Expanding Earth Model and Pre-Cambrian Evolution of Continents, Climate, and Life

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Abstract

TGD inspired quantum cosmology predicts that astrophysical objects do not follow cosmic expansion except in jerk-wise quantum leaps increasing the gigantic value of the gravitational Planck constant h_{gr} characterizing space-time mediating gravitational interactions between two masses or gravitational self interactions. This assumption provides explanation for the apparent cosmological constant. As a matter fact, gigantic value of h_{gr}. By Equivalence principle and independence of gravitational acceleration on mass it is enough to assume that only microscopic systems have the gravitational flux tube contacts with central mass. In this case the value range of h_{gr} is consistent with the identification as $h_{eff} = n \times h$ introduced with motivations coming from biology and in TGD framework following from the non-determinism of Kähler action.

Also planets are predicted to expand in a stepwise manner allowing to imagine a new version of Expanding Earth theory originally postulated to explain the intriguing findings suggesting that continents have once formed a connected continent covering almost the entire surface of Earth but with radius which was one half of the recent one.

This leads also to a rather fascinating vision about biology. The mysterious Cambrian Explosion in which a large number of new species emerged suddenly (realized already Darwin as the strongest objection against his theory) could be understood if the life would have gone to underground lakes and seas formed during the expansion period as fractures were formed and the underground cavities expanded and were filled with water. This would have allowed the life to escape cosmic radiation, meteoric bombardment, and the extremely cold climate during Proterozoic period preceding the Cambrian Explosion and migrate back as highly developed life forms as the period of glaciations ended.

Before the Proterozoic era the radius of Earth would have been one half of its recent value and started to grow with gradually accelerating rate. This forces to rewrite the entire geological and climate history of Earth during the Proterozoic period.

1. The postulated physically implausible cyclic appearance of single connected super-continent containing all land mass can be given up and replaced with a single continent containing large inland seas. There is no need to postulate the existence of series of super-oceans whose ocean floor would have subduced totally so that no direct information about them would exist nowadays.

2. The dominating model for pre-Cambrian climate is so called Snowball Earth model inspired by the finding that signatures of glaciations have been found at regions of Earth, which should have been near Equator during the Proterozoic. Snowball model has several difficulties: in particular, there is a lot of evidence that a series of ordinary glaciations was in question. For $R/2$ option the regions located to Equator would have actually been near North Pole so that the glaciations would have indeed been ordinary glaciations proceeding from the poles. A killer prediction is the existence of non-glaciated regions at apparent southern latitudes around about 45 degrees and there is evidence for these indeed exists! The model makes also testable paleomagnetic killer predictions. In particular, during periods when the magnetic dipole in the direction of rotation axis the directions of the magnetic fields for $R/2$ model are predicted to be same at South Pole and apparent Equator and opposite for the standard option.

1 Introduction

TGD inspired quantum cosmology [K10, K9] predicts that astrophysical objects do not follow cosmic expansion except in jerk-wise quantum leaps increasing the gigantic value of the gravitational Planck constant characterizing space-time mediating gravitational interactions between two masses or gravitational self interactions. This assumption provides explanation for the apparent cosmological constant.

Also planets are predicted to expand in a stepwise way. This provides a new version of Expanding Earth theory originally postulated to explain the intriguing findings suggesting that continents have once formed a connected continent covering almost the entire surface of Earth but with radius which was one half of the recent one [K9].

This leads also to a rather fascinating vision about biology. The mysterious Cambrian Explosion [I1] in which a large number of new species emerged suddenly (realized already Darwin as the strongest objection against his theory) could be understood if the life would have gone to underground lakes and seas formed during the expansion period as fractures were formed and the

underground cavities expanded and were filled with water. This would have allowed the life to escape cosmic radiation, meteoric bombardment, and the extremely cold climate during Proterozoic period preceding the Cambrian Explosion and migrate back as highly developed life forms as the period of glaciations ended.

Before the Proterozoic era the radius of Earth would have been one half of its recent value and started to grow with gradually accelerating rate. This forces to rewrite the entire geological and climate history of Earth during the Proterozoic period.

1. The postulated physically implausible cyclic appearance of single connected super-continent containing all land mass can be given up and replaced with a single continent containing large inland seas. There is no need to postulate the existence of series of super-oceans whose ocean floor would have subduced totally so that no direct information about them would exist nowadays. It is also possible that the underground oceans have burst into the surface during the phase transition.

   What is amusing that this kind of sea with water volume three times that in ordinary seas has been discovered quite recently (`http://time.com/2868283/subterranean-ocean-reservoir-core-ringwo` at depth of about 600 km to be compared to the depth of core which is about 2900 km. Water is associated with a mineral known as ringwoodite and ordinary sea water could have originated from this water.

2. The dominating model for pre-Cambrian climate is so called Snowball Earth model [F29] inspired by the finding that signatures of glaciations have been found at regions of Earth, which should have been near Equator during the Proterozoic. Snowball model has several difficulties: in particular, there is a lot of evidence that a series of ordinary glaciations was in question. For $R/2$ option the regions located to Equator would have actually been near North Pole so that the glaciations would have indeed been ordinary glaciations proceeding from the poles. A killer prediction is the existence of non-glaciated regions at apparent southern latitudes around about 45 degrees and there is evidence for these indeed exists [F46]! The model makes also testable paleomagnetic killer predictions. In particular, during periods when the magnetic dipole in the direction of rotation axis the directions of the magnetic fields for $R/2$ model are predicted to be same at South Pole and apparent Equator and opposite for the standard option.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L3].

2 Experimental Evidence For Accelerated Expansion Is Consistent With TGD based model

There are several pieces of evidence for accelerated expansion, which need not mean cosmological constant, although this is the interpretation adopted in [E2]. It is interesting to see whether this evidence is indeed consistent with TGD based interpretation.

2.1 The Four Pieces Of Evidence For Accelerated Expansion

2.1.1 Supernovas of type Ia

Supernovas of type Ia define standard candles since their luminosity varies in an oscillatory manner and the period is proportional to the luminosity. The period gives luminosity and from this the distance can be deduced by using Hubble's law: $d = cz/H_0$, H_0 Hubble's constant. The observation was that the farther the supernova was the more dimmer it was as it should have been. In other words, Hubble's constant increased with distance and the cosmic expansion was accelerating rather than decelerating as predicted by the standard matter dominated and radiation dominated cosmologies.

2.1.2 Mass density is critical and 3-space is flat

It is known that the contribution of ordinary and dark matter explaining the constant velocity of distance stars rotating around galaxy is about 25 per cent from the critical density. Could it be that total mass density is critical?

From the anisotropy of cosmic microwave background one can deduce that this is the case. What criticality means geometrically is that 3-space defined as surface with constant value of cosmic time is flat. This reflects in the spectrum of microwave radiation. The spots representing small anisotropies in the microwave background temperature is 1 degree and this correspond to flat 3-space. If one had dark matter instead of dark energy the size of spot would be.5 degrees!

Thus in a cosmology based on general relativity cosmological constant remains the only viable option. The situation is different in TGD based quantum cosmology based on sub-manifold gravity and hierarchy of gravitational Planck constants.

2.1.3 The energy density of vacuum is constant in the size scale of big voids

It was observed that the density of dark energy would be constant in the scale of 10^8 light years. This length scale corresponds to the size of big voids containing galaxies at their boundaries.

2.1.4 Integrated Sachs-Wolf effect

Also so called integrated Integrated Sachs-Wolf effect supports accelerated expansion. Very slow variations of mass density are considered. These correspond to gravitational potentials. Cosmic expansion tends to flatten them but mass accretion to form structures compensates this effect so that gravitational potentials are unaffected and there is no effect of CMB. Situation changes if dark matter is replaced with dark energy the accelerated expansion flattening the gravitational potentials wins the tendency of mass accretion to make them deeper. Hence if photon passes by an over-dense region, it receives a little energy. Similarly, photon loses energy when passign by an under-dense region. This effect has been observed.

2.2 Comparison With TGD

The minimum TGD based explanation for accelerated expansion involves only the fact that the embeddings of critical cosmologies correspond to accelerated expansion. A more detailed model allows to understand why the critical cosmology appears during some periods.

2.2.1 Accelerated expansion in classical TGD

The first observation is that critical cosmologies (flat 3-space) imbeddable to 8-D embedding space H correspond to negative pressure cosmologies and thus to accelerating expansion. The negativity of the counterpart of pressure in Einstein tensor is due to the fact that space-time sheet is forced to be a 4-D surface in 8-D embedding space. This condition is analogous to a force forcing a particle at the surface of 2-sphere and gives rise to what could be called constraint force. Gravitation in TGD is sub-manifold gravitation whereas in GRT it is manifold gravitation. This would be minimum interpretation involving no assumptions about what mechanism gives rise to the critical periods.

2.2.2 Accelerated expansion and hierarchy of Planck constants

One can go one step further and introduce the hierarchy of Planck constants. The basic difference between TGD and GRT based cosmologies is that TGD cosmology is quantum cosmology. Smooth cosmic expansion is replaced by an expansion occurring in discrete jerks corresponding to the increase of gravitational Planck constant. At space-time level this means the replacement of 8-D embedding space H with a book like structure containing almost-copies of H with various values of Planck constant as pages glued together along critical manifold through which space-time sheet can leak between sectors with different values of $\hbar$. This process is the geometric correlate for the phase transition changing the value of Planck constant.

During these phase transition periods critical cosmology applies and predicts automatically accelerated expansion. Neither genuine negative pressure due to "quintessence" nor cosmological

constant is needed. Note that quantum criticality replaces inflationary cosmology and predicts a unique cosmology apart from single parameter. Criticality also explains the fluctuations in microwave temperature as long range fluctuations characterizing criticality.

2.2.3 Accelerated expansion and flatness of 3-cosmology

Observations 1) and 2) about super-novae and critical cosmology (flat 3-space) are consistent with this cosmology. In TGD dark energy must be replaced with dark matter because the mass density is critical during the phase transition. This does not lead to wrong sized spots since it is the increase of Planck constant which induces the accelerated expansion understandable also as a constraint force due to embedding to H.

2.2.4 The size of large voids is the characteristic scale

The TGD based model in its simplest form model assigns the critical periods of expansion to large voids of size 10^8 ly. Also larger and smaller regions can express similar periods and dark space-time sheets are expected to obey same universal "cosmology" apart from a parameter characterizing the duration of the phase transition. Observation 3) that just this length scale defines the scale below which dark energy density is constant is consistent with TGD based model.

   The basic prediction is jerk-wise cosmic expansion with jerks analogous to quantum transitions between states of atom increasing the size of atom. The discovery of large voids with size of order 10^8 ly but age much longer than the age of galactic large voids conforms with this prediction. One the other hand, it is known that the size of galactic clusters has not remained constant in very long time scale so that jerk-wise expansion indeed seems to occur.

2.2.5 Do cosmic strings with negative gravitational mass cause the phase transition inducing accelerated expansion

Quantum classical correspondence is the basic principle of quantum TGD and suggest that the effective antigravity manifested by accelerated expansion might have some kind of concrete space-time correlate. A possible correlate is super heavy cosmic string like objects at the center of large voids which have negative gravitational mass under very general assumptions. The repulsive gravitational force created by these objects would drive galaxies to the boundaries of large voids. At some state the pressure of galaxies would become too strong and induce a quantum phase transition forcing the increase of gravitational Planck constant and expansion of the void taking place much faster than the outward drift of the galaxies. This process would repeat itself. In the average sense the cosmic expansion would not be accelerating.

3 Quantum Version Of Expanding Earth Theory

TGD predicts that cosmic expansion at the level of individual astrophysical systems does not take place continuously as in classical gravitation but through discrete quantum phase transitions increasing gravitational Planck constant and thus various quantum length and time scales. The reason would be that stationary quantum states for dark matter in astrophysical length scales cannot expand. One would have the analog of atomic physics in cosmic scales. Increases of $\hbar$ by a power of two are favored in these transitions but also other scalings are possible.

   This has quite far reaching implications.

1. These periods have a highly unique description in terms of a critical cosmology for the expanding space-time sheet. The expansion is accelerating. The accelerating cosmic expansion can be assigned to this kind of phase transition in some length scale (TGD Universe is fractal). There is no need to introduce cosmological constant and dark energy would be actually dark matter.

2. The recently observed void which has same size of about 10^8 light years as large voids having galaxies near their boundaries but having an age which is much higher than that of the large voids, would represent one example of jerk-wise expansion.

3. This picture applies also to solar system and planets might be perhaps seen as having once been parts of a more or less connected system, the primordial Sun. The Bohr orbits for inner and outer planets correspond to gravitational Planck constant which is 5 times larger for outer planets. This suggests that the space-time sheet of outer planets has suffered a phase transition increasing the size scale by a factor of 5. Earth can be regarded either as n=1 orbit for Planck constant associated with outer planets or n= 5 orbit for inner planetary system. This might have something to do with the very special position of Earth in planetary system. One could even consider the possibility that both orbits are present as dark matter structures. The phase transition would also explain why n=1 and n=2 Bohr orbits are absent and one only n=3, 4, and 5 are present.

4. Also planets should have experienced this kind of phase transitions increasing the radius: the increase by a factor two would be the simplest situation.

The obvious question - that I did not ask - is whether this kind of phase transition might have occurred for Earth and led from a completely granite covered Earth - Pangeia without seas - to the recent Earth. Neither it did not occur to me to check whether there is any support for a rapid expansion of Earth during some period of its history.

Situation changed when my son visited me and told me about a Youtube video [F45] by Neal Adams, an American comic book and commercial artist who has also produced animations for geologists. We looked the amazing video a couple of times and I looked it again yesterday. The video is very impressive artwork but in the lack of references skeptic probably cannot avoid the feeling that Neal Adams might use his highly developed animation skills to cheat you. I found also a polemic article [F1] of Adams but again the references were lacking. Perhaps the reason of polemic tone was that the concrete animation models make the expanding Earth hypothesis very convincing but geologists refuse to consider seriously arguments by a layman without a formal academic background.

3.1 The Claims Of Adams

The basic claims of Adams were following.

1. The radius of Earth has increased during last 185 million years (dinosaurs [I2] appeared for about 230 million years ago) by about factor 2. If this is assumed all continents have formed at that time a single super-continent, Pangeia, filling the entire Earth surface rather than only 1/4 of it since the total area would have grown by a factor of 4. The basic argument was that it is very difficult to imagine Earth with 1/4 of surface containing granite and 3/4 covered by basalt. If the initial situation was covering by mere granite -as would look natural- it is very difficult for a believer in thermodynamics to imagine how the granite would have gathered to a single connected continent.

2. Adams claims that Earth has grown by keeping its density constant, rather than expanded, so that the mass of Earth has grown linearly with radius. Gravitational acceleration would have thus doubled and could provide a partial explanation for the disappearance of dinosaurs: it is difficult to cope in evolving environment when you get slower all the time.

3. Most of the sea floor is very young and the areas covered by the youngest basalt are the largest ones. This Adams interprets this by saying that the expansion of Earth is accelerating. The alternative interpretation is that the flow rate of the magma slows down as it recedes from the ridge where it erupts. The upper bound of 185 million years for the age of sea floor requires that the expansion period - if it is already over - lasted about 185 million years after which the flow increasing the area of the sea floor transformed to a convective flow with subduction so that the area is not increasing anymore.

4. The fact that the continents fit together - not only at the Atlantic side - but also at the Pacific side gives strong support for the idea that the entire planet was once covered by the super-continent. After the emergence of subduction theory this evidence as been dismissed.

5. I am not sure whether Adams mentions the following objections [F5]. Subduction only occurs on the other side of the subduction zone so that the other side should show evidence of being much older in the case that oceanic subduction zones are in question. This is definitely not the case. This is explained in plate tectonics as a change of the subduction direction. My explanation would be that by the symmetry of the situation both oceanic plates bend down so that this would represent new type of boundary not assumed in the tectonic plate theory.

6. As a master visualizer Adams notices that Africa and South-America do not actually fit together in absence of expansion unless one assumes that these continents have suffered a deformation. Continents are not easily deformable stuff. The assumption of expansion implies a perfect fit of *all* continents without deformation.

Knowing that the devil is in the details, I must admit that these arguments look rather convincing to me and what I learned from Wikipedia articles supports this picture.

3.2   The Critic Of Adams Of The Subduction Mechanism

The prevailing tectonic plate theory [F26] has been compared to the Copernican revolution in geology. The theory explains the young age of the seafloor in terms of the decomposition of the litosphere to tectonic plates and the convective flow of magma to which oceanic tectonic plates participate. The magma emerges from the crests of the mid ocean ridges representing a boundary of two plates and leads to the expansion of sea floor. The variations of the polarity of Earth's magnetic field coded in sea floor provide a strong support for the hypothesis that magma emerges from the crests.

The flow back to would take place at so called oceanic trenches [F19] near continents which represent the deepest parts of ocean. This process is known as subduction. In subduction oceanic tectonic plate bends and penetrates below the continental tectonic plate, the material in the oceanic plate gets denser and sinks into the magma. In this manner the oceanic tectonic plate suffers a metamorphosis returning back to the magma: everything which comes from Earth's interior returns back. Subduction mechanism explains elegantly formation of mountains [F20] (orogeny), earth quake zones, and associated zones of volcanic activity [F35] .

Adams is very polemic about the notion of subduction, in particular about the assumption that it generates steady convective cycle. The basic objections of Adams against subduction are following.

1. There are not enough subduction zones to allow a steady situation. According to Adams, the situation resembles that for a flow in a tube which becomes narrower. In a steady situation the flow should accelerate as it approaches subduction zones rather than slow down. Subduction zones should be surrounded by large areas of sea floor with constant age. Just the opposite is suggested by the fact that the youngest portion of sea-floor near the ridges is largest. The presence of zones at which both ocean plates bend down could improve the situation. Also jamming of the flow could occur so that the thickness of oceanic plate increases with the distance from the eruption ridge. Jamming could increase also the density of the oceanic plate and thus the effectiveness of subduction.

2. There is no clear evidence that subduction has occurred at other planets. The usual defense is that the presence of sea is essential for the subduction mechanism.

3. One can also wonder what is the mechanism that led to the formation of single super continent Pangeia covering 1/4 of Earth's surface. How probable the gathering of all separate continents to form single cluster is? The later events would suggest that just the opposite should have occurred from the beginning.

3.3   Expanding Earth Theories Are Not New

After I had decided to check the claims of Adams, the first thing that I learned is that Expanding Earth theory [F5], whose existence Adams actually mentions, is by no means new. There are actually many of them.

The general reason why these theories were rejected by the main stream community was the absence of a convincing physical mechanism of expansion or of growth in which the density of Earth remains constant.

1. 1888 Yarkovski postulated some sort of aether absorbed by Earth and transforming to chemical elements (TGD version of aether could be dark matter). 1909 Mantovani postulated thermal expansion but no growth of the Earth's mass [F44].

2. Paul Dirac's idea about changing Planck constant led Pascual Jordan in 1964 to a modification of general relativity predicting slow expansion of planets. The recent measurement of the gravitational constant imply that the upper bound for the relative change of gravitational constant is 10 time too small to produce large enough rate of expansion. Also many other theories have been proposed but they are in general conflict with modern physics.

3. The most modern version of Expanding Earth theory is by Australian geologist Samuel W. Carey. He calculated that in Cambrian period (about 500 million years ago) all continents were stuck together and covered the entire Earth. Deep seas began to evolve then.

3.4   Summary Of TGD Based Theory Of Expanding Earth

TGD based model differs from the tectonic plate model but allows subduction which cannot imply considerable back-flow of magma. Let us sum up the basic assumptions and implications.

1. The expansion is or was due to a quantum phase transition increasing the value of gravitational Planck constant and forced by the cosmic expansion in the average sense.

2. Tectonic plates do not participate to the expansion and therefore new plate must be formed and the flow of magma from the crests of mid ocean ridges is needed. The decomposition of a single plate covering the entire planet to plates to create the mid ocean ridges is necessary for the generation of new tectonic plate. The decomposition into tectonic plates is thus prediction rather than assumption.

3. The expansion forced the decomposition of Pangeia super-continent covering entire Earth for about 530 million years ago to split into tectonic plates which began to recede as new non-expanding tectonic plate was generated at the ridges creating expanding sea floor. The initiation of the phase transition generated formation of deep seas.

4. The eruption of plasma from the crests of ocean ridges generated oceanic tectonic plates which did not participate to the expansion by density reduction but by growing in size. This led to a reduction of density in the interior of the Earth roughly by a factor $1/8$. From the upper bound for the age of the seafloor one can conclude that the period lasted for about 185 million years after which it transformed to convective flow in which the material returned back to the Earth interior. Subduction at continent-ocean floor boundaries and downwards double bending of tectonic plates at the boundaries between two ocean floors were the mechanisms. Thus tectonic plate theory would be more or less the correct description for the recent situation.

5. One can consider the possibility that the subducted tectonic plate does not transform to magma but is fused to the tectonic layer below continent so that it grows to an iceberg like structure. This need not lead to a loss of the successful predictions of plate tectonics explaining the generation of mountains, earthquake zones, zones of volcanic activity, etc...

6. From the video of Adams it becomes clear that the tectonic flow is East-West asymmetric in the sense that the western side is more irregular at large distances from the ocean ridge at the western side. If the magma rotates with slightly lower velocity than the surface of Earth (like liquid in a rotating vessel), the erupting magma would rotate slightly slower than the tectonic plate and asymmetry would be generated.

7. If the planet has not experienced a phase transition increasing the value of Planck constant, there is no need for the decomposition to tectonic plates and one can understand why there is no clear evidence for tectonic plates and subduction in other planets. The conductive flow of magma could occur below this plate and remain invisible.

The biological implications might provide a possibility to test the hypothesis.

1. Great steps of progress in biological evolution are associated with catastrophic geological events generating new evolutionary pressures forcing new solutions to cope in the new situation. Cambrian explosion indeed occurred about 530 years ago (the book "Wonderful Life" of Stephen Gould [I14] explains this revolution in detail) and led to the emergence of multicellular creatures, and generated huge number of new life forms living in seas. Later most of them suffered extinction: large number of phylae and groups emerged which are not present nowadays.

    Thus Cambrian explosion is completely exceptional as compared to all other dramatic events in the evolution in the sense that it created something totally new rather than only making more complex something which already existed. Gould also emphasizes the failure to identify any great change in the environment as a fundamental puzzle of Cambrian explosion. Cambrian explosion is also regarded in many quantum theories of consciousness (including TGD) as a revolution in the evolution of consciousness: for instance, micro-tubuli emerged at this time. The periods of expansion might be necessary for the emergence of multicellular life forms on planets and the fact that they unavoidably occur sooner or later suggests that also life develops unavoidably.

2. TGD predicts a decrease of the surface gravity by a factor 1/4 during this period. The reduction of the surface gravity would have naturally led to the emergence of dinosaurs 230 million years ago as a response coming 45 million years after the accelerated expansion ceased. Other reasons led then to the decline and eventual catastrophic disappearance of the dinosaurs. The reduction of gravity might have had some gradually increasing effects on the shape of organisms also at microscopic level and manifest itself in the evolution of genome during expansion period.

3. A possibly testable prediction following from angular momentum conservation ($\omega R^2 = constant$) is that the duration of day has increased gradually and was four times shorter during the Cambrian era. For instance, genetically coded bio-clocks of simple organisms during the expansion period could have followed the increase of the length of day with certain lag or failed to follow it completely. The simplest known circadian clock is that of the prokaryotic cyanobacteria. Recent research has demonstrated that the circadian clock of Synechococcus elongatus can be reconstituted in vitro with just the three proteins of their central oscillator. This clock has been shown to sustain a 22 hour rhythm over several days upon the addition of ATP: the rhythm is indeed faster than the circadian rhythm. For humans the average innate circadian rhythm is however 24 hours 11 minutes and thus conforms with the fact that human genome has evolved much later than the expansion ceased.

4. Scientists have found a fossil of a sea scorpion with size of 2.5 meters [I6], which has lived for about 10 million years for 400 million years ago in Germany. The gigantic size would conform nicely with the much smaller value of surface gravity at that time. The finding would conform nicely with the much smaller value of surface gravity at that time. Also the emergence of trees could be understood in terms of a gradual growth of the maximum plant size as the surface gravity was reduced. The fact that the oldest known tree fossil is 385 million years old [I11] conforms with this picture.

3.5 Did Intra-Terrestrial Life Burst To The Surface Of Earth During Cambrian Expansion?

Intra-terrestrial hypothesis [**?**] is one of the craziest TGD inspired ideas about the evolution of life and it is quite possible that in its strongest form the hypothesis is unrealistic. One can however try to find what one obtains from the combination of the IT hypothesis with the idea of

pre-Cambrian granite Earth. Could the harsh pre-Cambrian conditions have allowed only intra-terrestrial multicellular life? Could the Cambrian explosion correspond to the moment of birth for this life in the very concrete sense that the magma flow brought it into the day-light?

1. Gould emphasizes the mysterious fact that very many life forms of Cambrian explosion looked like final products of a long evolutionary process. Could the eruption of magma from the Earth interior have induced a burst of intra-terrestrial life forms to the Earth's surface? This might make sense: the life forms living at the bottom of sea do not need direct solar light so that they could have had intra-terrestrial origin. It is quite possible that Earth's mantle contained low temperature water pockets, where the complex life forms might have evolved in an environment shielded from meteoric bombardment and UV radiation.

