p-Adic Particle Massivation: New Physics

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Abstract

TGD certainly predicts a lot of new physics, actually infinite hierarchies of fractal copies of standard model physics, but the precise characterization of predictions has varied as the interpretation of the theory has evolved during years. No attempt to discuss systematically the spectrum of various exotic bosons and fermions, basically due to the ground states created by color super-canonical and Kac-Moody generators, will be made. Rather, the attempt is to summarize the new physics expected on basis of recent interpretation of quantum TGD.

1. Basic new physics predictions

Concerning new physics the basic predictions are following. TGD predicts a rich spectrum of massless states for which ground states of negative super-canonical conformal weight are created by colored super-generators. By color confinement these states do not however give rise to macroscopic long range forces. A hierarchy color and weak physics is predicted. Also dark matter hierarchy corresponding to a hierarchy of Planck constants brings in a hierarchy of variants of standard model physics labelled by the values of Planck constant. Thus in TGD the question is not about about predicting some exotic particle but entire fractal hierarchies of copies of standard model physics.

The family replication for fermions correspond in case of gauge bosons prediction of bosons labelled by genera of the two lightlike wormhole throats associated with the wormhole contact representing boson. There are very general arguments predicting that the number of fermionic genera is three and this means that gauge bosons can be arranged into genus-SU(3) singlet and octet. Octet corresponds to exotic gauge bosons and its members should develop Higgs expectation value. Completely symmetric coupling between Higgs octet and boson octet allows also the bosons with vanishing genus-SU(3) quantum numbers to develop mass.

Higgs field is predicted and its vacuum expectation value explains boson masses. By a general argument p-adic temperature for bosons is low and this means that Higgs contribution to the gauge boson mass dominates. Only p-adic thermodynamics is needed to explain fermion masses and the masses of super-canonical bosons and their super counterparts. There is an argument suggesting that vacuum expectation value of Higgs at fermion space-time sheets is not possible. Almost universality of the topological mixing inducing also CKM mixing allows to predict mass spectrum of these states.

2. A general vision about coupling constant evolution

The vision about coupling constant evolution has developed slowly and especially important developments have occurred during last few years. Therefore an overall view about recent understanding is in order.

Also QCD coupling constant evolution is discussed and it is found that asymptotic freedom could be lost making possible existence of several scaled up versions of QCD existing only in a finite length scale range. The basic counter arguments against lepto-hadron hypothesis are considered and it is found that the loss of asymptotic freedom could allow lepto-hadron physics. One can also consider the possibility that the copies of

say electro-weak characterized by Mersenne primes do not couple directly to each other so that the objections are circumvented.

The discovery of dark matter hierarchy about fifteen years after these argument were developed resolves the problems in much more elegant manner. TGD predicts an infinite hierarchy of electro-weak and color physics physics for which particles couple directly only via gravitons. Decoherence phase transitions can however induce processes allowing the decay of particles of a given physics to particles of another physics.

3. Summary of new physics effects

Various new physics effects are discussed.
a) There is a brief discussion of family replication phenomenon in the case of gauge bosons based on the identification of gauge bosons as wormhole contacts. Also an argument forcing the identification of partonic vertices as branchings of partonic 2-surfaces is developed.
b) ALEPH anomaly is interpreted in terms of a fractal copy of b-quark corresponding to k=197.
c) The possible signatures of M_{89} hadron physics in e^+e^- annihilation experiments are discussed using a naive scaling of ordinary hadron physics.
d) It is found that the newly born concept of Pomeron of Regge theory could be identified as the sea of perturbative QCD.
e) In p-adic context exotic representations of Super Virasoro with $M^2 \propto p^k$, $k = 1, 2, ..$m are possible. For $k = 1$ the states of these representations have same mass scale as elementary particles although in real context the masses would be gigantic. This inspires the question whether non-perturbative aspects of hadron physics could be assigned to the presence of these representations. The prospects for this are promising. Pion mass is almost exactly equal to the mass of lowest state of the exotic representation for $k = 107$ and Regge slope for rotational excitations of hadrons is predicted with three per cent accuracy assuming that they correspond to the states of $k = 101$ exotic Super Virasoro representations. This leads to the idea that hadronization and fragmentation correspond to phase transitions between ordinary and exotic Super Virasoro representations and that there is entire fractal hierarchy of hadrons inside hadrons and QCD:s inside QCD:s corresponding to p-adic length scales $L(k)$, $k = 107, 103, 101, 97, ...$

4. Cosmic primes and Mersenne primes

p-Adic length scale hypothesis suggests the existence of a scaled up copy of hadron physics associated with each Mersenne prime $M_n = 2^n - 1$,n prime: M_{107} corresponds to ordinary hadron physics. There is some evidence for exotic hadrons. Centauro events and the peculiar events associated with $E > 10^5\ GeV$ radiation from Cygnus X-3 could be understood as due to the decay of gamma rays to M_{89} hadron pair in the atmosphere. The decay $\pi_n \rightarrow \gamma\gamma$ produces a peak in the spectrum of the cosmic gamma rays at energy $\frac{m(\pi_n)}{2}$ and there is evidence for the peaks at energies $E_{89} \simeq 34\ GeV$ and $E_{31} \simeq 3.5 \cdot 10^{10}\ GeV$. The absence of the peak at $E_{61} \simeq 1.5 \cdot 10^6\ GeV$ can be understood as due to the strong absorption caused by the e^+e^- pair creation with photons of the cosmic microwave background. Cosmic string decays *cosmic string* $\rightarrow M_2$ *hadrons* $\rightarrow M_3$ *hadrons* ..$\rightarrow M_{107}$ *hadrons* is a new source of cosmic rays. The mechanism could explain the change of the slope in the hadronic cosmic ray spectrum at M_{61} pion rest energy $3 \cdot 10^6$ GeV. The cosmic ray radiation at energies near 10^9 GeV apparently consisting of protons and nuclei not lighter than Fe might be actually dominated by gamma rays: at these energies γ and p induced showers have same muon content and the decays of gamma rays to M_{89} and M_{61} hadrons in the atmosphere can mimic the presence of heavy nuclei in the cosmic radiation.

5. Anomalously large direct CP breaking in $K - \overline{K}$ system and exotic gluons

The recently observed anomalously large direct CP breaking in $K_L \rightarrow \pi\pi$ decays is explained in terms of loop corrections due to the predicted 2 exotic gluons having masses around 33.6 GeV. It will be also found that the TGD version of the chiral field theory believed to provide a phenomenological low energy description of QCD differs from its standard model version in that quark masses are replaced in TGD framework with shifts of quark masses induced by the vacuum expectation values of the scalar meson fields. This conforms with the TGD view about Higgs mechanism as causing only small mass shifts. It must be however emphasized that there is an argument suggesting that the vacuum expectation value of Higgs in fermionic case does not even make sense.

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1.2 Outline of the topics of the chapter

1.2.1 A general vision about coupling constant evolution

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Also QCD coupling constant evolution is discussed and it is found that asymptotic freedom could be lost making possible existence of several scaled up versions of QCD existing only in a finite length scale range. The basic counter arguments against lepto-hadron hypothesis are considered and it is found that the loss of asymptotic freedom could allow lepto-hadron physics. One can also consider the possibility that the copies of say electro-weak characterized by Mersenne primes do not couple directly to each other so that the objections are circumvented.

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1. There is a brief discussion of family replication phenomenon in the case of gauge bosons based on the identification of gauge bosons as wormhole

contacts. Also an argument forcing the identification of partonic vertices as branchings of partonic 2-surfaces is developed.

2. Fractal copies of quarks is basic prediction and now a key part of the model for hadron masses. ALEPH anomaly is interpreted in terms of a fractal copy of b-quark corresponding to k=197.

3. The possible signatures of M_{89} hadron physics in e^+e^- annihilation experiments are discussed using a naive scaling of ordinary hadron physics.

4. The possibility that the newly born concept of Pomeron of Regge theory might be identified as the sea of perturbative QCD is considered.

5. In p-adic context exotic representations of Super Virasoro with $M^2 \propto p^k$, $k = 1, 2, ..$m are possible. For $k = 1$ the states of these representations have same mass scale as elementary particles although in real context the masses would be gigantic. This inspires the question whether non-perturbative aspects of hadron physics could be assigned to the presence of these representations. The prospects for this are promising. Pion mass is almost exactly equal to the mass of lowest state of the exotic representation for $k = 107$ and Regge slope for rotational excitations of hadrons is predicted with three per cent accuracy assuming that they correspond to the states of $k = 101$ exotic Super Virasoro representations. This leads to the idea that hadronization and fragmentation correspond to phase transitions between ordinary and exotic Super Virasoro representations and that there is entire fractal hierarchy of hadrons inside hadrons and QCD:s inside QCD:s corresponding to p-adic length scales $L(k)$, $k = 107, 103, 101, 97, ...$

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2 General vision about real and p-adic coupling constant evolution

The unification of super-canonical and Super Kac-Moody symmetries allows new view about p-adic aspects of the theory forcing a considerable modification and refinement of the almost decade old first picture about color coupling constant evolution.

Perhaps the most important questions about coupling constant evolution relate to the basic hypothesis about preferred role of primes $p \simeq 2^k$, k an integer. Why integer values of k are favored, why prime values are even more preferred, and why Mersenne primes $M_n = 2^n - 1$ and Gaussian Mersennes seem to be at the top of the hierarchy?

Second bundle of questions relates to the color coupling constant evolution. Do Mersenne primes really define a hierarchy of fixed points of color coupling constant evolution for a hierarchy of asymptotically non-free QCD type theories both in quark and lepton sector of the theory? How the transitions $M_n \rightarrow M_{n(next)}$ occur? What are the space-time correlates for the coupling constant evolution and for for these transitions and how space-time description relates to the usual description in terms of parton loops? How the condition that p-adic coupling constant evolution reflects the real coupling constant evolution can be satisfied and how strong conditions it poses on the coupling constant evolution?

2.1 A general view about coupling constant evolution

2.1.1 Zero energy ontology

In zero energy ontology one replaces positive energy states with zero energy states with positive and negative energy parts of the state at the boundaries of future and past direct light-cones forming a causal diamond. All conserved quantum numbers of the positive and negative energy states are of opposite sign so that these states can be created from vacuum. "Any physical state is creatable from vacuum" becomes thus a basic principle of quantum TGD and together with the notion of quantum jump resolves several philosophical problems (What was the initial state of universe?, What are the values of conserved quantities for Universe, Is theory building completely useless if only single solution of field equations is realized?).

At the level of elementary particle physics positive and negative energy parts of zero energy state are interpreted as initial and final states of a particle reaction so that quantum states become physical events. Equivalence Principle would hold true in the sense that the classical gravitational four-momentum of the vacuum extremal whose small deformations appear as the argument of configuration space spinor field is equal to the positive energy of the positive energy part of the zero energy quantum state. Equivalence Principle is expected to hold true for elementary particles and their composites but not for the quantum states defined around non-vacuum extremals.

2.1.2 Does the finiteness of measurement resolution dictate the laws of physics?

The hypothesis that the mere finiteness of measurement resolution could determine the laws of quantum physics [C3] completely belongs to the category of not at all obvious first principles. The basic observation is that the Clifford algebra spanned by the gamma matrices of the "world of classical worlds" represents a von Neumann algebra [23] known as hyperfinite factor of type II_1 (HFF) [A9, C6, C3]. HFF [24, 30] is an algebraic fractal having infinite hierarchy of included subalgebras isomorphic to the algebra itself [31]. The structure of HFF is closely related to several notions of modern theoretical physics such as integrable statistical physical systems [32], anyons [27], quantum groups and conformal field theories[25, 26], and knots and topological quantum field theories [33, 29].

Zero energy ontology is second key element. In zero energy ontology these inclusions allow an interpretation in terms of a finite measurement resolution: in the standard positive energy ontology this interpretation is not possible. Inclusion hierarchy defines in a natural manner the notion of coupling constant evolution and p-adic length scale hypothesis follows as a prediction. In this framework the extremely heavy machinery of renormalized quantum field theory involving the elimination of infinities is replaced by a precisely defined mathematical framework. More concretely, the included algebra creates states which are equivalent in the measurement resolution used. Zero energy states are associated with causal diamond formed by a pair of future and past directed light-cones having positive and negative energy parts of state at their boundaries. Zero energy state can be modified in a time scale shorter than the time scale of the zero energy state itself.

On can imagine two kinds of measurement resolutions. The element of the included algebra can leave the quantum numbers of the positive and negative energy parts of the state invariant, which means that the action of subalgebra leaves M-matrix invariant. The action of the included algebra can also modify the quantum numbers of the positive and negative energy parts of the state such that the zero energy property is respected. In this case the Hermitian operators subalgebra must commute with M-matrix.

The temporal distance between the tips of light-cones corresponds to the secondary p-adic time scale $T_{p,2} = \sqrt{p}T_p$ by a simple argument based on the observation that light-like randomness of light-like 3-surface is analogous to Brownian motion. This gives the relationship $T_p = L_p^2/Rc$, where R is CP_2 size. The action of the included algebra corresponds to an addition of zero energy parts to either positive or negative energy part of the state and is like addition of quantum fluctuation below the time scale of the measurement resolution. The natural hierarchy of time scales is obtained as $T_n = 2^{-n}T$ since these insertions must belong to either upper or lower half of the causal diamond. This implies that preferred p-adic primes are near powers of 2. For electron the time scale in question is .1 seconds defining the fundamental biorhythm of 10 Hz.

M-matrix representing a generalization of S-matrix and expressible as a product of a positive square root of the density matrix and unitary S-matrix would define the dynamics of quantum theory [C3]. The notion of thermodynamical state would cease to be a theoretical fiction and in a well-defined sense quantum theory could be regarded as a square root of thermodynamics. M-matrix is identifiable in terms of Connes tensor product [30] and therefore exists and is almost unique. Connes tensor product implies that the Hermitian elements of the included algebra commute with M-matrix and hence act like infinitesimal symmetries. A connection with integrable quantum field theories is suggestive. The remaining challenge is the calculation of M-matrix and the needed machinery might already exist.

The tension is present also now. The connection with visions should come from the discretization in terms of number theoretic braids providing space-time correlate for the finite measurement resolution and making p-adicization in terms of number theoretic braids possible. Number theoretic braids give a connection with the construction of configuration space geometry in terms of Dirac determinant and with TGD as almost TQFT and with conformal field theory approach. The mathematics for the inclusions of hyper-finite factors of type II_1 is also closely related to that for conformal field theories including quantum groups relating closely to Connes tensor product and non-commutativity.

2.1.3 How do p-adic coupling constant evolution and p-adic length scale hypothesis emerge?

Zero energy ontology in which zero energy states have as imbedding space correlates causal diamonds for which the distance between the tips of future and past directed light-cones are power of 2 multiples of fundamental time scale implies in a natural manner coupling constant evolution.

Could the coupling constant evolution in powers of 2 implying time scale hierarchy $T_n = 2^n T_0$ induce p-adic coupling constant evolution and explain why p-adic length scales correspond to $L_p \propto \sqrt{p}R$, $p \simeq 2^k$, R CP_2 length scale? This looks attractive but there is a problem. p-Adic length scales come as powers of $\sqrt{2}$ rather than 2 and the strongly favored values of k are primes and thus odd so that $n = k/2$ would be half odd integer. This problem can be solved.

1. The observation that the distance traveled by a Brownian particle during time t satisfies $r^2 = Dt$ suggests a solution to the problem. p-Adic thermodynamics applies because the partonic 3-surfaces X^2 are as 2-D dynamical systems random apart from light-likeness of their orbit. For CP_2 type vacuum extremals the situation reduces to that for a one-dimensional random light-like curve in M^4. The orbits of Brownian particle would now correspond to light-like geodesics γ_3 at X^3. The projection of γ_3 to a time=constant section $X^2 \subset X^3$ would define the 2-D path γ_2 of the Brownian particle. The M^4 distance r between the end points of γ_2 would be given $r^2 = Dt$. The favored values of t would correspond to $T_n = 2^n T_0$ (the full light-like geodesic). p-Adic length scales would result as $L^2(k) = DT(k) = D2^k T_0$ for $D = R^2/T_0$. Since only CP_2 scale is available as a fundamental scale, one would have $T_0 = R$ and $D = R$ and $L^2(k) = T(k)R$.

2. p-Adic primes near powers of 2 would be in preferred position. p-Adic time scale would not relate to the p-adic length scale via $T_p = L_p/c$ as assumed implicitly earlier but via $T_p = L_p^2/R_0 = \sqrt{p}L_p$, which corresponds to secondary p-adic length scale. For instance, in the case of electron with $p = M_{127}$ one would have $T_{127} = .1$ second which defines a fundamental biological rhythm. Neutrinos with mass around .1 eV would correspond to $L(169) \simeq 5$ μm (size of a small cell) and $T(169) \simeq 1. \times 10^4$ years. A deep connection between elementary particle physics and biology becomes highly suggestive.

3. In the proposed picture the p-adic prime $p \simeq 2^k$ would characterize the thermodynamics of the random motion of light-like geodesics of X^3 so that p-adic prime p would indeed be an inherent property of X^3.

2.2 Both symplectic and conformal field theories are needed in TGD framework

Before one can say anything quantitative about coupling constant evolution, one must have a formulation for its TGD counterpart and thus also a more detailed formulation for how to calculate M-matrix elements. There is also the question about infinities. By very general arguments infinities of quantum field theories are predicted to cancel in TGD Universe - basically by the non-locality of Kähler function as a functional of 3-surface and by the general properties of the vacuum functional identified as the exponent of Kähler function. The precise mechanism leading to the cancellation of infinities of local quantum field theories has remained unspecified. Only the realization that the symplectic invariance of quantum TGD provides a mechanism regulating the short distance behavior of N-point functions changed the situation in this respect. This also leads to concrete view about the generalized Feynman diagrams giving M-matrix elements and rather close resemblance with ordinary Feynman diagrammatics.

2.2.1 Symplectic invariance

Symplectic (or canonical as I have called them) symmetries of $\delta M^4_+ \times CP_2$ (light-cone boundary briefly) act as isometries of the "world of classical worlds". One can see these symmetries as analogs of Kac-Moody type symmetries with symplectic transformations of $S^2 \times CP_2$, where S^2 is $r_M = constant$ sphere of lightcone boundary, made local with respect to the light-like radial coordinate r_M taking the role of complex coordinate. Thus finite-dimensional Lie group G is replaced with infinite-dimensional group of symplectic transformations. This inspires the question whether a symplectic analog of conformal field theory at $\delta M^4_+ \times CP_2$ could be relevant for the construction of n-point functions in quantum TGD and what general properties these n-point functions would have. This section appears already in the previous chapter about symmetries of quantum TGD [C1] but because the results of the section provide the first concrete construction recipe of M-matrix in zero energy ontology, it is included also in this chapter.

2.2.2 Symplectic QFT at sphere

Actually the notion of symplectic QFT emerged as I tried to understand the properties of cosmic microwave background which comes from the sphere of last scattering which corresponds roughly to the age of 5×10^5 years [D8]. In this situation vacuum extremals of Kähler action around almost unique critical Robertson-Walker cosmology imbeddable in $M^4 \times S^2$, where there is homologically trivial geodesic sphere of CP_2. Vacuum extremal property is satisfied for any space-time surface which is surface in $M^4 \times Y^2$, Y^2 a Lagrangian sub-manifold of CP_2 with vanishing induced Kähler form. Symplectic transformations of CP_2 and general coordinate transformations of M^4 are dynamical symmetries of the vacuum extremals so that the idea of symplectic QFT emerges natural. Therefore I shall consider first symplectic QFT at the sphere S^2 of last scattering with temperature fluctution $\Delta T/T$ proportional to the fluctuation of the metric component g_{aa} in Robertson-Walker coordinates.

1. In quantum TGD the symplectic transformation of the light-cone boundary would induce action in the "world of classical worlds" (light-like 3-surfaces). In the recent situation it is convenient to regard perturbations of CP_2 coordinates as fields at the sphere of last scattering (call it S^2) so that symplectic transformations of CP_2 would act in the field space whereas those of S^2 would act in the coordinate space just like conformal transformations. The deformation of the metric would be a symplectic field in S^2. The symplectic dimension would be induced by the tensor properties of R-W metric in R-W coordinates: every S^2 coordinate index

would correspond to one unit of symplectic dimension. The symplectic invariance in CP_2 degrees of freedom is guaranteed if the integration measure over the vacuum deformations is symplectic invariant. This symmetry does not play any role in the sequel.

2. For a symplectic scalar field $n \geq 3$-point functions with a vanishing anomalous dimension would be functions of the symplectic invariants defined by the areas of geodesic polygons defined by subsets of the arguments as points of S^2. Since n-polygon can be constructed from 3-polygons these invariants can be expressed as sums of the areas of 3-polygons expressible in terms of symplectic form. n-point functions would be constant if arguments are along geodesic circle since the areas of all sub-polygons would vanish in this case. The decomposition of n-polygon to 3-polygons brings in mind the decomposition of the n-point function of conformal field theory to products of 2-point functions by using the fusion algebra of conformal fields (very symbolically $\Phi_k\Phi_l = c_{kl}^m\Phi_m$). This intuition seems to be correct.

3. Fusion rules stating the associativity of the products of fields at different points should generalize. In the recent case it is natural to assume a non-local form of fusion rules given in the case of symplectic scalars by the equation

$$\Phi_k(s_1)\Phi_l(s_2) = \int c_{kl}^m f(A(s_1, s_2, s_3))\Phi_m(s)d\mu_s \quad . \tag{1}$$

   Here the coefficients c_{kl}^m are constants and $A(s_1, s_2, s_3)$ is the area of the geodesic triangle of S^2 defined by the sympletic measure and integration is over S^2 with symplectically invariant measure $d\mu_s$ defined by symplectic form of S^2. Fusion rules pose powerful conditions on n-point functions and one can hope that the coefficients are fixed completely.

4. The application of fusion rules gives at the last step an expectation value of 1-point function of the product of the fields involves unit operator term $\int c_{kl} f(A(s_1, s_2, s))Idd\mu_s$ so that one has

$$\langle\Phi_k(s_1)\Phi_l(s_2)\rangle = \int c_{kl} f(A(s_1, s_2, s))d\mu_s \quad . \tag{2}$$

   Hence 2-point function is average of a 3-point function over the third argument. The absence of non-trivial symplectic invariants for 1-point function means that $n = 1$- an are constant, most naturally vanishing, unless some kind of spontaneous symmetry breaking occurs. Since the function $f(A(s_1, s_2, s_3))$ is arbitrary, 2-point correlation function can have both signs. 2-point correlation function is invariant under rotations and reflections.

2.2.3 Symplectic QFT with spontaneous breaking of rotational and reflection symmetries

CMB data suggest breaking of rotational and reflection symmetries of S^2. A possible mechanism of spontaneous symmetry breaking is based on the observation that in TGD framework the hierarchy of Planck constants assigns to each sector of the generalized imbedding space a preferred quantization axes. The selection of the quantization axis is coded also to the geometry of "world of classical worlds", and to the quantum fluctuations of the metric in particular. Clearly, symplectic QFT with spontaneous symmetry breaking would provide the sought-for really deep reason for the quantization of Planck constant in the proposed manner.

1. The coding of angular momentum quantization axis to the generalized imbedding space geometry allows to select South and North poles as preferred points of S^2. To the three arguments s_1, s_2, s_3 of the 3-point function one can assign two squares with the added point being either North or South pole. The difference

$$\Delta A(s_1, s_2, s_3) \equiv A(s_1, s_2, s_3, N) - A(s_1, s_2, s_3, S) \tag{3}$$

   of the corresponding areas defines a simple symplectic invariant breaking the reflection symmetry with respect to the equatorial plane. Note that ΔA vanishes if arguments lie along a geodesic line or if any two arguments co-incide. Quite generally, symplectic QFT differs from conformal QFT in that correlation functions do not possess singularities.

2. The reduction to 2-point correlation function gives a consistency conditions on the 3-point functions

$$\langle(\Phi_k(s_1)\Phi_l(s_2))\Phi_m(s_3)\rangle = c^r_{kl}\int f(\Delta A(s_1, s_2, s))\langle\Phi_r(s)\Phi_m(s_3)\rangle d\mu_s \tag{4}$$

$$= c^r_{kl}c_{rm}\int f(\Delta A(s_1, s_2, s))f(\Delta A(s, s_3, t))d\mu_s d\mu_t \ . \tag{5}$$

   Associativity requires that this expression equals to $\langle\Phi_k(s_1)(\Phi_l(s_2)\Phi_m(s_3))\rangle$ and this gives additional conditions. Associativity conditions apply to $f(\Delta A)$ and could fix it highly uniquely.

3. 2-point correlation function would be given by

$$\langle\Phi_k(s_1)\Phi_l(s_2)\rangle = c_{kl}\int f(\Delta A(s_1, s_2, s))d\mu_s \tag{6}$$

4. There is a clear difference between $n > 3$ and $n = 3$ cases: for $n > 3$ also non-convex polygons are possible: this means that the interior angle associated with some vertices of the polygon is larger than π. $n = 4$ theory is certainly well-defined, but one can argue that so are also $n > 4$ theories and skeptic would argue that this leads to an inflation of theories. TGD however allows only finite number of preferred points and fusion rules could eliminate the hierarchy of theories.

5. To sum up, the general predictions are following. Quite generally, for $f(0) = 0$ n-point correlation functions vanish if any two arguments co-incide which conforms with the spectrum of temperature fluctuations. It also implies that symplectic QFT is free of the usual singularities. For symmetry breaking scenario 3-point functions and thus also 2-point functions vanish also if s_1 and s_2 are at equator. All these are testable predictions using ensemble of CMB spectra.

2.2.4 Generalization to quantum TGD

Since number theoretic braids are the basic objects of quantum TGD, one can hope that the n-point functions assignable to them could code the properties of ground states and that one could separate from n-point functions the parts which correspond to the symplectic degrees of freedom acting as symmetries of vacuum extremals and isometries of the 'world of classical worlds'.

1. This approach indeed seems to generalize also to quantum TGD proper and the n-point functions associated with partonic 2-surfaces can be decomposed in such a manner that one obtains coefficients which are symplectic invariants associated with both S^2 and CP_2 Kähler form.

2. Fusion rules imply that the gauge fluxes of respective Kähler forms over geodesic triangles associated with the S^2 and CP_2 projections of the arguments of 3-point function serve basic building blocks of the correlation functions. The North and South poles of S^2 and three poles of CP_2 can be used to construct symmetry breaking n-point functions as symplectic invariants. Non-trivial 1-point functions vanish also now.

3. The important implication is that n-point functions vanish when some of the arguments co-incide. This might play a crucial role in taming of the singularities: the basic general prediction of TGD is that standard infinities of local field theories should be absent and this mechanism might realize this expectation.

Next some more technical but elementary first guesses about what might be involved.

1. It is natural to introduce the moduli space for n-tuples of points of the symplectic manifold as the space of symplectic equivalence classes of n-tuples. In the case of sphere S^2 convex n-polygon allows $n + 1$ 3-sub-polygons

and the areas of these provide symplectically invariant coordinates for the moduli space of symplectic equivalence classes of n-polygons (2^n-D space of polygons is reduced to $n+1$-D space). For non-convex polygons the number of 3-sub-polygons is reduced so that they seem to correspond to lower-dimensional sub-space. In the case of CP_2 n-polygon allows besides the areas of 3-polygons also 4-volumes of 5-polygons as fundamental symplectic invariants. The number of independent 5-polygons for n-polygon can be obtained by using induction: once the numbers $N(k,n)$ of independent $k \leq n$-simplices are known for n-simplex, the numbers of $k \leq n+1$-simplices for $n+1$-polygon are obtained by adding one vertex so that by little visual gymnastics the numbers $N(k,n+1)$ are given by $N(k,n+1) = N(k-1,n) + N(k,n)$. In the case of CP_2 the allowance of 3 analogs $\{N,S,T\}$ of North and South poles of S^2 means that besides the areas of polygons (s_1,s_2,s_3), (s_1,s_2,s_3,X), (s_1,s_2,s_3,X,Y), and (s_1,s_2,s_3,N,S,T) also the 4-volumes of 5-polygons (s_1,s_2,s_3,X,Y), and of 6-polygon (s_1,s_2,s_3,N,S,T), $X,Y \in \{N,S,T\}$ can appear as additional arguments in the definition of 3-point function.

2. What one really means with symplectic tensor is not clear since the naive first guess for the n-point function of tensor fields is not manifestly general coordinate invariant. For instance, in the model of CMB, the components of the metric deformation involving S^2 indices would be symplectic tensors. Tensorial n-point functions could be reduced to those for scalars obtained as inner products of tensors with Killing vector fields of $SO(3)$ at S^2. Again a preferred choice of quantization axis would be introduced and special points would correspond to the singularities of the Killing vector fields.

   The decomposition of Hamiltonians of the "world of classical worlds" expressible in terms of Hamiltonians of $S^2 \times CP_2$ to irreps of $SO(3)$ and $SU(3)$ could define the notion of symplectic tensor as the analog of spherical harmonic at the level of configuration space. Spin and gluon color would have natural interpretation as symplectic spin and color. The infinitesimal action of various Hamiltonians on n-point functions defined by Hamiltonians and their super counterparts is well-defined and group theoretical arguments allow to deduce general form of n-point functions in terms of symplectic invariants.

3. The need to unify p-adic and real physics by requiring them to be completions of rational physics, and the notion of finite measurement resolution suggest that discretization of also fusion algebra is necessary. The set of points appearing as arguments of n-point functions could be finite in a given resolution so that the p-adically troublesome integrals in the formulas for the fusion rules would be replaced with sums. Perhaps rational/algebraic variants of $S^2 \times CP_2 = SO(3)/SO(2) \times SU(3)/U(2)$ obtained by replacing these groups with their rational/algebraic variants are involved. Tedrahedra, octahedra, and dodecahedra suggest themselves

as simplest candidates for these discretized spaces. Also the symplectic moduli space would be discretized to contain only n-tuples for which the symplectic invariants are numbers in the allowed algebraic extension of rationals. This would provide an abstract looking but actually very concrete operational approach to the discretization involving only areas of n-tuples as internal coordinates of symplectic equivalence classes of n-tuples. The best that one could achieve would be a formulation involving nothing below measurement resolution.

4. This picture based on elementary geometry might make sense also in the case of conformal symmetries. The angles associated with the vertices of the S^2 projection of n-polygon could define conformal invariants appearing in n-point functions and the algebraization of the corresponding phases would be an operational manner to introduce the space-time correlates for the roots of unity introduced at quantum level. In CP_2 degrees of freedom the projections of n-tuples to the homologically trivial geodesic sphere S^2 associated with the particular sector of CH would allow to define similar conformal invariants. This framework gives dimensionless areas (unit sphere is considered). p-Adic length scale hypothesis and hierarchy of Planck constants would bring in the fundamental units of length and time in terms of CP_2 length.

