Is the hierarchy of Planck constants behind the reported variation of Newton's constant?

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Abstract

It has been known for long time that the measurements of G give differing results with differences between measurements larger than the measurement accuracy. This suggests that there might be some new physics involved. In TGD framework the hierarchy of Planck constants $h_{eff} = nh_0$, $h = 6h_0$ together with the condition that theory contains CP_2 size scale R as only fundamental length scale, suggest the possibility that Newtons constant is given by $G = R^2/\hbar_{eff}$, where R replaces Planck length ($l_P = \sqrt{\hbar G} \rightarrow l_P = R$) and $\hbar_{eff}/h$ is in the range $10^6 - 10^7$. The spectrum of Newton' constant is consistent with Newton's equations if the scaling of $\hbar_{eff}$ inducing scaling G is accompanied by opposite scaling of M^4 coordinates in $M^4 \times CP_2$: dark matter hierarchy would correspond to discrete hierarchy of scales given by breaking of scale invariance. In the special case $h_{eff} = h_{gr} = GMm/v0$ quantum critical dynamics as gravitational fine structure constant $(v_0/c)/4\pi$ as coupling constant and it has no dependence of the value of G or masses M and m.

In this article I consider a possible interpretation for the finding of a Chinese research group measuring two different values of G differing by 47 ppm in terms of varying h_{eff}. Also a model for fountain effect of superfluidity as de-localization of wave function and increase of the maximal height of vertical orbit due to the change of the gravitational acceleration g at surface of Earth induced by a change of h_{eff} due to super-fluidity is discussed. Also Podkletnov effect is considered. TGD inspired theory of consciousness allows to speculate about levitation experiences possibly induced by the modification of G_{eff} at the flux tubes for some part of the magnetic body accompanying biological body in TGD based quantum biology.

Contents

1 Introduction

Nowadays it is fantastic to be a theoretical physicists with a predictive theory. Every week I get from FB links to fascinating experimental findings crying for explanation (I am grateful for people providing these links). The last link of this kind was to a popular article (see `http://tinyurl.com/ya2wekch`) telling about the article [E4] (see `http://tinyurl.com/yanvzxj6`) reporting measurements of Newton's constant G carried out by Chinese physicists Shan-Qing Yang, Cheng-Gang Shao, Jun Luo and colleagues at the Huazhong University of Science and Technology and other institutes in China and Russia. The outcomes of two experiments using different methods differ more than the uncertainties in the experiments, which forces to consider the possibility that G can vary.

1.1 The experiments

The experiments use torsion pendulum: this method was introduced by Henry Cavendish in 1978.

Remark: A remark about terminology is in order. Torque $\tau = F\times r$ on particle has dimensions Nm. Torsion (see `http://tinyurl.com/q8esymu`) in solid is essentially the density of torque per volume and has dimensions N/m^2. Twist angle is induced by torsion in equilibrium. The situation is governed by the theory of elasticity.

Basically one has torsion balance in which the gravitational torque produced by two source masses on masses associated with a torsion pendulum - dumbbell shaped system having identical masses at the ends of a bar and hanging from a thread at the middle point of the bar. As the source masses are rotated a twist of the thread emerges and twist angle corresponds to an equilibrium in which the torsion of the thread compensates the torque produced by gravitational interaction with source masses. Cavendish achieved 1 per cent accuracy in his measurements.

Refined variations of these measurements have been developed during years and the current precision is 47 parts per million (ppm). In some individual experiments the precision is 13.7 ppm. Disagreements larger than 500 ppm are reported, which suggests that new physics might be involved.

The latest experiments were made by the above mentioned research group. Two methods are used. TOS (Time Of Swing) and AAF (Angular Acceleration Feedback). AAF results deviates from the accepted value whereas TOS agrees. The accuracies were 11.64 ppm and 11.61 ppm in TOS and AAF respectively. AAF however gave by 45 ppm larger value of G.

In TOS technique the pendulum oscillates. The frequency of oscillation is determined by the positions of the external masses and G can be deduced by comparing frequencies for two different mass configurations. There are two equilibrium positions. The pendulum is either parallel to the line connecting masses relatively near to each other ("near" position). The pendulum orthogonal to the line connecting masses in "far" position. By measuring the different oscillation frequencies one can deduce the value of G.

Angular-acceleration feedback (AAF) method involves rotating the external masses and the pendulum on two separate turn tables. Twist angle is kept zero by changing the angular velocity of the other turn table: thus feedback is involved. If I have understood correctly, the torsion induced by gravitational torque compensates the torsion created by twisting of the thread around its axis in opposite direction and from the value of torsion for zero twist angle one deduces G. One could perhaps say that in AAF torsion is applied actively whereas in TOS it appears as reaction.

Why the measured value obtained for G would be larger for AAF? Could the active torsion inducing compensating twisting of the torsion pendulum actually increase G?

In TGD framework the hierarchy of Planck constants $h_{eff} = nh_0$, $h = 6h_0$ together with the condition that theory contains CP_2 size scale R as only fundamental length scale, suggest the possibility that Newtons constant is given by $G = R^2/\hbar_{eff}$, where R replaces Planck length ($l_P = \sqrt{\hbar G} \to l_P = R$) and $\hbar_{eff}/h$ is in the range $10^6 - 10^7$. The spectrum of Newton' constant is consistent with Newton's equations if the scaling of $\hbar_{eff}$ inducing scaling G is accompanied by opposite scaling of M^4 coordinates in $M^4 \times CP_2$: dark matter hierarchy would correspond to discrete hierarchy of scales given by breaking of a continuous scale invariance to a discrete one.

In the special case $h_{eff} = h_{gr} = GMm/v0$ - gravitational Planck constant originally introduced by Nottale [E1]- assignable to quantum critical dynamics gravitational fine structure constant $\alpha_{gr} = GMm/(4\pi\hbar_{gr}) = (v_0/c)/4\pi$ serves as coupling constant and has no dependence of the value of G or masses M and m in accordance with the universality of quantum critical dynamics.

In this article I consider a possible interpretation for the finding of a Chinese research group measuring two different values of G differing by 47 ppm in terms of varying h_{eff}. Also a model for fountain effect of superfluidity as de-localization of wave function and increase of the maximal height of vertical orbit due to the change of the gravitational acceleration g at surface of Earth induced by a change of h_{eff} due to super-fluidity is discussed. Also Podkletnov effect is considered. TGD inspired theory of consciousness allows to speculate about levitation experiences possibly induced by the modification of G_{eff} at the flux tubes for some part of the magnetic body accompanying biological body in TGD based quantum biology.

2 TGD based explanation of the variability of G

Some time ago I added a piece to an article telling about change in my view about Planck length [L10] (see `http://tinyurl.com/yclefxb2`). In TGD hierarchy of Planck constants is predicted: $\hbar_{eff} = nh_0$ is integer multiple of $h_0 = h/6$. During writing this, it became clear that h_0 need not be minimal value h_{min} of h_{eff} as I have assumed for some time. Tthe first guess was that h is the minimal value $h = 6h_0$ is suggested by some experimental findings and applications [L4, L11, L12]). One can even challenge the assumption h_0 is the minimal value.

This suggests also a hierarchy of Newton's constants $G_{eff} = l_P^2/\hbar_{eff}$ as subharmonics of l_P^2, where Planck length l_P is now re-identified as $l_P = R$, where R is CP$_2$ "radius", which for $G_{eff} = G$ is about $10^{3.5}$ larger than ordinary Planck length $l_P = \sqrt{\hbar G}$. The corresponding value of $\hbar_{eff}$, call it $\hbar_{eff}(gr)$, would be $\hbar_{eff}(gr)/h_{min} \simeq 2^{24}$.

Remark: This raises a problem to be discussed in the application to fountain effect. $h_{eff}(gr)$ is by factor of order 2^{24} larger than h, which looks strange since it would involve a de-localization of wave function to 2^{24} larger scale.

2.1 The explanation of the variation of G in terms of hierarchy of Newton's constants

Could the variation of G - or better to call it G_{eff} - correspond to a variation of $h_{eff}/h = n$ in G_{eff}? Newton's constant for dark matter would be different from that for ordinary matter and vary in huge limits.

1. This looks non-sensical at first but would guarantee that one can scale up the solutions to Newton's equations by $h_{eff}/\hbar$ by scaling lengths by $n/n_0 = n/6$: one would have thus scaling symmetry scaling also G_{eff} as is natural since it is dimensional parameter. Dark matter would be in rather precise sense zoomed up variants of ordinary matter and n would label the possible zoom ups.

2. h_{eff} has spectrum and as a special case one has $\hbar_{eff} = h_{gr} = GMm/v_0$. Is this case case the gravitational coupling become $G_{eff}Mm = v_0$ and does not depend on masses or G at all. In quantum scattering amplitudes a dimensionless parameter $(1/4\pi)v_0/c$ would appear in the role of gravitational fine structure constant and would be obtained from $\hbar_{eff} = h_{gr} = GMm/v_0$ consistent with Equivalence Principle. The miracle would be that G_{eff} would disappear totally from the perturbative expansion in terms of GMm as one finds by looking what $\alpha_{gr} = GMm/\hbar_{gr}$ is! This picture would work when GMm is larger than perturbative

expansion fails to converge. For Mm above Planck mass squared this is expected to be the case. What happens below this limit is yet unclear (n is integer).

