

# Introduction to "Quantum Hardware of Living Systems"

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June 19, 2019

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# 1 Basic Ideas Of Topological Geometrodynamics (TGD)

Standard model describes rather successfully both electroweak and strong interactions but sees them as totally separate and contains a large number of parameters which it is not able to predict. For about four decades ago unified theories known as Grand Unified Theories (GUTs) trying to understand electroweak interactions and strong interactions as aspects of the same fundamental gauge interaction assignable to a larger symmetry group emerged. Later superstring models trying to unify even gravitation and strong and weak interactions emerged. The shortcomings of both GUTs and superstring models are now well-known. If TGD - whose basic idea emerged 37 years ago - would emerge now it would be seen as an attempt trying to solve the difficulties of these approaches to unification.

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

## 1.1 Basic Vision Very Briefly

*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 basic vision and its relationship to existing theories is now rather well understood.

1. Space-times are representable as 4-surfaces in the 8-dimensional imbedding space  $H = M^4 \times CP_2$ , where  $M^4$  is 4-dimensional (4-D) Minkowski space and  $CP_2$  is 4-D complex projective space (see Appendix).
2. Induction procedure (a standard procedure in fiber bundle theory, see Appendix) allows to geometrize various fields. Space-time metric characterizing gravitational fields corresponds to the induced metric obtained by projecting the metric tensor of  $H$  to the space-time surface. Electroweak gauge potentials are identified as projections of the components of  $CP_2$  spinor connection to the space-time surface, and color gauge potentials as projections of  $CP_2$  Killing vector fields representing color symmetries. Also spinor structure can be induced: induced spinor gamma matrices are projections of gamma matrices of  $H$  and induced spinor fields just  $H$  spinor fields restricted to space-time surface. Spinor connection is also projected. The interpretation is that distances are measured in imbedding space metric and parallel translation using spinor connection of imbedding space.

The induction procedure applies to octonionic structure and the conjecture is that for preferred extremals the induced octonionic structure is quaternionic: again one just projects the octonion units. I have proposed that one can lift space-time surfaces in  $H$  to the Cartesian product of the twistor spaces of  $M^4$  and  $CP_2$ , which are the only 4-manifolds allowing twistor space with Kähler structure [A7]. Now the twistor structure would be induced in some sense, and should co-incide with that associated with the induced metric. Clearly, the 2-spheres defining the fibers of twistor spaces of  $M^4$  and  $CP_2$  must allow identification: this 2-sphere defines the  $S^2$  fiber of the twistor space of space-time surface. This poses constraint on the imbedding of the twistor space of space-time surfaces as sub-manifold in the Cartesian product of twistor spaces.

3. Geometrization of quantum numbers is achieved. The isometry group of the geometry of  $CP_2$  codes for the color gauge symmetries of strong interactions. Vierbein group codes for electroweak symmetries, and explains their breaking in terms of  $CP_2$  geometry so that standard model gauge group results. There are also important deviations from standard model: color quantum numbers are not spin-like but analogous to orbital angular momentum: this difference is expected to be seen only in  $CP_2$  scale. In contrast to GUTs, quark and lepton numbers are separately conserved and family replication has a topological explanation in terms of topology of the partonic 2-surface carrying fermionic quantum numbers.

$M^4$  and  $CP_2$  are unique choices for many other reasons. For instance, they are the unique 4-D space-times allowing twistor space with Kähler structure.  $M^4$  light-cone boundary allows

a huge extension of 2-D conformal symmetries. Imbedding space  $H$  has a number theoretic interpretation as 8-D space allowing octonionic tangent space structure.  $M^4$  and  $CP_2$  allow quaternionic structures. Therefore standard model symmetries have number theoretic meaning.

4. Induced gauge potentials are expressible in terms of imbedding space coordinates and their gradients and general coordinate invariance implies that there are only 4 field like variables locally. Situation is thus extremely simple mathematically. The objection is that one loses linear superposition of fields. The resolution of the problem comes from the generalization of the concepts of particle and space-time.

Space-time surfaces can be also particle like having thus finite size. In particular, space-time regions with Euclidian signature of the induced metric (temporal and spatial dimensions in the same role) emerge and have interpretation as lines of generalized Feynman diagrams. Particle in space-time can be identified as a topological inhomogeneity in background space-time surface which looks like the space-time of general relativity in long length scales.

One ends up with a generalization of space-time surface to many-sheeted space-time with space-time sheets having extremely small distance of about  $10^4$  Planck lengths ( $CP_2$  size). As one adds a particle to this kind of structure, it touches various space-time sheets and thus interacts with the associated classical fields. Their effects superpose linearly in good approximation and linear superposition of fields is replaced with that for their effects.

This resolves the basic objection. It also leads to the understanding of how the space-time of general relativity and quantum field theories emerges from TGD space-time as effective space-time when the sheets of many-sheeted space-time are lumped together to form a region of Minkowski space with metric replaced with a metric identified as the sum of empty Minkowski metric and deviations of the metrics of sheets from empty Minkowski metric. Gauge potentials are identified as sums of the induced gauge potentials. TGD is therefore a microscopic theory from which standard model and general relativity follow as a topological simplification however forcing to increase dramatically the number of fundamental field variables.

5. A further objection is that classical weak fields identified as induced gauge fields are long ranged and should cause large parity breaking effects due to weak interactions. These effects are indeed observed but only in living matter. A possible resolution of problem is implied by the condition that the modes of the induced spinor fields have well-defined electromagnetic charge. This forces their localization to 2-D string world sheets in the generic case having vanishing weak gauge fields so that parity breaking effects emerge just as they do in standard model. Also string model like picture emerges from TGD and one ends up with a rather concrete view about generalized Feynman diagrammatics. A possible objection is that the Kähler-Dirac gamma matrices do not define an integrable distribution of 2-planes defining string world sheet.

An even stronger condition would be that the induced classical gauge fields at string world sheet vanish: this condition is allowed by the topological description of particles. The  $CP_2$  projection of string world sheet would be 1-dimensional. Also the number theoretical condition that octonionic and ordinary spinor structures are equivalent guaranteeing that fermionic dynamics is associative leads to the vanishing of induced gauge fields.

The natural action would be given by string world sheet area, which is present only in the space-time regions with Minkowskian signature. Gravitational constant would be present as a fundamental constant in string action and the ratio  $\hbar/G/R^2$  would be determined by quantum criticality condition. The hierarchy of Planck constants  $\hbar_{eff}/\hbar = n$  assigned to dark matter in TGD framework would allow to circumvent the objection that only objects of length of order Planck length are possible since string tension given by  $T = 1/\hbar_{eff}G$  apart from numerical factor could be arbitrary small. This would make possible gravitational bound states as partonic 2-surfaces as structures connected by strings and solve the basic problem of super string theories. This option allows the natural interpretation of  $M^4$  type vacuum extremals with  $CP_2$  projection, which is Lagrange manifold as good approximations

for space-time sheets at macroscopic length scales. String area does not contribute to the Kähler function at all.

Whether also induced spinor fields associated with Kähler-Dirac action and de-localized inside entire space-time surface should be allowed remains an open question: super-conformal symmetry strongly suggests their presence. A possible interpretation for the corresponding spinor modes could be in terms of dark matter, sparticles, and hierarchy of Planck constants.

It is perhaps useful to make clear what TGD is not and also what new TGD can give to physics.

1. TGD is *not* just General Relativity made concrete by using imbeddings: the 4-surface property is absolutely essential for unifying standard model physics with gravitation and to circumvent the incurable conceptual problems of General Relativity. The many-sheeted space-time of TGD gives rise only at macroscopic limit to GRT space-time as a slightly curved Minkowski space. TGD is *not* a Kaluza-Klein theory although color gauge potentials are analogous to gauge potentials in these theories.

TGD space-time is 4-D and its dimension is due to completely unique conformal properties of light-cone boundary and 3-D light-like surfaces implying enormous extension of the ordinary conformal symmetries. Light-like 3-surfaces represent orbits of partonic 2-surfaces and carry fundamental fermions at 1-D boundaries of string world sheets. TGD is *not* obtained by performing Poincare gauging of space-time to introduce gravitation and plagued by profound conceptual problems.

2. TGD is *not* a particular string model although string world sheets emerge in TGD very naturally as loci for spinor modes: their 2-dimensionality makes among other things possible quantum deformation of quantization known to be physically realized in condensed matter, and conjectured in TGD framework to be crucial for understanding the notion of finite measurement resolution. Hierarchy of objects of dimension up to 4 emerge from TGD: this obviously means analogy with branes of super-string models.

TGD is *not* one more item in the collection of string models of quantum gravitation relying on Planck length mystics. Dark matter becomes an essential element of quantum gravitation and quantum coherence in astrophysical scales is predicted just from the assumption that strings connecting partonic 2-surfaces serve are responsible for gravitational bound states.

TGD is *not* a particular string model although AdS/CFT duality of super-string models generalizes due to the huge extension of conformal symmetries and by the identification of WCW gamma matrices as Noether super-charges of super-symplectic algebra having a natural conformal structure.

3. TGD is *not* a gauge theory. In TGD framework the counterparts of also ordinary gauge symmetries are assigned to super-symplectic algebra (and its Yangian [A1] [?, ?, ?]), which is a generalization of Kac-Moody algebras rather than gauge algebra and suffers a fractal hierarchy of symmetry breakings defining hierarchy of criticalities. TGD is *not* one more quantum field theory like structure based on path integral formalism: path integral is replaced with functional integral over 3-surfaces, and the notion of classical space-time becomes exact part of the theory. Quantum theory becomes formally a purely classical theory of WCW spinor fields: only state function reduction is something genuinely quantal.
4. TGD view about spinor fields is *not* the standard one. Spinor fields appear at three levels. Spinor modes of the imbedding space are analogs of spinor modes characterizing incoming and outgoing states in quantum field theories. Induced second quantized spinor fields at space-time level are analogs of stringy spinor fields. Their modes are localized by the well-definedness of electro-magnetic charge and by number theoretic arguments at string world sheets. Kähler-Dirac action is fixed by supersymmetry implying that ordinary gamma matrices are replaced by what I call Kähler-Dirac gamma matrices - this something new. WCW spinor fields, which are classical in the sense that they are not second quantized, serve as analogs of fields of string field theory and imply a geometrization of quantum theory.
5. TGD is in some sense an extremely conservative geometrization of entire quantum physics: *no* additional structures such as gauge fields as independent dynamical degrees of freedom are

introduced: Kähler geometry and associated spinor structure are enough. “Topological” in TGD should not be understood as an attempt to reduce physics to torsion (see for instance [?]) or something similar. Rather, TGD space-time is topologically non-trivial in all scales and even the visible structures of everyday world represent non-trivial topology of space-time in TGD Universe.

6. Twistor space - or rather, a generalization of twistor approach replacing masslessness in 4-D sense with masslessness in 8-D sense and thus allowing description of also massive particles - emerged originally as a technical tool, and its Kähler structure is possible only for  $H = M^4 \times CP_2$ . It however turned out that much more than a technical tool is in question. What is genuinely new is the infinite-dimensional character of the Kähler geometry making it highly unique, and its generalization to p-adic number fields to describe correlates of cognition. Also the hierarchies of Planck constants  $h_{eff} = n \times h$  reducing to the quantum criticality of TGD Universe and p-adic length scales and Zero Energy Ontology represent something genuinely new.

The great challenge is to construct a mathematical theory around these physically very attractive ideas and I have devoted the last 41 years for the realization of this dream and this has resulted 24 online books about TGD and nine online books about TGD inspired theory of consciousness and of quantum biology.

## 1.2 Two Visions About TGD And Their Fusion

As already mentioned, TGD can be interpreted both as a modification of general relativity and generalization of string models.

### 1.2.1 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 [A3, A6, A2, A5].

The identification of the space-time as a sub-manifold [A4, A9] 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 sub-manifold 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  $X^4$ .

The choice of  $H$  is unique from the condition that TGD has standard model symmetries. Also number theoretical vision selects  $H = M^4 \times CP_2$  uniquely.  $M^4$  and  $CP_2$  are also unique spaces allowing twistor space with Kähler structure.

### 1.2.2 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.

Quite recently, it has turned out that fermionic strings inside space-time surfaces define an exact part of quantum TGD and that this is essential for understanding gravitation in long length scales. Also the analog of AdS/CFT duality emerges in that the Kähler metric can be defined either in terms of Kähler function identifiable as Kähler action assignable to Euclidian space-time regions or Kähler action + string action assignable to Minkowskian regions.

The recent view about construction of scattering amplitudes is very “stringy”. By strong form of holography string world sheets and partonic 2-surfaces provide the data needed to construct scattering amplitudes. Space-time surfaces are however needed to realize quantum-classical correspondence necessary to understand the classical correlates of quantum measurement. There is a huge generalization of the duality symmetry of hadronic string models. Scattering amplitudes can be regarded as sequences of computational operations for the Yangian of super-symplectic algebra. Product and co-product define the basic vertices and realized geometrically as partonic 2-surfaces and algebraically as multiplication for the elements of Yangian identified as super-symplectic Noether charges assignable to strings. Any computational sequences connecting given collections of algebraic objects at the opposite boundaries of causal diamond (CD) produce identical scattering amplitudes.

### 1.2.3 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 and string like objects (counterpart of the “baby universes” of GRT) and the non-conservation of energy in GRT corresponds to the transfer of energy between different sheets of the space-time and possibly existence vapour phase.

