Topological description of family replication and evidence for higher gauge boson generations

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Abstract

TGD based explanation of family replication phenomenon is discussed. The TGD view about elementary particles and their reaction vertices is discussed first and the description of family replication phenomenon at QFT limit TGD is proposed. TGD predicts also 3 bosonic families, whose couplings to fermion generations necessarily break universality. Experimental evidence for the breaking of universality and for the predicted existence new weak bosons, whose masses can be estimated by simple scaling argument is summarized.

Contents

1 Introduction

Family replication phenomenon means that both quarks and leptons appear as generations that seem to be identical copies of each other apart from different masses. They couple identically to electroweak and color interactions, and there are no neutral weak currents changing the family (say transforming strange quark to d quark). Charged weak currents have the same property apart from the effects caused by different CKM mixing for U and D type quarks: similar effects are possible in the leptonic sector.

TGD strongly suggests the existence of higher generations of electroweak bosons and gluons: the three bosonic generations would correspond to Mersenne primes M_{89}, $M_{G,79}$ (Gaussian Mersenne) and M_{61}. The charge matrices characterizing the coupling of the gauge bosons to different fermion generations are 3×3 matrices in the 3-D Hilbert space of states with states labelled by the family index. One can regard charge matrices as $u(3)$ matrices and $u(3)$ can regraded as dynamically generated analog of gauge algebra. These charge matrices must be mutually orthogonal. For the first generation M_{89} charge matrix is identity matrix predicting the observed universality of color and electroweak couplings. For the two other generations this cannot be case. This predicts breaking of the universality for the couplings of these gauge bosons.

A general physical picture of particles and their interactions provided by quantum TGD is discussed. It is not obvious how to describe family replication phenomenon at QFT limit of TGD. The naive extension of standard model gauge group does not make sense and a proposal based on the replacement of standard model gauge algebra as a module having as coefficients the dynamical $u(3)$ algebra assignable to the family replication with Lie algebra product replaced with the commutative and associative product defined by the completely symmetric structure constants d_{abc} is proposed as a description of the couplings of various generations of standard model gauge bosons to fermions. Needless to say, this approach differs from naive unification by extending the gauge group or just considering a power of standard model gauge group.

During last 5 years indications suggesting the breakdown of the universality have begun to emerge as also findings suggesting the existence of predicted higher generation ew bosons. The latter part of the article summarizes almost as such the TGD based comments about these anomalies.

1. Breaking of universality in the decays of B meson to kaon and lepton pairs has been observed. The breaking of universality could be understood in terms of loops involving higher generations of weak bosons predicted by TGD. Breaking of the universality would be due to the charge matrices of higher gauge boson generations orthogonal to the universal charge matrix of the lowest boson generation. The breaking of universality should occur also in strong interactions and there is evidence also for this.

2. The decays of higher generation weak bosons corresponding to $M_{G,79}$ and M_{61} should take place and produce mono-chromatic lepton pairs. The first piece of evidence came 5 years ago (2013) from IceCuber detector. The proposal was that the neutrino event corresponds to a neutrino produced ain a decay of weal boson of M_{61} copy of electroweak physics. Later emerged evidence also for $MG,79$ copy of electroweak physics. Later more evidence has emerged.

3. The breaking of universality should make itself visible also through muon's anomalous anomalous magnetic moment. Also the anomaly of proton charge radius meaning that its measurement using ordinary atom and muonic atom with electron replaced by muon produce slightly different results, could be understood as breaking of universality.

2 Family replication phenomenon in TGD framework and its description at gauge theory limit of TGD

In TGD framework family replication phenomenon is described topologically [K1] (see `http://tinyurl.com/y7s8elpc`). The problem is to modify the gauge theory approach of the standard model to model to describe family replication phenomenon at QFT limit.

2.1 Original picture about family replication phenomenon

The original view about family replication phenomenon assumed that fermions correspond to single boundary component of the space-time surface (liquid bubble is a good analogy) and thus characterized by genus g telling the number of handles attached to the sphere to obtain the bubble topology.

1. Ordinary bosons would correspond to $g=0$ (spherical) topology and the absorption/emission of boson would correspond to 2-D topological sum in either time direction. This interpretation conforms with the universality of ordinary ew and color interactions.

2. The genera of particle and antiparticle would have formally opposite sign and the total genus would be conserved in the reaction vertices. This makes sense if the annihilation of fermion and anti-fermion to $g=0$ boson means that fermion turns backwards in time emitting boson. The vertex is essentially 2-D topological sum at criticality between two manifold topologies. In the vertex 2-surface would be therefore singular manifold. The analogy to closed string emission in string model is obvious.

2.2 The recent vision

Later the original picture was replaced with a more complex identification.

1. Fundamental particles - partons - serving as building bricks of elementary particles are partonic 2-surfaces identified as throats of wormhole contacts at which the Euclidian signature of the induced metric of the wormhole contact changes to Minkowskian one. The orbit of partonic 2-surface corresponds to a light-like 3-surface at which the Minkowskian signature of the induced metric changes to Euclidian, and carries fermion lines defining of boundaries of string world sheets. Strings connect different wormhole throats and mean generalization of the notion of point like particle leading to the notion of tensor network [K8] (see `http://tinyurl.com/y9kwnqfa`).

   Elementary particles are pairs of two wormhole contacts. Both fermions and bosons are pairs of string like flux tubes at parallel space-time sheets and connected at their ends by CP_2 sized wormhole contacts having Euclidian signature of induced metric. A non-vanishing monopole flux loop runs around the extremely flattened rectangle loop connecting wormhole throats at both space-time sheets and traverses through the contacts.

2. The throats of wormhole contacts are characterized by genus given by the number g of handles attached to sphere to get the topology. If the genera g_a, g_b of the opposite throats of given wormhole contact are same, one can assign genus to it : $g = g_a = g_b$. This can be defended by the fact, that the distance between the throats is given by CP_2 length scale and thus extremely short so that $g_a \neq g_b$ implies strong gradients and by Uncertainty Principle mass of order CP_2 mass.

   If the genera of the two wormhole contacts are same: $g_1 = g_2$, one one can assign genus g to the particle. This assumption is more questionable if the distance between contacts is of order of Compton length of the particle. The most general assumption is that all genera can be different.

3. There is an argument for why only 3 lowest fermion generations are observed [K1] (see `http://tinyurl.com/y7s8elpc`). Assume that the genus g for all 4 throats is same. For $g = 0,1,2$ the partonic 2-surfaces are always hyper-elliptic allowing thus a global conformal Z_2 symmetry. Only these 3 2-topologies would be realized as elementary particles whereas higher generations would be either very heavy or analogous to many-particle states with a continuum mass spectrum. For the latter option $g=0$ and $g=1$ state could be seen as vacuum and single particle state whereas $g=2$ state could be regarded as 2-particle bound state. The absence of bound n-particle state with $n>2$ implies continuous mass spectrum.

4. Fundamental particles would wave function in the conformal moduli space associated with its genus (Teichmueller space) [K1]. For fundamental fermions the wave function would be strongly localized to single genus. For ordinary bosons one would have maximal mixing with the same amplitude for the appearance of wormhole throat topology for all genera $g = 0,1,2$. For the two other $u(3)_g$ neutral bosons in octet one would have different mixing amplitudes and charge matrices would be orthogonal and universality for the couplings to ordinary

fermions would be broken for them. The evidence for the breaking of the universality [K3] (see http://tinyurl.com/y7axat8j) is indeed accumulating and exotic $u(3)_g$ neutral gauge bosons giving effectively rise to two additional boson families could explain this.

2.3 Two questions related to bosons and fermions

What about gauge bosons and Higgs, whose quantum numbers are carried by fermion and anti-fermion (or actually a superposition of fermion-anti-fermion pairs). There are two options.

1. **Option I**: The fermion and anti-fermion for elementary boson are located at opposite throats of wormhole contact as indeed assumed hitherto. This would explain the point-likeness of elementary bosons. $u(3)$ charged bosons having different genera at opposite throats would have vanishing couplings to ordinary fermions and bosons. Together with large mass of $g_a \neq g_b$ wormhole contacts this could explain why $g_a \neq g_b$ bosons and fermions are not observed and would put the Cartan algebra of $u(3)_g$ in physically preferred position. Ordinary fermions would effectively behave as $u(3)_g$ triplet.

2. **Option II**: The fermion and anti-fermion for elementary boson are located at throats of different wormhole contacts making them non-point like string like objects. For hadron like stringy objects, in particular graviton, the quantum numbers would necessarily reside at both ends of the wormhole contact if one assumes that single wormhole throats carries at most one fermion or anti-fermion. For this option also ordinary fermions could couple to (probably very massive) exotic bosons different genera at the second end of the flux tube.

There are also two options concerning the representation of $u(3)_g$ assignal to fermions corresponding ot $su(3)_g$ triplet 3 and $8 \oplus 1$.

