at the muscle level: the rest length of the muscle is known to oscillate with a frequency of about 50 Hz. Josephson clock implies a periodic variation of the density of the charge carriers inside the muscle and the sensitivity of the stable length of the muscle to the density of the charge carriers implies the oscillatory behavior of the muscle length, too. Oscillation could directly relate with the oscillation of the muscle cell resting potential with this frequency such that nerve pulses are generated when resting potential is near to its minimum.

3. The spatial dependence of the order parameter provides a tool for the spatial synchronization. The large scale variations constant in the length scale of an individual biological alarm clock imply that the clocks have nonrandom lag with respect to some reference clock. This means that the process started by the ringing of the clocks propagates in an orderly fashion. As far as morphogenesis is considered, the really nice feature of the alarm clock mechanism is that the only information stored is the time lapse to the ringing of the clock and this can be stored, when the clock is created rather than being stored in the DNA of the organism. The same can be said about the phase information needed for a spatial synchronization. What happens is the feeding of negentropy to the clock from the environment, when the reference current is generated.

4. Binary structures are very general in bio-systems and seem to be associated with pairs of p-adic primes whose p-adic length scales are related by a factor of two. There are amazingly very many of them in the p-adic length scale range relevant to bio-systems (DNA double helices, cell membranes, epithelial sheets, bi-layered structures of cortex). Typically these structures consist of a large number of smaller subunits (lipids in case of lipid layers of cell membrane, cells in case of the epithelial sheet, larger groups of cells in case of structures of cortex). These structures are optimal comparison circuits and thus also feature- and novelty detectors as well as clocks and alarm clocks. What is needed is that the components of the bilayered structure are weakly coupled superconductors of some kind.

5.4.5 A quantitative model for the bio-control performed by # contact BE condensate

Since # contacts are expected to form BE condensates at all space-time sheets of the topological condensate, they provide an ideal tool for the control and coordination in bio-systems. If bio-systems correspond to 4-surfaces, which are small deformations of the vacuum extremals of Kähler action, the idea about # contacts as the master and the geometry and 3-topology as slave is very attractive. For the coordination biological clocks are need. # contact BE condensate is very much like superconductor and Josephson junctions with an oscillating phase difference as well as propagating waves are possible. For bio-control localized kinks, solitons, representing a localized increment of the phase angle Ψ or Φ by a multiple of 2π could be crucial. These kinks should be created by a process analogous to the phase slippage process.

It is highly desirable to find a quantitative formulation for the coupling between # contact BE condensate and 3-geometry in terms of a variational principle. This kind of formulation is indeed possible and is obtained from the free action associated with the # contact condensate by writing it in the induced metric for the boundary of the space-time surface regarded as a dynamical object.

Formulation of the model

The physical constraints on the action are as follows:

1. The field equations for the # contact order parameter describe charged bosonic particles with mass m of order $m \sim 1/L(n)$, where $L(n)$ is the characteristics length scale associated with the condensate level n. This amounts to the addition of a term of form

$$L_0 = \bar{\psi}(-D^{\mu}D_{\mu} - m^2)\psi\sqrt{g} \ , \qquad (5.4.20)$$

to the action. Here D_μ is the covariant derivative in the induced metric including also the term giving coupling to the difference of the classical electromagnetic gauge potentials associated with the two space-time sheets involved. If coherent photons are present, a similar term associated with the topologically condensed coherent photons on the two space-time sheets, is present. Index raising is performed using the induced metric regarded as a dynamical variable.

2. The total electromagnetic charge of the 3-surface is fixed, so that the total charge associated with the BE condensate is $N(\#)$ and is conserved. This condition is included as a Lagrange multiplier term

$$S_1 = \int dt\lambda_1(t)\left[\int \bar{\psi}(i\partial_t^{\leftarrow} - i\partial_t^{\rightarrow})\psi\sqrt{g_2}d^2x - N(\#)\right] . \tag{5.4.21}$$

The term breaks manifest coordinate invariance.

3. At least in the length scales sufficiently larger than molecular length scales, the volume of the 3-surface can be assumed to be fixed since hydrodynamic flow is incompressible in excellent approximation. This amounts to the addition of a Lagrange multiplier term

$$S_2 = \int dt\lambda_2(t)\left[\int \sqrt{g_3}d^3x - V\right] . \tag{5.4.22}$$

This term gives rise to a term appearing as a source term in the equations determining the geometric form of the boundary of the 3-surface.

4. The intuitive expectation # contact BE condensate can exist in two phases analogous to superconductor of type I and II respectively. In the first phase the surface area is minimized and the density of the # contacts is maximized. This phases clearly corresponds to the situation in which the 3-surface is far from a vacuum extremal. In the second phase the surface area is maximized and the density of the # contacts is minimized. This phase corresponds to the 3-surface near to a vacuum extremal and the generation of regions of this phase can lead to the changes of the molecular conformations and to the changes of the macroscopic shape of the organ. The presence of the two phases is achieved by adding a "mass renormalization term"

$$\begin{aligned} L_\Delta &= \Delta m^2 n\sqrt{g} , \\ n &\equiv \bar{\psi}\psi . \end{aligned} \tag{5.4.23}$$

to the action and taking care that the # contacts propagate with a correct mass by using a Lagrange multiplier:

$$L_3 = \lambda_3 L_0 . \tag{5.4.24}$$

Δm^2 could also have a slow dependence on position.

5. The sign of Δm^2 determines the character of the system. If the sign is postive/negative the surface energy density is negative and surface area is minimized/maximized. Thus Δm^2 could serve as a control parameter, whose changes induce changes in the conformation of the 3-surface. The value of Δm^2 could be taken as input and could depend on parameter such as temperature and electromagnetic potential differences. One can imagine the existence of a critical temperature T_c such that $\Delta m^2 \propto T_c - T$ holds true. In low temperatures the 3-surface would freeze and minimizes the area of its outer boundary. In high temperatures 3-surface would become fractal like and random.

6. The maximization of the surface area with a fixed volume leads to an in-stability since a surface with a given volume can have an arbitrarily large surface area. This suggests that Δm^2 term contains also a regulating term nonlinear in ψ. In the spirit of Ginzburg-Landau action, one could have

$$\begin{aligned} L_{\Delta_1} &= \Delta_1 m^2 n\sqrt{g} \ , \\ \Delta_1 m^2 &= \lambda(n-n_0) \ , \\ n &\equiv \bar{\psi}\psi \ . \end{aligned} \tag{5.4.25}$$

The most reasonable choice for the sign of the term is dictated by the stability requirement. Below the critical value n_0 of the # contact density the 3-surface should be minimized (, which increases n) its area whereas above n_0 the area should be maximized (, which reduces n). This term need not appear in the wave equation as usually, if the constraint term gives wave equation. It however appears in the energy density and the ground state solution can be fixed by requiring the minimization of the energy.

Field equations

With these assumptions the field equations reduce to the wave equation for the order parameter in the induced metric

$$(-D^{\mu}D_{\mu} - m^2)\psi = 0 \ , \tag{5.4.26}$$

and to equations analogous to the conservation of the energy momentum associated with the order parameter:

$$\begin{aligned} D_{\beta}(T^{\alpha\beta}\partial_{\beta}h^k) &= \lambda_1 g_3^{n\beta}\partial_{\beta}h^k + ... \ , \\ T_{\alpha\beta} &= \bar{\psi}D_{\alpha}^{\leftarrow}D_{\beta}\psi - \frac{1}{4}g_{\alpha\beta}L_0 \ . \end{aligned} \tag{5.4.27}$$

The source term comes from the volume constraint. There are analogous source terms associated with the other constraints. These terms are present only provided the corresponding Lagrange multipliers are non-vanishing.

Neglecting the presence of the gauge potential terms, possibly not transformable away by a gauge transformation, the simplest stationary solution of the equations is of the form

$$\begin{aligned} \psi &= exp(imt)\psi_0 \ , \\ n = \bar{\psi}_0\psi_0 &= \frac{N(\#)}{mA} \ , \end{aligned} \tag{5.4.28}$$

where A is the total surface area. The terms involving time derivatives disappear from the field equations determining the 3-surface and if Δm^2 is non-vanishing the field equations reduce to the condition stating that the 3-surface minimizes/maximizes its surface area subject to the condition that its volume is fixed. In the critical case with $\Delta m^2 = 0$ the equations state nothing about the form of the boundary surface and it becomes completely random (but static) at criticality.

5.4.6 Model for weakly coupled wormhole superconductors

Wormhole superconductivity played a key role in earlier quantum model for EEG and nerve pulse. Although it turned out that the proposed role is very probably not realized in real world, weakly coupled wormhole superconductors are quite possible and there is even evidence for them. The hypothesis that potential differences associated with various Josephson junctions correspond to cyclotron frequencies, suggests that cell interior and exterior should form pair of weakly coupled wormhole superconductors such that the wormholes contacts in question connect $k = 169$ cellular space-time sheet and $k = 173$ space-time sheet at the next level of the hierarchy. The time scale associated with this particular wormhole superconductivity is obviously quite different from that associated with nerve pulse generation and EEG and the time scale in which possible quantum control takes corresponds to the natural time scale for molecular vibrational levels (photon energies in near infrared). In the following model for the Josephson junction of wormhole superconductors assumes for definiteness that lipid layers of the cell membrane are the coupled superconductors: reader can easily generalize the results to more general case.

Physical picture

The effective charge carriers are # contacts feeding em charge between two space-time sheets. There are actually opposite classical em currents at the two space-time sheets and in quantum field context there is just the current of extremely tiny Planck length scale dipoles having practically no coupling to photons (this makes dissipative effects very small!). # contacts couple to the difference ΔA of the classical gauge potentials and of the order parameters describing topologically condensed coherent photons associated with the two space-time sheets joined by the # contacts. This provides the needed coupling to the classical fields and to the coherent photons generated by micro-tubuli serving as quantum antennas. # contact BE condensate couples also to the geometry of the boundary of the 3-surface since the action defining the dynamics contains the induced metric of the boundary regarded as a dynamical variable. In the present context this coupling is not important.

The complex order parameter for # contacts satisfies d'Alembert type wave equation with minimal coupling to ΔA. The order of magnitude for the lowest excitation energies is $\Delta E \sim 1/L$, where L is the size of the join along boundaries condensate to which the # contacts are associated. The mass of # contact is from p-adic length scale hypothesis inversely proportional to the p-adic length scale $L(p)$ associated with the larger space-time sheet: $m \sim 1/L(p)$. For instance, for cell membrane the relevant p-adic length scale is roughly the thickness $L(p) \sim d \sim 10^{-8}$ meters of the cell membrane and one has $m(\#) \sim 10^2$ eV. Because of their small mass # contacts form a BE condensate, when temperature is below $T \sim 1/L$ (this estimate is probably too conservative): in the room temperature the largest size of join along boundaries condensate would be thus of order 10^{-4} meters, which is indeed the size of largest known information processing structures in cortex [K14] . It must be emphasized that thermal argument is probably conservative: large space-time sheets need not be in thermal equilibrium with atomic space-time sheet and in fact they are *not* in the TGD based realization of living matter as a hierarchy of weakly coupled superconductors. By their extremely small coupling to photons # contacts (photonic dissipation is minimal) might be able to form BE condensates even above $T \sim 1/L$. As far as mathematical description is considered, charged # contacts behave very much like Cooper pairs. In particular, the concept of Josephson junction generalizes.

For # contacts "Josephson junctions" are join along boundaries bonds connecting the lipid layers together on the smaller space-time sheet, the larger space-time sheet is a connected surface. These bonds could correspond to weak chemical bonds between the hydrophobic ends of the lipids and need not be stable. Also the proteins connecting lipid layers could serve as Josephson junctions. Josephson junctions are idealized with a continuous distribution so that one can imagine a continuous sheet of thickness $d \sim 10^{-9} - 10^{-10}$ meters between the lipid layers serving as a single Josephson junction. Join along boundaries contacts make possible the motion of the # contacts between the join along boundaries condensates associated with the lipid layers. This induces a coupling between the order parameters associated with the two lipid layers. One obtains Sine-Gordon equation coupled to gauge potential by generalizing the argument of Josephson from Schrödinger equation to almost massless d'Alembert type wave equation for the order parameter describing the BE condensates of # contacts at the boundaries of the two join along boundaries condensates. Sine-Gordon coupled to a gauge potential difference is obtained directly whereas for the Cooper pairs Sine-Gordon is obtained from the Maxwell equation $\nabla \times B = J$ by assuming that order parameter satisfies covariant constancy conditions, which in turn forces to make ad hoc assumptions and would lead in the recent case to difficulties.

Field equation for the phase difference

The basic assumptions of # contact models are following. For definiteness only axon (of radius R, typically of order $R \sim 10^{-6}$ meters) is considered. Lipid layers are regarded as cylindrical surface of thickness d of order $d \sim .5\times10^{-8}$ meters. The distribution of the join along boundaries contacts serving as Josephson junctions is replaced with a continuous density of the join along boundaries contacts of thickness of order $10^{-9} - 10^{-10}$ meters. The order parameter is assumed to have approximately constant modulus

$$\bar{\Psi}\Psi \approx constant \ . \tag{5.4.29}$$

This requires that # contact flow between the lipid layers induces only small fractional changes in the total charge. The phase of the order parameter is assumed to depend on the time coordinate t and the longitudinal coordinate z of axon only.

The order parameter is assumed to satisfy linear d'Alembert type equation derivable from an action containing no higher nonlinearities than quadratic mass terms. General Ginzburg-Landau type action for the order parameter allows also quartic nonlinearities. These couplings are indeed needed to guarantee the stability of the system but are not relevant for the recent discussion. The action contains also a coupling to the geometry of the boundary regarded as dynamical. The coupling is via the induced metric and the corresponding field equations are analogous to the conservation laws for energy momentum. Also this aspect is irrelevant for the recent purposes although it might be important for the understanding of the geometrodynamics of the cell membrane during the nerve pulse propagation (the opening/closing of various ion gates corresponds to a change of the topology for the cell membrane 3-surface).

Consider now the derivation of Sine-Gordon type equation for the phase difference associated with # contact condensates. The difference with respect to the standard derivation is that # contacts satisfy − not Schrödinger equation − but d'Alembert equation with very small mass and couple to the difference of gauge potentials associated with larger and smaller space-time sheet. Of course, nothing hinders using relativistic formulation also in case of ordinary super-conductors.

The coupling between the order parameters associated with the boundaries of two lipid layers is represented by a non-diagonal mass squared term $J_1 = \frac{1}{\Lambda^2}\Psi_2$, $J_2 = \frac{1}{\Lambda^2}\Psi_1$. Taking $x^0 = vt$ as time coordinate the equations read

$$\begin{aligned}
(D+m^2)\Psi_1 &= J_1 = -\frac{1}{2\Lambda^2}\Psi_2 \ , \\
(D+m^2)\Psi_2 &= J_2 = -\frac{1}{2\Lambda^2}\Psi_1 \ , \\
D &= D_\mu D^\mu = D_0^2 - \sum_i D_i D_i \\
D_\mu &= \partial_\mu + iQ\Delta A_\mu \ .
\end{aligned} \tag{5.4.30}$$

Q denotes the charge of # contact: if # contact is created, when electron is dropped from the atomic space-time sheet on the larger space-time sheet then its charge is positive: $Q = e$. Note that field equation of the same general form can be derived for weakly coupled superconductors quite generally.

If the fractional changes of the charge densities caused by Josephson current are small, the assumption that the moduli of Ψ_i are equal to same constant is a good approximation. Thus the ansatz is of the following general form

$$\begin{aligned}
\Psi_i &= R_i exp(i\omega t + \Phi_i) \ , \quad i = 1,2 \ ; \\
\omega &= mv
\end{aligned} \tag{5.4.31}$$

where $R_i = R$ is constant in the approximation used and v is the possibly reduced light velocity. By taking the difference for the imaginary parts of the field equations one obtains the following equation

$$D^\mu(\partial_\mu\Phi + Q\Delta A_\mu) = -\frac{1}{\Lambda^2} sin(\Phi) \ . \tag{5.4.32}$$

for the difference $\Phi = \Phi_2 - \Phi_1$ of the phases of the order parameters Ψ_1 and Ψ_2. This equation is 1+2-dimensional Sine-Gordon equation coupled to the gauge potential difference and reduces to Sine-Gordon if ΔA is small compared with the gradient of Φ. This is assumed to hold true in the sequel. It must be however emphasized that this coupling provides an important back-coupling term in the interaction between ordinary matter/coherent photons and the BE condensate of # contacts.

In cylindrical geometry the solutions can be assumed to be independent of the angle coordinate and one has 1+1-dimensional Sine-Gordon equation

$$\begin{aligned} (-\partial_0^2 + \partial_z^2)\Phi &= \frac{1}{\Lambda^2} sin(\Phi) \ , \\ x^0 &= vt \ , \end{aligned} \tag{5.4.33}$$

known to be a completely integrable system [B8] .

5.5 TGD and biochemistry

TGD brings in several new elements at the level of biochemistry.

1. Macro-temporal quantum coherence due to the spin glass degeneracy.
2. The geometric form of the bio-molecules ceases to be a phenomenological concept in TGD approach.
3. Chemical bond can be identified as the join along boundaries bond between two 3-surfaces.
4. # contacts might be the crucial step from the ordinary organic chemistry to biochemistry. For # contact superconductivity the conditions are rather mild since in TGD context the presence of light # contacts and thus their BE condensates is almost unavoidable. The hypothesis that some organic molecules might behave as # contact super conductors suggests a completely new manner to understand the bio-control at the level of DNA and proteins.
5. Almost vacuum space-time sheets carrying non-vanishing vacuum currents are possible in TGD and these currents generate coherent states of photons. The topologically condensed coherent photons can couple to the # contact BE condensates. Comorosan effect [I8, I29] is a good example of a phenomenon having an explanation in terms of a molecular # contact BE condensate coupling to coherent photons [K85] .
6. Nuclei can be regarded as completely ionized Z^0 ions and generate classical Z^0 fields screened by neutrinos. Z^0 fields seem to be fundamental for the understanding of the condensed matter stability and also the stability of molecules. The quantum control of the density of cellular water could explain the extreme effectiveness and sensitivity of catalysts. The axial part of classical Z^0 field can in turn explain the chirality selection of organic molecules in vivo. The central role of Z^0 force in biochemistry and pre-biotic evolution has become obvious only gradually and will be discussed in a separate section.

5.5.1 Macro-temporal quantum coherence and molecular sex

The formation of bound states is a generic mechanism for generating new quantum fluctuating degrees of freedom and could make possible quantum computation like processes and multiverse states of consciousness containing large amounts of conscious information. At macrolevel sexual organism could be basic example of multiverse state of oneness generated by the formation of quantum bound state between partners. Neuroscientists use to talk about rewards and punishments and one might argue that life involves kind of sexual pleasure as a reward for the formation of bound states at all levels of hierarchy. Spiritual experiences would represent a more abstract experiences of this kind involving the formation of bound states of the field bodies by MEs serving as field bridges.

Some examples are in order.

1. The binding of molecules by lock and key mechanism is a fundamental process in living matter and could generate large number of quantum fluctuating degrees of freedom and generate conscious intelligence. This could explain why long linear macromolecules are so important for life. From the viewpoint of classical chemistry it is not obvious why DNA is arranged into long chromosomes rather than separate short threads. In TGD universe the reason why would be that for chromosomes the number of quantum fluctuating degrees of freedom and thus the amount of conscious intelligence is maximized.

2. The Ca^{++} ions binding to micro-tubuli and molecules like calmodulin could act as switch like bridges between water clusters and micro-tubuli and thus able to dramatically increase the number of quantum fluctuating degrees of freedom and initiate quantum computation like process. The de-attachment of Ca^{++} ions would halt the process.

3. The binding of the information molecules to receptors is a universal control mechanism in living matter. In TGD universe information molecule would initiate genuine quantum information processing lasting for the lifetime of the information molecule-receptor complex. In particular, neurotransmitters could induce molecular states of oneness in receptor-neurotransmitter complex or perhaps even in larger-sized structures. If neurotransmitters have join along boundaries bonds to other neurons mediated by magnetic flux tube structures, they could act as conscious quantum links in quantum web and induce quantum computation like processes involving distant neurons just as link links in the web induce classical computations involving distance computers.

4. One could see information molecules and receptors as representatives of opposite sexes: information molecules being active quantum binders free to move from flower to flower whereas receptors would be the passive party attached to some structure. The binding of the information molecule to the receptor would be the analog of sexual intercourse. Usually the receptors are bound to larger structures such as cell membrane and also the zero modes for some parts of these larger structures could become quantum fluctuating in the process.

5.5.2 Organic polymers as topological field quanta

Organic polymers, in particular proteins formed as sequences of 20 different amino acids and DNA and related molecules formed as sequences of 4 basic nucleic acids, are the basic molecules of living matter and their characteristic features are their effective one-dimensionality and richness of structures. For example, proteins and nucleic acids can have several conformations: they can behave like aperiodic crystals or as random coils. Muscle proteins in turn can change their length in the contraction of the muscle. The conformation of the polymers is known to be sensitive to its electronic structure and to the properties (in particular pH) of the ionic environment. The chemical properties of silicon are very similar to those of carbon but for some reason(s) only carbon based life has developed.

A good TGD based model for organic polymers is as topological field quantum with approximate cylindrical symmetry. Linear structures are indeed in a very special position in TGD since the imbedding of the Kähler electric field associated with the field quantum gives no constraints on the length of the field quantum.

5.5.3 Organic molecules as super-conductors

The basic organic molecules appearing in regulative tasks (co-enzymes, vitamines, hormones) contain closed rings for which electron pairs are known to be delocalized along the ring, so that they could form superconductor. Also the basic building blocks of DNA contain closed rings although conjugated π bonds are absent [I33] . It is quite possible that the vacuum quantum number n_i associated with these loops are non-vanishing and therefore carriers of a biological information. Electronic superconductivity is not the only possibility: also # contacts could form supra currents flowing in these loops.

The changes in the vacuum quantum numbers associated with the closed loops of the organic polymer are generated by a phase slippage [D8] . Phase slippage generates a localized kink, which corresponds to a supra current analogous to a nerve pulse. An interesting possibility is that these kinks might control biochemical reactions.

Possible applications

One can imagine several applications for these excitations in the bio-control.

1. For the biochemical reaction to proceed it is necessary to have free energy, which enables to overcome activation energy barriers. This energy should be stored to the structure of the catalysts and possibly also of substrate in some form [I33] . According to [I33] the storage mechanism is not established yet. What certainly happens is that free energy liberated, when catalyst and substrate join together, must go to some degrees of freedom. One suggestion is that the vibrations of the compound molecule serve as a storage of free energy [I33] . The first TGD inspired alternative is that the free energy liberated in the joining of catalyst and substrate is stored to the kinetic energy of the supra charge carries rotating along the loops of the compound molecule (quantum number n_i) and can be used as an activation energy storage helping to overcome the activation energy barriers. As already noticed, the energy liberated form ATP is of the same order as the kinetic energy associated with a rotating charge carrier. A more radical TGD based alternative is that the loops of the organic molecules in vivo contain additional negentropy in the form of the slowly dissipating supra currents.

2. Josephson junctions between two super-conducting organic molecules (say the two strands of DNA) are possible [D8] are possible. Hydrogen bonds are good candidates for these Josephson junctions. An oscillating Josephson current flows in the junction [D8] . In presence of several junctions destructive interference can take place between the currents provided there are phase differences between various junctions if there are supra currents flowing in the rings of the two molecules joined together by several hydrogen bonds (say DNA double helix). The composite structure (say DNA double helix) is expected to become unstable if too large total Josephson current runs through the junctions. Therefore the supra currents can act as a stabilizing mechanism for the composite molecule and the decay of the molecule takes place, when supra current dissipates by phase slippages.

Why # contacts/Cooper pairs are ideal tools of bio-control

There are several good reasons for why # contacts/Cooper pairs could provide a tool of bio-control.

1. # contacts/Cooper pairs are in the same quantum state and therefore they serve as a source of negentropy and one can consider the possibility that the BE condensate of the charge carriers is actually the carrier of the most relevant bio-information. In case of the enzymes this negentropy would provide a source of free energy needed to overcome activation energy barriers in the catalysis of the various chemical reactions. The dissipation associated with the motion of the charge carriers resulting from the phase slippage mechanism is very small. Phase slippage in n_i takes typically by the splitting and rejoining of a join along boundaries bond. A measure for the rate of dissipation is the frequency for the splitting of the bond. The larger the bonding energy of the chemical bond, the smaller the rate of splitting is expected to be.

2. The complex order parameter describing the quantum state can be assumed to be covariantly constant in the ground state since the induced gauge fields are expected to vanish on the boundaries of the 3-surface. For Cooper pairs in the interior of 3-surface this assumption is probably also a reasonable approximation. As can be found in [K38] , some information about the homotopy of the 3-surface is directly coded into the phase of the ground state order parameter for supra phases and same holds true for # contacts, which couple to the difference of the gauge potentials associated with the two space-time sheets. Since the creation and destruction of the join along boundaries bonds changes the homotopy of 3-surface and since join along boundaries bonds are crucial for the properties of the macroscopic quantum system, this phase information is expected to be also biologically relevant. The spatial constancy of the density of # contacts /Cooper pair implies that the effects caused by the # contact/Cooper pair density are global so that the changes in the density produce co-operative effects.

3. In TGD the "act of free will", which is the most characteristic feature of bio-system, corresponds to a quantum jump between quantum histories. The quantum jumps induced change in the properties of the effective space-time and the BE condensate associated with it and the relevant

aspects of the change could therefore correspond to the change of the order parameters describing # contacts/Cooper pairs and coherent states of photons.

4. The conformations of the organic molecule are expected to be sensitive to the distribution of the # contacts/Cooper pairs. The creation of an in-stability leading to a new conformation would correspond to the generation of a region of a molecular 3-surface, which is a mall deformations of a vacuum extremal of the Kähler action. For instance, this kind of redistribution might lead easily to the destruction or creation of the join along boundaries contacts. The same of course applies to the Cooper pairs and it is known that the conformations are sensitive to the electronic configuration. It could however be that the electronic configurations are not the fundamental controllers but are controlled by the configurations of # contacts behaving as classical charges.

5. By their lightness (having inertial mass of order $1/L(n)$ on dimensional grounds), # contacts provide a rapid mechanism for control and the classical field energy needed to accelerate # contacts is small (recall that # contacts couple to the *difference* of the gauge potentials associated with the two space-time sheets. The dissipation effects (not desirable in control and coordination signals) are extremely small since the coupling to ordinary photons (as opposed to topologically condensed coherent light) is extremely small dipole coupling (dipole with size of CP_2 radius is in question!). Also Cooper pairs are light and therefore very mobile and the kinetic energy associated with their motion (supra currents along closed loops and kinks) is very small and quantized, so that the density of the Cooper pairs could serve as an ideal control switch. For example, the kink of width L possesses momentum of order $p \simeq 2\pi/L$ ($\bar{p} = \nabla\Phi$ for Cooper pairs), so that its energy is $E = \pi^2/m_e L^2$, which is in general smaller than the delocalization energy.

6. The importance of the aqueous environment (with $pH \simeq 7$) for organic molecules might be related to the partial ionization of water in the following manner. There are two kinds of effects. The appearance of protons (about 1 per $10^{-25} m^3$) is expected to in-stabilize the polymer since it creates classical gauge fields interacting with # contacts/Cooper pairs leading to the generation of density gradients. On the other hand, the presence of the hydrogen bonded polymers of the water molecules has a stabilizing effect since the join along boundaries bond between an organic molecule and structure of this kind increases the delocalization volume for the charge carriers.

contacts or Cooper pairs of both?

contact superconductivity at all levels of the # condensate, in particular in the case of organic molecules, seems almost unavoidable. A possible explanation for why it is not observed is the extremely weak interaction of the # contacts with ordinary photons and the interaction with laser light provides a test for the idea. The Comorosan effect involving the interaction of the laser light with organic molecules could in fact be regarded as a positive evidence for the concept.

In case of electrons, superconductivity is not at all obvious and the standard wisdom about macroscopic superconductors excludes this possibility. In TGD context, the dropping of electrons on larger space-time sheets could make it possible to have also electronic superconductivity. The interaction between electrons induced from the interaction of the electrons with the # contacts creating the excitations of # contact BE condensate, could give rise to the formation of the Cooper pairs.

Join along boundaries bond makes possible the delocalization of the valence electrons. The pairing of the valence electrons to the spin singlet states occurs invariably in this process. Valence electrons can delocalize to a volume of two neighboring atoms as in covalent bond or to a volume of several atoms as in case of the benzene ring. Hydrogen bond is related to the delocalization of the electrons in the saturated valence bonds, for example water molecules join together by a hydrogen bond. The hydrogen bond can be interpreted as a delocalization of the valence electron pairs to a volume of several molecules. In case of the ionic bond, the exchange of electrons between atoms takes place, so that atoms are ionized and an increase of the Coulombic binding energy is achieved.

If the delocalization of the electrons is complete, organic molecule becomes conductor. Even more, if the electrons are paired to spin singlet states a transition to superconducting phase might take place: in this manner it might be possible to minimize the increase of the electron kinetic energy implied by the Pauli Exclusion Principle. A possible mechanism of delocalization is the dropping of some electrons on larger space-time sheets from the atomic space-time sheets. In these sheets the density of charge is small and the interaction with # contacts could give rise to the formation of the Cooper pairs. An additional condition must be however met: the gap energy of electronic superconductor is extremely small unless the super conductor is effectively one-dimensional. The presence of weak magnetic fields guarantees this. Since the temperature at non-atomic space-time sheets can be extremely low, very weak magnetic fields are enough to achieve this.

The necessary condition for the appearance of superconductivity is that the delocalization energy of the electron given by the expression $E_{deloc} \simeq \frac{1}{2m_e\xi^2}$ is larger than the thermal energy and implies that critical temperature is of the order of $T_c \simeq 5\ eV = 0.5 \cdot 10^5\ K$, so that superconductivity is in principle possible in the biosphere.

The obvious counter argument against electronic super conductivity, is that in thermodynamic equilibrium the quantum numbers n_i vanish with a very high probability: the exponent $exp(-E/T)$ is extremely small. The point is however that living matter is not in thermodynamical equilibrium but rather an open system, to which entanglement entropy (rather than negentropy!) is fed continually. The entanglement entropy might be stored at molecular level to the supra currents and due to the small dissipation rate of supra currents these states are so long lived that thermodynamic equilibrium has not enough time to set up. The supra currents in turn might be created at the moment of the formation of the bio-molecule and guarantee the stability of the molecule. Later a model of DNA based on the idea that the closed rings associated with the basic units of DNA in vivo carry non-vanishing quantum numbers n_i DNA and guarantee the stability of double DNA helix, will be considered. If # contacts are the carriers of the supra current then the interaction with the ordinary, in particular thermal, photons is effectively absent and the thermodynamical argument does not apply. # contacts however couple to the topologically condensed coherent photons and this coupling might be crucial for the functioning of the bio-system. The TGD based explanation of the Comorosan effect [K85] is based on the assumption that this coupling exists.

Candidates for super-conducting organic molecules

Promising candidates for superconducting organic molecules are the compounds containing cyclic structures since the delocalization of the electron pairs is known to occur for certain hydrocarbon rings through the formation of the so called conjugated π bonds [I33] : benzene is a classic example of this phenomenon. In this case electronic super currents would correspond to $n_1 \neq 0$ excitations of the electron pairs with kinetic energy of order $n_1^2\pi^2/4m_eL^2$, where L is the radius of the loop in question: energies are of the order of few electron volts. For # contacts the energy is of order $\pi/L(n)$, where $L(n)$ is the relevant (actually p-adic) length scale.

Very many important organic monomers possess carbon rings of this type and the rings are good candidates also for the carriers of # contact supra currents.

1. The compounds AMP, ATP and ADP, which serve the role of energy batteries contains rings of this type. Also coenzymes, vitamines and hormones having central role in biological control contain rings of this type. One might well imagine that superconductivity appears in the single ring, so that non-vanishing supra currents correspond to non-vanishing quantum numbers n_1 associated with these rings. The excitation energies ($E = n_1^2\pi^2/m_eL^2$ for a loop of size $L \simeq 10^{-9}$ meters are typically of the order of electron volt).

2. Amino-acids, which serve as the basic building blocks of the proteins, do not contain any closed rings but the biologically active α helix form of the protein contains hydrogen bonds between the NH and CO groups and these bonds might might make # contact/ordinary superconductivity possible. In biologically nonactive random coil form these bonds are absent [I33] . This suggests that the presence of the supra phase indeed is what makes dead matter living.

3. Nucleic acids, the building blocks if DNA and related molecules, contain nitrogenous bases, which are rings but do not contain conjugated π bonds, so that it is not clear whether supra current are possible in this case. There are however indications that DNA is a source of the visible light [I3] . A possible TGD based explanation for this effect is as light emitted in the delocalization of the Cooper pairs. Biologically active helix form of DNA is also optically active unlike the random coil form [I33] .

4. For the electronic superconductivity, the gap energy for $L \sim 10^{-8}$ meters corresponds to the energy of the photon of the visible light, so that visible light is expected to be a particularly

effective localizer of a Cooper pair. An interesting question is whether this sensitivity might provide additional insight to the understanding of photo-biochemical reactions, in particular photosynthesis, and the mechanism of the vision. In fact, the decay of an electron pair to unpaired electrons is known to take place, when clorophyll molecule absorbs photon [I33] , which suggests that photon energy goes directly to the delocalization of the Cooper pairs. The hypothesis explains also why vision is sensitive to visible light only. Also the excitation of the # contacts from ground states on the boundaries of a surface having size of order cell size would involve photon absorption.

5.5.4 Bio-catalysis and TGD

The main function of the proteins (sequences of amino-acids) is to serve as catalysts for various biochemical reactions. The characteristic feature of the biochemical reactions is extreme selectivity, which necessitates an effective recognition mechanism between bio-molecules.

The simplest model for the catalytic action is the lock and key mechanism. The catalyst and substrate fit together like lock and key. This kind of a mechanism is indeed very natural in TGD inspired picture and corresponds to a partial join along boundaries. The lock and key mechanism fails to describe all features of the bio-catalysis: the conformations of the bio-molecules are known to be dynamic rather than static and sensitive to the electronic configuration. A refined version of the lock and key mechanism is the so called induced fit [I33] . The structures of the substrate and catalyst are not assumed to be static anymore. When substrate and catalyst have joined together they can change their conformational structures before the reaction takes place. TGD indeed predicts that the conformation of the resulting state is in general unstable. After the join along boundaries reaction however, a redistribution of # contacts/Cooper pairs in the whole reaction volume takes place and the conformation changes until a minimum of E is found.

By the previous considerations # contact BE condensates associated with the organic molecules could play important role on the catalytic mechanism. What happens in the Comorosan effect is that the stimulation of the organic molecules with laser light lasting a multiple of basic period $\tau \sim 5$ seconds enhances the catalytic activity. The TGD based explanation of the Comorosan effect [K85] relies heavily on the assumption that the Josephson junctions formed between enzyme and substrate molecules affects the rate of the reaction and also explains all the mysterious looking regularities of with the effect [I8, I29] .

5.5.5 TGD inspired model for the unwinding and replication of DNA

As an example consider a TGD inspired model for the unwinding and replication of DNA molecule. The unwinding is known to proceed either spontaneously or with the help of DNA polymerase during replication [I33] . It has turned out to be difficult to understand the mechanism behind the spontaneous unwinding of the double helix [I33] . The replication takes place in the following steps. The presence of the DNA polymeraze attached along the double helix causes the unwinding of the double helix by setting the strands in a rotational motion in the same direction and by splitting the hydrogen bonds between the nitrogenous basis of the composite strands. The hydrogen bonds are formed between the cyclic nitrogenous bases A(denine), C(ytocin), G(uanine) and T(hymine) and only A-T and C-G bonds are possible.

The difficulties are related to the understanding how the unwinding can take place so rapidly [I33] . The simplest mechanism explaining the unwinding is based on the assumption that DNA molecule rotates very rapidly along its axis at the beginning of the unwinding process. If one fixes the second end of the double strand then unwinding takes place automatically and the angular frequency for the unwinding is essentially equal to the rotation frequency. The estimate for the angular frequency of the rotation is however very large even for the shortest DNA molecules (having length of about 10^{-8} meters): rotation frequency is about 10^4 times per minute! This doesn't look sensible since dissipation should destroy the rotation of DNA rapidly. In fact this rotation rate corresponds to an angular momentum of few Planck units and this suggests that quantum effects are involved.

First model

The simplest TGD based model for the unwinding is based on the following assumptions. The model is formulated assuming that # contacts are the carriers of the supra current but it applies also in case of the Cooper pairs.

1. There is a condensate of # contacts along the whole DNA molecule. # contact supra current flows in the loops of DNA strands in same direction, so that there is a net angular momentum associated DNA molecule. The integers n_i associated with all loops along DNA molecule are identical by the complete delocalization of the charge carriers. Since supra phase is in question the dissipation rate for this angular momentum is low unlike for the ordinary rotational angular momentum of the double strand.
2. There are two mechanisms leading to the unwinding of the DNA molecule.
   (a) The destruction of some # contacts takes place so that the angular momentum of these pairs is transformed to the rotational angular momentum of the DNA molecule itself. The disappearance of the # contacts involves the transfer of charge between space-time sheets and might well involve a transfer of electrons from the "larger" space-time sheet to the atomic space-time sheet. Hence also the disappearance of the Cooper pairs from the larger space-time sheet (if present there) might be involved.

   (b) Phase slippage takes place along the whole DNA molecule, so that the integers n_i characterizing the behavior of the order parameter change in all loops along DNA and the angular momentum is liberated to a coherent rotational motion of the whole DNA molecule. The phase slippage liberates angular momentum of order $J = N_c \Delta n_1$, where N_c is the number of the # contacts in the molecule. For the shortest DNA molecules N_c should be about one. In general, the linear density of the # contacts should be about one pair per 10^{-8} meters.
3. If the second end of DNA molecule is fixed, DNA molecule unwinds. Otherwise the angular momentum of the DNA molecule is gradually dissipated.

Second model

The splitting of the double strand into single strands might be caused by the mere unwinding. It is also possible that the Josephson currents of # contacts are involved in the process. A more refined TGD inspired scenario for the unwinding and replication of DNA looks like follows.

1. The cyclic rings associated with the complementary bases are carriers of # contact supra currents. The hydrogen bonds between the rings (2 or 3 depending on situation) can be regarded as Josephson junctions. Therefore an oscillatory Josephson current flows between the complementary basis in the double helix of DNA. If the supra currents in the basis loops rotate in the same direction, the phase differences between the hydrogen bonds are maximal and a destructive interference between Josephson currents occurs and guarantees the stability of the double helix. Since the currents rotate in the same direction there is a net angular momentum associated with these supra currents.
2. The dissipation caused by the phase slippages implies that this supra current becomes small in the course of time. This can take place in several steps or in single step depending on the value of n_1. This effect is collective and take place for all loops of the DNA molecule propagating in a wave like manner from one end of the molecule to the second end. If the second end of the DNA molecule is fixed, this process leads to the unwinding of the DNA molecule.
3. When the critical phase slippage occurs, Josephson current achieves the critical value making the double helix structure unstable, so that the hydrogen bonds break and this leads to the splitting of the double strand.
4. The role of the DNA polymerase in DNA replication is to keep the second end of DNA fixed and possibly to generate the supra current kink, which interferes destructively with the super current in loops and leads to the amplification of the Josephson current.

5. The replication of the resulting strands is achieved by introducing the complementary nucleotides. The formation of the double DNA strand can be regarded as a time reversal of the unwinding of the double DNA. In this case catalyst must take care that correct pairs are glued together by the hydrogen bonds. The formation of the stable hydrogen bonds is possible only provided non-vanishing supra currents are generated in the loops associated with the complementary nitrogenous bases. Angular momentum conservation implies that the strands get into a winding motion provided the direction of the supra currents is correct. DNA double helix is formed.

6. The process doesn't lead to the unwinding of DNA unless the second end of DNA is fixed. In case that no unwinding occurs, there must exist some mechanism regenerating the original supra current in the DNA molecule since otherwise DNA molecule would gradually lose its angular momentum and its ability to unwind and replicate. In fact, the presence of the supra current might be essential for the stability of DNA and the rejoining of the hydrogen bonds after the phase slippage might automatically generate the needed supra current. In this process a feed of negentropy from the environment to DNA molecule obviously takes place.

5.6 TGD and morphogenesis

Morphogenesis, that this the formation of the spatial bio-structures during the development, is one of the not so well understood biological phenomena [A31] . There are several problems related to this phenomenon.

1. What dictates the size and the form of the bio-structures?

2. What are the basic control mechanisms altering the size of the existing structures, say, the length of the muscle?

3. What are the mechanisms controlling morphogenesis? What is the clock, or rather the alarm clock, taking care that the division of a cell or the formation of an organ during the morphogenesis begins at certain time? How is the information about the formation of the spatial structures contained in the developing embryo? How is the spatial ordering and synchronization of several parallel processes achieved?

In the sequel the generation of both spatial and temporal structures is considered and an actual realization for biological clocks and biological alarm clocks as supra current circuits by generalizing the ideas of the TGD based model of nerve pulse and EEG, is proposed. The role of genome in the control of the morphogenesis will be considered only very briefly and the ideas related to many-sheeted DNA are left to a separate chapter [K42] .

5.6.1 Topological field quantization and vacuum quantum numbers

Topological field quantization provides a TGD based first principle explanation for the existence of the spatial structures. The size of the bio-structure depends on the vacuum quantum numbers and is dictated by the stability criterion (the sum of Z^0 Coulombic energy and electronic delocalization energy is minimized). The hypothesis that bio-systems are superconductors at the first level of the condensation implies that supra currents are a basic tool of the bio-control. The density of the charge carriers dictates the stable size and form of the organ and also the nontrivial phase information carried by the order parameter is expected to be important.

There are handful of vacuum quantum numbers arising from the time and spatial behavior of the phase angles ϕ_i associated with the two complex CP_2 coordinates [K38] . One can express the dependence of these phase angles on space-time coordinates as a sum of Fourier expansion plus zero mode term linear in some coordinates and not allowing Fourier expansion. In linear Minkowski coordinates the vacuum quantum numbers would define components of four-momentum. In spherical coordinates vacuum quantum numbers correspond to frequency, momentum in given direction plus integer analogous to the component of the angular momentum in the direction of momentum. The set of vacuum quantum numbers associated with the two phase factors depends on the choice of the coordinates for M^4_+ and CP_2 and involves a selection of maximal number of mutually commuting observables in the Lie-algebras of Poincare group and color group. This is consistent with the fact that topological field quantization indeed is the classical counterpart of quantization. The construction of quantum TGD and understanding of the p-adic aspects of quantum TGD involves in an absolutely essential manner the choice of these quantization axes.

To fix the notation, the quantum numbers associated with the spherical coordinates will be denoted by (ω_i, k_i, n_i), $i = 1, 2$. detailed definitions of vacuum quantum numbers reader should consult the appendix of this book and [K38] . The first consequence is that given space-time sheet is characterized by two frequencies. A good working hypothesis is that the frequency difference associated with two space-time sheets connected by Josephson junctions corresponds directly to the voltage difference over Josephson junction: $\Delta\omega_1 = ZeV$. Besides the group theoretical quantum numbers topological field quantum is characterized by a fractal quantum number m, which roughly tells which power of fixed scaling is applied to standard topological field quantum to obtain the topological field quantum in question. An interesting possibility is that m might be related with p-adic scaling $x \to p^m x$. For a detailed definition of vacuum quantum numbers the reader can consult the appendix of this book.

5.6.2 Vacuum quantum number changing phase transitions and morphogenesis

In ordinary physics space-time is a fixed arena for the dynamics of the quantum fields. The space-time serves as a master and fields serve as slaves. The enormous vacuum degeneracy of the Kähler action suggests that the situation might be just the opposite for bio-systems in the TGD Universe. If the space-time surface is a small deformation of a vacuum extremal, there is indeed a good reason to expect a large ground state degeneracy (spin glass analogy) in the sense that ground states correspond to different configurations for 3-surfaces. In the bio-systems, the order parameter associated with some macroscopic quantum system could induce changes between these ground states and thus give rise to the changes of the macroscopic geometry and even the topology of the space-time sheet.

