A model for planets

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Abstract

I learned about a proposal that black-hole like stars, gravatars, could develop Russian doll-like nested structures, nestars. The proposal is interesting from the TGD point of view because TGD raises the question whether stars, and astrophysical objects in general could, have a layered structure. Nottale's model for planetary systems suggests Bohr orbitals for planets with gravitational Plack constant $\hbar_{gr} = GMm/\beta_0$. The value of the velocity parameter $\beta_0 = v_0/c \leq 1$ is from the model of Nottale about 2^{-11} for the inner planets and 1/5 times smaller for the outer planets. This might reflect the fact that originally the planets or what preceded them consisted of gravitationally dark matter or that the Sun itself consisted of gravitationally dark matter and perhaps still does so.

The model of stars and planets as gravitational harmonic oscillators turns out to be surprisingly successful. It turns out that the radius of the core of Earth corresponds to the Bohr radius for the first orbital, which suggests that the core of Earth, and more generally of the inner planets and Mars corresponds to an S-wave ground state. For the Sun the $n = 1$ S-wave orbital is 1.5 times the solar radius. The model applies also to the outer planets. Also the rings of giant planets can be understood at a rough quantitative level.

The second input was the discovery of a planet that was too heavy as compared to its mother star to exist. This led to a more precise form of the model for the formation of planets and as a byproduct also for the formation of stars. A dramatic prediction is that the abundances of elements of galaxies depend only weakly on cosmic time. There is actually evidence dating back to year 2003 and JWST is yielding similar evidence.

1 Introduction

I learned (thanks to Mark McWilliams and Grigol Asatiani) about a proposal that black-hole like stars, gravatars, could develop Russian doll-like nested structures, nestars (see this). Gravastar is a star proposed to replace blackhole. It has a thin layer of matter at the horizon and de-Sitter metric in the interior. Nestar would consist of nested gravastars.

This finding raised the question whether the layered structures of planets could be understood in the TGD framework and inspired what I call quantum gravitational harmonic oscillator model of star.

The second input came from the observation of a planet which is too massive as compared to its mother star to exist [E2] (see this). Could the TGD based model for the formation of planets [L6, L7] be consistent with this finding? Quite surprisingly, the detailed considerations led to more detailed ideas about the evolution of stars explaining the old but forgotten paradoxical finding that the abundances of elements do not seem to depend on cosmic time as predicted by the standard model of star formation in which the decay products of supernovae are reprocessed. JWST has in fact confirmed this finding.

1.1 Could planets and stars have a layered structure in the TGD Universe?

The proposal is interesting from the TGD point of view because TGD raises the question whether stars, and astrophysical objects, in general could have a layered structure.

1. One of the early "predictions" of TGD for stars coming from the study of what spherically symmetric metrics could look like, was that it corresponds to a spherical shell, possibly a hierarchical layered structure in which matter is condensed on shells. p-Adic length scale hierarchy suggests shells with radii coming as powers of $2^{1/2}$.

2. Nottale's model [E1] for planetary systems suggests Bohr orbitals for planets with gravitational Plack constant $\hbar_{gr} = GMm/\beta_0$. The value of the velocity parameter $\beta_0 = v_0/c \leq 1$ is from the model of Nottale about 2^{-11} for the inner planets and 1/5 times smaller for the outer planets. This might reflect the fact that originally the planets or what preceded them consisted of gravitationally dark matter or that the Sun itself consisted of gravitationally dark matter and perhaps still does so.

1.2 Nottale's model for solar and planetary interiors as gravitational harmonic oscillators

The Nottale model is especially interesting and one can look at what happens inside the Sun and planets, where the mass density is in a good approximation constant and gravitational potential is harmonic oscillator potential. Could particles be concentrated around the orbitals predicted by the Bohr model of harmonic oscillator with radii proportional to $n^{1/2}$, $n = 1, 2, 3, ...$ The lowest state would correspond to S-wave concentrated around origin, which is not realized as Bohr orbit. The wave function has nodes and would give rise to spherical layers of matter.

