Phase transition from M_{107} hadron physics to M_{89} hadron physics as counterpart for de-confinement phase transition?

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Abstract

Quark gluon plasma assigned to de-confinement phase transition predicted by QCD has turned out to be a problematic notion. The original expectation was that quark gluon plasma (QGP) would be created in heavy ion collisions. A candidate for QGP was discovered already at RHIC but did not have quite the expected properties such as black body spectrum behaving like an ideal liquid with long range correlations between charged particle pairs created in the collision. Then LHC discovered that this phase is created even in proton-heavy nucleus collisions. Now this phase have been discovered even in proton-proton collisions. The observed enhancement of production of strange particles is interpreted as a support for QGP but the details do not seem to conform with QCD predictions. It has been also found that the direct production of J/Ψ mesons containing c quark pair does not conform with Pythia simulation. These findings are something unexpected and both a challenge and opportunity to TGD.

In TGD framework QGP is replaced with quantum critical state appearing in the transition from ordinary hadron physics characterized by Mersenne prime M_{107} to dark variant of M_{89} hadron physics characterized by $h_{eff}/h = n = 512$. At criticality partons are hybrids of M_{89} and M_{107} partons with Compton length of ordinary partons and mass $m(89) \leq 512m(107)$. Inequality follows from possible 1/512 fractionization of mass and other quantum numbers.

The observed strangeness enhancement can be understood as a violation of quark universality if the gluons of M_{89} hadron physics correspond to second generation of gluons, whose couplings necessarily break quark universality. The simplest hypothesis is that the family charge matrices acting on family triplets are same for quarks and leptons and also for all bosons. This allows to understand qualitatively both the strangeness enhancement and the deviation of J/Ψ production from QCD predictions. Second generation weak bosons could in turn explain also the violations of lepton universality observed in B-meson decays, the anomaly of muon anomalous magnetic moment, and the different values of proton radius deduced from hydrogen and muonium atoms.

Contents

1 Introduction

Quark gluon plasma assigned to de-confinement phase transition predicted by QCD has turned out to be a problematic notion. The original expectation was that quark gluon plasma (QGP) would be created in heavy ion collisions. A candidate for QGP was discovered already at RHIC but did not have quite the expected properties such as black body spectrum [C2, C3, C4, C5] but behaved like an ideal liquid with long range correlations between charged particle pairs created in the collision. Then LHC discovered that this phase is created even in proton-heavy nucleus collisions [C6] (see `http://tinyurl.com/lt5reno` and `http://tinyurl.com/kkx4x2y`). Now this phase have been discovered even in proton-proton collisions [C1]. This does not conform with the expectations. The details for the enhanced production of strange mesons deviate form QCD predictions.

A second anomaly has been discovered by LHCb collaboration [C7] (see `http://tinyurl.com/mjucnwl`).

1. The production of J/Ψ mesons in proton-proton collisions in the Large Hadron Collider (LHC) at CERN does not agree with the predictions made by a widely used computer simulation, Pythia. The result comes from CERN's LHCb experiment studying the jets of hadrons created as protons collide at 13 TeV cm energy.

2. These jets contain large numbers of J/Ψ mesons consisting of charmed quark and a charmed anti-quark. The LHCb measured the ratio of the momentum carried by the J/Ψ mesons to the momentum carried by the entire jet. They were also able to discriminate between J/Ψ mesons created promptly (direct/prompt production) in the collision and J/Ψ mesons that were created after the collision by the decay of charmed hadrons produced by jets (jet production).

3. Analysis of the data demonstrates that PYTHIA - a Monte Carlo simulation used to model high-energy particle collisions - does not predict correctly the momentum fraction carried by prompt J/Ψ mesons. The conclusion is that the apparent shortcomings of PYTHIA could have a significant effect on how particle physics is done because the simulation is used both in the design of collider detectors and also to determine which measurements are most likely to reveal information about physics beyond the Standard Model of particle physics. Heretic could go further and ask whether the problem is really with Pythia: could it be with QCD?

These discoveries are unexpected and both a challenge and opportunity to TGD.

1. In TGD framework QGP is replaced with quantum critical state appearing in the transition from ordinary hadron physics characterized by Mersenne prime M_{107} to dark variant of M_{89} hadron physics characterized by $h_{eff}/h = n = 512$. At quantum criticality partons are hybrids of M_{89} and M_{107} partons with Compton length of ordinary partons and mass $m(89) \leq 512m(107)$ since also $1/n$-fractional quarks and gluons are possible.

2. TGD predicts besides ordinary bosons two additional boson generations, whose family charge matrices in the space of fermion families are hermitian, diagonal and orthogonal to each other to the unit charge matrix for ordinary bosons, and most naturally same for all bosons. The charge matrices for higher generations necessarily break the universality of fermion couplings. The model for strangeness enhancement and the violation of lepton universality in B-meson decays predicts that the bosonic family charge matrix for second generation favours decays to third generation quarks and dis-favors decays to quarks of first and second generation.

3. The observed strangeness enhancement can be understood as a violation of quark universality if the gluons of M_{89} hadron physics correspond to second generation of gluons whose couplings necessarily break quark universality. This also predicts that the rate for prompt production of J/Ψ is lower and jet production rate from b-hadron decays is higher than predicted by QCD.

2 Some background about TGD

In hope of making the representation more comprehensible, I list some of the basic ideas and notions of TGD involved.

2.1 Some Basic concepts and ideas

Here is a concise list about the basic notions and ideas of TGD related to particle physics.

1. There are several new geometric notions involved. Many-sheeted space-time (surface in $M^4 \times CP_2$) and topological field quantization implying the notions of field body and magnetic body and of magnetic flux tubes carrying monopole flux. The twistor lift of TGD replaces $M^4 \times CP_2$ to the Cartesian product of twistor spaces of M^4 and CP_2. The spaces are completely unique in the sense that they have Kähler structure [K14, K13, K15]. The analog of Kähler structure for M^4 predicts CP, P, and T violation in all scales having far reaching implications in many fields of physics, in particular in hadron physics [L3] and cosmology and galaxy models [L4].