2. Sea water is salty. It is often claimed that the average salt concentration inside cell is that of the primordial sea: I do not know whether this claim can be really justified. If the claim is true, the cellular salt concentration should reflect the salt concentration of the water inside the pockets. The water inside water pockets could have been salty due to the diffusion of the salt from ground but need not have been same as that for the ocean water (higher than for cell interior and for obvious reasons). Indeed, the water in the underground reservoirs in arid regions such as Sahara is salty, which is the reason for why agriculture is absent in these regions. Note also that the cells of marine invertebrates are osmoconformers able to cope with the changing salinity of the environment so that the Cambrian revolutionaries could have survived the change in the salt concentration of environment.

3. What applies to Earth should apply also to other similar planets and Mars [E1] is very similar to Earth. The radius is .533 times that for Earth so that after quantum leap doubling the radius and thus Schumann frequency scale (7.8 Hz would be the lowest Schumann frequency) would be essentially same as for Earth now. Mass is.131 times that for Earth so that surface gravity would be.532 of that for Earth now and would be reduced to.131 meaning quite big dinosaurs! have learned that Mars probably contains large water reservoirs in it's interior and that there is an un-identified source of methane gas usually assigned with the presence of life. Could it be that Mother Mars is pregnant and just waiting for the great quantum leap when it starts to expand and gives rise to a birth of multicellular life forms. Or expressing freely how Bible describes the moment of birth: in the beginning there was only darkness and water and then God saidLet the light come!

To sum up, TGD would not only provide the long sought mechanism of expansion of Earth but also a possible connection with the biological evolution. It would be indeed fascinating if Planck constant changing quantum phase transitions in planetary scale would have profoundly affected the biosphere.

4   Implications Of Expanding Earth Model For The Pre-Cambrian Evolution Of Continents, Of Climate, And Of Life

Expanding Earth hypothesis is by no means not new. It was proposed by Mantovani and I learned about it from the video animations of [F45, F1] demonstrating that the continents fit nicely to form a single continent covering entire Earth if the radius is one half of the recent radius. What TGD has to give is a new physics justification for Expanding Earth hypothesis: cosmic expansion is replaced with a sequence of fast expansion periods increasing the value of Planck constant and these transitions occur in all scales.

If Expanding Earth hypothesis is correct it forces to modify dramatically the view about pre-Cambrian period. The super-continent theory could be replaced by much simpler theory and it might be possible to give up the assumption about hypothetical super continents and super oceans. The view about glaciations [F7] must be modified dramatically. Concerning the evolution of life the natural hypothesis is that it escaped to the underground seas formed as a consequence of expansion during pre-Cambrian era and returned back to the surface in Cambrian Explosion. In

this section super-continent and super-ocean theory is discussed from TGD point of view. A model for glaciations based on the assumption that the radius of Earth was in good approximation one half of the recent radius during pre-Cambrian era is developed and shown to reduce to a sequence of ordinary glaciations initiated at pole caps. Snowball theory serves as a convenient reference. Expanding Earth theory is discussed also from paleomagnetic point of view and some experimental signatures of $R/2$ scenario differentiating it from standard scenarios are developed. Finally the hypothesis about underground evolution is discussed.

4.1   Super-Continent Theory

Super-continent theory assumes a cyclic formation of hypothetical super continents [F30]. Rodinia [F28], Pannotia [F24], and Pangea [F23] might have preceded by earlier super-continents. The period would be roughly 250 Myr.

1. The super-continent Rodinia [F28] is assumed to have existed during interval: 1100-750 Myr. 750 Myr ago Rodinia rifted into three continents: Proto-Laurasia which broke up and eventually reformed to form Laurasia (North America and Asia), the continental craton of Congo (part of Africa), and Gondwana (now southern hemisphere plus India).

2. Pannotia [F24] existed during time interval 600-540 Myr. Pannotia rifted in the beginning of Cambrian era to Laurentia (North America), Baltica, Siberia and Gondwana. See the illustration of Pannotia at [F13].

3. Wegener [F2] ended up to postulate that super-continent Pangea should have existed about 250 Myr ago [F23]. The support for its existence is rather strong since tectonic plate model and paleo-magnetic methods allows to trace the drift of the tectonic plates.

One can criticize the cyclic model. The concentration of land mass to Southern Hemisphere during Rodinia period does not look very probable event. The cyclically occurring formation of connected land mass surrounded by much larger ocean looks even less probable unless one can develop some very good physical mechanism forcing this. The basic motivation for super-continent theory are various correlations between distant parts of Earth which would cannot be understood otherwise. In $R/2$ model the continents would have been quite near to each other during the expansion and the notion of cyclic formation of super-continents becomes un-necessary since land bridges between the continents could explain the correlations. There would have been just single super-continent all the time.

4.2   Standard View About Oceans

In the standard model the total area covered by oceans has reduced since pre-Cambrian era due to the increase of the continental cover, which is nowadays 29 per cent. Oceans cover the remaining 71 per cent with Antarctica and Arctica included. The evolution of Oceans in standard model requires the introduction of hypothetical oceans which left no trace about their existence (subduction mechanism provides perhaps too convenient trash bin for hypothetical theoretical constructs).

1. Proto-Atlantic Ocean was introduced to explain some contradictions with Wegener's Pangea model allowing to conclude which parts at opposite sides of Atlantic Ocean had been in contact. Proto-Atlantic Ocean closed as Pangea formed and opened again in slightly different manner to form Atlantic Ocean. This process implied mixing of older pieces of the continents and explained the contradictions. Large inland sea is a natural counterpart of the Proto-Atlantic Ocean in $R/2$ option.

2. Mirovia [F17] was the super-ocean surrounding Rodinia. It transformed to Pan-African Ocean surrounding Pannotia. Pan-African ocean was then closed so that the ocean floor of Mirovia disappeared by subduction and left no signs about its existence.

3. In the rifting [F27] of Pannotia Panthalassic ocean [F25] emerged and was the precedessor of the Pacific ocean.

The presence of super-oceans is forced by the assumption that the radius of Earth was the recent one during the pre-Cambrian era plus the local data related to the evolution of continents. The questionable aspect is that these oceans did not leave any direct trace about their existence. In $R/2$ model there is no need for these super-oceans except possibly the counterpart of Panthalassic Ocean [F25].

4.3 Glaciations During Neoproterozoic Period

Glaciations dominated the Neoproterozoic period [F18] between 1-.542 billion years. The period is divided into Tonian [F34], Cryogenian [F3], and Ediacaran periods [F4]. The most severe glaciations occurred during Cryogenian period.

It is believed that during Cryogenian period [F3] two worldwide glaciations -Sturtian and Marinoan glaciations- took place. This involves extrapolation of continental drift model and plate tectonics theory. Also hypothesis about hypothetical super-continents is needed so that one must take these beliefs with some skepticism. In $R/2$ model the world wide glaciations are replaced with ordinary glaciations proceeding from poles.

1. Sturtian glaciation occurred 750-700 Myr. The breakup of Rodinia is believed to have occurred at this time. One can wonder whether there is a correlation between these events. $R/2$ model suggest that the energy needed to compensate the reduction of gravitational energy in expansion could have caused the cooling.

2. Marinoan (Varanger) glaciation ended around 635 Myr ago.

Deposits of glacial tillites [F32] at low latitudes serve as support for the claim that these glaciations were world wide. In $R/2$ model Equator corresponds to North pole in TGD framework where Rodinia covered entire Earth and the interpretation would as ordinary glaciations.

After the end of Marinoan glaciation followed Ediacaran period during 635-542 Myr [F4]. The first multicellular fossils appeared at this time. Their relationship to Cambrian fossils is unclear. The standard interpretation for the small number of fossils in pre-Cambrian period is that hard shells needed for fossilization were not yet developed. The problem is that these shells should have developed almost instantaneously in Cambrian explosion.

4.4 Snowball Earth Model For The Glaciation During Pre-Cambrian Era

Snowball Earth [F43, F38, F29] is recently the leading model for the glaciations [F8] during Proterozoic era. The term is actually somewhat misleading: Iceball Earth would more to the point. Slushball earth [F40] is a variant of Snowball Earth which does not assume total freezing near equator.

The history behind the Snowball Earth concept is roughly following [F29].

1. Mawson studied the Neoproterozoic stratigraphy of South Australia and identified extensive glacial sediments and speculated with the possibility of global glaciation. He did not know anything about continental drift hypothesis and plate tectonic theory and thought that the ancient position of Australia was the same as it is today. Continent drifting hypothesis however explained the finding as sediments deposited at the higher latitudes the hypothesis was forgotten.

2. Later Harland suggested on basis of geomagnetic data that glacial tillites [F32] in Svalbard and Greenland were deposited at tropical latitudes. In TGD framework with with $R \rightarrow R/2$ these tillites would have been at higher latitudes towards North Pole.

3. The facts are that Sun was 6 per cent fainter at that time and glaciations are known to occur. The question is whether they were global and long-lasting or a sequence of short-lasting possibly local glaciations. The Russian climatologist Budyko constructed a model based on energy balance and found that it is possible to have a global glaciation if the ice sheets proceeded enough from polar regions (to about 30 degree latitude). The model was based on the increased reflectiveness (albedo) of the Earth's surface due to the ice covering

giving rise to positive feedback loop. Budyko did not believe that global glaciation had occurred since the model offered no way to escape eternal glaciation.

4. Kirschwink introduced the term Snowball Earth, which is actually misleading. Iceball Earth would be more to the point. He found that the so called banded iron formations are consistent with a global glaciation. He also proposed a mechanism for melting the snowball. The accumulation of CO_2 from volcanoes would have caused ultra-greenhouse effect causing warming of the atmosphere and melting of the ice.

5. Slushball Earth [F40] differs from Snowball Earth in that only a thin ice cover or even its absence near equator is assumed. The model allows to explain various findings in conflict with Snowball Earth, such as the evidence for the presence of melt-water basins.

6. Zipper rift model [F39] assumes that there was a sequence of glaciations rather similar to the glaciations that have occurred later. The model assumes that the rifts [F27] of the super-continent Rodinia occurred simultaneously with glaciations. The associated tectonic uplift led to the formation of high plateaus hosting the glaciers. The iron band formation can be assigned with inland seas allowing complex chemistries and anoxicity near the sea floor.

4.4.1   The basic ideas of the Snowball Earth model

Snowball Earth [F43, F38, F29] differs from ordinary glaciations in that only oceans are frozen whereas in the ordinary glaciation land mass is covered by ice. The basic ideas of the snowball Earth relate to the mechanism initiating the global freezing and melting.

1. The glaciation would have been initiated by some event, say a creation of super-volcano. Also astrophysical mechanism might be involved. Somewhat paradoxically, tropical continents during cryogenian period [F3] are needed for the initiation because they reflect the solar radiation more effectively than tropical oceans.

2. The positive ice-albedo feedback is an essential concept: the more ice the larger the fraction of the radiation reflected back so that the more ice is generated. If the glaciation proceeds over a critical latitude about 30 degrees positive feedback forces a global glaciation.

3. The problem of the model is how to get rid of the glaciation. The proposal of Kirschvink was that the accumulation of CO_2 from volcanoes could have led to a global super-warming. The time scale for CO_2 emissions is measured in millions of years. The needed atmospheric concentration of CO_2 is by a factor 350 higher than the recent concentration. Due the ice cover the CO_2 could not be absorbed to the siliceous rocks and concentration would increase. The melting of the ice meant higher absorbtion of heat by uncovered land. Positive feedback loop was at work again but in different direction.

4.4.2   Evidence for and objections against Snowball Earth

Wikipedia article about Snowball Earth [F29] discusses both evidence for and objections against Snowball Earth. Low latitude sediments at tropical latitudes and tropical tillites at Equatorial latitudes provide strong piece of evidence for Snowball Earth. Calcium carbonate deposits having ^{13}C signature (per cent for the depletion of ^{13} isotope and large for organic material) consistent with that for mantle meaning abiotic origin is second evidence. Iridium anomaly located at the base of Calcium Carbonate deposits is third piece of evidence. The evidence for Snowball Earth will be discussed in more detail later since it is convenient to relate the evidence to $R/2$ model for glaciations.

1. Paleomagnetic data [F22] used to the dating of sediments assuming tectonic plane theory and super-continent drifting might be misleading. No pole wandering maps exist and the polarity of the magnetic field must be deduced by statistical methods. The primary magnetization could have been reset and the orientation of the magnetic minerals could have changed from the original one. It is also possible that magnetic field patterns were not dipolar. Also the assumption of hypothetical super-continents and oceans brings in uncertainties. In $R/2$ model of course the determination of the positions changes completely.

2. Carbon isotope ratios are not what they should be. There are rapid variations of ^{12}C/^{13}C ratio with organic origin. Suggests that freezing and melting followed each other in rapid succession. In standard framework this would suggest Slushball Earth meaning ice-free and ice-thin regions around the equator and hydrological cycles. In $R/2$ model the regions at Equator are near North Pole and the explanation would be in terms of ordinary glaciations.

3. The distribution of isotopes of element Boron suggest variations of pH of oceans. The explanation is in terms of buildup of carbon dioxide in atmosphere dissolved into oceans/seas. In $R/2$ model a sequence of glaciations would explain the findings.

4. Banded iron formations providing support for the model are actually rather rare and absent during Marinoan glaciation.

5. Wave-formed ripples, far-traveled ice-rafted debris and indicators of photosynthetic activity, can be found throughout sediments dating from the "Snowball Earth" periods. This serves a evidence open-water deposits. In snow-ball model these could be "oases" of melt-water but computer simulations suggest that large areas of oceans would have left ice-free. in $R/2$ model these would be signatures of ordinary glaciations.

6. Paleomagnetic data have led to the conclusion that Australia was at Equator. In $R/2$ model it would have been near North Pole. Namibia was also thought to be near Equator [F31]. Indirect arguments forced the conclusion that it at 75 degree Southern latitude. In $R/2$ model this corresponds to 60 degrees Southern latitude and ordinary glaciation proceeding from South Pole is a natural explanation and ordinary glaciation would be in question in both cases.

7. There is evidence for the continental ice cover does not fit with Snowball Earth predicts that there should be no continental ice-cover. The reason is that freezing of the ocean means that there is no evaporation from oceans and no water circulation so that ice-cover cannot develop on continents. There is considerable evidence that continents were covered by thick ice [F29]. This suggests ordinary glaciations possible in $R/2$ model.

4.5   TGD Point Of View About Pre-Cambrian Period

What is new in TGD based view about pre-Cambrian period is basically due to the $R/2$ hypothesis.

4.5.1   TGD view about evolution of continents

The hypothesis about the existence of the super-continent Pangea [F23] was inspired by the work of Wegener [F2]. The hypothesis about the existence of former super-continents were forced by the correlations with fossil records suggesting connected continent. This is not necessary if the gigantic ocean was absent during $R/2$ era. The continent Rodinia [F28] could look much like the Rodinia of standard geology except that they formed single connected region with radius $R/2$.

1. It is possible that there was only single super-continent with widening inland seas all the time until 250 billion Myr. The first option is R increased slowly and that inland lake formed. Rifts could have got wider gradually during this era. If there were land bridges between the continents there would be no need for postulating the cyclic re-formation of super-continent.

2. One can pose many questions about the character of the expansion.

   (a) What was the duration of the expansion? Could the expansion have occurred in the time period 750-100 Myr (100 Myr corresponds to the age of dinosaurs with large body size made possible by the reduced gravitation and oxygenation of the atmosphere)? Duration would have been about 650 Myr in this case. Or did it began already at the beginning of Neoproterozoic period [F18] when super-continent Rodinia began to break up? In this case the duration would be about 1 Myr. The estimate based on the quantum model of gravitational radiation predicts that the transition lasted for about 1.1 Gy so that the latter option would be more plausible in this framework.

(b) Did the expansion accelerate as does also cosmic expansion in TGD based universal model for the expansion periods containing only the duration of the expansion period as a parameter [K10] and applying in alls scales? It seems that accelerated expansion is the only sensible option since around 540 Myr the size of Earth should have been rather near to $R/2$ (perhaps so even at the period of Pangea around 250 My) unless one assumes that super-continent re-formed again.

3. One can also consider the possibility that the continents indeed broke up and reformed again during Cambrian era. One should however have a good physical reason for why this happened. Something must have connected the pieces together and created correlations. Gravitational magnetic flux tubes and phase transitions increasing and reducing Planck constant? Or could it be that the bridges connecting the continents acted like strings inducing oscillation of the distance between continents so that Pangea was surrounded by a large ocean?

4. The formation of the rift [F27] feeding magma from core to the surface would be due to the expansion leading to the formation of fractures. The induced local elevations would be like mountains. As in zipper-rift model ice could have covered these plateaus because the temperature was lower. This is not however essential for TGD based model of glaciations.

5. TGD based variant of Expanding Earth allows subduction but its role could have been small before the Pangeia period if the expansion was accelerating and led only to a relatively small increase of the radius before the Mesozoic period [F16] and continued with an accelerating rate during Mesozoic from 250 Myr to 65 Myr. It is interesting that Mesozoic period begins with the most intensive known extinction of history- so called Permian-Triassic extinction event [I4] - known as Great Dying. About 95 of marine species and 70 percent of terrestrial species became extinct. Maybe genetically determined bio-rhythms could not follow the rapidly changing circadian rhythm. Another explanation for the extinction is the warming of the climate. For this there is indeed support: there is evidence that Antarctica was climate refuge during the extinction [I13]. Perhaps both factors were involved and were not independent of each other since rapid expansion might have generated massive methane leakages from underground seas and lakes.

4.5.2   TGD based view about evolution of oceans

Continents would have covered most of the area during $R/2$ era and the covered fraction was slightly smaller than 1/4 of the recent area of Earth. This depends on the area taken by inland seas and polar caps. Nowadays the area covered by continents and inland seas is about 31 per cent so that continental area has increased and would be due to the expansion in vertical direction and deepening of the oceans. The area covered by oceans has increased from a small value to about 70 per cent. Only a small fraction of ocean floor would be subduced in Expanding Earth model. The Proto-Atlantic would have been only a small inland sea. Panthalassic Ocean was inland sea, which expanded to Pacific Ocean during expansion. Pacific Ocean could contain data about ancient ice ages if it was frozen. It however seems that data are consistent with the absence of global glaciation.

4.5.3   Model for glaciations

In TGD framework single super continent covering most of Earth becomes the counterpart of Rodinia [F28]. The hypothetical oceans are replaced with inland seas and polar caps. The super-continent covering most of Earth absorbs less solar heat than tropical oceans so that glaciations become more probable. Snowball Earth is replaced with a series of ordinary glaciations proceeding from poles since the places at Equator were near North Pole. There is no need for the glaciations to progress to the equator. The rifting for the counterpart of Rodinia is consistent with the formation of fractures due to the expansion of Earth. The reduction of gravitational binding energy due to the increase of the radius requires feed of energy and this could be one reason for the cooling and initiation of the glaciation.

There are several questions which must be answered if one wants to gain a more detailed understanding.

1. How does $R/2$ model modify the view about glaciations? Very probably there was a frozen polar cap. Snowball Earth could be replaced with ordinary glaciations proceeding from North and South Pole.

2. How does the predicted 3+3 hour diurnal cycle modify the ordinary picture? Certainly 3-hour day reduces the amplitude of the diurnal temperature variations. Could this period have left genetic traces to the mono-cellulars, say biological clocks with this period?

3. How does the predicted four times stronger surface gravity affect the glaciation process? Could strong gravity leave detectable signatures such as anomalously strong effects on the shape of surface of Earth or deeper signatures about the motion of ice.

There are also questions related to the energetics of the expansion.

1. The expansion required energy and could have induce glaciations in this manner. Energy conservation would hold for the total mechanical and gravitational energy of Earth given by

$$E \quad = \quad \frac{L^2}{2I} - k\frac{GM^2}{R} < 0 \ . \tag{4.1}$$

Here L is the conserved angular momentum of order $L \simeq I\omega$ and ω increases from $1/4\omega_{now}$ to ω_{now} during the expansion. The moment of inertia I is of order of magnitude $I \sim MR^2$ and k is a numerical constant not too far from unity. The kinetic energy is actually negligible as compared to the gravitational potential energy. The reduction of the gravitational binding energy requires a compensating energy, which could come both from Earth interior or from the Earth's surface. Both effects would induce a cooling possibly inducing glaciations.

2. One expects that in the initial stages of the expansion there was just an expansion. This meant stretching requiring also energy. The formation of rifts leading to the formation of oceans as magma flowed out would have started already in the beginning of Proterozoic period. Eventually fractures were formed and in TGD framework one might expect that the distribution of fractures could have been fractal. A considerable fraction of fractures was probably volcanoes so that CO_2 begun to leak to the atmosphere and local "oasis" were formed. Also hot springs liberating heat energy from Earth crust could have been formed as in Island. The pockets inside Earth increased in size and were filled with water. Life started to escaped to the walls of the fractures and to the water pockets. Also the recent oceans can be seen as widened cracks which transformed to the expanding sea floors whereas continents did not expand. As the continental crust ceased to expand no heat was needed for the expansion and this together with increased CO_2 content of atmosphere would explain why there was no further glaciations and heating of the Earth. At this period the flow of the magma from Earth core provided the energy needed to compensate the reduction of gravitational energy.

3. It must be emphasized that TGD variant of Expanding Earth theory is not in conflict with tectonic plate theory. It explains the formation of tectonic plates and the formation of magma flow from rifts giving also rise to subduction and is therefore a natural extension of the tectonic plate theory to times before the expansion ceased.

4.5.4   Estimate for the duration of the transition changing gravitational Planck constant

The reader without background in quantum physics and TGD can skip this section developing an estimate for the duration of the transition changing Planck constant and inducing the scaling of the radius of Earth by a factor two. The estimate is about 1.1 Gy. It must be emphasized that the estimate is not first principle calculation and relies strongly on quantum classical correspondence.

The duration of the quantum transition inducing the expansion of the gravitational space-time sheet of Earth and thus of Earth itself by a factor two can be estimated by using the same general formula as used to estimate the power of gravitational radiation emitted in a transition in which gravitational Planck constant assignable to star-planet system is reduced [K7].

1. The value of gravitational Planck constant characterizing the gravitational field body of Earth is GM^2/v_0, where the velocity parameter $v_0 < 1$ ($c = 1$) is expected to be larger than $v_0 \simeq 2^{-11}$ characterizing Sun-Earth system.

2. Assuming a constant mass density for Earth the gravitational potential energy of Earth is given by

$$V = \frac{M}{2}\omega^2 r^2 \;,\;\; \omega = \sqrt{\frac{6GM}{R^3}} \;. \tag{4.2}$$

As far as radial oscillations are considered, the system is mathematically equivalent with a harmonic oscillator with mass M. The energies for the radial oscillations are quantized as $E = (n + 1/2)\hbar_{gr}\omega$.

3. The radii of Bohr quantized orbits for the harmonic oscillator scale like $\sqrt{\hbar}$ so that $\hbar \to 4\hbar$ is needed to obtain $R \to 2R$ rather than $\hbar \to 2\hbar$ as the naïve Compton length argument would suggest. This requires the scaling $v_0 \to v_0/4$. The change of the ground state energy in this quantum transition is

$$\Delta E = \frac{1}{2}(\hbar_{gr,f}\omega_f - \hbar_{gr,i}\omega_i) \;,$$
$$\hbar_{gr,f} = 4\hbar_{gr,i} = \frac{4GMm}{v_{0,i}} \;,$$
$$\omega_i = 2^{3/2}\omega_f = 2^{3/2}\sqrt{\frac{6GM}{R_f^3}} \;. \tag{4.3}$$

$R_f = R$ denotes the recent radius of Earth.

4. From the estimate for the power of gravitational radiation in similar transition the estimate for the duration τ of the quantum transition is

$$\tau = a(v_{0,i}v_{0f})^{-k/2} \times \frac{(\hbar_{gr,i} + \hbar_{gr,f})}{2\Delta_E} \;,$$
$$= a2^{-k}v_{0f}^{-k} \times \frac{1 + r}{r\omega_f - \omega_i} \;,\;\; r = \frac{\hbar_f}{\hbar_i} = 4 \;. \tag{4.4}$$

The average of Planck constants associated with the initial and final states and geometric mean of the parameters v_{0i} and v_{0f} is dictated by time reversal invariance. The exponent k is chosen to be same as that obtained for from the condition that the ratio of the power to the classical radiation power emitted in the transition between planetary Bohr orbits does not depend on v_0 (quantum classical correspondence). This gives $k = 5$. The condition that the power of gravitational radiation from Hulse-Taylor binary is same as the power predicted by the classical formula (quantum classical correspondence) gives $a = .75$.

5. The explicit expression for τ reads as

$$\tau = K \times av_{0,f}^{-5} \times \left(\frac{R}{2GM}\right)^{1/2} \times \frac{R}{c} \;,$$
$$K = \frac{5 \times 2^{-7} \times (2 + 2^{1/2})}{3^{1/2}} \;. \tag{4.5}$$

6. The basic data are $M_{Sun} = 332900M$ (mass of Sun using Earth's mass as unit) and the mnemonic $r_{S,Sun} = 2GM_{Sun} = 2.95 \times 10^3$ m: together with $R = 6371 \times 10^3$ m these data allow a convenient estimation of $R/2GM$. For $k = 10$ and $a = .75$ this gives $\tau = 1.17$ Gyr. This is twice the estimate obtained by requiring that the transition begins at about 750 Myr (the beginning of Sturtian glaciation) and ends around 100 My (the age of gigantic animals whose evolution would be favored by the reduction of surface gravity). The estimate would suggest that the quantum transition began already around 1.1 Gyr, which in the accuracy used corresponds to the beginning of Neoproterozoic at 1 Gyr [F18]. The breaking of supercontinent Rodinia indeed began already at this time.

