The Recent View about TGD

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Abstract

Topological Geometro-Dynamics (TGD) proposes a unification of fundamental interactions by identifying space-times as 4-surfaces in 8-D space $H = M^4 \times CP_2$, whose geometry codes for standard model symmetries and geometrizes known fields. Point-like particle is replaced with 3-surface (3-space).

One ends up with the notions of many-sheeted space-time and magnetic body (MB) central in TGD inspired quantum biology. p-Adic and adelic physics follows from the extension of physics to describe also the correlates of cognition and imagination. Adelic physics emerges as a fusion of real physics and various p-adic physics assignableto extensions of p-adic number fields induced by given extension of rationals.

Adelic physics predicts a hierarchy of Planck constants $h_{eff} = n \times h_0$ - n is the dimension of extension - labelling phases of ordinary matter interpreted as dark matter: the predicted quantum coherence in arbitrarily long scales is crucial for quantum biology.

Quantum TGD replaces standard ontology with "zero energy ontology" (ZEO) replacing quantum state as time=constant snapshot with zero energy state (ZES) identified as a superposition of deterministic classical time evolutions connecting initial and finals states at different values of time - kind of quantum program. In biology this serves as a correlate for behavior or function.

In this chapter the recent state of TGD is discussed with emphasis with new developments taken place within few months.

1. Zero energy ontology (ZEO) is one of the cornerstones of TGD inspired quantum measurement theory which leads to a theory of consciousness. Quite recently I learned about strange observations suggesting that quantum measurement theory due to Bohr is not correct. ZEO predicting that the arrow of time changes in ordinary ("big") state function reductions explains the findings and also a direct connection with Libet's strange findings about active aspects of consciousness emerges and supports the view that conscious decision indeed corresponds to macroscopic counterpart of ordinary state function reduction.

2. McKay correspondence looks for physicists somewhat mysterious and the first step in the mathematical progress was dramatically improved understanding McKay correspondence in TGD framework. In particular, connection with the inclusion hierarchies of hyperfinite factors of type II_1 (HFFs) emerged.

3. There are good reasons to believe that TGD variant of SUSY is finally understood. This changed completely the existing standard interpretations - SUSY would have been staring directly to our face for almost century (leptons correspond to local composites for three antiquarks). This also led to a first completely concerete proposal for how to construct S-matrix directly in terms of deterministic time evolution of super-space-time surface and Dirac super-spinors.

4. The understanding of the notion twistor in TGD framework has improved considerably. There are two basic pictures corresponding to H and M^8. For H one has Cartesian product of ordinary 4-D twistor space and and CP_2 twistor space: $T(H) = T(M^4) \times T(CP_2)$. My original identification for the "geometric" twistor space of M^4 as $T(M^4) = M^4 \times S^2$ seems however wrong. $M^4 \times S^2$ seems to be only an to $CP_{3,h}$ - CP_3 with hypercomplex coordinates and signature (3,-3) for metric - this is the standard proposal. The improved understanding of $M^8 - H$ correspondence together with the assumption that $M^8 - H$ duality respects the extension of rationals defining adeles leads to a very

concrete proposal for the preferred extremals in $T(M^4) \times T(CP_2)$ so that TGD indeed seems to be exactly solvable theory. There are two equivalent views to interpret H: either as $M^4 \times CP_2$ and $CP_{2,h} \times CP_2$.

In M^8 picture based on light-like 8-momenta the twistor space would correspond to 12-D quaternionic projective space $HP_{3,h}$ rather than $CP_{3,h}$ - has "h" tells that it has signature (6,-6). Twistor sphere CP_1 is replaced with 4-D quaternionic sphere HP_1.

5. Also the notion of $M^8 - H$ duality allowing to see the dynamics in two manners evolved dramatically. $M^4 \subset M^8$ can be taken to be fixed in M^8 picture in which case 8-D light-like momenta have in general massive 4-D projection to M^4. $M^4 \subset M^8$ can be also chosen so that the light-like 8-momentum belongs to M^4 being thus light-like in 4-D sense: this corresponds to $M^4 \times CP_2$ picture. Mass becomes therefore a relative notion - something totally new. One can understand the massivation as described by p-adic thermodynamics as forced by the mixing of states with different mass squared.

Contents

1 Introduction

The purpose of this article is to summarize the recent state of Topological Geometrodynamics (TGD). The motivation is the need to minimize the possible confusion due to the strong fluctuation period during last few years during which several mathematical ideas have been searching their precise form. I have now a strong feeling that this form has been found so that a summary is in order. I will not talk much about the general evolution of TGD: this is discussed in [**?**].

The basic strategy in the development of TGD has been simple. Try to find weak points of existing theories as anomalies and propose a possible solution. This is very much like in solving a crossword puzzle. Internal logical coherence and applications to various real life situations have been central for the approach.

1.1 Basic idea of TGD

Topological Geometrodynamics (TGD) [**?**]see `http://tinyurl.com/y5byyhc2`) is a 41 year old proposal for a unification of fundamental interactions based on new view about space-time inspired by the difficulties of General Relativity (GRT) with classical conservation laws ("energy problem"). Poincare invariance implies the conservation laws of energy, momentum, and angular momentum via Noether's theorem in Special Relativity (SRT). Since matter makes GRT space-time curved, the symmetries of Minkowski space M^4 of SRT and by Noether's theorem also the classical conservation laws are lost.

If space-time is a 4-surface in space of form $H = M^4 \times S$, S some compact space with very small size, space-time isometries are raised to those of H to regain Poincare symmetries. $S = CP_2$ codes for the symmetries of standard model. Family replication phenomenon has topological explanation.

1. In classical TGD space-time is identified as a 4-surface $X^4 \subset H = X^4 \subset M^4 \times CP_2$. The new elements are many-sheeted space-time, which is topologically non-trivial in all scales, and topological field quantization implying that physical systems have field identity, field body, in particular magnetic body (MB) [**?**]ssential for the biological application (see `http://tinyurl.com/yxpomw9y`).

2. One ends up to a geometrization of gravitational field and gauge fields of the standard model as induced fields. The QFT limit is obtained by replacing the sheets of many-sheeted space-time with slightly curved region of M^4 and identifying gauge potentials and gravitational field as superpositions of induced fields at various space-time sheets. At fundamental level superposition of fields is replaced with the superposition of their effects and corresponds to disjoint union of space-time surfaces in regions with common M^4 projection.

3. TGD forces also to update the notion of classical field. Topological field quantization applies to electric and magnetic fields [**?**]see `http://tinyurl.com/yxpomw9y`). For instance, magnetic field decomposes to flux tubes having finite thickness. Radiation fields are topologically quantized to topological light rays [**?**]. Each system has its fields at separate space-time sheets touching each other only via wormhole contacts: system has field body, in particular magnetic body (MB) having hierarchical onion-like structure corresponding to the hierarchy of space-time sheets.

   MB serves as the intentional agent using biological body (BB) as motor instrument and sensory receptor. MB controls BB via dark photon dark photon beams with large h_{eff}. The pair BB + environment is replaced with the triple MB + BB+ environment.The vision about life as nothing but biochemistry is given up.

1.2 TGD as WCW Geometry

Quantum TGD replaces Wheeler's superspace with the "World of Classical Worlds" (WCW) as the space of 3-surfaces, which are by holography in 1-1 correspondence with space-time space-time surfaces identified as preferred extremals (PEs) of the basic variational principle and analogous to Bohr orbits: classical physics becomes an exact part of quantum physics [**?**]see `http://tinyurl.com/y3pycull`). Einstein's geometrization of classical physics extends to that of quantum physics.

The geometry of WCW and physics is highly unique from its mere existence requiring maximal group of isometries: a result proved by Freed for loop spaces [**?**].

In zero energy ontology (ZEO) to be discussed in more details later the isometries would correspond to symplectic transformations of the light-like boundaries of causal diamond (CD) being belonging to $\delta M^4_{\pm} \times CP_2$ where $\delta M^4_{\pm}$ is the boundary of future/past directed light-cone.

General Coordinate Invariance must be also realized. The geometrization of hermitian conjugation requires WCW to have Kähler metric and its Kähler function would be action for preferred extremal assigning unique space-time surface to 3-surface identified union of disjoint 3-surfaces at the boundaries of CD.

Also spinor structure is needed and gamma matrices of WCW would define the components of WCW metric as anti-commutators. Gamma matrices would in turn be super-symplectic super-Noether charges for which one can write explicit expressions in terms of second quantized induced spinor fields.

The recent progress in the undestanding of SUSY leads to a considerable progress in the understanding of WCW geometry and will be discussed later.

1.3 TGD as Generalized Number Theory

Number theoretical vision is also a part of TGD (see `http://tinyurl.com/y4cto4go`). p-Adic number fields serve as correlates of cognition and imagination. Space-time is replaced with a book like structure having both real and various p-adic space-time sheets as pages. The outcome is adelic physics as fusion of various p-adic physics [**?**] (see `http://tinyurl.com/ycbhse5c`). The extensions of rationals (EQ) induce extensions of p-adic numbers fields and of adeles giving rise to a hierarchy of physics having interpretation in terms of evolution induced by the increase of the complexity of the EQ. Adelic physics leads also the hierarchy of Planck constants $h_{eff}/h_0 = n$ with n identified as dimension of EQ making possible quantum coherence in arbitrarily long time scales essential for understanding living matter.

Cognitive representation is fundamental notion and consists of a discrete sent of points of space-time surface for which the preferred coordinates of imbedding space are in the extension of rationals defining the adele. This is required by number theoretical universality. Whether the continuum theory exists at all or whether it corresponds to the limit in which the extension of rationals approaches to algebraic numbers remains to be understood.

Second aspect of number theoretical vision are classical number fields: reals, complex numbers, quaternions and octonions. $M^8 - H$ correspondence [**?**]see `http://tinyurl.com/y5c4vnjj`) allowing to interpret complexified M^8 as complexified octonions allows to map surfaces of M^8 identified as roots of octonionic polynomials to preferred extremals (PEs) in $H = M^4 \times CP_2$. One can say that $M^8 - H$ duality relates the geometric and number theoretic visions about TGD based physics.

Infinite primes represent the third aspect of number theoretical vision. The discovery of the hierarchy of infinite primes and their correspondence with a hierarchy defined by a repeated 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 and tha infinite primes might forma the bridge between classical and quantum such that real numbers, p-adic numbers, and various generalizations of p-adics emerge dynamically from algebraic physics as various completions of the algebraic extensions of rational (hyper-)quaternions and (hyper-)octonions. Complete algebraic, topological and dimensional democracy would characterize the theory.

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

What is nice that extensions of rationals is shared by all these three threads.

1.4 What Does "T" in TGD Mean?

"T" in TGD refers to "Topological" whereas G refers to "Geometro-". "T" has several motivations.

1. The first motivation came from the realization that TGD space-time is non-trivial in all length scales. There are particle like 3-surfaces and also in long length scales one has many-sheeted space-time with sheets connected by wormhole contacts. In the case of GRT Minkowski signature of the metric poses strong constraints on the allowed geometries but in TGD also Euclidian signature of the induced metric is possible. For instance, so called CP_2 type extremals are metrically equivalent to CP_2 although they have light-like momentum.

   One implication is an explanation for the family replication phenomenon in terms of genus-generation correspondence stating that apart from topological mixing fermion (and also boson-) families correspond to topologies of partonic 2-surfaces for the lowest 3 genera which always allow Z_2 conformal symmetry unlike higher genera. Partonic 2-surfaces can be also characterized by homology charge (magnetic charge) in CP_2 and color confinement could have magnetic confinement as space-time correlate.

2. Second motivation comes from the topological field quantization meaning that classical fields in Maxwellian sense are replaced by their topologically quantized variants. For instance, magnetic field decomposes to flux quanta. This implies that physical systems have a field identity since the space-time sheets representing their field are in general disjoint and can only touch each other. Particles could but need not correspond to wormhole contacts.

3. Third motivation comes from the fact that space-time surfaces as preferred extremals extremize separately volume and Kähler action apart from string world sheets appearing as singularities. It is known that so called calibrations as minima of volume are unique in given homology equivalence class. In this sense one could say that TGD based physics might allow unique representatives for homology equivalence classes: note however that the appearance of singularities might affect the situation.

4. Fourth motivation for "T" came from the observation that under rather general assumptions about preferred extremals representable a maps from M^4 to CP_2 Kähler action reduces to Chern-Simons term associated with the 3-D light-like surfaces and ends of the space-time surface at the boundaries of causal diamond (CD) to be discussed later. In this sense one would have almost Abelian topological quantum field theory (TQFT). The addition of volume term forced by the twistor lift of TGD spoils this picture and TQFT property is broken more seriously.

   TQFTs are used to model braids. In TGD magnetic flux tubes are key objects and their braiding is possible and makes possible topological quantum computation (TQC). Also strings assignable to the strong world sheets give rise to braids. Also 2-D string world sheets can get knotted in 4-D space-time and this gives rise to 2-knots, which might be important in TGD inspired biology.

1.5 ZEO: from Quantum Measurement Theory to a Theory of Consciousness

Zero energy ontology (ZEO) relies on the notions of causal damond CD, zero energy state (ZES) and the notions of weak measurement and ordinary quantum measurement realized as "small" and "big" state function reductions (SSR and BSR) respectively.

1. ZEO involves the hierarchy of causal diamonds (CDs) as correlates for perceptive fields of selves. The idea about ZES as pair of states at time t_1 and t_2 is not natural in TGD framework and is replaced with a notion consistent with the infinite-dimensional symmetries of TGD assignable to the light-cone boundary and to light-like 3-surfaces which play key role in TGD.

2. M^4 causal diamond (cd) formed as an intersection of future and past directed light-cones of M^4 is the basic notion. cd is formed as spherical light front expands for time $T/2$ and

contracts for time $T/2$ after that. The temporal distance between the tips of cd is T. The boundary of cd has two pieces opposite to each other. They are parts of light-cone boundary meeting at the sphere $r = T/2$. At the level of H cd is replaced with CD $= cd \times CP_2 \subset M^4 \times CP_2$.

CD is identified as a imbedding space correlate for self determining the perceptive field of self. One has actually entire hierarchy of CDs within CDs with varying quantized size assignable to self hierarchy.

3. ZESs are superpositions of deterministic classical time evolutions connecting passive "lower" boundary P and active "upper" boundary A of CD. The classical deterministic time evolution corresponds to a space-time surface - preferred extremal (PE) - connecting the 3-surfaces at P and A. There are also spinor fields obeying deterministic dynamics dictated by super-conformal symmetry.

4. The active boundary A of CD moves farther away from the passive boundary P by unitary time evolutions inducing de-localization of A. SSR induces localization of A and after it ZES corresponds to single CD. The temporal distance between the tips of CD increases in statistical sense.

   In BSR the roles of A and P change and the former P begins to shift to opposite direction of geometric time. CD however increases in statistical sense all the subjective time. This increase would correspond to cosmic expansion. Could selves evolve gradually to entire cosmologies? Their energy content would increase. This is not prevented by ZEO: classical conservation laws hold true for all PEs but due to the localizations of CDs energy conservation in quantal sense can be broken slightly.

1.6 $M^8 - H$ duality

$M^8 - H$ duality allows to see the dynamics in two manners. If $M^4 \subset M^8$ is fixed in M^8, the projection of 8-D light-like momenta to M^4 is massive in general: this corresponds to M^8 picture in which the group $SO(4) = SU(2) \times SO(3)$ is the group of isometries and corresponds to $SU(2)_L \times SU(2)_R$ of old fashioned hadron physics.

In $M^4 \times CP_2$ picture $M^4 \subset M^8$ is chosen so that the light-like momentum belongs to it and is light-like in 4-D sense: this corresponds to $M^4 \times CP_2$ picture or equivalently to $CP_{2,h} \times CP_2$ picture emerging assuming that the twistor space of M^4 is the standard one ($CP_{3,h}$ with signature (3,-3)). Therefore there are actually 3 manners to see the dynamics. Mass becomes therefore relative notion - something totally new. One can understand also massivation as described by p-adic thermodynamics as forced by the mixing of zero energy states with different values of mass squared allowed by time-like entanglement in ZEO.

1.7 SUSY and TGD

Contrary to expectations standard SUSY was not discovered at LHC and is now in grave difficulties. TGD does not allow SUSY in standard sense since Majorana spinors are not consistent with TGD. Whether TGD predicts SUSY in some other sense has been a long-standing problem. What is certain that this SUSY must respect the conservation of fermion number so that the notion of super field must be modified. The proposal has been that construction of many-fermion states at partonic 2-surfaces could give rise to analogs of SUSY multiplets.

Quite recently [**?**] it became clear that spartners would correspond to local many-fermion states at the level of M^8 and $M^4 \times CP_2$ as well. The condition that propagators are consistent with statistics led to the notion of super-imbedding space and super-spinors and to the realization leptons could be regarded as local 3-quark composites. This picture is also forced by octonionic triality in which quarks, antiquarks, and imbedding space coordinates would form a triple.

This would solve the mystery of missing SUSY and allow to understand the mysterious matter-antimatter asymmetry. Spartners of quarks would have been known since 1897! Both matter and antimatter would be present as baryons and leptons and CP breaking predicted by TGD would be responsible for it.

1.8 Twistor Lift of TGD

Twistor lift of TGD generalizes ordinary twistor approach []smatrix2 so that 4-D masslessness implying problems in twistor approach is replaced with 8-D masslessness so that masses can be non-vanishing in 4-D sense. 4-D space-time surfaces are replaced with the analogs of their twistor bundles for which twistor structure is induced from 6+6-D twistor space $T(H)$ of H - a product of twistor spaces of M^4 and CP_2. Twistor space has Kähler structure only for M^4 and CP_2 [**?**] Since Kähler structure is necessary for the twistor lift of TGD, TGD is unique.

The original view was that the twistor space of M^4 is $M^4 \times S^2$. It turned out that this assumption is probably wrong and the standard identification $CP_{3,h}$ with hypercomplex coordinates is the correct view. The size of $CP_{3,h}$ would be however varying expressible as in terms of the scale of CP_2 serving as a unit. p-adic length scale hierarchy is strongly suggestive here. This suggests that causal diamonds (CDs) in M^8 are mapped to $CP_{3,h}$ and the discrete hierarchy of scales corresponds to spontaneous breaking of scale invariance. The inversions in M^4 would in turn generate a hierarchy of scales, in p-adic length scale hierarchies for given p-adic prime p identified as a ramified prime of extension of rationals defining the adele.

One outcome is length scale dependent cosmological constant - essentially the inverse squared for the scale of CD and $CP_3 3, h$ taking a central role in the theory (this identification differs from that proposed for $M^2 \times S^2$: in particular, one can understand the recent extremely small value of cosmological constant and its large value in the early cosmology in terms of dimensional reduction of 6-D Kähler action needed to induce twistor space structure from $T(H)$ to get twistor space of space-time surface. Cosmological constant takes the role of cutoff parameter in coupling constant evolution. The recent considerations related to SUSY in TGD sense strongly suggest quantization of cosmological constant.

Second interpretation of twistors would be as 8-D twistors associated with light-like 8-momenta in M^8 picture. Twistors would be pairs of quaternionic bi-spinors which are non-commutative. Now the twistor space would be $HP_{3,h}$, quaternionic variant of CP_3 with signature (6,-6). This suggests a representation of scatting amplitudes in terms of quaternionic Grassmannians instead of complex Grassmannians as usually.

Third representation of twistors could be assignable to space-time surface and now twistors would consist of non-commutative quantum bi-spinors. This would be essential for realizing 4-D massive particles.

2 TGD as a Geometry of "World of Classical Worlds" (WCW)

The great vision behind TGD is generalizaton of Einstein's program so that it applies to quantum physics. This would be achieved in terms of the geometry of "world of classical worlds" (WCW). I have considered this vision in detail in [**?**] and [**?**].

The super-space of Wheeler was the basic motivation for vision is that physics could reduce to the Kähler geometry of WCW. Wheeler defined is superspace as the space of 3-geometries. This approach however had problems.

4-D general coordinate invariance is needed and one should somehow assign it to 3-geometries. Somehow one should assign 4-D space-time to given 4-space. This leads to the notion of zero energy ontology (ZEO).

Second problem was related to fermions. The existence of infinite-D geometries is also third ver real problem as the study of loop spaces shows: in this case the existence of Riemann connection requires infinite-D group of isometries.

In TGD super-space is replaced with the space-time 3-surfaces. Quantum states would correspond to the modes of classical Dirac equation in WCW generalizing Schrödinger amplitude. Spinors would be replaced with the basic of fermionic Fock states. Apart from state function reduction quantum physics would reduce to classical physics in WCW.

2.1 Zero energy ontology (ZEO)

One can solve the basic problem of quantum measurement theory by replacing initial value problem of classical physics with boundary value problem [**?**].

1. What comes mind first is the replacement of time=constant snapshot with pair of them. A pair of time=constant snapshots is however not the optimal choice since it has infinite size.