2. Zero energy ontology (ZEO) is also crucial in the formulation of scattering amplitudes and in the interpretation of TGD, in particular of TGD inspired theory of consciousness. In ZEO causal diamond (CD) defines the perceptive field of conscious entity. Zero energy states coding scattering amplitudes are constructed using the data associated with preferred extremals of the action principle defined by twistor lift inside CD. CDs for a fractal hierarchy. ZEO leads to a generalization of quantum measurement theory giving rise to a theory of consciousness.

3. Strong holography (SH) following from strong form of general coordinate invariance (GCI) is a central notion [K9, K11].

   SH allows effective localization of fermions at string world sheets carrying vanishing induced W boson fields in the sense that effective action can be formulate in terms of induces spinor fields at string world sheets having sources at their boundaries. String world sheets would code for the data needed to construct scattering amplitudes and their boundaries at the orbits of partonic 2-surfaces correspond to world-lines of fundamental fermions serving as building bricks of all elementary particles.

   The dual 4-D description would be in terms of induced spinor fields in the interior of space-time surface having sources at light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian. SH applies also in bosonic degrees of freedom meaning that the 4-D action determining space-time surface reduces to 2-D effective action for string world sheets. The 4-D space-time surface are obtained by SH from these surfaces in analogy with analytic continuation process.

4. Number theoretic vision [K12] leads to the notion of adelic physics [L7] based on the fusion of real and various p-adic number fields to adeles. Adeles form a hierarchy labelled by extensions of rationals inducing extensions of p-adic number fields. The interpretation is as an evolutionary hierarchy with levels characterized by the complexity of extension.

   Various p-adic physics are interpreted as physics of cognition. p-Adic length scale hypothesis states that elementary particles are labelled by certain p-adic primes $p \simeq 2^k$. The most important p-adic length scales correspond to Mersenne primes and Gaussian Mersennes. Preferred p-adic primes $p \simeq 2^k$ could correspond to so called ramified primes for the extensions, which are winners in the fight for number theoretical survival.

The hierarchy of Planck constants $h_{eff}/h = n$ defining a hierarchy of phases of ordinary matter identifiable as dark matter hierarchy. Both hypothesis reduce in adelic physics to the number theory associated with extensions of rationals inducing extensions of p-adic number fields. For instance, $h_{eff}/h = n$ corresponds to the dimension of the Galois group of the extension giving the number of sheets of space-time surface as covering. A natural hypothesis is that second quantization in this discrete space of sheets is possible for fermions so that has fractional quarks, gluons, leptons and hadrons. One has extensions of extensions so that one should write $h_{eff,f}/h_{eff,i} = n_{if}$ to be precise.

2.2 TGD view about elementary particles

The TGD view of elementary particle relies crucially on many-sheeted space-time.

1. Elementary particles are 2-sheeted structures forming closed flux tubes carrying monopole flux assignable to the induced Kähler form of CP_2. Flux tube has shape of very long flattened square and has wormhole contacts at its turning points: wormhole contacts are regions with Euclidian induced metric. For fundamental fermions a neutrino pair at the throat of wormhole contact is assumed to neutralize weak spin. This neutralization would take place for all fermions and would be analogous to electroweak confinement.

2. To consider gauge bosons and TGD counterpart of Higgs, one can label the wormhole contacts as W_i, $i = 1, 2$ and the corresponding throats $T_{i,\pm}$. One could have at opposite throats $q \in T_{i,+}$ and $\overline{q} \in T_{i,-}$, $i = 1$ or $i = 2$. Neutrino-antineutrino pars neutralizing weak isopin would reside at opposite throats. Also more general configurations with $q \in T_{1,\pm}$ and $\overline{q} \in T_{2,\pm}$ are possible: they allow the decay of boson to fermion antifermion pair by re-connection of the flux tube splitting it. The quantum state should be superposition of these various states.

3. For mesons one can consider two different models.

   (a) Quark and antiquark are at different wormhole contacts of the same closed flux tube.

   (b) Meson consists of closed flux tubes associated with quark and antiquark feeding part of the color magnetic fluxes to hadronic space-time sheet, where they sum up to zero.

   The model for strangeness enhancement suggest that latter option is the more natural: the mesons would consist of quark antiquark represented as fermionic strings and also the magnetic flux tube at the hadronic space-time sheet would have stringy character.

The topological explanation of family replication phenomenon is essential piece of the picture [K1, K6] .

1. The boundaries of string world sheets are lines at the light-like orbits of partonic 2-surfaces. Partonic 2-surfaces at the boundaries of CD carrying fermions have topology characterized by genus g. Quantum states are superpositions of 3 lowest topologies for partonic 2-surfaces having genus $g = 0, 1, 2$ (sphere, torus, sphere with two handles) and topological mixing matrices U and D describe the mixing. These genera are exceptional that they are always hyper-elliptic allowing Z_2 global conformal symmetry. For higher genera this symmetry is possible only for special values of conformal moduli. The proposal is that the handles form at them free particles or bound states of at most 2 handles. Therefore higher genera would be many-particle states. The different mixings for U and D type quarks imply that CKM matrix appearing in W boson vertices is non-trivial.

2. Family replication phenomenon is predicted also for bosons. One has dynamical family-SU(3) with quarks and lepton generations defining triplets of this group. Bosons belong to singlet and octet representation of this group. Ordinary bosons correspond to singlet and have universal couplings. Only the two neutral members of octet representation (analogous to neutral pion and η in Gell-Mann's SU(3)) are light and have charged matrices orthogonal to that for singlet and therefore their couplings violate universality.

3. The TGD based model is based on the predicted higher generations of electroweak bosons, whose charge matrices necessarily break fermion universality since they are orthogonal with each other and orthogonal to the singlet charge matrix which is unit matrix and thus universal.

2.3 Quarks, gluons, and hadrons

The TGD view about color quantum numbers differs from the QCD view. One must consider both imbedding space level and space-time level.

1. At the level of imbedding space spinor harmonics define the ground states of super-symplectic representations. Color corresponds to CP_2 color partial waves and is not spin-like quantum number except approximately in length scales much longer than CP_2 size scale. This view about color makes possible separate conservation of baryon and lepton numbers that one must give up in GUTs. Note that no evidence for the decay of protons predicted by GUTs have been found.

2. Quantum classical correspondence (QCC) requires a correlate for color also at the level of space-time surfaces. Induced spinors do not have color as spin like quantum number and one cannot talk about color partial waves at space-time level.

