

Introduction to "Hyper-finite Factors and Hierarchy of Planck Constants"

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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 as 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] [?, ?, ?]), 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 [?]) 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 ¹

¹There 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

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 λ 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 $g(x) \in SU(3) \subset G_2$ 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 [L2].

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 adele [L1]. Similar discretization would take place for momenta. Loops would vanish at the level of discretization but what would happen at the possibly existing continuum limit: does the sequence of poles integrate to cuts? Or is representation as sum of resonances something much deeper?
3. Maybe it is! The basic idea of behind the original Veneziano amplitudes (see <http://tinyurl.com/yyhwvqbq>) was Veneziano duality. This 4-particle amplitude was generalized by Yoshiro Nambu, Holger-Bek Nielsen, and Leonard Susskind to N-particle amplitude (see <http://tinyurl.com/yyvkv7as>) 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 π 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 Hyper-finite Factors and Hierarchy of Planck Constants: Part I

The book "Bird's Eye of View about the Topics of Hyper-finite Factors and Hierarchy of Planck Constants: Part I" is organized to 2 parts.

The first part of the part I is devoted to hyper-finite factors and hierarchy of Planck constants.

1. Configuration space spinors indeed define a canonical example about hyper-finite factor of type II_1 . The work with TGD inspired model for quantum computation led to the realization that von Neumann algebras, in particular hyper-finite factors of type II_1 could provide the mathematics needed to develop a more explicit view about the construction of M-matrix. This has turned out to be the case to the extent that a general master formula for M-matrix with interactions described as a deformation of ordinary tensor product to Connes tensor products emerges.
2. The idea about hierarchy of Planck constants emerged from anomalies of biology and the strange finding that planetary orbits could be regarded as Bohr orbits but with a gigantic value of Planck constant. This led to the vision that dark matter corresponds to ordinary particles but with non-standard value of Planck constant and to a generalization of the 8-D imbedding space to a book like structure with pages partially characterized by the value of Planck constant. Using the intuition provided by the inclusions of hyper-finite factors of type II_1 one ends up to a prediction for the spectrum of Planck constants associated with M^4 and CP_2 degrees of freedom. This inspires the proposal that dark matter could be in quantum Hall like phase localized at light-like 3-surfaces with macroscopic size and behaving in many respects like black hole horizons.

In the 2nd part of part I some applications are discussed.

1. The first chapter is devoted to the applications of TGD view about quantum criticality and in various fields of physics and also in biology. There is also a chapter about the Nottale's formula for the gravitational Planck constant $h_{gr} = GMm/v_0 = n_{gr}h_0$. There are arguments suggesting how the value of the velocity parameter $v_0 < c$ is determined.
The possibility that Planck length l_P and CP_2 length R are identical is considered. The first guess $G = R^2/\hbar_{gr}$ holding true at gravitational flux tubes predicts too large variation of G . One can however interpret space-time surfaces as n_1 -fold coverings of CP_2 and n_2 -fold coverings of M^4 and one has $h_{gr} = n_1n_2$. The value of n_2 is expected to be bounded by strong constraints. The formula $G = R^2/n_2\hbar_0$ gives a correct size scale for G for $n_2 \sim 10^{3.5}$ and one could also understand why the variation of G is relatively small but too large to be consistent with the existing views.
2. TGD based view about quasars as TGD analogs of white holes is discussed. They would be much more structured than ordinary blackholes. Quasars, galaxies, and even stars and planets would emerge as tangles to cosmic strings, and have topology resembling that of dipole magnetic field. They would possess magnetic fields and empty disk around the central region, and lack horizon. The inspiration came from the notion of MECO and one can ask whether even ordinary blackholes are replaced in TGD framework by these objects or their time reversals.

3. There is also a chapter devoted to the vision about 3-space as a network with nodes connected by flux tubes making possible quantum entanglement between nodes possible in arbitrary long length scales due to the hierarchy of Planck constants.

2.1 The organization of "Hyper-finite Factors and Hierarchy of Planck Constants"

The book is organized to 4 parts. The 1st part of the book is devoted to hyper-finite factors and hierarchy of Planck constants.

1. Configuration space spinors indeed define a canonical example about hyper-finite factor of type II_1 . The work with TGD inspired model for quantum computation led to the realization that von Neumann algebras, in particular hyper-finite factors of type II_1 could provide the mathematics needed to develop a more explicit view about the construction of M-matrix. This has turned out to be the case to the extent that a general master formula for M-matrix with interactions described as a deformation of ordinary tensor product to Connes tensor products emerges.
2. The idea about hierarchy of Planck constants emerged from anomalies of biology and the strange finding that planetary orbits could be regarded as Bohr orbits but with a gigantic value of Planck constant. This led to the vision that dark matter corresponds to ordinary particles but with non-standard value of Planck constant and to a generalization of the 8-D imbedding space to a book like structure with pages partially characterized by the value of Planck constant. Using the intuition provided by the inclusions of hyper-finite factors of type II_1 one ends up to a prediction for the spectrum of Planck constants associated with M^4 and CP_2 degrees of freedom. This inspires the proposal that dark matter could be in quantum Hall like phase localized at light-like 3-surfaces with macroscopic size and behaving in many respects like black hole horizons.

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3. There is also a chapter devoted to the vision about 3-space as a network with nodes connected by flux tubes making possible quantum entanglement between nodes possible in arbitrary long length scales due to the hierarchy of Planck constants.

The 3rd part of the book is devoted to the applications of the hierarchy of Planck constants to particle and nuclear physics.

1. Already at seventies evidence for states formed in heavy nucleus collisions and decaying to electron-positrons pairs emerged and the TGD expansion is in terms of lepto-hadron physics inspired by the possibility that leptons (as also quarks) might have color partial waves which

are light. Whether the masses of these states can be light, is still an open question. The observed resonances could be string like entities analogous to mesons but formed from color excitations of leptons.

2. String like entities form a fractal like hierarchy in TGD Universe and should appear in all scales. Not only elementary particles but also nuclei could be string like entities. This leads to what I call nuclear string model. In this framework one also ends up to a proposal that dark nuclei can exist and would have smaller scale of binding energy scaling like \hbar/h_{eff} . This idea is applied to anomaly known as “cold fusion”.

The 4th part of the book is formally devoted to condensed matter physics but overlaps with dark nuclear physics so that it is somewhat a matter of taste whether to include the chapters in 4th part to the 3rd one.

1. The TGD based view about nuclear physics does not separate nuclear and condensed matter physics to completely isolated realms. This leads to speculations concerning the reported anomalies suggesting that these two physics indeed couple. Dark matter and dark nuclear physics would be central also for the understanding of living matter, in particular, genetic code would have a representation at the level of dark nuclei. This inspired me to write two chapters immediately after the idea about hierarchy of Planck constants emerged: these chapters are out-of-date but reflect the evolution of ideas so that I have kept them. I however added a third chapter devoted to the realization of dark realization of genetic code as sequences of 3-proton states representing genetic codons to provide a glimpse about the recent situation.
2. There are also chapters about super-conductivity and quantum Hall effect explained in terms of hierarchy of Planck constants. The last chapter is about a possible explanation of Shnoll effect.

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/yd6jf3o7>.

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.

4 The contents of the book

4.1 PART I: HYPER-FINITE FACTORS AND HIERARCHY OF PLANCK CONSTANTS

4.1.1 Was von Neumann Right After All?

The work with TGD inspired model for topological quantum computation led to the realization that von Neumann algebras, in particular so called hyper-finite factors of type II_1 , seem to provide the mathematics needed to develop a more explicit view about the construction of S-matrix. The original discussion has transformed during years from free speculation reflecting in many aspects my ignorance about the mathematics involved to a more realistic view about the role of these algebras in quantum TGD. The discussions of this chapter have been restricted to the basic notions are discussed and only short mention is made to TGD applications discussed in second chapter.

The goal of von Neumann was to generalize the algebra of quantum mechanical observables. The basic ideas behind the von Neumann algebra are dictated by physics. The algebra elements allow Hermitian conjugation $*$ and observables correspond to Hermitian operators. Any measurable function $f(A)$ of operator A belongs to the algebra and one can say that non-commutative measure theory is in question.

The predictions of quantum theory are expressible in terms of traces of observables. Density matrix defining expectations of observables in ensemble is the basic example. The highly non-trivial requirement of von Neumann was that identical a priori probabilities for a detection of states of infinite state system must make sense. Since quantum mechanical expectation values are expressible in terms of operator traces, this requires that unit operator has unit trace: $tr(Id) = 1$.

In the finite-dimensional case it is easy to build observables out of minimal projections to 1-dimensional eigen spaces of observables. For infinite-dimensional case the probability of projection to 1-dimensional sub-space vanishes if each state is equally probable. The notion of observable must thus be modified by excluding 1-dimensional minimal projections, and allow only projections for which the trace would be infinite using the straightforward generalization of the matrix algebra trace as the dimension of the projection.

The non-trivial implication of the fact that traces of projections are never larger than one is that the eigen spaces of the density matrix must be infinite-dimensional for non-vanishing projection probabilities. Quantum measurements can lead with a finite probability only to mixed states with a density matrix which is projection operator to infinite-dimensional subspace. The simple von Neumann algebras for which unit operator has unit trace are known as factors of type II_1 .

The definitions adopted by von Neumann allow however more general algebras. Type I_n algebras correspond to finite-dimensional matrix algebras with finite traces whereas I_∞ associated with a separable infinite-dimensional Hilbert space does not allow bounded traces. For algebras of type III non-trivial traces are always infinite and the notion of trace becomes useless being replaced by the notion of state which is generalization of the notion of thermodynamical state. The fascinating feature of this notion of state is that it defines a unique modular automorphism of the factor defined apart from unitary inner automorphism and the question is whether this notion or its generalization might be relevant for the construction of M-matrix in TGD. It however seems that in TGD framework based on Zero Energy Ontology identifiable as “square root” of thermodynamics a square root of thermodynamical state is needed.

The inclusions of hyper-finite factors define an excellent candidate for the description of finite measurement resolution with included factor representing the degrees of freedom below measurement resolution. This would also give connection to the notion of quantum group whose physical interpretation has remained unclear. This idea is central to the proposed applications to quantum TGD discussed in separate chapter.

4.1.2 Evolution of Ideas about Hyper-finite Factors in TGD

The work with TGD inspired model for quantum computation led to the realization that von Neumann algebras, in particular hyper-finite factors, could provide the mathematics needed to develop a more explicit view about the construction of M-matrix generalizing the notion of S-matrix in zero energy ontology (ZEO). In this chapter I will discuss various aspects of hyper-finite factors and their possible physical interpretation in TGD framework.

1. Hyper-finite factors in quantum TGD

The following argument suggests that von Neumann algebras known as hyper-finite factors (HFFs) of type III_1 appearing in relativistic quantum field theories provide also the proper mathematical framework for quantum TGD.

1. The Clifford algebra of the infinite-dimensional Hilbert space is a von Neumann algebra known as HFF of type II_1 . Therefore also the Clifford algebra at a given point (light-like 3-surface) of world of classical worlds (WCW) is HFF of type II_1 . If the fermionic Fock algebra defined by the fermionic oscillator operators assignable to the induced spinor fields (this is actually not obvious!) is infinite-dimensional it defines a representation for HFF of type II_1 . Super-conformal symmetry suggests that the extension of the Clifford algebra defining the fermionic part of a super-conformal algebra by adding bosonic super-generators representing symmetries of WCW respects the HFF property. It could however occur that HFF of type II_∞ results.

