QCD and TGD

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Abstract

During last week I have been listening some very inspiring Harward lectures relating to QCD, jets, gauge-gravity correspondence, and quark gluon plasma. Matthew Schwartz gave a talk titled *The Emergence of Jets at the Large Hadron Collider*. Dam Thanh Son's talk had the title *Viscosity, Quark Gluon Plasma, and String Theory.* Factorization theorems of jet QCD discussed in very clear manner by Ian Stewart in this talk titled *Mastering Jets: New Windows into Strong Interaction and Beyond.*

These lecture inspired several blog postings and also the idea about a systematical comparison of QCD and TGD. This kind of comparisons are always very useful - at least to me - since they make it easier to see why the cherished beliefs- now the belief that QCD is *the* theory of strong interactions - might be wrong.

1 Introduction

During last week I have been listening some very inspiring Harward lectures relating to QCD, jets, gauge-gravity correspondence, and quark gluon plasma. Matthew Schwartz gave a talk titled *The Emergence of Jets at the Large Hadron Collider* [8]. Dam Thanh Son's talk had the title *Viscosity,* *Quark Gluon Plasma, and String Theory* [9]. Factorization theorems of jet QCD discussed in very clear manner by Ian Stewart [10] in this talk titled *Mastering Jets: New Windows into Strong Interaction and Beyond*.

These lecture several blog postings and also inspired the idea about a systematical comparison of QCD and TGD. This kind of comparisons are always very useful -at lest to myself - since they make it easier to see why the cherished beliefs- now the belief that QCD is *the* theory of strong interactions - might be wrong.

There are several crucial differences between QCD and TGD.

1. The notion of color is different in these two theories. One prediction is the possibility of lepto-hadron physics [13] involving colored excitations of leptons.

2. In QCD AdS/CFT duality is hoped to allow the description of strong interactions in long scales where perturbative QCD fails. The TGD version of gauge-gravity duality is realized at space-time level and is much stronger: string-parton duality is manifest at the level of generalized Feynman diagrams.

3. TGD form of gauge-gravity duality suggests a stronger duality: p-adic-real duality. This duality allows to sum the perturbation theories in strong coupling regime by summing the p-adic perturbation series and mapping it to real one by canonical correspondence between p-adics and reals. This duality suggests that factorization "theorems" have a rigorous basis basis due to the fact that quantum superposition of amplitudes would be possible inside regions characterized by given p-adic prime. p-Adic length scale hypothesis suggests that p-adically scaled up variants of quarks are important for the understanding of the masses of low lying hadrons. Also scaled up versions of hadron physics are important and both Tevatron and LHC have found several indications for M_{89} hadron physics [7].

4. Magnetic flux tubes are the key entities in TGD Universe. In hadron physics color magnetic flux tubes carrying Kähler magnetic monopole fluxes would be responsible for the non-perturbative aspects of QCD [14]. Reconnection process for the flux tubes (or for the corresponding strings) would be responsible for the formation of jets and their hadronization. Jets could be seen as structures connected by magnetic flux tubes to form a connected structure and therefore as hadron like objects. Ideal QCD plasma would be single hadron like objects. In QCD framework quark-gluon plasma would be more naturally gas of partons.

5. Super-symmetry in TGD framework differs from the standard SUSY and the difficult-to-understand X and Y bosons believed to consist of charmed quark pair force to consider the possibility that they are actually smesons rather than mesons [7]. This leads to a vision in which squarks have the same p-adic length scale as quarks but that the strong mixing between smesons and mesons makes second mass squared eigenstate tachyonic and thus unphysical. This together with the fact that shadronization is a fast process as compared to electroweak decays of squarks weak bosons and missing energy would explain the failure to observer SUSY at LHC. An alternative option is that covariantly constant right handed neutrino generates gauge supersymmetry and as an operator creates zero norm state. The generator of SUSY would be color octet partial wave of right-handed neutrino. Color confinement would make impossible the decays producint the standard missing energy signatures of SUSY. This would allow to interpret leptohadrons as pion-like states formed from color octet sleptons.

6. p-Adic length scale hypothesis leads to the prediction that hadron physics should possess scaled variants. A good guess is that these scaled variants correspond to ordinary Mersenne primes $M_n = 2^n - 1$ or Gaussian (complex) Mersenne primes. $M_{89} = 2^{89} - 1$ hadron physics would be one such scaled variant of hadron physics. The mass scale of hadrons would be roughly 512 higher than for ordinary hadrons, which correspond to M_{107}. In zero energy ontology Higgs is not necessarily needed to give mass for gauge bosons and if Higgs like states are there, all of them are eaten by states which become massive. Therefore Higgs would be only trouble makers in TGD Universe.

   The neutral mesons of M_{89} hadron physics would however give rise to Higgs like signals since their decay amplitudes are very similar to those of Higgs even at quantitative level if one accepts the generalization of partially conserved axial current hypothesis.

The recent reports by ATLAS and CMS about Higgs search support the existence of Higgs like signal around about 125 GeV. In TGD framework the interpretation would be as pion like state. There is however also evidence for Higgs like signals at higher masses and standard Higgs is not able to explain this signals. Furthermore, Higgs with about 125 GeV mass is just at the border of vacuum stability, and new particles would be needed to stabilize the vacuum. The solution provided by TGD is that entire scaled up variant of hadron physics replaces Higgs. Within a year it should become clear whether the observed signal is Higgs or pionlike state of M_{89} hadron physics or something else.

2 Basic differences between QCD and TGD

The basic difference between QCD and TGD follow from different views about color, zero energy ontology, and from the notion of generalized Feynman diagram.

2.1 How the TGD based notion of color differs from QCD color?

TGD view about color is different from that of QCD. In QCD color is spin like quantum number. In TGD Universe it is like angular momentum and one can speak about color partial waves in CP_2. Quarks and leptons must have non-trivial coupling to CP_2 Kähler gauge potential in order to obtain a respectable spinor structure. This coupling is odd multiplet of Kähler gauge potential and for $n = 1$ for quarks and $n = 3$ for leptons one obtains a geometrization of electro-weak quantum numbres in terms of induced spinor structure and geometrization of classical and color gauge potentials. This has several far reaching implications.

1. Lepton and baryon numbers are separetely conserved. This is not possible in GUTs. Despite the intense search no decays of proton predicted by GUTs have been observed: a strong support for TGD approach.

2. Infinite number of color partial waves can assigned to leptons and quarks and they obey the triality rule: $t = 0$ or leptons and $t = +1/-1$ for quarks/antiquarks. The color partial waves however depend on charge and CP_2 handedness and therefore on M^4 chirality. The correlation is not correct. Also the masses are gigantic of order CP_2 mass as eigenvalues of CP_2 Laplace operator. Only right handed covariantly constant lepton would have correct color quantum numbers.

   The problem can be cured if one accepts super-conformal invariance. Conformal generators carrying color contribute to the color quantum numbers of the particle state. p-Adic mass calculations show that if ground states have simple negative conformal weight making it tachyon, it is possible to have massless states with correct correlation between electroweak quantum numbers and color [6].

3. Both leptons and quarks have color excited states. In leptonic sector color octet leptons are possible and there is evidence already from seventies that states having interpretation as leptopion are created in heavy ion collisions [13]. During last years evidence for muo-pions and tau-pions has emerged and quite recently CDF provided additional evidence for tau-pions.

