Higgs Or Something Else?

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Abstract

The question whether TGD predicts Higgs or not has been one of the longstanding issues of TGD. For 10 years ago I would not have hesitated to tell that TGD does not predict Higgs and had good looking arguments for my claim. During years my views have been alternating between Higgs and no-Higgs option. In the light of after wisdom the basic mistake has been the lack of a conscious attempt to localize precisely the location of the problem and suggest a minimal modification of standard theory picture to solve it.

Now the situation is settled experimentally: Higgs is there. It is however somewhat too light so that Higgs mechanism is not stable against radiative corrections. SUSY cannot take care of this problem since LHC demonstrated that SUSY mass scale is too high. One has the problem known as loss of "naturalness". Hence Higgs is not yet a fully written page in the history of physics. Furthermore, the experiments demonstrate the existence of Higgs, not the reality of Higgs mechanism. Higgs mechanism in fermionic sector is indeed an ugly duckling: the dimensionless couplings of fermions to Higgs vary in huge range: 12 orders of magnitude between neutrinos and top quark.

1. In TGD framework Higgs mechanism is replaced by p-adic thermodynamics. The couplings of Higgs to fermions are by dimensional arguments very naturally gradient couplings with coupling constant, which has dimensions of inverse mass. This dimensional coupling is same for all fermions so that naturalness is achieved.
2. Massivation of gauge bosons combines Higgs components and weak gauge bosons to massive particles in unitary gauge but leaves photon massless apart from small higher order corrections form p-adic thermodynamics. Unitary gauge is in TGD uniquely fixed by CP_2 geometry. This trivial observation means that there is no need for Higgs vacuum expectation value to define the em neutral direction in gauge algebra. Furthermore, the absence of covariantly constant holomorphic CP_2 vector fields strongly suggests that Higgs vacuum expectation does not make sense. This does not exclude the existence of Higgs like particle as the original wrong conclusion was.
3. W/Z mass squared ratio - the source of troubles in p-adic thermodynamics based approach - is expressible in terms of corresponding gauge coupling strengths g_i^2, $i = W, Z$, if the string tension of the flux tube connecting the two wormhole contacts assignable to gauge boson is proportional to g_i^2. This is definitely a new element in the physical picture and replaces Higgs vacuum energy with the energy of string.
4. p-Adic thermodynamics relying on super-conformal invariance can describe in its recent form only the contributions of wormhole contacts to the particle masses. The contributions from "long strings" connecting different wormhole contacts cannot be calculated. To achieve this one must generalize conformal invariance to include two conformal weights: the conformal weight assignable to the conformal weight for the light-like radial coordinate of light-cone boundary and the spinorial conformal weight assignable to the induced spinor fields at string world sheets. It seems that also an extension to Yangian algebra containing poly-local generators with locus defined as partonic 2-surface is needed: the number of partonic 2-surface would define a quantum number. p-Adic thermodynamics for the representations of Yangian with states labeled by these three integers could provide the complete description of the states.

   The recent construction of WCW geometry indeed leads to a picture allowing interpretation in terms of Yangian extension of super-conformal invariance. The matrix elements of WCW metrix are labelled by two conformal weights assignable to the light-like radial coordinate of light-cone boundary and to the coordinate along string defining the boundary of string world sheet at which fermions are located from the condition that spinor modes have a well-defined value of em charge.

In this chapter the recent view about Higgs is described and reader is saved from the many alternatives that I have considered during last years.

1 Introduction

The question whether TGD predicts Higgs or not has been one of the longstanding issues of TGD. For 10 years ago I would not have hesitated to tell that TGD does not predict Higgs and had good looking arguments for my claim. During years my views have been alternating between Higgs and no-Higgs option. In the light of after wisdom the basic mistake has been the conscious attempt to localize precisely the location of the problem and suggest a minimal modification of standard theory picture to solve it.

Now the situation is settled experimentally: Higgs is there. It is however somewhat too light so that Higgs mechanism is not stable against radiative corrections. SUSY cannot take care of this problem since LHC demonstrated that SUSY mass scale is too high. One has the problem known as loss of "naturalness". Hence Higgs is not yet a fully written page in the history of physics. Furthermore, the experiments demonstrate the existence of Higgs, not the reality of Higgs mechanism. Higgs mechanism in fermionic sector is indeed an ugly duckling: the dimensionless couplings of fermions to Higgs vary in huge range: 12 orders of magnitude between neutrinos and top quark.

This is what motivates to write a separate chapter about Higgs in TGD framework. Originally the idea was to represent various approaches to Higgs in TGD framework. I decided however to save reader from the sad story and try to tell about the recent situation. I am however unable to continue before I list my worst sins during last years.

1. I have considered the identification of Higgs candidate as pion (or perhaps sigma) of M_{89} hadron physics predicted by p-adic length scale hypothesis. There are good reasons to expect that this pion exists: the strange behavior of what was expected to be quark gluon plasma both in heavy ion collisions and in collisions of protons with heavy ions supports the existence of string like hadronic objects in TeV scale. M_{89} pion cannot be however identified with Higgs.

2. On basis of zero energy ontology (ZEO) I have proposed that there are no Higgs like states and even their superpartners should be absent. All massless multiplets would generate small mass and "eat" the generalized Higgs like states with smaller helicities than the defining helicity. Even photon and graviton would have small mass. This idea does not however have obvious realization based on gauge invariance: the gauge boson for which charge matrix commutes with Higgs direction must remain massless unless p-adic thermodynamics provides a small mass for it.

3. I have considered a hybrid of p-adic thermodynamics and Higgs mechanism in which Higgs develops a coherent state and gives masses to gauge bosons whereas fermions would get the dominating contribution to their mass from p-adic thermodynamics. Now this proposal looks ugly.

   To confess all, I have even discussed a proposal for a microscopic description of the tachyonic term in Higgs potential based on the coupling of pseudo-scalar Higgs to instanton term.

1.1 Can One Do Without Standard Model Higgs?

There are several arguments against standard model Higgs, which by definition provides masses for both weak gauge bosons and fermions.

1. Essentially one assumption, the separate conservation of quark and lepton numbers realized in terms of 8-D chiral invariance, excludes Higgs like states in scalar particles in *8-D sense* as also standard $\mathcal{N} = 1$ SUSY: here Higgs likeness means that the couplings to fermions are proportional to fermion masses.

   If Higgs like states exist, they must be Minkowski scalars and vectors in CP_2 tangent space or CP_2 spinors. Higgs doublets indeed have this interpretation. One motivation for assuming absence of Higgs is that CP_2 geometry does not allow any covariantly constant vector so that no acceptable classical correlate for Higgs vacuum expectation exists. I have however proposed that CP_2 part for the trace of the second fundamental form serve as this correlate: it cannot be however covariantly constant.

   The minimal conclusion is that Higgs particle can quite well exist but that its vacuum expectation value as coviantly constant CP_2 vector cannot.

2. Zero energy ontology led much later to an argument against Higgs: all Higgs like particles could be "eaten" by gauge bosons and even other particles with spin.

(a) The view about bosons as wormhole throats carrying fermionic quantum numbers are the opposite light-like wormhole throats of the contact makes it very difficult to assume that scalar particles would not exist. On the other hand, twistorial considerations force to assume that the wormhole throats as basic building bricks of particles are massless and that even virtual particles correspond to composites of on mass shell massless states with both signs of energy allowed. Massless fermions with unphysical helicity can indeed appear as virtual particles.

(b) This argument seems to force the conclusion that spin 1 particles are necessary massive. Higgs like wormhole throats can be however massless since the helicities of massless fermion and anti-fermion are opposite so that the light-like momenta are parallel.

This inspired the crazy proposal that all Higgs like particles might be eaten by gauge bosons (also photon would be massive). Even the super-partners of Higgs bosons would experience the same fate.

(c) The assumption that photon "eats" neutral Higgs is *not* consistent with the picture provided by gauge invariance: in unitary gauge weak bosons are massive and photon remains massless since em charge matrix commutes with the direction of Higgs field defined by its vacuum expectation value. In fact, in TGD framework CP_2 geometry fixes unique direction of Higgs field and thus unitary gauge so that vacuum expectation value is not needed for this purpose. p-Adic thermodynamics could take care of massivation of at least fermions. The massivation of gauge bosons requires something more [K5].

One should not however make too hasty conclusions: photon could get very small mass from p-adic thermodynamics as also weak bosons: weak bosons get additional mass by eating three components of Higgs like particle. In the case of photon one should however understand where the third polarization comes from.

3. There are very general arguments requiring new physics at TeV scale. Also standard model Higgs has its difficulties with radiative corrections and standard SUSY has been the candidate for this new physics. The data from LHC however suggest that standard SUSY is not the choice of Nature. TGD proposal has been new hadron physics obtained as scaled up variant of standard hadron physics. The pion of this hadron physics could yield decay signatures suggesting interpretation as Higgs like state. I have considered this option seriously but it is excluded by experimental facts.

1.2 Why Higgs Like Particle Is Needed?

There are also several arguments in favor of Higgs like particle. These arguments do not however require Higgs vacuum expectation value.

1. The W/Z mass ratio having group theoretic origin (Higgs should transform as $2 + \overline{2}$ under $U(2)$) and predicted correctly by Higgs mechanism is a strong argument in favor that gauge boson massivation can be understood in terms of Higgs mechanism. Higgs would provide the third polarization states of gauge bosons becoming manifest in unitary gauge: this however requires only gauge invariance and *some* condition defining the unitary gauge. In standard model Higgs vacuum expectation defines the unitary gauge. In TGD framework CP_2 geometry takes care of this so that Higgs vacuum expectation is not needed unless massivation requires it.

2. In TGD framework the masses of fermions are predicted with amazing accuracy by p-adic thermodynamics. It however fails to provide elegant explanation for W/Z mass ratio [K5]: it seems that the contribution of p-adic thermodynamics to gauge boson masses corresponds to same p-adic temperature as for photon and is therefore very small due to the lower p-adic temperature quantized as $T = 1/n$ (for fermions one has $T = 1$). Therefore one can consider the possibility that Higgs like state gives weak bosons their masses. This kind of hybrid model looks ugly.

3. A more elegant option is based on the realization that elementary particles correspond to pairs of wormhole contacts connected by strings assignable to 2-D string world sheet at

which fermionic modes are localized by the requirement that the modes are eigenstates of em charge. This suggests that there is an additional stringy contribution to the masses of the particles and that for weak bosons this contribution dominates over the contribution from p-adic thermodynamics. The contribution could be present also for fermions but would be small for leptons. In hadrons the contribution would dominate over quark contributions and is usually identified as gluonic contribution.

The stringy contribution to gauge boson mass squared could be expressed in terms of formula involving string tension just as the contribution from p-adic thermodynamics in degrees of freedom assignable to wormhole contacts. The proper mathematical framework for expressing this contribution could be Yangian symmetry expanding super-conformal symmetries and involving two conformal weights instead of one [K5].

The conclusion is that Higgs seems to be needed but that the vacuum expectation of Higgs is not encouraged by the propoerties of CP_2 geometry. Only the neutral Higgs particles having representation completely analogous to that for gauge bosons and fermions would appear in the spectrum in unitary gauge. The fermion content of Higgs is determined from the condition that it forms $SU(2)_L$ doublet and $SU(2)_R$ singlet.

1.3 The Recent Situation

The existence of Higgs like particle is now established. Often this is taken as proof for particle massivation based on Higgs mechanism. There are however two very disturbing findings. The mass of Higgs like particle is somewhat too small so that radiative corrections to the mass of the Higgs instabilize the situation and fine tuning is required to reproduce experimental mass. The original hope was $\mathcal{N}=1$ supersymmetry would help by cancelling the radiative corrections at high energies but on basis of observations made at LHC the mass scale of SUSY particles seems to be too high to achieve this. Predictivity is lost.

There is also the difficulty than one can only reproduce the fermion masses rather than being able to really predict them and the mass scales of fermion masses are widely different (consider only top/neutrino mass ratio of order 10^{12}!). It seems that one cannot avoid the introduction of the notion of mass scale depending on particle as a new degree of freedom.

Here TGD could finally add the missing piece of the puzzle. If one wants QFT description then the only possibility is the description based on Higgs mechanism but this is only an effective description - the best that one can have if one assumes point like particles. If one gives up this dogma, p-adic thermodynamics making sense in zero energy ontology provides the natural description and brings in the hierarchy of p-adic length scales via p-adic length scale hypothesis.

1. Higgs mechanism is replaced by p-adic thermodynamics. The couplings of Higgs to fermions are by dimensional arguments very naturally gradient couplings with coupling constant, which has dimensions of inverse mass. This dimensional coupling is same for all fermions so that naturalness is achieved.

2. Massivation of gauge bosons combines Higgs components and weak gauge bosons to massive particles in unitary gauge but leaves photon massless apart from small higher order corrections form p-adic thermodynamics.

3. W/Z mass squared ratio - the source of troubles in p-adic thermodynamics based approach - is expressible in terms of corresponding gauge coupling strengths g_i^2, $i=W,Z$, if the string tension of the flux tube connecting the two wormhole contacts assignable to gauge boson is proportional to g_i^2.

4. p-Adic thermodynamics relying on super-conformal invariance can describe only the contributions of wormhole contacts to the particle masses [K5]. The contributions from "long strings" connecting different wormhole contacts cannot be calculated. To achieve this one must generalize conformal invariance to Yangian invariance and define p-adic thermodynamics for the representations of Yangian.

   The recent construction of WCW geometry [K13] indeed leads to a picture allowing interpretation in terms of Yangian extension of super-conformal invariance. The matrix elements of WCW metrix are labelled by two conformal weights assignable to the light-like radial coordinate of light-cone boundary and to the coordinate along string defining the boundary of string world sheet at which fermions are located from the condition that spinor modes have a well-defined value of em charge.