Option I: Since only the wormhole throat carrying fermionic quantum numbers is active and since fundamental fermions naturally correspond to $u(3)_g$ triplets, one can argue that the wormhole throat carrying fermion quantum number determines the fermionic $u(3)_g$ representation and should be therefore 3 for fermion and $\overline{3}$ anti-fermion.

At fundamental level also bosons would in the tensor products of these representations and many-sheeted description would use these representations. Also the description of graviton-like states involving fermions at all 4 wormhole throats would be natural in this framework. At gauge theory limit sheets would be identified and in the most general case one would need $U(3)_g \times U(3)_g \times U(3)_g \times U(3)_g$ with factors assignable to the 4 throats.

1. The description of weak massivation as weak confinement based on the neutralization of weak isospin requires a pair of left and right handed neutrino located with ν_L and $\overline{\nu}_R$ or their CP conjugates located at opposite throats of the passive wormhole contact associated with fermion. Already this in principle requires 4 throats at fundamental level. Right-handed neutrino however carries vanishing electro-weak quantum numbers so that it is effectively absent at QFT limit.

2. Why should fermions be localized and $su(3)_g$ neutral bosons de-localized with respect to genus? If g labels for states of color triplet 3 the localization of fermions looks natural, and the mixing for bosons occurs only in the Cartan algebra in $u(3)_g$ framework: only $u(3)_g$ neutral states an mix.

Option II: Also fermions belong to $8 + 1$. The simplest assumption is that both fermions and boson having $g_1 \neq g_2$ have large mass. In any case, $g_1 \neq g_2$ fermions would couple only to $u(3)_g$ charged bosons. Also for this option ordinary bosons with unit charge matrix for $u(3)_g$ would couple in a universal manner.

1. The model for CKM mixing [K4] (see http://tinyurl.com/y7as5ed6) would be modified in trivial manner. The mixing of ordinary fermions would correspond to different topological mixings of the three states $su(3)$-neutral fermionic states for U and D type quarks and charged leptons and neutrinos. One could reduce the model to the original one by assuming that fermions do not correspond to generators Id, Y, and I_3 for $su(3)_g$ but their linear combinations giving localization to single valued of g in good approximation: they would correspond to diagonal elements e_{aa}, $a = 1, 2, 3$ corresponding to $g = 0, 1, 2$.

2. p-Adic mass calculations [K2] (see `http://tinyurl.com/y9cvb332`) assuming fixed genus for fermion predict an exponential sensitivity on the genus of fermion. In the general case this prediction would be lost since one would have weighted average over the masses of different genera with $g = 2$ dominating exponentially. The above recipe would cure also this problem. Therefore it seems that one cannot distinguish between the two options allowing $g_1 \neq g_2$. The differences emerge only when all 4 wormhole throats are dynamical and this is the case for graviton-like states (spin 2 requires all 4 throats to be active).

The conclusion seems to be that the two options are more or less equivalent for light fermions. In the case of exotic fermions expected to be extremely heavy the $8+1$ option looks more natural. At this limit however QFT limit need not make sense anymore.

2.4 Reaction vertices

Consider next the reaction vertices for the option in which particles correspond to string like objects identifiable as pairs of flux tubes at opposite space-time sheets and carrying monopole magnetic fluxes and with ends connected by wormhole contacts.

1. Reaction vertex looks like a simultaneous fusing of two open strings along their ends at given space-time sheets. The string ends correspond to wormhole contacts which fuse together completely. The vertex is a generalization of a Y-shaped 3-vertex of Feynman diagram. Also 3-surfaces assignable to particles meet in the same manner in the vertex. The partonic 2-surface at the vertex would be non-singular manifold whereas the partonic orbit would be singular manifold in analogy with Y shaped portion of Feynman diagram.

2. In the most general case the genera of all four throats involved can be different. Since the reaction vertex corresponds to a fusion of wormhole contacts characterized in the general case by (g_1, g_2), one must have $(g_1, g_2) = (g_3, g_4)$. The rule would correspond in gauge theory description to the condition that the quark and antiquark $su(3)_g$ charges are opposite at both throats in order to guarantee charge conservation as the wormhole contact disappears.

3. One has effectively pairs of open string fusing along their and and the situation is analogous to that in open string theory and described in terms of Chan-Paton factors. This suggests that gauge theory description makes sense at QFT limit.

   (a) If g is same for all 4 throats, one can characterize the particle by its genus. The intuitive idea is that fermions form a triplet representation of $u(3)_g$ assignable to the family replication. In the bosonic sector one would have only. $u(3)_g$ neutral bosons. This approximation is expected to be excellent.

   (b) One could allow $g_1 \neq g_2$ for the wormhole contacts but assume same g for opposite throats. In this case one would have $U(3)_g \times U(3)_g$ as dynamical gauge group with $U(3)_g$ associated with different wormhole contacts. String like bosonic objects (hadron like states) could be therefore seen as a nonet for $u(3)_g$. Fermions could be seen as a triplet.

   Apart from topological mixing inducing CKM mixing fermions correspond in good approximation to single genus so that the neutral members of $u(3)_g$ nonet, which are superpositions over several genera must mix to produce states for which mixing of genera is small. One might perhaps say that the topological mixing of genera and mixing of $u_3(g)$ neutral bosons are anti-dual.

   (c) If all throats can have different genus one would have $U(3)_g \times U(3)_g \times U(3)_g \times U(3)_g$ as dynamical gauge group $U(3)_g$ associated with different wormhole throats. This option is probably rather academic. Also fermions could be seen as nonets.

2.5 What would the gauge theory description of family replication phenomenon look like?

For the most plausible option bosonic states would involve a pair of fermion and anti-fermion at opposite throats of wormhole contact. Bosons would be characterized by adjoint representation of $u(3)_g = su(3)_g \times u(1)_g$ obtained as the tensor product of fermionic triplet representations 3 and $\overline{3}$.

1. $u(1)_g$ would correspond to the ordinary gauge bosons bosons coupling to ordinary fermion generations in the same universal manner giving rise to the universality of electroweak and color interactions.

2. The remaining gauge bosons would belong to the adjoint representation of $su(3)_g$. One indeed expects symmetry breaking: the two neutral gauge bosons would be light whereas charged bosons would be extremely heavy so that it is not clear whether QFT limit makes sense for them.

   Their charge matrices Q_g^i would be orthogonal with each other ($Tr(Q_g^i Q_g^j) = 0$, $i \neq j$) and with the unit charge matrix $u(1)_g$ charge matrix $Q^0 \propto Id$ ($Tr(Q_g^i) = 0$) assignable to the ordinary gauge bosons.These charge matrices act on fermions and correspond to the fundamental representation of $su(3)_g$. They are expressible in terms of the Gell-Mann matrices λ_i (see `http://tinyurl.com/y7ukgf5m`).

How to describe family replication for gauge bosons in gauge theory framework? A minimal extension of the gauge group containing the product of standard model gauge group and $U(3)_g$ does not look promising since it would bring in additional generators and additional exotic bosons with no physical interpretation. This extension would be analogous to the extension of the product $SU(2) \times SU(3)$ of the spin group $SU(2)$ and Gell-Mann's $SU(3)$ to $SU(6)$). Same is true about the separate extensions of $U(2)_{ew}$ and $SU(3)_c$.

1. One could start from an algebra formed as a tensor product of standard model gauge algebra $g = su(3)_c \times u(2)_{ew}$ and algebraic structure formed somehow from the generators of $u(3)_g$. The generators would be

$$J_{i,a} = T_i \otimes T_a \quad , \tag{2.1}$$

   where i labels the standard model Lie-algebra generators and a labels the generators of $u(3)_g$.

   This algebra should be Lie-algebra and reduce to the same as associated with standard model gauge group with generators T^b replacing effectively complex numbers as coefficients. Mathematician would probably say, that standard model Lie algebra is extended to a module with coefficients given by $u(3)_g$ Lie algebra generators in fermionic representation but with Lie algebra product for $u(3)_g$ replaced with a product consistent with the standard model Lie-algebra structure, in particular with the Jacobi-identities.

2. By writing explicitly commutators and Jacobi identifies one obtains that the product must be symmetric: $T_a \circ T_b = T_b \circ T_a$ and must satisfy the conditions $T_a \circ (T_b \circ T_c) = T_b \circ (T_c \circ T_a) = T_c \circ (T_a \circ T_b)$ since these terms appear as coefficients of the double commutators appearing in Jacobi-identities

$$[J_{i,a}, [J_{j,b}], J_{k,c}]] + [J_{j,b}, [J_{k,c}], J_{i,a}]] + [J_{k,c}, [J_{i,a}], J_{j,b}]] = 0 \quad . \tag{2.2}$$

   Commutativity reduces the conditions to associativity condition for the product $\circ$. For the sub-algebra $u(1)_g^3$ these conditions are trivially satisfied.

