New Physics Predicted by TGD

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Contents

Abstract

TGD predicts a lot of new physics and it is quite possible that this new physics becomes visible at LHC. Although the calculational formalism is still lacking, p-adic length scale hypothesis allows to make precise quantitative predictions for particle masses by using simple scaling arguments.

The basic elements of quantum TGD responsible for new physics are following.

1. The new view about particles relies on their identification as partonic 2-surfaces (plus 4-D tangent space data to be precise). This effective metric 2-dimensionality implies generalizaton of the notion of Feynman diagram and holography in strong sense. One implication is the notion of field identity or field body making sense also for elementary particles and the Lamb shift anomaly of muonic hydrogen could be explained in terms of field bodies of quarks.

   4-D tangent space data must relate to the presence of strings connecting partonic 2-surfaces and defining the ends of string world sheets at which the modes of induced spinor fields are localized in the generic case in order to achieve conservation of em charge. The integer characterizing the spinor mode should charactize the tangent space data. Quantum criticality suggests strongly and super-conformal invariance acting as a gauge symmetry at the light-like partonic orbits and leaving the partonic 2-surfaces at their ends invariant. Without the fermionic strings effective 2-dmensionality would degenerate to genuine 2-dimensionality.

2. The topological explanation for family replication phenomenon implies genus generation correspondence and predicts in principle infinite number of fermion families. One can however develop a rather general argument based on the notion of conformal symmetry known as hyper-ellipticity stating that only the genera $g = 0, 1, 2$ are light. What "light" means is however an open question. If light means something below CP_2 mass there is no hope of observing new fermion families at LHC. If it means weak mass scale situation changes.

   For bosons the implications of family replication phenomenon can be understood from the fact that they can be regarded as pairs of fermion and antifermion assignable to the opposite wormhole throats of wormhole throat. This means that bosons formally belong to octet and singlet representations of dynamical SU(3) for which 3 fermion families define 3-D representation. Singlet would correspond to ordinary gauge bosons. Also interacting fermions suffer topological condensation and correspond to wormhole contact. One can either assume that the resulting wormhole throat has the topology of sphere or that the genus is same for both throats.

3. The view about space-time supersymmetry differs from the standard view in many respects. First of all, the super symmetries are not associated with Majorana spinors. Super generators correspond to the fermionic oscillator operators assignable to leptonic and quark-like induced spinors and there is in principle infinite number of them so that formally one would have $\mathcal{N} = \infty$ SUSY. I have discussed the required modification of the formalism of SUSY theories and it turns out that effectively one obtains just $\mathcal{N} = 1$ SUSY required by experimental constraints. The reason is that the fermion states with higher fermion number define only short range interactions analogous to van der Waals forces. Right handed neutrino generates this super-symmetry broken by the mixing of the M^4 chiralities implied by the mixing of M^4 and CP_2 gamma matrices for induced gamma matrices. The simplest assumption is that particles and their superpartners obey the same mass formula but that the p-adic length scale can be different for them.

4. The new view about particle massivation involves besides p-adic thermodynamics also Higgs particle but there is no need to assume that Higgs vacuum expectation plays any role. All particles could be seen as pairs of wormhole contacts whose throats at the two space-time sheets are connected by flux tubes carrying monopole flux: closed monopole flux tube involving two space-time sheets would be ion question. The contribution of the flux tube to particle mass would dominate for weak bosons whereas for fermions second wormhole contact would dominate.

5. One of the basic distinctions between TGD and standard model is the new view about color.

   (a) The first implication is separate conservation of quark and lepton quantum numbers implying the stability of proton against the decay via the channels predicted by GUTs. This does not mean that proton would be absolutely stable. p-Adic and

dark length scale hierarchies indeed predict the existence of scale variants of quarks and leptons and proton could decay to hadons of some zoomed up copy of hadrons physics. These decays should be slow and presumably they would involve phase transition changing the value of Planck constant characterizing proton. It might be that the simultaneous increase of Planck constant for all quarks occurs with very low rate.

   (b) Also color excitations of leptons and quarks are in principle possible. Detailed calculations would be required to see whether their mass scale is given by CP_2 mass scale. The so called leptohadron physics proposed to explain certain anomalies associated with both electron, muon, and τ lepton could be understood in terms of color octet excitations of leptons.

6. Fractal hierarchies of weak and hadronic physics labelled by p-adic primes and by the levels of dark matter hierarchy are highly suggestive. Ordinary hadron physics corresponds to $M_{107} = 2^{107} - 1$ One especially interesting candidate would be scaled up hadronic physics which would correspond to $M_{89} = 2^{89} - 1$ defining the p-adic prime of weak bosons. The corresponding string tension is about 512 GeV and it might be possible to see the first signatures of this physics at LHC. Nuclear string model in turn predicts that nuclei correspond to nuclear strings of nucleons connected by colored flux tubes having light quarks at their ends. The interpretation might be in terms of M_{127} hadron physics. In biologically most interesting length scale range 10 nm-2.5 μm there are four Gaussian Mersennes and the conjecture is that these and other Gaussian Mersennes are associated with zoomed up variants of hadron physics relevant for living matter. Cosmic rays might also reveal copies of hadron physics corresponding to M_{61} and M_{31}

7. Weak form of electric magnetic duality implies that the fermions and antifermions associated with both leptons and bosons are Kähler magnetic monopoles accompanied by monopoles of opposite magnetic charge and with opposite weak isospin. For quarks Kähler magnetic charge need not cancel and cancellation might occur only in hadronic length scale. The magnetic flux tubes behave like string like objects and if the string tension is determined by weak length scale, these string aspects should become visible at LHC. If the string tension is 512 GeV the situation becomes less promising.

In this chapter the predicted new physics and possible indications for it are discussed.

1 Introduction

TGD predicts a lot of new physics and it is quite possible that this new physics becomes visible at LHC. Although calculational formalism is still lacking, p-adic length scale hypothesis allows to make precise quantitative predictions for particle masses by using simple scaling arguments. Actually there is already now evidence for effects providing further support for TGD based view about QCD and first rumors about super-symmetric particles have appeared.

Before detailed discussion it is good to summarize what elements of quantum TGD are responsible for new physics.

1. The new view about particles relies on their identification as partonic 2-surfaces (plus 4-D tangent space data to be precise). This effective metric 2-dimensionality implies generalization of the notion of Feynman diagram and holography in strong sense. One implication is the notion of field identity or field body making sense also for elementary particles and the Lamb shift anomaly of muonic hydrogen could be explained in terms of field bodies of quarks.

2. The topological explanation for family replication phenomenon implies genus generation correspondence and predicts in principle infinite number of fermion families. One can however develop a rather general argument based on the notion of conformal symmetry known as hyper-ellipticity stating that only the genera $g = 0, 1, 2$ are light [?] What "light" means is however an open question. If light means something below CP_2 mass there is no hope of observing new fermion families at LHC. If it means weak mass scale situation changes.

   For bosons the implications of family replication phenomenon can be understood from the fact that they can be regarded as pairs of fermion and anti-fermion assignable to the opposite wormhole throats of wormhole throat. This means that bosons formally belong to octet and singlet representations of dynamical SU(3) for which 3 fermion families define 3-D representation. Singlet would correspond to ordinary gauge bosons. Also interacting fermions suffer topological condensation and correspond to wormhole contact. One can either assume that the resulting wormhole throat has the topology of sphere or that the genus is same for both throats.

3. The view about space-time supersymmetry differs from the standard view in many respects. First of all, the super symmetries are not associated with Majorana spinors. Super generators correspond to the fermionic oscillator operators assignable to leptonic and quark-like induced spinors and there is in principle infinite number of them so that formally one would have $\mathcal{N} = \infty$ SUSY. I have discussed the required modification of the formalism of SUSY theories in [?]nd it turns out that effectively one obtains just $\mathcal{N} = 1$ SUSY required by experimental constraints. The reason is that the fermion states with higher fermion number define only short range interactions analogous to van der Waals forces. Right handed neutrino generates this super-symmetry broken by the mixing of the M^4 chiralities implied by the mixing of M^4 and CP_2 gamma matrices for induced gamma matrices. The simplest assumption is that particles and their superpartners obey the same mass formula but that the p-adic length scale can be different for them.

4. The new view about particle massivation based on p-adic thermodynamics raises the question about the role of Higgs field. The vacuum expectation value (VEV) of Higgs is not feasible in TGD since CP_2 does not allow covariantly constant holomorphic vector fields. The original too strong conclusion from this was that TGD does not allow Higgs. Higgs VEV is not needed for the selection of preferred electromagnetic direction in electro-weak gauge algebra (unitary gauge) since CP_2 geometry does that. p-Adic thermodynamics explains fermion masses bout the masses of weak bosons cannot be understood on basis of p-adic thermodynamics alone giving extremely small second order contribution only and failing to explain W/Z mass ratio. Weak boson mass can be associated to the string tension of the strings connecting the throats of two wormhole contacts associated with elementary particle (two of them are needed since the monopole magnetic flux must have closed field lines).

   At M^4 QFT limit Higgs VEV is the only possible description of massivation. Dimensional gradient coupling to Higgs field developing VEV explains fermion masses at this limit. The dimensional coupling is same for all fermions so that one avoids the loss of "naturalness" due to the huge variation of Higgs-fermion couplings in the usual description.

   The stringy contribution to elementary particle mass cannot be calculated from the first principles. A generalization of p-adic thermodynamics based on the generalization of super-conformal algebra is highly suggestive. There would be two conformal weights corresponding the the conformal weight assignable to the radial light-like coordinate of light-cone boundary and to the stringy coordinate and third integer characterizing the poly-locality of the generator of Yangian associated with this algebra (n-local generator acts on n partonic 2-surfaces simultaneously).

5. One of the basic distinctions between TGD and standard model is the new view about color.

   (a) The first implication is separate conservation of quark and lepton quantum numbers implying the stability of proton against the decay via the channels predicted by GUTs. This does not mean that proton would be absolutely stable. p-Adic and dark length scale hierarchies indeed predict the existence of scale variants of quarks and leptons and proton could decay to hadons of some zoomed up copy of hadrons physics. These decays should be slow and presumably they would involve phase transition changing the value of Planck constant characterizing proton. It might be that the simultaneous increase of Planck constant for all quarks occurs with very low rate.

   (b) Also color excitations of leptons and quarks are in principle possible. Detailed calculations would be required to see whether their mass scale is given by CP_2 mass scale. The so called lepto-hadron physics proposed to explain certain anomalies associated with both electron, muon, and τ lepton could be understood in terms of color octet excitations of leptons [?]

6. Fractal hierarchies of weak and hadronic physics labelled by p-adic primes and by the levels of dark matter hierarchy are highly suggestive. Ordinary hadron physics corresponds to $M_{107} = 2^{107} - 1$ One especially interesting candidate would be scaled up hadronic physics which would correspond to $M_{89} = 2^{89} - 1$ defining the p-adic prime of weak bosons. The corresponding string tension is about 512 GeV and it might be possible to see the first signatures of this physics at LHC. Nuclear string model in turn predicts that nuclei correspond to nuclear strings of nucleons connected by colored flux tubes having light quarks at their ends. The interpretation might be in terms of M_{127} hadron physics. In biologically most interesting length scale range 10 nm-2.5 μm contains four electron Compton lengths $L_e(k) = \sqrt{5}L)k)$ associated with Gaussian Mersennes and the conjecture is that these and other Gaussian Mersennes are associated with zoomed up variants of hadron physics relevant for living matter. Cosmic rays might also reveal copies of hadron physics corresponding to M_{61} and M_{31}

   The well-definedness of em charge for the modes of induced spinor fields localizes them at 2-D surfaces with vanishing W fields and also Z^0 field above weak scale. This allows to avoid undesirable parity breaking effects.

7. Weak form of electric magnetic duality implies that the fermions and anti-fermions associated with both leptons and bosons are Kähler magnetic monopoles accompanied by monopoles of opposite magnetic charge and with opposite weak isospin. For quarks Kähler magnetic charge need not cancel and cancellation might occur only in hadronic length scale. The magnetic flux tubes behave like string like objects and if the string tension is determined by weak length scale, these string aspects should become visible at LHC. If the string tension is 512 GeV the situation becomes less promising.

In this chapter the predicted new elementary particle physics and possible indications for it are discussed. Second chapter is devoted to new hadron physics and scaled up variants of hardon physics in both quark and lepton sector.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L3].

2 Scaled Variants Of Quarks And Leptons

2.1 Fractally Scaled Up Versions Of Quarks

The strange anomalies of neutrino oscillations [C30] suggesting that neutrino mass scale depends on environment can be understood if neutrinos can suffer topological condensation in several p-adic length scales [K10] . The obvious question whether this could occur also in the case of quarks led to a very fruitful developments leading to the understanding of hadronic mass spectrum in terms of scaled up variants of quarks. Also the mass distribution of top quark candidate exhibits structure which could be interpreted in terms of heavy variants of light quarks. The ALEPH anomaly [C26], which I first erratically explained in terms of a light top quark has a nice explanation in terms of b quark condensed at $k = 97$ level and having mass ~ 55 GeV. These points are discussed in detail in [K13] .

The emergence of ALEPH results [C26] meant a an important twist in the development of ideas related to the identification of top quark. In the LEP 1.5 run with $E_{cm} = 130 - 140\ GeV$, ALEPH found 14 e^+e^- annihilation events, which pass their 4-jet criteria whereas 7.1 events are expected from standard model physics. Pairs of dijets with vanishing mass difference are in question and dijets could result from the decay of a new particle with mass about 55 GeV.

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

Super symmetrized standard model suggests the interpretation in terms of super partners of quarks or/and gauge bosons [C25] . It seems now safe to conclude that TGD does not predict sparticles. If the exotic particles are gluons their presence does not affect Z^0 and W decay widths. If the condensation level of gluons is $k = 97$ and mixing is absent the gluon masses are given by $m_g(0) = 0$, $m_g(1) = 19.2\ GeV$ and $m_g(2) = 49.5\ GeV$ for option 1) and assuming $k = 97$ and hadronic mass renormalization. It is however very difficult to understand how a pair of $g = 2$ gluons could be created in e^+e^- annihilation. Moreover, for option 2), which seems to be the only sensible option, the gluon masses are $m_g(0) = 0$, $m_g(1) = m_g(2) = 30.6\ GeV$ for $k = 97$. In this case also other values of k are possible since strong decays of quarks are not possible.

The strong variations in the order of magnitude of mass squared differences between neutrino families [C30] can be understood if they can suffer a topological condensation in several p-adic length scales. One can ask whether also t and b quark could do the same. In absence of mixing effects the masses of $k = 97$ t and b quarks would be given by $m_t \simeq 48.7$ GeV and $m_b \simeq 52.3$ GeV taking into account the hadronic mass renormalization. Topological mixing reduces the masses somewhat. The fact that b quarks are not observed in the final state leaves only $b(97)$ as a realistic option. Since Z^0 boson mass is ~ 94 GeV, $b(97)$ does not appreciably affect Z^0 boson decay width. The observed anomalies concentrate at cm energy about $105\ GeV$. This energy is 15 percent smaller than the total mass of top pair. The discrepancy could be understood as resulting from the binding energy of the $b(97)\bar{b}(97)$ bound states. Binding energy should be a fraction of order $\alpha_s \simeq .1$ of the total energy and about ten per cent so that consistency is achieved.

2.2 Toponium at 30.4 GeV?

Prof. Matt Strassler tells about a gem found from old data files of ALEPH experiment (see `http://tinyurl.com/ze6l5wr`) by Arno Heisner [C6](see `http://tinyurl.com/hy8ugf4`). The 3-sigma bump appears at 30.40 GeV and could be a statistical fluctuation and probably is so. It has been found to decay to muon pairs and b-quark pairs. The particle that Strassler christens V (V for vector) would have spin 1.

Years ago [K11] I have commented a candidate for scaled down top quark reported by Aleph: this had mass around 55 GeV and the proposal was that it corresponds to p-adically scaled up b quark with estimated mass of 52.3 GeV.

Could TGD allow to identify V as a scaled up variant of some spin 1 meson?

1. p-Adic length scale hypothesis states that particle mass scales correspond to certain primes $p \simeq 2^k$, $k > 0$ integer. Prime values of k are of special interest. Ordinary hadronic space-time sheets would correspond to hadronic space-time sheets labelled by Mersenne prime $p = M_{107} = 2^{107} - 1$ and quarks would be labelled by corresponding integers k.

2. For low mass mesons the contribution from color magnetic flux tubes to mass dominates whereas for higher mass mesons consisting of heavy quarks heavy quark contribution is dominant. This suggests that the large mass of V must result by an upwards scaling of some light quark mass or downwards scaling of top quark mass by a power of square root of 2.

3. The mass of b quark is around 4.2-4.6 GeV and Upsilon meson has mass about 9.5 GeV so that at most about 1.4 GeV from total mass would correspond to the non-perturbative color contribution partially from the magnetic body. Top quark mass is about 172.4 GeV and p-adic mass calculations suggest $k = 94$ (M_{89}) for top. If the masses for heavy quark mesons are additive as the example of Upsilon suggests, the non-existing top pair vector meson (toponium) (see `http://tinyurl.com/nfzhnej`) would have mass about $m(toponium) = 2 \times 172.4$ GeV $= 344.8$ GeV.

4. Could the observed bump correspond to p-adically scaled down version of toponium with $k = 94 + 7 = 101$, which is prime? The mass of toponium would be 30.47 GeV, which is consistent with the mass of the bump. If this picture is correct, V would be premature toponium able to exist for prime $k = 101$. Its decays to b quark pair are consistent with this.

5. Tommaso Dorigo (see `http://tinyurl.com/zhgyecd`) argues that the signal is spurious since the produced muons tend to be parallel to b quarks in cm system of Z^0. Matt Strassler identifies the production mechanism as a direct decay of Z^0 and in this case Tommaso would

be right: the direct 3-particle decay of $Z^0 \rightarrow b + \overline{b} + V$ would produce different angular distribution for V. One cannot of course exclude the possibility that the interpretation of Tommaso is that muon pairs are from decays of V in its own rest frame in which case they certainly cannot be parallel to b quarks. So elementary mistake from a professional particle physicist looks rather implausible. The challenge of the experiments was indeed to distinguish the muon pairs from muons resulting from b quarks decaying semileptonically and being highly parallel to b quarks.

A further objection of Tommaso is that the gluons should have roughly opposite momenta and fusion seems highly implausible classically since the gluons tend to be emitted in opposite directions. Quantally the argument does not look so lethal if one thinks in terms of plane waves rather than wave packets. Also fermion exchange is involved so that the fusion is not local process.

6. How the bump appearing in $Z^0 \rightarrow b + \overline{b} + V$ would be produced if toponium is in question? The mechanism would be essentially the same as in the production of Ψ/J meson by a $c + \overline{c}$ pair. The lowest order diagram would correspond to gluon fusion. Both b and $\overline{b}$ emit gluon and these could annihilate to a top pair and these would form the bound state. Do virtual t and $\overline{t}$ have ordinary masses 172 GeV or scaled down masses of about 15 GeV? The checking which option is correct would require numerical calculation and a model for the fusion of the pair to toponium.

   That the momenta of muons are parallel to those of b and $\overline{b}$ might be understood. One can approximate gluons with energy about 15 GeV as a brehmstrahlung almost parallel/antiparallel to the direction of b /$\overline{b}$ both having energy about 45 GeV in the cm system of Z^0. In cm they would combine to V with helicity in direction of axis nearly parallel to the direction defined by the opposite momenta of b and $\overline{b}$. The V with spin 1 would decay to a muon pair with helicities in the direction of this axis, and since relativistic muons are in question, the momenta would by helicity conservation tend to be in the direction of this axis as observed.

Are there other indications for scaled variants of quarks?

1. Tony Smith [C35] has talked about indications for several mass peaks for top quark. I have discussed this in [K13] in terms of p-adic length scale hypothesis. There is evidence for a sharp peak in the mass distribution of the top quark in 140-150 GeV range). There is also a peak slightly below 120 GeV, which could correspond to a p-adically scaled down variant t quark with $k = 93$ having mass 121.6 GeV for $(Y_e = 0, Y_t = 1)$. There is also a small peak also around 265 GeV which could relate to $m(t(95)) = 243.2$ GeV. Therefore top could appear at least at p-adic scales $k = 93, 94, 95$. This argument does not explain the peak in 140-150 GeV range rather near to top quark mass.

2. What about Aleph anomaly? The value of $k(b)$ in $p_b \simeq 2^{k_b}$ uncertain. $k(b) = 103$ is one possible value. In [K11]. I have considered the explanation of Aleph anomaly in terms of $k = 96$ variant of b quark. The mass scaling would be by factor of $2^{7/2}$, which would assign to mass $m_b = 4.6$ GeV mass of about 52 GeV to be compared with 55 GeV.

To sum up, the objections of Tommasso Dorigo might well kill the toponium proposal and the bump is probably a statistical fluctuation. It is however amazing that its mass comes out correctly from p-adic length scale hypothesis which does not allow fitting.