It has recently become clear that the boundary conditions for the Kähler-Dirac equation lead to the appearence of analog of classical Higgs field but this seems to prove space-time counterpart for the stringy mass formula and could also allow to understand why the ground state conformal weight of super-conformal representations is negative half integer plus something p-adically small (tachyonicity).

This chapter is an attempt to summarize the recent view of related to the status of Higgs in TGD. It is certainly not a summary of final results in a concise form and can still contain contradictory arguments containing delicate errors. Also the recent situation is critical and the experimental results from LHC will be decisive for future developments.

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` [L1].

2 Background

In the following some general background related to particle massivation and Higgs is summarized.

2.1 Gut Paradigm

The leading thread in the story of particle physics is GUT paradigm, which emerged for four decades ago. It however has its problems besides the fact that not a single thread of evidence has accumulated to support it.

1. The basic idea of GUTs is to put all fermions and bosons to multiplets of some big gauge group extending the standard model gauge group. This idea is applied also in the generalization of gauge theories to supersymmetric gauge theories and in superstring models. Scalar fields developing vacuum expectations define a key element of this approach and give hopes of obtaining a realistic mass spectrum. This rather simple minded approach would make unification an easy job. There are however difficulties.

2. One of the basic implications is that baryon and lepton numbers are not conserved separately. Proton decays would make this non-conservation manifest. These decays have not been however observed, and one of the challenges of the GUT based models is fine-tuning of couplings so that proton is long-lived enough. This raises the question whether one could somehow understand the separate conservation of B and L from basic principles.

3. Putting all fermions in the same multiplet would suggest that the mass ratios for fermions should be simple algebraic numbers not too far from unity. Fermion families have however widely differing mass scales and the ratio of top quark mass scale to neutrino mass scale is gigantic. This suggests that fermion generations and even different charge states of fermions of single generation are characterized by inherent mass scales and do not belong to a multiplet of a big gauge group. Standard model gauge group would be the fundamental gauge group and the challenge would be to deduce it from some fundamental principles. In TGD framework number theoretical vision indeed leads to an explanation for standard model gauge group [K8].

   It is also an empirical fact that fermion generations are identical copies of each other apart from widely different masses. This suggests some non-group theoretic explanation for family replication phenomenon. In TGD framework 2-D wormhole throats characterized topological by their genus in orientable category are the fundamental particle like objects. This provides a possible explanation for the family replication phenomenon. One must of course explain why genera higher than $g = 2$ are heavy or absent from the spectrum, and one can indeed develop an argument for this based on the fact that $g \leq 2$ 2-surfaces allow always Z_2 as conformal symmetries unlike $g > 2$ 2-surfaces [K2].

4. Particle massivation is in GUT framework is described by coupling the fermions and gauge bosons to a scalar field. The vacuum expectation values of the scalar fields define the mass scales. In the case of standard model one has only single scalar/Higgs field and by choosing the couplings to Higgs field to be proportional to fermion mass one can reproduce particle masses. Only a reproduction is in question and theory is certainly not microscopic. Vacuum expectation value (VEV) paradigm is central also for the inflationary cosmology - in fact for the entire theoretical particle physics developed during last decades. The no-existence of Higgs would force to return to the roots to the situation four decades ago. Therefore the new spinless particle could be a turning point in the history of physics, and it is easy to understand why the attitudes against or on behalf of Higgs interpretation are so passionate and why facts tend to be forgotten.

2.2 How To Achieve Separate Conservation Of B And L?

A possible manner to understand the separate conservation of both B and L would be via the identification of spinors as different chiralities of higher-dimensional spinors.

1. This would however require the identification of color quantum numbers as angular momentum like quantum numbers assignable to partial waves in internal space. This is indeed the identification performed in TGD framework and $H = M^4 \times CP_2$ is the unique choice of imbedding space coding for the standard model quantum numbers. In TGD approach quarks and leptons correspond to different imbedding space chiralities, and this excludes Higgs as a genuine imbedding space scalar since it would couple to quark-lepton pairs. To get the couplings correctly Higgs should correspond to imbedding space vector having components only the direction of CP_2 but it is rather difficult to imagine how gauge bosons could "eat" components of Higgs in this case. As a matter fact, Higgs components should be characterized by same charge matrices as weak bosons and would be a TGD counterpart for a mixture of scalar and pseudo-scalar.

2. Chiral invariance is indeed essential for the renormalizability of 4-D gauge theories.The absence of 8-D scalars would allow also a generalization of chiral invariance from 4-D to 8-D context implying separate conservation of B and L. This is the case even in string model framework if separate conservation of B and L is assumed. It is worth of mentioning that the separate conservation of B and L is not consistent with the standard $\mathcal{N} = 1$ SUSY realized in terms of Majorana spinors. This is not a catastrophe since LHC has already excluded quite a considerable portion of parameter space for $\mathcal{N} = 1$ SUSY. $\mathcal{N} = 2$ SUSY however is and is generated in TGD framework by right-handed neutrino and its antiparticle.

   There are however quite intricate delicacies involved discussed in detail in [K12]. For instance, the modes of covariantly constant right-handed neutrino spinor of CP_2 generates 4-D generalization of super-conformal symmetry as modes de-localized into entire space-time surfaces whereas other modes are localized to 2-D surfaces and generate badly broken SUSY with very large value of $\mathcal{N}$. An open question is whether the ν_R covariantly constant also in M^4 degrees of freedom could generate $\mathcal{N} = 1$ SUSY analogous to the standard SUSY. In any case, TGD seems to be inconsistent with both scalar VEV paradigm and standard $\mathcal{N} = 1$ SUSY.

   The recent work with WCW geometry and spinors structure (definition of gamma matrices) suggests strongly that super-conformal symmetries generalizes to their Yangian variants meaning that one has two conformal weights and multi-locality. Second integer corresponds to the the integer assignable to strings connecting wormhole contacts.

3. p-Adic physics and p-adic length scale hypothesis allow to understand the widely different mass scales of fermions and various gauge bosons since p-adic prime and the primary p-adic length scale defined by it become the characterizers of elementary particle. Also the secondary p-adic length and time scales are important: for electron secondary p-adic time scale is.1 seconds and quite intriguingly the fundamental time scale of biology. p-Adic thermodynamics provides the microscopic theory of particle massivation leading to highly successful predictions not only for particle mass scale ratios but also for the particle masses. p-Adic

primes near powers of two - in particular Mersenne primes - pop up naturally and define positive integer characterizing given particle. Number theory becomes the tool of understanding the mystery number 10^{38} defined by the ratio of Planck mass and proton mass (this number is essentially the ratio of CP_2 mass to electron mass) [K5].

In TGD framework Higgs like states could provide gauge bosons with longitudinal polarizations. They are not needed for massivation except in the case of gauge bosons. Higgs like states are certainly possible in TGD framework, and if one does not accept them one must invent a good explanation for their absence.

2.3 Particle Massivation From P-Adic Thermodynamics

p-Adic thermodynamics defines a core element of p-adic mass calculations [K2, K5, K7]. p-Adic thermodynamics is thermodynamics for the conformal scaling generator L_0 in the tensor product representation of super-conformal algebra and the masses are fixed one the p-adic prime characterizing the particle is fixed. p-Adic length scale hypothesis $p \simeq 2^k$, k integer, implies an exponential sensitivity of the particle mass scale on k so that a fitting of particle masses is not possible.

1. The first thing that one can get worried about relates to the extension of conformal symmetries. If the conformal symmetries for light-like surfaces and $\delta M^4_\pm \times CP_2$ generalize to $D = 4$, how can one take seriously the results of p-adic mass calculations based on 2-D conformal invariance? There is actually no reason to worry. The reduction of the conformal invariance to 2-D one for the solutions of Kähler-Dirac equation takes care of this problem [K12] This however requires that the fermionic contributions assignable to string world sheets and/or partonic 2-surfaces - Super- Kac-Moody contributions - dictate the elementary particle masses. For hadrons also super-symplectic contributions would be present and would give the dominating contribution to baryon masses.

   The modes of right handed neutrino are de-localized to a 4-D region of space-time surface and characterized by two integers. The absence of all standard model interactions suggests that no thermalization takes place for them. These modes are de-localized either to a region of Euclidian signature identifiable as 4-D line of generalized Feynman graph or to a region of Minkowskian signature. Since Kähler-Dirac gamma matrices vanish identically for CP_2 type vacuum extremals, one can ask whether the 4-D neutrino modes are associated only with Minkowskian regions. In this case the counterpart of $\mathcal{N} = 1$ SUSY would assign spartner to a many-particle state rather than to elementary particle. This could explain for why LHC has not seen the analog of standard SUSY.

2. ZEO suggests that the wormhole throats carrying many-fermion states with parallel momenta are massless: this applies even to virtual wormhole throats [K11]. As a consequence, the twistor approach would work and the on mass shell kinematical constraints to the vertices would allow the cancellation of UV divergences. The 2-D Kac-Moody generators assignable to the boundaries of string world sheets would generate Yangian algebra [K9]. IR divergences would cancel because incoming and outgoing particles would be massive on mass shell particles as states involving several wormhole throats. The p-adic thermal expectation value is for the longitudinal M^2 momentum squared rather than for the four-momentum squared (the definition of CD selects $M^1 \subset M^2 \subset M^4$ as also does number theoretic vision). Also propagator would be determined by M^2 momentum. Lorentz invariance would be achieved by averaging over the moduli for CD including also Lorentz boosts of CD.

3. In the original approach states with arbitrary large values of L_0^{tot} were allowed as physical states. Usually one would require that the generator L_0^{tot} of conformal scaling annihilates the states. In the calculations however mass squared was assumed to be proportional L_0^{tot} apart from vacuum contribution. This is a questionable assumption. ZEO suggests that total mass squared vanishes and that one can decompose mass squared to a sum of longitudinal and transversal parts. If one can do the same decomposition for the longitudinal and transverse parts also for the Super Virasoro algebra, one can calculate longitudinal mass squared as a p-adic thermal expectation of L_0^{tr} in the transversal Super-Virasoro algebra and only states with $L_0^{tot} = 0$ would contribute and one would have conformal invariance in the standard

sense. The decomposition is indeed possible since longitudinal parts correspond to pure gauge degrees of freedom.

Thermodynamics - or rather, its square root - would become part of quantum theory in ZEO. M-matrix is indeed product of hermitian square root of density matrix multiplied by unitary S-matrix and defines the entanglement coefficients between positive and negative energy parts of zero energy state. Different M-matrices orthogonal to each other with respect to trace become rows of the unitary U-matrix.

4. The crucial constraint is that the number of super-conformal tensor factors is $N = 5$: this suggests that thermodynamics applied in Super-Kac-Moody degrees of freedom assignable to string world sheets is enough if one is interested in the masses of fermions and gauge bosons. Super-symplectic degrees of freedom can also contribute and determine the dominant contribution to baryon masses. Should also this contribution obey p-adic thermodynamics in the case when it is present? Or does the very fact that this contribution need not be present mean that it is not thermal? The symplectic contribution should correspond to hadronic p-adic length scale rather the much longer (!) p-adic length scale assignable to say u quark (this paradoxical looking result can be understood in terms of uncertainty principle and the assignment of quarks to the color magnetic body of hadron). Hadronic p-adic mass squared and partonic p-adic mass squared cannot be summed since primes are different. If one accepts the basic rules [K7], longitudinal energy and momentum are additive as indeed assumed in perturbative QCD.

5. Calculations work if the vacuum expectation value of the mass squared is assumed to be tachyonic. One could argue that the total mass squared has naturally tachyonic ground state expectation since for massless extremals (MEs, topological light rays [K1]) longitudinal momentum is light-like and transversal momentum squared is necessary present and non-vanishing by the localization to topological light ray of finite thickness of order p-adic length scale. Transversal degrees of freedom would be modeled with a particle in a box.

This is the general picture. One crucially important implication is that gauge conditions $p{\cdot}\epsilon = 0$ in Lorentz gauge must be satisfied.

1. Suppose that gauge bosons can be approximated as composites of fermion and antifermion characterized by polarization and total momentum. For massless gauge boson the four-momenta could be taken to be parallel such that second fermion has negative energy. The gauge conditions are separately satisfied by fermion and antifermion and one obtains two polarization states. For massive gauge bosons one can go to rest system and finds that three polarization states are possible since 3-momentum vanishes.

2. Number theoretical considerations and also parton model have motivated the proposal that only longitudinal M^2 momentum could appear in the propagators (recall that total mass squared vanishes and cannot appear in the propagator if virtual particles are massless). Therefore only M^2 momentum would appear in the gauge conditions: $p_L \cdot \epsilon = 0$ holds true and implies that also longitudinal polarization is allowed. Massivation is also unavoidable.

   The first approximation for gauge boson state is as a wormhole contact containing fermion and anti-fermion at 3-D light-like wormhole throats. One must have spin 1 but since fermion and anti-fermion are massless they must have non-parallel 3-momenta in order to have parallel spins. For instance, they could have parallel and massive longitudinal momenta but non-parallel transverse momenta. The longitudinal mass squared would be in general non-vanishing and hence mass squared as the average over moduli of CD involving also integration over Lorentz boosts of CD.

   Higgs could be *identified* in terms of spinless fermion antifermion pairs and gauge invariance would allow to eliminate all but neutral components of Higgs.

2.4 The Conservation Of EM Charge In TGD Framework

An important aspect of the standard model Higgs mechanism is that it respects em charge leaving photons massless. In standard model the conservation of em charge defined as isospin like quantum number is non-trivial since the presence of classical gauge fields induces transitions between different charge states of fermions. In second quantization this problem is circumvented by replacing classical gauge fields with quantized ones. The so called unitary gauge defined by a gauge transformation depending on Higgs fields allows to express the action in terms of physical (in general massive) fields and makes charge conservation explicit.

