General View About Physics in Many-Sheeted Space-Time: Part II

M. Pitkänen[1], April 8, 2007

[1] Department of Physical Sciences, High Energy Physics Division,
PL 64, FIN-00014, University of Helsinki, Finland.
matpitka@rock.helsinki.fi, http://www.physics.helsinki.fi/∼matpitka/.
Recent address: Puutarhurinkatu 10,10960, Hanko, Finland.

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Abstract

In this chapter the view about many-sheeted space-time is completed by a summary of the developments in TGD that have occurred during last few years (the year I am writing this is 2007). The most important steps of progress are following ones.

1. Parton level formulation of quantum TGD

The formulation of quantum TGD at partonic level identifying fundamental objects as light-like 3-surfaces having also interpretation as random light-like orbits of 2-D partons having arbitrarily large size. This picture reduces quantum TGD to an almost-topological quantum field theory and leads to a dramatic understanding of S-matrix. A generalization of Feynman diagrams emerges obtained by replacing lines of Feynman diagram with light-like 3-surfaces meeting along their ends at vertices. This picture is different from that of string models and means also a generalization of the view about space-time and 3-surface since these surfaces cannot be assumed to be a smooth manifold anymore.

2. Zero energy ontology

In zero energy ontology physical states are creatable from vacuum and have vanishing net quantum numbers, in particular energy. Zero energy states can be decomposed to positive and negative energy parts with definite geometro-temporal separation, call it T, and having interpretation in terms of initial and final states of particle reactions. Zero energy ontology is consistent with ordinary positive energy ontology at the limit when the time scale of the perception of observer is much shorter than T.

Zero energy ontology leads to the view about S-matrix as a characterizer of time-like entanglement associated with the zero energy state and a generalization of S-matrix to what might be called M-matrix emerges. M-matrix is complex square root of density matrix expressible as a product of real valued "modulus" and unitary matrix representing phase and can be seen as a matrix valued generalization of Schrödinger amplitude. Also thermodynamics becomes an inherent element of quantum theory in this approach.

3. Fusion of real and p-adic physics to single one

The fusion of p-adic physics and real physics to single coherent whole requires generalization of the number concept obtained by gluing reals and various p-adic number fields along common algebraic numbers. This leads to a new vision about how cognition and intentionality make themselves visible in real physics via long range correlations realized via the effective p-adicity of real physics. The success of the p-adic length scale hypothesis and p-adic mass calculations suggest that cognition and intentionality are present already at elementary particle

level. This picture leads naturally to an effective discretization of the real physics at the level of S-matrix and relying on the notion of umber theoretic braid.

4. Dark matter hierarchy and hierarchy of Planck constants

Dark matter revolution with levels of the hierarchy labelled by values of Planck constant forces a further generalization of the notion of imbedding space and thus of space-time. One can say, that imbedding space is a book like structure obtained by gluing together infinite number of copies of the imbedding space like pages of a book: two copies characterized by singular discrete bundle structure are glued together along 4-dimensional set of common points. These points have physical interpretation in terms of quantum criticality. Particle states belonging to different sectors (pages of the book) can interact via field bodies representing space-time sheets which have parts belonging to two pages of this book.

5. p-Adic coupling constant evolution

Kähler coupling strength is analogous to critical temperature. The understanding the spectrum for the values of α_K has been one of the basic challenges of quantum TGD. Second question has been whether Kähler coupling strength is invariant under p-adic coupling constant evolution or not. The recent view is that Kähler coupling constant is invariant in this sense and that its spectrum is very simple: $\alpha_K = 1/4k$, where k is the integer valued Chern-Simons coupling in the parton level formulation of quantum TGD in terms of Chern-Simons action for the induced Kähler form.

Also p-adic temperature is naturally given as $T_p = 1/k$. For elementary fermions and super-canonical quanta one has $k = 1$ and for gauge bosons $T_p = 26$ if one requires that Kähler coupling strength equals to electro-weak $U(1)$ coupling strength at electron length scale corresponding to Mersenne prime M_{127}. The hypothesis relates also the evolution of color coupling strength to that of $U(1)$ coupling strength.

This picture has profound consequences. For instance, gauge boson masses are in excellent approximation due to coupling to Higgs boson and fermion masses originate from p-adic thermodynamics. Also a detailed understanding of hadronic anatomy in terms of super-canonical quanta and a microscopic theory of black-holes emerge.

1 Introduction

In previous chapter "General View About Physics in Many-Sheeted Space-Time" the notion of many-sheeted space-time concept and the understanding of coupling constant evolution at space-time level were discussed without reference to the newest developments in quantum TGD. In this chapter this picture is completed by a summary of the new rather dramatic developments in TGD that have occurred during last few years (the year I am writing this is 2007). The most important steps of progress are following ones.

1.1 Parton level formulation of quantum TGD

The formulation of quantum TGD at partonic level identifying fundamental objects as light-like 3-surfaces having also interpretation as random light-like orbits of 2-D partons having arbitrarily large size. This picture reduces quantum TGD to an almost-topological quantum field theory and leads to a dramatic understanding of S-matrix. A generalization of Feynman diagrams emerges obtained by replacing lines of Feynman diagram with light-like 3-surfaces meeting along their ends at vertices. This picture is different from that of string models and means also a generalization of the view about space-time and 3-surface since these surfaces cannot be assumed to be a smooth manifold anymore.

Extended super-conformal invariance involving the fusion of ordinary Super-Kac Moody symmetries and so called super-canonical invariance generalizing the Kac-Moody algebra by replacing the Lie algebra of finite-dimensional Lie group with that for symplectic transformations of $\delta M^4_\pm \times CP_2$ plays a key role in this framework. The help of professionals in this branch of mathematics would be badly needed in order to develop a detailed understanding about the predicted particle spectrum.

1.2 Zero energy ontology

The notion of zero energy ontology emerged implicitly in cosmological context from the observation that the imbeddings of Robertson-Walker metrics are always vacuum extremals. In fact, practically all solutions of Einstein's equations have this property very naturally. The explicit formulation emerged with the progress in the formulation of quantum TGD. In zero energy ontology physical states are creatable from vacuum and have vanishing net quantum numbers, in particular energy. Zero energy states can be decomposed to positive and negative energy parts with definite geometro-temporal separation, call it T, and having interpretation in terms of initial and final states of particle reactions. Zero energy ontology is consistent with ordinary positive energy ontology at the limit when the time scale of the perception of observer is much shorter than T. One of the implications is a new view about fermions and bosons allowing to understand Higgs mechanism among other things.

Zero energy ontology leads to the view about S-matrix as a characterizer of time-like entanglement associated with the zero energy state and a generalization of S-matrix to what might be called M-matrix emerges. M-matrix is complex square root of density matrix expressible as a product of real valued "modulus" and unitary matrix representing phase and can be seen as a matrix valued generalization of Schrödinger amplitude. Also thermodynamics becomes an inherent element of quantum theory in this approach.

1.3 Fusion of real and p-adic physics to single one

The fusion of p-adic physics and real physics to single coherent whole requires generalization of the number concept obtained by gluing reals and various p-adic number fields along common algebraic numbers. This leads to a completely new vision about how cognition and intentionality make themselves visible in real physics via long range correlations realized via the effective p-adicity of real physics. The success of p-adic length scale hypothesis and p-adic mass calculations suggest that cognition and intentionality are present already at elementary particle level. This picture leads naturally to an effective discretization of the real physics at the level of S-matrix and relying on the notion of umber theoretic braid.

1.4 Dark matter hierarchy and hierarchy of Planck constants

Dark matter revolution with levels of the hierarchy labelled by values of Planck constant forces a further generalization of the notion of imbedding space and thus of space-time. One can say, that imbedding space is a book like structure obtained by gluing together infinite number of copies of the imbedding space like pages of a book: two copies characterized by singular discrete bundle structure are glued together along 4-dimensional set of common points. These points have physical interpretation in terms of quantum criticality. Particle states belonging to different sectors (pages of the book) can interact via field bodies representing space-time sheets which have parts belonging to two pages of this book.

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All this is a work in progress and there are many uncertainties involved. Despite this it seems that it is good to sum up the recent view in order to make easier to refer to the new developments in the existing chapters.

2 The new developments in quantum TGD

This section summarizes the developments in quantum TGD which have taken place during last few years.

2.1 Reduction of quantum TGD to parton level

It took surprisingly long time before the realization that quantum TGD can be reduced to parton level in the sense that fundamental objects are light-like 3-surfaces (of arbitrary size). This identification follows from 4-D general coordinate invariance. Light-likeness in turn implies effective 2-dimensionality of the fermionic dynamics. 4-D space-time sheets are identified as preferred extrema of Kähler action. A stronger form of holography is that modified Dirac action and Chern-Simons action for light-like partonic 3-surfaces defined the Kähler action as a logarithm of the fermionic determinant.

2.1.1 Magic properties of 3-D light-like surfaces and generalization of super-conformal symmetries

The very special conformal properties of both boundary $\delta M^4_\pm$ of 4-D light-cone and of light-like partonic 3-surfaces X^3 imply a generalization and extension of the super-conformal symmetries of super-string models to 3-D context [B2, B3, C1]. Both the Virasoro algebras associated with the light-like coordinate r and to the complex coordinate z transversal to it define super-conformal algebras so that the structure of conformal symmetries is much richer than in string models.

a) The canonical transformations of $\delta M^4_\pm \times CP_2$ give rise to an infinite-dimensional symplectic/canonical algebra having naturally a structure of Kac-Moody type algebra with respect to the light-like coordinate of $\delta M^4_\pm = S^2 \times R_+$ and with finite-dimensional Lie group G replaced with the canonical group. The conformal transformations of S^2 localized with respect to the light like coordinate act as conformal symmetries analogous to those of string models. The super-canonical algebra, call it SC, made local with respect to partonic 2-surface can be regarded as a Kac-Moody algebra associated with an infinite-dimensional Lie algebra.

b) The light-likeness of partonic 3-surfaces is respected by conformal transformations of H made local with respect to the partonic 3-surface and gives to a generalization of bosonic Kac-Moody algebra, call it KM, Also now the longitudinal and transversal Virasoro algebras emerge. The commutator $[KM, SC]$ annihilates physical states.

c) Fermionic Kac-Moody algebras act as algebras of left and right handed spinor rotations in M^4 and CP_2 degrees of freedom. Also the modified Dirac operator allows super-conformal symmetries as gauge symmetries of its generalized eigen modes.

2.1.2 Quantum TGD as almost topological quantum field theory at parton level

The light-likeness of partonic 3-surfaces fixes the partonic quantum dynamics uniquely and Chern-Simons action for the induced Kähler gauge potential of CP_2 determines the classical dynamics of partonic 3-surfaces [B4]. For the extremals of C-S action the CP_2 projection of surface is at most 2-dimensional.

