Moon is a mysterious object

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Matti Pitkänen

orcid:0000-0002-8051-4364.
email: matpitka6@gmail.com,
url: http://tgdtheory.com/public_html/,
address: Rinnekatu 2-4 A 8, 03620, Karkkila, Finland.

Abstract

The Moon looks like a rather mysterious object. The origin of the Moon is a mystery although the fact that its composition is the same as that of Earth gives hints; Moon is receding from us (cosmic recession velocity is 78 per cent of this velocity; it seems that the Moon has effectively turned inside out; the faces of the Moon are very different; the latest mystery that I learned of, are the magnetic anomalies of the Moon. The TGD based view of the origin of the Moon combined with the TGD view of magnetic fields generalizing the Maxwellian view explains all these mysterious looking findings.

Contents

1 Introduction

For a typical build of TOE, the Moon might look like a totally uninteresting object. In TGD, the situation is very different. During the last year I have learned that the Moon is a rather mysterious object from the point of view of standard astrophysics. In this article I have collected a list of mysteries that I know of and developed a TGD based explanation based on the TGD based view for the formation of astrophysical objects.

1.1 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 [L15, L16]. These explosions solve one basic problem of GRT based cosmology due to the fact that, although the astrophysical objects participate the cosmic expansion, they do not expand themselves. These rapid explosion would replace the smooth cosmic expansion of the GRT based cosmology. One of the applications has been a model for the Cambrian explosion for about .5 billion years ago. The sudden appearance of highly evolve multicellulars remains a mystery in standard biology. The proposal is that they evolved in underground oceans and bursted to the surface in rapid expansion of the Earth increasing its radius by factor 2 [L4, L10, L7, L14, L13]. Before this there would have been a single continentin the birth of Moon just like in the recent Mars.

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 giving rise to the Moon is replaced with a spherical shell of dark matter, which develops a hole and collapses under its own gravitatonal attraction. 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.

1.2 A model for the formation of Moon

The model for the formation of planets can be applied also to the mysteries of the Moon.

1. The origin of the Moon is a mystery although the fact that its composition is the same as that of Earth gives hints. Theia hypothesis proposes that the Moon was formed from the debris of a collision of a planet with mass of order mass of Mars. The TGD proposal is that the Moon was formed as Earth expanded suddenly, throwing out a spherical shell which then developed a hole and suffered a gravitational collapse to form the Moon.

2. Moon is receding from us. Cosmic recession velocity is 78 percent of this velocity, which suggests that surplus recession velocity is due to the explosion citebtartpreCE. The breaking of the spherical symmetry caused by the development of the hole plus the transformation of the gravitational binding energy to kinetic energy during the collapse would give the Moon a radial recession velocity which would gradually slow down to the cosmic recession velocity.

3. It seems that the Moon has effectively turned inside out [E1]. The natural explanation is that the far face of the Moon corresponds to the surface of the ancient Earth which remained solid in the explosion and formed an outwards directed bulge, since compression was not possible. The first guess is that the near face corresponds to the lower boundary of the expanding shell, which partially transformed to magma in the explosion, which liberated a lot of heat. It turns out that part of a large fraction of the spherical disk must have transformed to magma form in the final stages of the gravitational collapse. This conforms with the empirical facts.

4. The faces of the Moon are very different [E4]. The mechanism of the formation explains this.

5. The latest mystery that I learned of, are the magnetic anomalies of the Moon. The TGD based view of the origin of the Moon combined with the TGD view of magnetic fields generalizing the Maxwellian view explains all these findings. Monopole flux tubes have a closed cross section and there is no need for the currents to maintain the. This would also explain the stability of the Earth's magnetic field [L1] and the preservation of the magnetic fields in cosmic scales.

2 TGD view of formation of the Moon

The TDG based proposal for the formation of planets summarized briefly in the introduction assumes that planets have condensed from spherical shells of dark matter produced by "mini big bangs" as explosions of the star [L15, L16]. 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.

2.1 How did Moon originate?

The Moon is a rather mysterious object. The origin of the Moon is a mystery although the fact that its composition is the same as that of Earth gives hints; Moon is receding from us (cosmic recession velocity is 78 per cent of this velocity, which suggests that surplus recession velocity is due to the explosion) [L14]; it seems that the Moon has effectively turned inside out; the faces of the Moon are very different; the latest mystery that I learned of, are the magnetic anomalies of the Moon. The TGD based view of the origin of the Moon combined with the TGD view of magnetic fields generalizing the Maxwellian view explains all these mysterious looking findings.

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 $3\Delta R/R_E \simeq M_{Moon}/M_E$ gives $\Delta R \simeq 30$ km.

The group led by Weigang Liang has presented strong evidence that the Moon has turned inside out [E1]. The heavy elements, which should be in the core are at the surface. For a popular summary see this. Can the proposed model explain this mysterious looking finding?

During the condensation of the spherical layer to the Moon, the gravitational acceleration experienced by the outer parts of the shell was stronger than that experienced by the inner parts. This implied turning inside out. The outer parts containing originally lighter stuff went to the core and the heavier stuff on the inner boundary of the shell remained on the surface.

A more precise calculation shows that the turning inside out is suggestive even if the shell has a constant density.

