Expanding Earth Hypothesis and Pre-Cambrian Earth

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Abstract

In this article I continue to develop a more detailed TGD version of the Expanding Earth hypothesis explaining Cambrian Explosion (CE). A more detailed view of the pre-Cambrian biology, geology, and thermal evolution emerges and one can relate it to the standard view. This involves topics like faint Sun paradox, the mechanism of Great Oxygenation Event, understanding the TGD counterparts of supercontinents Rodinia and Pannotia preceding CE, snowball Earth, and CE that led to a sudden emergence of highly advanced multicellulars.

Also a more detailed view of what happened in the Cambrian explosion induced by the increase of the radius of Earth by factor 2 emerges (in the TGD Universe, a smooth continuous cosmological expansion is replaced with a sequence of short lasting and fast expansions). One ends up with a detailed model for the phase transition leading to the increase of the Earth radius. This phase transition requires a considerable energy feed provided by the phase transition thickening monopole flux tubes of the magnetic body of Earth and liberating energy. In analogy with the recent Mars, pre-Cambrian Earth had a solid core analogous to the inner core. In the phase transition to a liquid outer core with much larger volume. Part of the newly formed outer core could in turn have transformed to form a part of the mantle increasing its thickness.

I also discuss the empirical support for the Expanding Earth hypothesis that I have become aware of quite recently.

1. There is empirical support for the view that the oxygenation of oceans did not occur before CE. This conforms with the prediction that oxygenation was due to photosynthesis in underground oceans. TGD provides the new physics needed: dark photons from either Earth's core or Sun could have provided the metabolic energy making photosynthesis and therefore oxygenation possible.

2. Anomalously high recession velocities for the tectonic plates during CE have been observed and could be due to the radial expansion of the Earth lasting about 30 million years which corresponds to the duration of Cambrian explosion. A quantitative estimate for the expansion velocity gives an estimate consistent with the findings. Cambrian explosion would correspond to quantum tunnelling in astrophysical scale and involve "big" state function reductions and a temporary change of the arrow of time. The change of the arrow of time in scale of 30 million years could even allow to understand the plant fossils with age about 600 million years conflicting with the fact that the Cambrian explosion (CE) occurred about 540 million years ago.

3. The finding that the mantle-core boundary looks like a seafloor having even mountains has a rather convincing explanation in terms of the subduction of tectonic plates, which sink to the mantle. This however inspired the question whether life in underground oceans as porous structures containing water in some exotic form, most naturally the fifth phase of water studied by Pollack playing a key role in the TGD inspired view of biology, could make possible the needed thermal and chemical isolation. Pollack effect could provide this isolation and is certainly needed even if the temperature of the underground ocean is not far from the physiological temperature.

   Assuming that the Sun was faint so that the temperature at the surface of Earth was below the freezing point, one ends up with conflict with the isotopic determination of the temperature giving a temperature of oceans slightly higher than the temperature 38 C above which marine invertebrates cannot survive. The temperature about 30 degrees allows life but this requires a slightly lower amount of O^{18} isotope than prevailing in the recent oceans. The paradox can be solved if the warm water originated from underground oceans and mixed with the non-oxygenated water (or actually ice) at the surface of Earth so that the isotopic fraction was reduced. The optimal situation for life would have been at depths of order kilometer and one can say that life had no other option than developing underground.

1 Introduction

In this article I continue to develop the TGD version of the Expanding Earth hypothesis [L2]. More detailed views of the pre-Cambrian biology, geology, and thermal evolution of Earth and of what happened in the Cambrian explosion induced by the increase of the radius of Earth by factor 2 will be discussed.

The Expanding Earth Hypothesis (EEH) is discussed in various articles [L9, L5, L13].

1. Cosmic expansion according to general relativity (GRT) predicts that astrophysical objects should expand smoothly. This does not happen. In the TGD Universe, the expansion would be basically a quantum phenomenon and take place in rapid jerks and such a jerk would have induced Cambrian Explosion (CE).

2. Expandng Earth Hypothesis (EEH) statrd that the radius of Earth increased rather rapidly by a factor of about two in Cambrian Explosion (`https://cutt.ly/x2zaWAe`) (CE) that started about 541 million yours ago and lasted about 13-25 million years.

1.1 Vision of the evolution of life on pre-Cambrian Earth

The recent view of pre-Cambrian era has problems. How to solve faint Sun paradox (`https://rb.gy/mfhavz`): was some additional source of energy present and heat the surface of Earth to make liquid water possible? What happened in Great Oxygenation even (GOE) (`https://cutt.ly/K2jAxV9`)? Did deep oceans really exist? Did Snowball Earth (`https://rb.gy/qkoiah`) precede Cambrian Expolosion (CE) ()`https://cutt.ly/x2zaWAe`)? What happened in CE?

TGD view of EEH leads to a vision of how underground oceans could have served as seats for highly evolved photosynthesizing life, which bursted to the surface and formed the recent oceans.

1. Life would have evolved in underground oceans shielded from meteoritic bombardment and cosmic rays. The radius of Earth increased rapidly by a factor of about 2 during the Cambrian explosion (CE). The multicellular life utilizing photosynthesis bursted to the surface of Earth and formed recent oceans.

   There would have been no oceans before the CE. Hydrothermal vents could have existed. The possible lifeforms were very simple bacteria, which photosynthesized using H_2S since there was now water and oxygen.