   Light colored excitations of leptons and quarks are in conflict what is known about the decay width of intermediate gauge bosons and the way out is to assume that these states are dark matter in the sense that they have effective value of Planck constant coming as integer multiple of the ordinary Planck constant [4]. Only particles with the same value of Planck constant can appear in the same vertex of generalized Feynman diagram so that these particles are dark in the weakest possible sense of the world. The Planck constant can however change when particle tunnels between different sectors of the generalized imbedding spaces consisting of coverings of the imbedding space $M^4 \times CP_2$.

   The attribute "effective" applies in the simplest interpretation for the dark matter hierarchy based on many-valuedness of the normal derivatives of the imbedding space coordinates as functions of the canonical momentum densities of Kähler action. Many-valuedness is implied by the gigantic vacuum degeneracy of Kähler action: any 4-surfce with CP_2 projection which is Lagrangian manifold of CP_2 is vacuum extremal and preferred extremals are deformations of these. The branches co-incide at 3-D space-like ends of the space-time surface at boundaries of CD and at 3-D light-like orbits of wormhole throats at which the signature of the induced metric changes. The value of the effective Planck constant corresponds to the number of sheets of this covering of imbedding space and there are arguments suggesting that this integer is product of two integers assignable to the multiplicities of the branches of space-like 3-surfaces and light-like orbits. At partonic 2-surfaces the degeneracy is maximal since all $n = n_1 \times n_2$ sheets co-incide. This structure brings very strongly in mind the stack of branes infinitesimally near to each other appearing in AdS/CFT duality. TGD analogs of 3-branes of the stacks would be distinct in the interior of the space-time surface.

4. TGD predicts the presence of long ranged classical color gauge potentials identified as projections of CP_2 Killing forms to the space-time surface. Classical color gauge fields are proportional to induced Kähler form and Hamiltonians of color isometries: $G_A = H_A J$. Alle components of the classical gluon field have the same direction. Also long ranged classical electroweak gauge fields are predicted and one of the implications is an explanation for the large parity breaking in living matter (chiral selection of molecules).

   Long ranged classical color fields mean a very profound distinction between QCD color and TGD color and in TGD inspired hadron physics color magnetic flux tubes carrying classical color gauge fields are responsible for the strong interactions in long length scales. These color magnetic fields carrying Kähler magnetic monopole fluxes are absolutely essential in TGD based view about quark distribution functions and hadronic fragmentation functions of quarks and represent the long range hadron physics about which QCD cannot say much using analytic formulas: numerical lattice calculations provide the only manner to tackle the problem.

5. Twistorial approach to $\mathcal{N} = 4$ super-symmetric gauge theory could be seen as a diametrical opposite of jet QCD. It has been very successful but it is perturbative approach and I find it difficult to see how it could produce something having the explanatory power of color magnetic flux tubes.

2.2 Generalized Feynman diagrams and string-parton duality as gauge-gravity duality

Generalized Feynman diagrams reduce to generalized braid diagrams [14]. Braid strands have unique identification as so called Legendrean braids identifiable as boundaries of string world sheets which are minimal surfaces for which area form is proportional to Kähler flux. One can speak about sub-manifold braids.

There are no $n > 2$-vertices at the fundamental braid strand level. Together with the fact that in zero energy ontology (ZEO) all virtual states consist of on mass shell massless states assignable to braid strands, this means that UV and IR infinities are absent. All physical states are massive bound states of massless on mass shell states. Even photon, gluon, and graviton have small masses. No Higgs is needed since for the generalized Feynman diagrams the condition eliminating unphysical polarizations eliminates only the polarization parallel to the projection of the total momentum of the particle to the preferred plane M^2 defining the counterpart of the plane in which one usually projects Feynman diagrams.

The crossings for the lines of non-planar Feynman diagrams represent generalization of the crossings of the braid diagrams and integrable M^2 QFT is suggested to describe the braiding algebraically. This would mean that non-planar diagrams are obtained from planar ones by braiding operations and generalized Feynman diagrams might be constructucted like knot invariants by gradually trivializing the braid diagram. This would allow to reduce the construction of also non-planar Feynman amplitudes to twistorial rules.

One can interpret gluons emission by quark as an emission of meson like state by hadron. This duality is exact and does not require $N_c \to \infty$ limit allowing to neglect non-planar diagrams as AdS/CFT correspondence requires. The interpretation is in terms of duality: one might call this duality parton-hadron duality, gauge-gravity duality, or particle-string duality.

2.3 Q^2 dependent quark distribution functions and fragmentation functions in zero energy ontology

Factorization of the strong interaction physics in short and long time scales is one of the basic assumptions of jet QCD and originally motivated by parton model which preceded QCD [6, 7]. The physical motivation for the factorization in higher energy collision is easy to deduce at the level of parton model. By Lorentz contraction of colliding hadrons look very thin and by time dilation the collision time is very long in cm system. Therefore the second projectile moves in very short time through the hadron and sees the hadron in frozen configuration so that the state of the hadron can be thought of as being fixed during collision and partons interact independently. This looks very clear intuitively but it is not at all clear whether QCD predicts this picture.

2.3.1 Probabilistic description of quarks in ZEO

Probabilistic description requires further assumptions. Scattering matrix element is in good approximation sum over matrix elements describing scattering of partons of hadron from -say- the partons of another hadron or from elecron. Scattering amplitudes in the sum reduce to contractions of current matrix elements with gluon or gauge boson propagator. Scattering probability is the square of this quantity and contains besides diagonal terms for currents also cross terms. Probabilistic description demands that the sum of cross terms can be neglected. Why the phases of the terms in this sum should vary randomly? Does QCD really imply this kind of factorization?

Could the probabilistic interpretation require and even have a deeper justification?

1. p-Adic real correspondence to be discussed in more detail below suggest how to proceed. Quarks with different p-adic mass scales can correspond to different p-adic number fields with real amplitudes or probabilities obtained from their p-adic counterparts by canonical identificaton. Interference makes sense only for amplitudes in the same number field. Does this imply that cross terms involving different p-adic primes cannot appear in the scattering amplitudes?

2. Should one assume only a density matrix description for the many quark states formed from particles with different values of p-adic prime p? If so the probabilistic description would be un-avoidable. This does not look an attractive idea as such. Zero energy ontology however replaces density matrix with M-matrix defined as the hermitian square root of the density matrix multiplied by a universal unitary S-matrix. The modulus squared of M-matrix element gives scattering probability.

   One can one imagine that M-matrix at least approximately decomposes to a tensor product of M-matrices in different length scales: these matrices could correspond to different number fields before the map to real numbers and probabilities could be formed as "numbers" in the tensor product of p-adic number fields before the mapping to real numbers by canonical identification.

   In finite measurement resolution one sums over probabilities in short length scales so that the square of M-matrix in short scale gives density matrix. Could this lead to a probabilistic description at quark level? Distribution functions and fragmentation functions could indeed correspond to these probabilities since they emerge in QCD picture from matrix elements between initial and final states of quark in scattering process. Now these states correspond to the positive and negative energy parts of zero energy state.