Suppose that the order parameter, serving as a master, changes so that the covariant constancy condition for the order parameter characterizing the ground state of the supra phase is not satisfied anymore. As a consequence, space-time topology changes, new join along boundaries bonds are created and old are destroyed. The end result is that covariant constancy condition is satisfied in the final state. The size, shape and even the topology of the organ could change in this kind of phase transition. Self-organization is expected to lead to an asymptotic states in which covariant constancy conditions hold true. These covariant constancy conditions in time direction and in the direction of Josephson junction are indeed absolutely essential in the general model of Josephson junction leading to Sine-Gordon equation.

5.6.3 Vacuum quantum numbers and the size of the organ

The appendix of this book provides detailed information about vacuum quantum numbers (form more details see [K38]). Besides two Poincare quantum numbers (ω_i, n_i, k_i) $i = 1, 2$, there is also fractal quantum number m characterizing the members in a family of topological field quanta obtained from basic topological field quantum by iterating discrete scaling whose magnitude depends on topological field quantum. The considerations "Macroscopic quantum phases..." suggest that various bio-molecules and the structures formed by them correspond to the value of $\omega_1 = (10^{2.5} - 10^3)m_p$ and that cell and cell membrane could be identified as corresponding to structures having the values of fractal quantum number $m = 0$ and $m = 2$ respectively and $\omega_1 = (10^5 - 10^6)m_p$. There are good reasons to expect that larger organs correspond to larger values of ω_1 and that surface structures in general correspond to larger values of the fractal number.

There are reasons to expect that the value of ω_1 at the atomic condensation level is very rigid. At the other condensation levels the situation is not so clear but absolute minimization of Kähler action implying generalized Bohr rules together with quantum self-organization suggests that the values occurring in nature vary in very strict bounds. The fact that cell sizes vary between certain limits (typically $10^{-6} - 10^{-5}$ meters) might result from the variation of ω_1 by a factor of ten. If this is the case the growth of an organ or organelle, say cell, would correspond to a gradual increase of the parameter ω_1 at the appropriate level of condensation. It would be tempting to postulate that the variations in the value of ω_1 become larger the higher the level of condensation is.

Homology is a very general biological phenomenon. Same basic structure (for instance five fingers, spinal cord, etc..) appears with various sizes and detailed forms in different species. The simplest explanation is that these structures develop from identical initial structures but that the values of the vacuum quantum numbers, in particular ω_1 and possibly also the fractal quantum number m are different for these structures, so that the critical sizes are different. The differing sizes of the individuals belonging to the same species could be explained in a similar manner although the values of the other vacuum parameters affect the size, too. Fractal quantum number m might explain the fractal structures observed in the organic matter at the higher condensation levels [A18] .

5.6.4 Phase transitions changing the values of the vacuum quantum numbers

The surface density of the # contacts is constant in the stationary situation. The larger the electromagnetic charge of the space-time sheet, the larger the total number $N(\#)$ of the # contacts near its boundaries. The perturbation of the # contact surface density is expected to lead to the in-stability in the shape and possibly also the size of the 3-surface if 3-surface corresponds to a small deformation of a vacuum extremal. One can also consider the possibility that the 3-surface contains some critical regions near vacuum extremals. An attractive simplifying hypothesis is that the 3-surface suffers a rapid deformation in such a manner that the surface density $n(\#)$ of the # contacts is constant in the final situation. For instance, the reduction of # contact density at some section of a linear structure would generate a pinch and could lead to the splitting of the structure. This kind of mechanism is expected to lead to the splitting of the join along boundaries contacts.

Bio-systems consist mostly of water and hydrodynamics flows are in a good approximation incompressible, so that only the shape of the 3-surface is controllable. This suggests that, at least for sufficiently large space-time sheets, the volume of a given sheet of the 3-space is proportional to the number $N(\#)$ of the # contacts:

$$V = kN(\#) = kn(\#)A \ ,$$

so that the surface density of the # contacts would behave as

$$n(\#) = \frac{V}{kA} \ .$$

The smaller the surface density of the # contacts, the larger the surface area per volume and the more fractal the appearance of the surface. This is in accordance with the idea that for small surface densities of # contacts (and small total electromagnetic charges) 3-surface is nearer to a vacuum extremal and therefore the shape of the 3-surface becomes unstable.

These considerations suggests that the generation of the gradients in the density of # contacts or some other superconducting particles through the generation of the supra currents provide a control mechanism for the shape of the organ. Since # contacts couple to the difference ΔA of the classical gauge potentials associated with the two space-time sheets connected by # contacts, the changes in ΔA induce a change in the shape of the 3-surface. There is also a coupling to the difference of the order parameters (effectively classical gauge potentials) describing the topologically condensed coherent photons on the two space-time sheets in question. This could make possible for a coherent state of photons, perhaps generated by micro-tubuli and/or some other linear structures, to control the shape of the 3-surface.

The phase information is expected to be important even in the long length scales. A classic example, giving striking evidence for the presence of the complex order parameter in even macroscopic length scales, is related to the growth of a new "leg" or, actually its homological equivalent in lower organisms. The detailed description can be found in the book of Winfree [A29] . Suppose one removes left leg and replaces it with the right one. What happens is that two additional left legs grow! The explanation is based on the conservation of the phase difference around a circle surrounding the leg in the sense that this phase difference is constant along the leg. This quantum number is opposite for left and right legs: $n(L) = -n(R)$. In the situation considered the total quantum number is $2n(L) + n(R) = n(L)$.

At longer length scales, the changes of the vacuum quantum numbers affect the size and form of the organ.

1. The growth of the organ might correspond to a gradual increase of ω_1 and therefore of the stable size of corresponding field quantum.
2. A phase transition leading to a decrease of the quantum number ω_1 can take place for field quantum and reduces the size of a stable field quantum: this kind of phase transition implies the decomposition of the developing embryo into several sub-organs during morphogenesis.

To make these ideas more concrete consider some examples.

1. Cell division is the simplest example of a generation of a new structure and is difficult to understand in terms of purely biochemical concepts. The generation of the cellular membrane takes place spontaneously, when the mass of the growing cell becomes larger than some critical mass. The simplest model for the cell division is based on the decrease of the vacuum quantum number ω_1 at the cell level, so that the critical size of the cell decreases and cell divides. During the growth ω_1 increases until the critical cell size is achieved. At the first level of condensation the phase transition decreasing ω_1 must be triggered by some kind of an "alarm clock" to be discussed below.
2. Differentiation: the developing embryo divides at very early stage to a mosaic of separate regions, which later develop into various organs. Biochemical concepts do not throw much light to the description of this phenomenon and there are several indications [A31] that the phenomenon is topological rather than biochemical. For example, the number of the regions stays constant although the size of the embryo increases and is stable against external perturbations and the number and general structure of the organs is same for all individuals of the species independently of their size. It is natural to identify these regions as topological field quanta, whose size is determined by the value of ω_1 and increases during the growth. The stability against external perturbations corresponds to the stability against topological changes.

5.6.5 Biological alarm clocks and morphogenesis

In previous section very general model for biological alarm clocks based on weakly coupled superconductors was proposed. This kind of circuits could be an essential element of morphogenesis. Some examples are in order to show that this idea might have relevance.

1. The replication of cell is an extremely complicated process but could be understood as quantum self-organization process leading to final state pattern which only very mildly depends on the initial state. This process must be initiated by a 'wake-up' of a self representing perhaps the cell. The alarm clocks must now be contained to the membrane surrounding the cell nucleus and probably also to the cell membrane since the cell membrane is known to be coupled to the division process of the cell nucleus, too [I33] . The reference currents are generated, when the new cell is born. The process leading to the replication of the cell could involve a reduction of the density of some super-conducting charge carriers in the critical region and this could initiate the decay of the cell. This is achieved if Josephson currents run away from certain region of the membrane of the cell nucleus implying depletion of charge carriers.
2. The generation of a completely new spatial structures during the morphogenesis is second extremely complicated process which should be understandable in terms of quantum self-organization. An example is afforded by the generation of somites [A31] , which later give rise to brain and spinal cord. The homogenous longitudinal cell mass divides in a phase transition like manner into somites with clock wise regularity and the number of the somites is a constant characteristic for the species in question [A31] . The catastrophe theoretic models proposed in [A31] are based on the assumption that the pulse triggering the formation of somites is coupled to a biological clock, so that the motion of the boundary between differentiated and undifferentiated cell mass alternately slows down or fastens up and implies the generation of discrete regions, where the formation of the somites takes place.

A qualitative TGD based description is provided by the alarm clock model:

1. There is certain biorhythm realized using Josephson junctions (rhythms (minute scale) of this kind have indeed been identified [A31]) at cell level.

2. Josephson currents flow between the cells belonging to the longitudinal cell mass and neighboring cells in transversal direction. Due to the presence of the cell level reference currents, Josephson currents interfere destructively and variations in density of charge carriers are small.

3. There is slow dependence of the phase of the order parameter ψ along the linear cell mass implying a phase lag between the clocks.

4. Reference current dissipates gradually through phase slippages and when the time is ripe the amplitude of the Josephson current becomes large and makes the density of charge carriers small inside the longitudinal region. The formation of the somites begins since the stability criterion implies that the stable size of topological field quantum decreases.

5. Time regulation is achieved through the presence of the biological clock: nothing happens unless the phase of the clock is correct since Josephson current runs to a "wrong" direction.

6. The process begins from the cells, which were born first since the clocks associated with them were created first and propagates in the order, in which the cells were born. In fact, the spatial dependence of the phase of the order parameter might code this order. The spatial dependence of the phase means that the rate for the propagation of the somite formation varies with position and guarantees in this manner the formation of spatially separated structures (compare with clock wave front model of [A31]). The number of the somites is just the multiple of 2π:s that the phase of the order parameter increases along the longitudinal cell mass.

5.6.6 Could vacuum quantum numbers control gene expression via Josephson currents

Controlled and synchronized gene expression is the most fundamental aspect of morphogenesis and implies surprising determinism of the development. When developing organism achieves certain level of development, certain gene activates. This requires feedback mechanism from long length scales of size of order organ to the gene level. In standard physics, the most plausible mechanisms are chemical. Certainly it is very difficult to understand how organs size could control the activation of genes via chemical concentrations. Whether this is the case is an unanswered question as yet. In any case, the notion of many-sheeted space-time provides a fresh view to this process.

TGD leads to the notion of many-sheeted DNA [K42] , which means that DNA has # contacts to several space-time sheets. One can even consider the possibility that various space-time sheets associated with gene correspond to the expression domains of gene so that in a very abstract sense genome would be full grown organism compressed to a thin many-sheeted thread of thickness of order 10^{-8} meters and morphogenesis could be regarded as a decompression of this packed information. If self-organization determines what happens in transversal degrees of freedom, then one could say that gene codes the one-dimensional skeleton of the expression domain of the gene. Especially interesting from the point of view of bio-control are join along boundaries contacts connecting DNA space-time sheets with larger space-time sheets.

Many-sheeted space-time concept suggests hierarchies of biological alarm clocks whose ringing induces ringing of some clocks at a lower level of hierarchy so that finally the alarm clock waking-up and activating definite gene rings. A possible mechanism causing the ringing would be situation in which the potential difference associated with the Josephson junction becomes equal to the energy difference of a single particle state associated with either super-conductor: cyclotron resonance, which seems to be crucial for brain functioning and EEG, is basic example of this. This could at DNA level lead to the activation of gene and start up of a self-organization process. One could imagine complicated circuits in which ringing would occur only provided all required conditions are achieved. It must be emphasized that this option is not the only possible one and in [K21] a more plausible mechanism involving the new physics implied by TGD is developed.

The correlation of gene expression with the size of growing organ could be achieved as follows. If the potential difference corresponds to the difference of vacuum frequencies ω_1 associated with the coupled super conductors and if ω_i correlate with the sizes of the corresponding structures, the ringing of the clock would occur when the size difference is critical. If the first superconductor corresponds to some structure with a fixed size (say gene) and second superconductor corresponds to the growing organ, this mechanism would initiate new kind of gene expression when the growing organ reaches critical size.

Chapter 6

Quantum Control and Coordination in Bio-Systems: Part II

6.1 Introduction

This chapter is devoted to the aspects of quantum control and coordination involving the intentional action of the magnetic body and classical em and Z^0 fields. The previous chapters are warmly recommened in order to get an overall view about basic philosophy and ideas. The general understanding of the dynamics of Kähler action provides a considerable light to how topologically quantized induced Kähler field defines templates for bio-structures and for their self-organized dynamics. Time mirror mechanism is the most convincing mechanism for realizing intentional action discovered hitherto. The scalar wave pulses of Tesla might have TGD counterpart and provide perhaps the most elegant manner to transform intentions to actions. Also the possible role of classical Z^0 force in condensed matter and bio-chemistry is discussed.

6.1.1 Preferred extremals of Kähler action, thermodynamics, and biology

The vanishing of Lorentz 4-force for the induced Kähler field means that the vacuum 4-currents are in a mechanical equilibrium. Lorentz 4-force vanishes for all known solutions of field equations which inspires the hypothesis that at least the preferred extremals of Kähler action satisfy the condition. The vanishing of the Lorentz 4-force in turn implies local conservation of the ordinary energy momentum tensor. The corresponding condition is implied by Einstein's equations in General Relativity. The hypothesis would mean that the solutions of field equations are what might be called generalized Beltrami fields. The condition implies that vacuum currents can be non-vanishing only provided the dimension D_{CP_2} of the CP_2 projection of the space-time surface is less than four so that in the regions with $D_{CP_2} = 4$, Maxwell's vacuum equations are satisfied.

The hypothesis that Kähler current is proportional to a product of an arbitrary function ψ of CP_2 coordinates and of the instanton current generalizes Beltrami condition and reduces to it when electric field vanishes. Kähler current has vanishing divergence for $D_{CP_2} < 4$, and Lorentz 4-force indeed vanishes. The remaining task would be the explicit construction of the imbeddings of these fields and the demonstration that field equations can be satisfied.

By quantum classical correspondence the non-deterministic space-time dynamics should mimic the dissipative dynamics of the quantum jump sequence. Beltrami fields appear in physical applications as asymptotic self organization patterns for which Lorentz force and dissipation vanish. This suggests that the preferred extremals of Kähler action correspond to space-time sheets which asymptotically satisfy generalized Beltrami conditions so that one can indeed assign to the final (rather than initial!) 3-surface a unique 4-surface apart from effects related to non-determinism. Preferred extremal property stating that the extremal allows infinite number of second variations with a vanishing second variation abstracted to purely algebraic generalized Beltrami conditions would make sense also in the p-adic context.

This picture can be claimed to be internally contradictory since all known extremals would correspond to asymptotic self organization patterns. One should have space-time correlates also for the non-asymptotic situations.

1. The progress made in understanding the definition of the theory using the reduction to modified Dirac action clarified the situation [K26] . It turned out that one must add to the modified Dirac action a measurement interaction term coupling space-time geometry to conserved quantum numbers. One of the motivations for this was quantum classical correspondence. This induces also to Kähler action measurement interaction term and the asymptotic self-organization patters represented by the known extremals have the property that measurement interaction term vanishes.

2. Also the long-standing issue relating to the identification of preferred extremals playing the role of Bohr orbits and implying quantum holography was resolved. The preferred extremals defining the analogs of Bohr orbits must be critical in the sense of having an infinite number of deformations for which the second variation of Kähler action vanishes. The criticality of Kähler action would thus the basic dynamical principle of space-time dynamics and provide space-time correlate for quantum criticality required by quantum classical correspondence. Purely number theoretic conditions in turn lead to the conclusion that space-time surfaces must be hyper-quaternionic in the sense that the modified gamma matrices span hyper-quaternionic (asociative) or co-hyper-quaternionic (co-associative) plane at each point of the spacce-time surface. "Co-" means that the orthogonal complement of this plane is hyper-quaternionic (associative). Whether criticality and associativity (co-associativity) are consistent is not clear.

The intricate topological structures of DNA, RNA, and protein molecules are known to have a deep significance besides their chemical structure, and they could even define something analogous to the genetic code. Usually the topology and geometry of bio-molecules is believed to reduce to chemistry. TGD suggests that topologically quantized generalized Beltrami fields with space-like Kähler current serve as templates for the formation of bio-molecules and bio-structures in general. Indeed, Beltrami fields can be extremely complex but at the same time they are highly organized and ordered structures. The dynamics of bio-systems could in turn utilize periodic generalized Beltrami fields with time-like Kähler current as templates. There could even exist a mapping from the topology of magnetic flux tube structures serving as templates for bio-molecules to the templates of self-organized dynamics.

Thus the natural conjecture is that topologically quantized many-sheeted magnetic and Z^0 magnetic generalized Beltrami fields serve as templates for the helical molecules populating living matter, and explain both chirality selection, the complex linking and knotting of DNA and protein molecules, and even the extremely complex and self-organized dynamics of biological systems at the molecular level.

6.1.2 Time mirror mechanism as a fundamental mechanism transforming intentions to actions

What causality means in TGD framework?

In order to minimize confusion it is in order to clarify the various meanings that one can give to causality in TGD framework.

1. At the level of space-time surfaces the criticality of the preferred extrmals defines dynamics of the space-time surfaces and defines the causality of passive events at classical level. Induced spinors (spinors of the 8-D imbedding space restricted to the space-time surface) obey the super-symmetric variant of field equations for the space-time surface and single particle Schrödinger equation can be identified as the non-relativistic limit for the dynamics of the induced spinor fields. The finite size of the space-time sheet defines naturally the notions of coherence length and time for both classical fields and spinor fields. In both cases classical determinism is broken in its naive form. For p-adic space-time sheets p-adic variants of field equations hold true and have the inherent p-adic non-determinism.

2. At configuration space level general coordinate invariance together with huge super-conformal invariance related symmetries can be said to dictate the behavior configuration space spinor fields playing a role analogous to quantum states of quantum field theories. If the naive classical determinism of Kähler were not broken, the physics would reduce to the boundary of the future

light cone, the moment of big bang and time would be lost as in the canonical quantization of General Relativity. Fortunately this does not happen.

3. Quantum jumps can be said to realize the causality with respect to the subjective time, the causality of deeds. Selves can be seen as self-organization patterns acting as causal agents. At this level system's behavior is based on rules analogous to those governing the behavior of statistical cellular automatons and are a result of self-organization. The laws are not absolute but analogous to traffic rules obeyed or possibly disobeyed by intentional agents.

A further question concerns causal agents: everyday thinking suggests that deeds indeed have doers. In quantum consciousness theories based on standard quantum measurement theory doers are "observers" somewhere outside. In TGD causal agents are rather abstract: ensembles of quantum jumps deciding to some degree what kind of quantum jump they want to add to the ensemble defining them.

Materialization of intentions

Em fields, in particular ELF em fields, are crucial for the TGD inspired model of brain and a natural assumption is that p-adic–real phase transitions occur also for massless extremals (MEs).

A concrete picture about the materialization of intentions emerges, when one asks how a precisely targeted intention could be realized at the atomic or molecular level. The basic point is that molecules can only intend to make simple quantum transitions.

1. If the transition occurs to a lower energy state it can occur spontaneously whereas the transitions to a higher energy states cannot. Spontaneous transitions mask the possibly occurring intended transitions so that only the transitions which cannot occur spontaneously allow precisely targeted intention.

2. What would happen is that first a p-adic ME representing the intention to perform the transition is generated. Then the transition occurs and conservation laws require that the p-adic ME is transformed to a negative energy ME in the transition. Physical intuition suggests that the p-adic ME and the corresponding real ME resemble each other maximally in the sense that they go through the same rational imbedding space points in some p-adic resolution and with respect to the p-adic topology which is effective topology In the case of the real ME.

3. Quite generally, it seems that intention can be realized in a precisely targeted manner only for the transitions which cannot occur spontaneously, and thus involve the emission of negative energy MEs.

4. The generation of negative energy MEs utilizes the buy now-let others pay mechanism of metabolism, which implies extreme flexibility. Of course, there must exist an unselfish self, which is able to pay and this puts severe constraints on the mechanism.

Time mirror mechanism, scalar wave pulses, and wormhole magnetic fields

Many-sheeted space-time makes possible many-sheeted lasers since cold space-time sheets can contain Bose-Einstein condensates of ions and their Cooper pairs. If the system contains population inverted many-sheeted laser for which the increment of zero point kinetic energy corresponds to the energy of photons associated with negative energy MEs, the absorption of negative energy photons gives rise to a phase transition like dropping of particles to larger space-time sheet by the induced emission mechanism, and the control signal represented by negative energy MEs can be amplified if a critical number of particles drops to the larger space-time sheet. This control mechanism allows an instantaneous motor control in which intention is transformed to desired represented by negative energy MEs and generates in geometric past a reaction representing the desired response, say neuronal activity giving rise to motor action. This process probably involves entire hierarchy of magnetic selves realizing their intentions as desires communicated to lower level magnetic selves and the lowest level corresponds to the regions of brain responsible for liberating metabolic energy.

The simplest possibility is that the transformation of the intention to action corresponds to p-adic-to-real phase transition for negative energy topological light ray. It however seems that generation of p-adic scalar wave pulse transformed to real one is more promising mechanism. When scalar wave pulse moves in matter, charges end up to the space-time sheet of the scalar wave pulse and accelerate without dissipation. Instead of brehmstrahlung the accelerated charges emit negative energy "acceleration radiation" having negative energy MEs as space-time correlates. Since dissipation is negligible this leads to a generation of a strong negative energy signal. The resulting negative energy photons in turn induce the phase-transition like dropping of particles of population inverted many-sheeted laser to larger space-time sheets liberating a beam of positive energy photons which is much more intense than the control signal consisting of negative energy photons.

A good guess is that scalar wave pulses provide a fundamental control mechanism in living matter, and that nerve pulse represents only a special case of this control mechanism. p-Adic length scale hypothesis suggests the existence of a hierarchy of cognitive codes such that $p \simeq 2^k$, k integer, corresponds to a hierarchy of cognitive codes such that the code word has duration given by n-ary p-adic time scale $T(n,k)$, and the number of bits is a factor of k. These codes allow both pulse representations and frequency representations. For pulse representations bit 1/0 is represented by the presence/absence of scalar wave pulse. For frequency representations bit 1/0 would correspond to Fourier component with particular harmonic of fundamental frequency $f(n,k) = 1/T(n,k)$ above or below critical intensity. Pulse representations would be ideal for a precise bio-control whereas frequency representations might be ideal for communications of data from brain to magnetic body.

Intentions could be transformed also to actions by generation of magnetic flux tubes: so called wormhole magnetic fields correspond to pairs of magnetic flux tubes having opposite time orientations and therefore also opposite energies. Wormhole magnetic fields could be created by first generating their p-adic counterparts, and then transforming them to their real counterparts in quantum jump. The phase transition like changes of EEG spectrum involving emergence or dis-appearence of EEG band might be due to the generation of wormhole magnetic fields giving rise to EEG resonance frequencies via cyclotron transitions and thus represent motor actions of magnetic body [K21, K62] . Wormhole magnetic fields are discussed in detail in [K85] .

6.1.3 Electrets and scalar waves of Tesla

Living matter is full of electrets. Basic examples are micro-tubuli carrying a longitudinal electric field and cell membrane carrying a transversal electric field. One can see electret as a structure consisting of a topological field quantum of electric field plus atomic space-time sheets carrying ordinary bio-matter. Electrets carrying an electric field which has in a good approximation a constant magnitude, are indeed basic solutions of the field equations, and are in a well defined sense dual to the magnetic flux tubes. This duality reflects the fundamental duality of quantum TGD itself analogous to the duality of super string theories but having different physical content. Quantum criticality of TGD predicts that space-time sheets carrying electric field *resp.* magnetic fields with negative *resp.* positive Kähler action are like two phases, say water and ice, at the critical point. What is interesting is that electret type solutions contain as a special case electric pulses propagating with light velocity. These solutions are identifiable as TGD counterparts of Tesla's scalar waves having electric field in the direction of propagation. These solutions are not possible in Maxwell's electrodynamics. Bio-systems might use scalar waves for communication and control purposes. For instance, the generation of nerve pulse might induce scalar wave which in turn could induce nerve pulses and this could lead to a cascade of coherent neural firing. Second interesting aspect is that electret type solutions carry strong classical gravitational fields at their boundaries and the coupling of the classical gravitation to the field energy is given essentially by the square of CP_2 radius squared and is thus about 10^7 times stronger than the coupling of gravitons to the ordinary matter. Hence classical gravitation might be important for the functioning of living matter. The spin glass degeneracy broken only by classical gravitational energy suggests the same.

6.1.4 Ideas related to dark matter and living matter

I ended up with the idea about quantization of Planck constant and the identification of dark matter as phase with a non-standard value of Planck constant after having learned about the work of Da Rocha and Nottale. After that ideas developed rapidly and led to a profound generalization of the notion of imbedding space and the idea about dark matter as being responsible for the properties of living matter emerged.

Dark matter as a macroscopic quantum phase with gigantic Planck constant

D. Da Rocha and Laurent Nottale, the developer of Scale Relativity, have ended up with an highly interesting quantum theory like model for the evolution of astrophysical systems [E7] (I am grateful for Victor Christianto for informing me about the article). The model is simply Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant

$$\hbar \quad \rightarrow \quad \hbar_{gr} = \frac{GmM}{v_0} \quad . \tag{6.1.1}$$

Here I have used units $\hbar = c = 1$. v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. The peak orbital velocity of stars in galactic halos is 142 ± 2 km/s whereas the average velocity is 156 ± 2 km/s. Also subharmonics and harmonics of v_0 seem to appear.

The model makes fascinating predictions which hold true. For instance, the radii of planetary orbits fit nicely with the prediction of the hydrogen atom like model. The inner solar system (planets up to Mars) corresponds to v_0 and outer solar system to $v_0/5$.

It is important to notice that effectively a multiplication $n \rightarrow 5n$ of the principal quantum number is in question in the case of outer planets. If one accepts the interpretation that visible matter has concentrated around dark matter, which is in macroscopic quantum phase around Bohr orbits, this allows to consider also the possibility that $\hbar_{gr}$ has same value for all planets.

1. Some external gravitational perturbations have kicked dark matter from inner orbits to $n \, mod \, 5 = 0$ orbits. Gravitational perturbations might have caused the same for visible matter. The fact that the tilt angles of Earth and outer planets other than Pluto are nearly the same suggests that the orbits of these planets might be an outcome of some violent quantum process for dark matter preserving the orbital plane in a good approximation but kicking dark matter from $n = 5$ orbit of Earth to the orbits $n = 5k$, $k = 2, .., 7$. Pluto might in turn have experienced some violent collision changing its orbital plane.

2. There could exist at least small amounts of dark matter at all orbits but visible matter is concentrated only around orbits containing some critical amount of dark matter and these orbits satisfy $n = 5k$, $k = 2, 3, ...$ for some reason.

The predictions for the distribution of major axis and eccentrities have been tested successfully also for exo-planets. Also the periods of 3 planets around pulsar PSR B1257+12 fit with the predictions with a relative accuracy of few hours/per several months. Also predictions for the distribution of stars in the regions where morphogenesis occurs follow from the Schödinger equation.

What is important is that there are no free parameters besides v_0. In [E7] a wide variety of astrophysical data is discussed and it seem that the model works and has already now made predictions which have been later verified. A rather detailed model for the formation of solar system making quantitatively correct predictions follows from the study of inclinations and eccentricities predicted by the Bohr rules: the model proposed seems to differ from that of Nottale which makes predictions for the probability distribution of eccentricities and inclinations.

I had proposed already earlier the possibility that Planck constant is quantized. The inverse of the gravitational Planck constant could correspond a gravitational perturbation of this as $1/\hbar_{gr} = v_0/GMm$. The general philosophy would be that when the quantum system would become non-perturbative, a phase transition increasing the value of $\hbar$ occurs to preserve the perturbative character.

TGD predicts correctly the value of the parameter v_0 assuming that cosmic strings and their decay remnants are responsible for the dark matter. The harmonics of v_0 can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes n^2-fold: much like the replacement of a closed orbit with an orbit closing only after n turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes.

The study of inclinations (tilt angles with respect to the Earth's orbital plane) leads to a concrete model for the quantum evolution of the planetary system. Only a stepwise breaking of the rotational symmetry and angular momentum Bohr rules plus Newton's equation (or geodesic equation) are needed, and gravitational Shrödinger equation holds true only inside flux quanta for the dark matter.

1. During pre-planetary period dark matter formed a quantum coherent state on the (Z^0) magnetic flux quanta (spherical cells or flux tubes). This made the flux quantum effectively a single rigid body with rotational degrees of freedom corresponding to a sphere or circle (full SO(3) or SO(2) symmetry).

2. In the case of spherical shells associated with inner planets the $SO(3) \rightarrow SO(2)$ symmetry breaking led to the generation of a flux tube with the inclination determined by m and j and a further symmetry breaking, kind of an astral traffic jam inside the flux tube, generated a planet moving inside flux tube. The semiclassical interpretation of the angular momentum algebra predicts the inclinations of the inner planets. The predicted (real) inclinations are 6 (7) resp. 2.6 (3.4) degrees for Mercury resp. Venus). The predicted (real) inclination of the Earth's spin axis is 24 (23.5) degrees.

3. The $v_0 \rightarrow v_0/5$ transition allowing to understand the radii of the outer planets in the model of Da Rocha and Nottale can be understood as resulting from the splitting of (Z^0) magnetic flux tube to five flux tubes representing Earth and outer planets except Pluto, whose orbital parameters indeed differ dramatically from those of other planets. The flux tube has a shape of a disk with a hole glued to the Earth's spherical flux shell.

It is important to notice that effectively a multiplication $n \rightarrow 5n$ of the principal quantum number is in question. This allows to consider also alternative explanations. Perhaps external gravitational perturbations have kicked dark matter from the orbit or Earth to $n = 5k$, $k = 2, 3, ..., 7$ orbits: the fact that the tilt angles for Earth and all outer planets except Pluto are nearly the same, supports this explanation. Or perhaps there exist at least small amounts of dark matter at all orbits but visible matter is concentrated only around orbits containing some critical amount of dark matter and these orbits satisfy $n \ mod \ 5 = 0$ for some reason.

The most interesting predictions from the point of view of living matter are following.

1. The dark matter is still there and forms quantum coherent structures of astrophysical size. In particular, the (Z^0) magnetic flux tubes associated with the planetary orbits define this kind of structures. The enormous value of h_{gr} makes the characteristic time scales of these quantum coherent states extremely long and implies macro-temporal quantum coherence in human and even longer time scales.

2. The rather amazing coincidences between basic bio-rhythms and the periods associated with the orbits in solar system suggest that the frequencies defined by the energy levels of the gravitational Schrödinger equation might entrain with various biological frequencies such as the cyclotron frequencies associated with the magnetic flux tubes. For instance, the period associated with $n = 1$ orbit in the case of Sun is 24 hours within experimental accuracy for v_0. Second example is the mysterious 5 second time scale associated with the Comorosan effect [I8, I29] .

How the scaling of $\hbar$ affects physics and how to detect dark matter?

It is relatively easy to deduce the basic implications of the scaling of $\hbar$.

1. If the rate for the process is non-vanishing classically, it is not affected in the lowest order. For instance, scattering cross sections for say electron-electron scattering and e^+e^- annihilation are not affected in the lowest order since the increase of Compton length compensates for the reduction of α_{em}. Photon-photon scattering cross section, which vanishes classically and is proportional to $\alpha_{em}^4 \hbar^2/E^2$, scales down as $1/\hbar^2$.

2. Higher order corrections coming as powers of the gauge coupling strength α are reduced since $\alpha = g^2/4\pi\hbar$ is reduced. Since one has $\hbar_s/\hbar = \alpha Q_1 Q_2/v_0$, $\alpha Q_1 Q_2$ is effectively replaced with a universal coupling strength v_0. In the case of QCD the paradoxical sounding implication is that α_s would become very small.

Dark matter as quantum controller of ordinary matter

The notion of magnetic body containing macroscopic quantum phases responsible for bio-control, and the fact that dark matter would reside at magnetic flux tubes, motivate the hypothesis that living matter is actually dark matter with the large value of Planck constant determining the characteristic time and length scales of the conscious system. Complex conformal weights for single particles states and closely related to the zeros of Riemann Zeta would make the many-particle system living. p-Adic fractality allows to deduce rather striking similarities between biology, cosmology, and hadron physics.

One important implication is the possibility to relate the hierarchy of the time scales of consciousness defined by the effective durations of quantum jumps to the hierarchy of Planck constants. A beautiful mathematical formulation in terms of von Neumann algebras [A8, A15] as a hierarchy of quantum states emerges [K84] . The lowest level states represents ordinary matter whereas higher levels provide self representations of the dynamics of the system with S-matrix coding for the quantum physical laws represented as entanglement coefficients between positive and negative energy states forming states with vanishing net quantum numbers. The general construction of S-matrix gives also the Feynman rules for self representations and means a precise formulation of the quantum dynamics of cognition.

A refinement to the previously developed model of cold fusion [K71, K20] results in terms of a phase transition increasing the Compton length of protons and explains the known strange violations of standard nuclear physics rules [C7] . Sono-fusion [C2] can be seen as a special case of cold fusion. The fact that nuclear transmutations are reported to occur in living matter [C4] suggests that this phase might be important for living matter. Also the claimed properties of so called mono-atomic elements [H6] fit nicely with an interpretation as "partially dark" matter.

To sum up, the riddle of life, the riddle of dark matter, and the mysterious ability of living matter to behave like macroscopic quantum system despite the fact that ordinary quantum physics does not allow this, might have common very simple solution: $\hbar$ is dynamical rather than God given.

It must be added that the ideas about dark matter emerged about decade later than the first version of this chapter was written. I have not seen sensible to try to insert the dark matter related ideas to the existing text and this means that the representation is somewhat lopsided and partially out of date and should be taken as a documentary about how ideas have developed rather than a final summary.

6.2 Preferred extremals of Kähler action, second law of thermodynamics, and bio-systems

In this section field equations and their physical interpretation and relevance for bio-systems are discussed. Quantum classical correspondence suggests that the non-deterministic dynamics of Kähler action makes possible self-referential dynamics in the sense that larger space-time sheet perform smoothed out mimicry of the dynamics at smaller space-time sheets. The fact that the divergence of the energy momentum tensor, Lorentz 4-force, does not vanish in general makes possible the mimicry of even dissipation and of the second law. For asymptotic self organization patterns for which dissipation is absent the Lorentz 4-force must vanish. This condition is guaranteed if Kähler current is proportional to the instanton current in the case that CP_2 projection of the space-time sheet is smaller than four and vanishes otherwise. An attractive identification for the vanishing of Lorentz 4-force is as a condition equivalent with the absolute minimization of Kähler action so that this principle would be essentially equivalent with the second law of thermodynamics.

For a vanishing Kähler electric field the topologication of the Kähler current means that Kähler magnetic field is so called Beltrami field, that is an eigen vector of curl operator so that field pattern is typically helical unless the Kähler current vanishes. Beltrami field is characterized by a chirality defined by the relative sign of the current and magnetic field, which means parity breaking. Beltrami fields appear in hydrodynamics and magnetohydrodynamics, and a natural guess is that many-sheeted magnetic and Z^0 magnetic Beltrami fields and their generalizations serve as templates for the helical molecules populating living matter and explain both chirality selection and complex linking and knotting of DNA and protein molecules.

6.2.1 Field equations

The requirement that Kähler action is stationary leads to the following field equations in the interior of the four-surface

$$\begin{aligned} D_\beta(T^{\alpha\beta}h^k_\alpha) &- j^\alpha J_\alpha^{\ \beta} J^k_{\ l}\partial_\beta h^l = 0 \ , \\ T^{\alpha\beta} &= J^{\nu\alpha}J_\nu^{\ \beta} - \frac{1}{4}g^{\alpha\beta}J^{\mu\nu}J_{\mu\nu} \ . \end{aligned} \tag{6.2.1}$$

Here $T^{\alpha\beta}$ denotes the traceless canonical energy momentum tensor associated with the Kähler action. An equivalent form for the first equation is

$$\begin{aligned} T^{\alpha\beta}H^k_{\alpha\beta} &+ j^\alpha(J_\alpha^{\ \beta}h^k_{\ l} - J^k_{\ l}\partial_\alpha h^l) = 0 \ . \\ H^k_{\alpha\beta} &= D_\beta\partial_\alpha h^k \ . \end{aligned} \tag{6.2.2}$$

$H^k_{\alpha\beta}$ denotes the components of the second fundamental form and $j^\alpha = D_\beta J^{\alpha\beta}$ is the gauge current associated with the Kähler field.

On the boundaries of X^4 the field equations are given by the expression

$$T^{n\beta}\partial_\beta h^k + J^{n\alpha}(J_\alpha^{\ \beta}\partial_\beta h^k - J^k_{\ l})\partial_\alpha h^k) = 0 \ . \tag{6.2.3}$$

A general manner manner to solve the field equations on the boundaries is to assume that the induced Kähler field associated with the boundaries vanishes:

$$J_{\alpha\beta}(\delta) = 0 \ . \tag{6.2.4}$$

In this case the energy-momentum tensor vanishes identically on the boundary component. On the outer boundaries of the 3-surface this solution ansatz makes sense only provided the gauge fluxes and gravitational flux (defined by Newtonian potential in the non-relativistic limit) associated with the matter in the interior go somewhere. The only possibility seems to be that 3-surface is topologically condensed on a larger 3-surface and feeds its gauge fluxes to the larger 3-surface via # contacts (topological sum). This assumption forces the concept of topological condensate defined as a hierarchical structure of 3-surfaces condensed on each other and thus giving rise to the many-sheeted space-time.

An important thing to notice is that the boundary conditions do not force the normal components of the gauge fields to zero even if the Kähler electric field vanishes near the boundaries. This makes in principle possible gauge charge renormalization classically resulting from the hierarchical structure of the topological condensation.

6.2.2 Topologization and light-likeness of the Kähler current as alternative manners to guarantee vanishing of Lorentz 4-force

The general solution of 4-dimensional Einstein-Yang Mills equations in Euclidian 4-metric relies on self-duality of the gauge field, which topologizes gauge charge. This topologization can be achieved by a weaker condition, which can be regarded as a dynamical generalization of the Beltrami condition. An alternative manner to achieve vanishing of the Lorentz 4-force is light-likeness of the Kähler 4-current. This does not require topologization.

Topologization of the Kähler current for $D_{CP_2} = 3$: covariant formulation

The condition states that Kähler 4-current is proportional to the instanton current whose divergence is instanton density and vanishes when the dimension of CP_2 projection is smaller than four: $D_{CP_2} < 4$. For $D_{CP_2} = 2$ the instanton 4-current vanishes identically and topologization is equivalent with the vanishing of the Kähler current.

$$j^\alpha \equiv D_\beta J^{\alpha\beta} = \psi \times j^\alpha_I = \psi \times \epsilon^{\alpha\beta\gamma\delta}J_{\beta\gamma}A_\delta \ . \tag{6.2.5}$$

Here the function ψ is an arbitrary function $\psi(s^k)$ of CP_2 coordinates s^k regarded as functions of space-time coordinates. It is essential that ψ depends on the space-time coordinates through the CP_2 coordinates only. Hence the representation as an imbedded gauge field is crucial element of the solution ansatz.

The field equations state the vanishing of the divergence of the 4-current. This is trivially true for instanton current for $D_{CP_2} < 4$. Also the contraction of $\nabla\psi$ (depending on space-time coordinates through CP_2 coordinates only) with the instanton current is proportional to the winding number density and therefore vanishes for $D_{CP_2} < 4$.

The topologization of the Kähler current guarantees the vanishing of the Lorentz 4-force. Indeed, using the self-duality condition for the current, the expression for the Lorentz 4-force reduces to a term proportional to the instanton density:

$$\begin{aligned} j^\alpha J_{\alpha\beta} &= \psi \times j_I^\alpha J_{\alpha\beta} \\ &= \psi \times \epsilon^{\alpha\mu\nu\delta} J_{\mu\nu} A_\delta J_{\alpha\beta} \ . \end{aligned} \tag{6.2.6}$$

Since all vector quantities appearing in the contraction with the four-dimensional permutation tensor are proportional to the gradients of CP_2 coordinates, the expression is proportional to the instanton density, and thus winding number density, and vanishes for $D_{CP_2} < 4$.

Remarkably, the topologization of the Kähler current guarantees also the vanishing of the term $j^\alpha J^{k_l}\partial_\alpha s^k$ in the field equations for CP_2 coordinates. This means that field equations reduce in both M^4_+ and CP_2 degrees of freedom to

$$T^{\alpha\beta} H^k_{\alpha\beta} = 0 \ . \tag{6.2.7}$$

These equations differ from the equations of minimal surface only by the replacement of the metric tensor with energy momentum tensor. The earlier proposal that quaternion conformal invariance in a suitable sense might provide a general solution of the field equations could be seen as a generalization of the ordinary conformal invariance of string models. If the topologization of the Kähler current implying effective dimensional reduction in CP_2 degrees of freedom is consistent with quaternion conformal invariance, the quaternion conformal structures must differ for the different dimensions of CP_2 projection.

Topologization of the Kähler current for $D_{CP_2} = 3$: non-covariant formulation

In order to gain a concrete understanding about what is involved it is useful to repeat these arguments using the 3-dimensional notation. The components of the instanton 4-current read in three-dimensional notation as

$$\overline{j}_I = \overline{E} \times \overline{A} + \phi\overline{B} \ , \quad \rho_I = \overline{B}\cdot\overline{A} \ . \tag{6.2.8}$$

The self duality conditions for the current can be written explicitly using 3-dimensional notation and read

$$\begin{aligned} \nabla \times \overline{B} - \partial_t \overline{E} &= \overline{j} = \psi \overline{j}_I = \psi\left(\phi\overline{B} + \overline{E}\times\overline{A}\right) \ , \\ \nabla \cdot E &= \rho = \psi\rho_I \ . \end{aligned} \tag{6.2.9}$$

For a vanishing electric field the self-duality condition for Kähler current reduces to the Beltrami condition

$$\nabla \times \overline{B} = \alpha\overline{B} \ , \quad \alpha = \psi\phi \ . \tag{6.2.10}$$

The vanishing of the divergence of the magnetic field implies that α is constant along the field lines of the flow. When ϕ is constant and $\overline{A}$ is time independent, the condition reduces to the Beltrami condition with $\alpha = \phi = constant$, which allows an explicit solution [**?**] .

One can check also the vanishing of the Lorentz 4-force by using 3-dimensional notation. Lorentz 3-force can be written as

$$\rho_I \overline{E} + \overline{j} \times \overline{B} = \psi \overline{B} \cdot \overline{AE} + \psi \left(\overline{E} \times \overline{A} + \phi \overline{B} \right) \times \overline{B} = 0 \ . \tag{6.2.11}$$

The fourth component of the Lorentz force reads as

$$\overline{j} \cdot \overline{E} = \psi \overline{B} \cdot \overline{E} + \psi \left(\overline{E} \times \overline{A} + \phi \overline{B} \right) \cdot \overline{E} = 0 \ . \tag{6.2.12}$$

The remaining conditions come from the induction law of Faraday and could be guaranteed by expressing $\overline{E}$ and $\overline{B}$ in terms of scalar and vector potentials.

The density of the Kähler electric charge of the vacuum is proportional to the the helicity density of the so called helicity charge $\rho = \psi \rho_I = \psi B \cdot A$. This charge is topological charge in the sense that it does not depend on the induced metric at all. Note the presence of arbitrary function ψ of CP_2 coordinates.

Further conditions on the functions appearing in the solution ansatz come from the 3 independent field equations for CP_2 coordinates. What is remarkable that the generalized self-duality condition for the Kähler current allows to understand the general features of the solution ansatz to very high degree without any detailed knowledge about the detailed solution. The question whether field equations allow solutions consistent with the self duality conditions of the current will be dealt later. The optimistic guess is that the field equations and topologization of the Kähler current relate to each other very intimately.

Vanishing or light likeness of the Kähler current guarantees vanishing of the Lorentz 4-force for $D_{CP_2} = 2$

For $D_{CP_2} = 2$ one can always take two CP_2 coordinates as space-time coordinates and from this it is clear that instanton current vanishes so that topologization gives a vanishing Kähler current. In particular, the Beltrami condition $\nabla \times \overline{B} = \alpha \overline{B}$ is not consistent with the topologization of the instanton current for $D_{CP_2} = 2$.