2. WCW is a union of sub-WCWs associated with causal diamonds (CD) defined as intersections of future and past directed light-cones. One can allow also unions of CD s and the proposal is that CD s within CD s are possible. Whether CD s can intersect is not clear.
3. The assumption that the M^4 proper distance a between the tips of CD is quantized in powers of 2 reproduces p-adic length scale hypothesis but one must also consider the possibility that a can have all possible values. Since $SO(3)$ is the isotropy group of CD , the CD s associated with a given value of a and with fixed lower tip are parameterized by the Lobatchevski space $L(a) = SO(3,1)/SO(3)$. Therefore the CD s with a free position of lower tip are parameterized by $M^4 \times L(a)$. A possible interpretation is in terms of quantum cosmology with a identified as cosmic time. Since Lorentz boosts define a non-compact group, the generalization of so called crossed product construction strongly suggests that the local Clifford algebra of WCW is HFF of type III_1 . If one allows all values of a , one ends up with $M^4 \times M_+^4$ as the space of moduli for WCW.
4. An interesting special aspect of 8-dimensional Clifford algebra with Minkowski signature is that it allows an octonionic representation of gamma matrices obtained as tensor products of unit matrix 1 and 7-D gamma matrices γ_k and Pauli sigma matrices by replacing 1 and γ_k by octonions. This inspires the idea that it might be possible to end up with quantum TGD from purely number theoretical arguments. One can start from a local octonionic Clifford algebra in M^8 . Associativity (co-associativity) condition is satisfied if one restricts the octonionic algebra to a subalgebra associated with any hyper-quaternionic and thus 4-D sub-manifold of M^8 . This means that the induced gamma matrices associated with the Kähler action span a complex quaternionic (complex co-quaternionic) sub-space at each point of the sub-manifold. This associative (co-associative) sub-algebra can be mapped a matrix algebra. Together with $M^8 - H$ duality this leads automatically to quantum TGD and therefore also to the notion of WCW and its Clifford algebra which is however only mappable to an associative (co-associative) algebra and thus to HFF of type II_1 .

2. Hyper-finite factors and M-matrix

HFFs of type III_1 provide a general vision about M-matrix.

1. The factors of type III allow unique modular automorphism Δ^{it} (fixed apart from unitary inner automorphism). This raises the question whether the modular automorphism could be used to define the M-matrix of quantum TGD. This is not the case as is obvious already from the fact that unitary time evolution is not a sensible concept in zero energy ontology.
2. Concerning the identification of M-matrix the notion of state as it is used in theory of factors is a more appropriate starting point than the notion modular automorphism but as a generalization of thermodynamical state is certainly not enough for the purposes of quantum TGD and quantum field theories (algebraic quantum field theorists might disagree!). Zero energy ontology requires that the notion of thermodynamical state should be replaced with its “complex square root” abstracting the idea about M-matrix as a product of positive square root of a diagonal density matrix and a unitary S-matrix. This generalization of thermodynamical state -if it exists- would provide a firm mathematical basis for the notion of M-matrix and for the fuzzy notion of path integral.
3. The existence of the modular automorphisms relies on Tomita-Takesaki theorem, which assumes that the Hilbert space in which HFF acts allows cyclic and separable vector serving as ground state for both HFF and its commutant. The translation to the language of physicists states that the vacuum is a tensor product of two vacua annihilated by annihilation oscillator type algebra elements of HFF and creation operator type algebra elements of its commutant isomorphic to it. Note however that these algebras commute so that the two algebras are not hermitian conjugates of each other. This kind of situation is exactly what emerges in zero energy ontology (ZEO): the two vacua can be assigned with the positive and negative energy parts of the zero energy states entangled by M-matrix.
4. There exists infinite number of thermodynamical states related by modular automorphisms. This must be true also for their possibly existing “complex square roots”. Physically they would correspond to different measurement interactions meaning the analog of state function

collapse in zero modes fixing the classical conserved charges equal to the quantal counterparts. Classical charges would be parameters characterizing zero modes.

A concrete construction of M-matrix motivated the recent rather precise view about basic variational principles is proposed. Fundamental fermions localized to string world sheets can be said to propagate as massless particles along their boundaries. The fundamental interaction vertices correspond to two fermion scattering for fermions at opposite throats of wormhole contact and the inverse of the conformal scaling generator L_0 would define the stringy propagator characterizing this interaction. Fundamental bosons correspond to pairs of fermion and antifermion at opposite throats of wormhole contact. Physical particles correspond to pairs of wormhole contacts with monopole Kähler magnetic flux flowing around a loop going through wormhole contacts.

3. Connes tensor product as a realization of finite measurement resolution

The inclusions $\mathcal{N} \subset \mathcal{M}$ of factors allow an attractive mathematical description of finite measurement resolution in terms of Connes tensor product but do not fix M-matrix as was the original optimistic belief.

1. In ZEO \mathcal{N} would create states experimentally indistinguishable from the original one. Therefore \mathcal{N} takes the role of complex numbers in non-commutative quantum theory. The space \mathcal{M}/\mathcal{N} would correspond to the operators creating physical states modulo measurement resolution and has typically fractal dimension given as the index of the inclusion. The corresponding spinor spaces have an identification as quantum spaces with non-commutative \mathcal{N} -valued coordinates.
2. This leads to an elegant description of finite measurement resolution. Suppose that a universal M-matrix describing the situation for an ideal measurement resolution exists as the idea about square root of state encourages to think. Finite measurement resolution forces to replace the probabilities defined by the M-matrix with their \mathcal{N} “averaged” counterparts. The “averaging” would be in terms of the complex square root of \mathcal{N} -state and a direct analog of functionally or path integral over the degrees of freedom below measurement resolution defined by (say) length scale cutoff.
3. One can construct also directly M-matrices satisfying the measurement resolution constraint. The condition that \mathcal{N} acts like complex numbers on M-matrix elements as far as \mathcal{N} -“averaged” probabilities are considered is satisfied if M-matrix is a tensor product of M-matrix in $\mathcal{M}(\mathcal{N}$ interpreted as finite-dimensional space with a projection operator to \mathcal{N} . The condition that \mathcal{N} averaging in terms of a complex square root of \mathcal{N} state produces this kind of M-matrix poses a very strong constraint on M-matrix if it is assumed to be universal (apart from variants corresponding to different measurement interactions).

4. Analogs of quantum matrix groups from finite measurement resolution?

The notion of quantum group replaces ordinary matrices with matrices with non-commutative elements. In TGD framework I have proposed that the notion should relate to the inclusions of von Neumann algebras allowing to describe mathematically the notion of finite measurement resolution.

In this article I will consider the notion of quantum matrix inspired by recent view about quantum TGD and it provides a concrete representation and physical interpretation of quantum groups in terms of finite measurement resolution. The basic idea is to replace complex matrix elements with operators expressible as products of non-negative hermitian operators and unitary operators analogous to the products of modulus and phase as a representation for complex numbers.

The condition that determinant and sub-determinants exist is crucial for the well-definedness of eigenvalue problem in the generalized sense. The weak definition of determinant meaning its development with respect to a fixed row or column does not pose additional conditions. Strong definition of determinant requires its invariance under permutations of rows and columns. The permutation of rows/columns turns out to have interpretation as braiding for the hermitian operators defined by the moduli of operator valued matrix elements. The commutativity of all sub-determinants is essential for the replacement of eigenvalues with eigenvalue spectra of hermitian operators and sub-determinants define mutually commuting set of operators.

The resulting quantum matrices define a more general structure than quantum group but provide a concrete representation and interpretation for quantum group in terms of finite measurement resolution if q is a root of unity. For $q = \pm 1$ (Bose-Einstein or Fermi-Dirac statistics) one obtains quantum matrices for which the determinant is apart from possible change by sign factor invariant under the permutations of both rows and columns. One could also understand the fractal structure of inclusion sequences of hyper-finite factors resulting by recursively replacing operators appearing as matrix elements with quantum matrices.

5. Quantum spinors and fuzzy quantum mechanics

The notion of quantum spinor leads to a quantum mechanical description of fuzzy probabilities. For quantum spinors state function reduction cannot be performed unless quantum deformation parameter equals to $q = 1$. The reason is that the components of quantum spinor do not commute: it is however possible to measure the commuting operators representing moduli squared of the components giving the probabilities associated with “true” and “false”. The universal eigenvalue spectrum for probabilities does not in general contain (1,0) so that quantum qbits are inherently fuzzy. State function reduction would occur only after a transition to $q=1$ phase and decoherence is not a problem as long as it does not induce this transition.

4.1.3 TGD view about McKay Correspondence, ADE Hierarchy, Inclusions of Hyperfinite Factors, and Twistors

In this chapter 4 topics are discussed. McKay correspondence, SUSY, and twistors are discussed from TGD point of view, and new aspects of $M^8 - H$ duality are considered.

1. McKay correspondence in TGD framework

There are two mysterious looking correspondences involving ADE groups. McKay correspondence between McKay graphs characterizing tensor products for finite subgroups of $SU(2)$ and Dynkin diagrams of affine ADE groups is the first one. The correspondence between principal diagrams characterizing inclusions of hyper-finite factors of type II_1 (HFFs) with Dynkin diagrams for a subset of ADE groups and Dynkin diagrams for affine ADE groups is the second one.

These correspondences are discussed from number theoretic point of view suggested by TGD and based on the interpretation of discrete subgroups of $SU(2)$ as subgroups of the covering group of quaternionic automorphisms $SO(3)$ (analog of Galois group) and generalization of these groups to semi-direct products $Gal(K) \triangleleft SU(2)_K$ of Galois group for extension K of rationals with the discrete subgroup $SU(2)_K$ of $SU(2)$ with representation matrix elements in K . The identification of the inclusion hierarchy of HFFs with the hierarchy of extensions of rationals and their Galois groups is proposed.

A further mystery whether $Gal(K) \triangleleft SU(2)_K$ could give rise to quantum groups or affine algebras. In TGD framework the infinite-D group of isometries of “world of classical worlds” (WCW) is identified as an infinite-D symplectic group for which the discrete subgroups characterized by K have infinite-D representations so that hyper-finite factors are natural for their representations. Symplectic algebra SSA allows hierarchy of isomorphic sub-algebras SSA_n . The gauge conditions for SSA_n and $[SSA_n, SSA]$ would define measurement resolution giving rise to hierarchies of inclusions and ADE type Kac-Moody type algebras or quantum algebras representing symmetries modulo measurement resolution.

A concrete realization of ADE type Kac-Moody algebras is proposed. It relies on the group algebra of $Gal(K) \triangleleft SU(2)_K$ and free field representation of ADE type Kac-Moody algebra identifying the free scalar fields in Kac-Moody Cartan algebra as group algebra elements defined by the traces of representation matrices (characters).