   Earth was like Mars now: Mars has no oceans and no oxygen. There are indications of underground reservoirs of water and signs of simple life forms.

2. Highly developed multicellular animals and photosynthesizing algae bursted to the surface. Note that algae are responsible for the production of most oxygen also in the recent oceans. If hydrothermal vents contained sulphur based life it disappeared because the generation of the basic building blocks of biomolecules was too slow.

   Interestingly, the radius of Mars is roughly 1/2 of that for Earth. Could Mars have underground oceans teeming with life? When does the radius increase by factor two?

3. There is however a problem. How is photosynthesis possible underground? It is dark there! The basic proposal is that solar photons with energies in the visible and possibly infrared range arrive as dark photons along monopole flux tubes, which extend above the Earth and carry dark matter. The strength of the magnetic field would be about .2 Gauss and fraction 2/5 of the nominal value of the Earth's total magnetic field involving also a non-monopole part.

4. Also dark photons from the interior of Earth propagating along the flux tubes or associated with them could have served as an energy source. The temperature in the Earth's inner core (with radius about 20 percent of the Earth's radius) corresponds to about 5,500 K, which corresponds to a thermal energy scale of about .55 eV, which corresponds to the nominal value of the metabolic energy quantum.

   The energy at the maximum of the energy distribution is roughly 3 times larger than this energy and would be around 1.65 eV. The energy at the maximum wavelength of thermal energy distribution is 5 times higher and about 2.75 eV, which is the upper bound for the energy range 2-2.75 eV of visible photons.

   If the temperature of the inner core before CE has not differed appreciably from that now, which could hold true if the inner core was already before CE in the expanded state as also water containing regions, the idea about dark photons from the inner core as a metabolic energy source, which would make possible the evolution of photosynthesis in underground oceans, makes sense.

1.2 A model for the phase transition increasing the radius of Earth by factor 2

The idea about relatively fast growth of the Earth radius by factor 2 (during 13-25 million years) raises the eyebrows of standard physicists. How can such a large change of density make sense? It seems safe to exclude the possibility that the mass of Earth has increased roughly by a factor of 8 (mass should have arrived from dark magnetic flux tube structure to which the core of Earth is associated as a tangle). It must be admitted that the question of how this scaling could have occurred has remained poorly understood.

In this article, a model for how this scaling could have occurred is proposed. The key question that I was not previously aware of, relates to the energetics. Where did the required energy compensating for the decrease of the gravitational binding energy and providing the energy required by the expansion come from? Some new physics seems to be necessary.

In the TGD framework, the quantum phase transitions of the magnetic body (MB) increases the thickness of the flux tubes and reduce their string tension determined by Kähler magnetic energy and volume energy (to which a hierarchy of values of cosmological constant can be assigned). This leads to a liberation of energy and this energy feed could have made possible to induce ordinary phase transitions requiring energy.

The analogy between recent Mars and pre-Cambrian Earth suggests that the Earth had only a single core analogous to the recent inner core which is solid and consists mostly of Fe and Ni. The most natural phase transition would have transformed part of this core to the outer core which is liquid and has a smaller density and has also lower temperature. This could have forced at least the horizontal expansion of the mantle. The thickness of the mantle could have increased in a further transformation of the newly formed outer core to mantle or transfer of material from the outer core to the mantle.

In this article I continue to develop a more detailed TGD version of the Expanding Earth hypothesis explaining Cambrian Explosion (CE). In earlier articles [L2, L9, L18] a rather detailed view of the pre-Cambrian biology, geology, and thermal evolution is developed and one can relate it to the standard view. This involves topics like faint Sun paradox, the mechanism of the Great Oxygenation Event, understanding the TGD counterparts of supercontinents Rodinia and Pannotia preceding CE, snowball Earth, and CE that led to a sudden emergence of highly advanced multicellulars.

Also a more detailed view of what happened in the CE induced by the increase of the radius of Earth by factor 2 emerged in [L18] (in the TGD Universe, a smooth continuous cosmological expansion is replaced with a sequence of short lasting and fast expansions). One ends up with a detailed model for the phase transition leading to the increase of the Earth radius. This phase transition requires a considerable energy feed provided by the phase transition thickening monopole flux tubes of the magnetic body of Earth and liberating energy. In analogy with the recent Mars, the pre-Cambrian Earth had a solid core analogous to the inner core. In the phase transition to a liquid outer core with much larger volume. Part of the newly formed outer core could in turn have transformed to form a part of the mantle increasing its thickness.

In this article I discuss the empirical support for the Expanding Earth hypothesis that I have become aware of quite recently.

1. There is empirical support for the view that the oxygenation of oceans did not occur before CE. This conforms with the prediction that oxygenation was due to photosynthesis in underground oceans. TGD provides the new physics needed: dark photons from either Earth's core or Sun could have provided the metabolic energy making photosynthesis and therefore oxygenation possible.

2. Anomalously high recession velocities for the tectonic plates during CE have been observed and could be due to the radial expansion of the Earth lasting about 30 million years which corresponds to the duration of CE. A quantitative estimate for the expansion velocity gives an estimate consistent with the findings. CE would correspond to quantum tunnelling in astrophysical scale and involve "big" state function reductions and a temporary change of the arrow of time. One could even understand the plant fossils with age about 600 million years conflicting with the fact that the CE (CE) occurred about 540 million years ago.