3. In order to understand the conditions in the fundamental representation of $su(3)$, one can consider the product the $su(3)_g$ product defined by the anti-commutator in the matrix representation provided by Gell-Mann matrices λ_a (see `http://tinyurl.com/y7ukgf5m` and `http://tinyurl.com/y8smg8fz`):

$$\{\lambda_a, \lambda_b\} = \frac{4}{3}\delta_{a,b} Id + 4 d_{abc}\lambda^c \quad , \quad Tr(\lambda_a \lambda_b) = 2\delta_{ab} \quad , \quad d_{abc} = Tr(\lambda_a \{\lambda_b, \lambda_c\}) \quad . \tag{2.3}$$

   d_{abc} is totally symmetric under exchange of any pair of indices so that the product defined by the anti-commutator is both commutative and associative. The product extends to $u(3)_g$ by defining the anti-commutator of Id with λ_a in terms of matrix product. The product is consistent with $su(3)_g$ symmetries so that these dynamical charges are conserved. For complexified generators this means that generator and its conjugate have non-vanishing coefficient of Id.

Remark: The direct sum $u(n) \oplus u(n)_s$ formed by Lie-algebra $u(n)$ and its copy $u(n)_s$ endowed with the anti-commutator product $\circ$ defines super-algebra when one interprets anti-commutator of $u(n)_s$ elements as an element of $u(n)$.

4. Could $su(3)$ associated with 3 fermion families be somehow special? This is not the case. The conditions can be satisfied for all groups $SU(n)$, $n \geq 3$ in the fundamental representation since they all allow completely symmetric structure constants d_{abc} as also higher completely symmetric higher structure constants $d_{abc...}$ up to n indices. This follows from the associativity of the symmetrized tensor product: $((Adj \otimes Adj)_S \otimes Adj)_S = (Adj \otimes (Adj \otimes Adj)_S)_S$ for the adjoint representation.

To sum up, the QFT description of family replication phenomenon with the extension of the standard model gauge group would bring to the theory the commutative and associative algebra of $u(3)_g$ as a new mathematical element. In case of ordinary fermions and bosons and also in the case of $u(3)_g$ neutral bosons the formalism would be however rather trivial modification of the intuitive picture.

3 Experimental evidence for the higher generations of weak bosons

The evidence for the higher generations of weak bosons has accumulated gradually during years. I have written about this evidence in various articles [L2, L4, L3] and in books about TGD [K3]. I collect here pieces of the evidence in chronological order as I have described them. The changes to the earlier text are minimal.

3.1 Evidence for the anomalies in decays of B meson to K meson and lepton pair as evidence for higher generations of weak bosons

Jester (see http://tinyurl.com/y78flpbw, year 2015) told in his blog "Resonaances" about an evidence for anomalies in the decays of B meson to K meson and lepton pair. There exist several anomalies.

1. The 3.7 sigma deviation from standard model predictions in the differential distribution of the $B \rightarrow K^* \mu^+ \mu^-$ decay products (see http://tinyurl.com/ycwc5t9k) [C6].

2. The 2.6 sigma violation of lepton flavor universality in $B^+ \rightarrow K^+ l^+ l^-$ decays (see http://tinyurl.com/n7nbgrk) [C2].

The reported violation of lepton universality (, which need not be real) is especially interesting. The branching ratio $B(B^+ \rightarrow K^+ e^+ e^-)/B(B^+ \rightarrow K^+ \mu^+ \mu^-) \simeq .75$ holds true. Standard model expectation is very near to unity.

3.1.1 Explanation in terms of leptoquarks

Scalar lepto-quark (see http://tinyurl.com/y8vafz6v) [C1] has been proposed as an explanation of the anomaly. The lowest order diagram for lepton pair production in standard model is penguin diagram (see http://tinyurl.com/ycqrafo5) obtained from the self energy diagram for b quark involving tW^- intermediate in which W emits γ/Z decaying to lepton pair. Lepton universality is obvious. The penguin diagram involves 4 vertices and 4 propagators and the product of CKM matrix elements $V_{tb} V_{st}^*$.

In TGD framework, and very probably also in the model studied in the article, the diagram involving lepto-quark is obtained from the tW^- self-energy loop by allowing W^- to decay to virtual antineutrino $\overline{\nu}_\mu \equiv \overline{\nu}(g=1)$ and on mass shell charged lepton $L^-(g_1)$. Virtual antineutrino in turn decays to on-shell s quark and lepto-quark of type $\sum_g D(g)\overline{\nu}(g)$, which combines with t quark to form $l^+(g_2)$. The amplitude is proportional to the product $V_{tb}V^*_{tD(g_2)}$ implying breaking of lepton universality. The amplitude for production of e^+l^- pair is considerably smaller than that for μ^+l_- and τ^+l_-. If neutrino CKM mixing is taken into account, there is also a proportionality to the matrix element $V^L_{l(g_1)\nu_{g=1}}$. In absence of leptonic CKM mixing only $\mu^-l^+(g)$ pairs are produced and the possibility to have $g \neq 1$ is also a characteristic of lepton non-universality which is however induced by the hadronic CKM mixing: lepto-quark couplings are universal. The penguin diagram is expected to be proportional to the resonance factors $m_t^2/(m_t^2 - m_W^2)$ and $m_X^2/(m_X^2 - m_t^2)$ so that the dependence on the mass of X is not expected to be strong.

The diagram would induce the reported effective four-fermion coupling $\overline{b}_L\gamma^\mu s_L\mu_L^+\gamma_\mu\mu_L^-$ representing neutral current breaking universality. Authors propose a heavy scalar boson exchanges with quantum numbers of lepto-quark and mass of order 10 TeV to explain why no anomalous weak interactions between leptons and quarks by lepto-quark exchange have not been observed. Scalar nature would suggest Higgs type coupling proportional to mass of the lepton and this could explain why the effect of exchange is smaller in the case of electron pair. The effective left-handed couplings would however suggest vector lepto-quarks with couplings analogous to W boson coupling. Note that the effect should reduce the rate: the measured rate for $B_s \rightarrow \mu^-\mu^+$ is $.79 \pm .20$: reduction would be due to destructive interference of amplitudes.

3.1.2 A TGD based model for the B anomaly in terms of higher weak boson generations

An alternative model would explain the breaking of lepton universality in terms of bosonic analogs of higher fermion generations. The charge matrix of ordinary gauge boson is unit matrix in the 3-D state space assignable with the three generations representing various fermion families. Gauge bosons correspond to charge 3×3 matrices, which must be orthogonal with respect to the inner product defined by trace. Hence fermion universality is broken for the 2 higher gauge boson generations. The first guess is that the mass scale of the second boson generation corresponds to Gaussian Mersenne $M_{G,79}$ [K3] [L2].

The model for the breaking of universality in lepton pair production is in terms of $M_{G,79}$ bosons. In standard model the production of charged lepton pairs would be due to the decay of virtual W bosons appearing in self-energy loop of penguin diagram. W emits Z^0 or γ decaying to a charged lepton pair. If a virtual higher generation W_{79} boson appears in self energy loop, it can transform to W by emitting Z^0_{79} or γ_{79} decaying to lepton pair and inducing a breaking of lepton universality. Direct decays of W_{79} to $l\overline{\nu}_L$ pairs imply a breaking of lepton universality in lepton-neutrino pair production.

The breaking of the universality is characterized by charge matrices of weak bosons for the dynamical SU(3) assignable with family replication. The first generation corresponds to unit matrix whereas higher generation charge matrices can be expressed as orthogonal combinations of isospin and hypercharge matrices I_3 and Y. I_3 distinguishes between tau and lower generations (third experiment) but not between the lowest two generations. There is however evidence for this (the first two experiments above). Therefore a mixing the I_3 and Y should occur.

The coupling to second generation Z boson could thus explain the breaking of universality in the decays of B boson. In TGD Z′ would correspond to second generation Z boson. p-Adic length scale hypothesis plus assumption that new Z boson corresponds to Gaussian Mersenne $M_{G,79} = (1+i)^{79} - 1$ predicts that its mass is by factor 32 higher than mass of ordinary Z boson making 2.9 TeV for 91 GeV mass for Z. There are indications for a bump at this mass value. Lepto-quark made of right handed neutrino and quark is less plausible explanation but predicted by TGD as squark.

Recently additional more direct evidence (year 2016) for the existence of this kind of weak boson has emerged (see `http://tinyurl.com/gqrg9zt`). If I understood correctly, the average angle between the decay products of B meson is not quite what it is predicted to be. This is interpreted as an indication that Z′ type boson appears as an intermediate state in the decay.

Does the breaking of universality occur also for color interactions? If so, the predicted M_{89} and $M_{G,79}$ hadron physics would break universality in the sense that the couplings of their gluons to quark generations would not be universal. This also forces to consider to the possibility that there are new quark families associated with these hadron physics but only new gluons with couplings breaking lepton universality. This looks somewhat boring at first.