Could v_0 be fundamental coupling constant running only mildly? This does not seem to be the case: Nottale's original work proposing $\hbar_{gr}$ proposes that v_0 for outer planets is by factor 1/5 smaller than for the inner planets [K2, K4].

3. This picture works also for other interactions [?] Quite generally, nature would be theoretician friendly and induce a phase transition increasing $\hbar$ when the coupling strength exceeds the value below which perturbation series converges so that perturbation series converges. In adelic physics this would mean increase of the algebraic complexity since $h_{eff}/h = n$ is the dimension of extension of rationals inducing the extensions of various p-adic number fields and defining the particular level in the adelic hierarchy [L7, L8]. The parameters characterizing space-time surfaces as preferred extremals of the action principle would be numbers in this extension of rationals so that the phase transition would have a well-defined mathematical meaning. In TGD the extensions of rationals would label different quantum critical phases in which coupling constants would not run so that coupling constant evolution would be discrete as function of the extension.

4. This vision allows also to understand discrete coupling constant evolution replacing continuous coupling constant evolution of quantum field theories as being forced by the convergence of perturbation expansion and induced by the evolution defined by the hierarchy of extensions of rationals. When convergence is lost, a phase transition increasing algebraic complexity takes place and increases n. Extensions of rationals have also other characteristics than the dimension n.

   For instance, each extension is characterized by ramified primes and the the proposal is that favoured p-adic primes assignable to cognition and also to elementary particles and physics in general correspond to so called ramified primes analogous to multiple zeros of polynomials. Therefore number theoretic evolution would also give rise to p-adic evolution as analog of ordinary coupling constant evolution with length scale.

   At quantum criticality coupling constant evolution is trivial and in QFT context this would mean that loops vanish separately or at least they sum up to zero for the critical values of coupling constants. This argument however seems to make the whole argument about convergence of coupling constant expansion obsolete unless one allows only the quantum critical values of coupling constants guaranteeing that quantum TGD is quantum critical. There are strong reasons to believe that the TGD analog of twistor diagrammatics involves only tree diagrams and there are strong number theoretic argument for this: infinite sum of diagrams does not in general give a number in given extension of rationals. Quantum criticality would be forced by number theory.

5. This would solve a really big conceptual problem, which I did not realize as I discovered the twistor lift of TGD making the choice $M^4 \times CP_2$ unique [K7, K8] [L10]. The usual Planck length $l_P = \sqrt{\hbar G}$ as the radius of the M^4 twistor sphere would separate length scale from CP_2 scale R it is not a coupling constant like parameter and quantum criticality does not allow even in principle its understanding. The presence of two separate fundamental length scales in a theory intended to be unification does simply not make sense.

The variability of G with $\hbar_{eff}$ could explain the variation of G in various experiments since for gravitational flux tubes $\hbar_{eff}/\hbar \sim 10^7$ would be true. The smallest variation would be of order 10^{-7} as n varies by one unit. This is a testable prediction (see `http://tinyurl.com/yclefxb2`).

As already explained, the maximum for the variation of G is 500 ppm $= 5 \times 10^{-4}$. This would correspond to $\Delta n \sim 5 \times 10^3$. The difference between TOS and AAF is 47 ppm and would correspond to $\Delta n \sim 470$. The variation could be also due to a small variation, say $k \to k+1$, for a prime factor k of n. 47 ppm would give $k \simeq 2,128$. For $k = 2^{11} \to k-1$ in TOS to AAF and favored by number theoretic considerations would give $\Delta k/k = 49$ ppm.

Why small variations for the factors of n would be favored? If one assumes that number theoretical evolution corresponds to the increasing order of the Galois group such that the new Galois group contains the earlier Galois group as a subgroup (this would serve as an analogy for conserved genes in biological evolution). Larger Galois groups would naturally contain the "standard" Galois group associated with N as a sub-group. From number theoretic point of view the proposal $\hbar_{eff}/\hbar = N = 2^{24}$ is perhaps the simplest one since all Galois groups appearing as its sub-groups would have order with is 6×2^k for $h = 6h_0$. Larger values of $h_{eff}/\hbar$ should have N as a factor.

Why the presence of of the feedback torque on the torsion pendulum would reduce the value of $\hbar_{eff}/h = n$ by about 5×10^3 units in AAF for the gravitational flux tubes connecting the source masses to the masses of torsion pendulum from that in TOS? Somehow the value of h_{eff} should be reduced.

2.2 A little digression: Galois groups and genes

As found, the question about possible variations of G_{eff}, leads to the idea that subgroups of Galois group could be analogous to conserved genes in that they could be conserved in number theoretic evolution. In small variations such as above variation Galois subgroups as genes would change only a little bit. For instance, the dimension of Galois subgroup would change.

The analogy between subgoups of Galois groups and genes goes also in other direction. I have proposed long time ago that genes (or maybe even DNA codons) could be labelled by $h_{eff}/h = n$. This would mean that genes (or even codons) are labelled by a Galois group of Galois extension (see `http://tinyurl.com/zu5ey96`) of rationals with dimension n defining the number of sheets of space-time surface as covering space. This could give a concrete dynamical and geometric meaning for the notin of gene and it might be possible some day to understand why given gene correlates with particular function. This is of course one of the big problems of biology.

One should have some kind of procedure giving rise to hierarchies of Galois groups assignable to genes. One would also like to assign to letter, codon and gene and extension of rationals and its Galois group. The natural starting point would be a sequence of so called intermediate Galois extensions E^H leading from rationals or some extension K of rationals to the final extension E. Galois extension has the property that if a polynomial with coefficients in K has single root in E, also other roots are in E meaning that the polynomial with coefficients K factorizes into a product of linear polynomials. For Galois extensions the defining polynomials are irreducible so that they do not reduce to a product of polynomials.

Any sub-group $H \subset Gal(E/K))$ leaves the intermediate extension E^H invariant in element-wise manner as a sub-field of E (see `http://tinyurl.com/y958drcy`). Any subgroup $H \subset Gal(E/K))$ defines an intermediate extension E^H and subgroup $H_1 \subset H_2 \subset ...$ define a hierarchy of extensions $E^{H_1} > E^{H_2} > E^{H_3}...$ with decreasing dimension. The subgroups H are normal - in other words $Gal(E)$ leaves them invariant and $Gal(E)/H$ is group. The order $|H|$ is the dimension of E as an extension of E^H. This is a highly non-trivial piece of information. The dimension of E factorizes to a product $\prod_i |H_i|$ of dimensions for a sequence of groups H_i.

Could a sequence of DNA letters/codons somehow define a sequence of extensions? Could one assign to a given letter/codon a definite group H_i so that a sequence of letters/codons would correspond a product of some kind for these groups or should one be satisfied only with the assignment of a standard kind of extension to a letter/codon?

Irreducible polynomials define Galois extensions and one should understand what happens to an irreducible polynomial of an extension E^H in a further extension to E. The degree of E^H increases by a factor, which is dimension of E/E^H and also the dimension of H. Is there a standard manner to construct irreducible extensions of this kind?

1. What comes into mathematically uneducated mind of physicist is the functional decomposition $P^{m+n}(x) = P^m(P^n(x))$ of polynomials assignable to sub-units (letters/codons/genes) with coefficients in K for a algebraic counterpart for the product of sub-units. $P^m(P^n(x))$ would be a polynomial of degree $n+m$ in K and polynomial of degree m in E^H and one could assign to a given gene a fixed polynomial obtained as an iterated function composition. Intuitively it seems clear that in the generic case $P^m(P^n(x))$ does not decompose to a product of lower order polynomials. One could use also polynomials assignable to codons or letters as basic units. Also polynomials of genes could be fused in the same manner.

2. If this indeed gives a Galois extension, the dimension m of the intermediate extension should be same as the order of its Galois group. Composition would be non-commutative but

associative as the physical picture demands. The longer the gene, the higher the algebraic complexity would be. Could functional decomposition define the rule for who extensions and Galois groups correspond to genes? Very naively, functional decomposition in mathematical sense would correspond to composition of functions in biological sense.

3. This picture would conform with $M^8 - M^4 \times CP_2$ correspondence [L6] in which the construction of space-time surface at level of M^8 reduces to the construction of zero loci of polynomials of octonions, with rational coefficients. DNA letters, codons, and genes would correspond to polynomials of this kind.

Could one say anything about the Galois groups of DNA letters?

1. Since $n = h_{eff}/h$ serves as a kind of quantum IQ, and since molecular structures consisting of large number of particles are very complex, one could argue that n for DNA or its dark variant realized as dark proton sequences can be rather large and depend on the evolutionary level of organism and even the type of cell (neuron viz. soma cell). On the other, hand one could argue that in some sense DNA, which is often thought as information processor, could be analogous to an integrable quantum field theory and be solvable in some sense. Notice also that one can start from a background defined by given extension K of rationals and consider polynomials with coefficients in K. Under some conditions situation could be like that for rationals.

