Is Dark Matter Quantum Coherent in Astrophysical Scales?

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Abstract

There exists a considerable evidence that astrophysical objects obey quantization rules with a gigantic value of Planck constant. Nottale and Da Rocha explain the findings in terms of fractal hydrodynamics modellable in terms of Schrödinger equation with an effective Planck constant whose general form is fixed by Equivalence Principle. In this article an interpretation as a genuine quantum effect based on quantization of Planck constant allowing dark matter to be quantum coherent in astrophysical scales is discussed. The model predicts correctly the value of the velocity parameter appearing in the gravitational Planck constant and explains the appearance of its harmonics and sub-harmonics. A quantum model for the formation of planetary system is proposed. Some numerical co-incidences support the view that quantum coherent dark matter could be also responsible for the properties of living matter.

Keywords: Bohr quantization, planets, macroscopic quantum coherence, dark matter, living matter,

1 Introduction

D. Da Rocha and Laurent Nottale have ended up with a highly interesting model for the evolution of astrophysical systems [1]. The model is simply gravitational Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant

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

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 sub-harmonics and harmonics of v_0 seem to appear.

The model makes highly non-trivial 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 eccentricities have been tested successfully also for exo-planets. 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. These predictions follow from Bohr rules alone. Also predictions for the distribution of stars in the regions where morphogenesis occurs follow from the gravitational Schödinger equation.

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. A rather detailed model for the formation of solar system making quantitatively correct predictions follows from the study of inclinations and eccentricities predicted by the Bohr rules: the model proposed seems to differ from that of Nottale which makes predictions for the probability distribution of eccentricities and inclinations.

I have proposed already earlier [A1] 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 radii of planetary orbits can be understood assuming only single value of v_0 if the principal quantum number n is allowed to vary freely and the dark masses at the missing planetary orbits are assumed to be small enough. 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 Schrödinger equation holds true only inside flux quanta for the dark matter. A remnant of the dark matter would be still in a macroscopic quantum state at the flux quanta. It would couple to photons as a quantum coherent state but the coupling is extremely small due to the gigantic value of $\hbar_{gr}$ scaling α by $\hbar/\hbar_{gr}$: hence the darkness.

It is difficult to avoid the idea about identifying dark matter forming quantum coherent structures of astrophysical size as being responsible for the basic characteristics of living matter. The enormous value of h_{gr} makes the characteristic time scales of these quantum coherent states extremely long and implies macro-temporal quantum coherence in human and even longer time scales. The amazing coincidences between basic bio-rhythms and the periods associated with the orbits in solar system suggest that the frequencies defined by the energy levels predicted by the gravitational Bohr rules might entrain with various biological frequencies.

The interested reader can find a more detailed representation of the ideas discussed in this article in [A5]. How TGD predicts the quantization of Planck constant is discussed in [A2]. The chapters of [cbookI] and [cbookII] provide an overall view of the biological applications of the hypothesis that dark matter corresponds to a large $\hbar$ macroscopically quantum coherent phase.

2 The Interpretation of the Parameters v_0 and $\hbar_{gr}$

The parameter v_0 appearing in the gravitational Bohr rules 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 which could consists of cosmic strings. Cosmic strings could be orthogonal to the galactic plane going through the nucleus (jets) or they could be in galactic plane in which case the strings and their decay products would explain dark matter assuming that the length of cosmic string inside a sphere of radius R is or has been roughly R [A4]. 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.

The parameter $v_0 \simeq 2^{-11}$, which has actually the dimension of velocity unless on puts $c = 1$, and also its harmonics and sub-harmonics appear in the scaling of $\hbar$. v_0 corresponds to the velocity of distant stars in the model of galactic dark matter. TGD allows to identify this parameter as the parameter

$$v_0 = 2\sqrt{TG} = \sqrt{\frac{1}{2\alpha_K}}\sqrt{\frac{G}{R^2}} ,$$

$$T = \frac{1}{8\alpha_K}\frac{\hbar_0}{R^2} . \qquad (2)$$

Here T is the string tension of cosmic strings, R denotes the "radius" of CP_2 ($2R$ is the radius of geodesic sphere of CP_2). α_K is Kähler coupling strength, the basic coupling constant strength of TGD, whose evolution as a function of p-adic length scale is fixed by quantum criticality. The condition that G is invariant in the p-adic coupling constant evolution and number theoretical arguments predict

$$\begin{aligned} \alpha_K(p) &= k\frac{1}{log(p)+log(K)} , \\ K &= \frac{R^2}{\hbar_0 G} = 2\times 3\times 5\times 7\times 11\times 13\times 17\times 19\times 23 \ , \ k\simeq \pi/4 . \end{aligned} \qquad (3)$$

The predicted value of v_0 depends logarithmically on the p-adic length scale and for $p \simeq 2^{127}-1$ (electron's p-adic length scale) one has $v_0 \simeq 2^{-11}$.