   Rather, causal diamond (cd) formed as an intersection of future and past directed light-cones of M^4 is a more natural notion. cd is formed as spherical light front expands for time $T/2$ and contracts for time $T/2$ after that. The temporal distance between the tips of cd is T. The boundary of cd has two pieces opposite to each other. They are parts of light-cone boundary meeting at the sphere $r = T/2$. At the level of H cd is replaced with CD $=cd \times CP_2 \subset M^4 \times CP_2$. One has actually entire hierarchy of CDs within CDs with varying quantized finite size. This makes the boundary value problem well-defined.

2. CD is natural in WCW geometry since its boundary has symplectic transformations of light-cone boundary as infinite-D symmetries analogous to Kac-Moody symmetries with light-like radial coordinate in the same role as the complex coordinate in conformal field theories. The metric 2-D of light-cone boundary of M^4 also implies huge extension of ordinary conformal symmetries.

3. CD has a natural interpretation as a correlate for the perceptive field of conscious entity - self. The past-direct light-cone defines the region about which sensory input comes as classical signals. The intersection of future directed light-cone with past-directed light-cone boundary defines the region from which the sensory input from self as a conscious entity emerges.

4. ZEO allows to realized holography since one can assign to a pair of 3-surfaces highly unique space-time surface. As a matter of fact, the space-time surfaces are so called preferred extremals satisfying infinite number of additional conditions analogous to gauge conditions so that they are analogous to Bohr orbits. This gives rise to strong form of holography (SH) in which 2-D singularities of space-time surface - string world sheets and partonic 2-surface determine the space-time surface. Number theoretic intepretation ($M^8 - H$ duality) suggests that the quaternionic structure of either tangent or normal space becomes effectively 2-D at these 2-D surfaces because two imaginary quaternionic units are parallel so that the third one defined as their vector product vanishes.

   This means analogy with twistor Grassmannian approach where singularities of scattering amplitude determine scattering amplitude. Now singularities of space-time surface would determine space-time surface just like singularities of analytic function determine the analytic function.

2.2 Three manners to understand WCW geometry

2.2.1 WCW geometry as Kähler geometry determined by Kähler function

It is good to summarize the basic ideas related to WCW.

1. WCW is the space of 3-surfaces but was does one mean with 3-surface? The first trial was the identification as any 3-surface in H and the assumption that $X^4(X^3)$ is preferred extremal containing X^3) but general coordinate invariance in this case leads to problems since the space-time surface $X^4(Y^3)$ associated with any 3-surface Y^3 at $X^4(X^3)$ must be $X^4(X^3)$.

   Suppose that one assumes that 3-surfaces are pairs of 3-surfaces $X^3 = (X^3_i, X^3_f)$ with time-like separation and identify $X^4(X^3)$ as preferred extremals going through X^3_i and X^3_f defining initial and final values (boundary values). This leads to zero energy ontology (ZEO), which is now central in TGD inspired quantum measurement theory leading also to consciousness theory.

   One can choose X^3_i and X^3_f to belong to boundaries of causal diamond (CD), which is intersection of future and past directed light-cones of M^4 with points replaced with CP_2. This choices is basically motivated by the huge symplectic symmetries of light-cone boundary proposed to act as isometries of WCW.

   This picture leads to holography in in which X^3 dictates $X^4(X^3)$. Actually the holography turns out to be much stronger in the sense that $X^4(X^3)$ is analogous to Bohr orbit and more or less dictated by X^3_i or X^3_f. One ends up to even strong form of holography (SH)

in which 2-D datate determine $X^4(X^3)$. One can understand SH by requiring strong form of general coordinate invariance stating that $X^4(X^3)$ is fixed also by the data at light-like 3-surfaces defining boundaries between regions of X^4 with Minkowskian and Euclidian metric respectively. I calls these 3-surface - partonic orbits and they are assumed to carrying fundamental fermions.

2. Hermitian conjugation is geometrized to complex conjugation in WCW. This requires Kähler geometry defined by Kähler function. Quantum classical correspondence (QCC) states that classical physics is exact part of quantum physics. Kähler function is assumed to be identifiable as classical action for preferred extremal $X^4(X^3)$.

3. What is the action? The first guess was Kähler action as analog of Maxwell action associated with the CP_2 Kähler form induced to X^4. It has huge vacuum degeneracy. Any space-time surface having at most 2-D Lagrangian manifold as CP_2 projection is vacuum extremal. The action around canonically imbedded M^4 vanisishes in lowest 3 orders. This degeneracy corresponds formally to U(1) gauge invariance restricted to vacuum sector and the physical interpretation is in terms of spin glass degeneracy. Volume term having interpretation as cosmologicalonstant would change the situation and all known non-vacuum extremals are actually also minimal surfaces.

   Even in this case there are no hopes about perturbative approach and this led to WCW picture. Path integral is replaced with integral over 3-surfaces or equivalently over the preferred extremals. There is analogy with integrable theories in which path integral is given by semiclassical approximation.

4. The addition of volume term would lead to difficulties with the sign of energy. These difficulties might have led to the idea of twistor lift of TGD. Actually the amazing successes of the twistor approach to $\mathcal{N} = 4$ SUSY inspired the idea about twistor lift. Twistor lift replaces space-time surfaces with 6-D surfaces in the product $T(M^4) \times T(CP_2)$ of twistor spaces of M^4 and CP_2 having twistor sphere as fiber and X^4 as base. Dimensional reduction making the twistor spheres of $T(M^4)$ and $T(CP_2)$ non-dynamical is needed to obtain this bundle structure. The dimensionally reduced 6-D Kähler action action is sum of 4-D Kähler action and volume term having interpretation as cosmological constant.

   Space-time surfaces are minimal surfaces with 2-D string world sheets as singularities at which metric reduces effectively to 2-D metric. In M^8 picture singularity corresponds to linear dependence of two quaternion units implying together with the quaternionicity of the tangent space of space-time surface effective 2-dimensionality. One can interpret X^4 as analog of massless field having sources at the string world sheets. The action can be also seen as a generalization of dynamical of point like charge coupled to Kähler gauge potential obtained by replacing point-like particle with 3-surface.

2.2.2 WCW geometry from maximal symmetries needed to guarantee existence of Riemann connection

The construction of Kähler geometry of WCW ("world of classical worlds") is fundamental to TGD program. I ended up with the idea about physics as WCW geometry around 1985 and made a breakthrough around 1990, when I realized that Kähler function for WCW could correspond to Kähler action for its preferred extremals defining the analogs of Bohr orbits so that classical theory with Bohr rules would become an exact part of quantum theory and path integral would be replaced with genuine integral over WCW. The motivating construction was that for loop spaces leading to a unique Kähler geometry [**?**]. The geometry for the space of 3-D objects is even more complex than that for loops and the vision still is that the geometry of WCW is unique from the mere existence of Riemann connection.

The basic idea is that WCW is union of symmetric spaces G/H labelled by zero modes which do not contribute to the WCW metric. There have been many open questions and it seems the details of the ealier approach [**?**]ust be modified at the level of detailed identifications and interpretations.

1. A longstanding question has been whether one could assign Equivalence Principle (EP) with the coset representation formed by the super-Virasoro representation assigned to G and H

in such a manner that the four-momenta associated with the representations and identified as inertial and gravitational four-momenta would be identical. This does not seem to be the case. The recent view will be that EP reduces to the view that the classical four-momentum associated with Kähler action is equivalent with that assignable to Kähler-Dirac action supersymmetrically related to Kähler action: quantum classical correspondence (QCC) would be in question. Also strong form of general coordinate invariance implying strong form of holography in turn implying that the super-symplectic representations assignable to space-like and light-like 3-surfaces are equivalent could imply EP with gravitational and inertial four-momenta assigned to these two representations.

At classical level EP follows from the interpretation of GRT space-time 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 metrices of space-time sheets from Minkowski metric. Poincare invariance suggests strongly classical EP for the GRT limit in long length scales at least.

2. The detailed identification of groups G and H and corresponding algebras has been a long-standing problem. Symplectic algebra associated with$\delta M^4_{\pm} \times CP2$ ($\delta M^4_{\pm}$ is light-cone boundary - or more precisely, with the boundary of causal diamond (CD) defined as Cartesian product of CP_2 with intersection of future and past direct light cones of M^4 has Kac-Moody type structure with light-like radial coordinate replacing complex coordinate z. Virasoro algebra would correspond to radial diffeomorphisms. I have also introduced Kac-Moody algebra assigned to the isometries and localized with respect to internal coordinates of the light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian and which serve as natural correlates for elementary particles (in very general sense!). This kind of localization by force could be however argued to be rather ad hoc as opposed to the inherent localization of the symplectic algebra containing the symplectic algebra of isometries as sub-algebra. It turns out that one obtains direct sum of representations of symplectic algebra and Kac-Moody algebra of isometries naturally as required by the success of p-adic mass calculations.

3. The dynamics of Kähler action is not visible in the earlier construction. The construction also expressed WCW Hamiltonians as 2-D integrals over partonic 2-surfaces. Although strong form of general coordinate invariance (GCI) implies strong form of holography meaning that partonic 2-surfaces and their 4-D tangent space data should code for quantum physics, this kind of outcome seems too strong. The progress in the understanding of the solutions of Kähler-Dirac equation led however to the conclusion that spinor modes are localized at string world sheets with strings connecting different partonic 2-surfaces. This leads to a modification of earlier construction in which WCW super-Hamiltonians are essentially integrals with integrand identified as a Noether super current for the deformations in G Each spinor mode gives rise to super current and the modes of right-handed neutrino and other fermions differ in an essential manner.

   The matrix elements of WCW metric between Killing vectors are expressible as anti-commutators of super-Hamiltonians identifiable as contractions of WCW gamma matrices with these vectors and give Poisson brackets of corresponding Hamiltonians. The anti-commutation relates of induced spinor fields are dictated by this condition. Everything is 3-dimensional although one expects that symplectic transformations localized within interior of X^3 act as gauge symmetries so that in this sense effective 2-dimensionality is achieved. The components of WCW metric are labelled by standard model quantum numbers so that the connection with physics is extremely intimate.

4. An open question in the earlier visions was whether finite measurement resolution is realized as discretization at the level of fundamental dynamics. This would mean that only certain string world sheets from the slicing by string world sheets and partonic 2-surfaces are possible. The requirement that anti-commutations are consistent suggests that string world sheets correspond to surfaces for which Kähler magnetic field is constant along string in well defined sense ($J_{\mu\nu}\epsilon^{\mu\nu}g^{1/2}$ remains constant along string). It however turns that by a suitable choice of coordinates of 3-surface one can guarantee that this quantity is constant so that no additional constraint results.

5. Quantum criticality is one of the basic notions of quantum TGD and its relationship to coset construction has remained unclear. In this chapter the concrete realization of criticality in terms of symmetry breaking hierarchy of Super Virasoro algebra acting on symplectic and Kac-Moody algebras. Also a connection with finite measurement resolution - second key notion of TGD - emerges naturally.

Hierarchy of SSA algebras more explicitly in ZEO.

One challenge is the understanding of the spectrum of conformal weights of supersymplectic representations at boundaries of CD. Number theoretical universality requiring that cognitive representation are universal and therefore make sense for all p-adic primes, serves as a guideline.

1. The exponents of radial light-one radial coordinate r of light-like coordinate at the boundary of CD are naturally analogs of plane waves for coordinate $u = log(r/r_0)$: $f(r) = (r/r_0)^{iy} = exp(iyu)$. The natural choice for r_0 is as $r_0 = R(CP_2)$, where $R(CP_2)$ is CP_2 geodesic length apart from numerical constant. The natural choice for the size of CD is as $r_{max} = NR(CP_2)$. At this value of r periodic boundary conditions requiring $f(r_{max}) = 1$ should hold true.

2. For cognitive representations the values of $f(r)$ at the points r of the representation belonging to extension are roots of unity. Furthermore, periodic boundary conditions at the corner of CD at $r = L = NR(CP_2)$ require $(r/R(CP_2)^{iyL} = exp(im2\pi)$ giving $y = 2\pi m/log(N)$. At the points of cognitive representation one must have $(r/R)^{iy} = exp(i2\pi q)$, q rational. This gives $r/R(CP_2) = N^{q/m}$ so that one has fractality and analog of lattice is replaced with its logarithm and periodic plane waves with their logarithmic counterpart. This conforms with the scaling invariance. The values of $r/R(CP_2)$ in cognitive representation are roots $N^{q/m}$ of N whereas the values of $f(r)$ are roots $exp(i2\pi q)$ of unity meaning the the 2 extensions are closely related.

   Remark: Cognitive representations are number theoretically universal making sense in all p-adic number fields.

2.2.3 WCW metric as anticommutators of gamma matrices for WCW spinor Structure

They key idea is that the construction of WCW spinor structure reduces to that for the complexified gamma matrices of WCW and that these are expressible as linear combinations of oscillator operators of second quantized induced spinor fields satisfying modified Dirac action determined by super-symmetry from the bosonic action principle. The anti-commutators of WCW gamma matrices would in terms determined the components of WCW metric. Since the elements of metric are most naturally given as matrix elements between the vector fields defining Killing vector fields of isometries of WCW, the natural guess is that the anti-commutators of Noether super-currents assignable to these symmetries define the matrix elements of the metric. Once one knows the modified Dirac action, one can in principle calculate the matrix elements of WCW metric.

The hypothesis is that in zero energy ontology (ZEO) the symplectic group acting at the light-like boundaries of causal diamond (CD) (one has CD= $cd \times CP_2$, where cd is the intersection of future and past directed light-cones) acts as the isometries of the Kähler metric.

In this framework one can take a fresh approach to the construction of the spinor structure and Kähler metric of WCW. The basic vision is rather conservative. Rather than inducing ad hoc formulas for WCW gamma matrices one tries to identify Noether the elements super-algebra as Noether charges containing also the gamma matrices as Noether super charges.

1. The simplest guess is that the algebra generated by fermionic Noether charges Q^A for symplectic transformations $h^k \to h^k + \epsilon j^{Ak}$ assumed to induce isometries of WCW and Noether supercharges Q_n and their conjugates for the shifts $\Psi \to \Psi + \epsilon u_n$, where u_n is a solution of the modified Dirac equation, and ϵ is Grassmann number are enough to generate algebra containing the gamma matrix algebra.

2. The commutators $\Gamma^A_n = [Q^A, Q_n]$ are super-charges labelled by (A, n). One would like to identify them as gamma matrices of WCW. The problem is that they are labelled by (A, n) whereas isometry generators are labelled by A only just as symplectic Noether charges. Do

all supercharges Γ^A_n except Γ^A_0 corresponding to $u_0 = constant$ annihilate the physical states so that one would have 1-1 correspondence? This would be analogous to what happens quite generally in super-conformal algebras.

3. The anti-commutators of Γ^A_0 would give the components of the Kähler metric. The allowance of singular surfaces having 2-D string world sheets as singularities would give to the metric also stringy component besides 3-D component and possible 0-D components at the ends of string. Metric 2-D property would not be exact as assumed originally.

This construction can be blamed for the lack of explicitness. The general tendency in the development of TGD has been replacement of explicit but somewhat ad hoc formulas with principles. Maybe this reflects to my own ageing and increasing laziness but my own view is that principles are what matter and get abstracted only very slowly. The less formulas, the better!

One of the open questions from the beginning was whether both quarks and leptons can/must be allowed. There seemed to exist no special reason for both leptons and quarks but I have considered the possibility that quarks could be leptons analogous so anyons but this option did not look attractive. The solution to the problem came from the understanding of SUSY in TGD framework [**?**]. Only quarks are needed and leptons can be regarded as local composes of 3-antiquarks whereas baryons are 3-local composites of quarks. This picture follows also from $SO(1,7)$ triality as a symmetry of the space of octonion structures in M^8.

SUSY leads also to a generalization of super-spinor field but the vacuum expectations of anti-commutators of "super-supercharges" for super-symplectic algebra can still be identified as elements of WCW metric.

2.3 What Preferred Extremals Are?

Preferred extremal realizes general coordinate invariance in 4-D sense by associating unique space-time surface to given 3-surface.

The history of preferred extremals is rather tortuous.

1. Original assumption, which survived for decades was that preferred extremals are those of Kähler action - perhaps absolute minima of Kähler action. The problem that I did not see as problem was the infinite vacuum degeneracy due to surface with vanishing induced Kähler form. The positive effect of this finding was that it forced to give up path integral approach and to develop WCW geometry. The vacuum degeneracy however means that WCW geometry is singular at the limit when preferred extremal approaches canonical imbedding of Minkowski space.

2. The twistor lift led to a replacement of 4-D Kähler action with its 6-D counterpart for 6-D surfaces in $T(M^4) \times T(CP_2)$ having a structure of twistor space with twistor sphere as fiber space and space-time surface as based. The dimensionally reduced action is sum of 4-D Kähler action and volume term having interpretation in terms of cosmological constant.

   This inspired the hypothesis that preferred extremals are extremals of Kähler action and volume term simultaneously except at 2-D string world sheet singularities and possibly also at partonic 2-surfaces. At M^8 level the stringy singularities would be 2-D regions of space-time surface at which two quaternionic units become linearly dependent so that tangent space becomes metrically 2-D.

3. In TGD one has a fractal hierarchy of isomorphic supersymplectic algebras (SSAs) (the conformal weights of sub-algebra are integer multiples of those of algebra) with gauge conditions stating that given sub-algebra of SSA and its commutator with the entire algebra annihilates the physical states. The remnant of the full SSA symmetry algebra would be naturally KMA.

   The pair formed by full SSA and sub-SSA would correspond to pair formed by group G and normal subgroup H and the dynamical KMA would correspond to the factor group G/H. This conjecture generalizes: one can replace G with Galois group and $SU(2)$ KMA with a KMA continuing Gal as subgroup. One the other hand, one has also hierarchies of extensions of rationals such that $i+1$:th extension of rationals is extension of i:th extension. G_i is a

normal subgroup of G_{i+1} so that the group $Gal_{i+1,i} = Gal_{i+1}/Gal_i$ acts as the relative Galois group for $i+1$:th extension as extensions of i:th extension.

This suggests the conjecture that the Galois groups Gal_i for extension hierarchies correspond to the inclusion hierarchies $SSA_i \supset SSA_{i+1}$ of fractal sub-algebras of SSA such that the gauge conditions for SSA_i define a hierarchy KMA_i of dynamical KMAs acting as dynamical symmetries of the theory. The fusion algebra of KMA_i theory would be characterized by Galois group Gal_i.

This has connection with the notion of finite measurement resolution.

(a) Finite measurement resolution could be represented as inclusion of HFFs - at classical level it would correspond to a discretization with some resolution defined by the algebraic extension of rationals used and by the p-adic length scale cutoffs. The included algebra would act like gauge group in the sense that its elements in zero energy ontology would generate states not distinguishable from the original one.

(b) The space of physical states would be an analog of coset space but with fractal dimension given by the index of inclusion defined in terms of quantum phase. It might well be possible to act analog of gauge group with the inclusion.

(c) An alternative view is that the hierarchy of inclusions is associated with the hierarchy of sub-algebras of supersymplectic algebra acting gauge transformations. The sub-algebra would be isomorphic to the entire algebra with conformal weights coming as n-multiples of those for the entire algebra. This subalgebra would define measurement resolution, and one would indeed have gauge group interpretation in a wide sense of the word. $n = h_{eff}/h$ identification would give a direct connection with the hierarchy of Planck constants and dark matter hierarchy.

4. Besides the hierarchy formed by the sub-algebras SSA_n with conformal weights n-multiples of the conformal weights of the entire SSA there are also hierarchies of irreducible representations of $SO(3) \times SU(3)$ associated with the Hamiltonians of $S^2 \times CP_2$ and giving rise to SSA. The only sub-algebra consists of radially local symplectic isometries analogous to $SO(3) \times SU(3)$ gauge transformations. Finite measurement resolution strongly suggests that all higher algebra generators defined by Hamiltonians in higher representations of $SO(3) \times SU(3)$ annihilate the physical states and classical Noether charges vanish.

   Radial quantum number $n > 0$ would correspond to creation operator like generators and one can restrict to the non-negative values of n by considering only the half-algebras for which the hierarchy of inclusions makes sense.

   For $n = 0$ generators one can consider a central extension associated with both spin component L_3 and color hypercharge generator Y and possibly color I_3. $n = 0$ $L_3 > 0$ and $L_3 < 0$ generators could correspond to creation and annihilation operator type generators. For $(n, L_3) = (0, 0)$ $Y > 0$ and $Y < 0$ generators would correspond to creation and annihilation operator type generators and for $(n, L_3, Y) = (0, 0, 0)$ generators the sign of I_3 could determine whether the generator acts like creation or annihilation operator.

