

# Introduction to "TGD View of Bio-Systems as Self-Organizing Quantum Systems"

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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 towards the end of 1977 - would emerge now it would be seen as an attempt to solve the difficulties of these approaches to unification.

The basic physical picture behind the geometric vision of 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. After 1995 number theoretic vision started to develop and was initiated by the success of mass calculations based on p-adic thermodynamics. Number theoretic vision involves all number fields and is complementary to the geometric vision: one can say that this duality is analogous to momentum-position duality of wave mechanics. TGD can be also regarded as topological quantum theory in a very general sense as already the attribute "Topological" in "TGD" makes clear. Space-time surfaces as minimal surfaces can be regarded as representatives of homology equivalence classes and p-adic topologies generalize the notion of local topology and apply to the description of correlates of cognition.

## 1.1 Geometric 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 embedding 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 embedding space metric and parallel translation using spinor connection of embedding space.

Twistor lift of TGD means that one can lift space-time surfaces in  $H$  to 6-D surfaces a analogs of twistor space of space-time surface in 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]. The twistor structure would be induced in some sense, and should coincide 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 the space-time surface. This poses a constraint on the embedding of the twistor space of space-time surfaces as sub-manifold in the Cartesian product of twistor spaces. The existence of Kähler structure allows to lift 4-D Kähler action to its 6-D counterparts and the 6-D counterpart of twistor space is obtained by its dimensional reduction so that one obtains a sphere bundle. This makes possible twistorialization for all space-time surfaces: in general relativity the general metric does not allow this.

3. A 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 the 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.  $M^4$  and  $CP_2$  allow quaternionic structures. Therefore standard model symmetries have number theoretic meaning.

4. Induced gauge potentials are expressible in terms of embedding 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. Particles in space-time can be identified as a topological inhomogeneities 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 distances 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 the standard model and general relativity follow as a topological simplification, however forcing a dramatic increase of 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. The basic problem is that one has long ranged classical electroweak gauge fields. The resolution of the problem is that the quantum averages of induced weak and color gauge fields vanish due to the fact that color rotations affect both space-time surfaces and induced weak and color fields. Only the averages of electromagnetic fields are nonvanishing. The correlations functions for weak fields are nonvanishing below Compton lengths of weak bosons. In living matter large values of effective Planck constant labelling phases of ordinary matter identified as dark matter make possible long ranged weak fields and color fields.
6. General coordinate invariance requires holography so that space-time surfaces are analogous to Bohr orbits for particles identified as 3-surfaces. Bohr orbit property would be naturally realized by a 4-D generalization of holomorphy of string world sheets and implies that the space-time surfaces are minimal surfaces apart from singularities. This holds true for any action as long as it is general coordinate invariant and constructible in terms of the induced geometry. String world sheets and light-like orbits of partonic 2-surfaces correspond to singularities at which the minimal surface property of the space-time surfaces realizing the preferred extremal property fails. Preferred extremals are not completely deterministic, which implies what I call zero energy ontology (ZEO) meaning that the Bohr orbits are the fundamental objects. This leads to a solution of the basic paradox of quantum measurement

theory. Also the mathematically ill-defined path integral disappears and leaves only the well-defined functional integral over the Bohr orbits.

7. A string model-like picture emerges from TGD and one ends up with a rather concrete view about the topological counterpart of Feynman diagrammatics. The natural stringy action would be given by the string world sheet area, which is present only in the space-time regions with Minkowskian signature. Gravitational constant could be present as a fundamental constant in string action and the ratio  $\hbar/G/R^2$  would be determined by quantum criticality conditions. 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 superstring 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 induced spinor fields associated with Kähler-Dirac action and de-localized inside the 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 embeddings: 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 the 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 is 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 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] [B4, B2, B3]), 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 an 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 embedding 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 [B1]) or something similar. Rather, TGD space-time is topologically non-trivial in all scales and even the visible structures of the everyday world represent non-trivial topology of space-time in the 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 hierarchy of Planck constants  $h_{eff} = n \times h$  reduces to the quantum criticality of the 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 45 years to the realization of this dream and this has resulted in 26 online books about TGD and nine online books about TGD inspired theory of consciousness and of quantum biology.

A collection of 30 online books is now (August 2023) under preparation. The goal is to minimize overlap between the topics of the books and make the focus of a given book sharper.

## 1.2 Two Visions About TGD as Geometrization of Physics and Their Fusion

As already mentioned, TGD as a geometrization of physics 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.

The proposal is that 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 possible 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 the physical system does not possess this kind of field identity. The notion of the magnetic body is one of the key players in TGD inspired theory of consciousness and quantum biology. The existence of monopole flux tubes requiring no current as a source of the magnetic field makes it possible to understand the existence of magnetic fields in cosmological and astrophysical scales.

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 and identifiable as analogs of Bohr orbits. 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 of the lines of generalized Feynman diagrams is as light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian. Also the Euclidian 4-D regions can have a 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 a strong form of holography.

The understanding of the super symplectic invariance leads to the proposal that super symplectic algebra and other Kac-Moody type algebras labelled by non-negative multiples of basic conformal weights allow a hierarchy of symmetry breakings in which the analog of gauge symmetry breaks down to a genuine dynamical symmetry. This gives rise to fractal hierarchies of algebras and symmetry breakings. This breaking can occur also for ordinary conformal algebras if one restricts the conformal weights to be non-negative integers.

### 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 embedding 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. Particles topologically condense to several space-time sheets simultaneously and experience 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 embeddability to 8-D embedding space. One can also argue that Poincare invariant theory of gravitation cannot be consistent with General Relativity. The above interpretation makes it possible to understand the relationship to GRT space-time and how the 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 the space-time sheets from Minkowski metric. Poincare invariance strongly suggests classical EP for the GRT limit in long length scales at least. One can also consider 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 a very large cosmological constant in Einstein-Maxwell theory. Also gauge potentials of the 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 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.

### 1.4.1 World of Classical Worlds

The notion of WCW reduces the interacting quantum theory to a theory of free WCW spinor fields.

1. Quantum theory for extended particles is free(!), classical(!) field theory for a generalized Schrödinger amplitude identified as WCW spinor 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.
2. 4-D general coordinate invariance forces holography and replaces the ill-defined path integral over all space-time surfaces with a discrete sum over 4-D analogs of Bohr orbits for particles identified as 3-surfaces. Holography means that basic objects are these analogs of Bohr orbits. Since there is no quantization at the level of WCW, one has an analog of wave mechanics with point-like particles replaced with 4-D Bohr orbits.
3. One must geometrize WCW as the space of Bohr orbits. In an infinite-dimensional situation the existence of geometry requires maximal symmetries already in the case of loop spaces. Physics is unique from its mathematical existence.