2.2 Model for Planetary Orbits Without $v_0 \rightarrow v_0/5$ Scaling

Also harmonics and sub-harmonics of v_0 appear in the model of Nottale and Da Rocha. For instance, the outer planets (Jupiter, Saturn,...) 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 sub-harmonics 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 scaling is not necessary for the planetary orbits in TGD based model.

Effectively a multiplication $n \rightarrow 5n$ of the principal quantum number is in question in the case of outer planets. If one accepts the interpretation that visible matter has concentrated around dark matter, which is in macroscopic quantum phase around Bohr orbits, this allows to consider also the possibility that $\hbar_{gr}$ has the same value for all planets.

a) Some gravitational perturbation has kicked dark matter from the region of the asteroid belt to $n \simeq 5k$, $k = 2, .., 6$, orbits. The best fit is obtained by using values of n deviating somewhat from multiples of 5 which suggests that the scaling of v_0 is not needed. Gravitational perturbations might have caused the same for the visible matter. The fact that the tilt angles of Earth and outer planets other than Pluto are nearly the same suggests that the orbits of these planets might be an outcome of some violent quantum process for dark matter preserving the orbital plane in a good approximation. Pluto might in turn have experienced some violent collision changing its orbital plane.

b) There could exist at least small amounts of dark matter at all orbits but visible matter is concentrated only around orbits containing some critical amount of dark matter.

Table 1. The table represents the experimental average orbital radii of planets, the predictions of Titius-Bode law (note the failure for Neptune), and the predictions of Bohr orbit model assuming a)that the principal quantum number n corresponds to best possible fit, b) the scaling $\lambda \rightarrow \lambda/5$ for outer planets. Option a) gives the best fit with errors being considerably smaller than the maximal error $|\Delta R|/R \simeq 1/n$ except for Uranus.

	Exp.	Titius-Bode	$Bohr_1$	$Bohr_2$
Planet	R/R_M	R/R_M	$[n, R/R_M]$	$[n, R/R_M]$
Mercury	1	1	[3, 1]	
Venus	1.89	1.75	[4, 1.8]	
Earth	2.6	2.5	[5, 2.8]	
Mars	3.9	4	[6, 4]	
Asteroid belt	6.1-8.7	7	[(7, 8, 9), (5.4, 7.1, 9)]	
Jupiter	13.7	13	[11, 13.4]	[2 × 5,11.1]
Saturn	25.0	25	[3 × 5, 25]	[3 × 5, 25]
Uranus	51.5	49	[22, 53.8]	[4 × 5,44.4]
Neptune	78.9	97	[27 , 81]	[5 × 5, 69.4]
Pluto	105.2	97	[31, 106.7]	[6 × 5,100]

2.3 How to Understand the Harmonics and Sub-harmonics of v_0 in TGD Framework?

As found, harmonics and sub-harmonics of v_0 are not absolutely necessary in TGD based model for planetary orbits but this kind of phase transition might have occurred at the Earth's distance, which is critical in the sense that the interpretations as $n = 5$ orbit for v_0 and $n = 1$ orbit for $v_0/5$ are possible. Quantum criticality is the defining property of living systems in TGD Universe and this criticality might also relate to the very special position of Earth as the only living planet. If real, the scaling 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 $n \rightarrow 1$ 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 $n \rightarrow \infty$ limit has an interpretation as an approach to chaos [B2]. 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. 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.

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 [A4, A3].

2.4 The Interpretation of $\hbar_{gr}$ and Pre-planetary Period

$\hbar_{gr}$ could correspond 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 [3, 4] 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.

2.5 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

$$cos(\theta) = \frac{m}{\sqrt{j(j+1)}} \ , \quad |m| \leq j \ . \tag{4}$$

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

$$cos(\theta) = \frac{n}{\sqrt{n(n+1)}} \ . \tag{5}$$

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 [2] 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. For Mars and outer planets the tilt angles are predicted to have wrong sign for $m = j$. In a good approximation the inclinations vanish for outer planets except Pluto and this would allow to determine m as $m \simeq \sqrt{5n(n+1)/6}$: the fit is not good.