2. The simplest guess would be that the 4 DNA letters correspond to 4 non-trivial finite groups with smaller possible orders: the cyclic groups Z_2, Z_3 with orders 2 and 3 plus 2 finite groups of order 4 (see the table of finite groups in `http://tinyurl.com/j8d5uyh`). The groups of order 4 are cyclic group $Z_4 = Z_2 \times Z_2$ and Klein group $Z_2 \oplus Z_2$ acting as a symmetry group of rectangle that is not square - its elements have square equal to unit element. All these 4 groups are Abelian. Polynomial equations of degree not larger than 4 can be solved exactly in the sense that one can write their roots in terms of radicals.

3. Could there exist some kind of connection between the number 4 of DNA letters and 4 polynomials of degree less than 5 for whose roots one an write closed expressions in terms of radicals as Galois found? Could it be that the polynomials obtained by a a repeated functional composition of the polynomials of DNA letters have also this solvability property?

   This could be the case! Galois theory states that the roots of polynomial are solvable by radicals if and only if the Galois group is solvable meaning that it can be constructed from abelian groups using Abelian extensions (see `https://en.wikipedia.org/wiki/Solvable_group`).

   Solvability translates to a statement that the group allows so called sub-normal series $1 < G_0 < G_1 ... < G_k$ such that G_{j-1} is normal subgroup of G_j and G_j/G_{j-1} is an abelian group. An equivalent condition is that the derived series $G \triangleright G^{(1)} \triangleright G^{(2)} \triangleright ...$ in which $j+1$:th group is commutator group of G_j ends to trivial group. If one constructs the iterated polynomials by using only the 4 polynomials with Abelian Galois groups, the intuition of physicist suggests that the solvability condition is guaranteed! Wikipedia article also informs that for finite groups solvable group is a group whose composition series has only factors which are cyclic groups of prime order.

   Abelian groups are trivially solvable, nilpotent groups are solvable, p-groups (having order, which is power prime) are solvable and all finite p-groups are nilpotent. Every group with order less than 60 elements is solvable. Fourth order polynomials can have at most S_4 with 24 elements as Galois groups and are thus solvable. Fifth order polynomials can have the smallest non-solvable group, which is alternating group A_5 with 60 elements as Galois group and in this case are not solvable. S_n is not solvable for $n > 4$ and by the finding that S_n as Galois group is favored by its special properties (see `https://arxiv.org/pdf/1511.06446.pdf`).

   A_5 acts as the group icosahedral orientation preserving isometries (rotations). Icosahedron and tetrahedron glued to it along one triangular face play a key role in TGD inspired model of bio-harmony and of genetic code [L1, L14]. The gluing of tetrahedron increases the number of codons from 60 to 64. The gluing of tetrahedron to icosahedron also reduces the order of isometry group to the rotations leaving the common face fixed and makes it solvable: could this explain why the ugly looking gluing of tetrahedron to icosahedron is needed? Could the smallest solvable groups and smallest non-solvable group be crucial for understanding the number theory of the genetic code.

An interesting question inspired by M^8-H-duality [L6] is whether the solvability could be posed on octonionic polynomials as a condition guaranteeing that TGD is integrable theory in number theoretical sense or perhaps following from the conditions posed on the octonionic polynomials. Space-time surfaces in M^8 would correspond to zero loci of real/imaginary parts (in quaternionic sense) for octonionic polynomials obtained from rational polynomials by analytic continuation. Could solvability relate to the condition guaranteeing M^8 duality boiling down to the condition that the tangent spaces of space-time surface are labelled by points of CP_2. This requires that tangent or normal space is associative (quaternionic) and that it contains fixed complex sub-space of octonions or perhaps more generally, there exists an integrable distribution of complex subspaces of octonions defining an analog of string world sheet.

2.3 Does fountain effect involve non-standard value of G?

Deviations in the value of G are not new, and I have written about several gravitational anomalies. This could mean also anti-gravity effects in a well-defined sense which is however not the same as often thought (negative gravitational masses or repulsive gravitational force).

In particular, there is well-known fountain effect (`http://tinyurl.com/kx3t52r`) in superfluidity in which superfluid seems to defy gravitation. I have proposed that $h_{eff}/h = n$ increases at superfluid flux tubes to h_{gr} and this gives to the effect as a de-localition in much longer scale [K3]. If also G is reduced so that the effect would be possible also classically? Since in superfluidity one has h_{eff} larger than usually, this might happen if gravitons travel also along flux tubes at which super fluid flows. This would change the earlier quantum estimates: in Schrödinger equation kinetic term scales up like $(h_{eff}/h)^2$ as before but gravitational potential of Earth would now scaled down like h/h_{eff}.

A simple model for the situation discussed in [K3] would rely on Schrödinger equation at the flux quantum which is locally a thin hollow cylinder turning around at the top of the wall of the container. In the following a slightly modified discussing replacing the gravitational acceleration g at surface of Earth with g_{eff}

1. One obtains 1-dimensional Schrödinger equation

$$(-\frac{\hbar_{eff}^2\partial_z^2}{2m} + mg_{eff}z)\Psi = E\Psi \quad , \quad h_{eff} = nh_0 = \frac{nh}{6} \quad . \tag{2.1}$$

   It is easy to see that the energy spectrum is invariant under the scaling $h \rightarrow h_{eff} = xh$ and $z \rightarrow z/x$. One has $\Psi_{xh,g_{eff}=g/x}(z) = \Psi_{h,g}(z/x)$ so that simple scaling of the argument z in question. The energy of the solution is same. If the ordinary solution has size scale L, the scaled up solution has size scale xL.

   The height for a trajectory in gravitational field of Earth is scaled up for a given initial vertical velocity v_i is scaled as $h \rightarrow xh$ so quantum behavior corresponds to the classical behavior and de-localization scale is scaled up. Could this happen at various layers of magnetic body for dark particles so that they would be naturally at much higher heights. Cell scale would be scaled to Earth size scale of even larger sizes for the values of $\hbar_{eff}/h = n$ involved.

   For classical solution with initial initial vertical velocity $v_i = 1$ m/s the height of the upwards trajectory is $h = v_i^2/2g$ 5 cm. Quantum classical correspondence would be given by $E = mv_i^2/2 = E$ and this allows to look the delocalization scale of a solution.

2. One can introduce the dimensionless variable

$$u = \frac{z - \frac{E}{mg_{eff}}}{z_0} \quad , \qquad z_0 = \left[\frac{2m^2 g_{eff}}{\hbar_{eff}^2}\right]^{-1/3} = \frac{n}{6}(\frac{h_{eff}(gr)}{h_{eff}})^{1/3}(\frac{m}{m_p})^{1/3}x \times \frac{\hbar c}{m_p} \quad ,$$
$$\frac{\hbar c}{m_p} = \frac{L_p}{2\pi} \simeq .38 \times 10^{-12}\ \mathrm{m} \quad , \quad x = (\frac{m_p c^3}{\hbar g})^{1/3} \simeq 1.5 \times 10^{10} \quad . \tag{2.2}$$

Here m_p denotes proton mass and L_p proton Compton length. z_0 scales as $\hbar_{eff}$ as one might expect. z_0 characterizes roughly the scale of the solution.

This allows to cast the equation to the standard form of the equation for Airy functions encountered in WKB approximation

$$-\frac{d^2\Psi}{du^2} + u\Psi = 0 \ . \tag{2.3}$$

Remark: Note that the classical solution depends on m. In central force problem with $1/r$ and $h_{eff} = GMm/v_0$ the binding energy spectrum $E = E_0/n^2$ has scale $E_0 = v_0^2 m$ and is universal.

3. The interesting solutions correspond to Airy functions $Ai(u)$ which approach rapidly zero for the values of $u > 1$ and oscillate for negative values of u. These functions $Ai(u + u_1)$ are orthogonal for different values of u_1. The values of u_1 correspond to different initial kinetic energies for the motion in vertical direction. In the recent situation these energies correspond to the initial vertical velocities of the super-fluid in the film. $u = u_0 = 1$ defines a convenient estimate for the value of z coordinate above which wave function approaches rapidly to zero.

   For classical solution with initial initial vertical velocity $v_i = 1$ m/s the height of the upwards trajectory is $h = v_i^2/2g$ 5 cm. Quantum classical correspondence would be given by $E = mv_i^2/2 = E$ and this allows to look the delocalization scale of a solution.

   The Airy function $Ai(u)$ approaches rapidly to zero (see the graph of `https://en.wikipedia.org/wiki/Airy_function`) and one can say that above $u_0 = 3$ the function vanishes. Already at $u_0 = 1$ wave function is rather small as compared with its value at $u = 0$. This condition translates to a condition for z as

$$z_0 = z_{cl} + u_0 z_0 \ \ , \quad z_{cl} = \frac{E}{mg_{eff}} \ \ , \quad z_0 = \frac{h_{eff}}{h}\left[\frac{\hbar^2}{2m^2 g}\right]^{1/3} \ . \tag{2.4}$$

   The condition is consistent with the classical picture and the classical height z_{cl} scales like h_{eff}/h. The parameter $u_0 z_0$ defines the de-localization scale consistent with the expectations. Below z_{cl} the wave function oscillates which intuitively corresponds to the sum of waves in upwards and downwards directions.