   An interesting possibility is that symplectic transformations are analogous to gauge transformation or Kac-Moody generators. The action of symplectic transformation in CP_2 degrees of freedom is indeed as $U(1)$ gauge transformation formally. This would mean that physical states would be annihilated by all symplectic generators except $SO(3) \times SU(3)$ generators with $m > n$ and their commutators with SSA generators with $k \geq 0$. Corresponding symplectic charges would vanish. This would give effectively finite-D algebra consistent with the notion of finite measurement resolution.

5. The understanding of $M^8 - H$ duality based on the TGD view about SUSY led to the realization that the view about twistor space of M^4 is most naturally hyperbolic variant of CP_3, the standard twistor space. In this picture the correspondence between algebraic surfaces in M^8 and minimal surfaces in twistor space becomes extremely concrete: the polynomials at two sides have same degree. This comes from the condition that $M^8 - H$ duality respects the extension of rationals. The deep reason is that holomorphy reduces to purely algebraic

conditions. The representations of surfaces can be mapped from various imbedding space to each other holomorphically and minimal surface equations reduce to holomorphy.

2.4 Twistor lift of TGD and ZEO

Twistor lift of TGD and ZEO [**?**, **?**, **?**, **?**] meant a revolution in the view about WCW geometry and spinor structure.

1. The basic idea is to replace 4-D Kähler action with dimensionally reduced 6-D Kähler for the analog of twistor space of space-time surface. The induction procedure for the spinors would be generalized so that it applies to twistor structure [**?**]. The twistor structure of the imbedding space was originally identified as the product of twistor spaces $M^4 \times S^2$ of M^4 and $SU(3)/U(1) \times U(1)$ of CP_2. In momentum degrees of freedom the twistor space of M^4 would be the usual hyperboli variant of CP_3. The identification of "geometric" twistor space does not conform with standard wisdom. This point will be discussed later.

   Remarkably, M^4 and CP_2 are the only spaces allowing twistor space with Kähler structure [**?**]. In the case of M^4 the Kähler structure is a generalization of that for E^4. TGD would be unique from the existence of twistor lift. This predicts CP breaking at fundamental level possibly responsible for CP breaking and matter-antimatter asymmetry.

2. One would still have Kähler coupling strength α_K as the only single dimensionless coupling strength, whose spectrum is dictated by quantum criticality meaning that it is analogous to critical temperature. All coupling constant like parameters would be determined by quantum criticality. Cosmological constant would not be fundamental constant and this makes itself visible also in the concrete expressions for conserved Noether currents. The breaking of the scale invariance removing vacuum degeneracy of 4-D Kähler action would be analogous to spontaneous symmetry breaking and would remove vacuum degeneracy and classical non-determinism.

   The volume term would emerge from dimensional reduction required to give for the 6-surface the structure of S^2 bundle having space-time surfaces as base space. Cosmological constant would be determined by dynamics and depend on p-adic length scale depending in the average on length scale of space-time sheet proportional to the cosmic time sense like $1/a^2$, a cosmic time. This would solve the problem of large cosmological constant and predict extremely small cosmological constant in cosmic scales in the recent cosmology. This suggests that in long length scales one still has spin glass degeneracy realized in terms of many-sheeted space-time.

3. In ZEO 3-surface correspond to a union of 3-surfaces at the ends of space-time surfaces at boundaries of CD. There are many characterizations of quantum criticality.

   (a) Preferred extremal property and quantum criticality would mean that one has simultaneously an extremal of both 4-D Kähler action and volume term except at singular 2-surfaces identified as string world sheets and their boundaries. In accordance with the universality of quantum critical dynamics, one would have outside singularities local dynamics without dependence on Kähler coupling strength. The interpretation would be as geometric generalization of massless fields also characterizing criticality.

   (b) Another characterization of preferred extremal is as a space-time surfaces using subalgebra S_m of symplectic algebra S for which generators have conformal weights coming as m-tuples of those for the full symplectic algebra. Both S_m and $[S, S_m]$ would have vanishing Noether charges. For the induced spinor fields analogous condition would hold true. Effectively the infinite number of radial conformal weights of the symplectic algebra associated with the light-like radial coordinate of $\delta M^4_{\pm}$ would reduce to a finite number.

   (c) A further characterization would be in terms of $M^8 - H$ duality [**?**]. Preferred extremals in H would be images of of space-time surfaces in M^8 under $M^8 - H$ duality. The latter would correspond to roots of octonionic polynomials with coefficients in an extension of rationals. Therefore space-time surfaces in H satisfying field equations plus preferred

extremal conditions would correspond to surfaces described by algebraic equations in M^8. Algebraic dynamics would be dual to differential dynamics.

(d) In adelic physics [**?**, **?**] the hierarchy of Planck constants $h_{eff}/h_0 = n$ with n having an interpretation as dimensions of Galois group of extension of rationals would define further correlate of quantum criticality. The scaled up Compton lengths proportional to h_{eff} would characterize the long range fluctuations associated with quantum criticality.

Add the recent view about twistorialization!!!!!!!!

2.5 SUSY and WCW geometry

The recent progress in understanding of SUSY led to a considerable increase in understanding of WCW geometry.

1. Only quarks are needed, and the recent view about SUSY that emerged during last months indeed led to the realization that leptons can be regarded as local composites of 3 quarks defining spartners of quarks (not possible in standard model). SUSY in TGD sense is what makes this option possible, and it also includes second quantization since theta parameters are replaced with oscillator operatrs. Number theoretical vision requires that the number of non-vanishing fermionic Wick contractions is *finite*. This gives rise to conditions having interpretation in terms of conserved Noether currents. The number of corrections depends on the extension of rationals determined by the octonionic polynomial defining the space-time surface in M^8 and discrete coupling constant evolution assignable to the hierarchy of adeles corresponds to the increase of this number.

2. The proposed second quantization involves discretization based on cognitive representation of space-time surface and contains only the points for which the preferred coordinates of imbedding space are in the extension of rationals defining the adele. One can argue that the limit in which extension approaches algebraic numbers gives the analog of continuum theory. This would give rise to a hierarchy of discretized variants of WCW with given space-time surface have the points of cognitive representation as WCW coordinates in extension of rationals.

3. A better understanding of the discrete versions of Noether charges is required since charge densities are replaced with discrete charges at points of cognitive representation: what are the discrete counterparts of conserved currents. Super-symplectic transformations have discrete subgroups with matrix representations having matrix elements in the extension of rationals so that discrete analogs of Noether currents are required.

   At space-time level the field equations reduces to the conditions stating the vanishing of the isometry currents. This allows also formulation as vanishing of of total fluxes over boundaries of region considered. Also varios super-symplectic currents would be conserved. Physical intuition tells that for a given time period the change of charge at given point of discretization equals to sum of the changes of the charges at other points of discretization. The time interval could correspond to a causal diamond CD and one would have simply the conditions that the net charges as sums of discrete charge are same for the opposite boundaries of CD. CDs have highly symmetric nature so that this discretization would be rather elegant since there is no term corresponding to the leakage of current out in spatial directions. Hierarchy of CDs (as correlates of perceptive fields) allowing arbitrarily small CDs could allow arbitrary good precision.

   Can one imagine a discrete variant of local current conservation? What divergence could mean for a cognitive representation? Quantum groups provide a possible definition for the discretization of derivative. Could they provide a discretization of current conservation conditions? This would conform with the vision about quantum groups as a manner to describe finite measurement resolution. At the limit when the root of unity $U = exp(i\pi/n)$ characterizing the quantum group approaches unity ($n \to \infty$) one should obtain the counterpart of continuum theory.

4. The existence of a genuine continuum theory requires the cancellation of all Wick contractions. This could be achieved in ad hoc manner by defining the action principle by using normal ordering. Another option is that all Wick contraction vanish and would be guaranteed by the conservation of Noether currents. Does this mean that there is no coupling constant evolution now?

2.6 Variants of WCW geometry

Several variants of WCW geometry can be considered.

1. It seems that it is possible to regard space-time surfaces as surfaces in several imbedding spaces so that $M^8 - H$ duality extends to triality. There are 3 variants of WCW geometry corresponding to different equivalent choices of imbedding space as M^8, $H = M^4 \times CP_2$, and $H = CP_{2,h} \times CP_2$. Besides this one can consider twistors spaces of M^8 and H. This is similar to the occurrence in M-theory of dual Calabi-Yau manifolds claimed to yield identifical conformal field theories (see `http://tinyurl.com/y54xv836`).

   Variational principle is needed in order to define supersymplectic charges. The recent formulation of the physics at the level of M^8 is purely algebraic and based on the roots of octonion polymials and the assignment of variational principle to it together with action principle does not look like an attractive idea. One could of course argue that $M^8 - H$ duality is the manner to achieve this by assigning the conserved charges and supercharges with the images of space-time surfaces in H.

   Could one achieve the assignment via the twistor space of M^8 identifiable as HP_3, the quaternionic variant of CP_3 with signature (4,-4) of metric. Could the octonionic polynomials correspond to hypercomplex 6-surfaces in HP_3 defined by polynomials of same degree defined by 6-D Kähler action in HP_3. Could the projection to the base space allow to assign Noether charges to the super-symplectic algebra.

2. Is there need to define twistor variants of WCW geometry? Basic entities would 6-surfaces which by dimensional reduction reduces effectively to their base spaces represented by 4-surfaces. I would seem that this does not bring anything obviously new if S^2 dynamics is completely frozen.

3. Is there need for p-adic variants of WCW geometry. What seems clear that if p-Adic WCWs exist, they must be defined in terms of discrete cognitive representations. Geometry for cognitive representations is well-defined as a discrete geometry. This is true also for discretized WCW for which points correspond to cognitive representations for space-time surfaces. For instance, one can talk about distance between cognitive representations as minimal distance between their points. Is there any need for something more.

4. Can one define super-variant of WCW geometry as continuous geometry? It seems that this geometry cannot be obtained at the limit of algebraic numbers since for the continuum formulation anti-commutators are proportional to delta functions replacing Kronecker deltas.

   Cancellation of divergences requires at continuum limit that not only the infinite sum of all Wick contractions but all Wick contractions corresponding to given power of delta function at zero vanish. The vanishing conditions allow interpretation as conserved Noether current assignable to some symmetries and imply that oscillator operators behave effectively as theta parameters. Should one assume that this is the case also for all extensions of rationals? One would lose the identification of discrete coupling constant evolution in terms of number of Wick contractions. The coupling constant evolution reduces to the evolution implied by the hierarchy of extensions and could be trivial since α_K can depend on extension.

3 TGD as a Generalized Number Theory

3.1 p-Adic physics

3.1.1 How to end up with p-adic physics?

A brief summary about the basic elements of p-adic physics is in order.

1. I ended up to p-adic physics via p-adic mass calculations based on p-adic generalization of thermodynamics and super-conformal invariance [**?**, **?**] with number theoretical existence constrains leading to highly non-trivial and successful physical predictions. Here the notion of canonical identification mapping p-adic mass squared to real mass squared emerges and is expected to be key player of adelic physics and allow to map various invariants from p-adics to reals and vice versa.

2. This lead to the formulation of p-adicization of real physics. The existence of p-adic variants of definite integral, Fourier analysis, Hilbert space, and Riemann geometry is far form obvious, and various constraints lead to the idea of NTU and finite measurement resolution realized in terms of number theory. Maybe the only manner to overcome the problems relies on the idea that various angles and their hyperbolic analogs are replaced with their exponentials and 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.

   Another challenge is the correspondence between real and p-adic physics at various levels: space-time level, imbedding space level, and WCW level. Here the enormous symmetries of WCW and those of imbedding space are in crucial role. Strong form of holography (SH) allows a correspondence between real and p-adic space-time surfaces induced by algebraic continuation from string world sheets and partonic 2-surface, which can be said to be common to real and p-adic space-time surfaces.

3. The fusion of various p-adic physics to a bigger framework led to adelization as fusion of various p-adic physics to single coherent whole by a generalization of number concept fusing reals and p-adics to larger book like structure having algebraic extension of rationals as a kind of intersection. Also adelic space-time surfaces would be book-like structures having real and p-adic sheets for various value of p-adic prime p glued. Space-time sheets would be glued together along points of imbedding space with preferred coordinates in extension of rationals - the common points could be regarded as the back of the book.

4. Essential role is played by the extensions of rationals inducing extensions of p-adic number fields and therefore those of adele. One obtains a hierarchy of adeles. Since number theoretical complexity increases with the dimension of rationals, the natural interpretation is in terms of evolutionary hierarchy. The dimension n of extension is identifiable as effective Planck constant $h_{eff}/h_0 = nh$. The increase of n corresponds to increase of various quantum scales and time scales.

   The so called ramified prime of extension of rationals are expected to be in a special role physically and the proposal is that they correspond to the p-adic primes assignable to elementary particles. This will be discussed in more detail below. Ramified primes are special in the sense that their expression as a product of primes of extension contains higher than first powers and some these primes are absent since the total degree as sum of the expopnents equal to the degree of extension. They are identified as preferred p-adic primes characterizing space-time sheets assignable to elementary particles and even more general systems. It is not completely clear why ramified primes appears as p-adic primes.

5. Adelic physics has central role in TGD inspired theory of consciousness and quantum biology. The key notion is Negentropic entanglement (NE) characterized in terms of number theoretic entanglement negentropy (NEN). Negentropy Maximization Principle (NMP) would force the growth of NE. The interpretation would be in terms of evolution as increase of negentropy resources - Akashic records as one might poetically say. The newest finding is

that NMP in statistical sense follows from the mere fact that the dimension of extension of rationals defining adeles increases unavoidably in statistical sense - separate NMP would not be necessary.

3.1.2 p-Adic Physics as Physics of Cognition

The vision about p-adic physics as physics of cognition has gradually established itself as one of the key idea of TGD inspired theory of consciousness. There are several motivations for this idea.

The strongest motivation is the vision about living matter as something residing in the intersection of real and p-adic worlds. One of the earliest motivations was p-adic non-determinism identified tentatively as a space-time correlate for the non-determinism of imagination. p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piecewise constant functions in the p-adic context. More precisely, p-adic pseudo constants depend on the pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In the case of field equations this means roughly that the initial data are replaced with initial data given for a discrete set of time values chosen in such a manner that unique solution of field equations results. Solution can be fixed also in a discrete subset of rational points of the imbedding space. Presumably the uniqueness requirement implies some unique pinary cutoff. Thus the space-time surfaces representing solutions of p-adic field equations are analogous to space-time surfaces consisting of pieces of solutions of the real field equations. p-Adic reality is much like the dream reality consisting of rational fragments glued together in illogical manner or pieces of child's drawing of body containing body parts in more or less chaotic order.

The obvious interpretation for the solutions of the p-adic field equations is as a geometric correlate of imagination. Plans, intentions, expectations, dreams, and cognition in general are expected to have p-adic cognitive space-time sheets as their geometric correlates. A deep principle seems to be involved: incompleteness is characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general.

If one accepts the idea that real and p-adic space-time regions are correlates for matter and cognitive mind, one encounters the question how matter and mind interact. The original candidate for this interaction was as a phase transition leading to a transformation of the real space-time regions to p-adic ones and vice versa. These transformations would take place in quantum jumps. p-Adic-to-real phase transition would have interpretation as a transformation of thought into a sensory experience (dream or hallucination) or to an action. The reverse phase transition might relate to the transformation of the sensory experience to cognition. Sensory experiences could be also transformed to cognition by initial values realized as common rational points of a real space-time sheet representing sensory input and a p-adic space-time sheet representing the cognitive output. In this case the cognitive mental image is unique only in case that p-adic pseudo constants are ordinary constants.

It turned out that this interpretation leads to grave mathematical difficulties: one should construct U-matrix and M-matrix for transitions between different number fields, and this makes sense only if all the parameters involved are rational or algebraic. A more realistic view is that the interaction between real and p-adic number fields is that p-adic space-time surfaces define cognitive representations of real space-time surfaces (preferred extremals). One could also say that real space-time surface represents sensory aspects of conscious experience and p-adic space-time surfaces its cognitive aspects. Both real and p-adics rather than real or p-adics. The notion of p-adic manifold [**?**] tries to catch this idea mathematically.

Strong form of holography implied by strong form of General Coordinate Invariance leads to the suggestion that partonic 2-surfaces and string world sheets at which the induced spinor fields are localized in order to have a well-defined em charge (this is only one of the reasons) and having having discrete set as intersection points with partonic 2-surfaces define what might called "space-time genes". Space-time surfaces would be obtained as preferred extremals satisfying certain boundary conditions at string world sheets. Space-time surfaces are defined only modulo transformations of super-symplectic algebra defining its sub-algebra and acting as conformal gauge transformations so that one can talk about conformal gauge equivalences classes of space-time surfaces.

The map assigning to real space-time surface cognitive representation would be replaced by a correspondence assigning to the string world sheets preferred extremals of Kähler action in various

number fields: string world sheets would be indeed like genes. Mathematically this formulation is much more elegant that that based on p-adic manifold since discretization seems to be un-necessary at space-time level and applies only to the parameters characterizing string world sheet.

String world sheets and partonic 2-surfaces would be in the intersection of realities and p-adicities in the sense that the parameters characterizing them would be algebraic numbers associated with the algebraic extension of p-adic numbers in question. It is not clear whether the preferred extremal is possible for all p-adic primes but this would fit nicely with the vision that elementary particles are characterized by p-adic primes. It could be also that the classical non-determinism of Kähler action responsible for the conformal gauge symmetry corresponds to p-adic non-determinism for some particular prime so that the cognitive map is especially good for this prime.

The idea about p-adic pseudo constants as correlates of imagination is however too nice to be thrown away without trying to find an alternative interpretation consistent with strong form of holography. Could the following argument allow to save p-adic view about imagination in a mathematically respectable manner?

1. The construction of preferred extremals from data at 2-surfaces is like boundary value problem. Integration constants are replaced with pseudo-constants depending on finite number pinary digits of variables depending on coordinates normal to string world sheets and partonic 2-surfaces.

2. Preferred extremal property in real context implies strong correlations between string world sheets and partonic 2-surfaces by boundary conditions a them. One cannot choose these 2- surfaces completely independently. Pseudo-constant could allow a large number of p-adic configurations involving string world sheets and partonic 2-surfaces not allowed in real context and realizing imagination.

3. Could imagination be realized as a larger size of the p-adic sectors of WCW? Could the realizable intentional actions belong to the intersection of real and p-adic WCWs? Could the modes of WCW spinor fields for which 2-surfaces are extendable to space-time surfaces only in some p-adic sectors make sense? The real space-time surface for them be somehow degenerate, for instance, consisting of string world sheets only.

   Could imagination be search for those collections of string world sheets and partonic 2-surfaces, which allow extension to (realization as) real preferred extremals? p-Adic physics would be there as an independent aspect of existence and this is just the original idea. Imagination could be realized in state function reduction, which always selects only those 2-surfaces which allow continuation to real space-time surfaces. The distinction between only imaginable and also realizable would be the extendability by using strong form of holography.

I have the feeling that this view allows respectable mathematical realization of imagination in terms of adelic quantum physics. It is remarkable that strong form of holography derivable from - you can guess, strong form of General Coordinate Invariance (the Big E again!), plays an absolutely central role in it.

3.2 Adelic Physics as Fusion of Real and Various p-Adic Physics

Adelic physics has central role in TGD inspired theory of consciousness and quantum biology. The key notion is negentropic entanglement (NE) characterized in terms of number theoretic entanglement negentropy (NEN). Negentropy Maximization Principle (NMP) would force the growth of NE. The interpretation would be in terms of evolution as increase of negentropy resources - Akashic records as one might poetically say. The newest finding is that NMP in statistical sense follows from the mere fact that the dimension of extension of rationals defining adeles increases unavoidably in statistical sense - separate NMP would not be necessary.

3.2.1 What does adelization mean?

The adelization of ordinary physics fusing real number based physics and various p-adic variants of physics in order to describe cognition.

1. Adelic physics [**?**, **?**] gives powerful number theoretic constraints when combined with M^8-H duality and leads to the vision about evolutionary hierarchy defined by extensions of rationals. The higher the level in the hierarchy, the higher the dimension n of the extension identified in terms of Planck constant $h_{eff}/h = n$ labelling the levels of dark matter hierarchy.

2. Adelic hypothesis allows to sharpen the strong form of holography to a statement that discrete cognitive representations consisting of a finite number of points identified as points of space-time surface with M^8 coordinates in the extension of rationals fixes the space-time surface itself. This dramatic reduction would be basically due to finite measurement resolution realized as an inherent property of dynamics. Cognitive representation in fact gives the WCW coordinates of the space-time surface in WCW! WCW reduces to a number theoretic discretization of a finite-dimensional space with Kähler structure and presumably maximal isometries.

3. In ZEO space-time surface becomes analogous to a computer program determined in terms of finite net of numbers! Of course, at the QFT limit of TGD giving standard model and GRT space-time is locally much more complex since one approximates the many-sheeted space-time with single slightly curved region of M^4. This is the price paid for getting rid (or losing) the topological richness of the many-sheeted space-time crucial for the understanding living matter and even physics in galactic scales.