$D_{CP_2} = 2$ case can be treated in a coordinate invariant manner by using the two coordinates of CP_2 projection as space-time coordinates so that only a magnetic or electric field is present depending on whether the gauge current is time-like or space-like. Light-likeness of the gauge current provides a second manner to achieve the vanishing of the Lorentz force and is realized in case of massless extremals having $D_{CP_2} = 2$: this current is in the direction of propagation whereas magnetic and electric fields are orthogonal to it so that Beltrami conditions is certainly not satisfied.

Under what conditions topologization of Kähler current yields Beltrami conditions?

Topologization of the Kähler 4-current gives rise to magnetic Beltrami fields if either of the following conditions is satisfied.

1. The $\overline{E} \times \overline{A}$ term contributing besides $\phi \overline{B}$ term to the topological current vanishes. This requires that $\overline{E}$ and $\overline{A}$ are parallel to each other

$$\overline{E} \ = \ \nabla \Phi - \partial_t \overline{A} = \beta \overline{A} \tag{6.2.13}$$

This condition is analogous to the Beltrami condition. Now only the 3-space has as its coordinates time coordinate and two spatial coordinates and and $\overline{B}$ is replaced with $\overline{A}$. Since E and B are orthogonal, this condition implies $\overline{B} \cdot \overline{A} = 0$ so that Kähler charge density is vanishing.

2. The vector $\overline{E} \times \overline{A}$ is parallel to $\overline{B}$.

$$\overline{E} \times \overline{A} \ = \ \beta \overline{B} \tag{6.2.14}$$

The condition is consistent with the orthogonality of $\overline{E}$ and $\overline{B}$ but implies the orthogonality of $\overline{A}$ and $\overline{B}$ so that electric charge density vanishes

In both cases vector potential fails to define a contact structure since $B \cdot A$ vanishes (contact structures are discussed briefly below), and there exists a global coordinate along the field lines of $\overline{A}$ and the full contact structure is lost again. Note however that the Beltrami condition for magnetic field means that magnetic field defines a contact structure irrespective of whether $\overline{B} \cdot \overline{A}$ vanishes or not. The transition from the general case to Beltrami field would thus involve the replacement

$$(\overline{A}, \overline{B}) \rightarrow_{\nabla\times} (\overline{B}, \bar{j})$$

induced by the rotor.

One must of course take these considerations somewhat cautiously since the inner product depends on the induced 4-metric and it might be that induced metric could allow small vacuum charge density and make possible genuine contact structure.

Hydrodynamic analogy

The field equations of TGD are basically hydrodynamic equations stating the local conservation of the currents associated with the isometries of the imbedding space. Therefore it is intriguing that Beltrami fields appear also as solutions of ideal magnetohydrodynamics equations and as steady solutions of non-viscous incompressible flow described by Euler equations [B10] .

In hydrodynamics the role of the magnetic field is taken by the velocity field. For incompressible flow occurring along the field lines of the Z^0 magnetic field the velocity field is proportional to the Z^0 magnetic field and the Beltrami condition for the velocity field reduces to that for Z^0 magnetic field. Thus the flow lines of hydrodynamic flow should directly correspond to those of Z^0 magnetic field. The generalized Beltrami flow based on the topologization of the Z^0 current would allow to model also the non-stationary incompressible non-viscous hydrodynamical flows.

It would seem that one cannot describe viscous flows using flows satisfying generalized Beltrami conditions since the vanishing of the Lorentz 4-force says that there is no local dissipation of the classical field energy. One might claim that this is not a problem since in TGD framework viscous flow could be seen as a practical description of a quantum jump sequence by replacing the corresponding sequence of space-time surfaces with a single space-time surface.

One the other hand, quantum classical correspondence requires that also dissipative effects have space-time correlates. Kähler fields, which are dissipative, and thus correspond to a non-vanishing Lorentz 4-force, represent one candidate for correlates of this kind. If this is the case, then the fields satisfying the generalized Beltrami condition provide space-time correlates only for the asymptotic self organization patterns for which the viscous effects are negligible, and also the solutions of field equations describing effects of viscosity should be possible.

One must however take this argument with a grain of salt. Dissipation, that is the transfer of conserved quantities to degrees of freedom corresponding to shorter scales, could correspond to a transfer of these quantities between different space-time sheets of the many-sheeted space-time. Here the opponent could however argue that larger space-time sheets mimic the dissipative dynamics in shorter scales and that classical currents represent "symbolically" averaged currents in shorter length scales, and that the local non-conservation of energy momentum tensor consistent with local conservation of isometry currents provides a unique manner to mimic the dissipative dynamics. This view will be developed in more detail below.

The stability of generalized Beltrami fields

The stability of generalized Beltrami fields is of high interest since unstable points of space-time sheets are those around which macroscopic changes induced by quantum jumps are expected to be localized.

1. *Contact forms and contact structures*

The stability of Beltrami flows has been studied using the theory of contact forms in three-dimensional Riemann manifolds [B9] . Contact form is a one-form A (that is covariant vector field A_α) with the property $A \wedge dA \neq 0$. In the recent case the induced Kähler gauge potential A_α and corresponding induced Kähler form $J_{\alpha\beta}$ for any 3-sub-manifold of space-time surface define a contact form so that the vector field $A^\alpha = g^{\alpha\beta}A_\beta$ is not orthogonal with the magnetic field $B^\alpha = \epsilon^{\alpha\beta\delta}J_{\beta\gamma}$. This requires that magnetic field has a helical structure. Induced metric in turn defines the Riemann structure.

If the vector potential defines a contact form, the charge density associated with the topologized Kähler current must be non-vanishing. This can be seen as follows.

1. The requirement that the flow lines of a one-form X_μ defined by the vector field X^μ as its dual allows to define a global coordinate x varying along the flow lines implies that there is an integrating factor ϕ such that $\phi X = dx$ and therefore $d(\phi X) = 0$. This implies $dlog(\phi) \wedge X = -dX$. From this the necessary condition for the existence of the coordinate x is $X \wedge dX = 0$. In the three-dimensional case this gives $\overline{X} \cdot (\nabla \times \overline{X}) = 0$.

2. This condition is by definition not satisfied by the vector potential defining a contact form so that one cannot identify a global coordinate varying along the flow lines of the vector potential. The condition $\overline{B} \cdot \overline{A} \neq 0$ states that the charge density for the topologized Kähler current is non-vanishing. The condition that the field lines of the magnetic field allow a global coordinate requires $\overline{B} \cdot \nabla \times \overline{B} = 0$. The condition is not satisfied by Beltrami fields with $\alpha \neq 0$. Note that in this case magnetic field defines a contact structure.

Contact structure requires the existence of a vector ξ satisfying the condition $A(\xi) = 0$. The vector field ξ defines a plane field, which is orthogonal to the vector field A^α. Reeb field in turn is a vector field for which $A(X) = 1$ and $dA(X;) = 0$ hold true. The latter condition states the vanishing of the cross product $X \times B$ so that X is parallel to the Kähler magnetic field B^α and has unit projection in the direction of the vector field A^α. Any Beltrami field defines a Reeb field irrespective of the Riemannian structure.

2. Stability of the Beltrami flow and contact structures

Contact structures are used in the study of the topology and stability of the hydrodynamical flows [B9] , and one might expect that the notion of contact structure and its proper generalization to the four-dimensional context could be useful in TGD framework also. An example giving some idea about the complexity of the flows defined by Beltrami fields is the Beltrami field in R^3 possessing closed orbits with all possible knot and link types simultaneously [B9] !

Beltrami flows associated with Euler equations are known to be unstable [B9] . Since the flow is volume preserving, the stationary points of the Beltrami flow are saddle points at which also vorticity vanishes and linear instabilities of Navier-Stokes equations can develop. From the point of view of biology it is interesting that the flow is stabilized by vorticity which implies also helical structures. The stationary points of the Beltrami flow correspond in TGD framework to points at which the induced Kähler magnetic field vanishes. They can be unstable by the vacuum degeneracy of Kähler action implying classical non-determinism. For generalized Beltrami fields velocity and vorticity (both divergence free) are replaced by Kähler current and instanton current.

More generally, the points at which the Kähler 4-current vanishes are expected to represent potential instabilities. The instanton current is linear in Kähler field and can vanish in a gauge invariant manner only if the induced Kähler field vanishes so that the instability would be due to the vacuum degeneracy also now. Note that the vanishing of the Kähler current allows also the generation of region with $D_{CP_2} = 4$. The instability of the points at which induce Kähler field vanish is manifested in quantum jumps replacing the generalized Beltrami field with a new one such that something new is generated around unstable points. Thus the regions in which induced Kähler field becomes weak are the most interesting ones. For example, unwinding of DNA could be initiated by an instability of this kind.

6.2.3 How to satisfy field equations?

The topologization of the Kähler current guarantees also the vanishing of the term $j^\alpha J^{k_l}\partial_\alpha s^k$ in the field equations for CP_2 coordinates. This means that field equations reduce in both M^4_+ and CP_2 degrees of freedom to

$$T^{\alpha\beta}H^k_{\alpha\beta} = 0 \ . \tag{6.2.15}$$

These equations differ from the equations of minimal surface only by the replacement of the metric tensor with energy momentum tensor. The earlier proposal that quaternion conformal invariance in a suitable sense might provide a general solution of the field equations could be seen as a generalization of the ordinary conformal invariance of string models. If the topologization of the Kähler current implying effective dimensional reduction in CP_2 degrees of freedom is consistent with quaternion conformal invariance, the quaternion conformal structures must differ for the different dimensions of CP_2 projection. In the following somewhat different approach is however considered utilizing the properties of Hamilton Jacobi structures of M^4_+ introduced in the study of massless extremals and contact structures of CP_2 emerging naturally in the case of generalized Beltrami fields.

String model as a starting point

String model serves as a starting point.

1. In the case of Minkowskian minimal surfaces representing string orbit the field equations reduce to purely algebraic conditions in light cone coordinates (u,v) since the induced metric has only the component g_{uv}, whereas the second fundamental form has only diagonal components H^k_{uu} and H^k_{vv}.
2. For Euclidian minimal surfaces (u,v) is replaced by complex coordinates $(w,\overline{w})$ and field equations are satisfied because the metric has only the component $g^{w\overline{w}}$ and second fundamental form has only components of type H^k_{ww} and $H^{\overline{k}}_{\overline{w}\overline{w}}$. The mechanism should generalize to the recent case.

The general form of energy momentum tensor as a guideline for the choice of coordinates

Any 3-dimensional Riemann manifold allows always a orthogonal coordinate system for which the metric is diagonal. Any 4-dimensional Riemann manifold in turn allows a coordinate system for which 3-metric is diagonal and the only non-diagonal components of the metric are of form g^{ti}. This kind of coordinates might be natural also now. When $\overline{E}$ and $\overline{B}$ are orthogonal, energy momentum tensor has the form

$$T = \begin{pmatrix} \frac{E^2+B^2}{2} & 0 & 0 & EB \\ 0 & \frac{E^2+B^2}{2} & 0 & 0 \\ 0 & 0 & \frac{-E^2+B^2}{2} & 0 \\ EB & 0 & 0 & \frac{E^2-B^2}{2} \end{pmatrix} \tag{6.2.16}$$

in the tangent space basis defined by time direction and longitudinal direction $\overline{E}\times\overline{B}$, and transversal directions $\overline{E}$ and $\overline{B}$. Note that T is traceless.

The optimistic guess would be that the directions defined by these vectors integrate to three orthogonal coordinates of X^4 and together with time coordinate define a coordinate system containing only g^{ti} as non-diagonal components of the metric. This however requires that the fields in question allow an integrating factor and, as already found, this requires $\nabla\times X\cdot X = 0$ and this is not the case in general.

Physical intuition suggests however that X^4 coordinates allow a decomposition into longitudinal and transversal degrees freedom. This would mean the existence of a time coordinate t and longitudinal coordinate z the plane defined by time coordinate and vector $\overline{E}\times\overline{B}$ such that the coordinates $u=t-z$ and $v=t+z$ are light like coordinates so that the induced metric would have only the component g^{uv} whereas g^{vv} and g^{uu} would vanish in these coordinates. In the transversal space-time directions complex space-time coordinate coordinate w could be introduced. Metric could have also non-diagonal components besides the components $g^{w\overline{w}}$ and g^{uv}.

Hamilton Jacobi structures in M^4_+

Hamilton Jacobi structure in M^4_+ can understood as a generalized complex structure combing transversal complex structure and longitudinal hyper-complex structure so that notion of holomorphy and Kähler structure generalize.

1. Denote by m^i the linear Minkowski coordinates of M^4. Let (S^+, S^-, E^1, E^2) denote local coordinates of M^4_+ defining a *local* decomposition of the tangent space M^4 of M^4_+ into a direct, not necessarily orthogonal, sum $M^4 = M^2 \oplus E^2$ of spaces M^2 and E^2. This decomposition has an interpretation in terms of the longitudinal and transversal degrees of freedom defined by local light-like four-velocities $v_\pm = \nabla S_\pm$ and polarization vectors $\epsilon_i = \nabla E_i$ assignable to light ray. Assume that E^2 allows complex coordinates $w = E^1 + iE^2$ and $\overline{w} = E^1 - iE^2$. The simplest decomposition of this kind corresponds to the decomposition $(S^+ \equiv u = t + z, S^- \equiv v = t - z, w = x + iy, \overline{w} = x - iy)$.

2. In accordance with this physical picture, S^+ and S^- define light-like curves which are normals to light-like surfaces and thus satisfy the equation:

$$(\nabla S_\pm)^2 = 0 \quad .$$

   The gradients of $S_\pm$ are obviously analogous to local light like velocity vectors $v = (1, \overline{v})$ and $\tilde{v} = (1, -\overline{v})$. These equations are also obtained in geometric optics from Hamilton Jacobi equation by replacing photon's four-velocity with the gradient ∇S: this is consistent with the interpretation of massless extremals as Bohr orbits of em field. $S_\pm = constant$ surfaces can be interpreted as expanding light fronts. The interpretation of $S_\pm$ as Hamilton Jacobi functions justifies the term Hamilton Jacobi structure.

   The simplest surfaces of this kind correspond to $t = z$ and $t = -z$ light fronts which are planes. They are dual to each other by hyper complex conjugation $u = t - z \to v = t + z$. One should somehow generalize this conjugation operation. The simplest candidate for the conjugation $S^+ \to S^-$ is as a conjugation induced by the conjugation for the arguments: $S^+(t - z, t + z, x, y) \to S^-(t - z, t + z, x, y) = S^+(t + z, t - z, x, -y)$ so that a dual pair is mapped to a dual pair. In transversal degrees of freedom complex conjugation would be involved.

3. The coordinates $(S_\pm, w, \overline{w})$ define local light cone coordinates with the line element having the form

$$\begin{aligned} ds^2 &= g_{+-}dS^+dS^- + g_{w\overline{w}}dwd\overline{w} \\ &+ g_{+w}dS^+dw + g_{+\overline{w}}dS^+d\overline{w} \\ &+ g_{-w}dS^-dw + g_{-\overline{w}}dS^-d\overline{w} \ . \end{aligned} \quad (6.2.17)$$

   Conformal transformations of M^4_+ leave the general form of this decomposition invariant. Also the transformations which reduces to analytic transformations $w \to f(w)$ in transversal degrees of freedom and hyper-analytic transformations $S^+ \to f(S^+), S^- \to f(S^-)$ in longitudinal degrees of freedom preserve this structure.

4. The basic idea is that of generalized Kähler structure meaning that the notion of Kähler function generalizes so that the non-vanishing components of metric are expressible as

$$\begin{aligned} g_{w\overline{w}} &= \partial_w \partial_{\overline{w}} K \ , \quad g_{+-} = \partial_{S^+}\partial_{S^-} K \ , \\ g_{w\pm} &= \partial_w \partial_{S^\pm} K \ , \quad g_{\overline{w}\pm} = \partial_{\overline{w}}\partial_{S^\pm} K \ . \end{aligned} \quad (6.2.18)$$

   for the components of the metric. The expression in terms of Kähler function is coordinate invariant for the same reason as in case of ordinary Kähler metric. In the standard lightcone coordinates the Kähler function is given by

$$K = w_0\overline{w}_0 + uv \ , \quad w_0 = x + iy \ , \quad u = t - z \ , \quad v = t + z \ . \quad (6.2.19)$$

The Christoffel symbols satisfy the conditions

$$\{^{k}_{w\ \overline{w}}\} = 0 \ , \quad \{^{k}_{+-}\} = 0 \ . \tag{6.2.20}$$

If energy momentum tensor has only the components $T^{w\overline{w}}$ and T^{+-}, field equations are satisfied in M^4_+ degrees of freedom.

5. The Hamilton Jacobi structures related by these transformations can be regarded as being equivalent. Since light-like 3- surface is, as the dynamical evolution defined by the light front, fixed by the 2-surface serving as the light source, these structures should be in one-one correspondence with 2-dimensional surfaces with two surfaces regarded as equivalent if they correspond to different time=constant snapshots of the same light front, or are related by a conformal transformation of M^4_+. Obviously there should be quite large number of them. Note that the generating two-dimensional surfaces relate also naturally to quaternion conformal invariance and corresponding Kac Moody invariance for which deformations defined by the M^4 coordinates as functions of the light-cone coordinates of the light front evolution define Kac Moody algebra, which thus seems to appear naturally also at the level of solutions of field equations.

The task is to find all possible local light cone coordinates defining one-parameter families 2-surfaces defined by the condition $S_i = constant$, $i = +\ or\ \ = -$, dual to each other and expanding with light velocity. The basic open questions are whether the generalized Kähler function indeed makes sense and whether the physical intuition about 2-surfaces as light sources parameterizing the set of all possible Hamilton Jacobi structures makes sense.

Contact structure and generalized Kähler structure of CP_2 projection

In the case of 3-dimensional CP_2 projection it is assumed that one can introduce complex coordinates $(\xi, \overline{\xi})$ and the third coordinate s. These coordinates would correspond to a contact structure in 3-dimensional CP_2 projection defining transversal symplectic and Kähler structures. In these coordinates the transversal parts of the induced CP_2 Kähler form and metric would contain only components of type $g_{w\overline{w}}$ and $J_{w\overline{w}}$. The transversal Kähler field $J_{w\overline{w}}$ would induce the Kähler magnetic field and the components J_{sw} and $J_{s\overline{w}}$ the Kähler electric field.

It must be emphasized that the non-integrability of the contact structure implies that J cannot be parallel to the tangent planes of $s = constant$ surfaces, s cannot be parallel to neither A nor the dual of J, and ξ cannot vary in the tangent plane defined by J. A further important conclusion is that for the solutions with 3-dimensional CP_2 projection topologized Kähler charge density is necessarily non-vanishing by $A \wedge J \neq 0$ whereas for the solutions with $D_{CP_2} = 2$ topologized Kähler current vanishes.

Also the CP_2 projection is assumed to possess a generalized Kähler structure in the sense that all components of the metric except s_{ss} are derivable from a Kähler function by formulas similar to M^4_+ case.

$$s_{w\overline{w}} = \partial_w \partial_{\overline{w}} K \ , \quad s_{ws} = \partial_w \partial_s K \ , \quad s_{\overline{w}s} = \partial_{\overline{w}} \partial_s K \ . \tag{6.2.21}$$

Generalized Kähler property guarantees that the vanishing of the Christoffel symbols of CP_2 (rather than those of 3-dimensional projection), which are of type $\{^{k}_{\xi\ \overline{\xi}}\}$.

$$\{^{k}_{\xi\ \overline{\xi}}\} \ = \ 0 \ . \tag{6.2.22}$$

Here the coordinates of CP_2 have been chosen in such a manner that three of them correspond to the coordinates of the projection and fourth coordinate is constant at the projection. The upper index k refers also to the CP_2 coordinate, which is constant for the CP_2 projection. If energy momentum tensor has only components of type T^{+-} and $T^{w\overline{w}}$, field equations are satisfied even when if non-diagonal Christoffel symbols of CP_2 are present. The challenge is to discover solution ansatz, which guarantees this property of the energy momentum tensor.

A stronger variant of Kähler property would be that also s_{ss} vanishes so that the coordinate lines defined by s would define light like curves in CP_2. The topologization of the Kähler current however implies that CP_2 projection is a projection of a 3-surface with strong Kähler property. Using $(s,\xi,\overline{\xi},S^-)$ as coordinates for the space-time surface defined by the ansatz $(w=w(\xi,s),S^+=S^+(s))$ one finds that g_{ss} must be vanishing so that stronger variant of the Kähler property holds true for $S^-=constant$ 3-surfaces.

The topologization condition for the Kähler current can be solved completely generally in terms of the induced metric using $(\xi,\overline{\xi},s)$ and some coordinate of M^4_+, call it x^4, as space-time coordinates. Topologization boils down to the conditions

$$\begin{aligned} \partial_\beta(J^{\alpha\beta}\sqrt{g}) &= 0 \text{ for } \alpha\in\{\xi,\overline{\xi},s\} \ , \\ g^{4i}\neq 0 \ . \end{aligned} \tag{6.2.23}$$

Thus 3-dimensional empty space Maxwell equations and the non-orthogonality of x^4 coordinate lines and the 3-surfaces defined by the lift of the CP_2 projection.

A solution ansatz yielding light-like current in $D_{CP_2}=3$ case

The basic idea is that of generalized Kähler structure and solutions of field equations as maps or deformations of canonically imbedded M^4_+ respecting this structure and guaranteing that the only non-vanishing components of the energy momentum tensor are $T^{\xi\xi}$ and T^{s-} in the coordinates $(\xi,\overline{\xi},s,S^-)$.

1. The coordinates (w,S^+) are assumed to holomorphic functions of the CP_2 coordinates (s,ξ)

$$S^+=S^+(s) \ , \quad w=w(\xi,s) \ . \tag{6.2.24}$$

   Obviously S^+ could be replaced with S^-. The ansatz is completely symmetric with respect to the exchange of the roles of (s,w) and (S^+,ξ) since it maps longitudinal degrees of freedom to longitudinal ones and transverse degrees of freedom to transverse ones.

2. Field equations are satisfied if the only non-vanishing components of the energy momentum tensor are of type $T^{\xi\overline{\xi}}$ and T^{s-}. The reason is that the CP_2 Christoffel symbols for projection and projections of M^4_+ Christoffel symbols are vanishing for these lower index pairs.

3. By a straightforward calculation one can verify that the only manner to achieve the required structure of energy momentum tensor is to assume that the induced metric in the coordinates $(\xi,\overline{\xi},s,S^-)$ has as non-vanishing components only $g_{\xi\overline{\xi}}$ and g_{s-}

$$g_{ss}=0 \ , \quad g_{\xi s}=0 \ , \quad g_{\overline{\xi}s}=0 \ . \tag{6.2.25}$$

   Obviously the space-time surface must factorize into an orthogonal product of longitudinal and transversal spaces.

4. The condition guaranteing the product structure of the metric is

$$\begin{aligned} s_{ss} &= m_{+w}\partial_s w(\xi,s)\partial_s S^+(s)+m_{+\overline{w}}\partial_s\overline{w}(\xi,s)\partial_s S^+(s) \ , \\ s_{s\xi} &= m_{+w}\partial_\xi w(\xi)\partial_s S^+(s) \ , \\ s_{s\overline{\xi}} &= m_{+w}\partial_{\overline{\xi}} w(\overline{\xi})\partial_s S^+(s) \ . \end{aligned} \tag{6.2.26}$$

   Thus the function of dynamics is to diagonalize the metric and provide it with strong Kähler property. Obviously the CP_2 projection corresponds to a light-like surface for all values of S^- so that space-time surface is foliated by light-like surfaces and the notion of generalized conformal invariance makes sense for the entire space-time surface rather than only for its boundary or elementary particle horizons.

5. The requirement that the Kähler current is proportional to the instanton current means that only the j^- component of the current is non-vanishing. This gives the following conditions

$$\begin{aligned} & j^{\xi}\sqrt{g} = \partial_\beta(J^{\xi\beta}\sqrt{g}) = 0 \ , \quad j^{\bar{\xi}}\sqrt{g} = \partial_\beta(J^{\bar{\xi}\beta}\sqrt{g}) = 0 \ , \\ & j^{+}\sqrt{g} = \partial_\beta(J^{+\beta}\sqrt{g}) = 0 \ . \end{aligned} \tag{6.2.27}$$

Since $J^{+\beta}$ vanishes, the condition

$$\sqrt{g}j^{+} = \partial_\beta(J^{+\beta}\sqrt{g}) \quad = \quad 0 \tag{6.2.28}$$

is identically satisfied. Therefore the number of field equations reduces to three.

The physical interpretation of the solution ansatz deserves some comments.

1. The light-like character of the Kähler current brings in mind CP_2 extremals for which CP_2 projection is light like. This suggests that the topological condensation of CP_2 type extremal occurs on $D_{CP_2} = 3$ helical space-time sheet representing zitterbewegung. In the case of many-body system light-likeness of the current does not require that particles are massless if particles of opposite charges can be present. Field tensor has the form $(J^{\xi\bar{\xi}}, J^{\xi-}, J^{\bar{\xi}-})$. Both helical magnetic field and electric field present as is clear when one replaces the coordinates (S^+, S^-) with time-like and space-like coordinate. Magnetic field dominates but the presence of electric field means that genuine Beltrami field is not in question.

2. Since the induced metric is product metric, 3-surface is metrically product of 2-dimensional surface X^2 and line or circle and obeys product topology. If preferred extremals correspond to asymptotic self-organization patterns, the appearence of the product topology and even metric is not so surprising. Thus the solutions can be classified by the genus of X^2. An interesting question is how closely the explanation of family replication phenomenon in terms of the topology of the boundary component of elementary particle like 3-surface relates to this. The heaviness and instability of particles which correspond to genera $g > 2$ (sphere with more than two handles) might have simple explanation as absence of (stable) $D_{CP_2} = 3$ solutions of field equations with genus $g > 2$.

3. The solution ansatz need not be the most general. Kähler current is light-like and already this is enough to reduce the field equations to the form involving only energy momentum tensor. One might hope of finding also solution ansätze for which Kähler current is time-like or space-like. Space-likeness of the Kähler current might be achieved if the complex coordinates $(\xi, \bar{\xi})$ and hyper-complex coordinates (S^+, S^-) change the role. For this solution ansatz electric field would dominate. Note that the possibility that Kähler current is always light-like cannot be excluded.

4. Suppose that CP_2 projection quite generally defines a foliation of the space-time surface by light-like 3-surfaces, as is suggested by the conformal invariance. If the induced metric has Minkowskian signature, the fourth coordinate x^4 and thus also Kähler current must be time-like or light-like so that magnetic field dominates. Already the requirement that the metric is non-degenerate implies $g_{s4} \neq 0$ so that the metric for the $\xi = constant$ 2-surfaces has a Minkowskian signature. It might well be that there are no solutions with a space-like Kähler current, that the topologization of the Kähler current is equivalent with its light-likeness, and that $D_{CP_2} = 3$ solutions carry dominantly magnetic fields. Thus space-like Kähler current does not allow the lift of the CP_2 projection to be light-like.

Are solutions with time-like or space-like Kähler current possible in $D_{CP_2} = 3$ case?

The following ansatz gives good hopes for obtaining solutions with space-like and time-like Kähler currents.

1. Assign to light-like coordinates coordinates (T, Z) by the formula $T = S^+ + S^-$ and $Z = S^+ - S^-$. Space-time coordinates are taken to be $(\xi, \overline{\xi}, s)$ and coordinate Z. The solution ansatz with time-like Kähler current results when the roles of T and Z are changed. It will however found that same solution ansatz can give rise to both space-like and time-like Kähler current.

2. The solution ansatz giving rise to a space-like Kähler current is defined by the equations

$$T = T(Z, s) \ , \quad w = w(\xi, s) \ . \tag{6.2.29}$$

If T depends strongly on Z, the g_{ZZ} component of the induced metric becomes positive and Kähler current time-like.

3. The components of the induced metric are

$$\begin{array}{ll} g_{ZZ} = m_{ZZ} + m_{TT}\partial_Z T \partial_s T \ , & g_{Zs} = m_{TT}\partial_Z T \partial_s T \ , \\ g_{ss} = s_{ss} + m_{TT}\partial_s T \partial_s T \ , & g_{w\overline{w}} = s_{w\overline{w}} + m_{w\overline{w}}\partial_\xi w \partial_{\overline{\xi}}\overline{w} \ , \\ g_{s\xi} = s_{s\xi} \ , & g_{s\overline{\xi}} = s_{s\overline{\xi}} \ . \end{array} \tag{6.2.30}$$

Topologized Kähler current has only Z-component and 3-dimensional empty space Maxwell's equations guarantee the topologization.

In CP_2 degrees of freedom the contractions of the energy momentum tensor with Christoffel symbols vanish if T^{ss}, $T^{\xi s}$ and $T^{\xi\xi}$ vanish as required by internal consistency. This is guaranteed if the condition

$$J^{\xi s} \ = \ 0 \tag{6.2.31}$$

holds true. Note however that $J^{\xi Z}$ is non-vanishing. Therefore only the components $T^{\xi\overline{\xi}}$ and $T^{Z\xi}$, $T^{Z\overline{\xi}}$ of energy momentum tensor are non-vanishing, and field equations reduce to the conditions

$$\begin{aligned} \partial_{\overline{\xi}}(J^{\xi\overline{\xi}}\sqrt{g}) + \partial_Z(J^{\xi Z}\sqrt{g}) \ &= \ 0 \ , \\ \partial_\xi(J^{\overline{\xi}\xi}\sqrt{g}) + \partial_Z(J^{\overline{\xi}Z}\sqrt{g}) \ &= \ 0 \ . \end{aligned} \tag{6.2.32}$$

In the special case that the induce metric does not depend on z-coordinate equations reduce to holomorphicity conditions. This is achieve if T depends linearly on Z: $T = aZ$.

The contractions with M^4_+ Christoffel symbols come from the non-vanishing of $T^{Z\xi}$ and vanish if the Hamilton Jacobi structure satisfies the conditions

$$\begin{array}{l} \{^{\ k}_{T\ w}\} = 0 \ , \quad \{^{\ k}_{T\ \overline{w}}\} = 0 \ , \\ \{^{\ k}_{Z\ w}\} = 0 \ , \quad \{^{\ k}_{Z\ \overline{w}}\} = 0 \end{array} \tag{6.2.33}$$

hold true. The conditions are equivalent with the conditions

$$\{^{\ k}_{\pm\ w}\} = 0 \ , \quad \{^{\ k}_{\pm\ \overline{w}}\} = 0 \ . \tag{6.2.34}$$

These conditions possess solutions (standard light cone coordinates are the simplest example). Also the second derivatives of $T(s, Z)$ contribute to the second fundamental form but they do not give rise to non-vanishing contractions with the energy momentum tensor. The cautious conclusion is that also solutions with time-like or space-like Kähler current are possible.

$D_{CP_2} = 4$ **case**

The preceding discussion was for $D_{CP_2} = 3$ and one should generalize the discussion to $D_{CP_2} = 4$ case.

1. Hamilton Jacobi structure for M^4_+ is expected to be crucial also now.
2. One might hope that for $D = 4$ the Kähler structure of CP_2 defines a foliation of CP_2 by 3-dimensional contact structures. This requires that there is a coordinate varying along the field lines of the normal vector field X defined as the dual of the three-form $A \wedge dA = A \wedge J$. By the previous considerations the condition for this reads as $dX = d(log\phi) \wedge X$ and implies $X \wedge dX = 0$. Using the self duality of the Kähler form one can express X as $X^k = J^{kl} A_l$. By a brief calculation one finds that $X \wedge dX \propto X$ holds true so that (somewhat disappointingly) a foliation of CP_2 by contact structures does not exist.

For $D_{CP_2} = 4$ case Kähler current vanishes and this case corresponds to what I have called earlier Maxwellian phase since empty space Maxwell's equations are indeed satisfied.

1. Solution ansatz with a 3-dimensional M^4_+ projection

The basic idea is that the complex structure of CP_2 is preserved so that one can use complex coordinates (ξ^1, ξ^2) for CP_2 in which CP_2 Christoffel symbols and energy momentum tensor have automatically the desired properties. This is achieved the second light like coordinate, say v, is non-dynamical so that the induced metric does not receive any contribution from the longitudinal degrees of freedom. In this case one has

$$S^+ = S^+(\xi^1, \xi^2) \ , \quad w = w(\xi^1, \xi^2) \ , \quad S^- = constant \ . \tag{6.2.35}$$

The induced metric does possesses only components of type $g_{i\bar{j}}$ if the conditions

$$g_{+w} = 0 \ , \quad g_{+\overline{w}} = 0 \ . \tag{6.2.36}$$

This guarantees that energy momentum tensor has only components of type $T^{i\bar{j}}$ in coordinates (ξ^1, ξ^2) and their contractions with the Christoffel symbols of CP_2 vanish identically. In M^4_+ degrees of freedom one must pose the conditions

$$\left\{ {}^{\ k}_{w+} \right\} = 0 \ , \quad \left\{ {}^{\ k}_{\overline{w}+} \right\} = 0 \ , \quad \left\{ {}^{\ k}_{++} \right\} = 0 \ . \tag{6.2.37}$$

on Christoffel symbols. These conditions are satisfied if the the M^4_+ metric does not depend on S^+:

$$\partial_+ m_{kl} \ = \ 0 \ . \tag{6.2.38}$$

This means that m_{-w} and $m_{-\overline{w}}$ can be non-vanishing but like m_{+-} they cannot depend on S^+.

The second derivatives of S^+ appearing in the second fundamental form are also a source of trouble unless they vanish. Hence S^+ must be a linear function of the coordinates ξ^k:

$$S^+ \ = \ a_k \xi^k + \overline{a}_k \overline{\xi}^k \ . \tag{6.2.39}$$

Field equations are the counterparts of empty space Maxwell equations $j^\alpha = 0$ but with M^4_+ coordinates (u, w) appearing as dynamical variables and entering only through the induced metric. By holomorphy the field equations can be written as

$$\partial_j (J^{j\bar{i}} \sqrt{g}) = 0 \ , \quad \partial_{\bar{j}} (J^{\bar{j}i} \sqrt{g}) = 0 \ , \tag{6.2.40}$$

and can be interpreted as conditions stating the holomorphy of the contravariant Kähler form.

What is remarkable is that the M^4_+ projection of the solution is 3-dimensional light like surface and that the induced metric has Euclidian signature. Light front would become a concrete geometric object with one compactified dimension rather than being a mere conceptualization. One could see this as topological quantization for the notion of light front or of electromagnetic shock wave, or perhaps even as the realization of the particle aspect of gauge fields at classical level.

If the latter interpretation is correct, quantum classical correspondence would be realized very concretely. Wave and particle aspects would both be present. One could understand the interactions of charged particles with electromagnetic fields both in terms of absorption and emission of topological field quanta and in terms of the interaction with a classical field as particle topologically condenses at the photonic light front.

For CP_2 type extremals for which M^4_+ projection is a light like curve correspond to a special case of this solution ansatz: transversal M^4_+ coordinates are constant and S^+ is now arbitrary function of CP_2 coordinates. This is possible since M^4_+ projection is 1-dimensional.

2. Are solutions with a 4-dimensional M^4_+ projection possible?

The most natural solution ansatz is the one for which CP_2 complex structure is preserved so that energy momentum tensor has desired properties. For four-dimensional M^4_+ projection this ansatz does not seem to make promising since the contribution of the longitudinal degrees of freedom implies that the induced metric is not anymore of desired form since the components $g_{ij} = m_{+-}(\partial_{\xi^i} S^+ \partial_{\xi^j} S^- + m_{+-}\partial_{\xi^i} S^- \partial_{\xi^j} S^+)$ are non-vanishing.

1. The natural dynamical variables are still Minkowski coordinates $(w, \overline{w}, S^+, S^-)$ for some Hamilton Jacobi structure. Since the complex structure of CP_2 must be given up, CP_2 coordinates can be written as (ξ, s, r) to stress the fact that only "one half" of the Kähler structure of CP_2 is respected by the solution ansatz.

2. The solution ansatz has the same general form as in $D = 3$ case and must be symmetric with respect to the exchange of M^4_+ and CP_2 coordinates. Transverse coordinates are mapped to transverse ones and longitudinal coordinates to longitudinal ones:

$$(S^+, S^-) = (S^+(s,r), S^-(s,r)) \quad , \quad w = w(\xi) \ . \tag{6.2.41}$$

   This ansatz would describe ordinary Maxwell field in M^4_+ since the roles of M^4_+ coordinates and CP_2 coordinates are interchangeable.

It is however far from obvious whether there are any solutions with a 4-dimensional M^4_+ projection. That empty space Maxwell's equations would allow only the topologically quantized light fronts as its solutions would realize quantum classical correspondence very concretely.

$D_{CP_2} = 2$ case

Hamilton Jacobi structure for M^4_+ is assumed also for $D_{CP_2} = 2$, whereas the contact structure for CP_2 is in $D = 2$ case replaced by the induced Kähler structure. Topologization yields vanishing Kähler current. Light-likeness provides a second manner to achieve vanishing Lorentz force but one cannot exclude the possibility of time- and space-like Kähler current.

1. Solutions with vanishing Kähler current

1. String like objects, which are products $X^2 \times Y^2 \subset M^4_+ \times CP_2$ of minimal surfaces Y^2 of M^4_+ with geodesic spheres S^2 of CP_2 and carry vanishing gauge current. String like objects allow considerable generalization from simple Cartesian products of $X^2 \times Y^2 \subset M^4 \times S^2$. Let $(w, \overline{w}, S^+, S^-)$ define the Hamilton Jacobi structure for M^4_+. $w = constant$ surfaces define minimal surfaces X^2 of M^4_+. Let ξ denote complex coordinate for a sub-manifold of CP_2 such that the imbedding to CP_2 is holomorphic: $(\xi^1, \xi^2) = (f^1(\xi), f^2(\xi))$. The resulting surface $Y^2 \subset CP_2$ is a minimal surface and field equations reduce to the requirement that the Kähler current vanishes: $\partial_{\overline{\xi}}(J^{\xi\overline{\xi}}\sqrt{g_2}) = 0$. One-dimensional strings are deformed to 3-dimensional cylinders representing

magnetic flux tubes. The oscillations of string correspond to waves moving along string with light velocity, and for more general solutions they become TGD counterparts of Alfwen waves associated with magnetic flux tubes regarded as oscillations of magnetic flux lines behaving effectively like strings. It must be emphasized that Alfwen waves are a phenomenological notion not really justified by the properties of Maxwell's equations.

2. Also electret type solutions with the role of the magnetic field taken by the electric field are possible. $(\xi,\overline{\xi},u,v)$ would provide the natural coordinates and the solution ansatz would be of the form

$$(s,r) = (s(u,v), r(u,v)) \quad , \quad \xi = constant \quad , \tag{6.2.42}$$

and corresponds to a vanishing Kähler current.

3. Both magnetic and electric fields are necessarily present only for the solutions carrying non-vanishing electric charge density (proportional to $\overline{B}\cdot\overline{A}$). Thus one can ask whether more general solutions carrying both magnetic and electric field are possible. As a matter fact, one must first answer the question what one really means with the magnetic field. By choosing the coordinates of 2-dimensional CP_2 projection as space-time coordinates one can define what one means with magnetic and electric field in a coordinate invariant manner. Since the CP_2 Kähler form for the CP_2 projection with $D_{CP_2}=2$ can be regarded as a pure Kähler magnetic field, the induced Kähler field is either magnetic field or electric field.

The form of the ansatz would be

$$(s,r) = (s,r)\,(u,v,w,\overline{w}) \quad , \quad \xi = constant \quad . \tag{6.2.43}$$

As a matter fact, CP_2 coordinates depend on two properly chosen M^4 coordinates only.

1. Solutions with light-like Kähler current

There are large classes of solutions of field equations with a light-like Kähler current and 2-dimensional CP_2 projection.

1. Massless extremals for which CP_2 coordinates are arbitrary functions of one transversal coordinate $e=f(w,\overline{w})$ defining local polarization direction and light like coordinate u of M^4_+ and carrying in the general case a light like current. In this case the holomorphy does not play any role.

2. The string like solutions thickened to magnetic flux tubes carrying TGD counterparts of Alfwen waves generalize to solutions allowing also light-like Kähler current. Also now Kähler metric is allowed to develop a component between longitudinal and transversal degrees of freedom so that Kähler current develops a light-like component. The ansatz is of the form

$$\xi^i = f^i(\xi) \ \ , \ \ w = w(\xi) \ \ , \ \ S^- = s^- \ \ , \ \ S^+ = s^+ + f(\xi,\overline{\xi}) \ \ .$$

Only the components $g_{+\xi}$ and $g_{+\overline{\xi}}$ of the induced metric receive contributions from the modification of the solution ansatz. The contravariant metric receives contributions to $g^{-\xi}$ and $g^{-\overline{\xi}}$ whereas $g^{+\xi}$ and $g^{+\overline{\xi}}$ remain zero. Since the partial derivatives $\partial_\xi\partial_+h^k$ and $\partial_{\overline{\xi}}\partial_+h^k$ and corresponding projections of Christoffel symbols vanish, field equations are satisfied. Kähler current develops a non-vanishing component j^-. Apart from the presence of the electric field, these solutions are highly analogous to Beltrami fields.

3. Do scalar wave pulses represent a solution type with non-vanishing but not light-like Kähler current?

Since longitudinal polarizations are possible only for off mass shell virtual photons, physical intuition suggests that scalar wave pulse solutions describing the propagation of longitudinal electric field with light velocity cannot appear as asymptotic field patterns. This is also consistent with the claim that scalar wave pulses are associated with the transients involved with sudden switching of electric voltage on or off. Let $M^4 = M^2 \oplus E^2$ be the standard decomposition of M^4 to flat longitudinal and transversal spaces, and S^2 a homologically non-trivial geodesic sphere of CP_2. The simplest solution ansatz corresponds to a surface $X^2 \times Y^2$, $X^2 \subset E^2$, such that Y^2 is a surface defined by a map $S^2 \rightarrow M^2$ (or vice versa).

Energy momentum tensor is in both longitudinal and transversal degrees of freedom proportional to the corresponding part of the induced metric. Field equations are trivially true in the transversal degrees of freedom. The calculation of the divergence of energy momentum tensor demonstrates that Kähler current can be regarded as a vector field

$$j^\alpha = \frac{1}{4} J^{\alpha\beta} \partial_\beta L$$

defined by the Kähler action density acting as Hamiltonian. Poisson bracket is defined by the pseudo-symplectic form associated with the induced Kähler form with respect to the induced metric rather that that of S^2 (using S^2-coordinates as coordinates for Y^2, the square of this pseudo-symplectic form is equal to metric multiplied by the ratio $det(g(Y^2))/det(g(S^2))$).

In longitudinal degrees of freedom field equations are minimal surface equations with a source term proportional to the Kähler current divided by the Kähler action density. The vanishing of the Kähler current is possible only if Kähler action density is constant. This condition is true in the approximation that the induced metric for Y^2 is flat, that is at the limit when M^4 projection has size larger than size of CP_2 projection and that induced metric has Minkowskian signature). It is not clear whether the minimal surface property of Y^2 in $M^2 \times S^2$ is consistent with the constancy of the Kähler action density. This would suggest that classical gravitational interactions eliminate scalar wave pulses as asymptotic field patterns and cause the deviation from the minimal surface property and the non-vanishing of the Kähler current. The fact that solution becomes "instanton" like Euclidian solution when S^+ and S^- become constant suggests that the M^4 projection of the solution quite generally has a finite extension in time direction.

Could $D_{CP_2} = 2 \rightarrow 3$ transition occur in rotating magnetic systems?

I have studied the imbeddings of simple cylindrical and helical magnetic fields in various applications of TGD to condensed matter systems, in particular in attempts to understand the strange findings about rotating magnetic systems [K77] .