7. Note that the value of v_{0f} for the gravitational field body of Earth as it is now would be $v_{0f} = 2^{-10}$ to be compared with $v_0 \simeq 2^{-11}$ for Sun-Earth gravitational field body.

4.5.5 Snowball Earth from TGD point of view

In TGD framework the main justification for Snowball Earth disappears since the samples believed to be from Equator would be from North pole and glaciation could be initiated from pole caps. Consider next in more detail the evidence for Snowball Earth from TGD point of view.

1. Low latitude glacial deposits, glacial sediments at tropical latitudes, tropical tillites, etc. providing support for snowball Earth [F29] would be near North pole of at Northern latitudes. Ordinary glaciations proceeding from poles would explain the findings [F10]. If total glaciations were present, a rough scaling suggests that the evidence from them should be found from southern latitudes around 45 degrees in the standard model framework.

   The testable prediction is that the evidence for glaciations in ice-ball Earth framework should be found only below Equator and near South Pole. This finding would be of course extremely weird and would strongly favor $R/2$ option. Interestingly, in Southern Brasil all indicators for glaciations are absent (see [F46] and references therein). This region belonged to Godwana continent and there is evidence that its location was at middle latitudes at Southern Hemisphere.

2. Banded iron formations [F29] are regarded as evidence for Snowball Earth and occur at tropical levels (near North Pole in $R/2$ model). Iron dissolved in anoxic ocean would have become in a contact with photosynthetically produced oxygen and implied the formation of iron-oxide. The iron formation would have been produced at the tipping points of anoxic and oxygenated ocean. One can consider also an explanation in terms of deep inland seas, which become stagnant and anoxic near the sea floor.

   In TGD framework sea floor near North Pole could contain banded iron formations. This would explain also why the banded iron formations are rather rare. The oxygen could have come also from underground after the formation of cracks and led to the oxygenation of inland seas from bottom. The assumption that oxygenation took place already during the first glaciation, could explain why banded iron formations are absent during the second glaciation.

3. Calcium carbonate deposits [F29] have ^{13}C signature (per cent for the depletion of ^{13} isotope and large for organic material) is consistent with that for mantle meaning abiotic origin. The explanation of Calcium carbonate deposits in TGD framework could be the same as in Snowball Earth model. Atmospheric CO_2 could come from the volcanoes and react with the silicates during the ice-free periods to form calcium carbonate which then formed the deposits. CO_2 could have also biological origin and come from the underground life at the walls of the expanding fractures/volcanoes or in underground seas or lakes. In this case also methane is expected. This option would predict ^{13}C signature characteristic for organic matter. Also this kind of signatures have been observed and support ordinary glaciations. Also rapid fluctuations of the signature from positive to negative take place and might have signatures of temporary melting induced organic contribution to the calcium carbonate.

4. Iridium anomaly [F29] is located at the base of Calcium Carbonate deposits. In Snowball Earth model Iridium deposits derive from the Iridium of cosmic rays arriving at the frozen

ice surface. As the ice melts, Iridium deposits are formed. In $R/2$ model the condensation of Iridium would proceed through the same mechanism. The possible problem is whether the time is long enough for the development of noticeable deposits. Near poles (Equator and South pole in standard model) this could be the case.

4.6 Paleo-Magnetic Data And Expanding Earth Model

Paleomagnetic data from pre-Cambrian period might allow to test $R/2$ hypothesis. This data could in principle help to trace out the time development $R(t)$ from $R/2$ to R if the non-dipole contribution to magnetic field depends on $R(t)$.

4.6.1 About paleo-magnetism

Paleomagnetism [F22] provides quantitative methods to determine the latitude at which the sample of sedimentary rock was originally. Magnetic longitude cannot be determined because of rotational symmetry so that other information sources must be used. There are several methods allowing to deduce the direction and also the magnitude of the local magnetic field and from this the position of the sample during the time the sample was formed.

1. Below the Curie point thermal remanent magnetization is preserved in basalts of the ocean crust and not affected by the later magnetic fields unless they are too strong. This allows to deduced detail maps from continental drifting and polar wander maps after 250 Myr (Pangea period). During pre-Cambrian period the ocean floors of hypothetical oceans would have disappeared by subduction. In $R/2$ model there are no oceans: only inland seas.

2. In the second process magnetic grains in sediments may align with the magnetic field during or soon after deposition; this is known as detrital remnant magnetization (DRM). If the magnetization is acquired as the grains are deposited, the result is a depositional detrital remnant magnetization (dDRM); if it is acquired soon after deposition, it is a post-depositional detrital remnant magnetization (pDRM).

3. In the third process magnetic grains may be deposited from a circulating solution, or be formed during chemical reactions, and may record the direction of the magnetic field at the time of mineral formation. The field is said to be recorded by chemical remnant magnetization (CRM). The mineral recording the field commonly is hematite, another iron oxide. Red-beds, clastic sedimentary rocks (such as sandstones) that are red primarily because of hematite formation during or after sedimentary diagenesis, may have useful CRM signatures, and magnetostratigraphy [F15] can be based on such signatures. Snowball model predicts that nothing came to the bottoms of big oceans! How can we know that they existed at all!

During pre-Cambrian era the application of paleomagnetic methods [F22] is much more difficult.

1. Reliable paleomagnetic data range up to 250 My, the period of Pangaea, and magnetization direction serves as a reliable information carrier allowing detailed polar wander maps. During pre-Cambrian era one cannot use polar wander maps and the polarity of the magnetic field is unknown. Therefore theoretical assumptions are needed including hypothetical supercontinents, hypothetical oceans, and continental drift and plate tectonics. All this is on shaky grounds since no direct information about super-continents and ancient oceans exists. $R/2$ model suggests that continental drift and plate tectonics have not been significant factors before the expansion period when only inland seas and polar ice caps were present. Measurements have been however carried out about magnetization for pre-Cambrian sediments at continents recently and gives information about the strength of the magnetic field [F14]: the overall magnitude of the magnetic field is same as nowadays.

2. At Precambrian period the orientation of iron rich materials can serve as a record. The original records can be destroyed by various mechanisms (diagenesis). Also the orientations of the sediments can change in geological time scales.

3. Tens of thousands of reversals of the magnetic polarity [F6] have occurred during Earth's history. There have been long periods of stability and periods with a high frequency of reversals. The average duration of glaciation is around one Myr. The determination of the polarity of B possible by using samples from different points.

4. Mountain building orogeny [F21] releases hot water as a byproduct. This water can circulate in rocks thousands of kilometers and can reset the magnetic signature. The formation of fractures during the expansion of Earth could have released hot water having the same effect.

4.6.2 Could paleomagnetic data kill or prove $R/2$ model?

The first question is how one might kill $R/2$ model using data from pre-Cambrian era. Paleomagnetic data could do the job.

1. Remanent magnetization is proportional to the value of magnetic field causing it in weak magnetic fields. Therefore the magnetization in principle gives information about the magnetic fields that prevailed in early times.

2. Suppose that the currents generating the magnetic field can be idealized to conserved surface currents K around cylindrical surfaces of radius r and height h scaled down to to $r/2$ and $h/2$ and that the value of K is not affected in the process. With this assumptions the magnetic moment behaves $\mu \sim Ir^2h \to \mu/8$. A continuous current vortices with $j = k/\rho$, which is ir-rotational outside the symmetry axis, produce a similar result if the radius of the vortices scales as $r \to r/2$. Since dipole magnetic field scales as $1/r^3$ and is scaled up by a factor 8 in $R \to R/2$, the scalings compensate and the dipole magnetic fields at surface do not allow to distinguish between the two options. Non-dipole contributions might allow to make the distinction.

3. The group led by Lauri J. Pesonen in Helsinki University [F14] has studied paleomagnetic fields at pre-Cambrian era. The summary of results is a curve at the home page of the group and shows that the scale of the magnetic during pre-Cambrian era is same as nowadays. On the other hand, the recent thesis by Johanna Salminen- one of the group members- reports abnormally high values of magnetization in Pre-Cambrian intrusions and impact structures in both Fennoscandia and South Africa [F42]. No explanation for these values has been found but it is probably not the large value of primary magnetization.

Another manner to do test the $R/2$ model is by comparing the signs of the magnetizations at magnetic equator and poles. They should be of opposite sign for dipole field. The polarity of magnetic field varies and there are no pre-Cambrian polar wander maps. One can deduce from the condition $B_r/rB_\theta = 2cot(\theta)$ holding true for dipole field the azimutal distance $\Delta\theta$ along the direction of the measured magnetic field to the pole along geodesic circle in the direction of the tangential component of B. One cannot however tell the sign of $\Delta\theta$, in other words whether a given pre-Cambrian sample belongs to Norther or Southern magnetic hemisphere. There are however statistical methods allowing to estimate the actual pole position using samples from several positions (for an excellent summary see [F42]).

For instance, if the magnetic field is in North-South direction during Rodinian period [F28], standard model would predict that the sign at the Equator is opposite to that at South Pole. In $R/2$ model the sample would be actually near North Pole and polarizations would have same sign. The sign of magnetization at apparent southern latitude around 45 degrees would have been opposite to that at South pole which is in conflict with dipole field character. Maybe the global study of magnetization directions when magnetic field was approximately in North-South direction could allow to find which option is correct. Also the dependence of the strength of the magnetic field as function of θ could reveal whether $R/2$ model works or not. The testing requires precise dating and position determination of the samples and a detailed model for the TGD counterpart of Rodinia and its construction requires a specialist.

If the expansion continued after 250 Myr with an accelerating rate and Earth radius was still considerably below its recent value, the comparison of pole wandering charts deduced from ocean floor paleomagnetic data at faraway locations might allow to show that the hypothesis about

dipole field is not globally consistent for R option. Even information about the time evolution of the radius could be deduced from the requirement of global consistency.

4.7   Did Life Go Underground During Pre-Cambrian Glaciations?

The basic idea of Expanding Earth model is that the life developed in underground seas and emerged to the surface of Earth in Cambrian explosion. The series of pre-Cambrian glaciations explains why the life escaped underground and how the underground seas were formed.

1. If one believes that the reduction of gravitational binding energy was responsible the cooling, then the expansion of Earth could have begun at the same time as Sturtian glaciation [F3] . On the other hand, the TGD estimate for the duration of the expansion period giving 1.1 Gyr, suggests that the breakup of the Rodinia, which began in the beginning of Proterozoic period corresponds to the beginning of the expansion. The simplest assumption is that the radius of R at the beginning of Cambrian period was not yet much larger than $R/2$ and continued to increase during Cambrian period and ended up around 100 My, when dinosaurs and other big animals had emerged (possibly as a response to the reduction of gravity). This means that there were land bridges connecting the separate continents.

2. One must explain the scarcity of fossils during pre-Cambrian era. If the more primitive life forms at the surface of Earth did not have hard cells and left no fossils one can understand the absence of highly evolved fossils before Cambrian explosion [I1]. If life-forms emerged cracks and underground seas there would be no fossils at the surface of Earth. In the case of volcanoes dead organisms would have ended to gone to the bottom of the water containing volcano and burned away.

3. The expansion had formed the underground pockets and fractures made possible for the water to flow from the surface to the pockets. Life would have evolved in fractures and pockets. The first multicellular fossils appeared during Ediacaran period (segmented worms, fronds, disks, or immobile bags) [F4] and have little resemblance to recent life forms and their relationship with Cambrian life forms is also unclear. Ediacaran life forms could have migrated from the fractures and Cambrian fossils from from the underground seas and lakes. The highly evolved life-forms in Cambrian explosion could have emerged from underground seas through fractures.

One can make also questions about the underground life.

1. The obvious question concerns the sources of metabolic energy in underground seas. In absence of solar radiation photosynthesis was not possible plants were absent. The lowest levels in the metabolic hierarchy would have received their metabolic energy from the thermal or chemical energy of Earth crust or from volcanoes. The basic distinction between plants and animals might be that the primitive forms of plants developed at the surface of Earth and those of animals in underground seas.

2. At first it seems strange that the Cambrian life-forms had eyes although there was no solar radiation in the underground seas. This is actually not a problem. These life-forms had excellent reasons for possessing eyes and in absence of sun-light the life forms had to invent lamp. Indeed, many life forms in deep sea and sea trenches produce their own light [I3]. It would be interesting to try to identify from Cambrian fossils the body parts which could have served as the light source.

4.8   Great Unconformity As A New Piece Of Support For Expanding Earth Model

I hope that this chapter demonstrates convincingly that single hypothesis - a sudden phase transition increasing the radius of Earth by a factor 2 natural in the many-sheeted space-time of TGD - explains Cambrian explosion in biology (a sudden emergence of huge number of life forms after very slow Precambrian evolution), and also provides a model for Precambrian evolution of continents, climate and life.

Already Darwin realized that the absence of fossils from Precambrian era (see `http://tinyurl.com/65zeh5`) is a deep problem for his theory and assumed that this is an artefact due to the incomplete fossil record. Fossils of Precambrian origin have been indeed found after Darwin's time but they are simple and very rare, and the conclusion is that Cambrian explosion (see `http://tinyurl.com/3flhcw`) [I1] meaning a huge diversification was real. Two mysteries therefore remain. Why the development of life was so slow during Precambrian era? Why the diversification was so incredibly fast during Cambrian explosion? Various explanations have been proposed. Did the oxygen content of the atmosphere reach a critical value and lead to the diversification? Or did predation pose the evolutionary pressure making the pace of evolution dramatically faster?

In New Scientist (see `http://tinyurl.com/nenk8nq`) [F41] geologists Robert Gaines and Shanan Peters describe a geological finding perhaps related to the Cambrian Explosion: the mysterious "Great Unconformity" (see `http://tinyurl.com/bqm9ndz`) [F9], which is a juxtaposition of two different types of rock of very different geological ages along a prominent surface of erosion. This surface represents a very long span of "missing" time. More than 1 billion years of geological record is missing in many places! From the figure (see `http://tinyurl.com/y8tnbneb`) of the Wikipedia article [F9] about Great Unconformity visible in Grand Canyon the thickness of the missing layer can be estimated to be about 12.6 km. Somehow before the Cambrian the uppermost rocks of the continents were stripped away exposing the underlying crystalline basement rocks. The cause of this gap remains a complete mystery so that we have three mysteries! Plus the mysteries related to the evolution of climate (problems of Snowball Earth model).

The authors suggest that the formation of Great Unconformity relates to the Cambrian explosion. Large scale erosion and chemical weathering of the exposed crystalline rock caused mineralization of the sea water. The hypothesis is that this led to bio-mineralization: animal groups possessing mineral skeletons - such as silica shells and calcium carbonate shells - emerged. This hypothesis looks rather plausible but does not solve the three great mysteries.

The authors indeed leave open the question about the origin of Great Unconformity and of Cambrian explosion. The TGD based explanation of Cambrian explosion comes from the model realizing the old idea about Expanding Earth in terms of TGD inspired new physics. Already Wegener observed that continents can be fit together nicely and this led to the recent view about plate tectonics. Wegener's model however fits only "half" of the continent boundaries together. One could however do much better: the observation is that the continents would fit nicely to cover the entire surface of Earth if the radius of Earth were 1/2 of its recent value! Expanding Earth model postulates that the radius of Earth grows slowly. Geologists have not taken Expanding Earth model seriously: one good reason is that there is no physics allowing it.

As has been found, TGD predicts a candidate for the needed new physics.

1. At given sheet of the many-sheeted space-time cosmic expansion is predicted to take place as sudden phase transitions in which the size of some space-time sheet suddenly increases. By p-adic length scale hypothesis the preferred scaling factors are powers of 2 and the most favored scaling factor is just two. The proposal is that during the Precambrian era life resided in underground seas being thus shielded from meteor bombardment and cosmic rays. This explains the scarcity of the fossil records and the simplicity of the fossils found. The sudden phase transition was a very violent process increasing the area of the Earth's surface by a factor of 4. The area of continents is 29.1 per cent from the recent area of the Earth's surface - not too far from the naïvely predicted fraction 1/4.

2. It is easy to imagine that the uppermost rocks of the continent covering the entire Earth were stripped away and correspond nowadays to 100 km thick continental tectonic plates consisting of mainly silicon and aluminium). This expansion created split first the topmost layer as continental plates and regions between them giving rise to oceans. The magma which was uncovered by the process cooled down and solidified and the continued expansion gave rise to ocean plates with different composition (mainly silicon and magnesium).

3. The expansion phase corresponds to criticality so that fractality of the expansion is expected. At least for continental plates this process could have been fractal occurring in various length scales characterizing the thickness and the area of the sub-plates generated in the process. p-Adic length scale hypothesis suggests that the scales involved should appear as powers of $\sqrt{2}$ or 2. Generation of Great Unconformity as a process in which the underlying crystalline

basement rocks were uncovered could correspond to a splitting of a layer of the continental plates to pieces. The length scale characterizing the thickness is 12.6 km from the above estimate and with 1 per cent accuracy by a factor $1/8$ shorter than 100 km length scale for tectonic plates. This conforms with p-adic fractality. If the process of expansion involved a cascade of scalings by factor 2, one can wonder whether it proceeded from long to short length scales or vice versa. In other words: did continental and oceanic tectonic plates form first and after than the smaller structures such as the Great Unconformity or vice versa?

4. Note that the Compton scale $L_e(237)$ corresponding $p \simeq 2^{237}$ is 88 km - ten per cent smaller than 100 km. Maybe thermal expansion could account the discrepancy if the original thickness was $L(237)$. Second interpretation could be that besides electron Compton scale $L_e(239)$ the p-adic scale $L(239) = L_e(239)/\sqrt{5} \simeq 78.7$ km matters. The importance of $L(k)$ does not implicate that of scaled up electron, and the following argument suggests that it is p-adic length scale rather than corresponding electron Compton scale that matters now. Remarkably, also M_{241} is Gaussian Mersenne and corresponding electronic Compton scale is $L_e(241) = 154.7$ km.

   Note that 88 km is rather precisely the thickness of the atmosphere above which there is ionosphere (see `http://tinyurl.com/lqr85j`) [F11]. The thickness of Kennelly–Heaviside layer (see `http://tinyurl.com/25ur2tl`) [F12] inside which radio waves used in terrestrial radio communications propagate, has thickness about 150 km which roughly corresponds to $L(239)$. Note that Continental litosphere (see `http://tinyurl.com/d96kw`) [F26] has typical thickness of 200 km ($L(239)$) whereas oceanic litosphere is 100 km thick ($L(237)$). This fits at least qualitatively with the proposed formation mechanism of continental tectonic plates.

   There is a nice fractal analogy with cell membrane and connection with Gaussian Mersennes (see `http://tinyurl.com/pptxe9c`) [A1] expected to be of special importance in TGD Universe. The scales $L(239)$ and $L(241)$ would be in the same relation as the thickness $L_e(149)$ of the lipid layer of cell membrane to the cell membrane thickness $L_e(151)$ characterized by Gaussian Mersenne $M_{151,G}$. The two kinds of tectonic plates (continental and oceanic) would be analogous to the lipid layers of cell membrane.

5. The rapid expansion process could have also brought in daylight the underground seas and the highly developed life in them so that Cambrian diversification would have been only apparent. Skeptic can of course ask whether it is necessary to assume that life resided in underground seas during Precambrian era. Could just the violent geological process be enough to induce extremely fast diversification? This might of course be true.

6. There is one further argument in favor of the Expanding Earth model. The fact that the solar constant was during proto Earth period (see `http://tinyurl.com/pc83uvt`) [F33] only 73 per cent from its recent value, is a problem for the models of the very early evolution of life. If the radius of Earth was $1/2$ of its recent value the duration of day and night was from conservation of angular momentum only $1/4$: th of the recent value and thus 3 hours. This could have made the environment much more favorable for the evolution of life even at the surface of the Earth since the range for the temperature variation would have been much narrower.

4.9 Where Did The Oceans Come From?

TGD based vision about life has been developing rapidly thanks to the realization that hierarchy of Planck constants and dark matter could relate directly to criticality: consider only long range correlations, phase separation, and classical non-determinism near critical point as common aspects [?]. The article "Half of the Earth's water formed before the sun was born" (`http://news.sciencemag.org/earth/2014/09/half-earths-water-formed-sun-was-born`) describes research results proving additional support for the TGD inspired idea about the occurrence of prebiotic evolution in underground water reservoirs shielded from meteorites and cosmic rays. The idea relies on TGD inspired variant of Expanding Earth hypothesis [K7, L18].

1. Article represents first a standard argument in favor of late formation of oceans. The collisions by astroids and meteorites could have evaporated the water or blown off it in to space.

Hence surface water at Earth should have emerged much later. Note that one can replace "water" with "life" in the argument.

2. The researchers end up to propose that the water emerged already before Sun, and also oceans did so rather early. Carbonaceous chondrites (`http://tinyurl.com/75fh74p`), which formed at the same time as Sun and well before the planets, could have served as a source of water. These meteorites were formed very early, already earlier than Sun. Their composition resembles that of bulk solar system composition. By studying basaltic meteorites from asteroid Vesta, which is known to be formed in the same region as Earth, the reaserachers found that they contain same hydrogen isotopic composition as carbonaeous chondrites.

   This motivates the proposal that chondrites contained the water. A further proposal is that the water reservoirs formed at the surface of Earth as it formed. Here I beg to disagree: the objection represented in the beginning is difficult to circumvent!

The article stimulates several interestig questions in TGD based conceptual framework.

1. Why not to assume formation of underground water reservoir? Here meteorites and UV radiation did not form a problem. And there is indeed recent evidence for the previous existence of large underground reservoirs (`http://tinyurl.com/k2d2ttj`). The formation process for Earth could have naturally led to the evaporation of of chondrite water from the interior of Earth and its transfer nearer to surface and getting caught inside reservoirs.

   Also prebiotic life could have evolved in the underground water reservoirs and already in chondrites (DNA, RNA, aminoacids, tRNA represented as dark proton sequences at flux tubes) and transformed to the life as we know. Mother Gaia's womb was nice place: no meteorite bombardment, no cosmic rays, and metabolic energy provided by Mother Gaia as dark photons. Cambrian explosion as Earth's radius increased by a factor of two was the birthday of the life as we identify it, the (child) water burst to the surface and seas were formed and life began to evolve at the surface of Earth.

   Recall that in TGD continous cosmological expansion at level of space-time sheets is at quantum level replaced with a sequence of phase transitions increasing $h_{eff} = n \times h$ and/or p-adic length scale of the space-time sheet - by p-adic length scale hypothesis most naturally by a factor of two. This kind of transition explains why the continents of Earth fit nicely together to cover entire Earth if the radius is half of its recent value, the emergence of gigantic life forms, etc... [L18].

2. The basic objection relates to the basic mechanisms of metabolism. What replaced plants receiving metabolic energy from solar light as source of metabolic energy? What replaced Sun? Did the dark photon radiation generated by Earth - or maybe also Sun - and penetrating ordinary matter as dark radiation, replace sun light? Any critical system could generate this radiation and it should not be difficult to identify this kind of system: the boundary between core and mantle is the most obvious candidate for a critical system as also for a rapid self-organization process). I proposed for more than decade ago this option half-jokingly as metabolic sources of IT (intraterrestrial) life as I called it.

3. Dark photon radiation would have had a universal energy spectrum - the spectrum of biophotons in visible and UV range. Part of it would have transformed to biophotons (`http://tinyurl.com/yb9hnmu7`) taking the role of solar radiation as a metabolic energy source. An interesting question is whether the life at the bottom of oceans could give some hints about the counterpart of photosynthesis based on bio-photons? The discovery that the metabolic reactions thought to require complex catalytic maschinery can take place in the environment simulating ocean bottom (`http://tinyurl.com/ydc8g7r4`) supports the idea about the evolution of life from prebiotic life forms in the womb of Mother Gaia. In TGD framework these prebiotic life forms could correspond to dark proton sequences (dark nuclei) at magnetic flux tubes associated with the negatively charged exclusion zones discovered by Pollack [L4] (`http://tinyurl.com/oyhstc2`).

5 What about other planets?

5.1 How Was Ancient Mars Warm Enough for Liquid Water?

The popular article "Mars Mystery: How Was Ancient Red Planet Warm Enough for Liquid Water?" (see http://tinyurl.com/gsbwyhe) tells about a mystery related to the ancient presence of water at the surface of Mars. It is now known that the surface of Mars was once covered with rivers, streams, ponds, lakes and perhaps even seas and oceans. This forces to consider the possibility there was once also life in Mars and might be still. There is however a problem. The atmosphere probably contained hundreds of times less carbon dioxide than needed to keep it warm enought for liquid water to last. There are how these signature of flowing water there. Here is one more mystery to resolve.

The TGD version of Expanding Earth Hypothesis states that Earth has experienced a geologically fast expansion period in its past. The radius of the Earth's space-time sheet would have increased by a factor of two from its earlier value. Either the p-adic length scale or effective value of Planck constant $h_{eff}/h = n$ for the space-time sheet of Earth or both would have increased by factor 2.

This violent event led to the burst of underground seas of Earth to the surface with the consequence that the rather highly developed lifeforms evolved in these reservoirs shielded from cosmic rays and UV radiation burst to the surface: the outcome was what is known as Cambrian explosion. This apparent popping of advanced lifeforms out of nowhere explains why the earlier less developed forms of these complex organisms have not been found as fossile. I have discussed the model for how life could have evolved in underground water reservoirs [L7].