3. The finding that the mantle-core boundary looks like a seafloor having even mountains has a rather convincing explanation in terms of the subduction of tectonic plates, which sink to the mantle. This however inspired the question whether life in underground oceans as porous structures containing water in some exotic form, most naturally the fifth phase of water studied by Pollack playing a key role in the TGD inspired view of biology, could make possible the needed thermal and chemical isolation. Pollack effect could provide this isolation and is certainly needed even if the temperature of the underground ocean is not far from the physiological temperature.

   Assuming that the Sun was faint so that the temperature at the surface of Earth was below the freezing point, one ends up with conflict with the isotopic determination of the temperature giving a temperature of oceans slightly higher than the temperature 38 C above which marine invertebrates cannot survive. The temperature about 30 degrees allows life but this requires a slightly lower amount of O^{18} isotope than prevailing in the recent oceans. The paradox can be solved if the warm water originated from underground oceans and mixed with the non-oxygenated water (or actually ice) at the surface of Earth so that the isotopic fraction was reduced. The optimal situation for life would have been at depths of order kilometer and one can say that life had no other option than developing underground.

2 A possible view of the expansion of Earth?

The most natural TGD inspired guess is that a phase transition at the level of MB, increasing flux tube thickness, induces a phase transition at the level of ordinary matter by providing energy in the case that it requires energy. There are several questions to be answered.

2.1 Did the inner core participate the expansion?

Did the inner core (`https://cutt.ly/P2jSljB`) participate in the expansion?

1. Could it be that the outer core emerged and this led to a generation of convective currents giving rise to the Maxwellian part of the magnetic field. The temperature at the boundary of the inner core is the same as the solar surface temperature. Note that in the "standard model" the weak interactions within the mantle are assumed to produce energy.

   The recent radius of the inner core is $R/5$ and so small that there is no need for it to participate in the expansion: one would $4R/5 \to 8R/5$ for the outer and he radius would increase by factor 9/5: not far from 2.

2. Could it be that the outer core with the recent thickness 2400 km emerged in a phase transition transforming the Fe-Li solid of the inner core to Fe-liquid of the outer core so that the inner core could have reduced in size? Was the mantle+crust with recent thickness 2390 km (the recent Earth radius is 2890+2400+1220= 6370 km) scaled in the transition by factor 2 also in the radial direction or only horizontally?

   The scaling of the Earth radius by factor 2 gives the condition

   $$d(mantle, i) + d(inner, i) = (1/2)[d(mantle, f) + d(outer, f) + d(inner, f)] \ .$$

   One has $d(mantle, f) = 2890$ km, $d(outer, f) = 2200$ km, $d(inner, f) = 1220$ km.

   (a) If the mantle thickness was scaled by factor 2 ($d(mantle, i) = d(mantle, f)/2$), one has $d(inner, i) = 1810$ km, which is larger than 1220 km as required. For this option the initial value of the mantle thickness could have been small and the thickness of the inner core correspondingly larger.

   (b) The second option is that the newly formed outer core partially transformed to mantle and increased its thickness so that no radial scaling of the mantle was needed. This option is perhaps the most plausible one.

   (c) For the no-scaling option ($d(mantle, i) = d(mantle, f)$) one would have $d(inner, i) = 365$ km, which is suspiciously small and smaller than 1220 km. Therefore the scaling of the mantle thickness is the more realistic option.

2.2 How the outer core was formed?

What happened in the formation of the outer core?

1. The proposal is that regions of dark water with an increased value of $h_{eff} = h_{gr}$ were generated in the mantle. Inside these regions photosynthesis occurred using the dark photons carrying metabolic energy from the inner core and outer core. The range of energies is the same as in the radiation from Sun [L13].

2. Did the expansion of the volume force a formation of underground oceans in mantle containing dark water, which then bursted to the surface? Was the formation of oceans necessary? Were dark matter blobs enough? Did they condense to form larger dark water volumes, which eventually bursted to the surface?

3. The material in the core of Earth derives basically from chondrites, which contain water and also organic molecules. This suggests that the water of the underground oceans in the mantle derives from the chondrites and that the presence of the basic biomolecules in chondrites was essential for the evolution of life inside Earth.

4. In the case of water, superionic ice [D2] (`https://cutt.ly/uXUIkUQ` and `https://cutt.ly/3XUIWhX`) existing at extreme pressures is a possible candidate for the exotic phase of water. Superionic ice is proposed to appear in the mantles of giant planets such as Uranus and Neptune and in [L9, L5] the possibility that it could occuring the Earth's mantle was considered. The density of superionic ice is slightly less than 4 times the density of ordinary ice.

   Could superionic ice in the mantle have transformed to dark water with a volume larger a factor $4^{2/3}$. This would have contributed to the increase of the volume of the mantle. Note that the transition could have led to expansion only in horizontal directions increasing the 2-dimensional volume by a factor 4.

5. One can compare the situation with that in recent Mars. For Mars, the inner and outer core are one and the same thing so that the situation corresponds to that in pre-Cambrian Earth. Also the radii were nearly the same.

   On Mars, the temperature at the surface of the core is about 2000 K ($E = .21$ eV). If the temperature for the pre-CE Earth was the same, the temperature of the core came 1.5 times higher and inner core 2.5 times higher in the phase transition. This could be understood if energy was liberated in the thickening of the flux tubes.

2.3 The energetics of the transition

What can one say of the energetics of the phase transition?