The modified Dirac action obtained as its super-symmetric counterpart fixes the dynamics of the second quantized free fermionic fields in terms of which configuration space gamma matrices and configuration space spinors can be constructed. The essential difference to the ordinary massless Dirac action is that induced gamma matrices are replaced by the contractions of the canonical momentum densities of Chern-Simons action with imbedding space gamma matrices so that modified Dirac action is consistent with the symmetries of Chern-Simonas action. Fermionic statistics is geometrized in terms of spinor geometry of WCW since gamma matrices are linear combinations of fermionic oscillator operators identifiable also as super-canonical generators [B4]. Only the light-likeness property involving the notion of induced metric breaks the topological QFT property of the theory so that the theory is as close to a physically trivial theory as it can be.

The resulting generalization of $N = 4$ super-conformal symmetry [27] involves super-canonical algebra (SC)and super Kac-Moody algebra (SKM) [C1] There are considerable differences as compared to string models.

a) Super generators carry fermion number, no sparticles are predicted (at least super Poincare invariance is not obtained), SKM algebra and corresponding Virasoro algebra associated with light-like coordinates of X^3 and $\delta M^4_{\pm}$ do not annihilate physical states which justifies p-adic thermodynamics used in p-adic mass calculations, four-momentum does not appear in Virasoro generators so that there are no problems with Lorentz invariance, and mass squared is p-adic thermal expectation of conformal weight.

b) The conformal weights and eigenvalues of modified Dirac operator are complex and the conjecture is that they are closely related to zeros of Riemann Zeta [B4, C2]. This means that positive energy particles propagating into geometric future are not equivalent with negative energy particles propagating in geometric past so that crossing symmetry is broken. Complex conjugation for the super-canonical conformal weights and eigenvalues of the modified Dirac operator would transform laser photons to their phase conjugates for which dissipation seems to occur in a reversed direction of geometric time. Hence irreversibility would be present already at elementary particle level.

2.2 Quantum measurement theory with finite measurement resolution

Infinite-dimensional Clifford algebra of CH can be regarded as a canonical example of a von Neumann algebra known as a hyper-finite factor of type II_1 [16, 18](shortly HFF) characterized by the defining condition that the trace of infinite-dimensional unit matrix equals to unity: $Tr(Id) = 1$. In TGD framework the most obvious implication is the absence of fermionic normal ordering infinities whereas the absence of bosonic divergences is guaranteed by the basic properties of the configuration space Kähler geometry, in particular the non-locality of the Kähler function as a functional of 3-surface.

The special properties of this algebra, which are very closely related to braid and knot invariants [17, 26], quantum groups [19, 18], non-commutative geometry [23], spin chains, integrable models [21], topological quantum field theories [22], conformal field theories, and at the level of concrete physics to anyons [20], generate several new insights and ideas about the structure of quantum TGD.

Jones inclusions $\mathcal{N} \subset \mathcal{M}$ [24, 18] of these algebras lead to quantum measurement theory with a finite measurement resolution characterized by $\mathcal{N}$ [C6, C9]. Quantum Clifford algebra $\mathcal{M}/\mathcal{N}$ interpreted as $\mathcal{N}$-module creates physical states modulo measurement resolution. Complex rays of the state space resulting in the ordinary state function reduction are replaced by $\mathcal{N}$-rays and the notions of unitarity, hermiticity, and eigenvalue generalize [C9, C2].

The notion of entanglement generalizes so that entanglement coefficients are N-valued. Generalized eigenvalues are in turn N-valued hermitian operators. S- and U-matrices become N valued and probabilities are obtained from N-valued probabilities as traces.

Non-commutative physics would be interpreted in terms of a finite measurement resolution rather than something emerging below Planck length scale. An important implication is that a finite measurement sequence can never completely reduce quantum entanglement so that entire universe would necessarily be an organic whole. Topologically condensed space-time sheets could be seen as correlates for sub-factors which correspond to degrees of freedom below measurement resolution. Topological condensation in turn corresponds to the inclusion $\mathcal{N} \subset \mathcal{M}$. This is however not the only possible interpretation.

2.3 Hierarchy of Planck constants

The idea about hierarchy of Planck constants relying on generalization of the imbedding space was inspired both by empirical input (Bohr quantization of planetary orbits) and by the mathematics of hyper-finite factors of type II_1 combined with the quantum classical correspondence.

2.3.1 The generalization of imbedding space concept and hierarchy of Planck constants

Quantum classical correspondence suggests that Jones inclusions [24] have space-time correlates [C6, C9]. There is a canonical hierarchy of Jones inclusions labelled by finite subgroups of SU(2)[18] This leads to a generalization of the imbedding space obtained by gluing an infinite number of copies of H regarded as singular bundles over $H/G_a \times G_b$, where $G_a \times G_b$ is a subgroup of $SU(2) \times SU(2) \subset SL(2, C) \times SU(3)$. Gluing occurs along a factor for which the group is same. The generalized imbedding space has clearly a book like structure with pages of books intersecting along 4-D sub-manifold $M^2 \times S^2$, S^2 a geodesic sphere of CP_2 characterizing the choice of quantization axies. Entire configuration space is union over "books" corresponding to various choices of this sub-manifold.

The groups in question define in a natural manner the direction of quantization axes for for various isometry charges and this hierarchy seems to be an essential element of quantum measurement theory. Ordinary Planck constant, as opposed to Planck constants $\hbar_a = n_a \hbar_0$ and $\hbar_b = n_b \hbar_0$ appearing in the commutation relations of symmetry algebras assignable to M^4 and CP_2, is naturally quantized as $\hbar = (n_a/n_b)\hbar_0$, where n_i is the order of maximal cyclic subgroup of G_i. The hierarchy of Planck constants is interpreted in terms of dark matter hierarchy [C9]. What is also important is that $(n_a/n_b)^2$ appear as a scaling factor of M^4 metric so that Kähler action via its dependence on induced metric codes for radiative corrections coming in powers of ordinary Planck constant: therefore quantum criticality and vanishing of radiative corrections to functional integral over WCW does not mean vanishing of radiative corrections.

G_a would correspond directly to the observed symmetries of visible matter induced by the underlying dark matter [C9]. For instance, in living matter molecules with 5- and 6-cycles could directly reflect the fact that free electron pairs associated with these cycles correspond to $n_a = 5$ and $n_a = 6$ dark matter possibly responsible for anomalous conductivity of DNA [C9, J1] and recently reported strange properties of graphene [49]. Also the tedrahedral and icosahedral symmetries of water molecule clusters could have similar interpretation [50, F9].

A further fascinating possibility is that the observed indications for Bohr orbit quantization of planetary orbits [51] could have interpretation in terms of gigantic Planck constant for underlying dark matter [D6] so that macroscopic and -temporal quantum coherence would be possible in astrophysical length scales manifesting itself in many manners: say as preferred directions of quantization axis (perhaps related to the CMB anomaly) or as anomalously low dissipation rates.

Since the gravitational Planck constant is proportional to the product of the gravitational masses of interacting systems, it must be assigned to the field body of the two systems and characterizes the interaction between systems rather than systems themselves. This observation applies quite generally and each field body of the system (em, weak, color, gravitational) is characterized by its own Planck constant.

In the gravitational case the order of G_a is gigantic and at least GM_1m/v_0, $v_0 = 2^{-11}$ the favored value. The natural interpretation is as a discrete rotational symmetry of the gravitational field body of the system having both gravimagnetic and gravi-electric parts. The subgroups of G_a for which order is a divisor of the order of G_a define broken symmetries at the lower levels of dark matter hierarchy, in particular symmetries of visible matter.

The number theoretically simple ruler-and-compass integers having as factors only first powers of Fermat primes and power of 2 would define a physically preferred sub-hierarchy of quantum criticality for which subsequent levels would correspond to powers of 2: a connection with p-adic length scale hypothesis suggests itself. Ruler and compass hypothesis implies that besides p-adic length scales also their 3- and 5- multiples should be important. Note that in the structure of chromosomes p-adic length scale $L(151) \simeq 10$ characterizes beads-on-string structure of DNA whereas the length scale $3L(151)$ appears in the coiling of this structure.

2.3.2 Implications of dark matter hierarchy

The basic implication of dark matter hierarchy is hierarchy of macroscopic quantum coherent systems covering all length scales. The presence of this hierarchy is visible as exact discrete symmetries of field bodies reflecting at the level of visible matter as broken symmetries. In case of gravitational interaction these symmetries are highest and also the scale of quantum coherence is astrophysical. Together with ruler-and-compass hypothesis and p-adic length scale hypothesis this leads to very powerful predictions and p-adic length scale hypothesis might reduce to the ruler-and-compass hypothesis.

At the level of condensed matter one application is nuclear string model explaining also the selection rules of cold fusion and predicting that dark copy of weak physics with atomic scale defining the range of weak interaction is involved. Note that cold fusion has recently gained considerable support. High T_c super-conductivity is second application of dark matter hierarchy.

The 5- and 6-fold symmetries of the sugar backbone of DNA suggest that corresponding cyclic groups or cyclic groups having these groups as factors are symmetries of dark matter part of DNA presumably consisting of what is called as free electron pairs assignable to 5- and 6-cycles. The model allows to understand the observed high conductivity of DNA not consistent with the insulator property of DNA at the level of visible matter.

One also ends up with a speculative notion of N-atom providing a mechanism for the emergence of symbolic representations at the level of biomolecules and a general mechanism of bio-catalysis.

2.3.3 Dark matter and bio-control

The hierarchy of dark matters provides rather concrete realization for the vision about living matter as quantum critical system. This vision will be discussed in more detail later.

The large Planck constants characterize various field bodies of physical system. This gives justification to the notion of (magnetic) field body which plays key role in TGD inspired model of living matter serving as intentional agent controlling the behavior of field body. For instance, the model of EEG relies and of bio-control relies on this notion. The large value of the Planck constant is absolutely essential since for a given low frequency it allows to have gauge boson energy above thermal threshold. Large value of Planck constant is essential for time mirror mechanism which is behind the models of metabolism, long term memory, and intentional action.

The huge values of gravitational Planck constant supports the vision of Penrose [54] about the special role of quantum gravitation in living matter. In TGD framework the proposal of Penrose and Hameroff for the emergence of consciousness known as Orch-Or (Orchestrated Objective Reduction [55]) is however too restricted since it gives a very special role to micro-tubules.

A reasonable guess - based on the hypothesis that transition to dark matter phase occurs when perturbation theory for standard value of Planck constant fails - is that $GMm > 1$ is the criterion for the transition to dark phase for the gravitational field body characterizing the interaction between the two masses so that Planck mass becomes the critical mass for this transition. For the density of water this means size scale of .1 mm, the size of large neuron.

2.4 Zero energy ontology

Zero energy ontology has roots in TGD inspired cosmology [D5]. The problem has been that the imbeddings of Robertson-Walker cosmologies have vanishing densities of Poincare momenta identified as inertial momenta whereas gravitational energy density is non-vanishing. This led to the conclusion that one must allow space-time sheets with both time orientations such that the signs of Poincare energies are different for them and total density of inertial energy vanishes. Gravitational momenta can be identified as difference of the Poincare momenta and need not be conserved.