The first thing to notice is that unitary gauge is coded CP_2 geometry: the em neutral direction for electroweak algebra identified as holonomy algebra of CP_2 is uniquely fixed unlike in standard model. This has logically trivial but physically far reaching implication: Higgs vacuum expectation is not needed to define the electromagnetically neutral direction in electweak gauge algebra.

This does not yet guarantee the conservation and well-definedness of em charge as a quantum number characterizing modes of the induced spinor field. How the conservation of em charge is obtained in TGD?

1. Doesn't one have the same problem but as a much worse variant since classical long range electro-weak gauge fields are unavoidable in TGD and there is no path integral but preferred extremals? Could it make sense to speak about unitary gauge also in TGD framework? Could one turn around this idea to derive classical Higgs from the possibly existing gauge transformation to unitary gauge? The answer is negative. There is actually no need for the unitary gauge.

   As a matter fact, the conservation for em charge in spinorial sense leads to the earlier conjecture that the solutions of the Kähler-Dirac equations are localized at 2-D surfaces whose ends define braid strands at space-like 3-surfaces at the ends of causal diamonds and at the light-like 3-surfaces connecting them and defining lines for generalized Feynman diagrams. This picture was earlier derived from the notion of finite measurement resolution implying discretization at the level of partonic 2-surfaces and also from number theoretical vision suggesting that basic objects correspond to 2-D commutative and co-commutative identifiable as sub-manifolds of 4-D associative and co-associated surfaces.

2. The point is that the Kähler form of CP_2 is covariantly constant and one can identify covariantly constant em charge as a matrix of form $Q = aI + bJ_{kl}\Sigma^{kl}$: the coefficients a and B are different for quarks and leptons (different chiralities of H-spinors). This matrix is covariantly constant also with respect to the induced spinor structure and commutes with Dirac operator (be it the TGD counterpart of the ordinary massless Dirac operator or Kähler-Dirac operator). Therefore one should be able to choose the modes of induced spinor field to have a well-defined em charge at each point of space-time surface. The covariantly constant Kähler form of CP_2 is an important element in making possible the conservation of em charge and derives from the supersymmetry generated by covariantly constant right-handed neutrino.

   It also allows to define identified electromagnetic charge as a preferred direction in gauge algebra. This is just what is needed to define unitary gauge uniquely and in standard model Higgs vacuum expectation is needed to achieve this. This is however not enough as it became clear.

3. Rather unexpectedly, the challenge of understanding the charge conservation in the spinorial sense led to a breakthrough in understanding of the modes of the Kähler-Dirac equation. The condition for conservation leads to three separate analogs of Dirac equations and the two additional ones are satisfied if em charged projections of the generalized energy momentum currents defining components of modified gamma matrices vanish. If these components define Beltrami fields expressible as products $j = \Psi\nabla\Phi$ the conditions can be satisfied for $\Psi = 0$. Since Ψ is complex or hyper-complex, the conditions are satisfied for 2-dimensional surfaces of space-time surfaces identifiable as string world sheets and partonic 2-surfaces. This picture was earlier derived from various arguments. Em charge conservation does not there give rise to a counterpart of unitary gauge but leads to a bridge between Kähler-Dirac equation and general view about quantum TGD based on generalization of super-conformal invariance.

To sum up, higgsteria and all cold showers accompanying it has had quite powerful positive impact in TGD framework. Consider only the improved understanding of em charge, solutions of Kähler Dirac eqution and preferred extremals of Kähler action, of Higgs itself, and p-adic thermodynamics, its limitations and possible generalization!

3 About The Microscopic Description Of Gauge Boson Massivation

The conjectured QFT limit allows to estimate the quantitative predictions of the theory. This is not however enough. One should identify the microscopic TGD counterparts for various aspects of gauge boson massivation. There is also the question about the consistency of the gauge theory limit with the ZEO inspired view about massivation. The basic challenge are obvious: one should translate notions like Higgs vacuum expectation, massivation of gauge bosons, and finite range of weak interactions to the language of wormhole throats, Kähler magnetic flux tubes, and string world sheets. The proposal is that generalization of super-conformal symmetries to their Yangian counterparts is needed to meet this challenges in mathematically satisfactory manner.

3.1 The Counterpart Of Higgs Vacuum Expectation In TGD

The development of the TGD view about Higgs involves several wrong tracks involving a lot of useless calculation. All this could have been avoided with more precise definition of basic notions. The following view has distilled through several failures and might be taken as starting point.

The basic challenge is to translate the QFT description of gauge boson massivation to microscopic description.

1. One can say that gauge bosons "eat" the components of Higgs. In unitary gauge one gauge rotates Higgs field to electromagnetically neutral direction defined by the vacuum expectation value of Higgs. The rotation matrix codes for the degrees of freedom assignable to non-neutral part of Higgs and they are transferred to the longitudinal components of Higgs in gauge transformation. This gives rise to the third polarization direction for gauge boson. Photon remains massless because em charge commutes with Higgs.

2. The generation of vacuum expectation value has two functions: to make weak gauge bosons massive and to define the electromagnetically neutral direction to which Higgs field is rotated in the transition to the unitary gauge. In TGD framework only the latter function remains for Higgs if p-adic thermodynamics takes care of massivation. The notion of induced gauge field together with CP_2 geometry uniquely defines the electromagnetically neutral direction so that vacuum expectation is not needed. Of course, the essential element is gauge invariance of the Higgs gauge boson couplings. In twistor Grassmann approach gauge invariance is replaced with Yangian symmetry, which is excellent candidate also for basic symmetry of TGD.

3. The massivation of gauge bosons (all particles) involves two contributions. The contribution from p-adic thermodynamics in CP_2 scale (wormhole throat) and the stringy contribution in weak scale more generally, in hadronic scale. The latter contribution cannot be calculated yet. The generalization of p-adic thermodynamics to that for Yangian symmetry instead of mere super-conformal symmetry is probably necessary to achieve this and the construction WCW geometry and spinor structure strongly supports the interpretation in terms of Yangian.

One can look at the situation also at quantitative level.

1. W/Z mass ratio is extremely sensitive test for any model for massivation. In the recent case this requires that string tension for weak gauge boson depends on boson and is proportional to the appropriate gauge coupling strength depending on Weinberg angle. This is natural if the contribution to mass squared can be regarded as perturbative.

2. Higgs mechanism is characterized by the parameter m_0^2 defining the originally tachyonic mass of Higgs, the dimensionless coupling constant λ defining quartic self-interaction of Higgs. Higgs vacuum expectation is given by $\mu^2 = m_0^2/\lambda$, Higgs mass squared by $m_0^2 = \mu^2\lambda$, and weak boson mass squared is proportional $g^2\mu^2$. In TGD framework λ takes the role of g^2 in stringy picture and the string tensions of bosons are proportional to g_w^2, g_Z^2, λ respectively.

3. Whether λ in TGD framework actually corresponds to the quartic self-couplingof Higgs or just to the numerical factor in Higgs string tension, is not clear. The problem of Higgs

mechanism is that the mass of observed Higgs is somewhat too low. This requires fine tuning of the parameters of the theory and SUSY, which was hoped to come in rescue, did not solve the problem. TGD approach promises to solve the problem.

3.2 Elementary Particles In ZEO

Let us first summarize what kind of picture ZEO suggests about elementary particles.

1. Kähler magnetically charged wormhole throats are the basic building bricks of elementary particles. The lines of generalized Feynman diagrams are identified as the Euclidian regions of space-time surface. The weak form of electric magnetic duality forces magnetic monopoles and gives classical quantization of the Kähler electric charge. Wormhole throat is a carrier of many-fermion state with parallel momenta and the fermionic oscillator algebra gives rise to a badly broken large $\mathcal{N}$ SUSY [K4].

2. The first guess would be that elementary fermions correspond to wormhole throats with unit fermion number and bosons to wormhole contacts carrying fermion and anti-fermion at opposite throats. The magnetic charges of wormhole throats do not however allow this option. The reason is that the field lines of Kähler magnetic monopole field must close. Both in the case of fermions and bosons one must have a pair of wormhole contacts (see **Fig.** `http://tgdtheory.fi/appfigures/wormholecontact.jpg` or **Fig. ??** in the appendix of this book) connected by flux tubes. The most general option is that net quantum numbers are distributed amongst the four wormhole throats. A simpler option is that quantum numbers are carried by the second wormhole: fermion quantum numbers would be carried by its second throat and bosonic quantum numbers by fermion and anti-fermion at the opposite throats. All elementary particles would therefore be accompanied by parallel flux tubes and string world sheets.

3. A cautious proposal in its original form was that the throats of the other wormhole contact could carry weak isospin represented in terms of neutrinos and neutralizing the weak isospin of the fermion at second end. This would imply weak neutrality and weak confinement above length scales longer than the length of the flux tube. This condition might be un-necessarily strong.

   The realization of the weak neutrality using pair of left handed neutrino and right handed antineutrino or a conjugate of this state is possible if one allows right-handed neutrino to have also unphysical helicity. The weak screening of a fermion at wormhole throat is possible if ν_R is a constant spinor since in this case Dirac equation trivializes and allows both helicities as solutions. The new element from the solution of the Kähler-Dirac equation is that ν_R would be interior mode de-localized either to the other wormhole contact or to the Minkowskian flux tube. The state at the other end of the flux tube is spartner of left-handed neutrino.

   It must be emphasized that weak confinement is just a proposal and looks somewhat complex: Nature is perhaps not so complex at the basic level. To understand this better, one can think about how M_{89} mesons having quark and antiquark at the ends of long flux tube returning back along second space-time sheet could decay to ordinary quark and antiquark.

3.3 Virtual And Real Particles And Gauge Conditions In ZEO

ZEO and twistor Grassmann approach force to build a detailed view about real and virtual particles. ZEO suggests also new approaches to gauge conditions in the attempts to build detailed connection between QFT picture and that provided by TGD. The following is the most conservative one. Of course, also this proposal must be taken with extreme cautiousness.

1. In ZEO all wormhole throats - also those associated with virtual particles - can be regarded as massless. In twistor Grassmann approach [K9] this means that the fermionic propagators can be by residue integration transformed to their inverses which correspond to online massless states but having an unphysical polarization so that the internal lines do not vanish identically.

2. This picture inspired by twistorial considerations is consistent with the simplest picture about Kähler-Dirac action. The boundary term for K-D action is $\sqrt{g_4}\overline{\Psi}\Gamma^n_{K-D}\Psi d^3x$ and due to the localization of spinor modes to 2-D surfaces reduces to a term localized at the boundaries of string world sheets. The normal component Γ^n_{K-D} of the Kähler-Dirac gamma matrices defined by the canonical momentum currents of Kähler action should define the inverse of massless fermionic propagator. If the action of this operator on the induced spinor mode at stringy curves satisfies

$$\sqrt{g_4}\Gamma^n\Psi = p^k\gamma_k\Psi \ ,$$

this reduction is achieved. One can pose the condition $g_4 = constant$ as a coordinate condition on stringy curves at the boundaries of CD and the condition would correlate the spinor modes at stringy curve with incoming quantum numbers. This is extremely powerful simplification giving hopes about calculable theory. The residue integral for virtual momenta reduces the situation to integral over on mass shell momenta and only non-physical helicities contribute in internal lines. This would generalize twistorial formulas to fermionic context.

One however ends up with an unexpected prediction which has bothered me for a long time. Consider the representation of massless spin 1 gauge bosons as pairs as wormhole throat carrying fermion and antifermion having net quantum numbers of the boson. Neglect the effects of the second wormhole throat. The problem is that for on-mass shell massless fermion and antifermion with physical helicities the boson has spin 0. Helicity 1 state would require that second fermion has unphysical helicity. What does this mean?

1. Are all on mass shell gauge bosons - including photon - massive? Or is on mass shell massless propagation impossible? Massivation is achieved if the fermion and antifermion have different momentum directions: for instance opposite 3-momen but same sign of energy. Higher order contributions in p-adic thermodynamics could make also photon massive. The 4-D world-lines of fermion and antifermion would not be however parallel, which does not conform with the geometric optics based prejudices.

2. Or could on mass shell gauge bosons have opposite four-momenta so that the second gauge boson would have negative energy? In this manner one could have massless on mass shell states. ZEO ontology certainly allows the identification massless gauge bosons as on mass shell states with opposite directions of four-momenta. This would however require the weakening of the hypothesis that all incoming (outgoing) fundamental fermions have positive (negative) energies to the assumption that only the incoming (outgoing) particles have positive (negative) energies. In the case of massless gauge boson the gauge condition $p \cdot \epsilon = 0$ would be satisfied by the momenta of both fermion and antifermion. With opposite 3-momenta (massivation) but same energy the condition $p_{tot} \cdot \epsilon = 0$ is satisfied for three polarization since in cm system p_{tot} has only time component.

3. The problem is present also for internal lines. Since by residue argument only the unphysical fermion helicities contribute in internal lines, both fermion and antifermion must have unphysical helicity. For the same sign of energy the wormhole throat would behave as scalar particle. Therefore it seems that the energies must have different sign or momenta cannot be strictly parallel. This is required also by the possibility of space-like momenta for virtual bosons.

3.4 The Role Of String World Sheets And Magnetic Flux Tubes In Massivation

What is the role of string world sheets and flux tubes in the massivation? At the fundamental level one studies correlation functions for particles and finite correlation length means massivation.

1. String world sheets define as essential element in 4-D description. All particles are basically bi-local objects: pairs of string at parallel space-time sheets extremely near to each other and connected by wormhole contacts at ends. String world sheets are expected to represent correlations between wormhole throats.