One can perform the simple calculations to deduce the energy values and the radii of Bohr orbits in the gravitatational harmonic oscillator potential by using the Bohr orbit model.

1. The gravitational potential energy for a particle with mass m associated with a spherical object with a constant density would be $GmM(r)/r = GMmr^2/R^3$, where M is the mass of the Sun and R is the radius of the object. This is harmonic oscillator potential.

2. The oscillator frequency is

$$\omega = (\frac{r_s}{R})^{1/2}/R \ ,$$

   where $r_S = 2GM$ is the Schwartschild radius of the object, about 3 km for the Sun and 1 cm for Earth.

3. The orbital radii for Bohr orbits are proportional to $n^{1/2}$ inside the star. By the Equivalence Principle, the radius does not depend on particle mass. One obtains

$$r_n = n^{1/2}(2\beta_0)^{-1/2}(\frac{r_s}{R})^{1/4} \times R \ .$$

One must of course remember that in the recent Sun, Earth and other planets ordinary matter is probably not gravitationally dark: only the particles associated with the U-shaped monopole flux tubes mediating gravitational interaction could be gravitationally dark and would play an important role in biology.

The situation could have been different when the planets formed. I have proposed a formation mechanism by an explosive generation of gravitationally dark magnetic bubbles ("mini big bangs"), which then condensed to planets [L6, L7]. This would explain why the value of β_0 for the Earth interior is the same as for the system formed by the interior planets and Sun and Mars. The simple calculations to be carried out suggest that for the outer planets only the core region emerged in this way and the gravitational condensation gave rise to the layer above it. The core should have the properties of Mars in order that it could correspond to S-wave state.

The model of stars and planets as quantum gravitational harmonic oscillators turns out to be surprisingly successful. It turns out that the radius of the core of Earth corresponds to the Bohr radius for the first orbital, which suggests that the core of Earth, and more generally of the inner planets and Mars corresponds to an S-wave ground state. For the Sun the $n = 1$ S-wave orbital is 1.5 times the solar radius. The model applies also to the outer planets. Also the rings of giant planets can be understood at a rough quantitative level.

The second input was the discovery of a planet that was too heavy as compared to its mother star to exist. This led to a more precise form of the model for the formation of planets and as a byproduct also for the formation of stars. A dramatic prediction is that the abundances of elements of galaxies depend only weakly on cosmic time. There is actually evidence dating back to year 2003 and JWST is yielding similar evidence.

2 Application of the oscillator model to solar system

In this section the above simple model is applied to the solar system. Recall that the basic formula is

$$\frac{r_1}{R} = (2\beta_0)^{-1/2}(\frac{r_s}{R})^{1/4} \ .$$

where R refers to the radius of the object.

2.1 Oscillator models for the Sun and Earth

Consider first the model for the Sun assuming that the value of $\beta_0 = 2^{-11}$ holds true for Sun and inner planets. One can of course argue that the value of β_0 need not be the same for pairs formed by particles inside Sun and Sun.

1. For the Sun one has $\frac{r_s}{R} = 4.3 \times 10^{-6}$. For $\beta_0 = 2^{-11}$ holding true for the inner planets one obtains $r_1 = 1.45R$ so that the solar interior would correspond to a ground state S-wave with smaller than the maximal radius. For $\beta_0 = 10^{-3}$ would give the maximal radius $r^1 \simeq R$.

2. $\beta_0 = 1$ would give $r_1 = .032R$, which is considerably smaller than the radius of the solar core about $.2R$. $\beta_0 = 0.026$ would give $r_1 = .2R$. r_{25} would be near to the solar radius. The set of the nodes of a harmonic oscillator wave function would be rather dense: at the surface of the Sun the distance between the nodes would be .1R. Note that the convective zone extends to .7R.

What about the Earth?