On the other hand, there exist evidence for bumps at masses of M_{89} hadron physics predicted by scaling to be 512 time heavier than the mesons of the ordinary M_{107} hadron physics. According to the prevailing wisdom coming from QCD, the meson and hadron masses are however known to be mostly due to gluonic energy and current quarks give only a minor contribution. In TGD one would say that color magnetic body gives most of the meson mass. Thus the hypothesis would make sense. One can also talk about constituent quark masses if one includes the mass of corresponding portion of color magnetic body to quark mass. These masses are much higher than current quark masses and it would make sense to speak about constituent quarks for M_{89} hadron physics. Constituent quarks of the new hadron physics would be different from those of the standard hadron physics.

3.2 Further indications for the breaking of lepton universality due to the higher weak boson generations

Lepton and quark universality of weak interactions is a basic tenet of the standard model. Now the first indications for the breaking of this symmetry have been found.

1. 1915 LHCb released a preprint with title "Measurement of the ratio of branching ratios $(B_0 \rightarrow D^* + \tau\nu)/(B_0 \rightarrow D^* + \mu\nu)$" [C8]. The news is that the measured branching ratio is is about 33 per cent instead of 25 percent determined by mass ratios if standard model is correct. The outcome differs by 2.1 standard deviations from the prediction so that it might be a statistical fluke.

2. There are also indications for second B^0 anomaly discovered at LHCb (`http://tinyurl.com/n6525qs`). B mesons have to long and short-lived variants oscillating to their antiparticles and back - this relates to CP breaking. The surprise is that the second B meson - I could not figure out was it short- or long-lived - prefers to decay to $e\nu$ instead of $\mu\nu$.

3. There are also indications for the breaking of universality [C7] (`http://tinyurl.com/n7nbgrk`) from $B^+ \rightarrow K^+e^+e^-$ and $B^+ \rightarrow K^+\mu^+\mu;^-$ decays.

In TGD framework my first - and wrong - guess for an explanation was CKM mixing for leptons [K1]. TGD predicts that also leptons should suffer CKM mixing induced by the different mixings of topologies of the partonic 2-surfaces assignable to charged and neutral leptons. The experimental result would give valuable information about the values of leptonic CKM matrix. What new this brings is that the decays of W bosons to lepton pairs involve the mixing matrix and CKM matrix whose deviation from unit matrix brings effects anomalous in standard model framework.

The origin of the mixing would be topological - usually it is postulated in completely ad hoc manner for fermion fields. Particles correspond to partonic 2-surfaces- actually several of them but in the case of fermions the standard model quantum numbers can be assigned to one of the partonic surfaces so that its topology becomes especially relevant. The topology of this partonic 2- surface at the end of causal diamond (CD) is characterized by its genus - the number of handles attached to sphere - and by its conformal equivalence class characterized by conformal moduli.

Electron and its muon correspond to spherical topology before mixing, muon and its neutrino to torus before mixing etc. Leptons are modelled assuming conformal invariance meaning that the leptons have wave functions - elementary particle vacuum functionals - in the moduli space of conformal equivalence classes known as Teichmueller space.

Contrary to the naive expectation mixing alone does *not* explain the experimental finding. Taking into account mass corrections, the rates should be same to different charged leptons since neutrinos are *not* identified. That mixing does not have any implications follows from the unitary of the CKM matrix.

The next trial 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 $2^{(89-89)/2} = 32$. 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 anti-fermion at opposite throats of wormhole contact could have bosonic counterpart for family replication. Dynamical SU(3) assignable to three lowest fermion generations/genera 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 exists - correspond to this kind of state in the tensor product of triplet and anti-triplet? 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.

4. Can one imagine any pattern for the Mersennes and Gaussian Mersennes involved? Charged leptons correspond to electron (M_{127}), muon ($M_{G,113}$) and tau (M_{107}): Mersenne- Gaussian Mersenne-Mersenne. Does one have similar pattern for gauge bosons too: M_{89} - $M_{G,79}$ - M_{61}?

The orthogonality of the 3 weak bosons implies that their charge matrices are orthogonal. As a consequence, the higher generations of weak bosons do not have universal couplings to leptons and quarks. The breaking of universality implies a small breaking of universality in weak decays of hadrons due to the presence of virtual $M_{G,79}$ boson decaying to lepton pair. These anomalies should be seen both in the weak decays of hadrons producing $L\nu$ pairs via the decay of virtual W or its partner $W_{G,79}$ and via the decay of virtual Z of its partner $Z_{G,79}$ to L^+L^- . Also $\gamma_{G,79}$ could be involved.

This could explain the three anomalies associated with the neutral B mesons, which are analogs of neutral K mesons having long- and short-lived variants.

1. The two anomalies involving W bosons could be understood if some fraction of decays takes place via the decay $b \rightarrow c + W_{G,79}$ followed by $W_{G,79} \rightarrow L\nu$. The charge matrix of $W_{G,79}$ is not universal and CP breaking is involved. Hence one could have interference effects, which increase the branching fraction to $\tau\nu$ or $e\nu$ relative to $\mu\nu$ depending on whether the state is long- or short-lived B meson.

2. The anomaly in decays producing charged lepton pairs in decays of B^+ does not involve CP breaking and would be due to the non-universality of $Z_{G,79}$ charge matrix.

One expects that higher generation weak bosons are accompanied by a higher generation Higgses, which differ from SUSY Higgses in the sense that they all have only neutral component. The naive scaling of the Higgs mass by $2^{(-89-79)/2}$ gives mass of 4 TeV. There are indications for a scalar with this mass!

Year or two after writing the first version of this text, I realized that also the puzzle of proton charge radius due to the observation that the proton radius determined from hydrogen and muonic atom are slightly different could be understood in terms of a second generation of Z boson breaking lepton universality [L3]. This article also explains in more detail the notion of family-SU(3) for gauge bosons. Also the anomaly of anomalous magnetic moment of muon might be understood in this manner.

I also learned (April 2017) about new data concerning B meson anomalies (see `http://tinyurl.com/m7gahup`). The analysis of data is explained at `http://tinyurl.com/ml335qf`. It is interesting to look at these results in more detail from TGD point of view using the data of the first link.

1. There is about 4.0 σ deviation from τ/l universality ($l=\mu,e$) in $b\rightarrow c$ transitions. In terms of branching ratios ones has:

$$R(D^*) = \frac{Br(B\rightarrow D\tau\nu_\tau)}{Br(B\rightarrow D^* l\nu_l)} = 0.316\pm 0.016\pm 0.010 \ ,$$

$$R(D) = \frac{Br(B\rightarrow D\tau\nu_\tau)}{Br(B\rightarrow l\nu_l)} = 0.397\pm 0.040\pm 0.028 \ ,$$

   The corresponding SM values are $R(D^*)_{|SM}=0.252\pm 0.003$ and $R(D)_{|SM}=.300\pm .008$. My understanding is that the normalization factor in the ratio involves total rate to $D^*l\nu_l$, $l=\mu,e$ involving only single neutrino in final state whereas the $\tau\nu$ decays involve 3 neutrinos due to the neutrino pair from τ implying broad distribution for the missing mass.

   The decays to $\tau\nu_\tau$ are clearly preferred as if there were an exotic W boson preferring to decay $\tau\nu$ over $l\nu$, $l=e,\mu$. In TGD it could be second generation W boson. Note that CKM mixing of neutrinos could also affect the branching ratios.

2. Since these decays are mediated at tree level in the SM, relatively large new physics contributions are necessary to explain these deviations. Observation of 2.6 σ deviation of μ/e universality in the di-lepton invariant mass bin 1 GeV$^2 \leq q^2 \leq 6$ GeV^2 in $b\rightarrow s$ transitions:

$$R(K) = \frac{Br(B\rightarrow K\mu^+\mu^-)}{Br(B\rightarrow Ke^+e^-)} = 0.745^{+0.090}_{-0.074}\pm 0.038$$

   deviate from the SM prediction $R(K)_{|SM}=1.0003\pm 0.0001$.

   This suggests the existence of the analog of Z boson preferring to decay to e^+e^- rather than $\mu^+\mu^-$ pairs.

   If the charge matrices acting on dynamical family-SU(3) fermion triplet do not depend on electroweak bosons and neutrino CKM mixing is neglected for the decays of second generation W, the data for branching ratios of D bosons implies that the decays to e^+e^- and $\tau^+\tau^-$ should be favored over the decays to $\mu^+\mu-$. Orthogonality of the charge matrices plus the above data could allow to fix them rather precisely from data. It might be that one must take into account the CKM mixing.

3. CMS recently also searched for the decay $h\rightarrow \tau\mu$ and found a non-zero result of $Br(h\rightarrow \tau\mu)=0.84^{+0.39}_{-0.37}$, which disagrees by about 2.4σ from 0, the SM value. I have proposed an explanation for this finding in terms of CKM mixing for leptons [L1]. h would decay to W^+W^- pair, which would exchange neutrino transforming to $\tau\mu$ pair by neutrino CKM mixing.

