**Article**

# TGD View About Coupling Constant Evolution

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**Abstract**

New results related to the TGD view about coupling constant evolution are discussed. The results emerge from the discussion of the recent claim of Atyiah that fine structure constant could be understood purely mathematically. The new view allows to understand the recently introduced TGD-based construction of scattering amplitudes based on the analog of micro-canonical ensemble as a cognitive representation for the much more complex construction of full scattering amplitudes using real numbers rather than p-adic number fields. This construction utilizes number theoretic discretization of space-time surface inducing the "world of classical worlds" (WCW) and makes possible adelization of quantum TGD. The condition determining coupling constant evolution in the hierarchy of extensions of rationals defining that of adeles is extremely simple: $exp(S) = 1$, where $S$ is the complex action determining space-time surface as preferred extremal. The condition allows to circumvent the difficulties caused to the adelization by the fact that $exp(S)$ need not belong to the extension of rationals considered. The approach is also related to the view about coupling constant evolution based on the inclusions of hyper-finite factors of type $\mathrm{II}_1$, and it is proposed that Galois group replaces discrete subgroup of $SU(2)$ leaving invariant the algebras of observables of the factors appearing in the inclusion.

**Keywords**: Coupling constant, evolution, real number, world of classical world, TGD framework.

# 1 Introduction

Atyiah has recently proposed besides a proof of Riemann Hypothesis also an argument claiming to derive the value of the structure constant (see `http://tinyurl.com/y8xw8cey`). The mathematically elegant arguments of Atyiah involve a lot of refined mathematics including notions of Todd exponential and hyper-finite factors of type II (HFFs) assignable naturally to quaternions. The idea that $1/\alpha$ could result by coupling constant evolution from $\pi$ looks however rather weird for a physicist.

What makes this interesting from TGD point of view is that in TGD framework coupling constant evolution can be interpreted in terms of inclusions of HFFs with included factor defining measurement resolution [13, 7]. An alternative interpretation is in terms of hierarchy of extensions of rationals with coupling parameters determined by quantum criticality as algebraic numbers in the extension [19, 20].

In the following I will explain what I understood about Atyiah's approach. My critics includes the arguments represented also in the blogs of Lubos Motl (see `http://tinyurl.com/ycq8fhsy`) and Sean Carroll (see `http://tinyurl.com/y87f8psg`). I will also relate Atyiah's approach to TGD view about coupling evolution. The hasty reader can skip this part although for me it served as an inspiration forcing to think more precisely TGD vision.

There are two TGD based formulations of scattering amplitudes.

1. The first formulation is at the level of infinite-D "world of classical worlds" (WCW) [15] uses tools like functional integral. The huge super-symplectic symmetries generalizing conformal symmetries raise hopes that this formulation exists mathematically and that it might even allow practical calculations some day. TGD would be an analog of integrable QFT.

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2. Second - surprisingly simple - formulation [26] is based on the analog of micro-canonical ensemble in thermodynamics (quantum TGD can be seen as complex square root of thermodynamics). It relates very closely to TGD analogs of twistorialization and twistor amplitudes [11, 16].

   During writing I realized that this formulation can be regarded as a generalization of cognitive representations of space-time surfaces based on algebraic discretization making sense for all extensions of rationals to the level of scattering amplitudes. This formulation allows a continuation to p-adic sectors and adelization [19, 20] and adelizability is what leads to the concrete formula - something new - for the evolution of Kähler coupling strength $\alpha_K$ forced by the adelizability condition.

   The condition is childishly simple: the exponent of complex action $S$ (more general than that of Kähler function) equals to unity: $exp(S) = 1$ and thus is common to all number fields. This condition allows to avoid the grave mathematical difficulties cause by the requirement that $exp(S)$ exists as a number in the extension of rationals considered. Second necessary condition is the reduction of twistorial scattering amplitudes to tree diagrams implied by quantum criticality.

3. One can also understand the relationship of the two formulations in terms of $M^8-H$ duality. This view allows also to answer to a longstanding question concerning the interpretation of the surprisingly successful p-adic mass calculations [14]: as anticipated, p-adic mass calculations are carried out for a cognitive representation rather than for real world particles and the huge simplification explains their success for preferred p-adic prime characterizing particle as so called ramified prime for the extension of rationals defining the adeles.

4. I consider also the relationship to a second TGD based formulation of coupling constant evolution in terms of inclusion hierarchies of hyper-finite factors of type $\mathrm{II}_1$ (HFFs) [13, 7]. I suggest that this hierarchy is generalized so that the finite subgroups of $SU(2)$ are replaced with Galois groups associated with the extensions of rationals. An inclusion of HFFs in which Galois group would act trivially on the elements of the HFFs appearing in the inclusion: kind of Galois confinement would be in question.

5. The formulation of the twistor lift of Kähler action is essential for the understanding of the coupling constant evolution and leads to a more detailed view about the interpretation of cosmological constant as an approximate parameterization of the dimensionally reduced 6-D Kähler action (or energy) allowing also to understand how it can decrease so fast.

# 2 Criticism of Atyiah's approach

The basic idea of Atyiah is that $\pi$ and the inverse of the fine structure constant $1/\alpha = 137.035999....$ are related by coupling constant evolution - that is renormalization - which is a basic operation in quantum field theory and has physical interpretation. For a physicist it is easy to invent objections.

1. In quantum field theory fine structure constant and all coupling strengths obey a continuous evolution as function of mass scale or length scale and one should predict the entire evolution rather than say its value at electron length scale. In TGD framework the coupling constant evolution becomes discrete and would basically labelled by the hierarchy of extensions of rationals.

2. $\pi$ is purely geometric constant - kind of Platonic transcendental having very special role in the mathematical world order - whereas fine structure constant is a dynamical coupling parameter. Atyiah does not have any proposal for why these constants would be related in this manner. Also no explanation for what it would mean that the circumference of unit circle would grow from $2\pi$ to $2/\alpha$ is given.

   **Remark**: In TGD actually the coverings labelled by the value $h_{eff}/n_0 = n$ identified as the order of Galois group of extension of rationals defining given level of the hierarchy of evolutionary levels (entanglement coefficients would belong to this extension as also S-matrix elements). The full angle using $M^4$ rotation angle as coordinate increases effectively to $n \times 2\pi$ for the covering spaces of extensions introducing $n$:th root of unity. In TGD would however have $n$ instead of $1/(\alpha\pi)$.