WCW is endowed with metric and spinor structure so that one can define various metric related differential operators, say Dirac operators, appearing in the field equations of the theory <sup>1</sup>

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<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 a the bosonic action for Euclidian space-time regions

### 1.4.2 Identification of Kähler function

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 way 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 way 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.

### 1.4.3 WCW spinor fields

Classical WCW spinor fields are analogous to Schrödinger amplitudes and the construction of WCW Kähler geometry reduces to the second quantization of free spinor fields of  $H$ .

1. The WCW metric is given by anticommutators of WCW gamma matrices which also have interpretation as supercharges assignable to the generators of WCW isometries and allowing expression as non-conserved Noether charges. Holography implies zero energy ontology (ZEO) meaning that zero energy states are superpositions of Bohr orbits connecting boundaries of causal diamond (CD). CDs form a fractal hierarchy and their space forming the spine of WCW is finite-dimensional and can be geometrized. The alternative interpretation is as a superposition of pairs of ordinary 3-D fermionic states assignable to the ends of the space-time surfaces.
2. There are several Dirac operators. WCW Dirac operator  $D_{WCW}$  appears in Super-symplectic gauge conditions analogous to Super Virasoro conditions. The algebraic variant of the  $H$

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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 modified Dirac action in Minkowskian space-time regions. These two possible definitions reflect a duality analogous to AdS/CFT duality.

Dirac operator  $D_H$  appears in fermionic correlation functions: this is due to the fact that free fermions appearing as building bricks of WCW gamma matrices are modes of  $D_H$ . The modes of  $D_H$  define the ground states of super-symplectic representations. There is also the modified Dirac operator  $D_{X^4}$  acting on the induced spinors at space-time surfaces and it is dictated by symmetry one the action fixing the space-time surfaces as Bohr orbits is fixed.  $D_H$  is needed since it determines the expressions of WCW gamma matrices as Noether charges assignable to 3-surfaces at the ends of WCW.

#### 1.4.4 The role of modified Dirac action

1. By quantum classical correspondence, the construction of WCW spinor structure in sectors assignable to CDs reduces to the second quantization of the induced spinor fields of  $H$ . The basic action is so called modified Dirac action in which gamma matrices are replaced with the modified gamma matrices defined as contractions of the canonical momentum currents of the bosonic action defining the space-time surfaces with the embedding space gamma matrices. In this way one achieves super-conformal symmetry and conservation of fermionic currents among other things and a consistent Dirac equation.

Modified Dirac action is needed to define WCW gamma matrices as super charges assignable to WCW isometry generators identified as generators of symplectic transformations and by holography are needed only at the 3-surface at the boundaries of WCW. It is important to notice that the modified Dirac equation does not determine propagators since induced spinor fields are obtained from free second quantized spinor fields of  $H$ . This means enormous simplification and makes the theory calculable.

2. An important interpretational problem relates to the notion of the induced spinor connection. The presence of classical W boson fields is in conflict with the classical conservation of em charge since the coupling to classical W fields changes em charge.

One way out of the problem is the fact that the quantum averages of weak and gluon fields vanish unlike the quantum average of the em field. This leads to a rather precise understanding of electroweak symmetry breaking as being due the fact that color symmetries rotate space-time surfaces and also affect the induced weak fields.

One can also consider a stronger condition. If one requires that the 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 neutrinos generating super-symmetries forms an exception. The vanishing of the  $Z^0$  field is possible for Kähler-Dirac action and should hold true at least above weak length scales. This implies that the 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 would simplify the mathematics enormously 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 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 the massless Dirac equation is satisfied by the modes of the modified-Dirac action assignable to the Chern-Simons-Kähler action.

## 1.5 Construction of scattering amplitudes

### 1.5.1 Reduction of particle reactions to space-time topology

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.

During years this naïve and very rough vision has of course developed a lot and is not anymore quite equivalent with the original insight. In particular, the space-time correlates of Feynman graphs have emerged from theory as Euclidian space-time regions and the strong form of General Coordinate Invariance has led to a rather detailed and in many respects un-expected visions. This picture forces to give up the idea about smooth space-time surfaces and replace space-time surface with a generalization of Feynman diagram in which vertices represent the failure of manifold property. I have also 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!

### 1.5.2 Construction of the counterparts of S-matrices

What does one mean with the counterpart of S-matrix in the TGD framework has been a long standing problem. The development of ZEO based quantum measurement theory has led to a rough overall view of the situation.

1. There are two kinds of state function reductions (SFRs). ”Small” SFRs (SSFRs) following the TGD counterpart of a unitary time evolution defines a sequence of SFRs, which is analogous to a sequence of repeated quantum measurements associated with the Zeno effect. In wave mechanics nothing happens in these measurements. In quantum optics these measurements correspond to weak measurements. In TGD SSFR affects the zero energy state but leaves the 3-D state at the passive boundary of CD unaffected.
2. In TGD framework each SSFR is preceded by a counterpart of a unitary time evolution, which means dispersion in the space of CDs and unitary time evolution in fermionic degrees of freedom such that the passive boundary of CDs and 3-D states at it are unaffected but a superposition of CDs with varying active boundaries in the space of CDs is formed. In SSFR a localization in the space of CDs occurs such that the active is fixed. In a statistical sense the size of the CD increases and the increasing distance between the tips of the CD gives rise to the arrow of geometric time.
3. Also ”big” SFRs (BSFRs) can occur and they correspond to ordinary SFRs. In BSFR the roles of the active and passive boundary are changed and this means that the arrow of time is changed. Big SFR occurs when the SSFR corresponds to a quantum measurement, which does not commute with the operators, which define the states at the passive boundary of CD as their eigenstates. This means a radical deviation from standard quantum measurement theory and has predictions in all scales.
4. One can assign the counterpart of S-matrix to the unitary time evolution between two subsequent SSFRs and also to the counterpart of S-matrix associated with BSFR. At least in the latter case the dimension of the state space can increase since at least BSFRs lead to the increase of the dimension of algebraic extension of rationals assignable to the space-time surface by  $M^8 - H$  duality. Unitarity is therefore replaced with isometry.
5. I have also considered the possibility that unitary S-matrix could be replaced in the fermionic degrees of freedom with Kähler metric of the state space satisfying analogs of unitarity conditions but it seems that this is un-necessary and also too outlandish an idea.

### 1.5.3 The notion of M-matrix

1. The most ambitious dream is that zero energy states correspond to a complete solution basis for the Dirac operators associated with WCWs associated with the spaces of CDs with fixed passive boundary: this would define an S-matrix assignable to SFR. Also the analog of S-matrix for the localizations of the states to the active boundary assignable to the BSFR changing the state at the passive boundary of CD is needed.