2. New aspects of $M^8 - H$ duality

$M^8 - H$ duality is now a central part of TGD and leads to new findings. $M^8 - H$ duality can be formulated both at the level of space-time surfaces and light-like 8-momenta. Since the choice of M^4 in the decomposition of momentum space $M^8 = M^4 \times E^4$ is rather free, it is always possible to find a choice for which light-like 8-momentum reduces to light-like 4-momentum in M^4 - the notion of 4-D mass is relative. This leads to what might be called $SO(4) - SU(3)$ duality corresponding to the hadronic and partonic views about hadron physics. Particles, which are eigenstates of mass

squared are massless in $M^4 \times CP_2$ picture and massive in M^8 picture. The massivation in this picture is a universal mechanism having nothing to do with dynamics and results in zero energy ontology automatically if the zero energy states are superpositions of states with different masses. p-Adic thermodynamics describes this massivation. Also a proposal for the realization of ADE hierarchy emerges.

4-D space-time surfaces correspond to roots of octonionic polynomials $P(o)$ with real coefficients corresponding to the vanishing of the real or imaginary part of $P(o)$. These polynomials however allow universal roots, which are not 4-D but analogs of 6-D branes and having topology of S^6 . Their M^4 projections are time = constant snapshots $t = r_n, r_M \leq r_n$ 3-balls of M^4 light-cone (r_n is root of $P(x)$). At each point the ball there is a sphere S^3 shrinking to a point about boundaries of the 3-ball. These special values of M^4 time lead to a deeper understanding of ZEO based quantum measurement theory and consciousness theory.

3. Is the identification of twistor space of M^4 really correct?

The critical questions concerning the identification of twistor space of M^4 as $M^4 \times S^2$ led to consider a more conservative identification as CP_3 with hyperbolic signature (3,-3) and replacement of H with $H = cd_{conf} \times CP_2$, where cd_{conf} is CP_2 with hyperbolic signature (1,-3). This approach reproduces the nice results of the earlier picture but means that the hierarchy of CDs in M^8 is mapped to a hierarchy of spaces cd_{conf} with sizes of CDs. This conforms with Poincare symmetry from which everything started since Poincare group acts in the moduli space of octonionic structures of M^8 . Note that also the original form of $M^8 - H$ duality continues to make sense and results from the modification by projection from $CP_{3,h}$ to M^4 rather than $CP_{2,h}$.

The outcome of octo-twistor approach applied at level of M^8 together with modified $M^8 - H$ duality leads to a nice picture view about twistorial description of massive states based on quaternionic generalization of twistor (super-)Grassmannian approach. A radically new view is that descriptions in terms of massive and massless states are alternative options, and correspond to two different alternative twistorial descriptions and leads to the interpretation of p-adic thermodynamics as completely universal massivation mechanism having nothing to do with dynamics. As a side product emerges a deeper understanding of ZEO based quantum measurement theory and consciousness theory relying on the universal roots of octonionic polynomials of M^8 , which are not 4-D but analogs of 6-D branes. This part of article is not a mere side track since by $M^8 - H$ duality the finite sub-groups of $SU(2)$ of McKay correspondence appear quite concretely in the description of the measurement resolution of 8-momentum.

4.1.4 Does TGD Predict Spectrum of Planck Constants?

The quantization of Planck constant has been the basic theme of TGD since 2005. The basic idea was stimulated by the suggestion of Nottale that planetary orbits could be seen as Bohr orbits with enormous value of Planck constant given by $\hbar_{gr} = GM_1 M_2 / v_0$, where the velocity parameter v_0 has the approximate value $v_0 \simeq 2^{-11}$ for the inner planets. This inspired the ideas that quantization is due to a condensation of ordinary matter around dark matter concentrated near Bohr orbits and that dark matter is in macroscopic quantum phase in astrophysical scales. The second crucial empirical input were the anomalies associated with living matter. The recent version of the chapter represents the evolution of ideas about quantization of Planck constants from a perspective given by seven years' work with the idea. A very concise summary about the situation is as follows.

1. Basic physical ideas

The basic phenomenological rules are simple.

1. The phases with non-standard values of effective Planck constant are identified as dark matter. The motivation comes from the natural assumption that only the particles with the same value of effective Planck can appear in the same vertex. One can illustrate the situation in terms of the book metaphor. Effective embedding spaces with different values of Planck constant form a book like structure and matter can be transferred between different pages only through the back of the book where the pages are glued together. One important implication is that light exotic charged particles lighter than weak bosons are possible if they have non-standard value of Planck constant. The standard argument excluding them is based on decay widths of weak bosons and has led to a neglect of large number of particle physics anomalies.

2. Large effective or real value of Planck constant scales up Compton length - or at least de Broglie wave length - and its geometric correlate at space-time level identified as size scale of the space-time sheet assignable to the particle. This could correspond to the Kähler magnetic flux tube for the particle forming consisting of two flux tubes at parallel space-time sheets and short flux tubes at ends with length of order CP_2 size.

This rule has far reaching implications in quantum biology and neuroscience since macroscopic quantum phases become possible as the basic criterion stating that macroscopic quantum phase becomes possible if the density of particles is so high that particles as Compton length sized objects overlap. Dark matter therefore forms macroscopic quantum phases. One implication is the explanation of mysterious looking quantal effects of ELF radiation in EEG frequency range on vertebrate brain: $E = hf$ implies that the energies for the ordinary value of Planck constant are much below the thermal threshold but large value of Planck constant changes the situation. Also the phase transitions modifying the value of Planck constant and changing the lengths of flux tubes (by quantum classical correspondence) are crucial as also reconnections of the flux tubes.

The hierarchy of Planck constants suggests also a new interpretation for FQHE (fractional quantum Hall effect) in terms of anyonic phases with non-standard value of effective Planck constant realized in terms of the effective multi-sheeted covering of embedding space: multi-sheeted space-time is to be distinguished from many-sheeted space-time.

In astrophysics and cosmology the implications are even more dramatic. The interpretation of \hbar_{gr} introduced by Nottale in TGD framework is as an effective Planck constant associated with space-time sheets mediating gravitational interaction between masses M and m . The huge value of \hbar_{gr} means that the integer \hbar_{gr}/\hbar_0 interpreted as the number of sheets of covering is gigantic and that Universe possesses gravitational quantum coherence in astronomical scales. The gravitational Compton length $GM/v_0 = r_S/2v_0$ does not depend on m so that all particles around say Sun say same gravitational Compton length.

By the independence of gravitational acceleration and gravitational Compton length on particle mass, it is enough to assume that only microscopic particles couple to the dark gravitons propagating along flux tubes mediating gravitational interaction. Therefore $\hbar_{gr} = \hbar_{eff}$ could be true in microscopic scales and would predict that cyclotron energies have no dependence on the mass of the charged particle meaning that the spectrum ordinary photons resulting in the transformation of dark photons to ordinary photons is universal. An attractive identification of these photons would be as bio-photons with energies in visible and UV range and thus inducing molecular transitions making control of biochemistry by dark photons. This changes the view about gravitons and suggests that gravitational radiation is emitted as dark gravitons which decay to pulses of ordinary gravitons replacing continuous flow of gravitational radiation. The energy of the graviton is gigantic unless the emission is assume to take place from a microscopic systems with large but not gigantic \hbar_{gr} .

3. Why Nature would like to have large - maybe even gigantic - value of effective value of Planck constant? A possible answer relies on the observation that in perturbation theory the expansion takes in powers of gauge couplings strengths $\alpha = g^2/4\pi\hbar$. If the effective value of \hbar replaces its real value as one might expect to happen for multi-sheeted particles behaving like single particle, α is scaled down and perturbative expansion converges for the new particles. One could say that Mother Nature loves theoreticians and comes in rescue in their attempts to calculate. In quantum gravitation the problem is especially acute since the dimensionless parameter GMm/\hbar has gigantic value. Replacing \hbar with $\hbar_{gr} = GMm/v_0$ the coupling strength becomes $v_0 < 1$.

2. Space-time correlates for the hierarchy of Planck constants

The hierarchy of Planck constants was introduced to TGD originally as an additional postulate and formulated as the existence of a hierarchy of embedding spaces defined as Cartesian products of singular coverings of M^4 and CP_2 with numbers of sheets given by integers n_a and n_b and $\hbar = n\hbar_0$. $n = n_a n_b$.

With the advent of zero energy ontology (ZEO), it became clear that the notion of singular covering space of the embedding space could be only a convenient auxiliary notion. Singular means that the sheets fuse together at the boundary of multi-sheeted region. In ZEO 3-surfaces are unions

of space-like 3-surface at opposite boundaries of CD. The non-determinism of Kähler action due to the huge vacuum degeneracy would naturally explain the existence of several space-time sheets connecting the two 3-surfaces at the opposite boundaries of CD. Quantum criticality suggests strongly conformal invariance and the identification of n as the number of conformal equivalence classes of these space-time sheets. Also a connection with the notion of negentropic entanglement emerges.

4.1.5 Mathematical Speculations about the Hierarchy of Planck Constants

This chapter contains the purely mathematical speculations about the hierarchy of Planck constants (actually only effective hierarchy if the recent interpretation is correct) as separate from the material describing the physical ideas, key mathematical concepts, and the basic applications. These mathematical speculations emerged during the first stormy years in the evolution of the ideas about Planck constant and must be taken with a big grain of salt. I feel myself rather conservative as compared to the fellow who produced this stuff for 7 years ago. This all is of course very relative. Many readers might experience this recent me as a reckless speculator.

The first speculative question is about possible relationship between Jones inclusions of hyper-finite factors of type II_1 (hyper-finite factors are von Neuman algebras emerging naturally in TGD framework). The basic idea is that the discrete groups assignable to inclusions could correspond to discrete groups acting in the effective covering spaces of embedding space assignable to the hierarchy of Planck constants.

There are also speculations relating to the hierarchy of Planck constants, Mc-Kay correspondence, and Jones inclusions. Even Farey sequences, Riemann hypothesis and N-tangles are discussed. Depending on reader these speculations might be experienced as irritating or entertaining. It would be interesting to go this stuff through in the light of recent understanding of the effective hierarchy of Planck constants to see what portion of it survives.

4.1.6 Negentropy Maximization Principle

In TGD Universe the moments of consciousness are associated with quantum jumps between quantum histories. The proposal is that the dynamics of consciousness is governed by Negentropy Maximization Principle (NMP), which states the information content of conscious experience is maximal. The formulation of NMP is the basic topic of this chapter.

NMP codes for the dynamics of standard state function reduction and states that the state function reduction process following U -process gives rise to a maximal reduction of entanglement entropy at each step. In the generic case this implies at each step a decomposition of the system to unique unentangled subsystems and the process repeats itself for these subsystems. The process stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states. The natural assumption is that self loses consciousness when it entangles via bound state entanglement.

There is an important exception to this vision based on ordinary Shannon entropy. There exists an infinite hierarchy of number theoretical entropies making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that NMP favors the generation of negentropic entanglement (NE), which is not bound state entanglement in standard sense since the condition that state function reduction leads to an eigenstate of density matrix requires the final state density matrix to be a projection operator.

NE might serve as a correlate for emotions like love and experience of understanding. The reduction of ordinary entanglement entropy to random final state implies second law at the level of ensemble. For the generation of NE the outcome of the reduction is not random: the prediction is that second law is not a universal truth holding true in all scales. Since number theoretic entropies are natural in the intersection of real and p -adic worlds, this suggests that life resides in this intersection. The existence effectively bound states with no binding energy might have important implications for the understanding the stability of basic bio-polymers and the key aspects of metabolism. A natural assumption is that self experiences expansion of consciousness as it entangles in this manner. Quite generally, an infinite self hierarchy with the entire Universe at the top is predicted.