2. Correlation length for the propagator of the gauge boson characterizes its mass. Correlation length can be estimated by calculating the correlation function. For bosons this reduces to the calculation of fermionic correlations functions assignable to string world sheets connecting the upper and lower boundaries of CD and having four external fermions at the ends of CD. The perturbation theory reduces to functional integral over space-time sheets and deformation of the space-time sheet inducing the deformation of the induced spinor field expressible as convolution of the propagator associated with the Kähler-Dirac operator with vertex factor defined by the deformation multiplying the spinor field. The external vertices are braid ends at partonic 2-surfaces and internal vertices are in the interior of string world sheet. Recall that the conjecture is that the restriction to the wormhole throat orbits implies the reduction to diagrams involving only propagators connecting braid ends. The challenge is to understand how the coherent state assigned to the Euclidian pion field induces the finite correlation length in the case of gauge bosons other than photon.

3. The non-vanishing commutator of the gauge boson charge matrix with the vacuum expectation assigned to the Euclidian pion must play a key role. The study of the Kähler-Dirac operator suggests that the braid strands contain the Abelianized variant of non-integrable phase factor defined as $exp(i\int Adx)$. If A is identified as string world sheet Hodge dual of Kac-Moody charge the opposite edges of string world sheet with geometry of square given contributions which compensate each other by conservation of Kac-Moody charge if A commutes with the operators building the coherent Higgs state. For photon this would be true. For weak gauge bosons this would not be the case and this gives hopes about obtaining destructive interference leading to a finite correlation length.

One can also consider try to build more concrete manners to understand the finite correlation length.

1. Quantum classical correspondence suggests that string with length of order $L \sim \hbar/E$, $E = \sqrt{p^2+m^2}$ serves as a correlate for particle defined by a pair of wormhole contacts. For massive particle wave length satisfies $L \leq \hbar/m$. Here (p,m) must be replaced with (p_L, m_L) if one takes the notion of longitudinal mass seriously. For photon standard option gives $L = \lambda$ or $L = \lambda_L$ and photon can be a bi-local object connecting arbitrarily distant objects. For the second option small longitudinal mass of photon gives an upper bound for the range of the interaction. Also gluon would have longitudinal mass: this makes sense in QCD where the decomposition $M^4 = M^2 \times E^2$ is basic element of the theory.

2. The magnetic flux tube associated with the particle carries magnetic energy. Magnetic energy grows as the length of flux tube increases. If the flux is quantized magnetic field behaves like $1/S$, where S is the area of the cross section of the flux tube, the total magnetic energy behaves like L/S. The dependence of S on L determines how the magnetic energy depends on L. If the magnetic energy increases as function of L the probability of long flux tubes is small and the particle cannot have large size and therefore mediates short range interactions. For $S \propto L^\alpha \sim \lambda^\alpha$, $\alpha > 1$, the magnetic energy behaves like $\lambda^{-\alpha+1}$ and the thickness of the flux tube scales like $\sqrt{\lambda^\alpha}$. In case of photon one might expect this option to be true. Note that for photon string world sheet one can argue that the natural choice of string is as light-like string so that its length vanishes.

What kind of string world sheets are possible? One can imagine two options.

1. All strings could connect only the wormhole contacts defining a particle as a bi-local object so that particle would be literally the geometric correlate for the interaction between two objects. The notion of free particle would be figment of imagination. This would lead to a rather stringy picture about gauge interactions. The gauge interaction between systems S_1 and S_2 would mean the emission of gauge bosons as flux tubes with charge carrying end at S_1 and neutral end. Absorption of the gauge boson would mean that the neutral end of boson and neutral end of charge particle fuse together line the lines of Feynman diagram at 3-vertex.

2. Second option allows also string world sheets connecting wormhole contacts of different particles so that there is no flux tube accompanying the string world sheet. In this case particles would be independent entities interacting via string world sheets. In this case one could consider the possibility that photon corresponds to string world sheet (or actually parallel pair of them) not accompanied by a magnetic flux tube and that this makes the photon massless at least in excellent approximation.

The first option represents the ontological minimum.

Super-conformal symmetry involves two conformal weight like integers and these correspond to the conformal weight assignable to the radial light-like coordinate appearing in the role of complex coordiante in super-symplectic Hamiltonians and to the spinorial conformal weight assignable to the solutions of Kähler Dirac equation localized to string world sheets. These conformal weights are independent quantum numbers unless one can use the light-like radial coordinate as string coordinate, which is certainly not possible always. The latter conformal weight should correspond to the stringy contribution to the masses of elementary particles and hadron like states. In fact, it is difficult to distinguish between elementary particles and hadrons at the fundamental level since both involve the stringy aspect.

The Yangian symmetry variant of conformal symmetry is highly suggestive and brings in poly-locality with respect to partonic 2-surfaces. This integer would count the number of partonic 2-surfaces to which the generator acts and need not correspond to spinorial conformal weight as one might think first. In any case, Yangian variant of p-adic termodynamics provides an attractive approach concerning the mathematical realization of this vision.

3.5 Weak Regge Trajectories

The weak form of electric-magnetic duality suggests strongly the existence of weak Regge trajectories.

1. The most general mass squared formula with spin-orbit interaction term $M^2_{L-S}L\cdot S$ reads as

$$M^2 = nM_1^2 + M_0^2 + M^2_{L-S}L\cdot S \ , \quad n = 0,2,4 \text{ or } n = 1,3,5,..., \ . \tag{3.1}$$

M_1^2 corresponds to string tension and M_0^2 corresponds to the thermodynamical mass squared and possible other contributions. For a given trajectory even (odd) values of n have same parity and can correspond to excitations of same ground state. From ancient books written about hadronic string model one vaguely recalls that one can have several trajectories (satellites) and if one has something called exchange degeneracy, the even and odd trajectories define single line in M^2-J plane. As already noticed TGD variant of Higgs mechanism combines together $n=0$ states and $n=1$ states to form massive gauge bosons so that the trajectories are not independent.

2. For fermions, possible Higgs, and pseudo-scalar Higgs and their super partners also p-adic thermodynamical contributions are present. M_0^2 must be non-vanishing also for gauge bosons and be equal to the mass squared for the $n=L=1$ spin singlet. By applying the formula to $h=\pm 1$ states one obtains

$$M_0^2 = M^2(boson) \ . \tag{3.2}$$

The mass squared for transversal polarizations with $(h,n,L) = (\pm 1, n=L=0, S=1)$ should be same as for the longitudinal polarization with $(h=0, n=L=1, S=1, J=0)$ state. This gives

$$M_1^2 + M_0^2 + M^2_{L-S}L\cdot S = M_0^2 \ . \tag{3.3}$$

From $L\cdot S = [J(J+1) - L(L+1) - S(S+1)]/2 = -2$ for $J=0, L=S=1$ one has

$$M^2_{L-S} = -\frac{M_1^2}{2} \ . \quad (3.4)$$

Only the value of weak string tension M_1^2 remains open.

3. If one applies this formula to arbitrary $n = L$ one obtains total spins $J = L + 1$ and $L - 1$ from the tensor product. For $J = L - 1$ one obtains

$$M^2 = (2n + 1)M_1^2 + M_0^2 \ .$$

For $J = L + 1$ only M_0^2 contribution remains so that one would have infinite degeneracy of the lightest states. Therefore stringy mass formula must contain a non-linear term making Regge trajectory curved. The simplest possible generalization which does not affect n=0 and n=1 states is of from

$$M^2 = n(n-1)M_2^2 + (n - \frac{L \cdot S}{2})M_1^2 + M_0^2 \ . \quad (3.5)$$

The challenge is to understand the ratio of W and Z^0 masses, which is purely group theoretic and provides a strong support for the massivation by Higgs mechanism.

1. The above formula and empirical facts require

$$\frac{M_0^2(W)}{M_0^2(Z)} = \frac{M^2(W)}{M^2(Z)} = cos^2(\theta_W) \ . \quad (3.6)$$

in excellent approximation. Since this parameter measures the interaction energy of the fermion and anti-fermion decomposing the gauge boson depending on the net quantum numbers of the pair, it would look very natural that one would have

$$M_0^2(W) = g_W^2 M^2_{SU(2)} \ , \ M_0^2(Z) = g_Z^2 M^2_{SU(2)} \ . \quad (3.7)$$

Here $M^2_{SU(2)}$ would be the fundamental mass squared parameter for $SU(2)$ gauge bosons. p-Adic thermodynamics of course gives additional contribution which is vanishing or very small for gauge bosons.

2. The required mass ratio would result in an excellent approximation if one assumes that the mass scales associated with $SU(2)$ and $U(1)$ factors suffer a mixing completely analogous to the mixing of $U(1)$ gauge boson and neutral $SU(2)$ gauge boson W_3 leading to γ and Z^0. Also Higgs, which consists of $SU(2)$ triplet and singlet in TGD Universe, would very naturally suffer similar mixing. Hence $M_0(B)$ for gauge boson B would be analogous to the vacuum expectation of corresponding mixed Higgs component. More precisely, one would have

$$\begin{aligned} M_0(W) &= M_{SU(2)} \ , \\ M_0(Z) &= cos(\theta_W)M_{SU(2)} + sin(\theta_W)M_{U(1)} \ , \\ M_0(\gamma) &= -sin(\theta_W)M_{SU(2)} + cos(\theta_W)M_{U(1)} \ . \end{aligned} \quad (3.8)$$

The condition that photon mass is very small and corresponds to IR cutoff mass scale gives $M_0(\gamma) = \epsilon cos(\theta_W)M_{SU(2)}$, where ϵ is very small number, and implies

$$\begin{aligned} \frac{M_{U(1)}}{M(W)} &= tan(\theta_W) + \epsilon \ , \\ \frac{M(\gamma)}{M(W)} &= \epsilon \times cos(\theta_W) \ , \\ \frac{M(Z)}{M(W)} &= \frac{1 + \epsilon \times sin(\theta_W) cos(\theta_W)}{cos(\theta_W)} \ . \end{aligned} \tag{3.9}$$

There is a small deviation from the prediction of the standard model for W/Z mass ratio but by the smallness of photon mass the deviation is so small that there is no hope of measuring it. One can of course keep mind open for $\epsilon = 0$. The formulas allow also an interpretation in terms of Higgs vacuum expectations as it must. The vacuum expectation would most naturally correspond to interaction energy between the massless fermion and anti-fermion with opposite 3-momenta at the throats of the wormhole contact and the challenge is to show that the proposed formulas characterize this interaction energy. Since CP_2 geometry codes for standard model symmetries and their breaking, it woul not be surprising if this would happen. One cannot exclude the possibility that p-adic thermodynamics contributes to $M_0^2(boson)$. For instance, ϵ might characterize the p-adic thermal mass of photon.

If the mixing applies to the entire Regge trajectories, the above formulas would apply also to weak string tensions, and also photons would belong to Regge trajectories containing high spin excitations.

3. What one can one say about the value of the weak string tension M_1^2? The naive order of magnitude estimate is $M_1^2 \simeq m_W^2 \simeq 10^4$ GeV^2 is by a factor 1/25 smaller than the direct scaling up of the hadronic string tension about 1 GeV^2 scaled up by a factor 2^{18}. The above argument however allows also the identification as the scaled up variant of hadronic string tension in which case the higher states at weak Regge trajectories would not be easy to discover since the mass scale defined by string tension would be 512 GeV to be compared with the recent beam energy 7 TeV. Weak string tension need of course not be equal to the scaled up hadronic string tension. Weak string tension - unlike its hadronic counterpart- could also depend on the electromagnetic charge and other characteristics of the particle.

3.6 Low Mass Exotic Mesonic Structures As Evidence For Dark Scaled Down Variants Of Weak Bosons?

During last years reports about low mass exotic mesonic structures have appeared. It is interesting to combine these bits of data with the recent view about TGD analog of Higgs mechanism and find whether new predictions become possible. The basic idea is to derive understanding of the low mass exotic structures from LHC data by scaling and understanding of LHC data from data about mesonic structures by scaling back.

1. The article *Search for low-mass exotic mesonic structures: II. attempts to understand the experimental results* by Taticheff and Tomasi-Gustafsson (see `http://tinyurl.com/ybq323yy`) [C7] mentions evidence for exotic mesonic structures. The motivation came from the observation of a narrow range of dimuon masses in $\Sigma^+ \to pP^0$, $P^0 \to \mu^-\mu^+$ in the decays of P^0 with mass of $214.3 \pm .5$ MeV: muon mass is 105.7 MeV giving $2m_\mu = 211.4$ MeV. Mesonlike exotic states with masses $M = 62, 80, 100, 181, 198, 215, 227.5$, and 235 MeV are reported. This fine structure of states with mass difference 20-40 MeV between nearby states is reported for also for some baryons.

2. The preprint *Observation of the E(38) boson* by Kh.U. Abraamyan et al (see `http://tinyurl.com/y7zer8dw`) [C1, C2, C4] reports the observation of what they call E(38) boson decaying to gamma pair observed in d(2.0 GeV/n)+C,d(3.0 GeV/n)+Cu and p(4.6 GeV)+C reactions in experiments carried in JINR Nuclotron.

If these results can be replicated they mean a revolution in nuclear and hadron physics. What strongly suggests itself is a fine structure for ordinary hadron states in much smaller energy scale than characterizing hadronic states. Unfortunately the main stream, in particular the theoreticians interested in beyond standard model physics, regard the physics of strong interactions and weak interactions as closed chapters of physics, and are not interested on results obtained in nuclear collisions.

In TGD framework situation is different. The basic characteristic of TGD Universe is fractality. This predicts new physics in all scales although standard model symmetries are fundamental unlike in GUTs and are reduced to number theory. p-Adic length scale hypothesis characterizes the fractality.

1. In TGD Universe p-adic length scale hypothesis predicts the possibility of scaled versions of both strong and weak interactions. The basic objection against new light bosons is that the decay widths of weak bosons do not allow them. A possible manner to circumvent the objection is that the new light states correspond to dark matter in the sense that the value of Planck constant is not the standard one but its integer multiple [K3].