4. According to the reference, for Z' the lower bound for the mass is 2.9 TeV, just the TGD prediction if it corresponds to $M_{G,79}$ so that the mass would be 32 times the mass of ordinary Z boson!

3.3 Evidence for the decays of higher generation weak bosons

3.3.1 Has IceCube detected neutrinos coming from decays of p-adically scaled up copies of weak bosons?

Jester wrote for five years ago (2013) titled "Storm in IceCube" (see http://tinyurl.com/yd8yyzb3). IceCube is a neutrino detector located at South Pole. Most of the neutrinos detected are atmospheric neutrinos originating from Sun but what one is interested in are neutrinos from astrophysical sources.

1. Last year (2013) (see http://tinyurl.com/y887ktwf) the collaboration reported [C4] the detection for neutrino cascade events, with with energy around 1 PeV=10^6 GeV. The atmospheric background decreases rapidly with energy and at these energies the detection of a pair of events at these energies corresponds to about 3 sigma. The recent (see http://tinyurl.com/y9nqlutd) report [C9] tells about a broad excess of events (28 events) above 30 TeV: only about 10 are expected from atmospheric neutrinos alone. The flavor composition is consistent with 1: 1: 1 ratio of the 3 neutrino species as expected for distant sources for which the oscillations during the travel should cause complete mixing. The distribution of the observed events is consistent with isotropy.

2. There is a dip ranging from .4 PeV to about 1 PeV and the spectrum has probably a sharp cutoff somewhat above 1 TeV. This suggests a monochromatic neutrino line resulting from the decays of some particle decaying to neutrino and some other particle - possibly also neutrino [C10] (see http://tinyurl.com/yc9ohozf). Astrophysical phenomena with standard model physics are expected to produce smooth power-law spectrum - typically $1/E^2$ - rather than peak. The proposal is that the events around 1 PeV could come from the decay of dark matter particles with energy scale of 2 TeV. The observation of two events gives a bound for the life-time of dark matter particle in question: about 10^{21} years much longer than the age of the Universe. The bound of course depends on what density is assumed for the dark matter.

3. There is also a continuum excess in the range [.1, .4] PeV. This could result from many-particle decay channels containing more than 2 particles.

What says TGD?

1. TGD almost-predicts a fractal hierarchy of hadron physics and weak physics labelled by Mersenne primes $M_n = 2^n - 1$. Also Gaussian primes $M_{G,n} = (1+i)^n - 1$ are possible. M_{107} would correspond to the ordinary hadron physics. M_{89} would correspond to weak bosons and a scaled up copy of hadron physics, for which there are several indications: in particular, the breaking of perturbative QCD at rather high energies assignable at LHC to proton heavy nucleus collisions. The explanation in terms of AdS/CFT correspondence has not been successful and is not even well-motivated since it assumes strong coupling regime.

2. The next Mersenne prime is M_{61} and the first guess is that the observed TeV neutrinos result from the decay of W and Z bosons of scaled up copy of weak physics having mass near 1 TeV. The naivest estimate for the masses of these weak bosons is obtained by the naive scaling the masses of ordinary weak bosons by factor $2^{(89-61)/2} = 2^{14}$. For $m_W = 80$ GeV and $m_Z = 90$ GeV one obtains $m_{W(61)} = 1.31$ PeV and $m_{Z(61)} = 1.47$ PeV. The energy of the mono-chromatic neutrino would be about about.65 PeV and.74 PeV in the two cases. This is in the almost empty range between.4 PeV and 1 PeV and too small roughly by a factor of $\sqrt{2}$.

   An improved estimate for upper bound of Z^0 mass is based on the p-adic mass scale $m(M_{89})$ related to the p-adic mass scale M_{127} of electron by scaling factor $2^{(127-89)/2} = 2^{19}$ giving $m(M_{89}) \simeq 120$ GeV for $m_e = \sqrt{5+X} m(M_{127}) = .51$ MeV and $X = 0$ ($X \leq 1$ holds true for the second order contribution to electron mass [K2]). The scaling by the factor $2^{(89-61)/2} = 2^{14}$ gives $m(61) = 1.96$ TeV consistent with the needed 2 TeV. The exact value of weak boson mass depends on the value of Weinberg angle $sin^2(\theta_W)$ and the value of the second order contribution to the mass: $m(61)$ gives upper bound for the mass of $Z(61)$. The model predicts two peaks with distance depending on the value of Weinberg angle of M_{61} weak physics.

3. What about the interpretation of the continuum part of anomaly? The proposed interpretation for many-particle decays looks rather reasonable. The simplest possibility is the decay to a pair of light quarks of M_{61} hadron physics, followed by a decay of quark or antiquark via emission of W boson decaying to lepton-neutrino pair.

TGD predicts 3 generations of gauge bosons in analogy with In TGD the 3 generations of fermions correspond to the 3 lowest genera for 2-surfaces (handle number 0,1,2). One can formally interpret fermion generations as a triplet of broken dynamical symmetry $U(3)$. Gauge bosons correspond to pairs of fermions and antifermions. One obtains octet and singlet with respect $U(3)$. The 3 $U(3)$ "neutral" bosons are expected to be the lightest ones. There are 3 states of this kind analogous to neutral pion, η and η' of Gell-Mann model.

A possible interpretation for M_{61} weak bosons is as weak bosons of third generation. The second generation would correspond to M_{79} and the first generation to M_{89} and ordinary weak bosons. There is evidence for a bump at the mass of Higgs boson of M_{79} physics whose mass is obtained by scaling with the factor $2^{10/2} = 32$ from the ordinary Higgs mass 125 GeV. One obtains 4 TeV, which is the mass of the bump. M_{61} Higgs would have mass $2^9 = 512$ times higher mass - that is 2048 TeV= 2.048 PeV.

3.3.2 Further evidence for $M_{G,79}$ variant of electroweak physics

One of the latest pieces (December 2017) in the story emerged as I found in FB a link to a popular article "*Dark matter exists? Chinese satellite detects mysterious signals while measuring cosmic rays*" (see `http://tinyurl.com/ycoyr6bm`). There is an article in Nature with title "*Direct detection of a break in the teraelectronvolt cosmic-ray spectrum of electrons and positrons*" (see `http://tinyurl.com/y8sm5v36`) by DAMPE collaboration [C3] .

A Chinese satellite Dark Matter Particle Explorer (DAMPE), also called Wukong or "Monkey King", is reported to have made a discovery. The energy spectrum of cosmic ray electrons and positrons is measured. The surprise was that there is a break at about .9 TeV and a strange spike at around 1.4 TeV. The conclusion is that the spike indicates a particle with a mass of about 1.4 TeV on the spectrum. To me a more natural conclusion would be that there is a particle with mass 2.8 TeV decaying to electron positron pair. Unfortunately, the popular article does not allow to conclude what is the precise finding.

In any case, TGD predicts scaled up variant of electroweak physics and there are several pieces of evidence for its existence coming from the violation of lepton and quark universality [L4, L2, L3]. The mass scale for this physics would correspond to Gaussian Mersenne prime $M_{G,79} = (1+i)^{79} - 1$ and is obtained by scaling the mass scale of electroweak physics by a factor 32. This predicts the mass of Z boson of this physics to be 2.9 TeV. It would decay to electron positron pairs with members having energy 1.45 TeV in cm system. Also gluons could have scaled up variants and there is some evidence for this too from the breaking of the quark universality (see

Cosmic ray electron and positron spectra are found to have peak at 1.4 TeV. Could they result in the decays of the second generation Z boson with mass 2.9 TeV? In TGD framework this boson would not however solve dark matter puzzle. In TGD Universe dark matter has explanation as $h_{eff}/h = n$ phases of ordinary matter. Could the "break" at about .9 TeV (I am not quite sure what "break" really means) relate to massive photon of $M_{G,79}$ physics.

Article also mentions that the cosmic ray positron flux is higher than predicted above 70 GeV. That this energy corresponds to the mass of M_{89} pion, might not be an accident. The decay to gamma pairs dominates and gives a peak but the rate for the decay to $\gamma + e^+e^-$ pair would be by factor of order $\alpha \sim 1/137$ lower and would give a break rather than peak since the energy spectrum of pairs is continuous. Therefore support for both M_{89} and $M_{G,79}$ physics emerges. Maybe the long-waited breakthrough of TGD might not be in too far future.

3.3.3 The newest piece of evidence for the third (M_{61}) generation of weak bosons

Matt Strassler had a blog posting (see `http://tinyurl.com/y926u8q2`) about interesting finding from old IceCube data revealed at July 12, 2018 by IceCube team. The conclusion supports the view that so called blazars, thin jets of high energy particles suggested to emerge as matter falls into giant black hole, might be sources of high energy neutrinos. In TGD framework one could also think that blazars originate from cosmic strings containing dark matter and energy. Blazars themselves could be associated with cosmic strings thickened to magnetic flux tubes. The channeling to flux tubes would make possible observation of the particles emerging from the source whatever it might be.