2. If one allows entanglement between positive and energy parts of the zero energy state but assumes that the states at the passive boundary are fixed, one must introduce the counterpart of the density matrix, or rather its square root. This classical free field theory would dictate what I have called 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. A given M-matrix in turn would decompose to a product of a hermitian square root of density matrix and unitary S-matrix.
3. 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 a 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 algebras acting as symmetries of the S-matrix. Therefore quantum TGD would reduce to group theory in a well-defined sense.
4. 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.

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 [K10]. 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.

5. I have also considered the notion of U-matrix. 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. I have proposed a general representation for the U-matrix, reducing its construction to that of the S-matrix.

## 1.6 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 complexified counterparts of classical number fields, and the notion of infinite prime. Note that one can identify subrings such as hyper-quaternions and hyper-octonions as sub-spaces of complexified classical number fields with Minkowskian signature of the metric defined by the complexified inner product.

### 1.6.1 The Threads in the Development of Quantum TGD

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

1. 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 rather 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 three corresponding to geometric, number theoretic and topological views of physics.

TGD forces the generalization of physics to a quantum theory of consciousness, and TGD as a generalized number theory vision leads naturally to the emergence of p-adic physics as physics of cognitive representations.

### 1.6.2 Number theoretic vision very briefly

Number theoretic vision about quantum TGD involves notions like adelic physics,  $M^8 - H$  duality and number theoretic universality. A short review of the basic ideas that have developed during years is in order.

1. The physical interpretation of  $M^8$  is as an analog of momentum space and  $M^8 - H$  duality is analogous to momentum-position duality of ordinary wave mechanics.
2. Adelic physics means that all classical number fields, all p-adic number fields and their extensions induced by extensions of rationals and defining adeles, and also finite number fields are basic mathematical building bricks of physics.

The complexification of  $M^8$ , identified as complexified octonions, would provide a realization of this picture and  $M^8 - H$  duality would map the algebraic physics in  $M^8$  to the ordinary physics in  $M^4 \times CP_2$  described in terms of partial differential equations.

3. Negentropy Maximization Principle (NMP) states that the conscious information assignable with cognition representable measured in terms of p-adic negentropy increases in statistical sense.

NMP is mathematically completely analogous to the second law of thermodynamics and number theoretic evolution as an unavoidable statistical increase of the dimension of the algebraic extension of rationals characterizing a given space-time region implies it. There is no paradox involved: the p-adic negentropy measures the conscious information assignable to the entanglement of two systems regarded as a conscious entity whereas ordinary entropy measures the lack of information about the quantum state of either entangled system.

4. Number theoretical universality requires that space-time surfaces or at least their  $M^8 - H$  duals in  $M_c^8$  are defined for both reals and various p-adic number fields. This is true if they are

defined by polynomials with integer coefficients as surfaces in  $M^8$  obeying number theoretic holography realized as associativity of the normal space of 4-D surface using as holographic data 3-surfaces at mass shells identified in terms of roots of a polynomial. A physically motivated additional condition is that the coefficients of the polynomials are smaller than their degrees.

5. Galois confinement is a key piece of the number theoretic vision. It states that the momenta of physical states are algebraic integers in the extensions of rationals assignable to the space-time region considered. These numbers are in general complex and are not consistent with particle in box quantization. The proposal is that physical states satisfy Galois confinement being thus Galois singlets and having therefore total momenta, whose components are ordinary integers, when momentum unit defined by the scale of causal diamond (CD) is used.
6. The notion of p-adic prime was introduced in p-adic mass calculations that started the developments around 1995. p-Adic length scale hypothesis states that p-adic primes near powers of 2 have a special physical role (as possibly also the powers of other small primes such as  $p = 3$ ).

The proposal is that p-adic primes correspond to ramified primes assignable to the extension and identified as divisors of the polynomial defined by the products of the root differences for the roots of the polynomial defining space-time space and having interpretation as values of, in general complex, virtual mass squared.

### 1.6.3 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 structure. 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 embedding space and space-time concept and one can speak about real and p-adic space-time sheets. One can talk about adelic space-time, embedding space, and WCW.

The corresponds of real 4-surfaces with the p-adic ones is induced by number theoretical discretization using points of 4-surfaces  $Y^4 \subset M_c^8$  identifiable as 8-momenta, whose components are assumed to be algebraic integers in an extension of rationals defined by the extension of rationals associated with a polynomial  $P$  with integer coefficients smaller than the degree of  $P$ . These points define a cognitive representation, which is universal in the sense that it exists also in the algebraic extensions of p-adic numbers. The points of the cognitive representations associated with the mass shells with mass squared values identified as roots of  $P$  are enough since  $M^8 - H$  duality can be used at both  $M^8$  and  $H$  sides and also in the p-adic context. The mass shells are special in that they allow for Minkowski coordinates very large cognitive representations unlike the interiors of the 4-surfaces determined by holography by using the data defined by the 3-surfaces at the mass shells. The higher the dimension of the algebraic extension associated with  $P$ , the better the accuracy of the cognitive representation.

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 [K9].

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.



### 1.6.4 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 complexified quaternions and 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.

## 1.7 An explicit formula for $M^8 - H$ duality

$M^8 - H$  duality is a generalization of momentum-position duality relating the number theoretic and geometric views of physics in TGD and, despite that it still involves poorly understood aspects, it has become a fundamental building block of TGD. One has 4-D surfaces  $Y^4 \subset M_c^8$ , where  $M_c^8$  is complexified  $M^8$  having interpretation as an analog of complex momentum space and 4-D spacetime surfaces  $X^4 \subset H = M^4 \times CP_2$ .  $M_c^8$ , equivalently  $E_c^8$ , can be regarded as complexified octonions.  $M_c^8$  has a subspace  $M_c^4$  containing  $M^4$ .

**Comment:** One should be very cautious with the meaning of "complex". Complexified octonions involve a complex imaginary unit  $i$  commuting with the octonionic imaginary units  $I_k$ .  $i$  is assumed to also appear as an imaginary unit also in complex algebraic numbers defined by the roots of polynomials  $P$  defining holographic data in  $M_c^8$ .

In the following  $M^8 - H$  duality and its twistor lift are discussed and an explicit formula for the dualities are deduced. Also possible variants of the duality are discussed.

### 1.7.1 Holography in $H$

$X^4 \subset H$  satisfies holography and is analogous to the Bohr orbit of a particle identified as a 3-surface. The proposal is that holography reduces to a 4-D generalization of holomorphy so that  $X^4$  is a simultaneous zero of two functions of complex  $CP_2$  coordinates and of what I have called Hamilton-Jacobi coordinates of  $M^4$  with a generalized Kähler structure.