1. Let the outer and inner radii of the spherical shell be r_{out} and r_{in} respectively. The $r_{out}-r_{in} = \Delta_{out}$ gives the thickness of the shell. Since the shell is thin, one can write $r = r_{in} + \Delta$ and perform a Taylor approximation. One can write in a good approximation for the mass of the part of the shell extending from rin to $r = r_{in} + \Delta$ as

$$M_S(r = r_{in} + \Delta) = \rho 4\pi r_{in}^2 \Delta \simeq \frac{3M_E}{R_E^3} \quad .$$

where the approximation

$$\rho = \frac{3M_E}{4\pi R_E^3} \quad .$$

has been used.

2. The total gravitational mass affecting a particle at distance r is the sum of that caused by Earth without the shell and the portion of the shell below it and given by the sum of $M_E - M_{shell} = M_E - M(\Delta_{out})$ and $M(r)$.

3. One can write the gravitational potential as $V_{gr} = GV(r)$,where $V(r)$ is given by

$$V(r) = \frac{M_E - M_{shell} + M_S(r)}{r}$$

By expanding $V(r)$ as second order Taylor polynomial, one obtains

$$V(r) = \frac{M_E - M_{shell}}{r_{in}} + [-\frac{M_E - M_{shell}}{r_{in}^2}\Delta + \frac{3M_E}{R_E^3}(r_{in}\Delta - \Delta^2] \ .$$

4. The radial gravitational acceleration is given by

$$\frac{a(r)}{G} = \frac{dV}{dr} = -\frac{M_E - M_{shell}}{r_{in}^2} - \frac{3M_E}{R_E^3}](r_{in} + 2\Delta)$$

The first two terms give a constant acceleration, which cannot cause inversion. The second term gives inwards directed acceleration and can force the inversion even in the case that the density of the shell is constant.

2.2 Why the near and far faces of the Moon are so different?

In Bighthink there was an interesting story telling about the strange finding related to the faces of the Moon [E4]. The finding is that the faces of the Moon are very different. The rotaton perios of Moon and Earth are locked meaning that the we see always the same face of the Moon. In 1959 the first spacecraft flew around the Moon and it was found that the two sides of the Moon are very different.

The near side is heavily cratered and the lighter areas are in general more cratered that the dark areas known as maria. Craters have a fractal structure: craters within craters. Dark areas have different decomposition. At the far side there are relatively few dark maria and the dark side is thoroughly cratered and "rays" (not of light) appear to radiate out from them.

The "obvious" explanation for the difference between the two sides is that there is a massive bombardment by heavy towards the far side whereas Earth has shielded the near side. This explanation fails quantitatively: the number of collisions at the near side should be only 1 per cent smaller at the far side. The far side is about 30 per cent more heavily cratered than the near side. There is no explanation for the size and abundance difference of the maria.

The article [E4] discusses the explanation in terms of the Theia hypothesis stating that Moon was formed as a debris resulting from a collision of Mars size planet with Earth. If the Earth was very hot, certain elements would have been depleted from the surface of the Moon and chemical gradients would have changed its chemical decomposition. The very strong tidal forces when the Moon and Earth were near to each other would have led to a tidal locking. If the near side has thinner crust, Maria could be understood as resulting from molten lava flows into great basins and lowlands of the near side. If the maria solidified much later than the highlands one can understand why the number of craters is much lower. The impact did not leave any scars. The hot Earth near the Moon also explain the difference in crustal thickness.

The TGD based explanation for the finding that Moon has apparentely turned itself inside out explains also this finding. The proposal also explains why the compositions of Earth and Moon are similar. It is not however clear why Theia and Earth would have had similar compositions.

This spherical layer was unstable against gravitational condensation to form the Moon. If the condensation was such that there was no radial mixing, the layer's inner side remained towards the Earth. This together with the tidal locking could allow to understand the differences between the near and far sides of the Moon. The chemical composition of the near side would correspond to that in the Earth's interior at certain depth h. One can estimate the thickness h of the layer as $h = R_M^3/3R_E^2 \simeq R_E/192$ from $R_M \simeq R_E/4$. This gives $h \sim 33$ km, which corresponds to the base of the crust. The temperature of the recent Earth at this depth is around 700 K (see this). At the time of the formation of Moon, the temperature could have been considerably higher, and it could have been in molten magma state.

Orbital locking would rely on the same mechanism as in Theia model. The half-molten state would have favored the development of the locking. The far side would represent the very early Earth affected by the meteoric bombardment or possibly some other mechanism creating the craters.

2.3 The mystery of the magnetic field of the Moon

The magnetic field of the Moon (see the Wikipedia article) is mysterious. There are two Sciencealert articles about the topic (see this and this).

There is an article by Krawzynksi et al with the title *Possibility of Lunar Crustal Magnatism Producing Strong Crustal Magnetism* [E3] (see this). The article by Hemingway and Tikoo with the title *Lunar Swirl Morphology Constrains the Geometry, Magnetization, and Origins of Lunar Magnetic Anomalies* [E2] (see this) considers a model for the origin local magnetic anomalies of the Moon manifesting themselves as lunar swirls.

2.3.1 The magnetic anomalies of the Moon

Consider now the magnetic anomalies of the Moon.

1. The Moon has no global magnetic field but there are local rather strong magnetic fields. What puts bells ringing is that their ancient strengths according to [E2] are of the same order of magnitude as the strength of the Earth's magnetic field with a nominal value of $B_E \sim .5$ Gauss. Note that also Mars lacks long range magnetic field but has similar local anomalies so that Martian auroras are possible. The mechanism causing these fields might be the same.

