Gravitational Schrödinger equation as a quantum model for the formation of astrophysical structures and dark matter?

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Contents

Abstract

D. Da Rocha and Laurent Nottale have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.82 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The basic objection is that astrophysical systems are extremely classical whereas TGD predicts macrotemporal quantum coherence in the scale of life time of gravitational bound states. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale.

I have proposed already earlier the possibility that Planck constant is quantized and the spectrum is given in terms of logarithms of Beraha numbers: the lowest Beraha number B_3 is completely exceptional in that it predicts infinite value of Planck constant. The inverse of the gravitational Planck constant could correspond a gravitational perturbation of this as $1/\hbar_{gr} = v_0/GMm$. The general philosophy would be that when the quantum system would become non-perturbative, a phase transition increasing the value of $\hbar$ occurs to preserve the perturbative character and at the transition $n = 4 \rightarrow 3$ only the small perturbative correction to $1/\hbar(3) = 0$ remains. This would apply to QCD and to atoms with $Z > 137$ as well.

TGD predicts correctly the value of the parameter v_0 assuming that cosmic strings and their decay remnants are responsible for the dark

matter. The harmonics of v_0 can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes n^2-fold: much like the replacement of a closed orbit with an orbit closing only after n turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes.

The study of inclinations (tilt angles with respect to the Earth's orbital plane) leads to a concrete model for the quantum evolution of the planetary system. Only a stepwise breaking of the rotational symmetry and angular momentum Bohr rules plus Newton's equation (or geodesic equation) are needed, and gravitational Shrödinger equation holds true only inside flux quanta for the dark matter.

a) During pre-planetary period dark matter formed a quantum coherent state on the (Z^0) magnetic flux quanta (spherical cells or flux tubes). This made the flux quantum effectively a single rigid body with rotational degrees of freedom corresponding to a sphere or circle (full SO(3) or SO(2) symmetry).

b) In the case of spherical shells associated with inner planets the $SO(3) \rightarrow SO(2)$ symmetry breaking led to the generation of a flux tube with the inclination determined by m and j and a further symmetry breaking, kind of an astral traffic jam inside the flux tube, generated a planet moving inside flux tube. The semiclassical interpretation of the angular momentum algebra predicts the inclinations of the inner planets. The predicted (real) inclinations are 6 (7) resp. 2.6 (3.4) degrees for Mercury resp. Venus). The predicted (real) inclination of the Earth's spin axis is 24 (23.5) degrees.

c) The $v_0 \rightarrow v_0/5$ transition necessary to understand the radii of the outer planets can be understood as resulting from the splitting of (Z^0) magnetic flux tube to five flux tubes representing Earth and outer planets except Pluto, whose orbital parameters indeed differ dramatically from those of other planets. The flux tube has a shape of a disk with a hole glued to the Earth's spherical flux shell.

d) A remnant of the dark matter is still in a macroscopic quantum state at the flux quanta. It couples to photons as a quantum coherent state but the coupling is extremely small due to the gigantic value of $\hbar_{gr}$ scaling alpha by $\hbar/\hbar_{gr}$: hence the darkness.

The rather amazing coincidences between basic bio-rhythms and the periods associated with the states of orbits in solar system suggest that the frequencies defined by the energy levels of the gravitational Schrödinger equation might entrain with various biological frequencies such as the cyclotron frequencies associated with the magnetic flux tubes. For instance, the period associated with n=1 orbit in the case of Sun is 24 hours within experimental accuracy for v_0.

1 Introduction

D. Da Rocha and Laurent Nottale, the developer of Scale Relativity, have ended up with an highly interesting quantum theory like model for the evolution of astrophysical systems [1] (I am grateful for Victor Christianto for informing me about the article). The model is simply Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant

$$\hbar \quad \rightarrow \quad \hbar_{gr} = \frac{GmM}{v_0} \quad . \tag{1}$$

Here I have used units $\hbar = c = 1$. v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. The peak orbital velocity of stars in galactic halos is 142 ± 2 km/s whereas the average velocity is 156 ± 2 km/s. Also subharmonics and harmonics of v_0 seem to appear.

The model makes fascinating predictions which hold true. For instance, the radii of planetary orbits fit nicely with the prediction of the hydrogen atom like model. The inner solar system (planets up to Mars) corresponds to v_0 and outer solar system to $v_0/5$. The predictions for the distribution of major axis and eccentrities have been tested successfully also for exoplanets. Also the periods of 3 planets around pulsar PSR B1257+12 fit with the predictions with a relative accuracy of few hours/per several months. Also predictions for the distribution of stars in the regions where morphogenesis occurs follow from the Schödinger equation.

What is important is that there are no free parameters besides v_0. In [1] a wide variety of astrophysical data is discussed and it seem that the model works and has already now made predictions which have been later verified. In the following I shall discuss Nottale's model from the point of view of TGD.

2 The interpretation of the parameters v_0 and $\hbar_{gr}$

The parameter v_0 appearing in the gravitational Schrödinger equation is correctly predicted by quantum TGD. Also the harmonics and sub-harmonics of v_0 can be understood in TGD framework, and gravitational Schrödinger equation produces a self-consistent model for the dark matter in the galactic halo.

2.1 TGD prediction for the parameter v_0

One of the basic questions is the origin of the parameter v_0, which according to a rich amount of experimental data discussed in [1] seems to play a role of a constant of Nature. One of the first applications of cosmic strings in TGD sense was an explanation of the velocity spectrum of stars in the galactic halo in terms of dark matter consisting of cosmic strings and/or their decay products assuming that the length of cosmic string inside a sphere of radius R is or has been roughly R [A3]. The predicted value of the string tension is determined by the CP_2 radius whose ratio to Planck length is fixed by electron mass via p-adic mass calculations. The resulting prediction for the v_0 is correct and provides a working model for the constant orbital velocity of stars in the galactic halo.

Quite recently this model led to an explanation of also evolution of cosmological constant explaining its extremely small value as a consequence of p-adic length scale evolution predicting that the cosmological constant has reduced by a factor of two at half octaves of the cosmic time.