Only the highest energy cosmic neutrinos can enter the IceCube detector located deep under the ice. IceCube has already earlier discovered a new class of cosmic neutrinos with extremely high energy: Matt Strassler has written a posting also about this two years ago (see `http://tinyurl.com/ybu464q2`): the energies of these neutrinos were around PeV.

Last year one of these blazars flared brightly producing high energy neutrinos and photons: neutrinos and photons came from the same position in the sky and occurred during the same period. IceCube detector detected a collision of one (!) ultrahigh energy neutrino with proton generating muon. The debris produced in the collision contained also photons, which were detected. IceCube team decided to check whether old data could contain earlier neutrino events assignable to the same blazar and found a dramatic burst of neutrinos in 2014-2015 data during period of 150 days associated with the same flare; the number of neutrinos was 20 instead of the expected 6-7. Therefore it seems that the ultrahigh energy neutrinos can be associated with blazars.

By looking the article [C5] (see `http://tinyurl.com/y8jtclag`) one learns that neutrino energies are of order few PeV (Peta electron Volt), which makes 1 million GeV (proton has mass .1 GeV). What kind of mechanism could create these monsters in TGD Universe? TGD suggests scaled variants of both electroweak physics and QCD and the obvious candidate would be decays of weak bosons of a scaled variant of ew physics. I have already earlier considered a possible explanation in terms of weak bosons of scaled up variant of weak physics characterizes by Mersenne prime $M_{61} = 2^{61} - 1$ (see `http://tinyurl.com/y7axat8j`).

1. TGD "almost-predicts" the existence of three families of ew bosons and gluons. Their coupling matrices to fermions must be orthogonal. This breaks the universality of both ew and color interactions. Only the ordinary ew bosons can couple in the same manner to 3 fermion generations. There are indeed indications for the breaking of the universality in both quark and leptons sector coming from several sources such as B meson decays, muon anomalous anomalous (this is not a typo!) magnetic moment, and the the finding that the value of proton radius is different depending on whether ordinary atoms or muonic atoms are used to deduce it (see this chapter).

2. The scaled variant of W boson could decay to electron and monster neutrino having same energies in excellent approximation. Z^0 boson could decay to neutrino-antineutrino pair. The essentially mono-chromatic energy spectrum for the neutrinos would serve as a unique signature of the decaying weak boson. One might hope of observing two kinds of monster neutrinos with mass difference of the order of the scaled up W-Z mass difference. Relative mass difference would same as for ordinary W and Z - about 10 per cent - and thus of order .1 PeV.

One can look the situation quantitatively using p-adic length scale hypothesis and assumption that Mersenne primes and Gaussian Mersennes define preferred p-adic length scales assignable to copies of hadron physics and electroweak physics.

1. Ordinary ew gauge bosons correspond in TGD framework to Mersenne prime $M_k = 2^k - 1$, $k = 89$. The mass scale is 90 GeV, roughly 90 proton masses.

2. Next generation corresponds to Gaussian Mersenne Gaussian Mersenne prime $M_{G,79} = (1+i)^{79} - 1$. There is indeed has evidence for a second generation weak boson corresponding to $M_{G,79}$ (see this chapter). The predicted mass scale is obtained by scaling the weak boson mass scale of about 100 GeV with the factor $2^{(89-79/2} = 32$ and is correct.

3. The next generation would correspond to Mersenne prime M_{61}. The mass scale 90 GeV of ordinary weak physics is now scaled up by a factor $2^{(89-61)/2} = 2^{14} \simeq 64,000$. This gives a mass scale 1.5 PeV, which is the observed mass scale for the neutrino monsters detected by Ice-Cube. Also the earlier monster neutrinos have the same mass scale. This suggests that the PeV neutrinos are indeed produced in decays of $W(61)$ or $Z(61)$.

3.3.4 New indications for third generation weak bosons

There are indications (see `http://tinyurl.com/y8cwb98b`) that electron neutrinos appear observed by ICECUBE more often than other neutrinos. In particular, the seems to be a deficit of τ neutrinos. The results are very preliminary. In any case, there seems to be an inconsistency between two methods observing the neutrinos. The discrepancy seems to come from higher energy end of the energy range [13 TeV, 7.9 PeV] from energies above 1 PeV.

The article "Invisible Neutrino Decay Could Resolve IceCubes Track and Cascade Tension" by Peter Denton and Irene Tamborra tries to explain this problem by assuming that τ and μ neutrinos can decay to a superparticle called majoron [C12] (see `http://tinyurl.com/ycvwehmr`).

The standard model for the production of neutrinos is based on the decays of pions producing $e^+\nu_e$ and $\mu^+\nu_\mu$. Also μ^+ can travel to the direction of Earth and decay to $e^+\nu_e\overline{\nu}_\mu$ and double the electron neutrino fraction. The flavor ratio would be 2:1:0.

Remark: The article at (see `http://tinyurl.com/ycvwehmr`) claims that the flavor ratio is 1:2:0 in pion decays, which is wrong: the reason for the lapsus is left as an exercise for the reader.

Calculations taking into account also neutrino oscillations during the travel to Earth to be discussed below leads in good approximation to a predicted flavor ratio 1:1:1. The measurement teams suggest that measurements are consistent with this flavor ratio.

There are however big uncertainties involved. For instance, the energy range is rather wide [13 TeV, 7.9 PeV] and if neutrinos are produce in decay of third generation weak boson with mass about 1.5 PeV as TGD predicts, the averaging can destroy the information about branching fractions.

In TGD based model [L9] [K3] (see `http://tinyurl.com/y94zru7s`) third generation weak bosons - something new predicted by TGD - at mass around 1.5 TeV corresponding to mass scale assignable to Mersenne prime M_{61} (they can have also energies above this energy) would produce neutrinos in the decays to antilepton neutrino pairs.

1. The mass scale predicted by TGD for the third generation weak bosons is correct: it would differ by factor $2^{(89-61)/2} = 2^{14}$ from weak boson mass scale. LHC gives evidence also for the second generation: also now mass scale comes out correctly. Note that ordinary weak bosons would correspond to M_{89}.

2. The charge matrices of 3 generations must be orthogonal and this breaks the universality of weak interactions. The lowest generation has generation charge matrix proportional to (1,1,1) - this generation charge matrix describes couplings to different generations. Unit matrix codes for universality of ordinary electroweak and also color interactions. For higher generations of electro-weak bosons and also gluons universality is lost and the flavor ratio for the produced neutrinos in decays of higher generation weak bosons differs from 1:1:1.

   One example of charge matrices would be $\sqrt{3/2}(0,1,-1)$ for second generation and $(2,-1,-1)/\sqrt{2}$ for the third generation. In this case electron neutrinos would be produced 2 times more than muon and tau neutrinos altogether. The flavor ratio would be 0:1:1 for the second generation and 4:1:1 for the third generation in this particular case.

3. This changes the predictions of the pion decay mechanism. The neutrino energies are above the energy about 1.5 PeV in the range defined by the spectrum of energies for the decaying weak boson. If they are nearly at rest the energie are a peak around the rest mass of third generation weak boson. The experiments detect neutrinos at energy range [13 TeV, 7.9 PeV] having the energy of the neutrinos produced in the decay of third generation weak bosons in a range starting from 1.5 PeV and probably ending below 7.9 PeV. Therefore their experimental signature tends to be washed out if pion decays are responsible for the background.

These fractions are however not what is observed at Earth.

1. Suppose that $L+\nu_L$ pair is produced. It can also happen that L^+, say μ^+ travels to the direction of Earth. It can decay to $e^+\overline{\nu}_\mu\nu_e$. Therefore one obtains both ν_μ and ν_e. From the decy to $\tau^+\nu_\tau$ one obtains all three neutrinos. If the fractions of the neutrinos from the generation charge matrix are (X^e, X^μ, X^τ), the fractions travelling to each are proportional to

$$\{x^\alpha\} \leftrightarrow \{X^\alpha\} = (X^e, X^\mu, X^\tau) = (x^e + x^\mu + x^\tau, x^\mu + x^\tau, x^\tau) \ . \tag{3.1}$$

and the flavor ratio in the decays would be

$$X^e : X^\mu : X^\tau = x^e + x^\mu + x^\tau : x^\mu + x^\tau : x^\tau \ . \tag{3.2}$$

The decays to lower neutrino generations tend to increase the fraction of electronic and muonic neutrinos in the beam.

2. Also neutrino oscillations due to different masses of neutrinos (see http://tinyurl.com/oov344k) affect the situation. The analog of CKM matrix describing the mixing of neutrinos, the mass squared differences, and the distance to Earth determines the oscillation dynamics.

   One can deduce the mixing probabilities from the analog of Schrödinger equation by using approximation $E = p + m^2/2p$ which is true for energies much larger than the rest mass of neutrinos. The masses of mass eigenstates, which are superpositions of flavour eigenstates, are different.