2.4.1 Construction of S-matrix and zero energy ontology

The construction of S-matrix allows to formulate this picture more sharply. Zero energy states have positive and negative energy parts located in geometric past and future and S-matrix can be identified as time-like entanglement coefficients between these states. Positive energy ontology is a good approximation in time scales shorter than the temporal distance between positive and negative energy states. This picture leads also to a generalization of Feynman graphs obtained by gluing light-like partonic 3-surfaces together along their ends at vertices. These Feynman cobordisms become a basic element of quantum TGD having interpretation as almost topological QFT and category theoretical formulation of quantum TGD emerges.

2.4.2 Elementary particles and zero energy ontology

At the level of elementary particles zero energy ontology means that fermionic quantum numbers are located at the light-like throats of wormhole contacts connecting CP_2 type extremals with Euclidian signature of induced metric to space-time sheets with Minkowskian signature of induced metric. Gauge bosons in turn correspond to pieces of CP_2 type extremals connecting positive and negative energy space-time sheets with fermion and antifermion quantum numbers at the throats of the wormhole contact. Depending on the sign of net energy one has ordinary boson or its phase conjugate. Gravitons correspond to pairs of fermion or gauge boson pair with particle and antiparticle connected by flux tube. This string picture emerges automatically if one assumes that the fermions of the conformal field theory associated with partonic 3-surface are free. It is also possible to have gauge bosons corresponding to single wormhole throat: these particles correspond to bosonic generators of super-canonical algebra and excitations which correspond to genuine configuration space degrees of freedom so that description in terms of quantum field theory in fixed background space-time need not work.

2.5 U- and S-matrices

In quite early stage physical arguments led to the conclusion that the universal U-matrix associated with quantum jump must be distinguished from the S-matrix characterizing the rates of particle reactions. The notion of zero energy ontology was however needed before it became possible to characterize the difference between these matrices in a more precise manner.

2.5.1 Some distinctions between U- and S-matrices

The distinctions between U- and S-matrices have become rather clearer.

a) U-matrix is the universal unitary matrix assignable to quantum jump between zero energy states whereas S-matrix can be identified as time-like entanglement coefficients between positive and negative energy parts of the zero energy state. Thus S-matrix characterizes zero energy states.

b) U-matrix is always between zero energy states and the corresponding state function reduction reduces entanglement between zero energy states. State function reduction for S-matrix elements reduces the entanglement between positive and negative energy parts of a given zero energy state and is completely analogous to ordinary quantum measurement reducing entanglement between systems having space-like separation.

c) U-matrix is unitary whereas S-matrix can be unitary only for HFFs of type II_1. In the most general case S-matrix can be regarded as a "square" root of the density matrix assignable to time like entanglement: this hypothesis would unify the notions of S-matrix and density matrix and one could regard quantum states as matrix analogs of Schrö;dinger amplitudes expressible as products of its modulus (square root of probability density replaced with square root of density matrix) and phase (possibly universal unitary S-matrix). Thermal S-matrices define an important special case and thermodynamics becomes an integral part of quantum theory in zero energy ontology.

d) U-matrix can have elements between different number fields. In this case one must however assume number theoretical universality meaning that U-matrix has rational or at most algebraic matrix elements. In the case of HFFs of type II_1 this might imply triviality. U-matrix between p-adic and real number fields would relate to intentional action and the almost triviality would be a blessing meaning that the realization of intentional action occurs in a very precise manner and is restricted only by cutoff due to the algebraic character of number theoretic braids.

S-matrix as time-like entanglement matric is diagonal with respect to number field and number theoretical universality is not absolutely essential for its definition.

2.5.2 Number theoretic universality and S-matrix

The fact that zero energy states are created by p-adic to-real transitions and must be number theoretically universal suggests strongly that the data about partonic 2-surfaces contributing to S-matrix elements come from the intersection of real partonic 2-surface and its p-adic counterpart satisfying same algebraic equations. The intersection consists of algebraic points and contains as subset number theoretic braids central for the proposed construction of S-matrix.

The question is whether also states for which S-matrix receives data from non-algebraic points should be allowed or whether the data can come even from continuous string like structures at partonic 2-surfaces as standard conformal field theory picture would suggest. If also S-matrix is algebraic, one can wonder whether there is any difference between p-adic and real physics at all. The latter option would mean that intentional action is followed by a unitarity process U analogous to a dispersion of completely localized particle implied by Schröndinger equation.

The algebraic universality of S-matrix could mean that S-matrix is obtained as algebraic continuation of rational S-matrix by replacing incoming momenta and other continuous quantum numbers with real ones. Similar continuation should make sense in p-adic sector. S-matrix and U-matrix in a given algebraic extension of rationals or p-adics are not in general diagonalizable. Thus number theory would allows to avoid the paradoxical conclusion that S-matrix is always diagonal in a suitable basis.

2.6 Number theoretic ideas

p-Adic physics emerged roughly at the same time via p-adic mass calculations. The interpretation of p-adic physics as physics of cognition and intentionality emerged. The basic idea was that bosonic p-adic space-time sheets provide representations for intentions and the transformation of intention to action corresponds to a transformation of p-adic space-time sheet to a real one. Gauge bosons identified as pairs of wormhole throats carrying fermion and antifermion numbers so that a a more precise characterization of "bosonic" would be as "purely bosonic" meaning wormhole throat associated with CP_2 type extremal. These bosons would be exotic and correspond to states of super-canonical representations. If one accepts the hypothesis that fermionic Fock algebra represents Boolean cognition, one ends up the idea that fermions and their p-adic counterparts appear as pairs and that p-adic partonic 2-surface has interpretation as cognitive representation of fermion. This picture conforms nicely with interpretation in terms of infinite primes.

Cognition and intentionality would be present already at elementary particle level and p-adic fractality would be the experimental signature of it making itself visible in elementary particle mass spectrum among other things. The success of p-adic mass calculations provides strong siupport for the hypothesis.

This led gradually to the vision about physics as generalized number theory. It involves three separate aspects.

a) The p-adic approach led eventually to the program of fusing real physics and various p-adic physics to a single coherent whole by generalizing the number concept by gluing reals and various p-adics to a larger structure along common rationals and algebraics. This inspired the notion of algebraic universality stating that for instance S-matrix should result by algebraic continuation from rational or at most algebraic valued S-matrix.

The notion of number theoretic braid belonging to the algebraic intersection of real and p-adic partonic 2-surface obeying same algebraic equations emerged also and gives a further connection with topological QFT:s. The perturbation theoretic definition of S-matrix is definitely excluded in this approach and TGD indeed leads to the understanding of coupling constant evolution at the level of "free" theory as a discrete p-adic coupling constant evolution so that radiative corrections are not needed for this purpose.

b) Also the classical number fields relate closely to TGD and the vision is that imbedding space M^4xCP_2 emerges from the physics based on hyper-octonionic 8-space with associativity as the fundamental dynamical principle both at classical and quantum level. Hyper-octonion space M^8 with space-time surface identified as hyper-quanternionic sub-manifolds or their duals and M^4xCP_2 would provide in this framework dual manners to describe physics and this duality would provide TGD counterpart for compactication.

c) The construction of infinite primes is analogous to repeated second quantization of super-symmetric arithmetic quantum field theory. This notion implies a further generalization of real and p-adic numbers allowing space-time points to have infinitely complex number theoretic structure not visible at the level of real physics. The idea is that space-time points define the Platonia able to represent in its structure arbitrarily complex mathematical structures and that space-time points could be seen as evolving structures becoming quantum jump by quantum jump increasingly complex number theoretically. Even the world of classical worlds (light-like 3-surfaces) and quantum states of Universe might be represented in terms of the number theoretic anatomy of space-time points (number theoretic Brahman=Atman and algebraic holography).

2.6.1 S-matrix as a functor and the groupoid structure formed by S-matrices

In zero energy ontology S-matrix can be seen as a functor from the category of Feynman cobordisms to the category of operators. S-matrix can be identified as a "square root" of the positive energy density matrix $S = \rho_+^{1/2} S_0$, where S_0 is a unitary matrix and ρ_+ is the density matrix for positive energy part of the zero energy state. Obviously one has $SS^\dagger = \rho_+$. $S^\dagger S = \rho_-$ gives the density matrix for negative energy part of zero energy state. Clearly, S-matrix can be seen as matrix valued generalization of Schrödinger amplitude. Note that the "indices" of the S-matrices correspond to configuration space spinors (fermions and their bound states giving rise to gauge bosons and gravitons) and to configuration space degrees of freedom (world of classical worlds). For hyper-finite factor of II_1 it is not strictly speaking possible to speak about indices since the matrix elements are traces of the S-matrix multiplied by projection operators to infinite-dimensional subspaces from right and left.

The functor property of S-matrices implies that they form a multiplicative structure analogous but not identical to groupoid [30]. Recall that groupoid has associative product and there exist always right and left inverses and identity in the sense that ff^{-1} and $f^{-1}f$ are always defined but not identical and one has $fgg^{-1} = f$ and $f^{-1}fg = g$.

The reason for the groupoid like property is that S-matrix is a map between state spaces associated with initial and final sets of partonic surfaces and these state spaces are different so that inverse must be replaced with right and left inverse. The defining conditions for groupoid are replaced with more general ones. Also now associativity holds but the role of inverse is taken by hermitian conjugate. Thus one has the conditions $fgg^\dagger = f\rho_{g,+}$ and $f^\dagger fg = \rho_{f,-}g$, and the conditions $ff^\dagger = \rho_+$ and $f^\dagger f = \rho_-$ are satisfied. Here $\rho_\pm$ is density matrix associated with positive/negative energy parts of zero energy state. If the inverses of the density matrices exist, groupoid axioms hold true since $f_L^{-1} = f^\dagger \rho_{f,+}^{-1}$ satisfies $ff_L^{-1} = Id_+$ and $f_R^{-1} = \rho_{f,-}^{-1} f^\dagger$

satisfies $f_R^{-1}f = Id_-$.

There are good reasons to believe that also tensor product of its appropriate generalization to the analog of co-product makes sense with non-triviality characterizing the interaction between the systems of the tensor product. If so, the S-matrices would form very beautiful mathematical structure bringing in mind the corresponding structures for 2-tangles and N-tangles. Knowing how incredibly powerful the group like structures have been in physics, one has good reasons to hope that groupoid like structure might help to deduce a lot of information about the quantum dynamics of TGD.

A word about nomenclature is in order. S has strong associations to unitarity and it might be appropriate to replace S with some other letter. The interpretation of S-matrix as a generalized Schrödinger amplitude would suggest Ψ-matrix. Since the interaction with Kea's M-theory blog (with M denoting Monad or Motif in this context) was crucial for the realization of the the connection with density matrix, also M-matrix might work. S-matrix as a functor from the category of Feynman cobordisms in turn suggests C or F. Or could just Matrix denoted by M in formulas be enough?