2.2 How to understand the harmonics and sub-harmonics of v_0 in TGD framework?

Also harmonics and sub-harmonics of v_0 appear in the model of Nottale and Da Rocha. For instance, the outer planets (Jupiter, Saturnus,...) correspond to $v_0/5$ whereas inner planets correspond to v_0. Quite generally, it is found that the values seem to come as harmonics and subharmonics of v_0: $v_n = nv_0$ and v_0/n, and the argument [1] is that the different values of n relate to fractality. This quantization is a challenge for TGD since v_0 certainly defines a fundamental constant in TGD Universe.

a) Consider first the harmonics of v_0. Besides cosmic strings of type $X^2 \times S^2 \subset M^4 \times CP_2$ one can consider also deformations of these strings defining their multiple coverings so that the deformation is n-valued as a function of S^2-coordinates (Θ, Φ) and the projection to S^2 is thus an $n \to 1$ map. The solutions are higher dimensional analogs of originally closed orbits which after perturbation close only after n turns. This kind of surfaces emerge in the TGD inspired model of quantum Hall effect naturally [C1] and $n \to \infty$ limit has an interpretation as an approach to chaos [B2].

Using the coordinates (x, y, θ, ϕ) of $X^2 \times S^2$ and coordinates m^k for M^4 of the unperturbed solution the space-time surface the deformation can be expressed as

$$
\begin{aligned}
m^k &= m^k(x,y,\theta,\phi) \ , \\
(\Theta,\Phi) &= (\theta,n\phi) \ .
\end{aligned} \tag{2}
$$

The value of the string tension would be indeed n^2-fold in the first approximation since the induced Kähler form defining the Kähler magnetic field would be $J_{\theta\phi} = nsin(\Theta)$ and one would have $v_n = nv_0$. At the limit $m^k = m^k(x,y)$ different branches for these solutions collapse together.

b) Consider next how sub-harmonics appear in TGD framework. Cosmic strings are predicted to decay to magnetic flux tube structures by absolute minimization of Kähler action. The Kähler magnetic flux $\Phi = BS$ is conserved in the process but the thickness of the M^4 projection of the cosmic string increases field strength is reduced. This means that string tension, which is proportional to B^2S, is reduced (so that also Kähler action is reduced). The fact that space-time surface is Bohr orbit in generalized sense means that the reduced string tension (magnetic energy per unit length) is quantized. The task is to guess how the quantization occurs.There are two options.

a) The simplest explanation for the reduction of v_0 is based on the decay of a flux tube resembling a disk with a hole to n identical flux tubes so that $v_0 \rightarrow v_0/n$ results for the resulting flux tubes. It turns out that this mechanism is favored and explains elegantly the value of $\hbar_{gr}$ for outer planetary system. One can also consider small-p p-adicity so that n would be prime.

b) Second explanation is more intricate. Consider a magnetic flux tube. Since magnetic flux is quantized, the magnetic field strengths are quantized in integer multiples of basic strength: $B = nB_0$ and would rather naturally correspond to the multiple coverings of the original magnetic flux tube with magnetic energy quantized in multiples of n^2. The idea is to require internal consistency in the sense that the allowed reduced field strengths are such that the spectrum associated with B_0 is contained to the spectrum associated with the quantized field strengths $B_1 > B_0$. This would allow only field strengths $B = B_S/n^2$, where B_S denotes the field strength of the fundamental cosmic string and one would have $v_n = v_0/n$. Flux conservation requires that the area of the flux tube scales as n^2.

Sub-harmonics appear in the outer planetary system and there are indications for the higher harmonics below the inner planetary system [1]: for instance, solar radius corresponds to $n = 1$ orbital for $v_3 = 3v_0$. This would suggest that Sun and also planets have an onion like structure with highest harmonics of v_0 and strongest string tensions appearing in the solar core and highest sub-harmonics appearing in the outer regions. If the matter results as decay remnants of cosmic strings this means that the mass density inside Sun should correlate strongly with the local value of n characterizing the multiple covering of cosmic strings.

One can ask whether the very process of the formation of the structures could have excited the higher values of n just like closed orbits in a perturbed system become closed only after n turns. The energy density of the cosmic string is about one Planck mass per $\sim 10^7$ Planck lengths so that $n > 1$ excitation increasing this density by a factor of n^2 is obviously impossible except under the primordial cosmic string dominated period of cosmology during which the net inertial energy density must have vanished. The structure of the future solar system would have been dictated already during the primordial phase of cosmology when negative energy cosmic string suffered a time reflection to positive energy cosmic strings.

2.2.1 Nottale equation is consistent with the TGD based model for dark matter

TGD allows two models of dark matter. The first one is spherically symmetric and the second one cylindrically symmetric. The first thing to do is to check whether these models are consistent with the gravitational Schödinger equation/Bohr quantization.

1. Spherically symmetric model for the dark matter

The following argument based on Bohr orbit quantization demonstrates that this is indeed the case for the spherically symmetric model for dark matter. The argument generalizes in a trivial manner to the cylindrically symmetric case.

a) The gravitational potential energy $V(r)$ for a mass distribution $M(r) = xTr$ (T denotes string tension) is given by

$$V(r) = Gm\int_r^{R_0} \frac{M(r)}{r^2}dr = GmxTlog(\frac{r}{R_0}) \ . \tag{3}$$

Here R_0 corresponds to a large radius so that the potential is negative as it should in the region where binding energy is negative.

b) The Newton equation $\frac{mv^2}{r} = \frac{GmxT}{r}$ for circular orbits gives

$$v = xGT \ . \tag{4}$$

c) Bohr quantization condition for angular momentum by replacing $\hbar$ with $\hbar_{gr}$ reads as $mvr = n\hbar_{gr}$ and gives

$$
\begin{aligned}
r_n &= \frac{n\hbar_{gr}}{mv} = nr_1 \ , \\
r_1 &= \frac{GM}{vv_0} \ .
\end{aligned}
\tag{5}
$$

Here v is rather near to v_0.

d) Bound state energies are given by

$$
E_n = \frac{mv^2}{2} - xTlog(\frac{r_1}{R_0}) + xTlog(n) \ . \tag{6}
$$

The energies depend only weakly on the radius of the orbit.

e) The centrifugal potential $l(l+1)/r^2$ in the Schrödinger equation is negligible as compared to the potential term at large distances so that one expects that degeneracies of orbits with small values of l do not depend on the radius. This would mean that each orbit is occupied with same probability irrespective of value of its radius. If the mass distribution for the starts does not depend on r, the number of stars rotating around galactic nucleus is simply the number of orbits inside sphere of radius R and thus given by $N(R) \propto R/r_0$ so that one has $M(R) \propto R$. Hence the model is self consistent in the sense that one can regard the orbiting stars as remnants of cosmic strings and thus obeying same mass distribution.