The recent view about M-matrix described in [C3] is something almost unique determined by Connes tensor product providing a formal realization for the statement that complex rays of state space are replaced with $\mathcal{N}$ rays where $\mathcal{N}$ defines the hyper-finite sub-factor of type II_1 defining the measurement resolution. M-matrix defines time-like entanglement coefficients between positive and negative energy parts of the zero energy state and need not be unitary. It is identified as square root of density matrix with real expressible as product of of real and positive square root and unitary S-matrix. This S-matrix is what is measured in laboratory. There is also a general vision about how vertices are realized: they correspond to light-like partonic 3-surfaces obtained by gluing incoming and outgoing partonic 3-surfaces along their ends together just like lines of Feynman diagrams. Note that in string models string world sheets are non-singular as 2-manifolds whereas 1-dimensional vertices are singular as 1-manifolds. These ingredients we should be able to fuse together. So we try once again!

1. *Iteration* starting from vertices and propagators is the basic approach in the construction of n-point function in standard QFT. This approach does not work in quantum TGD. Symplectic and conformal field theories suggest that *recursion* replaces iteration in the construction. One starts from an n-point function and reduces it step by step to a vacuum expectation value of a 2-point function using fusion rules. Associativity becomes the fundamental dynamical principle in this process. Associativity in the sense of classical number fields has already shown its power and led to a

hyper-octoninic formulation of quantum TGD promising a unification of various visions about quantum TGD [E2].

2. Let us start from the representation of a zero energy state in terms of a causal diamond defined by future and past directed light-cones. Zero energy state corresponds to a quantum superposition of light-like partonic 3-surfaces each of them representing possible particle reaction. These 3-surfaces are very much like generalized Feynman diagrams with lines replaced by light-like 3-surfaces coming from the upper and lower light-cone boundaries and glued together along their ends at smooth 2-dimensional surfaces defining the generalized vertices.

3. It must be emphasized that the generalization of ordinary Feynman diagrammatics arises and conformal and symplectic QFTs appear only in the calculation of single generalized Feynman diagram. Therefore one could still worry about loop corrections. The fact that no integration over loop momenta is involved and there is always finite cutoff due to discretization together with recursive instead of iterative approach gives however good hopes that everything works. Note that this picture is in conflict with one of the earlier approaches based on positive energy ontology in which the hope was that only single generalized Feynman diagram could define the U-matrix thought to correspond to physical S-matrix at that time [E10].

4. One can actually simplify things by identifying generalized Feynman diagrams as maxima of Kähler function with functional integration carried over perturbations around it. Thus one would have conformal field theory in both fermionic and configuration space degrees of freedom. The light-like time coordinate along light-like 3-surface is analogous to the complex coordinate of conformal field theories restricted to some curve. If it is possible continue the light-like time coordinate to a hyper-complex coordinate in the interior of 4-D space-time sheet, the correspondence with conformal field theories becomes rather concrete. Same applies to the light-like radial coordinates associated with the light-cone boundaries. At light-cone boundaries one can apply fusion rules of a symplectic QFT to the remaining coordinates. Conformal fusion rules are applied only to point pairs which are at different ends of the partonic surface and there are no conformal singularities since arguments of n-point functions do not co-incide. By applying the conformal and symplectic fusion rules one can eventually reduce the n-point function defined by the various fermionic and bosonic operators appearing at the ends of the generalized Feynman diagram to something calculable.

5. Finite measurement resolution defining the Connes tensor product is realized by the discretization applied to the choice of the arguments of n-point functions so that discretion is not only a space-time correlate of finite resolution but actually defines it. No explicit realization of the measurement resolution algebra $\mathcal{N}$ seems to be needed. Everything should boil down to

the fusion rules and integration measure over different 3-surfaces defined by exponent of Kähler function and by imaginary exponent of Chern-Simons action. The continuation of the configuration space Clifford algebra for 3-surfaces with cm degrees of freedom fixed to a hyper-octonionic variant of gamma matrix field of super-string models defined in M^8 (hyper-octonionic space) and $M^8 \leftrightarrow M^4 \times CP_2$ duality leads to a unique choice of the points, which can contribute to n-point functions as intersection of M^4 subspace of M^8 with the counterparts of partonic 2-surfaces at the boundaries of light-cones of M^8. Therefore there are hopes that the resulting theory is highly unique. Symplectic fusion algebra reduces to a finite algebra for each space-time surface if this picture is correct.

6. Consider next some of the details of how the light-like 3-surface codes for the fusion rules associated with it. The intermediate partonic 2- surfaces must be involved since otherwise the construction would carry no information about the properties of the light-like 3-surface, and one would not obtain perturbation series in terms of the relevant coupling constants. The natural assumption is that partonic 2-surfaces belong to future/past directed light-cone boundary depending on whether they are on lower/upper half of the causal diamond. Hyper-octonionic conformal field approach fixes the n_{int} points at intermediate partonic two-sphere for a given light-like 3-surface representing generalized Feynman diagram, and this means that the contribution is just N-point function with $N = n_{out} + n_{int} + n_{in}$ calculable by the basic fusion rules. Coupling constant strengths would emerge through the fusion coefficients, and at least in the case of gauge interactions they must be proportional to Kähler coupling strength since n-point functions are obtained by averaging over small deformations with vacuum functional given by the exponent of Kähler function. The first guess is that one can identify the spheres $S^2 \subset \delta M^4_\pm$ associated with initial, final and, and intermediate states so that symplectic n-points functions could be calculated using single sphere.

These findings raise the hope that quantum TGD is indeed a solvable theory. The coupling constant evolution is based on the same mechanism as in QFT and symplectic invariance replaces ad hoc UV cutoff with a genuine dynamical regulation mechanism. Causal diamond itself defines the physical IR cutoff. p-Adic and real coupling constant evolutions reflect the underlying evolution in powers of two for the temporal distance between the tips of the light-cones of the causal diamond and the association of macroscopic time scale as secondary p-adic time scale to elementary particles (.1 seconds for electron) serves as a first test for the picture. Even if one is not willing to swallow any bit of TGD, the classification of the symplectic QFTs remains a fascinating mathematical challenge in itself. A further challenge is the fusion of conformal QFT and symplectic QFT in the construction of n-point functions. One might hope that conformal and symplectic fusion rules could be treated independently.

2.2.5 More detailed view about the construction of M-matrix elements

After three decades there are excellent hopes of building an explicit recipe for constructing M-matrix elements but the devil is in the details.

1. Elimination of infinities and coupling constant evolution

The elimination of infinities would follow from the symplectic QFT part of the theory. The symplectic contribution to n-point functions vanishes when two arguments co-incide. The UV cancellation mechanism has nothing to do with the finite measurement resolution which corresponds to the size of the causal diamonds inside which the space-time sheets representing radiative corrections are. There is also IR cutoff due to the presence of largest causal diamond.

On can decompose the radiative corrections two two types. First kind of corrections appear both at the level of positive/and negative energy parts of zero energy states. Second kind of corrections appear at the level of interactions between them. This decomposition is standard in quantum field theories and corresponds to the renormalization constants of fields *resp.* renormalization of coupling constants. The corrections due to the increase of measurement resolution in time comes as very specific corrections to positive and negative energy states involving gluing of smaller causal diamonds to the upper and lower boundaries of causal diamonds along any radial light-like ray. The radiative corresponds to the interactions correspond to the addition of smaller causal diamonds in the interior of the larger causal diamond. Scales for the corrections come as scalings in powers of 2 rather than as continuous scaling of measurement resolution.

2. Conformal symmetries

The basic questions are the following ones. How hyper-octonionic/-quaternionic/-complex super-conformal symmetry relates to the super-canonical conformal symmetry at the imbedding space level and the super Kac-Moody symmetry associated with the light-like 3-surfaces? How do the dual $HO = M^8$ and $H = M^4 \times CP_2$ descriptions (number theoretic compactifcation) relate?

Concerning the understanding of these issues, the earlier construction of physical states poses strong constraints [C1].

1. The state construction utilizes both super-canonical and super Kac-Moody algebras. Super-canonical algebra has negative conformal weights and creates tachyonic ground states from which Super Kac-Moody algebra generates states with non-negative conformal weight determining the mass squared value of the state. The commutator of these two algebras annihilates the physical states. This requires that both super conformal algebras must allow continuation to hyper-octonionic algebras, which are independent.

2. The light-like radial coordinate at $\delta M^4_\pm$ can be continued to a hyper-complex coordinate in $M^2_\pm$ defined the preferred commutative plane of

non-physical polarizations, and also to a hyper-quaternionic coordinate in $M^4_\pm$. Hence it would seem that super-canonical algebra can be continued to an algebra in $M^2_\pm$ or perhaps in the entire $M^4_\pm$. This would allow to continue also the operators G, L and other super-canonical operators to operators in hyper-quaternionic $M^4_\pm$ needed in stringy perturbation theory.

3. Also the super KM algebra associated with the light-like 3-surfaces should be continueable to hyper-quaternionic $M^4_\pm$. Here $HO-H$ duality comes in rescue. It requires that the preferred hyper-complex plane M^2 is contained in the tangent plane of the space-time sheet at each point, in particular at light-like 3-surfaces. We already know that this allows to assign a unique space-time surface to a given collection of light-like 3-surfaces as hyper-quaternionic 4-surface of HO hypothesized to correspond to (an obviously preferred) extremal of Kähler action. An equally important implication is that the light-like coordinate of X^3 can be continued to hyper-complex coordinate M^2 coordinate and thus also to hyperquaternionic M^4 coordinate.

4. The four-momentum appears in super generators G_n and L_n. It seems that the formal Fourier transform of four-momentum components to gradient operators to $M^4_\pm$ is needed and defines these operators as particular elements of the CH Clifford algebra elements extended to fields in imbedding space.

3. What about stringy perturbation theory?

The analog of stringy perturbation theory does not seems only a highly attractive but also an unavoidable outcome since a generalization of massless fermionic propagator is needed. The inverse for the sum of super Kac-Moody and super-canonical super-Virasoro generators G (L) extended to an operator acting on the difference of the M^4 coordinates of the end points of the propagator line connecting two partonic 2-surfaces should appear as fermionic (bosonic) propagator in stringy perturbation theory. Virasoro conditions imply that only G_0 and L_0 appear as propagators. Momentum eigenstates are not strictly speaking possible since since discretization is present due to the finite measurement resolution. One can however represent these states using Fourier transform as a superposition of momentum eigenstates so that standard formalism can be applied.

Symplectic QFT gives an additional multiplicative contribution to n-point functions and there would be also braiding S-matrices involved with the propagator lines in the case that partonic 2-surface carriers more than 1 point. This leaves still modular degrees of freedom of the partonic 2-surfaces describable in terms of elementary particle vacuum functionals and the proper treatment of these degrees of freedom remains a challenge.

4. What about non-hermiticity of the CH super-generators carrying fermion number?

TGD represents also a rather special challenge, which actually represents the fundamental difference between quantum TGD and super string models. The assignment of fermion number to CH gamma matrices and thus also to the super-generator G is unavoidable. Also M^4 and H gamma matrices carry fermion number. This has been a long-standing interpretational problem in quantum TGD and I have been even ready to give up the interpretation of four-momentum operator appearing in G_n and L_n as actual four-momenta. The manner to get rid of this problem would be the assumption of Majorana property but this would force to give up the interpretation of different imbedding space chiralities in terms of conserved lepton and quark numbers and would also lead to super-string theory with critical dimension 10 or 11. A further problem is how to obtain amplitudes which respect fermion number conservation using string perturbation theory if $1/G = G^{\dagger}/L_0$ carries fermion number.

The recent picture does not leave many choices so that I was forced to face the truth and see how everything falls down to this single nasty detail! It became as a total surprise that gamma matrices carrying fermion number do not cause any difficulties in zero energy ontology and make sense even in the ordinary Feynman diagrammatics.

1. Non-hermiticity of G means that the center of mass terms CH gamma matrices must be distinguished from their Hermitian conjugates. In particular, one has $\gamma_0 \neq \gamma_0^{dagger}$. One can interpret the fermion number carrying M^4 gamma matrices of the complexified quaternion space.

2. One might think that $M^4 \times CP_2$ gamma matrices carrying fermion number is a catastrophe but this is not the case in massless theory. Massless momentum eigen states can be created by the operator $p^k \gamma_k^{\dagger}$ from a vacuum annihilated by gamma matrices and satisfying massless Dirac equation. The conserved fermion number defined by the integral of $\overline{\Psi}\gamma^0\Psi$ over 3-space gives just its standard value. A further experimentation shows that Feynman diagrams with non-hermitian gamma matrices give just the standard results since fermionic propagator and boson-emission vertices give compensating fermion numbers.

3. If the theory would contain massive fermions or a coupling to a scalar Higgs, a catastrophe would result. Hence ordinary Higgs mechanism is not possible in this framework. Of course, also the quantization of fermions is totally different. In TGD fermion mass is not a scalar in H. Part of it is given by CP_2 Dirac operator, part by p-adic thermodynamics for L_0, and part by Higgs field which behaves like vector field in CP_2 degrees of freedom, so that the catastrophe is avoided.

4. In zero energy ontology zero energy states are characterized by M-matrix elements constructed by applying the combination of stringy and symplectic Feynman rules and fermionic propagator is replaced with its super-conformal generalization reducing to an ordinary fermionic propagator for

massless states. The norm of a single fermion state is given by a propagator connecting positive energy state and its conjugate with the propagator G_0/L_0 and the standard value of the norm is obtained by using Dirac equation and the fact that Dirac operator appears also in G_0.

5. The hermiticity of super-generators G would require Majorana property and one would end up with superstring theory with critical dimension $D = 10$ or $D = 11$ for the imbedding space. Hence the new interpretation of gamma matrices, proposed already years ago, has very profound consequences and convincingly demonstrates that TGD approach is indeed internally consistent.

In this framework coupling constant evolution would have interpretation in terms of addition of intermediate zero energy states corresponding to the generalized Feynman diagrams obtained by the insertion of causal diamonds with a new shorter time scale $T = T_{prev}/2$ to the previous Feynman diagram. p-Adic length scale hypothesis follows naturally. A very close correspondence with ordinary Feynman diagrammatics arises and and ordinary vision about coupling constant evolutions arises. The absence of infinities follows from the symplectic invariance which is genuinely new element. p-Adic and real coupling constant evolutions can be seen as completions of coupling constant evolutions for physics based on rationals and their algebraic extensions.

2.3 How p-adic and real coupling constant evolutions are related to each other?

The real and p-adic coupling constant evolutions should be consistent with each other. This means that the coupling constants $g(p_1, p_2, p_3)$ as functions of p-adic primes characterizing particles of the vertex should have the same qualitative behavior as real and p-adic functions. Hence the p-adic norms of complex rational valued (or those in algebraic extension) amplitudes must give a good estimate for the behavior of the real vertex. Hence a restriction of a continuous correspondence between p-adics and reals to rationals is highly suggestive. The restriction of the canonical identification to rationals would define this kind of correspondence but this correspondence respects neither symmetries nor unitarity in its basic form. Some kind of compromize between correspondence via common rationals and canonical identification should be found.

The compromize might be achieved by using a modification of canonical identification $I_{R_p \to R}$. Generalized numbers would be regarded in this picture as a generalized manifold obtained by gluing different number fields together along rationals. Instead of a direct identification of real and p-adic rationals, the p-adic rationals in R_p are mapped to real rationals (or vice versa) using a variant of the canonical identification $I_{R \to R_p}$ in which the expansion of rational number $q = r/s = \sum r_n p^n / \sum s_n p^n$ is replaced with the rational number $q_1 = r_1/s_1 = \sum r_n p^{-n} / \sum s_n p^{-n}$ interpreted as a p-adic number:

$$q = \frac{r}{s} = \frac{\sum_n r_n p^n}{\sum_m s_n p^n} \rightarrow q_1 = \frac{\sum_n r_n p^{-n}}{\sum_m s_n p^{-n}} \quad (7)$$

This variant of canonical identification is not equivalent with the original one using the infinite expansion of q in powers of p since canonical identification does not commute with product and division. The variant is however unique in the recent context when r and s in $q = r/s$ have no common factors. For integers $n < p$ it reduces to direct correspondence. R_{p1} and R_{p_2} are glued together along common rationals by an the composite map $I_{R\rightarrow R_{p_2}} I_{R_{p_1}\rightarrow R}$.

Instead of a re-interpretation of the p-adic number $g(p_1, p_2, p_3)$ as a real number or vice versa would be continued by using this variant of canonical identification. The nice feature of the map would be that continuity would be respected to high degree and something which is small in real sense would be small also in p-adic sense.

2.3.1 How to achieve consistency with the unitarity of topological mixing matrices and of CKM matrix?

It is easy to invent an objection against the proposed relationship between p-adic and real coupling constants. Topological mixing matrices U, D and CKM matrix $V = U^\dagger D$ define an important part of the electro-weak coupling constant structure and appear also in coupling constants. The problem is that canonical identification does not respect unitarity and does not commute with the matrix multiplication in the general case unlike gluing along common rationals. Even if matrices U and D which contain only ratios of integers smaller than p are constructed, the construction of V might be problematic since the products of two rationals can give a rational $q = r/s$ for which r or s or both are larger than p.

One might hope that the objection could be circumvented if the ratios of the integers of the algebraic extension defining the matrix elements of CKM matrix are such that the integer components of algebraic integers are smaller than p in U and D and even the products of integers in $U^\dagger D$ satisfy this condition so that modulo p arithmetics is avoided.

In the standard parametrization all matrix elements of the unitarity matrix can be expressed in terms of real and imaginary parts of complex phases ($p \ mod\ 4 = 3$ guarantees that $\sqrt{-1}$ is not an ordinary p-adic number involving infinite expansion in powers of p). These phases are expressible as products of Pythagorean phases and phases in some algebraic extension of rationals.

i) Pythagorean phases defined as complex rationals $[r^2 - s^2 + i2rs]/(r^2 + s^2)$ are an obvious source of potential trouble. However, if the products of complex integers appearing in the numerators and denominators of the phases have real and imaginary parts smaller than p it seems to be possible to avoid difficulties in the definition of $V = U^\dagger D$.

ii) Pythagorean phases are not periodic phases. Algebraic extensions allow to introduce periodic phases of type $exp(i\pi m/n)$ expressible in terms of p-adic numbers in a finite-dimensional algebraic extension involving various roots of rationals. Also in this case the product $U^\dagger D$ poses conditions on the size of integers appearing in the numerators and denominators of the rationals involved.

If the expectation that topological mixing matrices and CKM matrix characterize the dynamics at the level $p \simeq 2^k$, $k = 107$, is correct, number theoretical constraints are not expected to bring much new to what is already predicted. Situation changes if these matrices appear already at the level k. For $k = 89$ hadron physics the restrictions would be even stronger and might force much simpler U, D and CKM matrices.

k-adicity constraint would have even stronger implications for S-matrix and could give very powerful constraints to the S-matrix of color interactions. Quite generally, the constraints would imply a p-adic hierarchy of increasingly complex S-matrices: kind of a physical realization for number theoretic emergence. The work with CKM matrix has shown how powerful the number theoretical constraints are, and there are no reasons to doubt that this could not be the case also more generally since in the lowest order the construction would be carried out in finite (Galois) fields $G(p,k)$.

2.3.2 How generally the hybrid of canonical identification and identification via common rationals can apply?

The proposed gluing procedure, if applied universally, has non-trivial implications which need not be consistent with all previous ideas.

1. The basic objection against the new kind of identification is that it does not commute with symmetries. Therefore its application at imbedding space and space-time level is questionable.

2. The mapping of p-adic probabilities by canonical identification to their real counterparts requires a separate normalization of the resulting probabilities. Also the new variant of canonical identification requires this since it does not commute with the sum.

3. The direct correspondence of reals and p-adics by common rationals at space-time level implies that the intersections of cognitive space-time sheets with real space-time sheet have literally infinite size (p-adically infinitesimal corresponds to infinite in real sense for rational) and consist of discrete points in general. If the new gluing procedure is adopted also at space-time level, it would considerably de-dramatize the radical idea that the size for the space-time correlates of cognition is literally infinite and cognition is a literally cosmic phenomenon.

   Of course, the new kind of correspondence could be also seen as a manner to construct cognitive representations by mapping rational points to rational points in the real sense and thus as a formation of cognitive representations at space-time level mapping points close to each other in real sense to points close to each other p-adically but arbitrarily far away in real sense. The image would be a completely chaotic looking set of points in the wrong topology and would realize the idea of Bohm about hidden order in a very concrete manner. This kind of mapping might be used to code visual information using the value of p as a part of the code key.

4. In p-adic thermodynamics p-adic particle mass squared is mapped to its real counterpart by canonical identification. The objection against the use of the new variant of canonical identification is that the predictions of p-adic thermodynamics for mass squared are not rational numbers but infinite power series. p-Adic thermodynamics itself however defines a unique representation of probabilities as ratios of generalized Boltzmann weights and partition function and thus the variant of canonical identification indeed generalizes and at the same time raises worries about the fate of the earlier predictions of the p-adic thermodynamics.

Quite generally, the thermodynamical contribution to the particle mass squared is in the lowest p-adic order of form rp/s, where r is the number of excitations with conformal weight 1 and s the number of massless excitations with vanishing conformal weight. The real counterpart of mass squared for the ordinary canonical identification is of order CP_2 mass by $r/s = R + r_1 p + ...$ with $R < p$ near to p. Hence the states for which massless state is degenerate become ultra heavy if r is not divisible by s. For the new variant of canonical identification these states would be light. It is not actually clear how many states of this kind the generalized construction unifying super-canonical and super Kac-Moody algebras predicts.

A less dramatic implication would be that the second order contribution to the mass squared from p-adic thermodynamics is always very small unless the integer characterizing it is a considerable fraction of p. When ordinary canonical identification is used, the second order term of form rp^2/s can give term of form Rp^2, $R < p$ of order p. This occurs only in the case of left handed neutrinos.

The assumption that the second order term to the mass squared coming from other than thermodynamical sources gives a significant contribution is made in the most recent calculations of leptonic masses [F3]. It poses constraints on CP_2 mass which in turn are used as a guideline in the construction of a model for hadrons [F4]. This kind of contribution is possible also now and corresponds to a contribution Rp^2, $R < p$ near p.

The new variant of the canonical correspondence resolves the long standing problems related to the calculation of Z and W masses. The mass squared for intermediate gauge bosons is smaller than one unit when m_0^2 is used as a fundamental mass squared unit. The standard form of the canonical identification requires $M^2 = (m/n)p^2$ whereas in the new approach $M^2 = (m/n)p$ is allowed. Second difficult problem has been the p-adic description of the group theoretical model for m_W^2/m_Z^2 ratio. In the new framework this is not a problem anymore [F3] since canonical identification respects the ratios of small integers.

On the other hand, the basic assumption of the successful model for topological mixing of quarks [F4] is that the modular contribution to the masses is of form np. This assumption loses its original justification for this option and some other justification is needed. The first guess is that the conditions on mass squared plus probability conservation might not be consistent with unitarity unless the modular contribution to the mass squared remains integer valued in the mixing (note that all integer values are not possible [F4]). Direct numerical experimentation however shows that that this is not the case.

2.4 A revised view about the interpretation and evolution of Kähler coupling strength

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.

2.4.1 Formula for Kähler coupling constant

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

1. 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

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

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

$$S_K(CP_2) \rightarrow a \times S_K(CP_2) . \quad (9)$$

   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.

2. 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

$$\begin{aligned} G &= L_p^2 \times exp(-2aS_K(CP_2)) \ . \\ L_p &= \sqrt{p}R \ . \end{aligned} \tag{10}$$

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

$$\begin{aligned} \alpha_K &= \frac{a\pi}{4log(pK)} \ , \\ K &= \frac{R^2}{G} \ . \end{aligned} \tag{11}$$

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

$$K = 2 \times 3 \times 5 \times 7 \times 11 \times 13 \times 17 \times 19 \times 23 \times 2^{-3} * (15/17) \ . \tag{12}$$

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 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.

2.4.2 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

[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 approximation contained an error

$$\begin{aligned} v_0 &= \frac{b}{2\sqrt{\alpha_K K}} \ , \\ \alpha_K(p) &= \frac{a\pi}{4log(pK)} \ , \\ K &= \frac{R^2}{G} \ . \end{aligned} \tag{13}$$

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

$$\frac{a}{b} = \frac{4 * log(pK)}{\pi} \frac{2^{2m-1}}{K} \ . \tag{14}$$

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.

2.4.3 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 $\alpha_{U(1)}$:

$$\alpha_K = \alpha_{U(1)} = \frac{\alpha_{em}}{cos^2(\theta_W)} \simeq \frac{1}{104.1867} \ ,$$
$$sin^2(\theta_W)_{|10\ MeV} \simeq 0.2397(13) \ ,$$
$$\alpha_{em}(M_{127}) = 0.00729735253327 \ . \qquad (15)$$

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 [127] 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 $\alpha_{U(1)}(127)$.

2.4.4 Is gravitational constant an approximate RG invariant?

The original model for the p-adic evolution of α_K was based on the p-adic renormalization group invariance of gravitational constant. The starting point was the observation that on purely dimension analytic basis one can write $G = exp(-2S_K(CP_2))L_p^2$. If α_K is p-adic RG invariant, G scales like L_p^2 which looked completely non-sensible at that time so that the identification $\alpha_K = \alpha_{U(1)}$ was given up. Discrete p-adic evolution for α_K is consistent with RG invariance and quantum criticality at a given p-adic space-time sheet.

This view however leads to problems with the identification $\alpha_K = \alpha_{U(1)}$ since the evolution of α_K dictated by RG invariance of G is much faster than that of $\alpha_{U(1)}$. The condition

$$cos^2(\theta_W)(89) = \frac{log(M_{127}K)}{log(M_{89}K)} \times \frac{\alpha_{em}(M_{127})}{\alpha_{em}(M_{89})} \times cos^2(\theta_W)(127) \ . \qquad (16)$$

together with the experimental value $1/\alpha_{em}(M_{89}) \simeq 128$ as predicted by standard model, gives $sin^2(\theta_W)(89) = .0474$ to be compared with the measured valued .23120(15) at intermediate boson mass scale [127]!

Furthermore, if α_K evolves with p then v_0 is predicted to evolve too but $v_0 = 2^{-11}$ is consistent with experimental facts (apart from possible presence of sub-harmonics which can be however understood in TGD framework).

2.4.5 Or is α_K RG invariant?

One is forced to ask whether one must give up the existing scenario for the p-adic evolution of α_K and identify it with the evolution of $\alpha_{U(1)}$ or perhaps even p-adic RG invariance of α_K. The predicted very fast evolution $G \propto L_p^2$ in the approximation that α_K is RG invariant makes sense only if L_p characterizes the space-time sheets carrying gravitational interaction or even to gravitons and if these space-time sheet corresponds to $p = M_{127}$ under normal conditions.

If bosons correspond to Mersenne primes, this would be naturally the case since the Mersenne prime next to M_{127} corresponds to a completely super-astrophysical length scale. In this case p-adic length scale hypothesis would predict $v_0^{-2}(L(k)) = 2^{-22}2^{-k+127}$ if α_K is RG invariant so that it would behave as a power of 2. $\hbar_{gr}$ would scale as 2^{-k+127} and approach rapidly to zero as $L(k)$ increases whereas gravitational force would become strong.

If same p_0 characterizes all ordinary gauge bosons with their dark variants included, one would have $p_0 = M_{89} = 2^{89} - 1$. In this case however the gravitational coupling strength would be weaker by a factor 2^{-38}. M_{127} also defines a dark length scale in TGD inspired quantum model of living matter [F9, J6].

A further nice feature of this identification is that one can also allow the scaling of CP_2 metric and thus R^2 by $\lambda^2 = (\hbar/\hbar_0)^2$ inducing $K \rightarrow \lambda^2 K$. $1/v_0 \rightarrow \lambda/v_0$ implies that $\hbar_{gr}$ scales in the same manner as $\hbar$. Hence it would seem that $\hbar$ corresponds to M^4- and $\hbar_{gr}$ to CP_2 degrees of freedom and the huge value of $\hbar_{gr}$ would mean that there is that cosmology has quantal lattice like structure in cosmological length scales with H_a/G, $G \subset SL(2,C)$, serving as a basic lattice cell (here H_a denotes $a = constant$ hyperboloid of M^4_+). The observed sub-harmonics of v_0 could thus be understood in terms of scalings of CP_2 gravitational constant. This structure is supported also by the quantization of cosmological red shifts [126].

The huge value of h_{gr} assignable to color algebra does not mean that colored states would have huge values of color charges since fractionization of color quantum numbers occurs. It however means that dark color charges are de-localized in huge length scales and cosmological color could be seen as responsible for a macroscopic quantum coherence in astrophysical length scales.

2.4.6 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.

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

2. 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

$$\frac{1}{\alpha_{U(1)}} + \frac{1}{\alpha_s} = \frac{1}{\alpha_K} \quad . \tag{17}$$

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

$$\alpha_s = \frac{1}{\frac{1}{\alpha_K} - \frac{1}{\alpha_{U(1)}}} \quad . \tag{18}$$

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 $1/\alpha_{U(1)}(89) = 1/97.6374$.

1. $\alpha_K = \alpha_{em}(127)$ 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

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

   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.

2. 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.

2.5 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 [42] 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 $T_p = 1/k$.

2.5.1 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.

2.5.2 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

$$g_K^2 = \frac{\pi}{k} \ , \frac{1}{\alpha_K} = 4k \ . \tag{19}$$

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.

1. $\alpha_K = \alpha_{em}$ 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.

2. 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.

2.5.3 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.

1. To see what this symmetry might be consider the generalization of the [43] obtained by combining theta angle and gauge coupling to single complex number via the formula

$$\tau = \frac{\theta}{2\pi} + i\frac{4\pi}{g^2} \ . \tag{20}$$

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.

2. 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

$$\tau = 4k(1 - i) \ . \tag{21}$$

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

$\tau \to \tau + 4(1-i)$ 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.

3. 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 $k > 0$.

4. 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).

2.5.4 Is p-adicization needed and possible only in 3-D sense?

The action of CP_2 type extremal is given as $S = \pi/8\alpha_K = k\pi/2$. Therefore the exponent of Kähler action appearing in the vacuum functional would be $exp(k\pi)$ - Gelfond's constant - known to be a transcendental number [21]. Also its powers are transcendental. If one wants to p-adicize also in 4-D sense, this raises a problem.