   The assumption that only particles with the same value of Planck constant can appear in the vertex, would explain why weak bosons do not decay directly to light dark particles. One must however allow the transformation of gauge bosons to their dark counterparts. The 2-particle vertex is characterized by a coupling having dimensions of mass squared in the case of bosons, and p-adic length scale hypothesis suggests that the primary p-adic mass scale characterizes the parameter (the secondary p-adic mass scale is lower by factor $1/\sqrt{p}$ and would give extremely small transformation rate).

2. Ordinary strong interactions correspond to Mersenne prime M_n, $n = 2^{107}-1$, in the sense that hadronic space-time sheets correspond to this p-adic prime. Light quarks correspond to space-time sheets identifiable as color magnetic flux tubes, which are much larger than hadron itself. M_{89} hadron physics has hadronic mass scale 512 times higher than ordinary hadron physics and should be observed at LHC. There exist some pieces of evidence for the mesons of this hadron physics but masked by the Higgsteria. The expectation is that Minkowskian M_{89} pion has mass around 140 GeV assigned to CDF bump (see `http://tinyurl.com/yc98cau6`) [C3].

3. In the leptonic sector there is evidence for lepto-hadron physics for all charged leptons labelled by Mersenne primes M_{127}, $M_{G,113}$ (Gaussian Mersenne), and M_{107} [K10]. One can ask whether the above mentioned resonance P^0 decaying to $\mu^-\mu^+$ pair motivating the work described in [C7] could correspond to pion of muon-hadron physics consisting of a pair of color octet excitations of muon. Its production would presumably take place via production of virtual gluon pair decaying to a pair of color octet muons.

Returning to the observations of [C7]: the reported meson-like exotic states seem to be arranged along Regge trajectories but with string tension lower than that for the ordinary Regge trajectories with string tension $T = .9$ GeV^2. String tension increases slowly with mass of meson like state and has three values $T/GeV^2 \in \{1/390, 1/149.7, 1/32.5\}$ in the piecewise linear fit discussed in the article. The TGD inspired proposal is that IR Regge trajectories assignable to the color magnetic flux tubes accompanying quarks are in question. For instance, in hadrons u and d quarks - understood as constituent quarks - would have $k = 113$ quarks and string tension would be by naive scaling by a factor $2^{107-113} = 1/64$ lower: as a matter of fact, the largest value of the string tension is twice this value. For current quark with mass scale around 5 MeV the string tension would be by a factor of order $2^{107-121} = 2^{-16}$ lower.

Clearly, a lot of new physics is predicted and it begins to look that fractality - one of the key predictions of TGD - might be realized both in the sense of hierarchy of Planck constants (scaled variants with same mass) and p-adic length scale hypothesis (scaled variants with varying masses). Both hierarchies would represent dark matter if one assumes that the values of Planck constant and p-adic length scale are same in given vertex. The testing of predictions is not however expected to be easy since one must understand how ordinary matter transforms to dark matter and vice versa. Consider only the fact, that only recently the exotic meson like states have been observed and modern nuclear physics regarded often as more or less trivial low energy phenomenology was born born about 80 years ago when Chadwick discovered neutron.

3.7 Cautious Conclusions

The discussion of TGD counterpart of Higgs mechanism gives support for the following general picture.

1. p-Adic thermodynamics for wormhole contacts contributes to the masses of all particles including photon and gluons: in these cases the contributions are however small. For fermions they dominate. For weak bosons the contribution from string tension of string connecting wormhole contacts as the correct group theoretical prediction for the W/Z mass ratio demonstrates. The mere spin 1 character for gauge bosons implies that they are massive in 4-D sense unless massless fermion and anti-fermion have opposite signs of energy. Higgs provides the longitudinal components of weak bosons by gauge invariance and CP_2 geometry defines unitary gauge so that Higgs vacuum expectation value is not needed. The non-existence of covariantly constant CP_2 vector field does not mean absence of Higgs like particle as believed first but only the impossibility of Higgs vacuum expectation value.

   The usual space-time SUSY associated with imbedding space in TGD framework is not needed, and there are strong arguments suggesting that it is not present [?] For space-time regarded as 4-surfaces one obtains 2-D super-conformal invariance for fermions localized at 2-surfaces and for right-handed neutrino it extends to 4-D superconformal symmetry generalizing ordinary SUSY to infinite-D symmetry.

2. The basic predictions to LHC are following. M_{89} hadron physics, whose pion was first proposed to be identifiable as Higgs like particle, will be discovered. The findings from RHIC and LHC concerning collisions of heavy ions and protons and heavy ions already provide support for the existence of string like objects identifiable as mesons of M_{89} physics. Fermi satellite has produced evidence for a particle with mass around 140 GeV and this particle could correspond to the pion of M_{89} physics. This particle should be observed also at LHC and CDF reported already earlier evidence for it. There has been also indications for other mesons of M_{89} physics from LHC discussed in [K6].

3. Fermion and boson massivation by Higgs mechanism could emerge unavoidably as a theoretical artefact if one requires the existence of QFT limit leading unavoidably to a description in terms of Higgs mechanism. In the real microscopic theory p-adic thermodynamics for wormhole contacts and strings connecting them would describe fermion massivation, and might describe even boson massivation in terms of long parts of flux tubes. Situation remains open in this respect. Therefore the observation of decays of Higgs at expected rate to fermion pairs cannot kill TGD based vision.

The new view about Higgs combined with the stringy vision about twistor Grassmannian [K9] allows to see several conjectures related to ZEO in new light and also throw away some conjectures such as the idea about restriction of virtual momenta to plane $M^2 \subset M^4$.

1. The basic conjecture related to the perturbation theory is that wormhole throats are massless on mass shell states in imbedding space sense: this would hold true also for virtual particles and brings in mind what happens in twistor program. The recent progress [K12] in the construction of n-point functions leads to explicit general formulas for them expressing them in terms of a functional integral over four-surfaces. The deformation of the space-time surface fixes the deformation of basis for induced spinor fields and one obtains a perturbation theory in which correlation functions for imbedding space coordinates and fermionic propagator defined by the inverse of the Kähler-Dirac operator appear as building bricks and the electroweak gauge coupling of the Kähler-Dirac operator define the basic vertex. This operator is indeed 2-D for all other fermions than right-handed neutrino.

2. The functional integral gives some expressions for amplitudes which resemble twistor amplitudes in the sense that the vertices define polygons and external fermions are massless although gauge bosons as their bound states are massive. This suggests a stringy generalization of twistor Grassmannian approach [K9]. The residue integral would replace 4-D integrations of virtual fermion momenta to integrals over massless momenta. The outcome would be non-vanishing for non-physical helicities of virtual fermion. Also the problem due to

the fact that fermionic Super Virasoro generator carries fermion number in TGD framework disappears.

3. There are two conformal weights involved. The conformal weight associated with the light-like radial coordinate of $\delta M^4_\pm$ and the spinorial conformal weight associated with the fermionic string connecting wormhole throats and throats of wormhole contact. Are these conformal weights independent or not? For instance, could one use radial light-like coordinate as string coordinate in the generic situation so that the conformal weights would not define independent quantum numbers? This does not look feasible. The Yangian variant of conformal algebra [A1] [B3, B1, B2] involves two integers. Second integer would naturally be the number of partonic 2-surfaces acted by the generator characterizing the poly-locality of Yangian generators, and it is not clear whether it has anything to do with the spinorial conformal weight. One can of course consider also three integers! This would be in accordance with the idea that the basic objects are 3-dimensional.

   If the conjecture that Yangian invariance realized in terms of Grassmannians makes sense, it could allow to deduce the outcome of the functional integral over four-surfaces and one could hope that TGD can be transformed to a calculable theory. Also p-adic mass calculations should be formulated using p-adic thermodynamics assuming Yangian invariance and enlargened conformal algebra.

4 Two Options For Higgs Like States In TGD Framework

HCP2012 (see http://tinyurl.com/btudusw) conference (Hadron Collider Physics Symposium) at Kyoto will provide new data about Higgs candidate at next Wednesday. Resonaances (see http://tinyurl.com/ybzdxxcy) has summarized the basic problem related to the interpretation as standard model Higgs: two high yield of gamma pairs and too low yield of $\tau\overline{\tau}$ and and $b\overline{b}$ pairs. It is of course possible that higher statistics changes the situation.

4.1 Two Options Concerning The Interpretation Of Higgs Like Particle In TGD Framework

Theoretically the situation quite intricate. The basic starting point is that the original p-adic mass calculations provided excellent predictions for fermion masses. For the gauge bosons the situation was different: a natural prediction for the W/Z mass ratio in terms of Weinberg angle is the fundamental prediction of Higgs mechanism and this prediction did not follow automatically from the p-adic mass calculation in the original form. Classical Higgs field does not seem to have any natural counterpart in the geometry of space-time surface (the trace of the second fundamental form does not work since it vanishes for preferred extremals which are also minimal surfaces). This raised the question whether there is any Higgs boson in TGD Universe and for some time I took seriously the interpretation of the Higgs like state observed by LHC as a pion of M_{89}. To sum up, the evolution of ideas about TGD counterpart of Higgs mechanism (see http://tinyurl.com/yb8u9pbp) has been full of twists and turns. This summary is warmly recommended for a seriously interested reader.

p-Adic mass calculations and the results from LHC leave two options under consideration.

1. Option I: Only fermions get the dominating contribution to their masses from p-adic thermodynamics and in the case of gauge bosons the dominating contribution is due to the standard Higgs mechanism. p-Adic thermodynamics would contribute also to the boson masses, in particular photon mass but the contribution would be extremely small and correspond to p-adic temperature $T = 1/n$, $n > 2$. For this option only gauge bosons would have standard model couplings to Higgs whereas fermionic couplings could be small. Of course, standard model couplings proportional to fermion mass are also possible. One can criticize this option because fermions and bosons are in an asymmetric position. The beautiful feature is that one could get rid of the hierarchy problem due to the couplings of Higgs to heavy fermions.

   This option is excluded by the recent data about Higgs candidate demonstrating that it behaves in the predicted manner.

2. Option II: p-Adic mass calculations explain also the masses of gauge bosons and Higgs like particle. If Higgs like state develops a coherent state describable in terms of vacuum expectation value as M^4 QFT limit, this expectation value is determined by the mass spectrum determine by the p-adic mass calculations. The mass spectrum of particles determines Higgs expectation and the couplings of Higgs rather than vice versa! For this option Weinberg angle would be *defined* by the ratio of W and Z boson mass as $cos^2(\theta_W) = m_W^2/m_Z^2$ and these masses should be given by p-adic mass calculations. The fact that Higgs vacuum expectation has no space-time counterpart as covariantly constant CP_2 vector field supports the absence of Higgs mechanism but allows Higgs like field providing longitudinal polarizations of weak bosons.

   The recent view about particles as Kähler magnetic loops carrying monopole flux is forced by the assumption that the corresponding partonic 2-surfaces are Kähler magnetic monopoles (implied by the weak form of electric-magnetic duality). The loop proceeds from wormhole throat to another one, then traverses along wormhole contact to another space-time sheet and returns back and eventually is transferred to the first sheet via wormhole contact. The mass squared assignable to this flux loop could give the contribution usually assigned to Higgs vacuum expectation. If this picture is correct, then the reduction of the W/Z mass ratio to Weinberg angle might be much easier to understand. As a matter fact, I have proposed that the flux loop gives rise to a stringy spectrum of states with string tension determined by p-adic length scale associated with M_{89}.

   This option is attractive because fermions and bosons are in an exactly same position. Hierarchy problem is possible problem of this approach: note however that the considerations in the sequel imply that standard model action is predicted to be an effective action giving only tree diagrams so that there are no radiative corrections at M^4 QFT limit.

The original interpretation of Higgs like state was oas M_{89} pion. The recent observations from Fermi telescope (see http://tinyurl.com/hpeq4q3) suggest the existence of a boson with mass 135 GeV. It would be a good candidate for M_{89} pion. One can test the hypothesis by scaling the mass of ordinary neutral pion, which corresponds to M_{107}. The scaling gives mass 69.11 GeV. p-Adic length scale however allows also octaves of the minimum mass (they appear for lepto-pions) and scaling by two gives mass equal to 138.22 GeV not too far from 135 GeV.

There is also second encouraging numerical co-incidence. It is probably not an accident that Higgs vacuum expectation value corresponds to the minimum mass for $p = M_{89}$ if the p-adic counterpart of Higgs expectation squared is of order $O(p)$ in other words one has $\mu^2/m_{CP_2}^2 = p = M_{89}$.

My sincere hope is that the results of HCP2012 would allow to distinguish between these two options.

4.2 Microscopic Description Of Gauge Bosons And Higgs Like And Meson Like States

Under the pressures from LHC it has become gradually clear that the understanding of whether TGD has M^4 QFT limit or not, and how this limit can be defined, is essential for the understanding also the role of Higgs. This is basically an exercise in conceptual hygiene: one must make clear what is QFT and what is TGD. In the following a first attempt to understand this limit is made. I find it somewhat surprising that I am making this attempt only now but the understanding of the proper role of the classical gauge potentials has been quite a challenge.

1. By bosonic emergence also gauge bosons correspond at microscopic level to fermion and anti-fermion at opposite throats of wormhole contacts. Meson like states in turn correspond to fermion and anti-fermion at the ends of a flux tube connecting throats of two different wormhole contacts so that both Higgs, gauge bosons, and meson-like states are obtained using similar construction recipe.

2. The popular statement "gauge bosons eat almost all Higgs components" makes sense at the M^4 QFT limit and also in TGD proper: by gauge invariance just the transition to the unitary gauge fixed uniquely by CP_2 geometry effectively eliminates all but one of the components

of the Higgs like state and gauge bosons get the third polarization. Massivation could take place by p-adic thermodynamics extended so that it describes also gauge boson massivation by taking into account the stringy contributions to the mass. This favors option II.