1. One has $r_S = 1$ cm and $R = 6,378$ km. At the surface of Earth $\beta_0 = 1$ is the favoured value and would give $r_1 =\simeq 50.5$ km. The radius of the inner inner core is between 300 km and 400 km. $n = 36$ would correspond to 300 km and $n = 64$ to 400 km. β_0 scales like $(r_1/R_E)^2$. At the surface of Earth one would have $n = (R_E/r_1)^2 \sim 15996$ and the distance between two nodes would be $R_E/2n \simeq .197$ km.

   $\beta_0 \simeq 1$ should hold true above the surface of the Earth, which suggests that it characterizes the gravitational magnetic body of Earth. Gravitational magnetic bodies of the Sun and the Earth could combine to form a single entity.

2. One can write $\beta_0(r_1)$ as

$$\beta_0(r_1) = (\frac{50.5}{r_1})^2 \quad .$$

3. The value $\beta_0 = 2^{-11}$ for the inner planets would give $r_1 = .36R_E \simeq 2285$ km. This is equal to the radius $R_{Core} = .36R_E$ of the Earth's core (see this). Therefore the Earth's liquid core could correspond to the ground state S-wave for the gravitational harmonic oscillator and the mantle has gravitationally condensed above the core from the material coming from the environment.

   $n = 2$ orbit would correspond to the radius $.5R_E$, rather neat to the radius of Mars. The thickness of the mantle is about 45 per cent of the radius of Earth so that the crust of thickness 15-20 km might be associated with the $n < 8$ orbits. $n = 7$ would correspond to $.95R_E$ and to a depth of about 319 km. $n = 8$ would correspond to $1.018R_E$, which corresponds to 116 km above the Earth: the lower boundary of the ionosphere is at 80 km.

2.2 The radii of first Bohr orbits for planets modelled as gravitational harmonic oscillators

The above observations raise the question whether the value of β_0 for Sun and inner/outer planets is such that both the entire Sun or its core and the cores of at least some rocky planets correspond to the ground state S-waves for the value of the gravitational Planck constant assigned with the planet. The allowed $n \geq 1$ states could correspond to layers above the core.

Note that the Bohr orbital in plane corresponds to a wave function for Schrödinger equation localized to an orbital located near the orbital plane and that there are several orbitals for a given value of n. This state could have been the primordial dark matter state and the recent state could carry some information about this state.

The condition $r_1 \leq R_P$ requires

$$\frac{r_{S,P}}{R_P} \leq 4\beta_0^2(Sun, P) \quad .$$

Using M_E and R_E as units, this condition reads for inner planets as

$$\frac{r_{S,P}}{R_P} \leq 1$$

and for outer planets as

$$\frac{r_{S,P}}{R_P} \leq K^2 \ ,$$

where one has $K = 1$ or $K = 1/5$ depending on what option is assumed.

1. The first option giving $K = 1$ assumes that the principal quantum numbers n are of the form $n = 5k$, $k = 1, 2, ..$ for the outer planets. This is possible although it looks somewhat un-natural.

2. The second option, proposed originally by Nottale [E1], is $\beta_0(outer) = K\beta_0(inner)$, $K = 1/5$.

Recall that the prediction for the radius of the first Bohr orbital is $\frac{r_1}{R_P} = (2\beta_0)^{-1/2}(\frac{r_s}{R_P})^{1/4}$. It is interesting to see whether the condition holds true (see this).

2.2.1 Rocky planets

Consider first the rocky planets, which include inner planets and Mars. For Mercury the ratio $\frac{r_1}{R}_M$ is $(R_E/R_{Mars})(M_{Mars}/M_E)^{1/4}(r_1(E)/R_E) \simeq .388$. For Venus and Earth with nearly equal masses, which suggests that Venus has also a core of nearly the same radius, which corresponds to $r_1 \sim .36R$.

For Mars, which is also a rocky outer planet, the condition for the $K = 1/5$ option gives the value of $\frac{r_1}{R}$ for Mars by a scaling the value .36 for the Earth by the factor $(1/K)^{1/2} \times (R_E/R_{Mars})(M_{Mars}/M_E)^{1/4} \simeq .931$ so that one $r_1 = .33R_{Mars}$. The situation for the mantle region would be very similar to that for the Earth. Note that the values of $r_1(P)/r_P$ are rather near to each other, which suggests that all are formed by the condensation of the mantle on top of the core.