2.3.2 Q^2 dependence of distribution and fragmentation functions in ZEO

The probabilistic description of the jet QCD differs from that of parton model in that the parton distributions and fragmentation functions depend on the value of Q^2, where Q is defined as the possibly virtual momentum of the initial state of the parton level system. Q could correspond to the momentum of virtual photon annihilation to quark pair in the annihilation of e^+e^- pair to hadrons, to the virtual photon decaying to $\mu^+\mu^-$ pairs and emitted by quark after quark-quark scattering in Drell-Yan process, or to the momentum of gluon or quark giving rise to a jet, ... What is highly non-trivial is that distribution and fragmentation functions are universal in the sense that they do not depend on the scattering process. Furthermore, the dependence on Q^2 can be determined from renormalization group equations [6, 7].

What does Q^2s dependence mean in TGD framework?

1. In partonic model this dependence looks strange. If one thinks the scattering at quantum level, this dependence is very natural since it corresponds to the dependence of the matrix elements of current operators on the momentum difference between quark spinors in the matrix element. In QCD framework Q^2 dependence is not mysterious. It is the emergence of probabilistic description which is questionable in QFT framework.

2. One could perhaps say that Q^2 represents resolution and that hadron looks different in different resolutions. One could also say that there is no hadron "an sich": what hadron looks like depends on the process used to study it.

3. In zero energy ontology the very notion of state changes. Zero energy state corresponds to physical event or quantum superposition of them with M-matrix defining the time like entanglement coefficient and equal to a hermitian square root of density matrix and S-matrix. In this framework different values of Q correspond to different momentum differences for spinor pairs appearing in the matrix element of the currents and Q^2 dependence of the probabilistic description is very natural. The universality of distribution and fragmentation functions follows in zero energy ontology if one assumes the factorization of the dynamics in different length scales. This should follow from the universality of the S-matrix in given number field (in given p-adic length scale).

3 p-Adic physics and strong interactions

p-Adic physics provides new insights to hadron physics not provided by QCD.

3.1 p-Adic real correspondence as a new symmetry

The exactness of the gauge-gravity duality suggests the presence of an additional symmetry. Perhaps the non-converging perturbative expansion at long scales could make sense after all in some sense. p-Adic-real duality suggests how.

1. The perturbative expansion is interpreted in terms of p-adic numbers and the effective coupling constant g^2MN_c is interpreted as p-adic number which for some preferred primes is proportional to the p-adic prime p and therefore p-adically small. Hence the expansion convergeces rapidly p-adically. The p-adic amplitudes would be obtained by interpreting momenta as p-adic valued momenta. If the momenta are rationals not divisible by any non-trivial power of p the canonical identification maps the momenta to themselves. If momenta are small rationals this certainly makes sense but does so also more generally.

2. The converging p-adic valued perturbation series is mapped to real numbers using the generalization of the canonical identecation appearing in quantum arithmetics [15]. The basic rule is simple: replace powers of p with their inverses everywhere. The coefficients of powers of p are however allowed to be rationals for which neither numerator or denominator is divisible by p. This modification affects the predictions of p-adic mass calculations only in a negligible manner.

3. p-Adic-real duality has an interpretation in terms of cognition having p-adic physics as a correlat: it maps the physical system in long length scale to short length scales or vice versa and the image of the system assigning to physical object thought about it or vice versa provides a faithful representation. Same interpretation could explain also the successful p-adic mass calculations. It must be emphasized that real partonic 2-surfaces would obey effective p-adic topology and this would be due to the large number of common points shared by real and p-adic partonic 2-surfaces. Common points would be rational points in the simplest picture: in quantum arithmetics they would be replaced by quantum rationals.

p-Adic-real correspondence generalizes the canonical identification used to map the p-adic valued mass squared predicted by p-adic thermodynamics as the analog of thermal energy to a real number. An important implication is that *p-adic mass squared value is additive* [9].

1. For instance, for mesons consisting of pairs of quark and its antiquark the values of p-adic mass squared for quark and antiquark are additive and this sum is mapped to a real number: this kind of additivity was observed already at early days of hadron physics but there was no sensible interpretation for it. In TGD framework additivity of the scaling generator of Virasoro algebra is in question completely analogous to the additivity of energy.

2. For mesons consisting of quarks labelled by different value of p-adic prime p, one cannot sum mass squared values since they belong to different number fields. One must map both of them first to real numbers and after this sum real mass valueas (rather than mass squared values).

This picture generalizes. Only p-adic valued amplitudes belonging to same p-adic number field and therefore corresponding to the same p-adic length scales can be summed. There is no interference between amplitudes corresponding to different p-adic scales.

1. This could allow to understand at deeper level the somewhat mysterious and ad hoc assumption of jet QCD that the strong interactions in long scales and short scales factorize at the level of probalities. Typically the reaction rate is expressible using products of probabilities. The probability for pulling out quarks from colliding protons (non-perturbative QCD), the probability describing parton level particle reaction (perturbative QCD), and the probability that the scattering quarks fragment to the final state hadrons (non-perturbative QCD). Ordinary QCD would suggest the analog of this formula but with probability amplitudes replacing probabilities and in order to obtain a probabilitic description one must assume that various interference terms sum up to zero (decoherence). p-Adic-real duality would predict the relative docorence of different scales as an exact result. p-adic length scale hypothesis would also allow to define the notion of scale precisely. From the stance provided by TGD it seems quite possible that the standard belief that jet QCD follows from QCD is simply wrong. The repeated emphasis of this belief is of course part of the liturgy: it would be suicidical for a specialist of jet QCD to publicly conjecture that jet QCD is more than QCD.

2. The number theoretical decoherence would be very general and could explain the somewhat mysterious decoherence phenomenon. Decoherence could have as a number theoretical correlate the decomposition of space-time surfaces to regions characterized by different values of p-adic primes. In given region the amplitudes would be constructed as p-adic valued amplitudes and then mapped to real amplitudes by canonical identification. A space-time region characterized by given p would be the number theoretical counterpart of the coherence region. The regions with different value of p would behave classically with respect to each other and region with given p could understand what happens in regions with different values of p using classical probability. This would also the resolve paradoxes like whether the Moon is there when no-one is looking. It could also mean that the anticommutative statistics for fermions holds true only for fermionic oscilator operators associated with a space-time region with given value of p-adic prime p. Somewhat ironically, p-adic physics would bring quantum reality much nearer to the classical reality.

3.2 Logarithmic corrections to cross sections and jets

Even in the perturbative regime exclusive cross sections for parton-parton scattering contain large logarithmic corrections of form $log(Q^2/\mu^2)$ [6], where Q is cm energy and μ is mass scale which could be assigned to quark or - perhaps more naturally - to jet. These corrections spoil the convergence of the perturbative expansion at $Q^2 \rightarrow \infty$ limit. One can also say that the cross sections are singular at the limit of vanishing quark mass: this is the basic problem of the twistor approach.

For "infra-red safe" cross sections the logarithmic singularities can be eliminated by summing over all initial and final states not distinguishable from each other in the energy and angle resolutions available. It is indeed impossible to distinguish between quark and quark and almost collinear soft gluon and one must therefore sum over all final states containing soft gluons. A simple example about IR safe cross section is the cross section for e^+e^- annihilation to hadrons in finite measurement resolution, from which logarithms $log(Q/\mu)$ disappear.