The simplest choice of the Hamilton-Jacobi coordinates is defined by the decomposition  $M^4 = M^2 \times E^2$ , where  $M^2$  is endowed with hypercomplex structure defined by light-like coordinates  $(u, v)$ , which are analogous to  $z$  and  $\bar{z}$ . Any analytic map  $u \rightarrow f(u)$  defines a new set of light-like coordinates and corresponds to a solution of the massless d'Alembert equation in  $M^2$ .  $E^2$  has some complex coordinates with imaginary unit defined by  $i$ .

The conjecture is that also more general Hamilton-Jacobi structures for which the tangent space decomposition is local are possible. Therefore one would have  $M^4 = M^2(x) \times E^2(x)$ . These would correspond to non-equivalent complex and Kähler structures of  $M^4$  analogous to those possessed by 2-D Riemann surfaces and parametrized by moduli space.

### 1.7.2 Number theoretic holography in $M_c^8$

$Y^4 \subset M_c^8$  satisfies number theoretic holography defining dynamics, which should reduce to associativity in some sense. The Euclidian complexified normal space  $N^4(y)$  at a given point  $y$  of  $Y^4$  is required to be associative, i.e. quaternionic. Besides this,  $N^4(i)$  contains a preferred complex Euclidian 2-D subspace  $Y^2(y)$ . Also the spaces  $Y^2(x)$  define an integrable distribution. I have assumed that  $Y^2(x)$  can depend on the point  $y$  of  $Y^4$ .

These assumptions imply that the normal space  $N(y)$  of  $Y^4$  can be parameterized by a point of  $CP_2 = SU(3)/U(2)$ . This distribution is always integrable unlike quaternionic tangent space

distributions.  $M^8 - H$  duality assigns to the normal space  $N(y)$  a point of  $CP_2$ .  $M_c^4$  point  $y$  is mapped to a point  $x \in M^4 \subset M^4 \times CP_2$  defined by the real part of its inversion (conformal transformation): this formula involves effective Planck constant for dimensional reasons.

The 3-D holographic data, which partially fixes 4-surfaces  $Y^4$  is partially determined by a polynomial  $P$  with real integer coefficients smaller than the degree of  $P$ . The roots define mass squared values which are in general complex algebraic numbers and define complex analogs of mass shells in  $M_c^4 \subset M_c^8$ , which are analogs of hyperbolic spaces  $H^3$ . The 3-surfaces at these mass shells define 3-D holographic data continued to a surface  $Y^4$  by requiring that the normal space of  $Y^4$  is associative, i.e. quaternionic. These 3-surfaces are not completely fixed but an interesting conjecture is that they correspond to fundamental domains of tessellations of  $H^3$ .

What does the complexity of the mass shells mean? The simplest interpretation is that the space-like  $M^4$  coordinates (3-momentum components) are real whereas the time-like coordinate (energy) is complex and determined by the mass shell condition. One would have  $Re^2(E) - Im(E)^2 - p^2 = Re(m^2)$  and  $2Re(E)Im(E) = Im(m^2)$ . The condition for the real parts gives  $H^3$  when  $\sqrt{Re^2(E) - Im(E)^2}$  is taken as a time coordinate. The second condition allows to solve  $Im(E)$  in terms of  $Re(E)$  so that the first condition reduces to an equation of mass shell when  $\sqrt{(Re(E)^2 - Im(E)^2)}$ , expressed in terms of  $Re(E)$ , is taken as new energy coordinate  $E_{eff} = \sqrt{(Re(E)^2 - Im(E)^2)}$ . Is this deformation of  $H^3$  in imaginary time direction equivalent with a region of the hyperbolic 3-space  $H^3$ ?

One can look at the formula in more detail. Mass shell condition gives  $Re^2(E) - Im(E)^2 - p^2 = Re(m^2)$  and  $2Re(E)Im(E) = Im(m^2)$ . The condition for the real parts gives  $H^3$ , when  $\sqrt{Re^2(E) - Im(E)^2}$  is taken as an effective energy. The second condition allows to solve  $Im(E)$  in terms of  $Re(E)$  so that the first condition reduces to a dispersion relation for  $Re(E)^2$ .

$$Re(E)^2 = \frac{1}{2}(Re(m^2) - Im(m^2) + p^2)(1 \pm \sqrt{1 + \frac{2Im(m^2)^2}{(Re(m^2) - Im(m^2) + p^2)^2}}). \quad (1.1)$$

Only the positive root gives a non-tachyonic result for  $Re(m^2) - Im(m^2) > 0$ . For real roots with  $Im(m^2) = 0$  and at the high momentum limit the formula coincides with the standard formula. For  $Re(m^2) = Im(m^2)$  one obtains  $Re(E)^2 \rightarrow Im(m^2)/\sqrt{2}$  at the low momentum limit  $p^2 \rightarrow 0$ . Energy does not depend on momentum at all: the situation resembles that for plasma waves.

### 1.7.3 Can one find an explicit formula for $M^8 - H$ duality?

The dream is an explicit formula for the  $M^8 - H$  duality mapping  $Y^4 \subset M_c^8$  to  $X^4 \subset H$ . This formula should be consistent with the assumption that the generalized holomorphy holds true for  $X^4$ .

The following proposal is a more detailed variant of the earlier proposal for which  $Y^4$  is determined by a map  $g$  of  $M_c^4 \rightarrow SU(3)_c \subset G_{2,c}$ , where  $G_{2,c}$  is the complexified automorphism group of octonions and  $SU(3)_c$  is interpreted as a complexified color group.

This map defines a trivial  $SU(3)_c$  gauge field. The real part of  $g$  however defines a non-trivial real color gauge field by the non-linearity of the non-abelian gauge field with respect to the gauge potential. The quadratic terms involving the imaginary part of the gauge potential give an additional condition to the real part in the complex situation and cancel it. If only the real part of  $g$  contributes, this contribution would be absent and the gauge field is non-vanishing.

How could the automorphism  $g(x) \subset SU(3) \subset G_2$  give rise to  $M^8 - H$  duality?

1. The interpretation is that  $g(y)$  at given point  $y$  of  $Y^4$  relates the normal space at  $y$  to a fixed quaternionic/associative normal space at point  $y_0$ , which corresponds is fixed by some subgroup  $U(2)_0 \subset SU(3)$ . The automorphism property of  $g$  guarantees that the normal space is quaternionic/associative at  $y$ . This simplifies the construction dramatically.
2. The quaternionic normal sub-space (which has Euclidian signature) contains a complex sub-space which corresponds to a point of sphere  $S^2 = SO(3)/O(2)$ , where  $SO(3)$  is the quaternionic automorphism group. The interpretation could be in terms of a selection of spin quantization axes. The local choice of the preferred complex plane would not be unique

and is analogous to the possibility of having non-trivial Hamilton Jacobi structures in  $M^4$  characterized by the choice of  $M^2(x)$  and equivalently its normal subspace  $E^2(x)$ .