2.2.1 Aleph anomaly just refuses to disappear

I learned about evidence for a bump around 28 GeV (see `https://arxiv.org/abs/1808.01890`). The title of the preprint is "*Search for resonances in the mass spectrum of muon pairs produced in association with b quark jets in proton-proton collisions at* $\sqrt{s}$= *8 and 13 TeV*". An excess of events above the background near a dimuon mass of 28 GeV is observed in the 8 TeV data, corresponding to local significances of 4.2 and 2.9 standard deviations for the first and second event categories, respectively. At 13 TeV data the excess is milder. This induced two dejavu experiences.

1. *First dejavu*

Last year (2018) came a report from Aleph titled "Observation of an excess at 30 GeV in the opposite sign di-muon spectra of $Z \to b\bar{b} + X$ events recorded by the ALEPH experiment at LEP" (see `https://arxiv.org/pdf/1610.06536.pdf`). The article represents re-analysis of data from 1991-1992. The energy brings strongly in mind 28 GeV bump.

TGD - or more precisely p-adic fractality - suggests the existence of p-adically scaled variants of quarks and leptons with masses coming as powers of 2 (or perhaps even $\sqrt{2}$. They would be like octaves of a fundamental tone represented by the particle. Neutrino physics is plagued by anomalies and octaves of neutrino could resolve these problems.

Could one understand 30 GeV bump - possibly same as 28 GeV bump in TGD framework? b quark has mass 4.12 GeV or 4.65 GeV depending on the scheme used to estimate it. b quark could correspond to to p-adic length scale $L(k)$ for $k = 103$ but the identification of the p-adic scale is not quite clear. p-Adically scaling b-quark mass taken to be 4.12 GeV by factor 4 gives about 16.5 GeV ($k = 103 - 4 = 99$), which is one half of 32 GeV: could this correspond to the proposed 30 GeV resonance or even 28 GeV resonance? One must remember that these estimates are rough since already QCD estimates for b quark mass vary about 10 per cent.

28 GeV bump could correspond to p-adically scaled variant of b with $k = 99$. b quark would indeed appear as octaves. But how to understand the discrepancy: could one imagine that there are actually two mesons involved and analogous to pion and rho meson?

2. Second dejavu

Concerning quarks, I remember an old anomaly reported by Aleph at 56 GeV. This anomaly is mentioned in a preprint published last year (see `https://arxiv.org/pdf/hep-ph/9608264.pdf`) and there is reference to old paper: ALEPH Collaboration, D. Buskulic et al., CERN preprint PPE/96052.. What was observed was 4-jet events consisting of dijets with invariant mass around 55 GeV. What makes this interesting is that the mass of 28 GeV particle candidate would be one half of the mass of a particle with mass of mass of 56 GeV particle, quite near to 55 GeV.

My proposal for the identification of the 55 GeV bump was as a meson formed from scaled variants b and $\bar{b}$ corresponding to p-adic prime $p \simeq 2^k$, $k = 96$. The above argument suggests $k = 99 - 2 = 97$. Note that the production of the 28 GeV bump decaying to muon pair is associated with production of b quark and second jet.

3. What the resonance are and how could they be produced?

The troubling question is why the two masses around 28 GeV ad 30 GeV? Even worse: for 30 GeV candidate a dip is reported in at 28 GeV! Could the two candidates correspond to $\pi(28)$ and $\rho(30)$ having slightly different masses by color-magnetc spin-spin splitting?

The production mechanism should explain why the resonance is associated with b-quark and jet and also why two different mass values suggest themselves.

1. If one has 56 GeV pseudo-scalar resonance consisting mostly of $b\bar{b}$ - call it $\pi(56)$, it could couple to Z^0 by standard instanton density coupling, and one could have the decay $Z \to Z + \pi(56)$. The final state virtual Z would produce the b-tag in its decay.

2. $\pi(56)$ in turn would decay strongly to $\pi(28) + \rho(30)$ with spin 1 and analogous to the rho meson partner of ordinary pion. Masses would be naturally different for π and ρ.

It is easy to check that the observed spin-spin splitting is consistent with the simplest model for the spin-spin splitting obtained by extrapolating the for ordinary $\pi - \rho$ system.

1. At these mass scales the spin-spin splitting proportional to color magnetic moments and thus to inverses of the b quark masses should be small and indeed is.

2. Consider first ordinary $\pi - \rho$ system. The predicted masses due to spin-spin splitting are $m(\pi) = m - \Delta/2$ and $m(\rho) = m + 3\Delta/2)$, where one has $m = (3m(\pi) + m(\rho))/4$ and $\Delta = (m(\rho) - m(\pi))/2$. For $\pi - \rho$ system one has $r_1 = \Delta m/m \simeq .5$.

   $\Delta m/m$ is due to the interaction of color magnetic moments and of form xr, $r\alpha_s^2 m^2(\pi)/m^2(d)$. The small masses of u and d quarks - $m(d) \simeq 4.8$ MeV (Wikipedia value, the estimate vary widely) - implies that $m(\pi)/m(d) \simeq 28.2$ is rather large. The value of α_s is larger than $\alpha_s = .1$ achieved at higher energies, which gives $r_2 = \alpha_s^2 m^2(\pi)/m^2(d) > .28$. One has $r_1/r_2 \simeq .57$.

3. For $\pi(28)-\rho(30)$ system the values of the parameters are $m \simeq 29$ GeV and $\Delta m = 2$ GeV and $r_1 = \Delta m/m \simeq .07$. The mass ratio is roughly $m(\pi)/m(b) = 2$ for heavy mesons for which quark mass dominates in the meson mass. For $\alpha_s = .1$ the order of magnitude for $r_2 = \alpha_s^2 m^2(\pi(28))/m^2(b)$ is $r_2 \simeq .04$ and one has $r_1/r_2 = .57$ to be compared with $r_1/r_2 = .56$ for ordinary $\pi(28)-\rho(30)$ system so that the model looks realistic.

   Interestingly, the same value of α_s works in both cases: does this provide support for the TGD view about renormalization group invariance of coupling strengths [L9, L10]? This invariance is not global but implies discrete coupling constant evolution.

2.3 Could Neutrinos Appear In Several P-Adic Mass Scales?

There are some indications that neutrinos can appear in several mass scales from neutrino oscillations [C4]. These oscillations can be classified to vacuum oscillations and to solar neutrino oscillations believed to be due to the so called MSW effect in the dense matter of Sun. There are also indications that the mixing is different for neutrinos and antineutrinos [C12, C3].

In TGD framework p-adic length scale hypothesis might explain these findings. The basic vision is that the p-adic length scale of neutrino can vary so that the mass squared scale comes as octaves. Mixing matrices would be universal. The large discrepancy between LSND and MiniBoone results [C12] contra solar neutrino results could be understood if electron and muon neutrinos have same p-adic mass scale for solar neutrinos but for LSND and MiniBoone the mass scale of either neutrino type is scaled up. The existence of a sterile neutrino [C24] suggested as an explanation of the findings would be replaced by p-adically scaled up variant of ordinary neutrino having standard weak interactions. This scaling up can be different for neutrinos and antineutrinos as suggested by the fact that the anomaly is present only for antineutrinos.

The different values of Δm^2 for neutrinos and antineutrinos in MINOS experiment [C3] can be understood if the p-adic mass scale for neutrinos increases by one unit. The breaking of CP and CPT would be spontaneous and realized as a choice of different p-adic mass scales and could be understood in ZEO. Similar mechanism would break supersymmetry and explain large differences between the mass scales of elementary fermions, which for same p-adic prime would have mass scales differing not too much.

2.3.1 *Experimental results*

There several different type of experimental approaches to study the oscillations. One can study the deficit of electron type solar electron neutrinos (Kamiokande, Super-Kamiokande); one can measure the deficit of muon to electron flux ratio measuring the rate for the transformation of ν_μ to ν_τ (super-Kamiokande); one can study directly the deficit of ν_e ($\overline{\nu}_e$) neutrinos due to transformation to ν_μ $\nu_{\overline{\mu}}$ coming from nuclear reactor with energies in the same range as for solar neutrinos (KamLAND); and one can also study neutrinos from particle accelerators in much higher energy range such as solar neutrino oscillations (K2K,LSND,Miniboone,Minos).

1. Solar neutrino experiments and atmospheric neutrino experiments

The rate of neutrino oscillations is sensitive to the mass squared differences Δm_{12}^2, Δm_{12}^2, Δm_{13}^2 and corresponding mixing angles θ_{12}, θ_{13}, θ_{23} between ν_e, ν_μ, and ν_τ (ordered in obvious manner). Solar neutrino experiments allow to determine $sin^2(2\theta_{12})$ and Δm_{12}^2. The experiments involving atmospheric neutrino oscillations allow to determine $sin^2(2\theta_{23})$ and Δm_{23}^2.

The estimates of the mixing parameters obtained from solar neutrino experiments and atmospheric neutrino experiments are $sin^2(2\theta_{13}) = 0.08$, $sin^2(2\theta_{23}) = 0.95$, and $sin^2(2\theta_{12}) = 0.86$. The mixing between ν_e and ν_τ is very small. The mixing between ν_e and ν_μ, and ν_μ and ν_τ tends is rather near to maximal. The estimates for the mass squared differences are $\Delta m_{12}^2 = 8\times 10^{-5}$ eV^2, $\Delta m_{23}^2 \simeq \Delta m_{13}^2 = 2.4\times 10^{-3}$ eV^2. The mass squared differences have obviously very different scale but this need not means that the same is true for mass squared values.

2. The results of LSND and MiniBoone

LSND experiment measuring the transformation of $\overline{\nu}_\mu$ to $\overline{\nu}_e$ gave a totally different estimate for Δm_{12}^2 than solar neutrino experiments MiniBoone [C24]. If one assumes same value of $sin^2(\theta_{12})^2 \simeq .86$ one obtains $\Delta m_{23}^2 \sim .1$ eV^2 to be compared with $\Delta m_{12}^2 = 8\times 10^{-5}$ eV^2. This result is known as LSND anomaly and led to the hypothesis that there exists a sterile neutrino having no weak interactions and mixing with the ordinary electron neutrino and inducing a rapid mixing caused by the large value of Δm^2. The purpose of MiniBoone experiment [C12] was to test LSND anomaly.

1. It was found that the two-neutrino fit for the oscillations for $\nu_\mu \rightarrow \nu_e$ is not consistent with LSND results. There is an unexplained 3σ electron excess for $E < 475$ MeV. For $E > 475$ MeV the two-neutrino fit is not consistent with LSND fit. The estimate for Δm^2 is in the range $.1 - 1$ eV^2 and differs dramatically from the solar neutrino data.

2. For antineutrinos there is a small 1.3σ electron excess for $E < 475$ MeV. For $E > 475$ MeV the excess is 3 per cent consistent with null. Two-neutrino oscillation fits are consistent with LSND. The best fit gives $(\Delta m_{12}^2, sin^2(2\theta_{12}) = (0.064\ \ eV^2, 0.96)$. The value of Δm_{12}^2 is by a factor 800 larger than that estimated from solar neutrino experiments.

All other experiments (see the table of the summary of [C24] about sterile neutrino hypothesis) are consistent with the absence of $\nu_\mu \rightarrow n_e$ and $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$ mixing and only LSND and MiniBoone report an indication for a signal. If one however takes these findings seriously they suggest that neutrinos and antineutrinos behave differently in the experimental situations considered. Two-neutrino scenarios for the mixing (no sterile neutrinos) are consistent with data for either neutrinos or antineutrinos but not both [C24].

3. The results of MINOS group

The MINOS group at Fermi National Accelerator Laboratory has reported evidence that the mass squared differences between neutrinos are not same for neutrinos and antineutrinos [C3]. In this case one measures the disappearance of ν_μ and $\overline{\nu}_\mu$ neutrinos from high energy beam beam in the range .5-1 GeV and the dominating contribution comes from the transformation to τ neutrinos. Δm_{23}^2 is reported to be about 40 percent larger for antineutrinos than for neutrinos. There is 5 percent probability that the mass squared differences are same. The best fits for the basic parameters are $(\Delta m_{23}^2 = 2.35 \times 10^{-3}, sin^2(2\theta_{23} = 1)$ for neutrinos with error margin for Δm^2 being about 5 per cent and $(\Delta m_{23}^2 = 3.36 \times 10^{-3}, sin^2(2\theta_{23}) = .86)$ for antineutrinos with errors margin around 10 per cent. The ratio of mass squared differences is $r \equiv \Delta m^2(\overline{\nu})/\Delta m^2(\nu) = 1.42$. If one assumes $sin^2(2\theta_{23}) = 1$ in both cases the ratio comes as $r = 1.3$.

2.3.2 *Explanation of findings in terms of p-adic length scale hypothesis*

p-Adic length scale hypothesis predicts that fermions can correspond to several values of p-adic prime meaning that the mass squared comes as octaves (powers of two). The simplest model for the neutrino mixing assumes universal topological mixing matrices and therefore for CKM matrices so that the results should be understood in terms of different p-adic mass scales. Even CP breaking and CPT breaking at fundamental level is un-necessary although it would occur spontaneously in the experimental situation selecting different p-adic mass scales for neutrinos and antineutrinos. The expression for the mixing probability a function of neutrino energy in two-neutrino model for the mixing is of form

$$P(E) = sin^2(2\theta) sin^2(X) \ \ , \ \ X = k \times \Delta m^2 \times \frac{L}{E} \ \ .$$

Here k is a numerical constant, L is the length travelled, and E is neutrino energy.

1. LSND and MiniBoone results

LSND and MiniBoone results are inconsistent with solar neutrino data since the value of Δm_{12}^2 is by a factor 800 larger than that estimated from solar neutrino experiments. This could be understood if in solar neutrino experiments ν_μ and ν_w correspond to the same p-adic mass scale $k = k_0$ and have very nearly identical masses so that Δm^2 scale is much smaller than the mass squared scale. If either p-adic scale is changed from k_0 to $k_0 + k$, the mass squared difference increases dramatically. The counterpart of the sterile neutrino would be a p-adically scaled up version of the ordinary neutrino having standard electro-weak interactions. The p-adic mass scale would correspond to the mass scale defined by Δm^2 in LSND and MiniBoone experiments and therefore a mass scale in the range .3-1 eV. The electron Compton scale assignable to eV mass scale could correspond to $k = 167$, which corresponds to cell length scale of 2.5 μm. $k = 167$ defines one of the Gaussian Mersennes $M_{G,k} = (1+i)^k - 1$. $L_e(k) = \sqrt{5}L(k)$, $k = 151, 157, 163, 167$, varies in the range 10 nm (cell membrane thickness) and 2.5 μm defining the size of cell nucleus. These scales could be fundamental for the understanding of living matter [K4] .

2. MINOS results

One must assume also now that the p-adic mass scales for ν_τ and $\overline{\nu}_\tau$ are near to each other in the "normal" experimental situation. Assuming that the mass squared scales of ν_μ or $\overline{\nu}_\mu$ come as 2^{-k} powers of $m^2_{\nu_\mu} = m^2_{\nu_\tau} + \Delta m^2$, one obtains

$$m^2_{\nu_\tau}(k_0) - m^2_{\overline{\nu}_\mu}(k_0 + k) = (1 - 2^{-k})m^2{}_{nu_\tau} - 2^{-k}\Delta m^2_0 \ .$$

For $k = 1$ this gives

$$r = \frac{\Delta m^2(k=2)}{\Delta m^2(k=1)} = \frac{\frac{3}{2} - \frac{2r}{3}}{1-r} \ , \ r = \frac{\Delta m^2_0}{m^2_{\nu_\tau}} \ . \tag{2.1}$$

One has $r \geq 3/2$ for $r > 0$ if one has $m_{\nu_\tau} > m_{\nu_\mu}$ for the same p-adic length scale. The experimental ratio $r \simeq 1.3$ could be understood for $r \simeq -.31$. The experimental uncertainties certainly allow the value $r = 1.5$ for $k(\overline{\nu}_\mu) = 1$ and $k(\nu_\mu) = 2$.

This result implies that the mass scale of ν_μ and ν_τ differ by a factor 1/2 in the "normal" situation so that mass squared scale of ν_τ would be of order 5×10^{-3} eV^2. The mass scales for $\overline{\nu}_\tau$ and ν_τ would about .07 eV and .05 eV. In the LSND and MiniBoone experiments the p-adic mass scale of other neutrino would be around .1-1 eV so that different p-adic mass scale large by a factor $2^{k/2}$, $2 \leq 2 \leq 7$ would be in question. The different resuts from various experiments could be perhaps understood in terms of the sensitivity of the p-adic mass scale to the experimental situation. Neutrino energy could serve as a control parameter.

CPT breaking [B2] requires the breaking of Lorentz invariance. ZEO could therefore allow a spontaneous breaking of CP and CPT. This might relate to matter antimatter asymmetry at the level of given CD.

There is some evidence that the mixing matrices for neutrinos and antineutrinos are different in the experimental situations considered [C3, C12]. This would require CPT breaking in the standard QFT framework. In TGD p-adic length scale hypothesis allowing neutrinos to reside in several p-adic mass scales. Hence one could have apparent CPT breaking if the measurement arrangements for neutrinos and antineutrinos select different p-adic length scales for them [K11] .

2.3.3 *Is CP and T breaking possible in ZEO?*

The CKM matrices for quarks and possibly also leptons break CP and T. Could one understand the breaking of CP and T at fundamental level in TGD framework?

1. In standard QFT framework Chern-Simons term breaks CP and T. Kähler action indeed reduces to Chern-Simons terms for the proposed ansatz for preferred extremals assuming that weak form of electric-magnetic duality holds true.

   In TGD framework one must however distinguish between space-time coordinates and imbedding space coordinates. CP breaking occurs at the imbedding space level but instanton term and Chern-Simons term are odd under P and T only at the space-time level and thus distinguish between different orientations of space-time surface. Only if one identifies P and T at space-time level with these transformations at imbedding space level, one has hope of interpreting CP and T breaking as spontaneous breaking of these symmetries for Kähler action and basically due to the weak form of electric-magnetic duality and vanishing of $j \cdot A$ term for the preferred extremals. This identification is possible for space-time regions allowing representation as graphs of maps $M^4 \rightarrow CP_2$.

2. In order to obtain non-trivial fermion propagator one must add to Dirac action 1-D Dirac action in induced metric with the boundaries of string world sheets at the light-like parton orbits. Its bosonic counterpart is line-length in induced metric. Field equations imply that

the boundaries are light-like geodesics and fermion has light-like 8-momentum. This suggests strongly a connection with quantum field theory and an 8-D generalization of twistor Grassmannian approach. By field equations the bosonic part of this action does not contribute to the Kähler action. Chern-Simons Dirac terms to which Kähler action reduces could be responsible for the breaking of CP and T symmetries as they appear in CKM matrix.

3. The GRT-QFT limit of TGD obtained by lumping together various space-time sheets to a region of Minkowski space with effective metric defined by the sum of Minkowski metric and deviations of the induced metrics of sheets from Minkowski metric. Gauge potentials for the effective space-time would idenfied as sums of gauge potentials for space-time sheets. At this limit the identification of P and T at space-time level and imbedding space level would be natural. Could the resulting effective theory in Minkowski space or GRT space-time break CP and T slightly? If so, CKM matrices for quarks and fermions would emerge as a result of representing different topologies for wormhole throats with different topologies as single point like particle with additional genus quantum number.

4. Could the breaking of CP and T relate to the generation of the arrow of time? The arrow of time relates to the fact that state function reduction can occur at either boundary of CD [K1]. Zero energy states do not change at the boundary at which reduction occurs repeatedly but the change at the other boundary and also the wave function for the position of the second boundary of CD changes in each quantum jump so that the average temporal distance between the tips of CD increases. This gives to the arrow of psychological time, and in TGD inspired theory of consciousness "self" as a counterpart of observed can be identified as sequence of quantum jumps for which the state function reduction occurs at a fixed boundary of CD. The sequence of reductions at fixed boundary breaks T-invariance and has interpretation as irreversibility. The standard view is that the irreversibility has nothing to do with breaking of T-invariance but it might be that in elementary particle scales irreversibility might manifest as small breaking of T-invariance.

2.3.4 *Is CPT breaking needed/possible?*

Different values of Δm_{ij}^2 for neutrinos and antineutrinos would require in standard QFT framework not only the violation of CP but also CPT [B2] which is the cherished symmetry of quantum field theories. CPT symmetry states that when one reverses time's arrow, reverses the signs of momenta and replaces particles with their antiparticles, the resulting Universe obeys the same laws as the original one. CPT invariance follows from Lorentz invariance, Lorentz invariance of vacuum state, and from the assumption that energy is bounded from below. On the other hand, CPT violation requires the breaking of Lorentz invariance.

In TGD framework this kind of violation does not seem to be necessary at fundamental level since p-adic scale hypothesis allowing neutrinos and also other fermions to have several mass scales coming as half-octaves of a basic mass scale for given quantum numbers. In fact, even in TGD inspired low energy hadron physics quarks appear in several mass scales. One could explain the different choice of the p-adic mass scales as being due to the experimental arrangement which selects different p-adic length scales for neutrinos and antineutrinos so that one could speak about spontaneous breaking of CP and possibly CPT. The CP breaking at the fundamental level which is however expected to be small in the case considered. The basic prediction of TGD and relates to the CP breaking of Chern-Simons action inducing CP breaking in the Kähler-Dirac action defining the fermionic propagator [L2]. For preferred extremals Kähler action would indeed reduce to Chern-Simons terms by weak form of electric-magnetic duality.