Planet	$\frac{M_P}{M_E}$	$\frac{R_P}{R_E}$	$\frac{r_1}{R_P}$
Mercury	0.0553	0.383	.39
Venus	0.815	0.949	.35
Earth	1	1	0.36
Mars	0.107	0.532	.54

Table 1: Masses M_P and radii R_P for the inner planets and mass using mass M_E and radius R_E of Earth as units. The last column gives the ratio $\frac{r_1}{R_P}$ of the $n = 1$ Bohr orbit to the radius of planet

What is truly remarkable and raises hope that the proposed model has something to do with reality, that in the case of Earth r_1 is identifiable as the core radius.

The only rocky planets having moons are Earth and Mars.

1. For Earth, the harmonic oscillator orbit with a radius nearest to R_E corresponds to $n = 8$. The radius is $1.0188R_E$. The distance of the orbit from the Earth surface is 118.5 km, which corresponds to the thickness of the ionosphere. $n = 9$ corresponds to 512.2 km.

   The distance of the Moon is $60R_E$. For the harmonic oscillator model this would correspond to a rather large value $n = 2778$. The Bohr radius for gravitational Coulomb orbit is $a_{gr} =$ 20 km and the orbit of the Moon would correspond to $n = \sqrt{R_E/a_{gr}}$ giving $n = 138$. The interpretation as Coulomb orbit looks of course physically natural. Also Saturnus, Uranus, and Neptune have moons with large orbital radius and would naturally correspond to Coulombic moons (see this).

2. For Mars the oscillator orbit nearest to its radius has $n = 4$ and $1.08R_M$ and corresponds to a rather large distance of 943 km from the surface. Could this mean that Mars does not have the counterpart of the ionosphere, which seems to be essential for life in the TGD framework [L5]? Earth and Mars look clearly very different from each other.

   Mars has two moons: Phobos and Deimos. The radii for them are $2.76R_M$ and $6.91R_M$. In the harmonic oscillator model they would correspond in a good approximation to $n = 26$ and $n = 164$. The identification as Coulomb orbits would require much larger values of n of order 9.744×10^4 and 1.5418×10^5 and does not look natural.

2.2.2 Giant planets

The outer planets are gas giants apart from Mars and apart from Neptune, which is an ice giant.

1. The radii for $n = 1$ harmonic oscillator orbits The following table gives the ratios $r_1/R = (1/2\beta_0)^{1/2}(r_s(p)/R_P)^{1/4}$ for the first oscillator orbit. One can estimate the ratio $r_1(P)/R_P$ by scaling its value $r_1/R_E = .36$ for Earth. One has $r_r/R_P = K^{1/2}X \times .36$ where the scaling factor is $X = [(M_P/M_E) \times (R_E/R_P)]^{1/4}K^{1/2}$ and K is the scaling factor in $\beta_0 = 2^{-11}/K$. The model of Nottale indeed allows two options: either $K = 5$ or 1. The corrected calculations give for $K = 1/5$ $r_1/r_P \geq 1$ whereas $K = 1$ gives $r_1/R_P \leq 1$.

Planet	$\frac{M_P}{M_E}$	$\frac{R_P}{R_E}$	$\frac{r_1}{R_P}$
Jupiter	317.8	11.21	0.84
Saturn	95.2	9.45	0.64
Uranus	14.5	4.01	0.50
Neptune	17.1	3.88	0.52

Table 2: Masses M_P and radii R_P for outer planets using mass and radius of the Earth as units. The last column gives the ratio $\frac{r_1}{R_P}$ of the $n = 1$ Bohr orbit to the radius of planet assuming $K = 1$.