   The leptonic analog of CKM matrix $U_{\alpha i}$ (having in TGD interpretation in terms of different mixings of topologies of partonic 2-surfaces associated with different charge states of various lepton families [K1]) allows to express the flavor eigenstates ν_α as superpositions of mass eigenstates ν_i. As a consequence, one obtains the probabilities that flavor eigenstate ν_α transforms to flavour eigenstate ν_β during the travel. In the recent case the distance is very large and the dependence on the mass squared differences and distance disappears in the averaging over the source region.

   The matrix $P_{\alpha\beta}$ telling the transformation probabilities $\alpha \rightarrow \beta$ is given in Wikipedia article (see http://tinyurl.com/oov344k) in the general case. It is easy to deduce the matrix at the limit of very long distances by taking average over source region to get exressions having no dependence

$$P_{\alpha\beta} = \delta_{\alpha\beta} - 2\sum_{i>j} Re[U_{\beta i}U^\dagger_{i\alpha}U_{\alpha j}U^\dagger_{j\beta}] \ . \tag{3.3}$$

   Note that $\sum_\beta P_{\alpha\beta} = 1$ holds true since in the summation second term vanishes due to unitary condition $U^\dagger U = 1$ and $i > j$ condition in the formula.

3. The observed flavor fraction is $Y_e : Y_\mu : Y_\tau$, where one has

$$Y_\alpha = P_{\alpha\beta}X^\beta \ . \tag{3.4}$$

   It is clear that if the generation charge matrix is of the above form, the fraction of electron neutrinos increases both the decays of τ and μ and by this mechanism. Of course, the third generation could have different charge matrix, say $\sqrt{3/2}(0, 1, -1)$. In this case the effects would tend to cancel.

3.4 TGD view about ANITA anomalous events

I read an article [C11] (see https://arxiv.org/pdf/1809.09615.pdf) telling about 2 anomalous cosmic ray events detected by ANITA (The Antarctic Impulsive Transient Antenna) collaboration. Also ICECUBE collaboration has observed 3 events of this kind. What makes the events anomalous is that the cosmic ray shower emanates from Earth: standard model does not allow the generation of this kind of showers. The article proposes super-partner of tau lepton known as stau as a possible solution of the puzzle.

Before continuing it is good to summarize the basic differences between TGD and standard model at the level of elementary particle physics. TGD differs from standard model by three basic new elements: p-adic length scale hypothesis predicting a fractal hierarchy of hadron physics and electroweak physics; topological explanation of family replication phenomenon; and TGD view about dark matter.

1. p-Adic length scale hypothesis states that Mersenne primes M_n and Gaussian Mersennes $M_{G,n}$ give rise to scaled variants of ordinary hadron and electroweak physics with mass scale proportional to $\sqrt{M_n} = 2^{n/2}$. M_{127} would correspond to electron and possibly also to what I have called lepto-hadron physics [K5]. Muon and nuclear physics would correspond to $M_{G,113}$ and τ and hadron physics would correspond to M_{107}. Electroweak gauge bosons would correspond to M_{89}. $n_G = 73, 47, 29, 19, 11, 7, 5, 3, 2$ would correspond to Gaussian Mersennes and $n = 61, 31, 19, 17, 13, 7, 5, 3, 2$ to ordinary Mersennes. There are four Gaussian Mersennes corresponding to $n_G \in \{151, 157, 163, 167\}$ in biologically relevant length scale range 10 nm-2.5 μm (from cell membrane thickness to nucleus size): this can be said to be a number theoretical miracle.

2. The basic assumption is that the family replication phenomenon reduces to the topology of partonic 2-surfaces serving as geometric correlates of particles. Orientable topology is characterized by genus - the number of handles attached to sphere to obtain the topology. 3 lowest genera are assumed to give rise to elementary particles. This would be due to the Z_2 global conformal symmetry possible only for $g = 0, 1, 2$ [K1]. By this symmetry single handle behaves like particle and two handles like a bound state of 2 particles. Sphere corresponds to a ground state without particles. For the higher genera handles and handle pairs would behave like a many-particle states with mass continuum.

3. The model of family replication is based on $U(3)$ as dynamical "generation color" acts as a combinatorial dynamical symmetry assignable to the 3 generations so that fermions correspond to SU(3) multiplet and gauge bosons to U(3) octet with lowest generation associated with U(1). Cartan algebra of U(2) would correspond to two light generations with masses above intermediate boson mass scale.

   3 "generation neutral" (g-neutral) weak bosons (Cartan algebra) are assigned with $n = 89$ (ordinary weak bosons), $n_G = 79$ and $n_G = 73$ correspond to mass scales $m(79) = 2.6$ TeV and $m(73) = 20.8$ TeV. I have earlier assigned third generation with $n = 61$. The reason is that the predicted mass scale is same as for a bump detected at LHC and allowing interpretation as g-neutral weak boson with $m(61) = 1.3$ PeV.

   3+3 g-charged weak bosons could correspond to $n = 61$ with $m(61) = 1.3$ PeV (or $n_G = 73$ boson with $m(73) = 20.8$ TeV) and to $n_G = 47, 29, 19$ and $n = 31, 19$. The masses are $m(47) = .16$ EeV, $m(31) = 256 \times m(47) = 40$ EeV, $m(29) = 80$ EeV, $m(19) = 256$ EeV, $m(17) = .5 \times 10^3$ EeV, and $m(13) = 2 \times 10^3$ EeV. This corresponds to the upper limit for the energies of cosmic rays detected at ANITA.

   In TGD framework the most natural identification of Planck length would be as CP_2 length R which is about $10^{3.5}$ times the Planck length as it is usually identified [L8]. Newton's constant would have spectrum and its ordinary value would correspond to $G = R^2/\hbar_{eff}$ which $\hbar_{eff} \sim 10^7$. UHE cosmic rays would allow to get information about physics near Planck length scale in TGD sense!

4. TGD predicts also a hierarchy of Planck constants $h_{eff} = n \times h_0$, $h = 6h_0$, labelling phases of ordinary matter identified as dark matter. The phases with different values of n are dark matter relative to each other but phase transitions changing the value of n are possible. The hypothesis would realize quantum criticality with long length scale quantum fluctuations and it follows from what I call adelic physics [L5, L6].

   n corresponds to the dimension of extension of rationals defining one level in the hierarchy of adelic physics defined by extensions of rationals inducing extensions of p-adic number fields serving as correlates for cognition in TGD inspired theory of consciousness [L7]. p-Adic physics would provide extremely simple but information rich cognitive representations of the real number based physics and the understanding of p-adic physics would be easy manner to understand the real physics. This idea was inspired by the amazing success of p-adic mass calculations [K7], which initiated the progress leading to adelic physics.

It is natural to ask what TGD could say about the Anita anomaly serving as very strong (5 sigma) evidence for new physics beyond standard model. Consider first the basic empirical constraints on the model.

1. According to the article [C11], there are 2 anomalous events detected by ANITA collaboration and 3 such events detected by ICECUBE collaboration. For these events there is cosmic ray shower coming Earth's interior. Standard model does not allow this kind of events since the incoming particle - also neutrino - would dissipate its energy and never reach the detector.

   This serves as a motivation for the SUSY inspired model of the article proposing that stau, super-partner of tau lepton, is created and could have so weak interactions with the ordinary matter that it is able to propagate through the Earth. There must be however sufficiently strong interaction to make the detection possible. The mass of stau is restricted to the range .5-1.0 TeV by the constraints posed by LHC data on SUSY.

2. The incoming cosmic rays associated with anomalous events have energies around $\epsilon_{cr} = .5 \times 10^{18}$ eV. A reasonable assumption is that the rest system of the source is at rest with respect to Earth in an energy resolution, which corresponds to a small energy EeV scale. No astrophysical mechanism producing higher energy cosmic rays about 10^{11} GeV based on standard physic is known, and here the p-adic hierarchy of hadron physics and electroweak physics suggests mechanisms.

In TGD framework the natural question is whether the energy scale correspond to some Mersenne or Gaussian Mersenne so that neutrino and corresponding lepton could have been produced in a decay of W boson labelled by this prime. By scaling of weak boson mass scale Gaussian Mersenne $M_{G,47} = (1+i)^{47}-1$ would correspond to a weak boson mass scale $m(47) = 2^{(89-47)/2} \times 80$ GeV = .16 EeV. This mass scale is about roughly a factor 1/3 below the energy scale of the incoming cosmic ray. This would require that the temperature of the source is at least $6 \times m(47)$ at source if neutrino is produced in the decay of $M_{G,47}$ W boson. This option does not look attractive to me.

Could cosmic rays be (possibly dark) protons of $M_{G,47}$ hadron physics.

1. The scaling of the mass of the ordinary proton about $m_p(107) \simeq 1$ GeV gives $m_p(47) = 2^{(107-47)/2}$ GeV $\simeq 1$ EeV! This is encouraging! Darkness in TGD sense could make for them possible to propagate through matter. In the interactions with matter neutrinos and leptons would be generated.