In TGD one has breaking of translational invariance and the symmetry group reduces to Lorentz group leaving the tip of CD invariant. Positive and negative energy parts of zero energy states correspond to different Lorentz groups and zero energy states are superpositions of state pairs with differen values of mass squared. Is the breaking of Lorentz invariance in this sense enough for breaking of CPT is not clear.

One can indeed consider the possibility of a spontaneous breaking of CPT symmetry in TGD framework since for a given CD (causal diamond defined as the intersection of future and past directed light-cones whose size scales are assumed to come as octaves) the Lorentz invariance is broken due to the preferred time direction (rest system) defined by the time-like line connecting the tips of CD. Since the world of classical worlds is union of CDs with all boosts included the Lorentz invariance is not violated at the level of WCW. Spontaneous symmetry breaking would be analogous to that for the solutions of field equations possessing the symmetry themselves. The mechanism of breaking would be same as that for supersymmetry. For same p-adic length scale particles and their super-partners would have same masses and only the selection of the p-adic mass scale would induces the mass splitting.

2.3.5 Encountering the puzzle of inert neutrinos once again

Sabine Hossenfelder had an interesting link to Quanta Magazine article "*On a Hunt for a Ghost of a Particle*" telling about the plans of particle physicist Janet Conrad to find the inert neutrino (see `http://tinyurl.com/ybhcjwu6`).

The attribute "sterile" or "inert" (I prefer the latter since it is more respectful!) comes from the assumption this new kind of neutrino does not have even weak interactions and feels only gravitation. There are indications for the existence of inert neutrino from LSND experiments (see `http://tinyurl.com/y7ktyfrs`) and some Mini-Boone experiments(see `http://tinyurl.com/y74hmq7c`). In standard model it would be interpreted as fourth generation neutrino which would suggest also the existence of other fourth generation fermions. For this there is no experimental support.

The problem of inert neutrino is very interesting also from TGD point of view. TGD predicts also right handed neutrino with no electroweak couplings but mixes with left handed neutrino by a new interaction produced by the mixing of M^4 and CP_2 gamma matrices: this is a unique feature of induced spinor structure and serves as a signature of sub-manifold geometry and one signature distinguishing TGD from standard model. Only massive neutrino with both helicities remains and behaves in good approximation as a left handed neutrino.

There are indeed indications in both LSND and MiniBoone experiments for inert neutrino. But only in some of them. And not in the ICECUBE experiment (see `http://tinyurl.com/h79dyj3`) performed at was South Pole. Special circumstances are required. "Special circumstances" need not mean bad experimentation. Why this strange behavior?

1. The evidence for the existence of inert neutrino, call it $\overline{\nu}_I$, came from antineutrino mixing $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$ manifesting as mass squared difference between muonic and electronic antineutrinos. This difference was $\Delta m^2(LSND) = 1-10\ eV^2$ in the LSND experiment. The other two mass squared differences deduced from solar neutrino mixing and atmospheric neutrino mixing were $\Delta m^2(sol) = 8 \times 10^{-5}\ eV^2$ and $\Delta m^2(atm) = 2.5 \times 10^{-3}\ eV^2$ respectively.

2. The inert neutrino interpretation would be that actually $\overline{\nu}_\mu \rightarrow \overline{\nu}_I$ takes place and the mass squared difference for $\overline{\nu}_\mu and \overline{\nu}_I$ determines the mixing.

1. The explanation based on several p-adic mass scales for neutrinos

The first TGD inspired explanation proposed for a long time ago relies on p-adic length scale hypothesis predicting that neutrinos can exist in several p-adic length scales for which mass squared scale ratios come as powers of 2. Mass squared differences would also differ by a power of two. Indeed, the mass squared differences from solar and atmospheric experiments are in ratio 2^{-5} so that the model looks promising!

Writing $\Delta m^2(LSND) = x\ eV^2$ the condition $m^2(LSND)/m^2(atm) = 2^k$ has 2 possible solutions corresponding to $k = 9$, or $k = 10$ and $x = 2.5$ and $x = 1.25$. The corresponding mass squared differences 2.5 eV^2 and 1.25 eV^2.

The interpretation would be that the three measurement outcomes correspond to 3 neutrinos with nearly identical masses in given p-adic mass scale k but having different p-adc mass scales. The atmospheric and solar p-adic length scales would comes as powers $(L(atm), L(sol)) = (2^{n/2}, 2^{(n+10)/2}) \times L(k(LSND))$, $n = 9$ or $n = 10$. For $n = 10$ the mass squared scales would come as powers of 2^{10}.

How to estimate the value of $k(LSND)$?

1. Empirical data and p-adic mass calculations suggest that neutrino mass is of order .1 eV . The most natural candidates for p-adic mass scales would correspond to $k = 163, 167$ or $k = 169$.

The first primes $k = 163, 167$ correspond to Gaussian Mersenne primes $M_{G,n} = (1+i)^n - 1$ and to p-adic length scales $L(163) = 640$ nm and $L(167) = 2.56$ μm.

2. p-Adic mass calculations [K10] predict that the ratio $x = \Delta m^2/m^2$ for $\mu - e$ system has upper bound $x \sim .4$. This does not take into account the mixing effects but should give upper bound for the mass squared difference affected by the mixing.

3. The condition $\Delta m^2/m^2 = .4 \times x$, where $x \leq 1$ parametrizes the mass difference assuming $\Delta m(LSND)^2 = 2.5\ eV^2$ gives $m^2(LSND) \sim 6.25\ eV^2/x$.

   $x = 1/4$ would give $(k(LSND), k(atm), k(sol)) = (157, 167, 177)$. $k(LSND)$ and $k(atm)$ label two Gaussian Mersenne primes $M_{G,k} = (1+i)^k$ in the series $k = 151, 157, 163, 167$ of Gaussian Mersennes. The scale $L(151) = 10$ nm defines cell membrane thickness. All these scales could be relevant for DNA coiling. $k(sol) = 177$ is not Mersenne prime nor even prime. The correspoding p-adic length scale is 82 μm perhaps assignable to neuron. Note that $k = 179$ is prime.

This explanation looks rather nice because the mass squared difference ratios come as powers of two. What seems clear that the longer the path of neutrino travelled from the source to the detector, the smaller than mass squared: in other words one has $k(LSND) < k(atm) < k(sol)$. This suggest that neutrinos transform to lower mass neutrinos during the travel $k(LSND) \rightarrow k(atm) \rightarrow k(sol)$. The sequence could contains also other p-adic length scales.

What really happens when neutrino characterised by p-adic length scale $L(k_1)$ transforms to a neutrino characterized by p-adic length scale $L(k_2)$.

1. The simplest possibility would be that $k_1 \rightarrow k_2$ corresponds to a 2-particle vertex. The conservation of energy and momentum however prevent this process unless one has $\Delta m^2 = 0$. The emission of weak boson is not kinematically possible since Z^0 boson is so massive. For instance, solar neutrinos have energies in MeV range. The presence of classical Z^0 field could make the transformation possible and TGD indeed predicts classical Z^0 fields with long range. The simplest assumption is that all classical electroweak gauge fields except photon field vanish at string world sheets. This could in fact be guaranteed by gauge choice analogous to the unitary gauge.

2. The twistor lift of TGD however provides an alternative option. Twistor lift predicts that also M^4 has the analog of Kähler structure characterized by the Kähler form $J(M^4)$ which is covariantly constant and self-dual and thus corresponds to parallel electric and magnetic components of equal strength. One expects that this gives rise to both classical and quantum field coupling to fermion number, call this $U(1)$ gauge field U. The presence of $J(M^4)$ induces P, T, and CP breaking and could be responsible for CP breaking in both leptonic and quark sectors and also explain matter antimatter asymmetry [L5, L6] as well as large parity violation in living matter (chiral selection). The coupling constant strength α_1 is rather small due to the constraints coming from atomic physics (new $U(1)$ boson couples to fermion number and this causes a small scaling of the energy levels). One has $\alpha_1 \sim 10^{-9}$, which is also the number characterizing matter antimatter asymmetry as ratio of the baryon density to CMB photon density.

   Already the classical long ranged U field could induce the neutrino transitions. $k_1 \rightarrow k_2$ transition could become allowed by conservation laws also by emission of U boson. The simplest situation corresponds to parallel momenta for neutrinos and U. Conservation laws of energy and momentum give $E_1 = \sqrt{p_1^2 + m_1^2} = E_2 + E(U) = \sqrt{p_2^2 + m_2^2} + E(U)$, $p_1 = p_2 + p(U)$. Masslessness gives $E(U) = p(U)$. This would give in good approximation $p_2/p_1 = m_1^2/m_2^2$ and $E(U) = p_1 - p_2 = p_1(1 - m_1^2/m_2^2)$.

   One can ask whether CKM mixing for quarks could involve similar mechanism explaining the CP breaking. Also the transitions changing $h_{eff}/h = n$ could involve U boson emission.

2. The explanation based on several p-adic mass scales for neutrinos

Second TGD inspired interpretation would be as a transformation of ordinary neutrino to a dark variant of ordinary neutrino with $h_{eff}/h = n$ occurring only if the situation is quantum critical (what would this mean now?). Dark neutrino would behave like inert neutrino. One cannot exclude this option but it does not give quantitative predictions.

This proposal need not however be in conflict with the first one since the transition $k(LSND) \rightarrow k_1$ could produce dark neutrino with different value of $h_{eff}/h = 2^{\Delta k}$ scaling up the Compton scale by this factor. This transition could be followed by a transition back to a particle with p-adic length scale scaled up by 2^{2k}. I have proposed that p-adic phase transitions occurring at criticality requiring $h_{eff}/h > 1$ are important in biology [K9].

There is evidence for a similar effect in the case of neutron decays. Neutron lifetime is found to be considerably longer than predicted. The TGD explanation [K11] is that part of protons resulting in the beta decays of neutrino transform to dark protons and remain undetected so that lifetime looks longer than it really is [L7] (see `http://tinyurl.com/yc8d7sed`). Note however that also now conservation laws give constraints and the emission of U photon might be involved also in this case. As a matter of fact, one can consider the possibility that the phase transition changing $h_{eff}/h = n$ involve the emission of U photon too. The mere mixing of the ordinary and dark variants of particle would induce mass splitting and U photon would take care of energy momentum conservation.

2.3.6 LSND anomaly is here again!

MinibooNe collaboration published a highly interesting preprint [C10] “Observation of a Significant Excess of Electron-Like Events in the MiniBooNE Short-Baseline Neutrino Experiment” (see `https://arxiv.org/abs/1805.12028`).

The findings give strong support for old and forgotten LSND anomaly - forgotten because it is in so blatant conflict with the standard model wisdom. The significance level of the anomaly is 6.1 sigmas in the new experiment. 5 sigma is regarded as the threshold for a discovery. It is nice to see this fellow again: anomalies are the theoreticians best friends.

To me this seems like a very important event from the point of view of standard model and even theoretical particle physics: this anomaly together with other anomalies raises hopes that the patient could leave the sickbed after illness that has lasted for more than four decades after becoming a victim of the GUT infection.

LSND as also other experiments are consistent with neutrino mixing model. LSND however produces electron excess as compared to other neutrino experiments. Anomaly means that the parameters of the neutrino mixing matrix (masses, mixing angles, phases) are not enough to explain all experiments.

One manner to explain the anomaly would be fourth “inert” neutrino having no couplings to electroweak bosons. TGD predicts both right and left-handed neutrinos and right-handed ones would not couple electroweakly. In massivation they would however combine to single massive neutrino just like in Higgs massivation Higgs gives components for massive gauge bosons and only neutral Higgs having no coupling to photon remains. Therefore this line of thought does not loo promising in TGD framework.

For many years ago I explained the LSND neutrino anomaly in TGD framework as being due to the fact that neutrinos can correspond to several p-adic mass scales. p-Adic mass scale coming as power of $2^{1/2}$ would bring in the needed additional parameter. The new particles could be ordinary neutrinos with different p-adic mass scales. The neutrinos used in experiment would have p-adic length scale depending on their origin. Lab, Earth’s atmosphere, Sun, ... It is possible that the neutrinos transform during their travel to less massive neutrinos.

What is intriguing that the p-adic length scale range that can be considered as candidates for neutrino Compton lengths is biologically extremely interesting. This range could correspond to the p-adic length scales $L(k) \sim 2^{(k-151)/2}L(151)$, $k = 151, 157, 163, 167$ varying from cell membrane thickness 10 nm to 2.5 μm. These length scales correspond to Gaussian Mersennes $M_{G,k} = (1+i)^k - 1$. The appearance of four of 4 Gaussian Mersennes in such a short length scale interval is a number theoretic miracle. Could neutrinos or their dark variants with $h_{eff} = n \times h_0$ together with dark variants weak bosons effectively massless below their Compton length have a fundamental role in quantum biology?

Remark: $h = 6 \times h_0$ is the most plausible option at this moment [L4, L8] (see `http://tinyurl.com/ybxlqqsj` and `http://tinyurl.com/yafndef9`).

3 Family Replication Phenomenon And Super-Symmetry

3.1 Family Replication Phenomenon For Bosons

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

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

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

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

3.2 Supersymmetry In Crisis

Supersymmetry is very beautiful generalization of the ordinary symmetry concept by generalizing Lie-algebra by allowing grading such that ordinary Lie algebra generators are accompanied by super-generators transforming in some representation of the Lie algebra for which Lie-algebra commutators are replaced with anti-commutators. In the case of Poincare group the super-generators would transform like spinors. Clifford algebras are actually super-algebras. Gamma matrices anti-commute to metric tensor and transform like vectors under the vielbein group (SO(n) in Euclidian signature). In supersymmetric gauge theories one introduced super translations anti-commuting to ordinary translations.

Supersymmetry algebras defined in this manner are characterized by the number of super-generators and in the simplest situation their number is one: one speaks about $\mathcal{N} = 1$ SUSY and minimal super-symmetric extension of standard model (MSSM) in this case. These models are most studied because they are the simplest ones. They have however the strange property that the spinors generating SUSY are Majorana spinors- real in well-defined sense unlike Dirac spinors. This implies that fermion number is conserved only modulo two: this has not been observed experimentally. A second problem is that the proposed mechanisms for the breaking of SUSY do not look feasible.

LHC results suggest MSSM does not become visible at LHC energies. This does not exclude more complex scenarios hiding simplest $\mathcal{N} = 1$ to higher energies but the number of real believers is decreasing. Something is definitely wrong and one must be ready to consider more complex options or totally new view abot SUSY.

What is the analog of SUSY in TGD framework? I must admit that I am still fighting to gain understanding of SUSY in TGD framework [K21]. That I can still imagine several scenarios shows that I have not yet completely understood the problem but I am working hardly to avoid falling to the sin of sloppying myself.

At the basic level one has super-conformal invariance generated in the fermion sector by the super-conformal charges assignable to the strings emanating from partonic 2-surfaces and connecting them to each other. For elementary particles one has 2 wormhole contacts and 4 wormhole throats. If the number of strings is just one, one has symplectic super-conformal symmetry, which is already huge. Several strings must be allowed and this leads to the Yangian variant of super-conformal symmetry, which is multi-local (multi-stringy).

One can also say that fermionic oscillator operators generate infinite-D super-algebra. One can restrict the consideration to lowest conformal weights if spinorial super-conformal invariance acts as gauge symmetry so that one obtains a finite-D algebra with generators labelled by electro-weak quantum numbers of quarks and leptons. This super-symmetry is badly broken but contains the algebra generated by right-handed neutrino and its conjugate as sub-algebra.

The basic question is whether covariantly constant right handed neutrino generators $\mathcal{N} = \in$ SUSY or whether the SUSY is generated as approximate symmetry by adding massless right-handed neutrino to the state thus changing its four-momentum. The problem with the first option is that it the standard norm of the state is naturally proportional to four-momentum and vanishes at the limit of vanishing four-momentum: is it possible to circumvent this problem somehow? In the following I summarize the situation as it seems just now.

1. In TGD framework $\mathcal{N} = 1$ SUSY is excluded since B and L and conserved separately and imbedding space spinors are not Majorana spinors. The possible analog of space-time SUSY should be a remnant of a much larger super-conformal symmetry in which the Clifford algebra generated by fermionic oscillator operators giving also rise to the Clifford algebra generated by the gamma matrices of the "world of classical worlds" (WCW) and assignable with string world sheets. This algebra is indeed part of infinite-D super-conformal algebra behind quantum TGD. One can construct explicitly the conserved super conformal charges accompanying ordinary charges and one obtains something analogous to $\mathcal{N} = \infty$ super algebra. This SUSY is however badly broken by electroweak interactions.

2. The localization of induced spinors to string world sheets emerges from the condition that electromagnetic charge is well-defined for the modes of induced spinor fields. There is however an exception: covariantly constant right handed neutrino spinor ν_R: it can be de-localized along entire space-time surface. Right-handed neutrino has no couplings to electroweak fields. It couples however to left handed neutrino by induced gamma matrices except when it is covariantly constant. Note that standard model does not predict ν_R but its existence is necessary if neutrinos develop Dirac mass. ν_R is indeed something which must be considered carefully in any generalization of standard model.

3.2.1 *Could covariantly constant right handed neutrinos generate SUSY?*

Could covariantly constant right-handed spinors generate exact $\mathcal{N} = 2$ SUSY? There are two spin directions for them meaning the analog $\mathcal{N} = 2$ Poincare SUSY. Could these spin directions correspond to right-handed neutrino and antineutrino. This SUSY would not look like Poincare SUSY for which anti-commutator of super generators would be proportional to four-momentum. The problem is that four-momentum vanishes for covariantly constant spinors! Does this mean that the sparticles generated by covariantly constant ν_R are zero norm states and represent super gauge degrees of freedom? This might well be the case although I have considered also alternative scenarios.

3.2.2 *What about non-covariantly constant right-handed neutrinos?*

Both imbedding space spinor harmonics and the Kähler-Dirac equation have also right-handed neutrino spinor modes not constant in M^4 and localized to the partonic orbits. If these are responsible for SUSY then SUSY is broken.

1. Consider first the situation at space-time level. Both induced gamma matrices and their generalizations to Kähler-Dirac gamma matrices defined as contractions of imbedding space gamma matrices with the canonical momentum currents for Kähler action are superpositions of M^4 and CP_2 parts. This gives rise to the mixing of right-handed and left-handed neutrinos. Note that non-covariantly constant right-handed neutrinos must be localized at string world sheets.

   This in turn leads neutrino massivation and SUSY breaking. Given particle would be accompanied by sparticles containing varying number of right-handed neutrinos and antineutrinos localized at partonic 2-surfaces.

2. One an consider also the SUSY breaking at imbedding space level. The ground states of the representations of extended conformal algebras are constructed in terms of spinor harmonics

of the imbedding space and form the addition of right-handed neutrino with non-vanishing four-momentum would make sense. But the non-vanishing four-momentum means that the members of the super-multiplet cannot have same masses. This is one manner to state what SUSY breaking is.

3.2.3 *What one can say about the masses of sparticles?*

The simplest form of massivation would be that all members of the super-multiplet obey the same mass formula but that the p-adic length scales associated with them are different. This could allow very heavy sparticles. What fixes the p-adic mass scales of sparticles? If this scale is CP_2 mass scale SUSY would be experimentally unreachable. The estimate below does not support this option.

One can consider the possibility that SUSY breaking makes sparticles unstable against phase transition to their dark variants with $h_{eff} = n \times h$. Sparticles could have same mass but be non-observable as dark matter not appearing in same vertices as ordinary matter! Geometrically the addition of right-handed neutrino to the state would induce many-sheeted covering in this case with right handed neutrino perhaps associated with different space-time sheet of the covering.

This idea need not be so outlandish at it looks first.

1. The generation of many-sheeted covering has interpretation in terms of breaking of conformal invariance. The sub-algebra for which conformal weights are n-tuples of integers becomes the algebra of conformal transformations and the remaining conformal generators do note represent gauge degrees of freedom anymore. They could however represent conserved conformal charges still.

2. This generalization of conformal symmetry breaking gives rise to infinite number of fractal hierarchies formed by sub-algebras of conformal algebra and is also something new and a fruit of an attempt to avoid sloppy thinking. The breaking of conformal symmetry is indeed expected in massivation related to the SUSY breaking.

The following poor man's estimate supports the idea about dark sfermions and the view that sfermions cannot be very heavy.

1. Neutrino mixing rate should correspond to the mass scale of neutrinos known to be in eV range for ordinary value of Planck constant. For $h_{eff}/h = n$ it is reduced by factor $1/n$, when mass kept constant. Hence sfermions could be stabilized by making them dark.

2. A very rough order of magnitude estimate for sfermion mass scale is obtained from Uncertainty Principle: particle mass should be higher than its decay rate. Therefore an estimate for the decay rate of sfermion could give a lower bound for its mass scale.

3. Assume the transformation $\nu_R \rightarrow \nu_L$ makes sfermion unstable against the decay to fermion and ordinary neutrino. If so, the decay rate would be dictated by the mixing rate and therefore to neutrino mass scale for the ordinary value of Planck constant. Particles and sparticles would have the same p-adic mass scale. Large h_{eff} could however make sfermion dark, stable, and non-observable.