2. Cylindrically symmetric model for the galactic dark matter

TGD allows also a model of the dark matter based on cylindrical symmetry. In this case the dark matter would correspond to the mass of a cosmic string orthogonal to the galactic plane and traversing through the galactic nucleus. The string tension would the one predicted by TGD. In the directions orthogonal to the plane of galaxy the motion would be free motion so that the orbits would be helical, and this should make it possible to test the model. The quantization of radii of the orbits would be exactly the same as in the spherically symmetric model. Also the quantization of inclinations predicted by the spherically symmetric model could serve as a sensitive test. In this kind of situation general theory of relativity would predict only an angle deficit giving rise to a lens effect. TGD predicts a Newtonian $1/\rho$ potential in a good approximation.

Spiral galaxies are accompanied by jets orthogonal to the galactic plane and a good guess is that they are associated with the cosmic strings. The two models need not exclude each other. The vision about astrophysical structures as pearls of a fractal necklace would suggest that the visible matter has resulted in the decay of cosmic strings originally linked around the cosmic string going through the galactic plane and creating $M(R) \propto R$ for the density of the visible matter in the galactic bulge. The finding that galaxies are organized along linear structures [2] fits nicely with this picture.

3. MOND and TGD

TGD based model explains also the MOND (Modified Newton Dynamics) model of Milgrom [3] for the dark matter. Instead of dark matter the model assumes a modification of Newton's laws. The model is based on the observation that the transition to a constant velocity spectrum seems in the galactic halos seems to occur at a constant value of the stellar acceleration equal to $a_0 \simeq 10^{-11}g$, where g is the gravitational acceleration at the Earth. MOND theory assumes that Newtonian laws are modified below a_0.

The explanation relies on Bohr quantization. Since the stellar radii in the halo are quantized in integer multiples of a basic radius and since also rotation velocity v_0 is constant, the values of the acceleration are quantized as $a(n) = v_0^2/r(n)$ and a_0 correspond to the radius $r(n)$ of the smallest Bohr orbit for which the velocity is still constant. For larger orbital radii the acceleration would indeed be below a_0. a_0 would correspond to the distance above which the density of the visible matter does not appreciably perturb the gravitational potential of the straight string. This of course requires that gravitational potential is that given by Newton's theory and is indeed allowed by TGD.

2.3 The interpretation of $\hbar_{gr}$ and pre-planetary period

$\hbar_{gr}$ could corresponds to a unit of angular momentum for quantum coherent states at magnetic flux tubes or walls containing macroscopic quantum states. Quantitative estimate demonstrates that $\hbar_{gr}$ for astrophysical objects cannot correspond to spin angular momentum. For Sun-Earth system one would have $\hbar_{gr} \simeq 10^{77}\hbar$. This amount of angular momentum realized as a mere spin would require 10^{77} particles! Hence the only possible interpretation is as a unit of orbital angular momentum. The linear dependence of $\hbar_{gr}$ on m is consistent with the additivity of angular momenta in the fusion of magnetic flux tubes to larger units if the angular momentum associated with the tubes is proportional to both m and M.

Just as the gravitational acceleration is a more natural concept than gravitational force, also $\hbar_{gr}/m = GM/v_0$ could be more natural unit than

$\hbar_{gr}$. It would define a universal unit for the circulation $\oint v \cdot dl$, which is apart from $1/m$-factor equal to the phase integral $\oint p_\phi d\phi$ appearing in Bohr rules for angular momentum. The circulation could be associated with the flow associated with outer boundaries of magnetic flux tubes surrounding the orbit of mass m around the central mass $M \gg m$ and defining light like 3-D CDs analogous to black hole horizons.

The expression of $\hbar_{gr}$ depends on masses M and m and can apply only in space-time regions carrying information about the space-time sheets of M and and the orbit of m. Quantum gravitational holography suggests that the formula applies at 3-D light like causal determinant (CD) X_l^3 defined by the wormhole contacts gluing the space-time sheet X_l^3 of the planet to that of Sun. More generally, X_l^3 could be the space-time sheet containing the planet, most naturally the magnetic flux tube surrounding the orbit of the planet and possibly containing dark matter in super-conducting state. This would give a precise meaning for $\hbar_{gr}$ and explain why $\hbar_{gr}$ does not depend on the masses of other planets.

The simplest option consistent with the quantization rules and with the explanatory role of magnetic flux structures is perhaps the following one.

a) X_l^3 is a torus like surface around the orbit of the planet containing delocalized dark matter. The key role of magnetic flux quantization in understanding the values of v_0 suggests the interpretation of the torus as a magnetic or Z^0 magnetic flux tube. At pre-planetary period the dark matter formed a torus like quantum object. The conditions defining the radii of Bohr orbits follow from the requirement that the torus-like object is in an eigen state of angular momentum in the center of mass rotational degrees of freedom. The requirement that rotations do not leave the torus-like object invariant is obviously satisfied. Newton's law required by the quantum-classical correspondence stating that the orbit corresponds to a geodesic line in general relativistic framework gives the additional condition implying Bohr quantization.

b) A simple mechanism leading to the localization of the matter would have been the pinching of the torus causing kind of a traffic jam leading to the formation of the planet. This process could quite well have involved a flow of matter to a smaller planet space-time sheet Y_l^3 topologically condensed at X_l^3. Most of the angular momentum associated with torus like object would have transformed to that of planet and situation would have become effectively classical.

c) The conservation of magnetic flux means that the splitting of the orbital torus would generate a pair of Kähler magnetic charges. It is not clear whether this is possible dynamically and hence the torus could still be there. In fact, TGD explanation for the tritium beta decay anomaly [5, 6] in terms of classical Z^0 force [B1] requires the existence of this kind of torus containing neutrino cloud whose density varies along the torus. This picture suggests that the lacking $n=1$ and $n=2$ orbits in the region between Sun and Mercury are still in magnetic flux tube state containing mostly dark matter.

d) The fact that $\hbar_{gr}$ is proportional to m means that it could have varied continuously during the accumulation of the planetary mass without any effect in the planetary motion: this is of course nothing but a manifestation of Equivalence Principle.