3. That $1/\alpha \sim 137$ should have interpretation as renormalized value of angle $\pi$ looks rather weird to me. The normalization would be very large and it is extremely difficult to see why $1/\pi$ have a role of fine structure constant say at high energy limit if one accepts coupling constant evolution and identifies $1/\alpha$ as the value of $1/\alpha$ at zero momentum transfer.

In fact, Atyiah proposes a discrete evolution of $\pi$ to $1/\alpha$ defined by approximations of HFF as a finite-D algebra. Forgetting $\pi$ as the starting point of the evolution, this idea looks beautiful. At first the idea that all numbers suffer a renormalization evolution, looks really cute. Coupling constant evolution is however not a sequence of approximations but represents a genuine dependence of coupling constants on length scale.

**Remark**: In TGD framework I propose something different.The length scale evolution of coupling constants would correspond to a hierarchy of inclusions of HFFs rather than a sequence of finite-D approximations approaching HFF. The included factor would represent measurement resolution. Roughly, the transformations of states by operations defined in included factor would leave state invariant in the measurement resolution defined by the included factor. Different values of coupling constant would correspond to different measurement resolutions.

1. Atyiah mentions as one of his inspirers the definition of $2\pi$ via a limiting procedure identifying it as the length of the boundary of $n$-polygon inside unit circle. Amusingly, I have proposed similar definition of $2\pi$ in p-adic context, where the introduction of $\pi$ would give rise to infinite extension.

   Atyiah generalizes this definition to the area of quaternionic sphere so that the limiting procedure involves two integers. For sphere tesselations as analogs of lattices allow only Platonic solids. For torus one could have infinite hierarchy of tesselations [22] allowing to define the area of torus in this manner. The value of $n$ defined by the extension of rationals containing root of unity $exp(i2\pi/n)$ such that $n$ is maximal. The largest $n$ for the roots of unity appearing in the extension of p-adics would determine the approximation of $2\pi$ used.

2. Atyiah suggests a concrete realization for the coupling constant evolution of numbers, not only coupling constants. The evolution would correspond to a sequence of approximation to HFF converging to HFF. One can of course define this kind of evolution but to physicist it looks like a formal game only.

3. HFF is interpreted as an infinite tensor product of $2\times 2$ complex Clifford algebras $M_2(C)$, which can be also interpreted as complexified quaternions. One defines the trace by requiring that the trace of infinite tensor product of unit matrices equals to 1. The usual definition of schoolbooks would given infinite power of 2, which diverges. The inner product is the product of the usual inner products for the factors of the tensor product labelled by $n$ but divided by power $2^{-n_{max}}$ to guarantee that the trace of the identity matrix is unity as product of traces for factors otherwise equal to $2^n$. In fact, fermionic Fock algebra familiar to physicist is HFF although in hidden manner.

   **Remark**: The appearance of quaternions is attractive from TGD point of view since in $M^8 - H$ duality the dynamics at the level of $M^8$ is determined by associativity of either tangent or normal space of 4-surface in $M^8$ and associativity is equivalent with quaternionicity [18]. The hierarchy of HFFs is also basic piece of quantum TGD and realizable in terms of quaternions.

4. Atyiah tells there is an algebra isomorphism from complex numbers $C$ to the subset of commuting matrices in HFF. One can define the map to $C$ as either eigenvalue of the matrix and obtains to isomorphisms: $t_+$ and $t_-$. One can define the renormalization map $C \to C$ in terms of the inverse of $t_- \circ t_+^{-1}$ or its inverse. This would assign to a complex numbers $z$ its normalized value.

HFFs allow an excellent approximation by finite number of tensor factors and one can perform an approximation taking only finite number of tensor factors and at the limit of infinite number of factors get the the desired normalization map. The approximation would be $t_-(n) \circ t_+(n)$. I must confess that I did not really understand the details of this argument.

In any case, to me this does not quite correspond to what I understand with renormalization flow. Rather this is analogous to a sequence of approximations defining scattering amplitude as approximation containing only contributions up to power $g^n$. I would argue than one must consider the infinite sequence of inclusions of HFFs instead of a sequence of approximations defining HFF.

In this manner one would the renormalization map would be $t_-(n+1) \circ t_+^{-1}(n)$, where $n$ now labels the hierarchy of HFFs in the inclusion hierarchy. $t_\pm n$ is now the exact map from commuting sub-algebra to complex numbers.

There is however a rather close formal resemblance since simple inclusions correspond to inclusions of the sub-algebra with one $M_C^2$ factor replaced with mere identity matrix.

5. The proposal of Atyiah is that this renormalization of numbers is mediated by so called Todd exponentiation used in the construction of the characteristic classes. This map would be defined in terms of generating function $G(x) = x/(1-exp-x)$ applied to $x = \pi$. If I understood anything about the explanation, this map is extended to infinite number of tensor factors defining the HFF and the outcome would be that $x = \pi$ for single tensor factor would be replaced with $1/\alpha$. Why Todd exponentiation? Atyiah also argues that one has $T(\pi)/\pi = T(\gamma)/\gamma$, where $\gamma$ is Euler's constant. My mathematical education is so limited that I could not follow these arguments.

6. Atyiah also claims that the approximation $1/\alpha = 137$ assumed by Eddington to be exact has actually deeper meaning. There are several formulas in this approximation such as $1/\alpha = 2^0 + 2^3 + 2^7 = 1 + 8 + 128$. If I understood correctly, Atyiah tells that the numbers 1, 8, and 128 appear in the Bott periodicity theorem as dimensions of subsequent stable homotopy groups. My own favorite formula is in terms of Mersenne primes: $1/\alpha = M_2 + M_3 + M_7 = 3 + 7 + 127$. The next Mersenne prime would be $M_{127}$ and corresponds to the p-adic length scale of electron.

   **Remark**: A fascinating numerological fact is that $p \simeq 2^k$, $k \simeq 137$, corresponds to the p-adic length scale near to Bohr radius: kind of cosmic joke one might say. Fine structure constant indeed emerged from atomic physics!

It would be of course marvellous if the renormalization would not depend on physics at all but here physicist protests.

1. The coupling constant evolutions for the coupling strengths of various interactions are different and depend also on masses of the particles involved. One might however hope that this kind of evolution might make sense for fundamental coupling constants of the theory. In TGD Kähler coupling strength $1/\alpha_K$ would be such parameter.