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 rotation axes are more or less the same and by angular momentum conservation have not changed appreciably. The prediction for the tilt of the rotation 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 angular momentum would be much smaller than one). The tilt of the rotation 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, Venus, 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 [2].

2.6 Eccentricities and Comets

Bohr-Sommerfeld quantization allows also to deduce the eccentricities of the planetary and comet orbits:

$$e^2 = \frac{r_+ - r_-}{r_+} = \frac{2\sqrt{1-\frac{m^2}{n^2}}}{1+\sqrt{1-\frac{m^2}{n^2}}} . \tag{6}$$

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 $e > .32$.

2.7 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 simplest explanation is that there cannot be any direct quantum interactions between ordinary and dark matter in the sense that particles with different values of Planck constant could appear in the same particle vertex. This would allow also a fractal hierarchy copies of standard model physics to exist with different p-adic mass scales.

There is also second argument. The inability to observe dark matter could mean inability to perform state function reduction localizing the dark matter. The probability for this should be proportional to the strength of the measurement interaction. For photons the strength of the interaction is characterized by the fine structure constant. In the case of dark matter the fine structure constant is replaced with

$$\alpha_{em,gr} = \alpha_{em} \times \frac{\hbar}{\hbar_{gr}} = \alpha_{em} \times \frac{v_0}{GMm} . \qquad (7)$$

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. Note that $\alpha_{em,gr}$ cannot characterize elementary particles but the amplitude for the emission of photons by a macroscopic quantum coherent state 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 Universe 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

$$B_n = 4cos^2(\frac{\pi}{n}), \; n \geq 3 \tag{8}$$

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

$$\hbar(n) = \frac{log(B_\infty)}{log(B_n)} \times \hbar(\infty) = \frac{log(4)}{log(4cos^2(\pi/n))} \times \hbar(\infty) \ , \ n \geq 3 \ . \quad (9)$$

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 [A3].

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

$$\frac{\hbar}{\hbar_{gr}} = \frac{v_0}{GMm} \tag{10}$$

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

$$\Delta\phi = \frac{\pi}{3} - arcos(2^{\hbar/\hbar_{gr}-1}) \simeq \frac{log(2)}{\sqrt{3}}\frac{\hbar}{\hbar_{gr}} = \frac{log(2)}{\sqrt{3}}\frac{v_0}{GMm} \ . \tag{11}$$

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 $2^3 v_0^6 \sim 10^{-20}$.

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 $Z_1 Z_2 e^2/4\pi\hbar > 1$ 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

$$\hbar \rightarrow \frac{Q_1Q_2g^2}{v} \tag{12}$$

inducing

$$\frac{Q_1Q_2g^2}{4\pi\hbar} \rightarrow \frac{v}{4\pi} . \tag{13}$$

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 $Q_2 \gg Q_1$.

4 Dark Matter and Living Matter

An infinite self hierarchy is the basic prediction of TGD inspired theory of consciousness ("everything is conscious and consciousness can be only lost") [cbookI, cbookII]. Topological quantization allows to assign to any material system a field/magnetic body as the topologically quantized field pattern created by the system [D2, D1]. The 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. The life at Earth would have developed first as a self-organization of the super-conducting dark matter at magnetic flux tubes [D2].

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.

To get some idea about the possible connection of the quantum control possibly performed by the dark matter obeying gravitational Schrödinger equation (or at least Bohr rules), 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 $T = 2GM_Sn^2/v_0^3$ 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. Be as it may, the result supports the notion of quantum gravitational entrainment in the solar system.

Comorosan effect [5, 6, 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 non-living 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 [cbookI, cbookII] 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 $(a - b)/a = .0167$ [2].

5 Conclusions

TGD predicts correctly the value of the basic parameter v_0 appearing in the gravitational Bohr rules and its harmonics and sub-harmonics can be also understood. The gravitational Bohr rules reproduce the planetary orbital radii in a good approximation using single value of v_0 if the values of the principal quantum number n are allowed to be free. If the mass of a dark object is small enough, visible matter does not condense around it: hence the missing orbits could be only apparently missing. Also quantum transitions kicking dark matter objects to larger orbits could explain the missing orbits.

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[A4] The chapter *Cosmic Strings* of [TGD].

[A5] The chapter *TGD and Astrophysics* of [TGD].

[B1] The chapter *TGD and Nuclear Physics* of [padTGD].

[B2] The chapter *The Notion of Free Energy and Many-Sheeted Space-Time Concept* of [padTGD].

[C1] The chapter *Topological Quantum Computation in TGD Universe* of [cbookI].

[C2] The chapter *Wormhole Magnetic Fields* of [cbookI].

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