2. The crustal fields are a surface phenomenon and it is implausible that they could be caused by the rotation of plasma in the core of the Moon. The crustal magnetic fields seem to be associated with the lunar swirls, which are light-colored and therefore reflecting regions observed already at the 16^{th} century. Reiner Gamma is a classical example of a lunar swirl illustrated by Fig 1. of [E2] (see this). The origin of the swirlds is a mystery and several mechanisms have been proposed besides the crustal magnetism.

3. Since Moon does not have a global magnetic field shielding it from the solar wind and cosmic rays, weathering is expected to occur and change the chemistry of the surface so that it becomes dark colored and ceases to be reflective. In lunar maria this darkening has been indeed observed. The lunar swirls are an exception and a possible explanation is that they involve a relatively strong local magnetic field, which does the same as the magnetic field of Earth, and shields them from the weathering effects. It is known that the swirls are accompanied by magnetic fields much stronger than might be expected. What is interesting is that the opposite face of the Moon is mostly light-colored. Does this mean that there is a global magnetic field taking care of the shielding.

The article [E2] discusses a mechanism for how exceptionally strong magnetization could be associated with the vertical lava tubes and what are called dikes. The name indicates that the dikes are parallel to the surface.

1. The radar evidence indicates that the surface of the Moon once contained a molten rock. This suggest a period of high temperature and volcanic activity billions of years ago. Using a model of lava cooling rates Krawczynski and his colleagues have examined how a titanium-iron oxide, a mineral known as ilmenite - abundant on the Moon and commonly found in volcanic rock - could have produced a magnetization. Their experiments demonstrate that under the right conditions, the slow cooling of ilmenite can stimulate grains of metallic iron and iron-nickel alloys within the Moon's crust and upper mantle to produce a powerful magnetic field explaining the swirls.

2. The paleomagnetic analysis of the Apollo samples suggests that there was a global magnetic field during period $\sim$ 3.85–3.56 Ga (the conjectured Theia event would have occurred $\sim$ 4.5 Ga ago), which would have reached intensities $.78 \pm .43$ Gauss. The order of magnitude for this field is the same as that for the Earth's recent magnetic field. At the landing site of Apollo 16 magnetic fields as strong as $.327 \times 10^{-3}$ Gauss were detected. A further analysis suggests the possibility of crustal fields of order 10^{-2} Gauss to be compared with the Earth's magnetic field of .5 Gauss.

3. The lunar swirls consist of bright and dark surface markings alternating in a scale of 1-5 km. If their origin is magnetic, also the crustal magnetic fields must vary in the same scale. The associated source structures, modellable as magnetic dipoles, should have the same length scale. The restricted volume of the source bodies should imply strong magnetization. 300 nT crustal fields ($.3 \times 10^{-2}$ Gauss) are necessary to produce the swirl markings. The required rock magnetization would be higher than .5 A/m (note that 1 A/m corresponds to about 1.25×10^{-2} Gauss).

   The model assumes that below the surface there are vertical magnetic dipoles serving as sources of the local magnetic field. The swirls as light regions would be above the dipoles generating a vertical magnetic field. In the dark regions, the magnetic field would be weak and approximately tangential due the absence of magnetization.

4. A mechanism is needed to enhance the magnetization carrying capacity of the rocks. The proposal is that a heating associated with the magmatic activity would have thermodynamically altered the host rocks making possible magnetizations, which are by an order of magnitude stronger than those associated with the lunar mare basalts (the existence of which suggets that the surface was once in a magma state). The slow cooling would have enhanced the metal content of the rocks and magnetization would have formed a stable record of the ancient global magnetic field of the Moon.

2.3.2 The TGD based model for the magnetic field of the Moon

The above picture would conform with the TGD based model in which the face of the Moon opposite to us corresponds to the bottom of the ancient Earth's crust. It could have been at high enough temperature at the time of the explosion producing the Moon. The volcanic activity would have occurred in the Earth's crust and magnetization would be inherited from that period.

One can however wonder how the magnetized structures could have survived for such a long time. The magnetic fields generated by macroscopic currents in the core are unstable and their maintenance in the standard electrodynamics is a mystery to which TGD suggests a solution in terms of the monopole flux contribution of about $2B_E/5$ to the Earth's magnetic field which is topologically stable [L1]. If the TGD explanation for the origin of the Moon is correct, these stable monopole fluxes assignable with the ancient crust of the Earth should be present also in the recent Moon and could cause a strong magnetization.

The mysterious findings could be indeed understood in the TGD based model for the birth of the Moon as being due to an explosion throwing out the crust of Earth as a spherical shell which condensed to form the Moon.

1. The TGD based model for the magnetic field of the Earth [L1] predicts that the Earth's magnetic field is the sum of a Maxwellian contribution and monopole contribution, which is topologically stable. This part corresponds to monopole flux tubes reflecting the nontrivial topology of CP_2. The monopole flux tubes have a closed 2-surface as a cross section and, unlike ordinary Maxwellian magnetic fields, the monopole part requires no currents to generate it. This explains why the Earth's magnetic field is stable in conflict with prediction that it should decay rather rapidly. Also an explanation for magnetic fields in cosmic scales emerges.

2. The Moon's magnetic field is known to be a surface phenomenon and very probably does originate from the rotation of the Moon's core as the Earth's magnetic field is believed to originate. In TGD, the stable monopole part would induce the flow of charged matter generating Maxwellian magnetic field and magnetization would also take place.