4. Skeptic can argue that this discretization of WCW leads to the loss of WCW geometry based on real numbers. One can however consider also continuous values for the points of cognitive representations and assigning metric to the points of cognitive representation. Metric could be defined as kind of induced metric. One slices CD by parallel CDs by shift the CD along the axis connecting its tips. This allows to see the point of cognitive representation as point at one particular CD. One shifts slightly the point along its CD. Imbedding space metric allows to deduce the infinitesimal line element ds^2 and to deduce the metric components. This allows a definition of differential geometry so that the analog of WCW metric makes sense as a hierarchy of finite-dimensional metrics for space-time surfaces characterize by the cognitive representations.

   The interpretation in real context would be in terms of finite measurement resolution and the hierarchy would correspond to a hierarchy of hyper-finite factors (HFFs) [**?**, **?**], whose defining property is that they allow arbitrarily precise finite-dimensional approximations. What would be new is that the hierarchy of extensions of rationals would define a hierarchy of discretizations and hierarchy of HFFs.

The above list involves several unproven conjectures, which I can argue to be intuitively obvious with the experience of four decades: I cannot of course expect that a colleague reading for the first time about TGD would share these intuitions.

3.2.2 Adelic physics and cognition

It took more than 10 years to deduce hierarchy of dark matters as hierarchy of Planck constants from what I call adelic physics.

1. The notion of p-adic physics was introduced by colleagues already around 1990. In lack of any idea about the connection to reality it however remained purely formal exercises such as the construction of p-adic variants of quantum field theories.

   At that time I however realized that p-adic thermodynamics for a system with super-conformal invariance and standard model symmetries predicted by TGD provides extremely elegant description of particle massivation and that the predictions are correct with one per cent accuracy if p-adic length scale hypothesis stating that primes near certain powers of two are physically favored [**?**].

   This forced the question about interpretation and about how to integrate real and various p-adic physics to a larger coherent whole

2. Adelic physics is indeed a fusion of real physics for matter and various p-adic physics for cognition, p prime. Various number fields are like pages of a book having common back consisting of rational numbers common to all of them.

   Allowing extensions of rational numbers (by adding roots of N:th order polynomial) one obtain reals and induced extensions of p-adic number fields. Entire hierarchy of books defined by the extensions of rationals. This defines hierarchy of adelic physics identified as evolutionary hierarchy.

3. It became clear already in the beginning that that $h_eff/h = n$ naturally corresponds to the number of sheets of space-time surface representable as a covering space. Galois group of extension act as its automorphisms respecting arithmetics.

   Since cognitive representations correspond to intersections of real and p-adic space-time surfaces having points with coordinates in the extension of rationals as common points, Galois group has a natural action to this cognitive representation and gives rise to n-fold covering space. The identification of $h_eff/h = n$ as the dimension of extension dividing the order of Galois group is natural. Cognitive degrees of freedom are discrete degrees of freedom characterized by the Galois group of extensions.

   $n > 0$ measures the complexity of extension and it is bound to increase in quantum jumps like the distance from the origin in random walk at half line. This implies evolution. The Universe becomes algebraically increasingly complex. This also means that its negentropy (negentropic entanglement) increase on the long run. Universe learns and this learning changes it.

   Positive negentropy is made possible - as one might guess - by cognition that is p-adic number fields: for these one can indeed generalize Shannon entropy so that it gets negative values and has interpretation as negentropy [**?**]. This implies that NMP - originally postulated as a separate principle - follows from adelic physics and holds true in statistical sense. We do not live in the best possible world since this form of principle allows us to do stupid things.

4. p-Adic differential equations have a very special feature that one can have non-constant functions with zero derivative. Integration constants are piecewise constant functions and differential equations are non-deterministic. This corresponds to the non-determinism of imagination.

   If one has fixed the cognitive representation defined by points with coordinates in extension of rationals one can ask if it can be continued to a preferred extremals of action. In p-adic sectors pseudo-constants make this easy: one can speak of imagination realized as p-adic space-time surface. In real sector continuation need not be possible. In this case the imagination is not realizable.

   For some extensions of rationals there can be very many realizable imaginations. System is not only imaginative but also able to realize its imaginations. These extensions are winners in the fight for number theoretic survival.

   Extensions of rationals are characterized by so called ramified primes. The generic rational prime decomposes to a maximal number of primes of extension (order of the polynomial determining it). For ramified primes this number is not maximal. There are good reasons to identify them as preferred p-adic primes for the extension in question. The preferred p-adic primes near to powers of two or small prime could be ramified primes for extensions, which have survived [**?**].

Rationaalifukujen laajennukset määrittelevät p-adisten lukujen laajennuksia. Adele-hierarkia fysiikkojen hierarkiana. Evoluutio ja ekstensiot.

Adeliset avaruusaikapinnat. Samat liikeyhtälöt ja ratkaisujen tulkinta reaalisina tai p-adisina.

Preferoidut p-adiset alkuluvut voisivat olla ramified primes joille tavallisen alkuluvun dekompositio laajennuksen alkuluhuihin ei ole standardi. Normaalisti n n-D laajennuksen alkulukua. Ramifoidussa tapauksessa vähemmän mutta myös korkeampia potensseja. Analogiana polynomi jolla korkeampia juuria. Ramifioidut alkuluvut laajennuksen määrämän diskriminantin jakajina.

Kognitiiviset esitykset: p-adisten ja reaalisten avaruusaikapintojen yhteisinä pisteinä. Preferoidut H-koordinatit rationaalien laajennuksessa. äärellinen mittausresoluutio voisi vastata kognitiivisten esitysten käyttöä.

Avaruusaikapinta voidaan korvata kognitiiviselle esityksellään. WCW:n tasolla nämä esittäisivät äärellisen määrän koordinaatteja WCW: pisteelle.

3.2.3 Evolution and Extensions of Rationals

!!Siirra tekstia !!!! badenbaden tai joku muu

Extensions of rationals. Galois group. Hierarchies for extensions of rationals. Inclusion hierarchies.

Ramified primes as preferred p-adic primes

Yhteydet evoluutioon:

Evoluutio lukuteoreettisesti. The extension of rationals means increase in algebraic complexity. Extension bound to increase in statistical sense at least.

Survival of the fittest

Alkuperäinen idea. Systeemit joita labeloi p kilpailevat keskenään ja jotkut p:t ovat voittajia. Jostain syystä pt:t lähellä kakkosen potensseja.

Ramified primes annetulle ekstensiolle kuuluvat samaan ekstensioon ja luonnollisella tavalla muodotavat ko-operovan ryhmän lajeja hyin abstraktissa mielessä. Nämä tulevat toimeen keskenään ja sietävät toisiaan. Ekstensioiden ekstensioiden... ekstensioiden hierarkiassa Galois ryhmä alimmalle kuuluu korkeampiin. Jos lisäksi polynomeille pätee P(0)=0 hierarkian ylemmillä tasoilla niin perustason ramified primes ovat mukana myös korkeammilla tasoilla. Tapahtuu ikäänkuin geenien säilyminen. Geenit tai koodisanata tai jopa koodikirjaimet voisivat vastata laajennuksia rationaaleille.

Galois group as analog of conserved gene for Galois extensions. Conservation of ramified primes. Evolutionary hierarchies as inclusion hierarchies for supersymplectic sub-algebras and for HFFs.

3.3 Classical Number Fields and TGD

1. Taustahavainnot:

*Dimensiot klassisille lukukunnille reaaliluvut, kompleksiluvut, kvaterniot ja oktoniot esiintyvät TGD:ssä. Voisiko takana olla jotain syvällisempää. *SU(3) on aliryhmä oktonioiden isometrioille. ja rotaatioryhmä SO(3) vastaa kvternioiden isometrioita. Jotain syvempää?

$M^8 - H$ duality ($H = M^4 \times CP_2$) [**?**] has become one of central elements of TGD. $M^8 - H$ duality implies two descriptons for the states.

1. $M^8 - H$ duality assumes that space-time surfaces in M^8 have associative tangent- or normal space M^4 and that these spaces share a common sub-space $M^2 \subset M^4$, which corresponds to complex subspace of octonions (also integrable distribution of $M^2(x)$ can be considered). This makes possible the mapping of space-time surfaces $X^4 \subset M^8$ to $X^4 \subset H = M^4 \times CP_2$) giving rise to $M^8 - H$ duality.

   One should have a rigorous proof for the conjecture that space-time surfaces with associative tangent or normal space are equivalent with space-time surfaces for which "real" or "imaginary" part of of octonionic polynomial identified as root for the "real" or "imaginary" part of octonionic polynomial obtained as a continuation of a polynomial with real coefficients assumed to be rational numbers. The intuitive argument is that the inverse image of the tangent/normal space in the image space identifiable as "real"/"imaginary" octonions is associative as image under quaternionic map.

2. $M^8 - H$ duality makes sense also at the level of 8-D momentum space in one-one correspondence with light-like octonions. In $M^8 = M^4 \times E^4$ picture light-like 8-momenta are projected to a fixed quaternionic $M^4_T \subset M^8$. The projections to $M^4_T \supset M^2$ momenta are in general massive. The group of symmetries is for E^4 parts of momenta is $Spin(SO(4)) = SU(2)_L \times SU(2)_R$ and identified as the symmetries of low energy hadron physics.

   $M^4 \supset M^2$ can be also chosen so that the light-like 8-momentum is parallel to $M^4_L \subset M^8$. Now CP_2 codes for the E^4 parts of 8-momenta and the choice of M^4_L and color group $SU(3)$ as a subgroup of automorphism group of octonions acts as symmetries. This correspond to the usual description of quarks and other elementary particles. This leads to an improved understanding of $SO(4) - SU(3)$ duality. A weaker form of this duality $S^3 - CP_2$ duality:

the 3-spheres S^3 with various radii parameterizing the E^4 parts of 8-momenta with various lengths correspond to discrete set of 3-spheres S^3 of CP_2 having discrete subgroup of $U(2)$ isometries.

3. A radically new view is that descriptions in terms of massive and massless states are alternative options leads to the interpretation of p-adic thermodynamics as a completely universal massivation mechanism having nothing to do with dynamics. The problem is the paradoxical looking fact that particles are massive in H picture although they should be massless by definition. The massivation is unavoidable if zero energy states are superposition of massive states with varying masses. The M_L^4 in this case most naturally corresponds to that associated with the dominating part of the state so that higher mass contributions can be described by using p-adic thermodynamics and mass squared can be regarded as thermal mass squared calculable by p-adic thermodynamics.

4. As a side product emerges a deeper understanding of ZEO based quantum measurement theory and consciousness theory. 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.

   What suggests itself is following "braney" picture. 4-D space-time surfaces intersect the 6-spheres at 2-D surfaces identifiable as partonic 2-surfaces serving as generalized vertices at which 4-D space-time surfaces representing particle orbits meet along their ends. Partonic 2-surfaces would define the space-time regions at which one can pose analogs of boundary values fixing the space-time surface by preferred extremal property. This would realize strong form of holography (SH): 3-D holography is implied already by ZEO.

   This picture forces to consider a modification of the recent view about ZEO based theory of consciousness. Should one replace causal diamond (CD) with light-cone, which can be however either future or past directed. "Big" state function reductions (BSR) meaning the death and re-incarnation of self with opposite arrow of time could be still present. An attractive interpretation for the moments $t = r_n$ would be as moments assignable to "small" state function reductions (SSR) identifiable as "weak" measurements giving rise to sensory input of conscious entity in ZEO based theory of consciousness. One might say that conscious entity becomes gradually conscious about the roots of the polynomial in increasing order. The famous question "What it feels to be a bat" would reduce to "What it feels to be a polynomial?"! One must be however very cautious here. A less radical interpretation is that the roots correspond to "special moments in the life of self". Also the partonic 2-surfaces associated with the 6-D roots at which 4-D roots can meet along their ends could make the notion of strrong holography (SH) precise. The data at these partonic 2-surfaces would fix space-time surface as preferred extremal.

Can one imagine modifications of $M^8 - H$ duality? Such modification emerged as I became critical about the notion of twistor space of M^4.

1. I have assumed that what I call geometric twistor space of M^4 is simply $M^4 \times S^2$. It however turned out that one can consider standard twistor space CP_3 with metric signature (3,-3) as an alternative. This option reproduces the nice results of the earlier approach but the philosophy is different: there is no fundamental length scale but the hierarchy of causal diamonds (CDs) predicted by zero energy ontology (ZEO) gives rise to the breaking of the exact scaling invariance of M^8 picture.

2. M^4 in H would not be replaced with conformally compactified M^4 (M^4_{conf}) but conformally compactified 4-D causal diamond cd (cd_{conf}) for which a natural identification is as CP_2 with second complex coordinate replaced with hypercomplex coordinate. The sizes of twistor spaces of cd_{conf} using CP_2 size as unit would reflect the hierarchy of size scales for CDs.

$M^8 - H$ duality would map the points of M^4 to point of $CP_{3,h}$ and project it to a point of $CP_{2,h}$, where "h" tells that hyperbolic variant of CP_n is in question. $CP_{n,h}$ can be indeed defined as projective space. 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 $CP_{2,h}$.

Remark: 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 $CP_{2,h}$.

3.3.1 $M^8 - H$ duality at the level of space-time and associativity as dynamical principle

$M^8 - H$ duality [**?**] (see `http://tinyurl.com/yd43o2n2`) states that the purely algebraic dynamics determined by the vanishing of real or imaginary part for octonionic polynomial is dual to the dynamics dictated by partial differential equations for an action principle.

1. There are two options for how to identify M^8 counterparts of space-time surfaces in terms roots of four polynomials defining real or imaginary part of an octonionic polynomial obtained as a continuation of real polynomial.

   (a) One can allow all roots $x + iy$ and project them to M^4 or M^8 from M^8_c. One can decompose these surfaces to regions with associative (quaternionic) tangent space or normal space and they are analogous to external particles of a twistor diagram entering CD and to interaction regions in which associativity does not hold true and which correspond to interiors of CD. One can criticizes the projection as somewhat adhoc process.

   (b) It became later clear that that one can also consider space-time surface as Minkowskian real regions so that the projection to a sub-space $M^4 \subset M^8_c$ of complexified octonions is invariant under the conjugation $i \to -i, I_k \to -I_k$, where I_k are quaternionic units. M^4_c parts of space-time coordinates would be form $m = m^0 + iI_k m^k$, m^0, m^k real. This conditions need not or even cannot be posed on E^4_c coordinates since $M^8 - H$ duality assigns to the tangent space of space-time surface a CP_2 point irrespective of whether the point is in M^8_c or M^8.

2. At the level of H external particles correspond to minimal surfaces, which are also extremals of Kähler action and in accordance with the number theoretical universality and quantum criticality do not depend on the coupling parameters at all. They are obtained by a map taking the 4-surfaces in M^8 to those in H. These conditions should be equivalent with the condition that the 6-D surfaces X^6 in 12-D twistor space of H define twistor bundles of space-time surfaces X^4.

3. The space-time regions in the interiors of CDs need not be minimal surfaces so that Kähler action and volume term would couple dynamically and coupling parameters characterize the extremals. The analog is motion of point like particle in the Maxwell field defined by induced Kähler form: this is generalize to the motion of 3-D object with purely internal Kähler field and that associated with wormhole contacts and mediating interaction with larger and smaller space-time sheets.

   In these regions the map mediating $M^8 - H$ duality would not exist since one cannot label the tangent spaces of space-time surface by points of CP_2. The non-existence of this map would due to the failure of either associativity of tangent space or normal space at M^8 level. The initial values at boundaries of CD for the incoming preferred extremals however allows to fix the time evolution in the interior of CD. This is essentially due to the infinite number of gauge conditions for the super-symplectic algebra.

   A more stringent condition is that associativity holds everywhere and the minimal surface property fails only at string world sheets and partonic 2-surfaces at which the quaternionic tangent or normal space reduces to complex subspace due to the fact that two octonionic imaginary units in tangent or normal space become parallel (the tangent/normal space of these 2-surfaces would be trivially associative). At these surfaces there could be also a transfer

of conserved quantities between degrees of freedom assignable to the volume term and the 4-D Kähler action (coming as dimensionally reduced 6-D Kähler action for the twistor lift of TGD). One could say that space-time surface (or rather its tangent or normal space) becomes complex at these points.

Could one imagine the failure of associativity at a discrete set of points [**?**]. In strong sense this seems impossible. If the space-time surface is singular in the sense that several roots intersect at the same point the associativity can break down in the sense that the quaternionic tangent or normal space vectors from different intersecting branches fail to closed to quaternionic algebra. An attractive idea is that these points define cognitive representations and elementary fermions are assignable to these points.

6. $M^8 - H$ dualiteetti.

Miten M^8:n pinnat kuvautuvat H:n pinnoille. Kvaternioniset pinnat fiksatulla M^2:lla vastaavat CP_2 :n pisteitä. Valitaan M^4. Avaruusaikapinnan projektio sillä kuvataan M^4:lle. Pinnan normaaliavaruus tai tangenttiavaruus on kvaternionen ja kuvautuu CP_2 :n pisteelle. Saadaan H:n pinta.

Myöskin rationaaliluvut ja niiden laajennukset ovat mukana isossa kuvassa. Ja myöskin äärelliset lukukunnat modulo p approksimaatiossa. Ramified primes as preferred primes characterize the polynomials.

Voivatko dynamiikat vastata toisiaan?

*Koska M^8:n tangentti- tai normaaliavaruus kyseessä on mukana ei-lokaalia informaatiota ensimmäisten derivaattojen kautta ja H:n puolella dynamiikka on ei-lokaali. Osittais-differentiaalit yhtälöt vastaten vaikutusta ensimmäisin derivaatoihin on minimaalisesti ei-lokaali.

*Minimaalipinta-dynamiikka vastaa massattomia hiukkasia. Ei dimensionaalisia eikä muitakaan kytkentäparametreja. Vain singulaariset säieradat antavat informaatio. Kvanttikriittisyystulkinta. Molemmilla puolin kvanttikriittisyys. Oktoniopuolella oktonioanalyyttisyys korrelaattina ja konformi-invarianssin yleityksenä.

What could be the M^8 counterparts for string world sheets and partonic 2-surfaces. What about partonic orbits as light-like 3-surfaces and boundaries of string world sheets at them. They should relate somehow to the roots of octonionic polynomials. One can imagine two options.

1. Quaternions decompose to sum "real" and "imaginary" parts: $q = z_1 + Jz_2$, where z_i complex number. Could preferred 2-D surface correspond to the vanishing of z_1 or z_2. This definition would be completely analogous to the definition of quaternionicity. This would require prerred cordinates. At M^8 level the coordinates are indeed highly unique.

2. Second option is that these 2-surfaces are singularities of the quaternionic structure in the sense that two quaternionic tangent vectors become parallel so that the quaternionic tangent or normal space reduces effectively to 2-D space. At these singularities also simultaneous extremal property for Kähler action and volume term would fail and there would be energy transfer between these degrees of freedom.

   This could also provide a mechanism for the reduction of the supersymplectic symmetry fo H realized at boundaries of CD to super-symplectc symmetry defined isometries of H and reduced to Kac-Moody symmetry at string world sheets an partonic 2-surfaces. The basic question is how conformal weights of SSA and those of Kac-Moody algebra relate.

   What comes in mind is that the imaginary conformal weights at the boundary of CD and the real Kac-Moody type conformal weights assignable witht he light-like orbits of partonic 2-surfaces or with partonic 2-surfaces coming as half-integers combine to form complex conformal weights. One can consider the possibility that the combined conformal weights come as integer multiples of zeros of zeta or of Dirichlet zeta associated with the extension of rationals in question. p-Adic thermodynamics would be associated with the Kac-Moody part of the conformal weight.

2. $M^8 - H$ dualiteetti

Relatoi lukuteoreettisen ja geometrisen vision fysiikasta.

Spontaani kompaktifikaatio säiemalleissa dynaamisena. Ad hoc idea joka johti landscape katastrofiin. 10-D Minkowskiavaruus korvautuu efektiisesti dynaamisella kompaktifioidella vastineellaan. Yleinen suhteellisuusteoria dimensiossa 10.

Kuitenkin voi kysyä olisi spontaanilla kompaktifikaatiolla analogia TGD:ssä dualiteettina. Voisiko puhtaasti algebrallinen dynamiikka, joka on puhtaasti lokaali vastata osittaisi-differentiaaliyhtälöiden määräämää dynamikkaa H:ssa, joka sekin toteuttaa super-symplektiset mittaehdot ja toisaalta redusoituu minimaalipintojen dynamikkaan singulariteetteja lukuunottamatta?

Voisivatko avaruusaikapinnat M^8:ssa määritellä vaihtoehtoisen kuvailun dynamiikalle. Voisiko assosiatiivisuus toimia dynaamisena periaatteena? Kaksi vaihtoehtoa.

