Article

Modeling of Solar System as a Miniature Version of Spiral Galaxy

Matti Pitkänen [1]

Abstract

The fractality of the TGD Universe motivates a model for planetary systems as miniature version of the model of spiral galaxy. The first two key elements are many-sheeted space-time, the notion of magnetic flux tubes - both monopole flux tubes and gravitational flux tubes without monopole flux - and the identification of dark matter as phases of ordinary matter labelled by effective Planck constant $h_{eff} = n \times h_0$ ($h = 6h_0$ is a good guess). Also the TGD generalization of Nottale's model for planetary system as analog of Bohr atom is in key role. A further key aspect is the prediction of twistor lift of TGD that cosmological constant is length scale dependent and characterizes various systems. I did not originally end up with this model from general considerations. The first input were the problems related to the collision and accretion models for the formation of planets - TGD could replace these with quantal model. The discovery of "too" heavy blackholes and neutron stars by LIGO suggesting that TGD view about the formation of also planets could provide understanding about the role of angular momentum. There are also problems related to the understanding of the entire planetary system: the dramatic difference between terrestrial and giant planets is not really understood. The problematic aspects of the Bohr orbit model together with the poorly understood differences between terrestrial and giant planets lead to a proposal that phase transition increasing the $\hbar_{gr}$ by factor 5 and accompanying a transition reducing the length scale dependent cosmological constant Λ could have scaled up the orbital radii of former inner planets. The transition could have also scaled up the radii of the former inner planets so that they became giant planets.

1 Introduction

The fractality of the TGD Universe motivates a model for planetary systems as miniature version of the model of spiral galaxy discussed in [28]. The first two key elements are many-sheeted space-time, the notion of magnetic flux tubes - both monopole flux tubes and gravitational flux tubes without monopole flux - and the identification of dark matter as phases of ordinary matter labelled by effective Planck constant $h_{eff} = n \times h_0$ ($h = 6h_0$ is a good guess [13, 21]). Also the TGD generalization of Nottale's model for planetary system as analog of Bohr atom characterized by large gravitational Planck constant h_{gr} identified as h_{eff} is in a key role [20, 19, 10, 8, 5].

A further key aspect is the prediction of twistor lift of TGD [9, 26] that cosmological constant is length scale dependent and characterizes various systems in all scales. The phase transitions reducing the cosmological constant lead to expansion of space-time sheet and define a sequence of jerks replacing smooth cosmic expansion for astrophysical objects expected in standard cosmology but not observed.

TGD provides a model for "cold fusion" based on dark fusion [15, 12] and suggests the possibility of fusion outside stellar cores perhaps serving as "warm-up band" for hot fusion during pre-stellar evolution. Also a new view about nuclear fusion in stellar interiors is suggestive [27].

I did not originally end up with the model to be discussed from general theoretical considerations.

1. The first empirical input were the problems related to the collision - and accretion models for the formation of planets - TGD allows to consider the replacement of these models with quantal model involving the dark nuclear fusion in planetary cores.

[1] Correspondence: Matti Pitkänen http://tgdtheory.fi/. Address: Rinnekatu 2-4 8A, 03620, Karkkila, Finland. Email: matpitka6@gmail.com.

2. The discovery of ”too” heavy blackholes and neutron stars by LIGO [14] suggesting that TGD view about the formation of also planets could provide understanding about the role of angular momentum.

3. There are also problems related to the understanding of the entire planetary system: the dramatic difference between terrestrial and giant planets is not really understood.

The problematic aspects of the Bohr orbit model together with the poorly understood differences between terrestrial and giant planets lead to a proposal that phase transition increasing the $\hbar_{gr}$ by factor 5 and accompanying a transition reducing the length scale dependent cosmological constant Λ could have scaled up the orbital radii of former inner planets. The transition could have also scaled up the radii of the former inner planets so that they became giant planets.

2 Some observations challenging the standard picture about the formation of planets and stars

It is best to start from observations and observations problematic from the standard model point of view are the best.

2.1 Two observations about planetary formation

The following apparently mutually conflicting observations help to develop the TGD based model.

2.1.1 A surprising observation about the formation of Earth

The popular article published in Phys Org (`http://tinyurl.com/uj95y59`) tells about observations of he group led by Associate Professes Martin Schiller [4] suggests that the formation of the Earth's core took place in time which is about 1/1000 times shorter than the estimate 2.4 Gy for the existence of the Earth meaning that the formation time was about 2.5 My. The traditional theory assuming that Earth was formed by random collisions of increasingly larger planetary bodies predicts that the formation took 3-10 times longer time.