Before considering this problem, consider first the 4-D p-adicization more generally.

1. The definition of Kähler action and Kähler function in p-adic case can be obtained only by algebraic continuation from the real case since no satisfactory definition of p-adic definite integral exists. These difficulties are even more serious at the level of configuration space unless algebraic continuation allows to reduce everything to real context. If TGD is integrable theory in the sense that functional integral over 3-surfaces reduces to calculable functional integrals around the maxima of Kähler function, one might dream of achieving the algebraic continuation of real formulas. Note however that for light-like 3-surface the restriction to a category of algebraic surfaces essential for the re-interpretation of real equations of 3-surface as p-adic equations. It is far from clear whether also preferred extremals of Kähler action have this property.

2. Is 4-D p-adicization the really needed? The extension of light-like partonic 3-surfaces to 4-D space-time surfaces brings in classical dynamical variables necessary for quantum measurement theory. p-Adic physics defines correlates for cognition and intentionality. One can argue that these are not quantum measured in the conventional sense so that 4-D p-adic space-time sheets would not be needed at all. The p-adic variant for the

exponent of Chern-Simons action can make sense using a finite-D algebraic extension defined by $q = exp(i2\pi/n)$ and restricting the allowed light-like partonic 3-surfaces so that the exponent of Chern-Simons form belongs to this extension of p-adic numbers. This restriction is very natural from the point of view of dark matter hierarchy involving extensions of p-adics by quantum phase q.

If one remains optimistic and wants to p-adicize also in 4-D sense, the transcendental value of the vacuum functional for CP_2 type vacuum extremals poses a problem (not the only one since the p-adic norm of the exponent of Kähler action can become completely unpredictable).

1. One can also consider extending p-adic numbers by introducing $exp(\pi)$ and its powers and possibly also π. This would make the extension of p-adics infinite-dimensional which does not conform with the basic ideas about cognition. Note that e^p is not p-adic transcendental so that extension of p-adics by powers e is finite-dimensional and if p-adics are first extended by powers of π then further extension by $exp(\pi)$ is p-dimensional.

2. A more tricky manner to overcome the problem posed by the CP_2 extremals is to notice CP_2 type extremals are necessarily deformed and contain a hole corresponding to the light-like 3-surface or several of them. This would reduce the value of Kähler action and one could argue that the allowed p-adic deformations are such that the exponent of Kähler action is a p-adic number in a finite extension of p-adics. This option does not look promising.

2.5.5 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

$$T_p = \frac{1}{k} \ . \tag{22}$$

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.

2.6 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 [C5, E9] 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 [A9, D7]. 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.

2.6.1 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 [A9]. 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.

2.6.2 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.

2.7 The formula for the hadronic string tension

It is far from clear whether the strong gravitational coupling constant has same relation to the parameter $M_0^2 = 16m_0^2 = 1/\alpha' = 2\pi T$ as it would have in string model.

1. One could estimate the strong gravitational constant from the fundamental formula for the gravitational constant expressed in terms of exponent of Kähler action in the case that one has $\alpha_K = 1/4$. The formula reads as

$$\frac{L_p^2}{G_p} = exp(2aS_K(CP_2)) = exp(\pi/4\alpha_K) = e^{\pi} \ . \quad (23)$$

   a is a parameter telling which fraction the action of wormhole contact is about the full action for CP_2 type vacuum extremal and $a \sim 1/2$ holds true. The presence of a can take care that the exponent is rational number. For $a = 1$ The number at the right hand side is Gelfond constant and one obtains

$$G_p = exp(-\pi) \times L_p^2 \ . \quad (24)$$

2. One could relate the value of the strong gravitational constant to the parameter $M_0^2(k) = 16m(k)^2$, $p \simeq 2^k$ also assuming that string model

formula generalizes as such. The basic formulas can be written in terms of gravitational constant G, string tension T, and $M_0^2(k)$ as

$$\frac{1}{8\pi G(k)} = \frac{1}{\alpha'} = 2\pi T(k) = \frac{1}{M_0^2(k)} = \frac{1}{16 m(k)^2} \quad . \tag{25}$$

This allows to express G in terms of the hadronic length scale $L(k) = 2\pi/m(k)$ as

$$G(k) = \frac{1}{16^2\pi^2}L(k)^2 \simeq 3.9\times 10^{-4}L(k)^2 \quad . \tag{26}$$

The value of gravitational coupling would be by two orders of magnitude smaller than for the first option.

3 Exotic particles predicted by TGD

Besides lepto-hadrons and M_{89} hadrons TGD suggests also other new physics effects such as higher generations for bosons and fractally scaled up versions of quarks. The basic challenge is to decide on experimental grounds whether partonic vertices correspond to fusions or branchings and the physics of $M\overline{M}$ systems allows to do this. More exotic effects are related to the new concept of space time: for example the concept of topological evaporation (formation of Baby Universies in elementary particle length scale) suggests an explanation for the Pomeron. Also exotic p-adic Super Virasoro representations for which the CP_2 mass scale is replaced effectively divided by a power of p can be considered as possible associated with non-perturbative aspects of hadronic physics.

3.1 Higher gauge boson families

TGD predicts that also gauge bosons, with gravitons included, should be characterized by family replication phenomenon but not quite in the expected manner. The first expectation was that these gauge bosons would have at least 3 light generations just like quarks and leptons.

Only within last two years it has become clear that there is a deep difference between fermions and gauge bosons. Elementary fermions and particles superconformally related to elementary fermions correspond to single throat of a wormhole contact assignable to a topologically condensed CP_2 type vacuum extremal whereas gauge bosons would correspond to a wormhole throat pair assignable to wormhole contact connecting two space-time sheets. Wormhole throats correspond to light-like partonic 3-surfaces at which the signature of the induced metric changes.

In the case of 3 generations gauge bosons can be arranged to octet and singlet representations of a dynamical SU(3) and octet bosons for which wormhole throats have different genus could be massive and effectively absent from the spectrum.

Exotic gauge boson octet would induce particle reactions in which conserved handle number would be exchanged between incoming particles such that total handle number of boson would be difference of the handle numbers of positive and negative energy throat. These gauge bosons would induce flavor changing but genus conserving neutral current. There is no evidence for this kind of currents at low energies which suggests that octet mesons are heavy. Typical reaction would be $\mu + e \rightarrow e + \mu$ scattering by exchange of $\Delta g = 1$ exotic photon.

3.1.1 New view about interaction vertices and bosons

There are two options for the identification of particle vertices as topological vertices.

1. Option a)

The original assumption was that one can assign also to bosons a partonic 2-surface X^2 with more or less well defined genus g. The hypothesis is consistent with the view that particle reactions are described by smooth 4-surfaces with vertices being singular 3-surfaces intermediate between two three-topologies. The basic objection against this option is that it can induce too high rates for flavor changing currents. In particular $g > 0$ gluons could induce these currents. Second counter argument is that stable $n > 4$-particle vertices are not possible.

2. Option b)

According to the new vision (option 2)), particle decays correspond to branchings of the partonic 2-surfaces in the same sense as the vertices of the ordinary Feynman diagrams do correspond to branchings of lines. The basic mathematical justification for this vision is the enormous simplification caused by the fact that vertices correspond to non-singular 2-manifolds. This option allows also $n > 3$-vertices as stable vertices.

A consistency with the experimental facts is achieved if the observed gauge bosons have each value of $g(X^2)$ with the same probability. Hence the general boson state would correspond to a phase $exp(in2\pi g/3)$, $n = 0, 1, 2$, in the discrete space of 3 lowest topologies $g = 0, 1, 2$. The observed bosons would correspond to $n = 0$ state and exotic higher states to $n = 1, 2$.

The nice feature of this option is that no flavor changing neutral electro-weak or color currents are predicted. This conforms with the fact that CKM mixing can be understood as electro-weak phenomenon described most naturally by causal determinants X_l^3 (appearing as lines of generalized Feynman diagram) connecting fermionic 2-surfaces of different genus.

Consider now objections against this scenario.

1. Since the modular contribution does not depend on the gradient of the elementary particle vacuum functional but only on its logarithm, all three

boson states should have mass squared which is the average of the mass squared values $M^2(g)$ associated with three generations. The fact that modular contribution to the mass squared is due to the super-canonical thermodynamics allows to circumvent this objection. If the super-canonical p-adic temperature is small, say $T_p = 1/2$, then the modular contribution to the mass squared is completely negligible also for $g > 0$ and photon, graviton, and gluons could remain massless. The wiggling of the elementary particle vacuum functionals at the boundaries of the moduli spaces $\mathcal{M}_g$ corresponding to 2-surfaces intermediate between different 2-topologies (say pinched torus and self-touching sphere) caused by the change of overall phase might relate to the higher p-adic temperature T_p for exotic bosons.

2. If photon states had a 3-fold degeneracy, the energy density of black body radiation would be three times higher than it is. This problem is avoided if the the super-canonical temperature for $n = 1, 2$ states is higher than for $n = 0$ states, and same as for fermions, say $T_p = 1$. In this case two mass degenerate bosons would be predicted with mass squared being the average over the three genera. In this kind of situation the factor 1/3 could make the real mass squared very large, or order CP_2 mass squared, unless the sum of the modular contributions to the mass squared values $M^2_{mod}(g) \propto n(g)$ is divisible by 3. This would make also photon, graviton, and gluons massive. Fortunately, $n(g)$ is divisible by 3 as is clear form $n(0) = 0$, $n(1) = 9$, $n(2) = 60$.

3.1.2 Masses of genus-octet bosons

For option 1) ordinary bosons are accompanied by $g > 0$ massive partners. For option 2) both ordinary gauge bosons and their exotic partners have suffered maximal topological mixing in the case that they are singlets with respect to the dynamical SU(3). There are good reasons to expect that Higgs mechanism for ordinary gauge bosons generalizes as such and that $1/T_p > 1$ ($T_p = 1/26$ by the argument predicting also Kähler coupling strength) means that the contribution of p-adic thermodynamics to the mass is negligible. The scale of Higgs boson expectation would be given by p-adic length scale and mass degeneracy of octet is expected. A good guess is obtained by scaling the masses of electro-weak bosons by the factor $2^{(k-89)/2}$. Also the masses of genus-octet of gluons and photon should be non-vanishing and induced by a vacuum expectation of Higgs particle which is electro-weak singlet but genus-octet.

3.2 The physics of $M - \overline{M}$ systems forces the identification of vertices as branchings of partonic 2-surfaces

For option 2) gluons are superpositions of $g = 0, 1, 2$ states with identical probabilities and vertices correspond to branchings of partonic 2-surfaces. Exotic gluons do not induce mixing of quark families and genus changing transitions correspond to light like 3-surfaces connecting partonic 2-surfaces with different genera. CKM mixing is induced by this topological mixing. The basic testable predictions relate to the physics of $M\overline{M}$ systems and are due to the contribution of exotic gluons and large direct CP breaking effects in $K-\overline{K}$ favor this option.

For option 1) vertices correspond to fusions rather than branchings of the partonic 2-surfaces. The prediction that quarks can exchange handle number by exchanging $g>0$ gluons (to be denoted by G_g in the sequel) could be in conflict with the experimental facts.

1. CP breaking in $K-\bar{K}$ as a basic test

CP breaking physics in kaon-antikaon and other neutral pseudoscalar meson systems is very sensitive to the new physics. What makes the situation especially interesting, is the recently reported high precision value for the parameter ϵ'/ϵ describing direct CP breaking in kaon-antikaon system [105]. The value is almost by an order of magnitude larger than the standard model expectation. $K-\bar{K}$ mass difference predicted by perturbative standard model is 30 per cent smaller than the the experimental value and one cannot exclude the possibility that new physics instead of/besides non-perturbative QCD might be involved.

In standard model the low energy effective action is determined by box and penguin diagrams. $\Delta S=2$ piece of the effective weak Lagrangian, which describes processes like $s\bar{d}\rightarrow d\bar{s}$, determines the value of the $K-\bar{K}$ mass difference Δm_K and since this piece determines $K\rightarrow\bar{K}$ amplitude it also contributes to the parameter ϵ characterizing indirect CP breaking. $\Delta S=2$ part of the weak effective action corresponds to box diagrams involving two W boson exchanges.

2. Δm_K kills option a

For option 1) box diagrams involving Z and $g>0$ exchanges are allowed provided exchanges correspond to exchange of both Z and $g>0$ gluon. The most obvious objection is that the exchanges of $g>0$ gluons make strong $\Delta S>0$ decays of mesons possible: $K_S\rightarrow\pi\pi$ is a good example of this kind of decay. The enhancement of the decay rate would be of order $(\alpha_s(g=1)/\alpha_{em})^2(m_W/m_G(g=1)^2\sim 10^3$. Also other $\Delta S=1$ decay rates would be enhanced by this factor. The real killer prediction is a gigantic value of Δm_K for kaon-antikaon system resulting from the possibility of $\overline{s}d\rightarrow\overline{d}s$ decay by single $g=1$ gluon exchange. This prediction alone excludes option 1).

3. Option 2) could explain direct CP breaking

For option 2) box diagrams are not affected in the lowest order by exotic gluons. The standard model contributions to Δm_K and indirect CP breaking are correct for the observed value of the top quark mass which results if top corresponds to a secondary padic length scale $L(2,k)$ associated with $k=47$ (Appendix). Higher order gluonic contribution could increase the value of Δm_K predicted to be about 30 per cent too small by the standard model.

In standard model penguin diagrams contribute to $\Delta S=1$ piece of the weak Lagrangian, which determines the direct CP breaking characterized by the parameter ϵ'/ϵ. Penguin diagrams, which describe processes like $s\bar{d} \rightarrow d\bar{d}$, are characterized by effective vertices dsB, where B denotes photon, gluon or Z boson. dsB vertices give the dominant contribution to direct CP breaking in standard model. The new penguin diagrams are obtained from ordinary penguin diagrams by replacing ordinary gluons with exotic gluons.

For option 2) the contributions predicted by the standard model are multiplied by a factor 3 in the approximation that exotic gluon mass is negligible in the mass scale of intermediate gauge boson. These diagrams affect the value of the parameter ϵ'/ϵ characterizing direct CP breaking in $K - \bar{K}$ system found experimentally to be almost order of magnitude larger than standard model expectation [105].

3.3 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.

1. 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.

2. 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.

3. 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.

4. 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 [119] 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 [71]. 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 A new twist in the spin puzzle of proton

The so called proton spin crisis or spin puzzle of proton was an outcome of the experimental finding that the quarks contribute only 13-17 per cent of proton spin [113, 114] whereas the simplest valence quark model predicts that quarks contribute about 75 per cent to the spin of proton with the remaining 25 per cent being due to the orbital motion of quarks. Besides the orbital motion of valence quarks also gluons could contribute to the spin of proton. Also polarized sea quarks can be considered as a source of proton spin.

Quite recently, the spin crisis got a new twist [115]. One of the few absolute predictions of perturbative QCD (pQCD) is that at the limit, when the momentum fraction of quark approaches unity, quark spin should be parallel to the proton spin. This is due to the helicity conservation predicted by pQCD in the lowest order. The findings are consistent with this expectation in the case of protonic u quarks but not in the case of protonic d quark. The discovery is of a special interest from the point of view of TGD since it might have an explanation involving the notions of many-sheeted space-time, of color-magnetic flux tubes, the predicted super-canonical "vacuum" spin, and also the concept of quantum parallel dissipation.

3.4.1 The experimental findings

In the experiment performed in Jefferson Lab [115] neutron spin asymmetries A_1^n and polarized structure functions $g_{1,2}^n$ were deduced for three kinematic configurations in the deep inelastic region from e-^{3}He scattering using 5.7 GeV longitudinally polarized electron beam and a polarized ^3He target. A_1^n and $g_{1,2}^n$ were deduced for $x = .33, .47$, and .60 and $Q^2 = 2.7, 3.5$ and 4.8 (GeV/c)^2. A_1^n and g_1^n at $x = .33$ are consistent with the world data. At $x = .47$ A_1^n crosses zero and is significantly positive at $x = 0.60$. This finding agrees with the next-to-leading order QCD analysis of previous world data without the helicity conservation constraint. The trend of the data agrees with the predictions of the constituent quark model but disagrees with the leading order pQCD assuming hadron helicity conservation.

By isospin symmetry one can translate the result to the case of proton by the replacement $u \leftrightarrow d$. By using world proton data, the polarized quark distribution functions were deduced for proton using isospin symmetry between neuron and proton. It was found that $\Delta u/u$ agrees with the predictions of various models while $\Delta d/d$ disagrees with the leading-order pQCD.

Let us denote by $q(x) = q^{\uparrow} + q^{\downarrow}(x)$ the spin independent quark distribution function. The difference $\Delta q(x) = q^{\uparrow} - q^{\downarrow}(x)$ measures the contribution of quark q to the spin of hadron. The measurement allowed to deduce estimates for the ratios $(\Delta q(x) + \Delta \overline{q}(x))/(q(x) + \overline{q}(x))$.

The conclusion of [115] is that for proton one has

$$\frac{\Delta u(x) + \Delta \overline{u}(x)}{u(x) + \overline{u}(x)} \simeq .737 \pm .007 \ , \ \text{for} \ \ x = .6 \ .$$

This is consistent with the pQCD prediction. For d quark the experiment gives

$$\frac{\Delta d(x) + \Delta \overline{d}(x)}{d(x) + \overline{d}(x)} \simeq -.324 \pm .083 \ \text{for} \ \ x = .6 \ .$$

The interpretation is that d quark with momentum fraction $x > .6$ in proton spends a considerable fraction of time in a state in which its spin is opposite to the spin of proton so that the helicity conservation predicted by first order pQCD fails. This prediction is of special importance as one of the few absolute predictions of pQCD.

The finding is consistent with the relativistic $SU(6)$ symmetry broken by spin-spin interaction and the QCD based model interpolated from data but giving up helicity conservation [115]. $SU(6)$ is however not a fundamental symmetry so that its success is probably accidental.

It has been also proposed that the spin crisis might be illusory [116] and due to the fact that the vector sum of quark spins is not a Lorentz invariant quantity so that the sum of quark spins in infinite-momentum frame where quark distribution functions are defined is not same as, and could thus be smaller than, the spin sum in the rest frame. The correction due to the transverse momentum of the quark brings in a non-negative numerical correction factor which is in the range $(0,1)$. The negative sign of $\Delta d/d$ is not consistent with this proposal.

3.4.2 TGD based model for the findings

The TGD based explanation for the finding involves the following elements.

1. TGD predicts the possibility of vacuum spin due to the super-canonical symmetry. Valence quarks can be modelled as a star like formation of magnetic flux tubes emanating from a vertex with the conservation of color magnetic flux forcing the valence quarks to form a single coherent structure. A good guess is that the super-canonical spin corresponds classically to the rotation of the the star like structure.

2. By parity conservation only even values of super-canonical spin J are allowed and the simplest assumption is that the valence quark state is a superposition of ordinary $J=0$ states predicted by pQCD and $J=2$ state in which all quarks have spin which is in a direction opposite to the direction of the proton spin. The state of $J=1/2$ baryon is thus replaced by a new one:

$$
\begin{aligned}
|B,\frac{1}{2},\uparrow\rangle &= a|B,1/2,\frac{1}{2}\rangle|J=J_z=0\rangle + b|B,\frac{3}{2},-\frac{3}{2}\rangle|J=J_z=2\rangle \ , \\
|B,1/2,\frac{1}{2}\rangle &= \sum_{q_1,q_2,q_3} c_{q_1,q_2,q_3} q_1^{\uparrow} q_2^{\uparrow} q_3^{\downarrow} \ , \\
|B,\frac{3}{2},-\frac{3}{2}\rangle &= d_{q_1,q_2,q_3} q_1^{\downarrow} q_2^{\downarrow} q_3^{\downarrow} \ . \qquad (27)
\end{aligned}
$$

$|B,1/2,\frac{1}{2}\rangle$ is in a good approximation the baryon state as predicted by pQCD. The coefficients c_{q_1,q_2,q_3} and d_{q_1,q_2,q_3} depend on momentum fractions of quarks and the states are normalized so that $|a|^2+|b|^2=1$ is satisfied: the notation $p=|a|^2$ will be used in the sequel. The quark parts of $J=0$ and $J=2$ have quantum numbers of proton and Δ resonance. $J=2$ part need not however have the quark distribution functions of Δ.

3. The introduction of $J=0$ and $J=2$ ground states with a simultaneous use of quark distribution functions makes sense if one allows quantum parallel dissipation. Although the system is coherent in the super-canonical degrees of freedom which correspond to the hadron size scale, there is a de-coherence in quark degrees of freedom which correspond to a shorter p-adic length scale and smaller space-time sheets.

4. Consider now the detailed structure of the $J = 2$ state in the case of proton. If the d quark is at the rotation axis, the rotating part of the triangular flux tube structure resembles a string containing u-quarks at its ends and forming a di-quark like structure. Di-quark structure is taken to mean correlations between u-quarks in the sense that they have nearly the same value of x so that $x < 1/2$ holds true for them whereas the d-quark behaving more like a free quark can have $x > 1/2$.

   A stronger assumption is that di-quark behaves like a single colored hadron with a small value of x and only the d-quark behaves as a free quark able to have large values of x. Certainly this would be achieved if u quarks reside at their own string like space-time sheet having $J = 2$.

From these assumptions it follows that if u quark has $x > 1/2$, the state effectively reduces to a state predicted by pQCD and $u(x) \rightarrow 1$ for $x \rightarrow 1$ is predicted. For the d quark the situation is different and introducing distribution functions $q^{J)}(x)$ for $J = 0, 2$ separately, one can write the spin asymmetry at the limit $x \rightarrow 1$ as

$$\begin{aligned} A_d &\equiv \frac{\Delta d(x) + \Delta \overline{d}(x)}{d(x) + \overline{d}(x)} = \frac{p(\Delta d_0 + \Delta \overline{d}_0) + (1-p)(\Delta d_2 + \Delta \overline{d}_2)}{p(d_0 + \overline{d}_0) + (1-p)(d_2 + \overline{d}_2)} \ , \\ p &= |a|^2 \ . \end{aligned} \tag{28}$$

Helicity conservation gives $\Delta d_0/d_0 \rightarrow 1$ at the limit $x \rightarrow 1$ and one has trivially $\Delta d_2/d_2 = -1$. Taking the ratio

$$y = \frac{d_2}{d_0}$$

as a parameter, one can write

$$A_d \rightarrow \frac{p - (1-p)y}{p + (1-p)y} \tag{29}$$

at the limit $x \rightarrow 1$. This allows to deduce the value of the parameter y once the value of p is known:

$$y = \frac{p}{1-p} \times \frac{1 - A_d}{1 + A_d} \ . \tag{30}$$

From the requirement that quarks contribute a fraction $\Sigma = \sum_q \Delta q \in (13, 17)$ per cent to proton spin, one can deduce the value of p using

$$\frac{p \times \frac{1}{2} - (1-p) \times \frac{3}{2}}{\frac{1}{2}} = \Sigma \tag{31}$$

giving $p = (3+\Sigma)/4 \simeq .75$.

Eq. 30 allows estimate the value of y. In the range $\Sigma \in (.13, .30)$ defined by the lower and upper bounds for the contribution of quarks to the proton spin, $A_d = -.32$ gives $y \in (6.98, 9.15)$. $d_2(x)$ would be more strongly concentrated at high values of x than $d_0(x)$. This conforms with the assumption that u quarks tend to carry a small fraction of proton momentum in $J = 2$ state for which uu can be regarded as a string like di-quark state.

A further input to the model comes from the ratio of neutron and proton F_2 structure functions expressible in terms of quark distribution functions of proton as

$$R^{np} \equiv \frac{F_2^n}{F_2p} = \frac{u(x)+4d(x)}{4u(x)+d(x)} \ . \tag{32}$$

According to [115] $R^{np}(x)$ is a straight line starting with $R^{np}(x \rightarrow 0) \simeq 1$ and dropping below 1/2 as $x \rightarrow 1$. The behavior for small x can be understood in terms of sea quark dominance. The pQCD prediction for R^{np} is $R^{np} \rightarrow 3/7$ for $x \rightarrow 1$, which corresponds to $d/u \rightarrow z = 1/5$. TGD prediction for R^{np} for $x \rightarrow 1$

$$\begin{aligned} R^{np} &\equiv \frac{F_2^n}{F_2^p} = \frac{pu_0 + 4(pd_0 + (1-p)d_2)}{4pu_0 + pd_0 + (1-p)d_2} \\ &= \frac{p + 4z(p + (1-p)y}{4p + z(p + (1-p)y)} \ . \end{aligned} \tag{33}$$

In the range $\Sigma \in (.13, .30)$ which corresponds to $y \in (6.98, 9.15)$ for $A_d = -.32$ $R^{np} = 1/2$ gives $z \simeq .1$, which is 20 per cent of pQCD prediction. 80 percent of d-quarks with large x predicted to be in $J = 0$ state by pQCD would be in $J = 2$ state.

3.5 Fractally scaled up versions of quarks

The strange anomalies of neutrino oscillations [44] suggesting that neutrino mass scale depends on environment can be understood if neutrinos can suffer topological condensation in several p-adic length scales [F3]. The obvious question whether this could occur also in the case of quarks led to a very fruitful developments leading to the understanding of hadronic mass spectrum in terms of scaled up variants of quarks. Also the mass distribution of top quark candidate exhibits structure which could be interpreted in terms of heavy variants of light quarks. The ALEPH anomaly [49], which I first erratically explained in terms of a light top quark has a nice explanation in terms of b quark condensed at $k = 97$ level and having mass ~ 55 GeV. These points are discussed in detail in [F4].

The emergence of ALEPH results [49] meant a an important twist in the development of ideas related to the identification of top quark. In the LEP 1.5

run with $E_{cm} = 130 - 140\ GeV$, ALEPH found 14 e^+e^- annihilation events, which pass their 4-jet criteria whereas 7.1 events are expected from standard model physics. Pairs of dijets with vanishing mass difference are in question and dijets could result from the decay of a new particle with mass about 55 GeV.

The data do not allow to conclude whether the new particle candidate is a fermion or boson. Top quark pairs produced in e^+e^- annihilation could produce 4-jets via gluon emission but this mechanism does not lead to an enhancement of 4-jet fraction. No $b\bar{b}b\bar{b}$ jets have been observed and only one event containing b has been identified so that the interpretation in terms of top quark is not possible unless there exists some new decay channel, which dominates in decays and leads to hadronic jets not initiated by b quarks. For option 2), which seems to be the only sensible option, this kind of decay channels are absent.

Super symmetrized standard model suggests the interpretation in terms of super partners of quarks or/and gauge bosons [79]. It seems now safe to conclude that TGD does not predict sparticles. If the exotic particles are gluons their presence does not affect Z^0 and W decay widths. If the condensation level of gluons is $k = 97$ and mixing is absent the gluon masses are given by $m_g(0) = 0$, $m_g(1) = 19.2\ GeV$ and $m_g(2) = 49.5\ GeV$ for option 1) and assuming $k = 97$ and hadronic mass renormalization. It is however very difficult to understand how a pair of $g = 2$ gluons could be created in e^+e^- annihilation. Moreover, for option 2), which seems to be the only sensible option, the gluon masses are $m_g(0) = 0$, $m_g(1) = m_g(2) = 30.6\ GeV$ for $k = 97$. In this case also other values of k are possible since strong decays of quarks are not possible.

The strong variations in the order of magnitude of mass squared differences between neutrino families [44] can be understood if they can suffer a topological condensation in several p-adic length scales. One can ask whether also t and b quark could do the same. In absence of mixing effects the masses of $k = 97$ t and b quarks would be given by $m_t \simeq 48.7$ GeV and $m_b \simeq 52.3$ GeV taking into account the hadronic mass renormalization. Topological mixing reduces the masses somewhat. The fact that b quarks are not observed in the final state leaves only $b(97)$ as a realistic option. Since Z^0 boson mass is ~ 94 GeV, $b(97)$ does not appreciably affect Z^0 boson decay width. The observed anomalies concentrate at cm energy about 105 GeV. This energy is 15 percent smaller than the total mass of top pair. The discrepancy could be understood as resulting from the binding energy of the $b(97)\bar{b}(97)$ bound states. Binding energy should be a fraction of order $\alpha_s \simeq .1$ of the total energy and about ten per cent so that consistency is achieved.

3.6 What M_{89} Hadron Physics would look like?

TGD suggests the existence of the scaled up copies of hadron physics corresponding to the Mersenne primes $M_n = 89, 61, 31, ..$ at least in the sense that α_s has maximum at these length scales. The assumption of QCD:s decoupling completely from each other seems more unrealistic.

The requirement of unitarity forces the existence of Higgs particle in gauge theories. The failure of the p-adic mass calculations to predict intermediate gauge boson masses correctly forces to give up the idea that boson masses are of purely thermodynamical origin. A possible TGD counterpart for the Higgs fields is as the fields defined by the Kac-Moody generators associated with the complement of the $u(2)$ algebra of $su(3)$ associated with the conserved charges Q_J defined by the variation of the modified Dirac action with respect to the induced Kähler form. As found in the [F3], the small coupling of the Higgs to fermionic masses resolves the paradoxical situation created by the failure to detect Higgs boson. Also the fact that left handed electro-weak charge matrices are not covariantly constant could explain Higgs vacuum expectation value without an introduction of an elementary scalar field.

One could of course, consider also other explanations for Higgs. The only scalar mesons with masses in intermediate boson mass scale allowed by TGD are bound states of quark and antiquark of M_{89} hadron physics such that quark and antiquark have parallel spins and relative angular momentum $L=1$. The effective couplings of these states to leptons and quarks could mimic the couplings of Higgs boson to some degree. Scalar bound states of heavy quarks are also present in ordinary hadron physics. The coherent states formed by these particles could mimic the effects caused by a fundamental Higgs field.

M_{89} would be obtained in the first approximation by scaling the ordinary hadron physics by the ratio $\sqrt{\frac{M_{89}}{M_{107}}}$. This implies that QCD Λ, string tension, etc. get scaled by the appropriate power of this factor. If one estimates the u_{89} mass as $m(u_{89})=m(\rho_{89})/2$ one obtains the TGD prediction for its mass as $m(u_{89})=512m(\rho_{107})/2\simeq 197\ GeV$. Defining $u(89)$ mass by scaling the mass of ordinary u quark defined as one third of proton mass one obtains u_{89} mass about 160 GeV. This estimate for u_{89} mass happened to be within experimental uncertainties equal to the mass of the top candidate discovered just when the mass calculations were carried out and led to a tentative identification of the top candidate as u_{89}.