In hadronic reactions jets are studied instead of hadrons. IR safety is one criterion for what it is to be a jet. Jet can be imagined to result as a cascade. Parton annihilates to a pair of partons, resulting partons annihilate into softer partons, and so on... The outcome is a cascade of increasingly softer partons. The experimental definition of jet ris constrained by a finite measurement resolution for energy and angle, and jet is parameterized by the cm energy Q, by the energy resolution ϵ, and by the jet opening angle δ: apart from a fraction ϵ all cm energy Q of the jet is contained within a cone with opening angle δ. According to the estimate [6] the mass scale of the jet resulting at the k:th step of the cascade is rouhgly $\delta^k Q$.

What could be the counterpart for this description of jets in TGD framework?

1. Jet should be a structure with a vanishing total Kähler magnetic charge bound by flux tubes to a connected hadron like structure. By hadron-parton duality gluon emission from quark has interpretation as a meson emission from hadron: jets could be also interpreted as collections of hadrons at different space-time sheets. Reconnection process could play a key role in the decay of jet to hadrons. p-Adic length scale hypothesis suggests the interpretation of jets as hadron like objects which are off mass shell in the sense that the p-adic prime $p \simeq 2^k$ characterizing the jet space-time sheets is smaller than M_{107} characterizing the final state hadrons. One could say that jets represent p-adically hot hadron-like objects which cool and decay to hadrons. If so, the transition from M_{107} hadron physics to M_{89} hadron physics could be rather smooth. The only new thing would be the abnormally long lifetime of M_{89} hadrons formed as intermediate states in the process.

2. p-Adic length scale hypothesis suggests that the p-adic length scale assignable to the parton (hadron like object) at the $k+1$:th step is by power of $\sqrt{2}$ longer than that associated with k:th step: $p \rightarrow p_{next} \simeq 2 \times p$ is the simplest possibility. The naive formula $Q(k+1) \sim \delta \times Q(k)$ would probably require a generalization to $Q(k+1) \sim 2^{-r/2} \times Q(k)$, r integer with $\delta = 2^{-nr/2} \times 2\pi$, n an integer. $r = 1$ would be the simplest option. The cascade at the level of jet space-time sheets would stop when the p-adic length scale corresponds to M_{107}, which corresponds to .5 GeV mass scale. At the level of quarks one can imagine a similar cascade stopping at p-adic length scales corresponding to the mass scale about 5 MeV for u and d quarks.

3. Zero energy ontology brings in natural IR cutoffs since also gluons have small mass. Final and initial state quarks could emit only a finite number of gluons as brehmstrahlung and soft gluons could not produce IR divergences.

4. The notion of finite measurement resolution in QCD involves the cone opening angle δ and energy resolution characterized by ϵ. In TGD framework the notion of finite measurement resolution is fundamental and among other things implies the description in terms of braids. Could TGD simplify the QCD description for finite measurement resolution? Discretization in the space of momentum directions is what comes in mind first and is strongly suggested also by the number theoretical vision. One would not perform integral over the cone but sum over all events producing quark and a finite number of collinear gluons with an upper bound form them deducible from cm energy and gluon mass. For massive gluons the number of amplitudes to be summed should be finite and the jet cascade would have only finite number of steps.

Could number theoretical constraints allow additional insights? Are the logarithmic singularities present in the p-adic approach at all? Are they consistent with the number theoretical constraints?

1. The p-adic amplitudes might well involve only rational functions and thus be free of logarithmic singularities resulting from the loop integrals which are dramatically simplified in zero energy ontology by on mass shell conditions for massless partonic 2-surfaces at internal lines.

2. For the sheer curiosity one can consider the brehmstrahlung from a quark characterized by p-adic prime p. Do the logarithms $log((Q^2/\mu^2)$, where μ^2 is naturally p-adic mass scale, make sense p-adically? This is the case of one has $Q^2/\mu^2 = (1+O(p))$. The logarithm would be of form $O(p)$ and p-adically very small. Also its real counterpart obtained by canonical identification would be very small for $O(p) = np$, $n << p$. For $Q^2/mu^2 = m(1+O(p))$, m integer, one must introduce an extension of p-adic numbers guaranteeing that $log(m)$ exists for $1 < m < p$. Only single logarithm $log(a)$ and its powers are needed since for primitive roots a of unity one as $m = a^n \ mod \ p$ for some n. Since the powers of $log(a)$ are algebraically independent, the extension is infinite-dimensional and therefore can be questioned.

3. For the original form of the canonical identification one would have $O(p) = np$. In the real sense the value of Q^2 would be gigantic for $p = M_{107}$ (say). p-Adically Q^2 would be extremely near to μ^2. The modified form of canonical identification replaces pinary expansion $x = \sum x_n p^n$, $0 \leq x_n < p$, of the p-adic integer with the quantum rational $q = \sum q_n p^n$, where q_n are quantum rationals, which are algebraic numbers involving only the quantum phase $e^{i2\pi/p}$ and are not divisible by any power of p [15].

   This would allow physically sensible values for $Q^2/mu^2 = 1 + qp + ..$ in the real sense for arbitrarily large values of p-adic prime. In the canonical identification they would be mapped to $Q^2/mu^2 = 1 + q/p + ..$ appearing in the scattering amplitude. For q/p near unity logarithmic corrections could be sizable. If qp is of order unity as one might expect, the corrections are of order q/p and completely negligible. Even at the limit $Q^2 \rightarrow \infty$ understood in the real sense the logarithmic corrections would be always negligible if Q^2 is p-adic quantum rational. Similar extremely rapid convergence characterizes p-adic thermodynamics [6] and makes the calculations practically exact. Smallness of logarithmic corrections quite generally could thus distinguish between QCD and TGD.

4. In p-adic thermodynamics the p-adic mass squared defined as a thermal average of conformal weight is a ratio of two quantities infinite as real numbers. Even when finite cutoff of conformal weight is introduced one obtains a ratio of two gigantic real numbers. The limit taking cutoff for conformal weight to infinity does not exist in real sense. Does same true for scattering amplitudes? Quantum arithmetics would guarantee that canonical identification respects discretized symmetries natural for a finite measurement resolution.

3.3 p-Adic length scale hypothesis and hadrons

Also p-adic length scale hypothesis distinguishes between QCD and TGD. The basic predictions are scaled variants of quarks and the TGD variant of Gell-Mann Okubo mass formula indeed assumes that in light hadrons quarks can appear in several p-adic mass scales. One can also imagine the possibility that quarks can have short lived excitations with non-standard p-adic mass scale. The model for tau-pion needed to explain the 3-year old CDF anomaly for which additional support emerged recently, assumes that color octet version of tau lepton appears as three different mass scales coming as octaves of the basic mass scale [13]. Similar model has been applied to explain also some other other anomalies.

M_{89} hadron physics corresponds to a p-adic mass scale in TeV range [7]:: the proton of M_{89} hadron physics would have mass near 500 GeV if naive scaling holds true. The findings from Tevatron and LHC have provided support for the existence of M_{89} mesons and the bumps usually seen as evidence for Higgs would correspond to the mesons of M_{89} hadron physics. It is a matter of time to settle whether M_{89} hadron physics is there or not.