These two structures are independent apart from dependencies forced by the number theoretic dynamics. Hamilton-Jacobi structure means a selection of the quantization axis of spin and energy by fixing a distribution of light-like tangent vectors of  $M^4$  and the choice of the quaternionic normal sub-space fixes a choice of preferred quaternionic imaginary unit defining a quantization axis of the weak isospin.

3. The real part  $Re(g(y))$  defines a point of  $SU(3)$  and the bundle projection  $SU(3) \rightarrow CP_2$  in turn defines a point of  $CP_2 = SU(3)/U(2)$ . Hence one can assign to  $g$  a point of  $CP_2$  as  $M^8 - H$  duality requires and deduce an explicit formula for the point. This means a realization of the dream.
4. The construction requires a fixing of a quaternionic normal space  $N_0$  at  $y_0$  containing a preferred complex subspace at a single point of  $Y^4$  plus a selection of the function  $g$ . If  $M^4$  coordinates are possible for  $Y^4$ , the first guess is that  $g$  as a function of complexified  $M^4$  coordinates obeys generalized holomorphy with respect to complexified  $M^4$  coordinates in the same sense and in the case of  $X^4$ . This might guarantee that the  $M^8 - H$  image of  $Y^4$  satisfies the generalized holomorphy.
5. Also space-time surfaces  $X^4$  with  $M^4$  projection having a dimension smaller than 4 are allowed. I have proposed that they might correspond to singular cases for the above formula: a kind of blow-up would be involved. One can also consider a more general definition of  $Y^4$  allowing it to have a  $M^4$  projection with dimension smaller than 4 (say cosmic strings). Could one have implicit equations for the surface  $Y^4$  in terms of the complex coordinates of  $SU(3)_c$  and  $M^4$ ? Could this give for instance cosmic strings with a 2-D  $M^4$  projection and  $CP_2$  type extremals with 4-D  $CP_2$  projection and 1-D light-like  $M^4$  projection?

#### 1.7.4 What could the number theoretic holography mean physically?

What could be physical meaning of the number theoretic holography? The condition that has been assumed is that the  $CP_2$  coordinates at the mass shells of  $M_c^4 \subset M_c^8$  mapped to mass shells  $H^3$  of  $M^4 \subset M^4 \times CP_2$  are constant at the  $H^3$ . This is true if the  $g(y)$  defines the same  $CP_2$  point for a given component  $X_i^3$  of the 3-surface at a given mass shell.  $g$  is therefore fixed apart from a local  $U(2)$  transformation leaving the  $CP_2$  point invariant. A stronger condition would be that the  $CP_2$  point is the same for each component of  $X_i^3$  and even at each mass shell but this condition seems to be unnecessarily strong.

**Comment:** One can criticize this condition as too strong and one can consider giving up this condition. The motivation for this condition is that the number of algebraic points at the 3-surfaces associated with  $H^3$  explodes since the coordinates associated with normal directions vanish. Kind of cognitive explosion would be in question.

$SU(3)$  corresponds to a subgroup of  $G_2$  and one can wonder what the fixing of this subgroup could mean physically.  $G_2$  is 14-D and the coset space  $G_2/SU(3)$  is 6-D and a good guess is that it is just the 6-D twistor space  $SU(3)/U(1) \times U(1)$  of  $CP_2$ : at least the isometries are the same. The fixing of the  $SU(3)$  subgroup means fixing of a  $CP_2$  twistor. Physically this means the fixing of the quantization axis of color isospin and hypercharge.

#### 1.7.5 Twistor lift of the holography

What is interesting is that by replacing  $SU(3)$  with  $G_2$ , one obtains an explicit formula from the generalization of  $M^8 - H$  duality to that for the twistorial lift of TGD!

One can also consider a twistorial generalization of the above proposal for the number theoretic holography by allowing local  $G_2$  automorphisms interpreted as local choices of the color quantization axis.  $G_2$  elements would be fixed apart from a local  $SU(3)$  transformation at the components of 3-surfaces at mass shells. The choice of the color quantization axes for a connected 3-surface at a given mass shell would be the same everywhere. This choice is indeed very natural physically since 3-surface corresponds to a particle.

Is this proposal consistent with the boundary condition of the number theoretical holography mean in the case of 4-surfaces in  $M_c^8$  and  $M^4 \times CP_2$ ?

1. The selection of  $SU(3) \subset G_2$  for ordinary  $M^8 - H$  duality means that the  $G_{2,c}$  gauge field vanishes everywhere and the choice of color quantization axis is the same at all points of the 4-surface. The fixing of the  $CP_2$  point to be constant at  $H^3$  implies that the color gauge field at  $H^3 \subset M_c^8$  and its image  $H^3 \subset H$  vanish. One would have color confinement at the mass shells  $H_i^3$ , where the observations are made. Is this condition too strong?
2. The constancy of the  $G_2$  element at mass shells makes sense physically and means a fixed color quantization axis. The selection of a fixed  $SU(3) \subset G_2$  for entire space-time surface is in conflict with the non-constancy of  $G_2$  element unless  $G_2$  element differs at different points of 4-surface only by a multiplication of a local  $SU(3)_0$  element, that is local  $SU(3)$  transformation. This kind of variation of the  $G_2$  element would mean a fixed color group but varying choice of color quantization axis.
3. Could one consider the possibility that the local  $G_{2,c}$  element is free and defines the twistor lift of  $M^8 - H$  duality as something more fundamental than the ordinary  $M^8 - H$  duality based on  $SU(3)_c$ . This duality would make sense only at the mass shells so that only the spaces  $H^3 \times CP_2$  assignable to mass shells would make sense physically? In the interior  $CP_2$  would be replaced with the twistor space  $SU(3)/U(1) \times U(1)$ . Color gauge fields would be non-vanishing at the mass shells but outside the mass shells one would have  $G_2$  gauge fields. There is also a physical objection against the  $G_2$  option. The 14-D Lie algebra representation of  $G_2$  acts on the imaginary octonions which decompose with respect to the color group to  $1 \oplus 3 \oplus \bar{3}$ . The automorphism property requires that 1 can be transformed to 3 or  $\bar{3}$  to themselves: this requires that the decomposition contains  $3 \oplus \bar{3}$ . Furthermore, it must be possible to transform 3 and  $\bar{3}$  to themselves, which requires the presence of 8. This leaves only the decomposition  $8 \oplus 3 \oplus \bar{3}$ .  $G_2$  gluons would both color octet and triplets. In the TDG framework the only conceivable interpretation would be in terms of ordinary gluons and leptoquark-like gluons. This does not fit with the basic vision of TGD.