The geologically fast weakening of the gravitational force by factor 1/4 at surface explains the emergence of gigantic life forms like sauri and even ciant crabs. Continents were formed: before this the crust was like the surface of Mars now. The original motivation of EEH indeed was that the observation that the continents of recent Earth seem to fit nicely together if the radius were smaller by factor 1/2. This is just a step further than Wegener went at his time. The model explains many other difficult to understand facts and forces to give up the Snowball Earth model. The recent view about Earth before Cambrian Explosion is very different from that provided by EEH. The period of rotation of Earth was 4 times shorter than now - 6 hours - and this would be visible of physiology of organisms of that time. Whether it could have left remnants to the physiology and behavior of recently living organisms is an interesting question.

What about Mars? Mars now is very similar to Earth before expansion. The radius is one half of Earth now and therefore same as the radius of Earth before the Cambrian Explosion! Mars is near Earth so that its distance from Sun is not very different. Could also recent Mars contain complex life forms in water reservoirs in its interior. Could Mother Mars (or perhaps Martina, if the red planet is not the masculine warrior but pregnant mother) give rise to their birth? The water that has appeared at the surface of Mars could have been a temporarily leakage. An interesting question is whether the appearance of water might correspond to the same event that increased the radius of Earth by factor two.

Magnetism is important for life in TGD based quantum biology. A possible problem is posed by the very weak recent value of the magnetic field of Mars. The value of the dark magnetic field $B_{end} = .2$ Gauss of Earth deduced from the findings of Blackman about effects of ELF em fields on vertebrate brain has strength, which is 2/5 of the nominal value of B_E. Hence the dark MBs of living organisms perhaps integrating to dark MB of Earth seem to be entities distinct from MB of Earth. Could also Mars have dark magnetic fields?

Schumann resonances might be important for collective aspects of consciousness. In the simplest model for Schumann resonances the frequencies are determined solely by the radius of Mars and would be 2 times those in Earth now. The frequency of the lowest Schumann resonance would be 15.6 Hz.

5.2 New Horizons About Pluto

ew Horizons (see http://tinyurl.com/cjdzsk9) is a space probe that has just been passing by Pluto and has taken pictures about the surface of Pluto and its Moon Kharon. The accuracy of the pictures is at best measured in tens of meters. Pluto has lost its status as a genuine planet

and is now regarded as dwarf planet in the Kuiper belt - a ring of bodies beyond Neptune. Using Earthly unis its radius, mass (from New Horizons data), and distance from Sun are $R = .18R_E$, $M = .0022 \times M_E$ and $d = 40d_E$.

Pictures have yielded a lot of surprises. Pluto is not the geologically dead planet it was though to be. The following summarizes what I learned by reading a nice popular article by Markku Hotakainen in finnish weekly journal ("Suomen Kuvalehti") and also represents a TGD based interpretation of the findings.

1. Surprisingly, the surface of the Pluto is geologically young: the youngest surface shapes have age about 10^8 that is .1 billion years. This is strange since the temperature is about -240 °C at the cold side and it receives from Sun only 1/1000 of the energy received by Earth. Textbook wisdom tells that everything should have been geologically totally frozen for billions of years.

2. There is a large champaign - one guess is that it has born as an asteroid or comet has collided with the surface of Pluto. The region is now officially called Tombaugh Regio. The reader can Google the reason for this. The flat region does not seem to have any craters so that it should be rather young. The boundary of this lowland area is surrounded by high (up to 3.5 km) mountains. Also these formations seem to be young. Nitrogen, methane and CO-ice cannot form so high formations.

   Several explanations have been imagined for the absence of craters: maybe there are active processes destroying the craters very effectively. Maybe there is tectonic activity. This however requires energy source. Radioactivity inside Pluto? Underground seas liberating heat? Or maybe tidal forces: the motions of Pluto and its moon Kharon are locked and they turn always the same side towards each other. There is a small variation in the distance of Kharon causing tidal forces. Could this libration deform Pluto and force the liberation of heat produced by frictional forces?

3. The flat region decomposes to large polygons with diameter of 20-30 km. The mechanism producing the polygons is a mystery. Also their presence tells that the surface is geologically young: at some places only .1 billion years old.

4. The atmosphere of Pluto has also yielded a surprise. About 90 per cent of atmosphere (78 per cent at Earth) is nitrogen but it is estimated to leak with a rate of 500 tons per hour since the small gravitational acceleration (6 per cent of that on Earth) cannot prevent the gas molecules from leaking out. How Pluto manages to keep so much nitrogen in its atmosphere?

5. Kharon - the largest moon of Pluto - has radius which is half of that for Pluto. Also the surface texture of Kharon exhibits signs about upheavals and has similarities to that in Pluto. Craters seem to be lacking. North Pole has great dark region - maybe crater. Equator is surrounded by precipices with depths of hundreds of meters, maybe up to kilometers. If they are torn away so should have been also the precipices.

Can one understand the surface texture of Pluto and Kharon? For years I proposed a model for the finding that the continents of Earth seem to fit nicely to form a single supercontinent if the radius of Earth is taken to be one half of its recent radius. This led to a TGD variant of Expanding Earth theory [L18].

1. It is known that cosmic expansion does not occur locally. In many-sheeted space-time of TGD this could mean that the space-time sheets of astrophysical objects comove at the the large space-time sheet representing expanding background but do not themselves expand. Another possibility is that they expand in rapid jerks by phase transitions increasing the radius. p-Adic length scale hypothesis suggests that scaling of the radius by two is the simplest possibility.

2. If this kind of quantum phase transition occurred for the space-time sheet of Earth about .54 billion years ago it can explain the weird things associated with Cambrian explosion (see `http://tinyurl.com/ntvx38e`). Suddenly totally new life forms appeared as from nowhere to only disappear soon in fight for survival. Could highly evolved life in underground seas

shielded from UV radiation and meteoric bombardment have burst to the surface. The process would have also reduced the value of the gravitational acceleration by factor 1/4 and increased the length of the day by factor 4. The reduction of the surface gravity might have led to emergence of various gigantic lifeforms such as dinosauri, which later lost the evolutionary battle because of their small brains. Climate would have changed dramatically also and the Snowball Earth model is replaced by a new view.

If these sudden quantum phase transitions at the level of dark matter ($h_{eff} = n \times h$ phases of ordinary matter) is the manner how cosmic expansion universally happens then also Pluto might so the signs of this mechanism.

1. The surface of Pluto is indeed geologically young: the age is measured in hundreds of millions of years. Could the sudden jerkwise expansion have occurred - not only for Earth but - for objects in some region surrounding Earth and containing also Pluto?

2. The polygonal structure could be understood as a ripping of the surface of Pluto in the sudden expansion involving also cooling of magma and its compression (the analogy is what happens to the wet clay as it dries and becomes solid). The lowland region could correspond to the magma burst out from the interior of Pluto being analogous to the magma at the bottom of oceans at Earth. The young geological age of this region would explain the absence of craters. Also the surface texture of Kharon could be understood in the similar manner.

 Could one understand the presence of nitrogen?

1. If the gravitational acceleration was 4 times larger (24 percent of that in Earth) before the explosion, the leakage would have been slower before it. Could this make it easier to understand why Pluto has so much nitrogen? Could the burst of material from the interior have increased the amount of nitrogen in the atmosphere? Geochemist could probably answer these questions.

2. A more radical explanation is that primitive life forms have prevented the leakage by binding the nitrogen to organic compounds like methane. If underground oceans indeed existed (and maybe still exist) in Pluto as they seem to exist in Mars, one can wonder whether life has been evolving as an underground phenomenon also in Pluto - as so many nice things in this Universe must do;-). Could these lifeforms have erupted to the surface of Pluto in the sudden expansion from underground seas and could some of them - maybe primitive bacteria - have survived. Nitrogen (see `http://tinyurl.com/yb3yexsu`) is essential for life and binds the nitrogen to heavier chemical compounds so that its leakage slows down. Could there exist an analog of nitrogen cycle (see `http://tinyurl.com/yc4r39o8`) meaning that underground life bind the nitrogen from the atmosphere of Pluto and slow down its leakage?

6 Expanding Earth hypothesis, Platonic solids, and plate tectonics as symplectic flow

A FB discussion inspired by the evidence reported by Nasa for the existence of life in Mars coming from a generation of methane (see `http://tinyurl.com/y735g9kn`) (thanks to Nikolina Bedenikovic for the link). It seems that it must originate below the surface of Mars - possibly from underground oceans. The emission of methane is periodic having the year of Mars as a period and has maximum during summer time. This suggests that solar radiation somehow serves as a source of metabolic energy. The TGD based explanation might be in terms of dark photons able to propagate through the crust to the underground oceans.

The finding provides support for TGD based Expanding Earth model [L18] explaining Cambrian explosion, which is one of the mysteries of recent day biology. According to this model life would have evolved in underground oceans where it was shielded from UV light, cosmic rays, and meteor bombardment, and burst to the surface of Earth during the period when Earth expanded and the crust developed cracks.

One can wonder whether Expanding Earth model is consistent with plate tectonics and with the motivating claim of Adams that the continents fit together nicely to cover the entire surface

of Earth if its radius were one half of the recent radius. The outcome was what one might call Platonic plate tectonics.

1. The expansion would have started from or generated decomposition of the Earth's crust to an icosahedral lattice with 20 faces, which contain analogs of what is known as cratons and having a total area equal to that of Earth before expansion. The prediction for the recent land area fraction is 25 per cent is 4.1 per cent too low. The cause could be sedimentation or expansion continuing still very slowly.

2. Craton like objects (in the sequence briefly cratons) would move like 2-D rigid bodies and would fuse to form continents.

3. The memory about the initial state should be preserved: otherwise there would exist no simple manner to reproduce the observation of Adams by simple motions of continents combined with downwards scaling. This might be achieved if cratons are connected by flux tubes to form a network. For maximal connectivity given triangular face is connected by flux tube to to all 3 nearest neighbour faces. Minimal connectivity corresponds to an essentially unique dodecahedral Hamiltonian cycle connecting cratons to single closed string. At least for maximal connectivity this memory would allow to understand the claim of Adams stating that the reduction of radius by factor 1/2 plus simple motions for the continents allow to transform the continents to single continent covering the entire surface of the scaled down Earth.

4. The dynamics in scales longer than that of craton would be naturally a generalization of an incompressible liquid flow to area preserving dynamics defined by symplectic flow. The assumption that Hamilton satisfies Laplace equation and is thus a real or imaginary part of analytic function implies additional symmetry: the area preserving flow has dual. The flow has vanishing divergence and curl. Sources and sinks and rotation are however possible in topological sense if the tectonic plate has holes.

6.1 Summary of the model

6.1.1 Expanding Earth hypothesis in TGD framework

The TGD variant of Expanding Earth hypothesis [L18] (see `http://tinyurl.com/y75hku4x`) can be motivated by both cosmological and biological considerations.

1. The basic observation is that astrophysical objects seem to not take part of cosmic expansion but only to co-move. This leads to the idea that the corresponding space-time sheets experience cosmic expansion as relatively rapid jerks and have constant size between these jerks. Second motivation comes from the claim of Adams [F1] (see `http://tinyurl.com/fxsve`) that the continents would fit nicely together to form a single continent covering the entire surface of Earth if the radius of Earth were 1/2 its recent radius.

2. There is also a connection with biology. Cambrian explosion (see `http://tinyurl.com/ntvx38e`) is a poorly understood period in the history of life at Earth. Suddenly a burst of highly developed life forms emerged from some unknown source. TGD explanation would be in terms of rather rapid increase of the radius of Earth by factor of two from the recent size $R_{Mars} \simeq R_E/2$ of Mars to the recent size R_E of Earth with the consequences that the stretching developed cracks. Since the radial scaling caused similar stretching everywhere, the decomposition to a lattice at some critical value of the scale parameter λ would have generated the cracks. The generation of a lattice in drying clay serves as an analogy.

   The relatively highly developed underground life would had evolved below the surface of Earth, where it was shielded from the bombardment by meteors, cosmic rays, and UV radiation and was burst to the surface as the oceans were formed on the cracks.

   The increase of the radius of Earth by factor 2 increased the duration of day by factor 4 and reduced the surface gravity by a factor 1/4. The genetically conserved features preceding the expansion would be still seen in biology. For instance, there might exist a 3 hour bio-rhythm if the underground life received solar radiation somehow. The reduction of gravity could explain the emergence of giant sized organisms such as dinosaurs.

Underground life must have some source of metabolic energy and photosynthesis should have developed already before the Cambrian expansion. This suggests that visible light from some source must have been present. I have considered possible sources in [L7]. The most science fictive proposal is that part of the photons of solar radiation transform to dark photons identified as a phase of ordinary photons residing at magnetic flux tubes. They would have had a non-standard value of Planck constant $h_{eff} = n \times h_0$ and in absence of direct interactions with the ordinary manner would have managed to penetrate through the crust to the underground oceans.

In the recent biology bio-photons with energies in visible and UV range would emerge as energy conserving transformations of large h_{eff} photons to ordinary photons. The value of h_{eff} for charged particle of mass m would be by a generalization of Nottale's proposal equal to $\hbar_{eff} = n \times \hbar_0 = h_{gr}GMm/v_0$, where M could correspond to a dark mass assignable to Earth and v_0 is a parameter having dimensions of velocity. This hypothesis implies that cyclotron energies of charged particles do not depend at all on the mass of the charged particle so that cyclotron photons can induce transitions of bio-molecules [**?**, K8].

Remark: h_0 is the minimal value of h_{eff}: the best guess for the ordinary Planck constant corresponds to $n = 6$ [L10, L16].

This mechanism for the transfer of solar energy under the surface of Mars could explain the annual periodicity of the methane production in Mars. Magnetic fields serve as a shield against UV radiation and cosmic rays in the case of Earth. Mars has only weak and local magnetic fields above its surface. This gives a good reason why for the Martian life to stay below the surface. The strengthening of the Earth's magnetic field might have preceded or accompanied the proposed expansion of Earth.

3. This vision profoundly modifies the ideas about what happened before Cambrian explosion. In particular, Snowball Earth hypothesis (see `http://tinyurl.com/prem7nj`) about the climate evolution must be given up. The magnetic history of Earth allows to test the model.

6.1.2   Basic ideas of Platonic plate tectonics

The FB discussion raised the question whether the TGD based Expanding Earth model [L18] is consistent with plate tectonics and with the motivating claim of Adams that the continents fit nicely to cover the entire surface of Earth if its radius were one half of the recent radius. The outcome was what one might call Platonic plate tectonics.

1. The expansion would have started from or generated decomposition of the Earth's crust to an icosahedral lattice with 20 faces, which contain what could be identified as cratons (see `http://tinyurl.com/y8juty2q`) having a total area equal to that of Earth before expansion. Cratons represent the stable part of the continental litosphere and are found in the interiors of the tectonic plates. They consist of ancient crystalline basement rock and maybe be covered by younger sedimentary rock. They have a thick crust and deep litospheric roots. The prediction 25 per cent for the recent land area is 4.1 per cent too low. The simplest explanation is that expansion still continues but very slowly. Also the formation of sedimentary rocks could have increased the area.

2. The cratons would move like 2-D rigid bodies and would fuse to form continents.

3. The memory about the initial state should be preserved: otherwise there would exist no simple manner to reproduce the observation of Adams by simple motions of continents combined with downwards scaling. This could be achieved if cratons are connected by flux tubes to form a network (for tensor networks in TGD Universe see [L9]). For maximal connectivity given triangular face is connected by flux tube to to all 3 nearest neighbour faces. Minimal connectivity corresponds to an essentially unique dodecahedral Hamilton's cycle [A6] (see `http://tinyurl.com/pf33vkt`) connecting cratons to single closed string. At least for maximal connectivity this memory would allow to understand the claim of Adams stating that the reduction of radius by factor 1/2 plus simple motions for the continents allow to transform the continents to single continent covering the entire surface of the scaled down Earth.

4. The dynamics in scales longer than that of craton would be naturally a generalization of an incompressible liquid flow to area preserving dynamics defined by symplectic flow. The assumption that Hamilton satisfies Laplace equation and is thus a real or imaginary part of analytic function implies additional symmetry: the area preserving flow has dual. The flow has vanishing divergence and curl. Sources and sinks and rotation are however possible in topological sense if the tectonic plate has holes. This would suggest conformal invariance.

The proposal is that the expansion of Earth taking place as discrete jerkes is basically a quantum phenomenon in astrophysical scales.

1. In TGD framework magnetic flux tubes are carriers of dark matter identified as phases of ordinary matter with non-standard value of Planck constant. As explained, the value of gravitational Planck constant h_{gr} would be enormous and imply quantum coherence in the size scale of Earth at the magnetic body forcing coherence at the level of ordinary matter [K8]. The transitions changing the value of h_{eff} would change the length of flux tubes and these transitions would be crucial for the dynamics of water [L21] (see `http://tinyurl.com/ydhknc2c`).

2. Also the ability of biomolecules to find each other in molecular soup would rely on the same mechanism. In biology also the formation of organs and organelles from cells would involve the shortening of flux tubes [L20] (see `http://tinyurl.com/y9pxr9dx`). In brain synchronously firing neuron groups would form dynamical networks. An interesting question inspired by the huge value of h_{gr} is whether cratons could be seen as analogs of cells and continents as analogs of organs of Mother Gaia. Note that the magnetic bodies of living systems with EEG would have layers with size scale of Earth [K1].

6.1.3 What happened in the expansion of Earth and after that?

One can try to imagine what happened during and after the expansion of Earth.

1. The spherical crust developed at least one hole as the radius increased by factor 2: $R_f = 2R_i$. The crust free regions became frozen magma covered by ocean. The total area of crust was preserved. A stronger condition is that only some minimal stretching required by the increase of the radius occurred. Too large a stretching would have generated the cracks.

   The experimentation with toy models leads to the conclusion that minimal stretching is achieved if the crust decomposes into a spherical lattice - regular tessellation- having maximal number of cells. Platonic solids are the only regular tessellations of sphere. The dual P_D of platonic solid P has as its vertices the faces of P and vice versa. The list of Platonic solids (see `http://tinyurl.com/p4rwc76`) is short.

   - Self-dual tetrahedron (4 faces and 4 vertices).
   - Cube with 6 faces and 8 vertices faces and its dual octahedron.
   - Icosahedron and its dual dodecahedron with 20 and 12 faces respectively. For icosahedron the number of faces is maximal and the size of the face minimal and the local stretching is therefore minimal. The faces of icosahedron correspond to the vertices of the dual dodecahedron and icosahedral tessellation is the best candidate to begin with. Note however that the 6 faces of cube could correspond to the 6 continents. One can of course image that the moving cratons later evolved to form an approximate cubical tessselation.

   Remark: Surfaces with flat metric (plane and cylinder) allow warpings (see `http://tinyurl.com/ycyregve`) for which the induced metric remains flat so that the deformation can be regarded as an isometry with no stretching but non-trivial bending. For instance, for the surface $z(x,y) = z_0$ one can have warping $z = z_0 + f(x)$. The dynamics for the page of book provides a good example of this kind of warping. Could this kind of warpings leading to one-dimensional deformations of the surface of Earth happen for continents in sufficiently short scales?

2. During subsequent evolution radius R_f remains (approxmately) constant and the pieces of crust move along the surface of Earth. No stretching condition prevents the change of shape. If changes of shape are allowed, the first guess is that this evolution was area preserving and thus generated as by a Hamiltonian flow. This would be just classical Hamiltonian mechanics in 2-D phase phase associated with the piece of crust.

   If distances inside cratons were preserved (no stretching and change of shapce), the dynamics for small enough plates would reduce in a reasonable approximation to a rigid body rotation in the tangent plane at the center of mass of the plate and movement along a geodesic line along the Earth's surface plus collisions. If one accepts that the initial state was a tessellation defined by a Platonic solid, in particular icosahedron, the symplectic evolution trivializes in this manner. The faces contain cratons with area scaled down by factor 1/4. If craton like object is a disk with radius d one would have $d = (1/2\sqrt{20})R_E \simeq .11R_E$. Using $R_E = 6371$ km this gives $d = 1425$ km.

3. The first guess is that the expansion period is over now and one has $R_f = 2 \times R_i$ exactly. As found, the predicted fraction of land area for $R_f = 2 \times R_i$ is 4.1 per cent smaller than the actual value about 29.1 per cent. A possible explanation for 4.1 per cent is the generation of sedimentary rocks. This would give a probably testable prediction for the fractional area due to sedimentation. Subduction would increase this estimate.

   One can also ask whether the expansion still continues slowly so that the radius is not yet quite equal to $R_f = 2 \times R_i$ so that the fraction of land area is larger than 25 per cent. One would have $R_f = 2xR_i$, $x = .93$. Subduction tends to increase and sedimentation to reduce the value of x. The separation of expansion period from the period during, which R_f stays constant would be a good approximation if the time scales for tectonics are considerably shorter than for the expansion.

6.1.4   Could flux tube network reproduce the claims of Adams?

The triangular faces can move around and can scale down their size scale by factor 1/2 to the size of craton so that a fusion of cratons to larger units forming continents becomes possible. If one takes the claim of Adams [F1] (see `http://tinyurl.com/fxsve`) seriously, the subsequent dynamics for the faces containing the cratons must be such that it is easy to see how to move continents in the scaling down of the radius of Earth to achieve the gluing together without overlaps and holes (the mere scaling down does not allow to achieve this since the distances between scaled down continents would be 1/2 of the recent distances).

The dynamics must remember the initial regular icosahedral tessellation at S_i^2. In the ideal situation every face must "remember" its former nearest neighbours at S_i^2 even when some of them can be faraway at S_f^2. This requires a network connecting the faces. If the faces are connected by a large enough number of flux tubes able to change their lengths this can be realized and as the radius is imagined to decrease by a factor 1/2, all faces combine to form a spherical crust without overlaps. One can consider two extreme situations.

1. Maximal connectedness requires that every face of icosahedron is connected to each of its 3 nearest neighbours. In this case the dynamics can only involve condensation of the cratons/faces of the network to form continents and for this option the claim of Adams seems trivial.

2. The minimally connected network would correspond to a string connecting the 20 faces to single non-self-intersecting closed string identifiable as a Hamiltonian cycle at dodecahedron. One identifies cycles differing only by an isometry of dodecahedron and already Hamilton discovered that dodecahedron allows only single cycle if one identifies cycles differing only by an isometry of dodecahedron. Given triangle would be connected by flux tube to 2 (rather than 3) nearest neighbors.

   Remark: Hamilton's cycles at icosahedron [A6, A3, A5, A2, A4] with 12 vertices play fundamental role in TGD inspired model for music harmony lead to a model of genetic code and of bio-harmony. In this case there is large number of harmonies [K3] [L22].

Whether this option is consistent with the claim of Adams is not clear. One can argue that without additional assumptions the dynamics of the Hamiltonian cycle can destroy the information about the initial icosahedral tessellation by permuting the faces. Could the condition that no self intersections of the flux tubes (strings) of the cycle take place, be enough to preserve the information about initial configuration? The (unique apart from isometries) Hamiltonian cycle can have a fold so that it turns back. The cratons of the antiparallel nearby portions of string can fuse together. The pairing induced by the folding can take place in several ways: say ...(1,6)-(2,5)-(3,4) or ...(-1,6)-(0,5)-(1,4)-(2,3). Here (a,b) corresponding fusion of cratons and - for the Hamiltonian link between neighbouring faces. The increase of the land area by 4.1 percent forces some overlap in the final state if the expansion period has ceased.

6.2 Plate tectonics as a symplectic flow in scales longer than the size of craton?

For the icosahedral model the short scale dynamics reduces to much simpler dynamics of 2-D rigid bodies at S^2 having collisions leading to subductions. Cratons however fuse together to form continents having plate tectonics as their dynamics. Tectonic dynamics applies in length scales longer than craton size and cratons could be idealized as point like objects analogous to lipids in cell membrane.

The first guess for the dynamics after the expansion period is symplectic flow preserving the signed area of the continent defining an area preserving map for each value of the time parameter. The area preserving flow is analogous to an incompressible liquid flow in 3 dimensions and serves as a natural model for liquid crystals. For instance, cell membrane is liquid crystal. In this case lipids are idealized as point like objects with symplectic dynamics making sense in length scales longer than the thickness of lipid.

Symplectic flow would be therefore a natural model for plate tectonics (see `http://tinyurl.com/hmby9d4`), and the idealization of cratons as pointlike entities would allow to overcome the objection due to stretching. Symplectic flows could be also used to model the emergence of cracks using Hamiltonians discontinuous along cuts and to model "self-subductions" as flows, which become non-injective and generate mountains.

Remark: Symplectic flows could also be used to model the liquid magma in the outer core idealized as 2-D layer analogous to liquid crystal.

What conditions could one pose on the Hamiltonian defining the symplectic flow? The observation that Hamiltonians identified as real or imaginary parts of analytic functions have additional symmetry implying the existence of a dual flow for which flow lines are orthogonal to those for the flow. A good guess therefore that the local tectonics for a continent is defined by a Hamiltonian satisfying Laplace equation. There would be a nice connection between analytic functions and symplectic flows.