2.6.2 Number theoretic braids and braid replication

The notion of number theoretic braid is especially interesting from the point of view of quantum biology. Generalized Feynman diagrams obtained by gluing light-like partonic 3-surfaces (whose sizes can be arbitrarily large) along their ends and define what might be called Feynman cobordisms.

A key observation is that number theoretic braids replicate in annihilation vertices. This leads to a general interpretation of generalized Feynman diagrams. Incoming and outgoing "lines" give rise to topological quantum computations characterized by corresponding S-matrices, vertices give rise to replication of number theoretic braids analogous to DNA replication, and internal lines are analogous to quantum communications.

Number theoretic braids are associated with light-like 3-surfaces and can be said to have both dynamical and static characteristics. Partonic 2-surfaces as sub-manifolds of space-like 3-surface can also become linked and knotted and would naturally define space-like counterparts of tangles. Number theoretic braids could define dynamical topological quantum computation like operations whereas partonic 2-surfaces associated with say RNA could define as their space-like counterparts tangles and in special case braids analogous to printed quantum programs. An interesting question is how these two structures are transformed to each other: could this process correspond to a conscious reading like process and how closely DNA relates to language so that reading and writing would be fundamental processes appearing in all scales.

2.6.3 Dark matter hierarchy and hierarchy of quantum critical systems in modular degrees of freedom

Dark matter hierarchy corresponds to a hierarchy of conformal symmetries Z_n of partonic 2-surfaces with genus $g \geq 1$ such that factors of n define subgroups of conformal symmetries of Z_n. By the decomposition $Z_n = \prod_{p|n} Z_p$, where $p|n$ tells that p divides n, this hierarchy corresponds to an hierarchy of increasingly quantum critical systems in modular degrees of freedom. For a given prime p one has a sub-hierarchy Z_p, $Z_{p^2} = Z_p \times Z_p$, etc... such that the moduli at n+1:th level are contained by n:th level. In the similar manner the moduli of Z_n are sub-moduli for each prime factor of n. This mapping of integers to quantum critical systems conforms nicely with the general vision that biological evolution corresponds to the increase of quantum criticality as Planck constant increases. This hierarchy would also define a hierarchy of conscious entities and could relate directly to mathematical cognition.

The group of conformal symmetries could be also non-commutative discrete group having Z_n as a subgroup. This inspires a very short-lived conjecture that only the discrete subgroups of SU(2) allowed by Jones inclusions are possible as conformal symmetries of Riemann surfaces having $g \geq 1$. Besides Z_n one could have tedrahedral and icosahedral groups plus cyclic group Z_{2n} with reflection added but not Z_{2n+1} nor the symmetry group of cube. The conjecture is wrong. Consider the orbit of the subgroup of rotational group on standard sphere of E^3, put a handle at one of the orbits such that it is invariant under rotations around the axis going through the point, and apply the elements of subgroup. You obtain a Riemann surface having the subgroup as its isometries. Hence all discrete subgroups of SU(2) can act even as isometries for some value of g.

The number theoretically simple ruler-and-compass integers having as factors only first powers of Fermat primes and power of 2 would define a physically preferred sub-hierarchy of quantum criticality for which subsequent levels would correspond to powers of 2: a connection with p-adic length scale hypothesis suggests itself.

Spherical topology is exceptional since in this case the space of conformal moduli is trivial and conformal symmetries correspond to the entire $SL(2,C)$. This would suggest that only the fermions of lowest generation corresponding to the spherical topology are maximally quantum critical. This brings in mind Jones inclusions for which the defining subgroup equals to $SU(2)$ and Jones index equals to $\mathcal{M}/\mathcal{N} = 4$. In this case all discrete subgroups of $SU(2)$ label the inclusions. These inclusions would correspond to fiber space $CP_2 \rightarrow CP_2/U(2)$ consisting of geodesic spheres of CP_2. In this case the discrete subgroup might correspond to a selection of a subgroup of $SU(2) \subset SU(3)$ acting non-trivially on the geodesic sphere. Cosmic strings $X^2 \times Y^2 \subset M^4 \times CP_2$ having geodesic spheres of CP_2 as their ends could correspond to this phase dominating the very early cosmology.

3 New results related to coupling constant evolution

The understanding about p-adic coupling constant evolution has increased considerably during last two years and it is possible now to make a good guess about spectrum of Kähler coupling strength. This picture led also to a detailed view about the anatomy of hadrons and to a microscopic description of blackholes [F4, **?**].

3.1 A revised view about Kähler coupling strength and p-adic coupling constant evolution

The original hypothesis was that Kähler coupling strength is invariant under p-adic coupling constant evolution. Later I gave up this hypothesis and replaced it with the invariance of gravitational coupling since otherwise the prediction would have been that gravitational coupling strength is proportional to p-adic length scale squared. The recent view means return to the roots: Kähler coupling strength is invariant under p-adic coupling constant evolution and has value spectrum dictated by the Chern-Simons coupling k defining the theory at the parton level. Gravitational coupling constant corresponds in this framework to the largest Mersenne prime M_{127} which does not correspond to a completely super-astronomical p-adic length scale.

3.1.1 Formula for Kähler coupling constant

To construct expression for gravitational constant one can use the following ingredients.

a) The exponent $exp(2S_K(CP_2))$ defining the value of Kähler function in terms of the Kähler action $S_K(CP_2)$ of CP_2 type extremal representing elementary particle expressible as

$$S_K(CP_2) \ = \ \frac{\pi}{8\alpha_K} \ . \tag{1}$$

Since CP_2 type extremals suffer topological condensation, one expects that the action is modified:

$$S_K(CP_2) \ \rightarrow \ a \times S_K(CP_2) \ . \tag{2}$$

Naively one would expect reduction of the action so that one would have $a \leq 1$. One must however keep mind open in this respect.

b) The p-adic length scale L_p assignable to the space-time sheet along which gravitational interactions are mediated. Since Mersenne primes seem to characterized elementary bosons and since the Mersenne prime $M_{127} = 2^{127} - 1$ defining electron length scale is the largest non-super-astronomical length scale it is natural to guess that M_{127} characterizes these space-time sheets.

The formula for gravitational constant would read as

$$\begin{aligned} G &= L_p^2 \times exp(-2aS_K(CP_2)) \ . \\ L_p &= \sqrt{p}R \ . \end{aligned} \tag{3}$$

Here R is CP_2 radius defined by the length $2\pi R$ of the geodesic circle. The relationship boils down to

$$\begin{aligned} \alpha_K &= \frac{a\pi}{4log(pK)} \ , \\ K &= \frac{R^2}{G} \ . \end{aligned} \tag{4}$$

The value of K is fixed by the requirement that electron mass scale comes out correctly in the p-adic mass calculations and minimal value of K is factor. The uncertainties related to second order contributions however leave the precise value open.

The earlier calculations contained two errors. First error was related to the value of the parameter $K = R^2/G$ believed to be in good approximation given by the product of primes smaller than 26. Second error was that $1/\alpha_K$ was by a factor 2 too large for $a = 1$. This led first to a conclusion that α_K is very near to fine structure constant and perhaps equal to it. The physically more plausible option turned out to corresponds to $1/\alpha_K = 104$, which corresponds in good approximation to the value of electro-weak U(1) coupling at electron length scale but gave $a > 1$ whereas $a < 1$ would be natural since the action for a wormhole contact formed by a piece of CP_2 type vacuum extremal is expected to be smaller than the full action of CP_2 type vacuum extremal.

The correct calculation gives $a < 1$ for $\alpha_K = 1/104$. From the table one finds that if the parameter a equals to $a = 1/2$ the value of α_K is about 133. It would require $a = .6432$ for $Y_e = 0$ favored by the value of top quark mass. This value of a conforms with the idea that a piece of CP_2 type extremal defining a wormhole contact is in question. Note that a proper choices of value of a can make $K = R^2/G$ rational. The table gives values of various quantities assuming

$$K = 2 \times 3 \times 5 \times 7 \times 11 \times 13 \times 17 \times 19 \times 23 \times 2^{-3} * (15/17) \ . \quad (5)$$

giving simplest approximation as a rational for K producing K_R for $Y_e = 0$ with error of 2.7 per cent which is still marginally consistent with the mass of top quark. This approximation should not be taken too seriously.

Y_e	0	.5	.7798
$(m_0/m_{Pl})10^3$	.2437	.2323	.2266
$K_R \times 10^{-7}$	2.5262	2.7788	2.9202
$(L_R/\sqrt{G}) \times 10^{-4}$	3.1580	3.3122	3.3954
$1/\alpha_K$	133.7850	133.9064	133.9696
a_{104}	0.6432	0.6438	0.6441
a_α	0.4881	0.4886	0.4888
$K \times 10^{-7}$	2.4606	2.4606	2.4606
$(L/\sqrt{G}) \times 10^{-4}$	3.1167	3.1167	3.1167
$1/\alpha_K$	133.9158	133.9158	133.9158
a_{104}	0.6438	0.6438	0.6438
a_α	.4886	0.4886	0.4886
K_R/K	1.0267	1.1293	1.1868

Table 1. Table gives the values of the ratio $K_R = R^2/G$ and CP_2 geodesic length $L = 2\pi R$ for $Y_e \in \{0, 0.5, 0.7798\}$. Also the ratio of K_R/K, where $K = 2 \times 3 \times 5 \times 7 \times 11 \times 13 \times 17 \times 19 \times 23 \times 2^{-3} * (15/17)$ is rational number producing R^2/G approximately is given*[1]. The values of α_K deduced using

[1]The earlier calculations giving $K = 2 \times 3 \times 5 \times 7 \times 11 \times 13 \times 17 \times 19 \times 23$ in a good

the formula above are given for $a = 1/2$ and the values of $a = a_{104}$ giving $\alpha_K = 1/104$ are given. Also the values of $a = a_\alpha$ for which α_K equals to the fine structure constant $1/\alpha_{em} = 137.0360$ are given.

If one assumes that α_K is of order fine structure constant in electron length scale, the value of the parameter a is slightly below 1/2 cannot be far from unity. Symmetry principles do not favor the identification. Later it will be found that rather general arguments predict integer spectrum for $1/\alpha_K$ given by $1/\alpha_K = 4k$. For this option $\alpha_K = 1/137$ is not allowed whereas the $1/\alpha_K = 104 = 4 \times 26$ is.

3.1.2 Can one predict the value of gravitational constant?

A lot remains to be understood. The value of gravitational constant is one important example in this respect. For a given space-time sheet defined as a preferred extremal of Kähler action one can in principle calculate the value of G_{class}. Physical gravitational constant G is however expected to quantum average of G_{class} for a given quantum state.

For years ago I found a nice formula relating G to CP_2 length scale, the p-adic prime p characterizing gravitons and equal to M_{127} in the case of ordinary graviton, and Kähler coupling strength [?, ?]. Quantum formula is in question since the exponent for the Kähler action for CP_2 type vacuum extremals appears in it. The task would be to calculate explicitly the G_{class} and its quantum expectation value.