What one obtains is what I have christened as many-sheeted space-time (see **Fig.** <http://tgdtheory.fi/appfigures/manysheeted.jpg> or **Fig. ??** in the appendix of this book). 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 the pair of initial and final states of a physical event, say particle reaction.

At space-time level ZEO means that 3-surfaces are pairs of space-like 3-surfaces at the opposite light-like boundaries of CD. Since the extremals of Kähler action connect these, one can say that by holography the basic dynamical objects are the space-time surface connecting these 3-surfaces. This changes totally the vision about notions like self-organization: self-organization by quantum jumps does not take for a 3-D system but for the entire 4-D field pattern associated with it.

General Coordinate Invariance (GCI) 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.

### 1.3 Basic Objections

Objections are the most powerful tool in theory building. The strongest 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.

Second objection is that TGD space-time is quite too simple as compared to GRT space-time due to the imbeddability to 8-D imbedding space. One can also argue that Poincare invariant theory of gravitation cannot be consistent with General Relativity. The above interpretation allows to understand the relationship to GRT space-time and how Equivalence Principle (EP) follows from Poincare invariance of TGD. The interpretation of GRT space-time is as effective space-time obtained by replacing many-sheeted space-time with Minkowski space with effective metric determined as a sum of Minkowski metric and sum over the deviations of the induced metrics of space-time sheets from Minkowski metric. Poincare invariance suggests strongly classical EP for the GRT limit in long length scales at least. One can consider also other kinds of limits such as the analog of GRT limit for Euclidian space-time regions assignable to elementary particles. In this case deformations of  $CP_2$  metric define a natural starting point and  $CP_2$  indeed defines a gravitational instanton with very large cosmological constant in Einstein-Maxwell theory. Also gauge potentials of standard model correspond classically to superpositions of induced gauge potentials over space-time sheets.

#### 1.3.1 Topological field quantization

Topological field quantization distinguishes between TGD based and more standard - say Maxwellian - notion of field. In Maxwell's fields created by separate systems superpose and one cannot tell which part of field comes from which system except theoretically. In TGD these fields correspond to different space-time sheets and only their effects on test particle superpose. Hence physical systems have well-defined field identifies - field bodies - in particular magnetic bodies.

The notion of magnetic body carrying dark matter with non-standard large value of Planck constant has become central concept in TGD inspired theory of consciousness and living matter, and by starting from various anomalies of biology one ends up to a rather detailed view about the role of magnetic body as intentional agent receiving sensory input from the biological body and controlling it using EEG and its various scaled up variants as a communication tool. Among other things this leads to models for cell membrane, nerve pulse, and EEG.

### 1.4 P-Adic Variants Of Space-Time Surfaces

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. One might say that TGD space-time is adelic. Also the hierarchy of Planck constants forces



a generalization of the notion of space-time but this generalization can be understood in terms of the failure of strict determinism for Kähler action defining the fundamental variational principle behind the dynamics of space-time surfaces.

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.

## 1.5 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.

The theoretical framework involves several threads.

1. Quantum T(opological) G(eometro)D(ynamics) as a classical spinor geometry for infinite-dimensional WCW, 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.
2. 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” thread.
3. 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 strongly suggested by the failure of strict determinism for the fundamental variational principle. The identification of hierarchy of Planck constants labelling phases of dark matter 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.

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.

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 eight online books [K26, K17, K13, K32, K22, K31, K30, K21] about TGD and nine online books about TGD inspired theory of consciousness and of quantum biology [K25, K4, K14, K3, K8, K9, K11, K20, K29] are warmly recommended to the interested reader.

### 1.5.1 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  $CH$  (“world of classical worlds”, WCW) 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 [A8, A10, A11]. 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 WCW 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 unexpected 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 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 <sup>1</sup>
4. WCW Dirac operator appearing in Super-Virasoro conditions, imbedding space Dirac operator whose modes define the ground states of Super-Virasoro representations, Kähler-Dirac operator at space-time surfaces, and the algebraic variant of  $M^4$  Dirac operator appearing in propagators. 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 defined between positive and negative energy parts of zero energy states which form orthonormal rows of what I call U-matrix as a matrix defined between zero energy states. Given M-matrix in turn would decompose to a product of a hermitian square root of 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 square 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 M-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.

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 and would correspond to a hierarchy of CDs with the temporal distances between tips coming as integer multiples of the  $CP_2$  time.

<sup>1</sup>There are four kinds of Dirac operators in TGD. The geometrization of quantum theory requires Kähler metric definable either in terms of Kähler function identified as Kähler action for Euclidian space-time regions or as anti-commutators for WCW gamma matrices identified as conformal Noether super-charges associated with the second quantized modified Dirac action consisting of string world sheet term and possibly also Kähler Dirac action in Minkowskian space-time regions. These two possible definitions reflect a duality analogous to AdS/CFT duality.

The M-matrices associated with CDs are obtained by a discrete scaling from the minimal CD and characterized by integer  $n$  are naturally proportional to a representation matrix of scaling:  $S(n) = S^n$ , where  $S$  is unitary S-matrix associated with the minimal CD [K27]. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power of  $S$  and represented as scaling with respect to the logarithm of the proper time distance between the tips of CD.

U-matrix elements between M-matrices for various CDs are proportional to the inner products  $Tr[S^{-n_1} \circ H^i H^j \circ S^{n_2} \lambda]$ , where  $\lambda$  represents unitarily the discrete Lorentz boost relating the moduli of the active boundary of CD and  $H^i$  form an orthonormal basis of Hermitian square roots of density matrices.  $\circ$  tells that  $S$  acts at the active boundary of CD only. It turns out possible to construct a general representation for the U-matrix reducing its construction to that of S-matrix. S-matrix has interpretation as exponential of the Virasoro generator  $L_{-1}$  of the Virasoro algebra associated with super-symplectic algebra.

5. 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 (or Kähler-Dirac action) in which gamma matrices are replaced with the modified (Kähler-Dirac) 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. The Kähler-Dirac gamma matrices define as anti-commutators effective metric, which might provide geometrization for some basic observables of condensed matter physics. One might also 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 anti-fermion.
6. An important result relates to the notion of induced spinor connection. If one requires that spinor modes have well-defined em charge, one must assume that the modes in the generic situation are localized at 2-D surfaces - string world sheets or perhaps also partonic 2-surfaces - at which classical  $W$  boson fields vanish. Covariantly constant right handed neutrino generating super-symmetries forms an exception. The vanishing of also  $Z^0$  field is possible for Kähler-Dirac action and should hold true at least above weak length scales. This implies that string model in 4-D space-time becomes part of TGD. Without these conditions classical weak fields can vanish above weak scale only for the GRT limit of TGD for which gauge potentials are sums over those for space-time sheets.

The localization simplifies enormously the mathematics and one can solve exactly the Kähler-Dirac equation for the modes of the induced spinor field just like in super string models.

At the light-like 3-surfaces at which the signature of the induced metric changes from Euclidian to Minkowskian so that  $\sqrt{g_4}$  vanishes one can pose the condition that the algebraic analog of massless Dirac equation is satisfied by the nodes so that Kähler-Dirac action gives massless Dirac propagator localizable at the boundaries of the string world sheets.

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 would 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.

It took long time to realize that there is no discretization in 4-D sense - this would lead to difficulties with basic symmetries. Rather, the discretization occurs for the parameters characterizing co-dimension 2 objects representing the information about space-time surface so that they belong to some algebraic extension of rationals. These 2-surfaces - string world sheets and partonic 2-surfaces - are genuine physical objects rather than a computational approximation. Physics itself approximates itself, one might say! This is of course nothing but strong form of holography.

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 coming from metric would be imaginary so that one would obtain sum of real term identifiable as Kähler function and imaginary term identifiable as the ordinary Minkowskian 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 have topological 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 Coulomb 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.

### 1.5.2 TGD as a generalized number theory

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space (“world of classical worlds”, WCW), 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.

#### 1. *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 puzzles 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.

In string model context one tries to reduce the physics to Planck scale. The price is the inability to say anything about physics in long length scales. In TGD p-adic physics takes care of this shortcoming by predicting the physics also in long length scales.

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 WCW? 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 various uncertainties, the number of the applications of the poorly defined p-adic physics has grown 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. One can talk about adelic space-time, imbedding space, and WCW.

The notion of p-adic manifold [K33] identified as p-adic space-time surface solving p-adic analogs of field equations and having real space-time sheet as chart map provided a possible solution of the basic challenge of relating real and p-adic classical physics. One can also speak of real space-time surfaces having p-adic space-time surfaces as chart maps (cognitive maps, “thought bubbles”). Discretization required having interpretation in terms of finite measurement resolution is unavoidable in this approach and this leads to problems with symmetries: canonical identification does not commute with symmetries.

It is now clear that much more elegant approach based on abstraction exists [K34]. The map of real preferred extremals to p-adic ones is not induced from a local correspondence between points but is global. Discretization occurs only for the parameters characterizing string world sheets and partonic 2-surfaces so that they belong to some algebraic extension of rationals. Restriction to these 2-surfaces is possible by strong form of holography. Adelization providing number theoretical universality reduces to algebraic continuation for the amplitudes from this intersection of reality and various p-adicities - analogous to a back of a book - to various number fields. There are no problems with symmetries but canonical identification is needed: various group invariant of the amplitude are mapped by canonical identification to various p-adic number fields. This is nothing but a generalization of the mapping of the p-adic mass squared to its real counterpart in p-adic mass calculations.

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 (see **Fig.** <http://tgdtheory.fi/appfigures/cat.jpg> or **Fig. ??** in the appendix of this book). One can also understand how preferred p-adic primes could emerge as so called ramified primes of algebraic extension of rationals in question and characterizing

string world sheets and partonic 2-surfaces. Preferred p-adic primes would be ramified primes for extensions for which the number of p-adic continuations of two-surfaces to space-time surfaces (imaginings) allowing also real continuation (realization of imagination) would be especially large. These ramifications would be winners in the fight for number theoretical survival. Also a generalization of p-adic length scale hypothesis emerges from NMP [K12].

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 a 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.

### 2. The role of classical number fields

The vision about the physical role of the classical number fields relies on certain speculative questions inspired by the idea that space-time dynamics could be reduced to associativity or co-associativity condition. Associativity means here associativity of tangent spaces of space-time region and co-associativity associativity of normal spaces of space-time region.

1. Could space-time surfaces  $X^4$  be regarded as associative or co-associative (“quaternionic” is equivalent with “associative” ) surfaces of  $H$  endowed with octonionic structure in the sense that tangent space of space-time surface would be associative (co-associative with normal space associative) sub-space of octonions at each point of  $X^4$  [K24]. This is certainly possible and an interesting conjecture is that the preferred extremals of Kähler action include associative and co-associative space-time regions.
2. Could the notion of compactification generalize to that of number theoretic compactification in the sense that one can map associative (co-associative) surfaces of  $M^8$  regarded as octonionic linear space to surfaces in  $M^4 \times CP_2$  [K24] ? This conjecture -  $M^8 - H$  duality - would give for  $M^4 \times CP_2$  deep number theoretic meaning.  $CP_2$  would parametrize associative planes of octonion space containing fixed complex plane  $M^2 \subset M^8$  and  $CP_2$  point would thus characterize the tangent space of  $X^4 \subset M^8$ . The point of  $M^4$  would be obtained by projecting the point of  $X^4 \subset M^8$  to a point of  $M^4$  identified as tangent space of  $X^4$ . This would guarantee that the dimension of space-time surface in  $H$  would be four. The conjecture is that the preferred extremals of Kähler action include these surfaces.
3.  $M^8 - H$  duality can be generalized to a duality  $H \rightarrow H$  if the images of the associative surface in  $M^8$  is associative surface in  $H$ . One can start from associative surface of  $H$  and assume that it contains the preferred  $M^2$  tangent plane in 8-D tangent space of  $H$  or integrable distribution  $M^2(x)$  of them, and its points to  $H$  by mapping  $M^4$  projection of  $H$  point to itself and associative tangent space to  $CP_2$  point. This point need not be the original one! If the resulting surface is also associative, one can iterate the process indefinitely. WCW would be a category with one object.
4.  $G_2$  defines the automorphism group of octonions, and one might hope that the maps of octonions to octonions such that the action of Jacobian in the tangent space of associative or co-associative surface reduces to that of  $G_2$  could produce new associative/co-associative surfaces. The action of  $G_2$  would be analogous to that of gauge group.
5. One can also ask whether the notions of commutativity and co-commutativity could have physical meaning. The well-definedness of em charge as quantum number for the modes of the induced spinor field requires their localization to 2-D surfaces (right-handed neutrino is an exception) - string world sheets and partonic 2-surfaces. This can be possible only for Kähler action and could have commutativity and co-commutativity as a number theoretic counterpart. The basic vision would be that the dynamics of Kähler action realizes number theoretical geometrical notions like associativity and commutativity and their co-notions.

The notion of number theoretic compactification 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 a sub-space of

complexified octonions (addition of commuting imaginary unit  $i$ ) their tangent space or normal space is quaternionic- and thus maximally associative or co-associative. These surfaces can be mapped in natural manner to surfaces in  $M^4 \times CP_2$  [K24] provided one can assign to each point of tangent space a hyper-complex plane  $M^2(x) \subset M^4 \subset M^8$ . One can also speak about  $M^8 - H$  duality.

This vision has very strong predictive power. It predicts that the preferred extremals of Kähler action correspond to either quaternionic or co-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.