The fact that top candidate turned out to have production and decay characteristics of the real top forced to give up this hypothesis. Also the study of CKM matrix led to the cautious conclusion that only the mass of the experimental top candidate is consistent with CP breaking observed in $K-\bar{K}$ and $B-\bar{B}$ system (Appendix). Even more, the direct calculation of the u_{89} mass from p-adic thermodynamics gives $m(u_{89})\simeq 262$ GeV and demonstrates the the idea about identifying top quark as u_{89} quark was a result of sloppy order of magnitude thinking. The relatively high mass however leaves open the possibility that M_{89} physics exists.

M_{89} physics means the emergence of a new condensate level in the hadronic physics. One can visualize M_{89} hadrons as very tiny objects possibly condensed on the quarks and gluons of M_{107} hadron physics. The New Physics begins to reveal itself, when the collision energy is so high that M_{89} hadrons inside quarks and gluons can exist as on mass shell particles (M_{89} hadron inside M_{107} hadron is comparable to a bee of size of one cm in a room of size about 5 meters!).

The new Physics at the energies not much above the energy scale of top is essentially the counterpart of ordinary hadron physics at cm energies of the order of ρ/ω meson mass. Therefore M_{89} meson resonances and their interactions described rather satisfactorily by the old fashioned string model with string tension scaled by factor 2^{18} should describe the situation. The electro-weak interactions should be in turn describable using generalization of current algebra ideas, such as PCAC and vector dominance model. If M_{89} hadrons condense on quarks and gluons this physics must be convoluted with the distribution functions of M_{89} hadrons inside quarks and gluons. The resonance structures are partially smeared out by the convolution process.

M_{89} vector mesons should be observed as resonances in e^+e^- annihilation and charged M_{89} pion should be pair produced at e^+e^- collision energies achievable in near future at LEP. Gamma pairs form unique signature of neutral leptopion. The following table gives the naive scaling estimate for the masses of lowest lying M_{89} hadrons.

meson	m/GeV	baryon	m/GeV
π^0	69.1	p	480.4
π^+	71.5	n	481.0
K^+	252.8	Λ	571.2
K^0	254.8	Σ^+	609.0
η	281.0	Σ^0	610.4
η'	490.5	Σ^-	610.5
ρ	394.2	Ξ^0	673.2
ω	400.9	Ξ^-	676.5
K^*	456.7	Ω^-	856.2
Φ	522		

Table 3. Masses of low lying hadrons for M_{89} hadron physics obtained by scaling ordinary hadron masses by a factor of 512.

Consider next the estimation of the production and decay rates for $\rho(89)$ $/\omega(89)$ and more generally M_{89} mesons. In e^+e^- annihilation vector boson resonances are produced via the decay of virtual photon or Z^0. Since low energies are in question at M_{89} level the scaled up version of vector dominance model described in the nice book of Feynman [36] should give a satisfactory description for the production of M_{89} mesons via resonance mechanism. The idea is to introduce direct coupling $F_V = m_V^2/g_V$ of photon (or gauge boson) to vector boson (ρ, ω, ϕ). The diagrams describing the production of mesons via decay of vector boson contain vector boson propagator $\frac{1}{p^2-m_V^2+im_V\Delta}$ and the production rate is enhanced by a factor $R = 4\pi m_V^2/(\Delta^2 g_V^2)$ in the resonance: the factor should be same in M_{89} physics as in ordinary hadron physics. The ratio $r = \alpha_{em}R/\alpha_s$ gives a rough measure for the ratio of the rates of production for $u(89)$ and ordinary top quark. A rough estimate for what is to be expected is obtained by scaling the results of ordinary hadron physics. The table below gives the estimates for the quantity r and one has $r = 15.1$ for ω.

meson	$m/512\ MeV$	$\Delta/512\ MeV$	$g_V^2/4\pi$	r
ρ	770	150	2.27	0.52
ω	783	10	18.3	15.1
Φ	1019	4.2	13.3	230.8

Table 4. Scaled up resonance production parameters for ρ, ω and Φ. The last column of the table gives the value of the quantity $r = \alpha_{em}R/\alpha_s$, which should give a measure for the ratio of production rate of $u(_89)$ and of the production of ordinary top quark pair.

Centauro type events [97] might find nice explanation in terms of M_{89} hadron physics. If electro-weak decay channels dominate over hadronic decay channels for M_{89} mesons this might lead to anomalously small abundance of ordinary pions in Centauro events. In particular, neutral M_{89} pions are expected to decay dominantly to photon pairs and since monoenergetic gamma pairs are used as a signature of pions the observed abundance of ordinary pions becomes small. Evidence for M_{89} pions comes from anomalous gamma pairs detected in the decays of Z^0 bosons[106] with total energy of about 60 GeV. The pairs might be related to the decay of M_{89} exotic pion predicted to have mass $m_{89} \simeq 2^9 m_\pi \simeq 67.5\ GeV$.

The resonance production of M_{89} vector mesons via the graph $q\bar{q} \rightarrow \gamma(virt) \rightarrow M(M_{89})$ and their decay to dijets gives small contribution to dijet production rate.

At high enough cm energies, presumably of order $\sqrt{s} \sim 10\ TeV$ in $p\bar{p}$ collisions the jets of M_{89} hadron physics should begin to manifest themselves. The unique signature of M_{89} jets is that the p_T spectrum for the hadrons of the jet, which is of form $exp(-kp_T^2/\Lambda(89))$, is by factor 512 wider than the p_T spectrum of hadrons for ordinary jets.

Following list gives some of the unique signatures of New Physics.

1. At higher energies exotic pions are produced abundantly and might be detectable via annihilation to monoenergetic photon pair. π^0 of the New Physics should have mass 69.1 GeV and $\gamma\gamma$ annihilation width $512 \cdot 7.63\ eV = 3.9\ MeV$ (obtained by scaling from that for ordinary pion). The width for the decay by W emission from either quark of $\pi^0(89)$ (the second is assumed to act as spectator) is of order $G_F^2 m(u(89))^5/(192\pi^3)$ and of order 2.5 MeV.

2. The scaling of mass splittings inside isopin multiplets with the scale factor 512 as compared to ordinary hadron physics is a unique signature of M_{89} hadrons.

3. The scaled up versions of ρ and ω meson should be found at nearby energies. Kaon (and s quark) of the New Physics should be seen as a decay product of $\Phi(522\ GeV) \rightarrow K + \bar{K}$: from table 3.6 one finds that that Φ should have rather small hadronic width $\Delta \simeq 2.2\ GeV$ so that the pa-

rameter measuring its production rate to the production rate of ordinary quark is as high as $r \simeq 230.8$ at resonance.

3.7 Topological evaporation and the concept of Pomeron

Topological evaporation provides an explanation for the mysterious concept of Pomeron originally introduced to describe hadronic diffractive scattering as the exchange of Pomeron Regge trajectory [70]. No hadrons belonging to Pomeron trajectory were however found and via the advent of QCD Pomeron was almost forgotten. Pomeron has recently experienced reincarnation [71, 72, 74]. In Hera [71] $e-p$ collisions, where 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 small fraction of proton's momentum. This particle in turn collides with virtual photon (antiproton) whereas proton scatters essentially elastically.

The identification of the color singlet particle as Pomeron looks natural since Pomeron emission describes nicely diffractive scattering of hadrons. Analogous hard diffractive scattering events in pX diffractive scattering with $X = \bar{p}$ [72] or $X = p$ [74] have also been observed. What happens is that proton scatters essentially elastically and 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.

TGD framework leads to two alternative identifications of Pomeron relying on same geometric picture in which Pomeron corresponds to a space-time sheet separating from hadronic space-time sheet and colliding with photon.

3.7.1 Earlier model

The earlier model is based on the assumption that baryonic quarks carry the entire four-momentum of baryon. p-Adic mass calculations have shown that this assumption is wrong. The modification of the model requires however to change only wordings so that I will represent the earlier model first.

The TGD based identification of Pomeron is very economical: Pomeron corresponds to sea partons, when valence quarks are in vapor phase. In TGD inspired phenomenology events involving Pomeron correspond to pX collisions, where incoming X collides with proton, when valence quarks have suffered coherent simultaneous (by color confinement) evaporation into vapor phase. System X sees only the sea left behind in evaporation and scatters from it whereas 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 valence quarks in vapor phase.

Dimensional argument can be used to derive a rough order of magnitude estimate for f as $f \sim 1/\alpha = 1/137 \sim 10^{-2}$ for f: f is of same order of magnitude as the fraction (about 5 per cent) of peculiar events from all deep inelastic scattering events in Hera. 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 scenario. According to [72] 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 [72].

3.7.2 Updated model

The recent developments in the understanding of hadron mass spectrum involve the realization that hadronic $k=107$ space-time sheet is a carrier of super-canonical bosons (and possibly their super-counterparts with quantum numbers of right handed neutrino) [F4]. The model leads to amazingly simple and accurate mass formulas for hadrons. Most of the baryonic momentum is carried by super-canonical quanta: valence quarks correspond in proton to a relatively small fraction of total mass: about 170 MeV. The counterparts of string excitations correspond to super-canonical many-particle states and the additivity of conformal weight proportional to mass squared implies stringy mass formula and generalization of Regge trajectory picture. Hadronic string tension is predicted correctly. Model also provides a solution to the proton spin puzzle.

In this framework valence quarks would naturally correspond to a color singlet state formed by space-time sheets connected by color flux tubes having no Regge trajectories and carrying a relatively small fraction of baryonic momentum. In the collisions discussed valence quarks would leave the hadronic space-time sheet and suffer a collision with photon. The lightness of Pomeron and and electro-weak neutrality of Pomeron support the view that photon stripes valence quarks from Pomeron, which continues its flight more or less unperturbed. Instead of an actual topological evaporation the bonds connecting valence quarks to the hadronic space-time sheet could be stretched during the collision with photon.

The large value of $\alpha_K=1/4$ for super-canonical matter suggests that the criterion for a phase transition increasing the value of Planck constant [A9] and leading to a phase, where $\alpha_K \propto 1/hbar$ is reduced, could occur. For α_K to remain invariant, $\hbar_0 \rightarrow 26\hbar_0$ would be required. In this case, the size of hadronic space-time sheet, "color field body of the hadron", would be $26 \times L(107)=46$ fm, roughly the size of the heaviest nuclei. Hence a natural expectation is that the dark side of nuclei plays a role in the formation of atomic nuclei. Note that the sizes of electromagnetic field bodies of current quarks u and d with masses of order few MeV is not much smaller than the Compton length of electron. This would mean that super-canonical bosons would represent dark matter in a well-defined sense and Pomeron exchange would represent temporary separation of ordinary and dark matter.

Note however that the fact that super-canonical bosons have no electro-weak interactions, implies their dark matter character even for the ordinary value of Planck constant: this could be taken as an objection against dark matter hierarchy. My own interpretation is that super-canonical matter is dark matter in the strongest sense of the world whereas ordinary matter in the large hbar phase is only apparently dark matter because standard interactions do not reveal themselves in the expected manner.

3.7.3 Astrophysical counterpart of Pomeron events

Pomeron events have direct analogy in astrophysical length scales. In the collision of two galaxies dark and visible matter parts of the colliding galaxies have been found to separate by Chandra X-ray Observatory [117].

Imagine a collision between two galaxies. The ordinary matter in them collides and gets interlocked due to the mutual gravitational attraction. Dark matter, however, just keeps its momentum and keeps going on leaving behind the colliding galaxies. This kind of event has been detected by the Chandra X-Ray Observatory by using an ingenious manner to detect dark matter. Collisions of ordinary matter produces a lot of X-rays and the dark matter outside the galaxies acts as a gravitational lens.

3.8 Wild speculations about non-perturbative aspects of hadron physics and exotic Super Virasoro representations

If the canonical correspondence mapping the p-adic mass squared values to real numbers is taken completely seriously, then TGD predicts infinite hierarchy of exotic light representations of Super Virasoro. These exotic states are created by sub-algebras of Super Kac-Moody and SKM algebras whose generators have conformal weights divisible by p^n, $n = 1, 2, ...$ Ordinary representations would correspond to $n = 0$.

For the exotic representations the p-adic mass squared of the particle is proportional to Virasoro p^n. When the value of the p-adic mass squared is power of p: $M^2 \propto p^n$, $n = 1, 2, ..$, the real counterpart of the mass squared in canonical identification is extremely small since it is proportional to $1/p^n$ in this case. It is of course not at all clear whether these representations have have any real counterpart and if even this the case the could be thermally unstable in an environment with higher p-adic temperature.

Also ordinary low temperature ($T_p = 1/n$) Super Virasoro representations allow extremely light states but in this case there is no subalgebra generating these states. If these representations exist they could correspond to low energy-long length scale fractal copies of elementary particles. Due to the state degeneracy providing an enormous information storage capacity associated with these states these representations, if realized in nature, might have biological relevance [H2, J4].

There is however an objection against this idea: these representations are possible also in elementary particle length scales and for $M^2 \propto L_0 = npm_0^2$ the representations have same mass scale as ordinary elementary particles. These representations couple to ordinary elementary particles via classical gauge fields and could therefore be present also in elementary particle physics. For reasons which become clear below, exotic Super Virasoro representations might provide a model for low energy hadron physics.

1. The formula

$$M_R^2 = \frac{nm_0^2}{p}$$

is generalization of the mass formula of hadronic string models and reduces to it when the angular momentum

$$J = \alpha' M^2$$

of the hadronic state satisfies $J = n$. From this Regge slope α' and string tension T are given by

$$T = \frac{1}{2\pi\alpha'} \ , \quad \frac{1}{\alpha'} = \frac{m_0^2}{p} \ .$$

The observed value of the Regge slope is $\alpha' = .9/GeV^2$.

2. The value of the predicted string tension is easily found. The prediction of TGD based mass calculations for the value of the p-adic pion mass squared is

$$m_\pi^2 = pm_0^2 + O(p^2) \simeq pm_0^2 \ , \quad p = M_{107} \ .$$

$m_\pi \geq m_0/\sqrt{M_{107}}$ and $m_\pi = 134$ MeV gives upper bound for m_0 which is consistent with the prediction for the mass of electron. For $k = 107$ the value of α' would be roughly 64 times too large as simple calculation shows. For $k = 101$ one has

$$\alpha' = \frac{.87}{GeV^2} \ ,$$

which deviates from the value $\alpha' = .9/GeV^2$ determined from ρ Regge trajectory only by three per cent.

3. This would suggest that excited states of ordinary hadrons contain $k = 101$ space-time sheets with p-adic length scale of .3 fm condensed on $k = 107$ hadronic space-time sheet with 8 times larger p-adic length scale and that the angular momentum of these excitations is not assignable to the ordinary quarks but to the states of $k = 101$ exotic Super Virasoro representation. The slight deviation from $.9/GeV^2$ could be explained if the contribution of quarks and gluons to the mass squared decreases as a function of J so that the effective value of α' increases and effective string tension increases. This might be due to the transformation of parton mass squared to the mass squared associated with $k = 101$ exotic Super Virasoro states. Note that $n = 1$ excitation of $k = 101$ Super Virasoro has mass $m_1 = 1.07$ GeV, which is larger than proton mass: therefore the spin of these excitations cannot resolve the spin crisis of proton.

4. For $k = 103$ the predicted value of string tension is by a factor $1/4$ smaller. An interesting question is whether $k = 107$ and $k = 103$ excitations might be observable in low energy hadron physics.

The second thought provoking observation is that pion mass squared corresponds in excellent approximation to that for $n = 1$ state of exotic Super Virasoro representation for $k = 107$. This suggests that in case of pion quark masses are compensated apart from $O(p^2)$ contributions completely by various interaction energy and the energy associated with exotic Super Virasoro representation contributes to the mass squared. This would be p-adic articulation for the statement that pion is massless Goldstone boson. Since pion represents essentially non-perturbative aspects of QCD, this raises the possibility that exotic Super Virasoro representations could provide the long sought first principle theory of low energy hadronic physics.

1. In this theory hadrons would correspond to exotic Super Virasoro representations whereas quark-gluon plasma would correspond to ordinary p-adic Super Virasoro representations. In color confined phase p-adic α_c would have increased to the critical value $\alpha_c = p+O(p^2)$ implying dramatic drop of the real counterpart of α_c to $\alpha_c^R \simeq 1/p$ so that color interactions would disappear effectively and only electro-weak interactions and the geometric interactions between the space-time sheets would remain. What is important is that these phases can exist inside hadron for several values of p. This suggests a fractal hierarchy of hadrons inside hadrons and QCD:s inside QCD:s with the values of $\Lambda(k) \propto 1/L^2(k)$, $k = 107, 103, 101, ...$ In particular, rotational excitations would mean generation of $k = 101$ hadrons inside $k = 107$ hadrons.

2. Hadronization and fragmentation are semi-phenomenological aspects of QCD and would correspond at fundamental level to the phase transitions between the exotic Super Virasoro representations and ordinary Super Virasoro representations. Also the concepts of sea and Pomeron could be reduced the states of exotic Super Virasoro representations associated with $k = 107, 103, 101, 97, ...$

In light of the successes of the hadron model based on super-canonical many-particle states assigned to hadrons [F4] the exotic Super Virasoro representations do not look attractive from the point of view of ordinary hadron physics. Also the thermal instability is a good objection against them.

4 Simulating Big Bang in laboratory

Ultra-high energy collisions of heavy nuclei at Relativistic Heavy Ion Collider (RHIC) can create so high temperatures that there are hopes of simulating Big Bang in laboratory. The experiment with PHOBOS detector [118] probed the nature of the strong nuclear force by smashing two Gold atoms together at ultrahigh energies. The analysis of the experimental data has been carried out by Prof. Manly and his collaborators at RHIC in Brookhaven, NY [119]. The surprise was that the hydrodynamical flow for non-head-on collisions did not possess the expected longitudinal boost invariance.

This finding stimulates in TGD framework the idea that something much deeper might be involved.

1. The quantum criticality of the TGD inspired very early cosmology predicts the flatness of 3-space as do also inflationary cosmologies. The TGD inspired cosmology is 'silent whisper amplified to big bang' since the matter gradually topologically condenses from decaying cosmic string to the space-time sheet representing the cosmology. This suggests that one could model also the evolution of the quark-gluon plasma in an analogous manner. Now the matter condensing to the quark-gluon plasma space-time sheet would flow from other space-time sheets. The evolution of the quark-gluon plasma would very literally look like the very early critical cosmology.

2. What is so remarkable is that critical cosmology is not a small perturbation of the empty cosmology represented by the future light cone. By perturbing this cosmology so that the spherical symmetry is broken, it might possible to understand qualitatively the findings of [119]. Even more, the breaking of the spherical symmetry in the collision could be understood as a strong gravitational effect on distances transforming the spherical shape of the plasma ball to a non–spherical shape without affecting the spherical shape of its M^4_+ projection.

3. The model seems to work and predicts strong gravitational effects in elementary particle length scales so that TGD based gravitational physics would differ dramatically from that predicted by the competing theories. Standard cosmology cannot produce these effects without a large breaking of the cherished Lorentz and rotational symmetries forming the basis of elementary particle physics. Thus the the PHOBOS experiment gives direct support for the view that Poincare symmetry is symmetry of the imbedding space rather than that of the space-time.

4. This picture was completed a couple of years later by the progress made in hadronic mass calculations [F4]. It has already earlier been clear that quarks are responsible only for a small part of the mass of baryons (170 GeV in case of nucleons). The assumption that hadronic $k = 107$ space-time sheet carries a many-particle state of super-canonical particles with vanishing electro-weak quantum numbers (meaning darkness in the strongest sense of the wor

5. allows a model of hadrons predicting their masses with accuracy better than one per cent. The large value of Kähler coupling strength $\alpha_K = \alpha_s = 1/4$ for ordinary value of Planck constant motivates the hypothesis that a transition to large $\hbar$ phase occurs: $\hbar = 26 \times \hbar_0$ would leave the value of α_K for gauge boson field bodies ($\alpha_K = 1/104$) invariant [C5]. $J = 2$ excitations have identification as strong gravitons. In this framework color glass condensate can be identified as a state formed when the hadronic space-time sheets of colliding hadrons fuse to single long stringy object and collision energy is transformed to super-canonical hadrons.

4.1 Experimental arrangement and findings

4.1.1 Heuristic description of the findings

In the experiments using PHOBOS detector ultrahigh energy Au+Au collisions at center of mass energy for which nucleon-nucleon center of mass energy is $\sqrt{s_{NN}} = 130$ GeV, were studied [118].

1. In the analyzed collisions the Au nuclei did not collide quite head-on. In classical picture the collision region, where quark gluon plasma is created, can be modelled as the intersection of two colliding balls, and its intersection with plane orthogonal to the colliding beams going through the center of mass of the system is defined by two pieces of circles, whose intersection points are sharp tips. Thus rotational symmetry is broken for the initial state in this picture.

2. The particles in quark-gluon plasma can be compared to a persons in a crowded room trying to get out. The particles collide many times with the particles of the quark gluon plasma before reaching the surface of the plasma. The distance $d(z, \phi)$ from the point $(z, 0)$ at the beam axis to the point $(0, \phi)$ at the plasma surface depends on ϕ. Obviously, the distance is longest to the tips $\phi = \pm\pi/2$ and shortest to the points $\phi = 0, \phi = \phi$ of the surface at the sides of the collision region. The time $\tau(z, \phi)$ spent by a particle to the travel to the plasma surface should be a monotonically increasing function $f(d)$ of d:

$$\tau(z, \phi) = f(d(z, \phi)) \ .$$

For instance, for diffusion one would have $\tau \propto d^2$ and $\tau \propto d$ for a pure drift.

3. What was observed that for $z = 0$ the difference

$$\Delta\tau = \tau(z = 0, \pi/2) - \tau(z = 0, 0)$$

was indeed non-vanishing but that for larger values of z the difference tended to zero. Since the variation of z correspond that for the rapidity variable y for a given particle energy, this means that particle distributions depend on rapidity which means a breaking of the longitudinal boost invariance assumed in hydrodynamical models of the plasma. It was also found that the difference vanishes for large values of y: this finding is also important for what follows.

4.1.2 A more detailed description

Consider now the situation in a more quantitative manner.

1. Let z-axis be in the direction of the beam and ϕ the angle coordinate in the plane E^2 orthogonal to the beam. The kinematical variables are the rapidity of the detected particle defined as $y = log[E + p_z)/(E - p_z)]/2$ (E and p_z denote energy and longitudinal momentum), Feynman scaling variable $x_F \simeq 2E/\sqrt{s}$, and transversal momentum p_T.

2. By quantum-classical correspondence, one can translate the components of momentum to space-time coordinates since classically one has $x^\mu = p^\mu a/m$. Here a is proper time for a future light cone, whose tip defines the point where the quark gluon plasma begins to be generated, and $v^\mu = p^\mu/m$ is the four-velocity of the particle. Momentum space is thus mapped to an $a = constant$ hyperboloid of the future light cone for each value of a.

   In this correspondence the rapidity variable y is mapped to $y = log[(t + z)/(t - z)]$, $|z| \leq t$ and non–vanishing values for y correspond to particles which emerge, not from the collision point defining the origin of the plane E^2, but from a point above or below E^2. $|z| \leq t$ tells the coordinate along the beam direction for the vertex, where the particle was created. The limit $y \to 0$ corresponds to the limit $a \to \infty$ and the limit $y \to \pm\infty$ to $a \to 0$ (light cone boundary).

3. Quark-parton models predict at low energies an exponential cutoff in transverse momentum p_T; Feynman scaling $dN/dx_F = f(x_F)$ independent of s; and longitudinal boost invariance, that is rapidity plateau meaning that the distributions of particles do not depend on y. In the space-time picture this means that the space-time is effectively two-dimensional and that particle distributions are Lorentz invariant: string like space-time sheets provide a possible geometric description of this situation.

4. In the case of an ideal quark-gluon plasma, the system completely forgets that it was created in a collision and particle distributions do not contain

any information about the beam direction. In a head-on collision there is a full rotational symmetry and even Lorentz invariance so that transverse momentum cutoff disappears. Rapidity plateau is predicted in all directions.

5. The collisions studied were not quite head-on collisions and were characterized by an impact parameter vector with length b and direction angle ψ_2 in the plane E^2. The particle distribution at the boundary of the plane E^2 was studied as a function of the angle coordinate $\phi - \psi_2$ and rapidity y which corresponds for given energy distance to a definite point of beam axis.

The hydrodynamical view about the situation looks like follows.

1. The particle distributions $N(p^\mu)$ as function of momentum components are mapped to space-time distributions $N(x^\mu, a)$ of particles. This leads to the idea that one could model the situation using Robertson-Walker type cosmology. Co-moving Lorentz invariant particle currents depending on the cosmic time only would correspond in this picture to Lorentz invariant momentum distributions.

2. Hydrodynamical models assign to the particle distribution $d^2N/dyd\phi$ a hydrodynamical flow characterized by four-velocity $v^\mu(y, \phi)$ for each value of the rapidity variable y. Longitudinal boost invariance predicting rapidity plateau states that the hydrodynamical flow does not depend on y at all. Because of the breaking of the rotational symmetry in the plane orthogonal to the beam, the hydrodynamical flow v depends on the angle coordinate $\phi - \psi_2$. It is possible to Fourier analyze this dependence and the second Fourier coefficient v_2 of $cos(2(\phi - \psi_2)$ in the expansion

$$\frac{dN}{d\phi} \simeq 1 + \sum_n v_n cos(n(\phi - \psi_2)) \quad (34)$$

   was analyzed in [119].

3. It was found that the Fourier component v_2 depends on rapidity y, which means a breaking of the longitudinal boost invariance. v_2 also vanishes for large values of y. If this is true for all Fourier coefficients v_n, the situation becomes effectively Lorentz invariant for large values of y since one has $v(y, \phi) \rightarrow 1$.

   Large values of y correspond to small values of a and to the initial moment of big bang in cosmological analogy. Hence the finding could be interpreted as a cosmological Lorentz invariance inside the light cone cosmology emerging from the collision point. Small values of y in turn correspond to large values of a so that the breaking of the spherical symmetry of the cosmology should be manifest only at $a \rightarrow \infty$ limit. These observations suggest a radical re-consideration of what happens in the collision: the breaking of the spherical symmetry would not be a property of the initial state but of the final state.

4.2 TGD based model for the quark-gluon plasma

Consider now the general assumptions the TGD based model for the quark gluon plasma region in the approximation that spherical symmetry is not broken.

1. Quantum-classical correspondence supports the mapping of the momentum space of a particle to a hyperboloid of future light cone. Thus the symmetries of the particle distributions with respect to momentum variables correspond directly to space-time symmetries.

2. The M^4_+ projection of a Robertson-Walker cosmology imbedded to $H = M^4_+ \times CP_2$ is future light cone. Hence it is natural to model the hydrodynamical flow as a mini-cosmology. Even more, one can assume that the collision quite literally creates a space-time sheet which locally obeys Robertson-Walker type cosmology. This assumption is sensible in many-sheeted space-time and conforms with the fractality of TGD inspired cosmology (cosmologies inside cosmologies).

3. If the space-time sheet containing the quark-gluon plasma is gradually filled with matter, one can quite well consider the possibility that the breaking of the spherical symmetry develops gradually, as suggested by the finding $v_2 \rightarrow 1$ for large values of $|y|$ (small values of a). To achieve Lorentz invariance at the limit $a \rightarrow 0$, one must assume that the expanding region corresponds to $r = constant$ "coordinate ball" in Robertson-Walker cosmology, and that the breaking of the spherical symmetry for the induced metric leads for large values of a to a situation described as a "not head-on collision".

4. Critical cosmology is by definition unstable, and one can model the Au+Au collision as a perturbation of the critical cosmology breaking the spherical symmetry. The shape of $r = constant$ sphere defined by the induced metric is changed by strong gravitational interactions such that it corresponds to the shape for the intersection of the colliding nuclei. One can view the collision as a spontaneous symmetry breaking process in which a critical quark-gluon plasma cosmology develops a quantum fluctuation leading to a situation described in terms of impact parameter. This kind of modelling is not natural for a hyperbolic cosmology, which is a small perturbation of the empty M^4_+ cosmology.

4.2.1 The imbedding of the critical cosmology

Any Robertson-Walker cosmology can be imbedded as a space-time sheet, whose M^4_+ projection is future light cone. The line element is

$$ds^2 = f(a)da^2 - a^2(K(r)dr^2 + r^2 d\Omega^2) \ . \qquad (35)$$

Here a is the scaling factor of the cosmology and for the imbedding as surface corresponds to the future light cone proper time.

This light cone has its tip at the point, where the formation of quark gluon plasma starts. (θ, ϕ) are the spherical coordinates and appear in $d\Omega^2$ defining the line element of the unit sphere. a and r are related to the spherical Minkowski coordinates (m^0, r_M, θ, ϕ) by $(a = \sqrt{(m^0)^2 - r_M^2}, r = r_M/a)$. If hyperbolic cosmology is in question, the function $K(r)$ is given by $K(r) = 1/(1+r^2)$. For the critical cosmology 3-space is flat and one has $K(r) = 1$.

1. The critical cosmologies imbeddable to $H = M^4_+ \times CP_2$ are unique apart from a single parameter defining the duration of this cosmology. Eventually the critical cosmology must transform to a hyperbolic cosmology. Critical cosmology breaks Lorentz symmetry at space-time level since Lorentz group is replaced by the group of rotations and translations acting as symmetries of the flat Euclidian space.

2. Critical cosmology replaces Big Bang with a silent whisper amplified to a big but not infinitely big bang. The silent whisper aspect makes the cosmology ideal for the space-time sheet associated with the quark gluon plasma: the interpretation is that the quark gluon plasma is gradually transferred to the plasma space-time sheet from the other space-time sheets. In the real cosmology the condensing matter corresponds to the decay products of cosmic string in 'vapor phase'. The density of the quark gluon plasma cannot increase without limit and after some critical period the transition to a hyperbolic cosmology occurs. This transition could, but need not, correspond to the hadronization.

3. The imbedding of the critical cosmology to $M^4_+ \times S^2$ is given by

$$\begin{aligned} sin(\Theta) &= \frac{a}{a_m} \ , \\ \Phi &= g(r) \ . \end{aligned} \qquad (36)$$

   Here Θ and Φ denote the spherical coordinates of the geodesic sphere S^2 of CP_2. One has

$$\begin{aligned} f(a) &= 1 - \frac{R^2 k^2}{(1-(a/a_m)^2)} \ , \\ (\partial_r \Phi)^2 &= \frac{a_m^2}{R^2} \times \frac{r^2}{1+r^2} \ . \end{aligned} \qquad (37)$$

Here R denotes the radius of S^2. From the expression for the gradient of Φ it is clear that gravitational effects are very strong. The imbedding becomes singular for $a = a_m$. The transition to a hyperbolic cosmology must occur before this.