For $K = 5$ the values of r_1 for the giant planets are systematically somewhat larger than the orbital radius. The reason is that the value r_1 is proportional to $\sqrt{K}$. The second reason for this is that the large value of the mass of the planet increases like R_P^3 and makes $\hbar_{gr} \propto \frac{r_s}{R_P}$ large. Jupiter allows only $n = 1$ orbital as interior orbital and $n = 2$ orbital corresponds to radius $1.2R_J$. Saturn allows also $n = 2$ orbital as an interior orbital and $n = 3$ orbital has $r_3 = 1.1R_S$. Uranus allows $n = 4$ orbital corresponds to the radius of Uranus. One must of course take these rough estimates with a caution: only simple estimates are in question.

The simplest model is obtained if $\beta \simeq 2^{-11}$ holds true also for the outer planets. The predictions for the radii of the cores or both inner and outer planets are in principle testable. The prediction $r_{Core} = r_1 < R_P$ can be also tested for exoplanets.

2. Do giant planets have a shell structure for a gravitational harmonic oscillator in some sense?

The above observations give $\frac{r_1}{R_P} \leq 1$ for the outer planets if one has $\beta_0 = 2^{-11}$. Giant planets would containg at least one orbit inside the planet. There are suggestions that giant planets could have a rocky core containing metals for which there is evidence (see this) with smaller mass.

1. A natural mechanism for the formation of the giant planet would be gravitational condensation of the matter from the environment around the core region, which according to TGD based proposal [L6] would have been generated in an explosion of Sun throwing out a mass shell of dark matter in TGD sense, which then condensed to planets (in Kuiper belt this did not happen).

2. The region outside the core would correspond in the first approximation to harmonic oscillator orbitals determined by the average density with radii given as $r_n = n^{1/2}R_{core}(P)$.

One can develop a more detailed model as follows.

1. One can apply Newton's law for circular Bohr orbits and quantization condition for angular momentum in the gravitational potential $V(R) = GmM(R)/R$, where M(R) is

$$M(R) = M(core) + M(layer) \times [(R/R_P)^3 - (R_{core}/R_P)^3) \ .$$

Slightly below R(core) the force is harmonic force the interior R increases, the gravitational potential approaches to harmonic oscillator potential determined by M_P. For outer planets the average density is considerably smaller than the density of the core.

2. The first condition is

$$\frac{v^2}{R} = -\frac{dV(R)}{dR} = -\frac{d(GM(R)/R)}{dR} = \frac{GM(R)}{R^2} - G\frac{dM/dR)}{R} \ ,$$

where one has

$$\frac{dM}{dR} = \frac{3R^2}{R_P^3} \ .$$

One obtains

$$v(R)^2 = \frac{1}{2} \times \frac{r_S(core)}{R} - 3r_S(layer) \times (\frac{R}{R_P})^3) \ .$$

3. The second condition corresponds to the quantization of the angular momentum

$$vR = \frac{GM(core)}{\beta_0} \ .$$

gives for R the condition

$$\frac{R}{R_E} = \frac{r_S(core)/R_E}{\beta_0 v(R)} \ .$$

Mars is the natural choice for the core. From these data the radii of the Bohr orbits can be calculated. Near the boundary of the core the radii would go like $n^{1/2}R_{Mars}$. For large enough radii one would obtain harmonic oscillator potential.

Jupiter serves as a representative example. One has $M_J = 317.8M_E$ and $R_J = 11.2R_E \simeq 22.4R_{Mars}$. The core has radius $.64R_J$. The density of Jupiter is fraction .22 of the density of Earth. Most of the mass of Jupiter would be generated by the gravitational condensation of gas from the atmosphere. At least the dark matter at the gravitational magnetic body would be at the harmonic oscillator orbitals.

3. Could one understand the rings of giant planets in terms of the oscillator model?

One can consider two alternative models for the rings of giant planets. One could try to model the rings in terms of Bohr orbits with a small principal quantum number n for a harmonic oscillator potential or using a Coulomb potential for the gravitational analog of hydrogen atom assuming the same gravitational Planck constant as for the harmonic oscillator model ($\beta_0 \simeq 2^{-11}$). In this case the Bohr radius $a_{gr} = \beta_0^{-2} r_S/2 \simeq 2^{10} r_S$ is much smaller than the planet radius so that the scale of the rings does not emerge naturally.