Number theoretical compactification has inspired large number of conjectures. This includes 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 WCW metric and spinor structure in terms of second quantized induced spinor fields with modified Dirac action defined by Kähler action realizing the notion of finite measurement resolution and a connection with inclusions of hyper-finite factors of type  $II_1$  about which Clifford algebra of WCW 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.

Associativity (co-associativity) would be that tangent (normal) spaces of space-time surfaces associative (co-associative) in some sense and thus quaternionic (co-quaternionic). This can be formulated in two manners.

1. One can introduce octonionic tangent space basis by assigning to the “free” gamma matrices octonion basis or in terms of octonionic representation of the imbedding space gamma matrices possible in dimension  $D = 8$ .
2. Associativity (quaternionicity) would state that the projections of octonionic basic vectors or induced gamma matrices basis to the space-time surface generates associative (quaternionic) sub-algebra at each space-time point. Co-associativity is defined in analogous manner and can be expressed in terms of the components of second fundamental form.
3. For gamma matrix option induced rather than Kähler-Dirac gamma matrices must be in question since Kähler-Dirac gamma matrices can span lower than 4-dimensional space and are not parallel to the space-time surfaces as imbedding space vectors.

### 3. 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.

After the realization that infinite primes can be mapped to polynomials possibly 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.

The infinite primes at the first level of hierarchy, which represent analogs of bound states, can be mapped to irreducible polynomials, which in turn characterize the algebraic extensions of rationals defining a hierarchy of algebraic physics continuable to real and p-adic number fields. The products of infinite primes in turn define more general algebraic extensions of rationals. The interesting question concerns the physical interpretation of the higher levels in the hierarchy of infinite primes and integers mappable to polynomials of  $n > 1$  variables.

## 1.6 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.

### 1.6.1 Dark matter as large $\hbar$ phases

D. Da Rocha and Laurent Nottale [E1] 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 that astrophysical systems are at some levels of the hierarchy of space-time sheets macroscopic quantum systems. The space-time sheets in question would carry dark matter.

Nottale's hypothesis would predict a gigantic value of  $h_{gr}$ . Equivalence Principle and the independence of gravitational Compton length on mass  $m$  implies however that one can restrict the values of mass  $m$  to masses of microscopic objects so that  $h_{gr}$  would be much smaller. Large  $h_{gr}$  could 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 [K19].

It is natural to assign the values of Planck constants postulated by Nottale to the space-time sheets mediating gravitational interaction and identifiable as magnetic flux tubes (quanta) possibly carrying monopole flux and identifiable as remnants of cosmic string phase of primordial cosmology. 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.

Certain experimental findings suggest the identification  $h_{eff} = n \times h_{gr}$ . The large value of  $h_{gr}$  can be seen as a manner to reduce the string tension of fermionic strings so that gravitational (in fact all!) bound states can be described in terms of strings connecting the partonic 2-surfaces defining particles (analogous to AdS/CFT description). The values  $h_{eff}/h = n$  can be interpreted in terms of a hierarchy of breakings of super-conformal symmetry in which the super-conformal generators act as gauge symmetries only for a sub-algebras with conformal weights coming as multiples of  $n$ . Macroscopic quantum coherence in astrophysical scales is implied. If also Kähler-Dirac action is present, part of the interior degrees of freedom associated with the Kähler-Dirac part of conformal algebra become physical. A possible is that fermionic oscillator operators generate super-symmetries and sparticles correspond almost by definition to dark matter with  $h_{eff}/h = n > 1$ . One implication would be that at least part if not all gravitons would be dark and be observed only through their decays to ordinary high frequency graviton ( $E = hf_{high} = h_{eff}f_{low}$ ) of bunch of  $n$  low energy gravitons.



### 1.6.2 *Hierarchy of Planck constants from the anomalies of neuroscience and biology*

The quantal ELF 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 a 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.

The hypothesis  $h_{eff} = h_{gr}$  - at least for microscopic particles - implies that cyclotron energies of charged particles do not depend on the mass of the particle and their spectrum is thus universal although corresponding frequencies depend on mass. In bio-applications this spectrum would correspond to the energy spectrum of bio-photons assumed to result from dark photons by  $h_{eff}$  reducing phase transition and the energies of bio-photons would be in visible and UV range associated with the excitations of bio-molecules.

Also the anomalies of biology (see for instance [K15, K16, K28] ) support the view that dark matter might be a key player in living matter.

### 1.6.3 *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 [K7]. 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.

A more precise formulation is in terms of presence of large number of space-time sheets connecting given space-like 3-surfaces at the opposite boundaries of causal diamond. Quantum criticality presence of vanishing second variations of Kähler action and identified in terms of conformal invari-

ance broken down to to sub-algebras of super-conformal algebras with conformal weights divisible by integer  $n$  is highly suggestive notion and would imply that  $n$  sheets of the effective covering are actually conformal equivalence classes of space-time sheets with same Kähler action and same values of conserved classical charges (see **Fig.** <http://tgdtheory.fi/appfigures/planckhierarchy.jpg> or **Fig. ??** the appendix of this book).  $n$  would naturally correspond the value of  $h_{eff}$  and its factors negentropic entanglement with unit density matrix would be between the  $n$  sheets of two coverings of this kind. p-Adic prime would be largest prime power factor of  $n$ .

#### 1.6.4 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.

The recent view about the solutions of Kähler- Dirac action assumes that the modes have a well-defined em charge and this implies that localization of the modes to 2-D surfaces (right-handed neutrino is an exception). Classical  $W$  boson fields vanish at these surfaces and also classical  $Z^0$  field can vanish. The latter would guarantee the absence of large parity breaking effects above intermediate boson scale scaling like  $h_{eff}$ .

## 1.7 Twistors in TGD and connection with Veneziano duality

The twistorialization of TGD has two aspects. The attempt to generalize twistor Grassmannian approach emerged first. It was however followed by the realization that also the twistor lift of TGD at classical space-time level is needed. It turned out that that the progress in the understanding of the classical twistor lift has been much faster - probably this is due to my rather limited technical QFT skills.

### 1.7.1 Twistor lift at space-time level

8-dimensional generalization of ordinary twistors is highly attractive approach to TGD [K35]. The reason is that  $M^4$  and  $CP_2$  are completely exceptional in the sense that they are the only 4-D manifolds allowing twistor space with Kähler structure [A7]. The twistor space of  $M^4 \times CP_2$  is Cartesian product of those of  $M^4$  and  $CP_2$ . The obvious idea is that space-time surfaces allowing twistor structure if they are orientable are representable as surfaces in  $H$  such that the properly induced twistor structure co-incides with the twistor structure defined by the induced metric.

In fact, it is enough to generalize the induction of spinor structure to that of twistor structure so that the induced twistor structure need not be identical with the ordinary twistor structure possibly assignable to the space-time surface. The induction procedure reduces to a dimensional reduction of 6-D Kähler action giving rise to 6-D surfaces having bundle structure with twistor sphere as fiber and space-time as base. The twistor sphere of this bundle is imbedded as sphere in the product of twistor spheres of twistor spaces of  $M^4$  and  $CP_2$ .

This condition would define the dynamics, and the original conjecture was that this dynamics is equivalent with the identification of space-time surfaces as preferred extremals of Kähler action. The dynamics of space-time surfaces would be lifted to the dynamics of twistor spaces, which are sphere bundles over space-time surfaces. What is remarkable that the powerful machinery of complex analysis becomes available.

It however turned out that twistor lift of TGD is much more than a mere technical tool. First of all, the dimensionally reduction of 6-D Kähler action contained besides 4-D Kähler action also a volume term having interpretation in terms of cosmological constant. This need not bring anything new, since all known extremals of Kähler action with non-vanishing induced Kähler form are minimal surfaces. There is however a large number of imbeddings of twistor sphere of space-time surface to the product of twistor spheres. Cosmological constant has spectrum and depends on

length scale, and the proposal is that coupling constant evolution reduces to that for cosmological constant playing the role of cutoff length. That cosmological constant could transform from a mere nuisance to a key element of fundamental physics was something totally new and unexpected.

1. The twistor lift of TGD at space-time level forces to replace 4-D Kähler action with 6-D dimensionally reduced Kähler action for 6-D surface in the 12-D Cartesian product of 6-D twistor spaces of  $M^4$  and  $CP_2$ . The 6-D surface has bundle structure with twistor sphere as fiber and space-time surface as base.

Twistor structure is obtained by inducing the twistor structure of 12-D twistor space using dimensional reduction. The dimensionally reduced 6-D Kähler action is sum of 4-D Kähler action and volume term having interpretation in terms of a dynamical cosmological constant depending on the size scale of space-time surface (or of causal diamond CD in zero energy ontology (ZEO)) and determined by the representation of twistor sphere of space-time surface in the Cartesian product of the twistor spheres of  $M^4$  and  $CP_2$ .

2. The preferred extremal property as a representation of quantum criticality would naturally correspond to minimal surface property meaning that the space-time surface is separately an extremal of both Kähler action and volume term almost everywhere so that there is no coupling between them. This is the case for all known extremals of Kähler action with non-vanishing induced Kähler form.

Minimal surface property could however fail at 2-D string world sheets, their boundaries and perhaps also at partonic 2-surfaces. The failure is realized in minimal sense if the 3-surface has 1-D edges/folds (strings) and 4-surface 2-D edges/folds (string world sheets) at which some partial derivatives of the imbedding space coordinates are discontinuous but canonical momentum densities for the entire action are continuous.

There would be no flow of canonical momentum between interior and string world sheet and minimal surface equations would be satisfied for the string world sheet, whose 4-D counterpart in twistor bundle is determined by the analog of 4-D Kähler action. These conditions allow the transfer of canonical momenta between Kähler- and volume degrees of freedom at string world sheets. These no-flow conditions could hold true at least asymptotically (near the boundaries of CD).

$M^8 - H$  duality suggests that string world sheets (partonic 2-surfaces) correspond to images of complex 2-sub-manifolds of  $M^8$  (having tangent (normal) space which is complex 2-plane of octonionic  $M^8$ ).

3. Cosmological constant would depend on p-adic length scales and one ends up to a concrete model for the evolution of cosmological constant as a function of p-adic length scale and other number theoretic parameters (such as Planck constant as the order of Galois group): this conforms with the earlier picture.

Inflation is replaced with its TGD counterpart in which the thickening of cosmic strings to flux tubes leads to a transformation of Kähler magnetic energy to ordinary and dark matter. Since the increase of volume increases volume energy, this leads rapidly to energy minimum at some flux tube thickness. The reduction of cosmological constant by a phase transition however leads to a new expansion phase. These jerks would replace smooth cosmic expansion of GRT. The discrete coupling constant evolution predicted by the number theoretical vision could be understood as being induced by that of cosmological constant taking the role of cutoff parameter in QFT picture [L2].

### 1.7.2 Twistor lift at the level of scattering amplitudes and connection with Veneziano duality

The classical part of twistor lift of TGD is rather well-understood. Concerning the twistorialization at the level of scattering amplitudes the situation is much more difficult conceptually - I already mentioned my limited QFT skills.

1. From the classical picture described above it is clear that one should construct the 8-D twistorial counterpart of theory involving space-time surfaces, string world sheets and their

boundaries, plus partonic 2-surfaces and that this should lead to concrete expressions for the scattering amplitudes.

The light-like boundaries of string world sheets as carriers of fermion numbers would correspond to twistors as they appear in twistor Grassmann approach and define the analog for the massless sector of string theories. The attempts to understand twistorialization have been restricted to this sector.

2. The beautiful basic prediction would be that particles massless in 8-D sense can be massive in 4-D sense. Also the infrared cutoff problematic in twistor approach emerges naturally and reduces basically to the dynamical cosmological constant provided by classical twistor lift.

One can assign 4-momentum both to the spinor harmonics of the imbedding space representing ground states of super-conformal representations and to light-like boundaries of string world sheets at the orbits of partonic 2-surfaces. The two four-momenta should be identical by quantum classical correspondence: this could be seen as a concretization of Equivalence Principle. Also a connection with string model emerges.

3. As far as symmetries are considered, the picture looks rather clear. Ordinary twistor Grassmannian approach boils down to the construction of scattering amplitudes in terms of Yangian invariants for conformal group of  $M^4$ . Therefore a generalization of super-symplectic symmetries to their Yangian counterpart seems necessary. These symmetries would be gigantic but how to deduce their implications?
4. The notion of positive Grassmannian is central in the twistor approach to the scattering amplitudes in  $calN = 4$  SUSYs. TGD provides a possible generalization and number theoretic interpretation of this notion. TGD generalizes the observation that scattering amplitudes in twistor Grassmann approach correspond to representations for permutations. Since 2-vertex is the only fermionic vertex in TGD, OZI rules for fermions generalizes, and scattering amplitudes are representations for braidings.

Braid interpretation encourages the conjecture that non-planar diagrams can be reduced to ordinary ones by a procedure analogous to the construction of braid (knot) invariants by gradual un-braiding (un-knotting).

This is however not the only vision about a solution of non-planarity. Quantum criticality provides different view leading to a totally unexpected connection with string models, actually with the Veneziano duality, which was the starting point of dual resonance model in turn leading via dual resonance models to super string models.