This model for the quark-gluon plasma would predict Lorentz symmetry and $v = 1$ (and $v_n = 0$) corresponding to head-on collision so that it is not yet a realistic model.

4.2.2 TGD based model for the quark-gluon plasma without breaking of spherical symmetry

There is a highly unique deformation of the critical cosmology transforming metric spheres to highly non–spherical structures purely gravitationally. The deformation can be characterized by the following formula

$$sin^2(\Theta) = (\frac{a}{a_m})^2 \times (1 + \Delta(a,\theta,\phi)^2) \ . \quad (38)$$

1. This induces deformation of the g_{rr} component of the induced metric given by

$$g_{rr} = -a^2 \left[1 + \Delta^2(a,\theta,\phi)\frac{r^2}{1+r^2} \right] \ . \quad (39)$$

   Remarkably, g_{rr} does not depend at all on CP_2 size and the parameter a_m determining the duration of the critical cosmology. The disappearance of the dimensional parameters can be understood to reflect the criticality. Thus a strong gravitational effect independent of the gravitational constant (proportional to R^2) results. This implies that the expanding plasma space-time sheet having sphere as M^4_+ projection differs radically from sphere in the induced metric for large values of a. Thus one can understand why the parameter v_2 is non-vanishing for small values of the rapidity y.

2. The line element contains also the components g_{ij}, $i,j \in \{a,\theta,\phi\}$. These components are proportional to the factor

$$\frac{1}{1-(a/a_m)^2(1+\Delta^2)} \ , \quad (40)$$

   which diverges for

$$a_m(\theta,\phi) = \frac{a_m}{\sqrt{1+\Delta^2}} \ . \quad (41)$$

Presumably quark-gluon plasma phase begins to hadronize first at the points of the plasma surface for which $\Delta(\theta, \phi)$ is maximum, that is at the tips of the intersection region of the colliding nuclei. A phase transition producing string like objects is one possible space-time description of the process.

4.3 Further experimental findings and theoretical ideas

The interaction between experiment and theory is pure magic. Although experimenter and theorist are often working without any direct interaction (as in case of TGD), I have the strong feeling that this disjointness is only apparent and there is higher organizing intellect behind this coherence. Again and again it has turned out that just few experimental findings allow to organize separate and loosely related physical ideas to a consistent scheme. The physics done in RHIC has played completely unique role in this respect.

4.3.1 Super-canonical matter as the TGD counterpart of CGC?

The model discussed above explained the strange breaking of longitudinal Lorentz invariance in terms of a hadronic mini bang cosmology. The next twist in the story was the shocking finding, compared to Columbus's discovery of America, was that, rather than behaving as a dilute gas, the plasma behaved like a liquid with strong correlations between partons, and having density 30-50 times higher than predicted by QCD calculations [120]. When I learned about these findings towards the end of 2004, I proposed how TGD might explain them in terms of what I called conformal confinement [F2]. This idea - although not wrong for any obvious reason - did not however have any obvious implications. After the progress made in p-adic mass calculations of hadrons leading to highly successful model for both hadron and meson masses [F4], the idea was replaced with the hypothesis that the condensate in question is Bose-Einstein condensate like state of super-canonical particles formed when the hadronic space-time sheets of colliding nucleons fuse together to form a long string like object.

4.3.2 Fireballs behaving like black hole like objects

The latest discovery in RHIC is that fireball, which lasts a mere 10^{-23} seconds, can be detected because it absorbs jets of particles produced by the collision [121]. The association with the notion black hole is unavoidable and there indeed exists a rather esoteric M-theory inspired model "The RHIC fireball as a dual black hole" by Hortiu Nastase [123] for the strange findings.

The Physics Today article [122] "What Have We Learned From the Relativistic Heavy Ion Collider?" gives a nice account about experimental findings. Extremely high collision energies are in question: Gold nuclei contain energy of about 100 GeV per nucleon: 100 times proton mass. The expectation was that a large volume of thermalized Quark-Gluon Plasma (QCP) is formed in which partons lose rapidly their transverse momentum. The great surprise was the suppression of high transverse momentum collisions suggesting that in this phase strong collective interactions are present. This has inspired the proposal that quark gluon plasma is preceded by liquid like phase which has been christened as Color Glass Condensate (CGC) thought to contain Bose-Einstein condensate of gluons.

4.3.3 The theoretical ideas relating CGC to gravitational interactions

Color glass condensate relates naturally to several gravitation related theoretical ideas discovered during the last year.

1. Classical gravitation and color confinement

Just some time ago it became clear that strong classical gravitation might play a key role in the understanding of color confinement [E2]. Whether the situation looks confinement or asymptotic freedom would be in the eyes of beholder: one example of dualities filling TGD Universe. If one looks the situation at the hadronic space-time sheet one has asymptotic freedom, particles move essentially like free massless particles. But, and this is absolutely essential, in the induced metric of hadronic space-time sheet. This metric represents classical gravitational field becoming extremely strong near hadronic boundary. From the point of view of outsider, the motion of quarks slows down to rest when they approach hadronic boundary: confinement. The distance to hadron surface is infinite or at least very large since the induced metric becomes singular at the light-like boundary! Also hadronic time ceases to run near the boundary and finite hadronic time corresponds to infinite time of observer. When you look from outside you find that this light-like 3-surface is just static surface like a black hole horizon which is also a light-like 3-surface. Hence confinement.

2. Dark matter in TGD

The evidence for hadronic black hole like structures is especially fascinating. In TGD Universe dark matter can be (not always) ordinary matter at larger space-time sheets in particular magnetic flux tubes. The mere fact that the particles are at larger space-time sheets might make them more or less invisible.

Matter can be however dark in much stronger sense, should I use the word "black"! The findings suggesting that planetary orbits obey Bohr rules with a gigantic Planck constant [129, D7] would suggest quantum coherence of dark matter even in astrophysical length scales and this raises the fascinating possibility that Planck constant is dynamical so that fine structure constant for these charged coherent states would be proportional to $1/\hbar_{gr}$ and extremely small: hence darkness. This quantization saves from black hole collapse just as the quantization of hydrogen atom saves from the infrared catastrophe.

The obvious questions are following. Could black hole like objects/magnetic flux tubes/cosmic strings consist of quantum coherent dark matter? Does this dark matter consist dominantly from hadronic space-time sheets which have fused together and contain super-canonical bosons and their super-partners (with quantum numbers of right handed neutrino) having therefore no electroweak interactions.

Since $\alpha_K = \alpha_s = 1/4$ would indeed justify large value of Planck constant, $\hbar = 26\hbar_0$ would leave α_K unchanged and predicts that the size of the hadronic space-time sheet is that of a large nucleus. The hadronic string tension would be predicted correctly and strong gravitation would correspond to the exchange of super-canonical $J = 2$ quanta.

This overall view would be of enormous importance even for the understanding of living matter since dark matter at magnetic flux tubes would be responsible for the quantum control of the ordinary matter. Note however that TGD based quantum model for living matter involves also dark variants of ordinary elementary particles.

From outside non-stringy TGD analogs of black holes would look just like ordinary black holes but the interior metric would be of course different from the usual one since matter would not be collapsed to a point.

Dark matter option cannot be realized in a purely hadronic system at RHIC energies since the product GM_1M_2 characterizing the interaction strength of two masses must be larger than unity ($\hbar = c = 1$) for the phase transition increasing Planck constant to occur. Hence the collision energy should be above Planck mass for the phase transition to occur if gravitational interactions are responsible for the transition.

The hypothesis is however much more general and states that the system does its best to stay perturbative by increasing its Planck constant in discrete steps and applies thus also in the case of color interactions and governs the phase transition to the TGD counterpart of non-perturbative QCD. Criterion would be roughly $\alpha_s Q_s^2 > 1$ for two color charges of opposite sign. Hadronic string picture would suggests that the criterion is equivalent to the generalization of the gravitational criterion to its strong gravity analog $nL_p^2M^2 > 1$, where L_p is the p-adic length scale characterizing color magnetic energy density (hadronic string tension) and M is the mass of the color magnetic flux tube and n is a numerical constant. 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. The temperature during this phase could correspond to Hagedorn temperature (for the history and various interpretations of Hagedorn temperature see the CERN Courier article [124]) for strings and is determined by string tension and would naturally correspond also to the temperature during the critical phase determined by its duration as well as corresponding black-hole temperature. This temperature is expected to be somewhat higher than hadronization temperature found to be about $\simeq 176$ MeV. The density of inertial mass would be maximal during this phase as also the density of gravitational mass during the critical phase.

Lepto-hadron physics [F7], one of the predictions of TGD, is one instance of a similar situation. In this case electromagnetic interaction strength defined in an analogous manner becomes larger than unity in heavy ion collisions just above the Coulomb wall and leads to the appearance of mysterious states having a natural interpretation in terms of lepto-pion condensate. Lepto-pions are pairs of color octet excitations of electron and positron.

One can ask whether the Bose-Einstein condensed gluons at color magnetic flux tubes possess complex super-canonical conformal weights and whether conformal confinement could be responsible for the particle like behavior of CGC. An equally interesting question is whether ordinary liquid flow could involve Bose-Einstein condensates of particles which are not "conformal singlets".

3. Description of collisions using analogy with black holes

The following view about RHIC events represents my immediate reaction to the latest RHIC news in terms of black-hole physics instead of notions related to big bang. Since black hole collapse is roughly time reversal of big bang, the description is complementary to the earliest one.

In TGD context one can ask whether the fireballs possibly detected in RHIC are produced when a portion of quark-gluon plasma in the collision region formed by to Gold nuclei separates from hadronic space-time sheets which in turn fuse to form a larger space-time sheet separated from the remaining collision region by a light-like 3-D surface (I have used to speak about light-like causal determinants) mathematically completely analogous to a black hole horizon. This larger space-time sheet would contain color glass condensate of super-canonical gluons formed from the collision energy. A formation of an analog of black hole would indeed be in question.

The valence quarks forming structures connected by color bonds would in the first step of the collision separate from their hadronic space-time sheets which fuse together to form color glass condensate. Similar process has been observed experimentally in the collisions demonstrating the experimental reality of Pomeron, a color singlet state having no Regge trajectory [71] and identifiable as a structure formed by valence quarks connected by color bonds. In the collision it temporarily separates from the hadronic space-time sheet. Later the Pomeron and the new mesonic and baryonic Pomerons created in the collision suffer a topological condensation to the color glass condensate: this process would be analogous to a process in which black hole sucks matter from environment.

Of course, the relationship between mass and radius would be completely different with gravitational constant presumably replacement by the the square of appropriate p-adic length scale presumably of order pion Compton length: this is very natural if TGD counterparts of black-holes are formed by color magnetic flux tubes. This gravitational constant expressible in terms of hadronic string tension of .9 GeV^2 predicted correctly by super-canonical picture would characterize the strong gravitational interaction assignable to super-canonical $J = 2$ gravitons. I have long time ago in the context of p-adic mass calculations formulated quantitatively the notion of elementary particle black hole analogy making the notion of elementary particle horizon and generalization of Hawking-Bekenstein law [E5].

The size L of the "hadronic black hole" would be relatively large using protonic Compton radius as a unit of length. For $hbar = 26\hbar_0$ the size would be $26 \times L(107) = 46$ fm,and correspond to a size of a heavy nucleus. This large size would fit nicely with the idea about nuclear sized color glass condensate. The density of partons (possibly gluons) would be very high and large fraction of them would have been materialized from the brehmstrahlung produced by the de-accelerating nuclei. Partons would be gravitationally confined inside this region. The interactions of partons or conformal confinement would lead to a generation of a liquid like dense phase and a rapid thermalization would occur. The collisions of partons producing high transverse momentum partons occurring inside this region would yield no detectable high p_T jets since the matter coming out from this region would be somewhat like a thermal radiation from an evaporating black hole identified as a highly entangled hadronic string in Hagedorn temperature. This space-time sheet would expand and cool down to QQP and crystallize into hadrons.

4. Quantitative comparison with experimental data

Consider now a quantitative comparison of the model with experimental data. The estimated freeze-out temperature of quark gluon plasma is $T_f \simeq 175.76$ MeV [122, 123], not far from the total contribution of quarks to the mass of nucleon, which is 170 MeV [F4]. Hagedorn temperature identified as black-hole temperature should be higher than this temperature. The experimental estimate for the hadronic Hagedorn temperature from the transversal momentum distribution of baryons is $\simeq 160$ MeV. On the other hand, according to the estimates of hep-ph/0006020 the values of Hagedorn temperatures for mesons and baryons are $T_H(M) = 195$ MeV and $T_H(B) = 141$ MeV respectively.

D-dimensional bosonic string model for hadrons gives for the mesonic Hagedorn temperature the expression [124]

$$T_H = \frac{\sqrt{6}}{2\pi(D-2)\alpha'} , \qquad (42)$$

For a string in $D = 4$-dimensional space-time and for the value $\alpha' \sim 1\ \mathrm{GeV}^{-2}$ of Regge slope, this would give $T_H = 195$ MeV, which is slightly larger than the freezing out temperature as it indeed should be, and in an excellent agreement with the experimental value of [125]. It deserves to be noticed that in the model for fireball as a dual 10-D black-hole the rough estimate for the temperature of color glass condensate becomes too low by a factor 1/8 [123]. In light of this I would not yet rush to conclude that the fireball is actually a 10-dimensional black hole.

Note that the baryonic Hagedorn temperature is smaller than mesonic one by a factor of about $\sqrt{2}$. According to [125] this could be qualitatively understood from the fact that the number of degrees of freedom is larger so that the effective value of D in the mesonic formula is larger. $D_{eff} = 6$ would give $T_H = 138$ MeV to be compared with $T_H(B) = 141$ MeV. On the other hand, TGD based model for hadronic masses [F4] assumes that quarks feed their color fluxes to $k = 107$ space-time sheets. For mesons there are two color flux tubes and for baryons three. Using the same logic as in [125], one would have $D_{eff}(B)/D_{eff}(M) = 3/2$. This predicts $T_H(B) = 159$ MeV to be compared with 160 MeV deduced from the distribution of transversal momenta in p-p collisions.

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.

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

$$S_p = (\frac{M}{m(CP_2)})^2 \times log(p) \ , \tag{43}$$

   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.

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

$$S_p = klog(2) \times (\frac{M}{m(CP_2)})^2 , \tag{44}$$

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

3. Hawking-Bekenstein area law gives in the case of Schwartschild black-hole

$$S = \frac{A}{4G} \times \hbar = \pi G M^2 \times \hbar \ . \tag{45}$$

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.

4. 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 [D7] 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

$$\hbar_{gr} = \frac{GM^2}{v_0}\hbar_0 \ , \ \ v_0 = 1/2 \ . \tag{46}$$

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 [D7]. 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.

5. 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.

6. 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.

7. 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.

4.5 Conclusions

The model for quark-gluon plasma in terms of valence quark space-time sheets separated from hadronic space-time sheets forming a color glass condensate relies on quantum criticality and implies gravitation like effects due to the presence of super-canonical strong gravitons. At space-time level the change of the distances due to strong gravitation affects the metric so that the breaking of spherical symmetry is caused by gravitational interaction. TGD encourages to think that this mechanism is quite generally at work in the collisions of nuclei. One must take seriously the possibility that strong gravitation is present also in longer length scales (say biological), in particular in processes in which new space-time sheets are generated. Critical cosmology might provide a universal model for the emergence of a new space-time sheet.

The model supports TGD based early cosmology and quantum criticality. In standard physics framework the cosmology in question is not sensible since it would predict a large breaking of the Lorentz invariance, and would mean the breakdown of the entire conceptual framework underlying elementary particle physics. In TGD framework Lorentz invariance is not lost at the level of imbedding space, and the experiments provide support for the view about space-time as a surface and for the notion of many-sheeted space-time.

The attempts to understand later strange events reported by RHIC have led to a dramatic increase of understanding of TGD and allow to fuse together separate threads of TGD.

1. The description of RHIC events in terms of the formation of hadronic black hole and its evaporation seems to be also possible and essentially identical with description as a mini bang.

2. It took some time to realize that scaled down TGD inspired cosmology as a model for quark gluon plasma predicts a new phase identifiable as color glass condensate and still a couple of years to realize the proper interpretation of it in terms of super-canonical bosons having no counterpart in QCD framework.

3. Also dark matter could be identified as a macroscopic quantum phase in which individual particles have complex conformal weights. This phase could be even responsible for the properties of living matter. There is also a connection with the dramatic findings suggesting that Planck constant for dark matter has a gigantic value.

4. Black holes and their scaled counterparts would not be merciless information destroyers in TGD Universe. The entanglement of particles possessing different conformal weights to give states with a vanishing net conformal weight and having particle like integrity would make black hole like states ideal candidates for quantum computer like systems. One could even imagine that the galactic black hole is a highly tangled cosmic string in Hagedorn temperature performing quantum computations the complexity of which is totally out of reach of human intellect! Indeed, TGD inspired consciousness predicts that evolution leads to the increase of information and intelligence, and the evolution of stars should not form exception to this. Also the interpretation of black hole as consisting of dark matter follows from this picture.

Summarizing, it seems that thanks to some crucial experimental inputs the new physics predicted by TGD is becoming testable in laboratory.

5 Cosmic rays and Mersenne Primes

TGD suggests the existence of a scaled up copy of hadron physics associated with each Mersenne prime $M_n = 2^n - 1$, n prime: M_{107} corresponds to ordinary hadron physics. There is some evidence for exotic hadrons. Also Gaussian Mersennes $(1+i)^k-1$, could correspond to hadron physics. Four of them ($k = 151, 157, 163, 167$) are in the biologically interesting length scale range between cell membrane thickness and the size of cell nucleus.

Centauro events and the peculiar events associated with $E > 10^5\ GeV$ radiation from Cygnus X-3 could be understood as due to the decay of gamma rays to M_{89} hadron pair in the atmosphere. The decay $\pi_n \rightarrow \gamma\gamma$ produces a peak in the spectrum of the cosmic gamma rays at energy $\frac{m(\pi_n)}{2}$ and there is evidence for the peaks at energies $E_{89} \simeq 34\ GeV$ and $E_{31} \simeq 3.5 \cdot 10^{10}\ GeV$. The absence of the peak at $E_{61} \simeq 1.5 \cdot 10^6\ GeV$ can be understood as due to the strong absorption caused by the e^+e^- pair creation with photons of the cosmic microwave background.

Cosmic string decays *cosmic string* $\rightarrow M_2$ *hadrons* $\rightarrow M_3$ *hadrons* ..$\rightarrow M_{107}$ *hadrons* is a new source of cosmic rays. The mechanism could explain the change of the slope in the hadronic cosmic ray spectrum at $3 \cdot 10^6\ GeV$ which is not far from M_{61} pion rest energy $1.2 \cdot 10^6\ GeV$.

The cosmic ray radiation at energies near $10^9\ GeV$ apparently consisting of protons and nuclei not lighter than Fe might be actually dominated by gamma rays: at these energies γ and p induced showers have same muon content and the decays of gamma rays to M_{89} and M_{61} hadrons in the atmosphere can mimic the presence of heavy nuclei in the cosmic radiation.

The identification of the hadronic space-time sheet as a super-canonical mini black-hole [F4] suggests that part of ultra-high energy cosmic rays could be protons which have lost their valence quarks. These particles would have essentially same mass as proton and would behave like mini black-holes consisting of dark matter. They could even give a dominating contribution to the dark matter. Since electro-weak interactions are absent, the scattering from microwave background is absent, and they could propagate over much longer distances than ordinary particles. An interesting question is whether the ultrahigh energy cosmic rays having energies larger than the GZK cut-off of 5×10^{10} GeV are super-canonical mini black-holes associated with M_{107} hadron physics or some other copy of hadron physics.

5.1 Mersenne primes and mass scales

p-Adic mass calculations lead to quite detailed predictions for elementary particle masses. In particular, there are reasons to believe that the most importabnt fundamental elementary particle mass scales correspond to Mersenne primes $M_n = 2^n - 1$, $n = 2, 3, 7, 13, 17, 19, ...$

$$\begin{aligned} m_n^2 &= \frac{m_0^2}{M_n} \ , \\ m_0 &\simeq 1.41 \cdot \frac{10^{-4}}{\sqrt{G}} \ , \end{aligned} \tag{47}$$

where $\sqrt{G}$ is Planck length. The known elementary particle mass scales were identified as mass scales associated identified with Mersenne primes $M_{127} \simeq 10^{38}$ (leptons), M_{107} (hadrons) and M_{89} (intermediate gauge bosons). Of course, also other p-adic length scales are possible and it is quite possible that not all Mersenne primes are realized.

Theory predicts also some higher mass scales corresponding to the Mersenne primes M_n for $n = 89, 61, 31, 19, 17, 13, 7, 3$ and suggests the existence of a scaled up copy of hadron physics with each of these mass scales. In particular, masses should be related by simple scalings to the masses of the ordinary hadrons.

An attractive hypothesis is that the color interactions of the particles of level M_n can be described using the ordinary QCD scaled up to the level M_n so that that masses and the confinement mass scale Λ is scaled up by the factor $\sqrt{M_n/M_{107}}$.

$$\Lambda_n = \sqrt{\frac{M_n}{M_{107}}}\Lambda \ . \tag{48}$$

In particular, the masses of the exotic pions associated with M_n are given by

$$m(\pi_n) = \sqrt{\frac{M_n}{M_{107}}}m_\pi \ . \tag{49}$$

Here $m_\pi \simeq 135\ MeV$ is the mass of the ordinary pion.

The interactions between the different level hadrons are mediated by the emission of electro-weak gauge bosons and by gluons with cm energies larger than the energy defined by the confinement scale of level with smaller p. The decay of the exotic hadrons at level M_{n_k} to exotic hadrons at level $M_{n_{k+1}}$ must take place by a transition sequence leading from the effective M_{n_k}-adic space-time topology to effective $M_{n_{k+1}}$-adic topology. All intermediate p-adic topologies might be involved.

5.2 Cosmic strings and cosmic rays

Cosmic strings are fundamental objects in quantum TGD and dominated during early cosmology.

5.2.1 Cosmic strings

Cosmic strings (not quite the same thing in TGD as in GUTs) are basic objects in TGD inspired cosmology [D5, D4].

1. In TGD inspired galaxy model galaxies are regarded as mass concentrations around cosmic strings and the energy of the string corresponds to the dark energy whereas the particles condensed at cosmic strings and magnetic flux tubes resulting from them during cosmic expansion correspond to dark matter [D5, D4]. The galactic nuclei, often regarded as candidates

for black holes, are the most probable seats for decaying highly entangled cosmic strings.

2. Galaxies are known to organize to form larger linear structures. This can be understood if the highly entangled galactic strings organize around long strings like pearls in necklace. Long strings could correspond to galactic jets and their gravitational field could explain the constant velocity spectrum of distant stars in the galactic halo.

3. In [D5, D4, D7] it is suggested that decaying cosmic strings might provide a common explanation for the energy production of quasars, galactic jets and gamma ray bursters and that the visible matter in galaxies could be regarded as decay products of cosmic strings. The magnetic and Z^0 magnetic flux tubes resulting during the cosmic expansion from cosmic strings allow to assign at least part of gamma ray bursts to neutron stars. Hot spots (with temperature even as high as $T \sim \frac{10^{-3,5}}{\sqrt{G}}$) in the cosmic string emitting ultra high energy cosmic rays might be created under the violent conditions prevailing in the galactic nucleus.

The decay of the cosmic strings provides a possible mechanism for the production of the exotic hadrons and in particular, exotic pions. In [86] the idea that cosmic strings might produce gamma rays by decaying first into 'X' particles with mass of order 10^{15} GeV and then to gamma rays, was proposed. As authors notice this model has some potential difficulties resulting from the direct production of gamma rays in the source region and the presence of intensive electromagnetic fields near the source. These difficulties are overcome if cosmic strings decay first into exotic hadrons of type M_{n_0}, $n_0 \geq 3$ of energy of order $2^{-n_0+2}10^{25}$ GeV , which in turn decay to exotic hadrons corresponding to M_k, $k > n_0$ via ordinary color interaction, and so on so that a sequence of M_k:s starting some value of n_0 in $n = 2, 3, 7, 13, 17, 19, 31, 61, 89, 107$ is obtained. The value of n remains open at this stage and depends on the temperature of the hot spot and much smaller temperatures than the $T \sim m_0$ are possible: favored temperatures are the temperatures $T_n \sim m_n$ at which M_n hadrons become unstable against thermal decay.

5.2.2 Decays of cosmic strings as producer of high energy cosmic gamma rays

In [87] the gamma ray signatures from ordinary cosmic strings were considered and a dynamical QCD based model for the decay of cosmic string was developed. In this model the final state particles were assumed to be ordinary hadrons and final state interactions were neglected. In present case the string decays first to M_{n_0} hadrons and the time scale of for color interaction between M_{n_0} hadrons is extremely short (given by the length scale defined by the inverse of π_{n_0} mass) as compared to the time time scale in case of ordinary hadrons. Therefore the interactions between the final state particles must be taken into account and there are good reasons to expect that thermal equilibrium sets on and much simpler thermodynamic description of the process becomes possible.

A possible description for the decaying part of the highly tangled cosmic string is as a 'fireball' containing various M_{n_0} ($n \geq 3$) partons in thermal equilibrium at Hagedorn temperature T_{n_0} of order $T_{n_0} \sim m_{n_0} = 2^{-2+n_0}\frac{10^{-4}}{k\sqrt{G}}$, $k \simeq 1.288$. The experimental discoveries made in RHIC suggest [122] that high energy nuclear collisions create instead of quark gluon plasma a liquid like phase involving gluonic BE condensate christened as color glass condensate. Also black hole like behavior is suggested by the experiments.

RHIC findings inspire a TGD based model for this phase as a macroscopic quantum phase condensed on a highly tangled color magnetic string at Hagedorn temperature. The model relies also on the notion of dynamical but quantized $\hbar$ [J6] and its recent form to the realization that super-canonical many-particle states at hadronic space-time sheets give dominating contribution to the baryonic mass and explain hadronic masses with an excellent accuracy.

This phase has no direct gauge interactions with ordinary matter and is identified in TGD framework as a particular instance of dark matter. Quite generally, quantum coherent dark matter would reside at magnetic flux tubes idealizable as string like objects with string tension determined by the p-adic length scale and thus outside the "ordinary" space-time. This suggests that color glass condensate forms when hadronic space-time sheets fuse to single long string like object containing large number of super-canonical bosons.

Color glass condensate has black-hole like properties by its electro-weak darkness and there are excellent reasons to believe that also ordinary black holes could by their large density correspond to states in which super-canonical matter would form single connected string like structure (if Planck constant is larger for super-canonical hadrons, this fusion is even more probable).

This inspires the following mechanism for the decay of exotic boson.

1. The tangled cosmic string begins to cool down and when the temperature becomes smaller than $m(\pi_{n_0})$ mass it has decayed to M_{n_1} matter which in turn continues to decay to M_{n_2} matter. The decay to M_{n_1} matter could occur via a sequence $n_0 \rightarrow n_0 - 1 \rightarrow ...n_1$ of phase transitions corresponding to the intermediate p-adic length scales $p \simeq 2^k$, $n_1 \geq k > n_0$. Of course, all intermediate p-adic length scales are in principle possible so that the process would be practically continuous and analogous to p-adic length scale evolution with $p \simeq 2^k$ representing more stable intermediate states.

2. The first possibility is that virtual hadrons decay to virtual hadrons in the transition $k \rightarrow k-1$. The alternative option is that the density of final state hadrons is so high that they fuse to form a single highly entangled hadronic string at Hagedorn temperature T_{k-1} so that the process would resemble an evaporation of a hadronic black hole staying in quark plasma phase without freezing to hadrons in the intermediate states. This entangled string would contain partons as "color glass condensate".

3. The process continues until all particles have decayed to ordinary hadrons. Part of the M_n low energy thermal pions decay to gamma ray pairs and produce a characteristic peak in cosmic gamma ray spectrum at energies $E_n = \frac{m(\pi_n)}{2}$ (possibly red-shifted by the expansion of the Universe). The decay of the cosmic string generates also ultra high energy hadronic cosmic rays, say protons. Since the creation of ordinary hadron with ultra high energy is certainly a rare process there are good hopes of avoiding the problems related to the direct production of protons by cosmic strings (these protons produce two high flux of low energy gamma rays, when interacting with cosmic microwave background [86]).

5.2.3 Topologically condensed cosmic strings as analogs super-canonical black-holes?

Super-canonical matter has very stringy character. For instance, it obeys stringy mass formula due the additivity and quantization of mass squared as multiples of p-adic mass scale squared [F4]. The ensuing additivity of mass squared defines a universal formula for binding energy having no independence on interaction mechanism. Highly entangled strings carrying super-canonical dark matter are indeed excellent candidates for TGD variants of black-holes. The space-time sheet containing the highly entangled cosmic string is separated from environment by a wormhole contact with a radius of black-hole horizon. Schwartschild radius has also interpretation as Compton length with Planck constant equal to gravitational Planck constant $\hbar/\hbar_0 = 2GM^2$. In this framework the proposed decay of cosmic strings would represent nothing but the TGD counterpart of Hawking radiation. Presumably the value of p-adic prime in primordial stage was as small as possible, even $p = 2$ can be considered.

5.2.4 Exotic cosmic ray events and exotic hadrons

One signature of the exotic hadrons is related to the interaction of the ultra high energy gamma rays with the atmosphere. What can happen is that gamma rays in the presence of an atmospheric nucleus decay to virtual exotic quark pair associated with M_{n_k}, which in turn produces a cascade of exotic hadrons associated with M_{n_k} through the ordinary scaled up color interaction. These hadrons in turn decay $M_{n_{k+1}}$ type hadrons via mechanisms to be discussed later. At the last step ordinary hadrons are produced. The collision creates in the atmospheric nucleus the analog of quark gluon plasma which forms a second kind of fireball decaying to ordinary hadrons. RHIC experiments have already discovered these fireballs and identified them as color glass condensates [122]. It must be emphasized that it is far from clear whether QCD really predicts this phase.

These showers differ from ordinary gamma ray showers in several respects.

1. Exotic hadrons can have small momenta and the decay products can have isotropic angular distribution so that the shower created by gamma rays looks like that created by a massive particle.

2. The muon content is expected to be similar to that of a typical hadronic shower generated by proton and larger than the muon content of ordinary gamma ray shower [88].