1. Expansion requires energy. Where did the energy come from? The fraction of gravitational energy Earth from its mass is of the order of $GM/R \sim 10^{-9}$ and its reduction in the expansion was of the same order of magnitude 10^{-9}. Energy was needed to induce the expansion. Also the reduction of the average density and the increase of temperature required energy. Where did the energy come from? Did it come from the increase of the flux tube thickness reducing string tension?

2. Magnetic and volume energy should have been liberated in the model based on the thickening of cosmic strings or flux tubes. Generation of ordinary matter or a phase transition for an ordinary matter can be imagined.

   The liberated energy could have driven the expansion as an explosion. Also the heating of the matter would be an outcome.

3. The increase of h_{gr} by a factor 2 is one option that one can imagine. The reduction of the quantized velocity parameter β_0 by factor 1/2 could have happened $\beta_0 \to \beta_0/2$? This process should have had as a counterpart ordinary phase transition liberating energy.

One can consider two options for the phase transition at the level of the MB. The first option would correspond to a thickening of cosmic string to monopole flux tube and second option to that of an already thickened cosmic string. A more realistic mechanism involves the expansion of an already thickened flux tube with much smaller liberated energy. Factor of order 10^{-9} is enough.

1. The phase transition for the ordinary matter would have been induced by a phase transition at the level of the MB of the system involving thickening of the flux tubes. The ordinary matter would have been in the form Fe and Ni inside in the inner core.

2. The ordinary phase transition could have been melting of the inner core at its outer surface so that it would have gradually generated the outer core as a liquid layer between outer and inner cores. The process would still continue.

   Temperature would have increased in the melting from 2000 K to about 5000 K in the inner core and from 2000 K to 3000 in the outer core. The energy liberated in the thickening of the flux tubes would have provided this energy.

   The expansion of the core and the liberated energy would have driven the expansion of the volume above the contracting inner core. This process could have also forced the expansion of the outermost layer with recent thickness about .444 R_E. It is also possible that the newly formed outer core transformed partially to mantle so that no radial expansion of the mantle was not needed.

3 TGD view of the pre-Cambrian era

In the sequel a TGD view general view of pre-Cambrian era is proposed followed by a discussion as a series of questions. The basic idea is to take the recent Mars as a guideline in attempts to understand pre-Cambrian Earth.

3.1 A rough overall view of pre-Cambrian era

The recent view of pre-Cambrian era has problems. How to solve faint Sun paradox (`https://rb.gy/mfhavz`): was some additional source of energy present and heat the surface of Earth to make liquid water possible? What happened in Great Oxygenation even (GOE) (`https://cutt.ly/K2jAxV9`)? Did deep oceans really exist? Did Snowball Earth (`https://rb.gy/qkoiah`) precede CE?

3.1.1 Energetics during the pre-Cambrian era

The basic assumption is thermal flow equilibrium in which the energy from the Sun is temporarily stored and leaves the system in time determined by the planet. In the TGD framework, the flow of energy from the interior of Earth forces us to challenge this picture.

1. The total energy flux from the Sun would have been by a factor 1/4 smaller than now although local flux would have been the same. One can wonder whether this had some implications. If the biosphere is controlled by MB having quantum coherence in the scale of Earth, this might be the case. As a matter of fact, during CE the phase transition generating inner core would have feeded energy liberated in the thickening of flux tubes of the MB of Earth to also to the surface of Earth. Inner core and core could have also served as source of metabolic energy for the photosynthesizing life forms in underground oceans [L13].

2. Solar energy input and reradiation of energy by greenhouse gases storing the energy temporarily. Oceans bind 90 percent of the solar energy in the recent Earth. In the TGD framework, oceans would have been absent during the pre-Cambrian era and could not have stored energy in large scales so that the situation would have been similar to that in recent Mars. This would explain why multicellular life was virtually absent during pre-Cambrian period.

   Lakes and small oceans could have been present and the energy from the Earth interior could have warmed them. Also volcanic activity could have transferred energy to the Earth's

surface as it does also nowadays. Reradiation would have been missing unless greenhouse gases were present locally.

3. Sunlight absorption depends on various factors. The spin of Earth and the tilt of the orbit with respect to the rotation plane affect the absorption in the time scale of $10^4 - 10^5$ years. Milankovitch cycle for the ice ages relates to this dependence.

   The duration of the Carbon cycle corresponds to millions of years. Also weathering and volcanic activity affect the absorption. Greenhouse gases are an important factor on recent Earth. Also the distribution of continents affects the absorption (`https://cutt.ly/62jSQSU`).

3.1.2 The atmosphere of Earth before CE

What about the surface pressure before CE?

1. Pressure is determined by the concentrations of molecules and atoms in the atmosphere. The abundances of O and N were small before CE: the situation could have been as in Mars today.

2. The composition of the Earth's earliest atmosphere is not known with certainty. Present nitrogen, N_2, and carbon dioxide, CO_2, which are also the predominant nitrogen- and carbon-bearing gases produced by volcanism today. These are relatively inert gases.

   The leakage of molecules in CE Earth was not as intense as in Mars today since the gravitational field was 10 times stronger than in Mars. Leakage partially explains low surface pressure if the production of gases has roughly the same rate.

3. It is interesting to compare the percentages of various gases in the recent Earth and recent Mars .

   In the recent Earth: the fractions of N and O are 78 % and 21 % respectively. The variation of Oxygen fraction is between 10 and 35 per cent during the last 541 million years (`https://cutt.ly/22jSUzR`).