This picture however leads to an objection.

1. If one has $\hbar_{eff}(gr)/\hbar \simeq 2^{24}$ at the flux tubes mediating gravitational interaction for the ordinary value of g (the estimates for $R^2\hbar/G$ are within range $10^6 - 10^7$), one can argue that one must use this value of $\hbar$ in the Schrödinger equation for a particle in the gravitational field of Earth. One would have $z_0 \simeq 2^{-8} \times 250$ m. This is much larger than the value $z_0 \simeq 5.7$ mm for $\hbar$ and the high value might be excluded already by the existing data for neutron's behavior in Earth's gravitational field. This values is also higher than the de-localization scale of order 1 meter in fountain effect.

2. If one assumes $h_{eff} = h$ and scaled up value of g corresponding to $G_{eff} = R^2/\hbar$, one obtains scaling of z_0 by $(h/\hbar_{eff}(gr))^{1/3} \simeq 2^{-8}$ giving $z_0 \simeq .2$ mm from the previous equation - note however the dependence on E. This could correspond to the ordinary situation. At electromagnetic flux tubes h_{eff} would be smaller and also G_{eff} considerably smaller as the radially symmetric stationary extremals studied during eighties indeed suggested. The increased gravitation would be masked by much stronger electromagnetic interaction so that the testing of this prediction is difficult. At gravitational flux tubes one would have a spectrum of values and h_{gr} might represent the upper bound at quantum criticality for which the dependence of scattering amplitudes on masses disappears. $\hbar_{eff}(gr)$ would correspond to the measured valued of $G_{eff} = G$.

Remark: One can of course ask whether $h_0 = h/6$ indeed represents the minimal value of h_{eff}. In principle one can also consider smaller values $\hbar/k$ and this would give rise to $G_{eff} = kR^2$ with a shorter de-localization scale.

It seems that one must assume accept G_{eff} is indeed different for different flux tubes.

1. For proton mass $m = m_p$, $h_{eff} = h$, and $g_{eff} = 2^{24}g$ one would have $z_0 \simeq .2$ mm as one finds from the previous equation. $h_{eff}/h_{eff}(gr) = 2^{12}$ would give $z_0 \simeq 89.1$ cm, which makes sense for fountain effect. The value $h_{eff}/h = 2^{36}$ looks quite conceivable at flux tubes mediating electromagnetic interaction and carrying suprafluid flow. I have considered years ago the hypothesis that h_{eff}/h could come as powers of 2^{11}. Note that the estimate $v_0 \simeq 2^{-11}$ is also power of 2 so that powers of 2 are suggestive.

2. $\hbar_{eff} = \hbar_{gr} = GM_D m/v_0$ corresponds to a large value of h_{eff} and might be assignable to flux tubes mediating dark part of gravitational interaction

$$z_0 = \frac{c}{v_0}\frac{r_S}{2}\frac{M_D}{M_E}(\frac{m}{m_p})^{1/3} \quad , \quad x = (\frac{m_p c^3}{\hbar g})^{1/3} \simeq 1.5\times 10^{10} \quad , \quad r_S = 2GM_E \simeq 9 \text{ mm} \quad .$$

   More concretely:

$$z_0 \simeq \frac{M_D}{M_E}\times 6\times 10^7 \text{ km} \quad .$$

   The estimate for M_D/M_E is $M_D/M_E \sim 10^{-4}$. An open question is whether M_D should be interpreted as dark mass or whether one should interpret M_D/M_E as a mere parameterization for $\hbar_{eff} = (n/6)\hbar$ as $\hbar_{eff} = (M_D/M_E)\hbar_{gr}$. z_0 characterizes the de-localization scale for the solutions. It is clear that this scale is many orders of magnitudes larger than the de-localization scale about 1 m for superfluids.

2.4 Does Podkletnov effect involve non-standard value of G?

Podkletnov observed [H1] at eighties a few percent reduction of gravity: he immediately lost his job in Tampere University in Finland. It was regarded as a scandalous event. Something new might have been discovered in finnish laboratory!

I have considered a possible mechanism explaining the finding of Podkletnov [L2]. One could however ask whether the presence of superconductor involving also presence of phase with non-standard value of Planck constant could also affect the value of h_{eff} assignable to the flux tubes of the Kähler magnetic field mediating Earth's gravitational flux? The mechanism would be same as in fountain effect. The change $\Delta g_{eff}/g$ from the normal value would have been few per cent in this case.

2.5 Did LIGO observe non-standard value of G and are galactic blackholes really supermassive?

Also smaller values of G than the G_N are possible and in fact, in condensed matter scales it is quite possible that $n = R^2/G$ is rather small. Gravitation would be stronger but very difficult to detect in these scales. Neutron in the gravitational field of Earth might provide a possible test. The general rule would be that the smaller the scale of dark matter dynamics, the larger the value of G and maximum value would be $G_{max} = R^2/h_0$, $h = 6h_0$.

2.5.1 Are the blackholes detected by LIGO really so massive?

LIGO (see `http://tinyurl.com/bszfs29`) has hitherto observed 3 fusions of black holes giving rise to gravitational waves. For TGD view about the findings of LIGO see [L5, L3] (see `http://tinyurl.com/y79yqw6q` and `http://tinyurl.com/ya8ctxgc`). The colliding blackholes were deduced to have unexpectedly larger large masses: something like 10-40 solar masses, which is regarded as something rather strange.

Could it be that the masses were actually of the order of solar mass and G was actually larger by this factor and h_{eff} smaller by this factor? The mass of the colliding blackholes could be of order solar mass and G would larger than its normal value - say by a factor in the range (10,50). If so, LIGO observations would represent the first evidence for TGD view about quantum gravitation, which is very different from superstring based view. The fourth fusion was for neutron stars rather than black holes and stars had mass of order solar mass.

This idea works if the physics of gravitating system depends only on $G(M+m)$. That classical dynamics depends on $G(M+m)$ only, follows from Equivalence Principle. But is this true also for gravitational radiation? If the power of gravitational radiation distinguishes between different values of M when GM is kept constant, the idea is dead.

1. If the power of gravitational radiation distinguishes between different values of M+m, when $G(M+m)$ is kept constant, the idea is dead. This seems to be the case. The dependence on $G(M+m)$ only leads to contradiction at the limit when M+m approaches zero and $G(M+m)$ is fixed. The reason is that the energy emitted per single period of rotation would be larger than M+m. The natural expectation is that the radiated power per cycle and per mass M+m depends on $G(M+m)$ only as a dimensionless quantity.

2. From arXiv one can find an article (see `http://tinyurl.com/y99j3fpr`) in which the energy per unit solid angled and frequency radiated in collision of blackholes is estimated. The outcome is proportional to $E^2G(M+m)^2$, where E is the energy of the colliding blackhole.

   The result is proportional mass squared measured in units of Planck mass squared as one might indeed naively expect since $G(M+m)^2$ is analogous to the total gravitational charge squared measured using Planck mass.

   The proportionality to E^2 comes from the condition that dimensions come out correctly. Therefore the scaling of G upwards would reduce mass and the power of gravitational radiation would be reduced down like $M+m$. The power per unit mass depends on $G(M+m)$ only. Gravitational radiation allows to distinguish between two systems with the same Schwartschild radius, although the classical dynamics does not allow this.

3. One can express the classical gravitational energy E as gravitational potential energy proportional to GM/R This gives only dependence on GM as also Equivalence Principle for classical dynamics requires and for the collisions of blackholes R is measured by using $G(M+m)$ as a natural unit.

Remark: The calculation uses the notion of energym which in general relativity is precisely defined only for stationary solutions. Radiation spoils the stationarity. The calculations of the radiation power in GRT is to some degree artwork feeding in the classical conservation laws in post-Newtonian approximation lost in GRT. In TGD framework the conservation laws are not lost and hold true at the level of $M^4 \times CP_2$.

2.5.2 What about supermassive galactive blacholes?

What about supermassive galactic black holes in the centers of galaxies: are they really supermassive or is G super-large! The mass of Milky Way super-massive blackhole is in the range $10^5 - 10^9$ solar masses. Geometric mean is $n = 10^7$ solar masses and of the order of the standard value of $R^2/G_N = n \sim 10^7$. Could one think that this blackhole has actually mass in the range 1-100 solar masses and assignable to an intersection of galactic cosmic string with itself! How galactic blackholes are formed is not well understood. Now this problem would disappear. Galactic blackholes would be there from the beginning!

The general conclusion is that only gravitational radiation allows to distinguish between different masses $M+m$ for given $G(M+m)$ in a system consisting of two masses so that classically scaling the opposite scalings of G and $M+m$ is a symmetry.