2.4 Inclinations for the planetary orbits and the quantum evolution of the planetary system

The inclinations of planetary orbits provide a test bed for the theory. The semiclassical quantization of angular momentum gives the directions of angular momentum from the formula

$$cos(\theta) = \frac{m}{\sqrt{j(j+1)}} \ , \quad |m| \leq j \ . \tag{7}$$

where θ is the angle between angular momentum and quantization axis and thus also that between orbital plane and (x,y)-plane. This angle defines the angle of tilt between the orbital plane and (x,y)-plane.

$m=j=n$ gives minimal value of angle of tilt for a given value of n of the principal quantum number as

$$cos(\theta) \ = \ \frac{n}{\sqrt{n(n+1)}} \ . \tag{8}$$

For $n=3,4,5$ (Mercury, Venus, Earth) this gives $\theta=30.0$, 26.6, and 24.0 degrees respectively.

Only the relative tilt angles can be compared with the experimental data. Taking as usual the Earth's orbital plane as the reference the relative tilt angles give what are known as inclinations. The predicted inclinations are 6 degrees for Mercury and 2.6 degrees for Venus. The observed values [4] are 7.0 and 3.4 degrees so that the agreement is satisfactory. If one allows half-odd integer spin the fit is improved. For $j=m=n-1/2$ the predictions are 7.1 and 2.9 degrees for Mercury and Venus respectively. For Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto the inclinations are 1.9, 1.3, 2.5, 0.8, 1.8, 17.1 degrees. Nottale's quantization with $v_0 \rightarrow v_0/5$ with $n=1$ for Earth inclinations would have much larger scale and negative sign if $m=n=j$ is assumed. This suggests that the description in terms of Schrödinger equation fails for outer planets.

The assumption that matter has condensed from a matter rotating in (x,y)-plane orthogonal to the quantization axis suggests that the directions of the planetary spin axes are more or less the same and by angular momentum conservation have not changed appreciably. This is true except in the case of Uranus for which the spin axis is almost in the orbital plane: this is believed to be an outcome of some violent collision. The prediction for the tilt of the spin axis of the Earth is 24 degrees of freedom in the limit that the Earth's spin can be treated completely classically, that is for $m=j>>1$ in the units used for the quantization of the Earth's angular momentum. What is the value of $\hbar_{gr}$ for Earth is not obvious (using the unit $\hbar_{gr}=GM^2/v_0$ the Earth's spin angular momentum would be much smaller than one). The tilt of the spin axis of Earth with respect to the orbit plane is 23.5 degrees so that the agreement is again satisfactory. This prediction is essentially quantal: in purely classical theory the most natural guess for the tilt angle for planetary spins is 0 degrees.

The observation that the inner planets Mercury, Mars, and Earth have in a reasonable approximation the predicted inclinations suggest that they originate from a primordial period during which they formed spherical cells of dark matter and had thus full rotational degrees of freedom and were in eigen states of angular momentum corresponding to a full rotational symmetry. The subsequent $SO(3) \rightarrow SO(2)$ symmetry breaking leading to the formation of torus like configurations did not destroy the information about this period since the information about the value of j and m was coded by the inclination of the planetary orbit.

In contrast to this, the dark matter associated with Earth and outer planets up to Neptune formed a flattened magnetic or Z^0 magnetic flux tube resembling a disk with a hole and the subsequent symmetry breaking broke it to separate flux tubes. Earth's spherical disk was joined to the disk formed by the outer planets. The spherical disk could be still present and contain super-conducting dark matter. The presence of this "heavenly sphere" might closely relate to the fact that Earth is a living planet. The time scale $T=2\pi R/c$ is very nearly equal to 5 minutes and defines a candidate for a bio-rhythm.

If this flux tube carried the same magnetic flux as the flux tubes associated with the inner planets, the decomposition of the disk with a hole to 5 flux tubes corresponding to Earth and to the outer planets Mars, Jupiter, Saturn and Neptune, would explain the value of v_0 correctly and also the small inclinations of outer planets. That Pluto would not originate from this structure, is consistent with its anomalously large values of inclination $i = 17.1$ degrees, small value of eccentricity $e = .248$, and anomalously large value of inclination of equator to orbit about 122 degrees as compared to 23.5 degrees in the case of Earth [4].

2.5 Eccentricities and comets

Bohr-Sommerfeld quantization allows also to deduce the eccentricities of the planetary and comet orbits. One can write the quantization of energy as

$$\begin{aligned} \frac{p_r^2}{2m_1} + \frac{p_\theta^2}{2m_1 r^2} + \frac{p_\phi^2}{2m_1 r^2 sin^2(\theta)} - \frac{k}{r} &= -\frac{E_1}{n^2} \ , \\ E_1 = \frac{k^2}{2\hbar_{gr}^2} \times m_1 &= \frac{v_0^2}{2} \times m_1 \ . \end{aligned} \tag{9}$$

Here one has $k = GMm_1$. E_1 is the binding energy of $n = 1$ state. In the orbital plane ($\theta = \pi/2, p_\theta = 0$) the conditions are simplified. Bohr quantization gives $p_\phi = m\hbar_{gr}$ implying

$$\frac{p_r^2}{2m_1} + \frac{k^2\hbar_{gr}^2}{2m_1 r^2} - \frac{k}{r} = -\frac{E_1}{n^2} \ . \tag{10}$$

For $p_r = 0$ the formula gives maximum and minimum radii $r_\pm$ and eccentricity is given by

$$e^2 = \frac{r_+ - r_-}{r_+} = \frac{2\sqrt{1-\frac{m^2}{n^2}}}{1+\sqrt{1-\frac{m^2}{n^2}}} \ . \tag{11}$$

For small values of n the eccentricities are very large except for $m = n$. For instance, for $(m = n-1, n)$ for $n = 3,4,5$ gives $e = (.93,\ .89,\ .86)$ to be compared with the experimental values (.206, .007, .0167). Thus the planetary eccentricities with Pluto included ($e = .248$) must vanish in the lowest order approximation and must result as a perturbation of the magnetic flux tube.

The large eccentricities of comet orbits might however have an interpretation in terms of $m < n$ states. The prediction is that comets with small eccentricities have very large orbital radius. Oort's cloud is a system weakly bound to a solar system extending up to 3 light years. This gives the upper bound $n \leq 700$ if the comets of the cloud belong to the same family as Mercury, otherwise the bound is smaller. This gives a lower bound to the eccentricity of not nearly circular orbits in the Oort cloud as $e > .32$.