1. Quantum criticality in TGD framework means that coupling constant evolution is discrete in the sense that coupling constants are piecewise constant functions of length scale replaced by dynamical cosmological constant. Loop corrections would vanish identically and the recursion formulas for the scattering amplitudes (allowing only planar diagrams) deduced in twistor Grassmann would involve no loop corrections. In particular, cuts would be replaced by sequences of poles mimicking them like sequences of point charge mimic line charges. In momentum discretization this picture follows automatically.
2. This would make sense in finite measurement resolution realized in number theoretical vision by number-theoretic discretization of the space-time surface (cognitive representation) as points with coordinates in the extension of rationals defining the adèle [L1]. Similar discretization would take place for momenta. Loops would vanish at the level of discretization but what would happen at the possibly existing continuum limit: does the sequence of poles integrate to cuts? Or is representation as sum of resonances something much deeper?
3. Maybe it is! The basic idea of behind the original Veneziano amplitudes (see <http://tinyurl.com/yyhwvqb>) was Veneziano duality. This 4-particle amplitude was generalized by Yoshiro Nambu, Holger-Bek Nielsen, and Leonard Susskind to N-particle amplitude (see <http://tinyurl.com/yyv7as>) based on string picture, and the resulting model was called dual resonance model. The model was forgotten as QCD emerged. Later came superstring models and led to M-theory. Now it has become clear that something went wrong, and it

seems that one must return to the roots. Could the return to the roots mean a careful reconsideration of the dual resonance model?

4. Recall that Veneziano duality (1968) was deduced by assuming that scattering amplitude can be described as sum over s-channel resonances or t-channel Regge exchanges and Veneziano duality stated that hadronic scattering amplitudes have representation as sums over s- or t-channel resonance poles identified as excitations of strings. The sum over exchanges defined by t-channel resonances indeed reduces at larger values of  $s$  to Regge form.

The resonances had zero width, which was not consistent with unitarity. Further, there were no counterparts for the *sum* of s-, t-, and u-channel diagrams with continuous cuts in the kinematical regions encountered in QFT approach. What puts bells ringing is the u-channel diagrams would be non-planar and non-planarity is the problem of twistor Grassmann approach.

5. Veneziano duality is true only for s- and t- channels but not been s- and u-channel. Stringy description makes t-channel and s-channel pictures equivalent. Could it be that in fundamental description u-channels diagrams cannot be distinguished from s-channel diagrams or t-channel diagrams? Could the stringy representation of the scattering diagrams make u-channel twist somehow trivial if handles of string world sheet representing stringy loops in turn representing the analog of non-planarity of Feynman diagrams are absent? The permutation of external momenta for tree diagram in absence of loops in planar representation would be a twist of  $\pi$  in the representation of planar diagram as string world sheet and would not change the topology of the string world sheet and would not involve non-trivial world sheet topology.

For string world sheets loops would correspond to handles. The presence of handle would give an edge with a loop at the level of 3-surface (self energy correction in QFT). Handles are not allowed if the induced metric for the string world sheet has Minkowskian signature. If the stringy counterparts of loops are absent, also the loops in scattering amplitudes should be absent.

This argument applies only inside the Minkowskian space-time regions. If string world sheets are present also in Euclidian regions, they might have handles and loop corrections could emerge in this manner. In TGD framework strings (string world sheets) are identified to 1-D edges/folds of 3-surface at which minimal surface property and topological QFT property fails (minimal surfaces as calibrations). Could the interpretation of edge/fold as discontinuity of some partial derivatives exclude loopy edges: perhaps the branching points would be too singular?

A reduction to a sum over s-channel resonances is what the vanishing of loops would suggest. Could the presence of string world sheets make possible the vanishing of continuous cuts even at the continuum limit so that continuum cuts would emerge only in the approximation as the density of resonances is high enough?

The replacement of continuous cut with a sum of *infinitely* narrow resonances is certainly an approximation. Could it be that the stringy representation as a sum of resonances with *finite* width is an essential aspect of quantum physics allowing to get rid of infinities necessarily accompanying loops? Consider now the arguments against this idea.

1. How to get rid of the problems with unitarity caused by the zero width of resonances? Could *finite* resonance widths make unitarity possible? Ordinary twistor Grassmannian approach predicts that the virtual momenta are light-like but complex: obviously, the imaginary part of the energy in rest frame would have interpretation as resonance with.

In TGD framework this generalizes for 8-D momenta. By quantum-classical correspondence (QCC) the classical Noether charges are equal to the eigenvalues of the fermionic charges in Cartan algebra (maximal set of mutually commuting observables) and classical TGD indeed predicts complex momenta (Kähler coupling strength is naturally complex). QCC thus supports this proposal.

2. Sum over resonances/exchanges picture is in conflict with QFT picture about scattering of particles. Could *finite* resonance widths due to the complex momenta give rise to the QFT type scattering amplitudes as one develops the amplitudes in Taylor series with respect to the resonance width? Unitarity condition indeed gives the first estimate for the resonance width.

QFT amplitudes should emerge in an approximation obtained by replacing the discrete set of finite width resonances with a cut as the distance between poles is shorter than the resolution for mass squared.

In superstring models string tension has single very large value and one cannot obtain QFT type behavior at low energies (for instance, scattering amplitudes in hadronic string model are concentrated in forward direction). TGD however predicts an entire hierarchy of p-adic length scales with varying string tension. The hierarchy of mass scales corresponding roughly to the lengths and thickness of magnetic flux tubes as thickened cosmic strings and characterized by the value of cosmological constant predicted by twistor lift of TGD. Could this give rise to continuous QCT type cuts at the limit when measurement resolution cannot distinguish between resonances?

The dominating term in the sum over sums of resonances in  $t$ -channel gives near forward direction approximately the lowest mass resonance for strings with the smallest string tension. This gives the behavior  $1/(t - m_{min}^2)$ , where  $m_{min}$  corresponds to the longest mass scale involved (the largest space-time sheet involved), approximating the  $1/t$ -behavior of massless theories. This also brings in IR cutoff, the lack of which is a problem of gauge theories. This should give rise to continuous QFT type cuts at the limit when measurement resolution cannot distinguish between resonances.

## 2 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. The basic idea is that quantum jump can be identified as momentum of consciousness. Thus a general theory of consciousness is unavoidable outcome. This theory is developed in detail in the books [K25, K4, K14, K3, K8, K9, K11, K20, K29].

It is good to list first the basic challenges of TGD inspired theory of consciousness. The challenges can be formulated as questions. Reader can decide how satisfactory the answered proposed by TGD are.

1. What does one mean with quantum jump? Can one overcome the basic problem of the standard quantum measurement theory, that which forcing Bohr to give up totally the idea about objective reality?
2. How do the experienced time and geometric time relate in this framework? How the arrow of subjective time translates to that of geometric time?
3. How to define conscious information? Is it conserved or even increased during time evolution as biological evolution suggests? How does this increase relate to second law implied basically by the randomness of state function reduction?
4. Conscious entities/selves/observers seem to exist. If they are real how do they emerge?

### 2.1 Quantum Jump As A Moment Of Consciousness

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

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

where  $U$  is informational “time development” operator, which is unitary like the S-matrix characterizing the unitary time evolution of quantum mechanics.  $U$  is formally analogous to Schrödinger time evolution of infinite duration. The time evolution can however be interpreted as a sequence of discrete scalings and Lorentz boosts of causal diamond (CD) and the time corresponds to the change of the proper time distance between the tips of CD.

In TGD framework S-matrix is generalized to a triplet of U-, M-, and S-matrices. M-matrix is a hermitian square root of density matrix between positive and negative energy states multiplied by universal S-matrix depending on the scale of CD only. The square roots of projection operators form an orthonormal basis.  $U$ -matrix and  $S$ -matrix are completely universal objects characterizing the dynamics of evolution by self-organization.

The M-matrices associated with CDs are obtained by a discrete scaling from the minimal CD and characterized by integer  $n$  are naturally proportional to  $S^n$ , where  $S$  is the S-matrix associated with the minimal CD. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power of  $S$ .

$U$ -matrix elements between M-matrices for various CDs are proportional to the inner products  $Tr[S^{-n_1} \circ H^i H^j \circ S^{n_2} \lambda]$ , where  $\lambda$  represents unitarily the discrete Lorentz boost relating the moduli of the active boundary of CD and  $H^i$  form an orthonormal basis of Hermitian square roots of density matrices.  $\circ$  tells that  $S$  acts at the active boundary of CD only. It turns out possible to construct a general representation for the  $U$ -matrix reducing its construction to that of S-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”.

In ZEO  $U$ -matrix should correspond to zero energy states to each other and  $M$  matrices defining the rows of  $U$  matrix should be assignable to a fixed CD. Zero energy states should have wave function in the moduli space of CDs such that the second boundary of every CD would belong to a boundary of fixed light-cone but second boundary would be free with possible constraint that the distance between the tips of CD is multiple of  $CP_2$  time.

Zero energy states of ZEO 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 reduced/equivalently 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.

The first state function reduction at given boundary of CD must change the roles of the ends of CDs. This reduction can be followed by a sequence of reductions to the same boundary of CD and not changing the boundary nor the parts of zero energy states associated with it but changing the states at the second end and also quantum distribution of the second boundary in the moduli space of CDs. In standard measurement theory the follow-up reductions would not affect the state at all.

The understanding of how the arrow of time and experience about its flow emerge have been the most difficult problem of TGD inspired theory of consciousness and I have considered several proposals during years having the geometry of future light-cone as the geometric core element.

1. The basic objection is that the arrow of geometric time alternates at imbedding space level but we know that arrow of time looks the same in the part of the Universe we live. Possible exceptions however exist, for instance phase conjugate laser beams seem to obey opposite arrow of time. Also biological phenomena might involve non-standard arrow of time at some levels. This led Fantappiè [J1] to introduce the notion of syntropy. This suggests that the arrow of time depends on the size scale of CD and of space-time sheet.

2. It took some time to realize that the solution of the problem is trivial in ZEO. In the ordinary quantum measurement theory one must assume that state function reduction can occur repeatedly: the assumption is that nothing happens to the state during repeated reductions. The outcome is Zeno effect: the watched pot does not boil.

In TGD framework situation is different. Repeated state function reduction leaves the already reduce parts of zero energy state invariant but can change the part of states at the opposite boundary. One must allow a delocalization of the second boundary of CDs and one assumes that the second tip has quantized distance to the fixed one coming as multiple of  $CP_2$  time. Also Lorentz boosts leaving the second CD boundary invariant must be allowed. One must therefore introduce a wave function in the moduli space of CDs with second boundary forming part of fixed light-cone boundary ( $\delta M_{\pm}^4 \times CP_2$ ).

3. The sequence of state function reductions on a fixed boundary of CD leads to the increase of the average temporal distance between the tips of CDs and this gives rise to the experience about flow of time as shifting of contents of perception towards future if the change is what contributes to conscious experience and gives rise to a fixed arrow of time.
4. Contrary to original working hypothesis, state function reduction in the usual sense does not solely determine the ordinary conscious experience. It can however contribute to conscious experience and the act of free will is a good candidate in this respect. TGD view about realization of intentional action assumes that intentional actions involve negative energy signals propagating backwards in geometric time. This would mean that at some level of CD hierarchy the arrow of geometric time indeed changes and the reduction start to occur at opposite boundary of CD at some level of length scale hierarchy.

## 2.2 Negentropy Maximization Principle (NMP)

Information is the basic aspect of consciousness and this motivates the introduction of Negentropy Maximization Principle (NMP) [K12] as the fundamental variational principle of consciousness theory. The amount of negentropy of zero energy state should increase in each quantum jump. The ordinary entanglement entropy is also non-negative so that negentropy could be at best zero. Since p-adic physics is assumed to be a correlate of cognition, it is natural to generalize Shannon entropy to its number theoretic variant by replacing the probabilities appearing as arguments of logarithms of probabilities with their p-adic norms. This gives negentropy which can be positive so that NMP can generate entanglement.

Consistency with quantum measurement theory allows only negentropic density matrices proportional to unit matrix and negentropy has the largest positive value for the largest power of prime factor of the dimension of density matrix. Entanglement matrix proportional to unitary matrix familiar from quantum computation corresponds to unit density matrix and large  $h_{eff} = n \times h$  states are excellent candidates for forming negentropic entanglement (see **Fig. <http://tgdtheory.fi/appfigures/cat.jpg>** or **Fig. ??** in the appendix of this book).

The interpretation of negentropic entanglement is as a rule. The instances of the rule correspond to the pairs appearing in the superposition and the larger the number of pairs is, the higher the abstraction level of the rule is. NMP is not in conflict with the second law since negentropy in the sense of NMP is not single particle property. Ordinary quantum jumps indeed generate entropy at the level of ensemble as also quantum jumps for states for which the density matrix is direct sum of unit matrices with various dimensions.

NMP forces the negentropic entanglement resources of the Universe to grow and thus implies evolution. I have coined the name “Akashic records” for these resources forming something analogous to library. It has turned out that the only viable option is that negentropic entanglement is experienced directly.

## 2.3 The Notion Of Self

The concept of self seems to be absolutely essential for the understanding of the macroscopic and macro-temporal aspects of consciousness and would be counterpart for observer in quantum measurement theory.



1. The original view was that self corresponds to a subsystem able to remain un-entangled under the sequential informational “time evolutions”  $U$ . It is however unclear how it could be possible to avoid generation of entanglement.
2. In ZEO the situation changes. Self corresponds to a sequence of quantum jumps for which the parts of zero energy states at either boundary of CD remain unchanged. Therefore one can say that self defined in terms of parts of states assignable to this boundary remains unaffected as sub-system and does not generate entanglement. At the other boundary changes occur and give rise to the experience of time flow and arrow of time since the average temporal distance between the tips of CD tends to increase.