1. Olisivatko nelipinnat nollakohtia rationaalikertoimisen oktoniopolynomin reaali tai imaginaariosalle. Rationaalikertomisuus mahdollisesti kompleksisena vastaten oktonioiden kompleksifioinnin imaginaari-yksikköä. Takaa assosiatiivisuuden oktoniopolymomissa esiintyville tulolle.

Oktonio kahden kvaternionin avulla kuten reaaliluku kahden reaaliluvun avulla. Reaali ja imaginaariosat. Yleisessä tapauksessa 4-D pintoja. Erikoistapaus. Nollakohdat polynomilla rajoitettuna 8D valokartion reunalle. 6-palloja vastaten juuria. Braanien analogoita. Vastaavat vakioaikapintoja M^4:ssa. Näille avaruusaikapinnat liimautuvat päistään pitkin partonisia 2-pintoja jotka esittävät verteksejä. Holografia: kognitiivisen esityksen pisteet näillä partonisilla pinnoilla. Vastaavat kulmia säikeiden 2-D radoilla. Fermionit säiden reunoilla. Partoniset pinnat vastaavat topologista esitystä vertekseille 2- pintoina.

Polynomin fiksaa n arvo polynomille. Esimerkiksi juuret jotka 8-D valokartion reunalla vastaavat M^4:n tasolla juuri braaneja. äärellinen määrä dataa fiksaisi avaruusaikapinnan WCW:n pisteenä kognitiivisena esityksenä. Sironta-amplitudet kognitiviisina esityksinä. Hiukkaset tässä kuvassa pistemäisiä lukuunottamatta partonpintojen topologiaa ja homologiaa kuvaavaa dataa.

Huom: myös oktioniset jatkot reaalianalyyttisten funktioiden rationaalisin Tayler kertoimin mahdollisia.

Valinta oktonisille koordinaateille fiksattu lukuunottamatta siirtoa pitkin reaaliakselia. Lorentz symmetria redusoituu rotaatiosymmetriaksi. Translaatiot aikatranlaatioiksi. Valinta aika-akselille ja spinin kvantitus-akselille. Näitä valintoja parametrisoi geometrinen vastine twistoriavaruudelle. Preferoitu $M^2 \subset M^4 \subset M^8$.

$M^4 = M^2 \times E^2$ dekompositio mittakenttäteorioissa. M^2 vastaa ei-fysikaalisia polarisaatioita ja E^2 fysikaalisia. Jako vastaisi M^2 erottumista ylläesitetyllä tavalla. M^2 valinta joko sama globaalisti ja lokaali mutta integroituvat jolloin $M^2(x)$ tangenttiavaruus säikeen radalle. Hamilton-Jacobi rakenne. Ocotonionic structures!!! Calibrations!! Lift to imbedding space!!

2 . Special brane like solutions of polynomial equations.

The dual solutions intersect at them. Euclidian and Minkowskian. Do the light-like partonic orbits live on 6-branes? They should.

4. Singularities of space-time surfaces as string world sheets and partonic 2-surfaces. Are the pre-images of partonic orbits at light-cone boundary of M^8. Common points of partonic 2-surfaces and string world sheets common to Euclidian and Minkowskian regions.

5. Vaihtoehtoinen ehtoinen formulaatio dynamiikalle.

Avaruusaikapinnan tangenttitaso tai normaaliaso on assosiatiivinen ts. kvaternioninen. Vastaisi imaginaari tai reaaliosan häviämistä polynomille. Tämä argumentti pitäisi matemaatikon tarkistaa. Assosiatiivisuus dynamikalle hyvin luonnollinen.

3.3.2 $M^8 - H$ duality at the level of momentum space

(see `http://tgdtheory.fi/public_html/articles/padicM8HZEO.pdf`)

Basic problem of twistor approach. 8-D light-like momenta. Projection to M^4. Two options.

1. Fixed M^4. Mass squared depends on the choice of M^4. Mass relative notion. Could evolution of mass squared mean evolution for the choice of fixed M^4? $M^8 = M^4 \times E^4$ picture. Old-fashioned hadron physics. Non-perturbative phase.

2. M^4 chosen so that 8-D light-like 8-momentum is parallel to it. Masslessness in 4-D sense. This correspond to $M^4 x CP_2$ picture.

3.4 Infinite Primes and TGD

Do infinite primes at first level label extensions of rationals. Polynomial extensions at higher levels. Representation at the level of M^8. Families of space-time surfaces characterized by parameters appearing as additional coordinates of the polynomials.

Abstraction process in terms of wave functions in the space of space-time surfaces labelled by these additional parameters.

4 What Does "T" in TGD Refer to?

Mitä "T" tarkoittaa "TGD":ssä?

4.1 Topology and Elementary Particle Physics

1. Topologia perustasolla TGD:ssä

4.1.1 Genus-Generation Correspondence

Family replication as topogy of partonic 2-surfaces in TGD. $M^4 \times CP_2$ selittää standardimallin symmetria ja kentät mutta ei fermionien sukupolvia.Tässä topologinen selitys.

Fermionien family replication phenomenon.

1. Alkuperäinen malli. Partoninen 2-pinta reunakomponentti 3-pinnalle. 3 alinta genusta erikoisasemassa. CKM mixing topologisena miksauksena.

2. Vaihtoehtoinen kuva: partonisen pinnan rata valonkaltainen 3-pinta jolla indusoidun metriikan signatuuri muttuu. Sallittaisiin molemmat signatuurit. Jos ei sallita niin euklidiset pinnat reikiä avaruus-ajassa. Ei vieläkään täysin selvää kumpi vaihtoehto fysikaalinen.

3. Myöhempi malli alkeishiukaselle. Fundementaaliset fermionit. Suljettu homologisesti varattu flux tuubi. Kaksi avaruusaikalehteä. Kaksi wormhole kontaktia. Genus sama eri wormhole throateille. Hiukan barokkinen malli.

4. Supersymmetrian ymmärtäminen johti paluuseen juurille. Vain hadronit tällaisia ei-lokaaleja tiloja. Leptonit spartnereita kvarkeille ei-lokaaleinena 3-kvarkkikomposiitteina. Kvarkit homologisesti varattuha.

4.1.2 Homology of Partonic 2-Surfaces, Electric-Magnetic Duality, Color Confinement

Homology of partonic 2-surfaces, electric magnetic duality, color confinement

Electric-magnetic duality. Magneettiset monopolit ja perturbatiivinen faasi. Kvarkit magneettisina partonisina 2-pintoina jotka magneettisia monopoleja. Confinement. Baryonit ja gluonit.

Myös leptonit voivat muodostaa tällaisia. Suprajohtavuus: Cooperparit! Meissner efekti ja B suprajohteessa. Monopoli-vuoputket ja vahvasti vuorovaikuttavat elektronit. Kosmiset magneettikentät: ei tarvita virtaa.

4.2 TGD as Almost TQFT

2. TGD as almost TQFT

Topologinen dynamiikka. Metriikka ei esiinty lainkaan dynamiikassa. Vain kenttien topologia ja TGD:ssä avaruusajan topologia. TQFT:t. Chern-Simons action. Abelinenkin mielekäs.

TQFT ja braidien dynamiikka. Topolginen kvanttikomputaatio.

TGD:n kenttäteoriarajasta muutama sana.

TGD a almost TQFT. Varmasti vain almost koska muutoin metriikka ei esiintyisi lainkaan teorian dynamiiikassa.

4.3 TGD and Braids

3. TGD ja braidit

a) Kähler vaikutuksen M^4 tyyppisistä ekstremaaleista iso osa sellaisia että Kahler vaikutus joko häviää (MEs) tai redusoituu C-S termiksi. Voluumitermi ei redusoidu luonnollisella tavalla.

b) Kalibroinnit. Minimipinnat vastaavat homologi-ekvivalenssiluokkia. Yksi luokassaan ja minimoi tilavuuden.

c) Braidit

i) Säikeet voivat letittyä ja solmuuntua 3-pinnalla. Säiden radat voit solmuutua 4-D avaruusaikapinnalla. 2-solmut.

ii) Myös magneettiset vuoputket joihin säikeet liittyvät voivat letittyä. Kvanttibiologiassa keskeisessä roolissa. Topologinen kvanttikomputaatio.

d) Flux tubes as strings as correlates for entanglement. Counterpart of ER-EPR in TGD. Flux tubes replace wormholes. Tensor networks.

4.4 p-Adic Topology and Cognition

p-Adiset topologiat ja kognitio

5 SUSY and SUSY breaking in TGD

What SUSY and SUSY breaking mean in TGD has been long lasting head ache and I have probably considered all possible options. The most general option has been that fundamental fermions associated with the light-like orbits of partonic 2-surfaces and moving collinearly give rise to dynamically generated broken SUSY. The proposal has been that right-handed neutrino and antineutrino generate sub-SUSY which is minimally broken.

What SUSY in TGD framework very probably is was understood only recently [**?**]. The idea that sparticles correspond to local composites of fundamental fermions emerge first in M^8 picture, and the question what they could be in H picture led to an elegant picture, which I dare believe to be rather near to correct one. This led to the realization that quarks as fundamental particles are enough and that anti-leptons can be identified as sparticles which are local 3-quark composites. This led also to a dramatic simplification of the model of elementary particles and the outcome is very similar to the original model.

The idea about what SUSY breaking reduces to a selection of p-adic prime characterizing member of super-multiplet has been obvious from the beginning. The mass formulas would be essentially identical and given by p-adic thermodynamics and only the scale would be different. In ZEO the massivation of massless states follows in H-picture if the states are superpositions of states with different mass squared eigenvalue with dominating state the massless state. The maximally symmetric option is that the extension of rationals could be same for entire super-multiplet but that the p-adic prime identified as ramified prime is different for the members of the multiplet.

5.1 Evolution of ideas about SUSY in TGD

What SUSY is in TGD framework is a longstanding question which found a rather convincing answer rather recently. In twistor Grassmannian approach to $\mathcal{N} = 4$ SYM [**?**, **?**, **?**, **?**, **?**, **?**, **?**] twistors are replaced with supertwistors and the extreme elegance of the description of various helicity states using twistor space wave functions suggests that super-twistors are realizes at the level of M^8 geometry. These supertwistors are realized at the level of momentum space.

In TGD framework $M^8 - H$ duality allows to geometrize the notion of super-twistor in the sense that different components of super-field correspond to components of super-octonion each of which corresponds to a space-time surfaces satisfying minimal surface equations with string world sheets as singularities - this is geometric counterpart for masslessness.

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 sparticles 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 sparticle causes the mass splitting between members of super-multiplets although the mass formula is same for all of them. Super-octonion components of polynomials have different orders so that also the extension of rational assignable to them is different and therefore also the ramified primes so that p-adic prime as one them can be different for the members of SUSY multiplet and mass splitting is obtained.

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. $SO(1,7)$ duality allows only quarks as fundamental fermions. 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 consided. 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 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 define the analog of radiative corrections. $M^8 - H$ duality and number theoretic vision require that the number of non-vanishing Wick contractions is finite. This condition gives rise to conserved currents having an identification in terms of symmetries. The number of contractions increases with the degree of the octonionic polynomial and gives rise to a discrete coupling constant evolution parameterized by the extensions of rationals. The polynomial composition hierarchies correspond to inclusion hierarchies for isomorphic sub-algebras of super-symplectic algebra having interpretation in terms of inclusions of hyper-finite factors of type II_1.

One also ends up to the first completely concerete proposal for how to construct S-matrix directly from the solutions of super-Dirac equations and super-field equations for space-time super-surfaces. For cognitive representations the construction would involve 1-D fermion lines and vertices associated with partonic 2-surfaces identified as intersections of 4-D space-time surfaces as roots of octononionic polymials and universal roots which are 6-D spheres in M^8.

5.2 Background ideas

TGD ennustaa super-konformi-invarianssin ja super-symmetrian jo bosonisen vaikutuksen ja Diracin vaikutuksen tasolla. Onko tämä symmetria koko tarina. Vastaako se avaruusaika tason SUSY. Varmastikaan ei standardi mielessä. TGD:ssä fermioniluku säilyy ja Majoranafermionit eivät ole mahdollisia. Miten modifioida SUSYn käsitettä jotta se olisi mielekäs TGD:ssä.

The first attempt.

1. Vastaavatko SUSY multipletit monifermionitiloja partonisilla pinnoilla. Partonit liikkuisivat kollineaarisesti ja muodostaisivat efektiivisesti super-multipletin. Että SUSY rikkoutuu on melko ilmeistä jo siksi että elektroheikko symmetria rikkoutuu CP_2tasolla.

2. Vähiten rikkoutunut SUSY vastaisi oikeakätistä neutrinoa ja antineutrinoa. Se kuitenkin miksautuu vasenkätisen kanssa ja SUSY tässä mielessä näyttäisi katoavan.

   Tälle ei kuitenkaan ole löytynyt eleganttia muotoilua.

3. Spinorit ovat 4-D mutta vaikutuksella on singulariteetti 2-D string world sheeteillä ja myös näiden reunoilla. Merkitseekö tämä sitä että supersymmetriat vastaavat kaikkia näitä objekteja?

Second attempt. SUSY in M^8 formulation

1. SUSY multipletit vastaavat lokaaleja monifermioni-komposiitteja M^8 tasolla. Nämä vastaavat thetaparameterien tai luomis ja hävitysoperaattorien monomeja. Voisiko tällä olla H vastine?

2. Tälle vaihtoehdolle löytyy elegantti formulointi molemmilla tasoilla ja se näyttää lopultakin ratkaisevan kysymyksen SUSYsta. Lisäksi löytyy selitys sille miksi standardi SUSYa ei löydy.

Sensijaan TGD SUSY on ollut suoraan näkyvissä niin kauan kuin on tunnetty protoni ja elektroni joka olisi spartneri antikvarkille.

5.3 SUSY at the Level of M^8

$M^8 - H$ 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.

Can one imagine modifications of $M^8 - H$ duality? Such modification emerged when I became critical about the notion of twistor space of M^4.

I have assumed that what I call geometric twistor space of M^4 is simply $M^4 \times S^2$. It however turned out that one can consider variant $CP_{3,h}$ standard twistor space CP_3 with metric signature (3,-3) as an alternative. This option reproduces the nice results of the earlier approach but the philosophy is different: there is no fundamental length scale but the hierarchy of causal diamonds (CDs) predicted by zero energy ontology (ZEO) gives rise to the breaking of the exact scaling invariance of M^8 picture. 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 $CP_{2,h}$.

M^4 in H would not be replaced with conformally compactified 4-D causal diamond cd (cd_{conf}) for which a natural identification is as CP_2 with second complex coordinate replaced with hypercomplex coordinate. The sizes of twistor spaces of cd_{conf} using CP_2 size as unit would reflect the hierarchy of size scales for CDs. $M^8 - H$ duality would map the points of M^4 to point of $CP_{3,h}$ and project it to a point of $CP_{2,h}$, where "h" tells that hyperbolic variant of CP_n is in question. $CP_{n,h}$ can be indeed defined as projective space.

5.4 SUSY at the Level of H

If SUSY is realized at the level of M^8, it should have a formulation also at the level of H.

1. $M^8 - H$ duality is non-local and means that the dynamics at the level of H is not strictly local but dictated by partial differential equations for super-fields having interpretation as describing purely local many-fermion states made of fundamental fermions with quantum numbers of leptons and quarks (quarks do not possess color as spin like quantum number) ad their antiparticles.

2. Classical field equations and modified Dirac equation must result from this picture. Induction procedure for the spinors of H must generalize so that spinors are replaced by super-spinors Ψ_s having multi-spinors as components multiplying monomials of θ. The determinant of metric and modified gamma matrices depend on imbedding space coordinates h replaced with super coordinates h_s so that monomials of θ appear in two different manners. Hermiticity requires that sums of monomial and its hermitian conjugate appear in h_s. Monomials must also have vanishing fermion numbers. Otherwise on can obtained fermionic states propagating like bosons. For Dirac action one must assume tha Ψ_s involves only odd monomials of θ

possibly multiplied by monomials appearing in h_s to get only fermionic states and correct kind of propagators.

3. One Taylor expands both bosonic action density (Kähler action plus volume term) Super-Dirac action with respect to the super-coordinates h_s. The coefficients of the monomials of θ:s are obtained are partial derivatives of the action. Since the number of θ parameters is finite and corresponds to the number of spin-weak-isopin states of quarks and leptons, the number of terms is finite if the θ parameters anti-commute to zero. If not, one can get an infinite number of terms from the Taylor series for the action. Number theoretical considerations do not favor this and there should exist a cancellation mechanism for the radiative corrections coming from fermionic Wick contractions if thetas correspond to fermionic oscillator operators as it seems to be.

4. One can interpret the superspace as the exterior algebra of the spinors of H. This reminds of the result that the sections of the exterior algebra of Riemann manifold codes for the Riemann geometry (see `http://tinyurl.com/yxrcr8xv`). This generalizes the observation that one can hear the shape of a drum since the sound spectrum is determined by its frequency spectrum defined by Laplacian.

   Super-fields define a Clifford algebra generated by θ parameters as a kind of square root of exterior algebra which corresponds to the Clifford algebra of gamma matrices. Maybe this algebra could code also for the spinor structure of imbedding space or even that of space-time surface so that the super-fields could be seen as carriers of geometric information about space-time surface as a preferred extremal. In 8-D case there is also $SO(1,8)$ triality suggesting that corresponding three Clifford algebras correspond to exterior algebra fermionic and anti-fermionic algebras.

5. At M^8 level the components of super-octonion correspond to various derivatives of the basic polynomial $P(t)$ so that space-time geometry correlates with the quantum numbers assignable to super-octonion components - this is in accordance with QCC (quantum-classical correspondence). This is highly desirable at the level of H too.

6. Could the space-time surface in M^8 be same for super-field components with degree $d < d_{max}$ in some special cases? The polynomial associated with super octonion components are determined by the derivatives of the basic polynomial $P(t)$ with order determined by the degree of the super-monomial. If they have decomposition $P(t) = P_1^k(t)$, the monomials with degree $d < k$ the roots corresponding to the roots $P_1(t)$ co-incide. Besides this there are additional roots of $d^r P_1/dt^r$ for super-octonion component with r θ parameters.

   A possible interpretation could be as quantum criticality in which there is no SUSY breaking for components having $d < k$ (masses in p-adic thermodynamics could be the same since the extension defined by P_1 and corresponding ramified primes would be same). This would conform with the general vision about quantum criticality.

7. Usual super-field formalism involves Grassmann integration over θ parameters to give the action. M^8 formalism does not involve the θ integral at all. Should this be the case also at the level of H? This would guarantee that different components of H- coordinates as super-field would give rise to different spae-time surface and QCC would be realized. θ integration produces SUSY invariants naturally involved with the definition of vertices involving components of super-fields. Also vertices involving fermionic and bosonic states emerge since bosonic super-field components appear in super-coordinates in super-Dirac action.

5.4.1 Super Variants of Imbedding Space and of Super-Spinors

Miten tämä realisoidaan. Konsistenssi statistiikan kanssa perusvaatimus.

1. Superkoordinaatit H:lle. Superosa hermiittinen ja jokaiselle monomille kvarkkiluku nolla. Monomi + konjugaatti. Tätä vaatii statistiikka kun ei sallita Majorana fermioneja. Vaikutus super-Taylor sarjaksi.

   FFbar termit vastaavat suoraan mittabosoneja, Higgsiä ja sen pseudoskalaaripartneria. Gravitoni.

2. Superspinorit summa monomeja joilla pariton kvarkkiluku. Superspinorit kvarkeille ja konjugaatit. Kvarkkien spartnerit upotusavaruuskoordinaattien super-osista. Leptonit antikvarkkien spartnereita. Materia-antimateria asymmetria ja CP rikko M^4:n Kaehler muodosta.

5.4.2 Finiteness for the number of non-vanishing Wick contractions, quantum criticality, and discrete coupling constant evolution

The consistency with number theoretic vision requires that the number of terms in the super-Taylor expansion of action is finite - otherwise one is led out from the extension: this applies both to the action determining space-time surfaces and to the corresponding modified Dirac action. There are several options that one can consider.

1. Normal ordering of the fermionic oscillator operators would be a straightforward manner to handle the situation. One would obtain finite number of terms since the number of quark oscillator operators is $d = 4+4 = 8$. The maximal degree m_{max} of multiple partial derivative of action with respect to gradient of H-coordinate h would be $m_{max} = d = 8$ and correspond to monomial with 4+4 quark oscillator operators. Note that the normal ordering of this term gives rise to c-number.

   It however seems that the natural solution of the problem must involve cancellation of the Wick contractions when the degree m of the multiple partial derivative satisfies $m > m_{max}$. Some cancellation mechanism for $m \geq m_{max}$ should guarantee that Wick-contractions give in this case a vanishing contribution to each of the $d = 8$ monomials in the super-action.