The assignment of the rings of the giant planets with the harmonic oscillator orbitals seems to make sense at the order of magnitude level at least (see this,this, this and this).

1. For Jupiter the halo ring has average radius at $1.5R_J$ would be assigned with $n = 3$ orbit with radius $1.45R_J$. The main ring has average radius of $1.75R_J$ could correspond to $n = 4$ ring with radius $1.7R_J$.

2. Saturn would allow $n = 3$ orbit very close to the surface with radius $1.11R_S$: the smallest rings extend from $1.16R_S$ and could correspond to this orbit.

3. For Uranus the lowest ring has radius $1.48R_U$ with could correspond to $n = 9$ with radius $1.23R_U$ ($n = 4$ corresponds to the radius of Uranus).

4. For Neptune $n = 4$ orbital corresponds to $1.04R_N$. The $n = 12$ orbital could correspond to the lowest ring in this case.

2.2.3 Dwarf planets, Pluto, and some moons

One can also estimate the values of r_1 for some dwarf planets 3 known to be promising places for the evolution of organic life and the Moon and some moons of Jupter and Saturn. Table 3 gives the values of β_0 for some dwarf planets.

Object	M/M_E	R/R_E	$\frac{r_1}{R}$
Pluto	.00218	0.1818	.27
Eris	.0028	.182	.28
Ceres	1.57×10^{-4}	.2725	.17
Moon	.0123	.074	.17

Table 3: Masses M and radii R for Pluto, some dwarf planets and Moon using mass M_E and radius R_E of the Earth as units. The last column gives the ratio $\frac{r_1}{R}$ of the $n = 1$ Bohr orbit to the radius of the planet. The values $\beta_0 = 2^{-11}/5$ for outer planets and $\beta_0 = 2^{-11}$ for the Moon are used. In the case of Earth it this radius is identifiable as the core radius.

2.2.4 Blackhole-like object as a gravitational harmonic oscillator?

As described, in the TGD Universe blackhole-like objects are identified as monopole flux tube spaghettis and differ from the ordinary stars only in that for $h_{eff} = h$, the entire volume is filled by monopole flux tubes for which thickness is minimal and corresponds to a nucleon Compton length. For $h_{eff} > h$ also the flux tubes ordinary stars or star cores could fill the entire volume.

Just for fun, one can ask what the model of a gravitational harmonic oscillator gives in the case of Schwarzschild blackholes. The formula, $r_n = \sqrt{n}r_1$, $r_1/R = (r_s/sqrt2\beta_0)/times(r_s/R)^{1/4}$, gives for $R = r_s$ $r_1/r_s = 1/\sqrt{2\beta_0}$. $\beta_0 \leq 1/2$ gives $r_1/r_s \geq 1$ so that there would be no other states than the possible S-wave state ($n = 0$). $beta_0 = 1/2$ gives $r_1 = r_s$ and one would have just mass at $n = 0$ S-wave state and $n = 1$ orbital. For $\beta_0 = 1$ (the minimal value), one has $r_1/r_s = 1/\sqrt{2}$ and $r_2 = r_s$ would correspond to the horizon. There would be an interior orbit with $n = 1$ and the S-wave state could correspond to $n = 0$.

The model can be criticized for the fact that the harmonic oscillator property follows from the assumption of a constant mass density. This criticism applies also in the model for stars. The constant density assumption could be true in the sense that the mass difference $M(n+1) - M(n)$ at orbitals r_{n+1} and r_n for $n \geq 1$ is proportional to the volume difference $V_{n+1} - V_n$ proportional to $r_{n+1}^3 - r_n^3 = (n+1)^3 - n^3 = 3n^2 + 3n + 1$. This would give $M = m_0 + m(n_{max} + 1)^3$ leaving only the ratio of the parameters m_0 and m free. This could be fixed by assigning to the S-wave state a radius and constant density. This condition would give an estimate for the number of particles, say neutrons, associated with the oscillator Bohr orbits. If a more realistic description in terms of wave functions, this condition would fix the total amount of matter at various orbitals associated with a given value of n.