When the reductions begin to occur at the opposite boundary of CD, self “falls asleep”: symmetry suggests that new self living in opposite direction of geometric time is generated. Also in biological the change of time direction at some level of hierarchy might take place.

3. It looks natural to assume 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 sub-selves as kind of abstracted experience: the experiences of sub-selves  $S_i$  are not experienced as such but represent kind of averages  $\langle S_{ij} \rangle$  of sub-sub-selves  $S_{ij}$ . Entanglement between selves, most naturally realized by the formation of flux tube 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.
4. Self corresponds in neuro science to self model defining a model for organism and for the external world. Information or negentropy seems to be necessary for understanding self. Negentropically entangled states - Akashic records - are excellent candidates for selves and would thus correspond to dark matter in TGD sense since the number of states in superposition corresponds to the integer  $n$  defining  $h_{eff}$ . It is enough that self is potentially conscious: this could mean that its conscious experience about self is generated only in interaction free measurement. Repeated state function reductions to given boundary of CD is second possibility. This would assign irreversibility and definite arrow of time and experience of time flow with self.
5. 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). At space-time level space-time sheets in given p-adic length scale would be the natural correlates of selves. One ends also ends up with concrete ideas about how the localization of the contents of sensory experience and cognition to the “upper” (changing) boundary of CD could take place. One cannot exclude the possibility that state function reduction cascades could also take place in parallel branches of the quantum state.

## 2.4 Relationship To Quantum Measurement Theory

TGD based quantum measurement has several new elements. Negentropic entanglement and hierarchy of Planck constants, NMP, the prediction that state function reduction can take place to both boundaries of CD implying that the arrow of geometric time can change (this is expected to occur in microscopic scales whether the arrow of time is not established), and the possibility to understand the flow and arrow of geometric time.

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 WCW 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. The assumption that localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It is also consistent with 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!).
3. 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 WCW 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. In ZEO state preparation corresponds at some level of the self hierarchy to the a state function reduction to boundary opposite than before. In biology sensory perception and motor action would correspond to state function reduction sequences at opposite boundaries of CDs at some levels of the hierarchy.

Self measurement is governed by 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).

## 2.5 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 [K18]. 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.

ZEO brings in important additional element to the theory of self-organization. The maxima of Kähler function corresponds to the most probable 3-surfaces. Kähler function receives contributions only from the Euclidian regions (“lines” of generalized Feynman diagrams) whereas the contribution to vacuum functional from Minkowskian regions is exponent of imaginary action so that saddle points with stationary phase are in question in these regions. In ZEO 3-surfaces are replaced by pairs of 3-surfaces at opposite boundaries of CD. The maxima actually correspond to temporal patterns of classical fields connecting these 3-surfaces: this means that self-organization is four spatiotemporal rather than spatial patterns - a crucial distinction from the usual view allowing to understand the evolution of behavioral patterns quantally. In biology this allows to understand temporal evolutions of organisms as the most probable self-organization patterns having as correlates the evolutions of the magnetic body of the system.

## 2.6 Classical Non-Determinism Of Kähler Action

A further basic element is non-determinism of Kähler action. This led to the concepts of association sequence and cognitive space-time sheet, which are not wrong notions but replaced by new ones.

1. The huge vacuum degeneracy of the Kähler action suggests strongly that the preferred 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.
2. 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.

Later a more detailed view about non-determinism in the framework of ZEO has emerged and quantum criticality is here the basic notion. The space-time surface connecting two 3-surfaces at the ends of CD is not unique. Conformal transformations which act trivially at the ends of space-time surface generate a continuum of new extremals with the same value of Kähler action and classical conserved quantities. The number  $n$  of conformal equivalence classes is finite and defines the value of  $h_{eff}$  (see **Fig.** <http://tgdtheory.fi/appfigures/planckhierarchy.jpg> or **Fig. ??** in the appendix of this book). There exists a hierarchy of breakdowns of conformal symmetry labelled by  $n$ . The fractal hierarchy of CDs gives rise to fractal hierarchy of non-determinisms of this kind.

## 2.7 P-Adic Physics As Physics Of Cognition

A further 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  $p = 2, 3, 5, \dots$ . 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 binary 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 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 [K23]. The application of 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, see **Fig.** <http://tgdtheory.fi/appfigures/book.jpg> or **Fig. ??** in the appendix of this book). 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 binary digits a  $p$ -valued logic but as such this kind of logic does not have any reasonable identification. p-Adic length scale hypothesis suggests that the  $p = 2^k - n$  binary 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.

## 2.8 P-Adic And Dark Matter Hierarchies And Hierarchy Of Selves

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 [K6].

Dark matter hierarchy leads to detailed quantitative view about quantum biology with several testable predictions [K6]. 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 [K6]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [K10, K6]. 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 [K6].

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 [K5, K6]. The larger the value of Planck constant, the longer the life-time of self measured as the increase of the average distance between tips of CDs appearing in the quantum superposition during the period of repeated reductions not affecting the part of the zero energy state at the other boundary of CD- Quantum jumps form also a hierarchy with respect to p-adic and dark hierarchies and the geometric durations of quantum jumps scale like  $\hbar$ .

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self experience subselves as separate mental images. Averaging over experiences of sub-selves of sub-self would however occur.

### 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.

CD as an imbedding space correlate of self defines the time scale  $\tau$  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  $\tau$  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  $\tau$ .

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 [K6]. 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 [K10, K6]. 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.

### 3 Quantum Biology And Quantum Neuroscience In TGD Universe

Quantum biology - rather than only quantum brain - is an essential element of Quantum Mind in TGD Universe. Cells, biomolecules, and even elementary particles are conscious entities and the biological evolution is evolution of consciousness so that it would be very artificial to restrict the discussion to brain, neurons, or microtubules.

#### 3.1 Basic Physical Ideas

The following list gives the basic elements of TGD inspired quantum biology.

1. Many-sheeted space-time allows the interpretation of the structures of macroscopic world around us in terms of space-time topology. Magnetic/field body acts as intentional agent using biological body as a sensory receptor and motor instrument and controlling biological body and inheriting its hierarchical fractal structure. Fractal hierarchy of EEGs and its variants can be seen as communication and control tools of magnetic body. Also collective levels of consciousness have a natural interpretation in terms of magnetic body. Magnetic body makes also possible entanglement in macroscopic length scales. The braiding of magnetic flux tubes makes possible topological quantum computations and provides a universal mechanism of memory. One can also understand the real function of various information molecules and corresponding receptors by interpreting the receptors as addresses in quantum computer memory and information molecules as ends of flux tubes which attach to these receptors to form a connection in quantum web.
2. Magnetic body carrying dark matter and forming an onion-like structure with layers characterized by large values of Planck constant is the key concept of TGD inspired view about Quantum Mind to biology. Magnetic body is identified as intentional agent using biological body as sensory receptor and motor instrument. EEG and its fractal variants are identified as a communication and control tool of the magnetic body and a fractal hierarchy of analogs of EEG is predicted. Living system is identified as a kind of Indra's net with biomolecules representing the nodes of the net and magnetic flux tubes connections between them.

The reconnection of magnetic flux tubes and phase transitions changing Planck constant and therefore the lengths of the magnetic flux tubes are identified as basic mechanisms behind DNA replication and analogous processes and also behind the phase transitions associated with the gel phase in cell interior. The braiding of magnetic flux makes possible universal memory representation recording the motions of the basic units connected by flux tubes. Braiding also defines topological quantum computer programs updated continually by the flows of the basic units. The model of DNA as topological quantum computer is discussed as an application. In zero energy ontology the braiding actually generalize to 2-braiding for string world sheets in 4-D space-time and brings in new elements.

3. Zero energy ontology (ZEO) makes possible the proposed p-adic description of intentions and cognitions and their transformations to action. Time mirror mechanism (see **Fig.** <http://tgdtheory.fi/appfigures/timemirror.jpg> or **Fig. ??** in the appendix of the book) based on sending of negative energy signal to geometric past would apply to both long term memory recall, remote metabolism, and realization of intentional acting as an activity beginning in the geometric past in accordance with the findings of Libet. ZEO gives a precise content to the notion of negative energy signal in terms of zero energy state for which the arrow of geometric time is opposite to the standard one.

The associated notion of causal diamond (CD) is essential element and assigns to elementary particles new fundamental time scales which are macroscopic: for electron the time scale is 1 seconds, the fundamental biorhythm. An essentially new element is time-like entanglement which allows to understand among other things the quantum counterparts of Boolean functions in terms of time-like entanglement in fermionic degrees of freedom.

4. The assignment of dark matter with a hierarchy of Planck constants gives rise to a hierarchy of macroscopic quantum phases making possible macroscopic and macrotemporal quantum

coherence and allowing to understand evolution as a gradual increase of Planck constant. The model for dark nucleons leads to a surprising conclusion: the states of nucleons correspond to DNA, RNA, tRNA, and amino-acids in a natural manner and vertebrate genetic code as correspondence between DNA and amino-acids emerges naturally. This suggests that genetic code is realized at the level of dark hadron physics and living matter in the usual sense provides a secondary representation for it.

The hierarchy of Planck constants emerges from basic TGD under rather general assumptions. The key element is the huge vacuum degeneracy which implies that preferred non-vacuum extremals of Kähler action form a 4-D spin glass phase. The basic implications following from the extreme non-linearity of Kähler action is that normal derivatives of imbedding space coordinates at 3-D light-like orbits of partonic 2-surfaces and at space-like 3-surfaces at ends of CDs are many-valued functions of canonical momentum densities: this is one of the reasons that forced to develop physics as an infinite-D Kähler geometry vision instead of trying to develop path integral formalism or canonical quantization. A convenient manner to treat the situation is to introduce local many-sheeted covering of imbedding space such that the sheets are completely degenerate at partonic 2-surfaces. This leads in natural manner to the hierarchy of Planck constants as effective hierarchy hierarchy and integer multiples of Planck constants emerge naturally.

5. p-Adic physics can be identified as physics of cognition and intentionality. The hierarchy of p-adic length scales predicts a hierarchy of universal metabolic quanta as increments of zero point kinetic energies. Negentropic entanglement (see **Fig. <http://tgdtheory.fi/appfigures/cat.jpg>** or **Fig. ??** in the appendix of this book) possible for number theoretic entanglement entropy makes sense for rational (and even algebraic) entanglement and leads to the identification of life as something residing in the intersection of real and p-adic worlds. NMP respects negentropic entanglement and the attractive idea is that the experience of understanding and positively colored emotions relate to negentropic entanglement.
6. Living matter as conscious hologram is one of the basic ideas of TGD inspired biology and consciousness theory. The basic objection against TGD is that the interference of classical fields is impossible in the standard sense for the reason that that classical fields are not primary dynamical variables in TGD Universe. The resolution is based on the observation that only the interference of the effects caused by these fields can be observed experimentally and that many-sheeted space-time allows to realized the summation of effects in terms of multiple topological condensations of particles to several parallel space-time sheets. One concrete implication is fractality of qualia. Qualia appear in very wide range of scales: our qualia could in fact be those of magnetic body. The proposed mechanism for the generation of qualia realizes the fractality idea.

## 3.2 Brain In TGD Universe

Brain cognizes and one should find physical correlates for cognition. Also the precise role of brain in information processing and its relationship to metabolism should be understood. Here magnetic body brings as a third player to the couple formed by environment and organism.

1. An attractive idea is that the negentropic entanglement can be assigned with magnetic flux tubes somehow and that ATP serves as a correlate for negentropic entanglement. This leads to a rather detailed ideas about the role of phosphate bond and provides interpretation for the fact that the number of valence bonds tend to be maximized in living matter. In a loose sense one could even call ATP a consciousness molecule. The latest view encourages to consider the possibility that negentropic entanglement with what might be called Mother Gaia is what is transferred in metabolism.
2. The view about the function of brain differs from the standard view. The simplest option is that brain is a builder of symbolic representations building percepts and giving them names rather than the seat of primary qualia relevant to our conscious experience. Sensory organs would carry our primary qualia and brain would build sensory percepts as standardized mental images by using virtual sensory input to the sensory organs. The new view about time

is absolutely essential for circumventing the objections against this vision. The prediction is that also neuronal and even cell membranes define sensory maps with primary qualia assignable to the lipids serving as pixels of the sensory screen. These qualia would not however represent our qualia but lower level qualia. At this moment it is not possible to choose between these two options.

3. The role of EEG and its various counterparts at fractally scaled frequency ranges is to make possible communications to the various onion-like layers of the magnetic body and the control by magnetic body. Dark matter at these layers could be seen as the intentional agent and sensory perceiver.

### 3.3 Anomalies

Various anomalies of living matter have been in vital role in the development of not only TGD view about living matter but also TGD itself.