2. The strongest condition would be that all Wick contraction terms coming from the normal ordering vanish. The contraction terms are expressible as divergences of currents and the interpretation would be in terms of Noether current associated with some symmetry. Super-symplectic symmetry is the best candidate in this respect. Note that besides these currents also the Noether currents coming from the super-symplectic variations should have a vanishing divergence.

3. One can consider also a weaker condition. Wick contractions vanish for $m > m_{max}$ such that $m_{max} > 8$ is possible. This would give rise to the analog of radiative corrections, and if m_{max} can vary, one obtains the analog coupling constant evolution and discrete coupling constant evolution corresponds to the variation of m_{max}.

How the value of m_{max} could be determined?

1. M^8-H duality requires that M^8- and H-pictures are structurally similar. Octonionic polynomials are characterized by their order n and also the super-extremals should be characterized by n and even the individual terms of super-polynomial should have counterparts at H-level.

   One can define super-octonionic polynomials at M^8-level and also for these normal ordering terms appear. Ordinary derivatives of $P(o)$ with respect to o replace those of the action with respect to the gradients of H coordinates, and one obtains only finite number of Wick contractions. There is no need to require their vanishing now, and the hierarchy of degrees $n = h_{eff}/h_0$ for P defines a discrete coupling constant evolution with each level corresponding to its own values of coupling constants differing by the number of Wick contractions. This gives a connection with the ordinary coupling constant evolution with Wick contractions taking the role of loops.

   This picture should have direct image at H-side. In particular, one should have $m_{max} = n$.

2. The cancellation of Wick contractions for the action containing both Kähler term and cosmological term probably happens only for critical values of cosmological constant determined dynamically from the mechanism of dimensional reduction reducing 6-D surface in the product of twistor spaces $T(M^4) = M^4 \times S^2$ and $T(CP_2) = SU(3)/U(1) \times U(1)$ to S^2 bundle over space-time surface representing induced twistor structure. The cancellation condition for the higher terms could fix the value of cosmological constant emerging from the mechanism.

3. The picture could be interpreted in terms of quantum criticality. The polynomials $P(o)$ characterize quantum critical phases. Also Taylor series can be considered but they would not be critical and infinite amount of information would be required to specify them whereas the specification of critical dynamics requires by its universality only a finite number of parameters coded by the rational coefficients of polynomial.

   Criticality corresponds to the vanishing of not only function but also some of its derivatives at critical point. The criticality would be now infinite in the sense that all derivatives of $P(o)$ higher than n would vanish. This is indeed the view about quantum criticality that I ended up to long time ago. This implies that the parameter space for the functions describing criticality is finite-dimensional.

   In Thom's catastrophe theory which essentially describes a hierarchy of criticalities concretely, the finite-dimension of the space of control parameters is essential. For cusp catastrophe this space is 2-dimensional and catastrophe graph is defined by a fourth order polynomial so that all higher order derivatives vanish identically also now.

4. At the level of H criticality would mean that m-fold partial derivatives of action only up to $m = m_{max} = n$-fold partial derivatives contribute to the radiative corrections. The action would be polynomial of finite order in the multi-spinor components of super-coordinates and discrete coupling constant evolution would be realized. The ordinary variations of the action would be of course non-vanishing to arbitrary high order.

   Coupling constant evolution would reduce to the hierarchy of extensions of rationals since the degree n of P determines the dimension of extension. Evolution in terms of the hierarchy of extensions of rationals would dictate also coupling constant evolution. This evolution would also dictate the preferred p-adic length scales if preferred p-adic primes are identifiable as ramified primes. Ramified primes at the lowest level of hierarchy are ramified primes at higher levels if $P(0) = 0$ condition is true for them. Evolutionary hierarchies correspond to functional composition hierarchies for polynomials with degrees n_i such that n_{i+1} is divisible with n_i that is $n_{i+1}/n_i = k_i$.

   Remark: Functional composition occurs also in the construction of fractals like Mandelbrot fractal and as a special case one iterates single polynomial to get a hierarchy in powers of integers n_1. This interpretation would conform with the interpretation of the symmetries guaranteeing the cancellation of Wick terms as super-symplectic symmetries.

5. A connection with the inclusion hierarchies for super-symplectic algebra is highly suggestive. The fractal hierarchy of super-symplectic sub-algebras (fractality and conformal symmetry - now in generalized sense - are essential for quantum criticality) with levels labelled by n would naturally give rise to counterparts of the functional composition hierarchies.

   Inclusion hierarchies would correspond to sub-hierarchies of super-symplectic algebras formed by sequences of sub-algebras with weights divisible by integer n_i such that n_i divides n_{i+1}. n_i would correspond to a degree of polynomial in the hierarchy formed by their compositions in accordance with functional composition of polynomials.

6. The inclusion hierarchies of super-symplectic algebras would have interpretation in terms of inclusions of hyper-finite factors of type II_1. The ratios $n_{i+1}/n_i = k_i$ appearing in the composition hierarchies would correspond to the integers labelling the inclusions of HFFs and defining quantum phases $U = exp(i\pi/k_i)$ characterizing quantum algebras and quantum spaces as analogs of state spaces modulo finite measurement resolution [**?**, **?**].

   The interpretation of finite measurement resolution as an ability to detect only space-time sheets characterized by polynomials of order n below some fixed integer is natural. n would characterize the measurement resolution.

7. For continuum formulation anti-commutators are proportional to delta functions rather than Kronecker deltas and Wick contractions give powers of delta function at zero so that one must assume that for every power the sum of contributions vanishes. One does not obtain coupling constant evolution in the sense considered for cognitive representations. Does this mean that continuum limit does not exist? If real and p-adic variants of continuum theory exist one can

assign to the extensions of rationals coupling constant evolution as purely number theoretic evolution as in the case of cognitive representations.

Do *all* Wick contractions for n:th power of Kronecker delta proportional to a power of $\hbar_{eff}^n$ vanish also for cognitive representations? This is possible since the vanishing conditions reduce to conservation of currents identifiable as Noether currents for some symmetries. These conditions imply that in action oscillator operators behave effectively as theta parameters so that one would have analog of standard SUSY but in much weaker sense following from the cancellation of divergences. If coupling constant evolution is solely due to the evolution of the resolution then trivial coupling constant evolution in continuum case could be understood as being due to maximal resolution.

To sum up, this picture rather neatly fuses together several speculative visions about quantum TGD. The reduction of dynamics to polynomial dynamics at the level of M^8 has interpretation in terms of quantum criticality with finite-D space of control parameters implying universal dynamics involving very few coupling parameters, which are fixed points of coupling constant evolution for given value of n. $M^8 - H$ duality maps M^8 dynamics to the level of H, where it is realized in terms of a hierarchy of sub-algebras of super-symplectic algebra and sub-hierarchies correspond to sequences of integers n_i dividing n_{i+1}. A connection with the inclusions of HFFs and finite measurement resolution emerges. The notion of discrete coupling constant evolution finds a precise formulation, and the notion of radiation correction is realized in terms of Wick contractions.

5.5 $M^8 - H$ duality and SUSY

$M^8 - H$ duality and $h_{eff}/h_0 = n$ hypothesis pose strong constraints on SUSY in TGD sense.

1. $h_{eff}/h_0 = n$ interpreted as dimension of extension of rationals gives constraints. Galois extensions are defined by irreducible monic polynomials $P(t)$ extended to octonionic polynomials, whose roots correspond to 4-D space-surfaces and in special case 6-spheres at 7-D light-cones of M^8 taking the role of branes.

   The condition that the roots of extension defined by Q are preserved for larger extension $P \circ Q$ is satisfied if P has zero as root:

   $$P(0) = 0 \ .$$

   This simple observation is of crucial importance, and suggests an evolutionary hierarchy $P \circ Q$ with simplest possible polynomials Q at the bottom of the hierarchy are very naturally assignable to elementary particles. These polynomials have degree two and are of form $Q = x^2 \pm n$. Discriminant equals to $D = 2n$ and has the prime factors of n as divisors defining ramified primes identified as p-adic primes assignable to particles.

   Remark: Also polynomials $P(t) = t - c$ are in principle possible. The corresponding space-time surfaces at the level of H would be M^4 and CP_2 and they are extremals of Kähler action but do not have particle interpretation.

2. Octonionic super-polynomials decompose to a sum of octonionic polynomials with θ monomials having varying degree d. One can assign octonionic super-coordinates to both leptons and quarks for Option a). Option b) identifying leptons as local 3-quark local composites and thus spartners of quarks would mean that quarks (anti-quark) appear in the octonionic polynomial (its conjugate). This would realize $SO(1,7)$ triality.

3. This has important implications for SUSY in TGD sense. The degree d for the monomial of super-octonion polynomial in M^8 would corresponds to the degree $d = F + \overline{F}$ for the super-field in H. The number of fermions and anti-fermions giving rise to spartner is d.

   If the degree n of the octonionic polynomial is smaller than the number $N = 16$ of maximal degree of θ polynomial, only a fraction of spartners are possible. SUSY is realized only partially and one can say that part of spartners are absent at the lowest levels of evolutionary hierarchy. At the lowest level of hierarchy corresponding to $n = 2$ only fermions (quarks)

would be present as local states and would form non-local states such as baryons and mesons. Gauge bosons and Higgs like state would be bi-local states and graviton 4-local state.

Remark: Gauge bosons and Higgs like states as local fermion-anti-fermion composites at level $n = 2 \times 2$. For the option involving only quarks (color is not spin like quantum number). Note that the value of $n_0 = 3 \times 2 = 6$ in $h = n_0 \times h_0$ suggested by the findings of Randel Mills [**?**, **?**] would allow the known elementary particles.

5.6 SUSY at the level of WCW

Yleistys WCW tasolle.

Kognitiivinen esitys: pisteiden K-koodinaateille super-vastineet hyvin määriteltyjä ja vastaavat bosoneja. Spinorit samoin. Säilyvät Noether varaukset ja super-Noether varaukset. Antikommutaattorit näille ja WCW metriikka.

Onko mukana integraali yli thetojen joka siis vastaisi vakuumiekspektaatiota.

5.7 S-matrix and SUSY

The construction of S-matrix has been one of the eternity projects of TGD. There are many proposals such as the construction based on the quaternionic generalization of twistor Grassmannian approach for cognitive representations involving huge simplification due to the vanishing of loop diagrams [**?**, **?**, **?**] but also this approach is indirect. SUSY in TGD sense finally suggests a quite concrete fundamental approach.

1. The construction would be based on the explicit solution of the super-symmetrized field equations. In principle everything reduces formally to classical partial differential equations for super-space-time surface and super-spinors. One solves preferred extremal as its super-variants which means solving the space-time evolution of multi-spinors defining super-coordinates and in this background one solves super-Dirac equation. This is highly non-trivial but in principle a well-defined procedure. If one gives initial values of various multi-spinor mods at the first light-like boundary of causal diamond (CD), one can deduce super-spinor field at opposite boundary of CD and express it as a superposition of its basic modes with well-defined quark number and other quantum numbers. This gives S-matrix.

2. Situation simplifies dramatically for discrete cognitive representation replacing space-time surface with the set of points having imbedding space coordinates in extension of rationals defining the adele. Since finite set of points defining the preferred time scales $t = r_n$ as roots of a real polynomial determines the octonionic polynomia, $M^8 - H$ duality raises the hope that the discretization provided by cognitive representation is exact and improvement in UV/IR resolution means addition of new space-time sheets with smaller/bigger size.

3. Partonic 2-surfaces define topological vertices. They are identified as intersections of incoming particle like 4-surfaces as roots of octonionic polynomials with 6-sphere defining analogs of branes in M^8 as universal roots of octonionic polynomials and having M^4 time $t = r_n$ hyperplanes of M^4 as their intersections.

   Multi-quark-antiquark vertices at partonic 2-surfaces are points of cognitive representation having H-coordinates in an extension of rationals (or at least their pre-images in M^8 have this property). Lines defining local multi-quark states fuse and split again into new states in quark number conserving manner. Vertices are super-symmetric in TGD sense and determined as vacuum expectations of the bosonic action and super-Dirac action and analogous to those defined by θ integration in SUSY.

4. The counterparts of radiative corrections of QFTs are Wick contraction terms for the fermionic oscillator operators. $M^8 - H$ duality requires that their contribution from partial multi-derivatives of order higher than the order n of the octonionic polynomial are vanishing. This leads to the conditions having interpretation as conservation of Noether currents of symmetries. As n increases, the number of Wick contractions increases and this gives rise to discrete coupling constant evolution as function of the dimension of extension of rationals defined by the octonionic polynomial.

5. No further quantization is needed since super-symmetrization corresponds to second quantization. This is part of the realization of the dream about geometrizing also quantum theory. This should have been realized long time ago also by colleagues since SUSY algebra is Clifford algebra like also oscillator operator algebra.

6 Twistor lift of TGD

In twistor Grassmannian approach to $\mathcal{N} = 4$ SYM twistors are replaced with supertwistors and the extreme elegance of the description of various helicity states using twistor space wave functions suggests that super-twistors are realized at the level of M^8 geometry. These supertwistors are realized at the level of momentum space.

In TGD framework $M^8 - H$ duality allows to geometrize the notion of super-twistor at the level of M^8 in the sense that different components of super-field correspond to components of super-octonion each of which corresponds to a space-time surfaces satisfying minimal surface equations with string world sheets as singularities - this is geometric counterpart for masslessness.

6.1 Basic problem of twistor approach and mass as a relative notion in TGD framework

The basic problem of the ordinary twistor approach is that the states must be massless in 4-D sense. In TGD framework particles would be massless in 8-D sense. This leads to alternative descriptions depending on the choice of $M^4 \subset M^8$ and the 4-D mass of the particle depends on the choice of M^4. For M^4_L description $M^4_L \subset M^8$ is chosen so that states are massless in 4-D sense, and the description at momentum space level would be in terms of products of ordinary M^4 twistors and CP_2 twistors. For M^4_T description particles are massive in 4-D sense. How to generalize the twistor description to 8-D case?

The incidence relation for twistors suggests the replacement of the usual twistors with either non-commutative quantum twistors or with octo-twistors. Quantum twistors could be associated with the space-time level description of massive particles and octo-twistors with the description at imbedding space level. A possible alternative interpretation of quantum spinors is in terms of quantum measurement theory with finite measurement resolution in which precise eigenstates as measurement outcomes are replaced with universal probability distributions defined by quantum group. This has also application in TGD inspired theory of consciousness.

6.2 Criticizing the original TGD based view about twistor space of M^4

Twistor lift of TGD involves representation of space-time surfaces as 6-surfaces in twistor space of H having structure of S^2 bundle over space-time surface resulting in dimensional reduction. These 6-surfaces would be holomorphic and thus minimal surfaces represented in terms of polynomials having same degree as the corresponding M^8 octonionic polynomial by number theoretic universality. Theiy would have 2-D singularities as string world sheets and partonic 2-surfaces at which the quaternionic structure of tangent space or normal space would degenerate to 2-D one due to the the fact that two quaterionic units become parallel.

1. The original assumption was that the geometric twistor space of M^4 is simply $M^4 \times S^2$ rather than hyperbolic variant $CP_{3,h}$ of CP_3 with metric signature $(3,3)$. It however turned out that one can consider $CP_{3,h}$ with metric signature (3,3) as an alternative. This option reproduces the nice results of the earlier approach but the philosophy is different: there is no fundamental length scale but the hierarchy of causal diamonds (CDs) predicted by zero energy ontology (ZEO) gives rise to the breaking of the exact scaling invariance of M^8 picture. This forces to modify $M^8 - H$ correspondence so that it involves map from M^4 to CP_3 followed by a projection to hyperbolic variant of CP_2.

   M^4 in H would not be replaced with conformally compactified M^4 (M^4_{conf}) but conformally compactified cd (cd_{conf}) for which a natural identification is as CP_2 with second complex coordinate replaced with hypercomplex coordinate. The sizes of twistor spaces of cd_{conf} using CP_2 size as unit would reflect the hierarchy of size scales for CDs. The consideration

on the twistor space of M^8 in similar picture leads to the identification of corresponding twistor space as HP_3 - quaternionic variant of CP_3: the counterpart of CD_8 would be HP_2.

2. Octotwistors can be expressed as pairs of quaternionic twistors. Octotwistor approach suggests a generalization of twistor Grassmannian approach obtained by replacing the bi-spinors with complexified quaternions and complex Grassmannians with their quaternionic counterparts. Although TGD is not a quantum field theory, this proposal makes sense for cognitive representations identified as discrete sets of spacetime points with coordinates in the extension of rationals defining the adele [**?**] implying effective reduction of particles to point-like particles.

3. The outcome of octo-twistor approach together with $M^8 - H$ duality leads to a nice picture view about twistorial description of massive states based on quaternionic generalization of twistor 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. 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.

6.3 Twistors and super-twistors in TGD framework

What about super-twistors in TGD framework?

1. The parallel progress in the understanding SUSY in TGD framework [**?**] in turn led to the identification of the super-counterparts of M^8, H and of twistor spaces modifying dramatically the physical interpretation of SUSY. Super-spinors in twistor space would provide the description of quantum states. Super-Grassmannians would be involved with the construction of scattering amplitudes. Quaternionic super Grassmannians would be involved with M^8 description.

2. The great surprise from physics point of view is that in fermionic sector only quarks are allowed by $SO(1,7)$ triality and that anti-leptons are local 3-quark composites identifiable as spartners of quarks. Gauge bosons, Higgs and graviton would be also spartners and assignable to super-coordinates of imbedding space expressible as super-polynomials of quark oscillator operators. Super-symmetrization means also quantization of fermions allowing local many-quark states.

3. SUSY breaking would be caused by the same universal mechanism as ordinary massivation of massless states. The mass formulas would be supersymmetric but the choice of p-adic prime identifiable as ramified prime of extension of rationals would depend on the state of super-multiplet. ZEO would make possible symmetry breaking without symmetry breaking as Wheeler might put it.

What about the interpretation of quantum twistors? They could make sense as 4-D space-time description analogous to description at space-time level. Now one can consider generalization of the twistor Grassmannian approach in terms of quantum Grassmannians.

6.4 Spinors in twistor space

7 Some applications of TGD

7.1 Standard model as QFT limit of TGD

Induction procedure

Many-sheeted space-time

QFT limit
Valmis

7.2 TGD and particle physics

7.2.1 The development of the model for elementary particle

7.2.2 $M^8 - H$ duality and the two manners to describe particles

The isometry groups for $M^4 \times CP_2$ is $P \times SU(3)$ (P for Poincare group). The isometry group for $M^8 = M^4 \times E^4$ with a fixed choice of M^4 breaks down to $P \times SO(4)$. A further breaking by selection $M^4 \subset M^2$ of preferred octonionic complex plane M^2 necessary in the algebraic approach to space-time surfaces $X^4 \subset M^8$ brings in preferred rest system and reduces the Poincare symmetry further. At the space-time level the assumption that the tangent space of X^4 contains fixed M^2 or at least integral distribution of $M^2(x) \subset M^4$ is necessary for $M^8 - H$ duality [**?**].

The representations $SO(4)$ and $SU(3)$ could provide alternative description of physics so that one would have what I have called $SO(4) - SU(3)$ duality [**?**]. This duality could manifest in the description of strong interaction physics in terms of hadrons and quarks respectively (conserved vector current hypothesis and partially conserved axial current hypothesis based on $Spin(SO(4)) = SU(2) \times SU(2)_R$. The challenge is to understand in more detail this duality. This could allow also to understand better how the two twistor descriptions might relate.

$SO(4) - SU(3)$ duality implies two descriptions for the states and scattering amplitudes.

Option I: One uses projection of 8-momenta to a fixed $M^4_T \supset M^2$.

Option II: One assumes that $M^4_L \supset M^2$ is defines the frame in which quaternionic octonion momentum is parallel to M^4_L: this M^4_L depends on particle state and describes this dependence in terms of wave function in CP_2.

7.3 Option I: fixed $M^4_T \supset M^2$

For Option I the description would be in terms of a *fixed* $M^4_T \subset M^8 = M^4_T \times E^4$ and $M^2 \subset M^4_T$ fixed for both options. For given quaternionic light-like M^8 momentum one would have projection to M^4_T, which is in general massive. E^4 momentum would have same the length squared by light-likeness.

De-localization M^4_T mass squared equal to $p^2(M^4_T) = m^2$ in E^4 can be described in terms of $SO(4)$ harmonics at sphere having $p^2(E^4) = m^2$. This would be the description applied to hadrons and leptons and particles treated as massive particles. Particle mass would be due to the fixed choice of M^4_T. What dictates this choice is an interesting question. An interesting question is how these descriptions relate to QFT Higgs mechanism as (in principle) alternative descriptions: the choice of fixed M^4_T could be seen as analog for the generation of vacuum expectation of Higgs selecting preferred direction in the space of Higgs fields.