3. If one believes that M^4 QFT is a good approximation to TGD at low energy limit then the standard description of Higgs mechanism seems to be the only possibility: this just on purely mathematical grounds. The interpretation would however be that the masses of the particles determine Higgs vacuum expectation value and Higgs couplings rather than vice versa. This would of course be nothing unheard in the history of physics: the emergence of a microscopic theory - in the recent case p-adic thermodynamics - would force to change the direction of the causal arrow in "Higgs makes particles massive" to that in "Higgs expectation is determined by particle masses". In particular, fermionic couplings would be gradient couplings and dimensional coupling constant would be same for all fermions: a good news for a friend of "naturalness".

4. The existence of M^4 QFT limit is an intricate issue. In TGD Universe baryon and lepton number correspond to different chiralities of $H = M^4 \times CP_2$ spinors, and this means that Higgs like state cannot be H scalar (it would be lepto-quark in this case). Rather, Higgs like state must be a vector in CP_2 tangent space degrees of freedom. The decomposition of Higgs like state to fermion antifermion pairs suggests the $2+\overline{2}$ decomposition of CP_2 tangent vector representing Higgs under $SU(2)_L$. Complex structure of CP_2 would be essential and stanard CP_2 complex coordinates would be analogous to Higgs in group theoretical sense.

   Higgs like $M4$ scalar carries fermion and anti-fermion at opposite throat of the wormhole contact. In QFT context is easy to imagine that a coherent state having Higgs expectation as M^4 QFT correlate is formed. What coherent statesfor wormholeo contacts means is not at all clear. Most importantly, one cannot however have a covariantly constant vector field transforming like CP_2 coordinates so that Higgs vacuum expectation does not make sense at the fundamental level. The coherent state could be a formal description for the underlying stringy contribution to gauge boson masses.

4.3 Trying To Understand The QFT Limit Of TGD

The counterparts of gauge potentials and Higgs field are not needed in the microscopic description if p-adic thermodynamics gives the masses so that the gauge potentials and Higgs field should emerge only at M^4 QFT limit. It is not even necessary to speak about Higgs and YM parts of the action at the microscopic level. The functional integral defined by the vacuum function expressed as exponent of Kähler action for preferred extremals to which couplings of microscopic expressions of particles in terms of fermions coupled to the effective fields describing them at QFT limit should define the effective action at QFT limit.

The basic recipe is simple.

1. Start from the vacuum functional which is exponent of Kähler action for preferred extremals with Euclidian regions giving real exponent and Minkowskian regions imaginary exponent.

2. Add to this action terms which are bilinear in the microscopic expression for the particle state and the corresponding effective field appearing in the effective action.

3. Perform the functional integration over WCW ("world of classical worlds")and take vacuum expectation value in fermionic degrees of freedom.

4. This gives an effective field theory in $M^4 \times CP_2$. To get M^4 QFT integrate over CP_2 degrees of freedom in the action. This dimensional reduction is similar to that occurring in Kaluza-Klein theories.

The functional integration of WCW induces also integration of induced spinor fields which apart from right-handed neutrino are restricted to the string world sheets. In principle induced spinor fields could be non-vanishing also at partonic 2-surfaces but simple physical considerations suggest that they are restricted to the intersection points of partonic 2-surfaces and string world sheets defining the ends of braid strands. Therefore the effective spinor fields Ψ_{eff} would appear only at braid ends in the integration over WCW and one has good hopes of performing the functional integral.

1. One can assign to the induced spinor fields Ψ imbedding space spinor fields Ψ_{eff} appearing in the effective action. The dimensions of Ψ and Ψ_{eff} are $1/L^{3/2}$. A dimensionally correct guess is the term $\int d^2x\sqrt{g_2}\overline{\Psi_{eff}}(P)D^{-1}\Psi + h.c$, where Γ^α denotes the induced gamma matrices, P denotes the end point of a braid strand at the wormhole throat, and D denotes the "ordinary" massless Dirac operator $\Gamma^\alpha D_\alpha$ for the induced gamma matrices. Propagator contributes dimension L and is well-defined since Ψ is not annihilated by D but by the Kähler-Dirac operator in which Kähler-Dirac gamma matrices defined by the Kähler-Dirac action appear. Note that internal consistency does not allow the replacement of Kähler action with four-volume. Integral over the second wormhole throat contributes dimension L^2. Therefore the outcome is a dimensionless finite quantity, which reduces to the value of integrand at the intersection of partonic 2-surface and string world sheet - that is at ends of braid strand since induced spinors are localized at string world sheets unless right-handed neutrinos are in question. The fact that induced spinor fields are proportional to a delta function restricting them to string world sheets does not lead to problems since the Kähler-Dirac action itself vanishes by modified Dirac equation.

2. Both Higgs and gauge bosons correspond to bi-local objects consisting of fermion and anti-fermion at opposite throats of wormhole contact and restricted to braid ends. The are connected by the analog of non-integrable phase factor defined by classical gauge potentials. These bilinear fermionic objects should correspond to Higgs and gauge potentials at QFT limit. The two integrations over the partonic 2-surfaces contribute L^2 both, whereas the dimension of the quantity defining the gauge boson or Higgs like state is $1/L^3$ from the dimensions of spinor fields and from the dimension of generalized polarization vector compensated by that of gamma matrices. Hence the dimensions of the bi-local quantities are L for both gauge bosons and Higgs like particles. They must be coupled to their effective QFT counterparts so that a dimensionless term in action results. Note that delta functions associated with the induced spinor fields reduce them to the end points of braid strand connecting wormhole throats and finite result is obtained.

3. How to identify these dimensional bilinear terms defining the QFT limit? The basic problem is that the microscopic representation of the particle is bi-local and the effective field at QFT limit should be local. The only possibility is to consider an average of the effective field over the stringy curve connecting the points at two throats. The resulting quantities must have dimensions $1/L$ in accordance with naive scaling dimensions of gauge bosons and Higgs to compensate the dimension L of the microscopic representation of bosons. For gauge bosons having zero dimension as 1-forms the average $\int A_\mu dx^\mu/l$ along a unique stringy curve of length l connecting wormhole throats defines a quantity with dimension $1/L$. For Higgs components having dimension $1/L$ the quantities $\int H_A\sqrt{g_1}dx/l$, where g_1 corresponds to the induced metric at the stringy curve, has also dimension $1/L$. The presence of the induced metric depending on CP_2 metric guarantees that the effective action contains dimensional parameters so that the breaking of scale invariance results.

To sum up, for option II the parameters for the counterpart of Higgs action emerging at QFT limit must be determined by the p-adic mass calculations in TGD framework and the flux tube structure of particles would in the case of gauge bosons should give the standard contribution to gauge boson masses. For option I fermionic masses would emerge as mass parameters of the effective action. The presence of Euclidian regions of space-time having interpretation as lines of generalized Feynman diagrams is absolutely crucial in making possible Higgs like states. One must however emphasize that at this stage both option I and II must be considered.

4.4 To Deeper Waters

Higgs issue seems to divide theoreticians to two classes: the simple-minded pragmatists and real thinkers.

For pragmatists the existence of Higgs and Higgs mechanism is something absolute: Higgs exists of not and one can make a bet about it. Most bloggers and most phenomenologists applying numerical models belong to this group. In particular, bloggers have had heated discussions and have made bets proandco, mostly pro.

Thinkers see the situation in a wider perspective. The real issue is the status of quantum field theory as a description of fundamental forces. Is QFT something fundamental or is it only a low energy limit of a more fundamental microscopic theory? Could it even happen that QFT limit fails in some respects and could the description of particle massivation represent such an aspect?

Already string models taught (or at least should have taught) to see quantum field theory as an effective description of a microscopic theory working at low energy limit. Since string theorists have not been able cook up any convincing answer to the layman's innocent question "How would you describe atom using these tiny strings which are so awe inspiring?", QFT limits have become what string models actually are at the phenomenological level. AdS-CFT correspondence actually equates string theory with a conformal quantum field theory in Minkowski space so that hopes about genuine microscopic theory are lost. This is disappointing but not surprising since strings are still too simple: they are either open or closed, there is no interesting internal topology.

In TGD framework string world sheets are replaced with 4-D space-time surfaces. One ends up with a very concrete vision about matter based on the notion of many-sheeted space-time and the implications are highly non-trivial in all scales. For instance, blackhole interior is replaced with a space-time region with Euclidian signature of the induced metric characterizing any physical system be it elementary particle, condensed matter system, or astrophysical object. Therefore the key question becomes the following. Does TGD have QFT in M^4 as low energy limit or rather - as a limit holding true in a given scale in the infinite length scale hierarchies predicted by theory (p-adic length scale hierarchy and hierarchy of effective Planck constants and hierarchy of causal diamonds)?

4.4.1 Deeper question: Does QFT limit of the fundamental theory exist?

Could the QFT limit defined as QFT in M^4 fail to exist? After this question one cannot avoid questions about the character of Higgs and Higgs mechanism.

1. It is quite possible that in QFT framework Higgs mechanism is the only description of particle massivation. But this is just a mimicry, not a predictive description. QFT limit can only reproduce the spectrum of elementary particles masses or rather - mass ratios. The ratio of Planck mass (also an ad hoc concept) to proton mass remains a complete mystery.

   This failure has been convincingly demonstrated by a huge amount of work in particle phenomenology. First came the GUT theorists. They applied every imaginable gauge group with elementary particles put in all imaginable group representations to reproduce the known part of the particle spectrum. They have reproduced standard model gauge symmetries at low energy limit. They have also done the necessary fine-tuning to make proton long-lived enough, to give large enough masses for the exotics, and to make beta functions sensical.

   The same procedures have been repeated in SUSY framework and finally super string phenomenology has produced QFT limits with Higgs mechanism, and are now doing intense fine tuning to save poor SUSY from the aggressive attacks by LHC. During these 40 years of busy modelling practically nothing has been achieved but the work goes on since theoreticians have their methods and they must produce highly technical papers to preserve the illusion of hard science.

2. Higgs mechanism is also plagued by profound problems. The hierarchy problem means that the Higgs mechanism with mass of about 125 GeV is just at the border of stability. The problem is that the sign of mass squared term in Higgs potential can change by radiative corrections so that the vacuum with a vanishing Higgs expectation value becomes stable. SUSY was hoped to solve the hierarchy problem but LHC has made SUSY in standard sense implausible. Even if it exists cannot help in this issue. Another problem is that the coefficients of the fourth power in the Higgs potential can become negative so that vacuum becomes unstable: the bottom of a valley becomes top of a hill. The value of

Higgs mass is such that also this seems to happen! (see the posting of Resonaances (see `http://tinyurl.com/ycgmjrbc`)).

Quite generally, fine tuning problems are the characteristic issues of the QFT limit. Proton must be long-lived enough, baryon and lepton number violating decay rates cannot be too high, the predicted exotic particles implied by the extension of the standard model gauge group must be massive enough, and so on... This requires a lot of fine tuning. Theory has transformed from a healer to a patient: the efforts of theoreticians reduce to attempts to resuscitate the patient. All this becomes understandable as one realizes that QFT is just a mimicry, not the fundamental theory.

One could also see these two problems of the Higgs mechanism as the last attempt of the frustrated Nature to signal to the busy mainstream career builders something very profound about reality by using paradox as its last means. From TGD vantage point the intended message of Nature looks quite obvious.

4.4.2 Shut up and calculate

The problem in the recent theoretical physics is that thinking has not been allowed for more than half century. Thinking is seen as "philosophy" - something very very bad. The fathers of quantum theory were philosophers: they realized the deep problems of quantum measurement theory and considered possible conclusions for the world view. For instance, Bohr - whose view became orthodoxy - concluded that objective reality cannot exist at all and that quantum theory is just a collection of calculational recipes with Ψ having no real existence. Einstein had totally different view. He believed that quantum theory is somehow fundamentally wrong.

Neither of them was yet mature to see that the problem involves the conscious observer in a very intimate manner: in particular, how the subjective time and the geometric time of physicist - certainly not one and the same thing - relate to each other. Both were also unable to see that objective reality could be replaced by objective realities identified as "solutions of field equations" and that quantum jumps would take between them and give rise to conscious experience. This would resolve both the problem of time and the basic problem of quantum measurement theory.

Later theoreticians followed the advice which has been put to the mouth of Feynman, and decided to just shut up and calculate. This long silence has lasted more than half a century now. I belong to those few who refused to follow the advice with the consequence that the decision makers of Helsinki University gave me officially a label of a madman and besides intensive blackmailing did their best to prevent any support for my work motivated by a warning of young readers about the dangers of reading my blog - sent by presumably finnish physics authority calling himself Anonymous).

LHC has now demonstrated how catastrophic consequences can be when the profession of the theoretician reduces to mindless calculation. We have got lost generations of theoreticians who continue to fill hep-th and hep-ph with preprints with a minimal connection to physical reality and mostly trying to solve the problems created by the theory itself rather than those provided by physics. This is however what they are able to do: collective silence has lasted too long. Even string model gurus have lost their beliefs on The Only Possible Theory of Everything. Some of them have suffered a regression to surprisingly childish models of gravitation (entropic gravity). Some have begun to see everything as black-holes without realizing that blackholes as a mathematical failure of general relativity should have been the starting point rather than the end. Some are making bets and having learned debates about paradoxes related to blackholes (firewall paradox is the latest newcomer.

4.4.3 Or could thinking be a rewarding activity after all?

There are also some theoreticians who have followed their own star and have not been able to resist the temptation to think and imagine. I have used to call my own star TGD. As described in previous posting, p-adic thermodynamics (see `http://tinyurl.com/ybrcyvy4`) can be seen as a- or even *the* - microscopic mechanism of massivation in TGD framework. There are two options to consider. According to Option I p-adic thermodynamics alone explains only fermion masses and the microscopic counterpart of Higgs mechanism would give the dominant contribution to gauge boson masses. For Option II p-adic thermodynamics would produce both gauge boson and Higgs masses and Higgs mechanism could appear at QFT limit as a mere phenomenological description of the massivation.