6.2.1 A model for the continuous time evolution of tectonic plate

The simplest model for a continuous local evolution of given tectonic plate in length scales longer than the size of craton after the expansion period and formation of continents assumes the conservation of signed area meaning that the evolution is symplectic flow generated by some Hamiltonian defined in the region defined by the continent. The symplectic flow would be a 2-D variant of incompressible hydrodynamics.

1. The dynamics would be dictated by the conservation of signed area element $dS = R^2 sin(\theta)d\theta \wedge d\phi$ defined by the symplectic form of $J = J_{kl}ds^k \wedge ds^l$ of S^2. Symplectic transformations preserve the local area form and are generated by the exponentiation of Hamiltonian function H giving models for time evolutions as exponentiation of H defining a flow along the continent.

2. A model for the generation of cracks could be based on Hamiltonian function, which has line discontinuities completely analogous to discontinuities of imaginary or real part of an analytic function. The Hamiltonian flow would take the two sides of the cut to opposite

directions in the Hamiltonian flow and crack would develop. The cracks would be filled with water and become oceans.

3. Hamiltonian time evolution defines symplectic map for each value of the time parameter t, which can cease to be injection at some moment of time at some point and give rise to growing regions into which two different regions of the continent are mapped. Cusp catastrophe with 3 sheets gives a standard topological description for what would have happened. The folding would have 3 plates above each other in the fold region. This "self-subduction" would produce regions analogous to those formed in subduction in which two continents drifting at the surface of magma collide and subduce. Also this process can generate mountains.

   The signed area of the middle sheet of the cusp is negative if the area of the other sheets is positive. The formation of the cusp seems therefore to reduce the land area since the middle sheet and lowest sheet of the cusp are invisible. When plate subduces another plate visible land area is also lost. One can imagine two explanations for the missing 4.1 per cent: sedimentation has generated new land area or the expansion period has not yet ended.

One can formulate this picture in more detail as follows.

1. The area preserving symplectic time evolution obeys in general coordinates s^k for S^2 the formula

$$\frac{ds^k}{dt} = j^k = J^{kl}\partial_l H \quad , \quad J_k{}^r J^r{}_l = -s_{kl} \quad . \tag{6.1}$$

   where J_{kl} and s_{kl} are the symplectic form and standard metric of S^2. In spherical coordinates (θ, ϕ) one has $J_{\theta\phi} = -J_{\phi\theta} = sin(\theta)$. $H = H(\theta, \phi)$ is the function defining the Hamiltonian and subject to physical constraints. j^k has vanishing divergence:

$$D_k j^k = 0 \quad . \tag{6.2}$$

   This equation codes for the local conservation of area.

2. The real or imaginary part of an analytic function having cut along curve can serve as a Hamiltonian in this case. Analyticity would give strong additional constraints on the discontinuity since Laplace equation would be satisfied meaning that not only the current j^k but also the dual current $j_D = g^{kl}H_l$ is conserved:

$$D_k j_D^k = 0 \quad . \tag{6.3}$$

   j_D^k and j^k are orthogonal and correspond to real and imaginary parts of an analytic function. Also j_D^k defines an area preserving flow. This connection between conformal symmetries and symplectic symmetries for Hamiltonians satisfying Laplace equation does not seem to be very familiar to physicists. As a consequence the flow has vanishing divergence and curl. Sources and sinks and global rotation are possible in topological sense if the tectonic plate has holes. This would suggest conformal invariance in some sense.

   The absence of sinks implies that one can express j_D^k as a curl of vector field orthogonal to S^2. A possible interpretation is as induced Kähler magnetic field or Z^0 magnetic field. One of the first ideas related to the applications of TGD to condensed matter was that hydrodynamic flow could give rise to Z^0 magnetic fields just like em currents give rise to magnetic fields and that vortices of the flow correspond to magnetic flux tubes. This picture makes sense for Kähler magnetic field as well - an option that seems more natural now. The different directions of rotational axis and magnetic dipole axis of Earth would correspond to different directions of the ordinary magnetic field and Z^0 or Kähler magnetic field. These magnetic fields would be effective magnetic fields identified as sums of magnetic fields considered at

different space-time sheets at quantum field theory limit of TGD. The flow dynamics could be essentially that of induced Kähler magnetic field orthogonal to S^2.

Remark: At fundamental level only the effects of classical fields on test particle touching several space-time sheets sum up, not the fields. At QFT limit induced fields from different space-time sheets sum up.

The equation for the flow can be integrated for a given flow line as

$$s^k(t) = exp(tj^r\partial_r)s^k(0) \quad .\tag{6.4}$$

3. The model for the emergence of a crack requires Hamiltonian discontinuous along a 1-D cut. One has $H = H_\pm$ at the two sides of the cut. The expression of $s^k(t)$ for the flow lines beginning from the point $s^k(0) = s^k_\pm(0)$ of the cut and continuing to the side $\pm$ is given by

$$s^k_\pm(t) = exp(tJ^{rl}\partial_l H_\pm)\partial_r)s^k(0) \quad .\tag{6.5}$$

The model for the emergence of "self-subductions" and generation of mountains can be constructed using non-injective Hamiltonian evolutions in which regions having as pre-images two regions appear. These regions correspond to two continent plates above each other. Both self-subduction and subduction reduce the land area.

6.3   Appendix: Some mathematical details

The icosahedral model for the generation of continents was an outcome of experimentation. I started with a model inspired by the idea that an analog of super-continent Gondwana was generated as single cap during the expansion period but realized soon that it requires quite too large stretching unless one allows generation of cracks. Also a model with two gaps seemed non-realistic. Homogenous upwards scaling of the Earth's radius suggests strongly lattice like structure and the minimization of stretching led to icosahedral model. I however decided to include these attempts as Appendix - a kind of confession. Hasty reader can skip these parts of the Appendix.

6.3.1   Generation of one or two caps requires too much stretching

The basic objection against single cap model is that the proposed model for expansion requires quite much stretching, which requires large energy. It is also clear that too much stretching leads to a generation of cracks. The following argument is more precise formulation of this observation in terms of a toy model.

1. The first option is that supercontinent analogous to Gondwana (see `http://tinyurl.com/hcgjnrb`) was generated as an expanding hole hole in the crust of S^2_i emerged somewhere in what became Pasific Ocean - call this place "South pole". Gondwana hypothesis is consistent with Wegener's construction.

2. This period corresponds to a total area preserving map taking the spherical surface (crust) of S^2_i to a cap of S^2_f with the same area. The area of the cap should have been thus fraction $S_f/S_i = R^2_i/R^2_f = 1/4$ of the total area: this corresponds to 25 per cent of the area of Earth. The actual portion of continents from total area is 29.1 per cent. 4 per cent of new land area should have been generated later by some mechanism.

3. The expansion would take the crust covering entire S^2_i to a supercontinent covering part of S^2_f. The simplest map of this kind maps the surface of S^2_i to a cap of S^2_f defined by the condition $\theta_f \in [0, \pi/3]$: this corresponds to $[0, 60]$ degrees. $\theta_f = 0$ would correspond to the "North Pole". This model is certainly non-realistic since it requires large stretching at the bottom of the gap. The stretching is expected to cause cracks mainly in the direction of the coordinate lines of θ_f.

   For the cap at "North pole" the stretching along the coordinate circles of ϕ_f would be very large near the bottom of the cap. One possibility is that cracks in direction of θ_f were generated or that the boundary of cap or that the boundary was "wavy".

A slightly more plausible option reducing the stretching along coordinate circles of ϕ_f would assume generation of 2 caps located at "South pole" and "North pole" as a crack along equator was generated. Also now a wavy crack would allow to minimize the stretching along the coordinate circles of ϕ_f. There would be also stretching along coordinate lines of θ_f. In this case one would have two separate super-continents from the beginning and fitting together along their boundaries of the gaps.

6.3.2 Cap models for the expansion period

The expansion period as generation of one or two caps is unrealistic since it produces too much stretching. In the following however the details of the model are given.

1. There exists no isometry between the crust associated with S_i^2 and connected crust associated with S_f^2. Isometry would require that curvature scalars are same and this is impossible since the radii of S_i^2 and S_f^2 are different.

2. The conservation of total area in the map $S_i^2 \to S_f^2$ taking spherical crust to cap $0 \le \theta_f \le \theta_{max}$ with same area: $S_f = S_i$.

3. If the expansion begins from an icosahedral lattice the dynamics of expansion period could reduces to simple scaling in a reasonable approximation. The fraction of land area is however 29.1 per cent rather than 25 per cent however that the expansion is still occurring albeit very slowly. Therefore one cannot separate expansion period completely from the tectonic dynamics. One can however think of time dependent scaling combined with the motion and collisions of cratons leading to their fusion.

Consider a more detailed definition of the cap models.

1. In the case of single-cap model the simplest manner to guarantee this is to require $cos(\theta_{f,max}) = cos(\theta_{i,max})/4 + 3/4 = 1/2$ giving $cos(\theta_{f,max}) = 1/2$ and $\theta_{f,max} = \pi/3$, which corresponds to 60 degrees. As mentioned the large strength in ϕ_f direction requires either a wavy boundary of generations of cracks in θ_f direction.

2. For the two-cap model the hemispheres $\theta_i < \pi/2$ and $\theta_i > \pi/2$ are contracted to caps when the crack at $\theta_i = \pi/2$ is generated. The condition that no stretching occurs along the coordinate circles of ϕ_f is guaranteed if one has

$$2sin(\theta_f) = sin(\theta_i) \ . \tag{6.6}$$

For small values of $sin(\theta_f)$ near poles this condition reduces approximately to the condition $2\theta_f = \theta_i$, which guarantees that the distances along coordinate lines of θ_f are same as along those of θ_i so that stretching is minimal also along this direction near poles.

This correspondence is well-defined only for $sin(\theta_f) \le 1/2$, which corresponds to $|cos(\theta_f)| \ge \sqrt{3}/2$. On the other hand, the condition that the sum of the areas of the caps equals the area of S_i^2 gives $|cos(\theta_f)| \ge 3/4 < \sqrt{3}/2$ so that one must have larger gaps than allowed by no-stretching condition along coordinate circles of ϕ_f. A possible manner to solve the problem is to assume that the boundaries of the gaps are wave or that cracks are generated mainly in θ_f direction.

One can model the expansion period $t = (0, T)$ as a homotopy $R = R(t)$, $[R(0) = R_i = R, R(T) = R_f = 2R]$. During this period the cap develops and $\theta_{f,max}$ satisfies the formulas guaranteeing the conservation of distances along coordinate circles of ϕ_i and of total area.

1. For single-cap case one has

$$\frac{R(t)}{R_i}sin(\theta_f) = sin(\theta_i) \ , \quad (\frac{R(t)}{R_i})^2(1 - cos(\theta_{f,max})) = 2 \ . \tag{6.7}$$

The first condition can be satisfied only for $cos(\theta_f) \geq \sqrt{1 - (R_i/R(t))^2}$. This lower limit should be smaller than the limit given by the latter condition: $R_i/R(t) \leq \sqrt{7}/4$. For $R(t)/R_i > 4/\sqrt{7} < 2$ the conditions are consistent with each other.

2. The 2-gap case gives

$$\frac{R(t)}{R_i}sin(\theta_f) = sin(\theta_i) \quad , \quad (\frac{R(t)}{R_i})^2(1 - cos(\theta_{f,max})) = 1 \quad . \tag{6.8}$$

Also for this option one must have $cos(\theta_f) \geq \sqrt{1 - (R_i/R(t))^2}$. The condition $cos(\theta f, max) = 1 - (R_i/R(t))^2$ implies that the first condition cannot be satisfied for all values of $cos(\theta_f)$.

7 New support for the view about Cambrian explosion being caused by rapid increase of Earth radius

There was an interesting popular article in Quanta Magazine titled "*Oxygen and Stem Cells May Have Reshaped Early Complex Animals*" (see `http://tinyurl.com/y86ta45l`).

The article dicusses the work of geobiologist Emma Hammarlund and tumor biologist Sven Påhlman: their interdisciplinary hypothesis is published as article in Nature [I10] with title "*Refined control of cell stemness allowed animal evolution in the oxic realm*" (see `http://tinyurl.com/y85ufngz`).

Here is the abstract of their article.

Animal diversification on Earth has long been presumed to be associated with the increasing extent of oxic niches. Here, we challenge that view. We start with the fact that hypoxia ($\leq 1 - 3$ per cent O_2) maintains cellular immaturity (stemness), whereas adult stem cells continuously - and paradoxically- regenerate animal tissue in oxygenated settings. Novel insights from tumour biology illuminate how cell stemness nevertheless can be achieved through the action of oxygen-sensing transcription factors in oxygenated, regenerating tissue. We suggest that these hypoxia-inducible transcription factors provided animals with unprecedented control over cell stemness that allowed them to cope with fluctuating oxygen concentrations. Thus, a refinement of the cellular hypoxia-response machinery enabled cell stemness at oxic conditions and, then, animals to evolve into the oxic realm. This view on the onset of animal diversification is consistent with geological evidence and provides a new perspective on the challenges and evolution of multicellular life.

7.1 The proposal of Hammarlund and Påhlman

Cambrian explosion (see `http://tinyurl.com/ntvx38e`) during which highly advanced lifeforms suddenly emerged - prolifration and diversification of animal life are the terms used about this - is one of the mysteries of biology. For most of its 4.5-billion-year history, Earth has sustained life — but that life was largely limited to microbial organisms: bacteria, plankton, algae. For about 540 million years ago did larger, more complex species are assumed to dominate the oceans, but within just a few tens of millions of years (very short time on the evolutionary timescale), the planet had filled up with all kinds of animals. The fossil record from that period shows the beginnings of almost all modern animal lineages: animals with shells and animals with spines, animals that swam and animals that burrowed, animals that could hunt and animals that could defend themselves from predators. Also many lineages that disappeared were present as one learns from the book of Stephen Jay Gould describing in detail the Burgess Shale finding that revolutionized the picture about evolutionary biology and remains still a puzzle (see `http://tinyurl.com/y9orfy43`).

The belief is that the environment became considerable more oxic - that is contained oxygen - and lifeforms had to cope with this change. Before the change the animals in seas (believed to exist!) were anaerobic. The shifting to aerobic respiration was however an enormous metabolic advantage since the effectiveness of metabolic energy gain become roughly 20-fold. Increased metabolic feed in turn made possible the emergence of complexity during Cambrian period.

1. The proposal of the authors is that the evolution of the capacity to maintain stem cells even in an oxic environment allowed the animals to keep stocks of stem cells needed for tissue growth and repair for that this required at gene level new genes coding for so called HIFs.

2. Stem cells require low oxygen levels to preserve their stemness. Heightened oxygen levels cause them to differentiate abruptly. This explains why stems cells are often located in hypoxic regions of the body (say bone marrow) having low oxygen levels. There are however exceptions to this rule: stem cells can also survive in ocix regions such as skin or retina. Cancers also utilize stem cells to achieve growth.

3. Hammarlund and Påhlman turned their attention to HIFs (hypoxia-inducible transcription factors), which are proteins, which for hypoxic environment shift the metabolism from aerobic to an-aerobic. For oxic environment they are not needed.

   HIF-2α remains however active also in oxic environment and make the cells behave as if the environment were hypoxic. This would allow the stem cells to survive. HIF-2α would however keep the stem cells in immature state also in the case of cancer. The hypothesis of Hammarlund and Påhlman was that HIF-2α functions similarly in normal animal tissues. They have seen some preliminary evidence for the hypothesis but further work is needed.

4. HIFs could have helped the animals to survive in oxic environment. Consider an organism as a blob of cells. Before the oxygenation the stem cells would have been forced to the deep interior of the blob, where oxygen concentration was especially low. When oxygenation took place, and oxygen level varied, this trick did not work anymore and HIFs had to be invented.

5. Hammarlund and Påhman postulate what they call HIF-1, which would have helped stem cells to behave as if the environment were hypoxic. Later HIF-2α unique to vertebrates emerged and improved the situation further. Vertebrates are bigger and have longer time spans that invertebrates and they can live in oxygenated environments. Inveratebrates such as insects live most of their life as larvae under low-oxygen conditions and they cannot regenerate tissues as vertebrates can.

6. Cancer would be the price paid for this evolutionary advance since cancer cells can proliferate because HIF-2 keeps the stem cells alive. OH present in oxygen rich environment is an oxidant causing cancer.

What caused the oxygenation? So called Great Oxygenation Event (GOE,see `http://tinyurl.com/q7qfd55`) is believed to have occurred about about 2.25 billion years ago and thus preceded Cambrian explosion that occured about .5 billion years ago.The time lapse between these events is about 1.75 billion years and much longer than the duration of Cambrian period, which was only tens of millions years. Thus GOE was not the reason for the Cambrian explosion. What caused a further oxygenation or were the effects of GOE somehow postponed (wink-wink!)?

7.2 TGD view

My own proposal is that life evolved in underground oceans and entered to the surface of Earth in Cambrian explosion (see `http://tinyurl.com/ntvx38e`) when oceans were formed at the surface of Eearth from cracks formed when Earth expanded rapidly in geological time scale. Before the explosion Earth did not have oceans and continents and was like Mars nowadays: even its radius was that of Mars. This picture follows from TGD based variant of Expanding Earth hypothesis [L18, L17] (see `http://tinyurl.com/yc4rgkco` and `http://tinyurl.com/yb68uo3y`) .

The habitat changed in the rapid expansion of Earth from hypoxic to oxic and the emergence of the hypothetical HIF-1 transcription factor would have been forced by this evolutionary pressure and made it possible for the lifeforms to adapt oxygen based metabolism. This would have led to a rapid evolution of animals and emergence of vertebrates. One can of course think that oxygenation developed already in the underground oceans as cracks caused in the crust by the expansion of Earth began to develop and provided oxygen. The alternative - not so plausible sounding - option is that the highly developed organisms developed underground slowly and only bursted to the surface of Earth in the explosion.

1. Chemical markers (see `http://tinyurl.com/ntvx38e`) indeed indicate dramatic change in the environment at the start of the Cambrian period. The markers are consistent with a massive warming due to the release of methane ice (clathrate hydrate, see `http://tinyurl.`

com/peq9gmw) trapped within the crystal structure of water. Methane clathrate is found deep under the sediments at the ocean floors. Methane hydrates are believed to form by migration of gas from deep along geological faults (the cracks produced by rapid expansion of Earth [L17]!).

2. During the period before Cambrian explosion Earth would have been very much like in recent Mars. Even its radius would have been that of recent Mars! One can ask whether GOE forced the existing primitive lifeforms underground or saved only those already living underground. Situation would have been be very much like in the recent Mars, which also seems to possess undergound life.

The development of HIF proteins (hypoxia inducing factor) making possible for stem cells to survive in environments with varying and thus temporarily higher oxygen content would have been a natural reaction to the dramatic changes in habitat.

What can one say about the emergence of animal life in TGD framework?

1. The rapid evolution leading to the emergence of animals - if it was present - would relate to the quantum criticality associated with the increase of the effective Planck constant $h_{eff}/h_0 = n$ by factor 2 increasing the size scale of Earth. The increase of $h_{eff}/h_0 = n$ might have occurred at several levels of dark matter hierarchy, also at biological relevant scales and led to an increase of biological "IQ" (note that evolution corresponds in TGD to gradual increase of number theoretical complexity and n characterizes the dimension of extension of rationals characterizing the complexity [L13, L14]).

2. Animals use oxygen for breathing and are multicellular eukaryotes having cell membrane enclosing nucleus and other membrane bound organelles. The quantum critical period could have led to the emergence of a kind of symbiosis of various kind of organelles within cell membrane bounded volume. The p-adic length scale $L(k)$ determined by the value of n assignable to the outer membrane of organelles could correspond to the prime $k = 163$ (or 167). Inside plant cells having no cell membrane these organelles correspond to vacuoles (see http://tinyurl.com/yd879b2d). The outer membrane that emerged in the transition increasing h_{eff}/h_0 meant increase of the scale of quantum coherence to a longer p-adic length scale - say $k = 167$ (or $k = 169 = 13^2$ if doubling took place).

3. Mitochondria would have emerged and made possible oxygen based respiration whereas plant like organisms preceding them utilized anaerobic respiration. Methanogenesis (see http://tinyurl.com/y97gkym8) utilizing carbon instead of oxygen and producing carbon-dioxide and methane CH_4(water in O_2 based respiration) is the most natural option. The large methane storages underground would be due to methanogenesis.

   The recent findings (see http://tinyurl.com/y735g9kn) indicate that there is life in Mars: methane emissions occurring periodically with a period of Martian year have been detected. This suggests that solar radiation is somehow able to enter to the interior of Mars or that it heats the underground Oceans. In TGD one can consider also the possibility that some part of solar photons transforms to dark photons and is able to propagate to the underground oceans through the Martian crust [L17].

4. What was the primary source of metabolic energy? Direct solar radiation was absent in underground oceans. The immediate source of metabolic energy for the plant like organisms might have been dark nuclei consisting of dark proton sequences and liberating energy in the transitions reducing of $h_{eff}/h_0 = n$. Dark proton triplets give rise to dark variants of DNA, RNA, tRNA, and amino-acids [L8, L7, L19]. These dark proton sequences could have formed by Pollack effect at the surface of Earth possibly containing some water and could have propagated along dark flux tubes to the interior: also in "cold fusion" dark nuclei would be formed. Some fraction of them would transform to ordinary nuclei and liberate practically all the nuclear binding energy. Also transitions to dark nuclei with a smaller value of h_{eff}/h_0 is possible and liberates energy usable as metabolic energy. Most dark nuclei could leak out along magnetic flux tubes [L11]. The hen-egg problem - which came first, metabolism or genetic code - would trivialize in this framework.

For p-adic length scale $L(k = 149) = 5$ nm - thickness of cell membrane - the typical dark nuclear excitation energy was about .5 eV, the nominal value of metabolic energy quantum. For $L(151) = 10$ nm (thickness of neuronal membrane and DNA double strand its value is .25 eV. These estimates are based on the scaling of the typical nuclear excitation energy taken to be 1 MeV and are uncertain by a factor of 2 at least. One of course expects also higher excitation energies - even so high that they correspond to visible ordinary photons. Metabolic energy could have been liberated as dark photons in dark nuclear transitions transforming to ordinary photons and absorbed by the photosynthetic machinery.

The (rough) estimate for the typical value of the dark photon energy is considerably lower than in ordinary photosynthesis. Pollack effect [L4] occurring in presence of gel phase bounding water volume suggests that for $k = 149$ the transformation of dark proton sequences to ordinary ones: this mechanism would liberate energy per proton ~ 1.5 eV [L15], which corresponds to infrared photon. The small value of the metabolic energy quantum need not be a problem: there is recent evidence that IR light with energy 1.76 eV can be used in photosynthesis (see `http://tinyurl.com/yc6pqjed`).

7.3   Could Mars have intra-martial life?

A popular article in National Geographic (see `http://tinyurl.com/y5unt6y7`) tells about unexpected findings made by the first robotic geophysicist, the Insight lander revealed in the European Planetary Science Congress and in the American Astronomical Society. There are odd magnetic pulsations with frequency around 10 mHz [E5] (see `http://tinyurl.com/y3ll8kcg`) occurring at Martian night-time: for Earth these pulsations occur in frequency range 1 mHz to 1 Hz. Mars has much stronger magnetic field as expected. The magnetic field was detected at heights 96-400 km.

Besides this there is evidence for the existence for a global electrically conductive layer about 6 km below the surface, which suggest an underground reservoir of water. This has enormous implications for potential existence of life in Mars. There is also earlier evidence for the existence of salty, liquid water measuring about 19 km across (see `http://tinyurl.com/ycjaky5g`).

The strange findings about Mars can be understood in the framework provided by TGD based model for expanding Earth providing also explanation for the mysterious Cambrian explosion assuming that the life developed in Earth's interior, TGD based notion of magnetic field, and dark matter identified as phases with nonstandard value $h_{eff} = nh_0$ of Planck constant.

7.3.1   Connection with the model of Expanding Earth

These findings bring in mind TGD based model for expanding Earth [L18, L17] (see `http://tinyurl.com/yc4rgkco`, `http://tinyurl.com/yb68uo3y`, and `http://tinyurl.com/ya68nggs`).

1. The observation is that if Earth has radius one half of itse recent radius the continents fit nicely together to cover entire surface of Earth. This lead to the proposal that during Cambrian explosion in which highly developed life formed mysteriously emerged, the Earth radius grew by factor 2 in a relatively short time. The life would have evolved in Mother Gaia's womb, underground oceans perhaps between crust and astenosphere at depth not larger than 80 km, shielded from cosmic rays and meteoric bombardment.

2. The sudden expansion can be modelled in TGD inspired new physics as a phase transition increasing the p-adic length scale of Earth and reducing the scale dependent cosmological constant assignable to Earth by factor 1/4: these kind of phase transitions replace smooth cosmological expansion in TGD inspired cosmology.

   This led to the splitting of the continuous crust to continents and oceans emerged as the water from underground oceans containing the highly developed life forms bursted to the surface.

3. The intriguing coincidence is that Mars has radius which is 1/2 of Earth's recent radius. Could also Mars have underground ocean with rather developed life forms waiting for the moment of birth? Magnetic field is necessary in TGD based model of life and the article tells that Mars has unexpectedly strong magnetic field. It also tells about underground ocean

at death about 100 km! The boundary between Earth's core and astenosphere, where the ancient oceans might have been is at dept of about 80 km.

7.3.2   There is something weird in the magnetic field of Mars

The assumption that magnetic field of Mars can be approximated as a dipole field leads to a paradoxical situation in Maxwellian framework.