Let S^2 be the homologically non-trivial geodesic sphere of CP_2 with standard spherical coordinates $(U \equiv cos(\theta), \Phi)$ and let (t, ρ, ϕ, z) denote cylindrical coordinates for a cylindrical space-time sheet. The simplest possible space-time surfaces $X^4 \subset M^4_+ \times S^2$ carrying helical Kähler magnetic field depending on the radial cylindrical coordinate ρ, are given by:

$$\begin{array}{ll} U = U(\rho) \ , & \Phi = n\phi + kz \ , \\ J_{\rho\phi} = n\partial_\rho U \ , & J_{\rho z} = k\partial_\rho U \ . \end{array} \tag{6.2.44}$$

This helical field is not Beltrami field as one can easily find. A more general ansatz corresponding defined by

$$\Phi = \omega t + kz + n\phi$$

would in cylindrical coordinates give rise to both helical magnetic field and radial electric field depending on ρ only. This field can be obtained by simply replacing the vector potential with its rotated version and provides the natural first approximation for the fields associated with rotating magnetic systems.

A non-vanishing vacuum charge density is however generated when a constant magnetic field is put into rotation and is implied by the condition $\overline{E} = \overline{v} \times \overline{B}$ stating vanishing of the Lorentz force. This condition does not follow from the induction law of Faraday although Faraday observed this effect first. This is also clear from the fact that the sign of the charge density depends on the direction of rotation.

The non-vanishing charge density is not consistent with the vanishing of the Kähler 4-current and requires a 3-dimensional CP_2 projection and topologization of the Kähler current. Beltrami condition cannot hold true exactly for the rotating system. The conclusion is that rotation induces a phase transition $D_{CP_2} = 2 \rightarrow 3$. This could help to understand various strange effects related to the rotating magnetic systems [K77] . For instance, the increase of the dimension of CP_2 projection could generate join along boundaries contacts and wormhole contacts leading to the transfer of charge between different space-time sheets. The possibly resulting flow of gravitational flux to larger space-time sheets might help to explain the claimed antigravity effects.

6.2.4 Is preferred extremal property equivalent with the topologization/light-likeness of Kähler current and with second law?

The basic question is whether the Kähler current is either topologized or light-like for all extremals or only for the preferred extremals of Kähler action in some sense, presumably asymptotically as suggested by the fact that generalized Beltrami fields correspond to asymptotic self-organization patterns, when dissipation has become insignificant.

1. The generalized Beltrami conditions or light-likeness can hold true only asymptotically. First of all, generic non-asymptotic field configurations have $D_{CP_2} = 4$, and would thus carry a vanishing Kähler four-current if Beltrami conditions were satisfied universally rather than only asymptotically. $j^\alpha = 0$ would obviously hold true also for the asymptotic configurations, in particular those with $D_{CP_2} < 4$ so that empty space Maxwell's field equations would be universally satisfied for asymptotic field configurations with $D_{CP_2} < 4$.

2. The failure of the generalized Beltrami conditions would mean that Kähler field is completely analogous to a dissipative Maxwell field since $\overline{j} \cdot \overline{E}$ is non-vanishing (note that isometry currents are conserved although energy momentum tensor is not). Quantum classical correspondence states that classical space-time dynamics is by its classical non-determinism able to mimic the non-deterministic sequence of quantum jumps at space-time level, in particular dissipation in various length scales defined by the hierarchy of space-time sheets. Classical fields could represent "symbolically" the average dynamics, in particular dissipation, in shorter length scales. For instance, vacuum 4-current would be a symbolic representation for the average of the currents consisting of elementary particles.

Is preferred extremal property equivalent with generalized Beltrami conditions?

Previous findings inspire the hypothesis that generalized Beltrami conditions express algebraically the absolute minimization conditions so that they make sense also in the p-adic case.

1. Generalized Beltrami conditions are satisfied by the asymptotic field configurations representing self-organization patterns. For non-asymptotic fields vacuum Lorentz force is non-vanishing and does work in Maxwellian sense so that $\overline{j} \cdot \overline{E}$ is non-vanishing. This would mean that the dynamics defined by Kähler action could in principle predict even the values of the parameters related to dissipation such as conductivities and viscosities. The space-time sheets of the many-sheeted space-time would be busily modelling its own physics in shorter length scales.

2. Preferred extremal property implies that single space-time surface goes through given 3-surface apart from the non-uniqueness caused by the non-determinism of Kähler action. This gives *four* additional local conditions to the initial values of field equations fixing the time derivatives of the four dynamical imbedding space coordinates (conditions are analogous to Bohr conditions).

   The topologization of the Kähler current current gives also *four* local conditions:
   i) For $D_{CP_2} < 4$ the vanishing of instanton density gives one condition, and the proportionality of the Kähler current to instanton current gives 3 conditions since the proportionality factor is an arbitrary function of CP_2 coordinates. Altogether this makes four conditions.
   ii) For $D_{CP_2=4}$ the vanishing of the Kähler current gives four conditions.
   This encourages to think that the preferred extremal property forces the asymptotic behavior (final values instead of initial values) to correspond to dissipation-less state characterized by the generalized Beltrami conditions.

Is preferred extremal property equivalent with the second law?

The fact that Beltrami conditions are associated with the asymptotic dynamics suggests that preferred extremal property is equivalent with the second law at space-time level. Or putting it more cautiously: second law at space-time level could be equivalent with preferred extremal property.

For space-time sheets with negative time orientation and negative energy, say "massless extremals" representing phase conjugate laser waves, field configurations would approach non-dissipating ones in the geometric past, and the arrow of geometric time would be opposite to the standard one in this case. This situation is possible for space-time sheets of finite duration, in particular virtual particle like space-time sheets or the negative energy space-time sheets extending down to the boundary of imbedding space (moment of "big bang"). This would explain at the space-time level the change of arrow of time and breaking of the second law observed for the phase conjugate laser waves (used to generate healing and error correction for instance). In TGD framework second law is not a producer of a thermal chaos but Darwinian selector since state function reduction and state preparation by self measurements lead from a state with positive entanglement entropy to that with a negative entanglement entropy (defined number theoretically), and possessing only finitely extended rational entanglement identifiable as a bound state entanglement.

According to the recent view preferred extremal property corresponds to space-time correlate for quantum criticality and indeed induces long range correlations. The resulting non-local long range correlations could serve as correlates for bound state entanglement. More concretely, the stable join along boundaries bonds would be the correlates for bound state entanglement whereas topological light rays analogous to the exchange of virtual photons could serve as classical correlates for unbound entanglement. The closedness (periodicity) of the field lines of Beltrami fields for space-like Kähler current and periodicity of the field pattern for the time like Kähler current could be space-time correlates for the rational entanglement. The pinary expansions of rational numbers which are periodic after finite number of pinary digits indeed represent closed orbits in the set of integers modulo p. Amusingly, the first non-periodic pits of the expansion would in fact be analogous to the dissipative period.

Macro-temporal quantum coherence integrates sequences of quantum jumps to single effective quantum jump so that effectively a fractal hierarchy of quantum jumps emerges having the fractal hierarchy of time scales of dissipation resulting from many-sheetedness as a correlate. Even the anatomy of quantum jump could have space-time correlate. The final state of the quantum jump would correspond to highly negentropic and non-dissipating topologically quantized generalized Beltrami fields. State function reduction and preparation would correspond to the non-deterministic dissipative approach to the non-dissipative Beltrami field configuration. The points of space-time sheets with vanishing Kähler 4-currents would be unstable against quantum jumps generating an instability of the Beltrami field leading to a field configuration with a non-vanishing Lorentz 4-force and emission of topological light rays representing unstable entanglement. Quantum jump would have this kind of instability as a natural space-time correlate.

To sum up, the main lessons would be following.

1. The ability of basically non-dissipative dynamics to mimic dissipative dynamics in terms of energy momentum tensor would be the basic reason for why space-times must be 4-surfaces.

2. If prefered extremal property is correct principle, it must provide a space-time correlate for the second law, which is the Darwinian selector of the most information rich patterns rather than a thermal killer.

6.2.5 Generalized Beltrami fields and biological systems

The following arguments support the view that generalized Beltrami fields play a key role in living systems, and that $D_{CP_2} = 2$ corresponds to ordered phase, $D_{CP_2} = 3$ to spin glass phase and $D_{CP_2} = 4$ to chaos, with $D_{CP_2} = 3$ defining life as a phenomenon at the boundary between order and chaos.

Why generalized Beltrami fields are important for living systems?

Chirality, complexity, and high level of organization make $D_{CP_2} = 3$ generalized Beltrami fields excellent candidates for the magnetic bodies of living systems.

1. Chiral selection is one of the basic signatures of living systems. Beltrami field is characterized by a chirality defined by the relative sign of the current and magnetic field, which means parity breaking. Chirality reduces to the sign of the function ψ appearing in the topologization condition and makes sense also for the generalized Beltrami fields.

2. Although Beltrami fields can be extremely complex, they are also extremely organized. The reason is that the function α is constant along flux lines so that flux lines must in the case of compact Riemann 3-manifold belong to 2-dimensional $\alpha = constant$ closed surfaces, in fact two-dimensional invariant tori [B10] .

For generalized Beltrami fields the function ψ is constant along the flow lines of the Kähler current. Space-time sheets with 3-dimensional CP_2 projection serve as an illustrative example. One can use the coordinates for the CP_2 projection as space-time coordinates so that one space-time coordinate disappears totally from consideration. Hence the situation reduces to a flow in a 3-dimensional sub-manifold of CP_2. One can distinguish between three types of flow lines corresponding to space-like, light-like and time-like topological current. The 2-dimensional $\psi = constant$ invariant manifolds are sub-manifolds of CP_2. Ordinary Beltrami fields are a special case of space-like flow with flow lines belonging to the 2-dimensional invariant tori of CP_2. Time-like and light-like situations are more complex since the flow lines need not be closed so that the 2-dimensional $\psi = constant$ surfaces can have boundaries.

For periodic self-organization patterns flow lines are closed and $\psi = constant$ surfaces of CP_2 must be invariant tori. The dynamics of the periodic flow is obtained from that of a steady flow by replacing one spatial coordinate with effectively periodic time coordinate. Therefore topological notions like helix structure, linking, and knotting have a dynamical meaning at the level of CP_2 projection. The periodic generalized Beltrami fields are highly organized also in the temporal domain despite the potentiality for extreme topological complexity.

For these reasons topologically quantized generalized Beltrami fields provide an excellent candidate for a generic model for the dynamics of biological self-organization patterns. A natural guess is that many-sheeted magnetic and Z^0 magnetic fields and their generalizations serve as templates for the helical molecules populating living matter, and explain both chiral selection, the complex linking and knotting of DNA and protein molecules, and even the extremely complex and self-organized dynamics of biological systems at the molecular level.

The intricate topological structures of DNA, RNA, and protein molecules are known to have a deep significance besides their chemical structure, and they could even define something analogous to the genetic code. Usually the topology and geometry of bio-molecules is believed to reduce to chemistry. TGD suggests that space-like generalized Beltrami fields serve as templates for the formation of bio-molecules and bio-structures in general. The dynamics of bio-systems would in turn utilize the time-like Beltrami fields as templates. There could even exist a mapping from the topology of magnetic flux tube structures serving as templates for bio-molecules to the templates of self-organized dynamics. The helical structures, knotting, and linking of bio-molecules would thus define a symbolic representation, and even coding for the dynamics of the bio-system analogous to written language.

$D_{CP_2} = 3$ systems as boundary between $D_{CP_2} = 2$ order and $D_{CP_2} = 4$ chaos

The dimension of CP_2 projection is basic classifier for the asymptotic self-organization patterns.

1. $D_{CP_2} = 4$ phase, dead matter, and chaos

$D_{CP_2} = 4$ corresponds to the ordinary Maxwellian phase in which Kähler current and charge density vanish and there is no topologization of Kähler current. By its maximal dimension this phase would naturally correspond to disordered phase, ordinary dead matter. If one assumes that Kähler charge corresponds to either em charge or Z^0 charge then the signature of this state of matter would be em neutrality or Z^0 neutrality.

2. $D_{CP_2} = 2$ phase as ordered phase

By the low dimension of CP_2 projection $D_{CP_2} = 2$ phase is the least stable phase possible only at cold space-time sheets. Kähler current is either vanishing or light-like, and Beltrami fields are not possible. This phase is highly ordered and much like a topological quantized version of ferro-magnet. In particular, it is possible to have a global coordinate varying along the field lines of the vector potential also now. The magnetic and Z^0 magnetic body of any system is a candidate for this kind of system.

3. $D_{CP_2} = 3$ corresponds to living matter

$D_{CP_2} = 3$ corresponds to highly organized phase characterized in the case of space-like Kähler current by complex helical structures necessarily accompanied by topologized Kähler charge density $\propto \overline{A} \cdot \overline{B} \neq 0$ and Kähler current $\overline{E} \times \overline{A} + \phi \overline{B}$. For time like Kähler currents the helical structures are replaced by periodic oscillation patterns for the state of the system. By the non-maximal dimension of CP_2 projection this phase must be unstable against too strong external perturbations and cannot survive at too high temperatures. Living matter is thus excellent candidate for this phase and it might be that the interaction of the magnetic body with living matter makes possible the transition from $D_{CP_2} = 2$ phase to the self-organizing $D_{CP_2} = 3$ phase.

Living matter which is indeed populated by helical structures providing examples of space-like Kähler current. Strongly charged lipid layers of cell membrane might provide example of time-like Kähler current. Cell membrane, micro-tubuli, DNA, and proteins are known to be electrically charged and Z^0 charge plays key role in TGD based model of catalysis discussed in [K27] . For instance, denaturing of DNA destroying its helical structure could be interpreted as a transition leading from $D = 3$ phase to $D = 4$ phase. The prediction is that the denatured phase should be electromagnetically (and/or Z^0) neutral.

Beltrami fields result when Kähler charge density vanishes. For these configurations magnetic field and current density take the role of the vector potential and magnetic field as far as the contact structure is considered. For Beltrami fields there exist a global coordinate along the field lines of the vector potential but not along those of the magnetic field. As a consequence, the covariant consistency condition $(\partial_s - qeA_s)\Psi = 0$ frequently appearing in the physics of super conducting systems would make sense along the flow lines of the vector potential for the order parameter of Bose-Einstein condensate. If Beltrami phase is super-conducting, then the state of the system must change in the transition to a more general phase. Since the field lines of the vector potential define chaotic orbits in this phase, the loss of coherence of the order parameter implying the loss of superconductivity by random collisions of particles is what one expects to happen.

The existence of these three phases brings in mind systems allowing chaotic de-magnetized phase above critical temperature T_c, spin glass phase at the critical point, and ferromagnetic phase below T_c. Similar analogy is provided by liquid phase, liquid crystal phase possible in the vicinity of the critical point for liquid to solid transition, and solid phase. Perhaps one could regard $D_{CP_2} = 3$ phase and life as a boundary region between $D_{CP_2} = 2$ order and $D_{CP_2} = 4$ chaos. This would naturally explain why life as it is known is possible in relatively narrow temperature interval.

6.3 The scalar waves of Tesla, bio-systems as electrets, and electric-magnetic duality

The scalar waves or so called non-Hertzian waves of Nikola Tesla belong to the fringe region of science. Many proponents of free energy believe that scalar waves might provide a basis for a new energy and communication technologies. Tesla himself was isolated from the official science and found no place in text books because his hypothesis about scalar waves did not fit within the framework of the Maxwell's electrodynamics. Personally I justified my personal prejudices against scalar waves by the observation that the formulations for the notion of scalar waves that I had seen seemed to be in a conflict with the cherished gauge invariance of gauge theories. The discussions with a Finnish free energy enthusiast Juha Hartikka however led me to reconsider the status of the scalar waves.

The surprise was that one can understand the non-Hertzian waves of Tesla in TGD framework and that they are basically predicted by the electric-magnetic duality of TGD. As a matter fact, TGD predicts huge number of solutions of field equations representing constant energy density configurations of electric field assignable to bioelectrets which are in a well defined sense dual to the magnetic flux tube structures with analogous properties. Thus the deep symmetry principle of electric-magnetic duality allows to understand the basic structures of living matter. Also classical gravitational fields generated by classical field energy are predicted to be important in the living matter.

6.3.1 The properties of the scalar waves

Perhaps the most important properties of the scalar waves are following.

1. Scalar waves involve some kind of oscillatory process in the direction of the propagation of the wave. The analogy with sound waves suggests that the oscillation could relate to charge density, or more generally to 4-current in the direction of the wave. Even massless extremals (MEs), which are essentially topological light rays, involve vacuum current and vacuum charge density which oscillates in the direction of propagation.

2. Scalar waves are believed to carry electric field in the direction of the wave motion so that the identification of MEs as scalar waves is not possible. The presence of only electric field means that scalar wave is characterized solely by the scalar potential. This kind of solution is excluded by the gauge invariance and linearity of Maxwell's electrodynamics in vacuum.

6.3.2 Could nonlinearity of TGD allow scalar waves?

One is led to ask whether the nonlinearity of TGD might allow existence for scalar waves.

1. In TGD based electrodynamics CP_2 coordinates are the primary dynamical degrees of freedom gauge fields being secondary dynamical variables induced from the spinor curvature of CP_2. Field equations are extremely nonlinear allowing among other things vacuum 4-currents (even Faraday's unipolar generator involves vacuum charge density changing its sign when the direction of rotation of magnet changes its sign). This gives hopes about finding solutions of field equations with the properties assigned to the hypothetical scalar waves.

2. Interestingly, in TGD framework the canonical symmetries of CP_2 are dynamical symmetries and act as isometries of the configuration space of 3-surfaces. Canonical transformations act formally as $U(1)$ gauge transformations but, rather than being gauge symmetries, they are dynamical generating new physical configurations and are partially responsible for the quantum spin glass degeneracy of the TGD universe. As a matter fact, also diffeomorphisms of M^4 act as dynamical symmetries in the lowest order.

3. Magnetic flux tubes represent fundamental solutions of field equations and the simplest magnetic flux tubes can be characterized as maps from a region of a 2-dimensional Euclidian hyperplane E^2 of Minkowski space to a geodesic sphere S^2 of CP_2.

4. Electric-magnetic duality is a fundamental symmetry of the configuration space geometry. Therefore there should exist solutions dual to the magnetic flux tubes carrying only electric fields and perhaps allowing interpretation as waves. These solutions would be characterized by a map from a region of the Minkowskian hyperplane M^2 of Minkowski space to S^2. This kind solution ansatz makes sense since it formally provides the solutions of a field theory from M^2 to S^2.

6.3.3 Lowest order solution ansatz

One can write the field equations exlicitely. They are however extremely nonlinear and without physical intuition one cannot say much about the solution spectrum of these equations. One can however make simplifying assumptions to get grasp to the problem.

1. The effect of classical gravitation can be assumed to be extremely weak except possibly at some singular regions associated with the solutions.

2. In Maxwellian theory without sources gauge current vanishes identically. This would suggest that it is good to start from a zeroth order solution ansatz with this property so that the non-vanishing of the vacuum current would be solely due to gravitational effects. It deserves to be noticed that Tesla proposed also that non-Hertzian radiation fields involve a kind of radiation charge.

   In principle, one can imbed a portion of any solution of Maxwell's equations in empty space as a space-time sheet (note the occurrence of the topological quantization) using M^4 coordinates as preferred coordinates. Field equations are satisfied in the lowest order in R^2. The canonical symmetries of CP_2 act as dynamical symmetries for these solution ansätze and one obtains infinite degeneracy of the space-time surfaces representing the same Kähler field.

3. Constant electric field represents the simplest field configuration one can imagine. Therefore it is reasonable to start with this kind of solution ansatz and to look whether gravitational corrections affect the solution and bring in the wave aspect.

4. Since wave motion is hoped to result, it is useful to choose the space-time coordinates in an appropriate manner. Light like coordinates (x^+, x^-, x, y) of M^4 are thus very natural. They are defined by the conditions

$$t = (x^+ + x^-)/2 \ , \quad z = (x^+ - x^-)/2 \ ,$$

with (t, x, y, z) referring to the linear Minkowski coordinates such that t is time coordinate. In these coordinates the line element of M^2 has the form $ds^2 = -2dx^+dx^-$ so that one has $g_{+-} = -1$.

5. Using the spherical coordinates $(u = cos(\Theta), \Phi)$ for the geodesic sphere S^2 of CP_2, the zeroth order solution ansatz has the following form:

$$u \equiv u_0 = \omega_1 x^+ \ , \quad \Phi \equiv \Phi_0 = \omega_2 x^- \ . \qquad (6.3.1)$$

Since electromagnetic, Z^0 and color fields are proportional to Kähler form for the solution type considered, one can restrict the consideration to the induced Kähler form. Denoting the Kähler form of CP_2 by J_{kl}, by noticing that S^2 Kähler form is given by $J_{u\Phi} = 1$ (forgetting the precise normalization factor), and using the expressions $\left[s_{uu} = R^2/(1-u^2), s_{\Phi\Phi} = R^2(1-u^2)\right]$ for the metric of S^2, one can write the induced line element and the non-vanishing component of the induced Kähler form as

$$\begin{aligned} ds^2 &= -2dx^+dx^- + \frac{R^2\omega_1^2}{1-u^2}(dx^+)^2 + R^2\omega_2^2(1-u^2)(dx^-)^2 - dx^2 - dy^2 \ , \\ J_{+-} &= \partial_+ u \partial_- \Phi = \omega_1\omega_2 \ , \\ J^{+-} &= \frac{\omega_1\omega_2}{det(g)} \ . \end{aligned} \qquad (6.3.2)$$

Since the determinant of the induced metric is constant, J^{+-} describes constant electric field and that Kähler current j^α is vanishes. This means that Maxwell's equations hold true in the zeroth order approximation as required.

Apart from the normalization factors the energy momentum tensor in the longitudinal degrees of freedom is given by

$$T^{\alpha\beta}(long) = g^{\alpha\beta}L/4 \ ,$$

In the transversal degrees of freedom similar expression but with opposite sign holds true. Here L is Kähler action which is essentially electric energy density and constant.

In M^4 degrees of freedom the field equations express conservation of the energy momentum currents and are satisfied to order R^2 since the action is constant. These equations imply that action density is constant. This forces to ask whether all perturbatively constructible solutions represent a constant Kähler electric field locally.

In CP_2 degrees of freedom field equations involve a sum of two terms: the first term involves the contraction of the energy momentum tensor with the second fundamental form whereas the second term involves Kähler current. Since Kähler current vanishes, the latter term vanishes and one can say that field equations are satisfied in zeroth order approximation (the term involving energy momentum tensor is proportional to CP_2 length squared and thus small). For exactly vanishing vacuum current the field equations would reduce to the equations for a minimal surface:

$$g^{\alpha\beta}D_\beta\partial_\alpha h^k = 0 \ , \tag{6.3.3}$$

where the imbedding space coordinates h^k corresponds to u and Φ now. The same equations result also in M^4 degrees of freedom by requiring that the terms of order R^2 in the equation for the energy momentum conservation vanish.

This equation is not satisfied exactly as is easy to see. The non-vanishing components of the trace of the second fundamental form are given by

$$\begin{aligned} g^{\alpha\beta}D_\beta\partial_\alpha u &= -\{{}^{\ u}_{\Phi\ \Phi}\}\omega_2^2 \times \left[1-g^{++}\omega_1^2R^2/(1-u^2)\right] \ , \\ g^{\alpha\beta}D_\beta\partial_\alpha \Phi &= -\{{}^{\ \Phi}_{u\ \Phi}\}\omega_1\omega_2 \times \left[1-g^{--}\omega_2^2R^2(1-u^2)\right] \ . \end{aligned} \tag{6.3.4}$$

Here $\{{}^{\ \alpha}_{\beta\ \gamma}\}$ denote the components of the Riemann connection for sphere. It is seen that the connection term gives contributions which vanish only at $u=0$ which corresponds to the equator of the geodesic sphere S^2. At poles the minimal surface condition fails to be satisfied.

6.3.4 First order corrections to the solution ansatz

To take into account gravitational corrections one must modify the solution ansatz in such a manner that x^- does not appear in the field equations at all: this guarantees that field equations reduce to ordinary differential equations. The modification is following:

$$u = u_0 + u_1(x^+) \ , \quad \Phi = \Phi_0 + \Phi_1(x^+) \ . \tag{6.3.5}$$

The modification affects the electric field and vacuum current and allows the compensation of the terms resulting form the contractions of the energy momentum tensor and vacuum current. The modification means that wave equations are still satisfied for u and Φ. Note that second fundamental form does not contain second derivative terms in the lowest order approximation.

The derivation of the differential equations for u_1 and Φ_1 is completely straightforward but requires some patience with numerical factors (reader should check sign factors and numerical factors).

1. Calculate the the current contraction term

$$j^\alpha\left[J_r^k\,\partial_\alpha h^r - J^\mu_{\ \alpha}\partial_\mu h^k\right]$$

and energy momentum tensor contraction term

$$T^{\alpha\beta}D_\beta\partial_\alpha h^k$$

and equate these terms. Effective two-dimensionality makes the explicit calculations relatively simple.

2. The equations for u and Φ in terms of $j^\pm$ read as

$$j^-(1-u_0^2) + j^+\epsilon_1\epsilon_2 = \{{}^{\ u}_{\Phi\ \Phi}\}\frac{K\epsilon_2^2}{2} \equiv X_1 \ ,$$

$$j^+\frac{1}{(1-u_0^2)}j^-\epsilon_2^2 = -2\{{}^{\ \Phi}_{u\ \Phi}\}K\epsilon_1\epsilon_2 \equiv X_2 \ ,$$

Here the notations $\epsilon_i = \omega_i R$ and $K = \omega_1\omega_2^2$ are used. Linear second order differential equations are in question with the right side serving as an inhomogenuity term.

3. One can solve j^+ and j^- from these equations to get

$$\begin{pmatrix} j^+ \\ \\ j^- \end{pmatrix} = \frac{1}{\epsilon_1\epsilon_2^3-1} \times \begin{pmatrix} \epsilon_2^2 & -(1-u_0^2) \\ \\ -1/(1-u_0^2) & \epsilon_1\epsilon_2 \end{pmatrix} \times \begin{pmatrix} X_1 \\ \\ X_2 \end{pmatrix} \equiv \begin{pmatrix} Y_1 \\ \\ Y_2 \end{pmatrix}$$

From this form one can see that j^- becomes singular at $u_0 = \pm 1$ as $1/(1-u_0^2)$ which means that light like vacuum current is generated. The physical interpretation is that vacuum charge density at these points which correspond to the boundaries of the solution acting as the source of the vacuum electric field is in question.

4. One can calculate $j^{\pm}$ by calculating the covariant divergence of the induce Kähler field in the lowest non-trivial order. The calculation gives the following expression

$$\begin{pmatrix} j^+ \\ \\ j^- \end{pmatrix} = \omega_1 \begin{pmatrix} u_0\partial_+^2 u_1 + \epsilon_1\epsilon_2(1-u_0^2)\partial_+^2\Phi_1 \\ \\ \omega_1\epsilon_2\partial_+^2 u_1 - \epsilon_1(1-u_0^2)\partial_+^2\Phi_1 \end{pmatrix}$$

5. For u_1 one finds the equation

$$\begin{aligned} \partial_+^2 u_1 \quad &+ \quad \epsilon_1\epsilon_2^2\omega_1 u_0\partial_+ u_1 = \frac{1}{\omega_1} \times (Y_1 + \epsilon_1 Y_2) \\ &= \frac{\omega_2^2}{2}\frac{\epsilon_1}{\epsilon_1\epsilon_2^3 - 1} \times u_0 \times \left[-\epsilon_2^4(1-u_0^2) + \epsilon_1\epsilon_2(-2+\epsilon_1) - \epsilon_1^3\epsilon_2\frac{1}{1-u_0^2}\right] \ . \end{aligned} \tag{6.3.6}$$

This equation reduces to a first order differential equation for u_1 and one can solve it by variation of integration constants. The singularity at $u = \pm 1$ implies a logarithmic singularity of the derivative

$$\partial_+ u_1 \sim log(1-u_0^2)$$

but u remains finite as it should.

6. One can integrate Φ_1 from the second order inhomogenous and linear equation

$$\begin{aligned} \partial_2^+\Phi_1 &= \frac{1}{\epsilon_1\epsilon_2(1-u_0^2)}\left[j^- - \omega_2\partial_+^2 u_1\right] \ , \\ j^- &= \frac{\omega_1\omega_2^2\epsilon_1\epsilon_2}{2(\epsilon_1\epsilon_2^3-1)} \times u_0 \times \left[1 - \frac{2\epsilon_1^2}{1-u_0^2}\right] \ , \end{aligned} \tag{6.3.7}$$

once the solution for u_1 is known. Note that the most singular part corresponds to $u_0/(1-u_0^2)^2$ type term and one obtains logarithmic singularity also now.

6.3.5 Properties of the solution ansatz

The form of the differential equations for the first order corrections allows to conclude that the North and South poles of the geodesic sphere S^2 (the points $u_0 = \pm 1$) correspond to singularities of the solution. Both the components of the induced metric and the induced Kähler form become singular at these points. This means that classical gravitation becomes important near these points. These points correspond in the lowest order approximation to the lines $x^+ = \pm 1/\omega_1 \equiv T$ plus possibly the lines obtained by continuing the solution by assuming that $x^- = constant$ lines define a motion identifiable constant rotation along the big circle from $\theta = 0$ ($x_+ = T$) to $\theta = \pi$ ($x_+ = -T$) continuing in the same manner to $\theta = 0$ at ($x = 2T$) and so on. Therefore gravitational effects induce a periodical behavior of the solution such that gravitational effects become strong at $x^+ = (2n+1)T$.

In the next order electric field is not constant anymore and vacuum current is generated. The contravariant component of electric field, being proportional to $1/\partial_+ u$ near singularity, vanishes at the singularity whereas the tangential component j^- of the vacuum current diverges. The vacuum current should generate coherent photons.

By a straightforward calculation one finds that the curvature scalar behaves as $R \propto 1/(1-u_0^2)$ at the singularities so that the energy density of vacuum becomes singular and could generate a coherent state of gravitons. Since Einstein tensor vanishes identically in two-dimensional case, the longitudinal components G^{++}, G^{--} and G^{+-} of Einstein tensor vanish. The components of Einstein tensor in transverse degrees of freedom are given by $G^{alpha\beta} = -g^{\alpha\beta}R/2$. Therefore the energy momentum tensor defined by Einstein's equations would involve only space like momentum currents. The singularity is amplified by the fact that field energy couples to the classical gravitation with coupling which is 10^8 times stronger than the ordinary gravitational coupling. The singularity might relate to the claimed gravitational anomalies associated with the scalar waves.

As already found, Einstein tensor and gauge current have no components in the direction of x^+. Energy-momentum tensor behaves as $1/det(g)^{3/2}$ at the end points of the interval $[-T, T]$ and thus vanishes. Therefore conservation laws allow to restrict the solution into the x^+ interval $(-T, T)$. This restricted solution defines geometrically a particle like structure moving in x^- direction but with fields moving in x^+ direction so that one would have rather exotic kind of particle-wave dualism. In accordance with the quantum-classical correspondence, one could interpret this as classical space-time representation of the particle wave duality and the solution would be a particular example of topological field quantization.

6.3.6 More general solutions representing electric field of constant action density are possible

The solution ansatz just discussed represents a constant electric field in a region of space-time moving with ligth velocity in the direction of x^- coordinate. Also ordinary constant electric fied is a possible solution and is constructed iteratively in an essentially identical manner by starting from the solution ansatz

$$u = kz \ , \quad \Phi = \omega t \ . \tag{6.3.8}$$

Also now Kähler current vanishes in the lowest order and action density is constant so that lowest order field equations are satisfied. Higher order corrections are obtained using the ansatz $u_1 = u_1(z)$, $\Phi = \Phi_1(z)$. Minimal surface condition gives now essentially same kind of expressions for u_1 and Φ_1. Also now the singularities where gravitational interaction becomes strong are at $u = \pm 1$ and one can select the solution to represent a membrane like structure with thickness $L = 2/k$.

Cell membrane space-time sheets are good candidates for the realization of this kind of solutions. If so, one might expect that classical gravitational effects become important at the boundaries of the cell membrane. More generally, bio-systems are electrets and the proposed solution type might provide a fundamental model for bio-electrets. In particular, electrogravitatic effects due to the energy of the classical electric field might be of importance.

This observation relates interestingly to the sol-gel phase transitions occurring inside cell. In these transitions large scale bound states of water molecules are formed and could make possible macro-temporally quantum coherent systems able to perform quantum computations in time scales of order say .1 seconds. These bound states would be characterized by spin glass degeneracy broken only by the classical gravitation and spin glass degeneracy would make these bound states longlived. In the case of the proposed solution ansätze spin glass degeneracy corresponds to the canonical symmetries of CP_2 generating new solutions representing constant electric field.

Also M^4 diffeomorphisms are symmetries of the field equations broken only by the classical gravitation. Approximate diffeomorphism invariance means that one obtains solutions for which the lines of electric flux are curved and only the action density stays constant. In the case of magnetic flux tubes this symmetry makes possible curved magnetic flux tubes. Both electric fields and the magnetic flux tubes are fundamental for the TGD based model of living matter and relate deeply to the electric-magnetic duality symmetry and to the quantum criticality predicting that magnetic and electric space-time regions having opposite signs of Kähler action play a role similar to the ice and water regions at critical point of water, are important physically.

6.4 Time mirror mechanism

As explained in the introduction, time mirror mechanism is excellent candidate for the fundamental bio-control mechanism allowing magnetic body to act as an intentional agent and control biological body. For a physicist living in Newtonian world the idea that "me" corresponds to a field structure of an astrophysical size is of course difficult to swallow. p-Adic physics as physics if intentionality and cognition however supports this view strongly: what is infinitesimal p-adically (cognitively) is literally infinite in the real sense so that cognition and intention are cosmic phenomena. In this section the possible role of scalar wave pulses in the realization of intentional action is considered. Also some aspects related to the role of time mirror mechanism for consciousness are discussed and it is shown that Libet's experiments related to the strange delays of conscious experience provide support for both time mirror mechanism and the notion of magnetic body.

6.4.1 Scalar wave pulses as producers of phase conjugate waves and time mirror mechanism

If one wants to produce negative energy photons, one must break the second law of thermodynamics. TGD predicts that in a given n-ary p-adic length scale $L(n,k)$ (size of the space-time sheet) this is possible below the n-ary p-adic time scale $T(n,k) = L(n,k)/c$. One must only produce pulses having duration shorter than the p-adic time scale $T(n,k)$. Scalar wave pulses are excellent candidates this kind of pulses since they accelerate the current carriers, which have ended up to the space-time sheet of the scalar wave pulse, and during this period they can emit negative energy photons as "acceleration radiation" with quantized frequencies $f_n = n/T_p$, T_p the duration of the scalar wave pulse. If the pulses correspond to their own space-time sheets dissipation is negligible and the intensity of acceleration radiation is maximal.

Scalar wave pulses could be produced by very rapidly rising electric pulses for which electronic currents are too slow to generate the voltage change between given points of circuit so that scalar wave pulse behaving like moving capacitor with vacuum charges at its electrodes must do the job. The duration of the scalar wave pulse would be most naturally the rising time τ_r of the pulse. Scalar wave pulse could be generated in a simple closed circuit. Assume that there is a voltage source V between points A and B and that A and B are connected to points A_1 and B_1 at which the wire branches to two wires going through a capacitor and current switch. When the current switch is off there is voltage V through capacitor. When the current is switched on, capacitor dis-charges very rapidly but the voltage between A and B must be still present. This is guaranteed if positive energy scalar wave pulse generates the voltage. The voltage through the capacitor is nullified by the absorption of negative energy scalar wave pulse coming from future and generated in the switching off process. In the geometric future the capacitor in turn absorbs the positive energy scalar wave pulse to generate the voltage V again.

An especially interesting situation arises when the energies of the negative photons radiated by the charged particles accelerated inside the scalar wave pulse correspond to the increment of a zero point kinetic energy for some charged particle when it drops to a larger space-time sheet. In this case the negative energy radiation could make possible time mirror mechanism by generating a cascade like dropping of charged particles and an amplified emission of positive energy photons. In case of nerve pulse the rising time of the pulse would be a good candidate for the duration of the scalar wave pulse.

6.4.2 Bio-systems and unipolar pulses

One might think that besides Tesla also bio-systems might have invented the sharp pulses as a manner to break second law temporarily and produce negative energy topological light rays crucial for all basic mechanisms in TGD based quantum biology and theory of consciousness. Perhaps one function of nerve pulse is to produce phase conjugate waves and perhaps nerve pulse can be switched on by a scalar wave pulse reducing the membrane potential below the critical value.

This suggests the existence of biological variants of binary coils. Bio-systems are full of binary structures such as DNA double strand and cell membrane (consisting of two lipid layers). It is tempting to think that DNA double strand is a variant of bi-filar coil in which scalar wave pulses propagate along strand (associated with say gene) and return along the conjugate strand. Also now the effective inductance of the system would grow from zero to some maximum value and return back to zero and phase conjugate light would be generated. As a matter fact, the TGD based model for bio-photons lead to the hypothesis that the strand/conjugate strand generates positive/negative energy MEs and that these MEs move in opposite directions along strands [K37] .

6.4.3 Sensory perception, motor action, and time mirror mechanism

TGD view about sensory perception differs dramatically from that of the standard neuroscience in that sensory organs are carriers of basic sensory representations and the magnetic body rather than body or brain is the experiencer with which we can identify ourselves.

Sensory organs as seats of qualia

According to the music metaphor, sensory organs are responsible for the music whereas brain writes it into notes by building symbolic and cognitive representations communicated to the magnetic body. Back projection to the sensory organs is an essential aspect of this process and is discussed in the article "Quantum model of sensory receptor" of [L1] . Sensory perception at the level of magnetic body involves the generation of negative energy MEs entangling with sensory organs involving possibly also brain as an intermediate entangler.

The assumption that sensory organs are carriers of the sensory representations entangling with symbolic representations realized at the level of cortex does not mean any revolution of neuroscience, just adding something what is perhaps lacking [K29] .

Neuronal/symbolic level would do its best to symbolically represent what occurs naturally at the level of qualia. Color constancy could be understood as a basic characteristic of color qualia represented symbolically at the neuronal level. Center-surround opponency for the conjugate colors is the neural counterpart for the contrast phenomenon in which the boundary for a region of the perceptive field with a given color carries the conjugate color (black-white opponency associated with the luminance is only a special case of this). The contrast phenomenon at the level of visual qualia could derive from the vanishing of the net color quantum numbers for the electrodes of the retinal color capacitors.

The basic prediction is the presence of the back projection at least in the sensory modalities in which hallucinations are possible. MEs with MEs mechanism is the most natural candidate for realizing the back projection, negative/positive energy MEs would realize the back projection based on quantum/classical communications, and the capacitor model of the sensory receptor can be applied to model photoreceptors and retina. This picture integrates nicely with the various speculations about the role of the ciliary micro-tubules in vision. The obvious question is how the presence and character of the back projection reflects itself in the structure of the sensory pathways and sensory organs.

Basic facts about how gastrulation and neurulation proceed during the development of the embryo, lead to testable hypothesis about the character of the back projection for various sensory modalities. According to the hypothesis, one can speak about "brain senses" and "skin senses" according to whether the back projection is based on quantum or classical communications.

How motor action differs from sensory perception?

There is a deep similarity between sensory perception and motor action in TGD framework, the basic difference being that classical signals propagate in different direction in CNS. Motor action is initiated by the magnetic body by the sending of negative energy to motor organs by generating negative energy MEs, and proceeds by similar processes backwards in the geometric time to the level of brain and magnetic body, very much like an instruction of a boss at the top of organization to the lower levels of hierarchy and induces lower level instructions. The analogy with computer program calls (quantum communications, desires) and their executions (classical signals, actions) is also obvious. Also classical signals from the magnetic body to the body and brain are possible. Similar picture applies to sensory perception with motor organs replaced by sensory organs.

Sensory *resp.* motor imagination differ from sensory perception *resp.* motor action only in that the magnetic body entangles with some higher level of CNS. Therefore there is no danger that imagined motor action would become real or that imagined sensory perception would be experienced as real. This picture is in accordance with the idea of quantum credit card implying maximal flexibility, and with respect to the geometric time would mean that motor actions are only apparently initiated from the brain.

Time delays of consciousness: experiments related to the active role of consciousness

Libet has carried out classical experiments about active and passive aspects of consciousness [J17, J26] . It has gradually become clear that these experiments can be interpreted as a support for the identification of "me" as the personal magnetic body. The first class of experiments [J25, J26] is related to the active role of consciousness. For example, the human subject moves his hand at free will. What happens is that neurophysiological processes (changes in EEG, readiness potential) start $T_1 = .35 - .45$ seconds before the conscious decision to move the hand whereas the awareness about the decision to move the hand comes $T_2 = .2 - .1$ seconds before the hand movement. Decision seems to be followed by the action rather than action by decision! This is in apparent accordance with the point of view that consciousness is indeed a passive spectator and the act of free will is pure illusion. What is interesting from the p-adic point of view, is that the most plausible estimates for the time delays involved are $T_1 \simeq .45$ seconds and $T_2 = .1$ seconds [J25] . T_1 is very near to the p-adic time scale $T(6,43) = .4$ seconds and T_2 to the fundamental p-adic time scale $T(2,127)$ defining the duration of the memetic codon.

One can imagine two explanations for the paradoxical findings. The explanations turn out to be mutually consistent.

1. The geometric past changes in quantum jump

Quantum jump between histories picture explains the time delays associated with the active aspect of consciousness nicely and also gives an example of two kinds of causalities.

1. The simplest assumption is that the subjective experience of the hand movement corresponds to the moment, when subject person experiences that hand movement occurs.

2. The space-time surfaces (resulting as the final state of quantum jump) associated with the new quantum history differ in a detectable manner from the old quantum history already before the moment of hand movement since otherwise the new space-time surface would contain an instantaneous and discontinuous jump from the initial to final body configuration, which is not allowed by field equations. Same argument applies to the state of brain. $\Delta T \sim .5$ seconds seems to be the relevant time scale.

3. The attempt of the experimenter to be objective means that in an ideal experiment the observations correspond to the new deterministic history in the associated quantum jump and hence experimenter sees neurophysiological processes as the (apparent) cause of the hand movement with respect to geometric time. With respect to the subjective time the cause of the hand movement is the decision of the subject person.

2. Motor action is initiated from the magnetic body and proceeds to shorter length scales in reversed direction of geometric time

The vision that motor actions are initiated by magnetic body by feeding negative energy to motor organs and proceed upwards in CNS in a reversed time direction is in accordance with the idea of quantum credit card implying maximal flexibility and would mean that motor actions are only apparently initiated from brain. Motor organs send negative energy MEs to get metabolic energy, say to cortex. If there is lapse $\sim .5$ seconds involved then the observed lapse would find explanation. This view concretizes the idea about the editing of the geometric past and is consistent with the more general explanation discussed above.

This view about motor action means that it proceeds from long length scales to short ones whereas in the standard neuroscience view motor motor action would be planned and initiated in the brain and proceed to the level of motor organs, from short to long length scales. This certainly seems to be the case if one looks only the classical communications (say nerve pulse patterns). The extreme coherence of and synchrony of motor activities is however in conflict with this picture: neuronal communications are simply too slow to achieve the synchrony. This has been emphasized by Mae-Wan Ho [I21] . Since quantum communications proceed backwards in geometric time, classical signalling such as nerve pulses from brain to motor organs are actually reactions to the initiation of the motor action from the magnetic body.

Strange time delays of consciousness: experiments related to the passive role of consciousness

Libet's experiments [J17] about the strange time delays related to the passive aspects of consciousness have served as a continual source of inspiration and headache. Every time I read again about these experiments, I feel equally confused and must start explanations from scratch.

What is so important and puzzling is that the backwards time referral of sensory experience is so immensely long: about .5 seconds. The time taken for nerve pulses to travel through brain is not more than .01 seconds and the time to arrive from sensory organs is at most .1 seconds (for axon with length of 1 meter and very slow conduction velocity 10 m/s). For the purposes of survival it would be advantageous to have a sensory input with a minimal time delay.

Why then this long delay? TGD inspired answer is simple: the "me" does not correspond to the material body but to the magnetic body associated with the physical body, and is analogous to the manual of electronic instrument, kind of a monitor screen to which sensory, symbolic and cognitive representations are projected by quantum and classical communications. Since the size of the magnetic body is measured using Earth's circumference as a natural unit, the long time lapse results from the finite velocity of light .