3 The planet that should not exist: implications

The popular article in Futurism (see this) tells about a strange finding challenging the beliefs of the formation mechanism of planets. In the study published in Science, researchers out of Pennsylvania

State described a surprising discovery: a Neptune-sized planet that's 13 times the mass of Earth, which is orbiting a tiny ultracool star that's with mass by a factor 1/9 smaller than the mass of the Sun.

According to the abstract of the article [E2] (see this) planets form in protoplanetary disks of gas and dust around young stars that are undergoing their own formation process. The amount of material in the disk determines how big the planets can grow. Stefansson et al. observed a nearby low-mass star using near-infrared spectroscopy. They detected Doppler shifts due to an orbiting exoplanet of at least 13 Earth masses, which is almost the mass of Neptune. Theoretical models do not predict the formation of such a massive planet around a low-mass star (see the Perspective by Masset). The authors used simulations to show that its presence could be explained if the protoplanetary disk were 10 times more massive than expected for the host star. To sum up, Neptune sized planets (mass is $17.1M_E$ and radius $3.88R_E$) should not exist around stars with mass $M_E/9$.

The analysis of these findings led to a considerably more detailed view of the formation of planets and also formation of stars.

3.1 TGD view of formation of planets

The TDG based proposal for the formation of planets assumes that planets have condensed from spherical shells of dark matter produced by "mini big bangs" as explosions of the star [L6, L7]. These dark mass shells with a large value of h_{eff} would transform to ordinary matter around a seed giving rise to the core of the planet and the dark matter from the spherical shell would transform to ordinary matter and condense around this core. The seed region need not contribute much to the mass of the planet.

1. The basic difference with respect to the standard model would be that the disk is replaced with a spherical shell of dark matter. The open question is whether the mass of the shell condensing to form the planet can have a mass $\geq 13M_E$ for a star with mass as small as $M_{Sun}/9$. The mass mass ΔM of the mass shell should have been of the order $10^{-4}M_{star}$ and gives $\Delta R/R_{Sun} \sim 10^{-4}/3$. The radius of the star is not very sensitive to its mass so that $R_{star} = R_{Sun}$ is a reasonable estimate. Assuming $R_{star} \sim R_{Sun}$ and using $M_{Sun} = .333 \times 10^{-6}M_E$ and $R_{Sun} \sim 100R_E$, one obtains the estimate $\Delta R \sim 75$ km.

2. For the Earth-Sun system the thickness of the layer would satisfy $\Delta R/R_{Sun} \sim 1.1 \times 10^{-4}$ and give $\Delta R \sim .64$ km.

3. There are several theories about the origin of Moon. One of the theories states that Moon resulted from the debris coming from a collision of Mars sized object with Earth (see this). TGD suggests that Moon was created by the same mechanism as a planets, that is by an explosion creating a spherical layer, which condensed to form a Moon. The condition $4\Delta R/R_E \simeq M_{Moon}M_E$ gives $\Delta R \simeq 22$ km.

3.2 How could stars form in the TGD Universe?

Also the mechanism for the formation of stars would be different in the TGD framework and is inspired by the predicted quantum coherence in astrophysical scales and the general view of TGD inspired view of what happens in state function reductions, which also leads to a theory of consciousness and life as universal phenomena present in all scales, even astrophysical.

1. According to the standard model, stars condense from the interstellar gas, possibly from a material of a spherical or a disk-like structure. In the TGD framework this cannot apply to the first generation stars. Rather, the mass of the first stars could have come from the transformation of the analog of dark energy to ordinary matter as the energy of a cosmic string transforms to matter in a process analogous to the decay of the inflaton field. The string tension of the resulting monopole flux tube is much smaller and the process can repeat itself. This mechanism could play some roles later.