The choice of twistor as a selection of quantization axes should make sense also in the  $M^4$  degrees of freedom.  $M^4$  twistor corresponds to a choice of light-like direction at a given point of  $M^4$ . The spatial component of the light-like vector fixes the spin quantization axis. Its choice together with the light-likeness fixes the time direction and therefore the rest system and energy quantization axis. Light-like vector fixes also the choice of  $M^2$  and of  $E^2$  as its orthogonal complement. Therefore the fixing of  $M^4$  twistor as a point of  $SU(4)/SU(3) \times U(1)$  corresponds to a choice of the spin quantization axis and the time-like axis defining the rest system in which the energy is measured. This choice would naturally correspond to the Hamilton-Jacobi structure fixing the decompositions  $M^2(x) \times E^2(x)$ . At a given mass shell the choice of the quantization axis would be constant for a given  $X_i^3$ .

## 1.8 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.

### 1.8.1 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 [K18].

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 way 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.

### 1.8.2 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, K14] ) support the view that dark matter might be a key player in living matter.

### 1.8.3 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  $h_{eff}$ .

## 1.9 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 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.

### 1.9.1 Twistor lift at space-time level

8-dimensional generalization of ordinary twistors is highly attractive approach to TGD [K23]. 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 embeddings 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 embedding 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 [?].

### 1.9.2 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 embedding 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 [?]. 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/yyhwvbqb>) was Veneziano duality. This 4-particle amplitude was generalized by Yoshiro Nambu, Holber-Beck Nielsen, and Leonard Susskind to N-particle amplitude (see <http://tinyurl.com/yyvnx7as>) 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 width.

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 Bird's Eye of View about the Topics of "TGD View of Bio-Systems as Self-Organizing Quantum Systems"

This book represents the basic ideas of the TGD inspired view of quantum biology as they emerged long before the recent view of TGD was established. The material represents therefore older layers of TGD. I have organized the book in 3 parts.

1. In the first part of the book, the new TGD based physics proposed to be relevant to quantum biology is discussed. One key notion is dark matter as phases of ordinary matter with even very large values of effective Planck constant. Two chapters are devoted to new physics relevant to the TGD view of biosystems and to the model of high  $T_c$  super-conductivity relying strongly on the notions of quantum criticality and dark matter.
2. In the second part of the book, the notions of "massless extremal" (ME) or topological light ray, magnetic flux quantum as space-time surface, and field/magnetic body, distinguishing between TGD Universe and Maxwellian world, are introduced. The notion of a 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 second part of the book quantum antenna hypothesis inspired by ME is discussed. Two chapters are devoted to how quantum control and coordination could be realized in the TGD Universe.
4. In the third part of the book two chapters are devoted to the TGD view of quantum self-organization in living systems. One chapter is devoted to the possible implications of the p-adic length scale hypothesis. The material is rather old and I have added a chapter about homeostasis in zero energy ontology, representing the recent views based on zero energy ontology (ZEO).

I must apologize for the fact the implications of the dark matter revolution have not been thoroughly considered in this book. Same applies to the implications of ZEO.

## 3 Sources

The eight online books about TGD [K25, K24, K17, K12, K4, K11, K6, K20] and nine online books about TGD inspired theory of consciousness and quantum biology [K22, K3, K13, K2, K5, K7, K8, K19, K21] 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.

## 3.1 PART I: THE NEW PHYSICS OF LIVING MATTER

### 3.1.1 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 the Minkowskian regions where 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  $h_{eff} = n \times \hbar$  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.

### 3.1.2 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.

### 3.1.3 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.

## 3.1.4 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 super-conductor. 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 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 superconducting 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.

### 3.1.5 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 crystal 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 seems 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.

## 3.2 PART II: QUANTUM ANTENNA HYPOTHESIS

### 3.2.1 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.

### 3.2.2 Quantum Control and Coordination in Bio-Systems: Part I

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

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

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

The original proposal was that the formation of join the along boundaries bonds between the space-time sheets possibly representing different levels of the self hierarchy could be the basic mechanism of control and coordination. In the updated model join along boundaries are replaced by magnetic flux tubes with the motivation coming from the fact that boundary conditions might not allow boundaries at all! Boundaries would be replaced by boundaries of Minkowskian regions at which the signature of the induced metric changes from Minkowskian to Euclidian) with Euclidian

region defining the space-time sheet assignable to even macroscopic system.

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

Any harmonic perturbation with some magnetic transition frequency can induce magnetic quantum transitions and even magnetic quantum phase transitions. An attractive identification for this process is as basic tool of quantum control tool so that the resonance frequency appears as control parameter “waking up” subself at its critical value. Critical frequencies correspond to the magnetic and  $Z^0$  magnetic cyclotron frequencies in the model of super conductor relying on the presence of weak magnetic or  $Z^0$  magnetic field (magnetic field guarantees effective one-dimensionality of the super conductor and implies finite gap energy in TGD framework). Cyclotron frequency hypothesis has had rather dramatic success and leads to a rather detailed picture about brain as a macroscopic quantum system.

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

Decade later this picture has become considerably more detailed with more detailed model for how dark low frequency photons are used in living system the basic tool of control and coordination. In particular, the hypothesis that dark photons decay to ordinary photons with visible and UV energies identifiable as biophotons has emerged.

### 3.2.3 Quantum Control and Coordination in Bio-Systems: Part II

This chapter is devoted to the aspects of quantum control and coordination involving the intentional action of the magnetic body and classical em and possibly  $Z^0$  fields (as suggested by large parity breaking effects in living matter). The previous chapters are warmly recommended in order to get an overall view about basic philosophy and ideas. The general understanding of the dynamics of Kähler action provides a considerable light to how topologically quantized induced Kähler field defines templates for bio-structures and for their self-organized dynamics with self-organization understood in 4-D sense selecting 4-D time evolution patterns. Time mirror mechanism is the most convincing mechanism for realizing intentional action discovered hitherto. Also the possible role of classical  $Z^0$  force in condensed matter and bio-chemistry is discussed.

In the original version of the chapter I did not yet know anything about zero energy ontology (ZEO), the hierarchy of Planck constants defining dark matter hierarchy nor the notion of magnetic body carrying dark matter. ZEO provides justification and precise definition what negative energy signals propagating into past are. The notion of magnetic body containing macroscopic quantum phases responsible for bio-control, and the fact that dark matter would reside at magnetic flux tubes, motivate the hypothesis that living matter is actually dark matter with the large value of Planck constant determining the characteristic time and length scales of the conscious system.

## 3.3 PART III: SELF-ORGANIZATION IN LIVING MATTER

### 3.3.1 Quantum Theory of Self-Organization

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

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

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

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

In ZEO self-organization takes place for 4-D spatio-temporal patterns since 3-surfaces are pairs of space-like surfaces at the boundaries of CD and maxima of Kähler function are selected in the process. This brings in totally new and highly non-trivial aspect. These temporal patterns correspond to behaviors and functions in living matter. One could understand complex miracle the generation of complex spatio-temporal patterns such as morphogenesis as a sequence of 4-D trials. In this framework evolution in given time scale is not an outcome of random choice followed by selection as Darwinian dogma states.