The evidence comes from the dust of single meteorite CI (C is for carbocaneous chondrite and I to the place where the collision with Earth occurred) covering the entire Earth. The group found that this dust determines the Fe abundance a the surface of Earth and corresponds to that in solar Corona . In the standard view about the formation of Earth this makes sense only if the iron at the surface of Earth had already sinked into the core. Therefore the age of the CI obtained by radioactive dating gives an estimate for the formation time of the core. This excludes the model for the formation based on planetesimal collisions predicting 3-10 times longer age. The authors propose a model of formation based on the accretion of cosmic dust consisting of milli-meter size objects.

2.1.2 Conflicting observations about the formation time for Mars

There are conflicting observations about the formation of Mars [2].

1. From isotope ratios for tungsten one can conclude that the formation of Martian core took place in 2-4 My. This conforms with the the above estimate for the formation time of Earth coming from CI meteor.

2. A popular article (`http://tinyurl.com/wunpj85`) published in Phys Org tells that about the proposal of a research group led by Dr. Simone Marchi published in Science Advances [2] that formation time for long is longer than this - about 20 My years. There are a handful of meteorites at Earth thought to have emerged from Mars. The abundances of iron-philic (”iron loving”) elements vary

in a wide range. This suggests that the surface of Mars is heterogeneous and has a marble-cake like appearance that would have resulted in collisions of large planetesimals making even about 10 per cent of the mass of Mars. These collisions would have affected the isotope ratios for tungsten and the actual formation time would be about 20 My.

The two proposals are in conflict unless the formation mechanisms of Mars and Earth differ somehow. Could the formation mechanisms and formation times for the core be the same as in the case of Earth, and could formation of the core of Mars have followed by collisions with large planetesimals giving rise to to the surface layers? Jupiter is the planet next to Mars: Jupiter is a giant planet. Giant planets differ from terrestrial planets (Mercury, Venus, Earth, Mars), which are rocky and metallic and have no or very few Moons unlike giant planets (Jupiter has 79 Moons). Could the large planetesimals accompanying Jupiter have bombarded Mars and caused the different surface structure?

2.2 LIGO challenges the views about formation of neutron stars and their collisions

The observation of gravitational radiation by LIGO allowing interpretation as fusion of two neutron stars has challenged the views about neutrons stars and star formation: see the popular article in Quanta Magazine (`http://tinyurl.com/tqwnrne`) about the work of Enrico Ramirez-Ruiz and colleagues [3] (`https://arxiv.org/abs/2001.04502`). Single neutron star collision with exceptional characteristics as such is not enough for revolution. One can however ask what it could mean if this event is not a rare statistical fluctuation but business as usual.

1. The pair has too high total mass: only 10 per cent of stars are estimated to be massive enough to make so massive neutron stars. Something in the models for star formation might be badly wrong.
2. Also the models for the formation of neutron star pairs are unable to explain why the abundance of so massive pairs would be so high as LIGO would predict. There could be something wrong also in the models for the collisions of stellar objects.

TGD provides several new physics elements to the possible model.

1. Galaxies, stars, even planets are tangles in cosmic strings carrying dark energy and (also galactic) dark matter and thickened to monopole flux tubes not possible in standard gauge theories. This leads to a general model of stars and of final states of stars as flux tube tangles as spaghettis filling the volume and thus maximally dense. One obtains nice quantitative predictions plus a generalization of the notion of blackhole like entity (BHE) so that all final states of stars are BHEs: BHEs would be characterizied by the quantized thickness of the flux tube in question.

   Also a TGD based modification of the view about nuclear fusion required by a 10 year old nuclear physics anomaly and "cold fusion" is involved solving a long list of nuclear physics related anomalies (`http://tinyurl.com/tkkyyd2`).

2. Collision of stellar objects producing blackholes can occur much more often than expected. Suppose one has two long flux tube portions going very near to each other: they could be portions of the same closed flux tube or of two separate flux tubes. The situation would be this for instance in galactic nuclei of spiral galaxies (`http://tinyurl.com/sg9c4sd`).

   The colliding stellar objects correspond to flux tube tangles moving along them. Since the stellar objects are forced to move along these cosmic highways, their collisions as cosmic traffic accidents become much more frequent than for randomly moving objects in ordinary cosmology. The cosmic highways force them to come near to each other at crossings and gravitational attraction strengthens this tendency.