Option II is the most conservative option and apparently conforms with the standard model view. It also treats all particles in the same position. Note that in standard model Higgs itself like eye which cannot see itself since its tachyonic bare mass is put in by hand. Option II is also aesthetically more satisfactory if one believes that QFT limit of TGD indeed exists. For Option I one should invent new QFT mechanism describing fermion massivation in QFT framework or give up the idea about QFT limit altogether. In fact, experimental findings have selected Option II.

The existence of M^4 QFT limit is not obvious in TGD framework. This is due to a dramatic simplification in the microscopic description of particles. The only fundamental fields are spinors of $H = M^4 \times CP_2$ having just spin and electroweak quantum numbers and conserved carrying quark or lepton number depending on H-chirality. Color emerges and corresponds to color partial waves in H. Also bosons emerge meaning that gauge bosons, Higgs, and graviton have pairs of fermion and anti-fermion at the opposite throats of wormhole contacts as building bricks. Gauge fields, Higgs field, gravitational field and also Higgs mechanism can emerge in this approach only as a phenomenological description at M^4 QFT limit assuming that it exists. Fermionic families emerge from topology and also bosons are expected the analog of family replication phenomenon induced from the fermionic one.

Higgs like bosons might also develop coherent states characterized by the vacuum expectation value of Higgs but already this possibility must be taken critically since coherent states is a QFT based notion and it is not quite clear whether it generalizes to microscopic level. Covariantly constant complex CP_2 vector field should characterize vacuum expectation value. Tht this kind of vector fields do not exist is not an encouraging sign. The microscopic description in terms of string tension seems to be the only natural description of gauge boson massivation.

What is important that Higgs does not make fermions massive. For Option II this is true also for bosons. Rather, the couplings and vacuum expectation of Higgs are such that Higgs can pretend of achieving this feat. Higgs mechanism reproduces: p-adic thermodynamics predicts.

Standard model action is only an effective action providing tree diagrams so that the loop corrections leading to the hierarchy problem are not present unless the counterpart of fatal radiative corrections appear in the effective action which must depend on p-adic length scale (in TGD the discrete p-adic length scale evolution replaces the continuous renormalization group evolution of quantum field theories). Zero energy ontology however dramatically modifies the view about Feynman diagrammatics, and can save the situation since standard SUSY generalizes to super-conformal invariance.

There are of course lot of critical questions to be answered. I have written an entire book (see `http://tinyurl.com/y86lo57g`) motivated by the challenge of understanding why p-adic thermodynamics should be needed in real number based physics. p-Adic physics for single prime is definitely not enough: one must fuse p-adic physics for various primes p and real physics to single coherent whole and this requires a lot of not yet existing mathematics such as generalization of number concept. The connections of p-adic physics to the description of cognition in quantum consciousness theory are also obvious and p-adic space-time sheet would correspond to the "mind stuff" of Descartes. These few examples show how profound and totally unexpected new visions a more philosophical and imaginative attitude to physics generates.

Another book (see `http://tinyurl.com/ybrcyvy4`) is devoted to the physical implications of p-adic physics and of the hierarchy of effective Planck constants, a notion implied by the very special properties of the basic variational principle dictating the space-time dynamics in TGD framework.

4.5 Criticality Of Higgs: Is Planck Length Dogmatics Physically Feasible?

While studying the materials related to Convergence conference (see `http://tinyurl.com/opoa2oh`) running during this week at Perimeter institute I ended up with a problem related to the fact that the mass $M_h = 125.5 \pm .24$ GeV implies that Higgs as described by standard model (now new physics at higher energies) is at the border of metastability and stability - one might say near criticality (see and [C6] (see `http://tinyurl.com/ybyoshdp`) and [C5] (see `http://tinyurl.com/ybtf3py3`), and I decided to look from TGD perspective what is really involved.

Absolute stability would mean that the Higgs potential becomes zero at Planck length scale assumed to be the scale at which QFT description fails: this would require $M_h > 129.4$ GeV somewhat larger that the experimentally determined Higgs mass in standard model framework. Metastability means that a new deep minimum is developed at large energies and the standard model Higgs vacuum does not anymore correspond to a minimum energy configuration and is near to a phase transition to the vacuum with lower vacuum energy. Strangely enough, Higgs is indeed in the metastable region in absence of any new physics.

Since the vacuum expectation of Higgs is large at high energies, the potential is in a reasonable approximation of form $V = \lambda h^4$, where h is the vacuum expectation in the high energy scale considered and λ is dimensionless running coupling parameter. Absolute stability would mean $\lambda = 0$ at Planck scale. This condition cannot however hold true as follows from the input provided by top quark mass and Higgs mass to which λ at LHC energies is highly sensitive. Rather, the value of λ at Planck scale is small and negative: $\lambda(M_{Pl}) = -0.0129$ is the estimate [C6] (`http://tinyurl.com/ybyoshdp`) to be compared with $\lambda(M_t) = 0.12577$ at top quark mass. This implies that the potential defining energy density associated with the vacuum expectation value of Higgs becomes negative at high enough energies.The energy at which λ becomes negative is in the range $10^{10} - 10^{12}$ GeV, which is considerably lower than Planck mass about 10^{19} GeV. This estimate of course assumes that there is no new physics involved.

The plane defined by top and Higgs masses can be decomposed to regions displayed by figure 5 in `http://tinyurl.com/ybyoshdp` in which perturbative approach either fails (λ too large), there is only single minimum of Higgs potential (stability), there is no minimum of Higgs potential ($\lambda \leq 0$, instability), or a new minimum with a smaller energy is present (metastability). This metastability can lead to a transition to a lower energy state and could be relevant in early cosmology and also in future cosmology.

The value of λ turns out to be rather small at Planck mass. λ however vanishes and changes sign in a much lower energy range $10^{10} - 10^{12}$ GeV. Is this a signal that something interesting takes place considerably below Planck scale? Could Planck length dogmatics is wrong? Is criticality only an artefact of standard model physics and as such a signal for a new physics?

How could this relate to TGD? Planck length is one of the unchallenged notions of modern physics but in TGD p-adic mass calculations force to challenge this dogma. Planck length is replaced with CP_2 length scale which is roughly 10^4 longer than Planck length and determined by the condition that electron corresponds to the largest Mersenne prime (M_{127}), which does not define completely super-astrophysical p-adic length scale, and by the condition that electron mass comes out correctly. Also many other elementary particles correspond to Mersenne primes. In biological relevant scales there are several (4) Gaussian Mersennes.

In CP_2 length scale the QFT approximation to quantum TGD must fail since the replacement of the many-sheeted space-time with GRT space-time with Minkowskian signature of the metric fails, and space-time regions with Euclidian signature of the induced metric defining the lines of generalized Feynman diagrams cannot be anymore approximated as lines of ordinary Feynman diagrams or twistor diagrams. From electron mass formula and electron mass of .5 MeV one deduces that CP_2 mass scale is 2.53×10^{15} GeV - roughly three orders of magnitudes above 10^{12} GeV obtained if there is no new physics emerges above TeV scale.

TGD “almost-predicts” several copies of hadron physics corresponding to Mersenne primes M_n, $n = 89, 61, 31, ..$ and these copies of hadron physics are expected to affect the evolution of λ and maybe raise the energy 10^{12} GeV to about 10^{15} GeV. For M_{31} the electronic p-adic mass scale happens to be 2.2×10^{10} GeV. The decoupling of Higgs by the vanishing of λ could be natural at CP_2 scale since the very notion of Higgs vacuum expectation makes sense only at QFT limit becoming non-sensical in CP_2 scale. In fact, the description of physics in terms of elementary particles belonging to three generations might fail above this scale. Standard model quantum numbers make still sense but the notion of family replication becomes questionable since in TGD framework the families correspond to different boundary topologies of wormhole throats and the relevant physics is above this mass scale inside the wormhole contacts: there would be only single fermion generation below CP_2 scale.

This raises questions. Could one interpret the strange criticality of the Higgs as a signal about the fact that CP_2 mass scale is the fundamental mass scale and Newton’s constant might be only a macroscopic parameter. This would add one more nail to the coffin of superstring theory and of all theories relying on Planck length scale dogmatics. One can also wonder whether the criticality might somehow relate to the quantum criticality of TGD Universe. My highly non-educated guess is that it is only an artefact of the standard model description. Note however that below CP_2 scale the transition from the phase dominated by cosmic strings to a phase in which space-time sheets emerge and leading to the radiation dominated cosmology would take place: this period would be the TGD counterpart for the inflationary period and also involve a rapid expansion.

5 Still about induced spinor fields and TGD counterpart for Higgs

The understanding of the modified Dirac equation and of the possible classical counterpart of Higgs field in TGD framework is not completely satisfactory. The emergence of twistor lift of Kähler action [K14] [L2] inspired a fresh approach to the problem and it turned out that a very nice understanding of the situation emerges.

More precise formulation of the Dirac equation for the induced spinor fields is the first challenge. The well-definedness of em charge has turned out to be very powerful guideline in the understanding of the details of fermionic dynamics. Although induced spinor fields have also a part assignable space-time interior, the spinor modes at string world sheets determine the fermionic dynamics in accordance with strong form of holography (SH).

The well-definedness of em charged is guaranteed if induced spinors are associated with 2-D string world sheets with vanishing classical W boson fields. It turned out that an alternative manner to satisfy the condition is to assume that induced spinors at the boundaries of string world sheets are neutrino-like and that these string world sheets carry only classical W fields. Dirac action contains 4-D interior term and 2-D term assignable to string world sheets. Strong form of holography (SH) allows to interpret 4-D spinor modes as continuations of those assignable to string world sheets so that spinors at 2-D string world sheets determine quantum dynamics.

Twistor lift combined with this picture allows to formulate the Dirac action in more detail. Well-definedness of em charge implies that charged particles are associated with string world sheets assignable to the magnetic flux tubes assignable to homologically non-trivial geodesic sphere and neutrinos with those associated with homologically trivial geodesic sphere. This explains why neutrinos are so light and why dark energy density corresponds to neutrino mass scale, and provides also a new insight about color confinement.

A further important result is that the formalism works only for imbedding space dimension $D = 8$. This is due the fact that the number of vector components is the same as the number of spinor components of fixed chirality for $D = 8$ and corresponds directly to the octonionic triality.

p-Adic thermodynamics predicts elementary particle masses in excellent accuracy without Higgs vacuum expectation: the problem is to understand fermionic Higgs couplings. The observation that CP_2 part of the modified gamma matrices gives rise to a term mixing M^4 chiralities contain derivative allows to understand the mass-proportionality of the Higgs-fermion couplings at QFT limit.

5.1 More precise view about modified Dirac equation

Consistency conditions demand that modified Dirac equation with modified gamma matrices Γ^α defined as contractions $\Gamma^\alpha = T^{\alpha k}\gamma_k$ of canonical momentum currents $T^{\alpha k}$ associated with the bosonic action with imbedding space gamma matrices γ_k [K12, K13]. The Dirac operator is not hermitian in the sense that the conjugation for the Dirac equation for Ψ does not give Dirac equation for $\overline{\Psi}$ unless the modified gamma matrices have vanishing covariant divergence as vector at space-time surface. This says that classical field equations are satisfied. This consistency condition holds true also for spinor modes possibly localized at string world sheets to which one can perhaps assign area action plus topological action defined by Kähler magnetic flux. The interpretation is in terms of super-conformal invariance.

The challenge is to formulate this picture more precisely and here I have not achieved a satisfactory formulation. The question has been whether interior spinor field Ψ are present at all, whether only Ψ is present and somehow becomes singular at string world sheets, or whether both stringy spinors Ψ_s and interior spinors Ψ are present. Both Ψ and Ψ_s could be present and Ψ_s could serve as source for interior spinors with the same H-chirality.

The strong form of holography (SH) suggests that interior spinor modes Ψ_n are obtained as continuations of the stringy spinor modes $\Psi_{s,n}$ and one has $\Psi = \Psi_s$ at string world sheets. Dirac action would thus have a term localized at strong world sheets and bosonic action would contain similar term by the requirement of super-conformal symmetry. Can one realize this intuition?

1. Suppose that Dirac action has interior and stringy parts. For the twistor lift of TGD [L2] the interior part with gamma matrices given by the modified gamma matrices associated with the sum of Kähler action and volume action proportional to cosmological constant Λ. The variation with respect to the interior spinor field Ψ gives modified Dirac equation in the interior with source term from the string world sheet. The H-chiralites of Ψ and Psi_s would be same. Quark like and leptonic H-chiralities have different couplings to Kähler gauge potential and mathematical consistency strongly encourages this.

   What is important is that the string world sheet part, which is bilinear in interior and string world sheet spinor fields Ψ and Ψ_s and otherwise has the same form as Dirac action. The natural assumption is that the stringy Dirac action corresponds to the modified gamma matrices assignable to area action.

2. String world sheet must be minimal surface: otherwise hermiticity is lost. This can be achieved either by adding to the Kähler action string world sheet area term. Whatever the correct option is, quantum criticality should determine the value of string tension. The first string model inspired guess is that the string tension is proportional to gravitational constant $1/G = 1/l_P^2$ defining the radius fo M^4 twistor sphere or to $1/R^2$, R CP_2 radius. This would however allow only strings not much longer than l_P or R. A more natural estimate is that string tension is proportional to the cosmological constant Λ and depends on p-adic length scale as $1/p$ so that the tension becomes small in long length scales. Since Λ coupling contant type parameter, this estimate looks rather reasonable.