3. Due to the kinematics of the reactions of type $\gamma + p \rightarrow H_{M_n} + ... + p$ the only possibility at the available gamma ray energies is that M_{89} hadrons are produced at gamma ray energies above 10 TeV. The masses of these hadrons are predicted to be above 70 GeV and this suggests that these hadrons might be identified incorrectly as heavy nuclei (heavier than ^{56}Fe). These signatures will be discussed in more detail in the sequel in relation to Centauro type events, Cygnus X-3 events and other exotic cosmic ray events. For a good review for these events and models form them see the review article [103].

Some cosmic ray events [89, 90] have total laboratory energy as high as 3000 TeV which suggests that the shower contains hadron like particles, which are more penetrating than ordinary hadrons.

1. One might argue that exotic hadrons corresponding M_k, $k > 107$with interact only electro-weakly (color is confined in the length scale associated with M_n) with the atmosphere one might argue that they are more penetrating than the ordinary hadrons.

2. The observed highly penetrating fireballs could also correspond super-canonical dark matter part of incoming, possibly exotic, hadron fused with that for a hadron of atmosphere. Both hadrons would have lost their valence quarks in the collision just as in the case of Pomeron events. Large fraction of the collision energy would be transformed to super-canonical quanta in the process and give rise to a large color spin glass condensate. These condensates would have no direct electro-weak interactions with ordinary matter which would explain their long penetration lengths in the atmosphere. Sooner or later the color glass condensate would decay to hadrons by the analog of blackhole evaporation. This process is different from QCD type hadronization process occurring in hadronic collisions and this might allow to understand the anomalously low production of neutral pions.

Exotic mesons can also decay to lepton pairs and neutral exotic pions produce gamma pairs. These gamma pairs in principle provide a signature for the presence of exotic pions in the cosmic ray shower. If M_{89} proton is sufficiently long-lived enough they might be detectable.The properties of Centauro type events however suggest that M_{89} protons are short lived.

5.3 Peaks in cosmic gamma ray spectrum

The decay of the M_n pions at rest to two gamma rays produces gamma rays with energy $E_n = \frac{m(\pi_n)}{2}$. Therefore the cosmic gamma ray spectrum might show detectable signatures at these energies.

There is indeed some evidence for this kind of signatures in cosmic gamma ray background.

1. There are indications that the energy density of the cosmic gamma ray spectrum has peak at energy near 33.5 GeV ([91], see Fig. 8). A possible identification is as gamma rays produced by the decay of M_{89} pions. The energy distribution would be induced from the non-relativistic thermal distribution with temperature near $m(\pi_{89})$.

2. M_{61} corresponds to gamma ray threshold energy of $1.7 \cdot 10^6$ GeV. There is no visible signature at this energy but there is a good explanation for this. The e^+e^- pair production of the gamma rays with energy in certain energy range above 10^6 GeV with the photons of the cosmic microwave background implies strong reduction of the gamma ray flux by 2-3 orders of magnitude [87]. According to [87] the cutoff red-shift is of order $z-1 \simeq e^{-5}$ at this energy and corresponds to an upper bound of order 10^8 light years (the size of the large voids) for the distance of the source to be observable. The energy of the gamma rays coming from M_{61} pions happens to belong to the region with strongest absorption.

3. M_{31} corresponds to energy of the order of $1.7 \cdot 10^{10}$ GeV and jump in cosmic ray energy density is expected. As figure 8 shows, the cosmic ray spectrum contains indeed an bump at this energy [92, 86, 87]: the energy flux has a peak in short energy interval above $1.7 \cdot 10^{10}$ GeV. The simplest possibility is that the bump results from the decay of thermal M_{31} pions created in the decay of cosmic string. The effect is partially masked by the annihilation of gamma rays and photons of the cosmic radio wave background to e^+e^- pairs above the energy $5 \cdot 10^9$ GeV and the greatest effect comes at $3 \cdot 10^{10}$ GeV [87] (the mass of the exotic pion!).

   An alternative explanation for the bump is based on the assumption that cosmic rays are predominantly protons at these energies [93]. The proton component of the cosmic ray spectrum is predicted to effectively terminate at energy about $7 \cdot 10^{10}$ GeV due to pion production from cosmic microwave background. The experimental situation is unclear at this moment. Haverah Park detector claims the detection of 4 events with energies above 10^{11} GeV whereas Fly's Eye detector reports no events [94].

4. The theory predicts further peaks at $m_{19} = 64 \cdot m_{31} \simeq 2 \cdot 10^{12}$ GeV, $m_{17} = 2m_{19}$,... It might well be possible in not so far future to verify whether cosmic gamma ray flux contains these peaks.

5.4 Centauro type events, Cygnus X-3 and M_{89} hadrons

The results reported by Brazil-Japan Emulsion Chamber Collaboration [89, 95] on multiple production of hadrons induced by cosmic rays with energies $E_{lab} > 10^5$ GeV provide evidence for new Physics. The distributions for the transverse momentum p_T and longitudinal momentum fraction x for pions were found to differ from the distributions extrapolated from lower energies. The widening of the transversal momentum distributions has also been observed at accelerator energies (ISR above $\sqrt{s} = 63\ GeV$ and CERN SPS-p$\bar{p}$ Collider at $\sqrt{s} = 540\ GeV$). Furthermore, exotic events called Geminion, Centauro, Chiron with emission of $n_B \leq 100$ hundred baryons but practically no pions were detected. There are also peculiar events associated with the radiation coming from Cygnus X-3. A recent summary about peculiar events is given in the review article [103].

5.4.1 Mirim, Acu and Quacu

The exotic cosmic ray events are described in the review article of [89]. In [89] the multiple production of pions is classified into 3 jet types called Mirim, Acu and Quacu. Although the transverse momentum distributions for pions observed at low energies are universal, Acu and Quacu jets are characterized by wider transverse momentum distributions with larger value of average transverse momentum p_T than in low energy pionization: this widening is in accordance with accelerator results. The distributions for the longitudinal momentum fraction x scale but differ from the low energy situation for Acu and Quacu jets.

In [89, 96, 97] a description of these events in terms of 'fireballs' decaying into ordinary hadrons were considered. The p_T distribution associated with Mirim is just the ordinary low energy transverse momentum distribution whereas the distributions associated with Acu and Quacu are wider. The masses of the fireballs were assumed to be discrete and were found to be $M_0 \sim 2-3\ GeV$ (Mirim), $M_1 \sim 15-30\ GeV$ (Acu) , $M_2 \sim 100-300\ GeV$ (Quacu). It should be noticed that the upper bounds for the masses associated with Acu and Quacu fireballs are roughly by a factor of two smaller than the masses 481 GeV associated with M_{89} pion and M_{89} proton. The temperatures were found to be in range $0.4 - 10\ GeV$ for Acu and Quacu fireball and to be substantially larger than the ordinary Hagedorn temperature $T_H \simeq 0.16\ GeV$.

5.4.2 Chirons, Centauros, anti-Centauros, and Geminions

For the second class of events consisting of Chirons, Centauros and Geminions observed at laboratory energies $100 - 1000\ TeV$ pion production is strongly suppressed (gamma pairs resulting from the decay of neutral pions are almost absent) [89]. The primary event takes place few hundred meters above the detector and decay products are known to be hadrons and mostly baryons: about 15 (100) for Mini-Centauros (Centauros). This excludes the possibility that exotic hadrons decay in emulsion chamber and implies also that the decay mechanism of the primary particle is such that very few mesons are produced.

The fireball hypothesis has been applied also to Centauro type events assuming that fireballs corresponds to a different phase than in the case of Mirim, Acu and Quacu [89, 97]. The fireball masses associated with Mini-Centauro and Centauro are according to the estimate of [89] $M_{mini} = 35$ GeV and $M_{Centauro} = 23$ GeV. These masses are almost exactly one half of the masses of the M_{89} pion

(70 GeV) and proton (470 GeV) respectively!

$$\begin{aligned} M_{Mini} &\simeq \frac{m(\pi_{89})}{2} \ , \\ M_{Centauro} &\simeq \frac{m(p_{89})}{2} \ . \end{aligned} \tag{50}$$

This suggests that the decay of cosmic gamma ray to M_{89} quark pair which in turn hadronizes to (possibly virtual) M_{89} hadrons induced by the interaction with the nucleon of atmosphere is the origin of Mini-Centauro/Centauro events.

The basic difference between the decaying fireballs in Acu/Quacu events and Centauro type events is that Acu/Quacu decays produce neutral pions unlike Centauros.

The appearance of the factor of 1/2 in the mass estimates needs an explanation. One explanation is systematic error in the evaluation of hadronic energy: for instance, the gamma inelasticity k_γ telling which fraction of hadronic energy is transformed to electromagnetic energy might be actually smaller than believed by a factor of order two. An alternative explanation is related to the decay mechanism of M_{89} particle: if the decay takes place via a decay to two off mass shell M_{89} hadrons decaying in turn to hadrons then the average rest energy of the fireball is indeed one half of the mass of the decaying on mass shell particle. The reason for the necessity of off mass shell intermediate states is perhaps the stability of the on mass shell exotic hadrons against the direct decay to ordinary hadrons.

Anti-Centauros are much like Centauros except that neutral pions are overabundant [103]. The speculative model [104] relies on the notion of chiral condensates consisting of neutral pions in the case of Centauros and charged pions in the case of anti-Centauros.

5.4.3 The case of Cygnus X-3

There are peculiar events associated with the cosmic rays coming from Cygnus X-3 at gamma ray energies above $10^5\ GeV$ [98]. The primary particle must be massless particle and is most probably ordinary gamma ray. The structure of the shower however suggests that the decaying particle is very massive! Furthermore, the muon content of the shower is larger than that associated with gamma ray shower. A possible explanation is that the gamma rays coming from Cygnus X-3 with energy above the threshold $10^4\ GeV$ produce M_{89} hadrons, which in turn create the cosmic ray shower through the decay to M_{89} hadrons and the decay of these to the ordinary M_{107} hadrons: this indeed means that the gamma rays behave like a massive particles in the atmosphere.

5.5 TGD based explanation of the exotic events

The TGD based model for exotic events involve p-adic length scale hierarchy, many-sheeted space-time, and TGD inspired view about dark matter. A decisive empirical input comes from RHIC events suggesting that quark gluon plasma is actually a liquid like "macroscopic" quantum phase identifiable as a particular instance of dark matter.

5.5.1 General considerations

The mass estimates for the fireballs and the absence of neutral pions suggest that Mini-Centauro/Centauro type events correspond to the decay of M_{89} hadrons (pion/proton) to ordinary hadrons. The general model for the exotic events would be following.

1. Cosmic gamma ray decays first into M_{89} quark pair via electromagnetic interaction with the nucleon of the atmosphere. Pairs of Centauros/anti-Centauros and quark-gluon-plasma blobs explaing Mirim/Qcu/Quacu events would be naturally created in these collisions.

2. The quark pair in turn hadronizes to M_{89} hadrons decaying to virtual $k > 89$ hadrons which in turn end up via a sequential decay process to ordinary hadrons. This process is kinematically possible if the condition $E_{tot} > 2M^2/m_p$, is satisfied (M is the mass of the exotic hadron). For example, the energy of the gamma ray must be larger than 500 TeV for exotic proton pair production. For the exotic pion the corresponding lower bound is about 10 TeV. The energies of the exotic events are indeed above 100 TeV in accordance with these bounds. The average total energy is about $E_{tot} = 1740\ TeV$ for Centauros and $E_{tot} \simeq 903\ TeV$ for Mini-Centauros [97]. The mechanism implies that two M_{89} fireballs are produced. 'Binocular' events (Geminions) consisting of two widely separated fireballs have indeed been observed [89].

3. If anti-Centauros result via the same mechanism there must be a mechanism explaining why the production of neural pions varies from event to event. One proposal is that the difference is due to a formation of pion condensates consisting of neural *resp.* charged pions in the two situations [104]. This hypothesis would unify Centauro events with anti-Centauro events in which the production of neutral pions is abnormally high [103].

4. Mirim/Acu/Quacu events could correspond to the decay of a high temperature quark-gluon plasma blob, or rather color glass condensate, to hadrons (recall that the estimated plasma temperatures are much lower than for Centauros). The collision of M_{89} hadron possibly generated in the interaction of the cosmic gamma ray with ordinary nucleon could induce both the decay of M_{89} hadron to virtual hadrons and generate quark-gluon plasma blob in the atmospheric target nucleus. Hagedorn temperature $T(k)$, $89 < k \leq 107$ is a good guess for the temperature of this plasma blob. RHIC findings [122] suggest that the blob corresponds to highly tangled hadronic string containing super-canonical dark matter and decaying by de-coherence to ordinary hadrons [J6].

5.5.2 Connection with TGD based model for RHIC events

The counterparts of Centauros and other exotic events have not been observed in accelerator experiments. More than a decade after writing the first version of the model for Centauros came however data from RHIC experiment [122], which seems to provide a connection between laboratory and cosmic ray data. In RHIC collisions of very energetic Gold nuclei are studied. The collisions were expected to create a quark gluon plasma freezing to ordinary hadrons. The surprise was that the resulting state behaves like an ideal liquid and has also black hole like properties [122].

Recall that the TGD based model [D7, J6] for RHIC findings is following.

1. The state in question corresponds to a highly entangled hadronic string at Hagedorn temperature defining the analog of black hole and decaying by evaporation. The gravitational constant defined by Planck length is effectively replaced by a hadronic gravitational constant defined by the hadronic length scale. p-Adic length scale hypothesis predicts entire hierarchy of Hagedorn temperatures.

2. Bose-Einstein condensate of gluons referred to as color glass condensate has been proposed as an explanation for the liquid like behavior of the quark-gluon phase. TGD based explanation for the liquid like state is that that the state in question corresponds to a large Bose-Einstein condensate like state of super-canonical particles resulting as hadronic space-time sheets fuse. Super-canonical bosons have vanishing electro-weak quantum numbers since super-canonical generators are either purely bosonic or possess quantum numbers of right handed neutrino. Dark matter is in question.

3. The large value of $\alpha_K = \alpha_s = 1/4$ for super-canonical bosons for ordinary value of $\hbar$ motivates the assumption is that the super-canonical many-particle state corresponds to a large value of $\hbar$ increasing the length and time scales of quantum coherence since typical length and time scales are proportional to $\hbar$. In the lowest order in $\hbar$ (classical limit) the physics does not change but higher order corrections are reduced since gauge coupling strengths are reduced. For the situation involving non-perturbative effects (typically binding energies) the change of $\hbar$ induces more dramatic effects.

5.5.3 A more precise model for exotic events

A more detailed formulation necessitates a rough model for the transformation of M_{89} hadrons to M_{107} hadrons.

1. On mass shell exotic hadrons can be assumed to be stable against direct decay to ordinary hadrons so that their decay must take place via a sequential decay to off mass shell exotic hadrons characterized by $107 > k > 89$, which eventually decay to ordinary hadrons. The simplest decay mode is the decay to two virtual exotic hadrons with average mass, which is

one half of the mass of the decaying exotic hadron in accordance with observations.

2. M_{89} hadron decays to virtual hadrons with $p \simeq 2^k > M_{89}$ dominate over electro-weak decays since the characteristic time scale is defined by $\Lambda(QCD, M_{89}) = 512\Lambda(QCD, 107)$. This means that most of the energy in the process goes to virtual $k > 89$ virtual mesons. Neutral $k > 89$ virtual pions, if created, can decay to gamma pairs so that the problem of understanding the absence of neutral pions remains.

3. M_{89} hadronic space-time sheet suffers a topological phase transition to M_{107} hadronic space-time sheet via several steps $k = 89 \rightarrow k_1 > 89.. \rightarrow k_n = 107$. In the process the size of hadronic surface suffers a $2^9 = 512$-fold expansion meaning the increase of volume by a factor for $2^{27} \sim 10^9/8$ so that a small scale Big Bang is really in question! The expansion brings in mind liquid-vapor phase transition but the freezing to hadrons (due to the properties of color coupling constant evolution) makes the transition more like a liquid-solid phase transition.

   As noticed, all p-adic length scales in the range involved could be present but $p \simeq 2^k$ would define more stable intermediate states. A possible experimental signature for the sequence of the phase transitions labelled by $89 \leq k \leq 107$ is a bumpy structure of the detected hadronic cascades with a maximum of 17 maxima. This kind of structure with a constant distance between maxima and 11 maxima has been indeed observed for some cascades (see Fig. 8 of [103]).

   A good guess for the critical temperature of the Big Bang like phase transition to occur is $T_{cr}(89) = km_{89}$, where k is some numerical factor. TGD inspired model for the early cosmology provides a universal hydrodynamics model for this period as a mini Big Bang, or rather "a soft whisper amplified to a relatively big bang", containing the duration of the period as the only parameter [D5].

4. If the decay process is fast enough, the density of virtual hadrons in the final state becomes so high that they form single highly tangled cosmic string in Hagedorn temperature $T(k)$. An entire sequence of $T(k) = km_k$, $107 > k > 89$ of phase transition temperatures could be involved without intermediate freezing to hadrons. Since the transformation of $k = 89$ hadrons to $k = 107$ hadrons would be essentially a decay process, the distribution of decay products is isotropic in the center of mass frame of $k = 89$ hadron (Centauros/anti-Centauros). The same conclusion holds true for the decay of quark gluon plasma (Mirim/Qcu/Quacu).

5.5.4 How to understand the anomalous production of pions?

One can imagine two different explanations for the varying number of pions in the events.

1. Restoration of electro-weak symmetry?

The anomalous production of pions might relate to the restoration of electro-weak symmetry in case of M_{89} hadrons. For M_{89} hadrons the restoration of the electro-weak symmetry would be natural since in TGD framework classical induce fields are massless for known non-vacuum extremals below the p-adic length scale $L(89)$ defining the fundamental electro-weak length scale. The finite size of the space-time sheet carrying these fields brings in the length scale determining the boson mass when the space-time sheet in question looks point like in the length scale resolution used.

Both Centauros and anti-Centauros can be understood if the transformation of M_{89} hadrons to ordinary hadrons generates "mis-aligned" pionic BE condensates. $U(2)_{ew}$ symmetry is restored for M_{89} hadrons and there is no preferred isospin direction for the order parameter of M_{89} pionic BE condensate. This BE condensate is however excluded by energetic considerations. The sequence of phase transitions leading to M_{107} hadrons involving intermediate p-adic length scales could however generate this kind of BE condensate.

If an overcooling occurs in the sense that electro-weak symmetry is not lost, the first intermediate pion condensate can correspond to π_+,π_- or π_0. Charged π condensates would be created in pairs with opposite charges. In this kind of situation the number of gamma rays produced in the decay to ordinary hadrons would vary from event to event.

The presence of pionic BE condensates favors the decay to M_{107} hadrons via hadronic intermediate states rather than via the cooling of partonic phase condensed on single tangled string whose length grows. This and the idea that $U(2)_{ew}$ symmetry could be exact for the dark matter phase, encourages to consider also the possibility that M_{89} hadron decays to a state consisting of dark M_{107} hadrons forming a BE condensate like state behaving like single coherent unit and interacting with the ordinary matter only via emission of dark gauge boson BE condensates de-cohering to ordinary gauge bosons.

Dark pionic BE condensates with various charges could be present. These dark π condensates would decay coherently to pairs of dark ew boson "laser beams", which can interact with the ordinary matter only after they have de-cohered to ordinary ew gauge bosons and remain undetected if the de-coherence time for dark bosons is long enough, probably not so. Dark hadron option could thus explain also the abnormally long penetration lengths.

2. Is long range charge entanglement involved?

The variation for the number of pions could involve electromagnetic charge entanglement between particles produced in the event and ordinary matter. This would guarantee strict charge conservation when the quantization axis for weak isospin for the resulting hadrons differs from that for the ordinary matter. The decay of the pion to gamma pair becomes possible only after the entanglement is reduced and if de-coherence time is long enough it is possible to understand the variation.

5.6 Cosmic ray spectrum and exotic hadrons

The hierarchy of M_n hadron physics provides also a mechanism producing ultra high energy cosmic gamma rays and hadrons.

5.6.1 Do gamma rays dominate the spectrum at ultrahigh energies?

A possible piece of evidence for M_{89} hadrons is related to the analysis [100] of the cosmic ray composition near 10^9 GeV. The analysis was based on the assumption that the spectrum consists of nuclei. The assumptions and conclusions of the analysis can be criticized:

1. There is argument [101], which states that the interaction of protons having energy above 10^9 GeV with the cosmic microwave background implies pion pair creation and a rapid loss of proton energy so that the contribution of protons should be strongly suppressed in the cosmic ray spectrum above $E = 7 \cdot 10^{10}$ GeV. If protons dominate, cosmic ray spectrum should effectively terminate at energy of order $7 \cdot 10^{10}$ GeV: some events above $E = 10^{11}$ GeV have been however detected [94].

2. It is not obvious whether one can distinguish between protons and gamma rays at these energies since the muon content of the photon and proton showers are near to each other at these energies [86]. Therefore the particles identified as protons might well be gamma rays.

3. The spectrum can be fitted assuming that cosmic ray spectrum has two components. Light component ('protons') can be identified as protons and He nuclei. The heavy component ('Fe') corresponds to Fe and heavier nuclei. The nuclei between He and Fe seem to be peculiarly absent. Furthermore, there are also indications that spectrum contains only light nuclei in the range $3 \cdot 10^7 - 10^{11}$ GeV [102].

An alternative interpretation suggested also in [86] is that cosmic ray flux is dominated by gamma rays at these energies. 'Protons' correspond to gamma rays interacting ordinarily with matter. 'Fe nuclei' correspond to the fraction of gamma rays decaying first into M_{89} exotic quark pair producing corresponding exotic hadrons, which then decay to ordinary hadrons and produce showers resembling ordinary heavy nucleus shower. Super-canonical vision allows to consider the possibility that 'protons' correspond to super-canonical part of proton having essentially the same mass.

5.6.2 Hadronic component of the cosmic ray spectrum

The properties of the hadronic cosmic ray spectrum above $4 \cdot 10^5$ GeV are not well understood.

1. It has turned out difficult to invent acceleration mechanisms producing hadronic cosmic rays having energies above 10^5 GeV [100].

2. The spectrum contains a 'knee' (power $E^{-2.7}$ changes to about E^{-3} at the knee), which is at the energy $3\cdot 10^6$ GeV [100] and equals to the mass of M_{61} pion. It is difficult to understand how the knee is generated although several explanations have been proposed (these are reviewed shortly in [100]).

A possible solution of the problems is that part of the hadronic cosmic rays are generated in the decay of string like objects rather than by some acceleration mechanism. Assume that M_{n_k} hadron is created in the decay cascade. Since $M_{n_{k+m}}$, $m = 1, 2, ..$ hadrons can have rest masses above M_{n_k} threshold mass, one can consider the possibility that M_{n_k} hadron decays sequentially to ordinary M_{107} hadron with arbitrary large rest mass (even larger than M_{n_k} pion mass) and that this ordinary hadron in turn produces some very energetic low mass hadrons, say proton and antiproton, identifiable as cosmic rays. The most efficient producers of hadrons are M_{n_k} pions since these are produced most abundantly in the decay of $M_{n_{k+1}}$ hadrons. M_{n_k} pion at rest cannot however decay to ordinary hadrons with energy above M_{n_k} pion mass. Therefore the slope of the cosmic ray energy flux should become steeper above M_{n_k}, in particular M_{61}, threshold.

5.6.3 The problem of relic quarks and hierarchy of QCD:s

Baryon and lepton numbers are conserved separately in TGD and one of the basic problems of the gauge theories with conserved baryon number is the problem of relic quarks. Hadronization starts in temperature of the order of quark mass and since hadronization is basically many quark process it continues until the expansion rate of the Universe becomes larger than the rate of the hadronization. As a consequence the number density of relic quarks is much larger than the upper bound $n_{relic} < \rho_B/m_q = 10^{-9} n_\gamma m_p/m_q$ obtained from the requirement that the contribution of relic quarks to mass density is smaller than the baryonic mass density. There is also an experimental upper bound $n_{relic} < 10^{-28} n_\gamma$.

The assumption about the existence of QCD:s with a hierarchy of increasing scales $\Lambda_{QCD}(M_n)$ implies that the length scale $L(n) \sim 1/\sqrt{\Lambda_{QCD}(M_n)}$ below which quarks are free, decreases with increasing cosmic temperature and therefore the problem of the relic quarks disappears.

5.7 Ultrahigh energy cosmic rays as super-canonical quanta?

Near the end of year 2007 Pierre Auger Collaboration made a very important announcement relating to ultrahigh energy cosmic rays. I glue below a popular summary of the findings [128].

Scientists of the Pierre Auger Collaboration announced today (8 Nov. 2007) that active galactic nuclei are the most likely candidate for the source of the highest-energy cosmic rays that hit Earth. Using the Pierre Auger Observatory in Argentina, the largest cosmic-ray observatory in the world, a team of scientists from 17 countries found that the sources of the highest-energy particles are *not distributed uniformly across the sky. Instead, the Auger results link the origins of these mysterious particles to the locations of nearby galaxies that have active nuclei in their centers. The results appear in the Nov. 9 issue of the journal Science.*

Active Galactic Nuclei (AGN) are thought to be powered by supermassive black holes that are devouring large amounts of matter. They have long been considered sites where high-energy particle production might take place. They swallow gas, dust and other matter from their host galaxies and spew out particles and energy. While most galaxies have black holes at their center, only a fraction of all galaxies have an AGN. The exact mechanism of how AGNs can accelerate particles to energies 100 million times higher than the most powerful particle accelerator on Earth is still a mystery.

5.7.1 What has been found?

About million cosmic ray events have been recorded and 80 of them correspond to particles with energy above the so called GKZ bound, which is $.54 \times 10^{11}$ GeV. Electromagnetically interacting particles with these energies from distant galaxies should not be able to reach Earth. This would be due to the scattering from the photons of the microwave background. About 20 particles of this kind however comes from the direction of distant active galactic nuclei and the probability that this is an accident is about 1 per cent. Particles having only strong interactions would be in question. The problem is that this kind of particles are not predicted by the standard model (gluons are confined).

5.7.2 What does TGD say about the finding?

TGD provides an explanation for the new kind of particles.

1. The original TGD based model for the galactic nucleus is as a highly tangled cosmic string (in TGD sense of course [D4]. Much later it became clear that also TGD based model for black-hole is as this kind of string like object near Hagedorn temperature [D4]. Ultrahigh energy particles could result as decay products of a decaying split cosmic string as an extremely energetic galactic jet. Kind of cosmic fire cracker would be in question. Originally I proposed this decay as an explanation for the gamma ray bursts. It seems that gamma ray bursts however come from thickened cosmic strings having weaker magnetic field and much lower energy density [D7].

2. TGD predicts particles having only strong interactions [F2]. I have christened these particles super-canonical quanta. These particles correspond to the vibrational degrees of freedom of partonic 2-surface and are not visible at the quantum field theory limit for which partonic 2-surfaces become points.

5.7.3 What super-canonical quanta are?

Super-canonical quanta are created by the elements of super-canonical algebra, which creates quantum states besides the super Kac-Moody algebra present also in super string model. Both algebras relate closely to the conformal invariance of light-like 3-surfaces.

1. The elements of super-canonical algebra are in one-one correspondence with the Hamiltonians generating symplectic transformations of $\delta M^4_+ \times CP_2$. Note that the 3-D light-cone boundary is metrically 2-dimensional and possesses degenerate symplectic and Kähler structures so that one can indeed speak about symplectic (canonical) transformations.

2. This algebra is the analog of Kac-Moody algebra with finite-dimensional Lie group replaced with the infinite-dimensional group of symplectic transformations [B3]. This should give an idea about how gigantic a symmetry is in question. This is as it should be since these symmetries act as the largest possible symmetry group for the Kähler geometry of the world of classical worlds (WCW) consisting of light-like 3-surfaces in 8-D imbedding space for given values of zero modes (labelling the spaces in the union of infinite-dimensional symmetric spaces). This implies that for the given values of zero modes all points of WCW are metrically equivalent: a generalization of the perfect cosmological principle making theory calculable and guaranteing that WCW metric exists mathematically. Super-canonical generators correspond to gamma matrices of WCW and have the quantum numbers of right handed neutrino (no electro-weak interactions). Note that a geometrization of fermionic statistics is achieved.

3. The Hamiltonians and super-Hamiltonians have only color and angular momentum quantum numbers and no electro-weak quantum numbers so that electro-weak interactions are absent. Super-canonical quanta however interact strongly.

5.7.4 Also hadrons contain super-canonical quanta

One can say that TGD based model for hadron is at space-time level kind of combination of QCD and old fashioned string model forgotten when QCD came in fashion and then transformed to the highly unsuccessful but equally fashionable theory of everything.

1. At quantum level the energy corresponding to string tension explaining about 70 per cent of proton mass corresponds to super-canonical quanta [F4]. Supercanonical quanta allow to understand hadron masses with a precision better than 1 per cent.

2. Super-canonical degrees of freedom allow also to solve spin puzzle of the proton: the average quark spin would be zero since same net angular momentum of hadron can be obtained by coupling quarks of opposite

spin with angular momentum eigen states with different projection to the direction of quantization axis.

3. If one considers proton without valence quarks and gluons, one obtains a boson with mass very nearly equal to that of proton (for proton super-canonical binding energy compensates quark masses with high precision). These kind of pseudo protons might be created in high energy collisions when the space-time sheets carrying valence quarks and super-canonical space-time sheet separate from each other. Super-canonical quanta might be produced in accelerators in this manner and there is actually experimental support for this from Hera.

4. The exotic particles could correspond to some p-adic copy of hadron physics predicted by TGD and have very large mass smaller however than the energy. Mersenne primes $M_n = 2^n - 1$ define excellent candidates for these copies. Ordinary hadrons correspond to M_{107}. The protons of M_{31} hadron physics would have the mass of proton scaled up by a factor $2^{(107-31)/2} = 2^{38} \simeq 2.6 \times 10^{11}$. Energy should be above 2.6×10^{11} GeV and is above $.54 \times 10^{11}$ GeV for the particles above the GKZ limit. Even super-canonical quanta associated with proton of this kind could be in question. Note that CP_2 mass corresponds roughly to about 10^{14} proton masses.

5. Ideal blackholes would be very long highly tangled string like objects, scaled up hadrons, containing only super-canonical quanta. Hence it would not be surprising if they would emit super-canonical quanta. The transformation of supernovas to neutron stars and possibly blackholes would involve the fusion of hadronic strings to longer strings and eventual annihilation and evaporation of the ordinary matter so that only super-canonical matter would remain eventually. A wide variety of intermediate states with different values of string tension would be possible and the ultimate blackhole would correspond to highly tangled cosmic string. Dark matter would be in question in the sense that Planck constant could be very large.