7.4 Option II: varying $M^4_L \supset M^2$

For Option II the description would use $M^4_L \supset M^2$, which is *not fixed* but chosen so that it contains light-like M^8 momentum. This would give light-like momentum in M^4_L identifiable as quaternionic sub-space of complexified octonions.

1. One could assign to the state wave function function for the choices of M^4 and by quaternionicity of 8-momenta this would correspond to a state in super-conformal representation with vanishing M^4_L mass: CP_2 point would code the information about E^4 component light-like 8-momentum. This description would apply to the partonic description of hadrons in terms of massless quarks and gluons.

2. For this option one could use the product of ordinary M^4 twistors and CP_2 twistors. One challenge would be the generalization of the twistor description to the case of CP_2 twistors.

The natural question is what this means from the point of view of p-adic particle massivation [**?**]. The basic new result is that $M^8 - H$ duality allows to see particles in two manners. In M^8 picture

particles are massive and correspond to a fixed $M^4 \subset M^8$: in this case symmetry group os $SO(4)$: this could correspond to low energy hadron physics. In $M^4 \times CP_2$ picture particles are massless and symmetry group is $SU(3)$: this picture would correspond to high energy hadron physics with massless quarks and gluons. It is shown that p-adic mass calculations performed $M^4 \times CP_2$ picture are consistent with the massless of the particles: in zero energy ontology (ZEO) it is possible to have quantum superpositions of particles with different mass and this is consistent with the description of the situation in terms of p-adic thermodynamics.

At first glance the two pictures about description of light-like M^8 momenta do not seem to be quite consistent with the recent view about TGD in which H-harmonics describe massivation of massless particles.

What looks like a problem is following.

1. The resulting particles are massive in M^4. But they should be massless in $M^4 \times CP_2$ description. The non-vanishing mass would suggest the correct description in terms of Option I for which the description in terms of E^4 momenta with length equal to mass and thus identifiable as points of S^3. Momentum space wave functions at S^3 - essentially rigid body wave functions given by representation matrices of $SU(2)$ could characterize the states rather than CP_2 harmonic.

2. The description based on CP_2 color partial waves however works and this would favor Option II with vanishing M^4 mass. What goes wrong?

To understand what might be involved, consider p-adic mass calculations.

1. The massivation of physical fermion states includes also the action of super-conformal generators changing the mass. The particles are originally massless and p-adic mass squared is generated thermally and mapped to real mass squared by canonical identification map.

   For CP_2 spinor harmonics mass squared is of order CP_2 mass squared and thus gigantic. Therefore the mass squared is assumed to contain negative tachyonic ground state contribution due to the negative half-odd integer valued conformal weight $h_{vac} < 0$ of vacuum. The origin of this contribution has remained a mystery in p-adic thermodynamics but it makes possible to construct massless states. h_{vac} cancels the spinorial contributions and the contribution from positive conformal weights of super-conformal generators so that the particle states are massless before thermalization. This would conform with the idea of using varying M^4_L and thus CP_2 description.

2. What does the choice of M^4 mean in terms of super-conformal representations? Could the mysterious vacuum conformal weight h_{vac} provide a description for the effect of the needed $SU(3)$ rotation of M^4 from standard orientation on super-conformal representation. The effect would be very simple and in certain sense reversal to the effect of Higgs vacuum expectation value in that it would cancel mass rather than generate it.

   An important prediction is that heavy states should be absent from the spectrum in the sense that mass squared would be p-adically of order $O(p)$ or $O(p^2)$ (in real sense of order $O(1/p)$ or $O(1p^2)$). The trick would be that the generation of h_0 as a representation of SU(3) rotation of M^4 makes always the dominating contribution to the mass of the state vanishing.

   Remark: If the canonical identification I mapping the p-adic mass integers to their real numbers is of the simplest form $m = \sum_n x_n p^n \to I(m) = \sum_n x_n p^{-n}$, it can happen that the image of rational m/n with p-adic norm not larger than 1 represented as p-adic integer by expanding it in powers of p, can be near to the maximal value of p and the mass of the state can be of order CP_2 mass - about 10^{-4} Planck masses. If the canonical identification is defined as $m/n \to I/(m)/I(n)$ the image of the mass is small for small values of m and n.

7.5 ZEO forces p-adic particle massivation

Why p-adic massivation should occur at all? Here ZEO comes in rescue.

1. In ZEO one can have superposition of states with different 4-momenta, mass values and also other charges: this does not break conservation laws. How to fix M^4 in this case? One

cannot do it separately for the states in superposition since they have different masses. The most natural choices is as the M^4 associated with the dominating contribution to the zero energy state. The outcome would be thermal massivation described excellently by p-adic thermodynamics [**?**]. Recently a considerable increase in the understanding of hadron and weak boson masses took place [**?**].

2. In ZEO quantum theory is square root of thermodynamics in a well-defined formal sense, and one can indeed assign to p-adic partition function a complex square root as a genuine zero energy state. Since mass varies, one must describe the presence of higher mass excitations in zero energy state as particles in M^4 assigned with the dominating part of the state so that the observed particle mass squared is essentially p-adic thermal expectation value over thermal excitations. p-Adic thermodynamics would thus describe the fact that the choice of M_L^4 cannot not ideal in ZEO and massivation would be possible only in ZEO.

3. Current quarks and constituent quarks are basic notions of hadron physics. Constituent quarks with rather large masses appear in the low energy description of hadrons and current quarks in high energy description of hadronic reactions. That both notions work looks rather paradoxical. Could massive quarks correspond to M_T picture and current quarks to M_L^4 picture but with p-adic thermodynamics forced by the superposition of mass eigenstates with different masses.

   The massivation of ordinary massless fermion involves mixing of fermion chiralities. This means that the $SU(3)$ rotation determined by the dominating component in zero energy state must induce this mixing. This should be understood.

7.5.1 Particle spectrum from TGD view about SUSY

7.5.2 p-Adic Physics and Particle Massivation

p-Adinen fysiikka ja adelinen fysiikka

1. Taustaa:

Higgsin mekanismin ongelma: pelkkä parametrisointi. Ei oikeasti ennusta fermionimassoja. Bosonimassat myös vaikutuksen parametreista.

p-Adiset massalaskut. Massivoituminen täysin universaali p-adisen termodynamiikan kautta: ei riippuvuutta dynamiikan detaljeista.

p-Adinen termodynamiikka massan neliölle. Super-konformi-symmetria. Lukuteoreettinen olemassaolo Boltzmannin painoille. Korvaisi Higgsin mekanismi massivoitumisen kuvaajana. p-Adinen pituus-skaala-hypoteesi.

Mikä määrää preferoidut p-adiset alkuluvut?

7.5.3 Trying to understand why ramified primes are so special

Ramified primes (see `http://tinyurl.com/m32nvcz` and `http://tinyurl.com/y6yskkas`) are special in the sense that their expression as a product of primes of extension contains higher than first powers and the number of primes of extension is smaller than the maximal number n defined by the dimension of the extension. The proposed interpretation of ramified primes is as p-adic primes characterizing space-time sheets assignable to elementary particles and even more general systems.

In the article [**?**] Dedekind zeta functions (see `http://tinyurl.com/y5grktvp`) as generalization of Riemann zeta [**?**, **?**] are studied to understand what makes them so special. Dedekind zeta function characterizes given extension of rationals and is defined by reducing the contribution from ramified reduced so that effectively powers of primes of extension are replaced with first powers.

If one uses the naive definition of zeta as analog of partition function and includes full powers $P_i^{e_i}$, the zeta function becomes a product of Dedekind zeta and a term consisting of a finite number of factors having poles at imaginary axis. This happens for zeta function and its fermionic analog having zeros along imaginary axis. The poles would naturally relate to Ramond and N-S boundary conditions of radial partial waves at light-like boundary of causal diamond CD. The additional factor could code for the physics associated with the ramified primes.

The intuitive feeling is that quantum criticality is what makes ramified primes so special. In $O(p) = 0$ approximation the irreducible polynomial defining the extension of rationals indeed reduces to a polynomial in finite field F_p and has multiple roots for ramified prime, and one can deduce a concrete geometric interpretation for ramification as quantum criticality using $M^8 - H$ duality.

It would seem that the number theoretic fight for survival is between extensions of rationals. Intuition suggests that survivors tend to have maximal number of ramified primes representing primes able to living in symbiosis. They can live in same extension - to "co-operate". Ramified primes are by definition the primes dividing the discriminant D of the extension defined as the product $\prod_i i \neq j(r_i - r_j)$ of differences of the roots of the (irreducible) polynomial defining the extensions.

7.5.4 p-Adic mass calculations

Ramified primes as preferred primes. Collection of ramified primes assigned with particular physics. Analogy with genes.

p-Adic thermodynamics. Massless ground states. Thermodynamical mixing in ZEO implies massivation in M^4xCP_2 picture if massless ground state determines $M^4 \subset M^8$. Higher excitations are massive. Negative vacuum conformal weight finds an explanation. Quantization.

Do hadrons correspond to M^8 picture or is mass also now thermal expectation? Understanding of hadron masses. MB.

7.5.5 New particle physics predicted by TGD

7.6 TGD and astrophysics and cosmology

7.7 TGD and atomic and molecular physics

8 ZEO and Extension of Quantum Measurement Theory to a Theory of Consciousness

8.1 Motivations for ZEO

1. Motivaatioita.

a) Yleisen koordinaatti-invarianssin realisaatio. Onko mahdollista löytää 1-käsitteinen preferred exstremaali kolmipinnan kautta siten, että se on sama kaikille muille kolmipinnoille jotka preferred extremaalilla. Miksi esimerkiksi absoluuttinen minimi olisi sama kaikille. Tämä ei näytä todennäköiseltä jos kolmipinta t= vakio snaphotissa.

Entä jos valitaan pari kolmipintoja kahdessa eri t= vakio snapshoteissa. Tällöin niiden kautta kulkeva nelipinta voi olla hyvinkin yksikäsitteinen jos sitä yleensä on. Noether varaukset säilyvät. Kirjanpidollisesti mahdollista sanoa, että säilyvät suureet vastakkaiset kahdelle päälle. Kenttäteoriassa näin sanottaisiinkin. Nolla-energia-ontologia.

b) Supersymplektinen mitta-invarianssi aliryhmälle voi antaa lisäehtoja. Super-symplektinen mitta-invarianssi realisoituu luontevasti valokartion reunalla. Tarkka formulaatio Wick kontraktion kansellaation avulla. Ehdot näyttävät pätevän super-versiolle. Voisiko ajatella että kolmipinnat parissa ovat $CD = cd \times CP_2$:n vastakkaisilla reunoilla. CD:llä skaala-hierarkia.

CD tulkittavissa perkeptiivisenä kenttä tajuiselle entiteetille. Ylempi valokartio rajoittaa alueen josta aistisyötettä voi tulla. Alempi valokartio rajoittaa alueen josta "kehon sisäistä" aistisyötettä voi tulla. Näiden leikkaus rajoittaa alueen josta kehonsisäinen aistisyöte tulee.

Kysymyksiä: Twistori-lift pakottaa pinnan minimaalipinnaksi jolla säikeiden radat singulariteetteina. M^8 tasolla esittyminen polynomin nollakohtina antaa myös ehtoja. Ovatko ehdot ekvivalentit tai lisäehtoja.

b) Mitan kiinnittäminen yleiselle koordinaatti-invarianssille. Miten fiksata yksikäsitteisesti preferoitu kolmipinta?

Jos pinnat pareja pinnoista CD:n reunoilla niin tämä ongelma ratkeaa. Voi pohtia muitakin vaihtohtoja esimerksi oktoniopolymin juurien määräämiä M^4:n hypertasoja joihin liittyy S^6 braanina.

8.2 Direct experimental evidence for ZEO

I encountered a very interesting ScienceDaily article "*Physicists can predict the jumps of Schrdinger's cat (and finally save it)*" (see `http://tinyurl.com/y5lpe2eo`). The experimental findings described in the article are extremely interesting from the point of view provide by TGD inspired quantum measurement theory relying on Zero Energy Ontology (ZEO) and provides a test for it.

In standard quantum measurement theory (Copenhagen interpretation) of Bohr quantum jump is random in the sense that it occurs with predictable probabilities to an eigenstate of the measured observables. Quantum jumps are also instantaneous and their occurrence cannot be predicted and even less prevented - except by monitoring - Zeno effect.

The findings of Minev et al are described in the article "*To catch and reverse a quantum jump mid-flight*" [**?**] (see `https://arxiv.org/abs/1803.00545`). The outcome of quantum jump is indeed unpredictable but the time of occurrence is to high degree predictable: there is a detectable warning signal, period of "flight" from the initial to the final state!

A curious feature is that the external signal responsible for the quantum jump can be stopped during the "flight" from the initial to final state. As if the quantum jump is analogous to a domino effect. It is also claimed that the jump can be reversed during flight period by a control signal: if jump has already occurred then one might argue that the control signal induces quantum jump in opposite direction when applied at time which is roughly the mid-time of "flight".

If the findings by Minev et al are replicable, one is forced to give up the basic assumption of the standard quantum measurement theory stating that state function reductions occur completely randomly and instantaneously. State function reduction (SR) looks like a continuous, deterministic process. Bohr's theory would be dead also officially and one must finally go back to the blackboard and start serious thinking about fundamentals. It took 92 years - almost a century! State function reduction (SR) is definitely more complex phenomenon than predicted by Bohr.

What is most intriguing that SR looks smooth, deterministic classical time evolution although the outcome is not predictable. People loving hidden variables might be happy but better to think about this more precisely before jumping to any conclusions. Authors apply so called quantum trajectory theory to describe the findings [**?**] and report that the model is able to predict the parameters of the parameterization with one per cent accuracy.

Zero energy ontology (ZEO) based view about quantum measurement and the relationship between geometric and subjective time explains why state function reduction looks like a deterministic process. Unfortunately, what ZEO is, is not completely clear [**?**]. This allows to consider two options.

1. Both options imply that one can apparently anticipate quantum jump. This could be however an illusion: the observed classical time evolution could occur *after* the quantum jump in opposite direction of time. The fact that the absence of the signal inducing quantum jump does not affect the occurrence of quantum jump suggests that the "flight" period indeed represents the classical evolution after the quantum jump in the reversed direction of time so that the absence of the external signal would not anymore affect the situation.

   The most plausible interpretation for the control signal apparently stopping the reduction process is that it induces the reversal of the quantum jump already occurred. A careful analysis to distinguish between subjective and geometric time and arrows of time for the observer and atom would be needed.

2. The more conventional option nearer to the interpretation of experimenters is that the observed time evolution occurs *before* the quantum jump in standard direction. The period before quantum jump consists of a sequence of "small" state function reductions - "weak" measurements. $M^8 - H$ duality suggests a concrete assignment of the moments of time to them [**?**]nd there would be also the last moment of this kind. After these things proceed to "big" state function reduction in analogy with domino effect. It is not however obvious why the classical time evolution should appear to converge to the final outcome deterministically so that this option does not look plausible.

Interestingly, the Libet's findings that conscious decision is preceded by neural activity [**?**] could be interpreted in the same manner. Free will would not be an illusion anymore. Rather, the time reversed deterministic and smooth geometric time evolution starting from the final state of act of

free will (index finger raised) would lead to brain state in geometric past apparently giving rise to the raising of the index finger. The crucial point would be the fact that there are two times: subjective time and geometric time.

8.3 Generalization of Quantum Measurement Theory to a Theory of Consciousness

Materialism/physicalism is kind of meta problem eliminating altogether any serious consideration of the problem. Consciousness is assumed to be property of physical system completely fixed by its physical state. Free will would be illusion. The term conscious-"ness" already reflects the materialistic view. In finnish language the word "tajunta" avoids the interpretation as a property. To proceed, one must give up physicalism. One can proceed further to TGD inspired theory of consciousness by making questions.

Problem #1: How free will could be consistent with the determinism of field equations? What free will could be? It sees that behaviour is built from deterministic time evolutions connecting initial and final states: functions, behaviors, computer programs. Could free be in the selection between them. This suggests a new ontology in which deterministic time evolution becomes basic entity instead of time=constant snapshot of history.

Problem #2: Similar problem plagues quantum measurement theory. State function reduction (SR) is non-deterministic and Schrödinger equation deterministic. This has led to myriads of "interpretations".

The key idea is to replace the usual approach to physics equations as initial value problem with single time =constant snapshot with positions and initial velocities fixed with boundary value problem. One has two time=constant snapshots t_1 and t_2 and fixes now only the initial positions (but not velocities) at them. This can be generalized to fields and their initial values and even to space-time surfaces by replacing boundary values with 2 3-surfaces at time=constant snapshots. This picture is not quite correct but is concrete. A more precise picture will be described below.

Problem disappears if SR selecs between quantum history defined as a superposition of classical deterministic histories - preferred exremals (PEs) of classical action. Classical physics would become exact part of quantum theory rather than mere approximation. One could speak of zero energy ontology (ZEO): zero energy states (ZESs) would be superpositions of pairs of ordinary quantum states (time=constant snapshot) at different values t_1 and t_2 of time coordinates and only those pairs connected by deterministic time evolution would be allowed.

This would imply classical and quantum conservation laws and total quantum numbers for initial and final states would be same - for book keeping purposes one can say that total conserved quantum numbers are opposite at the two ends - this is the practice in quantum field theories. Hence the term ZES.

The classical time evolutions in the superposition defining ZES are analogous to events in classical sense. They are however not events in the sense of non-terministic SRs and cannot involve free will.

Problem #3: Experienced time and geometric time of physicist are very different. Subjective time however correlates with the geometric time: contents of sensory experience correspond to moment of geometric time with accuracy of .1 second.

Are there two times and two causalities? Could subjective time correspond to a sequence of SRs occurring between ZESs. The correlation between the two times requires that in SR the temporal distance $t_1 - t_2$ increases. Two arrows of time are possible- either t_1 or t_2 changes.

Problem #4: Observer is still an outsider in quantum theory. Observations affect the measured system but there is not attempt to understand the observer as a part of quantum system. Quantum theory of consciousness sould be a generalization of quantum measurement theory. The central notion is that of self replacing that of observer.

1. Self is a system having quantum identity and thus able to remain unentangled during time evolution. Schrödinger evolution with non-trivial interactions however entangles the system immediately.

   On the other hand, Zeno effect is known to occur and means that system remains un-entangled when observables are measured repeatedly. Isn't ordinary ontology enough? In some sense

conscious entity - self - should have part remaining un-entangled during subsequent measurements.

2. Here zero energy ontology (ZEO) comes in rescue. ZESs are superpositions of pairs of ordinary states at times t_1 and $t_2 > t_1$. Could the state assignable to self at say t_1 be un-entangled and remain unaffected during subsequent SRs affecting only the states at t_2? Self could be identified as the development of ZES by a sequence of unitary evolutions of the active part of the state at t_2 followed by SR each. Self would have passive part P corresponding to t_1 - the unchanging part of self and the active part A assignable to t_2 corresponding to sensory input and everything related to it.

   Self would be a generalized Zeno effect. t_2 would increase - at least in statistical sense in each unitary evolution between two SRs. The increase of t_2 would correspond to the increase of clock time. There would be the desired correspondence between experienced time as a sequence of these SRs and geometric/clock time as $t = t_2 - t_1$. The sensory input and all induced by it would come from these SRs and allow to assign clock time to experienced time flow.

   The SR in question cannot correspond to ordinary SR since in standard quantum theory nothing would happen in it (Zeno effect). This "small" SR (SSR) is however analogous to so called weak SR (see `http://tinyurl.com/zt36hpb`) which is much like classical measurement.

3. What about standard SR - the "big" SR (BSR)? Above it was assumed that t_1 corresponds to P. Why also why $t_2 > t_1$ could not correspond to P? The arrow of time a property of ZES would be reversed. Could BSRs correspond to SRs changing the roles of A and P. The identification would be as "death" of self and reincarnation as self with opposite arrow of time. These reduction would take place routinely in elementary particle scales, where the lifetimes of selves would be shorter. In the next BSR self would reincarnate in the original arrow of time.

Problem #5: Are we the only conscious systems or is pan-psychism realized in some sense? For physicist it is very difficult to imagine anything but pan-panpsychism. There would be self hierarchy corresponding to length scale hierarchy. Self would have sub-selves, which it experiences as mental images. Sub-sub-selves would be experienced as kind of averages. Self in turn defines mental image of self above it. These 3 preferred levels in hierarchy for given self would correspond to super-ego-ego-Id triplet of Freud.

The sequence of reincarnations can be experienced by self in the phenomenon of after images in which visual (say) mental image re-appears repeatedly. The time reversal of the mental images would not be experienced by self.

Problem #6: As already noticed, the realization of ZEO in terms of snapshots is not realistic. How to realize ZEO physically? Standard quantum theory does not allow the realization of ZEO. TGD framework led to ZEO and to a realization for the notion of self.

1. Quite generally, one can solve the basic problem of quantum measurement theory by replacing initial value problem of classical physics with boundary value problem. A pair of time=constant snapshots is however not the optimal choice.