2.6 Is it possible to determine experimentally whether gravitation is quantal interaction?

Marletto and Vedral have proposed an interesting method for measuring whether gravitation is quantal interaction (see `https://arxiv.org/pdf/1707.06036.pdf`).

I tried to understand what the proposal suggests and how it translates to TGD language.

1. If gravitational field is quantum it makes possible entanglement between two states. This is the intuitive idea but what it means in TGD picture? Feynman interpreted this as entanglement of gravitational field of an objects with the state of object. If object is in a state, which is superposition of states localized at two different points x_i, the classical gravitational fields ϕ_{gr} are different and one has a superposition of states with different locations

$$|I\rangle = \sum_{i=1,2} |m_i \ at \ x_i > |\phi_{gr,x_i}\rangle \equiv |L\rangle + |R\rangle \ .$$

2. Put two such de-localized states with masses m_i at some distance d to get state $|1\rangle|2\rangle$, $|i\rangle = |L\rangle_i + |R\rangle >_i$. The 4 components pairs of the states interact gravitationally and since there are different gravitational fields between different states the states get different phases, one can obtain entangled state.

   Gravitational field would entangle the masses. If one integrates over the degrees of freedom associated with gravitational field one obtains density matrix and the density matrix is not pure if gravitational field is quantum in the sense that it entangles with the particle position.

   That gravitation is able to entangle the masses would be a proof for the quantum nature of gravitational field. It is not however easy to detect this. If gravitation only serves as a parameter in the interaction Hamiltonian of the two masses, entanglement can be generated but does not prove that gravitational interaction is quantal. It is required that the only interaction between the systems is gravitational so that other interactions do not generate entanglement. Certainly, one should use masses having no em charges.

3. In TGD framework the view of Feynman is natural. One has superposition of space-time surfaces representing this situation. Gravitational field of particle is associated with the magnetic body of particle represented as 4-surface and superposition corresponds to a delocalized quantum state in the "world of classical worlds" with x_i representing particular WCW coordinates.

I am not specialist in quantum information theory nor as quantum gravity experimentalist, and hereafter I must proceed keeping fingers crossed and I can only hope that I have understood correctly. To my best understanding, the general idea of the experiment would be to use interferometer to detect phase differences generated by gravitational interaction and inducing the entanglement. Not for photons but for gravitationally interacting masses m_1 and m_2 assumed to be in quantum coherent state and be describable by wave function analogous to em field. It is assumed that gravitational interact can be describe classically and this is also the case in TGD by quantum-classical correspondence.

1. Authors think quantum information theoretically and reduce everything to qubits. The delocalization of masses to a superposition of two positions correspond to a qubit analogous to spin or a polarization of photon.

2. One must use and analog of interferometer to measure the phase difference between different values of this "polarization".

   In the normal interferometer is a flattened square like arrangement. Photons in superpositions of different spin states enter a beam splitter at the left-lower corner of interferometer dividing the beam to two beams with different polarizations: horizontal (H) and vertical (V). Vertical (horizontal) beam enters to a mirror which reflects it to horizontal (vertical beam). One obtains paths V-H and H-V meeting at a transparent mirror located at the upper right corner of interferometer and interfere.

   There is detector D_0 resp. D_1 detecting component of light gone through in vertical resp. horizontal direction of the fourth mirror. Firing of D_1 would select the H-V and the firing of D_0 the V-H path. This thus would tells what path (V-H or H-V) the photon arrived. The interference and thus also the detection probabilities depend on the phases of beams generated during the travel: this is important.

3. If I have understood correctly, this picture about interferometer must be generalized. Photon is replaced by mass m in quantum state which is superposition of two states with polarizations corresponding to the two different positions. Beam splitting would mean that the components of state of mass m localized at positions x_1 and x_2 travel along different routes. The wave functions must be reflected in the first mirrors at both path and transmitted through the mirror at the upper right corner. The detectors D_i measure which path the mass state arrived and localize the mass state at either position. The probabilities for the positions depend on the phase difference generated during the path. I can only hope that I have understood correctly: in any case the notion of mirror and transparent mirror in principle make sense also for solutions of Schrödinger eequation.

4. One must however have two interferometers. One for each mass. Masses m_1 and m_2 interact quantum gravitationally and the phases generated for different polarization states differ. The phase is generated by the gravitational interaction. Authors estimate that phases generate along the paths are of form

$$\Phi_i = \frac{m_1 m_2 G}{\hbar d_i}\Delta t \ .$$

$\Delta t = L/v$ is the time taken to pass through the path of length L with velocity v. d_1 is the smaller distance between upper path for lower $mass m_2$ and lower path for upper mass m_1. d_2 is the distance between upper path for upper mass m_1 and lower m_2. See Figure 1 of the article (see `https://arxiv.org/pdf/1707.06036.pdf`).

What one needs for the experiment?

1. One should have de-localization of massive objects. In atomic scales this is possible. If one has $h_{eff}/h_0 > h$ one could also have zoomed up scale of de-localization and this might be very relevant. Fountain effect of superfluidity pops up in mind.

2. The gravitational fields created by atomic objects are extremely weak and this is an obvious problem. Gm_1m_2 for atomic mass scales is extremely small: since Planck mass m_P is something like 10^{19} proton masses and atomic masses are of order 10-100 atomic masses.

   One should have objects with masses not far from Planck mass to make Gm_1m_2 large enough. Authors suggest using condensed matter objects having masses of order $m \sim 10^{-12}$ kg, which is about 10^{15} proton masses 10^{-4} Planck masses. Authors claim that recent technology allows de-localization of masses of this scale at two points. The distance d between the objects would be of order micron.

3. For masses larger than Planck mass one could have difficulties since quantum gravitational perturbation series need not converge for $Gm_1m_2 > 1$ (say). For proposed mass scales this would not be a problem.

What can one say about the situation in TGD framework?

1. In TGD framework the gravitational Planck $h_{gr} = Gm_1m_2/v_0$ assignable to the flux tubes mediating interaction between m_1 and m_2 as macroscopic quantum systems could enter into the game and could reduce in extreme case the value of gravitational fine structure constant from $Gm_1m_2/4\pi\hbar$ to $Gm_1m_2/4\pi\hbar_{eff} = \beta_0/4\pi$, $\beta_0 = v_0/c < 1$. This would make perturbation series convergent even for macroscopic masses behaving like quantal objects. The physically motivated proposal is $\beta_0 \sim 2^{-11}$. This would zoom up the quantum coherence length scales by $h_{gr}/\hbar$.

2. What can one say in TGD framework about the values of phases Φ?

   (a) For $\hbar \rightarrow \hbar_{eff}$ one would have

   $$\Phi_i = \frac{Gm_1m_2}{\hbar_{eff} d_i}\Delta t \ .$$

For $\hbar \rightarrow \hbar_{eff}$ the phase differences would be reduced for given Δt. On the other hand, quantum gravitational coherence time is expected to increase like h_{eff} so that the values of phase differences would not change if Δt is increased correspondingly. The time of 10^{-6} seconds could be scaled up but this would require the increase of the total length L of interferometer arms and/or slowing down of the velocity v.

(b) For $\hbar_{eff} = \hbar_{gr}$ this would give a universal prediction having no dependence on G or masses m_i

$$\Phi_i = \frac{v_0 \Delta t}{d_i} = \frac{v_0}{v}\frac{L}{d_i} \quad .$$

If Planck length is actually equal to CP_2 length $R \sim 10^{3.5}\sqrt{G_N \hbar}$, one would has $G_N = R^2/\hbar_{eff}$, $\hbar_{eff} \sim 10^7$. One can consider both smaller and larger values of G and for larger values the phase difference would be larger. For this option one would obtain $1/\hbar_{eff}^2$ scaling for Φ. Also for this option the prediction for the phase difference is universal for $h_{eff} = h_{gr}$.

(c) What is important is that the universality could be tested by varying the masses m_i. This would however require that m_i behave as coherent quantum systems gravitationally. It is however possible that the largest quantum systems behaving quantum coherently correspond to much smaller masses.

2.7 Fluctuations of Newton's constant in sub-millimeter scales as evidence for TGD

Sabine Hossenfelder had a post with link to an article "*Hints of Modified Gravity in Cosmos and in the Lab?*" [E3] (see `http://tinyurl.com/y6j8sntw`). Here is the part of abstract that I find the most interesting.

On sub-millimeter scales we show an analysis of the data of the Washington experiment (Kapner et al. (2007) searching for modifications of Newton's Law on sub-millimeter scales and demonstrate that a spatially oscillating signal is hidden in this dataset. We show that even though this signal cannot be explained in the context of standard modified theories (viable scalar tensor and f(R) theories), it is a rather generic prediction of nonlocal gravity theories.

What is interesting from TGD point of view that the effect - if it is indeed real - appears in scale of .085 mm about 10^{-4} μm, which is the scale defined by the density of dark energy in recent universe and thus by cosmological constant. This is also size scale of large neuron.

2.7.1 Findings

Washington group studied gravitational torque on torque pendulum for sub-millimeter distances of masses involved [E2] (see `http://tinyurl.com/y2un6686`). Figure 19 of [E3] (see `http://tinyurl.com/y6j8sntw`) illustrates data points representing the deviation of the gravitational torque from the Newtonian prediction as a function of distance in the range .05-10 mm.