The following explanation is a variant of the model of the sensory representations on the magnetic canvas outside the body and having size measured by typical EEG wave lengths [K39] . The basic sensory representations are realized at the level of the sensory organs and entangled with magnetic body whereas symbolic representations are either shared as mental images by or communicated classically to the magnetic body. This differs from the original scenario in which sensory representations were assumed to result by classical communications from brain to the magnetic body.

1. Communications from brain to magnetic body

One must consider two kinds of communications from body to magnetic body corresponding to positive energy MEs generated by at least brain and negative energy ME sent by magnetic body to at least sensory organs. The assumptions are following.

1. Negative energy MEs bound state entangle the magnetic body with the sensory representations realized at the level of sensory organs, and constructed using back projection from brain and possibly also from higher levels. Fusion and sharing sensory mental images is involved. Also the classical communication of memories to magnetic body could be involved with the build up of sensory and symbolic representations at the magnetic body. In both cases sensory representations are memories with the same time lapse determined by the length of the MEs involved, a fraction of second typically if the magnetic body is of an astrophysical size. During sensory and motor imagination magnetic body entangles by negative energy MEs with some higher level of CNS.

2. Symbolic representations in brain can entangle with the sensory representations entangling in turn with the magnetic body so that CNS defines tree like structure with roots corresponding to sensory organs and branches and leaves corresponding to the higher levels of CNS. Direction of attention selects some path along this tree somewhat analogous to the path defining computer file in some subdirectory.

3. Symbolic representations of the perceptive field can be projected to the magnetic body using also classical signalling by positive energy MEs with phase velocity in a good approximation equal to the light velocity. For instance, if perceptive field contains something important, classical signal to the magnetic body could induce the generation of negative energy MEs turning attention to a particular part of perceptive field. Projection to the magnetic flux tubes of the Earth's magnetic field is possible. The spatial direction of the object could be coded by the direction of ME located in brain whereas its distance could be coded by the dominating frequency of ME which corresponds to a magnetic transition frequency which varies along the radial magnetic flux tubes slowly so that place coding by magnetic frequency results. Field pattern could be realized the coding of information to bits in some time scale, perhaps even in the time scale of millisecond associated with the memetic code. Positive energy MEs generated by brain realize the representation and this implies time delay. In the original model it was assumed that the direction and distance of the object of perceptive field are coded as direction and distance at the

magnetic body. The representations are expected to be rather abstract, and it might be enough to perform this coding at the level of magnetic bodies associated with the sensory organs.

2. Libet's findings

Consider now Libet's findings. According to the summary of Penrose in his book 'Emperor's New Mind' these experiments tell the following.

1. With respect to the psychological time of the external observer subject person becomes conscious about the electric stimulation of skin in $\sim .5$ seconds.

2. Subject person feels no time delay. For instance, she can tell the time clock shows when the stimulus starts. This can be understood if the sensory representation, which is basically a geometric memory, takes care that the clock of the memory shows correct time: this requires backwards referral of about .5 seconds.

3. One can combine an electric stimulation of skin with the stimulation of the cortex. The electric stimulation of the cortex requires a duration longer than .5 seconds to become conscious. If the stimulation of the cortex begins (with respect to the psychological time of the observer) for not more than .5 seconds before the stimulation of the skin starts, both the stimulation of the skin and cortex are experienced separately but their time ordering is experienced as being reversed! If the cortical stimulation generates sensory mental image at sensory organ by back projection then one could understand the change of the time ordering as resulting from .5 second lapse for the generation of back projection.

4. If the stimulation of the cortex begins in the interval $.25 - .5$ seconds after the stimulation of the skin, the stimulation of the skin is not consciously perceived. This effect is known as a backward masking. From the source it is not clear whether a minimal duration of .5 seconds of cortical stimulation is required for backward masking.

3. Explanation of Libet's findings

Consider now how one could understand these strange findings in the proposed model.

1. Visual and tactile sensory inputs enter into cortex essentially simultaneously so that the construction of symbolic representations at magnetic body is possible. The projection to the magnetic canvas by positive energy MEs and the generation of the magnetic quantum phase transition might quite well explain the time lapse of .5 seconds. The symbolic representation could contain also information about where to direct sensory attention. After this time interval negative energy ME possibly directing the attention to a particular part of the perceptive field would be generated and induce sharing of mental images .5 seconds in the geometric past. Note that this would automatically guarantee that symbolic and sensory representations at the magnetic bodies of sensory organs correspond to the same value of the geometric time.

2. The stimulation of the cortex lasting at least .5 seconds would generate a back projection to sensory organs. The minimal duration of .5 seconds for the cortical stimulation would seem rather natural in order to avoid back projections due to random neuronal fluctuations. This would explain why the temporal order of the sensory experiences generated by cortical and skin stimulation is reversed when cortical stimulation starts before the skin stimulation.

3. Consider now how the backwards masking could be understood. The cortical stimulation could generate a negative energy ME sent to the sensory organ and editing its geometric past at temporal distance of .5 seconds and depleting energy resources so that sensory organ cannot receive negative energy ME from magnetic body during the period of the cortical stimulation. Magnetic body would become sensorily blind to the input from the corresponding point of skin. Sensory blinding could be a clever manner to signal to the magnetic body that back projection is to be expected.

The stimulated point of the cortical map would share the sensory mental image instead of the magnetic body and also give rise to a back projection: sensory mental image would be conscious to cortex but not to us! Magnetic body and cortex could be seen as competitors for resources in this kind of situation. Perhaps the electric stimulation induces some kind of neuronal starvation and forces the neuron to generate negative energy MEs entangling it with the sensory organs.

6.5 Did Tesla discover how to change the arrow of time?

After having made the inventions providing much of the basis technology for the modern electricity based society, Tesla used the rest of his life to study the strange phenomena related to sharp electric pulses. Tesla became convinced that pulse like rays carrying longitudinal electric fields exists although Maxwell's theory does not allow them. Needless to say, Tesla's findings were not taken seriously by the scientific establishment. On the other hand, for the developers of so called free energy technologies Tesla has remained a magic figure. To me it has gradually become clear that it might be possible to formulate the visions of Tesla using the language of modern physics, and the final breakthrough came with a discovery of a mechanism generating what I have used to call negative energy topological light rays having phase conjugate laser waves as physical counterparts.

Negative energy topological light rays provide the fundamental control mechanism in the TGD based model of living matter and appear in practically every mechanism of consciousness as a basic step. This is however not yet the whole story. One should also identify mechanisms allowing to control the generation of the negative energy topological light rays: direct transformation of p-adic MEs to negative energy MEs is probably not enough. The solution to the problem came from a quite unexpected direction. It was the attempt to understand the physics behind the visions of Tesla which led to an identification of a very general mechanism of this kind.

Phase conjugate laser waves break second law of thermodynamics and this is possible in TGD Universe below the p-adic time scale characterizing the system. Therefore short pulses are ideal for this purpose. Depending on the situation, electric pulses in electric circuits typically force the charge carriers to accelerate or decelerate. During deceleration positive energy photons are emitted as brehmstrahlung whereas during acceleration charges emit negative energy photons in order to receive energy. Thus generation of pulses provides a mechanism to generate negative energy topological rays which in turn serve for various control purposes. TGD indeed predicts the existence of scalar wave pulses propagating in vacuum with light velocity and carrying longitudinal electric fields.

One can understand the basic findings of Tesla at qualitative level in TGD framework and there are strong reasons to believe that Tesla was right after all. This of course raises the question how it is possible that the scientific community with all its technology remained silent about the findings of Tesla for an entire century. Experimentalists must have made occasional encounters with the phenomena reported by Tesla. Are modern experimentalists conditioned to take theorists quite too seriously?

6.5.1 Discussion of the basic ideas and concepts

Do negative energy space-time sheets have counterparts in quantum field theory?

Negative energy topological light rays seem to correspond to phase conjugate laser waves. In particular, the experiments of Feinberg [D3] are consistent with the transparency of matter for phase conjugate laser beams with photon energies above thermal energy. In optics phase conjugation requires optically non-linear system [D7] . For instance, in usual hologram the matter is optically non-linear in the sense that dielectric constant depends on the external electric field so that the electromagnetic radiation induces a change of the refraction coefficient which in turn codes for the hologram.

The dynamics of classical fields is indeed extremely nonlinear in TGD: the topological field quantization is one of the most dramatic outcomes of this non-linearity. Whether the phenomenological models for phase conjugate waves and for their generation are enough in TGD framework is an open question. The mechanism based for the generation of negative energy topological light rays based on short pulses to be discussed in this section does not seem to reduce to the framework of non-nonlinear optics.

There are also questions of principle involved.

1. Is phase conjugation properly understood in quantum field theories?

At the level of quantum physics negative energy photons would correspond to a system quantized in such a manner that both bosonic and fermionic annihilation and creation operators have changed their roles. Negative energy photons and fermions do not correspond to (non-existing) "anti-photons" and anti-fermions. Using the terminology of Dirac's bra-ket formalism: negative energy systems are like bras if positive energy photons are kets. Kets and bras correspond to Hilbert space and linear functionals defined in it. The space of bras is actually not equivalent with that of kets but in a well defined sense a more general concept. This conforms with the role of negative energy space-time sheets in TGD inspired theory of consciousness.

In quantum field theories time reversal transforms creation operators for fermions to creation operators for anti-fermions. Vacuum state is not changed. Time reversal in TGD sense would transform ket vacuum to bra vacuum so that the earlier creation operators annihilate the new vacuum state and genuine negative energy states result. This would suggest that negative energy states are something genuinely new and a genuine outcome of the many-sheeted space-time concept allowing either bra and ket type vacuum at a given space-time sheet. This difference might relate to matter-antimatter asymmetry whose origin is one of the deepest problems of cosmology. Perhaps dynamics favors space-time sheets containing negative energy matter instead of antimatter.

2. Phase conjugation and irreversibility

One interesting aspect associated with negative energy topological light rays is that they seem to be irreversible systems. On the other hand, phase conjugation can be used to eliminate perturbations on signal caused by thermal noise since the evolution proceeds from perturbed to non-perturbed signal. This could be seen as an objection against TGD based interpretation stating that topological light rays are essentially non-dissipative structures of classical physics.

The objection can be circumvented. Classical-quantum correspondence implies that space-time physics mimics also the dissipative aspects of quantum dynamics defined by quantum jump sequences. The classical non-determinism of the basic variational principle makes this possible. Classical fields are non-dissipative structures are even able to represent information about dissipation, analogous to a written text telling a story about growth, flourishing, and decay. In fact, in TGD framework space-time itself provides symbolic classical representations for quantum jump sequences determining the subjective, experienced reality. The implications of this representative aspect for biology are highly non-trivial. For instance, phase conjugate waves could provide a fundamental mechanism of healing and error correction.

Matter-antimatter asymmetry, phase conjugation for fermions, and new energy technology

If photons with negative energies are allowed, it is difficult to deny the possibility of fermions with negative energies. The possibility of having both signs of energy suggests an elegant solution to the problem of matter-antimatter asymmetry and a powerful new energy technology.

1. The standard second quantization of Dirac spinors postulates that ground state is annihilated by annihilation operators for fermions and anti-fermions. One can construct explicitly the state annihilated by annihilation operators. Suppose that there is state which is not annihilated by any annihilation operator and apply the product of all annihilation operators to this state. Electrons and positrons represent holes in this sea and are created by applying creation operators. The states have positive energy with respect to the ground state. The aesthetic problem of this quantization is that ground state has an infinitely high negative energy.

2. In TGD framework one could change the role of creation and annihilation operators so that the ground state would be obtained by applying the product of all creation operators to vacuum. This state would have infinite positive energy. Fermions and anti-fermions would be holes in Dirac sea of positive energy and behave as negative energy quanta. One might expect that these two quantizations correspond to two different time orientations for the space-time surface.

1. Two manners to circumvent the infinite vacuum energy

The infinite vacuum energy is definitely something very unsatisfactory, and one should overcome this problem somehow. The most elegant and predictive variant of TGD inspired cosmology assumes that the net energy of the Universe vanishes so that the universe could have been created intentionally from vacuum (and be created again and again in each quantum jump). The vanishing of the total energy follows automatically if one poses the condition that the energy flow through the light cone boundary ($H = M^4_+ \times CP_2$) vanishes. This requires that also fermionic vacuum energies cancel each other. There are two manners to achieve the cancellation.

1. If positive and negative energy space-time sheets are always created in a pairwise manner their vacuum energies could compensate each other, at least so if some additional conditions are satisfied. The success of elementary particle physics requires that this mechanism is at work in elementary particle length scales.

2. Vacuum energies could also cancel each other for each space-time sheet separately. This is achieved if the roles of creation and annihilation operators for either fermions or anti-fermions are exchanged. This implies automatically matter antimatter asymmetry since either fermions or anti-fermions would have negative energies. This option could be realized in long length scales and explain the absence of antimatter from the Universe as absence of positive energy antimatter. It would thus seem that all four ground states states are in principle possible and that the ground state characterizes the phase of matter.

2. Zero energy vacuum is matter-antimatter asymmetric

Consider now in more detail the latter option 2) assuming for definiteness that it is anti-fermions for which the roles of creation and annihilation operators are exchanged. The ground state is obtained by applying the product of all fermion annihilation operators and anti-fermion creation operators to vacuum. Fermions represent holes in a completely filled negative energy Dirac sea and have positive energy. Anti-fermions represent holes in positive energy Dirac sea and have thus negative energy. In this ground state annihilation of photon pair is possible only to an fermion with positive and anti-fermion with negative energy.

Obviously the state is matter-antimatter asymmetric since anti-fermions cannot appear as positive energy holes. Negative energy antimatter could be present but could have remained invisible. For instance, Pauli Exclusion Principle would make the scattering of negative energy anti-fermions impossible in the case that there are not sufficiently many holes in the sea. The same occurs for condensed matter electrons below the surface of the Fermi sphere. Even in the case that negative energy anti-fermions are present abundantly, they might have escaped detection. Due to the prevailing dogmas, no-one has tried to detect signatures for the scattering of negative energy anti-fermions or two photon annihilation to a pair of positive energy fermion and negative energy anti-fermion.

3. Creation of matter from vacuum by annihilation of laser waves and their phase conjugates?

The possibility of negative energy anti-fermions suggests a new energy technology. Photons and their phase conjugates with opposite energies could only annihilate to a pair of positive energy fermion and negative energy anti-fermion. Vacuum could effectively serve as an unlimited source of positive energy and make creation of matter from nothing literally possible. The idea could be tested by allowing laser beams and their phase conjugates to interact and by looking whether fermions pop out via two-photon annihilation. Fermion-anti-fermion pairs with arbitrarily large fermion masses could be generated by utilizing photons of arbitrarily low energy. The energies of the final state fermion is completely fixed from conservation laws so that it should be relatively easy to check whether the process really occurs. Generalized Feynman rules predict the cross section for the process and it should behave as $\sigma \propto \alpha^2/m^2$, where m is the mass of the fermion so that annihilation to electrons is the best candidate for study. Bio-systems might have already invented intentional generation of matter in this manner. Certainly the possible new energy technology should be applied with some caution in order to not to build a new quasar!

4. New view about inertial and gravitational energy

A longstanding puzzle of TGD inspired cosmology has been the conservation of energy implied by Poincare invariance which seems to be in conflict with the non-conservation of gravitational energy. It took time to discover the natural resolution of the paradox. In TGD Universe matter and antimatter have opposite energies and gravitational four-momentum is identified as difference of the four momenta of matter and antimatter (or vice versa, so that gravitational energy is positive). The vanishing of the inertial energy density in cosmological length scales is the proper interpretation for the fact that Robertson-Walker cosmologies correspond to vacuum extremals of Kähler action. The assumption that the net quantum numbers of Universe vanish is maximally predictive and allows to get rid of unpleasant philosophical questions like "What are the net conserved quantum numbers of the Universe".

That particle reactions can correspond to a creation of zero energy states from vacuum is consistent with the crossing symmetry of particle physics and the proposed identification of gravitational energy in absence of appreciable annihilation of positive and negative energy matter creates the illusory western view about objective reality possessing positive inertial energy. The classical non-determinism of vacuum extremals carrying non-vanishing gravitational energy density can be interpreted as being space-time correlate for the fact that Universe is partially engineered.

Pulses, Tesla transformers, and bi-filar coils

The function of quite a many free energy systems involve sharp pulse sequences. Often the bi-filar invented by Tesla [H12] are used to produce magnetic pulses. Together with general TGD based vision this leads to a theoretical picture allowing to understand the visions of Tesla theoretically.

1. The vision briefly

A very concise summary of the model goes as follows.

1. The basic prediction of TGD are negative energy topological light rays propagating backwards in geometric time. They can be accompanied by self-generated negative energy photons since in general case topological light rays carry light like vacuum 4-current. The interpretation as counterparts of phase conjugate laser waves [D7] seems to make sense. A sequence of pulses carrying constant electric field forces charge carriers to accelerate repeatedly provided the frequency of the pulses is sufficiently low for charged to come at rest. A decelerating system emits its energy as positive energy photons whereas the accelerating system might receive its energy by emitting negative energy photons if deceleration and acceleration are genuine time reversals of each other.

2. Negative energy photons are absorbed by any system which contains (possibly many-sheeted) population inverted lasers with appropriate excitation energy when bosonic particles return to their ground states. If sufficiently many bosonic particles return to the ground state, a phase transition return to the ground state occurs and is analogous to induced emission. Large number of positive energy photons are generated and a weak negative energy control signal is amplified to much stronger positive energy signal. The resulting energy is identifiable as "free energy".

The generation of negative energy photons breaks second law. In TGD Universe second law however holds true at a given p-adic length scale only in time scales longer than the corresponding p-adic time scale. This means that field patterns having a duration below the relevant p-adic time scale can appear as negative energy topological light rays. Sharp electric pulses carrying a constant electric field are ideal in this respect.

Suppose that electric pulses are feeded into a bi-filar coil and induce currents in the primary coil. Due to the large mutual inductance between loops of the primary and secondary coils composing the bi-filar coil, the current generated by the pulse in the primary loop is transmitted inductively to the nearby second loop, which in turn generates a positive feedback to primary. Thus the current is amplified and the propagation of the electric pulse induces a propagation of large rapidly varying currents in coils rotating in opposite direction so that the magnetic flux inside the bi-filar coil is small. First of all, this means that the sequence of electric pulses induces a currents through the two components of the bi-filar coil by effectively reducing the inductance of the coil. Secondly, the amplification of the current means amplified acceleration of the charge carriers optimal for the generation of negative energy photons as time reversed brehmstrahlung.

There are good reasons to expect that living matter has discovered the analogs of bi-filar coils long before humans, even before Tesla. Binary structures, such as DNA double strand and cell membrane consisting of two lipid layers, are good candidates for the counterparts of bi-filar coils and might play key control in the bio-control by serving as generators of negative energy photons in turn controlling the generation of positive energy photons.

2. Do electric pulses correspond to scalar wave pulses?

Interesting questions are related to the behavior of the electric field inside coils, in particular bi-filar coils. It seems that the expressive power of Maxwell's theory might not be enough here. It seems that the electric pulses propagating in any circuit could correspond to TGD counterparts of Tesla's scalar wave pulses.

1. The unipolar electric field is discontinuous at the ends of the pulse. In Maxwell's equations the rotor of the magnetic field equates to the sum of the current term j and the displacement current $\partial E/\partial t$. Either an infinitely sharp induction peak is allowed in the magnetic field or the displacement current must be compensated by the current term.

2. In Maxwell's electrodynamics a very high (ideally infinitely strong instantaneous) ohmic current would be needed to compensate the displacement current. This seems implausible. In TGD however vacuum charges and currents are possible. The electric square pulse is analogous to a moving capacitor and the charges of the capacitor plates could correspond to vacuum charges. At the level of space-time geometry the plates would correspond to propagating edges of the 3-surface. The induced electric field E_{rot} would induce a current pulse, whose direction would change in the middle of the magnetic pulse.

3. TGD indeed predicts the existence of scalar wave pulses [H12] . These pulses represent electric flux quanta, 3-surfaces inside which there is an almost constant longitudinal electric field. A capacitor moving with the velocity of light would be the analogy. These solutions are not possible in Maxwell's theory. Because also the pulses moving in circuits are very similar, there is a large temptation to identify them as scalar wave pulses. In this case the effective propagation velocity is reduced below light velocity by the interaction with matter. Intuitively, the particles topologically condensed in the region of 3-surface representing the pulse make it massive and slow down the effective speed of propagation.

One might imagine that the scalar wave pulses could leak out of the system. For instance, this might happen if the second end of the coil is free. Tesla indeed reported a production of scalar wave pulses using a transformer whose primary coil was feeded by a sequence of unipolar pulses. These pulses were amplified in a secondary coil in whose second end was free. Abnormally high voltage amplification with no current in secondary coil was reported [H13] .

If the propagation velocity of the scalar wave pulse is light velocity, the time T would be the time taken by the pulse to propagate through the first half of the bi-filar coil: $T = Z/v$, where Z is the length of the wire in the bi-filar coil and $v = c$ is light velocity. For $v = c$ T would be 3.3 ns if the length of the wire is 1 meter. The interaction with the matter induces inertial effects and is expected to reduce the effective propagation velocity of the scalar wave pulse representing the electric pulse to $v < c$.

3. Could electric pulses in circuits correspond to separate space-time sheets?

Scalar wave pulses could correspond directly to the space-time sheets of electric flux quanta moving with light velocity predicted by TGD [K23] rather than being regions of constant electric field at the space-time sheet of wire. These flux quanta would move along wire and have join along boundaries contacts connecting the space-time sheet of the flux quantum with the boundaries of small co-moving holes associated with the circuit's space-time sheet. Charged particles could flow to the flux quantum along these bridges at the first end of the electric flux quantum, accelerate there practically without dissipation, and flow possibly also back at the second end of the flux quantum. The direction of the flow would be determined by the sign of the charge. This would allow anomalous acceleration of the charge carriers making it possible to emit negative energy photons up to energies determined by the voltage difference associated with the flux quantum. The lowering of the effective propagation velocity would be a genuine quantum effect based on the same mechanism as the lowering of the effect phase velocity of topological light rays.

Scalar wave pulse is like a moving capacitor and should be attracted or repelled by a real charged capacitor depending on the sign of its polarization. Therefore scalar wave pulse could be reflected from a capacitor and begin to move forth and back around the loop connecting the plates of the capacitor in a circuit. This is a testable effect. For instance, if bi-filar coil is coupled between the capacitor the pulse should move forth and back through it. If scalar wave pulses correspond to separate space-time sheets they can leak out of the system. The open ends of the secondary coils used by Tesla in his transformers might be the places where the leakage occurs. The emission of a new kind of radiation observed by Modanese and Pokletnov [H8] to accompany the discharge of a capacitor for which the negatively charged plate was super-conducting might represent the emission of scalar wave pulses [K23] .

4. Sharp electric pulses as producers of phase conjugate waves?

Tesla transformers use ordinary coils as primary coils and open coil as a secondary coil. On basis of his experimental work Tesla claimed that Tesla transformers allow an anomalously high voltage amplification. Strangely, Tesla found no current in the secondary coil but the transformers induced charging of various metallic objects in large regions surrounding the transformer. This effect was able to penetrate even through Faraday cage.

The bi-filar coils discovered by Tesla [H12] , which are feeded by sharp unipolar electric pulses carrying constant electric field and analogous to moving capacitors, occur repeatedly in various free energy devices. This would suggest that bi-filar coils somehow produce phase conjugate laser waves (negative energy topological light rays accompanied by negative energy photons). These in turn would induce the dropping of bosonic charged particles to larger space-time sheets as a phenomenon analogous to induced emission when the intensity of negative energy photons is above some threshold. The challenge is to understand how square pulses propagating both in ordinary and bi-filar coils manage to produce phase conjugated light.

What is so special in the unipolar electric pulses circulating in bi-filar coils?

1. If one wants to produce negative energy photons, one must break the second law of thermodynamics. TGD predicts that in a given n-ary p-adic length scale $L(n,k)$ (size of the space-time sheet) this is possible below the n-ary p-adic time scale $T(n,k) = L(n,k)/c$. One must only produce pulses having duration shorter than the p-adic time scale $T(n,k)$. The sharp electric pulses are excellent candidates for this kind of pulses since they accelerate the charge carriers and during this period they can emit negative energy photons.

2. One class of important frequencies would correspond to harmonic multiples for the frequency $f = 1/T^E_{1/2}$, $T^E_{1/2} = T^E/2$, where T^E is the duration of the electric square pulse. A second important time scale is the time interval between the pulses which must be so long that the charges have time to come at rest. One expects that this time scale is of the order of $\tau = L/R$, where L and R characterize the (say) primary of the bi-filar coil. A third important time scale is the duration of the magnetic pulses generated in the pulsed bi-filar coil. The time T during which electric pulse propagates through the first half of the bi-filar coil is not so important as one might first think since mutual induction implies that the propagation of the electric pulse through the primary generates a propagation of a current also in the secondary. Besides these time scales important time scales are the time scales determined by the basic parameters L, C, R of the primary (secondary) of the bi-filar coil.

5. Bio-systems and unipolar pulses

One might think that besides Tesla also bio-systems might have invented the sharp pulses as a manner to break second law temporarily and produce negative energy topological light rays crucial for all basic mechanisms in TGD based quantum biology and theory of consciousness. Perhaps one function of nerve pulse is to produce phase conjugate waves and perhaps nerve pulse can be switched on by a scalar wave pulse reducing the membrane potential below the critical value.

This suggests the existence of biological variants of bi-filar coils. Bio-systems are full of binary structures such as DNA double strand and cell membrane (consisting of two lipid layers). It is tempting to think that DNA double strand is a variant of bi-filar coil in which scalar wave pulses propagate along strand (associated with say gene) and return along the conjugate strand. Also now the effective inductance of the system would grow from zero to some maximum value and return back to zero and phase conjugate light would be generated. As a matter fact, the TGD based model for bio-photons lead to the hypothesis that the strand/conjugate strand generates positive/negative energy MEs and that these MEs move in opposite directions along strands [K37] .

Could negative energy photons induce the transition to effective superconductivity?

The generation of negative energy photons involves temporary breakdown of the second law. Therefore the minimization of the resistance of the relevant part of the circuit, say bi-filar coil, should be favorable for the effect.

TGD based new physics might provide a possible mechanism reducing the resistance. If part of the current carrying electrons of the bi-filar coil drops down to the larger space-time sheets, where they propagate as Cooper pairs, the resistance of the system is reduced. The research group led by Hafedh Abdelmeik has found that the electric conductivity of axon grows by a factor of order 10 below a certain critical temperature, which is in the range 30-40 C of physiological temperatures [J18] . The TGD based model [K62] , [J19] explains the findings correctly at quantitative level.

A variant of this mechanism might be at work also in the case of electric circuits if appropriate conditions are satisfied.

1. The model for the realization of intentionality and motor activity relies on a process, which proceeds from long to short time and length scales, much like a desire for some action in an organization proceeds from boss to the bosses at lower level. In the same manner a hierarchy of phase transitions could proceed from longer to shorter length and time scales and reduce the resistance and increase the upper limit for the energy of negative energy photons.

2. The pulses propagating in say bi-filar coil could produce already in the normal situation a sufficient amount of negative energy photons at low frequencies to induce a phase transition increasing the conductivity. The growth of the intensity of the negative energy photons emitted at higher frequencies could in turn induce a similar phase transition in a shorter p-adic length scale and corresponding to higher zero point kinetic energy. At every stage the negative energy photons could first cool the system so that the phase transition occurs more easily. The dropped Cooper pairs would in turn increase the portion of the supra current flowing at the ground state space-time sheet and thus conductivity.

6.5.2 Does the model explain the basic observations of Tesla?

The basic vision of Tesla was that the sharp pulses involve physics not understood in the framework of Maxwell's theory. Tesla ended up with this vision on basis of certain empirical findings and it is interesting to find whether this observations could be understood in the proposed conceptual framework. In other words, could time reversal and the breaking of the second law below the p-adic time scales explain these findings.

Switching the current on as a time reversal for switching the current off

The basic observation of Tesla was that a sudden switching on of the current circuit produced strange phenomena. Besides sparks and light arcs strong charges were induced in the metal objects in environment. Physiological effects like electric shocks, pressure, sensations of heat, etc.. appeared. Also energy seemed to be liberated. The effects propagated through Faraday cage.

This kind of findings inspired Tesla to develop a technics to produce series of sharp pulses. In the system developed by Tesla, a magnet was repeatedly posed between the capacitor plates between which current was flowing to turn off the current for a moment. The outcome was a fast method for producing sharp current pulses. Tesla developed devices utilizing sharp pulses such as bi-filar coils and transformers, which produced much higher voltage in the secondary coil than one might have expected on basis of Maxwell's theory. The second end of the secondary coil was in freely in air and no current was observed at the end of the coil.

What was the source of these effects? The chapter "Rosetta Stone" in the book of Vassilatos [H13] contains a statement which gives a hint: when the current was switched on, the current carriers behaved as if they had collided with a wall and stopped for a moment. This sounds paradoxical since it is what one might expect to happen when the current is switched off so that resistance suddenly increases. Now just the opposite happened.

A possible solution to the paradox is provided the the reversal of geometric time. If the switching on of the current is time reversal of the switching off, the initial situation could be that the system is in a state resulting after closing off of the circuit and it might contain very high charge densities.

The resulting high electric fields could even induce the evaporation of the wire. This would mean that the second law of thermodynamics would enter the game and the process would not proceed in the desired manner. In fact, it is not necessary to assume even this as following argument demonstrates.

Time reversal allows to understand what happens in the case that the time reversed process proceeds.

1. When the current is switched off, charge carriers decelerate and emit their energy as positive energy photons. When the current is switched on, charges accelerate and get their energy by emitting negative energy photons. If the system starts from a situation in which charges have "collided with a wall" the amount of energy needed is especially high. This is however not necessary.

2. Condensed matter like water or biological matter are full of population inverted many-sheeted lasers. At certain resonance frequencies corresponding to the differences of the zero point kinetic energies negative energy photons induce phase transitions discharging the population inversion of the many-sheeted laser. From certain space-time sheets charged "drop" to large space-time sheets, say magnetic flux tubes. A cascade of positive energy photons is liberated and manifests itself as "free energy".

3. The metallic (for instance) objects receiving negative energy photons lose net charge to the large space-time sheets and generate a net charge of opposite sign so that a high voltage with respect to the environment is generated. This indeed was found by Tesla to occur, and the charge definitely did not originate from the circuit generating the effect. This in fact led Tesla to postulate that ether carrying the charges was emitted in the process. Process can occur in a wide region since negative energy photons of sufficiently high energy do not respect Faraday cage. The reason is that there is not system able to absorb them and thus drop to a lower energy state. The net charge is developed because the negative energy topological light rays act as "bridges" along which the charge can move between space-time sheets. Since there is an electric field in the direction of the bridges, the charges move only in second direction fixed by the sign of the charge.

4. Switching of the current on acts as a control process which switches much larger process in environment using negative energy photons. Basically the process is due to the inherent instability of the many-sheeted space-time. What happens is analogous to a transition from a bottom of potential well in a fractal spin glass energy landscape to a bottom of a deeper potential well. The process leads to a gradual transfer of matter to larger space-time sheets and cooling. The generation of larger space-time sheets means evolution of consciousness since the p-adic prime characterizing the space-time sheets identifiable as a kind of intelligence quotient grows in the process.

5. In order to maximize the intensity of negative energy photons and get as dramatic effect as possible, the parameters characterizing the pulse series can be optimized. The basic idea is that the system is rapidly shaken. This generates accelerations of opposite sign and the system is decelerated and accelerated in a fast tempo. There is however a limitation coming from the fact that charge carriers must have enough time to return to rest. We use instinctively this trick when we try to wake up a person who has lost consciousness.

Do scalar wave pulses appear also outside electric circuits?

The transients at the ends of voltage pulses correspond to a constant electric field propagating as scalar wave pulses with light velocity when the inertial quantum effects caused by the coupling with matter can be neglected. TGD allows solutions of field equations describing free scalar wave pulses with longitudinal electric field. Both positive and negative energy pulses are possible. The interesting question is whether the findings of Tesla necessitate the emission of free scalar wave pulses.

1. On basis of foregoing considerations it would seem that Tesla's scalar wave pulses outside the pulsed circuits are not necessary if one wants to understand the findings of Tesla. Of course, they could be involved.

2. In the chapter "Rosetta Stone" of the book of [H13] [H13] there is a summary of the properties of the electro-radiative event (ERE) observed by Tesla. It seems that one could understand them as effects induced by the emission of negative energy photons.

   In particular, ERE leaves wires and other circuit elements in a direction orthogonal to them. This favors strongly the interpretation in terms of topological light rays identifiable as TGD counterparts of ordinary radiation. In TGD topological light rays are however carriers of light like vacuum(!) 4-currents so that they generate coherent photons and can also carry Bose-Einstein condensates of parallel photons. The filament like light emitting structures orthogonal to metal coils could thus correspond to topological light rays. If they carry negative energy they should also generate coherent photons with negative energies.

3. Scalar wave pulses should leave an open wire in a direction parallel to the wire. The open secondary coil of Tesla transformer is a good candidate in this respect. From a capacitor the pulses should leave in a direction orthogonal to the capacitor plate and might reduce the voltage of the capacitor by carrying quanta of electric flux which are very much like small capacitors themselves moving with a light velocity.

Why the radiation observed by Tesla was so difficult to detect using photography?

In the chapter "Rosetta Stone" of his book [H13] Vassilatos tells that although the radiation emitted by the Tesla's circuits was perceived both visually and experienced as physiological effects it was very difficult to detect it instrumentally, for instance by photographing: long deposit times were required.

The explanation for this might be very simple. Body and especially retina are full of population inverted many-sheeted lasers which can amplify a weak signal of negative energy photons to a much stronger signal consisting of positive energy photons. Ordinary photographic film very probably is not able to do this.

This idea is supported also by the TGD based model for sensory receptors [K29] . In TGD Universe sensory organs are the carriers of primary qualia like color, and one can say that brain only writes the sensory music to notes. Since brain processes the sensory input in a selective manner, a back projection from brain to sensory organs making virtual sensory experiences possible must be present. Negative energy photons provide the most elegant manner to realize this mechanism since bio-matter is transparent to them unless there are many-sheeted lasers tuned to the wavelength in question.

Photo receptors indeed contain a lot of mitochondria serving as energy plants of the cell and mitochondria are known to generate visible light which is not a mere side product of metabolism [I6] . This suggests that the signal consisting of negative energy photons is amplified to a positive energy visual signal in retina. This would occur during dreaming and explain rapid eye movements. The mechanism would make it possible to see using negative energy photons and even seeing even through physical objects using phase conjugated photons as the findings of Feinberg demonstrate [D7] . A camera using negative energy photons is a possible technological application. The camera would make it possible to take images through walls.

How Tesla transformer manages to yield so high voltage amplification?

Tesla reported that his transformers have an anomalously high voltage amplification. There are two cases to be considered corresponding to pulsed ordinary and bi-filar primary coils. In both cases it might be possible to understand Tesla's findings.

1. In the case of the ordinary coil the repeated acceleration of charges induced by electric pulses generates magnetic pulses inducing in turn voltage over the secondary coil. This is what also Maxwell's theory predicts. The emission of negative energy photons inducing the increase of conductivity and an anomalous amplification of the primary current would however mean that also the voltage induced in the secondary coil is anomalously high.

2. Only the net current flowing in the pulsed bi-filar coil induces electromotive force in the secondary coil. Thus the magnetic pulses should become much sharper than in the case of the ordinary coil. Already this implies that induce voltage along the secondary coil, being proportional to the time derivative of the magnetic flux, is very high during the short pulse. The currents induced by the electric pulse in the bi-filar coil increase also rapidly the resonance mechanism

and eventually more or less compensate each other. The increase of conductivity is a further amplification mechanism possibly involved. By using a several primary bi-filar coils arranged around circle and having suitable phase lag, one could perhaps arrange a permanent anomalously large inductive effect.

Why no current was observed in the secondaries of Tesla transformers?

Tesla did not detect the emission of charge carriers from the open ends of the secondary coils of his transformers. What one would expect is that the voltage along the secondary generates a flow of charge carriers which are stuck to the open end and that part of them leaks out. Two factors are involved.

1. There was no current at atomic dissipative space-time sheets since the charge carriers were dropped to larger space-time sheets: perhaps at the flux tubes of the magnetic fields generated in the process or at the magnetic flux tubes of the Earth's magnetic field. An interesting possibility is that closed magnetic super conducting circuits involving primary and secondary coils are formed. The magnetic flux tubes could carry the charges also to environment and negative energy topological light rays might help to transfer the charge to the metallic objects in the environment.

2. Electric pulses correspond to a Tesla scalar wave pulses so that the surface charges associated with the ends of the pulse correspond to vacuum charges and vacuum currents. Therefore no ordinary charge carriers were associated with them.

6.6 Quantum criticality, $1/f$ noise and consciousness

Criticality is a necessary prerequisite of control. Unless the system to be controlled has some critical variables in which small change induces large changes in the state of the system, control is very ineffective. The quantum criticality of TGD Universe indeed guarantees, not only the existence of macroscopic quantum systems, but also possibility of quantum control. What is encouraging is that quantum criticality can be correlated with $1/f$ noise, a phenomenon which has remained poorly understood in standard physics approach.

6.6.1 $1/f$ noise

The so called $1/f$ noise deserves the often used attribute ubiqitous: it appears in widely different systems such as radio active decay, chemical systems, biology, fluid dynamics, astronomy, electronic devices, optical systems, network traffic and economics (references can be found in [D1]). An excellent article about $1/f$ noise in music by Martin Gardner in Scientific American [A12] gives a good grasp on the basic concepts. $1/f$ noise is less random than white noise with $1/f^0$ power spectrum and completely random correlation function and more random that Brownian noise having $1/f^2$ power spectrum (defined as the Fourier transform of the autocorrelation function $\langle A(t)A(t+T)\rangle$). In practice, the phrase $1/f$ noise is attributed also to power spectrum of form $1/f^\alpha$, $\alpha \simeq 1$.

There is no generally accepted explanation for $1/f$ noise. Power law with a negative value of exponent suggests that a system producing $1/f$ type noise is scaling invariant and has long range time and spatial correlations as a consequence. This suggests that fractal like structure is in question and Mandelbrot has indeed proposed that fractality is the basic underlying mechanism of $1/f$ noise. If this is the case, one however encounters the problem of identifying the underlying mechanism of fractality.

Critical systems are scaling invariant in the sense that regions of arbitrary large size of two phases can be present in the system. Critical systems are also known to exhibit fractal like structures. This suggests that criticality is the basic underlying cause of both fractals and $1/f^n$ type noise. The problem is however that critical systems are extremely unstable: arbitrarily small perturbation can change the value of the critical parameter (such as temperature) so that criticality is lost. This is certainly not in accordance with the universality of $1/f$ noise and of fractals.

The paradigm of self-organized criticality [B1] is based on the hypothesis that the dynamical systems have a tendency to develop asymptotically to critical states. It is however not at all clear whether these models can be derived from basic physics. It has been also argued [B7] that the criticality is somehow built into the structure of these models so that there actually exists a critical parameter and the dynamics is constructed in such a manner as to preserve the value of the critical parameter.

Topological Geometrodynamics (TGD) suggests quite different explanation of $1/f$ noise. The entire Universe predicted by TGD is quantum critical system in the sense that the vacuum functional of the theory is completely analogous to the partition function of a thermal system. The so called Kähler coupling strength α_K is analogous to temperature and the requirement that it corresponds to critical temperature fixes the theory uniquely. Since the critical parameter is fundamental constant of Nature, it is clearly not possible to generate perturbations leading away from criticality without Godly intervention and the basic argument against criticality as an explanation of $1/f$ noise can be cirvumvented.

Like its thermodynamical counterpart, quantum criticality implies long range quantum correlations. This in turn implies that macroscopic quantum systems of arbitrarily large size are possible. This result is a cornerstone for the TGD inspired theory of bio-systems as macroscopic quantum systems: what remains is to identify the mechanisms making bio-systems macroscopic quantum systems. TGD indeed predicts several, purely TGD based, mechanisms. Needless to emphasize, if quantum criticality could provide a general mechanism explaining the universality of the $1/f$ noice, one would have strong support not only for quantum criticality (and TGD!) but also for the possibility of macroscopic quantum systems. Therefore the hypothesis deserves a serious study.

6.6.2 Quantum criticality of TGD

Quantum criticality and p-adicity

As already explained quantum criticality emerges in TGD from the requirement that the theory is unique: as a consequence the value of the Kähler coupling strength, which is analogous to critical temperature, is fixed. The situation is actually somewhat more delicate. The considerations related to the value of gravitational constant lead to the hypothesis that configuration space of 3-surfaces decomposes into regions characterized by p-adic prime p such that the critical value of Kähler coupling strength depends on p and hence on p-adic length scale $L(p)$ in the manner characteristic for the length scale evolution of $U(1)$ coupling strengh.

The requirement that gravitational constant is invariant under the coupling constant evolution associated with p-adic prime p plus the requirement that electron mass scale is predicted correctly by p-adic mass calculations [K43] , fix the evolution of the Kähler coupling strength as a function of the p-adic length scale:

$$\begin{aligned} \frac{1}{\alpha_K(p)} &= k\left[log(p)+log(K^2)\right] \quad , \\ K &= \frac{R}{\sqrt{G}} \simeq 1.367\times 10^4 \quad . \end{aligned}$$

Here R denotes CP_2 'radius', G denotes gravitational constant and p is the p-adic prime. The value of the parameter k is $k=\frac{4}{\pi}$ in the scenario in which the value of Kähler function is integer for CP_2 type extremals and $k=137/107$ in the scenario allowing the expansion of Kähler function as power series existing p-adically. One can say that instead of single critical value Kähler coupling allows infinite number of critical values labelled by primes and each critical value corresponds to a particular effective p-adic topology.

It seems that a successful p-adicization requires the extension of rational numbers by introducing an infinite group of real units defined by products of ratios $U=(m/n)X/\Pi(m/n)$, where X is product of all finite primes and $\Pi(m/n)$ is an infinite prime. One has $U=1$ in a real sense but not p-adically. This extension is a multiplicative version for the addition of infinitesimals and seems much more better suited for the purposes of physicist. The p-adic norm of these units is $1/p$ for almost all primes and the remaining primes are cognitively very special. If the inverse of the Kähler coupling strength is proportional to this kind of unit the continuation of the Kähler function to p-adic realm becomes easy.

The notion of algebraic hologram suggests itself. This would mean that configuration space of 3-surfaces decomposes into sectors D_Q, Q infinite rational, such that Q defines the subgroup of units for the rational numbers at that point. The value of Q would be reflected in the properties of single point of space-time sheet and would affect decisively the p-adic physics of cognition but would not reflect itself directly at the level of the real physics. At the imbedding space level Q would correspond to an octonionic unit. Since octonionic primes could quite well be able to code the quantum state of the entire universe to their structure, one must consider seriously the possibility that single point codes in its structure the quantum state of the universe!

How quantum criticality is realized?

It is not completely clear how criticality is precisely realized in quantum TGD. In fact, criticality seems to be realized in several senses. The most general action containing no dimensional coupling constants is super position of Yang-Mills action for induced CP_2 spinor connection and of Kähler action. This action allows all 4-surfaces with one-dimensional CP_2 projection as vacuum extremals. When the Yang-Mills part of the action vanishes (Yang-Mills coupling becomes formally infinite) action has the huge vacuum degeneracy of Kähler action: any 4-surface whose CP_2 projection belongs to so called Legendre submanifold (generically 2-dimensional) of CP_2, is vacuum extremal. It is not clear whether this criticality could give rise to spin glass analogy irrespective of the value of the Kähler coupling strength.

The value of Kähler coupling strength gives rise to additional criticality. From the fact that Kähler electric/magnetic fields give negative/positive contribution to Kähler action it is clear that vacuum functional favors the formation of Kähler magnetic/electric fields below/above the critical value. Therefore configurations containing Kähler magnetic fields, in particular so called cosmic strings, should be favored below criticality. CP_2 type extremals [K43] with negative and finite Kähler action representing elementary particles and surfaces representable as deformations of vacuum extremals and containing Kähler electric fields should be more favored above criticality.