2.6 Why the quantum coherent dark matter is not visible?

The obvious objection against quantal astrophysics is that astrophysical systems look extremely classical. Quantal dark matter in many-sheeted space-time resolves this counter argument. As already explained, the sequence of symmetry breakings of the rotational symmetry would explain nicely why astral Bohr rules work. The prediction is however that delocalized quantal dark matter is probably still present at (the boundaries of) magnetic flux tubes and spherical shells. It is however the entire structure defined by the orbit which behaves like a single extended particle so that the localization in quantum measurement does not mean a localization to a point of the orbit. Planet itself corresponds to a smaller localized space-time sheet condensed at the flux tube.

One should however understand why this dark matter with a gigantic Planck constant is not visible. The fact that we do not observe dark matter could mean that we are not able to perform state function reduction localizing the dark matter. The probability for the state function reduction to occur is expected to be proportional to the strength of the measurement interaction, and in the case of photons the strength of the interaction is characterized by fine structure constant.

In the case of dark matter the fine structure constant is replaced with

$$\alpha_{em,gr} = \alpha_{em} \times \frac{\hbar}{\hbar_{gr}} = \alpha_{em} \times \frac{v_0}{GMm} \ . \tag{12}$$

For $M = m = m_{Pl} \simeq 10^{-8}$ kg the value of the fine structure constant is smaller than $\alpha_{em} v_0$ and completely negligible for astrophysical masses. Dark matter would be indeed dark.

It must be emphasized that that the coupling constant cannot characterize elementary particles but the amplitude for the emission of photons by a macroscopic quantum coherent state of dark matter behaving as a single dynamical unit. For a net charge Ne the effective fine structure becomes $N^2 \alpha_{em,gr}$ and is still extremely small for reasonable values of N.

3 Quantum interpretation of gravitational Schrödinger equation

Schrödinger equation in astrophysical length scales with a gigantic value of Planck constant looks sheer madness idea from the standard physics point of view. In TGD Universe situation might be different.

a) In TGD inertial four-momentum (or conserved four-momentum) is not positive definite and the net four-momentum of the Universe vanishes. Already in cosmological length scales the density of inertial mass vanishes. Gravitational masses and inertial masses can be identified only at the limit when one can neglect the interaction between positive and negative energy matter. The masses appearing in the gravitational Schrödinger equation are gravitational masses and one can ask whether inertial and gravitational Planck constants are different.

b) The fractality of the many-sheeted space-time predicts that quantum effects appear in all length and time scales. In particular, dark matter is at larger space-time sheets and hence almost invisible.

c) An even more weirder looks the idea that Planck constant could have a gigantic value in astrophysical length scales being of order of magnitude of product of masses using Planck mass as a unit for $\hbar = c = 1$. This would mean that gravitation at space-time sheets of astrophysical size would have super quantal character! But even the gigantic value of Planck constant might be understood in TGD framework.

3.1 Beraha numbers and spectrum of Planck constant

The infinite-dimensional Clifford algebra of the configuration space ("the world of classical worlds") gamma matrices defines so called von Neumann algebra with a hierarchy of type II_1 sub-factors. So called Beraha numbers

$$B_n \ = \ 4cos^2(\frac{\pi}{n}), \ \ n \geq 3 \tag{13}$$

relate very closely to these factors as also to braid groups and quantum groups. Roughly, B_n corresponds to the renormalized dimension d of 4-component spinors of $D = 4$ dimensional space whose dimension becomes also renormalized. The formula $d_n = B_n = 2^{D_n/2}$ relating the dimension of spinors to the space-time dimension gives for the renormalized space-time dimension the expression $D_n = 2log(B_n)/log(2)$ approaching $D = 4$ at the limit $n \rightarrow \infty$. Note that the spectrum of fractal space-time dimension would have upper limit $D = 4$. In fact, there is also a continuum of dimensions $D \geq 4$ for the dimensions of sub-factors of type II_1. Obviously, the dimensions behave like energy spectrum of a quantum mechanical systems. That $D = 4$ is the limiting value of bound state dimensions suggests strongly a connection with the fact that the infinities of quantum field theory appear for $D \geq 4$.

The TGD based model for topological quantum computation [C1] based on the braiding of magnetic flux tubes led to the idea that this braiding could be seen as space-time correlate for a spectral flow for conformal weights at the level of configuration space spinor fields so that the connection with type II_1 factors emerges naturally.

In [A1] I developed general ideas related to type II_1 factors of von Neumann algebras and their connection with the physics predicted by quantum TGD. The speculation was that Beraha numbers define an entire spectrum of values of $\hbar$ or equivalently spectrum of values of Kähler coupling strength $\alpha_K \equiv g_K^2/4\pi\hbar$. The values of $\hbar$ would be given by

$$\hbar(n) = \frac{log(B_\infty)}{log(B_n)} \times \hbar(\infty) = \frac{log(4)}{log(4cos^2(\pi/n))} \times \hbar(\infty) \ , \ n \geq 3 \ . \quad (14)$$

The proposed interpretation was that the spectrum corresponds to renormalization group evolution fixed points of α_K related to the angular/phase resolution whereas the p-adic length scale evolution of the Kähler coupling constant corresponds to length scale resolution. Small values of n would correspond to a poor angular/phase resolution.

The spectrum has remarkable features.

a) The ratio $\hbar(4)/\hbar(\infty) = 2$ means that in the range $n \geq 4$ $\hbar$ varies only by a factor of 2. The measured value of $\hbar$ is in the range $n \geq 4$: probably rather near to $\hbar(\infty)$. The cosmic evolution of $\hbar(n)$ induced by a gradual increase of the angular resolution might explain the reported increase of the fine structure constant $\alpha = e^2/4\pi\hbar c$ during cosmic evolution. The smallness of the increase implies that the recent value of n must be rather large so that $\hbar \simeq \hbar(\infty)$ should be a good approximation and it might be impossible to distinguish it from $\hbar(\infty)$ experimentally. Of course, the detection of varying values of fine structure constant in accordance with the prediction would be a victory for the proposed admittedly heuristic theory. It is known that different measurement methods give slightly different values for the fine structure constant so that it might be a good idea to check whether the variation could be understood in terms of Beraha numbers.

b) $n = 3$ is a complete exception since one has $\hbar(3) = \infty$ so that Kähler coupling strength and presumably also fine structure constant vanishes. This makes sense only if the Kähler action of the space-time sheet is vanishing in this phase. In fact, the requirement that the vacuum functional defined by the exponent of the Kähler function is non-vanishing for the entire universe, requires that Kähler per volume vanishes so that this condition is quite sensible and corresponds to a scale invariant situation. Vacuum extremals are a basic example of a phase with a vanishing Kähler action and correspond to a situation in which the energy densities of positive and negative energy matter cancel each other in the length scale considered. Robertson-Walker cosmologies are basic cosmological example in this respect [A2].