   If the Moon was born in the explosion throwing out the crust of Earth, the recent magnetic field should correspond to the part of the Earth's magnetic field associated with the monopole magnetic flux tubes in the crust. The flux tubes must be closed, which suggests that the loops run along the outer boundaries of the crust somewhat like dipole flux and return back along the inner boundaries of the crust. Therefore they formed a magnetic bubble. I have proposed that the explosions of magnetic bubbles of this kind generated in the explosions of the Sun gave rise to the planets [L15, L16].

3. After the explosion throwing out the expanding magnetic bubble, the closed monopole flux tubes could have suffered reconnections changing the topology. I have considered a model for the Sunspot cycle [L16] in terms of a decay and reversal of the magnetic field of Sun based on the mechanism in monopole flux tube loops forming a a magnetic bubble at the surface of the Sun split by reconnection to shorter monopole flux loops for which the reversal occurs easily and is followed by a reconnection back to long loops with opposite direction of the flux. This process is like death followed by decay and reincarnation and corresponds to a pair of "big" state function reductions (BSFRs) in the scale of the Sun. Actually biological death could involve a similar decay of the monopole flux tubes associated with the magnetic body of the organism and meaning reduction of quantum coherence.

4. The formation of the Moon would have started with an explosion in which a magnetic bubble with thickness ΔR deermined by the condition $4\pi R_{E,A}^2 \Delta R/4\pi R_E^3/2 = M_M/M_E \simeq .012$.

   One can consider two options for the ancient radius $R_{E,A} = xR_E$ of the Earth: either $x = 1$ or $x = 1/2$, which is suggested by the TGD based explanation of Cambrian explosion.

   One obtains $\Delta R/R_E = \frac{1}{3x^2}\frac{M_M}{M_E}$. From $M_M/M_E \simeq .012$ and $R_M/R_E \sim .27$ one obtains $\Delta R/R_E \simeq .004$ for $x = 1$ and $\Delta R/R_E \simeq .016$ for $x = 1/2$. These options give $\Delta R \sim 25.5$ km for $x = 1$ or $\Delta R \sim 102$ km for $x = 1/2$ for the thickness of the layer, perhaps the crust of the ancient Earth, which was thrown out. For $x = 1/2$, $R_M = .27R_E$ gives $R_M = .54R_{E,A}$, which looks rather reasonable.

5. A hole in the bubble was formed and after that the bubble developed to a disk at a surface of possibly expanding sphere, which contracted in the tangential direction to form the Moon. The monopole flux tubes of the shell followed matter in the process. In the first approximation, the Moon would have been a disk. The radius of Moon is less than one third of that for the Earth so that monopole flux tube loops of the crust with length of $2\pi R_{E,A}$ had to contract by a factor of about 1/3 to give rise to similar flux tubes of Moon. This would have increased the density by a factor of order 9 if the Moon were a disk, which of course does not make sense.

6. If the mass density did not change appreciably, the spherical shell with a hole had to transform to a structure filling the volume of the Moon. One can try to imagine how this happened.

   (a) The basic assumption is that the far side corresponds to the surface of the ancient Earth. Near side could correspond to the lower boundary of its crust. A weaker condition is that the near side and a large part of the interior correspond to magma formed in the explosion and in the gravitational collapse to form the Moon. There is indeed evidence that the near side of the Moon has been in a molten magma state. This suggests that the crust divided into a solid part and magma in the explosion, which liberated a lot of energy and heated the lower boundary of the crust.

   (b) Part of the solid outer part of the disk gave rise to the far side of the Moon. When the spherical disk collapsed under its own gravitational attraction, some fraction of the solid outer part, which could not contract, formed an outwards directed spherical bulge of radius $R_M = yR_E$, $y = .27$ whereas the magma formed an inwards directed bulge. The ratio of the mass of the sub-disk with radius R_M to the mass of the remaining part of the spherical disk is the ratio of the areas $r = R_M^2/(2R_E^2x^2 - R_M^2) = y^2/(2x^2 - y^2)$ and gives $r = .11$ for $x = 1/2$ and $r \simeq .004$ for $x = 1$. For $x = 1/2$ the remaining annular part of the spherical disk contributed 89 percent to the mass of the Moon. For $x = 1$ the contribution was 99.6 percent.

   The energy liberated in the gravitational collapse would have melted the remaining fraction of the spherical disk as it fused to the proto Moon. For both cases most of the spherical disk would melt in the gravitational collapse. The thin crust of the near side would have formed in the cooling process.

This model applies also to the formation of planets. The proposal indeed is that the planets formed by a collapse of a spherical disk produced in the explosion of Sun [L15, L16]. Moons of other planets could have formed from ring-like structures by the gravitational collapse of a split ring.

7. The magnitude of the dark monopole flux for Earth is about $B_M = 2B_E/5 \sim .2$ Gauss for the nominal value $B_E = .5$ Gauss. The monopole flux for the long loops is tangential but if reconnection occurs there are portions with length ΔR inside which the flux is vertical and connects the upper and lower boundaries of the layer. Note that in the TGD inspired quantum hydrodynamics also dark Z^0 magnetic fields associated with hydrodynamic flows are possible and could be important in superfluidity [L9].