   In recent Mars the fractions of CO_2, N and O are 96 %, 1.9 %, and .15 % respectively. The partial pressure of Oxygen present in the Martian atmosphere is $pO = .95 \times 10^{-2}$ atm which corresponds to the value of pO in the beginning of the second stage of GOE at Earth.

   Recent Mars could give some hints of the situation in CE Earth. CO_2 or other greenhouse gases should have been present. Also methane CH_4 was prosent. These gases could have been produced in the interior of Earth as in Mars and responsible for the warm Earth.

4. Ideal gas approximation gives the estimate $P = nT$. Hydrodynamic equilibrium requires that the pressure gradient is equal to gravitational force density, which determined by the density of the atmosphere and by the strength of the gravitational field, which was 4 times stronger for pre-Cambrian Earth according to TGD. Note that the gravitational energy of protons in the Earth's gravitational field is of order 1 eV and twice the nominal value .5 eV of the metabolic energy quantum [L12].

   The transfer of oxygenated fluid from underground oceans would have made oxygenation possible in pre-CE Earth. This would have caused local oxidation of iron without deep oceans.

5. The climax of the GOE caused be accelaring expansion of Earth corresponds CE. Before GOEs there is a slow oxygenation, which in the standard model is assumed to be caused by the photosynthesis of cyanobacteria. What really happened during CE is a mystery as is also CE. In the TGD framework, the underground oceans would played a key role. Also cyanobacteria could have emerged from the underground oceans.

3.1.3 Maybe deep oceans are not necessary?

According to the Wikipedia article (`https://cutt.ly/K2jAxV9`), the end of the deposition of banded iron formation at 1.85 billion years ago is interpreted as marking the oxygenation of the

deep ocean. Banded iron formation largely disappears from the geological record at 1.85 billion years ago, after peaking at about 2.5 billion years ago. Banded iron formations can form only when abundant dissolved ferrous iron is transported into depositional basins, and an oxygenated ocean blocks such transport by oxidizing the iron to form insoluble ferric iron compounds.

But are deep oceans really needed? One can compare the situation with the situation in recent Mars. Mars is red and contains oxidized iron.

1. Rivers and water flow at its surface and there are no deep oceans in the recent Mars. The simplest assumption is that the situation could have been the same always. This applies also to the existence of the Maxwellian part of the magnetic field requiring an inner core.

   Although the Martian atmosphere has a low Oxygen content, the iron rich material is oxidized in presence of water and develops rust giving the color red. Also in Mars, band iron formations consisting of non-oxidized iron and dating to times before the beginning of Martian GOE, should exist. The flow of a non-oxygenated water could have transported ferrous iron to the depositional basis.

2. The amount of oxygen in the Martian atmosphere is very low but he oxygenated water percolating from the underground oceans could induce the oxidation of iron. The same mechanism could be at work on the early Earth. The beginning of the oxygenation would correspond to the emergence of oxygen based life forms to the underground oceans.

3.2 Comparison with the recent Mars

The resemblances between Mars `https://cutt.ly/s2jAOFJ` and pre-Cambrian Earth according to TGD inspire the question whether the recent Mars could be like the pre-Cambrian Earth after the initiation of GOE. Could one use these resemblance to understand pre-Cambrian Earth in the TGD Universe.

1. For Mars the radius and distance from the Sun are $R = .53 \times R_E$ and $d = 1.523AU$. Similar tilt of a rotation axis.

   The mass of Mars is $M = .107M_E$ so that the surface gravitation is .38 g. For pre-CE Earth surface gravitation is roughly 10 times stronger.

2. Surface temperatures in Mars vary from 20 C to -153 C at poles. The average temperature is -62 C. The temperature drops rapidly with height and with the time of day since the atmosphere is very thin and cannot store heat energy. The ratio of energy fluxes to Mars and Earth is equal $d/d(Mars) = .43$ so that there is no big difference between Mars and Earth.

3. Surface pressure at Mars is $p(Mars) = 0.0628$ atm which is 6.3 % of the pressure $p(Eart) = 1$ atm.

   The Martian atmosphere contains 0.174 % Oxygen and 2.8 % Nitrogen. At the Earth, the corresponding abundances are 29 % O and 78 % N. Oxygen partial pressures for Oxygen is $pO(Mars) = 0.01$ atm. There are active sources of gases, such as methane, in the interior of Mars.

4. On Mars there are no oceans and continents are absent. If Earth is like Mars, the oceans could have been absent also on Earth. Instead of them small lakes and rivers could have been present as in the recent Mars. They would have contained oxygenated water from oceans inside the Earth interior, where photosynthesis was producing oxygen. Continents would have been absent so that the existing vision about the history of the continental drift before CE, should be obsolete albeit natural if one assumes that the radius of Earth has always been the recent one.

5. Could Mars be experiencing the analog of GOE? During the second stage of the Great Oxidation Event (GOE) (see the picture `https://cutt.ly/d2jAEd3` in Wikipedia article `https://cutt.ly/K2jAxV9`), the oxygen content of the atmosphere gradually increased during period 2.45-.84 Ga to values of .02 and .04 atm but it is assumed that Oxygen was

absorbed by the oceans and seabed rock. During the third stage of GOE, the oxygen content did not change. It is assumed that the oxygen started to gas out from oceans but was absorbed by land surfaces. At the fourth state of GOE, CE occurred and the oxygen content increased rapidly to the recent 21 per cent.