2. The quantum criticality of TGD Universe suggests that Atyiah's claim is true in a weaker sense. Quantum criticality is however a dynamical notion. I have actually proposed a model for the evolution of $1/\alpha_K$ based on the complex zeros of Riemann Zeta [5] and also a generalization to other coupling strengths assuming that the argument of zeta is replaced with its Möbius transform.

   Very strong consistency conditions should be met. Preferred primes would be primes near prime power of 2 and ramified primes of extension, and also the zero of zeta in question should belong to the extension in question. I am of course the first to admit that this model is motivated more by mathematical aesthetics than concrete physical calculations.

3. The idea about renormalization evolution in this manner could - actually should - generalize. One can consider a maximal set of commuting set of observables in terms of tensor product of HFFs

and define for them map to diagonal $n \times n$ matrices with complex eigenvalues. One would have infinite sum over the eigenvalues of diagonal matrices over factors: just as one has for many particle state in QFT containing contribution from all tensor factors which are now however ordered by the label $n$. The length scale evolution of these observables could be defined by the above formula for inclusion. Fine structure constant basically reduces to charge as eigenvalue of charge operator so that this could make sense.

The beauty of this view would be that renormalization could be completely universal. In TGD framework quantum criticality (QC) indeed strongly suggests this universality in some sense. The hierarchy of extensions of rationals would define the discrete coupling constant evolution.

# 3 About coupling constant evolution in TGD framework

It is often forgotten that fine structure constant depends on length scale. When Eddington was working with the problem, it was not yet known that fine structure constant is running coupling constant. For continuous coupling constant evolution there is not much point to ponder why its value is what it is at say electron length scale. In TGD framework - adelic physics - coupling parameters however obey discrete length scale evolution deriving from the hierarchy of extensions of rationals. In this framework coupling constants are determined by quantum criticality implying that they do not run at all in the phase assignable to given extension of rational. They are analogous to critical temperature and determined in principle by number theory.

## 3.1 Number theoretic vision about coupling constant evolution

Let us return to the question about the coupling constant evolution.

1. Each extension of rationals corresponds to particular values of coupling parameters determined by the extension so that it indeed makes sense to ponder what the spectrum of values for say fine structure constant is. In standard QFT this does not make sense.

2. Coupling constant evolution as a function of momentum or length scales reduces to p-adic coupling constant evolution in TGD as function of p-adic prime. Particles are characterized by preferred p-adic primes - for instance, electron corresponds to $M_{127} = 2^{127} - 1$ - the largest Mersenne prime which does not correspond to super-astronomical Compton length - and the natural identification is as so called ramified primes of extension.

Why the interpretation of p-adic primes as ramified primes?

1. As one increases length scale resolution particle decomposes to more elementary particles.

2. Particles correspond in TGD to preferred p-adic primes. This suggests that when a prime (ideal) of given extension is looked at improved precision determined by an extension of the orignal extension it decomposes into a product of primes. This indeed happens.

   The number of primes of the larger extension appearing in the decomposition to product equals to the dimension of extension as extension of the original extension. All these primes appear and only once in the generic case. Ramified primes of ordinary extension are however odd-balls. Some primes of extension are missing and some appear as higher powers than 1 in their decomposition.

3. Ramified primes are analogous to critical systems. Polynomial with a multiple root - now prime of extension appearing as higher power - corresponds to a critical system. TGD is quantum critical so that one expects that ramified primes are preferred physically and indeed correspond to quantum critical systems.

4. Only the momenta belonging to the extension of rationals are considered and one can identify them as real-valued or p-adic valued momenta. Coupling constants do not depend on the values of the momenta for given extension of rationals and are thus analogous to critical temperature.

   This involves interesting not totally resolved technical question inspired by p-adic mass calculations for which the p-adic mass squared value is mapped to its real value by canonical identification $S\sum x_n p^n \to \sum x_n p^{-n}$. The correspondence is continuous and can be applied to Lorentz invariants appearing in scattering amplitudes [9].

   Could this correspondence be applied also to momenta rather than only mass squared values and Lorentz invariants? $M^8 - H$ correspondence [18] selects fixed Poincare frame as moduli space for octonionic structures and at $M^8$ level this could make sense.

## 3.2 Cosmological constant and twistor lift of Kähler action

Cosmological constant $\Lambda$ is one of the biggest problems of modern physics.

1. Einstein proposed non-vanishing value of $\Lambda$ in Einstein action as a volume term at his time in order to get what could be regarded as a static Universe. It turned out that Universe expanded and Einstein concluded that this proposal was the greatest blunder of his life. For two decades ago it was observed that the expansion of the Universe acclerates and the cosmological constant emerged again. $\Lambda$ must be extremely small and have correct sign in order to give accelerating rather decelerating expansion in Robertson-Walker cooordinate. Here one must however notice that the time slicing used by Einstein was different and fr this slicing the Universe looked static.

2. $\Lambda$ can be however understood in an alternative sense as characterizing the dynamics in the matter sector. $\Lambda$ could characterize the vacuum energy density of some scalar field, call it quintessense, proportional to 3- volume in quintessence scenario. This $\Lambda$ would have sign opposite to that in the first scenario since it would appear at opposite side of Einstein's equations.

### 3.2.1 Cosmological constant in string models and in TGD

It has turned out that $\Lambda$ could be the final nail to the coffin of superstring theory.

1. The most natural prediction of M-theory and superstring models is $\Lambda$ in Einsteinian sense but with wrong sign and huge value: for instance, in AdS/CFT correspondence this would be the case. There has been however a complex argument suggesting that one could have a cosmological constant with a correct sign and even small enough size.

   This option however predicts landscape and a loss of predictivity, which has led to a total turn of the philosophical coat: the original joy about discovering the unique theory of everything has changed to that for the discovery that there are no laws of physics. Cynic would say that this is a lottery win for theoreticians since theory building reduces to mere artistic activity.

2. Now however Cumrun Vafa - one of the leading superstring theorists - has proposed that the landscape actually does not exist at all [4] (see `http://tinyurl.com/ycz7wvng`). $\Lambda$ would have wrong sign in Einsteinian sense but the hope is that quintessence scenario might save the day. $\Lambda$ should also decrease with time, which as such is not a catastrophe in quintessence scenario.

3. Theorist D. Wrase et al has in turn published an article [B1] (see `http://tinyurl.com/ychrhuxk`) claiming that also the Vafa's quintessential scenario fails. It would not be consistent with Higgs Higgs mechanism. The conclusion suggesting itself is that according to the no-laws-of-physics vision something catastrophic has happened: string theory has made a prediction! Even worse, it is wrong.