3.2.4 *A rough model for the neutrino mixing in TGD framework*

The mixing of neutrinos would be the basic mechanism in the decays of sfermions. The following argument tries to capture what is essential in this process.

1. Conformal invariance requires that the string ends at which fermions are localized at wormhole throats are light-like curves. In fact, light-likeness gives rise to Virasosoro conditions.

2. Mixing is described by a vertex residing at partonic surface at which two partonic orbits join. Localization of fermions to string boundaries reduces the problem to a problem completely analogous to the coupling of point particle coupled to external gauge field. What is new that orbit of the particle has edge at partonic 2-surface. Edge breaks conformal invariance since one cannot say that curve is light-like at the edge. At edge neutrino transforms from right-handed to left handed one.

3. In complete analogy with $\overline{\Psi}\gamma^t A_t\Psi$ vertex for the point-like particle with spin in external field, the amplitude describing $nu_R - \nu_L$ transition involves matrix elements of form $\overline{\nu}_R\Gamma^t(CP_2)Z_t\nu_L$ at the vertex of the CP_2 part of the Kähler-Dirac gamma matrix and classical Z^0 field.

   How Γ^t is identified? The Kähler-Dirac gamma matrices associated with the interior need not be well-defined at the light-like surface and light-like curve. One basis of weak form of electric magnetic duality the Kähler-Dirac gamma matrix corresponds to the canonical momentum density associated with the Chern-Simons term for Kähler action. This gamma matrix contains only the CP_2 part.

The following provides as more detailed view.

1. Let us denote by $\Gamma^t_{CP_2}(in/out)$ the CP_2 part of the Kähler-Dirac gamma matrix at string at at partonic 2-surface and by Z^0_t the value of Z^0 gauge potential along boundary of string world sheet. The direction of string line in imbedding space changes at the partonic 2-surface. The question is what happens to the Kähler-Dirac action at the vertex.

2. For incoming and outgoing lines the equation

$$D(in/out)\Psi(in/out) = p^k(in,out)\gamma_k\Psi(in/out) \ ,$$

   where the Kähler-Dirac operator is $D(in/out) = \Gamma^t(in/out)D_t$, is assumed. ν_R corresponds to "in" and ν_R to "out". It implies that lines corresponds to massless M^4 Dirac propagator and one obtains something resembling ordinary perturbation theory.

   It also implies that the residue integration over fermionic internal momenta gives as a residue massless fermion lines with non-physical helicities as one can expect in twistor approach. For physical particles the four-momenta are massless but in complex sense and the imaginary part comes classical from four-momenta assignable to the lines of generalized Feynman diagram possessing Euclidian signature of induced metric so that the square root of the metric determinant differs by imaginary unit from that in Minkowskian regions.

3. In the vertex $D(in/out)$ could act in $\Psi(out/in)$ and the natural idea is that $\nu_R - \nu_L$ mixing is due to this so that it would be described the classical weak current couplings $\overline{\nu}_R\Gamma^t_{CP_2}(out)Z^0_t(in)\nu_L$ and $\overline{\nu}_R\Gamma^t_{CP_2}(out)Z^0_t(in)\nu_L$.

To get some idea about orders of magnitude assume that the CP_2 projection of string boundary is geodesic circle thus describable as $\Phi = \omega t$, where Φ is angle coordinate for the circle and t is Minkowski time coordinate. The contribution of CP_2 to the induced metric g_{tt} is $\Delta g_{tt} = -R^2\omega^2$.

1. In the first approximation string end is a light-like curve in Minkowski space meaning that CP_2 contribution to the induced metric vanishes. Neutrino mixing vanishes at this limit.

2. For a non-vanishing value of ωR the mixing and the order of magnitude for mixing rate and neutrino mass is expected to be $R \sim \omega$ and $m \sim \omega/h$. p-Adic length scale hypothesis and the experimental value of neutrino mass allows to estimate m to correspond to p-adic mass to be of order eV so that the corresponding p-adic prime p could be $p \simeq 2^{167}$. Note that $k = 127$ defines largest of the four Gaussian Mersennes $M_{G,k} = (1+i)^k - 1$ appearing in the length scale range 10 nm -2.5 μm. Hence the decay rate for ordinary Planck constant would be of order $R \sim 10^{14}$/s but large value of Planck constant could reduced it dramatically. In living matter reductions by a factor 10^{-12} can be considered.

To sum up, the space-time SUSY in TGD sense would differ crucially from SUSY in the standard sense. There would no Majorana spinors and sparticles could correspond to dark phase of matter with non-standard value of Planck constant. The signatures of the standard SUSY do not apply to TGD. Of course, a lot of professional work would be needed to derive the signatures of TGD SUSY.

4 New Hadron Physics

4.1 Leptohadron Physics

TGD suggest strongly ("predicts" is perhaps too strong expression) the existence of color excited leptons. The mass calculations based on p-adic thermodynamics and p-adic conformal invariance lead to a rather detailed picture about color excited leptons.

1. The simplest color excited neutrinos and charged leptons belong to the color octets ν_8 and L_{10} and $L_{\overline{10}}$ decouplet representations respectively and lepto-hadrons are formed as the color singlet bound states of these and possible other representations. Electro-weak symmetry suggests strongly that the minimal representation content is octet and decouplets for both neutrinos and charged leptons.

2. The basic mass scale for lepto-hadron physics is completely fixed by p-adic length scale hypothesis. The first guess is that color excited leptons have the levels $k = 127, 113, 107, ...$ ($p \simeq 2^k$, k prime or power of prime) associated with charged leptons as primary condensation levels. p-Adic length scale hypothesis allows however also the level $k = 11^2 = 121$ in case of electronic lepto-hadrons. Thus both $k = 127$ and $k = 121$ must be considered as a candidate for the level associated with the observed lepto-hadrons. If also lepto-hadrons correspond non-perturbatively to exotic Super Virasoro representations, lepto-pion mass relates to pion mass by the scaling factor $L(107)/L(k) = k^{(107-k)/2}$. For $k = 121$ one has $m_{\pi_L} \simeq 1.057$ MeV which compares favorably with the mass $m_{\pi_L} \simeq 1.062$ MeV of the lowest observed state: thus $k = 121$ is the best candidate contrary to the earlier beliefs. The mass spectrum of lepto-hadrons is expected to have same general characteristics as hadronic mass spectrum and a satisfactory description should be based on string tension concept. Regge slope is predicted to be of order $\alpha' \simeq 1.02/MeV^2$ for $k = 121$. The masses of ground state lepto-hadrons are calculable once primary condensation levels for colored leptons and the CKM matrix describing the mixing of color excited lepton families is known.

The strongest counter arguments against color excited leptons are the following ones.

1. The decay widths of Z^0 and W boson allow only $N = 3$ light particles with neutrino quantum numbers. The introduction of new light elementary particles seems to make the decay widths of Z^0 and W intolerably large.

2. Lepto-hadrons should have been seen in e^+e^- scattering at energies above few MeV. In particular, lepto-hadronic counterparts of hadron jets should have been observed.

A possible resolution of these problems is provided by the loss of asymptotic freedom in lepto-hadron physics. Lepto-hadron physics would effectively exist in a rather limited energy range about one MeV.

The development of the ideas about dark matter hierarchy [K7, K16, K5, K3] led however to a much more elegant solution of the problem.

1. TGD predicts an infinite hierarchy of various kinds of dark matters which in particular means a hierarchy of color and electro-weak physics with weak mass scales labelled by appropriate p-adic primes different from M_{89}: the simplest option is that also ordinary photons and gluons are labelled by M_{89}.

2. There are number theoretical selection rules telling which particles can interact with each other. The assignment of a collection of primes to elementary particle as characterizer of p-adic primes characterizing the particles coupling directly to it, is inspired by the notion of infinite primes [K17] , and discussed in [K7] . Only particles characterized by integers having common prime factors can interact by the exchange of elementary bosons: the p-adic length scale of boson corresponds to a common primes.

3. Also the physics characterized by different values of h_{eff} are dark with respect to each other as far quantum coherent gauge interactions are considered. Laser beams might well correspond to photons characterized by p-adic prime different from M_{89} and de-coherence for

the beam would mean decay to ordinary photons. De-coherence interaction involves scaling down of the Compton length characterizing the size of the space-time of particle implying that particles do not anymore overlap so that macroscopic quantum coherence is lost.

4. Those dark physics which are dark relative to each other can interact only via graviton exchange. If lepto-hadrons correspond to a physics for which weak bosons correspond to a p-adic prime different from M_{89}, intermediate gauge bosons cannot have direct decays to colored excitations of leptons irrespective of whether the QCD in question is asymptotically free or not. Neither are there direct interactions between the QED:s and QCD:s in question if M_{89} characterizes also ordinary photons and gluons. These ideas are discussed and applied in detail in [K7, K16, K5] .

Skeptic reader might stop the reading after these counter arguments unless there were definite experimental evidence supporting the lepto-hadron hypothesis.

1. The production of anomalous e^+e^- pairs in heavy ion collisions (energies just above the Coulomb barrier) suggests the existence of pseudo-scalar particles decaying to e^+e^- pairs. A natural identification is as lepto-pions that is bound states of color octet excitations of e^+ and e^-.

2. The second puzzle, Karmen anomaly, is quite recent [C15] . It has been found that in charge pion decay the distribution for the number of neutrinos accompanying muon in decay $\pi \rightarrow \mu+\nu_\mu$ as a function of time seems to have a small shoulder at $t_0 \sim ms$. A possible explanation is the decay of charged pion to muon plus some new weakly interacting particle with mass of order 30 MeV [C8] : the production and decay of this particle would proceed via mixing with muon neutrino. TGD suggests the identification of this state as color singlet leptobaryon of, say type $L_B = f_{abc}L_8^aL_8^b\bar{L}_8^c$, having electro-weak quantum numbers of neutrino.

3. The third puzzle is the anomalously high decay rate of orto-positronium. [C21] . e^+e^- annihilation to virtual photon followed by the decay to real photon plus virtual lepto-pion followed by the decay of the virtual lepto-pion to real photon pair, $\pi_L\gamma\gamma$ coupling being determined by axial anomaly, provides a possible explanation of the puzzle.

4. There exists also evidence for anomalously large production of low energy e^+e^- pairs [C14, C19, C17, C33] in hadronic collisions, which might be basically due to the production of lepto-hadrons via the decay of virtual photons to colored leptons.

In this chapter a revised form of lepto-hadron hypothesis is described.

1. Sigma model realization of PCAC hypothesis allows to determine the decay widths of lepto-pion and lepto-sigma to photon pairs and e^+e^- pairs. Ortopositronium anomaly determines the value of $f(\pi_L)$ and therefore the value of lepto-pion-lepto-nucleon coupling and the decay rate of lepto-pion to two photons. Various decay widths are in accordance with the experimental data and corrections to electro-weak decay rates of neutron and muon are small.

2. One can consider several alternative interpretations for the resonances.

   Option 1: For the minimal color representation content, three lepto-pions are predicted corresponding to $8, 10, \overline{10}$ representations of the color group. If the lightest lepto-nucleons e_{ex} have masses only slightly larger than electron mass, the anomalous e^+e^- could be actually $e_{ex}^+ + e_{ex}^-$ pairs produced in the decays of lepto-pions. One could identify 1.062, 1.63 and 1.77 MeV states as the three lepto-pions corresponding to $8, 10, \overline{10}$ representations and also understand why the latter two resonances have nearly degenerate masses. Since d and s quarks have same primary condensation level and same weak quantum numbers as colored e and μ, one might argue that also colored e and μ correspond to $k = 121$. From the mass ratio of the colored e and μ, as predicted by TGD, the mass of the muonic lepto-pion should be about 1.8 MeV in the absence of topological mixing. This suggests that 1.83 MeV state corresponds to the lightest $g = 1$ lepto-pion.

   Option 2: If one believes sigma model (in ordinary hadron physics the existence of sigma meson is not established and its width is certainly very large if it exists), then lepto-pions are accompanied by sigma scalars. If lepto-sigmas decay dominantly to e^+e^- pairs (this might be forced by kinematics) then one could adopt the previous sceneario and could identify 1.062 state as lepto-pion and 1.63, 1.77 and 1.83 MeV states as lepto-sigmas rather than lepto-pions. The fact that muonic lepto-pion should have mass about 1.8 MeV in the absence of topological mixing, suggests that the masses of lepto-sigma and lepto-pion should be rather close to each other.

Option 3: One could also interpret the resonances as string model "satellite states" having interpretation as radial excitations of the ground state lepto-pion and lepto-sigma. This identification is not however so plausible as the genuinely TGD based identification and will not be discussed in the sequel.

3. PCAC hypothesis and sigma model leads to a general model for lepto-hadron production in the electromagnetic fields of the colliding nuclei and production rates for lepto-pion and other lepto-hadrons are closely related to the Fourier transform of the instanton density $\bar{E}\cdot\bar{B}$ of the electromagnetic field created by nuclei. The first source of anomalous e^+e^- pairs is the production of $\sigma_L\pi_L$ pairs from vacuum followed by $\sigma_L \rightarrow e^+e^-$ decay. If $e^+_{ex}e^-_{ex}$ pairs rather than genuine e^+e^- pairs are in question, the production is production of lepto-pions from vacuum followed by lepto-pion decay to lepto-nucleon pair.

   Option 1: For the production of lepto-nucleon pairs the cross section is only slightly below the experimental upper bound for the production of the anomalous e^+e^- pairs and the decay rate of lepto-pion to lepto-nucleon pair is of correct order of magnitude.

   Option 2: The rough order of magnitude estimate for the production cross section of anomalous e^+e^- pairs via $\sigma_l\pi_l$ pair creation followed by $\sigma_L \rightarrow e^+e^-$ decay, is by a factor of order $1/\sum N_c^2$ (N_c is the total number of states for a given colour representation and sum over the representations contributing to the ortopositronium anomaly appears) smaller than the reported cross section in case of 1.8 MeV resonance. The discrepancy could be due to the neglect of the large radiative corrections (the coupling $g(\pi_L\pi_L\sigma_L) = g(\sigma_L\sigma_L\sigma_L)$ is very large) and also due to the uncertainties in the value of the measured cross section.

   Given the unclear status of sigma in hadron physics, one has a temptation to conclude that anomalous e^+e^- pairs actually correspond to lepto-nucleon pairs.

4. The vision about dark matter suggests that direct couplings between leptons and lepto-hadrons are absent in which case no new effects in the direct interactions of ordinary leptons are predicted. If colored leptons couple directly to ordinary leptons, several new physics effects such as resonances in photon-photon scattering at cm energy equal to lepto-pion masses and the production of $e_{ex}\bar{e}_{ex}$ (e_{ex} is leptobaryon with quantum numbers of electron) and $e_{ex}\bar{e}$ pairs in heavy ion collisions, are possible. Lepto-pion exchange would give dominating contribution to $\nu - e$ and $\bar{\nu} - e$ scattering at low energies. Lepto-hadron jets should be observed in e^+e^- annihilation at energies above few MeV:s unless the loss of asymptotic freedom restricts lepto-hadronic physics to a very narrow energy range and perhaps to entirely non-perturbative regime of lepto-hadronic QCD.

During 18 years after the first published version of the model also evidence for colored μ has emerged. Towards the end of 2008 CDF anomaly gave a strong support for the colored excitation of τ. The lifetime of the light long lived state identified as a charged τ-pion comes out correctly and the identification of the reported 3 new particles as p-adically scaled up variants of neutral τ-pion predicts their masses correctly. The observed muon jets can be understood in terms of the special reaction kinematics for the decays of neutral τ-pion to 3 τ-pions with mass scale smaller by a factor 1/2 and therefore almost at rest. A spectrum of new particles is predicted. The discussion of CDF anomaly led to a modification and generalization of the original model for lepto-pion production and the predicted production cross section is consistent with the experimental estimate.

4.2 Evidence For TGD View About QCD Plasma

The emergence of the first interesting findings from LHC by CMS collaboration [C9, C1] provide new insights to the TGD picture about the phase transition from QCD plasma to hadronic phase and inspired also the updating of the model of RHIC events (mainly elimination of some remnants from the time when the ideas about hierarchy of Planck constants had just born).

In some proton-proton collisions more than hundred particles are produced suggesting a single object from which they are produced. Since the density of matter approaches to that observed in heavy ion collisions for five years ago at RHIC, a formation of quark gluon plasma and its subsequent decay is what one would expect. The observations are not however quite what QCD plasma picture would allow to expect. Of course, already the RHIC results disagreed with what QCD expectations. What is so striking is the evolution of long range correlations between particles in events containing more than 90 particles as the transverse momentum of the particles increases in the range 1-3 GeV (see the excellent description of the correlations by Lubos Motl in his blog [C5]).

One studies correlation function for two particles as a function of two variables. The first variable is the difference $\Delta\phi$ for the emission angles and second is essentially the difference for the velocities described relativistically by the difference $\Delta\eta$ for hyperbolic angles. As the transverse momentum p_T increases the correlation function develops structure. Around origin of $\Delta\eta$ axis a widening plateau develops near $\Delta\phi = 0$. Also a wide ridge with almost constant value as function of $\Delta\eta$ develops near $\Delta\phi = \pi$. The interpretation is that particles tend to move collinearly and or in opposite directions. In the latter case their velocity differences are large since they move in opposite directions so that a long ridge develops in $\Delta\eta$ direction in the graph.

Ideal QCD plasma would predict no correlations between particles and therefore no structures like this. The radiation of particles would be like blackbody radiation with no correlations between photons. The description in terms of string like object proposed also by Lubos Motl on basis of analysis of the graph showing the distributions as an explanation of correlations looks attractive. The decay of a string like structure producing particles at its both ends moving nearly parallel to the string to opposite directions could be in question.

Since the densities of particles approach those at RHIC, I would bet that the explanation (whatever it is!) of the hydrodynamical behavior observed at RHIC for some years ago should apply also now. The introduction of string like objects in this model was natural since in TGD framework even ordinary nuclei are string like objects with nucleons connected by color flux tubes [L1] , [L1] : this predicts a lot of new nuclear physics for which there is evidence. The basic idea was that in the high density hadronic color flux tubes associated with the colliding nucleon connect to form long highly entangled hadronic strings containing quark gluon plasma. The decay of these structures would explain the strange correlations. It must be however emphasized that in the recent case the initial state consists of two protons rather than heavy nuclei so that the long hadronic string could form from the QCD like quark gluon plasma at criticality when long range fluctuations emerge.

The main assumptions of the model for the RHIC events and those observed now deserve to be summarized. Consider first the "macroscopic description".

1. A critical system associated with confinement-deconfinement transition of the quark-gluon plasma formed in the collision and inhibiting long range correlations would be in question.

2. The proposed hydrodynamic space-time description was in terms of a scaled variant of what I call critical cosmology defining a universal space-time correlate for criticality: the specific property of this cosmology is that the mass contained by comoving volume approaches to zero at the initial moment so that Big Bang begins as a silent whisper and is not so scaring. Criticality means flat 3-space instead of Lobatchevski space and means breaking of Lorentz invariance to SO(4). Breaking of Lorentz invariance was indeed observed for particle distributions but now I am not so sure whether it has much to do with this.

The microscopic level the description would be like follows.

1. A highly entangled long hadronic string like object (color-magnetic flux tube) would be formed at high density of nucleons via the fusion of ordinary hadronic color-magnetic flux tubes to much longer one and containing quark gluon plasma. In QCD world plasma would not be at flux tube.

2. This geometrically (and perhaps also quantally!) entangled string like object would straighten and split to hadrons in the subsequent "cosmological evolution" and yield large numbers of

almost collinear particles. The initial situation should be apart from scaling similar as in cosmology where a highly entangled soup of cosmic strings (magnetic flux tubes) precedes the space-time as we understand it. Maybe ordinary cosmology could provide analogy as galaxies arranged to form linear structures?

3. This structure would have also black hole like aspects but in totally different sense as the 10-D hadronic black-hole proposed by Nastase to describe the findings. Note that M-theorists identify black holes as highly entangled strings: in TGD 1-D strings are replaced by 3-D string like objects.

4.3 The Incredibly Shrinking Proton

The discovery by Pohl et al (2010) [C20] was that the charge radius of proton deduced from detuerium - the muonic version of hydrogen atom - is .842 fm and about 4 per cent smaller than .875 fm than the charge radius deduced from hydrogen atom [C27, C29] is in complete conflict with the cherished belief that atomic physics belongs to the museum of science (for details see the Wikipedia article `http://tinyurl.com/jkt2mkv`). The title of the article *Quantum electrodynamics-a chink in the armour?* of the article published in Nature [C20] expresses well the possible implications, which might actually go well extend beyond QED.