   Color magnetic flux emanating from quark, which is identified as 2-sheeted structure, flows to a larger hadronic space-time sheet through wormhole contact and could define the correlate for color hyper charge. The flux of color magnetic hyper-charge is defined by Kähler form multiplied by hyper-charge Hamiltonian which is determined up to additive constant. This constant term should give the color flux as proportional to Kähler magnetic flux.

   The sum of Kähler magnetic fluxes (homology charges) must vanish for orientable surfaces and thus for hadronic space-time sheet must vanish unless one allows non-orientable 3-surfaces in which case it would vanish only modulo 2. Orientability is required by the well-definedness of induced gauge fields.

   Vanishing occurs if the values of Kähler magnetic charge are 2 and -1, -1 and would correspond to the values $2/3, -1/3, -1/3$ of color hyper charge for color triplet of quarks. For higher color partial waves color confinement condition requires large values of Kähler magnetic flux and this might prevent higher color partial waves for leptons and quarks or make them very massive. This is actually very inportant point since there is no evidence for higher color partial waves.

3. QCC suggests also space-time correlates for isospin and spin. Two-sheeted covering space structure for elementary particles could correspond to this. One would have 2-sheeted covering space completely analogously to how SU(2) serves as 2-sheeted covering of SO(3). The rotations would would lead from the point of wormhole throat to the point at opposite throat. This would apply to both color, spin, and electroweak spin, in which case parallel translation would define the transformation. Galois group permutes the space-time sheets and an attractive idea is that Galois group could represent discrete subgroups of the these symmetry groups.

A more precise view about gluons and hadrons is needed.

1. The general structure of bosons was already considered. The presence of configuration with $q \in T_{1,\pm}$ and $\overline{q} \in T_{2,\pm}$ makes possible decays of gluon to $q\overline{q}$ pairs by splitting of the closed gluon flux tube by reconnection to closed flux tubes representing quark and antiquark. In this process a neutrino pair neutralizing weak isospin is created at the emerging wormhole contacts. Similar superposition for weak bosons makes possible their decays to lepton and quark pairs.

2. Hadronic space-time sheet is the third space-time sheet involved and is present always and could corresponds to color magnetic body. Quarks and gluons feed color magnetic fluxes to hadronic spacetime sheet defining field body/magnetic body of hadron. The color magnetic flux entering along flux enter here and sum up to zero.

3. QCC would be analogous to electric-magnetic duality. At quark space-time sheets color and other quantum numbers would be quantum numbers. At the larger hadronic space-time sheet color hypercharge would correspond to Kähler magnetic charge for effective monopole like entity.

4. Hadronization would occur at hadronic space-time sheet as a formation combinations of quark flux tubes with vanishing total Kähler magnetic charge. Gluon flux tubes decay to pairs of quark and antiquark flux tubes and quarks as closed flux tubes. They feed color magnetic fluxes to hadronic space-time sheets and form in hadronization bound states of color magnetic monopoles with vanishing total color magnetic charge. The magnetic confinement process would occur at the level of hadronic space-time sheet since only magnetic singlets can escape the reactor volume.

   If this picture is correct, color confinement would reduce to second homology of CP_2 and hadronization would have a concrete topological description whereas in QCD it involves introduction of statistical jet hadronization functions characterization hadronization.

3 TGD based model for the enhanced strangeness production

With above prerequisites one can consider explicit model for the enhanced strangeness production.

3.1 What has been found?

The discovery of QGP candidate in proton proton collisions is discussed in popular article at `http://tinyurl.com/mcmekne` and in the article [C1] at `http://tinyurl.com/kse8p3t`). I glue below the abstract of the research article.

At sufficiently high temperature and energy density, nuclear matter undergoes a transition to a phase in which quarks and gluons are not confined: the quarkgluon plasma (QGP). Such an exotic state of strongly interacting quantum chromodynamics matter is produced in the laboratory in heavy nuclei high-energy collisions, where an enhanced production of strange hadrons is observed. Strangeness enhancement, originally proposed as a signature of QGP formation in nuclear collisions7, is more pronounced for multi-strange baryons. Several effects typical of heavy-ion phenomenology have been observed in high-multiplicity protonproton (pp) collisions, but the enhanced production of multi-strange particles has not been reported so far.

Here we present the first observation of strangeness enhancement in high-multiplicity proton-proton collisions. We find that the integrated yields of strange and multi-strange particles, relative to pions, increases significantly with the event charged-particle multiplicity. The measurements are in remarkable agreement with the pPb collision results, indicating that the phenomenon is related to the final system created in the collision. In high-multiplicity events strangeness production reaches values similar to those observed in PbPb collisions, where a QGP is formed.

Some comments are in order.

1. The enhanced production of hadrons containing strange quarks is taken as a signature for the production of the QGP candidate: why this enhancement should occur is not however obvious. In the case of nucleus-nucleus collisions this interpretation was justified as a first guess but not so in the case for proton-nucleus collisions and even less in the case of p-p collisions. Something exotic is produced and it is better to just ask what this something might be. One must be even ready to challenge the status of QCD.

2. The enhancement depends on the final state and only weakly on the initial state suggesting that some phase new phase is indeed created and responsible for the enhancement. Already in the case of nucleus-nucleus collisions the unexpected correlations associated with charged particle pairs in the final state led to ask whether string like objects decaying to quark pair, which eventually decaying eventually to ordinary hadrons, might be created. Also the presence of some kind of macroscopic quantum phase is suggested by long range correlations and also by chiral magnetic effect (CME) and chiral separation effect (CSE) for which a TGD inspired model is discussed in [L3] [K4].

3. The ratios of differential cross sections for pairs of strange particles K, λ, Ω to the cross section for production of pions are very similar to those in proton-nucleus collisions suggesting that also in this case proton-nucleus collision is the basic mechanism for creating the new unidentified phase (see http://tinyurl.com/kse8p3t)).

4. The integrated yields of strange particles increase with charged particle multiplicity. This is an hint about the production mechanism: the first step could be the decay of gluon like states to quark-antiquark pairs. Ordinary quarks need not be in question. The enhancement of strangeness production increases with the number of strange quarks in the hadron produced. According to the article, the existing models are not able to reproduce this behavior. Hence there might be the place for a new physics.

3.2 Enhanced strangeness production as a violation of quark universality

The TGD based explanation [K4] [L5] is in terms of topological explanation of family replication phenomenon using genus-generation correspondence [K1].