   **Remark**: In TGD framework Higgs is present as a particle but p-adic thermodynamics rather than Higgs mechanism describes at least fermion massivation. The couplings of Higgs to fermions are naturally proportional their masses and fermionic part of Higgs mechanism is seen only as a manner to reproduce the masses at QFT limit.

4. This has led to a new kind of string war: now inside superstring hegemony and dividing it into two camps. Optimistic outsider dares to hope that this leads to a kind of auto-biopsy and the gloomy period of superstring hegemony in theoretical physics lasted now for 34 years would be finally over.

String era need not be over even now! One could propose that both variants of $\Lambda$ are present, are large, and compensate each other almost totally! First I took this as a mere nasty joke but I realized that TGD indeed suggests something analogous to this!

The picture in which $\Lambda_{eff}$ parametrizes the total action as dimensionally reduced 6-D twistor lift of Kähler action could be indeed interpreted formally as sum of genuine cosmological term identified as volume action and Kähler action identified as an analog of quintessence. This picture is summarized below.

### 3.2.2 The picture emerging from the twistor lift of TGD

Consider first the picture emerging from the twistor lift of TGD.

1. Twistor lift of TGD leads via the analog of dimensional reduction necessary for the induction of 8-D generalization of twistor structure in $M^4 \times CP_2$ to a 4-D action determining space-time surfaces as its preferred extremals. Space-time surface as a preferred extremal defines a unique section of the induced twistor bundle. The dimensionally reduced Kähler action is sum of two terms. Kähler action proportional to the inverse of Kähler coupling strength and volume term proportional to the cosmological constant $\Lambda$.

   **Remark:** The sign of the volume action is negative as the analog of the magnetic part of Maxwell action and *opposite* to the sign of the area action in string models.

   Kähler and volume actions should have opposite signs. At $M^4$ limit Kähler action is proportional to $E^2 - B^2$ In Minkowskian regions and to $-E^2 - B^2$ in Euclidian regions.

2. Twistor lift forces the introduction of also $M^4$ Kähler form so that the twistor lift of Kähler action contains $M^4$ contribution and gives in dimensional reduction rise to $M^4$ contributions to 4-D Kähler action and volume term.

   It is of crucial importance that the Cartesian decomposition $H = M^4 \times CP_2$ allows the scale of $M^4$ contribution to 6-D Kähler action to be different from $CP_2$ contribution. The size of $M^4$ contribution as compared to $CP_2$ contribution must be very small from the smallness of CP breaking [25] [16].

   For canonically imbedded $M^4$ the action density vanishes. For string like objects the electric part of this action dominates and corresponding contribution to 4-D Kähler action of flux tube extremals is positive unlike the standard contribution so that an almost cancellation of the action is in principle possible.

3. What about energy? One must consider both Minkowskian and Euclidian space-time regions and be very careful with the signs. Assume that Minkowskian and Eucidian regions have *same time orientation*.

   (a) Since a dimensionally reduced 6-D Kähler action is in question, the sign of energy density is positive Minkowskian space-time regions and of form $(E^2 + B^2)/2$. Volume energy density proportional to $\Lambda$ is positive.

   (b) In Euclidian regions the sign of $g^{00}$ is negative and energy density is of form $(E^2 - B^2)/2$ and is negative when magnetic field dominates. For string like objects the $M^4$ contribution to Kähler action however gives a contribution in which the electric part of Kähler action dominates so that

$M^4$ and $CP_2$ contributions to energy have opposite signs. One can even consider the possibility that energies cancel in a good approximation and that the total energy is parameterized by effective cosmological constant $\Lambda_{eff}$.

The identification of the observed value of cosmological constant is not straightforward and I have considered several options without making explicit their differences even to myself. For Einsteinian option cosmological constant could correspond to the coefficient $\Lambda$ of the volume term in analogy with Einstein's action. For what I call quintessense option cosmological constant $\Lambda_{eff}$ would approximately parameterize the total action density or energy density.

1. Cosmological constant - irrespective of whether it is identified as $\Lambda$ or $\Lambda_{eff}$ - is extremely small in the recent cosmology. The natural looking assumption would be that as a coupling parameter $\Lambda$ or $\Lambda_{eff}$ depends on p-adic length scale like $1/L_p^2$ and therefore decreases in average sense as $1/a^2$, where $a$ is cosmic time identified as light-cone proper time assignable to either tip of CD. This suggests the following rough vision.

   The increase of the thickness of magnetic flux tubes carrying monopole flux liberates energy and this energy can make possible increase of the volume so that one obtains cosmic expansion. As the space-time surface expands, its cosmological constant is eventually reduced in a phase transition changing the p-adic length scale. This phase transition liberates volume energy and leads to an accelerated expansion. The space-time surface would expand by jerks in stepwise manner. This process is analogous to breathing. This process would replace continuous cosmic expansion of GRT. One application is TGD variant of Expanding Earth model explaining Cambrian Explosion, which is really weird event [8].

   One can however raise a serious objection: since the volume term is part of 6-D Kähler action, the length scale evolution of $\Lambda$ should be dictated by that for $1/\alpha_K$ and be very slow: therefore cosmological constant identified as Einsteinian $\Lambda$ seems to be excluded.

2. This leaves only $\Lambda_{eff}$ option. $\Lambda_{eff}$ would parameterize the value of the total action or energy of the space-time surface. $\Lambda_{eff}$ would be analogous to the sum of Einsteinian and quintessential cosmological constants.

   The gradual reduction of $\Lambda_{eff}$ could be interpreted in terms of the reduction of the total action or energy or both. The reduction of the total action would be by the cancellation of $M^4$ and $CP_2$ parts of Kähler action for string like objects. The reduction of the total energy would be by the cancellation of the contribution of Minkowskian and Euclidian regions. The p-adic length scale evolution of $\Lambda$ would be slow and induced by that of $\alpha_K$.

This picture still leaves the question whether one should assign $\Lambda_{eff}$ to action or energy or both in which case the assignments should be equivalent and action and energy should be proportional to each other. This identification is however the most detailed one developed hitherto.

### 3.2.3 Second manner to increase 3-volume

Besides the increase of 3-volume of $M^4$ projection, there is also a second manner to increase volume energy: many-sheetedness. The negative sign of $\Lambda$ could in fact force many-sheetedness.