Situation would be analogous in bio-chemistry: bio-catalysis would involve flux tubes connecting reactants and the reduction of effective Planck constants would reduce flux tube length and bring the reactants together and liberating the energy to overcome the potential wall making reaction extremely slow in ordinary chemistry.

Already the high rate of collisions might allow to understand why the first collision of neutron stars observed by LIGO was that for unexpectedly high total mass.

This model does not yet answer the question why so heavy neutron stars are possible at all. Also the fusion of "too heavy" blackholes has been observed by LIGO [14] (`http://tinyurl.com/y79yqw6q`). Thus the blackhole formation from a neutron star pair with unexpectedly high combined mass supports the expecation that "too" heavy stars are a rule rather than exception.

1. The problem is that during the formation of blackhole or neutron the radius of the star decreases and the star should throw out a lot of angular momentum to avoid too high spinning velocity in the collapse. This can be achieved by throwing out mass but this makes heavy blackholes and neutron stars impossible.

2. Can TGD provide a solution of this problem? Suppose that both galaxies and stars are tangles along long cosmic strings locally thickened to monopole flux tubes carrying dark matter and energy in TGD sense Long flux tube would provide new degrees of freedom. Could the angular momentum of collapsing star consisting of ordinary matter be transferred from the star to the cosmic string/flux tube without large loss of stellar mass.

   Suppose that one has single monopole flux tube or a pair of monopole flux tubes as analog of DNA double strand (flux tubes would combine to form a closed flux tube) forming a rotating helical structure. This structure could store the angular momentum to its rotation. Also the radiation and particles travelling around these helical flux tubes could take away part of the angular momentum but flux tubes themselves as TGD counterparts of galactic dark matter could do the main job. Heavy blackholes would be a direct signature for energy and angular mmentum transfer between ordinary matter and galactic dark matter in TGD sense.

3 Could one model planetary system as a miniature of spiral galaxy?

In the sequel a model for the formation of planetary systems based on the idea that they are miniature forms of spiral galaxies is considered. The motivations for the proposal come from several sources.

3.1 Could one generalize the model for the formation of spiral galaxies to that for planetary systems?

TGD based general model [23, 18, 24, 25, 28] for the formation of galaxies, stars, and planets relies on the notion of many-sheeted space-tme and the idea that they are tangles in long cosmic strings [6, 11, 7] thickened to flux tubes carrying monopole flux - possible only in TGD but not in Maxwellian electrodynamics. The model explains the flat velocity spectrum of distant stars of galaxy leading to the notion of galactic dark matter in terms of long range cylindrically symmetric gravitational field created by cosmic string possibly thickened to flux tube. String tension decreasing with the thickness of the flux tube parameterizes the model.

1. The model for planetary system should not only provide a model and a mechanism for the emergence of single planet [27] but also explain also the holistic characteristics of the planetary system.

The TGD based model for spiral galaxies [28] assumes two nearly orthogonal colliding flux tubes - one flux tube vertical to the galactic plane and second flux tube with spiral shape. What is so nice is that the collisions of moving flux tubes analogous to reconnections of strings are topologically unavoidable.

The fractality of TGD Universe raises the question whether planetary system could be a miniature version of a spiral galaxy.

2. Vertical flux tube would be long flux tube orthogonal to the galactic plane and the four rocky and metallic terrestrial planets would be assignable to it. The 4 giant planets would have formed as tangles of a spiral flux tube in the plane of solar system. Giant planets as tangles of planar flux tube would have entered solar system, reconnected as closed flux tube structures from it, and started to rotate around Sun.

   The Grand Tack Hypothesis stating that Jupiter has arrived in solar system (`http://tinyurl.com/cmhrtc3` has some resemblances with this picture. Grand Tack Hypothesis (`http://tinyurl.com/yx3sjl42` states that planets also terrestrial ones were formed when Jupiter came to solar system along spiral orbit. The predicted formation time scale for Earth is however inconsistent with the measured terrestrial composition, which suggests that terrestrial and non-terrestrial planets are different in some aspect.

3. The heterogenous surface structure distinguishing between Mars and Earth suggests (`http://tinyurl.com/uqrxz63`) that the formation of Martian core was followed by a period during which large planetesimals collided with proto-Mars. Giant planet Jupiter near Mars would be natural source of them. Also this supports the model of solar system as a miniature spiral galaxy. Note that this does not require that Jupiter arrived to the solar system from outside.