6 TGD based explanation for the anomalously large direct CP violation in $K \rightarrow 2\pi$ decay

KTeV collaboration in Fermilab [105] has measured the parameter $|\epsilon'/\epsilon|$ characterizing the size of the direct CP violation in the decays of kaons to two pions. The value of the parameter was found to be $|\epsilon'/\epsilon| = (2.8 \pm .1)10^{-3}$ and is almost by an order of magnitude larger than the naive standard model expectations based on the hypothesis that direct CP breaking is induced by CKM matrix. In [85] it was shown that the value of the parameter could be understood without introducing any new physics if the value of running strange quark mass at m_c is about $m_s(m_c) = .1$ GeV and $m_d << m_s$ holds true.

6.1 How to solve the problems in TGD framework

6.1.1 Problems

Also in TGD framework the situation looks confusing.

1. The TGD based prediction for the value of the CP breaking parameter for CKM matrices satisfying the constraints coming from p-adicity is within the experimental constraints $1.0 \times 10^{-4} \leq J \leq 1.7 \times 10^{-4}$ coming from the standard model so that J produces no problems (see [F4] or Appendix for the CKM matrix as predicted by TGD).

2. The dominating contributions of the chiral field theory to $Re(\epsilon'/\epsilon)$ are proportional to $1/(m_s + m_d)^2$. The predictions of p-adic thermodynamics for s and d quark masses for $k(d) = k(s) = 113$ are $m_d(113) = m_s(113) =$ 90 MeV and if this mass can be interpreted as $m_s(m_c) \simeq 0.1$ GeV, the prediction is too small by a factor 1/4. Even worse, if m_s corresponds to the scaled up mass $m_s(109) \simeq 360$ MeV of the s quark inside kaon, the situation changes completely and ϵ'/ϵ is too small by a factor $\sim 1/4.5^2 \simeq$ .05.

3. TGD predicts that family replication phenomenon has also a bosonic counterpart. In the original scenario gauge bosons had single light-like wormhole throat as space-time correlate just like fermions and two exotic gluons were predicted corresponding to $g = 1$ and $g = 2$. The assumption that fermions at partonic space-time sheets are free fermions however forces to identify gauge bosons as wormhole contacts such that the two light-like wormhole throats carry quantum numbers of fermion and antifermion. Gauge bosons can be arranged into SU(3) singlet corresponding to ordinary gauge bosons and octet, where SU(3) states correspond to pairs (g_1, g_2) of handle numbers $0 \leq g_i \leq 2$.

   The experimental non-existence of flavor changing currents suggest strongly that the masses of octet gauge bosons are high. This requires that they correspond to $L(89)$ or even shorter p-adic length scale. Hence these gauge bosons are not interesting from the point of view of CP breaking.

4. The recent breakthrough in p-adic mass calculations for hadrons [F4] led also the understanding of non-perturbative aspects of hadron physics in terms of super-canonical bosons which correspond to single light-like wormhole throat so that they couplings to quarks in the sense of generalized Feynman diagrams do not imply flavor changing neutral currents.

The basic prediction is that topologically mixed super-canonical bosons are responsible for the most of the mass of proton and that it is possible to deduce the super-canonical content of hadrons from their masses if their topological mixing is assumed to be same as for U type quarks. The masses of these bosons correspond to p-adic length scale $L(107)$ and are small in length scale $L(89)$

relevant for CP breaking. These observations suggest that higher gluon genera of the earlier model should be replaced with super-canonical gluons.

In the standard diagrammatic expression for the CP breaking parameter gluon propagators are replaced by a sum of ordinary massless and two exotic gluon massive gluon propagators. The fact that the matrix elements relevant for the estimation of the CP breaking parameter are estimated at momentum transfer of order $\mu = m_W$, implies that gluon masses do not significantly change the contribution of the super-canonical gluons to the amplitude apart from the change in value of color coupling strength. Hence the penguin amplitudes are simply multiplied by some factor X determined by the number of super-canonical gluons light in length scale $L(89)$ and by the coupling constants of these gluons and the ratio ϵ'/ϵ is multiplied by a factor X. Unfortunately, it is not possible to calculate this factor at this stage.

6.1.2 The model based on exotic gluons and current quarks

It is essential that exotic gluons correspond to single light-like wormhole throat and thus have family replication phenomenon analogous to that of fermions. Two models can be considered.

1. The original model based on the assumption that ordinary gauge bosons correspond to single wormhole throat. There are good reasons to believe that this interpretation is wrong.

2. The new model based on super-canonical exotic gluons whose number is not known but is multiple of 3. The couplings to quarks are not known. Also color single super-canonical bosons could be also present.

1. The difficulty of the original model

The problem of this model is that assuming exotic gluons in sense 1) ϵ'/ϵ would be still by a factor .15 too small for $m_s(109)$ relevant for kaons.

The basic observation is that the gluon contribution is proportional to $1/(m_s + md)^2$ and for $m_s(113)$ instead of $m_s(119)$ ϵ'/ϵ would be a fraction $(16+1)/2 = 8.5$ large and by a factor 1.275 larger than the experimental value since $m_d = m_s$ rather than $m_d << m_s$ holds true.

This observation stimulated the idea that a transition $s_{109} \rightarrow s_{113}$ occurs before electro-weak process and would have an interpretation as a transformation of a constituent quark to current quark. This requires that the amplitudes for the transition $s(109) \rightarrow s(113)$ and its reversal are near to unity.

The question is why $s(109) \rightarrow s(113)$ constituent-current transformation should occur in electro-weak interactions and why it occurs with amplitude $A \sim 1$. Of course it could also be that also d quark is transformed to a very low mass variant with mass about 4 MeV predicted by chiral field theory. This would correspond to $k = 125$. As a result the amplitude would be multiplied by a factor 4 and $A = 1/2$ would become possible.

For some reason the join along boundaries bonds feeding em gauge flux of s quark to $k = 109$ space-time sheet would be transferred to nuclear space-time sheets with $k = 113$ before the electro-weak scattering process responsible for the CP breaking. Note that the value of strange quark mass about 176 MeV deduced from τ lepton decay rate corresponds to $m_s(111)$ in a good approximation. Also this indicates that various scaled up variants of quark masses can appear in the electro-weak dynamics as intermediate states.

The assumption for the proportionality $\epsilon'/\epsilon \propto 1/(m_s + m_d)^2$ derivable from chiral field theory can be criticized. Finding a justification for this assumption seems to be a non-trivial challenge since it is not at all clear that chiral field theory based on $SU(3)$ flavor symmetry makes sense in TGD context.

2. Super-canonical variant of the original model

For super-canonical gluons one can predict only that the relevant gluon exchange amplitude increases by a factor

$$X = \sum_{i,j} \alpha_s(B_{i,j})) \quad ,$$

where $\alpha_s(B_{i,j})$ is the color coupling strength to j:th generation of the super-canonical gluon B_i. In principle also color neutral super-canonical bosons having spin might contribute.

For $\alpha_s(B_{i,j}) = \alpha_s(B_i)$ one would have

$$X = 3\sum_{i} \alpha_s(B_i) \quad .$$

If the number of light super-canonical gluons large enough, it is possible to have a large enough value of X to compensate for the factor .14 so that the assumption about the transformation $s(109) \rightarrow s(113)$ from constituent quark to current quark would become un-necessary. $X \sim 8$ would be needed.

Recall that super-canonical algebra is analogous to Kac-Moody algebra in the sense that finite-dimensional Lie-group is replaced with symplectic group. Super-canonical gluons correspond to states created by super-algebra generators, which are in one-one correspondence Hamiltonians of $\delta M^4_+ \times CP_2$ subject to some additional conditions making subset of states zero norm states. Therefore more than single octet of super-canonical bosons and also higher dimensional representations might be possible.

All depends on which of these super-canonical states correspond to light particles. This in turn depends on the details of super-canonical representations (they correspond to the states of negative conformal weight annihilated by Virasoro generators L_n, $n < 0$ [C1]). Here the help of a mathematician specialized to the representations of super-conformal algebras would be needed.

At this moment it is not possible to know whether the transformation to current quark is needed or even possible and this motivates the following discussion of the basic notions and chiral field theory approach in more detail in order to clarify what is involved.

6.2 Basic notations and concepts

Until 1963 CP symmetry was believed to be an exact symmetry of Nature. In this year it was however observed by Christensen, Cronin, Fitch and Turlay that CP symmetry is violated in hadronic decays of neutral kaons. In order to interpret the experimental evidence one must consider the strong Hamiltonian eigen states K^0 and its CP conjugate $\bar{K}^0$ as a mixture of physical short lived K_S decaying predominantly to two pions and long-lived K_L decaying mostly semi-leptonically and into 3 pion states. Two- and three pion final states have odd and even CP parity. In absence of CP breaking one would identify K_S and K_L as the CP even and CP odd states

$$\begin{aligned} K_1 &= (K^0 + \bar{K}^0)/\sqrt{2} \ , \\ K_2 &= (K^0 - \bar{K}^0)/\sqrt{2} \ . \end{aligned} \tag{51}$$

What was observed in 1963 was that K_L decays also to two-pion final states.

There are two mechanisms of CP violation. The indirect mechanism involves a slight mixing of K^1 and K^2 characterized by a complex mixing parameter $\bar{\epsilon}$

$$\begin{aligned} K_S &= \frac{K_1 + \bar{\epsilon} K_2}{1 + |\bar{\epsilon}|^2} \ , \\ K_L &= \frac{K_2 + \bar{\epsilon} K_1}{1 + |\bar{\epsilon}|^2} \ . \end{aligned} \tag{52}$$

Direct mechanism involves the direct decay of K_2 to two pion state and is induced by the weak interaction Lagrangian L_W directly. Both mechanisms can be parameterized in terms of the small ratios

$$\begin{aligned} \eta_{00} &= \frac{\langle \pi^0\pi^0 | L_W | K_L \rangle}{\langle \pi^0\pi^0 | L_W | K_S \rangle} \ , \\ \eta_{+-} &= \frac{\langle \pi^+\pi^- | L_W | K_L \rangle}{\langle \pi^+\pi^- | L_W | K_S \rangle} \ . \end{aligned} \tag{53}$$

Here L_W represents the $\Delta S = 1$ part of the weak Lagrangian. The equations for η parameters can be also written as

$$\begin{aligned} \eta_{00} &= \epsilon - \frac{2\epsilon'}{1 - \omega\sqrt{2}} \simeq \epsilon - 2\epsilon' \ , \\ \eta_{+-} &= \epsilon - \frac{2\epsilon'}{1 + \omega/\sqrt{2}} \simeq \epsilon + \epsilon' \ . \end{aligned} \tag{54}$$

Parameter $\bar{\epsilon}$ is simply related to ϵ. The parameter ω measures the ratio

$$|\omega| = \frac{|\langle(\pi\pi)_{I=2}|L_W|K_S\rangle|}{|\langle(\pi\pi)_{I=0}|L_W|K_S\rangle|} \simeq 1/22.2 \ . \tag{55}$$

$I = 0$ and $I = 2$ denote the isospin states of final state pions.

The CP violating parameters are expressible in terms of $K_{S,L}$ decay amplitudes as

$$\begin{aligned}
\epsilon &= \frac{\langle(\pi\pi)_{I=0}|L_W|K_L\rangle}{\langle(\pi\pi)_{I=0}|L_W|K_S\rangle} \ , \\
\epsilon' &= \frac{\epsilon}{\sqrt{2}}\left[\frac{\langle(\pi\pi)_{I=2}|L_W|K_L\rangle}{\langle(\pi\pi)_{I=0}|L_W|K_L\rangle} - \frac{\langle(\pi\pi)_{I=2}|L_W|K_S\rangle}{\langle(\pi\pi)_{I=0}|L_W|K_S\rangle}\right] \ .
\end{aligned} \tag{56}$$

By Watson's theorem one can write the generic amplitudes for K^0 and $\bar{K}^0$ decay as

$$\begin{aligned}
\langle(\pi\pi)_I|L_W|K^0\rangle &= -iA_I exp(i\delta_I) \ , \\
\langle(\pi\pi)_I|L_W|\bar{K}^0\rangle &= -iA_I^* exp(i\delta_I) \ ,
\end{aligned} \tag{57}$$

where the phases δ_I arise from the pion finals state interactions. In good approximation ($|\bar{\epsilon}ImA_0| \ll |ReA_0|$, $|\bar{\epsilon}|^2 \ll 1$) one can write

$$\begin{aligned}
\epsilon' &= exp(i(\pi/2 + \delta_2 - \delta_1)) \times \frac{\omega}{\sqrt{2}} \times (\frac{ImA_2}{ReA_2} - \frac{ImA_0}{ReA_0}) \ , \\
\omega &= \frac{ReA_2}{ReA_0} \ .
\end{aligned} \tag{58}$$

With the approximations used one obtains a relationship

$$\epsilon' = \bar{\epsilon} + i\frac{ImA_0}{ReA_0} \ . \tag{59}$$

One can find a more detailed representation of the subject in various review articles [112, 63]. The standard model of CP breaking is based on the presence of complex phases in CKM matrix.

The value of the parameter ϵ describing indirect CP violation is well established and given by

$$|\epsilon| = (2.266 \pm .017) \times 10^{-3} \ .$$

The phases of ϵ and ϵ' are in good approximation identical so that their signs are same. The value of $Re(\epsilon'/\epsilon)$ was finally established by KTeV collaboration at Fermi Lab to be

$$Re(\frac{\epsilon'}{\epsilon}) = (2.8 \pm .01) \times 10^{-3} \ .$$

The measurement is consistent with the result of the CERN experiment NA31, which has also found a non-vanishing value for this parameter.

There are several theories of CP violation. The so called milliweak theory predicts vanishing value of ϵ'. The model based on the presence of CP breaking phases in three-generation CKM matrix predicts non-vanishing value for the parameter. Also Higgs particles can effect the value of the parameter in standard model. Standard model predicts this parameter to be nonzero but the expectation has been that the value is roughly ten times smaller than the measured value.

A possible explanation of the effect which does not introduce new physics is based on the hypothesis that the mass of s quark is smaller than the mass of d quark: the running mass $m_s(2\ GeV) \simeq .1$ GeV is needed to explain the anomaly if CP breaking parameter J is taken to be in the range $(1-1.7)\times 10^{-4}$ claimed in [66] to follow from unitarity. There is however experimental evidence from τ decays for $m_s(m(\tau)) = (172 \pm 31)\ MeV$. This suggests that some new short length scale physics is involved.

Standard model prediction for $Re(\epsilon'/\epsilon)$ [85] can be summarized in a handy formula

$$\begin{aligned} Re(\frac{\epsilon'}{\epsilon}) &= J \times \left[-1.35 + R_s\left(A_6 B_6^{1/2} + A_8 B_8^{3/2}\right)\right] \ , \\ A_6 &= 1.1|r_Z^8| \ , \\ A_8 &= 1.0 - .67|r_Z^8| \ . \end{aligned} \quad (60)$$

The subscript Z refers to renormalization mass m_Z. The parameter R_s is given by

$$R_s \simeq \left[\frac{150\ MeV}{m_s(m_c) + m_d(m_c)}\right]^2 \ . \quad (61)$$

The dominating contributions to $Re(\frac{\epsilon'}{\epsilon})$ come from second (A_6) and third terms (A_8). These terms correspond to gluonic and electro-weak penguin diagram contributions to the CP breaking decays and of opposite sign. Clearly, the sum of the two terms is roughly one third of the gluonic term alone.

6.3 Separation of short and long distance physics using operator product expansion

The calculation of CP breaking parameters involves physics in very wide energy scale. The strategy is to derive low energy effective action by functionally integrating over the short distance effects coming from energies larger than m_c. This leads to Wilson expansion for the low energy electro-weak effective Lagrangian

$$L_{low,W} = -\sum_i C_i(\mu, m_c, m_b, m_t, m_W, ...)Q_i(\mu) \ . \tag{62}$$

The coefficients C_i of the operators Q_i in the low energy effective action for light quarks (u, d, s) are functionals of various parameters characterizing short distance physics. The coefficients $C_i(\mu)$ in Wilson expansion of electro-weak effective action can be written as

$$C_i(\mu) = \frac{G_F}{\sqrt{2}} V_{ud}V_{us}^* \left[x_i(\mu) + \tau y_i(\mu)\right] \ . \tag{63}$$

Here x_i and y_i are Wilson coefficients. V_{ij} denotes CKM matrix and τ is defined as $\tau = V_{td}V_{ts}^*/V_{ud}V_{us}^*$. $V_{td}V_{ts}^*$ is identical with CP breaking invariant J in standard parametrization. Coefficients $y_i(\mu)$ summarize short distance CP breaking physics and in order to determine CP breaking one needs to consider only the coefficients y_i.

Long distance physics is the difficult part of the calculation since it involves calculation of matrix elements of the quark operators Q_i between initial kaon state and final two-pion state. There are several approaches to the problem. Chiral field theory [82] is phenomenological approach and relies on the idea that low energy effective action for quarks can be expressed in a good approximation using meson fields. Lattice QCD is believed to provide a more fundamental direct method for the calculation of the correlation functions of Q_i.

6.3.1 Short distance physics

In present initial states are kaons and μ denotes the momentum exchange for a typical diagram associated with the scattering of $d\bar{s}$ quark to final state consisting of of light quarks. μ is taken to be of order m_W and by using renormalization group equations one can deduce the values of the coefficients $C_i(\mu)$ at energy scales, typically of order 1 GeV.

The basic standard diagrams contributing to the $\Delta S = 1$ and $\Delta S = 2$ processes are given by the figure below.

The quark operators Q_i appearing in the expansion can be classified. In present case the list of relevant operators correspond to various terms possible in four-fermion Fermi interaction and are given by the following list.

$$Q_1 = (\bar{s}_\alpha u_\beta)_{V-A}(\bar{u}_\beta d_\alpha)_{V-A} \ , \tag{64}$$

$$Q_2 = (\bar{s}u)_{V-A}(\bar{u}d)_{V-A} \ , \tag{65}$$

$$Q_{3,5} = (\bar{s}d)_{V-A}\sum_q (\bar{q}q)_{V\mp A} \ ,$$

$$
\begin{aligned}
Q_{4,6} &= (\bar{s}_\alpha d_\beta)_{V-A} \sum_q (\bar{q}_\beta q_\alpha)_{V\mp A} \quad , \\
Q_{7,9} &= \frac{3}{2}(\bar{s}d)_{V-A} \sum_q \hat{e}_q (\bar{q}q)_{V\pm A} \quad , \\
Q_{8,10} &= \frac{3}{2}(\bar{s}_\alpha d_\beta)_{V-A} \sum_q \hat{e}_q (\bar{q}_\beta q_\alpha)_{V\pm A} \quad .
\end{aligned} \tag{66}
$$

α, β denote color indices and $\hat{e}_q$ denote quark charges. $V \pm A$ refers to the Dirac structure $\gamma_\mu(1 \pm \gamma_5)$. Q_2 is induced by mere W exchange whereas gluonic loop corrections to Q_2 induce Q_1. QCD through penguin loop induces the penguin operators Q_{3-6}. Electro-weak loops, in which penguin gluon is replaced with electro-weak gauge boson, induce $Q_{7,9}$ and part of Q_3. The operators $Q_{8,10}$ are induced by the QCD renormalization of the electro-weak loop operators $Q_{7,9}$.

As far as the calculation of ϵ'/ϵ is considered, the dominating contributions come from the penguin diagrams, which are proportional to the vertices $s\bar{d}V$, where V is either gluon or electro-weak gauge boson and to the propagator denominator of V with momentum squared equal to momentum exchange between initial state quarks, which equals to $(p_i - p_j)^2 = \mu^2$. For option 2) the standard gluon contribution is replaced with a sum over contributions of ordinary and exotic gluons. For option 1) situation is more complicated since $g > 0$ gluons can change the genus of the fermion.

The operators Q_6 and Q_8 give the dominating contributions to ϵ'/ϵ and these contributions are competing. Q_6 and Q_8 differ only by the fact that in Q_8 penguin gluon is replaced with penguin electro-weak boson γ or Z^0. For neutral kaon initial state electro-weak penguin diagram is proportional to the product $e_q e_{\bar{q}} = -e_q^2$ of the virtual quark whereas in case of gluons the factor $Tr(T^a T^a) > 0$ appears. Therefore the contributions associated with Q_6 and Q_8 are of opposite sign and mutually competing.

Detailed calculations lead to the formula already described:

$$
\begin{aligned}
Re(\frac{\epsilon'}{\epsilon}) &= J \times \left[-1.35 + R_s \left(A_6 B_6^{1/2} + A_8 B_8^{3/2}\right)\right] \quad , \\
A_6 &= 1.1|r_Z^8| \quad , \\
A_8 &= 1.0 - .67|r_Z^8| \quad .
\end{aligned} \tag{67}
$$

for $Re(\epsilon'/\epsilon)$. The coefficients B_6 and B_8 code the long distance physics and their values do not differ too much from $B_6 = B_8 = 1$. Clearly, the sum of Q_6 and Q_8 contributions is roughly one third of the Q_6 contribution alone. From the general structure of Feynman diagrams it ss clear that for option 2) the effect caused by the introduction of exotic gluons is in a good approximation a simple scaling of the Q_6 contribution by a factor 3 in the approximation that gluon masses are negligible as compared to W mass, and that this new contribution can enhance direct CP breaking dramatically.

6.3.2 Chiral field theory approach

The basic problem is to calculate electro-weak matrix elements of the quark effective action between hadronic states. These matrix elements reduce to vacuum expectation values of various quark bi-linears appearing in four-fermion Fermi interaction Lagrangian. This problem is very difficult since non-perturbative QCD is involved in an essential manner. An attempt to circumvent this problem [82] is based on the hypothesis that low energy effective action for quarks is essentially equivalent with the low energy effective action, where pseudoscalar meson fields as dynamical fields and scalar, vector and axial vector meson fields occur as external fields not subject to variations. Quark masses are identified as vacuum expectation values of the external scalar meson field. The approximate symmetry of the chiral field theory is flavor $SU(3)_L \times SU(3)_R$ which is exact symmetry at the limit of massless quarks. This symmetry can be realized if mesons are represented by an element U of $SU(3)$ regarded as a dynamical field: the two $SU(3)$:s act on U from left and right respectively. For small perturbations around ground state mesons correspond to various Lie-algebra generators of $SU(3)$. Chiral field develops vacuum expectation value. If vacuum expectation is not proportional to unit matrix it corresponds to the presence of coherent states associated with the neutral components of the pseudo scalar meson field.

The basic formulation of the chiral field theory approach is described in [82] whereas its application to the calculation of ϵ'/ϵ is described in [63]. The strong part of the chiral action [82] is given by the formula

$$\begin{aligned} L_S &= \frac{f^2}{4}\left[Tr\{D_\mu U^\dagger D^\mu U\} + 2B_0 Tr\{(s-ip)U\} + 2B_0^* Tr\{(s+ip)U^\dagger\}\right] \\ &+ \frac{1}{12}H_0 D_\mu\theta D^\mu\theta \ . \end{aligned} \tag{68}$$

D_μ denotes the covariant derivative defined by the couplings to the left and right handed gauge bosons L_μ and R_μ defined as superpositions $R_\mu = v_\mu + a_\mu$ and $L_\mu = v_\mu - a_\mu$ of the vector and axial vector mesons fields v and a. Action contains three coupling constant parameters: f, B_0 and H_0, which is present because the presence of color instantons can lead to a non-vanishing value of the θ parameter in QCD. In lowest order f is pion decay constant f_π and B_0 sets the scale in the formula $M_M^2 = B_0(\sum_i m(q_i))$ inspired by broken $SU(3)$ symmetry and resulting as a prediction of the model. The components for the non-vanishing vacuum expectation value for the external scalar field are identified as quark masses. The generation of vacuum expectation value of s implies that quark condensates are developed:

$$\begin{aligned} \langle \bar{q}_i q_j \rangle &= B_0 f^2 \delta_{i,j} \ , \\ B_0 f^2 &= \frac{f_\pi^2 m_\pi^2}{(m_u + m_d)} = \frac{f_K^2 m_K^2}{(m_s + m_d)} \ . \end{aligned} \tag{69}$$

Note that the strong part of the chiral Lagrangian is invariant under the overall scaling of quark masses.

The weak part of the chiral action corresponds to the sigma model counterpart of the most general electro-weak four-fermion action. The recipe for constructing this action is described in more detail in [63] and can be summarized as rules associating with various fermionic bi-linears appearing in the generalized Fermi action corresponding terms of the weak part of the chiral action. In particular, the following rules hold true:

$$\begin{aligned}
\bar{q}^j_L\gamma^\mu q^i_L &\rightarrow -if_\pi^2(U^\dagger D_\mu U)_{ij} \ , \\
\bar{q}^j_R\gamma^\mu q^i_R &\rightarrow -if_\pi^2(UD_\mu U^\dagger)_{ij} \ , \\
\bar{q}^j_L\gamma^\mu q^i_R &\rightarrow -2B_0\left[\frac{f^2}{4}U + \text{higher order terms}\right]_{ij} \ , \\
\bar{q}^j_R\gamma^\mu q^i_L &\rightarrow -2B_0\left[\frac{f^2}{4}U^\dagger + \text{higher order terms}\right]_{ij} \ .
\end{aligned} \quad (70)$$

The chiral counterparts of the left and right handed currents are proportional to BM and depend on the ratios of quark masses only. The terms giving dominating contribution to the $\Delta S = 1$ part of the weak effective action involve the chiral counterparts of terms $\bar{q}^j_L q^i_R$ breaking chiral invariance. The chiral counterparts of these terms are proportional to B and, in accordance with expectations, fail to be invariant under the overall scaling of quark masses. The higher order contributions to these terms are important for the calculations of direct CP breaking effects but are not written explicitly here because they are not needed in the estimate for how the predictions of the standard model are modified in TGD framework. The terms breaking chiral symmetry give rise to ϵ'/ϵ a contribution, which is proportional to $1/(m_s+m_d)^2$.

The $\Delta S = 2$ part of effective quark action is involved with $K^0 \rightarrow \bar{K}^0$ transitions and the corresponding quark operator is given by

$$Q_{S2} = (\bar{s}_L\gamma^\mu d_L)(\bar{s}_L\gamma^\mu d_L) \ . \quad (71)$$

The chiral counterpart of this operator is obviously invariant under overall scaling of quark masses.

6.3.3 Does chiral theory approach make sense in TGD framework?

The TGD based model for the large direct CP breaking based on exotic gluons and on the transformation of s_{109} to s_{113} has been already discussed. The open question is whether the $1/(m_s+m_d)^2$ proportionality of the CP breaking amplitude can be justified in TGD context where it is not at all clear that chiral theory approach makes sense.

In standard model framework chiral field theory provides a phenomenological description of the low energy hadron physics and makes possible the calculation of various hadronic matrix elements needed to derive the predictions for CP breaking effect.

Chiral field theory limit however involves some questionable assumptions about the relationship between QCD and low energy hadron physics.

1. $SU(3)$ symmetry is assumed and allows description of light mesons in terms of $SU(3)$ valued chiral field U possessing $SU(3)_R \times SU(3)_R$ symmetry broken only by quark mass matrix. In TGD framework $SU(3)$ symmetry is purely phenomenological symmetry since the fundamental gauge group is the gauge group of the standard model.

2. The generation of quark masses is described as effective spontaneous symmetry breaking caused by the vacuum expectation value of $SU(3)$ Lie-algebra valued external scalar field s. Quark masses are identified as the components of the diagonal vacuum expectation value of this field. Physically the scalar field corresponds to scalar meson field so that quark masses would result from the coupling of the quarks to coherent states of scalar mesons. This cannot be a correct physical description in TGD framework, where p-adic thermodynamics gives rise to quark masses. Of course, the presence of the scalar field can give rise to a small shift in the values of the quark masses. Also Higgs field could be in question.

3. The coupling of the field s to chiral field U implies in the standard model context that the mass squared values of mesons are proportional to the sums of masses of the mesonic quarks: for instance, $M_\pi^2 = B_0(m_u + m_d)$ and $M_K^2 = B_0(m_s + m_d)$, where B_0 is one of the basic coupling constants of the chiral field theory. This formula is not consistent with the p-adic mass calculations, where quark mass squared is additive for quarks with the same value of k_q and quark mass for different values of k_q. Indeed, the formulas $M_\pi^2 = m_u^2 + m_d^2$ and $M_K^2 = (m_s + m_d)^2$ are true. The chiral field formula predicts $m_s/m_d \simeq 24$ requiring $m_u = m_d \simeq 13$ MeV ($k = 121$) for $m_s(113) = 320$ MeV whereas TGD predicts $m_s(109)/m_d(107) = 4$. For $m_s \simeq 100$ MeV the prediction is $m_d \simeq 4.2$ MeV. This looks suspiciously small.

To sum up, although the basic assumptions of chiral field theory limit look too specific in TGD framework, its predictions for low energy hadron physics are well-tested and TGD could be consistent with them. If this the case, the assumption about $s_{109} \rightarrow s_{107}$ transition allows a correct prediction of direct CP breaking amplitude using chiral field theory limit.

7 Appendix

7.1 Effective Feynman rules and the effect of top quark mass on the effective action

The effective low energy field theory relevant for $K-\bar{K}$ systems is in the standard model context summarized elegantly using the Feynman rules of effective field theory deriving from box and penguin diagrams. The rules in t'Hooft-Feynman gauge are summarized in excellent review article of Buras and Fleischer [64]. For box diagrams the rules are following:

$$\begin{aligned}
Box(\Delta S=2) &= \lambda_i^2 \frac{G_F^2}{16\pi^2} M_W^2 S_0(x_i)(\bar{s}d)_{V-A}(\bar{s}d)_{V-A} \ , \\
Box(T_3=-1/2) &= \lambda_i \frac{G_F}{\sqrt{2}} \frac{\alpha}{sin^2(\theta_W)} B_0(x_i)(\bar{s}d)_{V-A}(\bar{\mu}\mu)_{V-A} \ , \\
Box(T_3=1/2) &= \lambda_i \frac{G_F}{\sqrt{2}} \frac{\alpha}{sin^2(\theta_W)} \left[-4B_0(x_i)\right](\bar{s}d)_{V-A}(\bar{\nu}\nu)_{V-A} \ , \\
\lambda_i &= V_{is}^* V_{id} \ .
\end{aligned} \tag{72}$$

The box vertices listed here describe the decays $K_0 \rightarrow \bar{K}_0$ and contribute to $K_0 \rightarrow \bar{\mu}\mu$ and $K_0 \rightarrow \bar{\nu}\nu$ decays. $(\bar{q}_1 q_2)_{V-A}$ is shorthand notation for the left handed weak current involving gamma matrices and the products of fermionic bi-linears actually involve contraction of the gamma matrix indices.