3.2 Gravitational Planck constant as a small perturbation of $1/\hbar(3) = 0$

Although the value of $\hbar_{gr}$ in the Nottale's variant of Schrödinger equation is not strictly infinite, it is infinite for almost all numerical purposes. From the point of view of α_K $\hbar/\hbar_{gr}$ is the correct number to consider and the deviation of $\hbar/\hbar_{gr}$ from zero could be interpreted as a gravitational perturbative effect changing the value of x from zero. The modification would be given by

$$\frac{\hbar}{\hbar_{gr}} = \frac{v_0}{GMm} \tag{15}$$

would be extremely small, and would have a natural interpretation as resulting from the gravitational interaction between masses M and m.

What is interesting is that the modification is not proportional to GmM but to the small parameter v_0/GMm One could interpret the parameter as proportional to the product of Compton lengths associated with M and m using CP_2 radius R as the natural fundamental length unit.

A possible interpretation for the deviation of $\hbar/\hbar_{gr}$ from zero is as a deviation $\Delta\phi = \pi/3 - \phi$ of the angle ϕ defining Beraha number from the maximal value $\phi = \pi/3$. One would have

$$\Delta\phi = \frac{\pi}{3} - arcos(2^{\hbar/\hbar_{gr}-1}) \simeq \frac{log(2)}{\sqrt{3}}\frac{\hbar}{\hbar_{gr}} = \frac{log(2)}{\sqrt{3}}\frac{v_0}{GMm} . \tag{16}$$

The proposed picture would suggest that when the system size becomes very large $n = 3$ super quantum phase is approached. This requires that the extremals of Kähler action have vanishing or extremely small action. This is indeed the case for the vacuum extremals and Robertson-Walker cosmologies are the most important example of vacuum extremals cosmologically. What is interesting that inertial and gravitational Planck constants seem to lie at the opposite ends of the spectrum of Planck constants.

3.3 Gravitational Schrödinger equation as a means of avoiding gravitational collapse

Schrödinger equation provided a solution to the infrared catastrophe of the classical model of atom: the classical prediction was that electron would radiate its energy as brehmstrahlung and would be captured by the nucleus. The gravitational variant of this process would be the capture of the planet by a black hole, and more generally, a collapse of the star to a black hole. Gravitational Schrödinger equation could obviously prevent the catastrophe.

For $1/r$ gravitation potential the Bohr radius is given by $a_{gr} = GM/v_0^2 = r_S/2v_0^2$, where $r_S = 2GM$ is the Schwartchild radius of the mass creating the gravitational potential: obviously Bohr radius is much larger than the Schwartschild radius. That the gravitational Bohr radius does not depend on m conforms with Equivalence Principle, and the proportionality $\hbar_{gr} \propto Mm$ can be deduced from it. Gravitational Bohr radius is by a factor $1/2v_0^2$ larger than black hole radius so that black hole can swallow the piece of matter with a considerable rate only if it is in the ground state and also in this state the rate is proportional to the black hole volume to the volume defined by the black hole radius given by $2^3 v_0^6 \sim 10^{-20}$.

The $\hbar_{gr} \rightarrow \infty$ limit for $1/r$ gravitational potential means that the exponential factor $exp(-r/a_0)$ of the wave function becomes constant: on the other hand, also Schwartshild and Bohr radii become infinite at this limit. The gravitational Compton length associated with mass m does not depend on m and is given by GM/v_0 and the time $T = E_{gr}/\hbar_{gr}$ defined by the gravitational binding energy is twice the time taken to travel a distance defined by the radius of the orbit with velocity v_0 which suggests that signals travelling with a maximal velocity v_0 are involved with the quantum dynamics.

In the case of planetary system the proportionality $\hbar_{gr} \propto mM$ creates problems of principle since the influence of the other planets is not taken account. One might argue that the generalization of the formula should be such that M is determined by the gravitational field experienced by mass m and thus contains also the effect of other planets. The problem is that this field depends on the position of m which would mean that $\hbar_{gr}$ itself would become kind of field quantity.

3.4 Does the transition to non-perturbative phase correspond to a change in the value of $\hbar$?

Nature is populated by systems for which perturbative quantum theory does not work. Examples are atoms with $Z_1Z_2e^2/4\pi\hbar > 1$ for which the binding energy becomes larger than rest mass, non-perturbative QCD resulting for $Q_{s,1}Q_{s,2}g_s^2/4\pi\hbar > 1$, and gravitational systems satisfying $GM_1M_2/4\pi\hbar > 1$. Quite generally, the condition guaranteing troubles is of the form $Q_1Q_2g^2/4\pi\hbar > 1$. There is no general mathematical approach for solving the quantum physics of these systems but it is believed that a phase transition to a new phase of some kind occurs.

The gravitational Schrödinger equation forces to ask whether Nature herself takes care of the problem so that this phase transition would involve a change of the value of the Planck constant to guarantee that the perturbative approach works. The values of $\hbar$ would vary in a stepwise manner from $\hbar(\infty)$ to $\hbar(4) = \hbar(\infty)/2$ corresponding to $B(4)$ and the last step would be a transition to a phase which differs only slightly from the phase $1/\hbar(3) = 0$ would occur and correspond to

$$\hbar \quad \rightarrow \quad \frac{Q_1Q_2g^2}{v} \tag{17}$$

inducing

$$\frac{Q_1Q_2g^2}{4\pi\hbar} \rightarrow \frac{v}{4\pi} \ . \tag{18}$$

The simplest (and of course ad hoc) assumption making sense in TGD Universe is that v is a harmonic or subharmonic of v_0 appearing in the gravitational Schrödinger equation. For instance, for the Kepler problem the spectrum of binding energies would be universal (independent of the values of charges) and given by $E_n = v^2m/2n^2$ with v playing the role of small coupling. Bohr radius would be g^2Q_2/v^2 for $Q_2 \gg Q_1$.