4. One can deduce an upper bound for the string tension of the flux tubes involved from the condition that the cylindrically symmetric gravitational fields of the flux tubes do not have any observable effect on the dependence of the velocities of planets on their planetary orbital radii so that Kepler's low $v^2 = GM/R$ for planetary orbit must hold true in excellent approximation. String tension T of the flux tube provides additional contribution for the motion in the plane of string as $v^2 = GM/R + TG$ so that one must have $T \leq\leq M/R$.

   One can parameterize the string tension as $T = xT_{max}$, where $T_{max} \simeq 10^{-5}/G$ is the string tension of cosmic string with thickness given by the radius $R(CP_2) \simeq 10^{-30}$ of CP_2. This leads to the condition $x \leq\leq GM/R = r_S/2R$, where r_S is the Schwartshild radius of Sun. For Neptune one has $R = 4.5 \times 10^9$ km, which together with $r_S(Sun) = 3$ km gives $x \leq\leq 3 \times 10^{-10}$. Since T is inversely proportional to the square of flux tube radius r, one obtains $r \geq\geq 10^5 R(CP_2)$. The flux tube thickness for the flux tube in solar interior is about electron Compton length so that the condition looks trivial.

The basic objection against the models of both spiral galaxy and planetary system is the asymmetry between the two flux tubes involved. The vertical flux tube would be more cosmic string like and would have no other tangles near Sun but could have them at much larger distances as other stars of galaxy. The planar flux tube would have several tangles in the vicinity of Sun, which have reconnected off the long flux tube and formed planets rotating around Sun. This would suggest that the flux tube thickness is larger and the length scale dependent cosmological constant smaller for the flux tube in the planetary plane (for the flux tube in the galactic plane). Why this difference? Could small string tension increase the probability of re-connection?

The requirement that the long range gravitational field created by long flux tube has negligible effects in solar system requires only that the flux tube thickness is larger than the minimal thickness about CP_2 length by a factor much larger than 10^5. The flux tubes in solar interior estimated to have thickness about electron Compton radius so that the condition is trivial for the flux tubes in the core of Sun and presumably also in the planetary plane.

3.2 Nottale's model for planetary system as a guideline

Nottale proposed [1] that astrophysical systems could be regarded effectively as quantum systems in the sense that a system consisting of two masses M and m is characterized by gravitational Planck constant $\hbar_{gr} = GMm/v_0$, where $\beta_0 = v_0/c$ is a velocity parameter having the value $\beta_0 =\simeq 2^{-11}$ in solar system.

1. h_{gr} is not fundamental constant in the usual sense since it depends on M and m. In TGD framework [10, 8, 5, 20, 19] the proposal is that all systems are characterized by effective Planck constant $h_{eff} = nh_0$, $h = 6h_0$. h_{eff} would characterize dark matter at flux tubes. For gravitational flux tubes one woul have $h_{eff} = h_{gr}$ assignable to the gravitons at the flux tube. The flux tube could be either monopole flux tube or carryig vanishing magnetic flux: the latter optio is more plausible. Monopole flux tubes would in turn be crucial for the formation galaxies, stars, planets, and actully objects down to elementary particle scales.

   The actual Planck constant would be h_0 but for space-time surfaces representing n_1-fold covering of M^4 and n_2-fold covering of CP_2 there $n = n_1 \times n_2$ sheets related by Galois group for the extension of rationals defining the hierarchy level in adelic physics [16, 17] acting as symmetries and there are n identical contributions to the action so that one has effectively $h_{eff} = nh_0$. Ordinary Planck constant would correspond to 6-fold covering perhaps providing a geometric representation for half-odd integer spin and 3-value color of quarks.

2. A more general formulation of the Nottale's hypothesis would be in terms of zero energy ontology (ZEO). $h_{eff} = h_{gr}$ having rather large values would characterized gravitational flux tubes mediating gravitational interaction $n = h_{gr}/h_0$ would be very large and mean that gravitational interaction has very high evolutionary level - much higher than other interactions. This would relate not only to the long range but also non-screened character of gravitational interaction.

   Gravitational flux tubes would be algebraically very complex and essential for living systems. In ZEO one could assign the values of h_{eff} and thus also of h_{gr} the flux tubes of 3-surfaces assignable to the light-like boundaries of causal diamond (CD) define as an intersection of future- and past-directed light-cones.