8. As already noticed, the far side of the Moon, which would correspond to the surface of the ancient Earth, is light-colored, which suggests that the monopole magnetic fields might be global and tangential at the far side. If so, the reconnection of the monopole flux tubes have not taken place at the far side. If magnetic anomalies are absent at the far side, the monopole part of the magnetic field should have taken care of the shielding by capturing the ions of the solar wind and cosmic rays as I have proposed. The dark monopole flux tubes play a key role in the TGD based model for the terrestrial life and this raises the question whether life could be possible also in the Moon, perhaps in its interior.

2.3.3 About the energetics of the birth of Moon and Cambrian explosion

The proposed birth mechanism of Moon and Cambrian explosion are not possible in standard astrophysics since gravitational binding energy is considerably reduced in both processes. There should exist some internal or external source of energy compensating for the reduction of the gravitational energy.

In te Cambrian explosion the radius of Earth would have increases by factor 2 and reduces the gravitational binding energy by factor 1/2. The first guess in both cases is that the explosion started from the center of Earth. In the case of the birth of the Moon, it would have led to an expansion throwing the outer layer of Earth away. The energy could have been also liberated below the layer expanding it and thrown away the outer layer. The layer below would do work on the outer layer. Note that the energy liberated in the outer layer cannot throw it out since this requires work done on the system and mere heating cannot achieve this.

Concerning the birth of Moon, the simplest assumption is that the Earth does not appreciably expand in the process and only a layer of thickness ΔR_E is thrown out as the part of Earth below it generates a pressure and expands. In the initial state one would have $R_{E,A} = R_E x + \Delta R$ and $M_{E,A} = M_E + M_{Moon}$. In the final state one would have $M_{E,A} = M_E$ $R_{E,A} \simeq R_E x$, $x = 1$ or $x = 1/2$. For the Moon one has $R_{Moon} = yR_E$, $y = .27$ and $M_{Moon} = zM_E$, $z = .012$ and $\Delta R/R_E = (1/3x^2)z$, $x = M_{Moon}/M_E \simeq .012$. The expression for the difference between gravitational binding energies of Earth for the initial and final state is

$$r \equiv \frac{(E_{gr,f} - E_{gr,i})}{E_{gr,now}} = \frac{(1+z)^2}{x+(y/3x^2)} - \frac{1}{x}) \quad , \quad E_{gr,now} = \frac{GM_E^2}{R_E} = \frac{r_S}{2R_E} M_E \sim .78 \times 10^{-9} \times \quad .$$

In a good approximation, ne obtains $r \simeq 1.22$ for $X = 1/2$ and $R = .61$ for $x = 1$. As expected, the gravitational binding energy is reduced and there must exist a mechanism compensating for the reduction.

Note that the contribution of the gravitational binding energy of the Moon is $(z^2/y) \times E_{gr,now}$ and 4 orders of magnitude smaller. The gravitational binding energy between Earth and Moon is $yt \times E_{gr,now}$, where $t = R_E/D \simeq 1/60$ is the ratio of R_E and the distance of the Moon.

The mechanism of expansion could have been the same in the formation of Moon and in the Cambrian explosion it is proposed to involve an expansion of the Earth radius by factor 2. What could be the energy source needed to overcome the gravitational potential wall?

1. The TGD counterpart of inflation suggests a very general mechanism based on the liberation of the TGD counterpart of dark energy assignable to the magnetic monopole flux tubes [L17]. This energy contains magnetic (and possibly also electric part) part and volume part. In the primordial cosmic strings with 2-D M^4 projection, which is unstable against the increase of the dimension of the projection, dominated and the subsequent cosmic evolution consisted of phase transition increasing the thickness of the monopole flux tubes and liberating energy since string tension was reduced.

This mechanism could provide a universal mechanism providing metabolic energy in very general sense. This mechanism works in all scales. Cosmic strings would give rise to quasars developing to galaxies and also stars and planets would correspond to tangles of monopole flux tubes and for blackholes they would be volume filling. In biology the phase transitions of the monopole flux tubes might liberate energy.

2. The generation of the $h_{eff} > h$ phases of ordinary matter behaving like dark matter requires energy feed since the energies as function of h_{eff} quite generally increase with its value. This requires metabolic energy and the above mechanism might be universal mechanism of this kind. On the other hand, value of h_{eff} spontaneously decreates and a continual energy feed is requires. This process also liberates energy possibly usable as a metabolic energy.

   These phases explaing the missing baryonic matter whose proportion has been increasing during the cosmic evolution. A possible explanation is that the baryons are transformed to dark baryons with $h_{eff} > h$ and that this relfects evolution as increase of algebraic complexity. The metabolic energy needed would come from the phase transitions increasing the thickness of the monopole flux tubes.

3. Dark fusion corresponds to a formation of dark nuclei as sequences of dark protons with binding energy, which is much smaller than the ordinary nuclear binding energy. These nuclei then decay to ordinary nuclei liberating almost all nuclear binding energy. This would explain "cold fusion" and also the claims about biofusion since dark protons sequences realize genetic code in the TGD framework. Dark fusion could solve the well-known anomalies of nuclear physics, in particular give rise to nuclei heavier than iron which cannot be produced in stellar cores.

   Dark fusion could give rise to the protostars by heating the matter to a temperature in which ordinary nuclear fusion can take place. Dark fusion could take place also in the ordinary nuclear reactions if tunnelling correspond to a pair of "big" state function reductions.

Water is especially interesting candidate concerning the energy source.