Penguin diagrams can be characterized by the effective vertices $\bar{s}dB$, where B is photon, Z boson or gluon, which is treated as usual in effective field theory

$$\begin{aligned}
\bar{s}Zd &= i\lambda_i \frac{G_F}{\sqrt{2}} \frac{g_Z}{2\pi^2} M_Z^2 g_Z C_0(x_i)\bar{s}\gamma^\mu(1-\gamma_5)d \ , \\
\bar{s}\gamma d &= -i\lambda_i \frac{G_F}{\sqrt{2}} \frac{e}{8\pi^2} D_0(x_i)\bar{s}(q^2\gamma^\mu - q^\mu q^\nu \gamma_\nu)(1-\gamma_5)d \ , \\
\bar{s}G^a d &= -i\lambda_i \frac{G_F}{\sqrt{2}} \frac{g_s}{8\pi^2} E_0(x_i)\bar{s}(q^2\gamma^\mu - q^\mu q^\nu \gamma_\nu)(1-\gamma_5)T^a d \ .
\end{aligned} \tag{73}$$

The vertices above correspond to the exchange of Z, photon and gluon between the quarks. Boson propagator and second vertex is constructed using the standard Feynman rules. The counterparts of the sdB vertices are easily constructed for $g>0$ gluons. The orthogonality of single hadron states requires that flavor is conserved for $g>0$ exchanges.

The functions $B_0, C_0, ...$ characterize the low energy effective action at mass scale $\mu = m_W$. The subscript '0' refers to the values of these functions without QCD corrections, which are taken into account using renormalization group equations to deduced the functions at mass scale of order 1 GeV. The functions are listed below:

$$
\begin{aligned}
B_0(x_t) &= \frac{1}{4}\left[\frac{x_t}{y_t} + \frac{x_t log(x_t)}{y_t^2}\right] \quad , \\
C_0(x_t) &= \frac{x_t}{8}\left[-\frac{x_t - 6}{y_t} + \frac{3x_t + 2}{y_t^2} log(x_t)\right] \quad , \\
D_0(x_t) &= -\frac{4}{9} log(x_t) - \frac{25x_t^2 - 19x_t^3}{36y_t^3} + \frac{x_t^2(-6 - 2x_t + 5x_t^2)}{18y_t^3} log(x_t) \quad , \\
E_0(x_t) &= -\frac{2}{3} log(x_t) + \frac{x_t^2(15 - 16x_t - 4x_t^2)}{6y_t^4} log(x_t) + \frac{x_t(18 - 11x_t - x_t^2)}{12y_t^3} \quad , \\
S_0(x_t) &= \frac{4x_t - 11x_t^2 + x_t^3}{4y_t^2} - \frac{3x_t^2 log(x_t)}{2y_t^3} \quad , \\
S_0(x_c, x_t) &= x_c\left[log(\frac{x_t}{x_c}) - \frac{3x_t}{4y_t} - \frac{3x_t^2 log(x_t)}{4y_t^2}\right] \quad , \\
& x_c = (\tfrac{m_c}{m_W})^2 \quad x_t = (\tfrac{m_t}{m_W})^2 \quad , \quad y_t = 1 - x_t \quad . \qquad (74)
\end{aligned}
$$

Although x_t, being the interesting parameter, appears as the only argument of these functions, also the contributions coming from light quarks propagating in the loops are included. For comparison purposes it is useful to give the explicit relations between electro-weak coupling parameters and G_F.

$$
\begin{aligned}
\frac{G_F}{\sqrt{2}} &= \frac{g_W^2}{8m_W^2} \quad , \\
g_W &= \frac{e}{sin(\theta_W)} \quad , \\
g_Z &= \frac{e}{sin(\theta_W) cost(\theta_W)} \quad . \qquad (75)
\end{aligned}
$$

The following table summarizes the effect of the change of the top quark mass on the functions $B_0, C_0, ...$ What is given are the ratios $r(f) = f(55)/f(175)$ of the functions $B_0, C_0, ..$ evaluated for top quark masses 55 GeV and 175 GeV respectively.

f	$B_0(x_t)$	$C_0(x_t)$	$D_0(x_t)$	$E_0(x_t)$	$S_0(x_t)$	$S_0(x_c, x_t)$
r	.51	.09	$-.70$	3.44	.15	.81

(76)

These results leave allow only the identification of the experimental candidate as a realistic candidate for top quark.

1. The function B_0 is reduced only by a factor of 1/2 and there are no new physics contributions to B_0 in the lowest order. The function C_0 characterizing Z penguin diagrams is reduced by an order of magnitude. The coefficient $C_0(x_t) - 4B_0(x_t)$ characterizes the dominating contribution to $K \rightarrow \mu^+\mu^-$ decay in standard model and the decay amplitude is reduced

by a factor .27 so that this decay would provide a stringent test selecting between 55 GeV top quark and 175 GeV top quark. Unfortunately, the predicted $K \rightarrow \mu^+\mu^-$ rate is still by several orders of magnitude below the experimental upper bound.

2. The function $S_0(x_t)$ characterizing $B - \bar{B}$ and $K - \bar{K}$ mass differences is reduced almost by an order of magnitude. Note that in case of Δm_K the ratio $r(tt/ct)$ of the WW box diagram amplitudes with two top quarks and c and t in internal fermion lines is $r(tt/ct) \sim 738$ for $m_t = 175$ GeV and $r(tt/ct) \sim 138$ for $m_t = 55$ GeV (the moduli of the factors coming from CKM matrix are taken into account). Thus $m_t = 175$ GeV is the only sensible choice.

7.2 U and D matrices from the knowledge of top quark mass alone?

As already found, a possible resolution to the problems created by top quark is based on the additivity of mass squared so that top quark mass would be about 230 GeV, which indeed corresponds to a peak in mass distribution of top candidate, whereas $t\bar{t}$ meson mass would be 163 GeV. This requires that top quark mass changes very little in topological mixing. It is easy to see that the mass constraints imply that for $n_t = n_b = 60$ the smallness of V_{i3} and $V(3i)$ matrix elements implies that both U and D must be direct sums of 2×2 matrix and 1×1 unit matrix and that V matrix would have also similar decomposition. Therefore $n_b = n_t = 59$ seems to be the only number theoretically acceptable option. The comparison with the predictions with pion mass led to a unique identification $(n_d, n_b, n_b) = (5, 5, 59)$,$(n_u, n_c, n_t) = (4, 6, 59)$.

7.2.1 U and D matrices as perturbations of matrices mixing only the first two genera

This picture suggests that U and D matrices could be seen as small perturbations of very simple U and D matrices satisfying $|U| = |D|$ corresponding to $n = 60$ and having$(n_d, n_b, n_b) = (4, 5, 60)$, $(n_u, n_c, n_t) = (4, 5, 60)$ predicting V matrix characterized by Cabibbo angle alone. For instance, CP breaking parameter would characterize this perturbation. The perturbed matrices should obey thermodynamical constraints and it could be possible to linearize the thermodynamical conditions and in this manner to predict realistic mixing matrices from first principles. The existence of small perturbations yielding acceptable matrices implies also that these matrices be near a point at which two different matrices resulting as a solution to the thermodynamical conditions coincide.

D matrix can be deduced from U matrix since $9|D_{12}|^2 \simeq n_d$ fixes the value of the relative phase of the two terms in the expression of D_{12}.

$$|D_{12}|^2 = |U_{11}V_{12} + U_{12}V_{22}|^2$$

$$
\begin{aligned}
&= |U_{11}|^2|V_{12}|^2 + |U_{12}|^2|V_{22}|^2 \\
&+ 2|U_{11}||V_{12}||U_{12}||V_{22}|cos(\Psi) = \frac{n_d}{9} \quad , \\
\Psi &= arg(U_{11}) + arg(V_{12}) - arg(U_{12}) - arg(V_{22}) \quad .
\end{aligned} \tag{77}
$$

Using the values of the moduli of U_{ij} and the approximation $|V_{22}| = 1$ this gives for $cos(\Psi)$

$$
\begin{aligned}
\cos(\Psi) &= \frac{A}{B} \quad , \\
A &= \frac{n_d - n_u}{9} - \frac{9 - n_u}{9}|V_{12}|^2 \quad , \\
B &= \frac{2}{9|V_{12}|}\sqrt{n_u(9 - n_u)} \quad .
\end{aligned} \tag{78}
$$

The experimentation with different values of n_d and n_u shows that $n_u = 6, n_d = 4$ gives $cos(\Psi) = -1.123$. Of course, $n_u = 6, n_d = 4$ option is not even allowed by $n_t = 60$. For $n_d = 4, n_u = 5$ one has $cos(\Psi) = -0.5958$. $n_d = 5, n_u = 6$ corresponding to the perturbed solution gives $cos(\Psi) = -0.6014$.

Hence the initial situation could be $(n_u = 5, n_s = 4, n_b = 60)$, $(n_d = 4, n_s = 5, n_t = 60)$ and the physical U and D matrices result from U and D matrices by a small perturbation as one unit of t (b) mass squared is transferred to u (s) quark and produces symmetry breaking as $(n_d = 5, n_s = t, n_b = 59)$, $(n_u = 6, n_c = 4, n_t = 59)$.

The unperturbed matrices $|U|$ and$|D|$ would be identical with $|U|$ given by

$$
|U_{11}| = |U_{22}| = \tfrac{2}{3} \quad , \quad |U_{12}| = |U_{21}| = \tfrac{\sqrt{5}}{3} \quad , \tag{79}
$$

The thermodynamical model allows solutions reducing to a direct sum of 2×2 and 1×1 matrices, and since $|U|$ matrix is fixed completely by the mass constraints, it is trivially consistent with the thermodynamical model.

7.2.2 Direct search of U and D matrices

The general formulas for p^U and p^D in terms of the probabilities p_{11} and p_{21} allow straightforward search for the probability matrices having maximum entropy just by scanning the (p_{11}, p_{21}) plane constrained by the conditions that all probabilities are positive and smaller than 1. In the physically interesting case the solution is sought near a solution for which the non-vanishing probabilities are $p_{11} = p_{22} = (9 - n_1)/9$, $p_{12} = p_{21} = n_1/9$, $p_{33} = 1$, $n_1 = 4$ or 5. The inequalities allow to consider only the values $p_{11} \geq (9 - n_1)/9$.

1. Probability matrices p^U and p^D

The direct search leads to maximally entropic p^D matrix with $(n_d, n_s) = (5, 5)$:

$$p^D = \begin{pmatrix} 0.4982 & 0.4923 & 0.0095 \\ 0.4981 & 0.4924 & 0.0095 \\ 0.0037 & 0.0153 & 0.9810 \end{pmatrix} \ , \ p_0^D = \begin{pmatrix} 0.5556 & 0.4444 & 0 \\ 0.4444 & 0.5556 & 0 \\ 0 & 0 & 1 \end{pmatrix} \ . \tag{80}$$

p_0^D represents the unperturbed matrix p_0^D with $n(d=4), n_s = 5$ and is included for the purpose of comparison. The entropy $S(p^D) = 1.5603$ is larger than the entropy $S(p_0^D) = 1.3739$. A possible interpretation is in terms of the spontaneous symmetry breaking induced by entropy maximization in presence of constraints.

A maximally entropic p^U matrix with $(n_u, n_c) = (5, 6)$ is given by

$$p^U = \begin{pmatrix} 0.5137 & 0.4741 & 0.0122 \\ 0.4775 & 0.4970 & 0.0254 \\ 0.0088 & 0.0289 & 0.9623 \end{pmatrix} \tag{81}$$

The value of entropy is $S(p^U) = 1.7246$. There could be also other maxima of entropy but in the range covering almost completely the allowed range of the parameters and in the accuracy used only single maximum appears.

The probabilities p_{ii}^D *resp.* p_{ii}^U satisfy the constraint $p(i,i) \geq .492$ *resp.* $p_{ii} \geq .497$ so that the earlier proposal for the solution of proton spin crisis must be given up and the solution discussed in [D2] remains the proposal in TGD framework.

2. Near orthogonality of U and D matrices

An interesting question whether U and D matrices can be transformed to approximately orthogonal matrices by a suitable $(U(1)\times U(1))_L \times (U(1)\times U(1))_R$ transformation and whether CP breaking phase appearing in CKM matrix could reflect the small breaking of orthogonality. If this expectation is correct, it should be possible to construct from $|U|$ ($|D|$) an approximately orthogonal matrix by multiplying the matrix elements $|U_{ij}|$, $i,j \in \{2,3\}$ by appropriate sign factors. A convenient manner to achieve this is to multiply $|U|$ ($|D|$) in an element wise manner ($(A \circ B)_{ij} = A_{ij}B_{ij}$) by a sign factor matrix S.

1. In the case of $|U|$ the matrix $U = S \circ |U|$, $S(2,2) = S(2,3) = S(3,2) = -1$, $S_{ij} = 1$ otherwise, is approximately orthogonal as the fact that the matrix U^TU given by

$$U^TU = \begin{pmatrix} 1.0000 & 0.0006 & -0.0075 \\ 0.0006 & 1.0000 & -0.0038 \\ -0.0075 & -0.0038 & 1.0000 \end{pmatrix}$$

   is near unit matrix, demonstrates.

2. For D matrix there are two nearly orthogonal variants. For $D = S \circ |D|$, $S(2,2) = S(2,3) = S(3,2) = -1$, $S_{ij} = 1$ otherwise, one has

$$D^T D = \begin{pmatrix} 1.0000 & -0.0075 & 0.0604 \\ -0.0075 & 1.0000 & 0.0143 \\ 0.0604 & 0.0143 & 1.0000 \end{pmatrix} .$$

The choice $D = S \circ D$, $S(2,2) = S(2,3) = S(3,3) = -1$, $S_{ij} = 1$ otherwise, is slightly better

$$D^T D = \begin{pmatrix} 1.0000 & -0.0075 & 0.0604 \\ -0.0075 & 1.0000 & 0.0143 \\ 0.0601 & 0.0143 & 1.0000 \end{pmatrix} .$$

3. The matrices U and D in the standard gauge

Entropy maximization indeed yields probability matrices associated with unitary matrices. 8 phase factors are possible for the matrix elements but only 4 are relevant as far as the unitarity conditions are considered. The vanishing of the inner products between row vectors, gives 6 conditions altogether so that the system seems to be over-determined. The values of the parameters s_1, s_2, s_3 and phase angle δ in the "standard gauge" can be solved in terms of r_{11} and r_{21}.

The requirement that the norms of the parameters c_i are not larger than unity poses non-trivial constraints on the probability matrices. This should should be the case since the number of unitarity conditions is 9 whereas probability conservation for columns and rows gives only 5 conditions so that not every probability matrix can define unitary matrix. It would seem that that the constraints are satisfied only if the the 2 mass squared conditions and 2 conditions from the entropy maximization are equivalent with 4 unitarity conditions so that the number of conditions becomes 5+4=9. Therefore entropy maximization and mass squared conditions would force the points of complex 9-dimensional space defined by 3×3 matrices to a 9-dimensional surface representing group $U(3)$ so that these conditions would have a group theoretic meaning.

The formulas

$$\begin{aligned} r_{i2} &= \sqrt{[-\frac{n_i}{51} + \frac{20}{17}(1 - r_{i1}^2)]} \ , \\ r_{i3} &= \sqrt{[\frac{n_i}{51} - \frac{3}{17}(1 - r_{i1}^2)]} \ . \end{aligned} \tag{82}$$

and

$$U = \left[\begin{array}{ccc} c_1 & s_1c_3 & s_1s_3 \\ -s_1c_2 & c_1c_2c_3 - s_2s_3exp(i\delta) & c_1c_2s_3 + s_2c_3exp(i\delta) \\ -s_1s_2 & c_1s_2c_3 + c_2s_3exp(i\delta) & c_1s_2s_3 - c_2c_3exp(i\delta) \end{array} \right] \quad (83)$$

give

$$\begin{array}{ll} c_1 = r_{11} \ , & c_2 = \frac{r_{21}}{\sqrt{1-r_{11}^2}} \ , \\ s_3 = \frac{r_{13}}{\sqrt{1-r_{11}^2}} \ , & cos(\delta) = \frac{c_1^2c_2^2c_3^2+s_2^2s_3^2-r_{22}^2}{2c_1c_2c_3s_2s_3} \ . \end{array} \quad (84)$$

Preliminary calculations show that for $n_1 = n_2 = 5$ case the matrix of moduli allows a continuation to a unitary matrix but that for $n_1 = 4, n_2 = 6$ the value of $cos(\delta)$ is larger than one. This would suggest that unitarity indeed gives additional constraints on the integers n_i. The unitary (in the numerical accuracy used) $(n_d, n_s) = (5, 5)$ D matrix is given by

$$D = \left(\begin{array}{ccc} 0.7059 & 0.7016 & 0.0975 \\ -0.7057 & 0.7017 - 0.0106i & 0.0599 + 0.0766i \\ -0.0608 & 0.0005 + 0.1235i & 0.4366 - 0.8890i \end{array} \right) \ .$$

The unitarity of this matrix supports the view that for certain integers n_i the mass squared conditions and entropy maximization reduce to group theoretic conditions. The numerical experimentation shows that the necessary condition for the unitarity is $n_1 > 4$ for $n_2 < 9$ whereas for $n_2 \geq 9$ the unitarity is achieved also for $n_1 = 4$.

7.2.3 Direct search for CKM matrices

The standard gauge in which the first row and first column of unitary matrix are real provides a convenient representation for the topological mixing matrices: it is convenient to refer to these representations as U_0 and D_0. The possibility to multiply the rows of U_0 and D_0 by phase factors $(U(1)\times U(1))_R$ transformations) provides 2 independent phases affecting the values of $|V|$. The phases $exp(i\phi_j)$, $j = 2, 3$ multiplying the second and third row of D_0 can be estimated from the matrix elements of $|V|$, say from the elements $|V_{11}| = cos(\theta_c) \equiv v_{11}$, $sin\theta_c = .226\pm.002$ and $|V_{31}| = (9.6\pm.9)\cdot 10^{-3} \equiv v_{31}$. Hence the model would predict two parameters of the CKM matrix, say s_3 and δ_{CP}, in its standard representation.

The fact that the existing empirical bounds on the matrix elements of V are based on the standard model physics raises the question about how seriously they should be taken. The possible existence of fractally scaled up versions of light quarks could effectively reduce the matrix elements for the electro-weak decays $b \rightarrow c + W$, $b \rightarrow u + W$ *resp.* $t \rightarrow s + W$, $t \rightarrow d + W$ since the decays involving scaled up versions of light quarks can be counted as decays $W \rightarrow bc$ *resp.* $W \rightarrow tb$. This would favor too small experimental estimates for the matrix elements V_{i3} and V_{3i}, $i = 1, 2$. In particular, the matrix element $V_{31} = V_{td}$ could be larger than the accepted value.

Various constraints do not leave much freedom to choose the parameters n_{q_i}. The preliminary numerical experimentation shows that the choice $(n_d, n_s) = (5,5)$ and $(n_u, n_c) = (5,6)$ yields realistic U and D matrices. In particular, the conditions $|U(1,1)| > .7$ and $|D(1,1)| > .7$ hold true and mean that the original proposal for the solution of spin puzzle of proton must be given up. In [D2] an alternative proposal based on more recent findings is discussed. Only for this choice reasonably realistic CKM matrices have been found. For $n_t = 58$ the mass of $t\bar{t}$ meson mass is reduced by one percent from 2×163 GeV for $n(5) = 59$ so that $n_t = 58$ is still acceptable if the additivity of conformal weight rather than mass is accepted for diagonal mesons.

1. The requirement that the parameters $|V_{11}|$ (or equivalently, Cabibbo angle) and $|V_{31}|$ are produced correctly, yields CKM matrices for which CP breaking parameter J is roughly one half of its accepted value. The matrix elements $V_{23} \equiv V_{cb}$, $V_{32} \equiv V_{tc}$, and $V_{13} \equiv V_{ub}$ are roughly twice their accepted value. This suggests that the condition on V_{31} should be loosened.

2. The following tables summarize the results of the search requiring that
   i) the value of the Cabibbo angle s_{Cab} is within the experimental limits $s_{Cab} = .223 \pm .002$,
   ii) $V_{31} = (9.6 \pm .9) \cdot 10^{-3}$, is allowed to have value at most twice its upper bound,
   iii) V_{13} whose upper bound is determined by probability conservation, is within the experimental limits $.42 \cdot 10^{-3} < |V_{ub}| < 6.98 \cdot 10^{-3}$ whereas $V_{23} \simeq 4 \times 10^{-3}$ should come out as a prediction,
   iv) the CP breaking parameter satisfies the condition $|(J - J_0)/J_0| < .6$, where $J_0 = 10^{-4}$ represents the lower bound for J (the experimental bounds for J are $J \times 10^4 \in (1 - 1.7)$).

The pairs of the phase angles (ϕ_1, ϕ_2) defining the phases $(exp(i\phi_1), exp(i\phi_2))$ are listed below

$$\begin{array}{llllll} class\ \ 1: & \phi_1 & 0.1005 & 0.1005 & 4.8129 & 4.8129 \\ & \phi_2 & 0.0754 & 1.4828 & 4.7878 & 6.1952 \\ class\ \ 2: & \phi_1 & 0.1005 & 0.1005 & 4.8129 & 4.8129 \\ & \phi_2 & 2.3122 & 5.5292 & 0.7414 & 3.9584 \end{array} \tag{85}$$

The phase angle pairs correspond to two different classes of U, D, and V matrices. The U, D and V matrices inside each class are identical at least up to 11 digits(!). Very probably the phase angle pairs are related by some kind of symmetry.

The values of the fitted parameters for the two classes are given by

	$\lvert V_{11}\rvert$	$\lvert V_{31}\rvert$	$\lvert V_{13}\rvert$	$J/10^{-4}$
class 1	0.9740	0.0157	0.0069	.93953
class 2	0.9740	0.0164	0.0067	1.0267

V_{31} is predicted to be about 1.6 times larger than the experimental upper bound and for both classes V_{23} and V_{32} are roughly too times too large. Otherwise the fit is consistent with the experimental limits for class 2. For class 1 the CP breaking parameter is 7 per cent below the experimental lower bound. In fact, the value of J is fixed already by the constraints on V_{31} and V_{11} and reduces by a factor of one half if V_{31} is required to be within its experimental limits.

U, D and $|V|$ matrices for class 1 are given by

$$U = \begin{bmatrix} 0.7167 & 0.6885 & 0.1105 \\ -0.6910 & 0.7047 - 0.0210i & 0.0909 + 0.1310i \\ -0.0938 & 0.0696 + 0.1550i & 0.1747 - 0.9653i \end{bmatrix}$$
$$D = \begin{bmatrix} 0.7059 & 0.7016 & 0.0975 \\ -0.6347 - 0.3085i & 0.6358 + 0.2972i & 0.0203 + 0.0951i \\ -0.0587 - 0.0159i & -0.0317 + 0.1194i & 0.6534 - 0.7444i \end{bmatrix}$$
$$|V| = \begin{bmatrix} 0.9740 & 0.2265 & 0.0069 \\ 0.2261 & 0.9703 & 0.0862 \\ 0.0157 & 0.0850 & 0.9963 \end{bmatrix} \tag{86}$$

U, D and $|V|$ matrices for class 2 are given by

$$U = \begin{bmatrix} 0.7167 & 0.6885 & 0.1105 \\ -0.6910 & 0.7047 - 0.0210i & 0.0909 + 0.1310i \\ -0.0938 & 0.0696 + 0.1550i & 0.1747 - 0.9653i \end{bmatrix}$$
$$D = \begin{bmatrix} 0.7059 & 0.7016 & 0.0975 \\ -0.6347 - 0.3085i & 0.6358 + 0.2972i & 0.0203 + 0.0951i \\ -0.0589 - 0.0151i & -0.0302 + 0.1198i & 0.6440 - 0.7525i \end{bmatrix}$$
$$|V| = \begin{bmatrix} 0.9740 & 0.2265 & 0.0067 \\ 0.2260 & 0.9704 & 0.0851 \\ 0.0164 & 0.0838 & 0.9963 \end{bmatrix} \tag{87}$$

What raises worries is that the values of $|V_{23}| = |V_{cb}|$ and $|V_{32}| = |V_{ts}|$ are roughly twice their experimental estimates. This, as well as the discrepancy related to V_{31}, might be understood in terms of the electro-weak decays of b and t to scaled up quarks causing a reduction of the branching ratios $b \rightarrow c + W$, $t \rightarrow s + W$ and $t \rightarrow t + d$. The attempts to find more successful integer combinations n_i has failed hitherto. The model for pseudoscalar meson masses, the predicted relatively small masses of light quarks, and the explanation for $t\bar{t}$ meson mass supports this mixing scenario.

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8 Figures and Illustrations

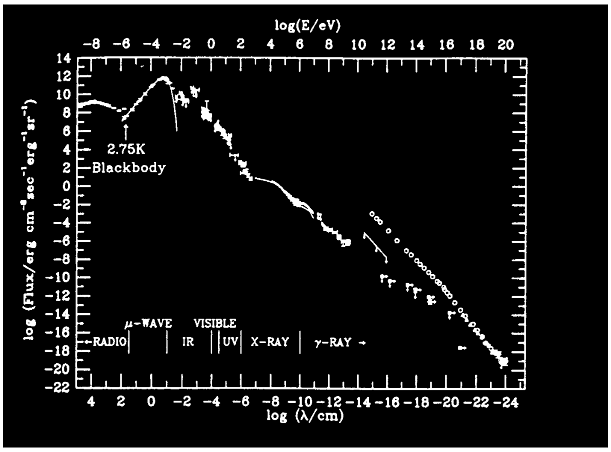

Figure 1: There are some indications that cosmic gamma ray flux contains a peak in the energy interval $10^{10} - 10^{11}$ eV. Figure is taken from [91].

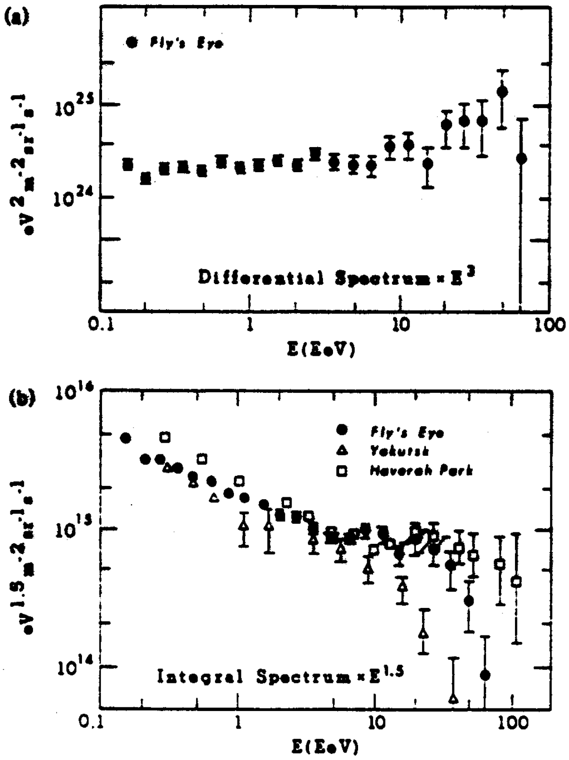

FIG. 2. (a) Differential spectrum $j(E)$ plotted as $E^3 j(E)$. A power-law best fit of the form $j(E) = aE^{-\gamma}$ yields $a = 109.6 \pm 2.2$ EeV^{-1} km^{-2} sr^{-1} yr^{-1} and $\gamma = 2.94 \pm 0.02$ for events at $E < 10$ EeV. Between 10 and 50 EeV we obtain $a = 34 \pm 17$ EeV^{-1} km^{-2} sr^{-1} yr^{-1} and $\gamma = 2.42 \pm 0.27$. The lack of events above 50 EeV indicates that the flattened slope does not continue. (b) Integral spectrum $I(>E)$ plotted as $E^{1.5} I(>E)$. Data from both Haverah Park and Yakutsk (Refs. 10, 12, and 13) experiments are also shown.

Figure 2:

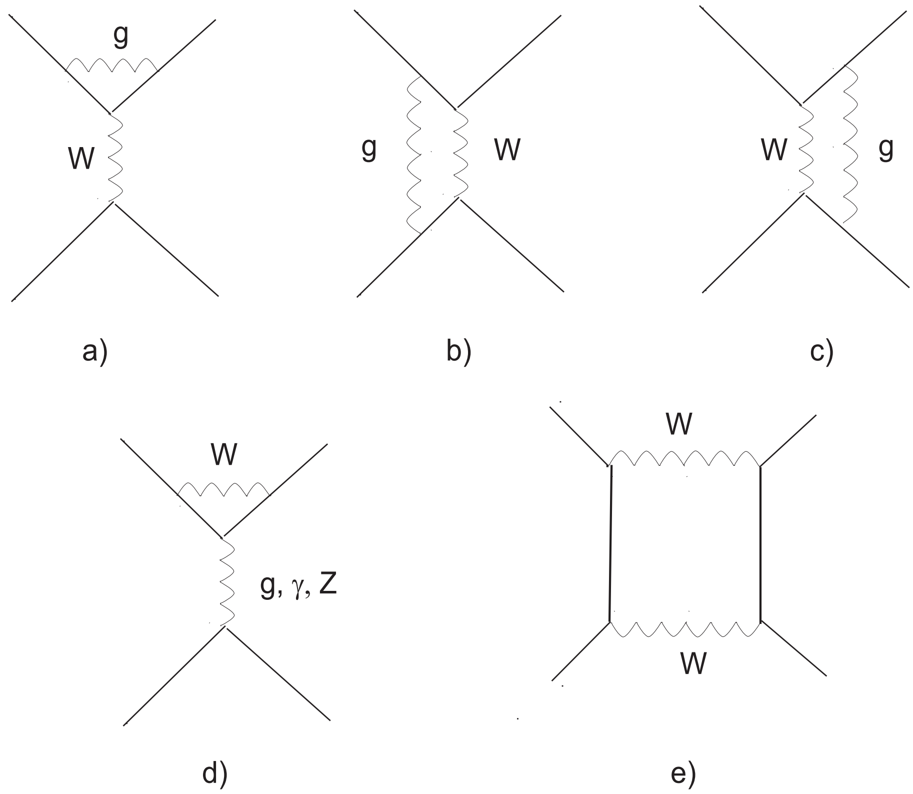

Figure 3: Standard model contributions to the matching of the quark operators in the effective flavor-changing Lagrangian