1. TGD approach to living matter was strongly motivated by the findings about strange behavior of cell membrane and of cellular water, and gel behavior of cytoplasm. Also the findings about effects of ELF em fields on vertebrate brain were decisive and led to the proposal of the hierarchy of Planck constants found later to emerge naturally from the non-determinism of Kähler action. Rather satisfactorily, the other manner to introduce the hierarchy of Planck constants is in terms of gravitational Planck constant: at least in microscopic scales the equivalence of these approaches makes sense and leads to highly non-trivial predictions. The basic testable prediction is that dark photons have cyclotron frequencies inversely proportional to their masses but universal energy spectrum in visible and UV range which corresponds to the transition energies for biomolecules so that they are ideal for biocontrol at the level of both magnetic bodies and at the level of biochemistry.
2. Water is in key role in living matter and also in TGD inspired view about living matter. The anomalies of water lead to a model for dark nuclei as dark proton strings with the surprising prediction that DNA, RNA, amino-acids and even tRNA are in one-one correspondence with the resulting 3-quark states and that vertebrate genetic code emerges naturally. This leads to a vision about water as primordial life form still playing a vital role in living organisms. The model of water memory and homeopathy in turn generalizes to a vision about how immune system might have evolved.
3. Metabolic energy is necessary for conscious information processing in living matter. This suggests that metabolism should be basically transfer of negentropic entanglement from nutrients to the organism. ATP could be seen as a molecule of consciousness in this picture and high energy phosphate bond would make possible the transfer of negentropy.

## 4 Bird's Eye of View about the Topics of the Book

This book is almost as it was when I wrote the chapters for the first time - roughly around year 2000. A lot of progress has taken place after that and many new ideas have emerged. The hierarchy of Planck constants crucial quintessential for the understanding of biological self-organization has a number theoretic interpretation in the framework of adelic physics. The notion of hyper-finite factor gives mathematical realization for the hierarchy of measurement resolutions. The development about ideas related to quantum criticality is relevant also for quantum self-organization. Zero energy ontology (ZEO) generalizes quantum measurement theory to a theory of consciousness and abstracts the notions of behavioral pattern and function central in biology to key physical concepts. The twistor lift of TGD leads to the understanding of the role of length scale dependent cosmological constant having - somewhat surprisingly - implications also for biology. Therefore this book should be read with patience: the ideas were just born and were inept like few month old children but developing vigorously.

In this book I will discuss in detail the view about the quantum hardware of living systems taking seriously the new physics predicted by TGD. Since the vision is bound to be look highly



speculative, it is good to emphasize that the most important predictions follow almost without any reference to the classical field equations using only quantum classical correspondence.

#### 4.1 The implications deriving from the topology of space-time surface and from the properties of induced gauge fields

Quantum classical correspondence and the properties of the simplest extremals of Kähler action have served as the basic guideline in the attempts to understand the new physics predicted by TGD. The most dramatic predictions follow without even considering field equations in detail by using only quantum classical correspondence. These predictions form the backbone of TGD and TGD inspired theory of living matter.

The notions of many-sheeted space-time, topological field quantization and the notion of field/magnetic body, follow from simple topological considerations. The observation that space-time sheets can have arbitrarily large sizes and their interpretation as quantum coherence regions forces to conclude that in TGD Universe macroscopic and macro-temporal quantum coherence are possible in arbitrarily long scales. It took a relatively long time to realize that perhaps the only manner to understand this is a generalization of the quantum theory itself by allowing Planck constant to be dynamical and quantized. TGD leads indeed to a “prediction” for the spectrum of Planck constants and macroscopic quantum phases with large value of Planck constant allow an identification as a dark matter hierarchy.

Also long ranged classical color and electro-weak fields are an unavoidable prediction and it took a considerable time to make the obvious conclusion: TGD Universe is fractal containing fractal copies of standard model physics at various space-time sheets and labeled by the collection of p-adic primes assignable to elementary particles and by the level of dark matter hierarchy characterized partially by the value of Planck constant labeling the pages of the book like structure formed by singular covering spaces of the imbedding space  $M^4 \times CP_2$  glued together along a four-dimensional back. Particles at different pages are dark relative to each other since purely local interactions defined in terms of the vertices of Feynman diagram involve only particles at the same page.

The new view about energy and time finding a rigorous formulation in terms of zero energy ontology means that the sign of inertial energy depends on the time orientation of the space-time sheet and that negative energy space-time sheets serve as correlates for communications to the geometric past. This alone leads to profoundly new views about metabolism, long term memory, and realization of intentional action.

#### 4.2 Vacuum degeneracy of Kähler action as a correlate for quantum criticality and 4-dimensional spin glass degeneracy

The general properties of Kähler action, in particular its vacuum degeneracy and the failure of the classical determinism in the conventional sense, have also very profound implications. Space-time surface as a generalization of Bohr orbit provides not only a representation for quantum state but also for sequences of quantum jumps and thus contents of consciousness. Vacuum degeneracy implies spin glass degeneracy in 4-D sense reflecting quantum criticality which is the fundamental characteristic of TGD Universe.

#### 4.3 The simplest extremals of Kähler action as correlates for asymptotic self organization patterns

The detailed study of the simplest extremals of Kähler action interpreted as correlates for asymptotic self organization patterns provides additional insights [K2].  $CP_2$  type extremals representing elementary particles, cosmic strings, vacuum extremals, topological light rays (“massless extremal”, ME), flux quanta of magnetic and electric fields represent the basic extremals. Pairs of wormhole throats identifiable as parton pairs define a completely new kind of particle carrying only color quantum numbers in ideal case and I have proposed their interpretation as quantum correlates for Boolean cognition. MEs and flux quanta of magnetic and electric fields are of special importance in living matter.

Topological light rays have interpretation as space-time correlates of “laser beams” of ordinary or dark photons or their electro-weak and gluonic counterparts. Neutral MEs carrying em and

$Z^0$  fields are ideal for communication purposes and charged  $W$  MEs ideal for quantum control. Magnetic flux quanta containing dark matter are identified as intentional agents quantum controlling the behavior of the corresponding biological body parts utilizing negative energy  $W$  MEs. Bio-system in turn is populated by electrets identifiable as electric flux quanta.

#### 4.4 Organization of “Quantum Hardware of Living Matter”

I have organized the book in 3 parts.

1. Two chapters in the 1st part of the book are devoted to the model of high  $T_c$  superconductivity relying strongly on the notions of quantum criticality and dark matter.
2. In 2nd part of the book quantum antenna hypothesis inspired by MEs and the notion of wormhole magnetic fields are discussed. Notice that the notion of wormhole magnetic field was introduced much before the hypothesis that elementary particles have a natural identification as pairs of wormhole contacts connected by flux tubes carrying monopole flux. In the recent interpretation wormhole contact pairs would be dark variants of p-adically scaled variants of ordinary particles.
3. In the 3rd part of the book two chapters are devoted to the possible biological implications of the hypothesis that dark matter corresponds to macroscopic quantum phases characterized by a large value of Planck constant and is the key actor in living matter.

I must apologize the fact the implications of the dark matter revolution have not been thoroughly considered in this book. Same applies to the implications of zero energy ontology (ZEO).

## 5 Sources

The eight online books about TGD [K26, K17, K32, K22, K13, K31, K30, K21] and nine online books about TGD inspired theory of consciousness and quantum biology [K25, K4, K14, K3, K8, K9, K11, K20, K29] are warmly recommended for the reader willing to get overall view about what is involved.

My homepage (<http://tinyurl.com/ybv8dt4n>) contains a lot of material about TGD. In particular, a TGD glossary at <http://tinyurl.com/yd6j3o7>.

I have published articles about TGD and its applications to consciousness and living matter in *Journal of Non-Locality* (<http://tinyurl.com/ycyrxj4o>) founded by Lian Sidorov and in *Prespacetime Journal* (<http://tinyurl.com/ycvktjhn>), *Journal of Consciousness Research and Exploration* (<http://tinyurl.com/yba4f672>), and *DNA Decipher Journal* (<http://tinyurl.com/y9z52khg>), all of them founded by Huping Hu. One can find the list about the articles published at <http://tinyurl.com/ybv8dt4n>. I am grateful for these far-sighted people for providing a communication channel, whose importance one cannot overestimate.

## 6 The contents of the book

### 6.1 PART I: BIO-SYSTEMS AS SUPER CONDUCTORS

#### 6.1.1 Bio-Systems as Super-Conductors: Part I

In this chapter various TGD based ideas related to the role of super-conductivity in bio-systems are studied. TGD inspired theory of consciousness provides several motivations for this.

1. *Empirical evidence for high  $T_c$  superconductivity in bio-systems*

There is evidence for super-conductivity in bio-systems. DNA should be insulator but under some circumstances it becomes conductor and perhaps even high  $T_c$  quantum critical superconductor. Also evidence for Josephson effect has been reported. The so called ORMEs patented by Hudson are claimed to behave like superconductors: unfortunately the academic world has not taken these claims seriously enough to test them. The claimed properties of ORMEs conform with high quantum critical  $T_c$  super-conductivity and superfluidity. The strange findings about the

strange quantal behavior of ionic currents through cell membranes suggest the presence of ionic supra currents.

### 2. Model for high $T_c$ superconductivity

A model for high  $T_c$  super-conductivity as quantum critical phenomenon is developed. The relies on the notions of quantum criticality, dynamical quantized Planck constant requiring a generalization of the 8-D imbedding space to a book like structure, and many-sheeted space-time. In particular, the notion of magnetic flux tube as a carrier of supra current of central concept.

With a sufficient amount of twisting and weaving these basic ideas one ends up to concrete model for high  $T_c$  superconductors as quantum critical superconductors consistent with the qualitative facts that I am personally aware. The following minimal model looks the most realistic option found hitherto.

1. The general idea is that magnetic flux tubes are carriers of supra currents. In anti-ferromagnetic phases these flux tube structures form small closed loops so that the system behaves as an insulator. Some mechanism leading to a formation of long flux tubes must exist. Doping creates holes located around stripes, which become positively charged and attract electrons to the flux tubes.
2. The basic mechanism for the formation of Cooper pairs is simple. Magnetic flux tubes would be carriers of dark particles and magnetic fields would be crucial for super-conductivity. Two parallel flux tubes carrying magnetic fluxes in opposite directions is the simplest candidate for super-conducting system. This conforms with the observation that antiferromagnetism is somehow crucial for high temperature super-conductivity. The spin interaction energy is proportional to Planck constant and can be above thermal energy: if the hypothesis that dark cyclotron energy spectrum is universal is accepted, then the energies would be in bio-photon range and high temperature super-conductivity is obtained. If fluxes are parallel spin  $S = 1$  Cooper pairs are stable.  $L = 2$  states are in question since the members of the pair are at different flux tubes.
3. The higher critical temperature  $T_{c1}$  corresponds to a formation local configurations of parallel spins assigned to the holes of stripes giving rise to a local dipole fields with size scale of the order of the length of the stripe. Conducting electrons form Cooper pairs at the magnetic flux tube structures associated with these dipole fields. The elongated structure of the dipoles favors angular momentum  $L = 2$  for the pairs. The presence of magnetic field favors Cooper pairs with spin  $S = 1$ .
4. Stripes can be seen as 1-D metals with delocalized electrons. The interaction responsible for the energy gap corresponds to the transversal oscillations of the magnetic flux tubes inducing oscillations of the nuclei of the stripe. These transverse phonons have spin and their exchange is a good candidate for the interaction giving rise to a mass gap. This could explain the BCS type aspects of high  $T_c$  super-conductivity.
5. Above  $T_c$  supra currents are possible only in the length scale of the flux tubes of the dipoles which is of the order of stripe length. The reconnections between neighboring flux tube structures induced by the transverse fluctuations give rise to longer flux tubes structures making possible finite conductivity. These occur with certain temperature dependent probability  $p(T, L)$  depending on temperature and distance  $L$  between the stripes. By criticality  $p(T, L)$  depends on the dimensionless variable  $x = TL/\hbar$  only:  $p = p(x)$ . At critical temperature  $T_c$  transverse fluctuations have large amplitude and makes  $p(x_c)$  so large that very long flux tubes are created and supra currents can run. The phenomenon is completely analogous to percolation.
6. The critical temperature  $T_c = x_c \hbar / L$  is predicted to be proportional to  $\hbar$  and inversely proportional to  $L$  (, which is indeed to be the case). If flux tubes correspond to a large value of  $\hbar$ , one can understand the high value of  $T_c$ . Both Cooper pairs and magnetic flux tube structures represent dark matter in TGD sense.
7. The model allows to interpret the characteristic spectral lines in terms of the excitation energy of the transversal fluctuations and gap energy of the Cooper pair. The observed 50

meV threshold for the onset of photon absorption suggests that below  $T_c$  also  $S = 0$  Cooper pairs are possible and have gap energy about 9 meV whereas  $S = 1$  Cooper pairs would have gap energy about 27 meV. The flux tube model indeed predicts that  $S = 0$  Cooper pairs become stable below  $T_c$  since they cannot anymore transform to  $S = 1$  pairs. Their presence could explain the BCS type aspects of high  $T_c$  super-conductivity. The estimate for  $\hbar/\hbar_0 = r$  from critical temperature  $T_{c1}$  is about  $r = 3$  contrary to the original expectations inspired by the model of living system as a super-conductor suggesting much higher value. An unexpected prediction is that coherence length is actually  $r$  times longer than the coherence length predicted by conventional theory so that type I super-conductor could be in question with stripes serving as duals for the defects of type I super-conductor in nearly critical magnetic field replaced now by ferromagnetic phase.

At qualitative level the model explains various strange features of high  $T_c$  superconductors. One can understand the high value of  $T_c$  and ambivalent character of high  $T_c$  super conductors, the existence of pseudogap and scalings laws for observables above  $T_c$ , the role of stripes and doping and the existence of a critical doping, etc...