The comparison with Rupert Sheldrake’s concepts of morphic field and morphic resonance leads to interesting ideas about how learning at the level of species could occur quantum-mechanically. The 4-D character of self-organization makes learning a basic spontaneously occurring process: each self is by definition a learning entity. For instance, the phenomenon of biofeedback suggests that self could quite generally effectively act on its subselves. In ZEO all quantum states have properties allowing to interpret them as memes or quanta of morphic fields and the challenge is to find their biological counterparts. DNA as topological quantum computer hypothesis suggest the identification of the biological memes as topological quantum computer programs assignable to the intronic portion of the genome and coded also by nerve pulse patterns. The notion of magnetic body as intentional agent leads to a concrete model for the morphic resonance as a transfer of topological quantum computation programs between separate brains with the mediation of the personal magnetic bodies and the magnetic body of Mother Gaia using EEG like communications. The model explains also “alike likes alike” rule. Spatio-temporal evolution of the magnetic body could serve as template for the evolution of dark and ordinary matter associated with it.

### 3.3.2 Biological Realization of Self Hierarchy

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

What self actually is in quantum sense, has taken long time to understand. The realization that in zero energy ontology (ZEO) sequences of repeated quantum jumps leave only the second half of zero energy state invariant but change the other one led to the identification of self as the

sequence of the quantum jumps reducing the state to the same boundary of causal diamond (CD). This also answers basic questions about the relationship of geometric and subjective time.

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

1. The assumption that various bio-molecules are selves allows to understand the miraculous abilities of living systems as outcome of quantum self-organization process in which dissipation selects very limited repertoire of self-organization patterns identifiable as survivors in Darwinian selection. For instance, one can understand protein folding and DNA replication as self-organization processes. The 4-D character of self-organization implies that the most probable outcomes are pairs of 3-surfaces at boundaries of causal diamond defining spatio-temporal rather than only spatial pattern. This allows totally new view about morphogenesis and development of skills.
2. The fact that bio-systems are liquid crystals, makes them ideal for the realization of the self hierarchy. The reason is that liquid crystals have ability to self-organize to very complicated structures and are ideal for communication purposes: for instance, mechanical signals can be coded to electric signals and vice versa. Liquid crystals are also electrets: the presence of electric fields is indeed an important prerequisite of cognition in TGD as discussed in the chapter "Information and consciousness". In fact, one could identify various bio-structures such as micro-tubuli, cell organelles and cells as generic outcomes of the self-organization of the liquid crystals. An especially important level of the self hierarchy is provided by collagen networks which could give rise to what might be called "body consciousness". Central nervous system is only one, although very important level in the self hierarchy, and TGD approach allows to understand why this is the case.
3. p-Adic length scale hypothesis allows quantitative grasp to the structure of the self hierarchy and one can build general picture about how various p-adic length scales emerged during the evolution. In particular, one can identify various p-adic length scales associated with the brain.
4. One level of the self hierarchy corresponds to the topological field quanta of ELF em fields associated with EEG. ELF (extremely low frequency) em fields are known to have dramatic effects on living matter and brain and the origin of these effects is poorly understood. A simple argument based on Uncertainty Principle leads to the conclusion that ELF photons in 10 Hz frequency range correspond to topological field quanta of size of entire Earth. This leads to a rather dramatic conclusion that our biological body is only a dip of an iceberg and we are much more than our neurons. The most important levels in our personal self hierarchy contains levels are of size of Earth! Support for this picture come from the quantitative success of the scenario: one can immediately understand various important neuro time scales in terms of the cyclotron frequencies of various charged particles in Earth's magnetic field.
5. Each bio-structure is accompanied by a topologically quantized magnetic field defining corresponding magnetic body and these magnetic bodies form a hierarchy. Magnetic bodies could serve as intentional agents, as templates for the formation of various biological control circuits crucial for homeostasis and biological information processing, define the basic structure making possible metabolism with universal metabolic energy currencies, and could even define what might be called Nature's own bio-laboratory.
6. The magnetic flux structures associated with body could be of crucial importance for understanding human consciousness. For instance, eyes generate magnetic fields. Also brain, in particular pineal gland (the "third eye" of mystics and the seat of soul for Descartes), contains magnetic materials. Corresponding magnetic transition frequencies correspond to time scales relevant for the self narrative in human time scales. Perhaps these higher levels of magnetic self hierarchy could relate with NDE experiences and represent structures surviving in biological death.

### 3.3.3 Possible Role of p-Adic Numbers in Bio-Systems

In this chapter p-adic physics, p-adic length scale hypothesis, and the special features of p-adic numbers are discussed from the point of view of biosystems. The identification of p-adic physics

as physics of cognition tentatively identified as a cognitive simulation of real physics is the basic philosophical guide line. Second key idea is that living matter in very general sense lives in the intersection of real and p-adic worlds making among other things possible negentropic entanglement so that Negentropy Maximization Principle drives the formation of increasingly larger structures with negentropic entanglement.

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

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

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

### 3.3.4 Homeostasis as self-organized quantum criticality?

This chapter was originally motivated as an attempt to understand the properties of cold shock - and heat shock proteins (CSPs and HSPs). As a matter of fact , these proteins are similar and have much more general functions and it is better to talk about stress proteins (SPs) having two different modes of operation.

Soon it became clear that this problem is only one particular facet of a much bigger problem: how self-organized quantum criticality (SOQC) is possible? Note that the self-organized criticality (SOC) is generalized to SOQC. Criticality means by definition instability but SOQC is stable, which seems to be in conflict with the standard thermodynamics. In fact, living systems as a whole are quantum critical and manage to stay near criticality, which means SOQC and SPQC is nothing but homeostasis.

Zero energy ontology (ZEO) forming the basics of TGD inspired quantum measurement theory extends to a quantum theory of consciousness and of living systems and predicts that the arrow of time changes in ordinary ("big") state function reductions. ZEO leads to a theory of quantum self-organization and time reversal means that dissipation in reversed direction looks like extraction of energy from the environment for the observer with standard time direction. The change of the arrow of time transforms critical states from repellers to attractors and makes possible SOQC.

## REFERENCES

### Mathematics

- [A1] Yangian symmetry. Available at: <https://en.wikipedia.org/wiki/Yangian>.
- [A2] Pope CN. Eigenfunctions and  $Spin^c$  Structures on  $CP_2$ , 1980.