There are two options to consider. Strong form of NMP, which would demand maximal negentropy gain: this would not allow morally responsible free will if ethics is defined in terms of evolution as increase of NE resources. Weak form of NMP would allow self to choose also lower-dimensional sub-space of the projector defining the final state sub-space for strong form of NMP. Weak form turns out to have several highly desirable consequences: it favours dimensions of final state space coming as powers of prime, and in particular dimensions which are primes near powers of prime: as a special case, p-adic length scale hypothesis follows. Weak form of NMP allows also quantum computations, which halt unlike strong form of NMP.

Besides number theoretic negentropies there are also other new elements as compared to the earlier formulation of NMP.

1. ZEO modifies dramatically the formulation of NMP since U -matrix acts between zero energy states and can be regarded as a collection of orthonormal M -matrices, which generalize the ordinary S -matrix and define what might be called a complex square root of density matrix so that kind of a square root of thermodynamics at single particle level justifying also p-adic mass calculations based on p-adic thermodynamics is in question.
2. The hierarchy of Planck constants labelling a hierarchy of quantum criticalities is a further new element having important implications for consciousness and biology.
3. Hyper-finite factors of type II_1 represent an additional technical complication requiring separate treatment of NMP taking into account finite measurement resolution realized in terms of inclusions of these factors.

NMP has wide range of important implications.

1. In particular, one must give up the standard view about second law and replace it with NMP taking into account the hierarchy of CDs assigned with ZEO and dark matter hierarchy labelled by the values of Planck constants, as well as the effects due to NE. The breaking of second law in standard sense is expected to take place and be crucial for the understanding of evolution.
2. Self hierarchy having the hierarchy of CDs as embedding space correlate leads naturally to a description of the contents of consciousness analogous to thermodynamics except that the entropy is replaced with negentropy.
3. In the case of living matter NMP allows to understand the origin of metabolism. NMP demands that self generates somehow negentropy: otherwise a state function reduction to the opposite boundary of CD takes place and means death and re-incarnation of self. Metabolism as gathering of nutrients, which by definition carry NE is the manner to avoid this fate. This leads to a vision about the role of NE in the generation of sensory qualia and a connection with metabolism. Metabolites would carry NE and each metabolite would correspond to a particular qualia (not only energy but also other quantum numbers would correspond to metabolites). That primary qualia would be associated with nutrient flow is not actually surprising!
4. NE leads to a vision about cognition. Negentropically entangled state consisting of a superposition of pairs can be interpreted as a conscious abstraction or rule: negentropically entangled Schrödinger cat knows that it is better to keep the bottle closed.
5. NMP implies continual generation of NE. One might refer to this ever expanding universal library as "Akaschic records". NE could be experienced directly during the repeated state function reductions to the passive boundary of CD - that is during the life cycle of sub-self defining the mental image. Another, less feasible option is that interaction free measurement is required to assign to NE conscious experience. As mentioned, qualia characterizing the metabolite carrying the NE could characterize this conscious experience.
6. A connection with fuzzy qubits and quantum groups with NE is highly suggestive. The implications are highly non-trivial also for quantum computation allowed by weak form of NMP since NE is by definition stable and lasts the lifetime of self in question.

4.1.7 Philosophy of Adelic Physics

The p-adic aspects of Topological Geometrophysics (TGD) will be discussed. Introduction gives a short summary about classical and quantum TGD. This is needed since the p-adic ideas are inspired by TGD based view about physics.

p-Adic mass calculations relying on p-adic generalization of thermodynamics and super-symplectic and super-conformal symmetries are summarized. Number theoretical existence constraints lead to highly non-trivial and successful physical predictions. The notion of canonical identification mapping p-adic mass squared to real mass squared emerges, and is expected to be a key player of adelic physics allowing to map various invariants from p-adics to reals and vice versa.

A view about p-adicization and adelization of real number based physics is proposed. The proposal is a fusion of real physics and various p-adic physics to single coherent whole achieved by a generalization of number concept by fusing reals and extensions of p-adic numbers induced by given extension of rationals to a larger structure and having the extension of rationals as their intersection.

The existence of p-adic variants of definite integral, Fourier analysis, Hilbert space, and Riemann geometry is far from obvious and various constraints lead to the idea of number theoretic universality (NTU) and finite measurement resolution realized in terms of number theory. An attractive manner to overcome the problems in case of symmetric spaces relies on the replacement of angle variables and their hyperbolic analogs with their exponentials identified as roots of unity and roots of e existing in finite-dimensional algebraic extension of p-adic numbers. Only group invariants - typically squares of distances and norms - are mapped by canonical identification from p-adic to real realm and various phases are mapped to themselves as number theoretically universal entities.

Also the understanding of the correspondence between real and p-adic physics at various levels - space-time level, embedding space level, and level of “world of classical worlds” (WCW) - is a challenge. The gigantic isometry group of WCW and the maximal isometry group of embedding space give hopes about a resolution of the problems. Strong form of holography (SH) allows a non-local correspondence between real and p-adic space-time surfaces induced by algebraic continuation from common string world sheets and partonic 2-surfaces. Also local correspondence seems intuitively plausible and is based on number theoretic discretization as intersection of real and p-adic surfaces providing automatically finite “cognitive” resolution. The existence p-adic variants of Kähler geometry of WCW is a challenge, and NTU might allow to realize it.

I will also sum up the role of p-adic physics in TGD inspired theory of consciousness. Negentropy entanglement (NE) characterized by number theoretical entanglement negentropy (NEN) plays a key role. Negentropy Maximization Principle (NMP) forces the generation of NE. The interpretation is in terms of evolution as increase of negentropy resources.

4.1.8 The Recent View about SUSY in TGD Universe

The progress in understanding of $M^8 - H$ duality throws also light to the problem whether SUSY is realized in TGD and what SUSY breaking does mean. It is now rather clear that particles are predicted and SUSY remains exact but that p-adic thermodynamics causes thermal massivation: unlike Higgs mechanism, this massivation mechanism is universal and has nothing to do with dynamics. This is due to the fact that zero energy states are superpositions of states with different masses. The selection of p-adic prime characterizing the particle causes the mass splitting between members of super-multiplets although the mass formula is same for all of them.

The question how to realize super-field formalism at the level of $H = M^4 \times CP_2$ led to a dramatic progress in the identification of elementary particles and SUSY dynamics. The most surprising outcome was the possibility to interpret leptons and corresponding neutrinos as local 3-quark composites with quantum numbers of anti-proton and anti-neutron. Leptons belong to the same super-multiplet as quarks and are antiparticles of neutron and proton as far quantum numbers are considered. One implication is the understanding of matter-antimatter asymmetry. Also bosons can be interpreted as local composites of quark and anti-quark.

Hadrons and hadronic gluons would still correspond to the analog of monopole phase in QFTs. Homology charge would appear as space-time correlate for color at space-time level and explain color confinement. Also color octet variants of weak bosons, Higgs, and Higgs like particle and the

predicted new pseudo-scalar are predicted. They could explain the successes of conserved vector current hypothesis (CVC) and partially conserved axial current hypothesis (PCAC).

One ends up with the precise understanding of quantum criticality and understand the relation between its descriptions at M^8 level and H -level. Polynomials describing a hierarchy of dark matters describe also a hierarchy of criticalities and one can identify inclusion hierarchies as sub-hierarchies formed by functional composition of polynomials. The Wick contractions of quark-antiquark monomials appearing in the expansion of super-coordinate of H could define the analog of radiative corrections in discrete approach. $M^8 - H$ duality and number theoretic vision require that the number of non-vanishing Wick contractions is finite. The number of contractions is indeed bounded by the finite number of points in cognitive representation and increases with the degree of the octonionic polynomial and gives rise to a discrete coupling constant evolution parameterized by the extensions of rationals.

Quark oscillator operators in cognitive representation correspond to quark field q . Only terms with quark number 1 appear in q and leptons emerge in Kähler action as local 3-quark composites. Internal consistency requires that q must be the super-spinor field satisfying super Dirac equation. This leads to a self-referential condition $q_s = q$ identifying q and its super-counterpart q_s . Also super-coordinate h_s must satisfy analogous condition $(h_s)_s = h_s$, where $h_s \rightarrow (h_s)_s$ means replacement of h in the argument of h_s with h_s .

The conditions have an interpretation in terms of a fixed point of iteration and expression of quantum criticality. The coefficients of various terms in q_s and h_s are analogous to coupling constants can be fixed from this condition so that one obtains discrete number theoretical coupling constant evolution. The basic equations are quantum criticality condition $h_s = (h_s)_s$, $q = q_s$, $D_{\alpha,s}\Gamma_s^\alpha = 0$ coming from Kähler action, and the super-Dirac equation $D_s q = 0$.

One also ends up to the first completely concrete proposal for how to construct S-matrix directly from the solutions of super-Dirac equations and super-field equations for space-time super-surfaces. The idea inspired by WKB approximation is that the exponent of the super variant of Kähler function including also super-variant of Dirac action defines S-matrix elements as its matrix elements between the positive and negative energy parts of the zero energy states formed from the corresponding vacua at the two boundaries of CD annihilated by annihilation operators and *resp.* creation operators. The states would be created by the monomials appearing in the super-coordinates and super-spinor.

Super-Dirac action vanishes on-mass-shell. The proposed construction relying on ZEO allows however to get scattering amplitudes between all possible states using the exponential of super-Kähler action. Super-Dirac equation is however needed and makes possible to express the derivatives of the quark oscillator operators (values of quark field at points of cognitive representation) so that one can use only the points of cognitive representation without introducing lattice discretization. Discrete coupling constant evolution conforms with the fact that the contractions of oscillator operators occur at the boundary of CD and their number is limited by the finite number of points of cognitive representation.

4.2 PART II: SOME APPLICATIONS

4.2.1 Quantum criticality and dark matter: part I

Quantum criticality is one of the corner stone assumptions of TGD. The value of Kähler coupling strength fixes quantum TGD and is analogous to critical temperature. TGD Universe would be quantum critical. What does this mean is however far from obvious and I have pondered the notion repeatedly both from the point of view of mathematical description and phenomenology. Dark matter as a hierarchy of phases of ordinary matter labelled by the value of effective Planck constant h_{eff} following as prediction of adelic physics suggests a general approach to quantum criticality. In the first part of the chapter about quantum criticality general ideas about quantum criticality and phase transitions are discussed.

4.2.2 Quantum criticality and dark matter: part II

Quantum criticality is one of the corner stone assumptions of TGD. The value of Kähler coupling strength fixes quantum TGD and is analogous to critical temperature. TGD Universe would be quantum critical. What does this mean is however far from obvious and I have pondered the notion

repeatedly both from the point of view of mathematical description and phenomenology. Dark matter as a hierarchy of phases of ordinary matter labelled by the value of effective Planck constant \hbar_{eff} following as prediction of adelic physics suggests a general approach to quantum criticality. In the second part of the chapter about quantum criticality condensed matter applications are discussed.

4.2.3 Quantum criticality and dark matter: part III

Quantum criticality is one of the corner stone assumptions of TGD. The value of Kähler coupling strength fixes quantum TGD and is analogous to critical temperature. TGD Universe would be quantum critical. What does this mean is however far from obvious and I have pondered the notion repeatedly both from the point of view of mathematical description and phenomenology. Dark matter as a hierarchy of phases of ordinary matter labelled by the value of effective Planck constant \hbar_{eff} following as prediction of adelic physics suggests a general approach to quantum criticality. In the third part of the chapter about quantum criticality biological applications are discussed.