Quite recently (2016) new more precise data has emerged from Pohl et al [C22] (see `http://tinyurl.com/jd2hwuq`). Now the reduction of charge radius of muonic variant of deuterium is measured. The charge radius is reduced from 2.1424 fm to 2.1256 fm and the reduction is .012 fm, which is about .8 per cent (see `http://tinyurl.com/j4z3yp9`). The charge radius of proton deduced from it is reported to be consistent with the charge radius deduced from deuterium. The anomaly seems therefore to be real. Deuterium data provide a further challenge for various models. The finding is a problem of QED or to the standard view about what proton is. Lamb shift [C2] is the effect distinguishing between the states hydrogen atom having otherwise the same energy but different angular momentum. The effect is due to the quantum fluctuations of the electromagnetic field. The energy shift factorizes to a product of two expressions. The first one describes the effect of these zero point fluctuations on the position of electron or muon and the second one characterizes the average of nuclear charge density as "seen" by electron or muon. The latter one should be same as in the case of ordinary hydrogen atom but it is not. Does this mean that the presence of muon reduces the charge radius of proton as determined from muon wave function? This of course looks implausible since the radius of proton is so small. Note that the compression of the muon's wave function has the same effect.

Before continuing it is good to recall that QED and quantum field theories in general have difficulties with the description of bound states: something which has not received too much attention. For instance, van der Waals force at molecular scales is a problem. A possible TGD based explanation and a possible solution of difficulties proposed for two decades ago is that for bound states the two charged particles (say nucleus and electron or two atoms) correspond to two 3-D surfaces glued by flux tubes rather than being idealized to points of Minkowski space. This would make the non-relativistic description based on Schrödinger amplitude natural and replace the description based on Bethe-Salpeter equation having horrible mathematical properties.

In the following two models of the anomaly will be discussed.

1. The basic idea of the original model is that muon has some probability to end up to the magnetic flux tubes assignable to proton. In this state it would not contribute to the ordinary Schrödinger amplitude. The effect of this would be reduction of $|\Psi|^2$ near origin and apparent reduction of the charge radius of proton. The weakness of the model is that it cannot make quantitative prediction for the size of the effect. Even the sign is questionable. Only S-wave binding energy is affected considerably but does the binding energy really increase by the interaction of muon with the quarks at magnetic flux tubes? Is the average of the charge density seen by muon in S wave state larger, in other words does it spend more time near proton or do the quarks spend more time at the flux tubes?

2. Second option is inspired by data about breaking of universality of weak interactions in neutral B decays possibly manifesting itself also in the anomaly in the magnetic moment of muon. Also the different values of the charge radius deduced from hydrogen atom and

muonium could reflect the breaking of universality. In the original model the breaking of universality is only effective.

3. TGD indeed predicts a dynamical U(3) gauge symmetry whose 8+1 gauge bosons correspond to pairs of fermion and antifermion at opposite throats of wormhole contact. Throats are characterized by genus $g = 0,1,2$, so that bosons are superpositions of states labelled by (g_1, g_2). Fermions correspond to single wormhole throat carrying fermion number and behave as U(3) triplet labelled by g.

   The charged gauge bosons with different genera for wormhole throats are expected to be very massive. The 3 neutral gauge bosons with same genus at both throats are superpositions of states (g,g) are expected to be lighter. Their charge matrices are orthogonal and necessarily break the universality of electroweak interactions. For the lowest boson family - ordinary gauge bosons - the charge matrix is proportional to unit matrix. The exchange of second generation bosons Z_1^0 and γ_1 would give rise to Yukawa potential increasing the binding energies of S-wave states. Therefore Lamb shift defined as difference between energies of S and P waves is increased and the charge radius deduced from Lamb shift becomes smaller.

4. The model thus predicts a correct sign for the effect but the size of the effect from naive estimate assuming only γ_1 contribution and $\alpha_1 = \alpha$ ad $M = 2.9$ TeV is almost by an order of magnitude too small. The values of the gauge couplings α_1 and $\alpha_1 Z, 1$ are free parameters as also the mixing angles between states (g,g). The effect is also proportional to the ratio $(m_\mu/M(boson)^2$. It turns out that the inclusion of Z_1^0 contribution and assumption α_1 and $\alpha_1 Z, 1$ are near color coupling strength α_s gives a correct prediction.

4.3.1 *Basic facts and notions*

In this section the basic TGD inspired ideas and notions - in particular the notion of field body - are introduced and the general mechanism possibly explaining the reduction of the effective charge radius relying on the leakage of muon wave function to the flux tubes associated with u quarks is introduced. After this the value of leakage probability is estimated from the standard formula for the Lamb shift in the experimental situation considered.

1. Basic notions of TGD which might be relevant for the problem

Can one say anything interesting about the possible mechanism behind the anomaly if one accepts TGD framework? How the presence of muon could reduce the charge radius of proton? Let us first list the basic facts and notions.

1. One can say that the size of muonic hydrogen characterized by Bohr radius is by factor $m_e/m_\mu = 1/211.4 = 4.7 \times 10^{-4}$ smaller than for hydrogen atom and equals to 250 fm. Hydrogen atom Bohr radius is .53 Angstroms.

2. Proton contains 2 quarks with charge 2e/3 and one d quark which charge -e/3. These quarks are light. The last determination of u and d quark masses [C18] (see `http://tinyurl.com/zqbj7x4`) gives masses, which are $m_u = 2$ MeV and $m_d = 5$ MeV (I leave out the error bars). The standard view is that the contribution of quarks to proton mass is of same order of magnitude. This would mean that quarks are not too relativistic meaning that one can assign to them a size of order Compton wave length of order $4 \times r_e \simeq 600$ fm in the case of u quark (roughly twice the Bohr radius of muonic hydrogen) and $10 \times r_e \simeq 24$ fm in the case of d quark. These wavelengths are much longer than the proton charge radius and for u quark more than twice longer than the Bohr radius of the muonic hydrogen. That parts of proton would be hundreds of times larger than proton itself sounds a rather weird idea. One could of course argue that the scales in question do not correspond to anything geometric. In TGD framework this is not the way out since quantum classical correspondence requires this geometric correlate.

3. There is also the notion of classical radius of electron and quark. It is given by $r = \alpha\hbar/m$ and is in the case of electron this radius is 2.8 fm whereas proton charge radius is .877 fm and smaller. The dependence on Planck constant is only apparent as it should be since

classical radius is in question. For u quark the classical radius is .52 fm and smaller than proton charge radius. The constraint that the classical radii of quarks are smaller than proton charge radius gives a lower bound of quark masses: p-adic scaling of u quark mass by $2^{-1/2}$ would give classical radius .73 fm which still satisfies the bound. TGD framework the proper generalization would be $r = \alpha_K\hbar/m$, where α_K is Kähler coupling strength defining the fundamental coupling constant of the theory and quantized from quantum criticality. Its value is very near or equal to fine structure constant in electron length scale.

4. The intuitive picture is that light-like 3-surfaces assignable to quarks describe random motion of partonic 2-surfaces with light-velocity. This is analogous to zitterbewegung assigned classically to the ordinary Dirac equation. The notion of braid emerges from the localization of the modes of the induced spinor field to 2-D surfaces - string world sheets and possibly also partonic 2-surfaces carrying vanishing W fields and Z^0 field at least above weak scale. It is implied by well-definedness of em charge for the modes of Kähler-Dirac action. The orbits of partonic 2-surface effectively reduces to braids carrying fermionic quantum numbers. These braids in turn define higher level braids which would move inside a structure characterizing the particle geometrically. Internal consistency suggests that the classical radius $r = \alpha_K\hbar/m$ characterizes the size scale of the zitterbewegung orbits of quarks.

   I cannot resist the temptation to emphasize the fact that Bohr orbitology is now reasonably well understood. The solutions of field equations with higher than 3-D CP_2 projection describing radiation fields allow only generalizations of plane waves but not their superpositions in accordance with the fact it is these modes that are observed. For massless extremals with 2-D CP_2 projection superposition is possible only for parallel light-like wave vectors. Furthermore, the restriction of the solutions of the Chern-Simons Dirac equation at light-like 3-surfaces to braid strands gives the analogs of Bohr orbits. Wave functions of -say electron in atom- are wave functions for the position of wormhole throat and thus for braid strands so that Bohr's theory becomes part of quantum theory.

5. In TGD framework quantum classical correspondence requires -or at least strongly suggests- that also the p-adic length scales assignable to u and d quarks have geometrical correlates. That quarks would have sizes much larger than proton itself how sounds rather paradoxical and could be used as an objection against p-adic length scale hypothesis. Topological field quantization however leads to the notion of field body as a structure consisting of flux tubesandthe identification of this geometric correlate would be in terms of Kähler (or color-, or electro-) magnetic body of proton consisting of color flux tubes beginning from space-time sheets of valence quarks and having length scale of order Compton wavelength much longer than the size of proton itself. Magnetic loops and electric flux tubes would be in question. Also secondary p-adic length scale characterizes field body. For instance, in the case of electron the causal diamond assigned to electron would correspond to the time scale of .1 seconds defining an important bio-rhythm.

2. Could the notion of field body explain the anomaly?

The large Compton radii of quarks and the notion of field body encourage the attempt to imagine a mechanism affecting the charge radius of proton as determined from electron's or muon's wave function.

1. Muon's wave function is compressed to a volume, which is about 8 million times smaller than the corresponding volume in the case of electron. The Compton radius of u quark more that twice larger than the Bohr radius of muonic hydrogen so that muon should interact directly with the field body of u quark. The field body of d quark would have size 24 fm which is about ten times smaller than the Bohr radius so that one can say that the volume in which muons sees the field body of d quark is only one thousandth of the total volume. The main effect would be therefore due to the two u quarks having total charge of 4e/3.

   One can say that muon begins to "see" the field bodies of u quarks and interacts directly with u quarks rather than with proton via its electromagnetic field body. With d quarks it would still interact via protons field body to which d quark should feed its electromagnetic flux. This could be quite enough to explain why the charge radius of proton determined from the expectation value defined by its wave function is smaller for muonium than for hydrogen. One must of course notice that this brings in also direct magnetic interactions with u quarks.

2. What could be the basic mechanism for the reduction of charge radius? Could it be that the muon is caught with some probability into the flux tubes of u quarks and that Schrödinger amplitude for this kind state vanishes near the origin? If so, this portion of state would not contribute to the charge radius and the since the portion ordinary state would smaller, this would imply an effective reduction of the charge radius determined from experimental data using the standard theory since the reduction of the norm of the standard part of the state would be erratically interpreted as a reduction of the charge radius.

3. This effect would be of course present also in the case of electron but in this case the u quarks correspond to a volume which million times smaller than the volume defined by Bohr radius so that electron does not in practice "see" the quark sub-structure of proton. The probability P for getting caught would be in a good approximation proportional to the value of $|\Psi(r_u)|^2$ and in the first approximation one would have

   $$\frac{P_e}{P_\mu} \sim (a_\mu/a_e)^3 = (m_e/m_\mu)^3 \sim 10^{-7} \quad .$$

   from the proportionality $\Psi_i \propto 1/a_i^{3/2}$, i=e,$\mu$.

3. A general formula for Lamb shift in terms of proton charge radius

The charge radius of proton is determined from the Lamb shift between 2S- and 2P states of muonic hydrogen. Without this effect resulting from vacuum polarization of photon Dirac equation for hydrogen would predict identical energies for these states. The calculation reduces to the calculation of vacuum polarization of photon inducing to the Coulomb potential and an additional vacuum polarization term. Besides this effect one must also take into account the finite size of the proton which can be coded in terms of the form factor deducible from scattering data. It is just this correction which makes it possible to determine the charge radius of proton from the Lamb shift.

1. In the article [C7] the basic theoretical results related to the Lamb shift in terms of the vacuum polarization of photon are discussed. Proton's charge density is in this representation is expressed in terms of proton form factor in principle deducible from the scattering data. Two special cases can be distinguished corresponding to the point like proton for which Lamb shift is non-vanishing only for S wave states and non-point like proton for which energy shift is present also for other states. The theoretical expression for the Lamb shift involves very refined calculations. Between 2P and 2S states the expression for the Lamb shift is of form

   $$\Delta E(2P_{3/2}^{F=2}2S_{1/2}^{F=1} = a - br_p^2 + cr_p^3 = 209.968(5)5.2248 \times r_p^2 + 0.0347 \times r_p^3 \ \ meV \quad . \tag{4.1}$$

   where the charge radius $r_p = .8750$ is expressed in femtometers and energy in meVs.

2. The general expression of Lamb shift is given in terms of the form factor by

   $$\begin{aligned} E(2P-2S) &= \int \frac{d^3q}{2\pi)^3} \times (-4\pi\alpha)\frac{F(q^2)}{q^2}\frac{\Pi(q^2)}{q^2} \times X \quad , \\ X &= \int (|\Psi_{2P}(r)|^2 - |\Psi_{2S}(r)|^2) exp(iq\cdot r) dV \quad . \end{aligned} \tag{4.2}$$

   Here Π is is a scalar representing vacuum polarization due to decay of photon to virtual pairs.

The model to be discussed predicts that the effect is due to a leakage from "standard" state to what I call flux tube state. This means a multiplication of $|\Psi_{2P}|^2$ with the normalization factor $1/N$ of the standard state orthogonalized with respect to flux tube state. It is essential that $1/N$ is larger than unity so that the effect is a genuine quantum effect not understandable in terms of classical probability.

The modification of the formula is due to the normalization of the 2P and 2S states. These are in general different. The normalization factor $1/N$ is same for all terms in the expression of Lamb shift for a given state but in general different for 2S and 2P states. Since the lowest order term dominates by a factor of ~ 40 over the second one, one one can conclude that the modification should affect the lowest order term by about 4 per cent. Since the second term is negative and the modification of the first term is interpreted as a modification of the second term when r_p is estimated from the standard formula, the first term must increase by about 4 per cent. This is achieved if this state is orthogonalized with respect to the flux tube state. For states Ψ_0 and Ψ_{tube} with unit norm this means the modification

$$\begin{aligned}\Psi_0 &\rightarrow \frac{1}{1-|C|^2}\times(\Psi_i - C\Psi_{tube}) \ , \\ C &= \langle\Psi_{tube}|\Psi_0\rangle \ . \end{aligned} \tag{4.3}$$

In the lowest order approximation one obtains

$$a - br_p^2 + cr_p^3 \quad\rightarrow\quad (1+|C|^2)a - br_p^2 + cr_p^3 \ . \tag{4.4}$$

Using instead of this expression the standard formula gives a wrong estimate r_p from the condition

$$a - b\hat{r}_p^2 + c\hat{r}_p^3 \rightarrow (1+|C|^2)a - br_p^2 + cr_p^3 \ . \tag{4.5}$$

This gives the equivalent conditions

$$\begin{aligned}\hat{r}_p^2 &= r_p^2 - \frac{|C|^2a}{b} \ , \\ P_{tube} &\equiv |C|^2 \simeq 2\frac{b}{a}\times r_p^2\times\frac{(r_p-\hat{r}_p)}{r_p}) \ . \end{aligned} \tag{4.6}$$

The resulting estimate for the leakage probability is $P_{tube} \simeq .0015$. The model should be able to reproduce this probability.

4.3.2 *A model for the coupling between standard states and flux tube states*

Just for fun one can look whether the idea about confinement of muon to quark flux tube carrying electric flux could make sense.

1. Assume that the quark is accompanied by a flux tube carrying electric flux $\int EdS = -\int \nabla\Phi\cdot dS = q$, where $q = 2e/3 = ke$ is the u quark charge. The potential created by the u quark at the proton end of the flux tube with transversal area $S = \pi R^2$ idealized as effectively 1-D structure is

   $$\Phi = -\frac{ke}{\pi R^2}|x| + \Phi_0 \ . \tag{4.7}$$

   The normalization factor comes from the condition that the total electric flux is q. The value of the additive constant V_0 is fixed by the condition that the potential coincides with Coulomb potential at $r = r_u$, where r_u is u quark Compton length. This gives

   $$e\Phi_0 = \frac{e^2}{r_u} + Kr_u \ , \quad K = \frac{ke^2}{\pi R^2} \ . \tag{4.8}$$

2. Parameter R should be of order of magnitude of charge radius $\alpha_K r_u$ of u quark is free parameter in some limits. $\alpha_K = \alpha$ is expected to hold true in excellent approximation. Therefore a convenient parameterization is

$$R = z\alpha r_u \ . \tag{4.9}$$

   This gives

$$K = \frac{4k}{\alpha r_u^2} \ , \ e\Phi_0 = 4(\pi\alpha + \frac{k}{\alpha})\frac{1}{r_u} \ . \tag{4.10}$$

3. The requirement that electron with four times larger charge radius that u quark can topologically condensed inside the flux tube without a change in the average radius of the flux tube (and thus in a reduction in p-adic length scale increasing its mass by a factor 4!) suggests that $z \geq 4$ holds true at least far away from proton. Near proton the condition that the radius of the flux tube is smaller than electron's charge radius is satisfied for $z = 1$.

1. Reduction of Schrödinger equation at flux tube to Airy equation

The 1-D Schrödinger equation at flux tube has as its solutions Airy functions and the related functions known as "Bairy" functions.

1. What one has is a one-dimensional Schrödinger equation of general form

$$-\frac{\hbar^2}{2m_\mu}\frac{d^2\Psi}{dx^2} + (Kx - e\Phi_0)\Psi = E\Psi \ , \ K = \frac{ke^2}{\pi R^2} \ . \tag{4.11}$$

   By performing a linear coordinate change

$$u = (\frac{2m_\mu K}{\hbar^2})^{1/3}(x - x_E) \ , \ x_E = \frac{-|E| + e\Phi_0}{K} \ , \tag{4.12}$$

   one obtains

$$\frac{d^2\Psi}{du^2} - u\Psi = 0 \ . \tag{4.13}$$

   This differential equation is known as Airy equation (or Stokes equation) and defines special functions $Ai(x)$ known as Airy functions and related functions $Bi(x)$ referred to as "Bairy" functions [B1] . Airy functions characterize the intensity near an optical directional caustic such as that of rainbow.

2. The explicit expressions for $A_i(u)$ and $Bi(u)$ are is given by

$$\begin{aligned} Ai(u) &= \frac{1}{\pi}\int_0^\infty cos(\frac{1}{3}t^3 + ut)dt \ , \\ Bi(u) &= \frac{1}{\pi}\int_0^\infty \left[exp(-\frac{1}{3}t^3) + sin(\frac{1}{3}t^3 + ut)dt\right] \ . \end{aligned} \tag{4.14}$$

   $Ai(u)$ oscillates rapidly for negative values of u having interpretation in terms of real wave vector and goes exponentially to zero for $u > 0$. $Bi(u)$ oscillates also for negative values of x but increases exponentially for positive values of u. The oscillatory behavior and its character become obvious by noticing that stationary phase approximation is possible for $x < 0$.

The approximate expressions of $Ai(u)$ and $Bi(u)$ for $u > 0$ are given by

$$\begin{aligned} Ai(u) &\sim \frac{1}{2\pi^{1/2}}exp(-\frac{2}{3}u^{3/2})u^{-1/4} \quad , \\ Bi(u) &\sim \frac{1}{\pi^{1/2}}exp(\frac{2}{3}u^{3/2})u^{-1/4} \quad . \end{aligned} \tag{4.15}$$

For $u < 0$ one has

$$\begin{aligned} Ai(u) &\sim \frac{1}{\pi^{1/2}}sin(\frac{2}{3}(-u)^{3/2})(-u)^{-1/4} \quad , \\ Bi(u) &\sim \frac{1}{\pi^{1/2}}cos(\frac{2}{3}(-u)^{3/2})(-u)^{-1/4} \quad . \end{aligned} \tag{4.16}$$

3. $u = 0$ corresponds to the turning point of the classical motion where the kinetic energy changes sign. $x = 0$ and $x = r_u$ correspond to the points

$$\begin{aligned} u_{min} \equiv u(0) &= -(\frac{2m_\mu K}{\hbar^2})^{1/3}x_E \quad , \\ u_{max} \equiv u(r_u) &= (\frac{2m_\mu K}{\hbar^2})^{1/3}(r_u - x_E) \quad , \\ x_E &= \frac{-|E| + e\Phi_0}{K} \quad . \end{aligned} \tag{4.17}$$

4. The general solution is

$$\Psi = aAi(u) + bBi(u) \quad . \tag{4.18}$$

The natural boundary condition is the vanishing of Ψ at the lower end of the flux tube giving

$$\frac{b}{a} = -\frac{Ai(u(0))}{Bi(u(0))} \quad . \tag{4.19}$$

A non-vanishing value of b implies that the solution increases exponentially for positive values of the argument and the solution can be regarded as being concentrated in an excellent approximation near the upper end of the flux tube.

Second boundary condition is perhaps most naturally the condition that the energy is same for the flux tube amplitude as for the standard solution. Alternative boundary conditions would require the vanishing of the solution at both ends of the flux tube and in this case one obtains very large number of solutions as WKB approximation demonstrates. The normalization of the state so that it has a unit norm fixes the magnitude of the coefficients a and b since one can choose them to be real.

2. Estimate for the probability that muon is caught to the flux tube

The simplest estimate for the muon to be caught to the flux tube state characterized by the same energy as standard state is the overlap integral of the ordinary hydrogen wave function of muon and of the effectively one-dimensional flux tube. What one means with overlap integral is however not quite obvious.