1. What is interesting is that the gravitational binding energy of proton at the surface of Earth is about 1 eV which is typical energy of biochemistry. Before Cambrian explosion this energy would have been 2 eV. For water the energy of hydrogen bond is .5 eV. This suggests that energy compesating for the the change of the gravitational binding energy in the formation of Moon and in Cambrian Explosion comes from chemical processes or their TGD counterparts involving also new physics predicted by TGD. Here dark protons are of special interest. Could their transformation to ordinary protons liberate the needed energy? Water involving dark proton sequences at monopole flux tubes is in a central role in TGD inspired biology. Dark water blob behaves as single quantum coherent unit and I have proposed that they are present even in the interior of the Earth.

2. If these dark water blobs behave like massive nuclei, they could by their large mass end up to even to the cores of the Sun and planets. There is standard argument claiming that iron and nickel form the Earth's core and inner core since they experience stronger gravitational force. This is not consistent with Equivalence Principle, stating that particles in gravitational field experience the same acceleration irrespective of the mass. In Newtonian mechanics, the reduced mass for mass m is $\mu = mM/(m+M) = m/(1+m/M)$ and the gravitational acceleration is $a = (GMm/\mu)(1/r^2) = GM(1+m/M)/r^2$ and increases with m but depends very weakly on m. Note however that the gravitational binding energy is maximize when the massive particles are nearest to the center.

   The reason for why the heavier nuclei end up to the core involves other than gravitational interactions and that chemistry, nuclear physics, and thermodynamical stability are important. For instance, light elements evaporate easily at the high temperature prevailing in the core. This does not occur for the dark phase of water which is thermally isolated from the ordinary matter. There are indications that water could exist in this kind of environments. If this the case, the phase transitions transforming dark water to ordinary water could liberate energy and this energy could be used to compensate the gravitational binding energy. In particular,

dark fusion outside stellar interiors, say planetary cores, could have generated dark variants of ordinary nuclei, also those heavier than Fe, with much smaller binding energy outside the stellar interiors. Their decay to ordinary nuclei would have liberated ordinary nuclear binding energy. This might explain why the stellar core consists of heavy nuclei.

3. In the model of Cambrian Explosion predicting that highly developed multicellulars evolved underground, I have used the Mother Gaia metaphor and the burst of multicellulars as analog of birth. Same metaphor could apply to the birth of the Moon. The phase transition of underground dark water to ordinary water could liberate the needed energy needed to compensate for the reduction of gravitational binding energy. For Cambrian Explosion increasing the Earth radius by factor 2, the gravitational binding energy is reduced by factor 2 and would mean for single proton reduction from 2 eV to 1 eV. The average density of the Earth would have reduced in the Cambrian Explosion by factor 1/8. Can one understand this?

The increase of the volume by factor 8 in Cambrian explosion [L4, L10, L7, L14, L13] sounds crazy but one can ask whether TGD based new physics could have caused the increase of the volume?

1. I have considered the possibility that atomic radii increased by factor 2 due to a phase transition changing the value of $h_{eff} = nh_0$ with $h = n_0 h_0$, $n_0 = (7!)^2$ [L8]. Atomic radius is proportional to $\hbar/2\alpha m_e$. $hbar \to 2\hbar$ would increase the atomic size by factor 2. This reduced the binding energy scale by factor 1/2. There is evidence that hydrogen atoms have states with energy scale, which is one half of the ordinary [D1] [L2]. Could they correspond to $\hbar_{eff} = \hbar/2$?

2. The objection is that the presence of the exotic atoms with $h_{eff} < h$ should have been observed. This kind of radiation looks like radiation from atoms but with effectively blue-shifted frequencies. The matter with $h_{eff} < h$ is dark with respect to us and the dark photons with $h_{eff} < h$ might be highly stable against a transformation to ordinary fermion pairs or ordinary photons. There is an analogy with the fact that the increase of h_{eff} requires energy feed.

   The densities of states of photons in a box with respect to geometric parameters λ and f do not depend on h_{eff} unlike those with respect momentum p and energy E. Therefore the measurement of wavelengths and frequencies (by frequency- or wavelength resonance [L5]) does not reveal the value of h_{eff} for photons. Energy resonance is needed: these two resonance mechanisms are central in TGD inspired quantum biology. I am not sure whether the detection of radiation from astrophysical objects always relies on frequency resonance.

   CMB radiation is detected by wavelength resonance using large radio antennas. Could the dark CMB radiation reveal the value of the associated h_{eff} via its temperature? The Boltzmann weights for CMB radiation are proportional to the exponent $exp(-E_n/T)$, $E_n = nh_{eff}f$. What does one mean with thermal equilibrium between different values of h_{eff}? One must distinguish between thermal equilibria with respect to frequency and energy.

   (a) If T does not depend on h_{eff}, the thermal frequency distributions do not depend on h_{eff} unlike energy distributions and the effective temperatures detected by an observer with $h_{eff} = h$ would scale as $T(h_{eff}) = T(h)(h/h_{eff})$. If the CMB radiation with $h_{eff} \neq h$ transforms partially to that with $h_{eff} = h$, it could be detected.

   (b) If the equilibrium is with respect to energy, one has $T(h_{eff}) = T(h)$ and the dark CMB would not allow the detection of h_{eff} of the source. Scaling invariance predicts that T scales like h_{eff}. The TGD inspired quantum biology suggests the interpretation of biological aging as a development of a thermal equilibrium between between the biological body with $h_{eff} = h$ and the associated magnetic bodies with $h_{eff} \geq h$ so that one has $T(h_{eff}) \to T(h)$ [L22]. Living systems would allow a thermal detection of h_{eff}.