### 3. *The model for superconductivity in living matter*

The model for high  $T_c$  superconductivity was inspired by the model of bio-superconductivity in which the flux tubes of magnetic fields are carriers of supra currents and the large value of Planck constant guarantees that gap energy and critical temperature are high enough. The transversal fluctuations of flux tubes provide the counterpart of phonons generating energy gap. Besides dark Cooper pairs also the Bose-Einstein condensates of dark bosonic ions define candidates for super-conducting phases provided that the gap energies in longitudinal and transversal magnetic degrees of freedom are high enough. High enough values of Planck constant can guarantee this.

## 6.1.2 Bio-Systems as Super-Conductors: Part II

This chapter is devoted to further applications of the theory of high  $T_c$  superconductors as quantum critical superconductors involving dark matter hierarchy and large values of  $h_{eff} = n \times h$ . A new element is the model of cell membrane acting as Josephson junction: at microscopic transmembrane proteins would define Josephson junctions. The theory is applied to explain the strange findings about ionic currents through cell membrane, and the possibility that superconductivity and Bose-Einstein condensates are involved with atmospheric phenomena is considered.

### 1. *Strange behavior of cellular water and quantal ionic currents through cell membrane*

The fact that cellular water does not leak out of cell in a centrifugal force suggests that some fraction of water inside cell is in different phase. One explanation is that the nuclei of water inside cell are in doubly dark phase whereas electrons are in singly dark phase (having Compton length of 5 nm and perhaps directly “visible” using day technology!) as indeed predicted by the model of high  $T_c$  superconductivity. This conceptual framework could explain various findings challenging the notions of ionic pumps.

The empirical findings challenging the notions of ionic pumps and channels, nicely summarized by G. Pollack in his book, provide a strong support for the notions of many-sheeted space-time and ionic super-conductivity.

1. The selectivity of the cell membrane implies that channels cannot be simple sieves and there must be complex information processing involved.
2. The needed number of pumps specialized to particular ions is astronomical and the first question is where to put all these channels and pumps. On the other hand, if the cell constructs the pump or channel specialized to a given molecule only when needed, how does it know what the pump looks like if it has never seen the molecule? The needed metabolic energy to achieve all the pumping and channelling is huge. Strangely enough, pumping does not stop when cell metabolism stops.
3. One can also wonder why the ionic currents through cell membrane look quantal and are same through cell membrane and silicon rubber membrane.

These observations suggest strongly the presence non-dissipative ionic currents and quantum self-organization. The TGD based explanation would be in terms of high  $T_c$  electronic and possibly even ionic superconductivity associated with cell membrane made possible by the large  $h_{eff}$  phase for nuclei and electrons in the interior of cell. The model for electronic Cooper pairs as pairs of large  $h_{eff}$  electrons at parallel magnetic flux tubes with same (opposite) direction of magnetic field and in  $S = 1$  ( $S = 0$ ) state generalizes.

The empirical input also supports a view about homeostasis as a many-sheeted ionic flow equilibrium controlled by larger space-time sheets with the mediation of massless extremals (MEs) serving as space-time correlates for Bose-Einstein condensates of massless bosons (also of scaled down dark electro-weak bosons and gluons).

In the proposed picture one could understand how extremely low densities of ions and their supra currents can control much higher ion densities at the atomic space-time sheets. The liquid supra nature of the bio-matter is crucial for the model. This vision allows also much better understanding of the effects of ELF em fields on bio-matter. Also the effects of homeopathic remedies and acupuncture known to crucially involve electromagnetic frequency signatures of chemicals can be understood if homeostasis is based on many-sheeted ionic flow equilibrium.

### 2. Two models of cell membrane

TGD inspires two views about cell membrane: the views need not be contradictory. For the first model cell is far from vacuum extremal, for the second model nearly vacuum extremal with classical  $Z^0$  fields in key role.

1. There are several constraints on the first model coming from the TGD based identification of bio-photons as energy conserving decay products of dark photons and one ends up to a new view about metabolism and generalization to of the notion of Josephson junction so that Josephson energy includes besides electrostatic energy also the difference of cyclotron energies at two sides of the membrane. It seem that that the first model might be enough when generalized along lines inspired by Pollack's findings about the fourth phase of water.
2. It has been clear from the beginning that the nearly vacuum extremals of Kähler action could play key role in living systems. The reason is their criticality making them ideal systems for sensory perception. These extremals carry classical em and  $Z^0$  fields related to each other by a constant factor and this could explain the large parity breaking effects characterizing living matter. The assumption that at least some cell membranes are nearly vacuum extremals and that nuclei can feed their  $Z^0$  charges to this kind of space-time sheets (not true for atomic electrons) in living matter leads to a modification of the model for the cell membrane as Josephson junction. Also a model of photoreceptors explaining the frequencies of peak sensitivity as ionic Josephson frequencies and allowing the dual identifications Josephson radiation as biophotons (energies) and EEG radiation (frequencies) emerge since the values of Planck constant can be very large. Contrary to the original believe, this model does not require non-standard value of Weinberg angle and this model and first model allow a hybrid.

### 3. Bose-Einstein condensates at magnetic flux quanta in astrophysical length scales

The model for the topological condensation at magnetic flux quanta of endogenous magnetic field  $B_{end} = .2$  Gauss is based on the dark matter hierarchy with levels characterized by the values of Planck constant. The hypothesis for the preferred values of Planck constants allows to build quantitative model for the Bose-Einstein condensation at magnetic flux quanta assuming that the value of  $B_{end}$  scales like  $1/h_{eff}$ . A justification for this hypothesis comes from flux quantization conditions and from the similar scaling of Josephson frequencies.

1. There are several levels of dynamics. In topological condensation the internal dynamics of ions is unaffected and  $h_{eff}$  has the ordinary value. For instance, the formation of Cooper pairs involves dynamics at  $k_d = 24 = 151 - 127$  level of dark matter hierarchy if one assumes that electrons and Cooper pairs have size given by the cell membrane thickness  $L(151)$ . Also the dynamics of ionic Cooper pairs remains unaffected in the topological condensation to magnetic flux quanta obeying  $k_d > 24$  dynamics.

2. Cyclotron energies scale as  $h_{eff}$  so that for a sufficiently high value of  $k_d$  thermal stability of cyclotron states at room temperature is achieved for a fixed value of  $B$ . Same applies to spin flip transitions in the recent scenario. The model for EEG based on dark matter hierarchy involves the hypothesis that EEG quanta correspond to Josephson radiation with energies in the visible and UV range and that they produce in the decay to ordinary photons either bunches of EEG photons or visible/UV photons. This identification allows to deduce the value of  $k_d$  when the frequency of the dark photon is fixed. The Mersenne hypothesis for the preferred p-adic length scales and values of Planck constants leads to very precise predictions.
3. Cyclotron energies  $E = (h_{eff}/2\pi) \times ZeB/Am_p$  are scaled up by a factor  $r = 2^{k_d}$  from their ordinary values and for 10 Hz cyclotron frequency are in the range of energies of visible light for  $k_d = 46$ .
4. These B-E condensates might be favored by the large negative spin interaction energies of spins with the magnetic field (proportional to  $h_{eff}$ ) so that spontaneous magnetization of the magnetic body becomes possible. This kind of process would make possible for the system to gain energy and angular momentum by feeding charged particles to its magnetic body.

#### 4. *The model of ionic superconductivity*

The model of ionic superconductivity is based on same mechanism as the electron one.

The general idea is that magnetic flux tubes are carriers of dark charged particles including ions and electrons. Usually magnetic field tends to destroy Cooper pairs since it tends to flip the spins of electrons of pair to same direction. In TGD flux quantization comes in rescue and magnetic fields favor the formation of Cooper pairs. If one has two parallel flux tubes with opposite directions of magnetic fluxes with large value of  $h_{eff} = n \times h$ ,  $S = 0$  Cooper pairs with even  $L \geq 2$  are favored. This situation is encountered in systems near antiferromagnetic phase transition in small scales leading to formation of sequences of flux loops carrying Cooper pairs. Macroscopic super-conductivity results when the loops are reconnected to two long flux tubes with opposite fluxes. If the magnetic fluxes have same sign,  $S = 1$  Cooper pairs with odd  $L \geq 1$  are favored.

This model applies to both electrons and fermionic ions and if the proposal that  $h_{eff}$  is proportional to the mass of ion, it predicts same binding energies for all Cooper pairs as their spin-spin interaction energy. This hypothesis predicts universal spectrum of bio-photons energies if they result from dark photons and is motivated by the identification of gravitational Planck constant with  $h_{eff}$ . In this case binding energies would be in eV range and much above thermal energy at room temperature.

#### 5. *Atmospheric phenomena and superconductivity*

There is a considerable evidence that various electromagnetic time scales associated with the atmospheric phenomena correspond to those associated with brain functioning. If magnetic sensory canvas hypothesis holds true, this is just what is expected. In this section these phenomena are considered in more detail with the aim being to build as concrete as possible vision about the dynamics involving the dark matter Bose-Einstein condensates at super-conducting magnetic flux quanta. A new element is the assumed presence of cell membrane like structures near vacuum extremals. If the potentials differences involved are same order of magnitude as in the case of cell membrane, the luminous phenomena can be understood in terms of effects caused by Josephson radiation at visible and UV frequencies.

Tornadoes and hurricanes provide the first example of self-organizing systems for which Bose-Einstein condensates of dark matter at magnetic and  $Z^0$  magnetic flux quanta might be of relevance. Auroras represent a second phenomenon possibly involving supra currents of Cooper pairs and of exotic ions. Lightnings, sprites and elves might also involve higher levels of dark matter hierarchy. p-Adic length scale hypothesis and the hierarchy of Planck constants provide a strong grasp to these far from well-understood phenomena and allow to build rather detailed models for them as well as to gain concrete understanding about how dark matter hierarchy manifests itself in the electromagnetic phenomena at the level of atmosphere.

## 6.2 PART II: TOPOLOGICAL LIGHT RAYS AND WORMHOLE MAGNETIC FIELDS

### 6.2.1 Quantum Antenna Hypothesis

So called MEs (MEs or topological light rays) are non-vacuum extremals of both Kähler action and the EYM action serving as effective action of the theory. These extremals have cylindrical geometry and are carriers of purely classical vacuum currents and Einstein tensor, which are both light like. These vacuum currents generate coherent states of photons and gravitons with frequencies coming as multiples of the basic frequency determined by the length of the microtubule. They can also carry Bose-Einstein condensates of massless particles. It is proposed that microtubules and other linear structures could act as quantum antennae so that coherent light would be for brain same as radiowaves for us. MEs associated with axonal microtubules or axons themselves could serve as waveguides for the photons of coherent light and realize the notion of neural window abstracted from the paradigm of holographic brain. Vacuum currents could be also behind the ability of the biosystems to form representations of the external world.

There is indeed evidence for the quantum antenna hypothesis: some monocellulars are known to possess primitive microtubular vision, biophotons of Popp could be generated by MEs and the observations of Callahan support the view that odour perception of insects relies on maser-like emissions by the odour molecules. The coherent light emitted in sonoluminescence could be generated by light-like vacuum currents associated with regions with size given roughly by the diameter of microtubule when vapour-to-liquid phase transition occurs at the final stage of the bubble collapse. Also the observed direct transformation of kinetic energy of fluid motion to chemical energy could involve generation of MEs.

The light-like boundaries of MEs might not be allowed by boundary conditions: MEs could appear as pairs glued together along boundaries or as a similar pair of ME and magnetic flux tube. If the boundaries are however possible, they have the same miraculous conformal properties as the boundary of future lightcone and MEs also allow holography in the sense of quantum gravity and string models and there are good hopes to generalize the construction of the WCW geometry and quantum TGD to take into account the classical non-determinism of Kähler action. MEs provide a justification for the intuition that the supersymplectic and superconformal symmetries of the lightcone boundary  $\delta M_+^4 \times CP_2$ , which are cosmological symmetries, generalize to approximate macroscopic symmetries acting on the light-like boundaries of the spacetime sheets inside future lightcone and broken only by quantum gravity. Supersymplectic symmetries almost-commute with Poincare symmetries and the gigantic almost-degenerate supersymplectic multiplets defined by genuinely quantum gravitational state functionals in the “world of worlds” correspond in a well-defined sense to higher abstraction level expected to be crucial for understanding consciousness. MEs are also tailor-made for quantum holography and teleportation. Quantum holography conceptualization inspires much more detailed views about how biosystems process information and how this information becomes conscious.

### 6.2.2 Wormhole Magnetic Fields

The first version of this chapter was written for almost two decades ago and some interpretations have changed since then. It was argued that two purely TGD based concepts: topological field quantization and wormhole BE condensate are fundamental for the understanding of biosystems. There is not reason to modify this claim. The ideas about the physical interpretation of wormhole contacts have however developed since then dramatically: in the recent formulation of the theory wormhole contacts define basic building bricks of elementary particles. Hierarchy of Planck constants assigned with dark matter is second new notion and this might allow to see wormhole BE-condensates as BE-condensates of dark variants of ordinary particles.

#### 1. Basic concepts

Quantum classical correspondence suggests that gauge charges and p-adic coupling constant should have space-time counterparts. The first problem is to define precisely the concepts like classical gauge charge, gauge flux, topological condensation and evaporation. The crucial ingredients in the model are so called  $CP_2$  type extremals. The realization that # contacts (topological sum

contacts and  $\#_B$  contacts (join along boundaries bonds) are accompanied by causal horizons which carry quantum numbers and allow identification as partons leads to a solution of this problem.