   Remark: The original formulation stated that flux tubes have M and m as their ends. A more precise formulation however forces to assume that M and m have topological sum contacts with the gravitational flux tubes.

3. If the value of h_{gr} becomes smaller than $\hbar_0$, one must assume that $h_{gr} = h_0$. The $Mm/m_{Pl}^2 \geq v_0\hbar_0$ poses a low bound for the product of the masses. For identical masses one has $M \geq \sqrt{v_0/6}M_{Pl}$ so that one has critical mass.

4. One can also construct a relativistic variant of Nottale's proposal by replacing Mm with the inner product $P_1 \cdot P_2$ of the 4-momenta of the two system.

3.2.1 A model of planetary system as analog of Bohr atom

Consider now a detailed model for planetary system as an analog of Bohr atom.

1. The central object with mass M in the formulate would correspond to dark matter whereas the small mass m by Equivalence Principle could correspond to even single elementary particle. How entire Sun can look like consisting of dark matter? This is the basic objection against the proposal.

2. The orbital radii R are same independently what the value of the mass m is. There is seems be an asymmetry. In fact, doing the little calculation for the circular Bohr orbits using angular momentum quantization $L = \mu v \times R = n\hbar$ and central force condition $\mu v^2/R = GMm/R^2$, one finds $v = v_0/n$ and $R = n^2G(M + m)/v_0^2$. Binding energies are give by $E = (v_0^2/4\pi n^2)/[G(M + m)]$ v depends on

v_0 only and R E depend only on the Scwartschild radius for mass $M_{tot} = M + m$ and depends on $M + m$ only so that there is a complete symmetry.

3. R is same for given M_{tot} so that one can consider a wave function in the space of mass pairs (M, m) with fixed total mass M_{tot} this would mean very large variation in the masses of the gravitationally bound systems.

   The quantization condition $\hbar_{gr}/\hbar_0 = N$ gives the condition

$$\Delta[(r_s(M_{tot}) - r_s(m))] = v_0 \frac{\hbar_0}{m} = v_0 L_c(m) \tag{3.1}$$

4. One can have a discrete wave function in the space of (M, m) pairs with discretization step proportional to the ordinary Compton length $L_c(m)$. Gravitational Compton length equals to $L_{gr,tot} = G(M + m)/v_0$ and one can write

$$\Delta[(L_{gr}(M_{tot}) - L_{gr}(m))] = L_c(m) \ . \tag{3.2}$$

   Also the formula obtained by replacing m with M holds true.Gravitational Compton lengths M and m would have Compton lengths of m and M as unit.

5. One could even consider variation of R since v does not depend on R. This would give a quantum superposition of single particle orbits with varying radius $R \propto M + m$. One could consider many-particle system with particles with varying masses treated independently and giving rise to a representation of non-point-like orbiting object.

One can make the model relativistic by the replacements

$$\begin{aligned} \mu &\rightarrow \frac{P_1 \cdot P_2}{|P_1 + P_2|} \ , \\ \hbar_{gr} &\rightarrow \frac{G p_1 \cdot P_2}{v_0} \end{aligned} \tag{3.3}$$

for the reduced mass μ and $\hbar_{gr}$. As a consequence, $M + m$ is replaced by $|P_1 + P_2|$ in the expressions for relativity velocity v, binding energy E, and orbital radius R.

For $|P_1 + P_2| = constant$, the quantization condition for $\hbar_{gr} = n\hbar_0$ implies $(G/v_0)\Delta(P_1 \cdot P_2) = 2n$, which in turn gives $(G/v_0)\Delta(P_1 - P_2)^2 = -n$ (note that $(P_1 - P_2)^2$ can be negative in Minkowski metric). One has

$$\frac{\Delta(P_1 - P_2)^2}{m_{Pl}^2} = -2n\beta_0 \ . \tag{3.4}$$

This gives a quantization rule for the relative momenta appearing in the wave function in terms of Planck mass. The rule is reminiscent of stringy mass mass formula.

3.2.2 Problems of the Bohr orbit model for the planetary system

The model of planetary orbits as Bohr orbits proposed originally by Nottale [1] leads to a rough quantum model of dark matter as a part of the solar system in TGD framework. This model is certainly only a rough approximation. There are however objections.