3. A phase transition increasing the algebraic complexity would have scaled down the binding energies by factor 1/2. The problem is that also this would have required energy feed. This

would have compensated for the decrease of E_{gr} from $GM^2/(R_E/2)$ to GM^2/R_E, which is of order eV per proton.

These phase transitions are now rather well-understood thanks to holography = holomorphy vision [L18].

1. Holography = holomorphy vision which leads to a detailed understand of the solutions of field equations in terms of generalize complex structure for $H = M^4 \times CP_2$ involving one hypercomplex coordinate with light-like coordinate lines and 3 complex coordinates [L21].

2. The space-time surface X^4 decomposes to regions corresponding to the roots of a pair P_1, P_2 of polynomials with coefficients in an extension F of rationals. The close analogy with catastrophe theory helps to understand the geometric picture. The root $P_i = 0$ defines a 6-D surface X_i^6 having interpretation as a generalized twistor space for M^4 *resp.* CP_2. Their intersection $X_1^6 \cap X_2^6$ defines X^4 a common base space of these spaces.

3. The simplest situation corresponds to the conditions $P_1 = 0$ and $P_2 = \xi - P(w) = 0$ or $P_2 = w - P(\xi) = 0$, where w is the complex coordinate for the light-cone boundary and ξ is the geodesic coordinate of geodesic sphere of CP_2. w is complex coordinate the twistor sphere S^2 assignable to the light-like boundary: their translates form a slicing of M^4 (or rather causal diamond *cd*). ξ corresponds to the twistor sphere of CP_2 of a given CP_2 point identifiable as homologically non-trivial geodesic sphere S^2 of CP_2 defined by the radial geodesics directed to the S^2 points.

4. These phase transitions tend to increase the dimension of the coefficient field F of P_i. This implies evolution as a collective increase of the algebraic complexity and dimension n of F. It might be identifiable in terms of the effective Planck constant $n = h_{eff}/h_0$, which is global. The increase of n would reflect itself at the level of, say, atomic spectra changing the energy scale and Bohr radius and induce volume change appearing at least in the Cambrian explosion.

   The extension depends on the degree of P_2 defining the winding number of the map P_2 between the twistor spheres of M^4 and CP_2 and the detailed form of the polynomial P_2. Note that since spheres are involved, one can also consider rational maps and birational maps are an especially interesting option.

5. There are also light-like fermion lines at the boundaries of 3-D light-like partonic orbits. At these lines the roots of polynomials can belong to an extension of a sub-field of F, even rationals. Also now the change of the polynomial P_2 induces phase transitions in general increasing the algebraic complexity at the fermion level. The dimension n_F of the extension defined by extension of F or of its subfield at the fermion line defines a candidate for a local h_{eff} as $h_{eff}/h_0 = n_F$.

   To sum up, these number theoretic phase transitions could have induced the expansion of the volume of the 3-surface and could quite generally be behind cosmic expansion reflecting directly the number theoretical evolution. The increase of $n = h_{eff}/h_0$ would correlate with the increase of the volume.

Consider now possible objections against this view.

1. The question is still where the needed energy came from. Did the dark water phases possibly present everywhere in the interior of Earth provide it by transforming to ordinary water? Or could one imagine that a monopole flux tube network proposed to connect astrophysical systems to a network provided it, perhaps by a phase transition thickening the flux tubes in the center of the Earth and liberating the needed energy as dark photons. Sun belongs to this network: could it have served as the source of energy? The paradox of faint Sun is also related to the evolution before Cambrian Explosion: it should have been possible at the surface of Earth and the TGD view solves this paradox.

2. A more concrete general explanation is as a liberation of energy in dark fusion of nucleons to form dark nuclei with binding energy much lower than the binding energy of normal

nuclei. Their spontaneous transformation to ordinary nuclei makes possible the production of elements heavier than Fe outside stars [L3, L6]. This process could have led to the formation of proto-stars and at some point ordinary nuclear fusion would have begun.

Almost all nuclear binding energy would be liberated in the dark fusion. The dark fusion could have occurred in the core of Earth and could have led to the generation of the Fe core by dark fusion. The temperature in the inner core is about 5400 K, much lower than the temperature of 15 million Kelvins, which makes ordinary nuclear fusion possible. Note that also the formation of molecules as bound states of atoms liberates energy and could make possible the generalized Pollack effect [L11] as an increase of h_{eff} to rather large values.

Could one think that the energy liberated in the dark cold fusion, as a kind of explosive chain reaction inside the core, inner core or the "inner inner" core, made possible the phase transition increasing the value of $h_{eff} < h$ to h for atoms of Earth?

3. There is also another objection. One can express α as $\alpha = e^2/4\pi\hbar$. Should one assume that α scales like $1/\hbar$ and e^2 does not change. This is assumed in the argument that the increase of h_{eff} saves perturbation theory failing otherwise [L12]. The atomic size would scale as $\hbar^2$ so that the minimum change of the scale would be by factor 4?

   The value of h_{eff} can be expressed as $h_{eff} = nh_0$. This allows rational scalings of $h \to rh$, $r = m/n$ such that n is a factor of $n_0 = (7!)^2$ with $r^2 \simeq 2$.