3. The variation of stringy Dirac action with action density

   $$L = [\overline{\Psi}_s D_s^{\rightarrow}\Psi - \overline{\Psi}_s D_s^{\leftarrow}\Psi]\sqrt{g_2} + h.c. \quad (5.1)$$

   with respect to stringy spinor field Ψ_s gives for Ψ Dirac equation $D_s\Psi = 0$ if there are no Lagrange multiplier terms (see below). The variation in interior gives $D\Psi = S = D_s\Psi_s$, where the source term S is located at string world sheets. Ψ satisfies at string world sheet the analog of 2-D massless Dirac equation associated with the induced metric. This is just what stringy picture suggests.

   The stringy source term for D equals to $D_s\Psi_s$ localized at string world sheets: the construction of solutions would require the construction of propagator for D, and this does not look an attractive idea. For $D_s\Psi_s = 0$ the source term vanishes. Holomorphy for Ψ_s indeed implies $D_s\Psi = 0$.

4. $\Psi_s = \Psi$ would realize SH as a continuation of Ψ_s from string world sheet to Ψ in the interior. Could one introduce Lagrange multiplier term

   $$L_1 = \overline{\Lambda}(\Psi - \Psi_s) + h.c.$$

   to realize $\Psi_s = \Psi$? Lagrange multiplier spinor field Λ would serve a source in the Dirac equation for $\Psi = \Psi_s$ and Ψ should be constructed at string world sheet in terms of stringy fermionic propagator with Λ as source. The solution for Ψ_s would require the construction of 2-D stringy propagator for Ψ_s but in principle this is not a problem since the modes can be solved by holomorphy in hypercomplex stringy coordinate. The problem of this option is that the H-chiralities of Λ and Ψ would be opposite and the coupling of opposite H-chiralities is not in spirit with H-chirality conservation.

   A possible cure is to replace the Lagrange multiplier term with

   $$L_1 = \overline{\Lambda}^k\gamma_k(\Psi - \Psi_s) + h.c. \ . \quad (5.2)$$

The variation with respect to the spin 3/2 field Λ^k would give 8 conditions - just the number of spinor components for given H-chirality - forcing $\Psi = \Psi_s$! $D = 8$ would be in crucial role! In other imbedding space dimensions the number of conditions would be too high or too low.

One would however obtain

$$D_s\Psi = D_s\Psi_s = \Lambda^k\gamma_k \ . \tag{5.3}$$

One could of course solve Ψ at string world sheet from $\Lambda^k\gamma_k$ by constructing the 2-D propagator associated with D_s. Conformal symmetry for the modes however implies $D_s\Psi = 0$ so that one has actually $\Lambda^k = 0$ and Λ^k remains mere formal tool to realize the constraint $\Psi = \Psi_s$ in mathematically rigorous manner for imbedding space dimension $D = 8$. This is a new very powerful argument in favor of TGD.

5. At the string world sheets Ψ would be annihilated both by D and D_s. The simplest possibility is that the actions of D and D_s are proportional to each other at string world sheets. This poses conditions on string world sheets, which might force the CP_2 projection of string world sheet to belong to a geodesic sphere or circle of CP_2. The idea that string world sheets and also 3-D surfaces with special role in TGD could correspond to singular manifolds at which trigonometric functions representing CP_2 coordinates tend to go outside their allowed value range supports this picture. This will be discussed below.

   (a) For the geodesic sphere of type II induced Kähler form vanishes so that the action of 4-D Dirac massless operator would be determined by the volume term (cosmological constant). Could the action of D reduce to that of D_s at string world sheets? Does this require a reduction of the metric to an orthogonal direct sum from string world sheet tangent space and normal space and that also normal part of D annihilates the spinors at the string world sheet? The modes of Ψ at string world sheets are locally constant with respect to normal coordinates.

   (b) For the geodesic sphere of type I induced Kähler form is non-vanishing and brings an additional term to D coming from CP_2 degrees of freedom. This might lead to trouble since the gamma matrix structures of D and D_s would be different. One could however add to string world sheet bosonic action a topological term as Kähler magnetic flux. Although its contribution to the field equations is trivial, the contribution to the modified gamma matrices is non-vanishing and equal to the contraction $J^{\alpha k}\gamma_k$ of half projection of the Kähler form with CP_2 gamma matrices. The presence of this term could allow the reduction of $D\Psi_s = 0$ and $D_s\Psi_s = 0$ to each other also in this case.

5.2 A more detailed view about string world sheets

In TGD framework gauge fields are induced and what typically occurs for the space-time surfaces is that they tend to "go out" from CP_2. Could various lower-D surfaces of space-time surface correspond to sub-manifolds of space-time surface?

1. To get a concrete idea about the situation it is best to look what happens in the case of sphere $S^2 = CP_1$. In the case of sphere S^2 the Kähler form vanishes at South and North poles. Here the dimension is reduced by 2 since all values of ϕ correspond to the same point. $sin(\Theta)$ equals to 1 at equator - geodesic circle - and here Kähler form is non-vanishing. Here dimension is reduced by 1 unit. This picture conforms with the expectations in the case of CP_2 These two situations correspond to 1-D and 2-D geodesic sub-manifolds.

2. CP_2 coordinates can be represented as cosines or sines of angles and the modules of cosine or sine tends to become larger than 1 (see `http://tinyurl.com/z3coqau`). In Eguchi-Hanson coordinates (r, Θ, Φ, Ψ) the coordinates r and Θ give rise to this kind of trigonometric coordinates. For the two cyclic angle coordinates (Φ, Ψ) one does not encounter this problem.

3. In the case of CP_2 only geodesic sub-manifolds with dimensions $D = 0, 1, 2$ are possible. 1-D geodesic submanifolds carry vanishing induce spinor curvature. The impossibility of 3-D geodesic sub-manifolds would suggest that 3-D surfaces are not important. CP_2 has two geodesic spheres: S^2_I is homologically non-trivial and S^2_{II} homologically trivial (see `http://tinyurl.com/z3coqau`).

   (a) Let us consider S^2_I first. CP_2 has 3 poles, which obviously relates to SU(3), and in Eguchi Hanson coordinates (r, θ, Φ, Ψ) the surface $r = \infty$ is one of them and corresponds - not to a 3-sphere - but homologically non-trivial geodesic 2- sphere, which is complex sub-manifold and orbits of $SU(2) \times U(1)$ subgroup. Various values of the coordinate Ψ correspond to same point as those of Φ at the poles of S^2. The Kähler form J and classical Z^0 and γ fields are non-vanishing whereas W gauge fields vanish leaving only induced γ and Z^0 field as one learns by studying the detailed expressions for the curvature of spinor curvature and vierbein of CP_2.

       String world sheet could have thus projection to S^2_I but both γ and Z^0 would be vanishing except perhaps at the boundaries of string world sheet, where Z^0 would naturally vanish in the picture provided by standard model. One can criticize the presence of Z^0 field since it would give a parity breaking term to the modified Dirac operator. SH would suggest that the reduction to electromagnetism at string boundaries might make sense as counterpart for standard model picture. Note that the original vision was that besides induced Kähler form and em field also Z^0 field could vanish at string world sheets.

   (b) The homologically trivial geodesic sphere S^2_{II} is the orbit of $SO(3)$ subgroup and not a complex manifold. By looking the standard example about S^2_I, one finds that the both J, Z_0, and γ vanish and only the W components of spinor connection are non-vanishing. In this case the notion of em charge would not be well-defined for S^2_{II} without additional conditions. Partonic 2-surfaces, their light-like orbits, and boundaries of string world sheets could do so since string world sheets have 1-D intersection with with the orbits. This picture would make sense for the minimal surfaces replacing vacuum extremals in the case of twistor lift of TGD.

       Since em fields are not present, the presence of classical W fields need not cause problems. The absence of classical em fields however suggests that the modes of induced spinor fields at boundaries of string worlds sheets must be em neutral and represent therefore neutrinos. The safest but probably too strong option would be right-handed neutrino having no coupling spinor connection but coupling to the CP_2 gamma matrices transforming it to left handed neutrino. Recall that ν_R represents a candidate for super-symmetry.

       Neither charged leptons nor quarks would be allowed at string boundaries and classical W gauge potentials should vanish at the boundaries if also left-handed neutrinos are allowed: this can be achieved in suitable gauge. Quarks and charged leptons could reside only at string world sheets assignable to monopole flux tubes. This could relate to color confinement and also to the widely different mass scales of neutrinos and other fermions as will be found.

To sum up, the new result is that the distinction between neutrinos and other fermions could be understood in terms of the condition that em charge is well-defined. What looked originally a problem of TGD turns out to be a powerful predictive tool.

5.3 Classical Higgs field again

A motivation for returning back to Higgs field comes from the twistor lift of Kähler action.

1. The twistor lift of TGD [K14] [L2] brings in cosmological constant as the coefficient of volume term resulting in dimensional reduction of 6-D Kähler action for twistor space of space-time surface realized as surface in the product of twistor space of M^4 and CP_2. The radius of the sphere of M^4 twistor bundle corresponds to Planck length. Volume term is extremely small but removes the huge vacuum degeneracy of Kähler action. Vacuum extremals are replaced

by 4-D minimal surfaces and modified Dirac equation is just the analog of massless Dirac equation in complete analogy with string models.

2. The well-definedness and conservation of fermionic em charges and SH demand the localization of fermions to string world sheets. The earlier picture assumed only em fields at string world sheets. More precise picture allows also W fields.

3. The first guess is that string world sheets are minimal surfaces and this is supported by the previous considerations demanding also string area term and Kähler magnetic flux tube. Here gravitational constant assignable to M^4 twistor space would be the first guess for the string tension.

What one can say about the possible existence of classical Higgs field?

1. TGD predicts both Higgs type particles and gauge bosons as bound states of fermions and antifermions and they differ only in that their polarization are in M^4 resp. CP_2 tangent space. p-adic thermodynamics [K5] gives excellent predictions for elementary particle masses in TGD framework. Higgs vacuum expectation is not needed to predict fermion or boson masses. Standard model gives only a parametrization of these masses by assuming that Higgs couplings to fermions are proportional to their masses, it does not predict them.

   The experimental fact is however that the couplings of Higgs are proportional to fermion masses and TGD should be able to predict this and there is a general argument for the proportonality, which however should be deduced from basic TGD. Can one achieve this?

2. Can one imagine any candidate for the classical Higgs field? There is no covariantly constant vector field in CP_2, whose space-time projection could define a candidate for classical Higgs field. This led years ago before the model for how bosons emerge from fermions to the wrong conclusion that TGD does not predict Higgs.

   The first guess for the possibly existing classical counterpart of Higgs field would be as CP_2 part for the divergence of the space-time vector defined modified gamma matrices expressible in terms of canonical momentum currents having natural interpretation as a generalization of force for point like objects to that for extended objects. Higgs field in this sense would however vanish by above consistency conditions and would not couple to spinors at all.

   Classical Higgs field should have only CP_2 part being CP_2 vector. What would be also troublesome that this proposale for classical Higgs field would involve second derivatives of imbedding space coordinates. Hence it seems that there is no hope about geometrization of classical Higgs fields.

3. The contribution of the induced Kähler form gives to the modified gamma matrices a term expressible solely in terms of CP_2 gamma matrices. This term appears in modified Dirac equation and mixes M^4 chiralities - a signal for the massivation. This term is analogous to Higgs term expect that it contains covariant derivative.

   The question that I have not posed hitherto is whether this term could at QFT limit of TGD give rise to vacuum expectation of Higgs. The crucial observation is that the presence of derivative, which in quantum theory corresponds roughly to mass proportionality of chirality mixing coupling at QFT limit. This could explain why the coupling of Higgs field to fermions is proportional to the mass of the fermion at QFT limit!

4. For S^2_{II} type string world sheets assignable to neutrinos the contribution to the chirality mixing coupling should be of order of neutrino mass. The coefficient $1/L^4$ of the volume term defining cosmological constant [L2] separates out as over all factor in massless Dirac equation and the parameter characterizing the mass scale causing the mixing is of order $m = \omega_1\omega_2 R$. Here ω_1 characterizes the scale of gradient for CP_2 coordinates. The simplest minimal surface is that for which CP_2 projection is geodesic line with $\Phi = \omega_1 t$. ω_2 characterizes the scale of the gradient of spinor mode.

   Assuming $\omega_1 = \omega_2 \equiv \omega$ the scale m is of order neutrino mass $m_\nu \simeq .1$ eV from the condition $m \sim \omega^2 R \sim m_\nu$. This gives the estimate $\omega \sim \sqrt{m_{CP_2} m_\nu} \sim 10^2 m_p$ from $m_{CP_2} \sim 10^{-4} m_P$, which is weak mass scale and therefore perfectly sensible. The reduction $\Delta c/c$ of the light velocity from maximal signal velocity due the replacement $g_{tt} = 1 - R^2\omega^2$ is $\Delta c/c \sim 10^{-34}$ and thus completely negligible. This estimate does not make sense for charged fermions, which correspond to S_I^2 type string world sheets.

A possible problem is that if the value of the cosmological constant Λ evolves as $1/p$ as function of the length mass scale the mass scale of neutrinos should increase in short scales. This looks strange unless the mass scale remains below the cosmic temperature so that neutrinos would be always effectively massless.

5. For S_I^2 type string world sheets assignable to charged fermions Kähler action dominates and the mass scales are expected to be higher than for neutrinos. For S_I^2 type strings the modified gamma matrices contain also Kähler term and a rough estimate is that the ratio of two contributions is the ratio of the energy density of Kähler action to vacuum energy density. As Kähler energy density exceeds the value corresponding to vacuum energy density $1/L^4$, $L \sim 40$ μm, Kähler action density begins to dominate over dark energy density.

To sum up, this picture suggest that the large difference between the mass scales of neutrinos and em charged fermions is due to the fact that neutrinos are associated with string world sheet of type II and em charged fermions with string world sheets of type I. Both strings world sheets would be accompanied by flux tubes but for charged particles the flux tubes would carry Kähler magnetic flux. Cosmological constant forced by twistor lift would make neutrinos massive and allow to understand neutrino mass scale.

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