The partons associated with topologically condensed  $CP_2$  type extremals carry elementary particle vacuum numbers whereas the parton pairs associated with  $\#$  contacts connecting two space-time sheets with Minkowskian signature of induced metric define parton pairs. These parton pairs do not correspond to ordinary elementary particles. Gauge fluxes through  $\#$  contacts can be identified as gauge charges of the partons. Gauge fluxes between space-time sheets can be transferred through  $\#$  and  $\#_B$  contacts concentrated near the boundaries of the smaller space-time sheet.

It has become clear that the notion of  $\#_B$  contact might require a modification. There are reasons to argue that boundary conditions do not allow space-time surfaces to have boundaries but are replaced by 2-fold coverings obtained by gluing two space-time sheets along their boundaries together. The 3-D light-like orbits of wormhole contacts at which Minkowskian signature of the induced metric changes to Euclidian, have replaced boundaries and  $\#_B$  contacts could be either magnetic flux tubes with Minkowskian metric or Euclidian flux tube like regions.

### 2. Model for topologically quantized magnetic fields

Topological field quantization replaces classical magnetic fields with bundles of flux tubes parallel to the field lines; flux tubes are cylindrical 3-surfaces with outer boundary. In particular, “wormhole magnetic fields” having charged wormholes situated at the boundaries of the flux tubes as their sources, are possible and are vacuum configurations in the sense that they do not contain ordinary matter at all. Since wormholes are very light particles, they can suffer BE condensation, and the resulting structure is macroscopic quantum system.

The recent view about particles suggests that wormhole BE-condensates are BE-condensates of particle with non-standard and large value of Planck constant. Magnetic fluxes and their braiding play key role in the TGD inspired model of topological quantum computation in living manner. This suggests that wormhole magnetic fields and more general structures of the same kind could realize quantum physicist’s version about the computer scientist’s dream about universe consisting of Turing machines emulating each other.

### 3. Models for Comorosan effect, phantom DNA effect, and homeopathy

It is shown that the concept of wormhole magnetic fields suggest a model of *Comorosan effect* and *phantom DNA effect*. Homeopathy could be explained in terms of the mind-like space-time sheets mimicking the properties of the drug and left to the solution in the repeated dilution of the drug. Wormhole magnetic fields provide a quantum mechanism of control from distance, say of the control of the behavior of cell organelles by cell nucleus as well as a model for the memory of bio-system in terms of integer valued winding numbers identifiable as quantized momenta of wormhole supra currents. Wormhole magnetic fields can also represent defects of electron and neutrino super conductors and serve as a templates for the topological condensation of ordinary matter. The fact that wormhole flux tubes are *hollow* cylinders, is in nice accordance with this idea (microtubules, axonal membranes, etc. are hollow cylinders).

### 4. TGD inspired model for psychokinesis

A model of psychokinesis (PK) based on the concept of wormhole magnetic field is proposed. The basic philosophy is that PK is not just some isolated exotic phenomenon but only a special case of the voluntary control of bodily motions, which we all routinely perform. The only difference is that the range of voluntary control extends over the boundaries of the body in case of PK. The conclusion is that PK phenomena must involve classical long range fields, which give for bio-systems spatial extension larger than what is visible (that is hands with which to grasp on external object!). According to TGD inspired theory of consciousness, cell, and even DNA can be conscious, and perform choices. Thus the model should also provide understanding about small scale bio-control such as the (possibly voluntary!) control of the motion of cell organelles performed by cell nucleus. There is also alternative approach to the understanding of psychokinesis based on the possibility of creation of space-time sheets having negative time orientation and negative classical energy density and one could consider the possibility that poltergeist effects could involve this mechanism. Many-sheeted space-time concept makes possible also psychokinesis based on levitation: what is needed that subsystem is able to topologically condense to a sufficiently large space-time sheet carrying



very weak gravitational fields.

## 6.3 PART III: DARK MATTER AND LIVING MATTER

### 6.3.1 Dark Nuclear Physics and Condensed Matter

In this chapter the possible effects of dark matter in nuclear physics and condensed matter physics are considered. The spirit of the discussion is necessarily rather speculative. The most general form of the hierarchy would involve both singular coverings and factor spaces of  $CD$  (causal diamond of  $M^4$ ) defined as intersection of future and past directed light-cones) and  $CP_2$ . There are grave objections against the allowance of factor spaces. In this case Planck constant could be smaller than its standard value and there are very few experimental indications for this. Quite recently came the realization that the hierarchy of Planck constants might emerge from the basic quantum TGD as a consequence of the extreme non-linearity of field equations implying that the correspondence between the derivatives of imbedding space coordinates and canonical momentum is many-to-one. This makes natural to the introduction of covering spaces of  $CD$  and  $CP_2$ .

Planck constant would be effectively replaced with a multiple of ordinary Planck constant defined by the number of the sheets of the covering. The space-like 3-surfaces at the ends of the causal diamond and light-like 3-surfaces defined by wormhole throats carrying elementary particle quantum numbers would be quantum critical in the sense of being unstable against decay to many-sheeted structures. Charge fractionization could be understood in this scenario. Biological evolution would have the increase of the Planck constant as one aspect. The crucial scaling of the size of  $CD$  by Planck constant can be justified by a simple argument. Note that primary p-adic length scales would scale as  $\sqrt{\hbar}$  rather than  $\hbar$  as assumed in the original model.

Recently the hierarchy of Planck constants have been traced to the non-determinism of Kähler action predicting in zero energy ontology (ZEO) that two space-like 3-surfaces at the ends of causal diamonds (CD) can be connected by several space-time surfaces. As a matter fact, by infinite number of them related by quantum critical deformations identifiable as conformal transformations respecting the light-likeness of partonic orbits at which the signature of the induced metric changes. The number of conformal equivalence classes of space-time sheets would be integer  $n$  defining the effective Planck constant  $h_{eff} = n \times h$ .

#### 1. *What darkness means?*

Dark matter is identified as matter with non-standard value of Planck constant. The weak form of darkness states that only some field bodies of the particle consisting of flux quanta mediating bound state interactions between particles become dark. One can assign to each interaction a field body (em,  $Z^0$ ,  $W$ , gluonic, gravitational) and p-adic prime and the value of Planck constant characterize the size of the particular field body. One might even think that particle mass can be assigned with its em field body and that Compton length of particle corresponds to the size scale of em field body.

Nuclear string model suggests that the sizes of color flux tubes and weak flux quanta associated with nuclei can become dark in this sense and have size of order atomic radius so that dark nuclear physics would have a direct relevance for condensed matter physics. If this happens, it becomes impossible to make a reductionistic separation between nuclear physics and condensed matter physics and chemistry anymore.

#### 2. *What dark nucleons are?*

The basic hypothesis is that nuclei can make a phase transition to dark phase in which the size of both quarks and nuclei is measured in Angstroms. For the less radical option this transition could happen only for the color, weak, and em field bodies. Proton connected by dark color bonds super-nuclei with inter-nucleon distance of order atomic radius might be crucial for understanding the properties of water and perhaps even the properties of ordinary condensed matter. Large  $\hbar$  phase for weak field body of  $D$  and  $Pd$  nuclei with size scale of atom would explain selection rules of cold fusion.

#### 3. *Anomalous properties of water and dark nuclear physics*

A direct support for partial darkness of water comes from the  $H_{1.5}O$  chemical formula supported

by neutron and electron diffraction in attosecond time scale. The explanation could be that one fourth of protons combine to form super-nuclei with protons connected by color bonds and having distance sufficiently larger than atomic radius.

The crucial property of water is the presence of molecular clusters. Tetrahedral clusters allow an interpretation in terms of magic  $Z=8$  protonic dark nuclei. The icosahedral clusters consisting of 20 tetrahedral clusters in turn have interpretation as magic dark dark nuclei: the presence of the dark dark matter explains large portion of the anomalies associated with water and explains the unique role of water in biology. In living matter also higher levels of dark matter hierarchy are predicted to be present. The observed nuclear transmutation suggest that also light weak bosons are present.

#### 4. *Implications of the partial darkness of condensed matter*

The model for partially dark condensed matter inspired by nuclear string model and the model of cold fusion inspired by it allows to understand the low compressibility of the condensed matter as being due to the repulsive weak force between exotic quarks, explains large parity breaking effects in living matter, and suggests a profound modification of the notion of chemical bond having most important implications for bio-chemistry and understanding of bio-chemical evolution.

### 6.3.2 Dark Forces and Living Matter

The unavoidable presence of classical long ranged weak (and also color) gauge fields in TGD Universe has been a continual source of worries for more than two decades. The basic question has been whether electro-weak charges of elementary particles are screened in electro-weak length scale or not. The TGD based view about dark matter assumes that weak charges are indeed screened for ordinary matter in electro-weak length scale but that dark electro-weak bosons correspond to much longer symmetry breaking length scale. The localization of the modes of Kähler-Dirac action to 2-D surfaces at which  $W$  fields vanish realizes this idea concretely. Also  $Z^0$  fields can vanish and are expected to do so above weak scale.

The large value of  $\hbar$  in dark matter phase implies that Compton lengths and -times are scaled up. In particular, the sizes of nucleons and nuclei become of order atom size so that dark nuclear physics would have direct relevance for condensed matter physics. It becomes impossible to make a reductionistic separation between nuclear physics and condensed matter physics and chemistry anymore. This view forces a profound re-consideration of the earlier ideas in nuclear and condensed physics context. It however seems that most of the earlier ideas related to the classical  $Z^0$  force and inspired by anomaly considerations survive in a modified form.

The weak form of electric-magnetic duality led to the identification of the long sought for mechanism causing the weak screening in electroweak scales. The basic implication of the duality is that Kähler electric charges of wormhole throats representing particles are proportional to Kähler magnetic charges so that the  $CP_2$  projections of the wormhole throats are homologically non-trivial. The Kähler magnetic charges do not create long range monopole fields if they are neutralized by wormhole throats carrying opposite monopole charges and weak isospin neutralizing the axial isospin of the particle's wormhole throat. One could speak of confinement of weak isospin. The weak field bodies of elementary fermions would be replaced with string like objects with a length of order  $W$  boson Compton length. Electro-magnetic flux would be feeded to electromagnetic field body where it would be feeded to larger space-time sheets. Similar mechanism could apply in the case of color quantum numbers. Weak charges would be therefore screened for ordinary matter in electro-weak length scale but dark electro-weak bosons correspond to much longer symmetry breaking length scale for weak field body. Large values of Planck constant would make it possible to zoop up elementary particles and study their internal structure without any need for gigantic accelerators.

One can still worry about large parity breaking effects - say in nuclear physics- since the couplings of spinors to classical weak fields are there. Around 2012 it became clear that the condition that induced spinor fields have well defined em charge localizes their modes in the generic case to 2-surfaces carrying vanishing induced  $W$  gauge fields. It is quite possible that this localization is consistent with Kähler-Dirac equation only in their Minkowskian regions were the effective metric defined by Kähler-Dirac gamma matrices can be effectively 2-dimensional.

One can pose the additional condition that also classical  $Z^0$  field vanishes - at least above weak

scale. Fundamental fermions would experience only em field so that the worries related to large parity breaking effects would disappear. The proportionality of weak scale to  $h_{eff} = n \times h$  however predicts that weak fields are effectively massless belong scaled up weak scale. Therefore worries about large parity breaking effects in ordinary nuclear physics can be forgotten.

In this chapter possible implications of the dark weak force for the understanding of living matter are discussed. The basic question is how classical  $Z^0$  fields could make itself visible. Large parity breaking effects in living matter suggests which direction one should look for the answer to the question. One possible answer is based on the observation that for vacuum extremals classical electromagnetic and  $Z^0$  fields are proportional to each other and this means that the electromagnetic charges of dark fermions standard are replaced with effective couplings in which the contribution of classical  $Z^0$  force dominates. This modifies dramatically the model for the cell membrane as a Josephson junction and raises the scale of Josephson energies from IR range just above thermal threshold to visible and ultraviolet. The amazing finding is that the Josephson energies for biologically important ions correspond to the energies assigned to the peak frequencies in the biological activity spectrum of photoreceptors in retina suggesting. This suggests that almost vacuum extremals and thus also classical  $Z^0$  fields could be in a central role in the understanding of the functioning of the cell membrane and of sensory qualia. This would also explain the large parity breaking effects in living matter.

A further conjecture is that EEG and its predicted fractally scaled variants which same energies in visible and UV range but different scales of Josephson frequencies correspond to Josephson photons with various values of Planck constant. The decay of dark ELF photons with energies of visible photons would give rise to bunches of ordinary ELF photons. Biophotons in turn could correspond to ordinary visible photons resulting in the phase transition of these photons to photons with ordinary value of Planck constant. This leads to a very detailed view about the role of dark electromagnetic radiation in biomatter and also to a model for how sensory qualia are realized. The general conclusion might be that most effects due to the dark weak force are associated with almost vacuum extremals.

### 6.3.3 About the New Physics Behind Qualia

This chapter was originally about the new physics behind qualia. The model of qualia indeed involves a lot of new physics: many-sheeted space-time; massless extremals; magnetic and cyclotron phase transitions associated with quantum critical quantum spin glass phases of exotic superconductors at cellular space-time sheets; classical color and electro-weak gauge fields in macroscopic length scales, to name the most important ingredients. Gradually the chapter however expanded so that it touches practically all new physics possibly relevant to TGD inspired quantum biology. Various physical mechanisms are discussed in exploratory spirit rather than restricting the consideration to those ideas which seem to be the final word about quantum biology or qualia just at this moment.

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