What seems clear is that G is state dependent. For instance, for quantum states concentrated around almost vacuum extremals (such as hadronic strings) G should be large since they are almost Kähler vacua and the model for hadrons indeed leads to the identification of strong gravitons with G_{strong} characterized by corresponding p-adic length scale.

One can write the basic formula for gravitational constant as

$$\frac{exp(-2S_K(CP_2)}{G(p)} = \frac{1}{pR^2} \ .$$

$S_K(CP_2)$ is Kähler action for CP_2 type vacuum extremals with small renormalization reflecting the fact that entire free CP_2 type extremal is not in question topological condensation. The two sides of this equation suggest an interpretation in terms of two thermodynamics. Vacuum functional defined by Kähler function defines the thermodynamics of the left hand side and Planck mass $M_{Pl}(p) = 1/\sqrt{G(p)}$ defining the fundamental mass equal to

approximation contained an error

Planck mass for $p = M_{127}$ but depending on p as $1/\sqrt{p}$. Right hand side would correspond to p-adic thermodynamics with CP_2 mass defining the fundamental mass.

3.1.3 Formula relating v_0 to α_K and R^2/G

If v_0 is identified as the rotation velocity of distant stars in galactic plane, one can use the Newtonian model for the motion of mass in the gravitational field of long straight string giving $v_0 = \sqrt{TG}$. String tension T can be expressed in terms of Kähler coupling strength as

$$T = \frac{b}{2\alpha_K R^2} \ ,$$

where R is the radius of geodesic circle. The factor $b \leq 1$ would explain reduction of string tension in topological condensation caused by the fact that not entire geodesic sphere contributes to the action.

This gives

$$\begin{aligned} v_0 &= \frac{b}{2\sqrt{\alpha_K K}} \ , \\ \alpha_K(p) &= \frac{a\pi}{4log(pK)} \ , \\ K &= \frac{R^2}{G} \ . \end{aligned} \tag{6}$$

The condition that α_K has the desired value for $p = M_{127} = 2^{127}-1$ defining the p-adic length scale of electron fixes the value of b for given value of a. The value of b should be smaller than 1 corresponding to the reduction of string tension in topological condensation.

The condition 6 for $v_0 = 2^{-m}$, say $m = 11$, allows to deduce the value of a/b as

$$\frac{a}{b} = \frac{4 * log(pK)}{\pi} \frac{2^{2m-1}}{K} \ . \tag{7}$$

The table gives the values of b calculated assuming $a = a_{104}$ producing $\alpha_K = 1/104$ for various values of Y_e.

Y_e	0	.5	.7798
$b_{9,104}$	0.9266	1.0193	1.0711
$b_{11,104}$	0.0579	0.0637	0.0669
$b_{9,\alpha}$	0.7032	0.7736	0.81291
$b_{11,\alpha}$	0.0440	0.0483	0.050

Table 2. Table gives the values of b for $Y_e \in \{0, .5, .7798\}$ assuming the values $a = a_{104}$ guaranteing $\alpha_K = 1/104$ and $\alpha_K = \alpha_{em}$. $b_{9,...}$ corresponds to $m = 9$ and $b_{11,...}$ corresponds to $m = 11$.

From the table one finds that for $\alpha_K = 1/104$ $m = 9$ corresponds to the almost full action for topological condensed cosmic string. $m = 11$ corresponds to much smaller action smaller by a factor of order $1/16$. The interpretation would be that as m increases the action of the topologically condensed cosmic string decreases. This would correspond to a gradual transformation of the cosmic string to a magnetic flux tube.

3.1.4 Does α_K correspond α_{em} or weak coupling strength $\alpha_{U(1)}$ at electron length scale?

The preceding arguments allow the original identification $\alpha_K \simeq 1/137$. On the other hand, group theoretical arguments encourage the identification of α_K as weak $U(1)$ coupling strength $\alpha_{U(1)}$:

$$\begin{aligned} \alpha_K &= \alpha_{U(1)} = \frac{\alpha_{em}}{cos^2(\theta_W)} \simeq \frac{1}{104.1867} \ , \\ sin^2(\theta_W)_{|10\ MeV} &\simeq 0.2397(13) \ , \\ \alpha_{em}(M_{127}) &= 0.00729735253327 \ . \end{aligned} \tag{8}$$

Here Weinberg angle corresponds to 10 MeV energy is reasonably near to the value at electron mass scale. The value $sin^2(\theta_W) = 0.2397(13)$ corresponding to 10 MeV mass scale [36] is used.

Later it will be found that general argument predicts that $1/\alpha_K$ is integer valued: $1/\alpha_K = 4k$. This option excludes identification as $\alpha_{em}(127)$ but encourages strongly the identification as $\alpha_{U(1)}(127)$.

3.1.5 What about color coupling strength?

Classical theory should be also able to say something non-trivial about color coupling strength α_s too at the general level. The basic observations are following.

a) Both classical color YM action and electro-weak U(1) action reduce to Kähler action.

b) Classical color holonomy is Abelian which is consistent also with the fact that the only signature of color that induced spinor fields carry is anomalous color hyper charge identifiable as an electro-weak hyper charge.

Suppose that α_K is a strict RG invariant. The first idea would be that the sum of classical color action and electro-weak U(1) action is RG invariant and thus equals to its asymptotic value obtained for $\alpha_{U(1)} = \alpha_s = 2\alpha_K$. Asymptotically the couplings approach to a fixed point defined by $2\alpha_K$ rather than to zero as in asymptotically free gauge theories.

Thus one would have

$$\frac{1}{\alpha_{U(1)}} + \frac{1}{\alpha_s} = \frac{1}{\alpha_K} \ . \tag{9}$$

The formula implies that the beta functions for color and $U(1)$ degrees of freedom are apart from sign identical and the increase of $U(1)$ coupling compensates the decrease of the color coupling. This gives the formula

$$\alpha_s = \frac{1}{\frac{1}{\alpha_K} - \frac{1}{\alpha_{U(1)}}} \ . \tag{10}$$

At least formally $\alpha_s(QCD)$ could become negative below the confinement length scale so that $\alpha_K < \alpha_{U(1)}$ for M_{127} is consistent with this formula. For M_{89} $\alpha_{em} \simeq 1/127$ gives $1/\alpha_{U(1)}(89) = 1/97.6374$.

a) $\alpha_K = \alpha_{em}(127)$ option does not work. Confinement length scale corresponds to the point at which one has $\alpha_{U(1)} = \alpha_K$ and in principle can be predicted precisely using standard model. In the case that $\alpha_s(107)$ diverges, one has

$$\alpha_{em}(107) = cos^2(\theta_W)\alpha_{U(1)} = cos^2(\theta_W)\alpha_K = \frac{cos^2(\theta_W)}{136} \ .$$

The resulting value of α_{em} is too small and the situation worsens for $k > 107$ since $\alpha_{U(1)}$ decreases. Hence this option is excluded.

b) TGD predicts that also M_{127} copy of QCD should exist and that M_{127} quarks should play a key role in nuclear physics [F8]. Hence one could argue that color coupling strength diverges at M_{127} (the largest not completely super-astrophysical Mersenne prime) so that one would have

$\alpha_K = \alpha_{U(1)}(M_{127})$. Therefore the precise knowledge of $\alpha_{U(1)}(M_{127})$ in principle fixes the value of parameter $K = R^2/G$ and thus also the second order contribution to the mass of electron. On ther other hand, quite a general argument predicts $\alpha_K = 1/104$ so that an exact prediction for $U(1)$ coupling follows.

The predicted value of $\alpha_s(M_{89})$ follows from $sin^2(\theta_W) = .23120$ and $\alpha_{em} \simeq 1/127$ at intermediate boson mass scale using $\alpha_{U(1)} = \alpha_{em}/cos^2(\theta_W)$ and $1/\alpha_s = 1/\alpha_K - 1/\alpha_{U(1)}$. The predicted value $\alpha_s(89) = 0.1572$ is quite reasonable although somewhat larger than QCD value. For $1/\alpha_K = 108 = 4 \times 27$ one would have $\alpha_s(89) = 0.0965$.

The new vision about the value spectrum of Kähler coupling strength and hadronic space-time sheet suggests $\alpha_K = \alpha_s = \alpha_s = 1/4$ at hadronic space-time sheet labelled by M_{107}. α_s here refers however to super-canonical gluons which do not consist of quark-antiquark pairs. If the two values of α_s are identical at $k = 107$ (ordinary gluons might be perhaps mix strongly with super-canonical ones at this length scale), one has $\alpha_{U(1)}(107) = 1/100$. Using $sint^2(\theta_W) = 2397$ at 10 MeV this predicts $\alpha_{em}(107) = 1/131.53$.

To sum up, the proposed formula would dictate the evolution of α_s from the evolution of the electro-weak parameters without any need for perturbative computations and number theoretical prediction for U(1) coupling at electron length scale would be exact. Although the formula of proposed kind is encouraged by the strong constraints between classical gauge fields in TGD framework, it should be deduced in a rigorous manner from the basic assumptions of TGD before it can be taken seriously.

3.2 Does the quantization of Kähler coupling strength reduce to the quantization of Chern-Simons coupling at partonic level?

Kähler coupling strength associated with Kähler action (Maxwell action for the induced Kähler form) is the only coupling constant parameter in quantum TGD, and its value (or values) is in principle fixed by the condition of quantum criticality since Kähler coupling strength is completely analogous to critical temperature. The quantum TGD at parton level reduces to almost topological QFT for light-like 3-surfaces. This almost TQFT involves Abelian Chern-Simons action for the induced Kähler form.

This raises the question whether the integer valued quantization of the Chern-Simons coupling k could predict the values of the Kähler coupling strength. I considered this kind of possibility already for more than 15 years ago but only the reading of the introduction of the [33] about his new approach to 3-D quantum gravity led to the discovery of a childishly simple argument that the inverse of Kähler coupling strength could indeed be proportional to the integer valued Chern-Simons coupling k: $1/\alpha_K = 4k$. $k = 26$ is forced by the comparison with some physical input. Also p-adic temperature could be identified as $T_p = 1/k$.

3.2.1 Quantization of Chern-Simons coupling strength

For Chern-Simons action the quantization of the coupling constant guaranteing so called holomorphic factorization is implied by the integer valuedness of the Chern-Simons coupling strength k. As Witten explains, this follows from the quantization of the first Chern-Simons class for closed 4-manifolds plus the requirement that the phase defined by Chern-Simons action equals to 1 for a boundaryless 4-manifold obtained by gluing together two 4-manifolds along their boundaries. As explained by Witten in his paper, one can consider also "anyonic" situation in which k has spectrum Z/n^2 for n-fold covering of the gauge group and in dark matter sector one can consider this kind of quantization.