The deviation can parameterized in terms of effective scaling $G \rightarrow kG$ of Newton's constant, which is assumed to be predictable rather than due to fluctuations and depend on the distance only

$$k = 1 + x cos(\frac{2\pi r}{\lambda} + \frac{3\pi}{4}) \quad .$$

x is a numerical parameter. The highly non-trivial assumption is that Newton's potential is modified by an oscillating term, which must go to zero at large distances: its amplitude could approach to zero like $1/r$. The model predicts an anomalous gravitational torque $\Delta\tau$ proportional to $k-1$ and having the form

$$\Delta\tau = a cos(\frac{2\pi r}{\lambda} + \frac{3\pi}{4}) \quad ,$$

where r is the distance between the masses. The parameter $\lambda = \hbar/m$ is formally analogous to Compton length for imaginary mass m.

The finding is that the statistical significance for the best fit to the data is $(a, \lambda) = (0.004\ fNm, 65\ mm^{-1})$ is more than 3σ, where a is the amplitude of the deviation. The highly non-trivial problem is however that one obtains also other minima of χ^2 measuring the goodness of the fit with different values of the parameter λ.

I am not specialist but while looking at the data, I cannot avoid the feeling that the fit does not make much sense and reflects theoretical prejudices (belief in modified gravity of some kind) rather than reality. My first impression that fluctuations in the value of Newton's constant G are in question. The value of G is indeed known to vary from experiment to experiment and the variation is too large to be explained in terms of measurement inaccuracies.

Could it be that the value of G fluctuates, and for some reason in the length scale range around .1 mm the fluctuations are especially large meaning different values of G are large? Could some kind of criticality enhanced rather dramatically below .1 mm be involved?

2.7.2 Could fluctuations in the value of G explain the findings?

Twistor lift of TGD [K7, K8, K5, K9] predicts that cosmological constant is length scale dependent and that Newton's constant G has a spectrum reflecting the spectrum of effective Planck constant $h_{eff} = nh_0$ ($h = 6h_0$ is a good guess [L4]): dark matter would correspond to $h_{eff} = nh_0$ phases of ordinary matter.

p-Adic length scale hypothesis allows to assign to cosmological constant Λ two length scales: the cosmological p-adic scale defined by Λ itself and the short p-adic length scale determined by the density of dark energy so that physics is cosmological scales and physics in microscopic scales reflect each other.

This encourages the idea that one might understand the experimental findings in terms of fluctuations of G induced by quantum fluctuations of h_{eff} at quantum criticality.

1. TGD suggests a spectrum for the values of G. The starting points is the expression for the effective Planck constant ass $h_{eff} = n \times h_0$. In adelic physics the value of n is identified as the number of sheets for the space-time surface as covering space and would correspond to the order of Galois group of extension of rationals inducing the extensions of p-adic number fields appearing in the adele [L7, L8].

2. An additional hypothesis is that space-time surface can be regarded as covering of both M^4 and CP_2 with numbers of sheets equal to n_1 and n_2: $n = n_1 n_2$. The number of sheets over M^4 would be n_1 so that CP_2 coordinates would be n_1-valued functions of M^4 coordinates. The number of sheets over CP_2 would be n_2 and one would have effective n_2 copies of n_1 valued regions in M^4.

   The gravitational Planck constant $\hbar_{gr} = GMm/v_0$ originally introduced by Nottale [E1] is proposed to correspond to $\hbar_{eff} = \hbar_{gr} = n_1 n_2 \hbar_0$. The real Planck length $l_P(real)$ would correspond to $l_P(real) = R$, the CP_2 size scale identified as geodesic length, and Newton's constant would correspond to

   $$G = \frac{R^2}{\hbar_1} = \frac{R^2}{n_1 \hbar_0} \ .$$

   One would have $n_1 \sim 6 \times 10^7$ from $l_P^2/R^2 \sim 10^7$.

3. The value of n_1 can fluctuate and induce fluctuations of G. The fluctuations could be even large. One can even ask whether the fountain effect of superfluidity involves a large value of n_1 responsible for macroscopic quantum coherence and due to the increase of the value of $\hbar eff$ caused the increase of n_1 in turn reducing the value of G [K3].

   Could the fluctuations of n_1 explain the findings about the value of G deduced from Washington experiment? The appearance of several values for parameter λ might signal about fluctuations of G rather than modification of the radial dependence of gravitational potential.

Why the fluctuations in the value of G would be so large in sub-millimeter length scales?

1. Cosmological constant $\Lambda \simeq 1.1 \times 10^{-52}$ m^{-2} has dimension of $1/L^2$, L length scale. The density of dark energy $\rho_{vac} = \Lambda/8\pi G$ has dimensions of $\hbar/L^4$. One can assign to Λ very long p-adic length scale $L(k_1) = 2^{k_1/2}R$ ($p_1 \simeq 2^{k_1}$), and to $\rho_{vac}/\hbar$ rather short p-adic length scale $L(k_2) = 2^{k_2/2}R$. One has

$$\frac{\rho_{vac}}{\hbar} = \frac{x_2}{L(k_2)^4} = \frac{x_1}{8\pi}\frac{1}{l_P^2 L(k_1)^2} \ ,$$

where x_1 and x_2 are numerical constants not far from unity. This would give

$$L(k_2) = (8\pi\frac{x_2}{x_1})^{1/4}(L(k_1)l_P)^{1/2} \ .$$

$L(k_2)$ would be proportional the geometric mean of $L(k_1)$ and l_P. This implies

$$2^{2k_2} = \frac{x_2}{x_1} \times 8\pi \times (\frac{l_P}{R})^2 2^{k_1} \ .$$

Very roughly, $k_1 \sim 2k_2 - 26$ would hold true for $x_2/x_1 \sim 1$. It turns out that k_2 corresponds to a p-adic length scale about 10^{-4} meters, which happens to be the size of large neuron suggesting that quantum gravitation is indeed highly relevant to biology but in manner different from that speculated by Penrose.

2. p-Adic fractality suggests that cosmological constant is not actually constant or even time varying but depends on p-adic length scales so that the values are indeed extremely large as one approaches CP_2 scale and get very small as one approaches cosmological scales. This would solve the cosmological constant problem. The dependence would be $\Lambda(k) \propto 1/L(k)^2$, where $L(k)$ is the p-adic length scale characterizing the size of the space-time sheet. There would be a sequence of phase transition reducing Λ and these phase transition would involve quantum criticality and long length scale fluctuations possibly assignable to those of h_{eff} and thus of n_2 and G.

   If one assumes that k_2 corresponds to preferred p-adic lengths scales assignable to elementary particles, nuclei, atomic physics and biology, one obtains a prediction that the corresponding p-adic length scales correspond to cosmologically important length scales via $k_1 \sim 2k_2$. One could study cosmology by studying gravitation in laboratory scales!

   In these scales quantum phase transitions changing cosmological constant could make themselves visible via microscopic physics. Phase transitions involve long length scale fluctuations characteristic for criticality. In TGD these quantum fluctuations correspond to fluctuations of h_{eff} since Compton lengths scale like h_{eff}. The fluctuations of n_1 in $n = \hbar_{eff}/\hbar = n_1 n_2$ would induce fluctuations of G.

3. Especially interesting are the p-adic length scales which are biologically important. The number theoretical miracle is that there are as many as 4 very closely located Gaussian Mersenne primes $M_{G,n} = (1+i)^m - 1$ in the range of cell membrane thickness and size of cell nucleus corresponding to $k = 151, 157, 163, 167$. The corresponding p-adic length scales $L(k) = 2^{(k-151)/2}L(151)$, $L(151) \simeq 10$ nm could be also gravitationally especially interesting. The hierarchical coiling of DNA might relate to the hierarchy of Gaussian Mersennes and phase transitions changing cosmological constant and the density of magnetic and volume energies assignable to the magnetic flux tubes playing key role in TGD inspired biology. These phase transitions would scale the thickness of the flux tubes determined by p-adic lengths scale.

   It should be relatively easy to check whether the p-adic length scale hierarchy up to biological length scales has scaled variant in astrophysical and cosmological scales.

2.8 Conscious experiences about antigravity

Conscious experiences about anti-gravitational effects have been also reported and since I have nothing to lose as a happy pensioner and consciousness theorist [L9] I can take the liberty to talk also about these effects, even at personal level.

1. There are stories about flying yoga masters. I am skeptic but I know from my own experience that out-of-body and levitation experiences - I mean indeed *experiences* - feel very real. I have proposed a model explaining them based on the notion of magnetic body as intentional agent carrying dark matter and using biological body as sensory receptor and motor instrument.

2. I have indeed spent at younger age many moments in a kind of between away-and-sleep state in the roof of bedroom trying to prove myself that I really am there and then suddenly returned back to normal in wake-up state. Even the matresse behaved how it is expected to behave as some-one falls on it. Maybe part of my magnetic body was out-of-biological body after having experienced $h_{eff}/h = n$ increasing phase transition! Sometimes I have experienced wakeup quite concretely as a kind of contraction in which I have returned to my body: reduction of $h_{eff}/h = n$ for some part of magnetic body would explain this.