This provides a new insight to the problems encountered in quantizing gravity. QED started from the model of atom solving the infrared catastrophe. In quantum gravity theories one has started directly from the quantum field theory level and the recent decline of the M-theory shows that we are still practically where we started. If the gravitational Schrödinger equation indeed allows quantum interpretation, one could be more modest and start from the solution of the gravitational IR catastrophe by assuming a dynamical spectrum of $1/\hbar$ fixed in the first approximation by Beraha numbers and perhaps containing perturbative additive corrections defined by the previous general formula which for $n = 3$ case would give the entire coupling. The implications would be profound: the whole program of quantum gravity would have been misled as far as the quantization of systems with $GM_1M_2/\hbar > 1$ is considered. In practice, these systems are the most interesting ones and the prejudice that their quantization is a mere academic exercise would have been completely wrong.

4 How do the magnetic flux tube structures and quantum gravitational bound states relate?

In the case of stars in galactic halo the appearence of the parameter v_0 characterizing cosmic strings as orbital rotation velocity can be understood classically. That v_0 appears also in the gravitational dynamics of planetary orbits could relate to the dark matter at magnetic flux tubes. The argument explaining the harmonics and sub-harmonics of v_0 in terms of properties of cosmic strings and magnetic flux tubes identifiable as their descendants strengthens this expectation.

4.1 The notion of magnetic body

In TGD inspired theory of consciousness the notion of magnetic body plays a key role: magnetic body is the ultimate intentional agent, experiencer, and performer of bio-control and can have astrophysical size: this does not sound so counter-intuitive if one takes seriously the idea that cognition has p-adic space-time sheets as space-time correlates and that rational points are common to real and p-adic number fields. The point is that infinitesimal in p-adic topology corresponds to infinite in real sense so that cognitive and intentional structures would have literally infinite size.

The magnetic flux tubes carrying various supra phases can be interpreted as special instance of dark energy and dark matter. This suggests a correlation between gravitational self-organization and quantum phases at the magnetic flux tubes and that the gravitational Schrödinger equation somehow relates to the ordinary Schrödinger equation satisfied by the macroscopic quantum phases at magnetic flux tubes. Interestingly, the transition to large Planck constant phase should occur when the masses of two interacting objects are above Planck mass. For the density of water about 10^3 kg/m^3 the volume carrying a Planck mass correspond to a cube with side 2.8×10^{-4} meters. This corresponds to a volume of a large neuron, which suggests that this phase transition might play an important role in neuronal dynamics.

4.2 Could gravitational Schrödinger equation relate to a quantum control at magnetic flux tubes?

An infinite self hierarchy is the basic prediction of TGD inspired theory of consciousness ("everything is conscious and consciousness can be only lost"). Topological quantization allows to assign to any material system a field body as the topologically quantized field pattern created by the system [D4, D1]. This field body can have an astrophysical size and would utilize the material body as a sensory receptor and motor instrument.

Magnetic flux tube and flux wall structures are natural candidates for the field bodies. Various empirical inputs have led to the hypothesis that the magnetic flux tube structures define a hierarchy of magnetic bodies, and that even Earth and larger astrophysical systems possess magnetic body which makes them conscious self-organizing living systems. In particular, life at Earth would have developed first as a self-organization of the superconducting dark matter at magnetic flux tubes [D4].

For instance, EEG frequencies corresponds to wavelengths of order Earth size scale and the strange findings of Libet about time delays of conscious experience [9, 10] find an elegant explanation in terms of time taken for signals propagate from brain to the magnetic body [D1]. Cyclotron frequencies, various cavity frequencies, and the frequencies associated with various p-adic frequency scales are in a key role in the model of bio-control performed by the magnetic body. The cyclotron frequency scale is given by $f = eB/m$ and rather low as are also cavity frequencies such as Schumann frequencies: the lowest Schumann frequency is in a good approximation given by $f = 1/2\pi R$ for Earth and equals to 7.8 Hz.

4.2.1 Quantum time scales as "bio-rhythms" in solar system?

To get some idea about the possible connection of the quantum control possibly performed by the dark matter with gravitational Schrödinger equation, it is useful to look for the values of the periods defined by the gravitational binding energies of test particles in the fields of Sun and Earth and look whether they correspond to some natural time scales. For instance, the period $T = 2GM_S n^2/v_0^3$ defined by the energy of n^{th} planetary orbit depends only on the mass of Sun and defines thus an ideal candidate for a universal "bio-rhytm".

For Sun black hole radius is about 2.9 km. The period defined by the binding energy of lowest state in the gravitational field of Sun is given $T_S = 2GM_S/v_0^3$ and equals to 23.979 hours for $v_0/c = 4.8233 \times 10^{-4}$. Within experimental limits for v_0/c the prediction is consistent with 24 hours! The value of v_0 corresponding to exactly 24 hours would be $v_0 = 144.6578$ km/s. As if as the frequency defined by the lowest energy state would define a "biological" clock at Earth! Mars is now a strong candidate for a seat of life and the day in Mars lasts 24hr 37m 23s! $n = 1$ and $n = 2$ are orbitals are not realized in solar system as planets but there is evidence for the $n = 1$ orbital as being realized as a peak in the density of IR-dust [1]. One can of course consider the possibility that these levels are populated by small dark matter planets with matter at larger space-time sheets. Bet as it may, the result supports the notion of quantum gravitational entrainment in the solar system.

The slower rhythms would become as n^2 sub-harmonics of this time scale. Earth itself corresponds to $n = 5$ state and to a rhythm of .96 hours: perhaps the choice of 1 hour to serve as a fundamental time unit is not merely accidental. The magnetic field with a typical ionic cyclotron frequency around 24 hours would be very weak: for 10 Hz cyclotron frequency in Earth's magnetic field the field strength would about 10^{-11} T. However, $T = 24$ hours corresponds with 6 per cent accuracy to the p-adic time scale $T(k = 280) = 2^{13}T(2, 127)$, where $T(2, 127)$ corresponds to the secondary p-adic time scale of .1 s associated with the Mersenne prime $M_{127} = 2^{127} - 1$ characterizing electron and defining a fundamental bio-rhytm and the duration of memetic codon [D3].

Comorosan effect [7, 8, C2] demonstrates rather peculiar looking facts about the interaction of organic molecules with visible laser light at wavelength $\lambda = 546\ nm$. As a result of irradiation molecules seem to undergo a transition $S \rightarrow S^*$. S^* state has anomalously long lifetime and stability in solution. $S \rightarrow S^*$ transition has been detected through the interaction of S^* molecules with different biological macromolecules, like enzymes and cellular receptors. Later Comorosan found that the effect occurs also in nonliving matter. The basic time scale is $\tau_C = 5$ seconds. p-Adic length scale hypothesis does not explain τ_C, and it does not correspond to any obvious astrophysical time scale and has remained a mystery.