The recent value $pO(Mars) = 0.01$ atm is below .02 atm at the end of the second phase of GOE but would correspond to the value of $pO \simeq .01$ on Earth in the beginning of the secon state of GOE. Could it be that GOE on Mars has begun? The naive guess is that there is still 2.45 Gy to the recent situation on Earth.

6. The interior of Mars consists of a crust, a mantle consisting of silicates and a solid metal core consisting of Fe and Ni as the solid inner core of Earth. Crust has a typical thickness of 50 km, which is not far from that on Earth.

   There is no liquid outer core, which in the case of Earth is responsible for the convective ionic currents creating the Maxwellian part of the magnetic field (note that the monopole part needs no source). In Mars the magnetic field is indeed absent in large scales. Martian Auroras have been observed however. In the TGD framework, this suggests that only the dark part of the Martian magnetic field has a considerable strength whereas the Maxwellian part is very small.

   This suggests that in the case of Earth the emergence of the Maxwellian part of the magnetic field made possible the shielding of life against cosmic rays and that life did not have any other option than to evolve in the womb of Gaia.

7. For the recent Earth, the volume fraction of the outer core of Earth 16.5 %. The outer core carries the convective currents giving rise to the Maxwellian part of the magnetic field of Earth. The inner core however feeds heat energy to the outer core and has a considerable effect on its dynamics. This conforms with the idea that the inner core serves as a source of heat energy.

8. The temperature $T = 1900 - 2000$ K at the boundary of Martian core corresponds to a thermal energy $\simeq .2$ eV, which is below the metabolic energy quantum .5 eV.

   On the recent Earth, one has $T = 3000$ K (.3 eV) at the upper boundary of the outer core and $T = 5000$ K (.5 eV) at the upper boundary of the inner core: the latter is the temperature at the surface of the Sun. These observations lead to the proposal [L13] that the energy feed from the inner and outer cores, realized as dark photons, could have served as a metabolic energy source for the evolving life in the underground oceans. Also the solar photons might have transformed into dark photons propagating along the flux tubes of the monopole part of the Earth's magnetic field to the interior of Earth. One can even ask whether this mechanism might be still at work at polar regions of Earth covered by ice or at the bottom of oceans.

There is now a considerable evidence that ancient Mars has had lakes or even oceans see this). Could underground life in Mars bursted much earlier to the surface of Mars?

1. The average density of Mars is near to that of recent Earth (mass is .1 Earth masses and radius roughly 1/2 of the Earth radius R_E). This leads to the question of whether Mars has already experienced a similar transition increasing its radius by 1/2 and density by factor 8? This would have brought the possible underground water to the surface. Later the water would have been lost. Mars would not have been as lucky as Earth.

2. The objection is that Mars has no plate tectonics, which should have emerged in the rapid expansion. The alternative option that I have discussed earlier is that Mars is still waiting for the expansion to take place. Intriguingly, Mars has the same radius as Earth before the Cambrian explosion. The ancient presence of oceans/large lakes does not support this view. One might however think that the water from underground oceans leaks to the surface and forms lakes and even shallow oceans.

3.3 Some questions related to the pre-Cambrian period

Pre-Cambrian period Cambrian explosion (CE) are not well-understood and there are several paradoxical aspects involved.

3.3.1 Why so few multicellular fossils from pre-Cambrian period?

There is very little evidence for multicellulars from pre-Cambrian period whereas fossils of monocellulars (cyanobacteria) exist. The oldest multicellular fossils are 1.2 billion years old. Multicellular fossils with an age of 600 million years and thus preceding CE, which began 541 million years ago have been also found (`https://cutt.ly/d2jAgzb`).

The multicellular organisms preceding CE are much simpler than plants and animals that emerged in CE. The standard explanation for the nearly complete absence of multicellular fossils is that they have disappeared almost completely because they had no hard parts. What is however very strange is that suddenly the fossils of rather complex multicellulars emerge suddenly in CE [I7].

3.3.2 Questions related to energetics

The first questions relate to energetics.

1. Faint Sun paradox means that solar radiation was only 70 per cent from the recent temperature. The Earth surface was however warm since liquid water existed. Could Earth's interior have served as a source of heat energy? This seems to require new physics.

2. In the TGD framework one can ask whether a quantum phase transition proceeding at the level of MB (MB) of Earth could have induced ordinary phase transition at the level of ordinary matter, say solid-liquid phase transition of the Fe-Ni at its boundary giving rise to the outer core. This would have made convective charged currents generating the Maxwellian part of the magnetic field of Earth providing a shield against cosmic rays. This kind of induction of ordinary phase transitions by quantum phase transitions could be crucial for the evolution of life [L12, L11].

3. Could the energy liberated in the phase transition of the MB increasing the thickness of the flux tubes have driven this solid-liquid phase transition and have also feeded heat energy to the surface of Earth increasing the temperature. Also the increase of the gravitational potential energy in the increase of the radius by factor 2 requires a lot of energy.

   Note that nuclear physics cannot be involved with the energy production. Basic stable isotopes of Fe and Ni have atomic numbers 56 and 58. Ni has also A= 60, 61, 62, 64 as stable isotopes. Fe has stable isotopes with A=54,57,58 besides A=56. Ordinary nuclear processes cannot transform Ni nuclei Fe nuclei and new physics is needed.