One possibility is that some kind of spontaneous Kähler magnetization occurs below criticality and that in criticality spin glass type structure consisting of regions containing Kähler magnetic fields is present whereas above criticality magnetization is absent. An attractive working hypothesis, motivated by the experience with critical systems, is that at criticality the formation of join along boundaries condensates with arbitrarily large sizes is possible: depending on whether the join along boundaries bonds contain Kähler electric or magnetic gauge fluxes, single stable join along boundaries condensate would be formed above/below criticality. This would mean that the topology of the many-sheetd space-time is extremely dynamical at criticality. This indeed would be necessary for the formation of macroscopic quantum systems of all possible sizes. Examples of join along boundaries bonds are color flux tubes between quarks, strong bonds between nucleons inside atomic nuclei, chemical bonds, MAPs between micro-tubuli and gap junctions between cells.

Information theoretic interpretation of Kähler function

The discovery that Kähler function has information theoretic interpretation led to a considerable progress in the understanding of quantum criticality. The work of Roy Frieden [B11, B18] suggest that the action principles of physics could have information theoretic interpretation. Although Frieden's original scenario does not seem to work in TGD framework, it turns out possible to deduce interpretation for the negative of the Kähler function as an entropy type measure for the cognitive information content of the space-time surface. Furthermore, the criticality of the Kähler action can be interpreted as a maximization of the cognitive information content of the space-time surface and quantum criticality makes TGD universe maximally interesting and maximizes its intelligence.

A detailed argument leading to these results goes as follows. The $I-J$ decomposition of the Kähler function in the manner suggested by Frieden's theory is not General Coordinate Invariant and therefore not promising in TGD context. On the other hand, the formal similarity of the vacuum functional with thermodynamical partition function suggests the interpretation of the vacuum functional as an exponent for the negative of some kind of entropy type variable so that the negative of the Kähler function would correspond to entropy.

The exponent $exp(-K_{cr})$ of the negative of Kähler function, for a suitable choice of the value α_{cr} of the Kähler coupling strength, should somehow measure the number of some kind of microstates. A natural identification of the "microstates" is as cognitive degeneracy caused by the classical nondeterminism of the Kähler action, which implies that configuration space integration over 3-surfaces Y^3 at the light cone boundary involves summation over all possible association sequences going through the same 3-surface Y^3 on the light cone boundary and having the same value of the Kähler function. This summation brings in a degeneracy factor, which will be referred to as N_d.

An educated guess is that the degeneracy factor N_d is in a good approximation proportional to the exponent of the negative of the Kähler function, when Kähler coupling strength has critical value α_{cr}:

$$N_d \simeq exp(-K_{cr}) \ . \tag{6.6.1}$$

Note that α_{cr} depends on the sector D_p of the configuration space since Kähler coupling strength depends on p-adic length scale in a logarithmic manner typically predicted by $U(1)$ gauge theories. This hypothesis allows to answer to the basic questions related to the definition of the Kähler function.

The first consequence of the hypothesis is that preferred extremal property maximizes cognitive information. This is achieved by generation of Kähler electric fields necessarily accompanied by mind like space-time sheets, whose contribution to N_d compensates the negative Kähler action. Perhaps this could partially explain why electric fields, in particular those associated with the cell membranes, are so important in bio-systems. The construction of cognitive systems artificially some day would thus involve construction of Kähler electric fields.

This hypothesis throws also new light to the precise mechanism of the quantum criticality. At quantum criticality the cognitive degeneracy factor N_d in the functional integral over the configuration space compensates the exponent of the negative Kähler function even when its value is infinite! Below quantum criticality the probabilities for 3-surfaces having negative Kähler function suffer exponential cutoff so that only the 3-surfaces for which the value of Kähler function per volume vanishes, are important. The resulting universe is obviously much less interesting than quantum critical universe, which maximizes complexity. Also the maximum for the total cognitive information content of the quantum jump is always finite for subcritical universe unlike for quantum critical universe. Above quantum criticality cognitive degeneracy dominates over vacuum functional and configuration space integral of the vacuum functional diverges so that the theory becomes mathematically ill defined. Therefore quantum critical universe possesses maximal complexity and is as interesting and intelligent as universe can be! Note that quantum criticality was already earlier realized to be crucial for consciousness since it makes possible long range quantum correlations and hence arbitrarily large macroscopic quantum systems.

Quantum criticality and $1/f$ noise

Criticality and fractality in quantum TGD are closely related to the properties of the Kähler function defining the Kähler geometry of the configuration space of all possible 3-surfaces in $H = M^4_+ \times CP_2$. Kähler function is defined as an absolute minimum of so called Kähler action. Kähler action allows huge number of vacuum extremals with finite size in both spatial and temporal degrees of freedom. These surfaces are not absolute minima of the Kähler action but one can consider the possibility that by gluing vacuum surfaces to nonvacuum surfaces the interaction with the nonvacuum surfaces makes them almost-vacuum extremals and as a consequence one obtains absolute minimum of Kähler action. Quantum criticality of the material system suggests that this weak interaction could generate large fluctuations with long time and length scales.

A natural hypothesis is that $1/f$ noise results when the space-time sheet containing the physical system is glued to a vacuum extremal. When almost vacuum extremal is created, some energy flows from the physical system to the vacuum extremal. On the other hand, when almost vacuum extremal disappears, this energy flows back to the space-time sheet of the physical system. This mechanism perturbs the physical system and causes a fluctuation. By quantum criticality even small energy flow can give rise to a large perturbation of the physical system. Spin glass analogy which is closely related to the vacuum degeneracy of the Kähler action, predicts that there indeed exist very many almost degenerate maxima of Kähler function and small perturbations could induce time development transforming the 3-surface to a new one. The transition would be analogous to a rapid classical time development leading from one sheet of a cusp catastrophe to another one.

Photons and gravitons (possibly virtual) are the most natural candidates for particles transferred to the nonvacuum space-time sheet. Uncertainty Principle suggests that the energy transferred by single quantum from a material space-time sheet to the almost vacuum space-time sheet of duration T is of order $E \simeq 1/T$. One can consider also a possibility that large number of quanta with energy $E \simeq 1/T$ is transferred to the nonvacuum space-time sheets. TGD predicts the presence of Bose-Einstein condensates of photons and gravitons generated by vacuum currents [K53] and a definite possibility is that a fraction of the topologically condensed coherent photons with energy $E \simeq 1/T$ are Bose-Einstein condensed at the almost nonvacuum space-time sheet. In this case only the amount of energy transferred would be larger and the changes to cause long length scale fluctuation of large amplitude and having frequency $\omega = E$ at the nonvacuum space-time sheet containing matter, would be better.

If one requires scaling invariance in the strongest possible sense, the only viable probability distribution for the durations of the almost vacuum space-time sheets is $dP(T) \propto dT/T$ since any other desitribution law would necessarily contain some dimensional parameter. By Uncertainty Principle the same distribution gives also the distribution of energies: $dP(E) \propto dE/E$. Obviously the proposed distribution implies duality between energy and time variables and is especially natural from the view point of quantum theory. Actually the spectrum is of the same form as brehmstrahlung spectrum and one can consider the possibility that the space-time sheets of finite time duration could be regarded many particle states formed by real and virtual collinear photons and gravitons.

Quite generally, one can identify energy E as the frequency ω of the fluctuation generated by the transfer of energy. Quantum criticality suggests that the the energy transferred to the nonvacuum space-time sheet serves only as a seed of a fluctuation whose average amplitude squared approaches constant at the limit $E = \hbar\omega = hf \rightarrow 0$. The non-vanishing of the constant in question follows from quantum criticality implying the presence of fluctuations at arbitrarily long time scales. With these assumptions one indeed obtains $1/f$ power distribution for the frequencies

$$S(f) \propto \frac{df}{f} \quad . \tag{6.6.2}$$

6.6.3 $1/f$ noise and thermalized arithmetic quantum field theory

Following arguments demonstrate that $1/f$ noise follows automatically from either p-adic or real thermodynamics applied to arithmetic quantum field theory with energies quantized as multiples of $log(p)$, p prime. There are small corrections to $1/f$ spectrum and these reflect directly the distribution of primes. Obviously this serves as a high precision test for the proposed explanation of $1/f$ noise.

Arithmetic quantum field theory with broken conformal symmetry describes critical systems

Two-dimensional critical systems allow description in terms of conformal quantum field theories [A5] . On the other hand, quantum TGD relies crucially on the realization of super conformal invariance made possible by the miraculous properties of the boundary of the four-dimensional future light cone [K16] . This background inspires the hypothesis that critical systems quite generally possess some form of conformal invariance possibly broken to some sub-algebra.

The generators of the full number-theoretic conformal symmetries are

$$L_q = q^z \frac{d}{dz} \quad , \tag{6.6.3}$$

where q is rational number. Commutators satisfy the commutation law

$$[L_{q_1}, L_{q_2}] = log(\frac{q_2}{q_1})L_{q_1 q_2} \tag{6.6.4}$$

respecting multiplication of rationals.

Generators are eigen states of $L_1 = d/dz$ under commutation. L_1 is analogous to energy (or momentum) since it generates translations. Energy eigenvalues are

$$E = E_0 log(q) = E_0 \sum_{k_i \in Z} k_i log(p_i) \quad , \tag{6.6.5}$$

where p_i are primes and k_i are integers which can be also negative. If physical states correspond to integers for which energy is always positive, one has

$$E = E_0 \sum_{k_i \geq 0} k_i log(p_i) \quad , \tag{6.6.6}$$

which is the energy spectrum of arithmetic quantum field theory, which describes the physics of infinite number of harmonic oscillators labelled by primes and having fundamental frequencies $f_p = log(p)f_0$ ($E_0 = hf_0$). The positivity of the spectrum suggests that the interpretation as energy rather than momentum is indeed more appropriate.

The generators L_p and $L_{1/p}$ generate the entire algebra by repeated commutations. What is remarkable, is that one obtains infinite hierarchy of symmetry breakings by dropping any subset of generators labelled by some subset of primes. An interesting hypothesis is that arithmetic quantum field theory with symmetry broken in this manner describes some critical systems. Analogous hierarchy of symmetry breakings is possible also for ordinary Super Virasoro algebra.

If one assumes $p \simeq 2^k$, k prime, one obtains special kind of breaking of conformal symmetry. In this case the scaled generators

$$\hat{L}_k \equiv \frac{L_{p \simeq 2^k}}{log(2)} \tag{6.6.7}$$

have energies $\hat{L_1} \simeq k$. The algebra commutators satisfy commutation relations

$$[L_{n_1}, L_{n_2}] \simeq (n_2 - n_1)L_{n_1+n_2} \quad , \tag{6.6.8}$$

so that one has in a good approximation standard conformal algebra of string models and statistical models of critical systems [A5] . This observation suggests a symmetry-based justification for p-adic length scale hypothesis besides the justification coming from the generalization of Bekenstein-Hawking law for black-hole entropy to elementary particle context [K43] .

Thermodynamics for arithmetic quantum field theory

$1/f$ spectrum follows in a straightforward manner by applying p-adic or ordinary thermodynamics to arithmetic quantum field theory.

1. The spectrum of frequencies in a mode p is harmonic oscillator spectrum:

$$f_n = nf_0 \times log(p) \quad , \tag{6.6.9}$$

   where n is integer identifiable as number of arithmetic bosons. f_0 is infrared cutoff for frequencies.

2. The average number of particles in the mode p is calculable form p-adic thermodynamics. In p-adic thermodynamics Boltzmann weight $exp(-\beta H)$, $\beta = 1/T$ (the units are $\hbar = c = k = 1$ in the following), does not exist as such p-adically and one must replace it by power of p which exists under certain constraints on the energy spectrum satisfied in conformally invariant theory:

$$exp(-\beta H) \rightarrow p^{\beta H} \quad . \tag{6.6.10}$$

   For number-theoretic reasons one must assume that

$$H \equiv \frac{L_1}{log(p)} \tag{6.6.11}$$

having integer valued spectrum is in the role of Hamiltonian H. This operator has eigenvalues $p^{\beta n}$. Inverse temperature β must be positive-integer valued from the requirement that Boltzman weights exist p-adically:

$$\beta = m \ . \tag{6.6.12}$$

3. The partition function for mode p is nothing but standard harmonic oscillator partition function

$$Z = 1 + p^m + p^{2m} + ... = \frac{1}{1-p^m} \ . \tag{6.6.13}$$

The average value of particle number in mode p is given by

$$\langle n \rangle = \frac{\sum_n np^{nm}}{Z} = \frac{p^m}{1-p^m} \ . \tag{6.6.14}$$

The real counterpart of average particle number is obtained using canonical identification

$$\sum x_n p^n \rightarrow \sum_n x_n p^{-n} \tag{6.6.15}$$

mapping p-adic observables to real ones and one obtains

$$\langle n \rangle_R = \frac{p^{-m}}{1-p^{-m}} \ . \tag{6.6.16}$$

For large primes one obtains in excellent approximation $\langle n \rangle_R \simeq p^{-m}$.

4. This construction applies with minor modification also in real context. In this case one has

$$\langle n \rangle = \frac{\sum_n np^{-\beta n}}{Z} \ , \quad Z = \sum_n p^{-\beta n} \ , \tag{6.6.17}$$

where one has $\beta = f_0/T$. The reslting expression is the same as given by p-adic thermodynamics except that β is now real-valued:

$$\langle n \rangle = \frac{p^{-\beta}}{1-p^{-\beta}} \ . \tag{6.6.18}$$

$1/f$ noise from thermal arithmetic quantum field theory

To deduce $1/f$ spectrum it is enough to calculate the average number of states $N(f)$ with frequency smaller than f using the approximate expresssion

$$\pi(x) \simeq \frac{1}{u} \quad , \quad u = log(x) \tag{6.6.19}$$

for the density of primes in the set of reals x [A27] . Thus, in the approximation $\langle n \rangle = p^{-\beta}$, one has

$$\begin{aligned} N(f) &= \sum_p \frac{p^{-\beta}}{1-p^{-\beta}} \simeq \int dx \frac{x^{-\beta}}{1-x^{-\beta}} \times \frac{1}{u} \\ &= \int_{log(2)}^{log(p)} du \times \frac{exp[(1-\beta)u]}{1-exp(-\beta u)} \times \frac{1}{u} \quad . \end{aligned} \tag{6.6.20}$$

From this one has

$$\frac{dN}{df} = \frac{exp\left[(1-\beta)\frac{f}{f_0}\right]}{\left[1-exp(-\beta\frac{f}{f_0})\right]} \times \frac{1}{f} \quad . \tag{6.6.21}$$

Approximate $1/f$ spectrum is obtained in the frequency range

$$\frac{1}{\beta} \ll \frac{f}{f_0} \ll \frac{1}{|\beta - 1|} \quad . \tag{6.6.22}$$

Clearly, $\beta \geq 1/2$ is required meaning that temperature is below $T = 2f_0$. For $\beta = 1$ $1/f$ spectrum becomes exact at sufficiently high frequencies and its normalization is fixed completely. It is important to notice that for reasonable cutoff frequencies, say of order $f_0 = 10$ Hz, the value of the temperature must be extremely low: or order $T \sim 10^{-10}$ Kelvin. Therefore new physics is necessarily involved.

$T \to \infty$ limit exist only in real context and gives

$$\frac{dN}{df} = \frac{f_0 exp(\frac{f}{f_0})}{\beta f^2} \quad . \tag{6.6.23}$$

Long range temporal correlations clearly disappear at this limit.

It is interesting to look how the situation changes when the allowed primes satisfy the constraint given by p-adic length scale hypothesis. The first observation is that for suitable unit of frequency frequencies are in good approximation prime-valued in this case, which is unique signature of the spectrum. The spectrum is given by

$$N(f) = \sum_{p \simeq 2^k} \frac{p^{-\beta}}{1-p^{-\beta}} \simeq \int dx \frac{2^{-x\beta}}{1-2^{-x\beta}} \times \frac{1}{log(x)} \quad . \tag{6.6.24}$$

$$\frac{dN}{df} = \frac{1}{f_0 log(\frac{f}{f_0})} \times \frac{2^{-\beta\frac{f}{f_0}}}{\left[1-2^{-\beta\frac{f}{f_0}}\right]} \quad . \tag{6.6.25}$$

Exponentially decaying spectrum is obtained for higher frequencies for finite values of the temperature reflecting very strong long range temporal correlations. For high temperatures the spectrum becomes

$$\frac{dN}{df} \simeq \frac{1}{log(2)\beta} \times \frac{1}{log(\frac{f}{f_0})f} \quad , \tag{6.6.26}$$

and differs from $1/f$ spectrum obtained in general case by different normalization factor and by logarithmic correction term. Thus the deviation of the normalization factor from unity could be interpreted as signature of the breaking of conformal symmetry implied by p-adic length scale hypothesis and the value of the temperature can be determined from cutoff frequency and normalization factor of $1/f$ spectrum. Note that in this case $1/f$ spectrum results for cutoff frequencies f_0 much smaller than room temperature, which corresponds to frequency of order 10^{13} Hz.

To sum up, thermalized arithmetic QFT implies $1/f$ spectrum and deviations from the precise $1/f$ spectrum reflect the properties of the distribution of primes since the dominating frequencies in the spectrum are essentially logarithms of primes in general case and primes in case that p-adic length scale hypothesis holds true. In p-adic thermodynamics $T/f_0 = 1/m$ are the only allowed temperatures and $T/f_0 = 1$ corresponds to the highest possible p-adic temperature: note that the calculation of the elementary particle masses using p-adic thermodynamics assumes also $T = 1$ [K43] . In its recent form TGD cannot predict the allowed values of f_0. Certainly transmutation of the fundamental p-adic length scale of order 10^4 Planck length is involved making possible small-p p-adicity at macroscopic length and time scales.

A possible connection between arithmetic quantum field theory, hydrodynamic turbulence, and chaos in excitable media

Turbulence in atmospheric hydrodynamics (flow is associated with a thin boundary layer of about 10 km) has fractal structure and is accompanied $1/f$ noise [K33] : both features associated with self-organized criticality and deterministic chaos. The mechanism giving rise to macroscopic coherent structures such like hurricanes and tornadoes has remained poorly understood in the framework of ordinary hydrodynamics [I26] . Typical structures involved are spiral vortices [I26]

$$\frac{r}{r_0} = \tau^{\frac{\theta}{\theta_0}} \ , \quad \tau = \frac{1+\sqrt{5}}{2} \ , \tag{6.6.27}$$

having the property that for large values of n the values of radii at $\theta_n = n\theta_0$ are proportional to Fibonacci numbers $F_n \simeq \tau^n$ (τ denotes Golden Mean). The favored value of θ_0 corresponds to $\theta_0 = 36$ degrees giving rise to Fibonacci spirals encountered widely in botany and associated with aperiodic Penrose tilings with five-fold rotation symmetry [A21] .

In TGD hydrodynamic vortices are accompanied by Z^0 magnetic fields whose flux tubes are parallel to the spiral vortex cores. At the tip of the vortex the conserved Z^0 magnetic flux must go somewhere. The only possibility seems to be that it flows to another space-time sheet. This suggests that spiral vortices are associated with what I have called wormhole magnetic fields [K85] . These are double-sheeted structures carrying opposite magnetic fields created by rotating extremely tiny elementary particle sized wormhole contacts at the boundaries of second sheet of the double sheeted structure and feeding electric gauge fluxes between the two space-time sheets. If second sheet has negative time orientation, its energy is negative, and the structure can have finite time duration and be created spontaneously without any energy cost. Thus mind like space-time sheet is in question by definition. This in accordance with the idea that $1/f$ noise involves mind like space-time sheets in essential manner. Wormhole magnetic fields form a fractal hierarchy since space-time sheets can be glued to space-time sheets and this hierarchy can be identified as a fractal hierarchy of vortices containing smaller vortices inside them.

This picture inspires the following hypothesis: it is the excitations associated with wormhole magnetic fields, which are described by arithmetic quantum field theory. The mode with energy $log(p)$ corresponds to a definite structure, perhaps smaller space-time sheet carrying magnetic field glued to the larger sheet. These structures are labelled by primes and thus the distribution of primes is reflected in the dynamics of the system. Wormhole magnetic fields might provide general description of the spiral waves associated with various excitable systems. In particular, generation of chaos by the decay of spiral waves [A29] could correspond to the development of magnetic chaos. Since the phase increment of the order parameter of super-conductor over a closed circuit surrounding magnetic flux tube gives essentially magnetic flux [K38] , magnetic chaos implies chaos for the phase of the order parameter of super conductor. Thus magnetic or Z^0 magnetic chaos at cellular level could spoil coherence of the macroscopic quantum phases crucial for bio-control in TGD inspired model of bio-control. For instance, this loss of quantum coherence could lead to heart failure known to involve the decay of spiral waves [A30, A10].

Connection with TGD inspired theory of conscious systems

For f_0 or order say 10 Hz, the temperature associated with $1/f$ noise is extremely low, something like 10^{-10} Kelvin. Standard physics does not certainly allow earthly systems with so low temperatures. In TGD Universe situation is different because the space-time is many-sheeted. In fact, TGD based theory of brain as a macroscopic quantum system relies crucially on the existence of cellular space-time sheets having ultra-low temperatures and allowing the presence of various types of Bose-Einstein condensates. It his view is correct, $1/f$ noise could be seen as a direct signature of consciousness. A natural TGD inspired interpretation for the arithmetic QFT could be as a statistical description of the dynamics at the mind like space-time sheets having by definition finite time duration $\tau = 1/f_0$. mind like space-time sheets are indeed suggested to give rise to $1/f$ noise which thus would become direct signature of consciousness [K14] . Around human brain τ could be even of the order of lifetime: mind like space-time sheets with this duration make possible long term episodal memories in the proposed general theory of qualia [K29] . Thus the standard formal trick of performing path integral over space-time of finite time duration to construct thermodynamical quantities [B4] seems to have deeper 'psycho-physical' meaning in TGD framework.

In TGD inspired theory of bio-systems as macroscopic quantum systems so called association sequences [K45] provide geometric representation for thoughts and in fact are almost vacuum space-time surfaces with a possibly finite duration. Therefore one can consider seriously the possibility that $1/f$ noise is closely related to the basic mechanism with which brain and living matter control the behavior of the matter.

More concretely, 'massless extremals' (MEs) are basic solutions of field equations of TGD and define an excellent candidate for an infinite hierarchy of life forms having huge information storage capacities and expected to control lower level selves such as super-conducting magnetic flux tube structures. MEs are accompanied by non-vanishing light like vacuum gauge currents generating coherent states of gravitons and photons [K53] . Linear structures such as micro-tubuli and DNA molecules are excellent candidates for quantum antennae generating coherent light and perhaps also gravitons. In fact, infinite fractal hierarchy of MEs extending from elementary particle length scales to cosmological length scales is predicted.

Coherent photons and gravitons could make possible, not only quantum counterpart of radio communication but also "matter mind interaction" between ordinary bio-matter and almost empty mind like space-time sheets representing thoughts. For instance, the generation of pairs of MEs with opposite energies and momenta in quantum jump would make it possible to provide material system with a coherent momentum. In particular, p-adic–real phase transition could give rise to a generation of pair of MEs with vanishing net energy and momentum. One basic mechanism could be brehmstrahlung representable classically as generation of MEs. Second mechanism would be emission of photons and gravitons induced by super-symplectic quantum phase transitions.

That also gravitons might be important is suggested by the fact that it is the classical gravitational field (induced metric) which destroys the exact $U(1)$ gauge invariance (gauge transformations being represented by canonical transformations of CP_2) of the ordinary Maxwell action when the ordinary Maxwell field is replaced with the induced CP_2 Kähler form [K8] . This gives rise to spin glass type degeneracy due to the huge number of almost physically equivalent gauge-related 4-surfaces. Also the fact that the super-symplectic representations associated with MEs are genuinely quantum gravitational states supports this view.

To sum up, this picture suggest that $1/f$ fluctuations could be even regarded as a physical signature for the presence life and cognitive consciousness: if this is true then the universality of $1/f$ noise could mean that even cognitive consciousness is everywhere.

6.7 The role of ELF fields in bio-control and coordination

In this section the evidence that higher levels of the biological self hierarchy control biological body using fields at ELF frequencies (EEG frequencies are in ELF range) is discussed. The basic inputs are topological field quantization, the idea of memetic code and the observations about the effects of ELF em fields to brain suggesting that the higher levels of our self hierarchy correspond to em selves with sizes of order wavelength of photons generated by EEG currents and thus realized as topological field quanta having size of order of Earth.

A very important and rather recent input (I am writing this towards the end of year 2005) is the model of high T_c superconductivity inspired by the notions of dark matter hierarchy based on the dynamic and quantized $\hbar$ having arbitrarily large values. Detailed models are not discussed here but are left to the chapters [K12, K13] of [K58] devoted to superconductivity in bio-systems.

6.7.1 Electromagnetic selves

Rather remarkably, the time scale of .1 seconds predicted by the model of the memetic code and also the time scales of the photons associated with the cyclotron frequencies of ions correspond to the time scale of EEG. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of size of Earth. The lowest Schumann frequency is roughly $f = c/2\pi R$, R radius of Earth, and equal to $f \simeq 7.8$ Hz. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies 7.8, 14, 20, 28, 33, 39,... Hz [F1] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere. The higher EEG frequencies seem to correlate with higher Schumann resonance frequencies: in particular, the frequencies 13 and 39 Hz which are also cyclotron resonance frequencies of Na_+, are very near to Schumann frequencies. Schumann frequencies vary in time and it has been found that also the variations of EEG frequencies correlate with this variation. Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and cortical instabilities such micro-seizures and epilepsies [J34, J36].

The photons generated in cyclotron transition associated with macroscopic ionic BE condensates in Earth's magnetic field have wavelengths of order Earth size and the topological field quanta representing classically the radiation field have size of Earth. A possible mechanism generating EEG waves would be the dropping of ions or their Cooper pairs from smaller space-time sheets to high n cyclotron states at the magnetic flux tubes of Earth and the decay of the cyclotron states via emission of radiation at harmonics of cyclotron frequency. It ho

EEG could be also generated as coherent photons generated by Josephson current varying at ELF frequency [K13] . Dark matter hierarchy indeed predicts a hierarchy of Josephson junctions and that ELF photons at sufficiently high level of dark matter hierarchy correspond to photon energies above thermal threshold. This model leads also to a new view about genetic code and to a model how cell membrane and nucleus co-operate to achieve bio-control. It is quite possible that both mechanisms are involved.

The fact that classical ELF em fields are represented by topological field quanta with size of order Earth size (by Uncertainty Principle alone) raises the question whether our "physical" body is only a dip of an iceberg and formed by the topological condensation of the bio-matter around electromagnetic topological field quanta serving as templates for the bio-structures.

These observations and arguments suggest the identification of the relevant selves in our self-hierarchy are electromagnetic selves having the size of Earth and correspond to EEG frequencies, and raises the idea that our magnetic body (or hierarchy of magnetic bodies) corresponds to "me" as intentional agent, and that also the magnetic bodies of other systems, in particular Earth itself, are conscious entities and intentional agents. Dark matter hierarchy discussed in [K12, K13] gives a precise quantitative content to this vision.

6.7.2 Neuro-psychological evidence for the importance of ELF fields

There is quite a lot of neuro-psychological evidence for the importance of ELF fields.

The work of Michael Persinger

Neuroscientist Michael Persinger [J35, J33, J39] from Laurentian University in Canada believes that temporal lobes are electrically unstable and may also be involved in sensing these fluctuations in the Earth's magnetic field. In-stability results in micro-seizures in sensitive individuals [1]. Persinger proposes that his tectonic strain theory [J35, J39] explains UFO experiences as natural phenomena generated by stresses and strains within Earth's crust. The anomalous luminous phenomena, UFO experiences and earthquake would be caused by the same process: earth stress causing local strains

[1] On basis of my personal experiences I have reasons to believe that I belong to those sensitive individuals

and eventually leading to sudden release of seismic energy. These phenomena are also reflected in geomagnetic field and most notable perturbation occurs at electromagnetic resonance frequency of 8 Hz of Earth for the propagation of electromagnetic fields in the spherical cavity below ionosphere This resonant frequency interacts with human brain and generates what would have been interpreted as spirit in Indian culture and is interpreted as UFO in our culture.

Altered states of consciousness can be also induced using patterns of magnetic fields with basic frequency of 8 Hz and Persinger suggests that these patterns could have something to do with the "fundamental algorithms" of brain [J33] . One example of the induced experiences is the experience about presence of something. If left brain half is stimulated, this something is experienced as friendly, when right half is stimulated it is experience as scary. Women experience this something as a man and vice versa. Persinger claims that also mystic and religious experiences can be induced using magnetic fields [J33] . The frequency range producing the claimed effects is around 10 Hz with accuracy of 1 Hz. Persinger has gone so far as to design a magnetic helmet that pulses the temporal lobes with earth resonance frequencies producing mystical experiences in student volunteers.

What is remarkable that Persinger uses magnetic pulses rather than smooth sine waves. This encourages to think that magnetic pulses induce scalar wave pulses, which accelerate charges particles at the space-time sheets of scalar wave pulses and generate negative energy "acceleration radiation" in turn inducing time mirror mechanism at the harmonics of frequency defined by the duration of the scalar wave pulse presumably equal to the rising time of the pulse.

It should be emphasized that Persinger is hard nosed neuro scientist and materialist and uses his findings as a support for the reduction of religious experiences to neuronal level and to geophysical phenomena. Persinger also claims that surprisingly many religious people have suffered some brain injury during some state of their life. Persinger bases his explanation of religious experiences to the instability of the frontal lobes against micro-seizures (invisible epilepsies) induced by the magnetic perturbations with certain resonance frequencies, which happens to be resonant frequency of the perturbations of Earth's magnetic field.

Even forgetting Persinger's materialistic starting assumptions, one can criticize Persinger's conclusions in several respects. Why brain would have developed this kind of instability if it produces only hallucinations? Why just the resonance frequency of Earth's magetic field? The content of these hallucinations is the experience about the existence of some higher level consciousness. On the other hand, these hallucinations are produced by interaction with Earth: could this be an accident?

Consider now the situation in which an oscillatory magnetic field varying with certain frequency is generated by Earth quake or artificially.

1. The interaction of brain with the nearby magnetic field must reduce to the interaction of magnetic flux tubes with some parts of brain. It is known that this interaction can lead to electric in-stability of frontal lobe leading to micro-seizures.

2. The coupling of the frontal lobes with Earth's magnetic field can be understood if the flux tubes of the magnetic and Z^0 magnetic fields of Earth serve as templates for the formation of bio-structures. This implies that the biological network of the magnetic flux tubes associated with axons is part of the much larger flux tube network characterizing Earth's magnetic field. The order of magnitude estimate for the thickness d of the magnetic flux tubes associated with Earth's magnetic field is obtained by assuming quantization of magnetization flux. This $d \sim \sqrt{2/eB}$ giving $d \sim 4 \times 10^{-6}$ meters for $B \sim .5 \times 10^{-4}$ Tesla. The diameter of flux tube is very near to the p-adic length scale L_p, $p \simeq 2^k$, $k = 169$: $L(169) \simeq 4.4 \times 10^{-4}$ meters. This length scale is the p-adic length scale associated with cells. Indeed, the quantitative TGD based models for nerve pulse and EEG, for cognition, and for the quantum correlates of sensory qualia, rely crucially on the magnetic transition frequencies of various super conducting charged particles in Earth's magnetic field.

3. The mechanism generating altered states of consciousness could be following. The perturbations of Earth's magnetic field with resonance frequencies cause oscillatory perturbations of the magnetic flux tubes. The interaction of these perturbations with the two-layered structures of brain glued to magnetic flux tubes makes possible resonant coupling with the "Indra's net" formed by the magnetic flux tubes and massless extremals describing the classical em field of Earth.

   More concretely, the resonant oscillations of Earth's magnetic field 'wake-up' some higher level sub-selves (mental images) in the self-hierarchy of a sensitive person so that the higher level component to our experiences becomes exceptionally intensive. The mechanism wake-up is resonance: some Schumann frequencies are very near to the magnetic transition frequencies of ions crucial for the function of brain. Indeed, both K_+ (7.5 Hz) and Cl_- (8.5 Hz) cyclotron frequencies are very near to the lowest Schumann frequency of about 7.8 Hz and $n = 1$ and $n = 3$ multiples Na_+ cyclotron frequency (13 Hz) are also very near to Schumann frequencies.

4. One can wonder why the coupling (possibly entanglement) with the higher level selves is not permanent, why strong oscillatory perturbations are required to achieve this. Perhaps this has to do with the dimensions. Two 4-surfaces in 8-dimensional space (now "Indra's web" and 4-surface associated with cell layers) have generically discrete set of stable intersection points. These must give rise to topological sum contacts giving rise to interaction of material space-time sheets with classical radiation fields. For magnetic flux tubes which are perturbed so that they oscillate with large amplitude one can expect that the number of intersections with the 4-surface describing cell layers, is proportional to the frequency of oscillation and to the amplitude of oscillation. Note that this picture realizes Feynman diagrammatics topologically and that the realization is possible only in dimension 8 since in higher dimensions two 4-surfaces have no intersections in the generic case.

Dark matter hierarchy with levels characterized by the values $\hbar = \lambda^{k_d}\hbar_0$, $\lambda \simeq 2^{11}$, allows to develop much more concrete ideas about the interaction of human brain with the Earth's magnetic field [K13] . In this model $k_d = 4$ level of the dark matter hierarchy corresponds to the space-time sheets of Earth's magnetic field to which brain is connected by magnetic flux sheets traversing through DNA. $k_d = 4$ flux sheets act as Josephson junctions of thickness $\sim$ 180 km connecting the region of Earth below litosphere to the magnetic flux quanta of Earth's magnetic field above ionosphere. In this picture organisms in biosphere can be seen as scaled up variants of proteins in the cell membrane acting also as Josephson junctions. The highly folded magnetic flux sheets mediate the perturbations of the flux quanta of Earth's magnetic field to brain and explain the strong effects of Schuman resonances and perturbations of Earth's magnetic field on consciousness.

Other evidence

There are also "mind machines" which anyone can buy (see for instance [J24]), which produce meditative states through entrainment of brain waves, using light and sound at ELF frequencies. For instance, by feeding in ears two audible frequencies differing by about 8-10 Hz, it is possible to generate mystic experiences. Also light and sound oscillating with these frequencies can be used to generate altered states of consciousness. Indeed, important cyclotron frequencies are in this range. That the alpha frequency of the brain as determined by electroencephalograph is in the range of 8 to 10 Hertz, may not be a coincidence. Perhaps when yogis and adepts are modulating their brain wave frequencies during meditation, they really are achieving altered states of consciousness by tuning in to the Earth. Resonant coupling would be the classical correlate of strong entanglement.

It has been also observed that magnetic pulses of duration of order millisecond and with frequencies between 1 and 50 Hz have profound effects on brain [J14] . For instance, depression can be cured in some cases by transcranial magnetic simulation (TMS) [J14] . Depression correlated with anomalously low neural activity of some parts of left frontal lobe (anterior cingulate cortex belonging to limbic system). During sadness this region is very active. This would suggest that depression is not about feeling sad but about not being able feeling sad. It might be that too much sadness causes numbness to sadness, depression. A prosaic explanation for the effect of 1 millisecond pulse sequence is that the pulses act like a sequence of kicks to broken household machine. Electro-convulsive therapy (ECT), which also stimulates brain act like a single big kick and causes micro-seizures and convulsions avoided in TMS.

One possible speculative explanation goes along following lines. TGD based model of cognition and nerve pulse [K60, K21, K62] relies on the notion of cognitive neutrino pairs associated with wormhole contacts. Neutrino and antineutrino are associated with the two light-like causal horizons of the wormhole contact and behave like partons. The total energy of the pair vanishes or is very small. Cognitive neutrinos couple to classical Z^0 fields. The Z^0 magnetic pulse associated with the nerve pulse (having duration of order millisecond!) induces a spin flip of cognitive neutrino and thus makes it possible to code nerve pulse patterns to temporal sequences of bits realized as the direction of antineutrino Z^0 magnetization. Magnetic pulse could induce nerve pulse or be accompanied by Z^0

magnetic pulse inducing spin flip of cognitive neutrino: as a result the cognitive state of the patient is changed.

It has been proposed that hauntings could be explained acoustically. On basis of his personal experiences Vic Tandy [J41] has proposed that resonant sound waves at frequency of about 19 Hz can cause experiences like cold chills, sense of paranoia and distress and visual hallucinations. Laboratory research has indeed shown that very low frequency infra sounds can cause unpleasant physiological effects like shivering, anxiety and breathlessness. The resonance frequency of eye is known to be about 18 Hz and this the resulting smearing of vision could explain hallucinations. On the other hand, second harmonic for Schumann resonance is roughly 20 Hz. Of course, one can ask whether there is some deeper reason for why the resonance frequency of eye is near to Schumann resonance and whether this frequency is closely related to some Z^0 magnetic Larmor frequency, which are of order 20 Hz for the 'emotional' $k = 173$ space-time sheet carrying Z^0 magnetic field having minimal field strength about $g_Z B_Z = eB/16$ by flux quantization.

More generally, one can also ask why various biorhythms are in Hz [E3] [F1] : one could indeed identify geophysical frequencies which are near to various frequencies of body. One can also aks why the effect of music to human brain is so deep. Could it be that also music wakes up higher level selves in our self-hierarchy? In fact, the quantum model for auditory experience leads to just this conclusion.

6.7.3 Effects of ELF- and ELF modulated em fields on living matter

The work by pioneers of of bio-electromagnetism (Wertheimer, Milham, Marino, Becker, Adey, Blackman and others) which began already at sixties led to amazing discoveries about ELF fields on brain. The review article of Blackman provides a detailed summary of these developments [J7].

1. Already at sixties Hamer discovered that ELF em fields in EEG frequency range had effects on the reaction times of human volunteers [J21] . At seventies Bawin and Adey [J3] discovered the effects of ELF em fields on calcium release in brain tissue. Maximum effect on Ca release was found at 16 Hz.

2. Blackman found 1979 that 50 MHz field modulated by 15 Hz ELF field increased Calcium ion release in chick brain tissue [J12] . Blackman also discovered that odd multiples 15, 45, 75, 105... of 15 Hz had much stronger effect on tissue than even multiples 30, 60, 90... Hz and realized the importance of Earth's magnetic field [J5, J6, J8] . The results and speculations of Blackman led Liboff to propose ionic cyclotron resonance model [J27] . This model was classical and subject to grave objections at the level of principle [K13] . Obviously cyclotron and Larmor frequencies in Earth's magnetic field are in the frequency range of EEG.

3. Also the Schumann resonances associated with Earth's em field are in EEG frequency range and it is known that geomagnetic fields interact strongly with brain and Persinger [J35, J33] has done valuable work related to this.

6.7.4 Summary about effects of ELF em fields on brain

The work by pioneers of bio-electromagnetism (Wertheimer, Milham, Marino, Becker, Adey, Blackman and many others) which began already at sixties led to amazing discoveries about ELF fields on brain. The article of Blackman [J7] provides a detailed summary of these developments. The results of the work of Bawin, Adey, Blackman and others can be summarized by saying that radio frequency em fields amplitude modulated by ELF frequencies affect in certain frequency and amplitude windows brain tissue [J3, J5, J8] . The function of the radio frequency carrier wave is to facilitate the penetration of em field into tissue and its frequency is not essential for the occurrence of the effect. Presumably nonlinear effects give rise to a secondary wave with modulation frequency which is the primary source of effects.

Basic effects

The effects of ELF em fields on brain include chemical, physiological and behavioral changes within windows in frequency and field intensity. It is essential that the effects have been observed only in vertebrates which thus possess EEG. A good summary is the online review article of Cherry [J13].

The well documented and established non-thermal biological effects of EMR include significant alteration of cellular calcium ion homeostasis, reduction of melatonin, and the detection of Schumann Resonances by human and avian brains. A key effect is change in Ca^{2+} homeostasis: Ca^{2+} it is involved with both pre- and postsynaptic steps of nerve pulse transmission and also with intracellular communication. For instance, Ca^{2+} is involved with gene expression, the development and plasticity of nervous system, modulation of synaptic strengths, and with $Ca^{2+} - c$AMP signal transduction process.

Change in Ca^{2+} homeostasis has harmful effects in central nervous system, endocrine system and immune system. At the level of CNS this means changes of reaction time and behavioral alternations. At the level of neuro-endocrine system a good example is the reduction of the melatonin production in pineal gland having wide variety of harmful effects since melatonin serves as effective scavenger of free radicals: among the effects are DNA strand breakage, chromosome aberrations and problems with gap junction communications. Melatonin is also crucial for healthy sleep and for the reduction of cholesterol and blood pressure. In case of immune system an example is provided by the change of functioning of lymphosytes in turn reducing the competence of immune system making the subject more vulnerable to allergens, toxins and viruses.

Amplitude windows

Two main amplitude windows have been seen. For the first window ELF em fields have values of electric field in tissue around 10^{-7} V/m. The effects are high level effects and associated with navigation and prey detection in marine vertebrates and with the control of human biological rhythms. For ELF modulated radio frequency fields (RF) and microwaves (MW) the intensities are around $1-10$ V/m. In this case the effects are neurophysiological effects are lower level effects at the level of the brain tissue. In case of brain tissue maximal sensitivity to electromagnetic fields occurs between 6 and 20 Hz.

In order to get grasp about orders of magnitude, it is good to notice that cell membrane electric field has a strength about 10^7 V/m whereas EEG electric fields in the range $5-10$ V/m. The fact that the second intensity window corresponds to $1-10$ V/m suggests that the em field simulates the em field associated with EEG: a valuable guideline in attempts to understand what is involved. For Schumann resonances electric field is of order .6 mV/m. For sferics (em perturbations associated with lightnings) magnetic field strength is not above nTesla: this corresponds to electric field strength 10 V/m associated also with EEG waves [J2] . Field strength of V/m corresponds roughly to energy flux $\mu W/m^2$.

The presence of windows and weak intensities implies that the effects cannot be thermal. A good metaphor is the effect of radio noise on radio receiver: it occurs at definite frequency and destroys the information content of the original transmission.

The effects occur at harmonics of cyclotron resonance frequencies

Blackman also discovered that odd multiples 15, 45, 75, 105... of 15 Hz had much stronger effect on tissue than even multiples 30, 60, 90... Hz and realized the role of Earth's magnetic field [J6] . A possible interpretation is that harmonics of cyclotron frequencies might be the information carrying frequencies in EEG.

In response to the results and speculations of Blackman, Liboff formulated ionic cyclotron resonance (ICR) model [J27] based on the realization that the frequencies in question correspond to multiples of the cyclotron frequencies of Ca^{2+} ion in Earth's magnetic field. This model was classical. Later Blanchard and Blackman proposed so called ionic parametric resonance model (IPR) [J10] . This phenomenological model combines ICR model with ideas about atomic physics. There are several objections against ICR model; classical orbits of ions in Earth's magnetic field have radius of order meters; dissipative effects and Brownian forces do not allow cyclotron orbits; charge-to mass ratios appearing in cyclotron frequencies correspond to vacuum rather than water environment characterized by large value of dielectric constant; it is difficult to understand why odd multiples of cyclotron frequencies give rise to stronger effects [J7]. Some of these objections apply also to IPR model.

The pattern of data seems to suggest that the interaction occurs at quantum level. This is in dramatic conflict with the predictions of the standard quantum theory and with the standard view about space-time. On the other hand, the fact that that effects at spin flip frequencies proportional have not been reported suggests that the effects are classical. Large $\hbar$ hierarchy however predicts that spin flip energies behave like $1/hbar$ whereas cyclotron energy do not depend on the value of $\hbar$ so that only cyclotron transitions are predicted to be important.

Are quantal effects in question?

The conclusion that the effect of ELF fields on brain represents quantum effects associated with the transitions of ions confined in magnetic field having same strength as Earth's magnetic field, is supported by the following observations.

1. The frequencies $15, 30, 45, 60, 75$ Hz having effect on primates are multiples of the same basic frequency $f = 15$ Hz, which turns out to be the cyclotron frequency of Ca^{2+} ion. That these frequencies come in multiples is a direct signature of quantum: in classical world only basic frequency $f = 15$ Hz should have effects (forcing ions to rotational motion around field lines with this frequency.