   The article tells that the energy ϵ_{cr} of the cosmic ray showers is $\epsilon_{cr} \sim .6$ EeV, roughly 60 per cent the rest mass of cosmic ray proton. I do not how precise the determination of the energy of the shower is. The production of dark particles during the generation of shower could explain the discrepancy.

2. What could one say about the interactions of dark $M(47)$ proton with ordinary matter? Does $p(47)$ transform to ordinary proton in stepwise manner as Mersenne prime is gradually reduced or in single step. What is the rate for the transformation to ordinary proton. The free path should be a considerable fraction of Earth radius by the argument used in [C11] for stau.

   The transformation to ordinary proton would generate a shower containing also tau leptons and tau neutrinos coming pion decays producing muons and electrons and their neutrinos. Neutrino oscillations would produce tau neutrinos: standard model predicts flavor ratio about 1:1:1.

3. What could happen in the strong interactions of dark proton with nuclei? Suppose that dark proton is relativistic with $E_p = xM_p = x$ EeV, $x > 1$, say $x \sim 2$. The total cm energy E_{cm} in the rest system of ordinary proton is for a relativistic)!) EeV dark proton + ordinary proton about $E_{cm} = (3/2)\sqrt{x}\sqrt{m_p M_p} = \sqrt{x} \times 5$ TeV, considerably above the rest energy

$m_p(89) = 512 m_p = .48$ TeV of M_{89} dark proton. The kinetic energy is transformed to rest energy of particles emanating from the collision of dark and ordinary proton.

If the collision takes place with a quark of ordinary proton with mass $m_q = 5$ MeV, E_{cm} is reduced by a factor of $\sqrt{5}10^{-3/2}$ giving $E = \sqrt{x}1.3$ TeV, which is still above for the threshold for transforming the cosmic ray dark proton to M_{89} dark proton.

This suggests that the interaction produce first dark relativistic M_{89} protons, which in further interactions transform to ordinary protons producing the shower and neutrinos. I have proposed already more than two decades ago that strange cosmic ray events such as Centauros generate hot spot involving M_{89} hadrons. At LHC quite a number of bumps with masses obtained by scaling from the masses of mesons of ordinary hadron physics are observed. I have proposed that they are associated with quantum critically assignable to a phase transition analogous to the generation of quark gluon plasma, and are dark in TGD sense having $h_{eff}/h = 512$ so that their Compton wavelengths are same as for ordinary hadrons [K3].

4. The free path of (possibly) dark $M_{G,47}$ proton in ordinary matter should be a considerable fraction of the Earth's radius since the process of tau regeneration based on standard physics cannot explain the findings. The interaction with ordinary matter possibly involving the transformation of the dark proton to ordinary one (or vice versa!) must be induced by the presence of ordinary matter rather than being spontaneous.

   Also the flux of cosmic ray protons at EeV energies must be high enough. It is known that UHE cosmic rays very probably are not gamma rays. Besides neutrinos dark $M_{G,47}$ protons would be a natural candidate for them.

3.5 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 [K3]. There is also anomaly in muon's magnetic moment discussed briefly in [K6]. 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.

REFERENCES

Particle and Nuclear Physics

[C1] CMS collaboration. r_k and future $b \to sl^+l^-$ bsm opportunities. Available at: `http://arxiv.org/abs/1408.1627`, 2014.

[C2] CMS collaboration. Test of lepton universality using $b^+ \to k^+l^+l^-$ decays. Available at: http://arxiv.org/abs/1406.6482, 2014.

[C3] DAMPE Collaboration. Direct detection of a break in the teraelectronvolt cosmic-ray spectrum of electrons and positrons. *Nature.http: // tinyurl. com/ y8sm5* , 2017.

[C4] IceCube collaboration. First observation of PeV-energy neutrinos with IceCube. Available at: http://arxiv.org/abs/1304.5356, 2013.

[C5] IceCube collaboration. Neutrino emission from the direction of the blazar TXS 0506+056 prior to the IceCube-170922A alert. *Science.* Available at: http://science.sciencemag.org/content/sci/361/6398/147.full.p, 361:147–151, 2018.

[C6] LHCb collaboration. Measurement of form-factor independent observables in the decay $b_0 \to k_0\mu^{+-}$. Available at: http://arxiv.org/abs/1308.1707, 2013.

[C7] LHCb collaboration. Test of lepton universality using $b^+ \to k^+l^+l^-$ decays. Available at: http://arxiv.org/abs/1406.6482, 2014.

[C8] LHCb collaboration. Measurement of the ratio of branching ratios $(b_0 \to d^* + \tau\nu_\tau)/(b_0 \to d^* + \mu\nu_\mu)$. Available at: http://arxiv.org/abs/1506.08614, 2015.

[C9] collaboration IceCube Halzenfor: F. IceCube: Neutrino Physics from GeV - PeV. Available at: http://arxiv.org/abs/1308.3171, 2013.

[C10] Feldstein B et al. Neutrinos at IceCube from Heavy Decaying Dark Matter. Available at: http://arxiv.org/abs/1303.7320, 2013.

[C11] Fox DB et al. The ANITA Anomalous Events as Signatures of a Beyond Standard Model Particle, and Supporting Observations from IceCube. Available at:https://arxiv.org/pdf/1809.09615.pdf, 2018.

[C12] Denton P and Tamborra I. Invisible Neutrino Decay Could Resolve IceCubes Track and Cascade Tension. *PRL.* Available at:http://tinyurl.com/ycvwehmr, 121(121802), 2018.

Books related to TGD

[K1] Pitkänen M. Construction of elementary particle vacuum functionals. In *p-Adic Physics*. Online book. Available at: http://www.tgdtheory.fi/public_html/padphys/padphys.html#elvafu, 2006.

[K2] Pitkänen M. Massless states and particle massivation. In *p-Adic Physics*. Online book. Available at: http://www.tgdtheory.fi/public_html/padphys/padphys.html#mless, 2006.

[K3] Pitkänen M. New Particle Physics Predicted by TGD: Part I. In *p-Adic Physics*. Online book. Available at: http://www.tgdtheory.fi/public_html/padphys/padphys.html#mass4, 2006.

[K4] Pitkänen M. p-Adic Particle Massivation: Hadron Masses. In *p-Adic Length Scale Hypothesis and Dark Matter Hierarchy*. Online book. Available at: http://www.tgdtheory.fi/public_html/padphys/padphys.html#mass3, 2006.

[K5] Pitkänen M. The Recent Status of Lepto-hadron Hypothesis. In *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: http://www.tgdtheory.fi/public_html/neuplanck/neuplanck.html#leptc, 2006.

[K6] Pitkänen M. SUSY in TGD Universe. In *p-Adic Physics*. Online book. Available at: http://www.tgdtheory.fi/public_html/padphys/padphys.html#susychap, 2012.

[K7] Pitkänen M. *p-Adic length Scale Hypothesis*. Online book. Available at: http://www.tgdtheory.fi/public_html/padphys/padphys.html, 2013.

[K8] Pitkänen M. Holography and Quantum Error Correcting Codes: TGD View. In *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: http://www.tgdtheory.fi/public_html/neuplanck/neuplanck.html#tensornet, 2014.

Articles about TGD

[L1] Pitkänen M. Some comments about $\tau - \mu$ anomaly of Higgs decays and anomalies of B meson decays. Available at: http://tgdtheory.fi/public_html/articles/taumuanomaly.pdf, 2015.

[L2] Pitkänen M. What is the role of Gaussian Mersennes in TGD Universe? Available at: http://tgdtheory.fi/public_html/articles/MG79.pdf, 2015.

[L3] Pitkänen M. Could second generation of weak bosons explain the reduction of proton charge radius? Available at: http://tgdtheory.fi/public_html/articles/protrad.pdf, 2017.

[L4] Pitkänen M. Indications for the breaking of Universality in B meson decays. Available at: http://tgdtheory.fi/public_html/articles/weak79.pdf, 2017.

[L5] Pitkänen M. Philosophy of Adelic Physics. In *Trends and Mathematical Methods in Interdisciplinary Mathematical Sciences*, pages 241–319. Springer.Available at: https://link.springer.com/chapter/10.1007/978-3-319-55612-3_11, 2017.

[L6] Pitkänen M. Philosophy of Adelic Physics. Available at: http://tgdtheory.fi/public_html/articles/adelephysics.pdf, 2017.

[L7] Pitkänen M. Re-examination of the basic notions of TGD inspired theory of consciousness. Available at: http://tgdtheory.fi/public_html/articles/conscrit.pdf, 2017.

[L8] Pitkänen M. Is the hierarchy of Planck constants behind the reported variation of Newton's constant? Available at: http://tgdtheory.fi/public_html/articles/variableG.pdf, 2018.

[L9] Pitkänen M. Topological description of family replication and evidence for higher gauge boson generations. Available at: http://tgdtheory.fi/public_html/articles/dabc.pdf, 2018.