   Rather, causal diamond (cd) formed as an intersection of future and past directed light-cones of M^4 is a more natural notion. cd is formed as spherical light front expands for time $T/2$ and contracts for time $T/2$ after that. The temporal distance between the tips of cd is T. The boundary of cd has two pieces opposite to each other. They are parts of light-cone boundary meeting at the sphere $r = T/2$. At the level of H cd is replaced with CD $=cd \times CP_2 \subset M^4 \times CP_2$.

   CD is identified as a imbedding space correlate for self determining the perceptive field of self. One has actually entire hierarchy of CDs within CDs with varying quantized size assignable to self hierarchy.

   (a) CD is more natural than pair of time=constant snapshots of H since the infinite size of the space-bounded by time=constant snapshots of H is mathematically problematic. The boundary of CD is also connected.

(b) CD is natural in WCW geometry since its boundary has symplectic transformations of light-cone boundary as infinite-D symmetries analogous to Kac-Moody symmetries with light-like radial coordinate in the same role as the complex coordinate in conformal field theories. The metric 2-D of light-cone boundary of M^4 also implies huge extension of ordinary conformal symmetries.

(c) CD has a natural interpretation as a correlate for the perceptive field of self. The past-direct light-cone defines the region about which sensory input comes as classical signals. The intersection of future directed light-cone with past-directed light-cone boundary defines the region from which the sensory input from self as a conscious entity emerges.

2. Zero energy ontology (ZEO) involves the hierarchy of causal diamonds (CDs) as correlates for perceptive fields of selves. The idea about ZES as pair of states at time t_1 and t_2 is not natural in TGD framework and is replaced with a notion consistent with the infinite-dimensional symmetries of TGD assignable to the light-cone boundary and to light-like 3-surfaces which play key role in TGD.

3. ZESs are superpositions of deterministic classical time evolutions connecting passive "lower" boundary P and active "upper" boundary A of CD. The classical deterministic time evolution corresponds to a space-time surface - preferred extremal (PE) - connecting the 3-surfaces at P and A. There are also spinor fields obeying deterministic dynamics dictated by super-conformal symmetry.

4. The active boundary A of CD moves farther away from the passive boundary P by unitary time evolutions inducing de-localization of A. SSR induces localization of A and after it ZES corresponds to single CD. The temporal distance between the tips of CD increases in statistical sense.

   In BSR the roles of A and P change and the former P begins to shift to opposite direction of geometric time. CD however increases in statistical sense all the subjective time. This increase would correspond to cosmic expansion. Could selves evolve gradually evolve to entire cosmologies? Their energy content would increase. This is not prevented by ZEO: classical conservation laws hold true for all PEs but due to the localizations of CDs energy conservation in quantal sense can be broken slightly.

In Appendix quite recent direct experimental evidence for ZEO provided by experiments of Minev et al [**?**] is discussed: a longer discussion can be found at [**?**]. These findings allow also to interpret Libet's findings related to the active aspects of consciousness [**?**].

Problem #7: What about the physical and possible space-time correlates for cognition and imagination?

1. p-Adic number fields, $p = 1, 2, 3, 5, 7...$ [**?**] obtained as completions of rationals emerged to TGD via p-adic mass calculations relying p-adic length scale hypothesis (see `http://tinyurl.com/y3auow4a`) are for several reasons natural candidates for the correlates of cognition. p-Adic topology defined by ultrametric was proposed already by Parisi [**?**] to be natural for description of cognition. Non-determinism of p-adic differential equations due to the p-adic pseudo-constants having vanishing derivative but depending on finite number of pinary digits serves as a natural space-time correlate for imagination. Only the regions in which pseudo-constant are genuine constants have real counterparts and are realizable imaginations.

2. p-Adic physics would be a natural correlate for cognition. Correlates of imagination would be space-time sheets obeying the same field equations as real ones. Cognitive representation are discrete and finite and would consist of a discrete sets of point of space-time surface for which imbedding space coordinates belong to an extension of rationals so that they are shared by real and various p-adic space-time sheets.

3. Ramified primes of n-D extension allow product composition as a product of primes of the extension such that the number of these primes is smaller than n with some primes of extension appearing as powers higher than 1. In the case of split primes this number has the

maximal value n and for non-split primes the number is 1: the numbers of these two kinds of primes are infinite whereas the number of ramified primes is finite. Furthermore, the p-adic counterparts of polynomials defining space-time surface in M^8 and extension of rationals via their roots have in $O(p) = 0$ approximation multiple roots so that they correspond to critical dynamics for cognition and physics too.

The quantum criticality of TGD therefore suggests that ramified primes are both cognitively and physically preferred (defining preferred p-adic length scales as kind of set of organisms able to live in symbiosis). Therefore the collection of ramified primes of extension defines a special set. For hierarchies of polynomials obtained by functional composition $P = P_{n_k} \circ P_{n_{k-1}} .... \circ P_{n_1}$ of irreducible polynomials with the property $P_r(0) = 0$ the ramified primes of all levels are ramified of P and analogous to conserved genes as also the extensions in the hierarchy. One obtains infinite number of evolutionary hierarchies with conserved "genes" having also interpretation as an abstraction hierarchy.

Problem #8: How to understand intelligence and evolution of intelligence?

1. p-Adic number fields allow an infinite number of extensions induced by finite-dimensional extensions of rationals: besides algebraic extensions one can have extensions defined by roots of e. These define a hierarchy in which algebraic complexity increases.

2. The natural interpretation for the increase of the dimension of algebraic extension of rationals is as increase of the complexity of cognition and evolution can be assigned to the increase of extension of rationals. This increase is unavoidable since the number of extensions with dimension larger than given integer n is infinite and those with dimension smaller than n is finite. The value of effective Planck constant $h_{eff}/h_0 = n$ introduced by observations about effects of ELF em fields on brain and proposed to label a hierarchy of dark matters as phases of ordinary matter could correspond to the dimension of extension. The larger the value of n, the large the scale of quantum coherence, and the more complex the living systems in question.

   Remark: Shannon formula with the logarithm of probability replaced with the logarithm of the p-adic norm of probability allows negative values of Shannon entropy having interpretation as information associated with the entanglement [**?**] (see `http://tinyurl.com/ycxm2tpd`. Ordinary entanglement entropy measures the ignorance about the state of either entangled system.

3. All p-adic numbers fields are needed and this leads to a fusion of reals and the extensions of p-adic number fields induced by given extension of rationals to form an adele [**?**, **?**] (see `http://tinyurl.com/ycbhse5c`). The hierarchy of adeles defines an evolutionary hierarchy. The dimension $n = h_{eff}/h_0$ of extension serves as a universal "IQ".

4. A physical correlate for ethics is suggestive. Good deeds increase conscious information of the Universe. Bad deeds reduce the conscious information. Bad deeds indeed force secrecy and reduction of conscious information: evil doer does not usually boast with his deeds and unethical acts lead to secrecy.

These question represent only a small fraction of what must be understood. What are the correlates for directed attention, intentionality, emotions, memory, anticipation, qualia, etc..

8.4 $M^8 - H$ duality and TGD inspired theory of consciousness

The relation to TGD inspired theory of consciousness [**?**] deserves a separate discussion.

[**?**]

Branes Special moments in the life of self.

8.5 Objections against ZEO based theory of consciousness

8.5.1 Why not pairs of time=constant snapshots instead of CD

The first objection against ZEO based view about consciousness is that a pair of time=constant snapshots looks more natural object than CD.

1. One can solve the basic problem of quantum measurement theory by replacing initial value problem of classical physics with boundary value problem. CD is more natural than pair of time=constant snapshots of H since the infinite size of the space-bounded by time=constant snapshots of H is problematic.

2. CD has natural interpretation as a correlate for the perceptive field of self. The past-direct light-cone defines the region about which sensory input comes as classical signals. The intersectionf future directed light-cone with past-directed light-cone boundary defines the region from which the sensory input from self as a conscious entity emerges.

One could invent also other defenses for pair of time= constant snapshots-

1. ZEO (zero energy ontology) based view about conscious entity can be regarded as a sequence of "small" state function reductions (SSRs) identifiable as analogs of so called weak measurements at the active boundary of causal diamond (CD) receding reduction by reduction farther away from the passive boundary, which is unchanged as also the members of state pairs at it. One can say that weak measurements commute with the observables, whose eigenstates the states at passive boundary are. This asymmetry assigns arrow of time to the self having CD as imbedding space correlate. "Big" state function reductions (BSRs) would change the roles of boundaries of CD and the arrow of time. The interpretation is as death and re-incarnation of the conscious entity with opposite arrow of time.

   The question is whether quantum classical correspondence (QCC) could allow to say something about the time intervals between subsequent values of temporal distance between weak state function reductions.

2. The questionable aspect of this view is that $t_M = constant$ sections look intuitively more natural as seats of quantum states than light-cone boundaries forming part of CD boundaries. The boundaries of CD are however favoured by the huge symplectic symmetries assignable to the boundary of M^4 light-cone with points replaced with CP_2 at level of H. These symmetries are crucial or the existence of the geometry of WCW ("world of classical worlds").

3. Second objection is that the size of CD increases steadily: this nice from the point of view of cosmology but the idea that CD as correlate for a conscious entity increases from CP_2 size to cosmological scales looks rather weird. For instance, the average energy of the state assignable to either boundary of CD would increase. Since zero energy state is a superposition of states with different energies classical conservation law for energy does not prevent this [**?**]: essentially quantal effect due to the fact that the zero energy states are not exact eigenstates of energy could be in question. In BSRs the energy would gradually increase. Admittedly this looks strange and one must be keen for finding more conventional options.

4. Third objection is that re-incarnated self would not have any "childhood" since CD would increase all the time.

One can ask whether $M^8 - H$ duality and this braney picture has implications for ZEO based theory of consciousness. Certain aspects of $M^8 - H$ duality indeed challenge the recent view about consciousness based on ZEO (zero energy ontology) and ZEO itself.

1. The moments $t = r_n$ defining the 6-branes correspond classically to special moments for which phase transition like phenomena occur. Could $t = r_n$ have a special role in consciousness theory?

   (a) For some SSRs the increase of the size of CD reveals new $t = r_n$ plane inside CD. One can argue that these SSRS define very special events in the life of self. This would not modify the original ZEO considerably but could give a classical signature for how many ver special moments of consciousness have occurred: the number of the roots of P would be a measure for the lifetime of self and there would be the largest root after which BSR would occur.

(b) Second possibility is more radical. One could one think of replacing CD with single truncated future- or past-directed light-cone containing the 6-D universal roots of P up to some r_n defining the upper boundary of the truncated cone? Could $t = r_n$ define a sequence of moments of consciousness? To me it looks more natural to assume that they are associated with very special moments of consciousness.

2. For both options SSRs increase the number of roots r_n inside CD/truncated light-one gradually and thus its size? When all roots of $P(o)$ would have been measured - meaning that the largest value r_{max} of r_n is reached -, BSR would be unavoidable.

   BSR could replace $P(o)$ with $P_1(r_1 - o)$: r_1 must be real and one should have $r_1 > r_{max}$. The new CD/truncated light-cone would be in opposite direction and time evolution would be reversed. Note that the new CD could have much smaller size size if it contains only the smallest root r_0. One important modification of ZEO becomes indeed possible. The size of CD after BSR could be much smaller than before it. This would mean that the re-incarnated self would have "childhood" rather than beginning its life at the age of previous self - kind of fresh start wiping the slate clean.

   One can consider also a less radical BSR preserving the arrow of time and replacing the polynomial with a new one, say a polynomial having higher degree (certainly in statistical sense so that algebraic complexity would increase).

8.5.2 Could one give up the notion of CD?

A possible alternative view could be that one the boundaries of CD are replaced by a pair of two $t = r_N$ snapshots $t = r_0$ and $t = r_N$. Or at least that these surfaces somehow serve as correlates for mental images. The theory might allow reformulation also in this case, and I have actually used this formulation in popular lectures since it is easier to understand by laymen.

1. Single truncated light-cone, whose size would increase in each SSR would be present now since the spheres correspond to balls of radius r_n at times r_n. If $r_0 = 0$, which is the case for $P(o) \propto o$, the tip of the light-cone boundary is one root. One cannot avoid association with big bang cosmology. For $P(0) \neq r_0$ the first conscious moment of the cosmology corresponds to $t = r_0$. One can wonder whether the emergence of consciousness in various scales could be described in terms of the varying value of the smallest root r_0 of $P(o)$.

   If one allows BSR:s this picture differs from the earlier one in that CDs are replaced with alternation of light-cones with opposite directions and their intersections would define CD.

2. For this option the preferred values of t for SSRs would naturally correspond to the roots of the polynomial defining $X^4 \subset M^8$. Moments of consciousness as state function reductions would be due to collisions of 4-D space-time surfaces X^4 with 6-D branes! They would replace the sequence of scaled CD sizes. CD could be replaced with light-one and with the increasing sequence $(r_0, ...r_n)$ of roots defining the ticks of clock and having positive and negative energy states at the boundaries r_0 and r_n.

3. What could be the interpretation for BSRs representing death of a conscious entity in the new variant of ZEO? Why the arrow of time would change? Could it be because there are no further roots of $P(o)$? The number of roots of $P(o)$ would give the number of small state function reductions?

   What would happen to $P(o)$ in BSR? The vision about algebraic evolution as increase of the dimension for the extension of rationals would suggest that the degree of $P(o)$ increases as also the number of roots if all complex roots are allowed. Could the evolution continue in the same direction or would it start to shift the part of boundary corresponding to the lowest root in opposite direction of time. Now one would have more roots and more algebraic complexity so that evolutionary step would occur.

   In the time reversal one would have naturally $t_{max} \geq r_{n_{max}}$ for the new polynomial $P(t-t_{max})$ having $r_{n_{max}}$ as its smallest root. The light-cone in M^8 with tip at $t = t_{max}$ would be in opposite direction now and also the slices $t - t_{max} = r'_n$ would increase in opposite direction! One would have two light-cones with opposite directions and the $t = r_n$ sections would

replace boundaries of CDs. The reborn conscious entity would start from the lowest root so that also it would experience childhood.

This option could solve the argued problems of the previous scenario and give concrete connection with the classical physics in accordance with QCC. On the other hand, a minimal modification of original scenario combined with $M^8 - H$ duality with moments $t = r_n$ as special moments in the life of conscious entity allows also to solve these problems if the active boundary of CD is interpreted as boundary beyond which classical signals cannot contribute to perceptions.

9 TGD based quantum biology

One can approach TGD inspired quantum biology by making questions.

Problem #1: How to understand coherence of living systems? If only bio-chemistry is involved, we would be sacks of water and sacks of water do not climb in trees or write poems. Could quantum coherence induce the coherence? What entity serve as intentional agent and how it could realize its intentions?

1. Topological field quantization applies to electric and magnetic fields [**?**] (see `http://tinyurl.com/yxpomw9y`). For instance, magnetic field decomposes to flux tubes having finite thickness. Radiation fields are topologically quantized to topological light rays. Each system has its fields at separate space-time sheets touching each other only via wormhole contacts: system has field body, in particular magnetic body (MB) having hierarchical onion-like structure corresponding to the hierarchy of space-time sheets.

2. MB serves as the intentional agent using biological body (BB) as motor instrument and sensory receptor. MB controls BB via dark photon dark photon beams with large h_{eff}. The double BB + environment is replaced with the triple MB + BB+ environment.The vision about life as nothing but biochemistry is given up.

3. Experiments of Blackman [**?**] and others demonstrated the quantal effects of ELF radiation on vertebrate brain. For the ordinary value of Planck constant these effects are however impossible since the energy $E = hf$ of EEG photons is extremely small. This motivated what eventually became $h_{eff}/h_0 = n$ hypothesis derivable now from adelic physics [**?**, **?**].

4. Dark matter at the flux tubes of MB corresponds to $h_{eff}/h_0 = n$ phases and induces coherence of visible living matter. The generalization and re-interpretation of Nottale's hypothesis [**?**], which reads as $h_{eff} = h_{gr} = GMm/v_0$, where $v_0 < c$ has dimensions of velocity and M and m are masses at the ends of the magnetic flux tube along which gravitons travel is essential element. The hypothesis implies that the cyclotron energy scale for charged particle is independent on m. The spectrum of Josephson frequencies for cell membrane is universal but now the energies are inversely proportional to h_{eff}.

Problem #2: How MB uses BB as sensory receptor and motor instrument?

1. Dark photons with large h_{eff} serve as as communication and control tools. Josephson frequencies would be involved with the communication of sensory data to MB and cyclotron frequencies with control by MB. Dark photons are assumed to transform to biophotons [**?**] [**?**] (see `http://tinyurl.com/y5z4bog3`) with energies covering visible and UV associated with the transitions of bio-molecules. The control by MB which layers having size even larger than that of Earth means that remote mental interactions are routine in living matter.

2. In ZEO field body and MB correspond to 4-D rather than 3-D field patterns. Quantum states are replaced by quantum counterparts of behaviors and biological functions. The basic mechanism used by MB would be generation of conscious holograms by using dark photon reference beams from MB and their reading. In ZEO also the time reversals of these processes are possible and make possible to understand memory as communications with geometric past. Sensory perception and memory recall would be time reversals of each other and correspond to sequences of SSRs. Motor action would correspond to BSRs.

Problem #3: Why metabolism? Particles with nonstandard h_{eff}/h_0 have higher energy as a rule. For instance, atomic binding energies are proportional to $1/h_{eff}^2$ and thus smaller. Cyclotron energies are proportional to h_{eff}. Metabolic rnergy is needed to excite particles to dark states and thus to increase their "IQ" .

This picture suggests a generalization of the view about self-organization based on non-equilibrium thermodynamics with a quantum view based on number theory, in particular the hierarchy of Planck constants [**?**]. In non-equililbrium thermodynamics energy feed is a prerequisite of self-organization leading to a generation of coherent structures in long length scales and master-slave hierarchy is central. TGD can be at least formally seen as complex square root of thermodynamics, which leads to the question whether also ordinary self-organization could reduce to the hierarchy of Planck constants so that quite generally the coherent structures in long length scales could be seen as analogs of life forms with coherence induced by quantum coherence at the level of MBs. Hierarchy of MBs defining master slave hierarchy with ordinary matter at the bottom of the hierarchy would replace ordinary master slave hierarchy and quantum theory would make itself visible in all scales.

Problem #4: What is evolution? Evolution as increase of $h_{eff}/h_0 = n$ means increase of the dimension of extension of rationals in statistical sense at least since the number of extensions with dimension larger than given integer n is infinite and those with dimension smaller n is finite: algebraic complexity increases.

Problem #5: What about genetic code?

1. Chemical genetic code need not be fundamental if chemistry is only a shadow of the dynamics of MB: more naturally it would be induced by MB mimicing genetic code at dark level. I have proposed a dark variant of genetic code associated with dark nuclei at magnetic flux tubes [**?**, **?**] (see `http://tinyurl.com/yalny39x`): dark proton triplet would serve as a codon. Dark DNA, RNA, tRNA, amino-acids (AAs) exist and the numbers of various codons and of AAs and also the numbers of genetic codons coding for given AA are correctly predicted.

2. Dark-dark and dark-visible communications are required. Frequency resonance mechanism could be involved with dark-dark communications and energy resonance with dark-visible communications. Cyclotron frequencies of dark protons at the magnetic field of flux tube and Josephson frequencies associated with cell membrane are natural frequencies.

3. Communication requires a code and genetic code is the natural guess. Ordinary codons would be replaced with 3-chords. One could speak of music of light. One ends up with this code from a model for harmony. Music expresses and creates emotions and "music of light" could provide correlates for moods/emotions at the molecular level (see `http://tinyurl.com/y3auow4a`).

   There is a connection with Platonic geometries speculated already by Pythagoras. Hamilton cycles at icosahedron *resp.* dodecahedron would realize 12-note *resp.* 20-note scale as closed self-non-intersecting curve connecting neighboring points and going through all vertices. For icosahedron the 20 triangular faces define 20 allowed 3-chords of the harmony: there is a large number of harmonies. For dodecahedron the 12 5-chords associated with 12 pentagonal faces define a unique harmony. There is a natural mapping of 5-chords to 3-chords. The fusion of 2 icosahedral and 2 dodecahedral harmonies gives 20+20+12+12 =64 chords allowing an identification in terms of the genetic code. The number 20 of triangular faces relates to the number of amino-acides. The numbers of codons coding for given amino-acid are predicted correctly.

   Problem #6: What is morphogenesis? If biology is mere chemistry, its is very difficult to answer this question. If space-time topology is non-trivial in all scales, situation changes dramatically. All structures - including bio-molecules, membrane like structures, organelles, organs, ... - would be 4-D space-time surfaces, dynamical patterns, and morphogenesis would emerge at classical level [**?**, **?**].

[**?**]
[**?**]
[**?**]