1. What looks highly unsatisfactory is that the model treats inner and outer planets differently. The value of the gravitational Planck constant $\hbar_{gr} = GMm/v_0$ characterizing the gravitational flux tubes to which Sun and planet are attached by topological sum to by factor 5 smaller for outer planets (includes Mars) $v_{0,in} = 5v_{0,out}$. Could this problem disappear if the colliding terrestrial and non-terrestrial planetary systems are assignable to vertical and plane flux tubes with different values of $\hbar_{gr}$?

2. Second unsatisfactory feature of the model is that the principal quantum numbers for the inner planets are $n = 3, 4, 5$ rather than $n = 1, 2, 3$ as the atomic physics based intuition would suggest. Could the gravitational attraction of Jupiter and/or the presence of monopole flux tubes have induced quantum jumps of the inner planets to larger orbits? It turns that classically the gravitational modification of orbital radii due to the presence of Jupiter is very small so that gravitationally induced transitions do not look plausible.

3. Furthermore, in the case of Mars $v_{0,in}$ should change to $v_{0,out} = v_{0,in}/5$. This suggests a phase transition reducing v_0 and scaling all planetary orbital radii by factor 25. Could this transition accompany a phase transition reducing the value cosmological constant predicted by twistor lift of TGD [9], and required by the condition that also astrophysical objects participate cosmic expansion occurring as jerks analogous to quantum transitions. Could this transition also scale up the sizes of the former inner planets to that for outer giant planets? TGD inspired Expanding Earth model assumes similar phase transition increasing the radius of Earth by factor 2 in Cambrian Explosion [22].

3.3 Two models for why terrestrial and giant planets are so different

One can consider two models for why terrestrial and giant planets are so different.

3.3.1 Could the approach of Jupiter have induced planetary quantum transitions ?

One can try to estimate the effect of Jupiter's approach on the orbit of Mercury and other terrestrial planets perturbatively assuming Newtonian mechanics and forgetting flux tubes and possible angular momentum exchanges between stars and helical flux tubes as also the Bohr orbitology.

1. Since the orbital radii are much smaller one can assume that angular momentum is conserved and that the orbit stays approximately circular and the radii are changed only slightly.

2. One can apply the condition stating that the sum of gravitational forces of Sun and Jupiter and centrifugal force cancel each other and angular momentum conservation in the transition $R \to R_1 = R + \Delta R, v_1 \to v_1 + \Delta v$:

$$\begin{aligned} \frac{v^2}{R_1} - \frac{GM_S}{R_1^2} + \frac{GM_J}{(R_J - R_1)^2} &= 0 \ . \\ vR &= v_1 R_1 \ . \end{aligned} \tag{3.5}$$

   Jupiter's mass $M_J \simeq x_J M_S$, $x_J = 10^{-3}$, is small and in the first order approximation treating the presence of Jupiter as a small perturbation.

3. A little calculation gives

$$\frac{\Delta R}{R} \simeq -\frac{1}{2\beta_{0,i}^2} x_J \frac{R_S}{R_J} \frac{R}{R_J} \ . \tag{3.6}$$

Contrary to the intuitive expectations, the radius decreases and rotation velocity increases if one assumes angular momentum conservation. In the case of Mercury one has $\Delta R/R \simeq -2\times 10^{-6}$. The change is very small also for other planets. The orbital velocities of planes vary in rather small range and $v/c = x\times 10^{-3}$,where x is near unity. In particular, the nearness of Jupiter to Mars should not have had dramatic effects and the small effect would have had even wrong sign.

It seems that in quantum situation gravitation cannot induced quantum transitions since the changes of orbit radii should be large.

3.3.2 Could non-gravitational interactions induce transitions increasing orbital radii?

One can challenge the assumption that only classical gravitation is involved. Could the perturbation caused by the planar flux tube intersecting the vertical flux tube cause large quantum effects near the Sun and affect dramatically the orbit of Mercury? Could the nearness of Jupiter have caused large quantum effect on Mars and even the reduction of $v_{0,in}$ by factor 1/5: this could be seen as a rough quantum analog for Grand Tack Hypothesis? Could the presence of monopole flux tubes induce non-inertial interactions at the level of dark matter affecting most strongly light masses.

The first option is that quantum transitions between the state atom like planetary system increased the radii of the Bohr orbits and thus the principal quantum number n for the Bohr orbits of the inner planets. One can also ask whether the nearness of Mars to Jupiter could have also changed the value of v_0 for Mars - here and this of course raises the question whether this happened for all orbits and whether a phase transition increasing length scale dependent cosmological constant was in question. One can consider 3 options.