4.2.4 Quantum criticality and dark matter: part IV

Quantum criticality is one of the corner stone assumptions of TGD. The value of Kähler coupling strength fixes quantum TGD and is analogous to critical temperature. TGD Universe would be quantum critical. What does this mean is however far from obvious and I have pondered the notion repeatedly both from the point of view of mathematical description and phenomenology. Dark matter as a hierarchy of phases of ordinary matter labelled by the value of effective Planck constant \hbar_{eff} following as prediction of adelic physics suggests a general approach to quantum criticality. In the fourth part of the chapter about quantum criticality applications, which might be labelled as miscellaneous, are discussed.

4.2.5 About the Nottale's formula for \hbar_{gr} and the possibility that Planck length l_P and CP_2 length R are identical giving $G = R^2/\hbar_{eff}$

Nottale's formula for the gravitational Planck constant $\hbar_{gr} = GMm/v_0$ involves parameter v_0 with dimensions of velocity. I have worked with the quantum interpretation of the formula but the physical origin of v_0 - or equivalently the dimensionless parameter $\beta_0 = v_0/c$ (to be used in the sequel) appearing in the formula has remained open hitherto. In this chapter a possible interpretation based on many-sheeted space-time concept, many-sheeted cosmology, and zero energy ontology (ZEO) is discussed. In ZEO the non-changing parts of zero energy states are assigned to the passive boundary of CD and β_0 should be assigned to it.

There are two measures for the size of the system. The M^4 size L_{M^4} is identifiable as the maximum of the radial M^4 distance from the tip of CD associated with the center of mass of the system along the light-like geodesic at the boundary of CD. System has also size L_{ind} defined in terms of the induced metric of the space-time surface, which is space-like at the boundary of CD. One has $L_{ind} < L_H$. The identification $\beta_0 = L_{M^4}/L_H$ does not allow the identification of $L_H = L_{M^4}$. L_H would however naturally corresponds to the size of the magnetic body of the system in turn identifiable as the size of CD.

One can deduce an estimate for β_0 by approximating the space-time surface as Robertson-Walker cosmology expected to be a good approximation near the passive light-like boundary of CD. The resulting formula is tested for planetary system and Earth. The dark matter assignable to Earth can be identified as the innermost part of inner core with volume, which is .01 per cent of the volume of Earth. Also the consistency of the Bohr quantization for dark and ordinary matter is discussed and leads to a number theoretical condition on the ratio of the ordinary and dark masses.

$\beta_0/4\pi$ is analogous to gravitational fine structure constant for $\hbar_{eff} = \hbar_{gr}$. Could one see it as fundamental coupling parameter appearing also in other interactions at quantum criticality in which ordinary perturbation series diverges? Remarkably, the value of G does not appear at all in the perturbative expansion in this region! Could G have several values? This suggests the generalization $G = l_P^2/\hbar \rightarrow G = R^2/\hbar_{eff}$ so that G would indeed have a spectrum and that Planck length l_P would be equal to CP_2 radius R so that only one fundamental length would be associated

with twistorialization. Ordinary Newton's constant would be given by $G = R^2/h_{eff}$ with h_{eff}/h_0 having value in the range $10^7 - 10^8$.

The second topic of the chapter relates to the the fact that the measurements of G give differing results with differences between measurements larger than the measurement accuracy. This suggests that there might be some new physics involved. In TGD framework the hierarchy of Planck constants $h_{eff} = nh_0$, $h = 6h_0$ together with the condition that theory contains CP_2 size scale R as only fundamental length scale, suggest the possibility that Newton's constant is given by $G = R^2/h_{eff}$, where R replaces Planck length ($l_P = \sqrt{\hbar G} \rightarrow l_P = R$) and \hbar_{eff}/\hbar is in the range $10^6 - 10^7$. The spectrum of Newton's constant is consistent with Newton's equations if the scaling of \hbar_{eff} inducing scaling G is accompanied by opposite scaling of M^4 coordinates in $M^4 \times CP_2$: dark matter hierarchy would correspond to discrete hierarchy of scales given by breaking of scale invariance. In the special case $h_{eff} = h_{gr} = GMm/v_0$ quantum critical dynamics as gravitational fine structure constant $(v_0/c)/4\pi$ as coupling constant and it has no dependence of the value of G or masses M and m .

In this chapter I consider a possible interpretation for the finding of a Chinese research group measuring two different values of G differing by 47 ppm in terms of varying h_{eff} . Also a model for fountain effect of superfluidity as de-localization of wave function and increase of the maximal height of vertical orbit due to the change of the gravitational acceleration g at surface of Earth induced by a change of h_{eff} due to super-fluidity is discussed. Also Podkletnov effect is considered. TGD inspired theory of consciousness allows to speculate about levitation experiences possibly induced by the modification of G_{eff} at the flux tubes for some part of the magnetic body accompanying biological body in TGD based quantum biology.

4.2.6 TGD View about Quasars

The work of Rudolph Schild and his colleagues Darryl Letier and Stanley Robertson (among others) suggests that quasars are not supermassive blackholes but something else - MECOs, magnetic eternally collapsing objects having no horizon and possessing magnetic moment. Schild et al argue that the same applies to galactic blackhole candidates and active galactic nuclei, perhaps even to ordinary blackholes as Abhas Mitra, the developer of the notion of MECO proposes.

In the sequel TGD inspired view about quasars relying on the general model for how galaxies are generated as the energy of thickened cosmic strings decays to ordinary matter is proposed. Quasars would not be blackhole like objects but would serve as an analog of the decay of inflaton field producing the galactic matter. The energy of the string like object would replace galactic dark matter and automatically predict a flat velocity spectrum.

TGD is assumed to have standard model and GRT as QFT limit in long length scales. Could MECOs provide this limit? It seems that the answer is negative: MECOs represent still collapsing objects. The energy of inflaton field is replaced with the sum of the magnetic energy of cosmic string and positive volume energy, which both decrease as the thickness of flux tube increases. The liberated energy transforms to ordinary particles and their dark variants in TGD sense. Time reversal of blackhole would be more appropriate interpretation. One can of course ask, whether the blackhole candidates in galactic nuclei are time reversals of quasars in TGD sense.

The writing of the article led also to a considerable understanding of two key aspects of TGD. The understanding of twistor lift and p-adic evolution of cosmological constant improved considerably. Also the understanding of gravitational Planck constant and the notion of space-time as a covering space became much more detailed in turn allowing much more refined view about the anatomy of magnetic body.

4.2.7 Solar Surprise

The detection of gamma rays from Sun has yielded a surprises. There are 5 times more gamma rays than expected and the spectrum has a deep and narrow dip around 30-50 GeV. Spectrum continues to much higher energies than expected, at least up to 100 GeV. One proposal is that there could be dark matter in the interior of Sun yielding the gamma rays but is unclear how they could get to the surface without experiencing the same fate as ordinary gammas from nuclear reactions.

The findings provide a test bench for TGD based view about magnetic fields and the first challenge is to understand the solar cycle. The model follows from the model for the formation of galaxies, stars, and planets as tangles of long cosmic strings thickened to flux tube. Wormhole magnetic fields correspond to closed flux tubes with monopole flux returning along different sheet. If M^4 projections of the sheets co-incide and test particle touching them experiences no net magnetic force but the energy of flux tubes is dark making itself visible through gravitational fields. For disjoint projections sheets carry measurable magnetic fields.

Polarization reversal could be understood as a quantum analog of spontaneous magnetization generating first dipole loops of type II (I) taking measured B to zero. After this dipole loops of type I (II) would split by reconnection and decay to smaller loops and leave Sun. This defines first half-cycle and for second half-cycle the roles of loops are changed.

The model discussed explains qualitatively the findings in terms of cosmic rays entering to the flux tubes of dipole fields and accelerated in the electric field of the closed flux tube and making possibly several cycles before being detected. This predicts band structure of the spectrum.

The model suggests also inversion as a Z_2 symmetry changing the roles of the flux tube portions in the interior and exterior of the solar surface. Inversion symmetry is also a symmetry of Maxwell's equations. The notions of monopole flux tube and associated approximate Z_2 symmetry acting either as reflection or inversion could be universal. Z_2 can be also represented as a subgroup of the group of Galois symmetries predicted by adelic physics.

This picture leads to highly non-trivial predictions. For instance, the "Axis of Evil" anomaly of CMB can be understood. For instance, quantum correlations in cosmological scales explain why the plane of planetary system makes itself visible in CMB. One can also add highly non-trivial detail to the TGD inspired view about quantum biology and consciousness.

4.2.8 Holography and Quantum Error Correcting Codes: TGD View

Preskill et al suggest a highly interesting representation of holography in terms of quantum error correction codes. The idea is that time = constant section of AdS, which is hyperbolic space allowing tessellations, can define tensor networks. So called perfect tensors are building bricks of the tensor networks providing representation for holography and at the same time defining error correcting codes by mapping localized interior states (logical qubits) to highly entangled non-local boundary states (physical qubits).

There are three observations that put bells ringing and actually motivated this article.

1. Perfect tensors define entanglement which TGD framework corresponds negentropic entanglement playing key role in TGD inspired theory of consciousness and of living matter.
2. In TGD framework the hyperbolic tessellations are realized at hyperbolic spaces $H_3(a)$ defining light-cone proper time hyperboloids of M^4 light-cone.
3. TGD replaces AdS/CFT correspondence with strong form of holography.

A very attractive idea is that in living matter magnetic flux tube networks defining quantum computational networks provide a realization of tensor networks realizing also holographic error correction mechanism: negentropic entanglement - perfect tensors - would be the key element. As I have proposed, these flux tube networks would define kind of central nervous system make it possible for living matter to experience consciously its biological body using magnetic body.

These networks would also give rise to the counterpart of condensed matter physics of dark matter at the level of magnetic body: the replacement of lattices based on subgroups of translation group with infinite number of tessellations means that this analog of condensed matter physics describes quantum complexity.

4.3 PART III: P-ADIC LENGTH SCALE HYPOTHESIS AND DARK MATTER HIERARCHY: PARTICLE AND NUCLEAR PHYSICS

4.3.1 Recent Status of Lepto-Hadron Hypothesis

TGD suggests strongly the existence of lepto-hadron physics. Lepto-hadrons would be bound states of color excited leptons and the anomalous production of e^+e^- pairs in heavy ion collisions finds a nice explanation as resulting from the decays of lepto-hadrons with basic condensate level

$k = 127$ and having typical mass scale of one MeV . The recent indications on the existence of a new fermion with quantum numbers of muon neutrino and the anomaly observed in the decay of orthopositronium give further support for the lepto-hadron hypothesis. There is also evidence for anomalous production of low energy photons and e^+e^- pairs in hadronic collisions.

The identification of lepto-hadrons as a particular instance in the predicted hierarchy of dark matters interacting directly only via graviton exchange allows to circumvent the lethal counter arguments against the lepto-hadron hypothesis (Z^0 decay width and production of colored lepton jets in e^+e^- annihilation) even without assumption about the loss of asymptotic freedom.