1. The basic condition is that the modified "standard" state is orthogonal to the flux tube state. One can write the expression of a general state as

$$\begin{aligned}\Psi_{nlm} &\rightarrow N\times(\Psi_{nlm}-C(E,nlm)\Phi_{nlm}) \ ,\\ \Phi_{nlm} &= Y_{lm}\Psi_E \ ,\\ C(E,nlm) &= \langle\Psi_E|\Psi_{nlm}\rangle \ .\end{aligned} \tag{4.20}$$

   Here Φ_{nlm} depends a flux tube state in which spherical harmonics is wave function in the space of orientations of the flux tube and Ψ_E is flux tube state with same energy as standard state. Here an inner product between standard states and flux tube states is introduced.

2. Assuming same energy for flux tube state and standard state, the expression for the total total probability for ending up to single flux tube would be determined from the orthogonality condition as

$$P_{nlm} = \frac{|C(E,nlm)|^2}{1-|C(E,lmn)|^2} \ . \tag{4.21}$$

   Here E refers to the common energy of flux tube state and standard state. The fact that flux tube states vanish at the lower end of the flux tube implies that they do not contribute to the expression for average charge density. The reduced contribution of the standard part implies that the attempt to interpret the experimental results in "standard model" gives a reduced value of the charge radius. The size of the contribution is given by P_{nlm} whose value should be about 4 per cent.

One can consider two alternative forms for the inner product between standard states and flux tube states. Intuitively it is clear that an overlap between the two wave functions must be in question.

1. The simplest possibility is that one takes only overlap at the upper end of the flux tube which defines 2-D surface. Second possibility is that that the overlap is over entire flux tube projection at the space-time sheet of atom.

$$\begin{aligned}\langle\Psi_E|\Psi_{nlm}\rangle &= \int_{end}\overline{\Psi}_r\Psi_{nlm}dS \ \text{(Option I)} \ ,\\ \langle\Psi_E|\Psi_{nlm}\rangle &= \int_{tube}\overline{\Psi}_r\Psi_{nlm}dV \ \text{(Option II)} \ .\end{aligned} \tag{4.22}$$

2. For option I the inner product is non-vanishing only if Ψ_E is non-vanishing at the end of the flux tube. This would mean that electron ends up to the flux tube through its end. The inner product is dimensionless without introduction of a dimensional coupling parameter if the inner product for flux tube states is defined by 1-dimensional integral: one might criticize this assumption as illogical. Unitarity might be a problem since the local behaviour of the flux tube wave function at the end of the flux tube could imply that the contribution of the flux tube state in the quantum state dominates and this does not look plausible. One can of course consider the introduction to the inner product a coefficient representing coupling constant but this would mean loss of predictivity. Schrödinger equation at the end of the flux tubes guarantees the conservation of the probability current only if the energy of flux tube state is same as that of standard state or if the flux tube Schrödinger amplitude vanishes at the end of the flux tube.

3. For option II there are no problems with unitary since the overlap probability is always smaller than unity. Option II however involves overlap between standard states and flux tube states even when the wave function at the upper end of the flux tube vanishes. One can however consider the possibility that the possible flux tube states are orthogonalized with respect to standard states with leakage to flux tubes. The interpretation for the overlap integral would be that electron ends up to the flux tube via the formation of wormhole contact.

3. Option I fails

The considerations will be first restricted to the simpler option I. The generalization of the results of calculation to option II is rather straighforward. It turns out that option II gives correct order of magnitude for the reduction of charge radius for reasonable parameter values.

1. In a good approximation one can express the overlap integrals over the flux tube end (option I) as

$$\begin{aligned} C(E,nlm) &= \int_{tube} \overline{\Psi}_E \Psi_{nlm} dS \simeq \pi R^2 \times Y_{lm} \times C(E,nl) \ , \\ C(E,nl) &= \overline{\Psi}_E(r_u) R_{nl}(r_u) \ . \end{aligned} \tag{4.23}$$

An explicit expression for the coefficients can be deduced by using expression for Ψ_E as a superposition of Airy and Bairy functions. This gives

$$\begin{aligned} C(E,nl) &= \overline{\Psi}_E(r_u) R_{nl}(r_u) \ , \\ \Psi_E(x) &= a_E Ai(u_E) + bBi(u_E) \ , \ \frac{a_E}{b_E} = -\frac{Bi(u_E(0))}{Ai(u_E(0))} \ , \\ u_E(x) &= (\frac{2m_\mu K}{\hbar^2})^{1/3}(x - x_E) \ , \ x_E = \frac{|E| - e\Phi_0}{K} \ , \\ K &= \frac{ke^2}{\pi R^2} \ , \ R = z\alpha_K r_u \ , \ k = \frac{2}{3} \ . \end{aligned} \tag{4.24}$$

The normalization of the coefficients is fixed from the condition that a and b chosen in such a manner that Ψ has unit norm. For these boundary conditions Bi is expected to dominate completely in the sum and the solution can be regarded as exponentially decreasing function concentrated around the upper end of the flux tube.

In order to get a quantitative view about the situation one can express the parameters u_{min} and u_{max} in terms of the basic dimensionless parameters of the problem.

1. One obtains

$$\begin{aligned} u_{min} \equiv u(0) &= -2(\frac{k}{z\alpha})^{1/3}\left[1 + \pi\frac{z}{k}\alpha^2(1 - \frac{1}{2}\alpha r)\right] \times r^{1/3} \ , \\ u_{max} \equiv u(r_u) &= u(0) + 2\frac{k}{z\alpha} \times r^{1/3} \ , \\ r &= \frac{m_\mu}{m_u} \ , \ R = z\alpha r_u \ . \end{aligned} \tag{4.25}$$

   Using the numerical values of the parameters one obtains for $z = 1$ and $\alpha = 1/137$ the values $u_{min} = -33.807$ and $u_{max} = 651.69$. The value of u_{max} is so large that the normalization is in practice fixed by the exponential behavior of Bi for the suggested boundary conditions.

2. The normalization constant is in good approximation defined by the integral of the approximate form of Bi^2 over positive values of u and one has

$$N^2 \simeq \frac{dx}{du} \times \int_{u_{min}}^{u_{max}} Bi(u)^2 du \ , \ \frac{dx}{du} = \frac{1}{2}(\frac{z^2\alpha}{k})^{1/3} \times r^{1/3} r_u \ , \tag{4.26}$$

By taking $t = exp(\frac{4}{3}u^{3/2})$ as integration variable one obtains

$$\begin{aligned} \int_{u_{min}}^{u_{max}} Bi(u)^2 du &\simeq \pi^{-1}\int_{u_{min}}^{u_{max}} exp(\frac{4}{3}u^{3/2})u^{-1/2}du \\ &= (\frac{4}{3})^{2/3}\pi^{-1}\int_{t_{min}}^{t_{max}} \frac{dt}{log(t)^{2/3}} \simeq \frac{1}{\pi}\frac{exp(\frac{4}{3}u_{max}^{3/2})}{u_{max}} \ . \end{aligned} \tag{4.27}$$

This gives for the normalization factor the expression

$$N \simeq \frac{1}{2}(\frac{z^2\alpha}{k})^{2/3} r^{1/3} r_u^{1/2} exp(\frac{2}{3}u_{max}^{3/2}) \ . \tag{4.28}$$

3. One obtains for the value of Ψ_E at the end of the flux tube the estimate

$$\Psi_E(r_u) = \frac{Bi(u_{max})}{N} \simeq 2\pi^{-1/2}\times(\frac{k}{z^2\alpha})^{2/3} r^{1/3} r_u^{-1/2} \ , \ r = \frac{r_u}{r_\mu} \ . \tag{4.29}$$

4. The inner product defined as overlap integral gives for the ground state

$$\begin{aligned} C_{E,00} &= \Psi_E(r_u)\times\Psi_{1,0,0}(r_u)\times\pi R^2 \\ &= 2\pi^{-1/2}(\frac{k}{z^2\alpha})^{2/3} r^{1/3} r_u^{-1/2}\times(\frac{1}{\pi a(\mu)^3})^{1/2}\times exp(-\alpha r)\times\pi z^2\alpha^2 r_u^2 \\ &= 2\pi^{1/2}k^{2/3}z^{2/3}r^{11/6}\alpha^{17/6}exp(-\alpha r) \ . \end{aligned} \tag{4.30}$$

The relative reduction of charge radius equals to $P = C_{E,00}^2$. For $z = 1$ one obtains $P = C_{E,00}^2 = 5.5\times 10^{-6}$, which is by three orders of magnitude smaller than the value needed for $P_{tube} = C_{E,20}^2 = .0015$. The obvious explanation for the smallness is the α^2 factor coming from the area of flux tube in the inner product.

4. Option II could work

The failure of the simplest model is essentially due to the inner product. For option II the inner product for the flux tube states involves the integral over the area of flux tube so that the normalization factor for the state is obtained from the previous one by the replacement $N \rightarrow N/\sqrt{\pi R^2}$. In the integral over the flux tube the exponent function is is in the first approximation equal to constant since the wave function for ground state is at the end of the flux tube only by a factor .678 smaller than at the origin and the wave function is strongly concentrated near the end of the flux tube. The inner product defined by the overlap integral over the flux tube implies $N \rightarrow NS^{1/2}$, $S = \pi R^2 = z^2\alpha^2 r_u^2$. In good approximation the inner product for option II means the replacement

$$\begin{aligned} C_{E,n0} &\rightarrow A\times B\times C_{E,n0} \ , \\ A &= \frac{\frac{dx}{du}}{\sqrt{\pi R^2}} = \frac{1}{2\sqrt{\pi}} z^{-1/3}k^{-1/3}\alpha^{-2/3}r^{1/3} \ , \\ B &= \frac{\int Bi(u)du}{\sqrt{Bi(u_{max})}} = u_{max}^{-1/4} = 2^{-1/4}z^{1/2}k^{-1/4}\alpha^{1/4}r^{-1/12} \ . \end{aligned} \tag{4.31}$$

Using the expression

$$R_{20}(r_u) = \frac{1}{2\sqrt{2}}\times(\frac{1}{a_\mu})^{3/2}\times(2 - r\alpha)\times exp(-r\alpha) \ , \ r = \frac{r_u}{r_\mu} \tag{4.32}$$

one obtains for $C_{E,20}$ the expression

$$C_{E,20} = 2^{-3/4}z^{5/6}k^{1/12}\alpha^{29/12}r^{25/12} \times (2 - r\alpha) \times exp(-r\alpha) \ . \tag{4.33}$$

By the earlier general argument one should have $P_{tube} = |C_{E,20}|^2 \simeq .0015$. $P_{tube} = .0015$ is obtained for $z = 1$ and $N = 2$ corresponding to single flux tube per u quark. If the flux tubes are in opposite directions, the leakage into 2P state vanishes. Note that this leakage does not affect the value of the coefficient a in the general formula for the Lamb shift. The radius of the flux tube is by a factor 1/4 smaller than the classical radius of electron and one could argue that this makes it impossible for electron to topologically condense at the flux tube. For $z = 4$ one would have $P_{tube} = .015$ which is 10 times too large a value. Note that the nucleus possess a wave function for the orientation of the flux tube. If this corresponds to S-wave state then only the leakage beween S-wave states and standard states is possible.

4.3.3 *Are exotic flux tube bound states possible?*

There seems to be no deep reason forbidding the possibility of genuine flux tube states decoupling from the standard states completely. To get some idea about the energy eigenvalues one can apply WKB approximation. This approach should work now: in fact, the study on WKB approximation near turning point by using linearization of the potential leads always to Airy equation so that the linear potential represents an ideal situation for WKB approximation. As noticed these states do not seem to be directly relevant for the recent situation. The fact that these states have larger binding energies than the ordinary states of hydrogen atom might make possible to liberate energy by inducing transitions to these states.

1. Assume that a bound state with a negative energy E is formed inside the flux tube. This means that the condition $p^2 = 2m(E - V) \geq 0$, $V = -e\Phi$, holds true in the region $x \leq x_{max} < r_u$ and $p^2 = 2m(E - V) < 0$ in the region $r_u > x \geq x_{max}$. The expression for x_{max} is

   $$x_{max} = \frac{\pi R^2}{k}(-\frac{|E|}{e^2} + \frac{1}{r_u} + \frac{kr_u}{\pi R^2})\hbar \ . \tag{4.34}$$

   $x_{max} < r_u$ holds true if one has

   $$|E| < \frac{e^2}{r_u} = E_{max} \ . \tag{4.35}$$

   The ratio of this energy to the ground state energy of muonic hydrogen is from $E(1) = e^2/2a(\mu)$ and $a = \hbar/\alpha m$ given by

   $$\frac{E_{max}}{E(n=1)} = \frac{2m_u}{\alpha m_\mu} \simeq 5.185 \ . \tag{4.36}$$

   This encourages to think that the ground state energy could be reduced by the formation of this kind of bound state if it is possible to find a value of n in the allowed range. The physical state would of course contain only a small fraction of this state. In the case of electron the increase of the binding energy is even more dramatic since one has

   $$\frac{E_{max}}{E(n=1)} = \frac{2m_u}{\alpha m_e} = \frac{8}{\alpha} \simeq 1096 \ . \tag{4.37}$$

   Obviously the formation of this kind of states could provide a new source of energy. There have been claims about anomalous energy production in hydrogen [D1] . I have discussed these claims from TGD viewpoint in [K18]

2. One can apply WKB quantization in the region where the momentum is real to get the condition

$$I = \int_0^{x_{max}} \sqrt{2m(E+e\Phi)}\frac{dx}{\hbar} = n+\frac{1}{2} \ . \quad (4.38)$$

   By performing the integral one obtains the quantization condition

$$\begin{aligned} I &= k^{-1}(8\pi\alpha)^{1/2}\times \frac{R^2}{r_u^{3/2}r_\mu}\times A^{3/2} = n+\frac{1}{2} \ , \\ A &= 1+kx^2-\frac{|E|r_u}{e^2} \ , \\ x &= \frac{r_u}{R} \ , \ k=\frac{2}{3\pi} \ , \ r_i = \frac{\hbar}{m_i} \ . \end{aligned} \quad (4.39)$$

3. Parameter R should be of order of magnitude of charge radius $\alpha_K r_u$ of u quark is free parameter in some limits. $\alpha_K=\alpha$ is expected to hold true in excellent approximation. Therefore a convenient parameterization is

$$R = z\alpha r_u \ . \quad (4.40)$$

   This gives for the binding energy the general expression in terms of the ground state binging energy $E(1,\mu)$ of muonic hydrogen as

$$\begin{aligned} |E| &= C\times E(1,\mu) \ , \\ C &= D\times(1+Kz^{-2}\alpha^{-2}-(\frac{y}{z^2})^{2/3}\times(n+1/2)^{2/3}) \ , \\ D &= 2y\times(\frac{K^2}{8\pi\alpha})^{1/3} \ , \\ y &= \frac{m_u}{m_\mu} \ , \ K=\frac{2}{3\pi} \ . \end{aligned} \quad (4.41)$$

4. There is a finite number of bound states. The above mentioned consistency conditions coming from $0<x_{max}<r_\mu$ give $0<C<C_{max}=5.185$ restricting the allowed value of n to some interval. One obtains the estimates

$$\begin{aligned} n_{min} &\simeq \frac{z^2}{y}(1+Kz^{-2}\alpha^{-2}-\frac{C_{max}}{D})^{3/2}-\frac{1}{2} \ , \\ n_{max} &= \frac{z^2}{y}(1+Kz^{-2}\alpha^{-2})^{3/2}-\frac{1}{2} \ . \end{aligned} \quad (4.42)$$

   Very large value of n is required by the consistency condition. The calculation gives $n_{min}\in\{1.22\times10^7, 4.59\times10^6, 1.48\times10^5\}$ and $n_{max}\in\{1.33\times10^7, 6.66\times10^6, 3.34\times10^6\}$ for $z\in\{1,2,4\}$. This would be a very large number of allowed bound states -about 3.2×10^6 for $z=1$.

The WKB state behaves as a plane wave below x_{max} and sum of exponentially decaying and increasing amplitudes above x_{max}:

$$\frac{1}{\sqrt{k(x)}}\left[Aexp(i\int_0^x k(y)dy) + Bexp(-i\int_0^x k(y)dy)\right] \ ,$$
$$\frac{1}{\sqrt{\kappa(x)}}\left[Cexp(-\int_{x_{max}}^x \kappa(y)dy + Dexp(\int_{x_{max}}^x \kappa(y)dy\right] \ ,$$
$$k(x) = \sqrt{2m(-|E| + e\Phi)} \ , \ \kappa(x)\sqrt{2m(|E| - e\Phi)} \ . \tag{4.43}$$

At the classical turning point these two amplitudes must be identical.

The next task is to decide about natural boundary conditions. Two types of boundary conditions must be considered. The basic condition is that genuine flux tube states are in question. This requires that the inner product between flux tube states and standard states defined by the integral over flux tube ends vanishes. This is guaranteed if the Schrödinger amplitude for the flux tube state vanishes at the ends of the flux tube so that flux tube behaves like an infinite potential well. The condition $\Psi(0) = 0$ at the lower end of the flux tube would give $A = -B$. Combined with the continuity condition at the turning point these conditions imply that Ψ can be assumed to be real. The $\Psi(r_u) = 0$ gives a condition leading to the quantization of energy.

The wave function over the directions of flux tube with a given value of n is given by the spherical harmonics assigned to the state (n, l, m).

4.3.4 Could second generation of weak bosons explain the reduction of proton charge radius?

The above proposed speculative model is not the only one that one can imagine. The observation could be explained also as breaking of the universality of weak interactions. Also other anomalies challenging the universality exists. The decays of neutral B-meson to lepton pairs should be same apart from corrections coming from different lepton masses by universality but this does not seem to be the case [K11]. There is also anomaly in muon's magnetic moment discussed briefly in [K21]. This leads to ask whether the breaking of universality could be due to the failure of universality of electroweak interactions.

The proposal for the explanation of the muon's anomalous magnetic moment and anomaly in the decays of B-meson is inspired by a recent very special di-electron event and involves higher generations of weak bosons predicted by TGD leading to a breaking of lepton universality. Both Tommaso Dorigo (`http://tinyurl.com/pfw7qqm`) and Lubos Motl (`http://tinyurl.com/hqzat92`) tell about a spectacular 2.9 TeV di-electron event not observed in previous LHC runs. Single event of this kind is of course most probably just a fluctuation but human mind is such that it tries to see something deeper in it - even if practically all trials of this kind are chasing of mirages.

Since the decay is leptonic, the typical question is whether the dreamed for state could be an exotic Z boson. This is also the reaction in TGD framework. The first question to ask is whether weak bosons assignable to Mersenne prime M_{89} have scaled up copies assignable to Gaussian Mersenne M_{79}. The scaling factor for mass would be $2^{(89-79)/2} = 32$. When applied to Z mass equal to about .09 TeV one obtains 2.88 TeV, not far from 2.9 TeV. Eureka!? Looks like a direct scaled up version of Z!? W should have similar variant around 2.6 TeV.

TGD indeed predicts exotic weak bosons and also gluons.

1. TGD based explanation of family replication phenomenon in terms of genus-generation correspondence forces to ask whether gauge bosons identifiable as pairs of fermion and antifermion at opposite throats of wormhole contact could have bosonic counterpart for family replication. Dynamical SU(3) assignable to three lowest fermion generations labelled by the genus of partonic 2-surface (wormhole throat) means that fermions are combinatorially SU(3) triplets. Could 2.9 TeV state - if it would exist - correspond to this kind of state in the tensor product of triplet and antitriplet? The mass of the state should depend besides p-adic mass scale also on the structure of SU(3) state so that the mass would be different. This difference should be very small.

2. Dynamical SU(3) could be broken so that wormhole contacts with different genera for the throats would be more massive than those with the same genera. This would give SU(3)

singlet and two neutral states, which are analogs of $\eta\prime$ and η and π^0 in Gell-Mann's quark model. The masses of the analogs of η and π^0 and the analog of $\eta\prime$, which I have identified as standard weak boson would have different masses. But how large is the mass difference?

3. These 3 states are expected top have identical mass for the same p-adic mass scale, if the mass comes mostly from the analog of hadronic string tension assignable to magnetic flux tube. connecting the two wormhole contacts associates with any elementary particle in TGD framework (this is forced by the condition that the flux tube carrying monopole flux is closed and makes a very flattened square shaped structure with the long sides of the square at different space-time sheets). p-Adic thermodynamics would give a very small contribution genus dependent contribution to mass if p-adic temperature is $T = 1/2$ as one must assume for gauge bosons ($T = 1$ for fermions). Hence 2.95 TeV state could indeed correspond to this kind of state.

Could the exchange of massive $M_{G,79}$ photon and Z^0 give rise to additional electromagnetic interaction inducing the breaking of Universality?