3.3.3 Did large oceans really exist?

The existence of oceans covering most of the surface of Earth is assumed in the standard view of pre-Cambrian period. But did Earth have oceans at its surface before CE?

1. Could it be that the situation before CE was like in the recent Mars. This plus the assumption that the radius of Earth was only 1/2 of the recent radius would totally change the views about pre-CE Earth both biologically, geologically, and thermodynamically.

2. The simplest working hypothesis is that plate tectonics was not present before CE. Standard view (`https://cutt.ly/I2zf8v8`) however is that roughly 750 million years ago, the earliest-known supercontinent Rodinia, began to break apart.

   Did the breaking apart of Rodinia initiate the expansion of Earth, which gradually accelerated? If so, the area covered by the analogues of oceans between continents was much smaller than on the recent Earth. The narrow fissures would have contained water which had bursted from the underground oceans and brough multicellular life forms.

   The analogues of continents would have later recombined to form Pannotia 600–540 Ma. Did the expansion involve a pulsation leading to the formation of Pannotia, which then split again to continents separated by narrow analogs of oceans. The multicellular lifeforms giving rise to 600 Ma old fossils could have emerged from underground oceans in the breaking apart of Pannotia.

3.3.4 Snowball Earth hypothesis from TGD point of view

The assumption is that snowball Earth dating back to 650 Ma, involving several large scale glaciations, preceded CE. The Earth would have suffered a global glaciation but evidence exists only for local glaciations.

What could be the TGD counterpart of the snowball Earth? Milankovitch cycles (`https://cutt.ly/12zkeoF`) with a period of order 100,000 years were present and could have caused local glaciations explaining the observed glaciations. The two large scale glaciations associated with snowball Earth could relate to the expansion of Earth. Did the glaciation take place for the oceans defined by the narrow fissures between the analogues of continents formed in the splitting of Rodinia?

3.3.5 The Great Oxygenation Event

The Great Oxygenation Event oxidized the atmosphere and made oxygen based life possible at the surface of Earth.

1. The oxygen content of the atmosphere and assumed oceans was very low before CE and could not support oxygen based life. During the Great Oxygenation Event (GOE) (see the Wikipedia article (`https://cutt.ly/K2jAxV9`), which started for about 2.45 Gy ago, the oxygenation of atmosphere proceeded very slowly (see the Wikipedia picture `https://cutt.ly/d2jAEd3`).

   In CE (CE) the oxygen content of the atmosphere increased very rapidly to the recent level of about 21 per cent. The oxidation is made manifest by the observed layers of oxidized iron. The absence of oxygen for more than 2.45 Gy ago is demonstrated by layers of iron based compounds, which are not oxidized.

2. Usually it is assumed that the oceans were present during the pre-Cambrian period and that the sea water was oxidized gradually. On Mars the situation is however different. There are local sources of oxygenated water such as lakes and rivers but no oceans. There is also evidence for underground life on Mars.

   Could the situation on Earth have been like in Mars during the pre-Cambrian Earth? Could the underground oceans, serving as a kind of womb shielding the evolving life from meteoric bombardment and cosmic rays, have made possible the evolution of the photosynthesizing life and multicellulars producing oxygen, which bursted to the surface of Earth in CE?

3. Suppose that the water from the underground oceans, containing highly developed multicellulars, bursted to the surface during the GOE. What could be the time scale of the process? Was GOE implied by this process and did it accelerate during CE? Did this increasing rate of bursts lead to oceans of increasing size so that the scale of glaciations was dramatically increased during the last two glaciations before CE.

3.3.6 Was CE a quantum phase transition in Earth scale?

The TGD view of CE explains the sudden appearance of multicellulars and also implies that the gravitation would have been 4 times stronger before CE so that the possible lifeforms surviving at the surface of Earth are expected to have a flat shape. The reduction of surface gravitation after CE in turn could in turn explain the emergence of giant plants and animals.

In the TGD framework the evolution of life would have involved quantum criticality and quantum phase transitions closely related to ordinary criticality and phase transitions [L11]. CE would be naturally a quantum phase transition in the scale of Earth involving in an essential manner gravitational Planck constant h_{gr} making possible dramatic reduction of gravitational binding energy in the scaling up of Earth radius by factor 2.

In the TGD framework the standard ontology of quantum theory is replaced with zero energy ontology (ZEO) solving the basic paradox of the quantum measurement theory [L4, L7, L6, L10].

Interesting questions relate to the proposal that a pair of "big" state function reductions (BSFRs) in astrophysical scales (counterpart for quantum tunnelling) changing the arrow of time was in question. Could one interpret the time reversed classical time evolution after the first BSFR,

that is GOE, as a classical correlate for the pair of BSFR making the process effectively to look like deterministic and smooth classical process [L3] [L3]?

3.3.7 oxygenation of oceans did not precede Cambrian Explosion as TGD strongly suggests and empirical study concludes

There was an interesting article in Futurism about the findings challenging the basic assumption related to the origin of life (`https://futurism.com/the-byte/textbooks-wrong-origin-life`). The research article "Widespread seafloor anoxia during generation of the Ediacaran Shuram carbon isotope excursion" [I2] can be found at
urlhttps://onlinelibrary.wiley.com/doi/10.1111/gbi.12557.

On the basis of empirical evidence it is claimed that the view of the gradual oxygenation of oceans is wrong. The abstract of the article explains the findings.