3.2.2 Formula for the Kähler coupling strength

The quantization argument for k seems to generalize to the case of TGD. What is clear that this quantization should closely relate to the quantization of the Kähler coupling strength appearing in the 4-D Kähler action defining Kähler function for the world of classical worlds and conjectured to result as a Dirac determinant. The conjecture has been that g_K^2 has only single value. With some physical input one can make educated guesses about this value. The connection with the quantization of Chern-Simons coupling would however suggest a spectrum of values. This spectrum is easy to guess.

1. Wick rotation argument

The U(1) counterpart of Chern-Simons action is obtained as the analog of the "instanton" density obtained from Maxwell action by replacing $J \wedge *J$ with $J \wedge J$. This looks natural since for self dual J associated with CP_2 type vacuum extremals Maxwell action reduces to instanton density and therefore to Chern-Simons term. Also the interpretation as Chern-Simons action associated with the classical SU(3) color gauge field defined by Killing vector fields of CP_2 and having Abelian holonomy is possible. Note however that *instanton density is multiplied by imaginary unit in the action exponential of path integral*. One should find justification for this

"Wick rotation" not changing the value of coupling strength and later this kind of justification will be proposed.

Wick rotation argument suggests the correspondence $k/4\pi = 1/4g_K^2$ between Chern-Simons coupling strength and the Kähler coupling strength g_K appearing in 4-D Kähler action. This would give

$$g_K^2 \;=\; \frac{\pi}{k} \;, \frac{1}{\alpha_K} = 4k \;. \qquad (11)$$

The spectrum of $1/\alpha_K$would be integer valued. The result is very nice from the point of number theoretic vision since the powers of α_K appearing in perturbative expansions would be rational numbers (ironically, radiative corrections should vanish by number theoretic universality but this might happen only for these rational values ofα_K!).

2. Are more general values of k possible

Note however that if k is allowed to have values in Z/n^2, the strongest possible coupling strength is scaled to $n^2/4$ unless $\hbar$ is not scaled: already for $n = 2$ the resulting perturbative expansion might fail to converge. In the scalings of $\hbar$ associated with M^4 degrees of freedom $\hbar$ however scales as $1/n^2$ so that the spectrum of α_K would remain invariant.

3. Experimental constraints on α_K

It is interesting to compare the prediction with the experimental constraints on the value of $1/\alpha_K$. As already found, there are two options to consider.

a) $\alpha_K = \alpha_{em}$ option suggests $1/\alpha_K = 137$ inconsistent with $1/\alpha_K = 4k$ condition. $1/\alpha_K = 136 = 4\times 34$ combined with the formula $1/\alpha_s + 1/\alpha_{U(1)} = 1/\alpha_K$ leads to nonsensical predictions.

b) For $1/\alpha_s + 1/\alpha_{U(1)} = 1/\alpha_K = 104$ option option the basic empirical input is that electro-weak $U(1)$ coupling strength reduces to Kähler coupling at electron length scale. This gives $\alpha_K = \alpha_{U(1)}(M_{127}) \simeq 104.1867$, which corresponds to $k = 26.0467$. $k = 26$ would give $\alpha_K = 104$: the difference would be only .2 per cent and one would obtain exact prediction for $\alpha_{U(1)}(M_{127})$. Together with electro-weak coupling constant evolution this would also explain why the inverse of the fine structure constant is so near to 137 but not quite. Amusingly, $k = 26$ is the critical space-time dimension of the bosonic string model. Also the conjectured formula for the gravitational constant in terms of α_K and p-adic prime p involves all primes smaller than 26.

3.2.3 Justification for Wick rotation

It is not too difficult to believe to the formula $1/\alpha_K = qk$, q some rational. $q = 4$ however requires a justification for the Wick rotation bringing the imaginary unit to Chern-Simons action exponential lacking from Kähler function exponential.

In this kind of situation one might hope that an additional symmetry might come in rescue. The guess is that number theoretic vision could justify this symmetry.

a) To see what this symmetry might be consider the generalization of the [34] obtained by combining theta angle and gauge coupling to single complex number via the formula

$$\tau = \frac{\theta}{2\pi} + i\frac{4\pi}{g^2} \ . \tag{12}$$

What this means in the recent case that for CP_2 type vacuum extremals [D1] Kähler action and instanton term reduce by self duality to Kähler action obtained by the replacement g^2 with $-i\tau/4\pi$. The first duality $\tau \rightarrow \tau + 1$ corresponds to the periodicity of the theta angle. Second duality $\tau \rightarrow -1/\tau$ corresponds to the generalization of Montonen-Olive duality $\alpha \rightarrow 1/\alpha$. These dualities are definitely not symmetries of the theory in the recent case.

b) Despite the failure of dualities, it is interesting to write the formula for τ in the case of Chern-Simons theory assuming $g_K^2 = \pi/k$ with $k > 0$ holding true for Kac-Moody representations. What one obtains is

$$\tau = 4k(1-i) \ . \tag{13}$$

The allowed values of τ are integer spaced along a line whose direction angle corresponds to the phase $exp(i2\pi/n)$, $n = 4$. The transformations $\tau \rightarrow \tau + 4(1-i)$ generate a dynamical symmetry and as Lorentz transformations define a subgroup of the group E^2 leaving invariant light-like momentum (this brings in mind quantum criticality!). One should understand why this line is so special.

c) This formula conforms with the number theoretic vision suggesting that the allowed values of τ belong to an integer spaced lattice. Indeed, if one requires that the phase angles are proportional to vectors with rational components then only phase angles associated with orthogonal triangles with short sides having integer valued lengths m and n are possible. The additional condition that the phase angles correspond to *roots of unity*! This leaves only $m = n$ and $m = -n > 0$ into consideration so that one would have $\tau = n(1-i)$ from $k > 0$.

d) Notice that theta angle is a multiple of $8k\pi$ so that a trivial strong CP breaking results and no QCD axion is needed (this of one takes seriously the equivalence of Kähler action to the classical color YM action).

3.2.4 Is the p-adic temperature proportional to the Kähler coupling strength?

Kähler coupling strength would have the same spectrum as p-adic temperature T_p apart from a multiplicative factor. The identification $T_p = 1/k$ is indeed very natural since also g_K^2 is a temperature like parameter. The simplest guess is

$$T_p = \frac{1}{k} . \tag{14}$$

Also gauge couplings strengths are expected to be proportional to g_K^2 and thus to $1/k$ apart from a factor characterizing p-adic coupling constant evolution. That all basic parameters of theory would have simple expressions in terms of k would be very nice from the point of view quantum classical correspondence.

If U(1) coupling constant strength at electron length scales equals $\alpha_K = 1/104$, this would give $1/T_p = 1/26$. This means that photon, graviton, and gluons would be massless in an excellent approximation for say $p = M_{89} = 2^{89} - 1$, which characterizes electro-weak gauge bosons receiving their masses from their coupling to Higgs boson. For fermions one has $T_p = 1$ so that fermionic light-like wormhole throats would correspond to the strongest possible coupling strength $\alpha_K = 1/4$ whereas gauge bosons identified as pairs of light-like wormhole throats associated with wormhole contacts would correspond to $\alpha_K = 1/104$. Perhaps $T_p = 1/26$ is the highest p-adic temperature at which gauge boson wormhole contacts are stable against splitting to fermion-antifermion pair. Fermions and possible exotic bosons created by bosonic generators of super-canonical algebra would correspond to single wormhole throat and could also naturally correspond to the maximal value of p-adic temperature since there is nothing to which they can decay.

A fascinating problem is whether $k = 26$ defines internally consistent conformal field theory and is there something very special in it. Also the thermal stability argument for gauge bosons should be checked.

What could go wrong with this picture? The different value for the fermionic and bosonic α_K makes sense only if the 4-D space-time sheets associated with fermions and bosons can be regarded as disjoint space-time regions. Gauge bosons correspond to wormhole contacts connecting (deformed pieces of CP_2 type extremal) positive and negative energy space-time sheets whereas fermions would correspond to deformed CP_2 type extremal glued to single space-time sheet having either positive or negative energy. These space-time sheets should make contact only in interaction vertices of the generalized Feynman diagrams, where partonic 3-surfaces are glued together along their ends. If this gluing together occurs only in these vertices, fermionic and bosonic space-time sheets are disjoint. For stringy diagrams this picture would fail.

To sum up, the resulting overall vision seems to be internally consistent and is consistent with generalized Feynman graphics, predicts exactly the spectrum of α_K, allows to identify the inverse of p-adic temperature with k, allows to understand the differences between fermionic and bosonic massivation, and reduces Wick rotation to a number theoretic symmetry. One might hope that the additional objections (to be found sooner or later!) could allow to develop a more detailed picture.

3.3 What could happen in the transition to non-perturbative QCD?

What happens mathematically in the transition to non-perturbative QCD has remained more or less a mystery. The number theoretical considerations of [A7, O3] inspired the idea that Planck constant is dynamical and has a spectrum given as $\hbar(n) = n\hbar_0$, where n characterizes the quantum phase $q = exp(i2\pi/n)$ associated with Jones inclusion. The strange finding that the orbits of planets seem to obey Bohr quantization rules with a gigantic value of Planck constant inspired the hypothesis that the increase of Planck constant provides a unique mechanism allowing strongly interacting system to stay in perturbative phase [C9, D6]. The resulting model allows to understand dark matter as a macroscopic quantum phase in astrophysical length and time scales, and strongly suggest a connection with dark matter and biology.

The phase transition increasing Planck constant could provide a model for the transition to confining phase in QCD. When combined with the recent ideas about value spectrum of Kähler coupling strength one ends up with a rather explicit model about non-perturbative aspects of hadron physics already successfully applied in hadron mass calculations [F4]. Mersenne primes seem to define the p-adic length scales of gauge bosons and of hadronic space-time sheets. The quantization of Planck constant provides additional insight to p-adic length scales hypothesis and to the preferred role of Mersenne primes.

3.3.1 Super-canonical gluons and non-perturbative aspects of hadron physics

According to the model of hadron masses [F4], in the case of light pseudoscalar mesons the contribution of quark masses to the mass squared of meson dominates whereas spin 1 mesons contain a large contribution identified as color interaction conformal weight (color magnetic spin-spin interaction conformal weight and color Coulombic conformal weight). This conformal weight cannot however correspond to the ordinary color interactions alone and is negative for pseudo-scalars and compensated by some unknown contribution in the case of pion in order to avoid tachyonic mass. Quite generally this realizes the idea about light pseudoscalar mesons as Goldstone bosons. Analogous mass formulas hold for baryons but in this case the additional contribution which dominates.

The unknown contribution can be assigned to the $k = 107$ hadronic space-time sheet and must correspond to the non-perturbative aspects of QCD and the failure of the quantum field theory approach at low energies. In TGD the failure of QFT picture corresponds to the presence of configuration space degrees of freedom ("world of classical worlds") in which super-canonical algebra acts. The failure of the approximation assuming single fixed background space-time is in question.

The purely bosonic generators carry color and spin quantum numbers: spin has however the character of orbital angular momentum. The only electro-weak quantum numbers of super-generators are those of right-handed neutrino. If the super-generators degrees carry the quark spin at high energies, a solution of proton spin puzzle emerges.