1. A natural starting point is another anomalous finding by LHC: the decays of B and K mesons seem to violate lepton universality. The observations are summarized at http://tinyurl.com/m7gahup and the analysis of data is explained at http://tinyurl.com/ml335qf. This suggests the existence of heavy variants of W resp. Z bosons, which prefer to decay to $\tau\nu$ resp. $\tau^+\tau^-$ pairs. Also the anomaly for the anomalous magnetic moment of muon suggests a violation of lepton universality as do also the different values of proton charge radii deduced from hydrogen and muonium atom [L5].

2. Ordinary electroweak bosons would correspond to Mersenne prime M_{89}. The Gaussian Mersenne $M_{G,79}$ would characterize the second generation of weak bosons and one prediction is enhanced production of τ pairs due to the larger coupling of second generation weak bosons to τ pairs. If the charge matrices of second generation gluons in the space defined by triplet of fermion generations are same for triplets electroweak bosons and gluons, the decays of second generation gluons should produce more $g = 2$ quark pairs (t or b pairs) than $g < 2$ pairs. The decay of $g = 2$ quarks to c and s quarks followed by the decay of c quarks to s and u plus the long lifetime of s would lead to strangeness enhancement.

   The weak boson families would correspond to subsequent (possibly Gaussian) Mersennes M_{89}, $M_{G,79}$, M_{61}.

3. The model for enhanced strangeness production is implied by e TGD based model for the violation of lepton universality. Also gluons and even gravitons should possess higher generations and this suggests that strangeness enhancement is a signal about violation of flavor universality due to second generation gluons.

   Two additional gluon families are predicted and the 3 gluon generations would naturally correspond to subsequent Mersennes M_{107}, M_{89}, $M_{G,79}$. Their couplings to quarks would violate universality. The simplest hypothesis is that the charge matrices for family-SU(3) are same for gluons and ew bosons and maybe even gravitons of which only the singlet graviton is expected to be massless.

4. What charge matrices could look like? Ordinary gauge bosons correspond by universality to charge matrix $(1, 1, 1)$. All charge matrices are orthogonal to each other and thos for second and third generation bosons are hermitian, diagonalmatrices with vanishing trace. The simplest proposal for second generation charge matrix is as matrix proportional to hyper charge matrix $Y = (-1/3, -1/3, 2/3)$. Third generation charge matrix is proportional to $I_3 = (1/2, -1/2, 0)$. The coupling by hypercharge matrix would be two times stronger than by isospin matrix and favor decays of gluons to third generation quarks. This guess might hold true in absence of topological mixing of the partonic topologies with genus $g = 0, 1, 2$.

   Topological mixing for fermions would cause mixing of fermion families depending on the charge state of fermion: U resp. D type quarks are mixed by unitary matrix U resp D. For first generation neutral weak bosons and gluons the charge matrices are not affected. For higher generations one has $Q_i \rightarrow UQU^\dagger$ and $Q_i \rightarrow DQ_iD^\dagger$. For charge weak bosons one has $Q_i \rightarrow UQ_iD^\dagger$ giving for the lowest generation CKM matrix $CKM = UD^\dagger$ and its along for higher generations. CKM matrix would therefore show itself in the couplings. If one accepts the identification of charge matrices as Y and I_3 the model predicts the couplings apart from the normalization of these matrices.

A similar 3-levelled hierarchy of hadron physics is highly suggestive.

1. A more precise formulation of M_{89} hadron physics emerges [K4]. The original hypothesis was that M_{89} hadron physics is just a copy of the usual M_{107} hadron physics with masses scale by a factor 512 in the first approximation.

2. In the refined vision M_{89} gluons would be actually second generation gluons, whose couplings violate universality by preferring to decay to $g = 2$ quark pairs (t, and b pairs) just as second generation of weak bosons prefer to decay to $g = 2$ lepton pairs. The explanation for the appearance of bumps with masses of ordinary mesons scaled by factor 512 provides the basic support for the presence of M_{89} hadron physics [L6] [K4].

3.3 Is QGP replaced with criticality for the phase transition from M_{107} hadron physics to M_{89} hadron physics?

The view about quantum criticality assigned to quark-gluon plasma also sharpens. Quantum criticality would be associated with the phase transition from M_{107} (standard gluons) to M_{89} hadron physics associated with the second generation gluons.

1. I have proposed that the dark variants of M_{89} mesons appear at quantum criticality for a phase transition usually interpreted as formation of QGP. The long range correlations associated with quantum criticality would correspond to $h_{eff}/h = n$ phases with Compton lengths scaled up by factor n. By quantum classical correspondence (QCC) also the scales of space-time sheets would be scaled up in this manner.

   This quantum criticality might be also associated with the collision producing the bumps with the masses of M_{89} mesons for which there is evidence [L6] [K4] but forgotten as it turned out that the interpretation in terms of SUSY is not possible. One possibility is peripheral collisions since for these the electromagnetic instanton density would be large and give rise to a generation of M_{89} pseudo scalars coupling to it. For $h_{eff}/h = 512$t dark M_{89} hadrons and ordinary hadrons would have the same size scale.

2. For gluons these $n = 512$-sheeted structures would be analogous to Bose-Einstein condensates of ordinary hadrons and gluons. At the level of quarks Fermi sphere is a better analogy. If all sheets are occupied the mass would $n = 512$ the mass of the ordinary hadron. The simplest option is $1/512$-fractionization for spins and other quantum numbers.

   An attractive idea is that also partly filled Fermi spheres are possible and that the fractional quarks thrown out from full Fermi spheres correspond to sea quarks. If one has this kind of 512-sheeted dark M_{89} gluon preferring to decay to t and b quark pairs, one indeed obtains strangeness enhancement. TGD Universe is quantum critical and the idea that quantum criticality would be realized in this manner is attractive.

A comment about a long standing problem related to the fractionization of quantum numbers is in order although it is not absolutely relevant for the recent situation. One can consider two interpretations for what $h_{eff}/n = n$ means depending on whether the quantum numbers are fractionized or not. The first option works for the above model and second option leads to strange results.