1. Wikipedia article about Earth's magnetosphere (see `http://tinyurl.com/y3t78oka`) gives a criterion for the height below which magnetic field can survive under the pressure caused by solar wind. The criterion reads

$$\frac{R_{CF}}{R_P} = \left(\frac{B^2}{\rho_{sw} v_{sw}^2}\right)^{1/6} \quad .$$

   Here R_P is planet radius, B is the strength of the magnetic field at its surface, and ρ_{sw} and v_{sw} are the mass density and velocity of solar wind. The ratio R_{CF}/R_P is essentially the ratio of the density of magnetic energy and density of kinetic energy. This implies that the strength of B is about 10 times higher than the strength of the Earth's magnetic field at surface about .5 Gauss. The recent findings should increase the earlier estimate $R_{CF}/R_P \sim 1$ given in Wikipedia. For Earth the thickness of magnetosphere is about 10 times Earth radius giving $R_{CF}/R_P \sim 11$.

2. The strength of magnetic field behaves like $1/r^3$ in dipole approximation and scaling R_P by factor 2 would reduce magnetic field strength at surface down by factor $1/8$, which is near to value of the Earth's magnetic field strength B_E. Could one think that also Earth had similar magnetic field before the expansion an that the expansion of Earth radius by factor 2 gave rise to the recent magnetic field? $B_{Mars} \sim 10 B_E$ however suggests that the magnetic field of Mars in dipole approximation should actually extend equally far as the Earth's magnetic field! This does not seem to make sense.

   Could one think that the matter at the flux tubes of Martian magnetic field is dark matter as $h_{eff} = n h_0$ phases and is not visible in the ordinary sense. For instance, cyclotron energies proportional to $h_{eff} e B/m$ would be much higher than expected. Another option is that the magnetic field corresponds carries monopole fluxes at its flux tubes carrying dark particles.

What looks mysterious is that if Martian magnetic field is dipole field in reasonable approximation, it should be more or less like Earth's magnetic field! One would expect cyclotron radiation and van Allen belts. Why they are not seen? The answer could be simple.

1. Also Earth's magnetic field would decompose to stable part for which flux tubes carry quantized monopole flux and ordinary part. Monopole part does not need current to sustain it and this has been used to explain why Earth's magnetic field has not disappeared long time ago. The varying part of the Earth's magnetic field would be created by convection currents in the solar. Since Mars does not have outer core, it would not have this part of magnetic field. I have proposed this model for the maintenance of Earth's magnetic field at [L6] (see `http://tinyurl.com/y5anawyk`).

2. I have assumed that dark matter as $h_{eff} = n h_0$ phases of ordinary matter essential for life resides at the flux tubes of this field having strength which is $2/5$ of the Earth's ordinary magnetic field. I have called this field endogenous magnetic field and its existence and existence of h_{eff} hierarchy was deduced from the explanation of quantal effects of ELF em fields on vertebrate brain. If Mars has only dark magnetic field, the magnetic field of Mars could be invisible! The ordinary part of this magnetic field should appear in the analog of Cambrian explosion as the radius of Mars increases to that of Earth and core radius increase by factor 2 and the core becomes unstable against division to two layers.

3. It has been thought that Martian magnetic field is so weak because the outer core of Mars has been seized up in distant past leading to a collapse of the magnetic field. Could one think that the reverse of this process took place for Earth in the expansion and created the

outer core, perhaps by splitting of the core to outer and inner core? This picture would fit nicely with the p-adic length scale hypothesis suggesting layered structures with thickness of layer coming as some power of 2: the thickness of core would have double and core would have divided to two layers. If the strength of the Earth's magnetic field has been stronger by factor 8 before Cambrian explosion, this should be seen in magnetic records.

The rotation of the outer core would create ordinary magnetic field after the expansion. Before that various ions from solar wind would have entered to the dark flux tubes and entered to the interior of Mars. Same would have happened also in Earth and would explain how oxygen atmosphere emerged in Cambrian explosion and life could burst safely to the surface of Mars.

4. Intriguingly, Mars has its own version of Northern lights (see `http://tinyurl.com/y5z7jlkb`). Without magnetic field auroras should not exist! Could it be that they are dark auroras associated with dark magnetic field of Mars. In reconnections of the magnetic field o Martian magnetic field and those associated with solar wind dark ions would transform to ordinary ones and create Norther and Souther lights. Van Allen belts are in the height range .6-58 Mm (Earth radius is 6,4 Mm). Mars should have dark van Allen belts along which ions of solar wind would end down to the interior of Mars.

5. What about the pulsed oscillations of Martian magnetic field at frequency around 10 ms, which corresponds to a period of 3.33... minutes detected at the night-side of Mars?

The pulsations could correspond to a biorhythm. Also Earth's magnetic field has pulsations with frequencies varying between 1 mHz and 1 Hz. 1 mHz corresponds to 3/3.6 minutes and 1 Hz to average DNA cyclotron frequency in endogenous magnetic field $B_{end} = .2$ Gauss identifiable as dark magnetic field.

Could these pulsations correspond to a heartbeat or breathing of Martian magnetic Mother Gaia - rather concrete pulsation of its magnetic body made from flux tubes and/or sheets? Why the pulsations appear only at the dark side? Could the pressure of the solar wind prevent the pulsations at the day-side?

One can wonder what the measured magnetic field is. Is it the sum of dark and ordinary part or only ordinary part. If test particles touch all space-time sheets involved, they experience the sum of the magnetic fields so that the usual measurements should give the sum. If it is only the ordinary part, one would still have the problem why the field having strength near to Earth's magnetic field is not visible as van Allen belts for instance. The QFT limit of TGD indeed corresponds to the replacement of space-times sheets with single region of Minkowski space and the identification of fields as the sums of the induced fields from various space-time sheets.

7.3.3   Intraplanetary life

The new observations allow to make the existing model for intra-planetary life much more detailed. The following applies to both Earth and Mars.

1. At Earth the multicellular life forms would have emerged in Cambrian explosion suddenly from the Earth interior as its size increased by factor 2. The expansion would be one stepwise cosmic expansion and associated with the decrease of length scale dependent cosmological constant associated with Earth. Same should happen in Mars sooner or later. So that there is no reason to worry. If we destroy our species and many other at the same time, intelligent life forms will develop in Mars.

2. If the multicellular life forms represented intraterrestrial life, photosynhesis and even oxygen based life should have evolved in underground ocean. The breathing animals would be like fishes using the oxygen in water.

3. The dark magnetic flux tubes of planet would served as channels for solar photons propagating as dark photons to the ocean in the interior of the planet. Dark photons would have transformed to ordinary photons (that is bio-photons) and used in photosynthesis making possible chemical energy storage. Photosythesis would have produced oxygen O_2, which

would not have been lost to outer space now: a good reason for intraplanetary life when oxygen atmosphere is missing.

Thus breathing animals would have become possible besides plants like organisms performing the photosynthesis. Also animal-plants doing photosynthesis themselves can be considered. Even we could use the metabolic energy stored chemically in manner analogous to photosynthesis. The machinery is very similar and there is evidence that even humans can use sunlight as metabolic energy. Pollack effect [L4] would be key element here. Pollack effect generates charge separation and thus voltage and this gives rise to a battery.

4. The evolution of life inside planets could solve Fermi paradox. Universe is full of planetary systems. Life would be everywhere but inside the planets in planetary wombs. We might be pioneers. An alternative solution is that we are already in telepathic contact with higher life forms at dark magnetic bodies but do not realize it. We ourselves would have magnetic bodies with Earth sized and perhaps even galaxy sized layers.

   This is not the only possible TGD inspired solution of Fermi paradox. Our own magnetic body would have layers with size of Earth scale and perhaps even galactic scale. We could be in continual contact with the magnetic bodies of members of other civilizations without knowing it - say during dream states. We could have even neural machinery activating these flux tube contacts. DMT is the only psychelic produced by body itself, and is assigned with pineal gland, which Descartes identified as the seat seat of soul. In zero energy ontology light velocity would not be a problem for communications with distant civlization since signals could propagate in both directions and time reflection would make communications forth and back in time possible [L5].

The newest news from Mars tells that scientists have measured the seasonal variation of methane CO_2 and oxygen O_2 in the Gale Crater of Mars.

1. The largest amount of methane CO_2 hitherto, 21 parts per billion volume units has been measured in Mars by Curiosity Mars rover (see `http://tinyurl.com/w2p4uh8`). The presence of high level of methane discovered by Curiosity has been known for years. Methane is associated with living organisms. At Earth it is produced by microbes but can be also created through interactions between rocks and water. Curiosity cannot determine whether the source is local or is the methane present everywhere and whether the source is biology or geology. The recent measurement gave an increased level of methane but it is not known how long the transient lasts and whether there is a seasonal variation. The transient however suggests that the source of methane is local. Chemically reactive soil containing sources and sinks of methane has been considered.

2. Also oxygen was observed to behave in an unexpected manner (see `http://tinyurl.com/wlu4xq5`). The knowledge of the surface chemistry allows to estimate the yearly variation of oxygen, and the predictions confirm with measurements almost all the year. At spring time of Mars the rules of chemistry are however broken, and the concentration of oxygen rises as much as 30 per cent during spring and summer and the returns to the levels predicted by the chemistry. Something gives oxygen and then takes it back.

7.3.4   What smoothed out Earth's surface for 600 million years ago - or was it already smooth?

I learned about new fascinating finding (see `http://tinyurl.com/y339u6qo`) related to the geological history of Earth. During a geologically very brief period Earth's surface would have somehow lost its surface details such as rivers and lakes. This would have happened for 600 million years ago. Before this there would have been period of snowball Earth.

TGD provides different view about the renovation of the surface of Earth by loss of details and about the period before this change: snowball Earth hypothesis seems un-necessary [L18, L17]. There were no oceans. The situation would have been the same as in Mars now. Water was in underground oceans as has been observed recently in Mars. One could deduce the story of Earth from what we know about Mars on basis of latest discoveries.

Cambrian explosion, in which complex multicellulars suddenly and mysteriously emerged took
place about 512 million years whereas the loss of details is claimed to have happened about 600
million years ago. TGD based theory of expanding Earth assumes that Cambrian explosion hap-
pened because of geologically very fast expansion of Earth so that the radius of Earth increased
by a factor 2. Amusingly, the radius of Earth would have been before the expansion same as that
of Mars now!

Expansion would correspond to one fast jerk in the sequence of jerks, which replaces smooth
cosmic expansion in TGD Universe: it is indeed known that astrophysical objects co-move in
expansion but do not expand themselves (except by jerks). These jerks would be induced by
reduction of length scale dependent cosmological constant by factor 1/4, or more generally, negative
power of 2. The findings suggest that the expansion started about 600 million years ago and
happened geologically very fast. Note that length scale dependent cosmological constant solves
the basic problem of standard cosmology, which has killed many theories, also superstring theory.

Before this life would have evolved in underground oceans - the womb of Mother Gaia - shielded
from cosmic rays and meteors. Oxygen and other important molecules could not leak out so that
oxygen based life could evolve. In the expansion the core of Earth split into two parts (Mars has
same radius as Earth and only single core) and the rotation of the outer core created ordinary
magnetic field preventing oxygen and other important molecules to leak out. Otherwise the life at
surface would not have survived. The surface of Earth split into pieces giving rise to continents
and underground oceans gave rise to the oceans.

Consider now the mystery of lost details.

1. The surface of Earth before expansion should have looked very much the same as that of
   Mars now. Since there was very little water, rivers, lakes and this kind of features would
   have been practically absent. I do not know whether this is enough to explain the findings.

2. If the surface of Earth was stretched in the sudden expansion, the details of Earth's surface
   would have tended to disappear since gradients are reduced in the stretching. Whether the
   stretching really occured is however not clear: one could argue that the surface split into
   pieces like clay soil as it dries and formed continents.

3. The bottoms of oceans consisted of the magma from the interior of Earth and they should
   have been rather smooth. Also this might help to understand the findings.

7.4   Earhquakes and volcanic eruptions as macroscopic quantum jumps in zero energy ontology

In ZEO the signature of "big" (ordinary) state function reduction is the change of the arrow of
time at some level of the hierarchy of space-time sheets (selves) and one could start to search
evidence for this effect. Also "small" state function reductions are possible and correspond to
"weak" measurements. I did not however have the change of the arrow of time in mind when
I encountered a highly interesting article "*Cosmic-solar radiation as the cause of earthquakes
and volcanic eruptions*" by Jamal Shrair (see `http://tinyurl.com/y3g3khtd`) telling about the
findings related to earthquakes and volcanic eruptions challenging the rational mind making its
deductions in standard ontology.

1. The occurrence of earthquakes up to 34 kilometers below the surface of Earth and volcanic
   eruptions up to 9 km below the surface has strong correlation with the sunspot minima (solar
   activity) and cosmic ray flux. One could think that the system consisting of tectonic plates
   or magma is critical and sensitive to small perturbations. But how do the cosmic rays get so
   deep in Earth interior without losing their energy?

   TGD based answer is simple. During sunspot minimum the dark monopole part of the
   magnetic field of Sun is strong and the charged particles of solar wind arrive along the flux
   tubes and by reconnection end up to the flux tubes of the Earth's dark magnetic field (van
   Allen belts) and along them to the interior of Earth, where they end up to quantum critical
   system formed by magma or tectonic plates and induces the eruption of earthquake.

2. This however requires that the number of dark monopole flux tubes is large during sunspot minima. Sunspots would be formed in reconnections of very long U-shaped monopole flux tubes coming from Sun and carrying solar wind as dark particles. This would reduce the number of monopole flux tubes but generate ordinary magnetic field by creating currents creating them - monopole flux tubes do not need any current. Therefore the number of monopole flux tubes would be maximal during sunspot minima.

   Quite generally, cosmic rays would arrive to Sun along monopole flux tubes of flux tube network [L27] connecting galaxies and having flux tubes of stellar objects as sub-tangles and continue from Sun to Earth. The highly energetic dark cosmic rays preserving their energy as dark particles could end up to the Earth interior along monopole flux tubes and could induce eruptions and earthquakes. This mechanism would also take dark ions of solar wind to underground oceans in Earth interior in the model of prebiotic life [L18].

Consider now the observations in this framework.

1. In the model of Japanese researchers led by Toshikazu Ebisuzaki cosmic muons are assumed to induce volcanic eruptions. The assumption is that solar magnetic field repulses cosmic rays. When it is weak as believed to be during solar minima, the cosmic rays can arrive to Earth. Volcano would act as a volcanic bubble chamber in which the cosmic rays induce a phase transition (see `http://tinyurl.com/y3d52r7c`). The model however considered only the eruptions not deeper that 10 m below surface rather whereas most eruptions occur at depths up to 10 km. The objection is obvious: for the cosmic muons as ordinary particles it is difficult to get so deep into the interior.

2. NASA researchers reported that earthquakes are preceded by large fluctuations of densities of electrons and other charged particles in the upper part of atmosphere. Perturbations are detected at at heights 100-600 km above Earth's surface. For Earth quakes the depths vary down to 35 km. If cosmic rays induce the earth quakes, one would expect that the time order as indeed proposed by NASA researchers in their model. The problem is that electric perturbations precede the earthquakes rather than vice versa.

   Here ZEO comes in rescue: The time order was indeed opposite. Macroscopic quantum jump of a quantum critical system took place changing the direction of time. There is precise analogy with the findings of Minev *et al* in atomic systems showing that a deterministic and smooth time evolution seems to lead to the final state of quantum jump [L24] [L24]. The time evolution however has opposite arrow of time and starts from the final state. Libet's findings [J1] have the same explanation in terms of act of free will realized as state function reduction. Now the "big" state function reduction would correspond to the earthquake/volcanic eruption and would be induced by cosmic rays serving as stimulus. The bad news is that when the electromagnetic fluctuation are detected, the quantum jumps has already occurred and nothing can be done to prevent the catastrophe.

3. In Maxwellian picture one expects that the magnetic pressure of solar magnetic field is minimum during sunspot minimum: just the opposite is true as experiments show (see `http://tinyurl.com/y3g3khtd`! The stronger the solar minimum the stronger the magnetic pressure. This is indeed the case in TGD picture if the detected magnetic field corresponds to the sum of magnetic field associated with monopole flux tubes and ordinary flux tubes! This is what the QFT limit of TGD predicts since spacetime at this limit carries the sum of induced fields associated with the sheets of the many-sheeted space-time.

   These findings inspired the proposal of the article that motivated these comments (see `http://tinyurl.com/y3g3khtd`): the magnetic pressure of solar wind could induce the earthquake/volcanic eruption somehow but leaves the detailed mechanism open. In TGD this assumption is not needed. The dark cosmic rays from the monopole flux tubes of solar magnetic field reconnected to with similar flux tubes of the Earth's magnetic field would travel along them to the interior of Earth.

4. The article of Shrair also mentions earth lights, which are luminous phenomena associated with the lines of tectonic activity. I have proposed already earlier an explanation in terms

of dark photons liberated from the regions with high tectonic stresses. These dark photons could be phase conjugate photons with non-standard arrow of time accompanying mini earthquakes already occurred with respect to subjective time. Even bigger earthquakes could be in question if the irradiation of phase conjugate dark photons with non-standard time direction continues for a long time after the earthquake, which will happen in our geometric future.

7.5 Correlation between earthquakes and volcanic eruptions with the spin dynamics of Earth

Wes Johnson send a link (`http://tinyurl.com/ydqhngkq`) telling about te correlation between the dynamics of Earth's spin and earthquakes and volcanic eruptions. There are two directions involved corresponding to geographic axis and rotation axis. The direction of Earth's magnetic field defines the geographic axis. These events tend to occur and are largest when the angle between Earth's rotation axis and geographic (magnetic) axis is largest. This is is an excellent benchmark test for TGD based view about magnetic fields.

   The new findings might have a connection with the TGD inspired solution of several other mysteries.

1. Quantal effects of radiation at ELF frequencies on vertebrate brain discovered by Blackman and others [J2]. Photon energies are ridiculously small: there should be no effects.

2. Maintenance problem of Earth's magnetic field.

3. Why the direction of Earth's magnetic field is different from that for the rotation axis which is a natural direction for convective plasma currents?

4. What causes the precession of Earth's rotation axis? The explanation in terms of gravitational effects fails.

5. There are time anomalies associated with earthquakes and volcanic eruptions. Cause and effect seem to be in wrong order.

   Earth's magnetic field should have disappeared long time ago. TGD based solution relies on difference between magnetic fields in Maxwellian theory and TGD:

1. TGD provides a solution to the maintenance problem [L6] (`http://tinyurl.com/yjstfvg3`.

   In TGD framework magnetic field has two parts.

   (a) Monopole flux tube part with strength B_{end} = about .2 Gauss (B_E has nominal value of .5 Gauss). The existence of B_{end} is deduced from the effects of radiation at ELF frequencies on vertebrate brain (Problem 1). It would carry dark matter in TGD sense ($h_{eff} = n \times h_0$ phases of ordinary matter) and be crucial in biology. This part needs no current to maintain it and this solves the maintenance problem for Earth's B_E having nominal value B_E = .5 Gauss (Problem 2).

   (b) Second part B_o is the ordinary Maxwellian part and currents are needed to maintain it since it decays exponentially due to the dissipation of the currents. The change of the direction of monopole flux induces currents refreshing B_o. Just now monopole flux part is changing direction and this causes the direction of B_o part to change: magnetic North Pole is moving towards Siberia rather fast. A good first guess for the direction of B_o is the rotation axis of Earth.

   It would not be surprising if the difference between directions of B_{end} and B_o would have physical effects and that the effects occur when Θ becomes large enough. The size of the effects would naturally increase as Θ increases. Earthquakes and volcanic eruptions could be these effects.

   Remark: The direction of monopole flux part is not that of geographic axis since it represents direction of the entire magnetic field having nominal value $B_E = 0.5$ Gauss. The angle Θ between B_{end} and rotation axis is larger than that of geographic and rotational axis.

2. Monopole flux tubes provide also a solution to the precession problem [L1] (`http://tinyurl.com/ybezl7tj`).

   The change of the direction of monopole part B_{end} inducing change of the rotation axis could be due to the change direction of flux tubes in much longer length scale than that of Earth. Precession of the rotation axis could be the outcome and precession would not be caused by gravitational effects in solar system. TGD explanation involves magnetic flux tubes and dark matter in TGD sense in much larger scale than that of Earth.

3. TGD suggests also a solution to the time anomalies associated with earthquakes and volcanic eruptions [L26] (`http://tinyurl.com/yjpjgozk`).

   Zero energy ontology (ZEO) is the corner stone of TGD based quantum measurement theory solving its basic paradox and allowing to extend it to a theory of consciousness. ZEO changes profoundly the views about the relationship between experienced time and geometric time. The arrow of time changes in the counterpart of the ordinary state function reduction and is preserved in the counterpart of weak measurement.

   (a) Earthquakes and volcanic eruptions would be induced by macroscopic quantum jumps - ordinary state function reductions in ZEO - involving large value of $h_{eff} = nh_0$ and its change at the level of magnetic body (MB) of the system. MB would correspond to flux tubes of B_{end}.

   (b) In ZEO these quantum jumps change the arrow of time temporarily at the level of MB involved and induce effects in "wrong" direction of time also at the level of ordinary matter. Indeed, ELF radiation has been observed *before* the earthquake as it would cause the earthquake it - not very realistic sounding idea - and could therefore used to predict the Earth quakes.

      The original model however predicted that ELF should occur after the earthquake as is indeed very natural. The ZEO based explanation of the paradox is that the arrow of time changes at MB. This would be the effect of Minev *et al* [L24] [L24] (`http://tinyurl.com/yj9prkho`) observed recently in atomic systems but in macroscopic scale. Also Libet's finding [J1] that neural activity seems to precede conscious decision would be similar illusion and at the same time proof the idea that act of free will corresponds to macroscopic quantum jump in ZEO.

This picture suggests an understanding of the correlation between earthquakes and volcanic eruptions and the dynamics of Earth's spin. As noticed, the macroscopic quantum jumps associated with changes of directions of B_{end} and B_o are expected to cause more dramatic effects when the deviation between the B_{end} and B_o (rotation axis) is largest. The angle Θ would change in these events. If B_{end} flux tubes change direction, a current is induced. This would change the direction of rotation axis if it is same as the direction of convective current generating B_o.

Question: Could the precession of the rotation axis consist of small steps changing the directions of B_{end} and B_o and their relative direction and be associated to earthquakes and volcanic eruptions?

7.6 No continents before Cambrian Explosion

I learned about highly interesting finding by geobiologists Benjamin Johnson and Boswell Wing. One can find a a popular article about the work with title "*Earth Could Have Once Been a Waterworld Covered by a Global Ocean, Study Suggests*" (`http://tinyurl.com/uwjgfew`). The research article with title "*Limited Archaean continental emergence reflected in an early Archaean 18O-enriched ocean* " is published in Nature Geoscience (`http://tinyurl.com/rq7o4t9`).

The finding is very interesting from the point of view of TGD based Expanding-Earth model [L18] (`http://tinyurl.com/yc4rgkco`) allowing to understand Cambrian Explosion (CE) (`http://tinyurl.com/ntvx38e`) that happened about .54 billion years ago leading to a sudden and rather mysterious emergence of multi-cellular life in a rather short time scale (13-25 million years).

TGD inspired cosmology predicts that cosmic expansion occurs for various astrophysical objects as relatively rapid jerks rather than smoothly. This allows to understand the paradoxical finding that astrophysical objects participate in cosmic expansion but do not seem to expand

themselves. The expansion occurs in jerks in which the value of scale dependent cosmological constant characterizing the system decreases.

1. The radius of Earth would have expanded by a factor 2 in relatively short time scale from a value near to the radius of recent Mars and led to the formation of continents as the Earth's crust ripped. Multi-cellular life would had evolved in underground oceans shielded from meteoric bombardment and cosmic rays and bursted to the newly formed oceans at the surface.

2. The basic prediction of the model is that before CE there were no continents. This also kills the so called Snowball Earth model (`http://tinyurl.com/prem7nj`) for the climate before CE.

The findings give a direct support for the absence of continents before CE. What the researchers did was following.

1. The goal was to understand the temperature ancient Earth about 3.2 billion years ago, and the researchers studied what they believed to be a bottom of an ancient sea. The isotope ratio of ^{16}O to ^{18}O decreases with temperature. The researchers constructed the temperature profile of the ancient Earth, and the surprising finding was that there was 3.2 per cent more ^{18}O than expected. This is 4 per cent more than in today's relatively ice-free oceans and much higher than the previous estimates.

2. The isotope ratio is sensitive to landmass. The conclusion of researchers is that the unexpectedly low ratio could be due to the lack of landmasses. The Earth's surface could have been wet but there is no need to assume oceans. TGD prediction does not exclude wet surface but just the existence of continents. The high wetness could have been due to the percolation of water from underground oceans preceding the great burst - note that 3.2 billion years is by factor about 6 longer time than .54 billion years.

This picture however poses difficult questions. When and how did the continents emerge? How did life emerge if there were no landmasses so that standard model must be given up?

As already explained, TGD based model for Expanding Earth solving basic mystery of standard cosmology provides an answer to these questions and also to the mystery of Cambrian Explosion.

8 Updated version of Expanding Earth model

This section was motivated by several articles. The first popular article "Was ancient Earth a water world?" (`https://cutt.ly/fbFqydU` tells that Earth could have been covered by water for billions of years ago. As the Earth cooled, this water later sinked in the interior of Earth as water of crystallization forming underground "oceans". The amount of salty crystal water inside the Earth is estimated to be of the same order of magnitude as in the recent oceans.