The presence of these degrees of freedom means that there are two contributions to color interaction energies corresponding to the ordinary gluon exchanges and exchanges of super-canonical gluons. It turns out the model assuming same topological mixing of super-canonical bosons identical to that experienced by U type quarks leads to excellent understanding of hadron masses assuming that hadron spin correlates with the super-canonical particle content of the hadronic space-time sheet.

According to the argument already discussed, at the hadronic $k = 107$ space electro-weak interactions would be absent and classical $U(1)$ action should vanish. This is guaranteed if $\alpha_{U(1)}$ diverges. This would give

$$\alpha_s = \alpha_K = \frac{1}{4} \ .$$

This would give also a quantitative articulation for the statement that strong interactions are charge independent.

This α_s would correspond to the interaction via super-canonical colored gluons and would lead to the failure of perturbation theory. By the general criterion stating that the failure of perturbation theory leads to a phase transition increasing the value of Planck constant one expects that the value of $\hbar$ increases [C9]. The value leaving the value of α_K invariant would be $\hbar \rightarrow 26\hbar$ and would mean that p-adic length scale L_{107} is replaced with length scale $26L_{107} = 46$ fm, the size of large nucleus so that also the basic length scale nuclear physics would be implicitly coded into the structure of hadrons.

3.3.2 Why Mersenne primes should label a fractal hierarchy of physics?

There are motivations for the working hypothesis stating that there is fractal hierarchy of copies of standard model physics, and that Mersenne primes label both hadronic space-time sheets and gauge bosons. The reason for this is not yet well understood and I have considered several speculative explanations.

1. First picture

The first thing to come in mind is that Mersenne primes correspond to fixed points of the discrete p-adic coupling constant evolution, most naturally to the maxima of the color coupling constant strength. This would mean that gluons are emitted with higher probability than in other p-adic length scales.

There is however an objection againt this idea. If one accepts the new vision about non-perturbative aspects of QCD, it would seem that super-canonical bosons or the interaction between super-canonical bosons and quarks for some reason favors Mersenne primes. However, if color coupling strength corresponds to $\alpha_K = \alpha_s = 1/4$ scaled down by the increase of the Planck constant, the evolution of super-canonical color coupling strength does not seem to play any role. What becomes large should be a geometric "form factor", when the boson in the vertex corresponds to Mersenne prime rather than "bare" coupling.

The resolution of the problem could be that boson emission vertices $g(p_1, p_2, p_3)$ are functions of p-adic primes labelling the particles of the vertices so that actually three p-adic length scales are involved instead of single length scale as in the ordinary coupling constant evolution. Hence one can imagine that the interaction between particles corresponding to primes near powers of 2 and Mersenne primes is especially strong and analogous to a resonant interaction. The geometric resonance due to the fact that the length scales involved are related by a fractal scaling by a power of 2 would make the form factors $F(p_1 \simeq 2^{k_1}, p_2 \simeq 2^{k_2}, M_n)$ large. The selection of primes near powers of two and Mersenne bosons would be analogous to evolutionary selection of a population consisting of species able to interact strongly.

Since $k = 113$ quarks are possible for $k = 107$ hadron physics, it seems that quarks can have join along boundaries bonds directed to M_n space-times with $n < k$. This suggests that neighboring Mersenne primes compete for join along boundaries bonds of quarks. For instance, when the p-adic length scale characterizing quark of M_{107} hadron physics begins to approach M_{89} quarks tend to feed their gauge flux to M_{89} space-time sheet and M_{89} hadron physics takes over and color coupling strength begins to increase. This would be the space-time correlate for the loss of asymptotic freedom.

2. Second picture

Preferred values of Planck constants could play a key role in the selection of Mersenne primes. Ruler-and-compass hypothesis predicts that Planck constants, which correspond to ratios of ruler and compass integers proportional to a product of distinct Fermat primes (four of them are known) and any power of two are favored. As a special case one obtains ruler and compass integers. As a consequence, p-adic length scales have satellites obtained by multiplying them with ruler-and-compass integers, and entire fractal hierarchy of power-of-two multiples of a given p-adic length scale results.

Mersenne length scales would be special since their satellites would form a subset of satellites of shorter Mersenne length scales. The copies of standard model physics associated with Mersenne primes would define a kind of resonating subset of physics since corresponding wavelengths and frequencies would coincide. This would also explain why fermions labelled by primes near power of two couple strongly with Mersenne primes.

3.4 Super-canonical bosons as a particular kind of dark matter

3.4.1 Super-canonical bosons

TGD predicts also exotic bosons which are analogous to fermion in the sense that they correspond to single wormhole throat associated with CP_2 type vacuum extremal whereas ordinary gauge bosons corresponds to a pair of wormhole contacts assignable to wormhole contact connecting positive and negative energy space-time sheets. These bosons have super-conformal partners with quantum numbers of right handed neutrino and thus having no electro-weak couplings. The bosons are created by the purely bosonic part of super-canonical algebra [B2, B3, B4], whose generators belong to the representations of the color group and 3-D rotation group but have vanishing electro-weak quantum numbers. Their spin is analogous to orbital angular momentum whereas the spin of ordinary gauge bosons reduces to fermionic spin. Recall that super-canonical algebra is crucial for the construction of configuration space Kähler geometry. If one assumes that super-canonical gluons suffer topological mixing identical with that suffered by say U type quarks, the conformal weights would be (5,6,58) for the three lowest generations. The application of super-canonical bosons in TGD based model of hadron masses is discussed in [F4] and here only a brief summary is given.

As explained in [F4], the assignment of these bosons to hadronic space-time sheet is an attractive idea.

a) Quarks explain only a small fraction of the baryon mass and that there is an additional contribution which in a good approximation does not depend on baryon. This contribution should correspond to the non-perturbative aspects of QCD. A possible identification of this contribution is in terms of super-canonical gluons. Baryonic space-time sheet with $k = 107$ would contain a many-particle state of super-canonical gluons with net conformal weight of 16 units. This leads to a model of baryons masses in which masses are predicted with an accuracy better than 1 per cent.

b) Hadronic string model provides a phenomenological description of non-perturbative aspects of QCD and a connection with the hadronic string model indeed emerges. Hadronic string tension is predicted correctly from the additivity of mass squared for $J = 2$ bound states of super-canonical quanta. If the topological mixing for super-canonical bosons is equal to that for U type quarks then a 3-particle state formed by 2 super-canonical quanta from the first generation and 1 quantum from the second generation would define baryonic ground state with 16 units of conformal weight. A very precise prediction for hadron masses results by assuming that the spin of hadron correlates with its super-canonical particle content.

c) Also the baryonic spin puzzle caused by the fact that quarks give only a small contribution to the spin of baryons, could find a natural solution since these bosons could give to the spin of baryon an angular momentum like contribution having nothing to do with the angular momentum of quarks.

d) Super-canonical bosons suggest a solution to several other anomalies related to hadron physics. The events observed for a couple of years ago in RHIC [35] suggest a creation of a black-hole like state in the collision of heavy nuclei and inspire the notion of color glass condensate of gluons, whose natural identification in TGD framework would be in terms of a fusion of hadronic space-time sheets containing super-canonical matter materialized also from the collision energy. In the collision, valence quarks connected together by color bonds to form separate units would evaporate from their hadronic space-time sheets in the collision, and would define TGD counterpart of Pomeron, which experienced a reincarnation for few years ago [45]. The strange features of the events related to the collisions of high energy cosmic rays with hadrons of atmosphere (the particles in question are hadron like but the penetration length is anomalously long and the rate for the production of hadrons increases as one approaches surface of Earth) could be also understood in terms of the same general mechanism.

3.4.2 Topological evaporation, quark gluon plasma and Pomeron

Topological evaporation of elementary particles means nothing if CP_2 type vacuum extremal evaporates so that one must assume that it is quark space-time sheet or join along boundaries block of quark space-time sheets which evaporates. Second new element is the identification of valence quarks as dark matter in the sense of having large $\hbar$: $\hbar_s \simeq (n/v_0)\hbar$, $v_0 \simeq 2^{-11}$, $n = 1$ so that Compton length is scaled by the same factor. Quark gluon plasma would correspond to a phase with ordinary value $\hbar$ and possibly also sea partons can be regarded as this kind of phase. Color bonds between partons are possible also in this phase.

Concerning the evaporation there are two options.

a) The space-time sheets of sea partons are condensed at much larger space-time sheets defined by the space-time sheets of valence quarks connected by color bonds. Topological evaporation of the parton sea would correspond to the splitting of # contacts connecting sea partons space-time sheets to valence quark space-time sheets.

b) Sea partons condensed at a larger space-time sheet which in turn condenses at the space-time sheet of valence quarks. In this case topological evaporation occurs for the entire sea parton space-time sheet.

One can consider two possible scenarios for topological evaporation of quarks and gluons.

a) Color gauge charge is not identified as gauge flux and single secondarily condensed quark space-time sheet can suffer topological evaporation. In this case quark gluon plasma could be identified as vapor phase state for quarks and gluons.

b) Color gauge charge is identified as gauge flux and only join along boundaries blocks formed from quarks can evaporate. Join along boundaries contacts are naturally identified as color flux tubes between quarks. These tubes need not be static. Quark gluon plasma corresponds to condensed state in which the join along boundaries contacts between quark like 3-surfaces are broken. The evaporation of single quark is possible but as a consequence a compensating color charge develops on the interior of the outer boundary of the evaporated quark and the process probably can be interpreted as an emission of meson from hadron. The production of hadrons in hadron collision could be interpreted as a topological evaporation process for sea and valence quarks.

The problematic feature of scenario a) is the understanding of color confinement In scenario b) color confinement of the vapor phase particles is an automatic consequence of the assumption that color charge corresponds to gauge flux classically (gauge field is $H^A J_{\alpha\beta}$, H^A being the Hamiltonian of the color isometry. This does not however exclude the possibility that hadron might feed part of its color isospin or hypercharge gauge flux to surrounding condensate. The concept of anomalous hypercharge introduced in earlier work as proportional to electromagnetic charge indeed suggests this kind of possibility. It should be noticed that for the vacuum extremals of Kähler action induced Kähler field and thus also color fields vanish identically.

The alternatives a) and b) have an additional nice feature that they lead to elegant description for the mysterious concept of Pomeron originally introduced to describe hadronic diffractive scattering as the exchange of Pomeron Regge trajectory [44]. No hadrons belonging to Pomeron trajectory were however found and via the advent of QCD Pomeron was almost forgotten. Pomeron has recently experienced reincarnation [45, 46, 48]. In Hera [45] $e-p$ collisions, in which proton scatters essentially elastically whereas jets in the direction of incoming virtual photon emitted by electron are observed. These events can be understood by assuming that proton emits color singlet particle carrying a small fraction of proton's momentum. This particle in turn collides with the virtual photon (antiproton) whereas proton scatters essentially elastically.