4 Magnetic flux tubes and and strong interactions

Color magnetic flux tubes carrying Kähler magnetic monopole flux define the key element of quantum TGD and allow precise formulation for the non-perturbative aspects of strong interaction physics.

4.1 Magnetic flux tube in TGD

The following examples should make clear that magnetic flux tubes are the central theme of entire TGD present in all scales.

1. Color magnetic flux tubes are the key element of hadron physics according to TGD and will be discussed in more detail below.

2. In TGD Universe atomic nucleus is modelled as nuclear string with nucleons connected by color magnetic flux tubes which have length of order Compton length of u and d quark [12, 8]. One of the basic predictions is that the color flux tubes can be also charged. This predicts a spectrum of exotic nuclei. The energy scale of these states could be small and measured using keV as a natural unit. These exotic states with non-standard value of Planck constant giving to the flux tubes the size of the atom and the scaling up electroweak scale to atomic scale could explain cold fusion for which empirical support is accumulating.

3. Magnetic flux tubes are also an essential element in the model of high T_c super conductivity. The transition to super-conductivity in macroscopic scale would be a percolation type process in which shorter flux tubes would combine at critical point to form long flux tubes so that the supra currents could flow over macroscopic distances [2]. The basic prediction is that there are two critical temperatures. Below the first one the super-conductivity is possible for "short" flux tubes and at lower critical temperature the "short" flux tubes fuse to form long flux tubes. Two critical temperatures have been indeed observed.

4. Magnetic flux tubes carrying dark matter are the corner stone of TGD inspired quantum biology, where the notion of magnetic body is in a central role. For instance, the vision about DNA as topological quantum computer is based on the braiding of flux tubes connecting DNA nucleotides and the lipids of nuclear or cellular membrane [3].

5. In the very early TGD inspired cosmology [11] string like objects with 2-D M^4 projection are the basic objects. Cosmic evolution means gradual thickening of their M^4 projection and flux conservation means that the flux weakens. If the lengths of the flux tubes increase correspondingly, magnetic energy is conserved. Local phase transitions increasing Planck constant locally can occur and led to a thickening of the flux tube and liberation of magnetic energy as radiation which later gives rise to radiation and matter. This mechanism replaces the decay of the energy of inflation field to radiation as a mechanism giving rise to stars and galaxies [10]. The magnetic tension is responsible for the negative pressures explaining accelerated expansion and magnetic energy has identification as the dark energy.

4.2 Reconnection of color magnetic flux tubes and non-perturbative aspects of strong interactions

The reconnection of color magnetic flux tubes is the key mechanism of hadronization and a slow process as compared to quark gluon emission.

1. Reconnection vertices have interpretation in terms of stringy vertices $AB + CD \rightarrow AD + BC$ for which interiors of strings serving as representatives of flux tubes touch. The first guess is that reconnection is responsible for the low energy dynamics of hadronic collisions.

2. Reconnection process takes place for both the hadronic color magnetic flux tubes and those of quarks and gluons. For ordinary hadron physics hadrons are characterized by Mersenne prime M_{107}. For M_{89} hadron physics reconnection process takes place in much shorter scales for hadronic flux tubes.

3. Each quarks is characterized by a p-adic length scale: this scale characterizes the length scale of the magnetic bodies of the quark. Therefore reconnection at the level of the magnetic bodies of quarks take places in several time and length scales. For top quark the size scale of magnetic body is very small as is also the reconnection time scale. In the case of u and d quarks with mass in MeV range the size scale of the magnetic body would be of the order of electron Compton length. This scale assigned with quark is longer than the size scale of hadrons characterized by M_{89}. Classically this does not make sense but in quantum theory Uncertainty Principle predicts it from the smallness of the light quark masses as compared to the hadron mass. The large size of the color magnetic body of quark could explain the strange finding about the charge radius of proton [7].

4. Reconnection process in the beginning of proton-proton collision would give rise to the formation of jets identified as big hadron like entities connected to single structure by color magnetic flux tubes. The decay of jets to hadrons would be also reconnection process but in opposite time direction and would generate the hadrons in the final state (negative energy part of the zero energy state). The short scale process would be the process in which partons scatter from each other and produce partons. These processes would have a dual description in terms of hadronic reactions.

5. Factorization theorems are the corner stone of jet QCD. They are not theorems in the mathematical sense of the word and one can quite well ask whether they really follow from QCD

or whether they represent correct physical intuitions transcending the too rigid framework provided by QCD as a gauge theory. Reconnection process would obviously represent the slow non-perturbative aspects of QCD and occur both for the flux tubes associated with quarks and those assigmnable to hadrons. Several scales would be present in case of quarks corresponding to p-adic length scales assigned to quarks which even in light hadrons would depend on hadron [9]. The hadronic p-adic length scale would correspond to Mersenne prime M_{107}. One of the basic predictions of TGD is the existence of M_{89} hadron physics and there are several indications that LHC has already observed mesons of this hadron physics. p-Adic-real duality would provide a further mathematical justification for the factorization theorems as a consequence of the fact that interference between amplitudes belong to different p-adic number fields is not possible.

Reconnection process is not present in QCD although it reduces to string re-connection in the approximation that partonic 2-surfaces are replaced by braids. An interesting signature of 4-D stringyness is the knotting of the color flux tubes possible only because the strings reside in 4-D space-time. This braiding ad knotting could give rise to effects not predicted by QCD or at least its description using AdS/CFT strings. The knotting and linking of color flux tubes could give rise to exotic topological effects in nuclear physics if nuclei are nuclear strings.

4.3 Quark gluon plasma

A detailed qualitative view about quark-gluon plasma in TGD Universe can be found from [14].

1. The formation of quark gluon plasma would involve a reconnection process for the magnetic bodies of colliding protons or nuclei in short time scale due to the Lorentz contraction of nuclei in the direction of the collision axis. Quark-gluon plasma would correspond to a situation in which the magnetic fluxes are distributed in such a manner that the system cannot be decomposed to hadrons anymore but acts like a single coherent unit. Therefore quark-gluon plasma in TGD sense does not correspond to the thermal quark-gluon plasma in the naive QCD sense in which there are no long range correlations. Ideal quark gluon plasma is like single very large hadron rather than a gas of partons bound to single unit by the conservation of magnetic fluxes connecting the quarks and antiquarks.

2. Long range correlations and quantum coherence suggest that the viscosity to entropy ratio is low as indeed observed [7]. The earlier arguments suggest that the preferred extremals of Kähler action have interpretation as perfect fluid flows [5]. This means at given space-time sheet allows global time coordinate assignable to flow lines of the flow and defined by conserved isometry current defining Beltrami flow. As a matter fact, all conserved currents are predicted to define Beltrami flows. Classically perfect fluid flow implies that viscosity, which is basically due to a mixing causing the loss of Beltrami property, vanishes. Viscosity would be only due to the finite size of space-time sheets and the radiative corrections describable in terms of fractal hierarchy CDs within CDs. In quantum field theory radiative corrections indeed give rise to the absorbtive parts of the scattering amplitudes. In the case of quark gluon plasma viscosity is very large although the viscosity to entropy ratio is near to its minimum $\eta/s = \hbar/4\pi$ predicted by AdS/CFT correspondence. In TGD framework the lower bound is smaller [14].