PCAC hypothesis and its sigma model realization lead to a model containing only the coupling of the lepto-pion to the axial vector current as a free parameter. The prediction for e^+e^- production cross section is of correct order of magnitude only provided one assumes that lepto-pions decay to lepto-nucleon pair $e_{ex}^+e_{ex}^-$ first and that lepto-nucleons, having quantum numbers of electron and having mass only slightly larger than electron mass, decay to lepton and photon. The peculiar production characteristics are correctly predicted. There is some evidence that the resonances decay to a final state containing $n > 2$ particle and the experimental demonstration that lepto-nucleon pairs are indeed in question, would be a breakthrough for TGD.

During 18 years after the first published version of the model also evidence for colored μ has emerged. Towards the end of 2008 CDF anomaly gave support for the colored excitation of τ . The lifetime of the light long lived state identified as a charged τ -pion comes out correctly and the identification of the reported 3 new particles as p-adically scaled up variants of neutral τ -pion predicts their masses correctly. The observed muon jets can be understood in terms of the special reaction kinematics for the decays of neutral τ -pion to 3 τ -pions with mass scale smaller by a factor $1/2$ and therefore almost at rest. A spectrum of new particles is predicted. The discussion of CDF anomaly led to a modification and generalization of the original model for lepto-pion production and the predicted production cross section is consistent with the experimental estimate.

4.3.2 TGD and Nuclear Physics

This chapter is devoted to the possible implications of TGD for nuclear physics. In the original version of the chapter the focus was in the attempt to resolve the problems caused by the incorrect interpretation of the predicted long ranged weak gauge fields. What seems to be a breakthrough in this respect came around 2005, more than a decade after the first version of this chapter, and is based on TGD based view about dark matter inspired by the developments in the mathematical understanding of quantum TGD. In this approach condensed matter nuclei can be either ordinary, that is behave essentially like standard model nuclei, or be in dark matter phase in which case they generate long ranged dark weak gauge fields responsible for the large parity breaking effects in living matter. This approach resolves trivially the objections against long range classical weak fields.

About 7 years later (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 $h_{eff} = n \times h$ however predicts that weak fields are effectively massless below scaled up weak scale. Therefore worries about large parity breaking effects in nuclear physics can be forgotten.

The basic criterion for the transition to dark matter phase having by definition large value of \hbar is that the condition $\alpha Q_1 Q_2 \simeq 1$ for appropriate gauge interactions expressing the fact that the perturbation series does not converge. The increase of \hbar makes perturbation series converging since the value of α is reduced but leaves lowest order classical predictions invariant.

This criterion can be applied to color force and inspires the hypothesis that valence quarks inside nucleons correspond to large \hbar phase whereas sea quark space-time sheets correspond to the ordinary value of \hbar . This hypothesis is combined with the earlier model of strong nuclear force based on the assumption that long color bonds with p-adically scaled down quarks with mass of order MeV at their ends are responsible for the nuclear strong force.

1. *Is strong force due to color bonds between exotic quark pairs?*

The basic assumptions are following.

1. Valence quarks correspond to large \hbar phase with p-adic length scale $L(k_{eff} = 129) = L(107)/v_0 \simeq 2^{11}L(107) \simeq 5 \times 10^{-12}$ m whereas sea quarks correspond to ordinary \hbar and define the standard size of nucleons.
2. Color bonds with length of order $L(127) \simeq 2.5 \times 10^{-12}$ m and having quarks with ordinary \hbar and p-adically scaled down masses $m_q(dark) \simeq v_0 m_q$ at their ends define kind of rubber bands connecting nucleons. The p-adic length scale of exotic quarks differs by a factor 2 from that of dark valence quarks so that the length scales in question can couple naturally. This large length scale as also other p-adic length scales correspond to the size of the topologically quantized field body associated with system, be it quark, nucleon, or nucleus.
3. Valence quarks and even exotic quarks can be dark with respect to both color and weak interactions but not with respect to electromagnetic interactions. The model for binding energies suggests darkness with respect to weak interactions with weak boson masses scaled down by a factor v_0 . Weak interactions remain still weak. Quarks and nucleons as defined by their $k = 107$ sea quark portions condense at scaled up weak space-time sheet with $k_{eff} = 111$ having p-adic size 10^{-14} meters. The estimate for the atomic number of the heaviest possible nucleus comes out correctly.

The wave functions of the nucleons fix the boundary values of the wave functionals of the color magnetic flux tubes idealizable as strings. In the terminology of M-theory nucleons correspond to small branes and color magnetic flux tubes to strings connecting them.

2. *General features of strong interactions*

This picture allows to understand the general features of strong interactions.

1. Quantum classical correspondence and the assumption that the relevant space-time surfaces have 2-dimensional CP_2 projection implies Abelianization. Strong isospin group can be identified as the $SU(2)$ subgroup of color group acting as isotropies of space-time surfaces. and the $U(1)$ holonomy of color gauge potential defines a preferred direction of strong isospin. Dark color isospin corresponds to strong isospin. The correlation of dark color with weak isospin of the nucleon is strongly suggested by quantum classical correspondence.
2. Both color singlet spin 0 pion type bonds and colored spin 1 bonds are allowed and the color magnetic spin-spin interaction between the exotic quark and anti-quark is negative in this case. p-p and n-n bonds correspond to oppositely colored spin 1 bonds and p-n bonds to colorless spin 0 bonds for which the binding energy is free times higher. The presence of colored bonds forces the presence of neutralizing dark gluon condensate favoring states with $N - P > 0$.
3. Shell model based on harmonic oscillator potential follows naturally from this picture in which the magnetic flux tubes connecting nucleons take the role of springs. Spin-orbit interaction can be understood in terms of the color force in the same way as it is understood in atomic physics.

3. *Nuclear binding energies*

1. The binding energies per nucleon for $A \leq 4$ nuclei can be understood if they form closed string like structures, nuclear strings, so that only two color bonds per nucleon are possible. This could be understood if ordinary quarks and exotic quarks possessing much smaller mass behave as if they were identical fermions. p-Adic mass calculations support this assumption. Also the average behavior of binding energy for heavier nuclei is predicted correctly.
2. For nuclei with $P = N$ all color bonds can be pion type bonds and have thus largest color magnetic spin-spin interaction energy. The increase of color Coulombic binding energy between colored exotic quark pairs and dark gluons however favors $N > P$ and explains also the formation of neutron halo outside $k = 111$ space-time sheet.

3. Spin-orbit interaction provides the standard explanation for magic numbers. If the maximum of the binding energy per nucleon is taken as a criterion for magic, also $Z=N=4,6,12$ are magic. The alternative TGD based explanation for magic numbers $Z = N = 4, 6, 8, 12, 20$ would be in terms of regular Platonic solids. Experimentally also other magic numbers are known for neutrons. The linking of nuclear strings provides a possible mechanism producing new magic nuclei from lighter magic nuclei.

4. *Stringy description of nuclear reactions*

The view about nucleus as a collection of linked nuclear strings suggests stringy description of nuclear reactions. Microscopically the nuclear reactions would correspond to re-distribution of exotic quarks between the nucleons in reacting nuclei.

5. *Anomalies and new nuclear physics*

The TGD based explanation of neutron halo has been already mentioned. The recently observed tetra-neutron states are difficult to understand in the standard nuclear physics framework since Fermi statistics does not allow this kind of state. The identification of tetra-neutron as an alpha particle containing two negatively charged color bonds allows to circumvent the problem. A large variety of exotic nuclei containing charged color bonds is predicted.

The proposed model explains the anomaly associated with the tritium beta decay. What has been observed is that the spectrum intensity of electrons has a narrow bump near the endpoint energy. Also the maximum energy E_0 of electrons is shifted downwards. I have considered two explanations for the anomaly. The original models are based on TGD variants of original models involving belt of dark neutrinos or antineutrinos along the orbit of Earth. Around 2008)I realized that nuclear string model provides much more elegant explanation of the anomaly and has also the potential to explain much more general anomalies.

Cold fusion has not been taken seriously by the physics community but the situation has begun to change gradually. There is an increasing evidence for the occurrence of nuclear transmutations of heavier elements besides the production of ^4He and ^3H whereas the production rate of ^3He and neutrons is very low. These characteristics are not consistent with the standard nuclear physics predictions. Also Coulomb wall and the absence of gamma rays and the lack of a mechanism transferring nuclear energy to the electrolyte have been used as an argument against cold fusion. TGD based model relying on the notion of charged color bonds could explain the anomalous characteristics of cold fusion. The basic mechanism making possible to circumvent Coulomb wall could be large h_{eff} phase for weak bosons scaling the weak length scale to atomic length scale so that proton could transform to neutron by the exchange of dark W boson with target nucleus.

4.3.3 Nuclear String Hypothesis

Nuclear string hypothesis is one of the most dramatic almost-predictions of TGD. The hypothesis in its original form assumes that nucleons inside nucleus form closed nuclear strings with neighboring nuclei of the string connected by exotic meson bonds consisting of color magnetic flux tube with quark and anti-quark at its ends. It is also possible that neutrons and protons form their own strings. The lengths of flux tubes correspond to the p-adic length scale of electron and therefore the mass scale of the exotic mesons is around 1 MeV in accordance with the general scale of nuclear binding energies. The long lengths of em flux tubes increase the distance between nucleons and reduce Coulomb repulsion. A fractally scaled up variant of ordinary QCD with respect to p-adic length scale would be in question and the usual wisdom about ordinary pions and other mesons as the origin of nuclear force would be simply wrong in TGD framework as the large mass scale of ordinary pion indeed suggests.

1. $A > 4$ nuclei as nuclear strings consisting of $A \leq 4$ nuclei

In this article a more refined version of nuclear string hypothesis is developed.

1. It is assumed ^4He nuclei and $A < 4$ nuclei and possibly also nucleons appear as basic building blocks of nuclear strings. $A \leq 4$ nuclei in turn can be regarded as strings of nucleons. Large number of stable lightest isotopes of form $A = 4n$ supports the hypothesis that the number

of ${}^4\text{He}$ nuclei is maximal. Even the weak decay characteristics might be reduced to those for $A < 4$ nuclei using this hypothesis.

2. One can understand the behavior of nuclear binding energies surprisingly well from the assumptions that total *strong* binding energy associated with $A \leq 4$ building blocks is *additive* for nuclear strings.
3. In TGD framework tetra-neutron is interpreted as a variant of alpha particle obtained by replacing two meson-like stringy bonds connecting neighboring nucleons of the nuclear string with their negatively charged variants. For heavier nuclei tetra-neutron is needed as an additional building brick.

2. Bose-Einstein condensation of color bonds as a mechanism of nuclear binding

The attempt to understand the variation of the nuclear binding energy and its maximum for Fe leads to a quantitative model of nuclei lighter than Fe as color bound Bose-Einstein condensates of pion like colored states associated with color flux tubes connecting ${}^4\text{He}$ nuclei. The color contribution to the total binding energy is proportional to n^2 , where n is the number of color bonds. Fermi statistics explains the reduction of E_B for the nuclei heavier than Fe . Detailed estimate favors harmonic oscillator model over free nucleon model with oscillator strength having interpretation in terms of string tension.

