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

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June 20, 2019

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 [K6, K5] 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 manner. 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 [K5].

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 [F44]! 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` [L1].

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 imbeddings 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 imbedding 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 imbedding 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 imbedding 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 imbedding 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 [F43] 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 [F42].

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 [I9] 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 [I7] conforms with this picture.

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

Intra-terrestrial hypothesis [K2] 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 [F43, 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 predecessor 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 [F41, F36, 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 [F38] 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 $R \to R/2$ 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 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 [F38] differs from Snowball Earth in that 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 [F37] 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 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 [F41, F36, 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 [K6] 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 [I8]. 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

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

   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 [K4].

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 naive 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

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

   $R_f = R$ 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

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

   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 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

$$\begin{aligned} \tau &= K \times a v_{0,f}^{-5} \times (\frac{R}{2GM})^{1/2} \times \frac{R}{c} \ , \\ K &= \frac{5 \times 2^{-7} \times (2 + 2^{1/2})}{3^{1/2}} \ . \end{aligned} \tag{4.5}$$

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 [F44] 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 super-continents, 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 [F40]. 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 [F40]).

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`) [F39] 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 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 naively 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 KennellyHeaviside 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 [K7]. 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 [K4, K3].

1. Article represents first a standard argument in favor of late formation of oceans. The collisions by astreroids 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... [K3].

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 [I5] (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 [K9].

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 [K3].

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 [K3] 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 [K3] (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 [K9]. 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 [K7, K8].

Remark: h_0 is the minimal value of h_{eff}: the best guess for the ordinary Planck constant corresponds to $n = 6$ [L3, L4].

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 [K3] 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 [L2]). 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 [L6] (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 [L5] (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 tesselation- having maximal number of cells. Platonic solids are the only regular tesselations 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 tesselation 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 tesselation 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 tesselation 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 [K10] [L7].

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 tesselation 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 manners: 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_i^2 to a supercontinent covering part of S_f^2. The simplest map of this kind maps the surface of S_i^2 to a cap of S_f^2 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 $0 \leq \theta_f \leq \theta_{max}$ 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

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

   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 $sin(\theta_f) \leq 1/2$, which corresponds to $|cos(\theta_f)| \geq \sqrt{3}/2$. On the other hand, the condition that the sum of the areas of the caps equals the area of S_i^2 gives $|cos(\theta_f)| \geq 3/4 < \sqrt{3}/2$ 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

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

   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 $cos(\theta_f)$.

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The various models used for climate projections and mitigation and VIA analyses overlap in scope and would benefit from a broad perspective of Earth system prediction. Shown are the domains of ESMs, mitigation models, and VIA models along axes from VIA to climate processes (horizontal) and from primarily serving the research community to informing societal needs (vertical).Â They are the most complex in the ongoing evolution of global models of Earthâ€™s atmosphere, ocean, cryosphere, and land (Fig.Â Ongoing model development aims to more authentically represent plant demography and life history characteristics using cohorts of individuals of similar functional traits in vertically structured plant canopies (18). Earth scientists have long been concerned with deciphering the historyâ€”and predicting the futureâ€”of this active planet. Over the past four decades, Earth scientists have made great strides in understanding Earthâ€™s workings. Scientists have ever-improving tools to understand how Earthâ€™s internal processes shape the planetâ€™s surface, how life can be sustained over billions of years, and how geological, biological, atmospheric, and oceanic processes interact to produce climateâ€”and climatic change.Â Answering such questions will. for life and relatively stable for the past 10,000 years and suitable for life for over 3 billion years.Â diction, the evolution of continents