1. Classical considerations involving only gravitational interaction would favor a small effect and $n = (3,4,5,6)$ in the initial situation for terrestrial planets. Only the orbit of Mars would be affected and the fractional change of radius would be

$$\frac{\Delta R}{R} = (\frac{n_f\beta_{0,i})}{n_{0,i}\beta_{0,i}})^2 - 1) = \frac{16}{9} \quad .$$

   If Mars has in initial state $n = 10$, radius, remains unaffected. The transition cannot be induced by gravitation. The missing orbits with $n = 1,2$ are an aesthetic problem taking into account that exoplanets can have very small orbital radii.

2. The assumption $n_1 = (1,2,3,4)$ and $v_{0,i} = 2^{-11})$ for terrestrial planets in the initial situation is aesthetically attractive. In the final situation one has $n_f = (3,4,5)$ for inner planets and $n_f = 2$ and $\beta_{0,f} = \beta_{0,i}/5$ for Mars. The radii of (Mercury, Venus, Earth, Mars, Jupiter) are $(.4,.7,1.0,1.5,5.2)$ AU. The changes of the radii proportional to Δn^2 relate like $8:12:17:84$. This is in qualitative accordance with the fact that the gravitational force caused by Jupiter increases with the distance from Sun.

   The scalings of the radii would be

$$\frac{R_f}{R_i} = (\frac{n_f v_{i,0}}{n_i v_{0,f}})^2 \quad ,$$

   and given by $(9,4,25/9,25/4)$. It is not quite clear to me whether relative or linear scale should be used asa measure for the size of the effects. For inner planets the relative change in the radius is largest for Mercury: neither the largest distance from Jupiter nor Equivalence Principle favour this.

   If also non-gravitational forces possibly assignable to monopole flux tube connections between Jupiter and other planets are important, the mass of the planet matters. The masses of Mercury, Venus, Earth, and Mars are $0.055,0.82,1.0,0.12)M_E$. Mercury's mass is the smallest one.

3. A more conservative option is $n = (2,3,4,5)$ for terrestrial planets in the initial situation. The changes of the radii would relate like $5 : 13 : 16 : 75$. The scalings of radii would be given by $(9/4, 16/9, 25/16, 25/4)$. For inner planets the relative change of the radius of Mercury is still largest. For both options the relative change for the radius of Mars is largest and conforms with the nearness of the Jupiter.

Neither of these options looks attractive. In particular, there is no proposal for a physical mechanism causing the quantum transition.

3.3.3 Did a phase transition $\beta_{0,in} \rightarrow \beta_{0,out} = \beta_{0,in}/5$ generate giant planets from Earth-like planets

The twistor lift of TGD [9] predicts that cosmological constant Λ is length scale dependent and every space-time sheet is characterized by "personal" Λ, which determines the thickness of the monopole flux tubes assignable to the magnetic body (MB) of the system. Λ scales like $1/L^2(k)$, and approaches zero in p-adic scales $L(k)$ characterizing space-time sheets. This solves the problem related to the huge value of cosmological constant and also predicts correctly its sign.

Cosmological expansion takes for all space-time sheets. Not continuously but as jerks, phase transitions in which Λ for the system decreases and the magnetic flux tubes thicken. This provides also a justification for the Expanding Earth model [22] in which the radius of Earth is scaled up by factor 2 during Cambrian explosion in rather short time scale and having rather dramatic implications for geology, climate, and biology.

These observations together with the discovery of exoplanets - in particular, hot Jupiters - orbiting very near their Suns, inspire the question why Sun does not have planets very near to its surface, and allows to imagine very different origin of giant planets as resulting in a phase transition decreasing Λ and β_0 for the planet system and providing at the same time explanation for why the values of β_0 differ for inner and outer planets.

1. Phase transitions increasing the length scale dependent cosmological constant Λ and the size scale the size of of the system - presumably by some power of $r = \beta_{0,i}/\beta_{0,f}$. For the atomic model of solar system, second power of r would be in question. This phase transition would also involve increase of $n = h_{eff}/\hbar_0 = h_{gr}/\hbar_0$ having interpretation as dimension for extension of rationals by factor factor 5 so that an evolutionary step increasing algebraic complexity would be in question.