The article "Constraining the Volume of Earth's Early Oceans With a Temperature-Dependent Mantle Water Storage Capacity Model" [F36] (`https://cutt.ly/wbFqekI`) The model of the article assumes that the water in the mantle and crust is water of crystallization `https://cutt.ly/nbD65jZ`. The water bound on on salt and metal crystals is not chemically bound but forms hydrogen bonds. In heating this water is liberated. For proteins the amount of crystal water can per 50 per cent. Heating leads to a loss of water of crystallization. Cooling induces opposite process and this would have led to the leakage of the water at the surface to the interior, even to mantle, where it bonded with crystals.

The water of crystallization does not however seem to be the only form of water inside Earth. The popular article "Pockets of water may lie deep below Earth's surface" (`https://cutt.ly/4bFqi8M`) told about pockets of exotic solid water - ice VII - in the mantle, which corresponds to the range of depths 610-800 km. The temperature in this range varies between 1300-4000 K and the corresponding thermal is in the range .13-.4 eV. The solid form is made possible by the large pressure.

The article also tells about the presence of freely flowing liquid water in the transition zone between Earth's crust and mantle. This corresponds to the depth range 410-660 km (`https:`

//`cutt.ly/4bD0JIr`) and temperatures below 1300 K. Underground life is known to exist at surprisingly large depths although high temperature and pressure pose strong constraints.

The popular article "Life Thrives Within the Earth's Crust" published in TheScientist provides a nice summary about what is known (`https://cutt.ly/qbD0A0N`. From the article one learns that bacteria found at depths reaching 6 km. Fungi (multicellulars differing from animals in that they have chitin in their cell walls) and even animals are found at depths 700-800 m.   The article "Anaerobic consortia of fungi and sulfate reducing bacteria in deep granite fractures" [I7] (`https://cutt.ly/VbD0Gvb`)tells about sulfate reducing bacteria and fungi found at at granite fractures at depth 740 m.

The reason why these articles are so interesting from the TGD point of view, is that they lead to a more detailed   version of the TGD inspired Expanding Earth model (EEM) [L18, L17]. EEM predicts that Earth suffered in the Cambrian Explosion (CE) about half billion years ago a relatively rapid expansion during which the radius of Earth increased by factor 2.   There are however several objections against this model and the article provides insights allowing to circumvent these objections and supports the original vision.

In the sequel motivations for and objections against EEM are summarized. Also a resolution of objections based on a more precise model for EEMis discussed.

8.1   Motivations for EEM

There are three basic motivations for EEM.

1. The theoretical motivation is that the occurrence of this rapid expansion of Earth fits with the TGD view about cosmological expansion [L25] as rapid phase transitions replacing smooth cosmological expansion of GRT and solve the problem of GRT caused by the fact that astrophysical objects are not found to expand themselves although they participate to expansion by comoving with it.

2. The geological motivation is that   the continents seem to fit nicely together to cover the entire Earth if the radius of Earth is   1/2 of its recent radius.

3. Cambrian explosion (CE) (`https://cutt.ly/AbFljuv`) serves as a biological motivation. CE started roughly 541 million years and   lasted about $13 - 25$ million years. During this relatively short period highly advanced multicellular life forms emerged. From the times before this there are only monocellular fossils.

4. Fermi paradox summarizes the empirical fact that there is no evidence for life as we understand it anywhere in the known Universe. One can imagine several reasons for this. A possible TGD based explanation is that life is present in the interiors of planets as it was in the interior of Earth before CE.

The rapid expansion would have broken the crust of Earth to pieces creating   continents and the water from the interior of Earth containing multicellular life would have bursted to the surface and created oceans, absent before CE. The rapid evolution would have occurred during CE or already before CE in the "womb of Mother Gaia" in water pockets or even underground oceans shielded from cosmic rays and meteor bombardments.

8.1.1   The effects of Cambrian Explosion in deep mantle

Roughly a year after writing the original version of this article I learned about a possibe new piece of evidence for the TGD view about Cambrian Explosion. The popular article titled "Traces of life in the Earth's deep mantle" in Phys-Org (`https://cutt.ly/AAIj7Ss`) told about the work of Giuliani *et al* about discussed in the article "Perturbation of the deep-Earth carbon cycle in response to the Cambrian Explosion" [F37] (`https://cutt.ly/wAIko6S`).

The sudden emergence of advanced multicellular lifeforms in the Cambrian Explosion (CE) about 540 Ma ago is still one of the great mysteries of mainstream biology. The team led by ETH

researcher Andrea Giuliani found in rocks from deep mantle what can be regarded as traces of CE. The proposal is that partly organic material would have been subducted to the deep mantle after CE and changed the isotopic compositions of Carbon and other elements. Also other elements, for instance strontium and hafnium showed a pattern similar to carbon.

The group of Giuliani examined rare diamond-containing volcanic rocks known as kimberlites from different epochs of the Earth's history. These special rocks originate from the lowest regions of the Earth's mantle. The isotopic composition of carbon in about 150 samples of these special rocks was determined. The composition of younger kimberlites, which are less than 250 million years old, was found to vary considerably from that of older rocks. In many of the younger samples, the composition of the carbon isotopes differs significantly from that expected for typical rocks from the mantle.

The isotope ratio $R = {}^{13}C/{}^{12}C$ for Carbon in the deep mantle is considerably lower for the kimberlites younger than 250 Ma whereas the value for kimberlites older than 250 Ma is typical mantle value. The values of younger kimberlites are also more variable. More quantitatively, $\delta^{13}C = (R_{sample}/R_{standard} - 1) \times 10^3$ serves as a parameter. For a typical sample from the mantle, the value is $\delta \simeq -5 \pm 1$ per mille whereas for the studied samples δ is in the range [-20.-30] per mille.

The increased subduction caused by plate tectonics of the material from the surface of Earth could explain this. The estimate is that it takes 200 Ma for the material from the surface to reach the lower mantle. In the standard geology, the natural interpretation is that the dramatic increase in the generation of organic matter in CE has reduced the carbon isotope ratio. One must however assume that the partly organic material from the surface should have ended down to the deep mantle along specific routes by subduction.

Is the TGD inspired hypothesis for Cambrian Explosion life consistent with these findings?

1. The proposal is that life evolved in underground oceans ("womb of Mother Gaia") and suddenly emerged to the surface in the CE as highly developed multicellular organisms. CE was caused by a rapid increase of Earth radius by factor 2, which generated bursts of the underground water reservoirs to the surface and created the oceans. The expansion broke the Earth's crust to pieces and led to the emergence of plate tectonics, subduction, and oceans. Note that in Mars this tectonics is not present and the radius of Mars is actually roughly 1/2 of the radius of Earth.

2. The rapid increase of the Earth radius is the TGD counterpart for a smooth increase of Earth radius in cosmic expansion. All astrophysical objects look as if they would not participate in cosmic expansion: this is a mystery in general relativity. In TGD this mystery is resolved by replacing smooth cosmological expansion with a sequence of rapid expansions followed by stationary periods [L18] [L36].

Is the TGD view consistent with the findings of Giuliani *et al*?

1. The conclusion of Giuliani *et al* seems undeniable: the isotope decomposition in the mantle changed 200 Ma ago and was caused by the transport of the material affected by CE to the lower mantle.

2. In the TGD framework these findings do not however force the conclusion that life emerged suddenly in CE. Rather, multicellular life was present in the underground oceans before CE but plate tectonics and subduction were absent.

   The increase of the radius of Earth reduced the average density of Earth dramatically, and created the proposed subduction routes to the lower mantle, which dramatically increased the rate of transport of the organic material to the deep mantle.

3. Interestingly, the process analogous to CE appears to have occurred episodically throughout most of Earth's history, with the oldest diamonds that contain eclogitic inclusions forming at roughly 3 billion years (Ga) [F37]. In the TGD framework this suggests that the rapid expansions of Earth have occurred episodically and have led to the emergence of life forms from the interior to the surface and the transport of the material containing organic carbon to the mantle.

8.2 Objections against EEM and their resolution

There are several objections against EEM.

8.2.1 The reduction of density by factor 1/8 is impossible in standard physics

New physics is needed to make so dramatic a reduction of the density possible. The natural assumption is that the thickness of flux tubes of the magnetic body basically responsible for the density of condensed matter increased by a factor 2 and induced the increase of the radius of atomic volume. One can consider two options for what happened at the atomic level.

Option I. The value of h_{eff} labelling dark matter as phases of ordinary matter increased by factor 2, which led to scaling of atomic sizes by this factor and induced the reduction of the density by factor 1/8. The findings of Randel Mills can be explained if one has $h_{eff} = 6h_0$, where h_0 is the minimum value of $h_{eff} = nh_0$. The problem is that the total binding energy of electrons must have been compensated in the transition and it is not clear whether the energy liberated in the thickening of the flux tubes can provide the needed energy.

For Fe, which is also biologically important, the needed energy is for for $h_{eff} = h/2$ about 52 keV and seems quite too large if the string tension of atomic flux tubes is scaled to atomic scale from the hadronic string tension giving energy of order 10 keV per atomic length $L(137)$. The phase transition should have been entropy driven.

Note that in the TGD framework, the second law is implied by the negentropy maximization principle (NMP) for the sum of non-positive entanglement negentropy in the real sector, and the non-negative p-adic entanglement negentropy assignable to cognition. NMP forces the increase of the total entanglement negentropy and its positivity. This also forces the increase of entanglement entropy of ordinary matter. Thus the entropy driven phase transition allowing the emergence of Fe essential for oxygen based life would have meant an increase in negentropy and an evolutionary leap as it indeed meant. $h/2$ option is of course non-realistic but the argument applies also to the second option.

$h/2$ phase could have prevailed only during the period when the temperature was so high that atoms were unstable against ionization for the ordinary value of h. One can argue that as atomic physics with $h_{eff} = h$ became thermodynamically possible, it emerged in a phase transition. The electronic binding energies in question are of order $(Z/n)^2 E_H$, $E_H = 13.6$ eV. For instance, for Ca this temperature is about 2.7×10^8 K and corresponds to the temperature at which nuclear reactions become possible. The possible $h/2$ atomic physics might make itself visible at these temperatures.

Option II. Chemistry, and therefore the density of the condensed matter, is believed to be determined by chemical bonds, in particular by valence electrons. The TGD based view of valence bonds is discussed in [L12, L39]. Could the thickening of flux tubes by a factor 2 have induced the increase of h_{eff} of the valence electrons by a factor 2.

In the sequel these two options will be considered.

8.2.2 How could photosynthesis emerge in the Earth interior?

The animals that emerged in EEM performed photosynthesis. How could photosynthesis emerge inside Earth where ordinary solar light cannot get? I have proposed that dark photons with non-standard value of h_{eff} travelling along magnetic flux tubes managed to reach the evolving life inside Earth.

The recent proposals allow variants of this explanation.

Option I. The solar radiation with $h_{eff}/h_0 = 6$ was dark relative to the environment surrounding the water pockets. Life could have evolved already before or during CE in the water pockets with $h_{eff} = h = 6h_0$ larger than $h_{eff} = 3h_0$ in the environment. Solar photons with $h_{eff} = h = 6h_0$ did not "see" the presence of the environment because via direct interactions describable as Feynman graphs. Only the transformation $h_{eff} = 6h_0 \to 3h_0$ of the solar photon made scattering and absorption possible.

Option II. If the values of h_{eff} for the valence electrons were scaled up by a factor 2 inside the water blobs with flux tubes having thickness twice of those in the environment, and if valence

electrons indeed determine what atoms are chemically, the water blobs would have behaved like dark matter relative to environment, and could have survived inside Earth.

8.2.3   The temperatures in crust and mantle are too high to allow the emergence of multicellular life

One can argue that the temperature in the crust and   mantle is too high to allow the presence of multicellular or even monocellular life. However, if the pockets and environment were dark relative to each other, the situation changes. There would have been a very low rate of transfer of energy between these phases. The temperatures of pockets could have been much lower than that of the environment.

The gradual approach to thermal equilibrium characterized at magnetic body (MB) by Hagedorn temperature would have led to "death" of these primitive life forms but the occurrences of ordinary ("big") state function reduction reversing the arrow of time would have meant reincarnation with opposite arrow of time. This would conform with the TGD based view about life based on zero energy ontology (ZEO) [L38].

The original proposal that multicellular life evolved in the Earth's interior already before CE, is consistent with both options.   The water at the surface of Earth was present already billions of years ago, and could have been dark in either of the proposed senses so that it could have leaked to the Earth interior   and formed pockets with low temperature and low pressure. Note that solar light must have had $h_{eff} = 6$ already at time and for Option I could have induced the h_{eff} changing phase transition for the water molecules and perhaps also of the other molecules at the surface of Earth.

The proposed explanation of the Fermi paradox in terms of intra-planetary life would be nice but the obvious objection is that the circumstances in the interior make chemical life (as we know it) impossible unless some new physics, which allows the thermo-dynamical conditions prevailing at the surface of Earth, is involved.

Option I. Could the dark planets with $h_{eff} = h/2$ contain intra-planetary life as Earth did before CE, so that both the darkness of these planets   and the lower evolutionary level of this life would be the reason for the failure to observe this life.

Option II. Also the scaling $h_{eff} \to 2h_{eff}$ for valence electrons could allow dark water blobs inside all planets if one believes that valence electrons dictate chemistry.

8.3   How the reduction of the density of Earth was possible?

The increase of the radius of Earth by a factor of 2 means that the average density is reduced by a factor $1/8$ (in the case the system is genuinely 3-D; one can consider also effectively 1-D flux tube spaghetti).   In standard condensed matter physics this kind of change in the local density is impossible.

The reason is that the density ρ - and thus the number density $n = \rho/mp$ of nucleons of condensed matter increases slowly with the mass number A (`https://cutt.ly/LbGMu9u`. Only very high pressures and chemical composition involving heavy elements can affect n significantly. For instance, the density of Earth varies from 2.2 g/cm^3 in the crust to   13 g/cm^3 in the inner core (`https://cutt.ly/4bD0JIr`) and therefore roughly by a factor 6.

Interestingly, the density of water is 1 g/cm^3 and by a factor $r < 1/2$ lower than the densities of the components of the crust.   The low mass density of water might make it somehow special. Could water be seen as a mixture of phases with varying densities corresponding to varying radii for the flux tubes as suggested in [L21] to explain the numerous thermodynamic anomalies of water.   The phases would correspond to different values of $h_{eff} = nh_0$ for flux tubes. The thickness of the flux tube would correspond to the p-adic length scale   determined by the p-adic prime identified as   a ramified prime associated with the extension.

If the local density at least in the mantle and crust contributing roughly one half to the total mass of Earth remained unchanged, a kind porous structure with pores filling 7/8 of the volume would have been formed. This looks implausible.

It seems that the expansion - if it happens at all - involves new physics.

8.3.1   Does the TGD view about dark matter allow to understand the reduction of the density

The basic prediction of the adelic physics [L13, L14, L2] is the identification of dark matter as hierarchy of phases of ordinary matter with effective Planck constant $h_{eff} = nh_0$.

1. In adelic physics n is interpreted as a degree of polynomial determining the space-time regions which corresponds to the particle. n measures the algebraic complexity of space-time region and serves as a kind of IQ and measure of the scale of quantum coherence.   Evolution would corresponds to the increase of algebraic complexity and therefore also to the increase of n.

2. Functional composition of polynomials would give rise to evolutionary hierarchies in which the degree of polynomial at a given level divides the degrees at higher levels [L29, L30]. For instance $n = 3 \rightarrow n = 6$ conforms with this picture.

3. $n = 1$ would correspond to the simplest form of matter: the roots of polynomials defining the the space-time region would be rational and if the polynomial is   irreducible, it is linear polynomials with rational coefficients. It is not clear whether $n = 1$ phase does exist.

   The phases with different values of n would not have direct couplings with ordinary matter describable in terms of Feynman diagrams.   The transformation of particles, say photons, with different values of h_{eff} to each other are however possible and would occur for photons. Biophotons would be ordinary photons resulting from $h_{eff} > h$ dark photons by this kind of transition.

There are two guidelines available.

1. The scaling by factor 2 suggests a transition $h_{eff} \rightarrow 2h_{eff}$. Option I and II are possible.

2. The findings of Randel Mills [?] can be understood if $h_{eff} = h = 6h_0$ holds true   for ordinary matter [L10] and in the experiments of Milss a phase with $h_{eff} = 3h_0$ was formed. This would support Option I.

Although it turns out that Option I is not plausible model for CE, the phase transition $h_{eff} = 3 \rightarrow h_{eff} = 6$ is interesting as such.

1. This transition could have preceded by a transition $h_{eff} = h_0 \rightarrow 3h_0$ of $n = 1$ phase is possible at all. One could imagine a hierarchy in which cosmic strings correspond to $n = 1$ and flux tubes obtained by their thickening correspond to $n > 1$ phases. n cannot however directly relate to the value p-adic length scale characterizing the string like object.

2. Fine structure constant is proportional to $1/h_{eff}$ and would have decreased by a factor $1/2$ from its value before the transition. The atomic binding energy scale would have been 4 times larger.

   If $h_{eff} = 3$ is possible for stars, the radiation from them has an energy spectrum scaled up by factor 4. $h_{eff} = 3$ photons should transform to ordinary $h_{eff} = 6$ photons before interaction with the ordinary matter. The rate for this transformation could be low so that this kind of stars are difficult to observe.   Dark matter could therefore be partially also $h_{eff} < 6$ matter.

3. One can ask whether the $h_{eff} = 3 \rightarrow 6$ transformation of the planetary matter near the planetary surface was induced by the interaction with solar radiation.   The second question is whether it took place for each planet independently or whether a collective phase transition in cosmological scales occurred.   The minimal assumption is that this transition is part of the evolution of the astrophysical object and those objects for which it has not occurred are dark relative to us.

   $h_{eff} < h$ phase would represent only one form of dark matter when darkness is regarded as a relative notion. Valence electrons would also represent dark matter with $h_{eff} = h_{em} > h$ as also dark protons assignable to hydrogen bonds. Another form would be the Kähler magnetic and volume energy and possibly dark particles at cosmic strings transformed to flux tubes. This includes the dark matter satisfying Nottale hypothesis $h_{eff} = h_{gr} = GMm/v_0$ and associated with gravitational flux tubes [E3].

4. Both planets and observed exoplanets must have $h_{eff} = 6$ since the reflection of solar light from the surface is expected to be occur only if the $h_{eff} = 6$ stellar photons transform to $h_{eff} = 3$ photons. Note that the known exoplanets belong to the Milky Way whose size is about 50,000 ly and much shorter scale than the 500 million ly defined by the time of CE.

5. Planet 9 (`https://en.wikipedia.org/wiki/Planet_Nine`, whose existence has been proposed because its gravitational field could explain the unusual clustering of orbits for a group of extreme trans-Neptunian objects (ETNOs), bodies beyond Neptune that orbit the Sun at distances averaging more than 250 times that of the Earth. Planet 9 is too distant to be seen directly. Witten has proposed an interpretation as a blackhole [E4].   An alternative identification would be as an $h_{eff}/h_0 < h$ object.

6. The $h_{eff} = 6h_0$ life in the interiors of $h_{eff} = 3$ planets could be considered as a possible solution of the Fermi paradox. In the proposed model, the life below the surface of Mars would be possible only near its surface and mono-cellular as most of the life in the Earth's crust.

8.3.2   Cambrian explosion as a quantum jump in a planetary scale?

In ZEO [L28, L32] based quantum measurement theory, there are two kinds of state function reductions (SFRs): "big" (ordinary) state function reductions (BSFR), which involve time reversal and "small" SFRs, which correspond to "weak" measurements in which the arrow of time is preserved. The sequence of SSFRs defines a conscious entity and aBSFR can be regarded as death in a universal sense.

In biology BSFR [K5] [L38, L37] corresponds to the death of subsystem and its re-incarnation with an   opposite arrow of time occurring at the level of magnetic body (MB) of the system controlling it because of this higher IQ due to the much larger value of h_{eff}. h_{eff} hierarchy predicts that quantum coherence and SFRs are possible in all scales at the level of MB.

Although BSFR is discontinuous, it looks for an observer with a standard arrow of time (briefly, "outsider")   like average over deterministic time evolutions leading to the final state of BSFR. In the ZEO framework,   the   Universe looks therefore classical in all scales.

Could CE correspond to BSFR, or actually two BSFRs to achieve original arrow of time - at the level of MB? The duration of the average deterministic classical time evolution of this BSFR seen by an outsider would be about 13-25 million years.

What CE as BSFR could look like for an outsider?

1. Water has a unique role in biology since living matter consists mostly of water.   In TGD inspired quantum biology it is seen as a primitive life form preceding chemical life.   For instance, water memory would be behind the immune system [K4].

   Pollack effect [L4, I15, I12], associated with water irradiated in the presence of gel phase and leading to the formation of negatively charged exclusion zones (EZs), would be behind charge separation associated with cell, DNA, and microtubules.   Part of protons would become dark and would be transferred to magnetic flux tubes where they could give rise to a fundamental representation of genetic code [L8, L23]. An attractive assumption is that the phase transition thickening the flux tubes by factor of 2 occurred first for the water phase. The density of water is one half of that from that for the density of the crust and this could be understood if water consists of flux tube-like structures.

2. Since solar radiation was present already billions of years ago and also Earth was covered by water, it is possible that the solar radiation induced the phase transition for water at the surface of Earth. Call this water activated water.

   For both Options I and II, the electromagnetic interactions of the activated water with the matter of primordial Earth were very weak and it could leak to the Earth interior - not as a crystal water but as pockets with much lower temperature and pressure inside Earth. The solar radiation also reached the interior of the Earth so that an evolution leading to photosynthesis and metabolic machinery could have indeed occurred in the interior in the womb of Mother Gaia.

Note that the TGD based model for valence bonds [L12] requires that solar radiation corresponds to several values of h_{eff} or that the transitions of $h_{eff} = 6 \rightarrow h_{eff} > h$ are possible.

3. Pollack effect could have led to the formation of the basic structures of the chemical life inside these pockets. The flux tube connections with large h_{eff} between pockets could have formed and made possible larger structures consisting of separate units and controlled by its MB. Even underground oceans can be imagined.

4. One can consider two options for the evolution of multicellulars. According to the original option, multicellular life evolved already before CE. The standard view about CE is that it occurred during CE. In the TGD framework, the original option looks more plausible. The emergence of life would mean a scaling $h_{eff} \rightarrow 2h_{eff}$ for valence electrons (Option II) $h_{eff} = 3 < h$. Scaling $h/2 \rightarrow 2h$ for all electrons (Option I) looks implausible. Maybe the liquid phase and low density could allow to understand why.

8.4 The transition increasing flux tube thickness as a phase transition induced by magnetic body

There are two options to consider: I and II. Option I assuming that the thickening of flux tubes by factor 2 induces the phase transition $h/2 \rightarrow h$ does not seem realistic. It is however possible that this phase transition has occurred much earlier at temperatures allowing nuclear fusion and could also occur in the laboratory in these circumstances.

The following discussion applies to both options: the only difference is that the total electron binding energy E_B is replaced with that for valence electrons.

The best manner to proceed is to develop objections against the proposals. It is easy to develop a rather scaring objection.

8.4.1 Minimization of free energy as basic principle

The minimization of free energy F can be taken as a basic principle since temperature is expected to remain constant during the phase transition.

1. If the temperature stays constant in the transition,the basic thermodynamic condition is that free energy decreases

$$\Delta F = \Delta E - T\delta S \leq 0 \ . \tag{8.1}$$

2. One can express ΔE as

$$\Delta E = \Delta E_B + \Delta E_{MB} \ . \tag{8.2}$$

The subscript "B" refers to the binding energy which for Option I is the total binding energy $E_B = E_{B,atom}$ and for Option II the total binding energy $E_{B,val}$ of valence electrons. The subscript "MB" refers to the magnetic body assignable in the TGD framework to magnetic flux tubes, whose thickening by a factor 2 would liberate energy and kick the atoms to new ground states.

3. From the $1/h_{eff}^2$ proportionaly of the binding energies, the reduction of the binding energy in the transition is given by

$$\Delta E_B = \frac{3E_B}{4} \ . \tag{8.3}$$

The thickness of the flux tube is expected to correspond to the atomic length scale of order Angstrom so that atomic physics would involve a new length scale relevant for the density of condensed matter.

$$\Delta E = \Delta E_{B,tot} + \Delta E_{MB} \ .$$

(8.4)

4. One can express ΔS in an analogous manner

$$\Delta S = \Delta S_{atom} + \Delta S_{MB} \ .$$ (8.5)

The subscript "atom" refers to entropy assignable to scaledup atoms and "MB" to magnetic body.

One can consider two ways to satisfy this condition depending on whether the transition is energy or entropy driven.

1. For $\Delta S = 0$, one has $\Delta E \leq 0$. This would mean that the energy needed to kick electrons to new states with binding energy reduced by factor $1/4$ must come somewhere. The fundamental quantum phase transition at MB should provide it, most naturally as energy liberated when the string tension of flux tubes is reduced as they thicken.

2. The alternative option is that that the transition develops a lot of entropy

$$\Delta S \geq \frac{\Delta E}{T} \ .$$ (8.6)

It is important to note that in the TGD framework negentropy maximization principle (NMP) is the basic principle and implies second law for ordinary matter.