1. Charge fractionization means that the unit of charge (say spin) is scaled down by $1/n$, $h_{eff}/h = n$. The dark matter fermion with all n sheets of covering containing $1/n$-fractional fermion is analogous to a full Fermi sphere and has non-fractional quantum numbers. Also fractional filling is possible. Total quantum numbers must be however fractional and one

has anyonic states consisting of several fractional particles [K7]. The transition to ordinary phase at single particle level is possible only for a particle with full Fermi sphere. Otherwise anyons with complementary Fermi spheres must fuse to give ordinary particles.

For years ago I proposed that pairs formed by dark fractional particle and its complement assignable to a pair of biomolecules could have meant the emergence of symbolic dynamics at molecular level and of what might be called molecular sex [K3, K10]. This could correspond to the assignment of fractional proton triplets to DNA codon and its complementary fractional triplet to conjugate codon. DNA double strand would represent the visible part of molecular marriage of dark DNA sequences.

2. Half-odd integer value of the total angular momentum for the many-anyon system guarantees that the action of 2π rotation in Minkowski space is consistent with the ordinary statistics. One can also consider rotations a the level of space-time surface. For n-fold covering only the M^4 rotation of $n \times 2\pi$ acting on point of space-time surface has the usual effect and one can say that the particle has fractional spin at space-time level.

3. There is however an objection to fractionization. The original idea behing hierarchy of Planck constants was that the energy $E = hf$ associated with frequency f is scaled up to $E = h_{eff}f$. For cyclotron frequencies $f_c \propto qB/m$. Suppose transition to dark phase occurs and all sheets are filled. The fractionizations of q and m compensate each other. If B has the original values at all n sheets, the cyclotron energies increases by factor n as required. One has n copies of the original space-time sheet carrying the original magnetic field so that a kind of space-time correlate for Bose-Einstein condensation is in question.

Deconfinement phase transition does not make sense in TGD framework. Only the scale in which magnetic monopoles are free, can increase.

1. M_{107} gluons of first generation would become dark M_{89} dark gluons of second generation in number theoretic phase transition increasing the dimension of Galois group identified as $h_{eff}/h = n$ with the sheets of n-sheeted objects permuted by Galois group. Kind of Bose-Einstein condensation of ordinary gluons to n-sheeted structures would be in question. Ordinary M_{89} hadron would result in the decay reducing the value of h_{eff}/h by factor 2^{-9}. Alternatively bunches of $m \leq n$ M_{107} hadrons could result in the decay.

2. At quantum criticality one would have hybrids of M_{107} and M_{89} hadrons. M_{89} dark particles the spatial scale would correspond to M_{107} but mass scale to M_{89}. Voice would be Jacob's voice but the hands wold be Esau's hands. Large size scale for them would correspond to quantum fluctuations and long range correlations associated with $M_{107} \rightarrow M_{89}$ phase transition. Instead of liberation of ordinary quarks one would have almost-liberation of M_{89} quarks having size scale of ordinary hadrons equal 512 times their ordinary Compton length.

3.4 Model for strangeness enhancement

Consider now the mechanism for strangeness enhancement.

1. If gluons consist dominantly of $g = 2$ quark pairs (t and b), they prefer to decay to $g = 2$ quark pairs. These in turn prefer to decay via W boson emission to $g = 1$ pairs (c and s). c quarks in turn decay to s and u quark. The lifetimes of strange mesons are so long that they are not detected in the reactor volume. The outcome is strangeness enhancement. Note however that CKM mixing is involved, which allows to produce also d quarks in the decays of c quarks.

2. Why the enhancement of strange baryons would increase with the number of strange quarks in hadron? Could M_{89} gluon define the volume in which process occurs? The density of ordinary gluons would very small in this volume, and the probability that hadronization produces hadrons containing u and d quarks would be due to the decay products of second generation gluons and therefore small.

Hadronization would correspond to the formation of color bound/magnetically bound states of quarks coming from the decays of second generation gluons to quark pairs with t and b pairs preferred. These quarks forming effectively magnetic monopoles at throats of wormhole contacts would then form mesons and baryons as color bound states and the probability for the hadron to contain first generation quarks would be the lower the higher the number of them is. This would explain why the production rate for hadrons decreases with the number of non-strange light quarks.

3. Could the region containing very few light ordinary quarks correspond to dark M_{89} gluon occupying the volume with a size scale of ordinary hadron? This could be the case if the decay of dark M_{89} gluon to quark pairs occurs first and is followed by the decay of this M_{89} 512×2-sheeted structure to dark M_{89} quark pairs in turn decay decay to 512 ordinary quarks and antiquarks. If the partonic 2-surface tends to have $g = 2$ then all the decay products would tend to have also $g > 0$ and consist of strange quarks.

4 Anomalous J/Ψ production and TGD

A new anomaly [C7] (see `http://tinyurl.com/l3xnxtj`) has been discovered by LHCb collaboration. For popular summary see `http://tinyurl.com/mjucnwl`. The production of J/Ψ mesons in proton-proton collisions in the Large Hadron Collider (LHC) at CERN does not agree with the predictions made by a widely used computer simulation, Pythia. The result comes from CERN's LHCb experiment studying the jets of hadrons created as protons collide at 13 TeV cm energy. The production of J/Ψ mesons in proton-proton collisions in the Large Hadron Collider (LHC) at CERN does not agree with the predictions made by a widely used computer simulation, Pythia. The result comes from CERN's LHCb experiment studying the jets of hadrons created as protons collide at 13 TeV cm energy.

These jets contain large numbers of J/Ψ mesons consisting of charmed quark and a charmed anti-quark. The LHCb measured the ratio of the momentum carried by the J/Ψ mesons to the momentum carried by the entire jet. They were also able to discriminate between J/Ψ mesons created promptly (direct/prompt production) in the collision and J/Ψ mesons that were created after the collision by the decay of charmed hadrons produced by jets (jet production).

Analysis of the data demonstrates that PYTHIA - a Monte Carlo simulation used to model high-energy particle collisions - does not predict correctly the momentum fraction carried by prompt J/Ψ mesons. The conclusion is that the apparent shortcomings of PYTHIA could have a significant effect on how particle physics is done because the simulation is used both in the design of collider detectors and also to determine which measurements are most likely to reveal information about physics beyond the Standard Model of particle physics. Heretic could go further and ask whether the problem is really with Pythia: could it be with QCD?