2. All planets would have had initially the same value of $\beta_0 \simeq 2{-}11$ as inner planets have now. Proto variants of Earth, Mars, Jupiter, Saturn, Uranus, and Neptune had had $n = (1,2,3,4,5,6)$. The phase transition $\beta_0 \rightarrow \beta_0/5$ accompanying the change of the scaled dependent cosmological constant scaled up their orbital radii by factor 25. The orbital radius of proto-Earth in ground state, proto-Jupiter, and proto-Neptune would have been $AU/25 = .04AU \simeq 8.6R_S$, R_S solar radius, $(3/5)^2AU \simeq .08AU$, and $(6/5)^2AU \sim 7AU/5$.

3. Gas giants proto-Jupiter with $n = 3$ and proto-Saturn with $n = 4$ are problematic since these values would correspond also to Mercury and Venus. Could Mercury and Venus be remnants from proto-Jupiter and proto-Saturn at different space-time sheets, which did not follow the expansion. This kind of remnant cannot be planetary core since all planets have it. Earth has also inner and "inner-inner" cores. Could Mercury and Venus be either of these structures, which did no follow the former pro-planet in the expansion or where formed later? Maybe they did correspond to different space-time sheet.

4. Why didn't Earth and Mars with $n = 1$ and $n = 2$ leave any remnants: does this relate somehow to terrestriality? Interestingly, without this phase transition biological life in solar system would not have been possible. Note also that the Earth would have been the lowest orbital, which could explain its special role. If the orbitals correspond to wave functions then Earth would correspond

to a unique state having non-vanishing dark matter wave function down to the solar interior - this would be true also now.

5. Why the outer planets have radii are by an order of magnitude larger than the radii of inner planets (http://tinyurl.com/sowh6cn)? Could the expansion have scaled up - not only the planetary plane but also - the radii of the planets by a power of v_0 as the reduction of the scale dependent Λ would suggest. This would have reduced the density of proto-planet and the densities of giant planets are indeed considerably lower than those of terrestrial planets. Accretion of matter would have increased the mass of the giant planets. It would be nice to understand whether and how the phase transition could lead to the formation of moons and rings of giant planets.

   Note that the presence of Jupiter like exoplanets very near to their host stars however suggests that giant planets were giants already during their proto-stage.

3.4 The problem of angular momentum balance

Angular momentum balance is poorly understood in the models for the formation of stars. If there is no angular momentum in the initial situation the question is where the compensating angular momentum of the star resides. As already explained, LIGO has observed "too" heavy neutron stars and blackholes in the sense that standard model for stellar evolution does not allow them: the star must throw away must to keep its rotation velocity small enough. In TGD picture the angular momentum would be transferred to the orthogonal flux helical flux tube (or pair of them) to which the system is associated as a tangle.

The spins of the terrestrial planets and even their angular momenta for the motion around Sun could be compensated by the spin of the local helical cosmic string portion assignable to them. The planetary angular momenta for the rotation around Sun could be also compensated by the helical spin of the long vertical cosmic string going through Sun. If the solar tangle intersects the planet, the "personal" flux tube is part of solar flux tube tangle. The angular momentum transfer would be made possible by gravitational or monopole flux tubes: and the latter would lead to effect breaking Equivalence Principle. This could apply also to the non-terrestrial planets.

3.5 Could dark fusion be responsible for the formation of planetary cores?

As already described, the formation time of Earth is according to the latest findings considerably shorter than the model based on collisions of planetesimals of increasing size predicts (http://tinyurl.com/uj95y59). The accretion of milli-meter sized objects is suggested as a formation mechanism.

TGD does not exclude accretion mechanism - as at least part of the formation mechanism - but the formation of planet seed giving rise to the core as a tangle of cosmic string is highly attractive option. The dark fusion outside stellar core [12, 15, 27] provides a mechanism of "cold fusion" and could provide a "warm-up band" for ordinary fusion in stellar core and also the seed for the solar core. This mechanism could provide also the iron core of the stellar object as a seed for planet so that sinking of iron from the surface to the core would not be needed. The explanation for why CI determines the abundance of iron at the surface of Earth's would be that the density of the iron at the surface of Earth has been always much lower than believed.

It is not clear whether also ordinary fusion could have been initiated, and led to the formation of the planetary iron core. Note that TGD based vision about nuclear physics [27] the tunnelling in ordinary fusion could take place via the formation of intermediate dark nuclei as "on-mass-shell states". This would be in accordance with quantum-classical correspondence. The structures above core could have formed by accretion.

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