1. Superconductors of type II (see `http://tinyurl.com/ydxto55f` provide a helpful analogy. In superconductors of type II Meissner effect is not complete unlike for those of type. Below critical value $H_{c,1}$ external magnetic field penetrates as flux quanta, which can be cylindrical flux tube and also form complex effectively 2-D thin 3-surfaces maximizing their area near critical field $H_{c,1}$ for which magnetic field penetrates the entire superconductor. The reason is that the surface energy for the boundary of non-super-conducting and super-conducting phase is negative for superconductors

of type II so that the area in question is maximized. Note that near criticality also volume energy is minimized.

2. In TGD the negative volume energy associated with $\Lambda$ is analogous to the surface energy in superconductors of type II. The thin 3-surfaces in superconductors could have similar 3-surface analogs in TGD since their volume is proportional to surface area - note that TGD Universe can be said to be quantum critical.

   This is not the only possibility. The sheets of many-sheeted space-time having overlapping $M^4$ projections provide second mechanism. The emergence of many-sheetedness could also be caused by the increase of $n = h_{eff}/h_0$ as a number of sheets of Galois covering.

3. Could the 3-volume increase during deterministic classical time evolution? If the minimal surface property assumed for the preferred extremals as a realization of quantum criticality is true everywhere, the conservation of volume energy prevents the increase of the volume. Minimal surface property is however assumed to fail at discrete set of points due to the transfer of conserved charged between Kähler and volume degrees of freedom. Could this make possible the increase of volume during classical time evolution so that volume and Kähler energy could increase?

4. ZEO allows the increase of average 3-volume by quantum jumps. There is no reason why each "big" state function reduction changing the roles of the light-like boundaries of CD could not decrease the average volume energy of space-time surface for the time evolutions in the superposition. This can occur in all scales, and could be achieved also by the increase of $h_{eff}/h_0 = n$.

5. The geometry of CD suggests strongly an analogy with Big Bang followed by Big Crunch. The increase of the volume as increase of the volume of $M^4$ projection does not however seem to be consistent with Big Crunch. One must be very cautious here. The point is that the size of CD itself increases during the sequence of small state function reductions leaving the members of state pairs at passive boundary of CD unaffected. The size of 3-surface at the active boundary of CD therefore increases as also its 3-volume.

   The increase of the volume during the Big Crunch period could be also due to the emergence of the many-sheetedness, in particular due to the increase of the value of $n$ for space-time sheets for sub-CDs. In this case, this period could be seen as a transition to quantum criticality accompanied by an emergence of complexity.

6. In type II superconductivity magnetic energy and negative surface energy for flux quanta compete. Now one has Kähler magnetic energy and negative volume energy. By energy conservation they compete. Could this analog be helpful in TGD? Could the penetration of Kähler magnetic flux tubes to a system give rise to generation of space-time sheets and perhaps increase of $n$ in order to reduce total energy?

## 3.3 How could one understand basic the evolution of Kähler coupling strength from quantum criticality?

The challenge is to reduce the coupling constant evolution to quantum criticality. One should understand how quantum criticality could determine the values of $\alpha_K$ and cosmological constant $\Lambda$ - or equivalently the vacuum energy density $\rho$. Basically one would like to have a formula for Kähler coupling strength.

### 3.3.1 What can one conclude about $\alpha_K$ on basis of quantum criticality?

What could one conclude about $\alpha_K$ on basis of quantum criticality?

1. Quantum criticality suggests that all preferred extremals are minimal surfaces except at discrete set of points at which there is a transfer of conserved charges between Kähler term and volume term [23]. Minimal surface property means that there is no coupling between Kähler term and volume term except at these points and the dynamics does not depend on coupling parameters at all. This corresponds to the universality of quantum criticality. The exceptional points corresponds to matter as point-like particles. By $M^8 - H$ duality [18] this has counterpart at the level of $M^8$. Algebraic surfaces in $M^8$ with associative tangent space or normal space are mapped to $H$ by this duality. Associativity together with the condition that the integrable distribution of tangent or normal spaces contain an integrable distribution of complex planes of octonionic $M^8$ realizes universality since also this dynamics is independent of coupling parameters.

2. The volume term in the action becomes very large at the limit of space-time surfaces with very long temporal duration $T$ (large causal diamond (CD). Same is true also for cosmic strings and their deformations to flux tubes. Their sum is proportional to $T$ and the exponent of action is very large or small depending on the sign of the action. The manner to prevent this is that Kähler term and volume term sum up to a finite contribution which is very small as compared to the time scale $T$ of CD. This kind of condition is inelegant. The exact vanishing of the entire complex action turns out to be too strong a condition but the condition that the exponent of action equals to unity: $exp(S) = 1$. The real part of action vanishes and imaginary part is multiple of $2\pi$. This does just what it is required to do - to get rid of the number theoretic problems related to the adelization.

### 3.3.2 Two approaches to quantum TGD

There are two approaches to TGD: geometric and number theoretic. The "world of classical worlds" (WCW) is central notion of TGD as a geometrization of quantum physics rather than only classical physics.

1. WCW consists of 3-surfaces and by holography realized by assigning to these 3-surfaces unique 4-surfaces as preferred extremals. In zero energy ontology (ZEO) these 3-surfaces are pairs of 3-surfaces, whose members reside at opposite boundaries of causal diamond (CD) and are connected by preferred extremal analogous to Bohr orbit. The full quantum TGD would rely on real numbers and scattering amplitudes would correspond to zero energy states having as arguments these pairs of 3-surfaces. WCW integration would be involved with the definition of inner products.

2. The theory could be seen formally as a complex square root of thermodynamics with vacuum functional identified as exponent of Kähler function. Kähler geometry would allow to eliminate ill-defined Gaussian determinants and metric determinant of Kähler metric and they would simply disappear from scattering amplitudes. WCW is infinite-D space and one might argue that this kind of approach is hopeless. The point is however that the huge symmetries of WCW - super-symplectic invariance - give excellent hopes of really construction the scattering amplitudes: TGD would be integrable theory.

3. A natural interpretation would be that Kähler action as the analog of Hamiltonian defines the Kähler function of WCW and functional integral defined by it allows definition of full scattering amplitudes.

The number theoretic approach could be called adelic physics [19, 20] providing also the physics of cognition.