The identification of the color singlet particle as Pomeron looks natural since Pomeron emission describes nicely the diffractive scattering of hadrons. Analogous hard diffractive scattering events in pX diffractive scattering with $X = \bar{p}$ [46] or $X = p$ [48] have also been observed. What happens is that proton scatters essentially elastically and the emitted Pomeron collides with X and suffers hard scattering so that large rapidity gap jets in the direction of X are observed. These results suggest that Pomeron is real and consists of ordinary partons.

The TGD identification of Pomeron is as sea partons in vapor phase. In TGD inspired phenomenology events involving Pomeron correspond to pX collisions, where incoming X collides with proton, when sea quarks have suffered coherent simultaneous (by color confinement) evaporation into vapor phase. System X sees only the sea left behind in the evaporation and scatters from it whereas dark valence quarks continue without noticing X and condense later to form quasi-elastically scattered proton. If X suffers hard scattering from the sea, the peculiar hard diffractive scattering events are observed. The fraction of these events is equal to the fraction f of time spent by sea quarks in vapor phase.

Dimensional arguments suggest a rough order of magnitude estimate for $f \sim \alpha_K \sim 1/137 \sim 10^{-2}$ for f. The fraction of the peculiar deep inelastic scattering events at Hera is about 5 percent, which suggest that f is about 6.8 times larger and of same order of magnitude as QCD α_s The time spent in condensate is by dimensional arguments of the order of the p-adic legth scale $L(M_{107})$, not far from proton Compton length. Time dilation effects at high collision energies guarantee that valence quarks indeed stay in vapor phase during the collision. The identification of Pomeron as sea explains also why Pomeron Regge trajectory does not correspond to actual on mass shell particles.

The existing detailed knowledge about the properties of sea structure functions provides a stringent test for the TGD based scenario. According to [46] Pomeron structure function seems to consist of soft ($(1-x)^5$), hard ($(1-x)$) and super-hard component (delta function like component at $x = 1$). The peculiar super hard component finds explanation in TGD based picture. The structure function $q_P(x, z)$ of parton in Pomeron contains the longitudinal momentum fraction z of the Pomeron as a parameter and $q_P(x, z)$ is obtained by scaling from the sea structure function $q(x)$ for proton $q_P(x, z) = q(zx)$. The value of structure function at $x = 1$ is non-vanishing: $q_P(x = 1, z) = q(z)$ and this explains the necessity to introduce super hard delta function component in the fit of [46].

3.4.3 Simulating big bang in laboratory

An important steps in the development of ideas were stimulated by the findings made during period 2002-2005 in Relativist Heavy Ion Collider (RHIC) in Brookhaven compared with the finding of America and for full reason.

a) The first was finding of longitudinal Lorentz invariance at single particle level suggesting a collective behavior. This was around 2002.

b) The collective behavior which was later interpreted in terms of color glass condensate meaning the presence of a blob of liquid like phase decaying later to quark gluon plasma since it was found that the density of what was expected to be quark gluon plasma was about ten times higher than expected.

c) The last finding is that this object seems to absorb partons like black hole and behaves like evaporating black hole.

In my personal Theory Universe the history went as follows.

a) I proposed 2002 a model for Gold-Gold collision as a mini big bang identified as a scaled down variant of TGD inspired cosmology. This makes sense because in TGD based critical cosmology the initial state has vanishing mass per comoving volume instead of being infinite as in radiation dominated cosmology. Any phase transition involving a generation of a new space-time sheet might proceed in this universal manner.

b) Cosmic string soup in the primordial stage is replaced by a tangle of color flux tubes containing the color glass condensate. CGC is made macroscopic quantum phase by conformal confinement (the conformal weights of partons are complex and relate to zeros of zeta) and only the net conformal weight is real in this phase). Flux tubes correspond to flow lines of incompressible liquid flow and non-perturbative phase with a very large $\hbar$ is in question. Gravitational constant is replaced by strong gravitational constant defined by the relevant p-adic length scale squared since color flux tubes are analogs of hadronic strings. Presumably L_p, $p = M_107 = 2^107 - 1$, is the p-adic length scale since Mersenne prime M_{107} labels the space-time sheet at which partons feed their color gauge fluxes. Temperature during this phase could correspond to Hagedorn temperature for strings and is determined by string tension. Density would be maximal.

c) Next phase is critical phase in which the notion of space-time in ordinary sense makes sense and 3-space is flat since there is no length scale in critical system (so that curvature vanishes). During this critical phase phase a transition to quark gluon plasma occurs. The duration of this phase fixes all relevant parameters such as temperature (which is the analog of Hagedorn temperature corresponding since critical density is maximal density of gravitational mass in TGD Universe).

d) The next phase is radiation dominated quark gluon plasma phase and then follows hadronization to matter dominated phase provided cosmological picture still applies.

Since black hole formation and evaporation is very much like formation big crunch followed by big bang, the picture is more or less equivalent with the picture in which black hole like object consisting of string like objects (mass is determined by string length just as it is determined by the radius for black holes) is formed and then evaporates. Black hole temperature corresponds to Hagedorn temperature and to the duration of critical period of the mini cosmology.

3.4.4 Are ordinary black-holes replaced with super-canonical black-holes in TGD Universe?

Some variants of super string model predict the production of small black-holes at LHC. I have never taken this idea seriously but in a well-defined sense TGD predicts black-holes associated with super-canonical gravitons with strong gravitational constant defined by the hadronic string tension. The proposal is that super-canonical black-holes have been already seen in Hera, RHIC, and the strange cosmic ray events.

Baryonic super-canonical black-holes of the ordinary M_{107} hadron physics would have mass 934.2 MeV, very near to proton mass. The mass of their M_{89} counterparts would be 512 times higher, about 478 GeV if quark massses scale also by this factor. This need not be the case: if one has $k = 113 \rightarrow 103$ instead of 105 one has 434 GeV mass. "Ionization energy" for Pomeron, the structure formed by valence quarks connected by color bonds separating from the space-time sheet of super-canonical black-hole in the production process, corresponds to the total quark mass and is about 170 MeV for ordinary proton and 87 GeV for M_{89} proton. This kind of picture about black-hole formation expected to occur in LHC differs from the stringy picture since a fusion of the hadronic mini black-holes to a larger black-hole is in question.

An interesting question is whether the ultrahigh energy cosmic rays having energies larger than the GZK cut-off of 5×10^{10} GeV are baryons, which have lost their valence quarks in a collision with hadron and therefore have no interactions with the microwave background so that they are able to propagate through long distances.

In neutron stars the hadronic space-time sheets could form a gigantic super-canonical black-hole and ordinary black-holes would be naturally replaced with super-canonical black-holes in TGD framework (only a small part of black-hole interior metric is representable as an induced metric). This obviously means a profound difference between TGD and string models.

a) Hawking-Bekenstein black-hole entropy would be replaced with its p-adic counterpart given by

$$S_p = (\frac{M}{m(CP_2)})^2 \times log(p) \ , \tag{15}$$

where $m(CP_2)$ is CP_2 mass, which is roughly 10^{-4} times Planck mass. M is the contribution of p-adic thermodynamics to the mass. This contribution is extremely small for gauge bosons but for fermions and super-canonical particles it gives the entire mass.

b) If p-adic length scale hypothesis $p \simeq 2^k$ holds true, one obtains

$$S_p = klog(2) \times (\frac{M}{m(CP_2)})^2, \tag{16}$$

$m(CP_2) = \hbar/R$, R the "radius" of CP_2, corresponds to the standard value of $\hbar_0$ for all values of $\hbar$.

c) Hawking-Bekenstein area law gives in the case of Schwartschild black-hole

$$S = \frac{A}{4G} \times \hbar = \pi G M^2 \times \hbar \ . \tag{17}$$

For the p-adic variant of the law Planck mass is replaced with CP_2 mass and $klog(2) \simeq log(p)$ appears as an additional factor. Area law is obtained in the case of elementary particles if k is prime and wormhole throats have M^4 radius given by p-adic length scale $L_k = \sqrt{k}R$ which is exponentially smaller than L_p. For macroscopic super-canonical black-holes modified area law results if the radius of the large wormhole throat equals to Schwartschild radius. Schwartschild radius is indeed natural: in [D3] I have shown that a simple deformation of the Schwartschild exterior metric to a metric representing rotating star transforms Schwartschild horizon to a light-like 3-surface at which the signature of the induced metric is transformed from Minkowskian to Euclidian.

d) The formula for the gravitational Planck constant appearing in the Bohr quantization of planetary orbits and characterizing the gravitational field body mediating gravitational interaction between masses M and m [D6] reads as

$$\hbar_{gr} = \frac{GMm}{v_0}\hbar_0 \ .$$

$v_0 = 2^{-11}$ is the preferred value of v_0. One could argue that the value of gravitational Planck constant is such that the Compton length $\hbar_{gr}/M$ of the black-hole equals to its Schwartshild radius. This would give

$$\hbar_{gr} = \frac{GM^2}{v_0}\hbar_0 \ , \ v_0 = 1/2 \ . \tag{18}$$

The requirement that $\hbar_{gr}$ is a ratio of ruler-and-compass integers expressible as a product of distinct Fermat primes (only four of them are known) and power of 2 would quantize the mass spectrum of black hole [D6]. Even without this constraint M^2 is integer valued using p-adic mass squared unit and if p-adic length scale hypothesis holds true this unit is in an excellent approximation power of two.

e) The gravitational collapse of a star would correspond to a process in which the initial value of v_0 , say $v_0 = 2^{-11}$, increases in a stepwise manner to some value $v_0 \leq 1/2$. For a supernova with solar mass with radius of 9 km the final value of v_0 would be $v_0 = 1/6$. The star could have an onion like structure with largest values of v_0 at the core as suggested by the model of planetary system. Powers of two would be favored values of v_0. If the formula holds true also for Sun one obtains $1/v_0 = 3 \times 17 \times 2^{13}$ with 10 per cent error.

f) Black-hole evaporation could be seen as means for the super-canonical black-hole to get rid of its electro-weak charges and fermion numbers (except right handed neutrino number) as the antiparticles of the emitted particles annihilate with the particles inside super-canonical black-hole. This kind of minimally interacting state is a natural final state of star. Ideal super-canonical black-hole would have only angular momentum and right handed neutrino number.

g) In TGD light-like partonic 3-surfaces are the fundamental objects and space-time interior defines only the classical correlates of quantum physics. The space-time sheet containing the highly entangled cosmic string might be separated from environment by a wormhole contact with size of black-hole horizon.

This looks the most plausible option but one can of course ask whether the large partonic 3-surface defining the horizon of the black-hole actually contains all super-canonical particles so that super-canonical black-hole would be single gigantic super-canonical parton. The interior of super-canonical black-hole would be a space-like region of space-time, perhaps resulting as a large deformation of CP_2 type vacuum extremal. Black-hole sized wormhole contact would define a gauge boson like variant of the black-hole connecting two space-time sheets and getting its mass through Higgs mechanism. A good guess is that these states are extremely light.

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