2. Even multiples of 15 Hz have a weak but non-vanishing effect. Transitions are not possible at all in the lowest order of perturbation theory since the interaction Hamiltonian describing the transitions in question has non-vanishing matrix elements only between states of opposite parities in the dipole approximation applying when the wavelength of the radiation is much larger than the size of the radiating system [B3] . Odd and even values of n for cyclotron states have opposite parities so that Δn odd rule results. In higher orders of perturbation theory also transitions for which transition frequency is even multiple of the cyclotron frequency are possible. This observation provides additional strong support for the hypothesis that quantum transitions are involved.

There are however also objections.

1. The cyclotron energy scale is about 10^{-14} eV and ridiculously small as compared to the energy scale .086 eV defined by room temperature so that quantal effects should be masked completely by thermal noise.

2. Also ELF em fields at spin flip frequencies (Larmor frequencies) should induce transitions. These have not been reported.

3. The wave functions of ions in Earth's magnetic field are confined in a region of size of order

$$r_n \sim \sqrt{2n/eB} \ ,$$

which is of the order of cell size: macroscopic quantum state is in question. In fact, the value $.5 \times 10^{-4}$ Tesla for Earth's magnetic fields corresponds to the p-adic length scale $L(169) = 5$ μm rather precisely for minimal value of the magnetic flux quantized as $ZeBS = n2\pi$ obtained for $n = 1$ (S denotes the area of the flux tube) and $Z = 2e$. If one requires quantum classical correspondence, very large values of n are required and cyclotron radii would be much larger than flux tube radius.

A common resolution of all these objections is provided by large $\hbar$ phases and hierarchy of magnetic flux sheets with B scaling like $1/hbar$ meaning that cyclotron frequencies scale down similarly and cyclotron energies remain invariant. Since spin is invariant under scalings of $\hbar$ spin flip energy scales down as $1/\hbar$ so that its contribution to magnetic energy is very small as compared to the cyclotron contribution and spin degrees of freedom are thermalized. Hence the system behaves classically in spin degrees of freedom. By the quantization of the magnetic flux, predicted by TGD also classically, the minimal radius of the magnetic flux tube for the magnetic field of Earth of cell size for ordinary value of $\hbar$ but scales like $\hbar$ if magnetic field remains invariant and flux quantization $BS = n2\pi\hbar$ implying $S \propto \hbar$ holds true. This implies consistency with classical theory for large values of $\hbar = \lambda^k \hbar_0$, $\lambda \simeq 2^{11}$.

A brief summary of the model

Some work is required to end up with the following interpretation based on a model for how the different levels of dark matter hierarchy communicate and control.

1. Ions with charge Z, mass m and spin S in the external magnetic field behave quantum mechanically like harmonic oscillator with energies quantized as

$$E = E_c + E_L \ , \quad E_c = (n+\frac{1}{2})\hbar\omega_c \ , \quad E_L = S_z\frac{g\omega_c}{2} \ , \quad \omega_c = \frac{ZeB}{m} \ \ (c=1) \ . \tag{6.7.1}$$

   The first contribution corresponds to cyclotron contribution. For a given value of n the component of angular momentum in the direction of B has $n+1$ values $n, n-2, ..., -n$. E_L denotes spin (Larmor) contribution. g is so called Lande factor which for free elementary fermions equals to $g = 2$. Since S_z is invariant under the scalings of $\hbar$, Larmor contribution is negligible as compared to cyclotron contribution for large values of $\hbar$. The contribution to energy coming from the free motion in the direction of magnetic field has not been written.

2. The model for high T_c superconductivity involving competition of two superconductivities, one associated with cell interior and second with cell membrane is the starting point. These phases coexist in a narrow range around critical temperature and 36-37 C range where the effects are observed is a good candidate for this range.

3. Experimental findings suggests strongly that external em field induces resonant transitions between cyclotron states: these transitions are identified as transitions inside the cell/nucleus or its fractally scaled up variant. For $k = 4$ level of dark matter hierarchy cyclotron energy scale turns out to be above the thermal energy $2.88T$ of photons at maximum intensity of black body radiation at room temperature for $A \leq 223Z$. Cyclotron radiation can drive charged particles to smaller space-time sheets and this is essential for the metabolism and this process is expected to be part of the interaction of ELF em fields with cell nucleus. The scale of cyclotron energies for $k = 4$ level of dark matter hierarchy is indeed turns out to be consistent with this assumption.

4. The ELF em field used in the experiments have electric fields strengths in two windows: one around 10^{-7} V/m and second corresponding to $1 - 10$ V/m. Even in the latter case the field is by a factor of order million weaker than membrane potential: the notion of many-sheeted space-time allows to understand why so weak fields can have effects on biomatter. Amplitude windows are a further mystery related with the interaction of ELF em fields with brain tissue: if ELF em field defines potential difference eV associated with a Josephson junction, one might understand this effect in terms of quantum jumps induced by Josephson current with frequency $f = ZeV/2\pi$.

5. Dark matter hierarchy leads to the hypothesis that there is entire hierarchy of EEGs generated as coherent photon states by Josephson currents associated with the Josephson junctions whose thickness scales as $\hbar$ and frequency scales as $1/\hbar$ so that cyclotron energy remains invariant and is above the thermal threshold. For each value of $\hbar$ there is also p-adic hierarchy corresponding to $k = 151, ..., 169$ with same Josephson frequency: these levels combine to form single block for dark matter hierarchy formed from the scaled up variants of this block. At least the magnetic flux tube structure of DNA and membrane structure appear as scaled up copies. The lowest level corresponds to cellular or nuclear membrane and ordinary value of $\hbar$.

6. Josephson current is of form $J \propto sin(2eVt + 2e\int V_1 dt)$ and its amplitude does not depend on the strength of the perturbation V_1. V_1 is same for all values of $\hbar$ but scales like $L(k)$ as function of p-adic length scale for given value of $\hbar$. Perturbation is represent as EEG pattern communicated to the magnetic body of fractally scaled up variant of cell or cell nucleus, which reacts appropriately. At the limit when the Josephson frequency $f_J^1 = 2eV_1/2\pi\hbar$ of perturbation satisfies $f_J^1 \gg f_c$, the amplitude of perturbation is coded to frequencies $f_\pm = f_J^1 \pm f_J$ in the EEG in a good approximation.

7. The response of the system is that of AND gate. V_1 induces in the neuronal nucleus or its scaled up counterpart cyclotron transitions if the frequency is correct. If this the case, cell nucleus opens up communication line receiving possible control signals from the magnetic body at higher level of hierarchy. V_1 induces in Josephson junctions effects if the amplitude is in the amplitude window guaranteing that the frequencies $f_{\pm}$ belong to EEG resonance bands (or their scaled up variants. In this case magnetic body receives representation of V_1 as coherent photons and responds. If communication line is open the response induces in the cell nucleus gene translation and other activities necessary for the biological response. The model implies that cyclotron frequencies code for the biologically relevant information carried out by classical electric fields so that noise is eliminated very effectively. A detailed discussion of the model is left to [K13] , where also the implications for the understanding of genetic code are discussed.

What about Z^0 magnetic transitions?

The idea that Z^0 magnetic magnetic transitions might be relevant for biomatter have been discussed already earlier. The identification of the sources of long ranged classical weak fields as dark matter forces however a profound modification of the earlier picture.

The TGD based models for atomic nuclei [K71] and condensed matter [K22] suggest strongly that the dark variant of $k = 113$ copy of $k = 89$ electro-weak physics is essential for understanding of not only the anomalies of water but also the basic properties of condensed matter. Also other copies of electro-weak physics with arbitrarily small weak mass scale are implied by the fact that long ranged classical weak fields are unavoidable in TGD Universe. Also the scaled down copies of color physics with arbitrarily low mass scales for quarks are a basic prediction of TGD.

If classical Z^0 magnetic field is present and if nuclei possess anomalous weak charges due to the presence of color bonds with quark and antiquark at their ends carrying non-vanishing net weak charges coupling to $k = 113$ dark weak bosons, one must consider also Z^0 cyclotron frequencies given by

$$
\begin{aligned}
&\Omega = \frac{N(u\overline{d})}{A} \times Q_Z(u\overline{d}) \times \frac{g_Z B_Z}{eB} \times \Omega_p \ , \quad \Omega_p = \frac{eB}{m_p} \ , \\
&Q_Z(u\overline{d}) = \frac{1}{2} - sin^2(\theta_W) \ .
\end{aligned}
\tag{6.7.2}
$$

Here $N(u\overline{d})$ is anomalous Z^0 charge of the nucleus due to weakly charged color bonds connecting nucleons with quark and antiquark at their ends using $u\overline{d}$ Z^0 charge $Q(u\overline{d})$ as unit. Ω_p is proton cyclotron frequency, which is about 300 Hz for $B = B_E = .5$ Gauss. The dependence on the Z^0 magnetic transition frequencies on the mass of nucleus is same as in the electromagnetic case.

The doubly dark weak bosons with weak length scale $L_w = 2^{22}L_w(113) = .2\ \mu$m should be key actors in TGD based model of living matter. Since the quantization of magnetic flux uses $\hbar$ as unit the quantum of Z^0 flux over a given area is multiplied by a factor 2^{22} for doubly dark weak bosons. Also the energy $\hbar\omega_c$ associated with the cyclotron frequency is multiplied by a factor 2^{22} so that energies are by a factor 2^{44} higher for cyclotron transitions in flux quantized Z^0 magnetic field than one might expect. In the case of dark quarks it would be natural to use $2(Q_Z(u\overline{d})$ as unit of charge in the quantization of magnetic flux so that the flux quantization reads $2Q_Z(u\overline{d}) \int B_Z dA = n2^{22}\hbar 2\pi$.

Z^0 flux quanta with radius $L_w = .2\ \mu$m are expected to be of special interest. Consider the field corresponding to single flux quantum in this case. Using the fact that Earth's magnetic field taken to have nominal value .4742 Tesla corresponds to a single quantum of flux through a disk of radius $L(k = 169)$, one obtains that the Z^0 cyclotron frequency and energy in this case are given by

$$
\begin{aligned}
\Omega_c(2^{22}\hbar) &= 2^{22}\Omega_c(\hbar)2^{22}\frac{N(u\overline{d})}{A} \times Q_Z(u\overline{d}) \times (\frac{L(169)}{L_w})^2\omega_p(B_{end}) \\
&\simeq \frac{N(u\overline{d})}{A} \times 750\ \ GHz \ , \\
E_c(2^{22}\hbar) &= 2^{44}E_c(\hbar) \simeq \frac{N(u\overline{d})}{A} \times 10^4\ \ eV \ .
\end{aligned}
\tag{6.7.3}
$$

Here $B_{end} = .2$ Gauss corresponds to the endogenous magnetic field explaining the effects of ELF em fields on vertebrate brain: the value of B_{end} differs from the nominal value $B_E = .5$ Gauss for the Earth's magnetic field. Note that Ω_c and E_c do not depend on the unit of flux quantization. Cyclotron frequencies are in 10^{12} GHz range but energies in 10^4 eV range and corresponds to ordinary photon wavelength of about atomic length scale. In the earlier picture frequencies were in 10 Hz range. The energies involved are well above the thermal energy in room temperature. For the first level of dark matter hierarchy the frequency scale would be .375 GHz and energy scale 25 meV which is below thermal energy at room temperature.

Also ordinary nuclei containing charged color bonds would couple to dark weak bosons with weak length scale having nominal value $L_w = 2^{11}L_w(113) = 1$ Angstrom. In this case Z^0 magnetic fields would have 2^{11} stronger strength that in previous case and cyclotron energies would be same.

6.7.5 A general view about the role of classical fields in quantum control, coordination and communication

The following general overview about quantum communication and control emerges from the model for EEG hierarchy as correlate for dark matter hierarchy discussed in detail in [K21] .

1. Cyclotron frequencies relate to the control of the biological body by the magnetic body and could be assigned with the magnetic flux sheets going through DNA since it is genome where protein synthesis is initiated and is thus the optimal intermediate step in the cellular control.

2. One of the basic functions of cell membranes is to perceive the chemical environment using various kinds of receptors as sensors. Neurons have specialized to receive symbolic representations of the sensory data of primary sensory organs about the situation in the external world. Receptor proteins would communicate cell level sensory input to the magnetic body via MEs parallel to magnetic flux tubes connecting them to the magnetic body. We ourselves would be in an abstract sense fractally scaled up counterparts of receptor proteins and associated with dark matter iono-lito Josephson junction connecting the parts of magnetosphere below litosphere and above magnetosphere.

3. This picture would explain why the temperature of brain must be in the narrow range 36-37 K to guarantee optimal functionality of the organism. If interior superconductivity is lost, magnetic body receives sensory data but is paralyzed since its desires cannot be realized. If boundary superconductivity is lost, magnetic body can move but is blind.

4. In the length scales below the weak length scale L_w also charged weak bosons behave as massless particles and the exchange of virtual W bosons makes possible a nonlocal charge transfer. Dark quark-antiquark pairs associated with the color bonds of the atomic nuclei can become charged via the emission of dark W boson and thus produce and exotic ion. The same can happen at the higher levels of dark matter hierarchy.

5. Massless extremals (MEs, topological light rays) serve as correlates for coherent states and Bose-Einstein condensates of dark bosons. Besides neutral massless extremals (MEs) TGD predicts also charged massless extremals obtained from their neutral counterparts by a mere color rotation (color and weak quantum numbers are not totally independent in TGD framework). The second nonlocal quantum control mechanism is based on em charge entanglement involving a superposition of ordinary ions/atoms and exotic ions connected by a W massless extremal joining magnetic body and biological body. In quantum jump this state would be reduced to exotic charge state with some probability increasing with the strength of the classical W field. Charged massless extremals could be seen as correlates for nonlocal quantum control by affecting charge equilibria whereas neutral MEs would serve as correlates for coordination and communication. Color charged MEs could also induce color charge polarization and flows of color charges and thus generate visual color qualia by the capacitor mechanism discussed in [K29] .

6. These nonlocal quantal mechanisms can induce or change electromagnetic polarization in turn inducing ordinary charge flows and thus making possible quantum control of nervous system by magnetic body. The generation of nerve pulse could rely on the spontaneous state function reduction occurring for charge entangled state reducing the resting potential below the critical

value by this kind of mechanism inducing charge transfer between cell interior and exterior. Also remote mental interactions, in particular telekinesis, might rely on this mechanism.

6.8 Dark matter and living matter as quantum phases with large value of Planck constant

The TGD based model for topological quantum computation [B16] inspired the proposal that Planck constant might be dynamical and quantized in terms of logarithms of so called Beraha numbers $B_n = 4cos^2(\pi/n)$, $n \geq 3$ [K83] . Some recent discoveries in astrophysics [E7] and hadron physics [C5, C6], cold fusion anomaly [C7] , etc. suggest that this might be the case. In particular, dark matter could correspond to quantum coherent phase with a large value of Planck constant [K67, K20] . The theoretical background for the quantization of Planck constant is discussed in [K84] .

One implication is that living systems would correspond to a large value of Planck constant. This would mean that elementary quantum units correspond to systems consisting of very many elementary particles and that characteristic time and length scales are scaled up from those predicted by ordinary quantum theory so that macroscopic and macro-temporal quantum coherence become possible in the simplest manner one can imagine: indeed, the characteristic time and length scales are proportional to $\hbar$. This vision is discussed in detail in the [K20] . Here only a brief summary about basic ideas is given

6.8.1 Quantum criticality, hierarchy of dark matters, and dynamical $\hbar$

Quantum criticality is the basic characteristic of TGD Universe and quantum critical superconductors provide an excellent test bed to develop the ideas related to quantum criticality into a more concrete form.

Quantization of Planck constants and the generalization of the notion of imbedding space

The recent geometric interpretation for the quantization of Planck constants is based on Jones inclusions of hyper-finite factors of type II_1 [K25] .

1. Different values of Planck constant correspond to imbedding space metrics involving scalings of M^4 *resp.* CP_2 parts of the metric deduced from the requirement that distances scale as $\hbar(M^4)$ *resp.* $\hbar(M^4)$. Denoting the Planck constants by $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_b\hbar_0$, one has that covariant metric of M^4 is proportional to n_b^2 and covariant metric of CP_2 to n_a^2. In Kähler action only the effective Planck constant $\hbar_{eff}/\hbar_0 = \hbar(M^4)/\hbar(CP_2)$ appears and by quantum classical correspondence same is true for Schödinger equation. Elementary particle mass spectrum is also invariant. Same applies to gravitational constant. The alternative assumption that M^4 Planck constant is proportional to n_b would imply invariance of Schrödinger equation but would not allow to explain Bohr quantization of planetary orbits and would to certain degree trivialize the theory.

2. M^4 and CP_2 Planck constants do not fully characterize a given sector $M^4_\pm \times CP_2$. Rather, the scaling factors of Planck constant given by the integer n characterizing the quantum phase $q = exp(i\pi/n)$ corresponds to the order of the maximal cyclic subgroup for the group $G \subset SU(2)$ characterizing the Jones inclusion $\mathcal{N} \subset \mathcal{M}$ of hyper-finite factors realized as subalgebras of the Clifford algebra of the "world of the classical worlds". This means that subfactor $\mathcal{N}$ gives rise to G-invariant configuration space spinors having interpretation as G-invariant fermionic states.

3. $G_b \subset SU(2) \subset SU(3)$ defines a covering of M^4_+ by CP_2 points and $G_a \subset SU(2) \subset SL(2,C)$ covering of CP_2 by M^4_+ points with fixed points defining orbifold singularities. Different sectors are glued together along CP_2 if G_b is same for them and along M^4_+ if G_a is same for them. The degrees of freedom lost by G-invariance in fermionic degrees of freedom are gained back since the discrete degrees of freedom provided by covering allow many-particle states formed from single particle states realized in G group algebra.

4. Phases with different values of scalings of M^4 and CP_2 Planck constants behave like dark matter with respect to each other in the sense that they do not have direct interactions except at criticality corresponding to a leakage between different sectors of imbedding space glued together along M^4 or CP_2 factors. In large $\hbar(M^4)$ phases various quantum time and length scales are scaled up which means macroscopic and macro-temporal quantum coherence. In particular, quantum energies associated with classical frequencies are scaled up by a factor n_a/n_b which is of special relevance for cyclotron energies and phonon energies (superconductivity). For large $\hbar(CP_2)$ the value of $\hbar_{eff}$ is small: this leads to interesting physics: in particular the binding energy scale of hydrogen atom increases by the factor n_b/n_a^2.

Preferred values of Planck constants

Number theoretic considerations favor the hypothesis that the integers corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, are favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of n_F of fundamental p-adic length scale. $n_F = 2^{11}$ corresponds in TGD framework to a fundamental constant expressible as a combination of Kähler coupling strength, CP_2 radius and Planck length appearing in the expression for the tension of cosmic strings, and the powers of 2^{11} seem to be especially favored as values of n_a in living matter [K21] .

How Planck constants are visible in Kähler action?

$\hbar(M^4)$ and $\hbar(CP_2)$ appear in the commutation and anticommutation relations of various superconformal algebras. Only the ratio of M^4 and CP_2 Planck constants appears in Kähler action and is due to the fact that the M^4 and CP_2 metrics of the imbedding space sector with given values of Planck constants are proportional to the corresponding Planck constants [K25] . This implies that Kähler function codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of $\hbar$ coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high T_c superconductors.

Phase transitions changing the level in dark matter hierarchy

The identification of the precise criterion characterizing dark matter phase is far from obvious. TGD actually suggests an infinite number of phases which are dark relative to each other in some sense and can transform to each other only via a phase transition which might be called de-coherence or its reversal and which should be also characterized precisely.

A possible solution of the problem comes from the general construction recipe for S-matrix. Fundamental vertices correspond to partonic 2-surfaces representing intersections of incoming and outgoing light-like partonic 3-surfaces.

1. If the characterization of the interaction vertices involves all points of partonic 2-surfaces, they must correspond to definite value of Planck constant and more precisely, definite groups G_a and G_b characterizing dark matter hierarchy. Particles of different phases could not appear in the same vertex and a phase transition changing the particles to each other analogous to a de-coherence would be necessary.

2. If transition amplitudes involve only a discrete set of common orbifold points of 2-surface belonging to different sectors then the phase transition between relatively dark matters can be described in terms of S-matrix. It seems that this option is the correct one. In fact, also propagators are essential for the interactions of visible and dark matter and since virtual elementary particles correspond at space-time level CP_2 type extremals with 4-dimensional CP_2 projection,

they cannot leak between different sectors of imbedding space and therefore cannot mediate interactions between different levels of the dark matter hierarchy. This would suggest that the direct interactions between dark and ordinary matter are very weak.

If the matrix elements for real-real partonic transitions involve all or at least a circle of the partonic 2-surface as stringy considerations suggest [K17] , then one would have clear distinction between quantum phase transitions and ordinary quantum transitions. Of course, the fact that the points which correspond to zero of Riemann Zeta form only a small subset of points common to real partonic 2-surface and corresponding p-adic 2-surface, implies that the rate for phase transition is in general small. On the other hand, for the non-diagonal S-matrix elements for ordinary transitions would become very small by almost randomness caused by strong fluctuations and the rate for phase transition could begin to dominate.

Transition to large $\hbar$ phase and failure of perturbation theory

A further idea is that the transition to large $\hbar$ phase occurs when perturbation theory based on the expansion in terms of gauge coupling constant ceases to converge: Mother Nature would take care of the problems of theoretician. The transition to large $\hbar$ phase obviously reduces gauge coupling strength α so that higher orders in perturbation theory are reduced whereas the lowest order "classical" predictions remain unchanged. A possible quantitative formulation of the criterion is that maximal 2-particle gauge interaction strength parameterized as $Q_1Q_2\alpha$ satisfies the condition $Q_1Q_2\alpha \simeq 1$.

A justification for this picture would be that in non-perturbative phase large quantum fluctuations are present (as functional integral formalism suggests). At space-time level this would mean that space-time sheet is near to a non-deterministic vacuum extremal. At parton level this would mean that partonic surface contains large number of CP_2 orbifold points so that S-matrix elements for the phase transition becomes large. At certain critical value of coupling constant strength one expects that the transition amplitude for phase transition becomes very large.

Dark matter and standard physics

The hierarchy of phases behaving like dark or partially dark matter with respect to the ordinary matter [K28] seem to be essential for the understanding of even ordinary hadronic, nuclear and condensed matter physics [K28, K71, K22] . This strengthens the motivations for finding whether dark matter might be involved with quantum critical super-conductivity.

6.8.2 Hadronic black holes and new view about dark matter

Important steps in the development of ideas were stimulated by the findings made during period 2002-2005 in Relativist Heavy Ion Collider (RHIC) in Brookhaven compared with the discovery of America and for full reason [C5, C6]. In particular, the observed production of black-hole like object in heavy ion collisions support the view that in non-perturbative phase of QCD matter possesses large value of $\hbar$ and becomes thus analogous to dark matter. Even more, the earlier model for macroscopic quantum states as resulting when conformal weights of partons become complex such that net conformal weight is real, leads to a general hypothesis that conformal confinement is what forces the system to behave like single coherent quantum unit with large value of $\hbar$. Surprisingly precise analogies with black hole formation and evaporation or equivalently with big crush followed by big bang describable as scaled down version of TGD inspired cosmology, emerge.

6.8.3 Dark atoms and dark cyclotron states

The development of the notion of dark atom involves many side tracks which make me blush. The first naive guess was that dark atom would be obtained by simply replacing Planck constant with its scaled counterpart in the basic formulas and interpreting the results geometrically. After some obligatory twists and turns it became clear that this assumption is indeed the most plausible one. The main source of confusion has been the lack of precise view about what the hierarchy of Planck constants means at the level of imbedding space at space-time.

The rules are very simple when one takes the singular coverings assigned to the many-valuedness of the time-derivatives of imbedding space coordinates as functions of canonical momentum densities as a starting point.

1. The mass and charge of electron are fractionized as is also the reduced mass in Schrödinger equation. This implies the replacements $e \rightarrow e/r$, $m \rightarrow m/r$, and $\hbar \rightarrow r\hbar_0$, $r = n_a n_b$, in the general formula for the binding energy assigned with single sheet of the covering. If maximal number $n_a n_b$ are present corresponding to a full "Fermi sphere", the total binding energy is r times the binding energy associated with single sheet.

2. In the case of hydrogen atom the proportionality $E \propto m/\hbar^2$ implies that the binding energy for single sheet of the covering scales as $E \rightarrow E/(n_a n_b)^3$ and maximal binding energy scales as $E \rightarrow E/(n_a n_b)^2$. This conforms with the naive guess. For high values of the nuclear charge Z it can happen that the binding energy is larger than the rest mass and fractionization might take place when binding energy is above critical fraction of the rest mass.

3. In the case of cyclotron energies one must must decide what happens to the magnetic flux. Magnetic flux quantization states that the flux is proportional to $\hbar$ for each sheet separately. Hence one has $\Phi \rightarrow r\Phi$ for each sheet and the total flux scales as r^2. Since the dimensions of the flux quantum are scaled up by r the natural scaling of the size of flux quantum is by r^2. Therefore the quantization of the magnetic flux requires the scaling $B \rightarrow B/r$. The cyclotron energy for single sheet satisfies $E \propto \hbar qB/m$ and since both mass m and charge q become fractional , the energy E for single sheet remains invariant whereas total cyclotron energy is scaled up by r in accordance with the original guess and the assumption used in applications.

4. Dark cyclotron states are expected to be stable up to temperatures which are r times higher than for ordinary cyclotron states. The states of dark hydrogen atoms and its generalizations are expected to be stable at temperatures scaled down by $1/r^2$ in the first approximation.

5. Similar arguments allow to deduce the values of binding energies in the general case once the formula of the binding energy given by standard quantum theory is known.

The most general option option allows fractional atoms with proton and electron numbers varying from $1/r$ to 1. One can imagine also the possibility of fractional molecules. The analogs of chemical bonds between fractional hydrogen atoms with $N-k$ and k fractional electrons and protons can be considered and would give rise to a full shell of fractional electrons possessing an exceptional stability. These states would have proton and electron numbers equal to one.

Catalytic sites are one possible candidate for fractal electrons and catalyst activity might be perhaps understood as a strong tendency of fractal electron and its conjugate to fuse to form an ordinary electron.

6.8.4 How dark matter and visible matter interact?

The hypothesis that the value of $\hbar$ is dynamical, quantized and becomes large at the verge of a transition to a non-perturbative phase in the ordinary sense of the word has fascinating implications. In particular, dark matter, would correspond to a large value of $\hbar$ and could be responsible for the properties of the living matter. In order to test the idea experimentally, a more concrete model for the interaction of ordinary matter and dark matter must be developed and here of course experimental input and the consistency with the earlier quantum model of living matter is of considerable help.

How dark photons transform to ordinary photons?

The transitions of dark atoms naturally correspond to coherent transitions of the entire dark electron BE condensate and thus generate N_{cr} dark photons and behave thus like laser beams. Dark photons do not interact directly with the visible matter. An open question is whether even ordinary laser beams could be identified as beams of dark photons: the multiple covering property at the level of imbedding space and the fact that MEs are possible in all sectors suggests that this is not the case. Note that the transition from dark to ordinary photons implies the scaling of wave length and thus also of coherence length by a factor n_b/n_a.

Dark $\leftrightarrow$ visible transition should have also a space-time correlate. The so called topological light rays or MEs ("massless extremals") represent a crucial deviation of TGD from Maxwell's ED and have all the properties characterizing macroscopic classical coherence. Therefore MEs are excellent candidates for the space-time correlate of BE condensate of dark photons.

MEs carry in general a superposition of harmonics of some basic frequency determined by the length of ME. A natural expectation is that the frequency of classical field corresponds to the generalized de Broglie frequency of dark photon and is thus $\hbar/\hbar_s$ times lower than for ordinary photons. In completely analogous manner de Broglie wave length is scaled up by $k = \hbar_s/\hbar$. Classically the decay of dark photons to visible photons would mean that an oscillation with frequency f inside topological light ray transforms to an oscillation of frequency f/k such that the intensity of the oscillation is scaled up by a factor k. Furthermore, the ME in question could naturally decompose into $1 < N_{cr} \leq 137$ ordinary photons in case that dark atoms are in question. Of course also MEs could decay to lower level MEs and this has an interpretation in terms of hierarchy of dark matters to be discussed next.

About the criterion for the transition increasing the value of Planck constant

An attractive assumption is that the transition to dark matter phase occurs when the interaction strength satisfies the criticality condition $Q_1Q_2\alpha \simeq 1$. A special case corresponds to self interaction with $Q_1 = Q_2$. This condition applies only to gauge interactions so that particles can be characterized by gauge charges. A more general characterization would be that transition occurs when perturbation theory ceases to converge. The criterion cannot be applied to phenomenological QFT description of strong force in terms of, say, pion exchange.

Some examples are in order to test this view.

1. Transition from perturbative phase in QCD to hadronic phase is the most obvious application. The identification of valence quarks and gluons as dark matter would predict for them QCD size ($k = 107$ space-time sheet) of about electron Compton length. This does not change the QCD cross sections in the lowest order perturbation theory but makes them excellent predictions. It also provides completely new view about how color force determines the nuclear strong force indeed manifesting itself as long ranged harmonic oscillator potential, the long range of which becomes manifest in case of neutron halos of size of 2.5×10^{-14} m [C3] . One can also understand tetraneutron in this framework. This criterion applies also in QCD plasma and explains the formation of liquid like color glass condensate detected in RHIC [C5]. A possible interpretation for QCD size would be as a length of the cylindrical magnetic walls defining the magnetic body associated with u and d type valence quarks, nucleons, and nuclei. There is no need to assume that conformal weights are complex in this phase.

2. QCD size of quark must be distinguished from the electromagnetic size of quark associated with $k = 113$ space-time sheets of u and d quarks and assignable to the height of the magnetic body and defining the length scale of join along boundaries contacts feeding quark charges to $k = 113$ space-time sheets.

3. In the case of atomic nuclei the criterion would naturally apply to the electromagnetic interaction energy of two nucleon clusters inside nucleus or to to self energy ($Q^2\alpha_{em} = 1$). Quite generally, the size of the electromagnetic $k = 113$ space-time sheet would increase by a $n_F = 2^k\prod_s F_s$, where F_s are different Fermat primes (the known ones being $3, 5, 17, 257, 2^{16}+1$), in the transition to large $\hbar$ phase. Especially interesting values of n_F seem to be of form $n_F = 2^{k11}$ and possibly also $n_F = 2^{k11}\prod_s F_s$. Similar criterion would apply in the plasma phase. Note that many free energy anomalies involve the formation of cold plasma [K77] .

The criterion would give in the case of single nucleus and plasma $Z \geq 12$ if the charges are within single space-time sheet. This is consistent with cold fusion involving Palladium nuclei [C7] . Since u and d quarks have $k = 113$, they both and thus both neutrons and protons could make a transition to large $\hbar$ phase. This is consistent with the selection rules of cold fusion since the production of ^3He involves a phase transition pnp$_d$ $\rightarrow$ pnp and the contraction of p_d to p is made un-probable by the Coulomb wall whereas the transition nnp$_d$ $\rightarrow$nnp producing tritium does not suffer from this restriction.

Strong and weak physics of nuclei would not be affected in the phase transition. Electromagnetic perturbative physics of nuclei would not be affected in the process in the lowest order in $\hbar$ (classical approximation) but the height of the Coulomb wall would be reduced by a factor $1/n_F$ by the increase in the electromagnetic size of the nucleus. Also Pd nuclei could make the transition and Pd nuclei could catalyze the transition in the case the deuterium nuclei.

6.8.5 Dark matter and exotic color and electro-weak interactions

The presence of classical electro-weak and color gauge fields in all length scales is an unavoidable prediction of TGD and the interpretation in terms of hierarchy of dark matters in some sense is also more or less unavoidable.

Does dark matter provide a correct interpretation of long ranged classical electro-weak gauge fields?

For two decades one of the basic interpretational challenges of TGD has been to understand how the un-avoidable presence of long range classical electro-weak gauge fields can be consistent with the small parity breaking effects in atomic and nuclear length scales. Also classical color gauge fields are predicted, and I have proposed that color qualia correspond to increments of color quantum numbers [K29] . The proposed model for screening cannot banish the unpleasant feeling that the screening cannot be complete enough to eliminate large parity breaking effects in atomic length scales so that one one must keep mind open for alternatives.

p-Adic length scale hypothesis suggests the possibility that both electro-weak gauge bosons and gluons can appear as effectively massless particles in several length scales and there indeed exists evidence that neutrinos appear in several scaled variants [C1] (for TGD based model see [K43]).

This inspires the working hypothesis that long range classical electro-weak gauge and gluon fields are correlates for light or massless dark electro-weak gauge bosons and gluons.

1. In this kind of scenario ordinary quarks and leptons could be essentially identical with their standard counterparts with electro-weak charges screened in electro-weak length scale so that the problems related to the smallness of atomic parity breaking would be trivially resolved.

2. In condensed matter blobs of size larger than neutrino Compton length (about 5 μm if $k = 169$ determines the p-adic length scale of condensed matter neutrinos) the situation could be different. Also the presence of dark matter phases with sizes and neutrino Compton lengths corresponding to the length scales $L(k)$, $k = 151, 157, 163, 167$ in the range 10 nm-2.5 μm are suggested by the number theoretic considerations (these values of k correspond to so called Gaussian Mersennes [K36]). Only a fraction of the condensed matter consisting of regions of size $L(k)$ need to be in the dark phase.

3. Dark quarks and leptons would have masses essentially identical to their standard model counterparts. Only the electro-weak boson masses which are determined by a different mechanism than the dominating contribution to fermion masses [K43, K43] would be small or vanishing.

4. The large parity breaking effects in living matter would be due to the presence of dark nuclei and leptons. Later the idea that super-fluidity corresponds to Z^0 super-conductivity will be discussed: it might be that also super-fluid phase corresponds to dark neutron phase.

The basic prediction of TGD based model of dark matter as a phase with a large value of Planck constant is the scaling up of various quantal length and time scales. A simple quantitative model for condensed matter with large value of $\hbar$ predicts that $\hbar$ is by a factor $\sim 2^{11}$ determined by the ratio of CP_2 length to Planck length larger than in ordinary phase meaning that the size of dark neutrons would be of order atomic size. In this kind of situation single order parameter would characterize the behavior of dark neutrinos and neutrons and the proposed model could apply as such also in this case.

Dark photon many particle states behave like laser beams decaying to ordinary photons by decoherence meaning a transformation of dark photons to ordinary ones. Also dark electro-weak bosons and gluons would be massless or have small masses determined by the p-adic length scale in question. The decay products of dark electro-weak gauge bosons would be ordinary electro-weak bosons decaying rapidly via virtual electro-weak gauge boson states to ordinary leptons. Topological light rays ("massless extremals") for which all classical gauge fields are massless are natural space-time correlates for the dark boson laser beams. Obviously this means that the basic difference between the chemistries of living and non-living matter would be the absence of electro-weak symmetry breaking in living matter (which does not mean that elementary fermions would be massless). If both nuclear neutrons and neutrinos are in dark phase, it is possible to achieve a rather complete local cancelation of Z^0 charge density.

The model for neutrino screening was developed years before the ideas about the identification of the dark matter emerged. The generalization of the discussion to the case of dark matter option should be rather trivial and is left to the reader as well as generalization of the discussion of the effects of long range Z^0 force on bio-chemistry.

Criterion for the presence of exotic electro-weak bosons and gluons

Classical gauge fields directly are space-time correlates of quantum states. The gauge fields associated with massless extremals ("topological light rays") decompose to free part and a part having non-vanishing divergence giving rise to a light-like Abelian gauge current. Free part would correspond to Bose-Einstein condensates and current would define a coherent state of dark photons.

The dimension D of the CP_2 projection of the space-time sheet serves as a criterion for the presence of long ranged classical electro-weak and gluon fields. D also classifies the (possibly asymptotic) solutions of field equations [K8] .

1. For $D = 2$ induced gauge fields are Abelian and induced Kähler form vanishes for vacuum extremals: in this case classical em and Z^0 fields are proportional to each other. The non-vanishing Kähler field implies that induced gluon fields are non-vanishing in general. This raises the question whether long ranged color fields and by quantum classical correspondence also long ranged QCD accompany non-vacuum extremals in all length scales. This makes one wonder whether color confinement is possible at all and whether scaled down variants of QCD appear in all length scales.

   The possibility to add constants to color Hamiltonians appearing in the expression of the classical color gauge fields allows to have vanishing color charges in the case of an arbitrary space-time sheet. The requirement that color quantum numbers of the generator vanish allows to add the constant only to the Hamiltonians of color hyper charge and isospin so that for $D = 2$ extremals color charges can be made vanishing. This might allow to understand how color confinement is consistent with long ranged induced Kähler field.

2. For $D \geq 3$ all classical long ranged electro-weak fields and non-Abelian color fields are present. This condition is satisfied when electric and magnetic fields are not orthogonal and the instanton density $A \wedge J$ for induced Kähler form is non-vanishing. The rather strong conclusion is that in length scales in which exotic electro-weak bosons are not present, one has $D = 2$ and gauge fields are Abelian and correspond trivially to fixed points of renormalization group realized as a hydrodynamic flow at space-time sheets [K2] .

Quantum classical correspondence suggests the existence of electro-weak gauge bosons with mass scale determined by the size of the space-time sheets carrying classical long range electro-weak fields. This would mean the existence of new kind of gauge bosons.

The obvious objection is that the existence of these gauge bosons would be reflected in the decay widths of intermediate gauge bosons. The remedy of the problem is based on the notion of space-time democracy suggested strongly by the fact that the interactions between space-time sheets possessing different p-adic topologies proceed with very slow rates simply because the number of common rational (algebraic points of partonic 2-surfaces appearing in the vertex is small.

For light exotic electro-weak bosons also the corresponding leptons and quarks would possess a large weak space-time sheet but lack the ordinary weak partonic 2-surface so that there would be no direct coupling to electro-weak gauge bosons. These space-time sheets are dark in weak sense but need not have a large value of $\hbar$. This picture implies the notion of partial darkness since any space-time sheets with different ordinary of Gaussian primes are dark with respect to each other.

Do Gaussian Mersennes define a hierarchy of dark electro-weak physics?

Gaussian Mersennes are defined as Gaussian primes of form $g_n = (1+i)^n - 1$, where n must be prime. They have norm squared $g\overline{g} = 2^n - 1$. The list of the first Gaussian Mersennes corresponds to the following values of n.

2, 3, 5, 7, 11, 19, 29, 47, 73, 79, 113, 151, 157, 163, 167, 239, 241, 283, 353, 367, 379, 457, 997, 1367, 3041, 10141, 14699, 27529, 49207, 77291, 85237, 106693, 160423 and 203789.

The Gaussian primes $k = 113, 151, 157, 163, 167$ correspond to length scales which are of most obvious interest but in TGD framework one cannot exclude the twin prime $239, 241$ corresponds to length scales $L(k) \simeq 160$ km and 320 km. Also larger primes could be of relevant for bio-systems and consciousness. Also the secondary and higher length scales associated with $k < 113$ could be of importance and their are several length scales of this kind in the range of biologically interesting length scales. Physics and biology inspired considerations suggests that particular Gaussian primes correspond to a particular kind of exotic matter, possibly also to large $\hbar$ phase.

$k = 113$ corresponds to the electromagnetic length scale of u and d quarks and nuclear p-adic length scale. For dark matter these length scales are scaled up by a factor $\sim 2^{11}n$, where n is an integer. For $k = 113$ one obtains atomic length scale .8 A for $n = 1$. $k = 151, 153, 163, 167$ correspond to biologically important p-adic length scales varying in the range 10 nm-2.5 μm with the scaled up length scales varying in the range 2 μm- 5 mm.

On basis of biological considerations (large parity breaking in living matter) there is a temptation to assign to these length scales a scaled down copy of electro-weak physics and perhaps also of color physics. The mechanism giving rise to these states would be a phase transition transforming the ordinary $k = 89$ Mersenne of weak space-time sheets to a Gaussian Mersenne and thus increasing its size dramatically.

If given space-time sheet couples considerably only to space-time sheets characterized by same prime or Gaussian prime, the bosons of these physics do not couple directly to ordinary particles, and one avoids consistency problems due to the presence of new light particles (consider only the decay widths of intermediate gauge bosons [K47]) even in the case that the loss of asymptotic freedom is not assumed.

A question arises about the interpretation of structures of the predicted size. The strong interaction size of u and d quarks, hadrons, and nuclei is smaller than $L(k = 113) \simeq 2 \times 10^{-4}$ m for even heaviest nuclei if one accepts the formula $R \sim A^{1/3} \times 1.5 \times 10^{-15}$ m. A natural interpretation for this length scale would be as the size of the field body/magnetic body of system defined by its topologically quantized gauge fields/magnetic parts of gauge fields. The (possibly dark) p-adic length scale characterizes also the lengths of join along boundaries bonds feeding gauge fluxes from elementary particle to the space-time sheet in question. The delocalization due these join along boundaries bonds in p-adic length scale in question would determine the scale of the contribution to the mass squared of the system as predicted by p-adic thermodynamics.

6.8.6 Dark matter and living matter

The hypothesis that the value of $\hbar$ is dynamical, quantized and becomes large at the verge of a transition to a non-perturbative phase in the ordinary sense of the word has fascinating implications. In particular, dark matter, would correspond to a large value of $\hbar$ and could be responsible for the properties of the living matter. In order to test the idea experimentally, a more concrete model for the interaction of ordinary matter and dark matter must be developed and here of course experimental input and the consistency with the earlier quantum model of living matter is of considerable help.

Hierarchy of dark matters and hierarchy of minds

The notion of dark matter is only relative concept in the sense that dark matter is invisible from the point of view of the ordinary matter. One can imagine an entire hierarchy of dark matter structures corresponding to the hierarchy of space-time sheets for which p-adic length scales differ by a factor $1/v_0 \sim 2^{11}$. The BE condensates of N_{cr} ordinary matter particles would serve as dynamical units for "dark dark matter" invisible to the dark matter. The above discussed criticality criterion can be applied at all levels of the hierarchy to determine the value of the dynamical interaction strength for which BE condensates of BE condensates are formed.

This hierarchy would give rise to a hierarchy of the values of $\hbar_n/\hbar$ coming as powers of v_0^{-n} as well as a hierarchy of wavelengths with same energy coming as powers or v_0^n. For zero point kinetic energies proportional to $\hbar^2$ this hierarchy would come in powers of v_0^{-2n}, for magnetic interaction energies proportional to $\hbar$ the hierarchy would come in powers v_0^{-n} whereas for atomics energy levels the hierarchy would come in powers of v_0^{2n} (assuming that this hierarchy makes sense).

The most interesting new physics would emerge from the interaction between length scales differing by powers of v_0 made possible by the decay of BE condensates of dark photons to ordinary photons having wavelength shorter by a factor $\sim v_0$. This interaction could provide the royal road to the quantitative understanding how living matter manages to build up extremely complex coherent interactions between different length and time scales.

In the time domain dark matter hierarchy could allow to understand how moments of consciousness organize to a hierarchy with respect to the time scales of moment of consciousness coming as 2^{11k} multiples of CP_2 time scale. Even human life span could be seen as single moment of consciousness at $k = 14^{th}$ level of the dark matter hierarchy whereas single day in human life would correspond to $k = 12$.

Realization of intentional action and hierarchy of dark matters

How long length scales are able to control the dynamics in short length scales so that the extremely complex process extending down to atomic length scales realizing my intention to write this word is possible. This question has remained without a convincing answer in the recent day biology and there strong objections against the idea that this process is planned and initiated at neuronal level.

I have proposed a concrete mechanism for the realization of intentional action in terms of time mirror mechanism involving the emission of negative energy photons and proceeding as a cascade in a reversed direction of geometric time from long to short length scales [K81] . This cascade would induce as a reaction analogous processes proceeding in the normal direction of geometric time as a response and would correspond to the neural correlates of intentional action in very general sense of the word.

The counterparts for the negative energy signals propagating to the geometric past would be phase conjugate (negative energy) laser beams identifiable as Bose-Einstein condensates of dark photons. In the time reflection these beams would transform to positive energy dark matter photons eventually decaying to ordinary photons. The space-time correlate would be MEs decaying into MEs and eventually to CP_2 type extremals representing ordinary photons.