3. There are good motivations for challenging the belief that QCD predicts strongly interacting quark gluon plasma having very large viscosity begin more like glass than a gas of partons. The reason for the skepticism is that classical color magnetic fields carrying magnetic monopole charges are absent. Also the notion of many-sheeted space-time is essential element of the description. The recent evidence for the failure of AdS/CFT correspondence in the description of jet fragmentation in plasma support the pessimistic views.

4.4 Super-symmetry and hadron physics

So called X and Y bosons are mysterious creatures having no obvious place in the quark model. They seem to consist of charmed quarks but they decay systematics suggest that something differentiates between these quarks and charmed quarks in the ordinary charmonium states. The TGD proposal [7] is that the super-partners of quarks have same the p-adic mass scale and even mass as quarks. There would be however a mixing between mesons and smesons and for light mesons this mixing would be very large making the second eigen state of mass squared matrix tachyonic and kicking it out of spectrum so that light mesons would be strong mixtures of mesons and smesons. For heavier quarks such as c the mixing would not be so large since color couplings strength would be reasonably small and one would obtain both mesons and smesons. The prediction is that also the mesons consisting of bbar pair would have smeson counterparts.

A further obvious objection is that intermediate gauge boson decay widths exclude light fermions. TGD based view about dark matter as ordinary particles with non-standard value of Planck constant and the fact that particles with different values of Planck constant cannot appear in the same vertex, allows to circumvent this objection. The superpartners would correspond to non-standard value of Planck constant.

Same picture about squarks would apply to M_{89} hadron physics and the failure to detect spartners at LHC would be the use of wrong signatures. Shadronization would be much faster process than the decay of squarks to quarks and electro-weak gauge bosons and missing energy so that these events would not be observed. Shadrons would in turn decay to hadrons by gluino exchanges.

This looks nice but there are objections.

1. The first objection relates to the tachyonicity. Mesons and smesons consisting of squark pair mix and for large α_s the mixing is large and can indeed make second eigenvalue of the mass squared matrix negative. If so, these states disappears from spectrum. At least to me this looks however somewhat unaesthetic.

   Luckily, the transformation of second pion-like state to tachyon and disappearance from spectrum is not the only possibility. After a painful search I found experimental work [1] claiming the existence of states analogous to ordinary pion with masses 60, 80, 100, 140,.... MeV. 100 GeV is first downwards half-octave of pion with mass about 140 MeV and also second half octave is there. Could it be that one of these states is spion predicted by TGD SUSY for ordinary hadrons? (But what about other states? They are not spartners: what are they?)

2. The second objection relates to the missing energy. SUSY signatures involving missing energy have not been observed at LHC. This excludes standard SUSY candidates and could do the same in the case of TGD. In TGD framework the missing energy would be eventually right handed neutrinos resulting from the decays of sfermions to fermion and sneutrino in turn decaying to neutrino and right handed neutrino. The above naive argument says that strong interactions are faster than weak decays of squarks to quark and spartner of weak boson whose decay would produce the usual signatures of SUSY so that shadronization would take place instead of production of the SUSY signatures. The problem with this argument is that the weak decays of squarks producing right handed neutrinos as missing energy are still there!

   This objection forces to consider the possibility that covariantly constant right handed neutrino which generates SUSY is replaced with a color octet. Color excitations of leptons of leptohadron hypothesis would be sleptons which are color octets so that SUSY for leptons would have been seen already at seventies in the case of electron. The whole picture would be nicely unified. Sleptons and squark states would contain color octet right handed neutrino the same wormhole throats as their em charge resides. In the case of squarks the tensor product $3 \otimes 8 = 3 + \overline{6} + 15$ would give several colored exotics. Triplet squark would be like ordinary quark with respect to color.

   Covariantly constant right-handed neutrino as such would represent pure gauge symmetry, a super-generator annihilating the physical states. Something very similar can occur in the reduction of ordinary SUSY algebra to sub-algebra familiar in string model context. By color confinement missing energy realized as a color octet right handed neutrino could not be produced and one could overcome the basic objections against SUSY by LHC.

This is view about TDG SUSY is just one possibility. The situation is not completely settled and one must keep mind open.

4.5 Exotic pion like states: "infra-red" Regge trajectories or Shnoll effect?

TGD based view about non-perturbative aspects of hadron physics (see this) relies on the notion of color magnetic flux tubes. These flux tubes are string like objects and it would not be surprising if the outcome would be satellite states of hadrons with string tension below the pion mass scale. One would have kind of infared Regge trajectories satisfying in a reasonable approximation a mass formula analogous to string mass fomula. What is amazing that this phenomenon could allow new interpretation for the claims for a signal interpreted as Higgs at several masses (115 GeV by ATLAS, at 125 GeV by ATLAS and CMS, and at 145 GeV by CDF). They would not be actually statistical fluctuations but observations of states at IR Regge trajectory of pion of M_{89} hadron physics!

Consider first the mass formula for the hadrons at IR Regge trajectories.

1. There are two options depending on whether the mass squared or mass for hadron and for the flux tubes are assumed to be additive. p-Adic physics would suggest that if the p-adic primes characterizing the flux tubes associated with hadron and hadron proper are different then mass is additive. If the p-adic prime is same, the mass squared is additive.

2. The simplest guess is that the IR stringy spectrum is universal in the sense that m_0 does not depend on hadron at all. This is the case if the flux tubes in question correspond to hadronic space-time sheets characterized by p-adic prime M_{107} in the case of ordinary hadron physics. This would give for the IR contribution to mass the expression

$$m^2 = \sqrt{m_0^2 + nm_1^2} \ .$$

3. The net mass of hadron results from the contribution of the "core" hadron and the stringy contribution. If mass squared is additive, one obtains $m(H_n) = \sqrt{m^2(H_0) + m_0^2 + nm_1^2}$, where H_0 denotes hadron ground state and H_n its excitation assignable to magnetic flux tube. For heavy hadrons this would give the approximate spectrum

$$m(H_n) \simeq m(H_0) + \frac{m_0^2 + nm_1^2}{2m(H_0)} \ .$$

   The mass unit for the excitations decreases with the mass of the hadron.

4. If mass is additive as one indeed expects since the p-adic primes characterizing heavy quarks are smaller than hadronic p-adic prime, one obtains

$$m(H_n) = m^(H_0) + \sqrt{m_0^2 + nm_1^2} \ .$$

   For $m_0^2 \gg m_1^2$ one has

$$m(H_n) = m^(H_0) + m_0 + n\frac{m_1^2}{2m_0} \ .$$

   If the flux tubes correspond to p-adic prime. This would give linear spectrum which is same for all hadrons.

There is evidence for this kind of states.

The experimental claim of Tatischeff and Tomasi-Gustafsson is that pion is accompanied by pion like states with mass 60, 80, 100, 140, 181, 198, 215, 227.5, and 235 MeV means that besides spion also other pion like states should be there. Similar satellites have been observed for nucleons with ground state mass 934 MeV: the masses of the satellites are 1004, 1044, 1094 MeV. Also the signal cross sections for Higgs to gamma pairs at LHC [2, 3] suggest the existence of several pion and spion like states, and this was the reason why I decided to to again the search for data about this kind of states (I remembered vaguely that Tommaso Dorigo had talked about them but I failed to find the posting). What is their interpretation? One can imagine two explanations which could be also equivalent.