The p-adic contribution to entanglement negentropy coming from cognition ispositive unlike real contribution, which is non-positive. NMP implies that in adelic physics p-adic contribution to negentropy exceeds in general real contribution. The generation of p-adic negentropy however forces also a generation of real entropy and this conforms with the paradoxical proposal of Jeremy England that living systems produce entropy.

In the recent case the generation of large entropy at the level of visible matter would correspond to a generation of large p-adic negentropy assignable to the MBs in question. Hence the Cambrian phase transition would mean a cognitive revolution of some kind.

8.4.2 Estimates for the total binding energy

The following rough estimates assume Bohr model. In Bohr model, the atomic energies at a given shell n, which corresponds to the row of the Periodic Table. The energy shell contains n^2 states with angular momenta $l = 0, .., n-1$ are given by $E_n = (Z^2/n^2)E_H$. The number of states in full shell is $2n^2$. Full shells are realized only for $n = 1, 2$. The total binding energy in a full shell is $nZ^2 E_H$, $E_H \simeq 13.6$ eV.

One could naively argue that the filling of all sub-shells l is energetically more favorable since the total binding energy would be maximized in this manner. However, already for $n > 3$ only the 8 states at s and p subshells are realized and d shell is missing so that the $n = 3$ shell contains the same angular momentum eigenstates as $n = 2$ shell. For $n = 3$ shell Argon corresponds to configuration $[Ne]s^2p^6$. K does not correspond to$[Ne]s^2p^6d$ but to $[Ar]4s$. The reason for this is not clear to me and one can of course ask whether the $h/2 \to h$ could have favored smaller binding energies and even led to the increase of n instead of full shell.

The expression for the total binding energy is given by

$$E_B = \sum_n N_n \frac{Z^2}{n^2} E_H \quad , \quad E_H = 13.6 \; eV \; . \qquad (8.7)$$

For full shells (the rows $n = 1, and 2$) $N_n = 2n^2$ and the energy is $2Z^2$.

    The following equations represent the total binding energies in Bohr model for some important ions in biology.

atom	Z	configuration	E_B/E_H	E_B/keV	$\lambda/\text{Å}$	
O	8	$[He]2s^2 2p^4$	$8^2(2+3/2) = 224$	3.05	4.1	
P	15	$[Ne]3s^2 3p^3$	$15^2(2+2+5/9) = 1025$	13.9	.9	(8.8)
Ca	20	$[Ar]4s^2 = [Ne]3s^2 p^6 4s^2$	$20^2(2+2+8/9+1/8) = 2050 - 400/9 \simeq 2005.6$	27.3	.45	
Fe	26	$[Ar]3d^6 4s^2$	$26^2(2+2+14/9+1/8) = 3840.1$	52.2	.22	

Note that Bohr radius is .53 Å so that for Ca the wavelength defined λ defined formally by the total binding energy is rather near to Bohr radius. The energies are rather high. For valence electrons the total binding energies are much lower and for Fe one has $E_{val}(Fe) = 1.15 keV$.

    These results support the view that Option II is more realistic than Option I.

1. The flux tubes are characterized by a p-adic length scale L_p, where p-adic length scale hypothesis states $p \simeq 2^k$. One has $L_p \equiv L(k) \simeq 2^{(k-151)/2} L(151)$, $p \simeq 2^k$, $L(151) \simeq 10$ nm. p-adic length scale $L(137) = 2^{-7} L(151)$, corresponds to .78 Å and $L(139)$ to 1.56 Å.

2. The magnetic flux tubes assignable to condensed matter and determining the density of the condensed matter should have thickened by a factor 2 in the transition. The phase transition $k = 137 \to 139$ is a natural candidate. Note that this pair defines twin primes.

   An estimate for the value of string tension follows from the hadronic string tension $T_H \simeq 1$ GeV^2, which corresponds to $k = 107$: this gives $T(137) = 2^{-137-127} T_H = 2^{-30} T_H \simeq 1 eV^2$. The energy of a string portion with length $L(137)$ is $E(137) \simeq 10$ keV. An energy of this order would would be been liberated in the transition $k = 137 \to 139$.

3. Option I does not look realistic. From **Eqs.** 8.8 one finds that for Ca the total binding energy is 27.3 keV. For Fe the energy is 46.1 keV. These energies are too large: the transition in the case of Fe should be strongly entropy driven.

4. Option II looks more reasonable. For Fe the total binding energy assignable to the valence bonds is $E_{val} = 1.2$ keV. The maximal binding energy of valence electrons is $Z^2(n^2 - 1)/n^2 E_H \simeq Z^2 E_H$. Not all angular momentum subshells are however filled and this energy is maximum for atoms towards the right end of the row and for Krypton one has $n = 3$ is $D_{val} = 1.1$ keV. 1.24 keV corresponds to the energy of a photon with a wavelength of 1 Angstrom, qhixh looks also reasonable. Since the energy liberated from the flux tube portion is considerably higher than E_{val}, it would have induced expansion.

8.4.3 What could one say about the phase transition at the level of MB?

The phase transition at the level of MB induces the phase transition at the lower levels. Can one say anything about the phase transition at the level of MB?

1. The twistor lift of TGD predicts that energy of the magnetic flux tube is a sum $E = E_1 + E_2$ of two terms.

   The first term is a volume term proportional to the TGD counterpart of cosmological constant Λ predicted to be length scale dependent and by dimensional considerations proportional to $1/L_p^2 G$. Λ would be reduced by a factor $1/4$ in the proposed transition transitions. This terms gives a contribution

$$E_1 = aSL \; ,$$

where S is the transversal area of the flux tube and L its lengthThe scaling $a \to a/2$ would occur in the transition.

The energy also contains Kähler magnetic energy. If the flux tube carriesmonopole flux, the contribution is of form

$$E_2 = \frac{b}{S}L \ \ ,$$

Assume that the scaling $b \to b/2$ occurs in the transition.

2. The minimization of the total energy

$$E = E_1 + E_2 = aS + \frac{b}{S} \tag{8.9}$$

with respect to S is assumed and gives

$$E = 2\sqrt{ab} \ \ . \tag{8.10}$$

In the scaling the energy transforms as $E \to E/2$. The liberated energy $E/2$ could be used to reduce the binding energy of the atoms by $3E_B/4$.

3. The natural expectation is that the total energy for a flux tube portion of length L_p is of order of photon with a wavelength L_p. This energy is given by $E = \hbar/L_p = 1.24/L_p/\mu m$. For $k = 137$ this gives energy $E \simeq 16$ keV. For Ca one has $3E_B/4 = 20.5$ keV and for P one has $3E_B/4 = 10.3$ keV.

This suggests that the first phase transition could take place only for the biologically important atoms and molecules formed from them - in particular water molecules - and would not produce much entropy. Second phase transitions identifiable as Cambrian explosion would take place for heavier atoms and require large ΔS in turn requiring large generation of negentropy at the level of MB. This would accompany a rapid evolution of life at the surface of Earth.

8.5   Cambrian explosion, the Great Oxidation Event, and Expanding Earth hypothesis

I encountered two interesting articles related to the Great Oxidation Event that started long before the Cambrian Explosion (CE) and reached its climax during CE (about 541 million years ago) leading to the oxygen based multicellular life in a very rapid time scale.

The standard view is that oceans before CE had very low oxygen content. The emergence of photosynthesizing cyanobacteria producing oxygen as a side product led to the oxygenation of the atmosphere and to mysteriously rapid evolution of life. How this is possible at all is not understood.

The first popular article (`https://cutt.ly/UQWZA31`) discusses the proposal [I9] that the slowing down of the spinning of Earth was somehow related to this. The idea is that the lengthening of the day made photosynthesis by cyanobacteria more effective since their reaction to the dawn of the day was slow. The second article in Quanta Magazine (`https://cutt.ly/PQWZDzD`) tells about the finding [I8] that during the Cambrian Explosion (`https://cutt.ly/1QWZF4E`) the oxygen content of the studied shallow ocean show fluctuations with with about 4-5 peaks. The reduction/increase of the oxygen content was even 40 per cent, which is a huge number. The reduction of oxygen content caused extinctions and its increase was accompanied by the emergence of new species. The mystery is how this could happen so fast and which caused the fluctuations.

8.5.1 Expanding Earth hypothesis

Expanding Earth theory hypothesis is not originally TGD based but TGD provides its realization. The proposal is that the Cambrian Explosion was caused by a rapid increase of the radius of Earth by factor 2 [L18, L36].

This hypothesis also solves one of the basic mysteries of cosmology. Astrophysical objects participate in cosmological expansion by comoving with it but do not expand themselves. Why? The prediction that the expansion of the astrophysical objects did not occur smoothly but as rapid phase transitions and the expansion was very slow in the intermediate states. Cambrian Explosion would correspond to one particular jerk of this kind in which the radius of Earth grew by a factor 2 (p-adic length scale hypothesis). The length of the day increased by factor 4 from conservation of angular momentum. This might relate to the conjecture of the first article.

The rapid expansion led to the breakage of the Earth crust and to the birth of plate tectonics. It also led to the burst of underground oceans to the surface of the Earth. The photosynthesizing multicellular life had developed in these oceans and emerged almost instantaneously and led to a rapid oxygenation of the atmosphere. One can say that life evolved in the womb of Mother Gaia shielded from meteorites and cosmic rays. No superfast evolution was needed. Already Charles Darwin realized that the sudden appearance of trilobites was a heavy objection against the theory of natural selection.

Possible scenarios for the phase transition are discussed in [L36]. The thickening of magnetic flux tubes for water blobs at the surface of Earth led to the increase of the volume of water blob and induced the increase of h_{eff} a factor 2 for valence electrons but not for the inner electrons. Since valence electrons are responsible for chemistry, atoms became effectively dark and the water blobs could leak to the interior of Earth. By their darkness they could have much lower temperature and pressure than the matter around them and the life could evolve.

8.5.2 How photosynthesis was possible underground?

What made photosynthesis possible in the underground oceans? One possible explanation is that the photons from the Sun propagated along flux tubes of the "endogenous" part of the Earth's magnetic field as dark photons with $h_{eff} = nh_0 > h$. Endogenous part would be the part of Earth's magnetic field with a strength about 2/5 of the Earth's magnetic field for which flux tubes carry monopole flux: this is possible in TGD but not in Maxwell's theory.

Since these photons behave like dark matter with respect to the ordinary matter, they were not absorbed considerably and reached the water blobs (or actually their magnetic bodies consisting of flux tubes) in underground oceans having a portion with the same value of $h_{eff} \geq h$. Of course, several values of h_{eff} were possible since this is the case in quantum critical system (large values of h_{eff} characterize the quantum scales of long range fluctuations). One can also consider other variants of the model. The ordinary matter in Earth's crust had $h_{eff} = h/2$ and photons with $h_{eff} = h$ propagated to the interior and reached the water blobs with $h_{eff} = h$.

8.5.3 The sudden emergence of multicellulars and oxygen fluctuations

Before the expansion period was much like the surface of Mars now and contained no oceans, perhaps some ponds allowing primitive monocellular lifeforms. As the ground of Earth broke here and there during the rapid expansion period, lakes and oceans were formed at the surface of Earth. The multicellulars bursted to these oceans and oxygenation of the atmosphere started locally.

Since the oxygen rich water was mixed with the water in the shallow oceans, the local oxygen content of the burst water was reduced and this led to an eventual extinction of many multicellulars in the burst. Burgess Shale fauna contained entire classes, which suffered extinction. In the average sense the oxygen concentration increased and led to the apparent very rapid evolution of multicellulars, which had actually already occurred underground. Of course, also evolution at the surface of Earth took place.

9 Has venus turned itself inside-out and why its magnetic field vanishes?

News about unexpected findings relating to the physics of astrophysical objects emerge on an almost daily basis. The most recent news (`https://cutt.ly/YQSZgpv`) told about the lack of craters and volcanic activity in Venus (`https://cutt.ly/wQSZzaS`). The findings are actually not new. The resurfacing history of Venus was summarized 1979 by Schaber *et al* [E6] . Turcotte and Rome have proposed cyclic global catastrophic events as an analog of the plate tectonics allowing a heat transfer from the interior of Venus and effectively turning Venus inside out [E7].

The Venus does not have appreciable magnetic field although dynamo mechanism suggests magnetic field as in the case of Earth, has been also known.

9.1 Has Venus turned itself inside-out?

The surface of Venus was expected to have craters, just like the surface of Earth, Moon, and Mars but the number of craters is very small. The surface of Venus also has weird features and many volcanoes. Also trace signs of erosion and tectonic shifts were found. The impression is that the surface of Venus had been turned inside out in a catastrophic event that occurred about 750 million years ago.

Since Venus is our sister planet with almost the same mass and radius, it is interesting to notice that the biology of Earth experienced the Cambrian explosion 541 million years ago.

1. The TGD explanation for Cambrian Explosion relies on Expanding Earth Model (EEM) [L18, L17, L36]. The model assumes that there was a relatively fast increase of the Earth's radius by factor, which led to the burst of underground oceans to the surface of the Earth and led to the formation of oceans. Standard cosmology predicts a continuous smooth expansion of astrophysical objects. Contrary to this prediction, astrophysical objects do not seem to expand smoothly. In the TGD Universe, the smooth expansion is replaced by rapid jerks and the Cambrian Explosion would be associated with this kind of phase transitions.

2. In this expansion the multicellular photosynthesizing life burst to the surface. This explains the sudden emergence of highly evolved life forms during the Cambrian Explosion that Darwin realized to be a heavy objection against his theory.

3. There are many objections to be circumvented. For instance, how photosynthesis could evolve in the underground ocean. Here TGD views dark matter as $h_{eff} = nh_0$ phases of ordinary matter, which are relatively dark with respect to each other, come in rescue. Dark water blobs could leak into the interior of Earth and the solar light possessing a dark portion could do the same so that photosynthesis became possible [L36].

4. Did Venus experience a similar rapid expansion 200 million years earlier, about 750 million years ago (or maybe roughly at the same time). Venus does not have water at its surface. This can be understood in terms of heat from solar radiation forcing the evaporation of water and subsequent loss. This also prevented the leakage of the water to the interior of Venus. If there were no water reservoirs inside Venus, no oceans were formed. The cracks of the crust created expanding areas of magma, which were like the bottoms of the oceans at Earth. Also at Earth a fraction about 2/3 of the Earth's surface is sea bottom.

9.2 Why does Venus not possess a magnetic field?

Venus also offers a second puzzle. Venus does not have an appreciable magnetic field although it has been speculated that it has had it (`https://cutt.ly/VQSZt9m`). The solar dynamo mechanism would suggest its presence.

1. TGD predicts that there are two kinds of flux tubes carrying Earth's magnetic field B_E with a nominal value of .5 Gauss. This applies quite generally. The flux tubes have a closed cross section - this is possible only in TGD Universe, where the space-time is 4-surface in

$M^4 \times CP_2$. The flux tubes can have a vanishing Kähler magnetic flux or non-vanishing quantized monopole flux: this has no counterpart in Maxwellian electrodynamics.

For Earth, the monopole part would correspond to about .2 Gauss - 2/5 of the full strength of B_E.

2. Monopole part needs no currents to maintain it and this makes it possible to understand how the Earth's magnetic field has not disappeared a long time ago. This also explains the existence of magnetic fields in cosmological scales.

   The orientation of the Earth's magnetic field is varying. In the TGD based model the monopole part plays the role of master. When the non-monopole part becomes too weak, the magnetic body defined by the monopole part changes its orientation. This induced currents refresh the non-monopole part [L6]. The standard dynamo model is part of this model.

3. There is an interesting (perhaps more than) analogy with the standard phenomenological description of magnetism in condensed matter. One has $B = H + M$. H field is analogous to the monopole part and the non-monopole part is analogous to the magnetization M induced by H. $B = H + M$ would represent the total field. If this description corresponds to the presence of two kinds of flux tubes, the TGD view about magnetic fields would have been part of electromagnetism from the beginning!

   Flux tubes can also carry electric fields and also for them this kind of decomposition makes sense. Could also the fields D, P, and E have a similar interpretation?

   In the linear model of magnetism, one has $M = \chi H$ and $B = \mu H = (1+\chi)H$. For diamagnets one has $\chi \leq 0$ and for paramagnets $\chi \geq 0$. Earth would be paramagnetic with $\chi \simeq 3/2$ if the linear model works. χ is a tensor in the general case so that B and H can have different directions.

4. All stars and planets, also Venus, correspond to flux tube tangles formed from monopole flux tubes. This leaves only one possibility. Venus behaves like a super-conductor and is an ideal diamagnet with $\chi = -1$ so that B vanishes. The monopole part would be present however.

   This could provide a totally new insight to the Meissner effect and loss of superconductivity. In TGD the based model [L31], monopole flux tubes carry supracurrent. The BCS model however requires the absence of a magnetic field. Could the induced non-monopole field cancelling the monopole part. Venus would indeed be a superconductor!

5. The TGD based model of superconductivity [L31] also predicts superconductivity driven by an external energy feed would be also above critical temperature. The energy feed would increase the value of h_{eff} and below the critical temperature it would be provided by the energy liberated in the formation of Cooper pairs, which need not actually be the current carriers since dark electrons can carry the current without dissipation. In TGD inspired biology and quite universally, the basic role of metabolic energy feed is to prevent the reductions of the values of h_{eff}.

   Superconductivity means in the TGD framework large h_{eff} and therefore complexity, intelligence, and long quantum coherence length [L39]. Could Venus be alive but in a very different sense than Earth?

6. Could the superconductivity be forced by the thermal energy feed from the interior of Venus? The tilt of the rotation axis relative to the plane of rotation around the Sun is very small for Venus, about 3 degrees and much smaller than for the Earth. This implies that the surface temperature of Venus is roughly constant. At Earth plate tectonics makes possible the heat transfer from the interior to the surface and its leakage to outer space. For Venus this is not possible. Could the energy flow from the interior of Venus force the superconductivity by increasing the values of h_{eff}. This would in turn force the vanishing of the magnetic field of Venus.

7. Sun has an enormous feed of metabolic energy from the core: could it be alive? Also in the case of Earth, the energy feed from the interior could have been crucial for the development of life in the interior of Earth and made possible even the development of photosynthesis.

The possibility that life actually appears in cosmic scales and is associated with quantum coherent flux tube networks associated with the active galactic nuclei usually identified as supermassive blackholes containing stellar and planetary systems as tangles is suggested by the TGD based model of galactic jets [L35] explaining also ultrahigh energy cosmic rays. The model inspires the proposal that active galactic nuclei having typically sizes 1-2 AU (!) involve gravitationally quantum coherent regions of radius at most of the Schwartschild radius defining a minimal gravitational Compton length [L35].

8. Also Mars lacks the global magnetic field although it has auroras assigned with local fields. Could also Mars be alive in the same same sense as Venus? Note that the recent radius of Mars is about 1/2 of Earth's radius. If Venus expanded by factor 2, all these 3 planets would have had roughly the same radius for about 750 million years ago. Mars would be waiting for the moment of expansion.

9.3 Could superionic phase of water give rise to planetary super-conductivity and Meissner effect?

A superionic ice-like phase of water at high temperature and pressure (20 GPa but much less than the expected pressure, which is higher than 50 GPa) has been discovered. Inside Earth, 20-25 GPa pressure exists in the transition zone between upper and lower mantle. The new phases, bcc and fcc cubic lattices emerge at T=2000 K. See the popular article "*Scientists find strange black 'superionic ice' that could exist inside other planets*" (`https://www.eurekalert.org/news-releases/933099`) and the article "*Structure and properties of two superionic ice phases*" of Prakapenka *et al* [**?**] (`https://cutt.ly/7TPvYlL`).

The bonds between hydrogen atoms and oxygen ions are broken in this phase and ionized hydrogen atoms form a fluid, a kind of proton ocean in which the oxygen lattice floats.

In the TGD framework dark proton sequences with effective Planck constant $h_{eff} \geq h$ at monopole magnetic tubes play a key role in quantum biology. Dark DNA codons would be 3-proton triplets at monopole flux tubes parallel to DNA strands and would give rise to a fundamental realization of the genetic code.

One can wonder whether the protons of this superionic could be dark in the TGD sense and reside in monopole flux tubes. Could they form a superfluid-like or superconductor-like phase by a universal mechanism which I call Galois confinement, which requires that the total momenta of composites of dark protons with are algebraic integer valued momenta are ordinary integers in suitable units (periodic boundary conditions) [L33, L34].

It is conjectured that this kind phase could reside in the interiors of Neptune and Uranus perhaps even deep inside the Earth. Could superionic phases of water in the interior of planets like Mars and Venus give rise to the speculated super-conductivity implying the vanishing of large scale magnetic field via the TGD variant of the Meissner effect?

Could superionic ice appear in the interior of Earth? Could one consider the following scenario?

Primordial Earth had a vanishing magnetic field by the Meissner effect caused by superionic ice. Part of the superconducting superionic water melted and formed ordinary water at lower temperature and pressure and gave rise to underground oceans. Superconductivity was lost in the Earth scale but the monopole flux based magnetic field and the ordinary magnetic field induced by the currents that it generated remained but did not cancel each other anymore. In the transition increasing the radius of Earth by factor 2 during the Cambrian explosion the water in these oceans bursted to the surface of Earth.

9.3.1 Earthquakes that should not occur

There is an interesting finding, which seems to relate to the superionic ice. It has been discovered that there are earthquakes much deeper in the interior of Earth than expected (`https://cutt.ly/VTSEe5j`). These earthquakes are in the transition zone between upper and lower mantle and (the depth range 410-620 km) even below it (750 km). The pressure range is 20-25 GPa. The temperature at the base of the transition zone is estimated to be about 1900 K (`https://cutt.ly/jTSWxbA`). This parameter range inspires the question whether superionic could emerge at the base of the transition zone and whether the appearance of hydrogen as liquid in pores could

make possible the earthquakes below the transition zone just as the presence of ordinary liquid in pores is believed to make them possible above the transition zone.

In the crust above 20 km depth the rocks are cold and brittle and prone to breaking and most earthquakes occur in this region. At deeper the rocks deform under high pressures and no breaking occurs. Deeper in the crust the matter is hotter and pressure higher and breaking does not occur easily.

Around a depth of 400 km, just above the transition zone, the upper mantle of the rock consists of olivine, which is brittle. In the transition zone olivine is believed to transform to wadsleyite and at deeper depth ringwoodite. At 680 km, where the upper mantle ends, ringwoodite would transform to bridgmanite and periclase. The higher pressure phases are analogous to graphite, which deforms easily under pressure and does not break whereas olivine is analogous to diamond and is brittle.

One can understand the earthquakes down to 400 km near the upper boundary of the transition zone in terms of the model in which water in the proposed upper mantle is pushed away from the pores by pressure, which leads to breaking. Below this depth water is believed to be totally squeezed out from the pores so that mechanism does not work. The deepest reported earthquake occurs at a depth 750 km and looks mysterious. There are several proposals for its origin.

The area of Bonin island is a subduction zone and it has been proposed that the boundary between upper and lower mantle is at a larger depth than thought. The cold Earth crust could allow a lower temperature so that matter would remain brittle since the transition to high pressure forms of rock would not occur. Another proposal is that the region considered is not homogenous and different forms of rock are present. Even direct transition of olivine to ringwoodite is possible and it has been suggested that this could make the earthquakes possible.

9.3.2 Could superionic ice and earthquakes relate?

TGD allows us to consider the situation from a new perspective by bringing in the notions of magnetic flux tubes carrying dark matter. Also the zero energy ontology (ZEO) might be highly relevant. The following represents innocent and naive questions of a layman at the general level.

1. ZEO inspires the proposal that earthquakes correspond to "big" state function reductions (BSFRs) in which the arrow of time at the magnetic body of the system changes. This would explain the generation of ELF radiation before the earthquake although one would expect it after the earthquake [L26].

   The BSFRs would occur at quantum criticality and the question is what this quantum criticality corresponds to. Could the BSFR correspond to the occurrence of a phase transition in which the superionic ice becomes ordinary water? If this is the case, the transition zone, and also a region below it, would be near quantum criticality and prone to earthquakes.

2. The dark magnetic flux tubes are 1-D objects and possess Hagedorn temperature T_H as a limiting temperature. The heat capacity increases without limit as T_H is approached. Could a considerable part of thermal energy go to the flux tube degrees of freedom so that the temperature of the ordinary matter would remain lower than expected and the material could remain in a brittle olivine form.

3. Could the energy liberated in the earthquake correspond to the dark magnetic energy (for large enough value of h_{eff} assignable to gravitational magnetic flux tubes) assignable to the flux tubes rather than to the elastic energy of the rock material? Could the liberated energy be dark energy liberated as h_{eff} decreases and flux tubes suddenly shorten? Could this correspond to a phase transition in which superionic ice transforms to an ordinary phase of water?

One can also ask more concrete questions.

1. Suppose that water below the transition zone (P$\geq$ 20 GPa and T $\geq$ 1900 K) can exist in superionic ice containing hydrogen ions in liquid form. Could the high pressure force the superionic liquid out from the pores and induce the breaking?

2. In the range 350-655 km, the temperature varies in the range 1700-1900 K (`https://cutt.ly/jTSWxbA`). The temperature at the top of transition zones would be slightly above 1700 K. Could regions of superionic ice appear already at 1700 K, which is below T=2000 K?

3. Could the transition zone be at criticality against the phase transition to superionic water? This idea would conform with the proposal that the region in question is not homogenous.

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