2. The emerging matter could be mostly ordinary matter but can transform to a phase, which has a large effective Planck constant $h_{eff} > h$. These phases of ordinary matter would

explain the missing baryonic mass [L2] and would have a key role in biology. Evolution as a gradual increase of h_{eff} serving as a measure of algebraic complexity conforms with this view.

The galactic dark matter in turn would correspond to the dark energy assignable to the string tension of very long cosmic strings orthogonal to the galactic plane and creating a transversal $1/\rho$ gravitational field explaining the flat velocity spectrum of distant stars.

3. This model for the generation of stars should explain the fact that there are star generations: stars die as supernovae and are regenerated later. Zero energy ontology (ZEO) [L3] provides a possible solution to the problem. The end of the life of the star as supernova could correspond to "big" state function reduction (BSFR) (the TGD counterpart of the ordinary state function reduction) in astrophysical scale changing the arrow of time. This process would be highly analogous to a biological death involving a decay process identifiable as supernova explosion.

   After a supernova explosion the star would live a life with an opposite arrow of geometric time and reincarnate in the original time direction as a star which would partially consist of the decay products of the earlier star(s). The evolutionary age of the star increases steadily in this sequence of lives forth and back in geometric time although the cosmological age increases much slower. JWST has indeed discovered stars and galaxies older than the universe [L8].

The model should also explain how the core of the daughter star is generated.

1. The TGD based model is motivated by the problem caused by the fact that stellar fusion cannot produce elements heavier than iron plus the fact that the model for their production in supernova explosions has problems. Also the observed abundances of lighter elements are problematic. "Cold fusion", which is usually admitted as a real phenomenon, is the third problem [L1, L2, L4].

2. The TGD based model assumes that the dark "cold fusion" of dark nucleons produces nuclei with much smaller binding energy than that of normal nuclei and can occur at low temperatures. The potential energy wall preventing the occurrence of fusion is much lower if it scales as the inverse size scale of the dark nuclei. This predicts the formation of dark nucleon sequences which can transform to ordinary nuclei by the reduction of the value of h_{eff} and liberate in this process almost all ordinary nuclear binding energy. This process would lead to the generation of the core of the protostar and when the temperature is high enough, ordinary nuclear fusion reactions begin.

3. In this framework elements heavier than Fe would be formed outside stellar interiors during the period leading to the formation of the protostar. Also the formation of the cores of planets could involve this process but would not lead to the ignition temperature at which ordinary nuclear fusion begins. The seeds for the formation of stars could correspond to tangles of thickening cosmic strings producing ordinary matter as the energy of the string is liberated.

3.3 Are the abundances of elements independent of cosmic time?

The model predicts that effects of reprocessing, which are central in the standard model, would be weak and the abundances produced by the nuclear fusion itself inside the star should depend only weakly on cosmic time! The TGD Universe would be an expanding steady state Universe!

ZEO strengthens this prediction. The sequence of reincarnations leads to an asymptotic state: the abundances of the nuclei in the interstellar space should not depend on time: this was actually one of the first "almost-predictions" of the TGD inspired model of nuclei as string-like entities [K1]. Standard model makes different prediction: the abundances of the heavier nuclei should gradually increase as the nuclei are repeatedly re-processed in stars and blown out to interstellar space in a supernova explosion. What is the situation in real life?

Amazingly, there is empirical support for this highly non-trivial prediction of TGD [E3]. The 25 measured elemental abundances (elements up to $Sn(50,70)$ (tin) and $Pb(82,124)$ (lead)) of a 12 billion years old galaxy turned out to be very nearly the same as those for the Sun. For instance, oxygen abundance was 1/3 of that from that estimated for the Sun. Standard model would predict that the abundances should be .01-.1 from that for the Sun as measured for stars in our galaxy. The conjecture was that there must be some unknown law guaranteeing that the distribution of stars of various masses is time independent. The alternative conclusion would be that heavier elements are created mostly in the interstellar gas and dust.

The findings of JWST, in particular the discovery of stars and galaxies which seem to be older than the Universe, conforms with this picture.

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