Fractal scaling argument allows to understand ${}^4\text{He}$ and lighter nuclei as strings of nucleons with nucleons bound together by color bonds. Three fractally scaled variants of QCD corresponding $A > 4$, $A = 4$, and $A < 4$ nuclei are involved. The binding energies of also $A \leq 4$ are predicted surprisingly accurately by applying simple p-adic scaling to the model of binding energies of heavier nuclei.

3. Giant dipole resonance as de-coherence of Bose-Einstein condensate of color bonds

Giant resonances and so called pygmy resonances are interpreted in terms of de-coherence of the Bose-Einstein condensates associated with $A \leq 4$ nuclei and with the nuclear string formed from $A \leq 4$ nuclei. The splitting of the Bose-Einstein condensate to pieces costs a precisely defined energy. For ${}^4\text{He}$ de-coherence the model predicts singlet line at 12.74 MeV and triplet at ~ 27 MeV spanning 4 MeV wide range.

The de-coherence at the level of nuclear string predicts 1 MeV wide bands 1.4 MeV above the basic lines. Bands decompose to lines with precisely predicted energies. Also these contribute to the width. The predictions are in rather good agreement with experimental values. The so called pygmy resonance appearing in neutron rich nuclei can be understood as a de-coherence for $A = 3$ nuclei. A doublet at ~ 8 MeV and MeV spacing is predicted. The prediction for the position is correct.

4. Dark nuclear strings as analogs of DNA-, RNA- and amino-acid sequences and baryonic realization of genetic code

A speculative picture proposing a connection between homeopathy, water memory, and phantom DNA effect is discussed and on basis of this connection a vision about how the hardware for topological quantum computation (TQC) represented by the genome is actively developed by subjecting it to evolutionary pressures represented by a virtual world representation of the physical environment. The speculation inspired by this vision is that genetic code as well as DNA-, RNA- and amino-acid sequences should have representation in terms of nuclear strings. The model for dark baryons indeed leads to an identification of these analogs and the basic numbers of genetic code including also the numbers of amino-acids coded by a given number of codons are predicted correctly. Hence genetic code would be universal rather than being an accidental outcome of the biological evolution.

4.3.4 Cold Fusion Again

During years I have developed two models of cold fusion and in this article these models are combined together. The basic idea of TGD based model of cold is that cold fusion occurs in two steps. First dark nuclei (large $h_{eff} = n \times h$) with much lower binding energy than ordinary nuclei are formed at magnetic flux tubes possibly carrying monopole flux. These nuclei can leak out the

system along magnetic flux tubes. Under some circumstances these dark nuclei can transform to ordinary nuclei and give rise to detectable fusion products.

An essential additional condition is that the dark protons can decay to neutrons rapidly enough by exchanges of dark weak bosons effectively massless below atomic length scale. Also beta decays in which dark W boson decays to dark electron and neutrino can be considered. This allows to overcome the Coulomb wall and explains why final state nuclei are stable and the decay to ordinary nuclei does not yield only protons. Thus it seems that this model combined with the TGD variant of Widom-Larsen model could explain nicely the existing data.

In this chapter I will describe the steps leading to the TGD inspired model for cold fusion combining the earlier TGD variant of Widom-Larsen model with the model inspired by the TGD inspired model of Pollack's fourth phase of water using as input data findings from laser pulse induced cold fusion discovered by Leif Holmlid and collaborators. I consider briefly also alternative options (models assuming surface plasma polariton and heavy electron). After that I apply TGD inspired model in some cases (Pons-Fleischman effect, bubble fusion, and LeClair effect). The model explains the strange findings about cold fusion - in particular the fact that only stable nuclei are produced - and suggests that also ordinary nuclear reactions might have more fundamental description in terms of similar model.

4.3.5 Could TGD provide new solutions to the energy problem?

Topological Geometrophysics (TGD) leads to new physics both classically and at quantum level. This new physics could provide a solution to the energy problem. Artificial photosynthesis, nuclear fission, hot fusion and also "cold fusion" have received a considerable attention as solutions of this problem. TGD has led to a model of "cold fusion" (CF), which was later generalized to a model for nuclear physics applicable also to hot fusion and to explain a 10 year old anomaly in the nuclear physics of Sun.

TGD leads also to a model of quantum biology relying on new quantum physics. This model could provide a theoretical basis for the understanding of photosynthesis. This article provides first an introduction to CF, and then a brief summary about TGD as a unification of fundamental interactions and its applications to quantum biology and to theory of consciousness as generalization of quantum measurement theory. Finally TGD based model of CF and how it could help in the development of energy technology is discussed.

What is remarkable that both CF and ordinary nuclear reactions would proceed by essentially the same mechanism as bio-catalysis made possible by quantum criticality and phase transitions changing length scale dependent cosmological constant predicted by TGD. By fractality of TGD Universe this mechanism could actually apply in all scales from astrophysics to hadron physics and even in phase transition that was expected to correspond to color de-confinement.

4.3.6 Comparing Electric Universe hypothesis and TGD

Electric Universe scenario in its extreme form postulates that electromagnetic fields are enough to explain gravitation and even nuclear fusion. From TGD viewpoint this vision is unrealistic. Wes Johnson however gave links to two Youtube videos related to Electric Universe telling about extremely interesting physical findings providing applications for TGD if take seriously. The first video was about the anomalies related to the craters of the Moon and second describe the claimed findings of SAFIRE team having a nice interpretation in TGD framework using the notions of monopole flux tubes and dark matter as hierarchy of phases of ordinary matter with non-standard value of Planck constant implying that electromagnetism has deep implications in arbitrarily long scales. The question in TGD is therefore not about whether electromagnetism (of gauge interactions in general) or gravitation is enough to understand cosmology and astrophysics: both are needed and in the sense of TGD.

4.3.7 Solar Metallicity Problem from TGD Perspective

For ten years ago it was thought that Sun is a well-understood system but more precise computations demonstrated a problem. The metallicities deduced from the spectroscopic data deviate strongly from those deduced from helio-seismology and solar neutrino data.

The abundances used are determined from meteorites and these estimates are more accurate and consistent with the values determined by Asplund et al using 3-D modelling of solar surface used also to extrapolate the metallicities in core.

1. The metallicity of Sun deduced from spectroscopy by Asplund et al would be 1.3 per cent whereas the older model and also helio-seismology give 1.8 per cent metallicity. Is the metallicity indeed 1.3 per cent using standard model to extrapolate the spectroscopic data at surface? Or is it 1.8 per cent deeper in the interior in which case the extrapolation used to deduce metallicity in the interior would not be realistic.
2. There are also other discrepancies. The height of convective zone at which radiative energy transfer is replaced with convection is given by $R_{CZ} = .724R$. The predicted He abundance at surface is $Y_{surf} = .231$. These values are in conflict with $R_{CZ} = .713R$ and $Y_{surf} = .248$ deduced from helio-seismological data. Also density and sound velocity profiles deviate from those deduced from the helio-seismology. Ironically, the earlier model approximating solar surface as 2-D structure is in excellent accordance with the helio-seismological data.

When one has a paradox one must challenge the basic assumptions. Do the metallicities outside Sun and inside solar core really mean same thing? Dark matter identified as $h_{eff} = nh_0$ phases has become key player in TGD inspired new physics being now a crucial element of TGD based view about living matter. Dark nuclear fusion is proposed to provide the new physics allowing to understand “cold fusion”. In the following it will be found that dark matter in TGD associated with solar core could provide an elegant solution also to the solar metallicity problem.

In TGD classical physics is an exact part of quantum physics. The tunnelling phenomenon essential for nuclear physics based model of solar nuclear fusion would correspond in TGD to a state function reduction creating a phase consisting of dark nuclei which can fuse without tunnelling due to the reduction of the binding energy scale. State function reduction to ordinary phase leads to the final state of the reaction. In ZEO “big” (ordinary) state function reduction (BFSR) would reverse the arrow of time so that if tunnelling phenomenon is assignable to BFSR rather than “small” state function reduction (SFSR) as TGD counterpart of “weak” measurement, ZEO would make possible nuclear fusion.

The missing nuclear matter inside core would be dark variants of nuclei associated with dark flux tubes. This would explain the conflict between the metallicities deduced from spectroscopic and meteoritic data on one hand and those derived from helio-seismic data. The reason is that sound waves and photons in the core couple to both ordinary and dark matter so that helio-seismology gives metallicities as sums of ordinary and dark metallicities. Using the estimate for the thickness of the dark flux tube coming from the TGD based model of “cold fusion”, one can estimate the length of dark flux tube inside solar core and it turns out to fill about 30 per cent of its volume.

One can relate the model also to the model for the formation of galaxies, stars, and planets as tangles assignable to cosmic strings thickened to flux tubes implying the decay of their Kähler magnetic energy to ordinary matter in analogy with the decay of inflaton field and nice quantitative estimates follow. Also a connection with twistor lift of TGD predicting hierarchy of cosmological constants emerges and the radius of solar core turns out to corresponds to the value of cosmological constant implied by the amount of missing matter identified as dark matter at flux tubes.

The view about the role of new nuclear physics predicted by TGD in the model of solar interior gives excellent guidelines for attempts to develop a more detailed understanding about TGD counterparts of blackholes as volume filling flux tube tangles. One ends up to rather detailed picture making correct predictions about minimum radii of blackholes and neutron stars. The idea about ordinary stars as blackhole like objects emerges.

The standard blackhole thermodynamics is replaced by two thermodynamics. The first thermodynamics is assignable to the flux tubes as string like entities having Hagedorn temperature T_H as maximal temperature. The second thermodynamics is assignable to gravitational flux tubes characterized by the gravitational Planck constant \hbar_{gr} : Hawking temperature T_B is scaled up by the ratio \hbar_{gr}/\hbar to $T_{B,D}$ and is gigantic as compared to the ordinary Hawking temperature but the intensity of dark Hawking radiation is extremely low. The condition $T_H = T_{B,D}$ for thermodynamical equilibrium fixes the velocity parameter $\beta_0 = v_0/c$ appearing in the Nottale formula for \hbar_{gr} and suggests $\beta_0 = 1/h_{eff}$ for the dark nuclei at flux tubes defining star as blackhole like entity in TGD sense. This also predicts the Hagedorn temperature of the counterpart of blackhole in

GRT sense to to be hadronic Hagedorn temperature assignable to the flux tube containing dark nuclei as dark nucleon sequences so that there is a remarkable internal consistency. In zero energy ontology (ZEO) quasars and galactic blackholes can be seen as time reversals of each other.

The flux tube picture about galaxies and larger structures is discussed with application to some anomalies strongly suggesting the presence of coherence in scales of even billion light years. Also “too” fast spinning galaxies are discussed. The local galaxy supercluster Laniakea is discussed in the flux tube picture as a flux tube tangle in scale of .5 Gly.

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4.3.8 Cosmic string model for the formation of galaxies and stars

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The cosmological time anomalies such as stars older than the Universe can be understood. In ZEO the time evolution for the zero energy states associated with causal diamonds (CDs) by sequences of small state function reductions (weak measurements) gives rise to conscious entity, self. Self dies and re-incarnates with an opposite arrow of time in big (ordinary) state function reduction reversing the arrow of time. These reincarnations define kind of universal Karma’s cycle. If the Karma’s cycle leaves the sizes of CDs bounded and their position in M^4 unaffected, quantum dynamics reduces to a local dynamics inside CDs defining sub-cosmologies. In particular, the age distributions and properties of stars depend only weakly on the value of cosmic time - stars older than the Universe become possible in standard view about time.