1. At space-time level p-adicization as description of cognition requires discretization. Cognitive representations at space-time level consist of finite set of space-time points with preferred coordinates $M^8$ in extension of rationals inducing the extensions of p-adic number fields. These representations would realize the notion of finite measurement resolution. p-Adicization and adelization for given

extension of rationals are possible only in this manner since these points can be interpreted as both real and p-adic numbers.

2. What about cognitive representations at the level of WCW? The discrete set of space-time points would replace the space-time surface with a finite discrete set of points serving also as its WCW coordinates and define the analog of discretization of WCW using polynomials in $M^8$ fixed by their values at these points [18]. If the space-time surface is represented by a polynomial, this representation is all that is needed to code for the space-time surface since one can deduce the coefficients of a polynomial from its values at finite set of points. Now the coefficients belong to extension of rationals. If polynomials are replaced by analytic functions, polynomials provide approximation defining the cognitive representation.

   While writing this I realized that what I have micro-canonical ensemble [26] as kind of complex square root of its counterpart in thermodynamics can serve as a cognitive representation of scattering amplitudes. Cognitive representations of space-time surfaces would thus give also cognitive representations of WCW and micro-canonical ensemble would realize cognitive representations for the scattering amplitudes. Cognitive representations define only a hierarhcy of approximations. The exact description would involve the full WCW, its Kähler geometry, and vacuum functional as exponent of Kähler function.

   The idea of micro-canonical ensemble as a subset of space-time surfaces with the same vanishing action would select a sub-set of surfaces with the same values of coupling parameters so that the fixing the coupling parameters together with preferred extremal property selects the subset with vanishing real part of the action. The role of coupling parameters would be analogous to the role of temperature and pressure applied.

   I have also proposed [26] that the analog of micro-canonical ensemble makes sense meaning that all space-time surfaces contributing to the scattering amplitude have the same action. As a consequence, the action exponential and the usual normalization factor would cancel each other and one would obtain just a sum over space-time surfaces with same action: otherwise action exponential would not appear in the scattering amplitudes - this is the case also in perturbative QFTs. This is crucial for the p-adicization and adelization since these exponential factors belong to the extension of rationals only under very strong additional conditions.

## 3.4 Can one require that the exponent of action equals to unity for the micro-canonical ensemble

In gauge theories conformal invariance implies the vanishing of action. Could the entire action $S$ or at least its real part $Re(S)$ vanish allowing therefore to avoid large exponents. Could the vanishing occur at least approximately or could it be exact for the preferred extremals? Or could one just require $exp(S) = 1$ implying $Re(S) = 0$ and $Im(S) = n \times 2\pi$?

One can can criticize the approximate vanishing as a fundamental law since it involves only the leading term. A formal possibility is that one considers the limit $T \to \infty$, which is appropriate at QFT limit but this looks too technical at this level.

One should choose between $S = 0$, $Re(S) = 0$, $Im(S) = 0$, and $exp(S) = 1$. The crucial question is why the exponent of action should be unity for micro-canonical example [26]. The answer is that this makes possible p-adicization and adelization without tears. The exponent of the action is indeed a nuisance in this process since very strong conditions would be required to guarantee that it belongs to the extension of rational considered and therefore to the extensions of p-adic numbers induced by it. Putting $exp(S) = 1$ would solve all problems. This would give the conditions

$$Re(S) = 0 \ , \quad Im(S) = n \times 2\pi \tag{3.1}$$

making the phase trivial. These conditions would be analogous to the quantization of action used in quantum theory. This would give non-trivial condition leading to the quantization of Kähler action for real $\Lambda$. For this option the quantization of $1/\alpha_K$ and $\Lambda$ would guarantee that the exponent of action is trivial.

If real part of Kähler action and volume term are proportional to each other as implied by $Re(S) = 0$, one can add also to the vacuum function of WCW an imaginary exponential as a kind of wave function since the crucial cancellation of Gaussian and metric determinants is not lost and propagators are changed only by a scale factor.

Consider now the objections.

1. Kähler metric for WCW is determined by second derivatives of Kähler action with respect to complex coordinate and their conjugates in the set of preferred extremals defining sector of WCW with fixed values of coupling parameters and would thus vanish identically. One could not speak of functional integral at all. This argument does not bite if the micro-canonical ensemble is only a cognitive representation and WCW functional integral corresponds to the full theory differing from cognitive representations.

   There is however no deep reason to believe that the action exponential for micro-canonical ensemble equals with the exponent Kähler function for the full theory. In fact, Kähler function is real and action exponential is complex. One could think that Kähler action for preferred extremals defines Kähler function of WCW and thus its metric: this was the original proposal and the basic motivation. Twistorialization however forces the volume term [11, 16].

   The minimal surface property (realizing quantum criticality!) and vanishing condition would force the real part of Kähler action and volume term to be identical apart from sign - this is extremely important point - and one could use any non-vanishing combination of these two with real coefficients to define Kähler function of WCW. This would give consistency with twistorialization.

   One could say that by the minimal surface property super-conformal invariance is not actually lost although the dimensionality of $\Lambda$ as coupling would suggests this (minimal surfaces are extremals of also Kähler action!).

2. There are good reasons to believe that $1/\alpha_K$ is complex [5]: this conforms with the idea about quantum TGD as complex square root of thermodynamics. The most natural guess is that $\Lambda$ is real. For $exp(S) = 1$ the Kähler action is proportional to the volume term and Kähler action in turns is multiple of $2\pi$.

   That the values of action are constant for given values of coupling parameters is not a problem since one has cognitive representations selecting only a discrete subset from the set of all preferred extremals, which might also contain at $M^8$ level surfaces assignable to octonion analytic continuations of analytic functions rather than only polynomials.

3. One might argue that vacuum functional should cause interference effects at WCW level. One can however counter-argue that these effects come from from the superposition of scattering amplitudes. The action exponential disappears also in perturbative QFTs and the interference effects take place at space-time level. Now at imbedding space level, where imbedding space spinors define the basic building bricks for the ground states of representations of super-symplectic algebra. It is the plane-waves assignable to these spinor modes that lead to interference effects.

### 3.4.1 A more detailed picture

Consider now the situation more explicitly.