3. I have had also altered states of consciousness between wake-up and sleep in which I felt my body like oscillating and being attracted by refrigerator, whose sound had started to amplify. I experienced the refrigerator as a living being and I was afraid that it intended engulf my consciousness! I had to decide whether I let it go but did not have courage to do it and I returned to the normal state.

4. In dreams I have been also routinely flying and with somewhat childish narcissism pretended to the other people in dream that this is perfectly normal for me, it just occurred me that it would be fun to fly but honestly: I did not realize that it might make you scared! What was remarkable that I never got above about 10 meters: could this correspond to jumping in air in a reduced gravitational field? As a matter of fact, in dream I was typically going down in stairs and then decided to fly. I often landed at the end of stairs. This would fit with reduced gravity implying weaker downwards gravitational acceleration.

3 Appendix: About the dependence of scattering amplitudes on $\hbar_{eff}$

In TGD $\hbar$ is replaced with $\hbar_{eff} = nh_0 = nh/6$ [L4, L11, L12], and it is important to know the general dependence of scattering amplitudes on $\hbar_{eff}$. In QFT formalism the standard choice of units is $\hbar = 1, c = 1$ so that it requires some work to deduce the general dependence of the scattering amplitudes and rate on $\hbar_{eff}$. One must also check whether this dependence is consistent TGD with view about coupling constant evolution as a discrete sequence of phase transitions between quantum critical states.

3.1 General observations about the dependence of n-particle scattering amplitudes on $\hbar$

The "*Quantum Field Theory*" by Itzykson and Zuber [B1] provides the information about the general dependence of scattering amplitudes on $\hbar$ albeit in implicit form since units $\hbar = 1, c = 1$ are used.

1. Since putting $\hbar = 1$ is not possible in TGD framework, one must carefully check how the scattering amplitudes and rates depend on $\hbar$. In this respect tree scattering amplitudes in Abelian gauge theory like QED are characterized by the number of vertices. Each vertex involves g. Besides this there are delta functions expressing on mass shell conditions and momentum conservation.

   The amplitude involving n gauge boson-fermion vertices is proportional to g^n and scattering rate is proportional to g^{2n}. g^2 has dimension of $\hbar$ so that the condition that the coupling parameters give dimensionless factor requires additional power of $\hbar$ giving rise to α^{2n} factor, where $\alpha = g^2/4\pi$ is the analog of fine structure constant.

2. The general rule must be that gFF vertex involves factor $g/\sqrt{4\pi\hbar}$. The origin of $1/\sqrt{4\pi\hbar}$ factor can be traced out to the dimensions $[\sqrt{\hbar}/L]$ of scalar and vector boson fields, and the dimension $[\sqrt{\hbar}/L^{3/2}]$ spinor fields following from the condition that Hamiltonian for free fields has dimension $[\hbar/L]$ of energy. This implies that in gauge boson-fermion vertex one has $g/\sqrt{\hbar}$ and in a gauge theory having no dimensional couplings $g/\sqrt{\hbar}$ appears as coupling constant quite generally. In non-abelian gauge theory 3-boson vertices involving g and 4-boson vertices involving g^2 are also present and this rule gives power α^n, $n = n_3 + 2n_4$, where n_3 is the number of 3-vertices (BBB and BBF) and n_4 is the number of bosonic 4-vertices.

   This is however gauge theory limit at which particles become points-like and the flux tubes giving rise to a tensor network are neglected. In this framework one could interpret $g^2/4\pi\hbar$ as coupling parameter assignable to the flux tube connecting particles and this is indeed more natural number theoretically since $\hbar_{eff}/h_0$ is integer. In case of gravitation this seems to be the only possibility.

3. The density of states factor appearing in the rate does not depend on $\hbar$. In particle-in-the box quantization momenta are given by $p = n\hbar/L$ and density of states is $d^3n = Vd^3p/\hbar^3$. When one scales up $\hbar$ also V is scaled so that d^3n remains invariant.

One can now look the scattering amplitudes and rates in more detail. The "*Quantum Field Theory*" by Itzykson and Zuber [B1] provides examples of practical calculations and allows to deduce simple rules for $\hbar$ dependence of scattering amplitudes and rates.

1. For fermion-fermion scattering in Abelian gauge theories in the lowest order $2 \rightarrow 2$ scattering $\hbar$ disappears from the scattering cross section, and one obtains just the classical result. For instance, electrodynamics lowest order scattering cross sections - say for Compton scattering or electro-electron scattering - are proportional to α^2/m^2 in units $\hbar = 1$, $c = 1$. Putting in $\hbar$ one obtains $\alpha^2\hbar^2/m^2$. $\alpha = e^2/4\pi\hbar$ implies that $\hbar$ disappears so that its value does not matter. Therefore there is strong dependence on $\hbar_{eff}$ for fermion-fermion in gauge theory in tree approximation. For the radiative corrections to 2-2 scattering coming in powers of α the value of $\hbar$ matters and the larger its value the smaller the corrections are and this gives hopes about the convergence of the perturbation theory. The theoretician friendly Nature would induce a phase transition increasing h_{eff} to guarantee the convergence of perturbation series.

2. For a gauge theory scattering of type $2 \rightarrow n > 2$ via tree diagrams there are n vertices and the total scattering cross section is proportional to α^n/m^2 and thus depends on $\hbar$ for $n > 2$. The rate for production of states with higher particle number decrease with $\hbar_{eff}$. Hence $\hbar$ is measurable also in this manner.

3. For particle decays the rate is proportional to $1/\hbar_{eff}$: $\alpha^2 m$ is the basic dependence from dimensional analysis. Increase of $\hbar_{eff}$ scales up life-time as one might expect. For the decay of positronium non-perturbative effects due to bound state nature bring in additional power of α and the life time scales like a higher power of $\hbar_{eff}$.

4. It is often sloppily argued that classical limit corresponds to the limit $\hbar = 0$. This limit however completely fails as an approximation in situations in which $\hbar \rightarrow 0$ limit does not make sense. For instance, for atoms bound state energies are proportional to $1/\hbar^2$ and approach to infinite value as $\hbar$ goes to zero.

Clearly, $2 \rightarrow 2$ scattering for massive particles is very special in that for tree diagrams in QED and gauge theories the outcome does not depend on $\hbar_{eff}$ at all. It is intriguing that $2 \rightarrow 2$ scattering is main provider of information. This leaves room for the possibility of $\hbar_{eff}$ hierarchy.

3.2 Photon-photon scattering as objection against TGD view about discrete coupling constant evolution

Twistor approach suggests in TGD framework that perturbative corrections for a given extension of rationals vanish altogether [K6, K7, K8].

1. The weak form of the proposal is that this occurs only for critical values of coupling constants so that the sum over loop diagrams would vanish in these cases. Coupling constants would depend on extension of rationals and coupling constant evolution would be induced by the hierarchy of these extensions and coupling constant evolution would be discrete. This picture follows if space-time surfaces correspond to zero loci for real or imaginary parts of octonionic polynomials at M^8 side of M^8-H duality [L6].

   One could argue that the hierarchy of extensions of rationals defines a hierarchy of cognitive resolutions obtained by approximation analytic functions of octonions at M^8 side of M^8-H duality with polynomials. For space-time surfaces represented as zero loci of real or imaginary part of an *arbitrary* analytic function, the radiative corrections would not vanish.

2. Strong form of the proposal would mean that that individual loop corrections vanish identically.

An objection against vanishing of loops is photon-photon scattering, which occurs via box diagram at QFT limit of TGD. This gives for sigma the behavior α^4/E^2 by dimensional argument. The rate is proportional to $1/\hbar_{eff}^2$. Photon-photon scattering is observed and QED predictions are correct.

What the vanishing of loops - in particular box diagrams - at QFT limit TGD could mean for photon-photon scattering? Does this kill the idea about the reduction of scattering amplitudes to tree level?

1. TGD description is based on many-sheeted space-time and the fundamental scattering events in twistor diagrams are for fermions. It is this level at which one would have only the analogs of tree diagrams. QFT limit is only an effective description, and the action is expected to be standard model action in a good approximation. If so, the problem disappears.

2. How photon-photon scattering could emerge at the fundamental level? TGD picture relies on twistor diagrams rather than Feynman diagrams. The proposal is that at fundamental level twistor diagrams at $M^4\times CP_2$ side of M^8-H duality involve only fermions and their bound states.

   At M^8 side of M^8-H duality the geometric variant of approach would be realized. Components of super field would correspond to components of super-octonion and polynomial of super-octonion would be analogs of super-field. The vanishing of the real or imaginary part (in quaternionic sense) for the component polynomials would assign to to each component of this super-polynomial a space-time surface in M^8.