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4.4 PART IV: P-ADIC LENGTH SCALE HYPOTHESIS AND DARK MATTER HIERARCHY: CONDENSED MATTER PHYSICS

4.4.1 Dark Nuclear Physics and Condensed Matter

In this chapter the possible effects of dark matter in nuclear physics and condensed matter physics are considered. The spirit of the discussion is necessarily rather speculative. The most general form of the hierarchy would involve both singular coverings and factors spaces of CD (causal diamond of M^4) defined as intersection of future and past directed light-cones) and CP_2 . There are grave objections against the allowance of factor spaces. In this case Planck constant could be smaller than its standard value and there are very few experimental indications for this. Quite

recently came the realization that the hierarchy of Planck constants might emerge from the basic quantum TGD as a consequence of the extreme non-linearity of field equations implying that the correspondence between the derivatives of embedding space coordinates and canonical momentum is many-to-one. This makes natural to the introduction of covering spaces of CD and CP_2 .

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

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

1. *What darkness means?*

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

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

2. *What dark nucleons are?*

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

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

A direct support for partial darkness of water comes from the $H_{1.5}O$ chemical formula supported by neutron and electron diffraction in attosecond time scale. The explanation could be that one fourth of protons combine to form super-nuclei with protons connected by color bonds and having distance sufficiently larger than atomic radius.

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

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

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

4.4.2 Dark Forces and Living Matter

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

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

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

One can still worry about large parity breaking effects - say in nuclear physics- since the couplings of spinors to classical weak fields are there. Around 2012 it became clear that the condition that induced spinor fields have well defined em charge localizes their modes in the generic case to 2-surfaces carrying vanishing induced W gauge fields. It is quite possible that this localization is consistent with Kähler-Dirac equation only in 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 $\hbar_{eff} = n \times \hbar$ 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.

4.4.3 Super-Conductivity in Many-Sheeted Space-Time

In this chapter 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 embedding 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...

4.4.4 Quantum Hall effect and Hierarchy of Planck Constants

In this chapter I try to formulate more precisely the recent TGD based view about fractional quantum Hall effect (FQHE). This view is much more realistic than the original rough scenario, which neglected the existing rather detailed understanding. The spectrum of ν , and the mechanism producing it is the same as in composite fermion approach. The new elements relate to the not so well-understood aspects of FQHE, namely charge fractionization, the emergence of braid statistics, and non-abelianity of braid statistics.

1. The starting point is composite fermion model so that the basic predictions are same. Now magnetic vortices correspond to (Kähler) magnetic flux tubes carrying unit of magnetic flux. The magnetic field inside flux tube would be created by delocalized electron at the boundary of the vortex. One can raise two questions.

Could the boundary of the macroscopic system carrying anyonic phase have identification as a macroscopic analog of partonic 2-surface serving as a boundary between Minkowskian and Euclidian regions of space-time sheet? If so, the space-time sheet assignable to the macroscopic system in question would have Euclidian signature, and would be analogous to blackhole or to a line of generalized Feynman diagram.

Could the boundary of the vortex be identifiable a light-like boundary separating Minkowskian magnetic flux tube from the Euclidian interior of the macroscopic system and be also analogous to wormhole throat? If so, both macroscopic objects and magnetic vortices would be rather exotic geometric objects not possible in general relativity framework.

2. Taking composite model as a starting point one obtains standard predictions for the filling fractions. One should also understand charge fractionalization and fractional braiding statistics. Here the vacuum degeneracy of Kähler action suggests the explanation. Vacuum degeneracy implies that the correspondence between the normal component of the canonical momentum current and normal derivatives of embedding space coordinates is 1- to- n . These

kind of branchings result in multi-furcations induced by variations of the system parameters and the scaling of external magnetic field represents one such variation.

3. At the orbits of wormhole throats, which can have even macroscopic M^4 projections, one has $1 \rightarrow n_a$ correspondence and at the space-like ends of the space-time surface at light-like boundaries of causal diamond one has $1 \rightarrow n_b$ correspondence. This implies that at partonic 2-surfaces defined as the intersections of these two kinds of 3-surfaces one has $1 \rightarrow n_a \times n_b$ correspondence. This correspondence can be described by using a local singular n -fold covering of the embedding space. Unlike in the original approach, the covering space is only a convenient auxiliary tool rather than fundamental notion.
4. The fractionalization of charge can be understood as follows. A delocalization of electron charge to the n sheets of the multi-furcation takes place and single sheet is analogous to a sheet of Riemann surface of function $z^{1/n}$ and carries fractional charge $q = e/n$, $n = n_a n_b$. Fractionalization applies also to other quantum numbers. One can have also many-electron states of these states with several delocalized electrons: in this case one obtains more general charge fractionalization: $q = \nu e$.
5. Also the fractional braid statistics can be understood. For ordinary statistics rotations of M^4 rotate entire partonic 2-surfaces. For braid statistics rotations of M^4 (and particle exchange) induce a flow braid ends along partonic 2-surface. If the singular local covering is analogous to the Riemann surface of $z^{1/n}$, the braid rotation by $\Delta\Phi = 2\pi$, where Φ corresponds to M^4 angle, leads to a second branch of multi-furcation and one can give up the usual quantization condition for angular momentum. For the natural angle coordinate Φ of the n -branched covering $\Delta\Phi = 2/\pi$ corresponds to $\Delta\Phi = n \times 2\pi$. If one identifies the sheets of multi-furcation and therefore uses Φ as angle coordinate, single valued angular momentum eigenstates become in general n -valued, angular momentum in braid statistics becomes fractional and one obtains fractional braid statistics for angular momentum.
6. How to understand the exceptional values $\nu = 5/2, 7/2$ of the filling fraction? The non-abelian braid group representations can be interpreted as higher-dimensional projective representations of permutation group: for ordinary statistics only Abelian representations are possible. It seems that the minimum number of braids is $n > 2$ from the condition of non-abelianity of braid group representations. The condition that ordinary statistics is fermionic, gives $n > 3$. The minimum value is $n = 4$ consistent with the fractional charge $e/4$.

The model introduces Z_4 valued topological quantum number characterizing flux tubes. This also makes possible non-Abelian braid statistics. The interpretation of this quantum number as a Z_4 valued momentum characterizing the four delocalized states of the flux tube at the sheets of the 4-furcation suggests itself strongly. Topology would correspond to that of 4-fold covering space of embedding space serving as a convenient auxiliary tool. The more standard explanation is that $Z_4 = Z_2 \times Z_2$ such that Z_2 's correspond to the presence or absence of neutral Majorana fermion in the two Cooper pair like states formed by flux tubes.

What remains to be understood is the emergence of non-abelian gauge group realizing non-Abelian fractional statistics in gauge theory framework. Electroweak gauge group defined non-abelian braid group in large \hbar_{eff} phase weak length above atomic length scale so that weak bosons and even fermion behave as effectively massless particles below scaled up weak scale. TGD also predicts the possibility of dynamical gauge groups and maybe this kind of gauge group indeed emerges. Dynamical gauge groups emerge also for stacks of N branes and the n sheets of multifurcation are analogous to the N sheets in the stack for many-electron states.

4.4.5 A Possible Explanation of Shnoll Effect

Shnoll and collaborators have discovered strange repeating patterns of random fluctuations of physical observables such as the number n of nuclear decays in a given time interval. Periodically occurring peaks for the distribution of the number $N(n)$ of measurements producing n events in a series of measurements as a function of n is observed instead of a single peak. The positions of the peaks are not random and the patterns depend on position and time varying periodically in time scales possibly assignable to Earth-Sun and Earth-Moon gravitational interaction.

These observations suggest a modification of the expected probability distributions but it is very difficult to imagine any physical mechanism in the standard physics framework. Rather, a universal deformation of predicted probability distributions could be in question requiring something analogous to the transition from classical physics to quantum physics.

TGD gives hints about the nature of the modification.

1. TGD inspired quantum measurement theory proposes a description of the notion of finite measurement resolution in terms of inclusions of so called hyper-finite factors of type II_1 (HFFs) and closely related quantum groups parameterized by quantum phase $q_m = \exp(i\pi/m)$. Canonical identification mapping p-adic integers to their real counterparts is central element of TGD. For $m = p$ one can consider also the quantum variant of p-adic integer n mapped to n_R by canonical identification. There are 2 candidates for quantum-p-adics depending on whether the pinary digits are interpreted as quantum integers as such or mapped to a product of quantum counterparts of their prime factors.
2. Adelic physics provides a possible unification of real number based physics as physics of sensory experience and various p-adics physics as physics of cognition and predicts a hierarchy of Planck constants $h_{eff} = nh_0$ and suggests the identification of preferred p-adic prime p as a ramified prime of extension of rationals associated with the adele.

p-Adicization or perhaps even quantum-padicization could explain the findings of Shnoll.

1. The universality of the modified distribution $P(n)$ would reduce to the interpretation of the integer n in the distribution $P(n|\lambda)$ of counts as a p-adic integer or its counterpart mapped by canonical identification to a real number n_R appearing as argument of $P(n|\lambda)$. Same can be applied to $n!$. The fractality implied by the quantum criticality of TGD Universe suggests that $P(n)$ should be approximately scaling invariant under $n \rightarrow p^k n$.
2. TGD can be regarded formally as complex square root of thermodynamics, which suggest the representation $P(n) = |\Psi(n)|^2$, where $\Psi(n)$ would be wave function in the space of counts expressible as product of classical part and “quantum factor”. One could have wave functions in the space of counts n expressible as superpositions of “plane waves” q_m^{kn} , with k playing the role of momentum.

A more concrete model relies on wave function proportional to $(kn)_{q_p} \propto q_m^{kn} + q_m^{-kn}$ - analog to a superposition of plane waves with momenta k propagating to opposite directions in the space of counts reduced effectively to a box $0 \leq n < p = m$ representing modulo p counter. One would have effectively wave functions in finite field G_p . The symmetries of quantum factor would correspond to a multiplication or shift of k by element r of F_p .

Various additional rational-valued parameters characterizing the probability distribution can be mapped to (possibly quantum-) p-adics mapped to reals by canonical identification. The parameters taking care of the converge such as the parameter λ in Poisson distribution must be mapped to a power of p in p-adic context.

The model can be applied to explain the findings of Shnoll.

1. The model makes rather detailed predictions about the periodically occurring positions of the peaks of $P(n)$ as function of p based on number theoretical considerations and in principle allows to determine these parameters for given distribution. There is p -periodicity due to the fact that the lowest pinary digit of n_R gives first approximation to n_R .
2. The slow variation of the p-adic prime p and integer $m = p$ characterizing quantum integers could explain the slow variation of the distributions with position and time. The periodic variations occurring with both solar and sidereal periods could be understood in two manners. The value of p could be characterized by the sum a_{net} of gravitational accelerations assignable to Earth-Sun and Earth-Moon systems and could vary. If the value of p is outcome of state function process, it is not determined by deterministic dynamics but should have a distribution. If this distribution is peaked around one particular value, one can understand the findings of Shnoll.
3. An alternative explanation would be based on slow dependence of quantum factor of $\Psi(n)$ on gravitational parameters and on time. For instance, the momentum k defining the standing wave in the space of counts modulo p could change so that the peaks of the diffraction pattern would be permuted.

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