1. The additional contribution in the effective Coulomb potential is Yukawa potential. In S-wave state this would give a contribution to the binding energy in a good approximation given by the expectation value of the Yukawa potential, which can be parameterized as

$$V(r) = g^2\tfrac{e^{-Mr}}{r} \ \ , \quad g^2 = 4\pi k\alpha \ \ . \tag{4.44}$$

. The expectation differs from zero significantly only in S-wave state characterized by principal quantum number n. Since the exponent function goes exponentially to zero in the p-adic length scale associated with 2.9 TeV mass, which is roughly by a factor 32 times shorter than intermediate boson mass scale, hydrogen atom wave function is constant in excellent approximation in the effective integration volume. This gives for the energy shift

$$\begin{aligned} \Delta E &= g^2|\Psi(0|^2\times I \ \ , \\ |\Psi(0|^2 &= \frac{2^2}{n^2}\frac{1}{a_0^3} \ \ , \ \ a_0 = \frac{1}{m\alpha} \ \ , \\ I &= \int \frac{e^{-Mr}}{r}r^2drd\Omega = \frac{4\pi}{M^2} \ \ . \end{aligned} \tag{4.45}$$

For the energy shift and its ratio to ground state energy

$$E_n = \frac{\alpha^2}{2n^2}\times m \tag{4.46}$$

on obtains the expression

$$\begin{aligned} \Delta E_n &= \frac{64\pi^2\alpha}{n^2}\alpha^3(\frac{m}{M})^2\times m \ \ , \\ \frac{\Delta E_n}{E_n} &= 2^7\pi^2\alpha^2k^2(\frac{m}{M})^2 \ \ . \end{aligned} \tag{4.47}$$

For $k = 1$ and $M = 2.9$ TeV one has $\Delta E_n/E_n \simeq 8.9\times 10^{-11}$ for muon.

Consider next Lamb shift.

1. Lamb shift as difference of energies between S and P wave states (see `http://tinyurl.com/y99ctyn4`) is approximately given by

$$\frac{\Delta_n(Lamb)}{E_n} = \frac{13\alpha^3}{2n} \ . \tag{4.48}$$

   For $n = 2$ this gives $\Delta_2(Lamb)/E_2 = 4.9 \times 10^{-7}$.

2. Recall that the previous parameterization for the theoretical Lamb shift reads as

$$\Delta E(r_p(th)) = a - br_p^2 + cr_p^3 = 209.968(5)5.2248 \times r_p^2 + 0.0347 \times r_p^3 \ \ meV \ . \tag{4.49}$$

   where the charge radius $r_p = .8750$ is expressed in femtometers and energy in meVs.

3. The reduction of r_p by 3.3 per cent allows to estimate the reduction of Lamb shift (attractive additional potential reduces it). The relative change of the Lamb shift is

$$\begin{aligned} x &= \frac{\Delta E(r_p(th)) - \Delta E(r_p(exp))}{\Delta E(r_p(th))} \\ &= \frac{5.2248 \times (r_p^2(th) - r_p^2(exp)) + 0.0347 \times (r_p^3(th) - r_p^3(exp))}{209.968(5)5.2248 \times r_p^2(th) + 0.0347 \times r_p^3(th)} \ . \end{aligned} \tag{4.50}$$

   The estimate gives $x = 1.2 \times 10^{-3}$.

This value can be compared with the prediction. For $n = 2$ ratio of $\Delta E_n/\Delta E_n(Lamb)/$ is

$$x = \frac{\Delta E_n}{\Delta E_n(Lamb)} = k^2 \times \frac{2^9\pi^2}{13\alpha} \times (\frac{m}{M})^2 \ . \tag{4.51}$$

For $M = 2.9$ TeV the numerical estimate gives $x \simeq k^2 \times 10^{-4}$. The value of x deduced from experimental data is $x \simeq 1.2 \times 10^{-3}$. For $k = 3$ a correct order of magnitude is obtained. There are thus good hopes that the model works.

The contribution of Z_1^0 exchange is neglected in the above estimate. Is it present and can it explain the discrepancy?

1. In the case of deuterium the weak isospins of proton and deuterium are opposite so that their contributions to the Z_1^0 vector potential cancel. If Z_1^0 contribution for proton can be neglected, one has $\Delta r_p = \Delta r_d$.

   One however has $\Delta r_p \simeq 2.75\Delta r_d$. Hence Z_1^0 contribution to Δr_p should satisfy $\Delta r_p(Z_1^0) \simeq 1.75 \times \Delta r_p(\gamma_1)$. This requires $\alpha_{Z,1} > \alpha_1$, which is true also for the ordinary gauge bosons. The weak isospins of electron and proton are opposite so that the atom is weak isospin singlet in Abelian sense, and one has $I_p^3 I_\mu^3 = -1/4$ and attractive interaction. The condition relating r_p and r_Z suggests

$$\frac{\alpha_{Z,1}}{\alpha_1} \simeq \frac{28}{6} = 4 + \frac{1}{3} \ .$$

   In standard model one has $\alpha_Z/\alpha = 1/[sin^2(\theta_W)cos^2(\theta_W)] = 5.6$ for $sin^2(\theta_W) = .23$. One has upper bound $\alpha_{Z,1}/\alpha_1 \geq 4$ saturated for $sin^2(\theta_{W,1}) = 1/2$. Weinberg angle can be expressed as

$$sin^2(\theta_{W,1}) = \frac{1}{2}\left[1 - \sqrt{1 - 4\frac{\alpha_1}{\alpha_{Z,1}}}\right] \ .$$

   $\alpha_{Z,1}/\alpha_1 \simeq 28/6$ gives $sin^2(\theta_{W,1}) = \frac{1}{2}[1-\sqrt{1/7}] \simeq .31$.

   The contribution to the axial part of the potential depending on spin need not cancel and could give a spin dependent contribution for both proton and deuteron.

2. If the scale of α_1 and $\alpha_{Z,1}$ is that of $\alpha_s \simeq .1$ at TeV energy scale and if the factor 2.75 emerges in the proposed manner, one has $k^2 \simeq 2.75 \times 10 = 27.5$ rather near to the rough estimate $k^2 \simeq 27$ from data for proton. This would give $\alpha_1 \simeq 1/13.7$.

   Note however than there are mixing angles involved corresponding to the diagonal hermitian family charge matrix $Q = (a, b, c)$ satisfying $a^2 + b^2 + c^2 = 1$ and the condition $a + b + c = 0$ expressing the orthogonality with the electromagnetic charge matrix $(1, 1, 1)/\sqrt{3}$ expressing electroweak universality for ordinary electroweak bosons. For instance, one could have $(a, b, c) = (0, 1, -1)/\sqrt{2}$ for the second generation and $(a, b, c) = (2, -1, -1)/\sqrt{6}$ for the third generation. In this case the above estimate would would be scaled down: $\alpha_1 \rightarrow 2\alpha_1/3 \simeq 1/20.5$.

To sum up, the proposed model is successful at quantitative level allowing to understand the different changes for charge radius for proton and deuteron and estimate the values of electroweak couplings of the second generation of weak bosons apart from the uncertainty due to the family charge matrix. Muon's magnetic moment anomaly and decays of neutral B allow to test the model and perhaps fix the remaining two mixing angles.

4.4 Misbehaving b-quarks and the magnetic body of proton

Science news tells about misbehaving bottom quarks (see `http://tinyurl.com/jpkwey4` and ICHEP conference talk at `http://tinyurl.com/z4lqtvz`). Or perhaps one should talk about misbehaving b-hadrons - hadrons containing b- quarks. The mis-behavior appears in proton-proton collisions at LHC. This is not the only anomaly associated with proton. The spin of proton is still poorly understood and proton charge radius if quite not what it should be. Now we learn that there are more b-containing hadrons (b-hadrons) in the directions deviating considerably from the direction of proton beam: discrepancy factor is of order two.

How this could reflect the structure of proton? Color magnetic flux tubes are the new TGD based element in the model or proton: could they help? I assign to proton color magnetic flux tubes with size scale much larger than proton size - something like electron Compton length: most of the mass of proton is color magnetic energy associated with these tubes and they define the non-perturbative aspect of hadron physics in TGD framework. For instance, constituent quarks would be valence quarks plus their color flux tubes. Current quarks just the quarks whose masses give rather small contribution to proton mass.

What happens when two protons collide? In cm system the dipolar flux tubes get contracted in the direction of motion by Lorentz contraction. Suppose b-hadrons tend to leave proton along the color magnetic flux tubes (also ordinary em flux tubes could be in question). Lorentz contraction of flux tubes means that they tend to leave in directions orthogonal to the collision axis. Could this explain the misbehavior of b-hadrons?

But why only b-hadrons or some fraction of them should behave in this manner? Why not also lighter hadrons containing c and s? Could this relate to the much smaller size of b-quark defined by its Compton length $L = \hbar/m(b)$, $m(b) = 4.2 GeV$, which is much shorter than the Compton length of u-quark (the mass of constituent u quark is something like 300 MeV and the mass of current u quark is few MeVs. Could it be that lighter hadrons do not leave proton along flux tubes? Why? Are these hadrons or corresponding quarks too large to fit (topologically condense) inside protonic flux tube? b-quark is much more massive and has considerably smaller size than say c-quark with mass $m(c) = 1.5$ GeV and could be able to topologically condense inside the protonic flux tube. c quark should be too large, which suggests that the radius of flux tubes is larger than proton Compton length. This picture conforms with the view of perturbative QCD in which the primary processes take place at parton level. The hadronization would occur in longer time scale and generate the magnetic bodies of outgoing hadrons. The alternative idea that also the color magnetic body of hadron should fit inside the protonic color flux tube is not consistent with this view.

4.5 Dark Nuclear Strings As Analogs Of DNA-, RNA- And Amino-Acid Sequences And Baryonic Realization Of Genetic Code?

Water memory is one of the ugly words in the vocabulary of a main stream scientist. The work of pioneers is however now carrying fruit. The group led by Jean-Luc Montagnier, who received Nobel prize for discovering HIV virus, has found strong evidence for water memory and detailed information about the mechanism involved [K8, K19] , [I1] . The work leading to the discovery was motivated by the following mysterious finding. When the water solution containing human cells infected by bacteria was filtered in purpose of sterilizing it, it indeed satisfied the criteria for the absence of infected cells immediately after the procedure. When one however adds human cells to the filtrate, infected cells appear within few weeks. If this is really the case and if the filter does what it is believed to do, this raises the question whether there might be a representation of genetic code based on nano-structures able to leak through the filter with pores size below 200 nm.

The question is whether dark nuclear strings might provide a representation of the genetic code. In fact, I posed this question year before the results of the experiment came with motivation coming from attempts to understand water memory. The outcome was a totally unexpected finding: the states of dark nucleons formed from three quarks can be naturally grouped to multiplets in one-one correspondence with 64 DNAs, 64 RNAS, and 20 amino-acids and there is natural mapping of DNA and RNA type states to amino-acid type states such that the numbers of DNAs/RNAs mapped to given amino-acid are same as for the vertebrate genetic code.

The basic idea is simple. Since baryons consist of 3 quarks just as DNA codons consist of three nucleotides, one might ask whether codons could correspond to baryons obtained as open strings with quarks connected by two color flux tubes. This representation would be based on entanglement rather than letter sequences. The question is therefore whether the dark baryons constructed as string of 3 quarks using color flux tubes could realize 64 codons and whether 20 amino-acids could be identified as equivalence classes of some equivalence relation between 64 fundamental codons in a natural manner.

The following model indeed reproduces the genetic code directly from a model of dark neutral baryons as strings of 3 quarks connected by color flux tubes.

1. Dark nuclear baryons are considered as a fundamental realization of DNA codons and constructed as open strings of 3 dark quarks connected by two colored flux tubes, which can be also charged. The baryonic strings cannot combine to form a strictly linear structure since strict rotational invariance would not allow the quark strings to have angular momentum with respect to the quantization axis defined by the nuclear string. The independent rotation of quark strings and breaking of rotational symmetry from SO(3) to SO(2) induced by the direction of the nuclear string is essential for the model.

   (a) Baryonic strings could form a helical nuclear string (stability might require this) locally parallel to DNA, RNA, or amino-acid) helix with rotations acting either along the axis of the DNA or along the local axis of DNA along helix. The rotation of a flux tube portion around an axis parallel to the local axis along DNA helix requires that magnetic flux tube has a kink in this portion. An interesting question is whether this kink has correlate at the level of DNA too. Notice that color bonds appear in two scales corresponding to these two strings. The model of DNA as topological quantum computer [K6] allows a modification in which dark nuclear string of this kind is parallel to DNA and each codon has a flux tube connection to the lipid of cell membrane or possibly to some other bio-molecule.

   (b) The analogs of DNA -, RNA -, and of amino-acid sequences could also correspond to sequences of dark baryons in which baryons would be 3-quark strings in the plane transversal to the dark nuclear string and expected to rotate by stringy boundary conditions. Thus one would have nuclear string consisting of short baryonic strings not connected along their ends. In this case all baryons would be free to rotate.

2. The new element as compared to the standard quark model is that between both dark quarks and dark baryons can be charged carrying charge $0, \pm 1$. This is assumed also in nuclear string model and there is empirical support for the existence of exotic nuclei containing charged color bonds between nuclei.

3. The net charge of the dark baryons in question is assumed to vanish to minimize Coulomb repulsion:

$$\sum_q Q_{em}(q) = -\sum_{flux\ tubes} Q_{em}(flux\ tube) \ . \tag{4.52}$$

   This kind of selection is natural taking into account the breaking of isospin symmetry. In the recent case the breaking cannot however be as large as for ordinary baryons (implying large mass difference between Δ and nucleon states).

4. One can classify the states of the open 3-quark string by the total charges and spins associated with 3 quarks and to the two color bonds. Total em charges of quarks vary in the range $Z_B \in \{2,1,0,-1\}$ and total color bond charges in the range $Z_b \in \{2,1,0,-1,-2\}$. Only neutral states are allowed. Total quark spin projection varies in the range $J_B = 3/2, 1/2, -1/2, -3/2$ and the total flux tube spin projection in the range $J_b = 2,1,-1,-2$. If one takes for a given total charge assumed to be vanishing one representative from each class (J_B, J_b), one obtains $4\times 5 = 20$ states which is the number of amino-acids. Thus genetic code might be realized at the level of baryons by mapping the neutral states with a given spin projection to single representative state with the same spin projection. The problem is to find whether one can identify the analogs of DNA, RNA and amino-acids as baryon like states.

4.5.1 *States in the quark degrees of freedom*

One must construct many-particle states both in quark and flux tube degrees of freedom. These states can be constructed as representations of rotation group SU(2) and strong isospin group SU(2) by using the standard tensor product rule $j_1 \times j_2 = j_1 + j_2 \oplus j_1 + j_2 - 1 \oplus ... \oplus |j_1 - j_2|$ for the representation of SU(2) and Fermi statistics and Bose-Einstein statistics are used to deduce correlations between total spin and total isospin (for instance, $J = I$ rule holds true in quark degrees of freedom). Charge neutrality is assumed and the breaking of rotational symmetry in the direction of nuclear string is assumed.

Consider first the states of dark baryons in quark degrees of freedom.

1. The tensor product $2 \otimes 2 \otimes 2$ is involved in both cases. Without any additional constraints this tensor product decomposes as $(3 \oplus 1) \otimes 2 = 4 \oplus 2 \oplus 2$: 8 states altogether. This is what one should have for DNA and RNA candidates. If one has only identical quarks uuu or ddd, Pauli exclusion rule allows only the 4-D spin 3/2 representation corresponding to completely symmetric representation -just as in standard quark model. These 4 states correspond to a candidate for amino-acids. Thus RNA and DNA should correspond to states of type uud and ddu and amino-acids to states of type uuu or ddd. What this means physically will be considered later.

2. Due to spin-statistics constraint only the representations with $(J, I) = (3/2, 3/2)$ (Δ resonance) and the second $(J, I) = (1/2, 1/2)$ (proton and neutron) are realized as free baryons. Now of course a dark -possibly p-adically scaled up - variant of QCD is considered so that more general baryonic states are possible. By the way, the spin statistics problem which forced to introduce quark color strongly suggests that the construction of the codons as sequences of 3 nucleons - which one might also consider - is not a good idea.

3. Second nucleon like spin doublet - call it 2_{odd} - has wrong parity in the sense that it would require $L = 1$ ground state for two identical quarks (uu or dd pair). Dropping 2_{odd} and using only $4 \oplus 2$ for the rotation group would give degeneracies $(1,2,2,1)$ and 6 states only. All the representations in $4 \oplus 2 \oplus 2_{odd}$ are needed to get 8 states with a given quark charge and one should transform the wrong parity doublet to positive parity doublet somehow. Since open string geometry breaks rotational symmetry to a subgroup SO(2) of rotations acting along the direction of the string and since the boundary conditions on baryonic strings force their ends to rotate with light velocity, the attractive possibility is to add a baryonic stringy excitation with angular momentum projection $L_z = -1$ to the wrong parity doublet so that

the parity comes out correctly. $L_z = -1$ orbital angular momentum for the relative motion of *uu* or *dd* quark pair in the open 3-quark string would be in question. The degeneracies for spin projection value $J_z = 3/2, ..., -3/2$ are $(1, 2, 3, 2)$. Genetic code means spin projection mapping the states in $4 \oplus 2 \oplus 2_{odd}$ to 4.

4.5.2 *States in the flux tube degrees of freedom*

Consider next the states in flux tube degrees of freedom.

1. The situation is analogous to a construction of mesons from quarks and antiquarks and one obtains the analogs of π meson (pion) with spin 0 and ρ meson with spin 1 since spin statistics forces $J = I$ condition also now. States of a given charge for a flux tube correspond to the tensor product $2 \otimes 2 = 3 \oplus 1$ for the rotation group.

2. Without any further constraints the tensor product $3 \otimes 3 = 5 \oplus 3 \oplus 1$ for the flux tubes states gives 8+1 states. By dropping the scalar state this gives 8 states required by DNA and RNA analogs. The degeneracies of the states for DNA/RNA type realization with a given spin projection for $5 \oplus 3$ are $(1, 2, 2, 2, 1)$. $8\times$ 8 states result altogether for both *uud* and *udd* for which color bonds have different charges. Also for *ddd* state with quark charge -1 one obtains $5 \oplus 3$ states giving 40 states altogether.

3. If the charges of the color bonds are identical as the are for *uuu* type states serving as candidates for the counterparts of amino-acids bosonic statistics allows only 5 states ($J = 2$ state). Hence 20 counterparts of amino-acids are obtained for *uuu*. Genetic code means the projection of the states of $5 \oplus 3$ to those of 5 with the same spin projection and same total charge.

4.5.3 *Analogs of DNA,RNA, amino-acids, and of translation and transcription mechanisms*

Consider next the identification of analogs of DNA, RNA and amino-acids and the baryonic realization of the genetic code, translation and transcription.

1. The analogs of DNA and RNA can be identified dark baryons with quark content *uud*, *ddu* with color bonds having different charges. There are 3 color bond pairs corresponding to charge pairs $(q_1, q_2) = (-1, 0), (-1, 1), (0, 1)$ (the order of charges does not matter). The condition that the total charge of dark baryon vanishes allows for *uud* only the bond pair $(-1, 0)$ and for *udd* only the pair $(-1, 1)$. These thus only single neutral dark baryon of type *uud resp. udd*: these would be the analogous of DNA and RNA codons. Amino-acids would correspond to *uuu* states with identical color bonds with charges $(-1, -1)$, $(0, 0)$, or $(1, 1)$. *uuu* with color bond charges (-1,-1) is the only neutral state. Hence only the analogs of DNA, RNA, and amino-acids are obtained, which is rather remarkable result.

2. The basic transcription and translation machinery could be realized as processes in which the analog of DNA can replicate, and can be transcribed to the analog of mRNA in turn translated to the analogs of amino-acids. In terms of flux tube connections the realization of genetic code, transcription, and translation, would mean that only dark baryons with same total quark spin and same total color bond spin can be connected by flux tubes. Charges are of course identical since they vanish.

3. Genetic code maps of $(4\oplus 2\oplus 2)\otimes(5\oplus 3)$ to the states of 4×5. The most natural map takes the states with a given spin to a state with the same spin so that the code is unique. This would give the degeneracies $D(k)$ as products of numbers $D_B \in \{1, 2, 3, 2\}$ and $D_b \in \{1, 2, 2, 2, 1\}$: $D = D_B \times D_b$. Only the observed degeneracies $D = 1, 2, 3, 4, 6$ are predicted. The numbers $N(k)$ of amino-acids coded by D codons would be

$$[N(1), N(2), N(3), N(4), N(6)] = [2, 7, 2, 6, 3] \ .$$

The correct numbers for vertebrate nuclear code are $(N(1), N(2), N(3), N(4), N(6)) = (2, 9, 1, 5, 3)$. Some kind of symmetry breaking must take place and should relate to the emergence of stopping codons. If one codon in second 3-plet becomes stopping codon, the 3-plet becomes doublet. If 2 codons in 4-plet become stopping codons it also becomes doublet and one obtains the correct result $(2, 9, 1, 5, 3)$!

4. Stopping codons would most naturally correspond to the codons, which involve the $L_z = -1$ relative rotational excitation of uu or dd type quark pair. For the 3-plet the two candidates for the stopping codon state are $|1/2, -1/2\rangle \otimes \{|2, k\rangle\}$, $k = 2, -2$. The total spins are $J_z = 3/2$ and $J_z = -7/2$. The three candidates for the 4-plet from which two states are thrown out are $|1/2, -3/2\rangle \otimes \{|2, k\rangle, |1, k\rangle\}$, $k = 1, 0, -1$. The total spins are now $J_z = -1/2, -3/2, -5/2$. One guess is that the states with smallest value of J_z are dropped which would mean that $J_z = -7/2$ states in 3-plet and $J_z = -5/2$ states 4-plet become stopping codons.