   For twistor diagrams the analogs of virtual particles are possible but they would have on-mass-shell complex momenta. Photon-photon scattering could occur as on-mass-shell process in this sense and involve the decay of photon to fermion antifermion pair with complex momenta. Second incoming photon would absorb the antifermion with complex momentum. The reaction would proceed in the similar manner in the remaining two vertices.

3.3 What about quantum gravitation for dark matter with large enough $\hbar_{eff}$?

It is interesting to look what h_{gr} hypothesis implies for quantum gravitation for dark matter. Does the QFT type description for quantum gravitation of dark matter make sense in TGD framework?

1. One can consider two identifications for the fundamental parameter as either G or l_P^2. These identifications lead to same predictions as far the dependence of scattering amplitudes on $\hbar_{eff}$ is considered.

(a) G is the fundamental parameter GMm has same dimension $[hbar]$ as $Z_1Z_2e^2$ and thus one can define the analog of gravitational fine structure constant as GM_P^2. The 2-2 scattering cross section is completely analogous to that for Coulomb scattering and does not depend on $\hbar_{eff}$ at all. This result is rather satisfactory.

(b) Second option is that Planck length l_P defines fundamental length and G is identified as $G = l_p^2/\hbar_{eff}$. This gives $GMm = l_P^2 Mm/\hbar_{eff}$ with Plack length identified as CP_2 radius R: $l_P = R$ [L13]. The independence of the cross section or $2 \to 2$ scattering on $\hbar_{eff}$ in lowest order holds true also now. $\sqrt{\hbar_{eff}}M/M_P = \sqrt{G}M = Ml_P/\sqrt{\hbar}$ would serve as analog of e now.

2. In the lowest order the scattering amplitude for $2 \to 2$ scattering by graviton exchange should be essentially Fourier transform of Newton's gravitational potential at the static limit. The independence of $2 \to 2$ scattering cross section on h_{eff} looks a natural condition since in the lowest order the scattering would not depend at all on the value of $\hbar_{eff}$. Coupling strength GMm is analogous to $Z_1Z_2e^2$ and both have dimension $[\hbar]$. Therefore the cross section for $2 \to 2$ scattering does not depend on $\hbar$ if one expresses $G = l_P^2/\hbar_{eff}$, $l_P = R$. This implies that QFT type description with point-like particles can serve as an approximate description of gravitational interaction.

   This and Nottale's proposal [E1] would require that $GMm/\hbar_{eff}$ serves as dimensionless coupling parameter. Coupling strength α_{gr} would characterize pair of interacting particles rather than particle and would be naturally associated with flux tube mediating the interaction as graviton exchange and has an interpretation as generalization of string model picture. This picture makes sense also for gauge bosons.

3. Does the description of two-particle system with masses M and m make sense using Schrödinger equation? De-localization might cause problems and TGD proposal is that only the de-localization of dark matter occurs and also this takes place only on flux tubes along the orbits of planets [K2, K1, K4].

   The first observation is that the parameter $GMm/\hbar$ is for planetary systems so huge so that perturbation series fails. $Mm = m_P^2 = \hbar/l_P^2$ serves as an estimate for the upper bound of Mm. For $\hbar_{gr}$ situation changes and one can write the gravitational analog of Schrödinger equation as

$$(-\frac{\nabla_u^2}{2} + \frac{\beta_0^2}{u})\Psi = e\Psi \quad , \quad e = \frac{E\beta_0^2}{m} \quad , \quad u = GM = \frac{r_S}{2} \quad . \tag{3.1}$$

   $\beta_0 = v_0/c = v_0$ for $c = 1$ clearly occurs in the role of e and the scaling $E = me/\beta_0^2$.

4. If gravitational Shrödinger equation makes sense, the gravitational analogs of atomic transitions should also make sense. For h_{gr} huge pulses of gravitational radiation would accompany the transitions of the gravitational analog of hydrogen atom since binding energies are proportional to mv_0^2/n^2, m the mass of the planet. What would happen would be emission of dark graviton with energy equal to say energy difference of initial and final states (planetary Bohr orbits), which would then decay to a bunch of ordinary gravitons [K1].

   One could estimate the rate of transitions using the existing results from atomic physics. One can also try to estimate the transition rate from a generalization of Uncertainty Principle (UP): $\Delta T = \hbar_{gr}/\Delta E$. Order of magnitude is about GMn^2/v_0^3 ($c = 1$). This gives 10^5n^2 seconds for $v_0/c = 2^{-11}$. This time is of order 30 hours! The transition would be associated with dark matter. This looks totally unrealistic. This estimate makes sense only if there is de-localization of dark matter to analogs of hydrogen orbitals.

   A better estimate should include the interaction with dark graviton field rather than mere UP. Here one can use Fermi's Golden Rule (see `http://tinyurl.com/yblec2on`). The change of energy would be huge and therefore also graviton's energy and momentum. Wave vector however matters and would be give by $k = p/\hbar_{gr}$ and de Broglie wavelength would be of order of planetary orbit so that the analog of dipole approximation $exp(ik.x) = 1 + ik \cdot x$ would make sense. The time for transition would be about $\Delta T = \hbar_{gr}\Delta E/E^2$ and of the same order of magnitude as previous estimate. This does not make sense. De-localization of dark parts of planets in the scale of solar system would lead to surreal effects.

5. In TGD picture the dark matter is assumed to be de-localized only at the flux tubes associated with planetary orbits. TGD approach relies on zero energy ontology (ZEO) in which quantum states correspond to quantum superpositions of preferred extremals of action (sum of Kähler action and volume term proportional to cosmological constant). The transition would involve classical orbits transforming to each other by dark graviton emission. The transition would occur as a replacement of flux tube trajectory with given energy with a trajectory having lower energy. If one assumes Bohr quantization for the trajectories, the energy liberated as dark graviton in the transition is huge using normal standards for quantum transitions.

   The basic condition is that the trajectories intersect. For instance, if the original trajectory is circle, the final trajectory could be ellipsoidal trajectory with a lower energy and located inside the circular trajectory and touching it at diametrically opposite points. A natural expectation is that the transition rate is proportional to $P = (V_{12}/\sqrt{V_1V_2})^2$, where V_{12} is the volume shared by the two flux tubes V_i are flux tube volumes. The square roots $\sqrt{V_i}$ of the flux tube volumes would correspond to normalization factors for dark matter wave functions at flux tubes. The square of this factor would give a very small coefficient and make the transition very slow despite the factor that the dimensionless coupling analogous to α would be $\beta_0/4\pi$.

   One would have $V_{12} \sim d^3$, where d is flux tube thickness. Flux tube volume would be $2\pi^2 Rd^2$ so that one would have orer of magnitude estimate $P \sim (1/4\pi^4)(d/R)^2$ determined by the ratio of the thickness of the flux tube to the area of the orbit determined by it. If the thickness of the flux tube is of the order of planet radius, P for Earth has order of magnitude 10^{-11}. By multiplying the estimate about 30 hours given by Uncertainty Principle would would obtain a rough estimate 10^9 years for the lifetime of the flux tube orbit of Earth.

   This kind of transitions should correspond to "big" state function reductions analogous to ordinary quantum measurements rather than "small" state function reductions having so called weak measurements (see `http://tinyurl.com/zt36hpb`) as analogs. In "big" state function reductions the arrow of geometric time changes in the sense that the roles of passive and active boundary of causal diamond (CD) change and the sequence of weak measurements occurs at opposite boundary of CD shifting farther away from the passive boundary, which was active boundary before the "big" state function reduction. Note that the temporal distance between the tips of CD increases and gives rise to clock time as a counterpart of experienced time defined by the sequence of "small" state function reductions)

6. For QFT description of quantum gravitation $\sqrt{\hbar}E/M_P = El_P/\sqrt{\hbar} = E\sqrt{G}$ would serve the role of the coupling parameter analogous to e. To get some idea what happens one can look graviton-graviton scattering amplitude for 4 gravitons having all 2 positive 2 negative helicities and known as M^{--++}. Lowest order calculations without loops at Minkowski limit (tree diagrams, see `http://tinyurl.com/y82rsw9y`) give an expression as a sum of terms proportional to x^2, where the dimensionless variable x is $x = El_P/\sqrt{\hbar_{eff}}$: $E$is energy scale. Amplitude is proportional $1/\hbar_{eff}$ and the scattering amplitude approaches zero for large values of h_{eff}.

3.4 A little sidetrack: How a finite number of terms in perturbation expansion can give a good approximation although perturbation series fails to converge?

The perturbative expansion of electrodynamics does not converge. This looks paradoxical since the predictions of QED are extremely accurate. This statement is of course somewhat sloppy since there are many notions of convergence. For instance, converge could occur in some kinematical regions and fail to do so in some other regions.

If convergence does not occur in kinematically important regions, how can then apply the perturbative expansion at all? Part of the explanation is certainly that in $2 \rightarrow 2$ scattering the lowest order does not depend on $\hbar$ at all so that it could be calculated by using so large a value of

$\hbar$ that convergence occurs. Could one take the convergent result cut to a finite number of powers of α in convergence region and continue it by replacing α with its actual value to region where the convergence fails? Finite cutoffs would not deviate much from the correct result but the remainder would be infinite.

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