1. The states could be "infrared" Regge trajectories assignable to magnetic flux tubes of order Compton length of u and d quark (very long and with small string tension) could be the explanation. Hadron mass spectrum would have microstructure. This is something very natural in many-sheeted space-time with the predicted p-adic fractal hierarchy of physics. This conforms

with the proposal that all baryons have the satellite states and that they correspond to stringy excitations of magnetic flux tubes assignable to quarks. Similar fine structure for nuclei is predicted for nuclei in nuclear string model [8]. In fact, the first excited state for ^4He has energy equal to 20 MeV not far from the average energy difference 17.5 MeV for the excited states of pion with energies 198, 215, and 227.5 MeV so that this state might correspond to an excitation of a color magnetic flux tube connecting two nucleons.

2. The p-adic model for Shnoll effect [1] relies on universal modification of the notion of probability distribution based on the replacement of ordinary arithmetics with quantum arithmetics. Both the rational valued parameters characterizing the distribution and the integer or rational valued valued arguments of the distribution are replaced with quantum ratinals. Quantum arithmetics is characterized by quantum phase $q = exp(i2\pi/p)$ defined by the p-adic prime p. The primes in the decomposition of integer are replaced with quantum primes except p which remains as such. In canonical identification powers of p are mapped to their inverses. Quite generally, distributions with single peak are replaced with many peaked ones with sub-peak structure having number theoretic origin. A good example is Poisson distribution for which one has $P(n) = \lambda^n/n!$. The quantum Poisson distribution is obtained by replacing λ and $n!$ with their quantum counterparts. Quantum Poisson distribution could apply in the case of resonance bump for which the number of count in a given mass squared interval is integer valued variable.

   There are objections against Shnoll effect based explanation.

   (a) If the p-adic prime assignable to quark or hadron characterizes quantum arithmetics it is not distinguishable from ordinary arithmetics since the integers involved are certainly much smaller than say $M_{107} = 2^{107} - 1$. In the case of nuclear physics Shnoll effect involves small primes so that this argument is not water tight. For instance, if $p = 107$ defines the quantum arithmetics, the effects would be visible in good enough resolution and one might even expect variations in the bump structure in the time scale of year.

   (b) The effect is present also for nucleons but the idea about a state with large width splitting into narrower bumps does not fit nicely with the stability of proton.

   For Higgs like signals IR-Regge trajectories/Shnoll effect would be visible as a splitting of wide bumps for spion and pion of M_{89} physics to sub-bumps. This oscillatory bumpy structure is certainly there but is regarded as a statistical artifact. It would be really fascinating to see this quantum deformation of the basic arithmetics at work even in elementary particle physics.

Second piece of evidence comes from two articles by Eef van Beveren and George Rupp. The first article is titled *First indications of the existence of a 38 MeV light scalar boson* [4]. Second article has title *Material evidence of a 38 MeV boson* [5]. The basic observations are following. The rate for the annihilation $e^+ + e^- \rightarrow u\overline{u}$ assignable to the reaction $e^+ + e^- \rightarrow \pi^+\pi^-$ has a small periodic oscillation with a period of 78±2 MeV and amplitude of about 5 per cent. The rate for the annihilation $e^+ + e^- \rightarrow b\overline{b}$, assignable to the reaction $e^+ + e^- \rightarrow \Upsilon\pi^+\pi^-$ has similar oscillatory behavior with a period of 73 ± 3 MeV and amplitude about 12.5 per cent. The rate for the annihilation $p\overline{p} \rightarrow c\overline{c}$ assignable to the reaction $e^+ + e^- \rightarrow J/\Psi\pi^+\pi^-$ has similar oscillatory behavior with period of 79 ± 5 MeV and amplitude .75 per cent.

In these examples universal Regge slope is consistent with the experimental findings and supports additive mass formula and the assignment of IR Regge trajectories to hadronic flux tubes with fixed p-adic length scale. There is also consistency with the experiments of Tatitscheff and Tomasi-Gustafsson.

What does one obtain if one scales up the IR Regge trajectories to the M_{89} which replaces Higgs in TGD framework?

1. In the case of M_{89} pion the mass differences 20 MeV and 40 MeV appearing in the IR Regge trajectories of pion would scale up to 10 GeV and 20 GeV respectively. This would suggest the spectrum of pion like states with masses 115, 125, 145, 165 GeV. What makes this interesting that ATLAS reported during last year evidence for a signal at 115 GeV taken as evidence for Higgs and CDF reported before this signal taken as evidence for Higgs around 145 GeV! 125 GeV is the mass of the the most recent Higgs candidate. Could it be that all these reported signals have been genuine signals - not for Higgs- but for M_{89} pion and corresponding spion consisting of squark pair and its IR satellites?

2. I the case of M_{89} hadron physics the naive scaling of the parameters m_0 and m_1 by factor 512 would scale 38 MeV to 19.5 GeV.

5 Higgs or M_{89} hadron physics?

The newest results about Higgs search using 4.9/fb of data were published yesterday and there are many articles in arXiv. The overall view is that there is evidence for something around 125 GeV. . The evidence comes basically from what might be interpreted as decays of Higgs to $\gamma\gamma$. There are some ZZ and WW events. CMS represented also data for more rare events including also b quark pairs and tau lepton pairs. There are also indications about something at higher masses and the interpretation of them depends on the belief system of the theoretician.

In TGD framework Higgs like states seem to be un-necessary. Zero energy ontology predicts that all states with spin 1 are massive and the third polarization state is allowed by the generalization of the gauge condition excluding the third polarization in the case of massless states [14]. If one assumes Higgs like states, the particles which become massive "eat" all of them. Also photon, gluon, and graviton become massive and the small mass allows to get rid of infrared divergences plaguing gauge theories.

The basic question is whether the data could be interpreted as signatures of Higgs or of M_{89} hadron physics. This question is discussed in detail in [7]. Here I represent just the main arguments.

1. The basic observation is that the generalization of PCAC hypothesis leads to very similar predictions for the direct couplings of pseudo-scalar mesons as Higgs has and the decay rates are of the same form. The generalization of the hadronic sigma model with vacuum expectation value of sigma field replacing that of Higgs field makes it easy to understand the close resemblance but does not seem to be absolutely necessary unless one wants additional predictions. What is remarkable that the vacuum expectation of sigma field equals apart from sign to W boson mass.

2. If one believes in the indications about structures at higher masses than 125 GeV, one must conclude that standard Higgs hypothesis fails. M_{89} hadron physics might be able to explain these structures but the coupling X defined by $f_\pi = X m_\pi$ would be smaller for these higher pion-like states. One of them would be around 139 GeV.

3. TGD suggests that the spartners of quarks correspond to the same mass scale as quarks. The pion-like states with masses 139 GeV and 125 GeV would correspond to pion and spion (pair of squarks) which could have suffered mixing by exchange of gluino. The original proposal that spartners are generated by covariantly constant right-handed neutrino and antineutrino has the problem that it might produce just the same missing energy signatures of SUSY as ordinary SUSY and thus be excluded experimentally.