The realization of intentional action as desires of boss expressed to lower level boss would naturally represented the decay of the phase conjugate dark laser beam to lower level laser beams decaying to lower level laser beams decaying to... . This would represent the desire for action whereas the time reflection at some level would represent the realization desire as stepwise decay to lower level laser beams and eventually to ordinary photons. The strong quantitative prediction would be that these levels correspond to a length and time scale hierarchies coming in powers of $1/v_0 \sim 2^{11}$.

Wave-length hierarchy, coherent metabolism, and proton-electron mass ratio

The fact that a given wavelength length corresponds to energies related to each other by a scaling with powers of v_0 provides a mechanism allowing to transfer energy from long to short long scales by a de-coherence occurring either in the standard or reversed direction of geometric time. De-coherence in the reversed direction of time would be associated with mysterious looking processes like self-assembly allowing thus an interpretation as a normal decay process in reversed time direction.

It is perhaps not an accident that the value of $v_0 \simeq 4.6 \times 10^{-4}$ is not too far from the ratio of $m_e/m_p \simeq 5.3 \times 10^{-4}$ giving the ratio of zero point kinetic energies of proton and electron for a given space-time sheet. This co-incidence could in principle make possible a metabolic mechanism in which dark protons and ordinary electrons co-operate in the sense that dark protons generate dark photon BE condensates with wave length λ transforming to ordinary photons with wavelength $v_0\lambda$ absorbed by ordinary electrons.

Some examples are in order to illustrate these ideas.

1. As already found, in the case of dark atoms the scaling of binding energies as $1/\hbar^2$ allows the coupling of ~ 9 cm scale of brain hemisphere with the length scale ~ 50 μm of large neuron. $N_{cr} \leq 137$ ordinary IR photons would be emitted in single burst and interacting with neuron.

2. For a non-relativistic particle in a box of size L the energy scale is given by $E_1 = \hbar^2\pi^2/2mL^2$ so that the visible photons emitted would have energy scaled up by a factor $(\hbar_s/\hbar)^2 \simeq 4\times 10^6$. The collective dropping of N_{cr} dark protons to larger space-time sheet would liberate a laser beam of dark photons with energy equal to the liberated zero point kinetic energy. For instance, for

the p-adic length scale $L(k = 159 = 3 \times 53) \simeq .63\ \mu$m this process would generate laser beam of IR dark photons with energy $\sim .5$ eV also generated by the dropping of ordinary protons from $k = 137$ atomic space-time sheet. There would thus be an interaction between dark protons in cell length scale and ordinary protons in atomic length scale. For instance, the dropping of dark protons in cell length scale could induce driving of protons back to the atomic space-time sheet essential for the metabolism [K37] . Similar argument applies to electrons with the scale of the zero point kinetic energy about 1 keV.

3. If the energy spectrum associated with the conformational degrees of freedom of proteins, which corresponds roughly to a frequency scale of 10 GHz remains also invariant in the phase transition to dark protein state, coherent emissions of dark photons with microwave wave lengths would generate ordinary infrared photons. For instance, metabolic energy quanta of $\sim .5$ eV could result from macroscopic Bose-Einstein condensates of 58 GHz dark photons resulting from the oscillations in the conformational degrees of freedom of dark proteins. A second option is that the conformal energies are scaled by $\hbar_s/\hbar$ (ω would remain invariant). In this case these coherent excitations would generate ordinary photons with energy of about 1 keV able to drive electrons back to the atomic $k = 137$ space-time sheet.

4. Since magnetic flux tubes have a profound role in TGD inspired theory of consciousness, it is interesting to look also for the behavior of effective magnetic transition energies in the phase transition to the dark matter phase. This transition increases the scale of the magnetic interaction energy so that anomalously large magnetic spin splitting $\hbar_s eB/m$ in the external magnetic field could serve as a signature of dark atoms. The dark transition energies relate by a factor $\hbar_s/\hbar$ to the ordinary magnetic transition energies.

For instance, in the magnetic field of Earth with a nominal value $.5\times 10^{-4}$ Tesla dark electron cyclotron frequency is 6×10^5 Hz and corresponds to ordinary microwave photon with frequency ~ 1.2 GHz and wavelength $\lambda \simeq 25$ cm. For proton the cyclotron frequency of 300 Hz would correspond to energy of ordinary photon with frequency of 6×10^5 Hz and could induce electronic cyclotron transitions and spin flips in turn generating for instance magneto-static waves.

It is easy to imagine a few step dark matter hierarchy connecting EEG frequencies of dark matter with frequencies of visible light for ordinary photons. This kind of hierarchy would give considerable concreteness for the notion of magnetic body having size scale of Earth.

A connection with the scaling law of homeopathy

The value of the parameter $1/v_0 \simeq 2083$ is essentially the ratio of CP_2 radius and Planck length scale (as also the ratio of Compton lengths of electron and proton) and rather near to $2^{11} = 2048$. Interestingly, much larger number $2 \times 10^{11} \simeq 25 \times 2^{33}$ appears in the simplest form for what I have christened the scaling law of homeopathy [K32] . This rule has been proposed on basis of experimental findings [I32] but has no convincing theoretical justification. The scaling law of homeopathy states that high frequency em radiation transforms to a low frequency radiation and vice versa preferably with the frequency ratio $f_{high}/f_{low} \simeq 2 \times 10^{11}$.

In [K32] I have discussed some mechanisms for the transformation of high energy photons to low energy photons consistent with the rule and proposed a generalization of the rule based on p-adic length scale hypothesis. For instance, high energy visible photons of frequency f could induce an excitation of the receiving system having same frequency, propagating with velocity $\beta = v/c \simeq 10^{-11}/2$, and having wave length equal $\lambda_0 = f/v = \lambda/\beta$. This excitation would in turn couple to photons of wavelength λ_0 and frequency $f_0 = \beta f$.

A much deeper explanation for the scaling law of homeopathy is based on the quantization of Planck constant. Number theoretical arguments suggest a general formula for the allowed values of λ [K25] as $\lambda = n$ where n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [K84] . The values of n for which quantum phase is expressible using only iterated square root operation are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. $n = 2^{11}$ obviously satisfies this condition. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17, F_3 = 257, F_4 = 2^{16} + 1$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales.

The scaling factor 2×10^{11} corresponds with 1.5 per cent accuracy to the integer $n_F = 2^{36} \times 3 \simeq 2.03 \times 10^{11}$ defining a Fermat polygon. This suggests an interpretation in terms of a decay of dark photon with a given wave-length to a bundle of n_F ordinary photons with the same wavelength. The energy of the dark photon would be by a factor n_F higher. This process could serve as an effective tool of bio-control. Dark photon could also transform to an ordinary photon with wavelength shorter by factor $1/n_F$. There is a lot of evidence that the powers of $n = 2^{11}$ define preferred scalings of $\hbar$: n_F corresponds to $n_F = 2^{3\times 11} \times 24$ which suggests that also the scale factors $n_F = 2^{k\times 11} \times 24$ could be favored. Quite generally, integers n_F defining Fermat polygons are a reasonable guess for the generalization of the scaling law of homeopathy and the search for these scaling factors could provide an experimental means of identifying the values of Planck constant relevant for living matter.

The time units of everyday life could reflect the properties of the dark matter hierarchy responsible for the control of living matter, in particular those of the sub-hierarchy defined by Fermat polygons. Indeed, one year corresponds to $n_F = 4 \times 3$ months, one month to $n_F = 2 \times 3 \times 5$ days, one day to $n_F = 8 \times 3$ hours, one hour to $n_F = 60 = 4 \times 3 \times 5$ minutes, and one minute to $n_F = 60$ seconds.

A connection with bio-photons

The biologically active radiation at UV energies was first discovered by Russian researcher Gurwitz using a very elegant experimental arrangement [I19] . Gurwitz christened this radiation mitogenetic radiation since it was especially intense during the division of cell.

A direct proof for the biological activity of mitogenetic radiation consisted of a simple experiment in which either quartz or glass plate was put between two samples. The first sample contained already growing onion roots whereas the second sample contained roots which did not yet grow. In the case of quartz plate no stimulation of growth occurred unlike for glass plate. Since quartz is not transparent to UV light whereas the ordinary glass is, the conclusion was that the stimulation of growth is due to UV light.

The phenomenon was condemned by skeptics as a pseudo science and only the modern detection technologies demonstrated its existence [I11] , and mitogenetic radiation became also known as bio-photons (the TGD based model for bio-photons is discussed in [K37]). Bio-photons form a relatively featureless continuum at visible wavelengths continuing also to UV energies, and are believed to be generated by DNA or at least to couple with DNA. The emission of bio-photons is most intense from biologically active organisms and the irradiation by UV light induces an emission of mitogenetic radiation by a some kind of amplification mechanism. It has been suggested that bio-photons represent some kind of leakage of a coherent light emitted by living matter.

According to Russian researcher V. M. Injushin [I25] , mitochondrios emit red light at wavelengths 620 nm and 680 nm corresponding to energies 2 eV and 1.82 eV. According to the same source, the nucleus of cell sends UV light at wavelengths 190, 280 and 330 nm corresponding to the energies 6.5, 4.4 and 3.8 eV. The interpretation as a kind of leakage of coherent light would conform with the identification in terms of BE condensates of dark photons with $\hbar_s/\hbar \simeq 2^{11}$ emitted at wavelengths varying in the range $.3 - 1.25$ mm and decaying to photons with energies visible and UV range. For instance, 1.82 eV radiation corresponds to a dark photon wave length of 1.4 mm for $v_0(eff) = 2^{-11}$. A bio-control of ordinary bio-matter at sub-cellular level performed by dark matter from the millimeter length scale could be in question. This proposal conforms with the fact that 1 mm defines the scale of the blobs of neurons serving as structural units in cortex.

The analysis of Kirlian photographs has shown that the pattern of visible light emitted by various body parts, for instance ear, code information about other body parts [I18] . These bio-holograms for which a general model is discussed in [K10] could be realized as dark photon laser beams.

In phantom DNA effect [**?**] a chamber containing DNA is irradiated with a visible laser light and the DNA generates as a response coherent visible radiation at same wavelength. Strangely enough, the chamber continues to emit weak laser light even after the removal of DNA. This effect could be due to the decay of a dark photon BE condensate remaining in the chamber. Also the findings of Peter Gariaev [I16] about the effects of visible laser light on DNA, in particular the stimulated emission of radio waves in kHz-MHz frequency range might also relate to dark photons somehow.

Chapter 1

Appendix

A-1 Basic properties of CP_2

A-1.1 CP_2 as a manifold

CP_2, the complex projective space of two complex dimensions, is obtained by identifying the points of complex 3-space C^3 under the projective equivalence

$$(z^1, z^2, z^3) \equiv \lambda(z^1, z^2, z^3) \ . \tag{A-1.1}$$

Here λ is any non-zero complex number. Note that CP_2 can be also regarded as the coset space $SU(3)/U(2)$. The pair z^i/z^j for fixed j and $z^i \neq 0$ defines a complex coordinate chart for CP_2. As j runs from 1 to 3 one obtains an atlas of three oordinate charts covering CP_2, the charts being holomorphically related to each other (e.g. CP_2 is a complex manifold). The points $z^3 \neq 0$ form a subset of CP_2 homeomorphic to R^4 and the points with $z^3 = 0$ a set homeomorphic to S^2. Therefore CP_2 is obtained by "adding the 2-sphere at infinity to R^4".

Besides the standard complex coordinates $\xi^i = z^i/z^3$, $i = 1, 2$ the coordinates of Eguchi and Freund [A25] will be used and their relation to the complex coordinates is given by

$$\begin{aligned} \xi^1 &= z + it \ , \\ \xi^2 &= x + iy \ . \end{aligned} \tag{A-1.2}$$

These are related to the "spherical coordinates" via the equations

$$\begin{aligned} \xi^1 &= rexp(i\frac{(\Psi + \Phi)}{2})cos(\frac{\Theta}{2}) \ , \\ \xi^2 &= rexp(i\frac{(\Psi - \Phi)}{2})sin(\frac{\Theta}{2}) \ . \end{aligned} \tag{A-1.3}$$

The ranges of the variables r, Θ, Φ, Ψ are $[0, \infty], [0, \pi], [0, 4\pi], [0, 2\pi]$ respectively.

Considered as a real four-manifold CP_2 is compact and simply connected, with Euler number Euler number 3, Pontryagin number 3 and second $b = 1$.

A-1.2 Metric and Kähler structure of CP_2

In order to obtain a natural metric for CP_2, observe that CP_2 can be thought of as a set of the orbits of the isometries $z^i \rightarrow exp(i\alpha)z^i$ on the sphere S^5: $\sum z^i \bar{z}^i = R^2$. The metric of CP_2 is obtained by projecting the metric of S^5 orthogonally to the orbits of the isometries. Therefore the distance between the points of CP_2 is that between the representative orbits on S^5.

The line element has the following form in the complex coordinates

$$ds^2 = g_{a\bar{b}} d\xi^a d\bar{\xi}^b \ , \tag{A-1.4}$$

where the Hermitian, in fact Kähler metric $g_{a\bar{b}}$ is defined by

$$g_{a\bar{b}} = R^2 \partial_a \partial_{\bar{b}} K \ , \tag{A-1.5}$$

where the function K, Kähler function, is defined as

$$\begin{aligned} K &= log(F) \ , \\ F &= 1 + r^2 \ . \end{aligned} \tag{A-1.6}$$

The Kähler function for S^2 has the same form. It gives the S^2 metric $dzd\bar{z}/(1+r^2)^2$ related to its standard form in spherical coordinates by the coordinate transformation $(r, \phi) = (tan(\theta/2), \phi)$.

The representation of the CP_2 metric is deducible from S^5 metric is obtained by putting the angle coordinate of a geodesic sphere constant in it and is given

$$\frac{ds^2}{R^2} = \frac{(dr^2 + r^2\sigma_3^2)}{F^2} + \frac{r^2(\sigma_1^2 + \sigma_2^2)}{F} \ , \tag{A-1.7}$$

where the quantities σ_i are defined as

$$\begin{aligned} r^2\sigma_1 &= Im(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_2 &= -Re(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_3 &= -Im(\xi^1 d\bar{\xi}^1 + \xi^2 d\bar{\xi}^2) \ . \end{aligned} \tag{A-1.8}$$

R denotes the radius of the geodesic circle of CP_2. The vierbein forms, which satisfy the defining relation

$$s_{kl} = R^2 \sum_A e_k^A e_l^A \ , \tag{A-1.9}$$

are given by

$$\begin{aligned} e^0 &= \tfrac{dr}{F} \ , \quad & e^1 &= \tfrac{r\sigma_1}{\sqrt{F}} \ , \\ e^2 &= \tfrac{r\sigma_2}{\sqrt{F}} \ , \quad & e^3 &= \tfrac{r\sigma_3}{F} \ . \end{aligned} \tag{A-1.10}$$

The explicit representations of vierbein vectors are given by

$$\begin{aligned} e^0 &= \tfrac{dr}{F} \ , & e^1 &= \tfrac{r(sin\Theta cos\Psi d\Phi + sin\Psi d\Theta)}{2\sqrt{F}} \ , \\ e^2 &= \tfrac{r(sin\Theta sin\Psi d\Phi - cos\Psi d\Theta)}{2\sqrt{F}} \ , & e^3 &= \tfrac{r(d\Psi + cos\Theta d\Phi)}{2F} \ . \end{aligned} \tag{A-1.11}$$

The explicit representation of the line element is given by the expression

$$ds^2/R^2 = \frac{dr^2}{F^2} + \frac{r^2}{4F^2}(d\Psi + cos\Theta d\Phi)^2 + \frac{r^2}{4F}(d\Theta^2 + sin^2\Theta d\Phi^2) \ . \tag{A-1.12}$$

The vierbein connection satisfying the defining relation

$$de^A = -V^A_B \wedge e^B \ , \tag{A-1.13}$$

is given by

$$\begin{array}{lllllll} V_{01} & = & -\frac{e^1}{r} \ , & V_{23} & = & \frac{e^1}{r} \ , \\ V_{02} & = & -\frac{e^2}{r} \ , & V_{31} & = & \frac{e^2}{r} \ , \\ V_{03} & = & (r-\frac{1}{r})e^3 \ , & V_{12} & = & (2r+\frac{1}{r})e^3 \ . \end{array} \tag{A-1.14}$$

The representation of the covariantly constant curvature tensor is given by

$$\begin{array}{llllll} R_{01} & = & e^0 \wedge e^1 - e^2 \wedge e^3 \ , & R_{23} & = & e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ R_{02} & = & e^0 \wedge e^2 - e^3 \wedge e^1 \ , & R_{31} & = & -e^0 \wedge e^2 + e^3 \wedge e^1 \ , \\ R_{03} & = & 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , & R_{12} & = & 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ . \end{array} \tag{A-1.15}$$

Metric defines a real, covariantly constant, and therefore closed 2-form J

$$J = -ig_{a\bar{b}}d\xi^a d\bar{\xi}^b \ , \tag{A-1.16}$$

the so called Kähler form. Kähler form J defines in CP_2 a symplectic structure because it satisfies the condition

$$J^k_{\ r} J^{rl} = -s^{kl} \ . \tag{A-1.17}$$

The form J is integer valued and by its covariant constancy satisfies free Maxwell equations. Hence it can be regarded as a curvature form of a $U(1)$ gauge potential B carrying a magnetic charge of unit $1/2g$ (g denotes the gauge coupling). Locally one has therefore

$$J = dB \ , \tag{A-1.18}$$

where B is the so called Kähler potential, which is not defined globally since J describes homological magnetic monopole.

It should be noticed that the magnetic flux of J through a 2-surface in CP_2 is proportional to its homology equivalence class, which is integer valued. The explicit representations of J and B are given by

$$\begin{array}{lll} B & = & 2re^3 \ , \\ J & = & 2(e^0 \wedge e^3 + e^1 \wedge e^2) = \frac{r}{F^2}dr \wedge (d\Psi + cos\Theta d\Phi) + \frac{r^2}{2F}sin\Theta d\Theta d\Phi \ . \end{array} \tag{A-1.19}$$

The vierbein curvature form and Kähler form are covariantly constant and have in the complex coordinates only components of type (1,1).

Useful coordinates for CP_2 are the so called canonical coordinates in which Kähler potential and Kähler form have very simple expressions

$$\begin{array}{lll} B & = & \sum_{k=1,2} P_k dQ_k \ , \\ J & = & \sum_{k=1,2} dP_k \wedge dQ_k \ . \end{array} \tag{A-1.20}$$

The relationship of the canonical coordinates to the "spherical" coordinates is given by the equations

$$\begin{aligned} P_1 &= -\frac{1}{1+r^2} \ , \\ P_2 &= \frac{r^2 cos\Theta}{2(1+r^2)} \ , \\ Q_1 &= \Psi \ , \\ Q_2 &= \Phi \ . \end{aligned} \tag{A-1.21}$$

A-1.3 Spinors in CP_2

CP_2 doesn't allow spinor structure in the conventional sense [A22] . However, the coupling of the spinors to a half odd multiple of the Kähler potential leads to a respectable spinor structure. Because the delicacies associated with the spinor structure of CP_2 play a fundamental role in TGD, the arguments of Hawking are repeated here.

To see how the space can fail to have an ordinary spinor structure consider the parallel transport of the vierbein in a simply connected space M. The parallel propagation around a closed curve with a base point x leads to a rotated vierbein at x: $e^A = R^A_B e^B$ and one can associate to each closed path an element of $SO(4)$.

Consider now a one-parameter family of closed curves $\gamma(v) : v \in (0,1)$ with the same base point x and $\gamma(0)$ and $\gamma(1)$ trivial paths. Clearly these paths define a sphere S^2 in M and the element $R^A_B(v)$ defines a closed path in $SO(4)$. When the sphere S^2 is contractible to a point e.g., homologically trivial, the path in $SO(4)$ is also contractible to a point and therefore represents a trivial element of the homotopy group $\Pi_1(SO(4)) = Z_2$.

For a homologically nontrivial 2-surface S^2 the associated path in $SO(4)$ can be homotopically nontrivial and therefore corresponds to a nonclosed path in the covering group Spin(4) (leading from the matrix 1 to -1 in the matrix representation). Assume this is the case.

Assume now that the space allows spinor structure. Then one can parallel propagate also spinors and by the above construction associate a closed path of Spin(4) to the surface S^2. Now, however this path corresponds to a lift of the corresponding $SO(4)$ path and cannot be closed. Thus one ends up with a contradiction.

From the preceding argument it is clear that one could compensate the non-allowed -1- factor associated with the parallel transport of the spinor around the sphere S^2 by coupling it to a gauge potential in such a way that in the parallel transport the gauge potential introduces a compensating -1-factor. For a $U(1)$ gauge potential this factor is given by the exponential $exp(i2\Phi)$, where Φ is the magnetic flux through the surface. This factor has the value -1 provided the $U(1)$ potential carries half odd multiple of Dirac charge $1/2g$. In case of CP_2 the required gauge potential is half odd multiple of the Kähler potential B defined previously. In the case of $M^4 \times CP_2$ one can in addition couple the spinor components with different chiralities independently to an odd multiple of $B/2$.

A-1.4 Geodesic sub-manifolds of CP_2

Geodesic sub-manifolds are defined as sub-manifolds having common geodesic lines with the imbedding space. As a consequence the second fundamental form of the geodesic manifold vanishes, which means that the tangent vectors h^k_α (understood as vectors of H) are covariantly constant quantities with respect to the covariant derivative taking into account that the tangent vectors are vectors both with respect to H and X^4.

In [A14] a general characterization of the geodesic sub-manifolds for an arbitrary symmetric space G/H is given. Geodesic sub-manifolds are in 1-1-correspondence with the so called Lie triple systems of the Lie-algebra g of the group G. The Lie triple system t is defined as a subspace of g characterized by the closedness property with respect to double commutation

$$[X,[Y,Z]] \in t \ \text{ for } \ X,Y,Z \in t \ . \tag{A-1.22}$$

$SU(3)$ allows, besides geodesic lines, two nonequivalent (not isometry related) geodesic spheres. This is understood by observing that $SU(3)$ allows two nonequivalent $SU(2)$ algebras corresponding to subgroups $SO(3)$ (orthogonal 3×3 matrices) and the usual isospin group $SU(2)$. By taking any subset of two generators from these algebras, one obtains a Lie triple system and by exponentiating this system, one obtains a 2-dimensional geodesic sub-manifold of CP_2.

Standard representatives for the geodesic spheres of CP_2 are given by the equations

$$S^2_I \ : \ \xi^1 = \bar{\xi}^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Psi = 0) \ ,$$

$$S^2_{II} \ : \ \xi^1 = \xi^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Phi = 0) \ .$$

The non-equivalence of these sub-manifolds is clear from the fact that isometries act as holomorphic transformations in CP_2. The vanishing of the second fundamental form is also easy to verify. The first geodesic manifold is homologically trivial: in fact, the induced Kähler form vanishes identically for S^2_I. S^2_{II} is homologically nontrivial and the flux of the Kähler form gives its homology equivalence class.

A-2 CP_2 geometry and standard model symmetries

A-2.1 Identification of the electro-weak couplings

The delicacies of the spinor structure of CP_2 make it a unique candidate for space S. First, the coupling of the spinors to the $U(1)$ gauge potential defined by the Kähler structure provides the missing $U(1)$ factor in the gauge group. Secondly, it is possible to couple different H-chiralities independently to a half odd multiple of the Kähler potential. Thus the hopes of obtaining a correct spectrum for the electromagnetic charge are considerable. In the following it will be demonstrated that the couplings of the induced spinor connection are indeed those of the GWS model [B14] and in particular that the right handed neutrinos decouple completely from the electro-weak interactions.

To begin with, recall that the space H allows to define three different chiralities for spinors. Spinors with fixed H-chirality $e=\pm 1$, CP_2-chirality l,r and M^4-chirality L,R are defined by the condition

$$\begin{aligned} \Gamma\Psi &= e\Psi \ , \\ e &= \pm 1 \ , \end{aligned} \qquad \text{(A-2.1)}$$

where Γ denotes the matrix $\Gamma_9 = \gamma_5\times\gamma_5$, $1\times\gamma_5$ and $\gamma_5\times 1$ respectively. Clearly, for a fixed H-chirality CP_2- and M^4-chiralities are correlated.

The spinors with H-chirality $e=\pm 1$ can be identified as quark and lepton like spinors respectively. The separate conservation of baryon and lepton numbers can be understood as a consequence of generalized chiral invariance if this identification is accepted. For the spinors with a definite H-chirality one can identify the vielbein group of CP_2 as the electro-weak group: $SO(4) = SU(2)_L\times SU(2)_R$.

The covariant derivatives are defined by the spinorial connection

$$A = V + \frac{B}{2}(n_+ 1_+ + n_- 1_-) \ . \qquad \text{(A-2.2)}$$

Here V and B denote the projections of the vielbein and Kähler gauge potentials respectively and $1_{+(-)}$ projects to the spinor H-chirality $+(-)$. The integers $n_\pm$ are odd from the requirement of a respectable spinor structure.

The explicit representation of the vielbein connection V and of B are given by the equations

$$\begin{array}{lllllll} V_{01} &=& -\frac{e^1}{r} \ , & V_{23} &=& \frac{e^1}{r} \ , \\ V_{02} &=& -\frac{e^2}{r} \ , & V_{31} &=& \frac{e^2}{r} \ , \\ V_{03} &=& (r-\frac{1}{r})e^3 \ , & V_{12} &=& (2r+\frac{1}{r})e^3 \ , \end{array} \qquad \text{(A-2.3)}$$

and

$$B = 2re^3 \ , \qquad \text{(A-2.4)}$$

respectively. The explicit representation of the vielbein is not needed here.

Let us first show that the charged part of the spinor connection couples purely left handedly. Identifying Σ_3^0 and Σ_2^1 as the diagonal (neutral) Lie-algebra generators of $SO(4)$, one finds that the charged part of the spinor connection is given by

$$A_{ch} = 2V_{23}I_L^1 + 2V_{13}I_L^2 \ , \tag{A-2.5}$$

where one have defined

$$\begin{aligned} I_L^1 &= \frac{(\Sigma_{01} - \Sigma_{23})}{2} \ , \\ I_L^2 &= \frac{(\Sigma_{02} - \Sigma_{13})}{2} \ . \end{aligned} \tag{A-2.6}$$

A_{ch} is clearly left handed so that one can perform the identification

$$W^{\pm} = \frac{2(e^1 \pm ie^2)}{r} \ , \tag{A-2.7}$$

where $W^{\pm}$ denotes the charged intermediate vector boson.

Consider next the identification of the neutral gauge bosons γ and Z^0 as appropriate linear combinations of the two functionally independent quantities

$$\begin{aligned} X &= re^3 \ , \\ Y &= \frac{e^3}{r} \ , \end{aligned} \tag{A-2.8}$$

appearing in the neutral part of the spinor connection. We show first that the mere requirement that photon couples vectorially implies the basic coupling structure of the GWS model leaving only the value of Weinberg angle undetermined.

To begin with let us define

$$\begin{aligned} \bar{\gamma} &= aX + bY \ , \\ \bar{Z}^0 &= cX + dY \ , \end{aligned} \tag{A-2.9}$$

where the normalization condition

$$ad - bc = 1 \ ,$$

is satisfied. The physical fields γ and Z^0 are related to $\bar{\gamma}$ and $\bar{Z}^0$ by simple normalization factors.

Expressing the neutral part of the spinor connection in term of these fields one obtains

$$\begin{aligned} A_{nc} &= [(c+d)2\Sigma_{03} + (2d-c)2\Sigma_{12} + d(n_+1_+ + n_-1_-)]\bar{\gamma} \\ &+ [(a-b)2\Sigma_{03} + (a-2b)2\Sigma_{12} - b(n_+1_+ + n_-1_-)]\bar{Z}^0 \ . \end{aligned} \tag{A-2.10}$$

Identifying Σ_{12} and $\Sigma_{03} = 1 \times \gamma_5\Sigma_{12}$ as vectorial and axial Lie-algebra generators, respectively, the requirement that γ couples vectorially leads to the condition

$$c = -d \ . \tag{A-2.11}$$

Using this result plus previous equations, one obtains for the neutral part of the connection the expression

$$A_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \tag{A-2.12}$$

Here the electromagnetic charge Q_{em} and the weak isospin are defined by

$$\begin{aligned} Q_{em} &= \Sigma^{12} + \frac{(n_+ 1_+ + n_- 1_-)}{6} \ , \\ I_L^3 &= \frac{(\Sigma^{12} - \Sigma^{03})}{2} \ . \end{aligned} \tag{A-2.13}$$

The fields γ and Z^0 are defined via the relations

$$\begin{aligned} \gamma &= 6d\bar{\gamma} = \frac{6}{(a+b)}(aX + bY) \ , \\ Z^0 &= 4(a+b)\bar{Z}^0 = 4(X - Y) \ . \end{aligned} \tag{A-2.14}$$

The value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{3b}{2(a+b)} \ , \tag{A-2.15}$$

and is not fixed completely. Observe that right handed neutrinos decouple completely from the electro-weak interactions.

The determination of the value of Weinberg angle is a dynamical problem. The angle is completely fixed once the YM action is fixed by requiring that action contains no cross term of type γZ^0. Pure symmetry non-broken electro-weak YM action leads to a definite value for the Weinberg angle. One can however add a symmetry breaking term proportional to Kähler action and this changes the value of the Weinberg angle.

To evaluate the value of the Weinberg angle one can express the neutral part F_{nc} of the induced gauge field as

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+ 1_+ + n_- 1_-) \ , \tag{A-2.16}$$

where one has

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \end{aligned} \tag{A-2.17}$$

in terms of the fields γ and Z^0 (photon and Z- boson)

$$F_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \tag{A-2.18}$$

Evaluating the expressions above one obtains for γ and Z^0 the expressions

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{03} \ , \\ Z^0 &= 2R_{03} \ . \end{aligned} \tag{A-2.19}$$

For the Kähler field one obtains

$$J = \frac{1}{3}(\gamma + sin^2\theta_W Z^0) \ . \tag{A-2.20}$$

Expressing the neutral part of the symmetry broken YM action

$$\begin{aligned} L_{ew} &= L_{sym} + fJ^{\alpha\beta}J_{\alpha\beta} \ , \\ L_{sym} &= \frac{1}{4g^2}Tr(F^{\alpha\beta}F_{\alpha\beta}) \ , \end{aligned} \quad \text{(A-2.21)}$$

where the trace is taken in spinor representation, in terms of γ and Z^0 one obtains for the coefficient X of the γZ^0 cross term (this coefficient must vanish) the expression

$$\begin{aligned} X &= -\frac{K}{2g^2} + \frac{fp}{18} \ , \\ K &= Tr\left[Q_{em}(I_L^3 - sin^2\theta_W Q_{em})\right] \ , \end{aligned} \quad \text{(A-2.22)}$$

In the general case the value of the coefficient K is given by

$$K = \sum_i \left[-\frac{(18+2n_i^2)sin^2\theta_W}{9}\right] \ , \quad \text{(A-2.23)}$$

where the sum is over the spinor chiralities, which appear as elementary fermions and n_i is the integer describing the coupling of the spinor field to the Kähler potential. The cross term vanishes provided the value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{9\sum_i 1}{(fg^2 + 2\sum_i(18+n_i^2))} \ . \quad \text{(A-2.24)}$$

In the scenario where both leptons and quarks are elementary fermions the value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{9}{(\frac{fg^2}{2} + 28)} \ . \quad \text{(A-2.25)}$$

The bare value of the Weinberg angle is 9/28 in this scenario, which is quite close to the typical value 9/24 of GUTs [B22] .

A-2.2 Discrete symmetries

The treatment of discrete symmetries C, P, and T is based on the following requirements:
a) Symmetries must be realized as purely geometric transformations.
b) Transformation properties of the field variables should be essentially the same as in the conventional quantum field theories [B5] .

The action of the reflection P on spinors of is given by

$$\Psi \rightarrow P\Psi = \gamma^0 \otimes \gamma^0\Psi \ . \quad \text{(A-2.26)}$$

in the representation of the gamma matrices for which γ^0 is diagonal. It should be noticed that W and Z^0 bosons break parity symmetry as they should since their charge matrices do not commute with the matrix of P.

The guess that a complex conjugation in CP_2 is associated with T transformation of the physicist turns out to be correct. One can verify by a direct calculation that pure Dirac action is invariant under T realized according to

$$\begin{aligned} m^k &\rightarrow T(M^k) \ , \\ \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \gamma^1\gamma^3 \otimes 1\Psi \ . \end{aligned} \quad \text{(A-2.27)}$$

The operation bearing closest resemblance to the ordinary charge conjugation corresponds geometrically to complex conjugation in CP_2:

$$\begin{aligned} \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \Psi^\dagger \gamma^2 \gamma^0 \otimes 1 \ . \end{aligned} \tag{A-2.28}$$

As one might have expected symmetries CP and T are exact symmetries of the pure Dirac action.

A-3 Basic facts about induced gauge fields

Since the classical gauge fields are closely related in TGD framework, it is not possible to have space-time sheets carrying only single kind of gauge field. For instance, em fields are accompanied by Z^0 fields for extremals of Kähler action. Weak forces is however absent unless the space-time sheets contains topologically condensed exotic weakly charged particles responding to this force. Same applies to classical color forces. The fact that these long range fields are present forces to assume that there exists a hierarchy of scaled up variants of standard model physics identifiable in terms of dark matter.

Classical em fields are always accompanied by Z^0 field and some components of color gauge field. For extremals having homologically non-trivial sphere as a CP_2 projection em and Z^0 fields are the only non-vanishing electroweak gauge fields. For homologically trivial sphere only W fields are non-vanishing. Color rotations does not affect the situation.

For vacuum extremals all electro-weak gauge fields are in general non-vanishing although the net gauge field has U(1) holonomy by 2-dimensionality of the CP_2 projection. Color gauge field has $U(1)$ holonomy for all space-time surfaces and quantum classical correspondence suggest a weak form of color confinement meaning that physical states correspond to color neutral members of color multiplets.

A-3.1 Induced gauge fields for space-times for which CP$_2$ projection is a geodesic sphere

If one requires that space-time surface is an extremal of Kähler action and has a 2-dimensional CP$_2$ projection, only vacuum extremals and space-time surfaces for which CP$_2$ projection is a geodesic sphere, are allowed. Homologically non-trivial geodesic sphere correspond to vanishing W fields and homologically non-trivial sphere to non-vanishing W fields but vanishing γ and Z^0. This can be verified by explicit examples.

$r = \infty$ surface gives rise to a homologically non-trivial geodesic sphere for which e_0 and e_3 vanish imply the vanishing of W field. For space-time sheets for which CP$_2$ projection is $r = \infty$ homologically non-trivial geodesic sphere of CP_2 one has

$$\gamma = (\frac{3}{4} - \frac{sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8} \ .$$

The induced W fields vanish in this case and they vanish also for all geodesic sphere obtained by $SU(3)$ rotation.

$Im(\xi^1) = Im(\xi^2) = 0$ corresponds to homologically trivial geodesic sphere. A more general representative is obtained by using for the phase angles of standard complex CP_2 coordinates constant values. In this case e^1 and e^3 vanish so that the induced em, Z^0, and Kähler fields vanish but induced W fields are non-vanishing. This holds also for surfaces obtained by color rotation. Hence one can say that for non-vacuum extremals with 2-D CP$_2$ projection color rotations and weak symmetries commute.

A-3.2 Space-time surfaces with vanishing em, Z^0, or Kähler fields

In the following the induced gauge fields are studied for general space-time surface without assuming the extremal property. In fact, extremal property reduces the study to the study of vacuum extremals and surfaces having geodesic sphere as a CP_2 projection and in this sense the following arguments are somewhat obsolete in their generality.

Space-times with vanishing em, Z^0, or Kähler fields

The following considerations apply to a more general situation in which the homologically trivial geodesic sphere and extremal property are not assumed. It must be emphasized that this case is possible in TGD framework only for a vanishing Kähler field.

Using spherical coordinates (r,Θ,Ψ,Φ) for CP_2, the expression of Kähler form reads as

$$\begin{aligned} J &= \frac{r}{F^2}dr\wedge(d\Psi+cos(\Theta)d\Phi)+\frac{r^2}{2F}sin(\Theta)d\Theta\wedge d\Phi \ , \\ F &= 1+r^2 \ . \end{aligned} \quad \text{(A-3.1)}$$

The general expression of electromagnetic field reads as

$$\begin{aligned} F_{em} &= (3+2p)\frac{r}{F^2}dr\wedge(d\Psi+cos(\Theta)d\Phi)+(3+p)\frac{r^2}{2F}sin(\Theta)d\Theta\wedge d\Phi \ , \\ p &= sin^2(\Theta_W) \ , \end{aligned} \quad \text{(A-3.2)}$$

where Θ_W denotes Weinberg angle.

a) The vanishing of the electromagnetic fields is guaranteed, when the conditions

$$\begin{aligned} \Psi &= k\Phi \ , \\ (3+2p)\frac{1}{r^2F}(d(r^2)/d\Theta)(k+cos(\Theta)) &+ (3+p)sin(\Theta)=0 \ , \end{aligned} \quad \text{(A-3.3)}$$

hold true. The conditions imply that CP_2 projection of the electromagnetically neutral space-time is 2-dimensional. Solving the differential equation one obtains

$$\begin{aligned} r &= \sqrt{\frac{X}{1-X}} \ , \\ X &= D\left[|\frac{(k+u}{C}|\right]^{\epsilon} \ , \\ u &\equiv cos(\Theta) \ , \ C=k+cos(\Theta_0) \ , \ D=\frac{r_0^2}{1+r_0^2} \ , \ \epsilon=\frac{3+p}{3+2p} \ , \end{aligned} \quad \text{(A-3.4)}$$

where C and D are integration constants. $0\leq X\leq 1$ is required by the reality of r. $r=0$ would correspond to $X=0$ giving $u=-k$ achieved only for $|k|\leq 1$ and $r=\infty$ to $X=1$ giving $|u+k|=[(1+r_0^2)/r_0^2)]^{(3+2p)/(3+p)}$ achieved only for

$$sign(u+k)\times[\frac{1+r_0^2}{r_0^2}]^{\frac{3+2p}{3+p}}\leq k+1 \ ,$$

where $sign(x)$ denotes the sign of x.

The expressions for Kähler form and Z^0 field are given by

$$\begin{aligned} J &= -\frac{p}{3+2p}Xdu\wedge d\Phi \ , \\ Z^0 &= -\frac{6}{p}J \ . \end{aligned} \quad \text{(A-3.5)}$$

The components of the electromagnetic field generated by varying vacuum parameters are proportional to the components of the Kähler field: in particular, the magnetic field is parallel to the Kähler magnetic field. The generation of a long range Z^0 vacuum field is a purely TGD based feature not encountered in the standard gauge theories.

b) The vanishing of Z^0 fields is achieved by the replacement of the parameter ϵ with $\epsilon=1/2$ as becomes clear by considering the condition stating that Z^0 field vanishes identically. Also the relationship $F_{em}=3J=-\frac{3}{4}\frac{r^2}{F}du\wedge d\Phi$ is useful.

c) The vanishing Kähler field corresponds to $\epsilon = 1, p = 0$ in the formula for em neutral space-times. In this case classical em and Z^0 fields are proportional to each other:

$$\begin{aligned} Z^0 &= 2e^0 \wedge e^3 = \frac{r}{F^2}(k+u)\frac{\partial r}{\partial u}du \wedge d\Phi = (k+u)du \wedge d\Phi \ , \\ r &= \sqrt{\frac{X}{1-X}} \ , \ X = D|k+u| \ , \\ \gamma &= -\frac{p}{2}Z^0 \ . \end{aligned} \tag{A-3.6}$$

For a vanishing value of Weinberg angle ($p = 0$) em field vanishes and only Z^0 field remains as a long range gauge field. Vacuum extremals for which long range Z^0 field vanishes but em field is non-vanishing are not possible.

The effective form of CP_2 metric for surfaces with 2-dimensional CP_2 projection

The effective form of the CP_2 metric for a space-time having vanishing em,Z^0, or Kähler field is of practical value in the case of vacuum extremals and is given by

$$\begin{aligned} ds^2_{eff} &= (s_{rr}(\frac{dr}{d\Theta})^2 + s_{\Theta\Theta})d\Theta^2 + (s_{\Phi\Phi} + 2ks_{\Phi\Psi})d\Phi^2 = \frac{R^2}{4}[s^{eff}_{\Theta\Theta}d\Theta^2 + s^{eff}_{\Phi\Phi}d\Phi^2] \ , \\ s^{eff}_{\Theta\Theta} &= X \times \left[\frac{\epsilon^2(1-u^2)}{(k+u)^2} \times \frac{1}{1-X} + 1 - X\right] \ , \\ s^{eff}_{\Phi\Phi} &= X \times \left[(1-X)(k+u)^2 + 1 - u^2\right] \ , \end{aligned} \tag{A-3.7}$$

and is useful in the construction of vacuum imbedding of, say Schwartchild metric.

Topological quantum numbers

Space-times for which either em, Z^0, or Kähler field vanishes decompose into regions characterized by six vacuum parameters: two of these quantum numbers (ω_1 and ω_2) are frequency type parameters, two (k_1 and k_2) are wave vector like quantum numbers, two of the quantum numbers (n_1 and n_2) are integers. The parameters ω_i and n_i will be referred as electric and magnetic quantum numbers. The existence of these quantum numbers is not a feature of these solutions alone but represents a much more general phenomenon differentiating in a clear cut manner between TGD and Maxwell's electrodynamics.

The simplest manner to avoid surface Kähler charges and discontinuities or infinities in the derivatives of CP_2 coordinates on the common boundary of two neighboring regions with different vacuum quantum numbers is topological field quantization, 3-space decomposes into disjoint topological field quanta, 3-surfaces having outer boundaries with possibly macroscopic size.

Under rather general conditions the coordinates Ψ and Φ can be written in the form

$$\begin{aligned} \Psi &= \omega_2 m^0 + k_2 m^3 + n_2\phi + \text{Fourier expansion} \ , \\ \Phi &= \omega_1 m^0 + k_1 m^3 + n_1\phi + \text{Fourier expansion} \ . \end{aligned} \tag{A-3.8}$$

m^0,m^3 and ϕ denote the coordinate variables of the cylindrical M^4 coordinates) so that one has $k = \omega_2/\omega_1 = n_2/n_1 = k_2/k_1$. The regions of the space-time surface with given values of the vacuum parameters ω_i,k_i and n_i and m and C are bounded by the surfaces at which space-time surface becomes ill-defined, say by $r > 0$ or $r < \infty$ surfaces.

The space-time surface decomposes into regions characterized by different values of the vacuum parameters r_0 and Θ_0. At $r = \infty$ surfaces n_2,ω_2 and m can change since all values of Ψ correspond to the same point of CP_2: at $r = 0$ surfaces also n_1 and ω_1 can change since all values of Φ correspond to same point of CP_2, too. If $r = 0$ or $r = \infty$ is not in the allowed range space-time surface develops a boundary.

This implies what might be called topological quantization since in general it is not possible to find a smooth global imbedding for, say a constant magnetic field. Although global imbedding exists it decomposes into regions with different values of the vacuum parameters and the coordinate u in general possesses discontinuous derivative at $r = 0$ and $r = \infty$ surfaces. A possible manner to avoid edges of space-time is to allow field quantization so that 3-space (and field) decomposes into disjoint quanta, which can be regarded as structurally stable units a 3-space (and of the gauge field). This doesn't exclude partial join along boundaries for neighboring field quanta provided some additional conditions guaranteing the absence of edges are satisfied.

For instance, the vanishing of the electromagnetic fields implies that the condition

$$\Omega \equiv \frac{\omega_2}{n_2} - \frac{\omega_1}{n_1} = 0 \ , \tag{A-3.9}$$

is satisfied. In particular, the ratio ω_2/ω_1 is rational number for the electromagnetically neutral regions of space-time surface. The change of the parameter n_1 and n_2 (ω_1 and ω_2) in general generates magnetic field and therefore these integers will be referred to as magnetic (electric) quantum numbers.

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