1. The reduction of the action exponential to unity implies following conditions giving an expression for $1/\alpha_K$ from either of the following conditions

$$
\begin{aligned}
Re(S) &= 0 \ , \\
Im(S) &= n \times 2\pi \ , \\
S &= \frac{S_K}{4\pi\alpha_K} - \frac{\Lambda}{8\pi G} Vol_4 \ . 
\end{aligned} \tag{3.2}
$$

If $\Lambda$ is real, one has

$$
\begin{aligned}
& Re(\frac{1}{\alpha_K})S_K - \frac{\Lambda}{2G} \times Vol \ , \\
& Im(\frac{1}{4\pi\alpha_K})S_K = n \times 2\pi \ .
\end{aligned} \tag{3.3}
$$

One would have two conditions giving good hope that both $1/\alpha_K$ and $\Lambda$ can be dedermined.

Some further comments about the formulas are in order.

1. The formulas contain Newton's constant $G$ so that gravitation is explicitly involved albeit in totally different manner as in GRT. I have recently proposed that Newton's constant $G$ is actually expressible as $G = R^2/\hbar_{eff}$ therefore is inversely proportional to the dimension of extension of rationals [24]. $CP_2$ would be Planck length and $\hbar_{eff}/h \simeq 10^7$ would hold true.

   For Galois covering with $n$ sheets the effective value of $1/\alpha_K$ obtained by treating the sheets as single sheet as in QFT limit would be proportional to $n$. The increase of $h_{eff}$ guarantees that the perturbation series converges: this was the original motivation for the hierarchy of Planck constants [6]. Also the formula $G = R^2/\hbar_{eff}$ can ve understood in this manner. This interpretation makes sense since $G$ only in cosmological term. The proposal $G = R^2/\hbar_{eff}$ would be actually a prediction rather than conjecture.

2. The expression of $\Lambda$ as a function of p-adic length scale must be also known and simple scaling arguments and also the required similar behavior of Kähler magnetic action and volume term predicts this dependence [17]. The p-adic length scale associated with $\Lambda$ should correspond to a ramified prime for the extension of rationals considered.

3. The vanishing condition is especially interesting for space-time surfaces with vanishing induced Kähler form (such as canonically imbedded $M^4$ or its warped (that is flat) variants) or for which Kähler action vanishes (massless extremals). $Re(S) = 0$ would imply $\Lambda = 0$ whereas $Im(S_K) = n \times 2\pi$ condition would trivialize.

   $\Lambda = 0$ could correspond to a limiting situation in which space-time surface can be arbitrary large and perhaps also to the QFT-GRT limit of TGD in cosmological scales. This would justify the earlier model for Robertson-Walker cosmology in terms of cosmological solutions identified as vacuum extremals having vanishing action but failing to be minimal surfaces [12, 10]. Also massless extremals would correspond to extremals for which $\Lambda$ must vanish in accordance with the conformal invariance of these extremals. This picture would be essentially identical with the picture deduced from Kähler action except that now the exponent of action vanishes in good approximation and $\alpha_K$ is determined from quantum criticality.

4. An educated guess is that the values of $1/\alpha_K$ correspond to nontrivial zeros $s = 1/2+iy$ of Riemann zeta of Riemann Zeta [5] . Is this guess consistent with the above proposal? $Re(1/\alpha_K) = 1/2$ implies

that $Im(s)$ does not occur at all in $Re(S) = 0$. This looks natural. The condition $Im(S) = n2\pi$ would state that $S_K$ is equal to

$$S_K = \frac{n \times 8\pi^2}{y} \quad . \tag{3.4}$$

Interestingly, the volume of $CP_2$ equals to $8\pi^2$, using $R$ length $R$ of $CP_2$ geodesic as length unit. The Kähler action for $CP_2$ is proportional to this number. Hence the condition is non-trivial and should follow from the dynamics of minimal surfaces.

These arguments show that the details of the general physical picture are very delicate and require still a lot of distilling. What is however important that the first explicit formula allowing to constrain or even determine the values of $1/\alpha_K$ and $\Lambda$ has emerged and it is interesting to see whether the guess for the values of $1/\alpha_K$ in terms of zeros of Riemann Zeta is consistent with this proposal.

## 3.5 TGD view about inclusions of HFFs as a manner to understand coupling constant evolution

The hierarchy of inclusions of HFFs is an alternative TGD inspired proposal for understanding coupling constant evolution and the intuitive expectation is that the inclusion hierarchies of extensions and their Galois groups contain the inclusion hierarchies of HFFs as special case. The included factor would define measurement resolution in well-defined sense. This notion can be formulated more precisely using Connes tensor product [1, 2].

### 3.5.1 How Galois groups and finite subgroups of could $SU(2)$ relate

The hierarchy of finite groups associated with the inclusions of HFF corresponds to the finite subgroups of $SU(2)$. The set of these groups is very small as compared to the set of Galois groups - if I have understood correctly, any finite group can appear as Galois group. Should the hierarchy of inclusions of HFFs be replaced by much more general inclusion hierarchy? Is there a map projecting Galois groups to discrete subgroup of $SU(2)$?

By $M^8 - H$ duality quaternions appear at $M^8$ level and since $SO(3)$ is the automorphism group of quaternions, the discrete subgroups of $SU(2)$ could appear naturally in TGD. In fact, the appearance of quaternions as a basic building brick of HFFs in the simplest construction would fit with this picture.

It would seem that the elements of the discrete subgroups of $SU(2)$ must be in the extension of rationals considered. The elements of finite discrete subgroups $G$ of $SU(2)$ are expressible in terms of rather small subset of extensions of rationals. Could the proper interpretation be that the hierarchy of extensions defines a hierarchy of discrete groups with elements in extension and the finite discrete subgroups in question are finite discrete subgroups of these groups. There would be correlation with the inclusion and extension. For instance, the fractal dimension of extension is an algebraic number defined in terms of root of unity so that the extension must contain this root of unity.

For icosahedron and dodecahedron the group action can be expressed using extension of rationals by $cos(\pi/n)$ and $sin(\pi/n)$ for $n = 3, 5$. For tetrahedron and cube one would have $n = 2, 3$. For tetrahedon, cube/octahedron and icosahedron basic geometric parameters are also expressible in terms of algebraic numbers in extension but in case of dodecahedron it is not clear for me whether the surface area proportional to $\sqrt{25 + 20\sqrt{5}}$ allows this (see `http://tinyurl.com/p4rwc7`).

It is very feasible that the finite sub-groups of also other Lie groups than $SU(2)$ are associated with the inclusions of HFFs or possibly more general algebras. In particular, finite discrete subgroups of color group $SU(3)$ should be important and extension of rationals should allow to represent these subgroups.