   The simplest way out is the assumption that covariantly constant neutrino generates gauge supersymmetry and thus creates zero norm states. It would be color octet state of neutrino that would generate the dynamical supersymmetry and states with a non-vanishing norm. Color confinement would not allow the usual missing energy signature so that everything would be consistent with what we have learned from LHC. Lepto-hadrons [13] would consist of pairs of sleptons which would be color octets so that same picture would apply to both leptons and quarks.

4. This is however not quite enough. There is evidence for a bumpy structure of signal cross section. The easy explanation is in terms of statistical fluctuations and time will show whether this explanation works. The bumpy structure suggests the existence of additional states not explainable in terms of the doubling predicted by TGD SUSY.

   Rather remarkably, the already mentioned quite recent anomaly suggests that similar phenomenon is encountered also in ordinary hadron physics. According to a three-year old discovery [1], there is evidence for narrow pion-like and nucleon like states with a mass splitting which is of order few tens of MeV. p-Adic fractality predicts the same in the case of M_{89} hadron physics and the observed bumpy structure might have interpretation in terms of "infra-red" Regge trajectory with string tension assignable to the color magnetic flux tubes accompanying light quarks. This string tension is dramatically smaller than the hadronic string tension of order 1 GeV and measured using 10 MeV as a unit.

Needless to say, the existence of the exotic hadrons would kill QCD as a theory of strong interactions and provide a strong support for the notion of color magnetic flux tube central for TGD vision about hadrons.

An alternative explanation would be rely on Shnoll effect [1] implying the splitting of resonances to separate peaks. It is not clear whether the explanations exclude each other. The question "Higgs of M_{89} hadron physics or something else?" will be probably answered within a year as the statistics from LHC improves.

Books related to TGD

[1] M. Pitkänen. A Possible Explanation of Shnoll Effect. In *p-Adic Length Scale Hypothesis and Dark Matter Hierarchy*. Onlinebook. http://tgdtheory.com/public_html/paddark/paddark.html#ShnollTGD, 2006.

[2] M. Pitkänen. Bio-Systems as Super-Conductors: part I. In *Quantum Hardware of Living Matter*. Onlinebook. http://tgdtheory.com/public_html/bioware/bioware.html#superc1, 2006.

[3] M. Pitkänen. DNA as Topological Quantum Computer. In *Genes and Memes*. Onlinebook. http://tgdtheory.com/public_html/genememe/genememe.html#dnatqc, 2006.

[4] M. Pitkänen. Does TGD Predict the Spectrum of Planck Constants? In *Towards M-Matrix*. Onlinebook. http://tgdtheory.com/public_html/tgdquant/tgdquant.html#Planck, 2006.

[5] M. Pitkänen. Does the Modified Dirac Equation Define the Fundamental Action Principle? In *Quantum Physics as Infinite-Dimensional Geometry*. Onlinebook. http://tgdtheory.com/public_html/tgdgeom/tgdgeom.html#Dirac, 2006.

[6] M. Pitkänen. Massless states and particle massivation. In *p-Adic Length Scale Hypothesis and Dark Matter Hierarchy*. Onlinebook. http://tgdtheory.com/public_html/paddark/paddark.html#mless, 2006.

[7] M. Pitkänen. New Particle Physics Predicted by TGD: Part I. In *p-Adic Length Scale Hypothesis and Dark Matter Hierarchy*. Onlinebook. http://tgdtheory.com/public_html/paddark/paddark.html#mass4, 2006.

[8] M. Pitkänen. Nuclear String Hypothesis. In *p-Adic Length Scale Hypothesis and Dark Matter Hierarchy*. Onlinebook. http://tgdtheory.com/public_html/paddark/paddark.html#nuclstring, 2006.

[9] M. Pitkänen. p-Adic Particle Massivation: Hadron Masses. In *p-Adic Length Scale Hypothesis and Dark Matter Hierarchy*. Onlinebook. http://tgdtheory.com/public_html/paddark/paddark.html#mass3, 2006.

[10] M. Pitkänen. TGD and Astrophysics. In *Physics in Many-Sheeted Space-Time*. Onlinebook. http://tgdtheory.com/public_html/tgdclass/tgdclass.html#astro, 2006.

[11] M. Pitkänen. TGD and Cosmology. In *Physics in Many-Sheeted Space-Time*. Onlinebook. http://tgdtheory.com/public_html/tgdclass/tgdclass.html#cosmo, 2006.

[12] M. Pitkänen. TGD and Nuclear Physics. In *p-Adic Length Scale Hypothesis and Dark Matter Hierarchy*. Onlinebook. http://tgdtheory.com/public_html/paddark/paddark.html#padnucl, 2006.

[13] M. Pitkänen. The Recent Status of Lepto-hadron Hypothesis. In *p-Adic Length Scale Hypothesis and Dark Matter Hierarchy*. Onlinebook. http://tgdtheory.com/public_html/paddark/paddark.html#leptc, 2006.

[14] M. Pitkänen. Generalized Feynman Diagrams as Generalized Braids. In *Towards M-Matrix*. Onlinebook. http://tgdtheory.com/public_html/tgdquant/tgdquant.html#braidfeynman, 2011.

[15] M. Pitkänen. Quantum Arithmetics and the Relationship between Real and p-Adic Physics. In *TGD as a Generalized Number Theory*. Onlinebook. http://tgdtheory.com/public_html/tgdnumber/tgdnumber.html#qarithmetics, 2011.

Particle and Nuclear Physics

[1] E. Tomasi-Gustafsson B. Taticheff. Search for low-mass exotic mesonic structures: II. Attempts to understand the experimental results. *Part. Nucl. Lett.*, 5(5):709–713, 2008.

[2] ATLAS collaboration. Search for the Standard Model Higgs boson in the diphoton decay channel with with 4.9 fb^1 of pp collisions at $\sqrt{s} = 7$ TeV. http://cdsweb.cern.ch/record/1406356/files/ATLAS-CONF-2011-161.pdf, 2011.

[3] CMS collaboration. Search for a Higgs boson decaying into two photons in the CMS detector. http://cdsweb.cern.ch/record/1406346/files/HIG-11-030-pas.pdf, 2011.

[4] G. Rupp E. van Beveren. First indications of the existence of a 38 MeV light scalar boson. http://arxiv.org/pdf/1102.1863v2.pdf, 2011.

[5] G. Rupp E. van Beveren. Material evidence of a 38 MeV boson, 2011.

[6] P. Hoyer. Jet Analysis. *Acta Physica Polonica*, B11(2):133–165, 1980.

[7] D. E. Soper J. Collins and G. Sterman. Factorization of Hard Processes in QCD. http://arxiv.org/abs/hep-ph/0409313, 2004.

[8] M. Schwartz. The Emergence of Jets at the Large Hadron Collider. http://media.physics.harvard.edu/video/?id=COLLOQ_SCHWARTZ_101711, 2011.

[9] D. T. Son. Viscosity, Quark Gluon Plasma, and String Theory. http://media.physics.harvard.edu/video/?id=LOEB_SON_041811, 2011.

[10] I. Stewart. Mastering Jets: New Windows into the Strong Interaction and Beyond. .