5. One can ask why just vertebrate code? Why not vertebrate mitochondrial code, which has unbroken $A - G$ and $T - C$ symmetries with respect to the third nucleotide. And is it possible to understand the rarely occurring variants of the genetic code in this framework? One explanation is that the baryonic realization is the fundamental one and biochemical realization has gradually evolved from non-faithful realization to a faithful one as kind of emulation of dark nuclear physics. Also the role of tRNA in the realization of the code is crucial and could explain the fact that the code can be context sensitive for some codons.

4.5.4 *Understanding the symmetries of the code*

Quantum entanglement between quarks and color flux tubes would be essential for the baryonic realization of the genetic code whereas chemical realization could be said to be classical. Quantal aspect means that one cannot decompose to codon to letters anymore. This raises questions concerning the symmetries of the code.

1. What is the counterpart for the conjugation $ZYZ \rightarrow X_cY_cZ_c$ for the codons?

2. The conjugation of the second nucleotide Y having chemical interpretation in terms of hydrophoby-hydrophily dichotomy in biology. In DNA as TQC model it corresponds to matter-antimatter conjugation for quarks associated with flux tubes connecting DNA nucleotides to the lipids of the cell membrane. What is the interpretation in now?

3. The A-G, T-C symmetries with respect to the third nucleotide Z allow an interpretation as weak isospin symmetry in DNA as TQC model. Can one identify counterpart of this symmetry when the decomposition into individual nucleotides does not make sense?

Natural candidates for the building blocks of the analogs of these symmetries are the change of the sign of the spin direction for quarks and for flux tubes.

1. For quarks the spin projections are always non-vanishing so that the map has no fixed points. For flux tube spin the states of spin $S_z = 0$ are fixed points. The change of the sign of quark spin projection must therefore be present for both $XYZ \rightarrow X_cY_cZ_c$ and $Y \rightarrow Y_c$ but also something else might be needed. Note that without the symmetry breaking $(1, 3, 3, 1) \rightarrow (1, 2, 3, 2)$ the code table would be symmetric in the permutation of 2 first and 2 last columns of the code table induced by both full conjugation and conjugation of Y.

2. The analogs of the approximate $A - G$ and $T - C$ symmetries cannot involve the change of spin direction in neither quark nor flux tube sector. These symmetries act inside the A-G and T-C sub-2-columns of the 4-columns defining the rows of the code table. Hence this symmetry must permute the states of same spin inside 5 and 3 for flux tubes and 4 and 2 for quarks but leave 2_{odd} invariant. This guarantees that for the two non-degenerate codons coding for only single amino-acid and one of the codons inside triplet the action is trivial. Hence the baryonic analog of the approximate $A - G$ and $T - C$ symmetry would be exact symmetry and be due to the basic definition of the genetic code as a mapping states of same flux tube spin and quark spin to single representative state. The existence of full 4-columns coding for the same amino-acid would be due to the fact that states with same quark spin inside $(2, 3, 2)$ code for the same amino-acid.

3. A detailed comparison of the code table with the code table in spin representation should allow to fix their correspondence uniquely apart from permutations of n-plets and thus also the representation of the conjugations. What is clear that Y conjugation must involve the change of quark spin direction whereas Z conjugation which maps typically 2-plets to each other must involve the permutation of states with same J_z for the flux tubes. It is not quite clear what X conjugation correspond to.

4.5.5 *Some comments about the physics behind the code*

Consider next some particle physicist's objections against this picture.

1. The realization of the code requires the dark scaled variants of spin 3/2 baryons known as Δ resonance and the analogs (and only the analogs) of spin 1 mesons known as ρ mesons. The lifetime of these states is very short in ordinary hadron physics. Now one has a scaled up variant of hadron physics: possibly in both dark and p-adic senses with latter allowing arbitrarily small overall mass scales. Hence the lifetimes of states can be scaled up.

2. Both the absolute and relative mass differences between Δ and N *resp.* ρ and π are large in ordinary hadron physics and this makes the decays of Δ and ρ possible kinematically. This is due to color magnetic spin-spin splitting proportional to the color coupling strength $\alpha_s \sim .1$, which is large. In the recent case α_s could be considerably smaller - say of the same order of magnitude as fine structure constant 1/137 - so that the mass splittings could be so small as to make decays impossible.

3. Dark hadrons could have lower mass scale than the ordinary ones if scaled up variants of quarks in p-adic sense are in question. Note that the model for cold fusion that inspired the idea about genetic code requires that dark nuclear strings have the same mass scale as ordinary baryons. In any case, the most general option inspired by the vision about hierarchy of conscious entities extended to a hierarchy of life forms is that several dark and p-adic scaled up variants of baryons realizing genetic code are possible.

4. The heaviest objection relates to the addition of $L_z = -1$ excitation to $S_z = |1/2, \pm 1/2\rangle_{odd}$ states which transforms the degeneracies of the quark spin states from $(1, 3, 3, 1)$ to $(1, 2, 3, 2)$. The only reasonable answer is that the breaking of the full rotation symmetry reduces $SO(3)$ to $SO(2)$. Also the fact that the states of massless particles are labeled by the representation of $SO(2)$ might be of some relevance. The deeper level explanation in TGD framework might be as follows. The generalized imbedding space is constructed by gluing almost copies of the 8-D imbedding space with different Planck constants together along a 4-D subspace like pages of book along a common back. The construction involves symmetry breaking in both rotational and color degrees of freedom to Cartan sub-group and the interpretation is as a geometric representation for the selection of the quantization axis. Quantum TGD is indeed meant to be a geometrization of the entire quantum physics as a physics of the classical spinor fields in the "world of classical worlds" so that also the choice of measurement axis must have a geometric description.

The conclusion is that genetic code can be understand as a map of stringy baryonic states induced by the projection of all states with same spin projection to a representative state with the same spin projection. Genetic code would be realized at the level of dark nuclear physics and biochemical representation would be only one particular higher level representation of the code. A hierarchy of dark baryon realizations corresponding to p-adic and dark matter hierarchies can be considered. Translation and transcription machinery would be realized by flux tubes connecting only states with same quark spin and flux tube spin. Charge neutrality is essential for having only the analogs of DNA, RNA and amino-acids and would guarantee the em stability of the states.

5 Cosmic Rays And Mersenne Primes

Sabine Hossenfelder has written two excellent blog postings about cosmic rays. The first one is about the GKZ (see `http://tinyurl.com/ybdflmgl`) cutoff for cosmic ray energies and second one about possible indications for new physics above 100 TeV (see `http://tinyurl.com/ydewc2ug`). This inspired me to read what I have said about cosmic rays and Mersenne primes- this was around 1996 - immediately after performing for the first time p-adic mass calculations. It was unpleasant to find that some pieces of the text contained a stupid mistake related to the notion of cosmic ray energy. I had forgotten to take into account the fact that the cosmic ray energies are in the rest system of Earth- what a shame! The recent version should be free of worst kind of blunders. Before continuing it should be noticed I am now living year 2012 and this section was written for the first time for around 1996 - and as it became clear - contained some blunders due to the confusion with what one means with cosmic ray energy. The recent version should be free of worst kind of blunders.

TGD suggests the existence of a scaled up copy of hadron physics associated with each Mersenne prime $M_n = 2^n - 1$, n prime: M_{107} corresponds to ordinary hadron physics. Also lepto-hadrons are predicted. Also Gaussian Mersennes $(1+i)^k - 1$, could correspond to hadron physics. Four of them ($k = 151, 157, 163, 167$) are in the biologically interesting length scale range between cell membrane thickness and the size of cell nucleus. Also leptonic counterparts of hadron physics assignable to certain Mersennes are predicted and there is evidence for them (see `http://tinyurl.com/ybfkptns`) [K20].

The scaled up variants of hadron physics corresponding to $k < 107$ are of special interest. $k = 89$ defines the interesting Mersenne prime at LHC, and the near future will probably tell whether the 125 GeV signal corresponds to Higgs or a pion of M_{89} physics. Also cosmic ray spectrum could provide support for M_{89} hadrons and quite recent cosmic ray observations [C34] are claimed to provide support for new physics around 100 TeV (see `http://tinyurl.com/y8s8swa5`). M_{89} proton would correspond to.5 TeV mass considerably below 100 TeV but this mass scale could correspond to a mass scale of a scaled up copy of a heavy quark of M_{107} hadron physics: a naive scaling of top quark mass by factor 512 would give mass about 87 TeV. Also the lighter hadrons of M_{89} hadron physics should contribute to cosmic ray spectrum and there are indeed indications for this.

The mechanisms giving rise to ultra high energy cosmic rays are poorly understood. The standard explanation would be acceleration in huge magnetic fields. TGD suggests a new mechanism based on the decay cascade of cosmic strings. The basis idea is that cosmic string decays *cosmic string* $\rightarrow M_2$ *hadrons* $\rightarrow M_3$ *hadrons* $.... \rightarrow M_{61} \rightarrow M_{89} \rightarrow M_{107}$ *hadrons* could be a new source of cosmic rays. Also variants of this scenario with decay cascade beginning from larger Mersenne prime can be considered. One expects that the decay cascade leads rapidly to extremely energetic ordinary hadrons, which can collide with ordinary hadrons in atmosphere and create hadrons of scaled variants of ordinary hadron physics. These cosmic ray events could serve as a signature for the existence of these scale up variants of hadron physics.

1. Centauro events and the peculiar events associated with $E > 10^5$ GeV radiation from Cygnus X-3. E refers to energy in Earth's rest frame and for a collision with proton the cm energy would be $E_{cm} = \sqrt{2EM} > 10$ TeV in good approximation whereas M_{89} variant of proton would have mass of.5 TeV. These events be understood as being due to the collisions of energetic M_{89} hadrons with ordinary hadrons (nucleons) in the atmosphere.

2. The decay $\pi_n \rightarrow \gamma\gamma$ produces a peak in the spectrum of the cosmic gamma rays at energy $\frac{m(\pi_n)}{2}$. These produce peaks in cosmic gamma ray spectrum at energies which depend on the energy of π_n in the rest system of Earth. If the pion is at rest in the cm system of incoming proton and atmospheric proton one can estimate the energy of the peak if the total energy of the shower can be estimated reliably.

3. The slope in the hadronic cosmic ray spectrum changes at $E = 3 \cdot 10^6$ GeV. This corresponds to the energy $E_{cm} = 2.5$ TeV in the cm system of cosmic ray hadron and atmospheric proton. This is not very far from M_{89} proton mass .5 TeV. The creation of M_{89} hadrons in atmospheric collisions could explain the change of the slope.

4. The ultra-higher energy cosmic ray radiation having energies of order 10^9 GeV in Earth's rest system apparently consisting of protons and nuclei not lighter than Fe might be actually dominated by gamma rays: at these energies γ and p induced showers have same muon content. $E = 10^9$ GeV corresponds to $E_{cm} = \sqrt{2Em_p} = 4 \times 10^4$ GeV. M_{89} nucleon would correspond to mass scale 512 GeV.

5. So called GKZ cutoff should take place for cosmic gamma ray spectrum due to the collisions with the cosmic microwave background. This should occur around $E = 6 \times 10^{10}$ GeV, which corresponds to $E_{cm} = 3.5 \times 10^5$ GeV. Cosmic ray events above this cutoff (see `http://tinyurl.com/y75jho96`) are however claimed. There should be some mechanism allowing for ultra high energy cosmic rays to propagate over much longer distances as allowed by the limits. Cosmic rays should be able to propagate without collisions. Many-sheeted space-time suggests manners for how gamma rays could avoid collisions with microwave background. For instance, gamma rays could be dark in TGD sense and therefore have large value of Planck constant. One can even imagine exotic variants of hadrons, which differ from ordinary hadrons in that they do not have quarks and therefore no interactions with the microwave background.

6. The highest energies of cosmic rays are around $E = 10^{11}$ GeV, which corresponds to $E_{cm} = 4 \times 10^5$ GeV. M_{61} nucleon and pion correspond to the mass scale of 6×10^6 GeV and 8.4×10^5 GeV. These events might correspond to the creation of M_{61} hadrons in atmosphere.

The identification of the hadronic space-time sheet as super-symplectic mini black-hole [K13] suggests the science fictive possibility that part of ultra-high energy cosmic rays could be also protons which have lost their valence quarks. These particles would have essentially same mass as proton and would behave like mini black-holes consisting of dark matter. They could even give a large contribution to the dark matter. Since electro-weak interactions are absent, the scattering from microwave background is absent, and they could propagate over much longer distances than ordinary particles. An interesting question is whether the ultrahigh energy cosmic rays having energies larger than the GZK cut-off of 5×10^{10} GeV in the rest system of Earth are super-symplectic mini black-holes associated with M_{107} hadron physics or some other copy of hadron physics.

5.1 Mersenne Primes And Mass Scales

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

$$\begin{aligned} m_n^2 &= \frac{m_0^2}{M_n} \ , \\ m_0 &\simeq 1.41 \cdot \frac{10^{-4}}{\sqrt{G}} \ , \end{aligned} \tag{5.1}$$

where $\sqrt{G}$ is Planck length. The lower bound for n can be of course larger than $n = 2$. The known elementary particle mass scales were identified as mass scales associated identified with Mersenne primes $M_{127} \simeq 10^{38}$ (leptons), M_{107} (hadrons) and M_{89} (intermediate gauge bosons). Of course, also other p-adic length scales are possible and it is quite possible that not all Mersenne primes are realized. On the other hand, also Gaussian Mersennes could be important (muon and atomic nuclei corresponds to Gaussian Mersenne $(1+i)^k - 1$ with $k = 113$).

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

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

$$\Lambda_n = \sqrt{\frac{M_n}{M_{107}}}\Lambda \ . \tag{5.2}$$

In particular, the naive scaling prediction for the masses of the exotic pions associated with M_n is given by

$$m(\pi_n) \quad = \quad \sqrt{\frac{M_n}{M_{107}}} m_\pi \ . \tag{5.3}$$

Here $m_\pi \simeq 135\ MeV$ is the mass of the ordinary pion. This estimte is of course extremely naive and the recent LHC data suggests that the 125 GeV Higgs candidate could be M_{89} pion. The mass would be two times higher than the naive estimate gives. p-Adic scalings by small powers of $\sqrt{2}$ must be considered in these estimates.

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

5.2 Cosmic Strings And Cosmic Rays

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

5.2.1 Cosmic strings

Cosmic strings (not quite the same thing in TGD as in GUTs) are basic objects in TGD inspired cosmology [K2, K15].

1. In TGD inspired galaxy model galaxies are regarded as mass concentrations around cosmic strings and the energy of the string corresponds to the dark energy whereas the particles condensed at cosmic strings and magnetic flux tubes resulting from them during cosmic expansion correspond to dark matter [K2, K15]. The galactic nuclei, often regarded as candidates for black holes, are the most probable seats for decaying highly entangled cosmic strings.

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

3. In [K2, K15, K14] it is suggested that decaying cosmic strings might provide a common explanation for the energy production of quasars, galactic jets and gamma ray bursters and that the visible matter in galaxies could be regarded as decay products of cosmic strings. The magnetic and Z^0 magnetic flux tubes resulting during the cosmic expansion from cosmic strings allow to assign at least part of gamma ray bursts to neutron stars. Hot spots (with temperature even as high as $T \sim \frac{10^{-3,5}}{\sqrt{G}}$) in the cosmic string emitting ultra high energy cosmic rays might be created under the violent conditions prevailing in the galactic nucleus.

The decay of the cosmic strings provides a possible mechanism for the production of the exotic hadrons and in particular, exotic pions. In [C16] the idea that cosmic strings might produce gamma rays by decaying first into "X" particles with mass of order $10^{15}\ GeV$ and then to gamma rays, was proposed. As authors notice this model has some potential difficulties resulting from the direct production of gamma rays in the source region and the presence of intensive electromagnetic fields near the source. These difficulties are overcome if cosmic strings decay first into exotic hadrons of type M_{n_0}, $n_0 \geq 3$ of energy of order $2^{-n_0+2}10^{25}\ GeV$, which in turn decay to exotic hadrons corresponding to M_k, $k > n_0$ via ordinary color interaction, and so on so that a sequence of M_k: s starting some value of n_0 in $n = 2, 3, 7, 13, 17, 19, 31, 61, 89, 107$ is obtained. The value of n remains open at this stage and depends on the temperature of the hot spot and much smaller temperatures than the $T \sim m_0$ are possible: favored temperatures are the temperatures $T_n \sim m_n$ at which M_n hadrons become unstable against thermal decay.

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

In [C32] the gamma ray signatures from ordinary cosmic strings were considered and a dynamical QCD based model for the decay of cosmic string was developed. In this model the final state particles were assumed to be ordinary hadrons and final state interactions were neglected. In the recent case the string decays first to M_{n_0} hadrons and the time scale of for color interaction between M_{n_0} hadrons is extremely short (given by the length scale defined by the inverse of π_{n_0} mass) as compared to the time time scale in case of ordinary hadrons. Therefore the interactions between the final state particles must be taken into account and there are good reasons to expect that thermal equilibrium sets on and much simpler thermodynamic description of the process becomes possible.

A possible description for the decaying part of the highly tangled cosmic string is as a "fireball" containing various M_{n_0} $(n \geq 3)$ partons in thermal equilibrium at Hagedorn temperature T_{n_0} of order $T_{n_0} \sim m_{n_0} = 2^{-2+n_0}\frac{10^{-4}}{k\sqrt{G}}$, $k \simeq 1.288$. The experimental discoveries made in RHIC suggest [C31] that high energy nuclear collisions create instead of quark gluon plasma a liquid like phase involving gluonic BE condensate christened as color glass condensate. Also black hole like behavior is suggested by the experiments.

RHIC findings inspire a TGD based model for this phase as a macroscopic quantum phase condensed on a highly tangled color magnetic string at Hagedorn temperature. The model relies also on the notion of dynamical but quantized $\hbar$ [K3] and its recent form to the realization that super-symplectic many-particle states at hadronic space-time sheets give dominating contribution to the baryonic mass and explain hadronic masses with an excellent accuracy.

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

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

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

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

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

3. The process continues until all particles have decayed to ordinary hadrons. Part of the M_n low energy thermal pions decay to gamma ray pairs and produce a characteristic peak in cosmic gamma ray spectrum at energies $E_n = \frac{m(\pi_n)}{2}$ (possibly red-shifted by the expansion of the Universe). The decay of the cosmic string generates also ultra high energy hadronic cosmic rays, say protons. Since the creation of ordinary hadron with ultra high energy is certainly a rare process there are good hopes of avoiding the problems related to the direct production of protons by cosmic strings (these protons produce two high flux of low energy gamma rays, when interacting with cosmic microwave background [C16]).

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

Super-symplectic matter has very stringy character. For instance, it obeys stringy mass formula due the additivity and quantization of mass squared as multiples of p-adic mass scale squared [K13]. The ensuing additivity of mass squared defines a universal formula for binding energy having no independence on interaction mechanism. Highly entangled strings carrying super-symplectic dark matter are indeed excellent candidates for TGD variants of black-holes. The space-time sheet containing the highly entangled cosmic string is separated from environment by a wormhole contact with a radius of black-hole horizon. Schwartschild radius has also interpretation as Compton length with Planck constant equal to gravitational Planck constant $\hbar/\hbar_0 = 2GM^2$. In this framework the proposed decay of cosmic strings would represent nothing but the TGD counterpart of Hawking radiation. Presumably the value of p-adic prime in primordial stage was as small as possible, even $p = 2$ can be considered.

5.2.4 Exotic cosmic ray events and exotic hadrons

One signature of the exotic hadrons is related to the interaction of the ultra high energy gamma rays with the atmosphere. What can happen is that gamma rays in the presence of an atmospheric nucleus decay to virtual exotic quark pair associated with M_{n_k}, which in turn produces a cascade of exotic hadrons associated with M_{n_k} through the ordinary scaled up color interaction. These hadrons in turn decay $M_{n_{k+1}}$ type hadrons via mechanisms to be discussed later. At the last step ordinary hadrons are produced. The collision creates in the atmospheric nucleus the analog of quark gluon plasma which forms a second kind of fireball decaying to ordinary hadrons. RHIC experiments have already discovered these fireballs and identified them as color glass condensates [C31]. It must be emphasized that it is far from clear whether QCD really predicts this phase.

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

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

2. The muon content is expected to be similar to that of a typical hadronic shower generated by proton and larger than the muon content of ordinary gamma ray shower [C28].

3. Due to the kinematics of the reactions of type $\gamma + p \rightarrow H_{M_n} + ... + p$ the only possibility at the available gamma ray energies is that M_{89} hadrons are produced at gamma ray energies above 10 TeV. The masses of these hadrons are predicted to be above 70 GeV and this suggests that these hadrons might be identified incorrectly as heavy nuclei (heavier than ^{56}Fe). These signatures will be discussed in more detail in the sequel in relation to Centauro type events, Cygnus X-3 events and other exotic cosmic ray events. For a good review for these events and models form them see the review article [C13].

Some cosmic ray events [C23, C11] have total laboratory energy as high as 3000 TeV which suggests that the shower contains hadron like particles, which are more penetrating than ordinary hadrons.

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

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

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

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