2.4 Martian dichotomy from the TGD point of view

Mars has a very strange property called Martian dichotomy (see this). The Northern and Southern hemispheres of Mars are very different. The crust is significantly thicker in southern highlands than in northern lowlands. The mountains at southern highlands rise even 6 kilometers higher than in northern lowlands. Southern rocks are magnetized suggesting that Mars has had a large scale magnetic field. Mars still has short scale magnetic fields as the appearance of Martian auroras tells. Southern highlands appear to be older than the northern lowlands: the age is estimated from the density of impact craters. It is also believed that there has been a vast water ocean in northern lowlands.

Several explanations have been proposed. A mega-impact or several impacts could have produced the depression in the crust in the northern lowlands area. Second explanation is in terms of plate tectonics which would be asymmetric.

Also Mars has analogues of earthquakes. They could be called marsquakes. According to the popular article (see this), it is claimed that the study of the marsquakes has led to the understanding of the Martian dichotomy [E5]. Its origin would relate to the dynamics deep inside the planet. The new finding is that the seismic waves associated with the marsquakes lose energy quicker in southern highlands. This would mean that the temperature in highlands is higher. These findings suggest that the asymmetry is caused by the internal dynamics of Mars rather than impacts.

What could one say about the Martian dichotomy in the TGD framework? TGD adds two new pieces to the puzzle.

1. Moon has an analogous asymmetry but now the hemispheres correspond to the hemisphere that we see always and the hemisphere we never see. This is due to the phase locking of the spinning rotation of the Moon with its orbital rotation around Earth. The TGD based model [L19] assumes that Earth has lost its upper layer in a mini big bang [L15, L16], which then formed the Moon. The inner and outer surfaces of the Moon would correspond to the lower and upper boundary of the layer respectively and this would explain their difference.

2. The crazy idea is that the northern and southern hemispheres of Mars could have lost different masses in an asymmetric mini big bang leading to the birth of Phobos and Deimos, the two Moons of Mars (this). The asymmetry should reflect itself in the properties of these moons. The moons have an irregular shape. Phobos has a diameter of 22.2 km, mass 1.1×10^{16} kg, and semimajor axis 13.5 km. Deimos has a diameter of 12.6 km, mass 1.5×10^{15} kg, and semimajor axis 23.5 km.

3. This suggests the associations **northern hemisphere-more massive Deimos-thicker crust-earlier-farther from Mars** and **southern hemisphere-lighter Phobos-thinner crust-later-nearer to Mars**.

   The more massive Deimos would have originated in a mini big bang throwing out a considerably thicker layer from the northern Martian hemisphere. This would explain the thinner northern crust. Large fraction of the magnetic field associated with the surface layer would have blown out. The TGD view of magnetic fields of the Earth and Sun the monopole flux tube part of the magnetic fields would have a part concentrated in a surface layer. Deimos would have originated later than Phobos. One could understand why the southern hemisphere has thicker crust, why it has more impact craters and therefore looks older, and why it still has a magnetic field consisting of monopole flux tubs. The orbital parameters do not depend on the mass of the Moon (Equivalence Principle). Deimos would have however originated earlier and received a recoil momentum and would be now farther from Mars and Phobos.

The key question concerns the energetics of the transition. Where comes the energy compensating the reduction of the gravitational binding energy. An analogous question is encountered in the model for the formation of the Moon as a mini Big Bangs throwing a spherical layer from the surface of Earth. It is also encountered in the TGD version of the Expanding Earth model [L4] [L14] assuming that the radius of Earth grew by a factor 2 in a relatively short time scale and induced Cambrian Explosion as life from underground oceans bursted to the surface. Mini Big Bangs would also cause the formation of planets as a surface layer of a star explodes [L15, L16]. Also Super Novas would be explosions of this kind. Micro Big Bangs could give rise to solar wind and solar eruptions [L20].

The magnetic fields should play an important role so that an estimate for the cyclotron energy in the case of a solar magnetic field is in order.

1. For the Earth the cyclotron frequency of proton in the endogenous magnetic field, with a nominal value $B_{end} = .2$ Gauss assigned with the monopole flux tubes, is 300 Hz, and the corresponding energy is $E_c = \hbar_{gr,E} eB/m_p = 4.6$ eV. This energy is higher than the gravitational binding energy of protons of about 1 eV at the surface of Earth. This could make it possible for transition $\hbar_{gr,E} \to \hbar$ or a transition $1/\beta_0 = n \to n-1$ to provide the energy needed for the explosion throwing a surface layer of the Earth giving rise to Moon.

   The existence of this kind a layer and reduction of $\hbar_{gr}$, say a transition $1/\beta_0 = 2 \to 1$ could make energetically possible also the expansion of the radius of the Earth by a factor 2.

2. What does one obtain in the case of Mars? Could the gravitational binding energy be compensated by the liberation of dark cyclotron energy as the value $\hbar_{gr} = GMm_p/\beta_0$ for Mars is reduced to a smaller value. The ratio of the mass of Mars to that of Earth is $M_{Mars}/M_E \simeq .1$. If the monopole flux tubes carry a magnetic field of strength $B_{end,E} = .2$ Gauss the cyclotron energy of the proton is scaled down to .46 eV. The gravitational binding energy for protons at the surface of the Earth is about 1 eV and at the surface of Mars about .1 eV. Also now the liberation of the dark cyclotron energy for protons in a phase transition increasing the value of β_0 could make the explosion of the surface layer possible.

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