The TGD explanation for the finding is same as that for strangeness enhancement in p-p collisions in the same energy range at which the de-confinement phase transition is predicted to occur in QCD. In TGD one would have quantum criticality for a phase transition from the ordinary M_{107} hadron physics to M_{89} hadron physics with hadronic mass scale by a factor 512 higher than for ordinary hadrons. The gluons and quarks at quantum criticality would be dark in the sense of having $h_{eff}/h = n = 512$. Also $1/n$-fractional quarks and gluons are possible.

TGD predicts besides ordinary bosons two additional boson generations, whose family charge matrices in the space of fermion families are hermitian, diagonal and orthogonal to each other to the unit charge matrix for ordinary bosons, and most naturally same for all bosons. The charge matrices for higher generations necessarily break the universality of fermion couplings. The model for strangeness enhancement and the violation of lepton universality in B-meson decays predicts that the bosonic family charge matrix for second generation favours decays to third generation quarks and dis-favors decays to quarks of first and second generation. This predicts that the rate for prompt production of J/Ψ is lower and jet production rate from b-hadron decays is higher than predicted by QCD.

4.1 The prediction for prompt production of J/Ψ does not conform with the Pythia simulation

The abstract of the article [C7] published in Phys Rev Letters (see `http://tinyurl.com/l3xnxtj`) gives a more technical summary about the discovery.

The production of J/Ψ mesons in jets is studied in the forward region of proton-proton collisions using data collected with the LHCb detector at a center-of-mass energy of 13 TeV. The fraction of the jet transverse momentum carried by the J/Ψ meson, $z(J/\Psi) \equiv p_T(J/\Psi)/p_T(jet)$, is measured using jets with $p_T(jet) \geq 20$ GeV in the pseudorapidity range $2.5 \leq \eta(jet) \leq 4.0$. The observed z(J/Ψ) distribution for J/Ψ mesons produced in b-hadron decays is consistent with expectations.

However, the results for prompt $p_T(J/\Psi)$ production do not agree with predictions based on fixed-order non-relativistic QCD. This is the first measurement of the p_T fraction carried by $promp_T$ J/Ψ mesons in jets at any experiment.

Some explanation about the basic notions are needed before continuing.

1. Pythia is a simulator producing QCD predictions in p-p, p-N, and N-N collisions. The collisions are extremely complex so that this kind of simulation involves uncertainties. QCD model involves distribution functions for partons inside hadron and fragmentation functions for jets telling the probabilities for production of various hadrons from the jet initiated by quark or gluon. Furthermore, at energy range believed to correspond to the transition from confined phase of quarks and gluons to quark-gluon plasma the modelling becomes especially difficult. Situation is made even more difficult by the fact that the quark-gluon plasma (QGP) does not look like plasma but more like ideal fluid with long range correlations. The problem might with QCD itself.

2. There are two mechanisms for J/Ψ production.

   (a) In direct/prompt production J/Ψ is produced in gluon annihilation. Two gluons from the colliding nucleons annihilate to quark pair either via intermediate gluon or by quark exchange. For this mechanism the production is fast, there is large transverse polarization of J/Ψ reflecting the polarization of gluon pair fusing to $c\overline{c}$ pair, and J/Ψ events are isolated in the momentum space. For $z(J/\Psi) = p_T(J/\Psi)/p_T(jet) > .6$ normalized distribution $d\sigma/dz(J/\Psi)/\sigma$ is considerably smaller than predicted by QCD (see Fig. 4 of `http://tinyurl.com/l3xnxtj`).

   (b) In jet production of J/Ψ mesons come from the decays of b-hadrons (hadrons containing b-quarks) resulting in the fragmentation of b-jets to hadrons. The mechanism is slow since c quark results from the weak decay of b quark. Pythia simulation gives a good fit in this case (see Fig. 4 of `http://tinyurl.com/l3xnxtj`)

3. LHCb team measures the ratio of the transversal momentum of the part of jet consisting of J/Ψ mesons to the transverse momentum of the jet. This is consistent with the jet model. The team manages also to separate the jet production from prompt production and concludes that prompt production is smaller than predicted by Pythia.

The heretic questions are following. Could the direct production be smaller than predicted by QCD? Could b-quarks giving rise to jets containing more b-hadrons than QCD predicts?

4.2 TGD inspired model

Before going to the model it is good to explain some background.

1. Rather recently I proposed a TGD inspired model explaining the enhanced strangeness production observed in p-p collisions [L8] [K4]. TGD predicts 3 generations for all bosons and the family charge matrices act in the triplet representation defined by 3 fermion families for what could be called family-SU(3) acting as a spectrum generating group.

   The additional two boson generations necessarily violate the universality of standard model interactions since they must be orthogonal with each other and with the charge matrix of ordinary bosons. The strongest assumption is that the charge matrices are identical for all bosons (including Higgs, photon, and even graviton).

   I have talked for years about scaled-up copy of hadrons assignable to the Mersenne prime $M_{89} = 2^{89} - 1$ (ordinary hadron physics would correspond to M_{127}). The mass scale for the hadrons of M_{89} hadron physics would 512 times that for ordinary hadron physics and in the first approximation the masses of the scaled up hadron physics would be 512 those of the ordinary hadron physics. There are indications for roughly 10 bumps identifialbe as M_{89} hadrons and having the predicted masses.

If second generation gluons prefer to decay to a quark pair of third generation (t or b pair), strangeness enhancement can be understood qualitatively since the third generation quarks would decay to c and s quarks by weak boson emission and c quarks in turn would decay to s quarks, which are rather long-lived.

2. The violation of the universality would take place also for weak interactions. Second generation of weak bosons in turn explain the anomalous CP violation and the violation of the lepton universality observed in the decays b-mesons. Also now it is essential that the second generation of weak bosons prefers to decay to a pair of third generation leptons, that is τ pair. Also the anomaly of muon's anomalous magnetic moment and different values of charge proton radius deduced from hydrogen atom and muoniums atom could be understood in terms of the violation of lepton universality induced by the same mechanism [L5].

For these reasons and also because both c quark and s quark correspond to the second quark generation, it is interesting to see whether the too low yield of prompt c quarks and perhaps too high yield of c quarks from jets could be understood in terms of second generation of gluons preferring to decay to b quark pair and having reduced coupling to first and and second fermions.

Let us look what the assumptions of this model could be.