### 3.5.2 Once again about ADE correspondence

For a non-mathematician like me Mc-Kay correspondence is an inspiring and frustrating mystery (see `http://tinyurl.com/y8jzvogn`). What could be its physical interpretation?

Mac-Kay correspondence assigns to the extended Dynkin diagrams of ADE type characterizing Kac-Moody algebras finite subgroups of $SU(2)$. One can assign also to inclusions of HFFs of index $d \geq 4$ with ADE type Dynkin diagrams. To inclusions with index $d < 4$ one can assign subset of ADE type diagrams for Lie groups (rather than Kac-Moody groups) and they correspond to sub-groups of $SU(2)$. The correspondence generalizes to subgroups of other Lie groups.

1. As explained in [3] , for $\mathcal{M} : \mathcal{N} < 4$ one can assign to the inclusion Dynkin graph of ADE type Lie-algebra $g$ with $h$ equal to the Coxeter number $h$ of the Lie algebra given in terms of its dimension and dimension $r$ of Cartan algebra $r$ as $h = (dim(g) - r)/r$. For $\mathcal{M} : \mathcal{N} < 4$ ordinary Dynkin graphs of $D_{2n}$ and $E_6, E_8$ are allowed. The Dynkin graphs of Lie algebras of $SU(n)$, $E_7$ and $D_{2n+1}$ are however not allowed. $E_6, E_7$, and $E_8$ correspond to symmetry groups of tetrahedron, octahedron/cube, and icosahedron/dodecahedron. The group for octahedron/cube is missing: what could this mean?

   For $\mathcal{M} : \mathcal{N} = 4$ one can assign to the inclusion an extended Dynkin graph of type ADE characterizing Kac Moody algebra. Extended ADE diagrams characterize also the subgroups of $SU(2)$ and the interpretation proposed in [2] is following.

   The ADE diagrams are associated with the $n = \infty$ case having $\mathcal{M} : \mathcal{N} \geq 4$. There are diagrams corresponding to infinite subgroups: $A_\infty$ corresponding to $SU(2)$ itself, $A_{-\infty,\infty}$ corresponding to circle group $U(1)$, and infinite dihedral groups (generated by a rotation by a non-rational angle and reflection.

   One can construct also inclusions for which the diagrams corresponding to finite subgroups $G \subset SU(2)$ are extension of $A_n$ for cyclic groups, of $D_n$ dihedral groups, and of $E_n$ with $n = 6, 7, 8$ for tetrahedron, cube, dodecahedron. These extensions correspond to ADE type Kac-Moody algebras.

   The extension is constructed by constructing first factor $R$ as infinite tensor power of $M_2(C)$ (complexified quaternions). Sub-factor $R_0$ consists elements of of $R$ of form $Id \otimes x$. $SU(2)$ preserves $R_0$ and for any subgroup $G$ of $SU(2)$ one can identify the inclusion $N \subset M$ in terms of $N = R_0^G$ and $M = R^G$, where $N = R_0^G$ and $M = R^G$ consists of fixed points of $R_0$ and $R$ under the action of $G$. The principal graph for $N \subset M$ is the extended Coxeter-Dynk graph for the subgroup $G$.

   Physicist might try to interpret this by saying that one considers only sub-algebras $R_0^G$ and $R^G$ of observables invariant under $G$ and obtains extended Dynkin diagram of $G$ defining an ADE type Kac-Moody algebra. Could the condition that Kac-Moody algebra elements with non-vanishing conformal weight annihilate the physical states state that the state is invariant under $R_0$ defining measurement resolution. Besides this the states are also invariant under finite group $G$? Could $R_0^G$ and $R^G$ correspond just to states which are also invariant under finite group $G$.

   Could this kind of inclusions generalize so that Galois groups would replace $G$. If this is possible it would assign to each Galois group an inclusion of HFFs and give a precise number theoretic formulation for the notion of measurement accuracy.

2. At $M^8$-side of $M^8 - H$ duality the construction of space-time surfaces reduces to data at finite set of points of space-time surface since they are defined by an octonionic extension of a polynomial of real variable with coefficients in extension of rationals. Space-time surfaces would have quaternionic tangent space or normal space. The coordinates of quaternions are restricted to extension of rationals and the the subgroup of automorphisms reduce to a subgroup for which matrix elements belong to an extension of rationals.

   If the subgroup is finite, only the subgroups appearing in ADE correspondence are possible and the extension must be such that it allows the representation of this group. Does this mean that the extension can is obtained from an extension allowing this representation? For $\mathcal{M} : \mathcal{N} = 4$ case this sub-group would leave the states invariant.

### 3.6 Entanglement and adelic physics

In the discussion about fine structure constant I asked about the role entanglement in coupling constant evolution. Although entanglement does not have direct relationship to coupling constant evolution, I will discuss entanglement from number theoretic point of view since it enlightens the motivations of adelic physics.

1. For given extension of rationals determining the values of coupling parameters by quantum criticality, the entanglement coefficients between positive and negative energy parts of zero energy states are in the extension of rationals. All entanglement coefficients satisfy this condition.

2. Self the counterpart of observer in the generalization of quantum measurement theory - as conscious entity [21] corresponds to sequence of unitary evolutions followed by weak measurements. The rule for weak measurements is that only state function for which the eigenvalues of the density matrix is in the extension of rationals can occur. In general they are in a higher-D extension as roots of $N$:th order polynomials, $N$ the dimension of density matrix. Therefore state function reduction cannot occur in the generic case. State cannot decohere and entanglement is stable under weak measurements except in special situations when the eigenvalues of density matrix are in original extension.

3. The extension can change only in big state function reductions in which the arrow of clock time changes: this can be seen as an evolutionary step. From the point of view of consciousness theory big state function reduction means what might be called death and reincarnation of system in opposite time direction.

4. The number theoretical stabilization of entanglement at the passive boundary of CD makes possibility quantum computation in longer time scales than possible in standard quantum theory. $h_{eff}/h_0 = n$ equals to the dimension of extension of rationals and is therefore directly related to this.

This could have profound technological implications.

1. Ordinary quantum computation as single unitary step is replaced by a sequence of them followed by the analog of weak measurement.

2. ZEO allows also quantum computations in opposite time direction. This might allow shorten dramatically the duration of quantum computations from the perspective of the observed since most of the computation could be done with opposite arrow of clock time.

   The philosophy of adelic physics is discussed in article in book published by Springer [20, 19] (see `http://tinyurl.com/ybzkfevz` and `http://tinyurl.com/ybqpkwg9`).

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