- [A3] Hanson J Eguchi T, Gilkey B. *Phys Rep*, 66, 1980.
- [A4] Eisenhart. *Riemannian Geometry*. Princeton University Press, 1964.
- [A5] Pope CN Gibbons GW.  $CP_2$  as gravitational instanton. *Comm Math Phys*, 55, 1977.
- [A6] Pope CN Hawking SW. Generalized Spin Structures in Quantum Gravity. *Phys Lett*, (1), 1978.
- [A7] N. Hitchin. Kählerian twistor spaces. *Proc London Math Soc*, 8(43):133–151, 1981.. Available at: <https://tinyurl.com/pb8zpqo>.
- [A8] Milnor J. *Topology form Differential Point of View*. The University Press of Virginia, Virginia, 1965.
- [A9] Spivak M. *Differential Geometry I,II,III,IV*. Publish or Perish, Boston, 1970.
- [A10] Thom R. *Comm Math Helvet*, 28, 1954.
- [A11] Wallace. *Differential Topology*. W. A. Benjamin, New York, 1968.

## Theoretical Physics

- [B1] Rapoport D. Stochastic processes in conformal Riemann-Cartan-Weyl gravitation, 1991. Available at: <https://link.springer.com/article/10.1007/BF00675614>.
- [B2] Witten E Dolan L, Nappi CR. Yangian Symmetry in  $D = 4$  superconformal Yang-Mills theory, 2004. Available at: <https://arxiv.org/abs/hep-th/0401243>.
- [B3] Plefka J Drummond J, Henn J. Yangian symmetry of scattering amplitudes in  $\mathcal{N} = 4$  super Yang-Mills theory, 2009. Available at: <https://cdsweb.cern.ch/record/1162372/files/jhep052009046.pdf>.
- [B4] Arkani-Hamed N et al. The All-Loop Integrand For Scattering Amplitudes in Planar  $N=4$  SYM, 2010. Available at: <https://arxiv.org/abs/1008.2958>.

## Cosmology and Astro-Physics

- [E1] Nottale L Da Rocha D. Gravitational Structure Formation in Scale Relativity, 2003. Available at: <https://arxiv.org/abs/astro-ph/0310036>.

## Books related to TGD

- [K1] Pitkänen M. *Topological Geometro-dynamics*. 1983. Thesis in Helsinki University 1983.
- [K2] Pitkänen M. *Bio-Systems as Conscious Holograms*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/holography.html>, 2023.
- [K3] Pitkänen M. *Bio-Systems as Self-Organizing Quantum Systems*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/bioselforg.html>, 2023.
- [K4] Pitkänen M. Classical TGD. In *Topological Geometro-dynamics: Overview: Part I*:<https://tgdtheory.fi/tgdhtml/Btgdview1.html>. Available at: <https://tgdtheory.fi/pdfpool/tgdclass.pdf>, 2023.
- [K5] Pitkänen M. *Genes and Memes*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/genememe.html>, 2023.
- [K6] Pitkänen M. *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/neuplanck.html>, 2023.
- [K7] Pitkänen M. *Magnetospheric Consciousness*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/magnconsc.html>, 2023.
- [K8] Pitkänen M. *Mathematical Aspects of Consciousness Theory*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/mathconsc.html>, 2023.

- [K9] Pitkänen M. Negentropy Maximization Principle. In *TGD Inspired Theory of Consciousness: Part I*. <https://tgdtheory.fi/tgdhtml/Btgdconsc1.html>. Available at: <https://tgdtheory.fi/pdfpool/nmpc.pdf>, 2023.
- [K10] Pitkänen M. Number theoretic vision, Hyper-finite Factors and S-matrix. In *Quantum TGD: Part I*. <https://tgdtheory.fi/tgdhtml/Btgdquantum1.html>. Available at: <https://tgdtheory.fi/pdfpool/UandM.pdf>, 2023.
- [K11] Pitkänen M. *p-Adic length Scale Hypothesis*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/padphys.html>, 2023.
- [K12] Pitkänen M. Physics as a Generalized Number Theory. In *Topological Geometrodynamics: Overview: Part I*. <https://tgdtheory.fi/tgdhtml/Btgdview1.html>. Available at: <https://tgdtheory.fi/pdfpool/tgdnumber.pdf>, 2023.
- [K13] Pitkänen M. *Quantum Hardware of Living Matter*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/bioware.html>, 2023.
- [K14] Pitkänen M. Quantum Mind and Neuroscience. In *TGD and EEG: Part I*. <https://tgdtheory.fi/tgdhtml/Btgddeeg1.html>. Available at: <https://tgdtheory.fi/pdfpool/lianPN.pdf>, 2023.
- [K15] Pitkänen M. Quantum Model for Bio-Superconductivity: I. In *TGD and Quantum Biology: Part I*. <https://tgdtheory.fi/tgdhtml/Bqbio1.html>. Available at: <https://tgdtheory.fi/pdfpool/biosupercondI.pdf>, 2023.
- [K16] Pitkänen M. Quantum Model for Bio-Superconductivity: II. In *TGD and Quantum Biology: Part I*. <https://tgdtheory.fi/tgdhtml/Bqbio1.html>. Available at: <https://tgdtheory.fi/pdfpool/biosupercondII.pdf>, 2023.
- [K17] Pitkänen M. *Quantum TGD*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/tgdquantum.html>, 2023.
- [K18] Pitkänen M. TGD and Astrophysics. In *Physics in Many-Sheeted Space-Time: Part II*. <https://tgdtheory.fi/tgdhtml/Btgdclass2.html>. Available at: <https://tgdtheory.fi/pdfpool/astro.pdf>, 2023.
- [K19] Pitkänen M. *TGD and EEG*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/tgddeeg.html>, 2023.
- [K20] Pitkänen M. *TGD and Fringe Physics*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/freenergy.html>, 2023.
- [K21] Pitkänen M. *TGD Based View About Living Matter and Remote Mental Interactions*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/tgdlian.html>, 2023.
- [K22] Pitkänen M. *TGD Inspired Theory of Consciousness*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/tgdconsc.html>, 2023.
- [K23] Pitkänen M. The classical part of the twistor story. In *Quantum TGD: Part III*. <https://tgdtheory.fi/tgdhtml/Btgdquantum3.html>. Available at: <https://tgdtheory.fi/pdfpool/twistorstory.pdf>, 2023.
- [K24] Pitkänen M. The Geometry of the World of the Classical Worlds. In *Topological Geometrodynamics: Overview: Part I*: <https://tgdtheory.fi/tgdhtml/Btgdview1.html>. Available at: <https://tgdtheory.fi/pdfpool/tgdgeom.pdf>, 2023.
- [K25] Pitkänen M. *Topological Geometrodynamics: an Overview*. Online book. Available at: <https://www.tgdtheory.fi/tgdhtml/tgdview.html>, 2023.