1. Second generation gluons are somehow created in the collision, and they fuse to quark pair. t quark pairs (if kinematically possible) and b quark pairs are preferred due to their charge matrix in family-space for fermions. The decay to first and second generation quark pairs would disfavored by the properties of the charge matrix. This could be enough to explain why direct production is reduced and jet production enhanced. Situation would be very similar to strangeness enchancement which should be due to the jet production.

2. De-confinement phase transition is believed to produce QGP. The behavior of the QGP candidaate produced at RHIC and LHC is however not that of QGP. The presence of this phase even in p-p collisions looks rather strange. The TGD based model for enhanced production of strange hadrons assumes that the quantum criticality for deconfinement corresponds to that for the transition to QCD for second generation gluons. Quantum criticality for a phase transition from M_{107} hadron physics to M_{89} hadron physics would be in question.

   Quantum criticality corresponds to a creation of phase with non-standard value $h_{eff}/n = n$ of Planck constant, and $n = 512$ would imply that the Compton length of second generation gluons with given energy 512 longer than for ordinary gluons: this would be a counterpart for long range quantum fluctions at quantum criticality. The counterpart for the mass scale Λ_{QCD} wuld be by a factor 512 higher than its value in ordinary QCD and correspond to a mass scale about 75 GeV slightly higher tham the mass of M_{89} pion.

3. If quantum criticality is accepted and family-charge matrices are universal , the fusion mechanism would produce from dark M_{89} gluons a pair of dark M_{89} quarks with preferring to decay to b or t quark pair and disfavoring decays to lower generation quark pairs. These quarks would transform to ordinary quarks and after that the situation would be as in ordinary QCD.

How the second generation gluons could be generated at quantum criticality?

1. Could ordinary gluons make a direct single particle transition to dark second generation gluons with ordinary quantum numbers or could they decay to dark fractional gluons of second generation? For both options the gluon distributions of incoming nucleons appear in the convolution giving the cross section for gluon fusion as function of collision energy. If this assumption is not made, the distribution functions would be replaced by their analogs for the intermediate state created in the collision and having weak dependence on colliding particles. This might be tested experimentally.

2. Depending on whether one approaches critical energy range from below or above, $M_{107} - M_{89}$ quantum criticality means that either the ordinary M_{107} or M_{89} hadron physics becomes unstable. Long range quantum fluctuations correspond to the scaling of the correlation length by $h_{eff}/h = n = 512$. The quantum critical phase would be hybrid of these two hadron physics. This hybrid nature would resolve the paradox due to the fact that two distinct phases become single phase at criticality.

   There should exist some critical parameters such as collision energy, whose variation induces the transition and the bosonic counterparts of elementary particle vacuum functionals [K1] in the moduli space of partonic 2-surfaces should change in the transition. What would happen at the level of partonic 2-surfaces? Certainly their size for ordinary M_{89} hadrons would be by a factor 1/512 smaller.

5 Could ordinary nuclei contain dark $M_{G,113}$ variants of ordinary nucleons?

It is usually assumed that nuclear nucleons do not differ from free nucleons. The above proposal however raises questions about their true identity. What one can say about quarks and gluons inside atomic nuclei for which Gaussian Mersenne $M_{G,113}$ characterizes nuclear space-time sheet as an analog of hadronic space-time sheet?

Could ordinary M_{107} gluon and quarks be replaced with their dark variants with $h_{eff}/h = n = 2^6 = 64$ inside nuclei. I have consider TGD view about nuclear physics in [K8, K5, K2] and developed what I call nuclear string modeld. I have also considered the possibility that $M_{G,113}$ hadron physics could be involved with atomic nuclei [L1, L2] but have not proposed that they could be dark and correspond to the p-adic length scale $M_{G,113}$ of nuclei requiring $h_{eff}/h = n = 2^6$.

One can imagine several options.

1. Option I: Nuclear string model [K5] assumes that ordinary nuclei consist of nucleons bound together by $M_{G,113}$ meson-like flux tubes to form strings. The mass of $M_{G,113}$ pion would be about $m(\pi)/64 \simeq 2.8$ MeV, which corresponds to the scale of binding energy per nucleon for nuclear strong interactions. Nucleus could consist of strings formed by nucleons connected by meson-like flux tubes. There is an obvious analogy with the pearl-in-necklace model of galaxies. The galaxies would be ordinary matter suggesting that also the nuclear nucleons are ordinary nucleons.

2. Option II: Meson-like flux tubes are dark 64-sheeted structures with $m \leq 64$-sheeted fractional quarks-antiquark pairs at ends. For $m = 64$ the flux tube has mass of ordinary pion, which does not make sense. Fractionization would be necessary. The total quantum numbers should be non-fractional. For baryon number this gives no constraint since it vanishes for mesons. Neither does spin give constraints if the bonds are pion-like spin singlets.

3. Option III: Also nuclear nucleons are dark having Compton lengths of order nuclear size inside nuclei and give rise to a kind of superfluid. Could one have distinct superfluids for protons and neutrons? $M_{G,113}$ nuclei would have masses $m = m_N/64 \simeq 14.9$ MeV and dark variants of ordinary M_{107} nucleons would contain at most 64 for of them - at most one at each sheet of the Galois covering and have fractionized spin and other quantum numbers. The analog with partially filled Fermi sphere is suggestive.

   An interesting question is whether the decay of nuclei could produce a bunch of 64 M_{113} nuclei with ordinary value of h_{eff}. This kind of events would be rather spectacular. The rate for them should be however very small.

What about free nucleons and colliding nucleons?

1. In collisions of hadron with proton target the nucleons of target would be dark $M_{G,113}$ nucleons. What about proton-proton and proton-antiproton collisions. Would the protons in this case be ordinary? Or could a phase transition to dark $M_{G,113}$ phase take place so that the quarks making nucleon become fractional and one would have more than 3 genuinely

fractional quarks such that the total baryon number is one. Could the resulting quarks carrying small fraction of baryon number and spin be assigned with parton sea? Could this allow to explain the proton spin puzzle.

2. What happens lepton proton collisions allow to see proton as consisting of ordinary valence quarks only? This does not look plausible. Could one think that in accordance with quantum criticality of TGD, nucleons are quantum critical systems and that even electromagnetic interaction with leptons generates the dark $M_{G,113}$ phase?

What about quark masses? One can imagine two options.