The idea about astro-quantal dark matter as a fundamental bio-controller inspires the guess that τ_C could correspond to some Bohr radius R for a solar system via the correspondence $\tau = R/c$. As observed by Nottale, $n = 1$ orbit for $v_0 \rightarrow 3v_0$ corresponds in a good approximation to the solar radius. For $v_0 \rightarrow 2v_0$ $n = 1$ orbit corresponds to $\tau = AU/(4 \times 25) = 4.992$ seconds:

here $R = AU$ is the astronomical unit equal to the average distance of Earth from Sun. The deviation from τ_C is only one per cent and of the same order of magnitude as the variation of the radius for the orbit due to orbital eccentricity $(a-b)/a = .0167$ [4].

4.2.2 Earth-Moon system

For Earth serving as the central mass the Bohr radius is about 18.7 km, much smaller than Earth radius so that Moon would correspond to $n = 147.47$ for v_0 and $n = 1.02$ for the sub-harmonic $v_0/12$ of v_0. For an afficionado of cosmic jokes or a numerologist the presence of the number of months in this formula might be of some interest. Those knowing that the Mayan calendar had 11 months and that Moon is receding from Earth might rush to check whether a transition from $v/11$ to $v/12$ state has occurred after the Mayan culture ceased to exist: the increase of the orbital radius by about 3 per cent would be required! Returning to a more serious mode, an interesting question is whether light satellites of Earth consisting of dark matter at larger space-time sheets could be present. For instance, in [D4] I have discussed the possibility that the larger space-time sheets of Earth could carry some kind of intelligent life crucial for the bio-control in the Earth's length scale.

The period corresponding to the lowest energy state is from the ratio of the masses of Earth and Sun given by $M_E/M_S = (5.974/1.989) \times 10^{-6}$ given by $T_E = (M_E/M_S) \times T_S = .2595$ s. The corresponding frequency $f_E = 3.8535$ Hz frequency is at the lower end of the theta band in EEG and is by 10 per cent higher than the p-adic frequency $f(251) = 3.5355$ Hz associated with the p-adic prime $p \simeq 2^k$, $k = 251$. The corresponding wavelength is 2.02 times Earth's circumference. Note that the cyclotron frequencies of Nn, Fe, Co, Ni, and Cu are $5.5, 5.0, 5.2, 4.8$ Hz in the magnetic field of $.5 \times 10^{-4}$ Tesla, which is the nominal value of the Earth's magnetic field. In [D4] I have proposed that the cyclotron frequencies of Fe and Co could define biological rhythms important for brain functioning. For $v_0/12$ associated with Moon orbit the period would be 7.47 s: I do not know whether this corresponds to some bio-rhytm.

It is better to leave for the reader to decide whether these findings support the idea that the super conducting cold dark matter at the magnetic flux tubes could perform bio-control and whether the gravitational quantum states and ordinary quantum states associated with the magnetic flux tubes couple to each other and are synchronized.

4.3 p-Adic length scale hypothesis and $v_0 \rightarrow v_0/5$ transition at inner-outer border for planetary system

The obvious question is whether inner to outer zone as $v_0 \rightarrow v_0/5$ transition could be interpreted in terms of the p-adic length scale hierarchy.

a) The most important p-adic length scale are given by primary p-adic length scales $L(k) = 2^{(k-151)/2} \times 10$ nm and secondary p-adic length scales $L(2,k) = 2^{k-151} \times 10$ nm, k prime.

b) The p-adic scale $L(2,139) = 114$ Mkm is slightly above the orbital radius 109.4 Mkm of Venus. The p-adic length scale $L(2,137) \simeq 28.5$ Mkm is roughly one half of Mercury's orbital radius 57.9 Mkm. Thus strong form of p-adic length scale hypothesis could explain why the transition $v_0 \rightarrow v_0/5$ occurs in the region between Venus and Earth ($n = 5$ orbit for v_0 layer and $n = 1$ orbit for $v_0/5$ layer).

c) Interestingly, the *primary* p-adic length scales $L(137)$ and $L(139)$ correspond to fundamental atomic length scales which suggests that solar system be seen as a fractally scaled up "secondary" version of atomic system.

d) Planetary radii have been fitted also using Titius-Bode law predicting $r(n) = r_0 + r_1 \times 2^n$. Hence on can ask whether planets are in one-one correspondence with primary and secondary p-adic length scales $L(k)$. For the orbital radii $58, 110, 150, 228$ Mkm of Mercury, Venus, Earth, and Mars indeed correspond approximately to k= $276, 278, 279, 281$: note the special position of Earth with respect to its predecessor. For Jupiter, Saturn, Uranus, Neptune, and Pluto the radii are 52,95,191,301,395 Mkm and would correspond to p-adic length scales $L(280 + 2n))$, $n = 0, ..., 3$. Obviously the transition $v_0 \rightarrow v_0/5$ could occur in order to make the planet–p-adic length scale one-one correspondence possible.

e) It is interesting to look whether the p-adic length scale hierarchy applies also to the solar structure. In a good approximation solar radius 700 Mkm corresponds to $L(270)$, the lower radius 496 Mkm of the convective zone corresponds to $L(269)$, and the lower radius 174 Mkm of the radiative zone (radius of the solar core) corresponds to $L(266)$. This encourages the hypothesis that solar core has an onion like sub-structure corresponding to various p-adic length scales. In particular, $L(2,127)$ ($L(127)$ corresponds to electron) would correspond to 28 Mm. The core is believed to contain a structure with radius of about 10 km: this would correspond to $L(231)$. This picture would suggest universality of star structure in the sense that stars would differ basically by the number of the onion like shells having standard sizes.

Quite generally, in TGD Universe the formation of join along boundaries bonds is the space-time correlate for the formation of bound states. This encourages to think that (Z^0) magnetic flux tubes are involved with the formation of gravitational bound states and that for $v_0 \rightarrow v_0/k$ corresponds either to a splitting of a flux tube resembling a disk with a whole to k pieces, or to the scaling down $B \rightarrow B/k^2$ so that the magnetic energy for the flux tube thickened and stretched by the same factor k^2 would not change.

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