1. If dark current quark with mass of say 5 MeV consists of 64 $M_{G,113}$ fractional quarks, the fractional variant with minimal mass has mass .08 MeV. This option conforms with the view that most of the mass of hadron is due the energy of the color magnetic body of the hadron. Note that one would have spectrum of quark masses between .08 MeV and 5 MeV.

2. If current quark with mass of 5 MeV actually corresponds to dark $M_{G,113}$ fractional quark with minimal mass, ordinary quark would have 64 times larger mass of 320 MeV, quite near to one third of proton mass identified as mass of constituent quark in the quark model proposed by Gell-Mann at sixties.

   This identification might make sense if the dark nucleus like state is generated also in proton-proton and proton-antiproton collisions as intermediate state. One could also imagine free proton is dark $M_{G,113}$ proton. Is the mass of 5 MeV too high to allow realistic masses for the meson like bonds correcting the nucleons? The scaled down pion mass is a reasonable estimate and would give a mass of 2.8 MeV, which looks realistic.

One can wonder about the TGD description for the mechanism giving rise to the nuclear binding energy. Could it be understood at deeper level in terms of splitting of nucleon to fractional nucleons and re-organization of color magnetic fluxes?

Are there any experimental findings justifying these speculative questions?

1. EMC (see `http://tinyurl.com/mvj5vwj`) observed around 1980 that the nucleons inside deuterium and iron behave differently as polarized targets and could have different quark sub-structures. The presence of color flux tube bonds between ordinary nucleons alone could explain this effect but also the possible 64-sheetedness of flux tubes and even the possible darkness of nuclear nucleons themselves could relate to the effect.

2. EMC also discovered the spin crisis of proton: quark model explains only a faction of proton's spin (see `http://tinyurl.com/n6ghs6v`). In the experiment, a polarized muon beam collided with polarized proton target, whose protons are nuclear protons and could thus be dark variants of ordinary protons.

   The first guess would be that the presence of ρ meson like flux tube bonds carrying spin could solve the spin crisis: there would be no need for dark nucleons.

   Dark nucleons and fractionization of quark quantum numbers suggests second explanation. If also the colliding nucleons are dark and genuinely fractional, the fractionization baryon number and dark quark spin as $n/64 \leq 1$-multiple of $\hbar/2$ could transfer part of dark quark spin to the parton sea. Fermi sphere provides a good analogy. Ideal nuclear nucleon has all 64 levels filled with fractional $M_{G,113}$ quarks. Interacting and even free nucleons could have lost some fraction of baryon number and spin from full Fermi sphere. These additional fractional nucleons could be part of parton sea besides gluons and the quark pairs from their decays.

   The phase transition to dark phase should occur also for proton-proton collisions suggesting the existence of a kind of intermediate nucleus.

One can wonder about the TGD description for the mechanism giving rise to the nuclear binding energy.

1. One expects that the fundamental description involves Yangian extension of super-symplectic symmetry assigning to the system multi-local algebra generators giving hopes about first principle description of bound states [**?**] Since fractionization of quantum numbers is associated also with the Yangians and various quantum groups, one might expect that there is a close relationship between adelic physics and fractionization due to $h_{eff}/h = n$ hierarchy associated with the extensions of rationals.

   Super-conformal invariance allows to express mass squared operator in terms of Casimir operator in vibrational degrees of freedom of Super-Virasoro algebra represented in terms of local Kac-Moody algebra generators. One might expect something analogous but for the Yangian algebra of super-symplectic algebra multilocal with respect to partonic 2-surfaces. Multilocal generators in the mass squared operator could serve as the analog of interaction Hamiltonian. I am however unable to say anything more detailed about this idea. One can however be less ambitious and make questions.

2. Somehow the nucleons lose some of their mass. Could one imagine a description of this loss without phenomenological notions like potential energy or interaction Hamiltonian? Adelic physics suggests that the formation of bound states represents an evolutionary step identifiable as emergence of number theoretical complexity. That is extension of rationals with a larger Galois group with order identifiable as $h_{eff}/h = n$. n represents the number of sheets of covering and the natural hypothesis is that second quantization in this discrete space of sheets is possible for fermions so that one indeed has fractional quarks, gluons, and nucleons.

   Could the binding energy be understood in terms of splitting of nucleon to fractional nucleons and re-organization of color magnetic fluxes? Quantum classical correspondence suggests the possibility of classical description in terms of color-magnetic energy and one can check whether this could make any sense.

3. Suppose that color magnetic energy explains the energy of nucleus apart from a small 1 per cent contribution of quarks. Idealize this energy by associating it with single color-magnetic flux tube carrying constant Kähler magnetic field. Suppose that the nucleon splits into $(64-m)/64$-fractional nucleon and $m/64$-fractional nucleon such that the total color flux is conserved and that color flux is fractionize unlike Kähler flux. This requires that the additive constants in the color hypercharge Hamiltonian become scaled by $(64-m)/64$ and $m/64$. Suppose also that the thickness of flux tubes is scaled up by $S/S_0 = 64$. Kähler magnetic field scales as $(S_0/S)^2$: the reason is that there are 64 sheets in the covering. Kähler magnetic energy scales as $(S_0/S) = 1/64$.

4. What happens to the color magnetic energy in the splitting? Suppose that color magnetic energy is integral I of B_Y^2 and same order of magnitude as integral of B_K^2. The division to two flux tubes gives E as sum of integrals $E_1 = [(64-m)/64]^2 X$ and $E_2 = [m/64]^2 \times X$, $X = (S_0/S) \times I$, giving $E = E_1 + E_2 = (1 - m/32) \times X$. The change of the color magnetic energy is $\Delta E = -mX/2^{11}$ for $S_0/S = 1/64$. If the energy of constituent quarks makes about 1 per cent of hadron mass, one has $I \simeq 930$ MeV for proton and $\Delta E/I = -m/2^{11}$. One would have $\Delta E \simeq -m \times .47$ MeV . For $m = 1$ this is considerably smaller than the typical binding energy per nucleon. 5 MeV binding energy per nucleon would require $m \sim 10$. m could characterize the binding energy of nucleon. Note that color bonds between nucleons give a positive contribution to the energy per nucleon in nuclear string model. Scaled down pion mass is only 2.6 MeV. This contribution must be smaller in size that the contribution from fractionization.

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