Reconstructing the oxygenation history of Earth's oceans during the Ediacaran period (635 to 539 million years ago) has been challenging, and this has led to a polarizing debate about the environmental conditions that played host to the rise of animals. One focal point of this debate is the largest negative inorganic C-isotope excursion recognized in the geologic record, the Shuram excursion, and whether this relic tracks the global-scale oxygenation of Earth's deep oceans.

To help inform this debate, we conducted a detailed geochemical investigation of two siliciclastic-dominated successions from Oman deposited through the Shuram Formation. Iron speciation data from both successions indicate formation beneath an intermittently anoxic local water column. Authigenic thallium (Tl) isotopic compositions leached from both successions are indistinguishable from bulk upper continental crust ($\epsilon^{205}Tl_A \simeq -2$) and, by analogy with modern equivalents, likely representative of the ancient seawater ϵ^{205} Tl value. A crustal seawater $\epsilon^{205}Tl$ value requires limited manganese (Mn) oxide burial on the ancient seafloor, and by extension widely distributed anoxic sediment porewaters.

This inference is supported by muted redox-sensitive element enrichments (V, Mo, and U) and consistent with some combination of widespread (a) bottom water anoxia and (b) high sedimentary organic matter loading. Contrary to a classical hypothesis, our interpretations place the Shuram excursion, and any coeval animal evolutionary events, in a predominantly anoxic global ocean.

The absence of oxygenation before the Expolosion is also the TGD based prediction. The TGD based model predicts that the mysterious Cambrian Explosion in which advanced multicellulars suddenly emerged involved an increase of Earth radius by factor 2 in a geologically short time scale [L2] [L9].

This view conforms with TGD inspired cosmology in which a smooth cosmological expansion is replaced with a serious rapid step-wise expansions, which are essentially quantum phase transitions involving astrophysical quantum coherence scales.

The Earth would have been like Mars now (not much water at surface, even the radius would have been very near to Mars radius) and life would have evolved in underground oceans (being shielded from cosmic rays and meteors), in the womb of Mother Gaia. The evidence for the underground life on Mars is accumulating. The water in underground oceans would have oxygenated by photosynthesizing life and the underground water would have bursted to the surface and give rise to the oxygenated oceans covering most of the Earth's surface since then.

The basic objection is that photosynthesis was not possible. The core of the Earth however produces radiation in the same wavelength range as the Sun and in the TGD framework this could allow the development of photosynthesis [L13]. Now Quanta Magazine article (`rebrand.ly/jbvkwtp`) told that in a research [I3] published last month in Nature Communications, researchers reported that in groundwater reservoirs 200 meters below the fossil fuel fields of Alberta, Canada, they discovered abundant microbes that produce unexpectedly large amounts of oxygen even in the absence of light. Photosynthesis is the standard way to produce oxygen. But how could photosynthesis work underground? This looks like a complete mystery in the standard physics framework.

Whether the interpretation of the article that life evolved in anoxic global ocean is consistent with the TGD view that this oceans was essentially absent, is not of course clear.

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What objections can one invent against the TGD view? The first objection against the TGD proposal is that fossils of complex multicellular life forms have been found with age of 600 million years to be compared with the fossils dating back to 550 years ago when Cambrian explosion could have started. The story of their discovery told in the popular article "How 2 Teens Accidentally Solved Charles Darwin's Most Vexing Problem" (`rebrand.ly/uk0ntuk`) is fascinating.

In 1956, a teenage girl by the name of Tina Negus found a strange looking fossil in Charnwood Forest in Leicestershire, England. The plant fossil should not have been there since the rock was 600 million years old and the Cambrian explosion started roughly 60 million years later. Tina Negus showed a pencil rubbing to his geography teacher but he didn't believe her.

A year later, in 1957, three teenage boys were playing near the same rock face when they, too, noticed the same fossil. One of these teens, fifteen-year-old Roger Mason, found the second fossil. Roger Mason contacted Trevor Ford, a local geologist, who wrote about the finding to the Journal of the Yorkshire Geological Society. The new plant was named Charnia Masoni. Charnia is a genus of frond-like life forms belonging to the Ediacaran biota. Charnia came from Charnwood Forest in Leicestershire, England where Tina Engus found it. Masoni is after Roger Mason.

Does the TGD based view survive these findings? Note first that the Charmia Masoni does not conform with the conclusion that the oceans that possibly existed at that time did not contain oxygen. Furthermore, Charnia Masoni does not change the basic facts: complex multicellular life forms emerged as if from nowhere. The time span from Charnia Masoni fossils about 600 billion years to the beginning of Cambrian Explosion about 538.8 million years ago is about 10 per cent.

Can one explain the finding in the TGD view of the Cambrian explosion?

1. If the surface of Earth did not contain much water before the Cambrian Explosion, one can imagine that water leaked from the underground oceans locally at some places but not everywhere. Instead of oceans, there were oxygenated lakes, where multicellular life forms survived.

2. Another possibility is that the expansion of Earth involves periodic oscillation typical of resonances so that bursts of oxygenated water containing the highly evolved life forms emerged to the surface. I have considered this kind of explanation for the periodic oscillations found to be associated with the Cambrian explosion.

3. One can also imagine that the rock containing the fossil has emerged from the older of a sediment rock a the "bottom" underground water reservoir when a crack was formed in the geologically fast expansion.

There is also indirect evidence for the presence of life about 3.85 billion years ago (`rebrand.ly/ebz2q92`). The interaction of rocks with life forms lowers the C-13 ratio of rocks to a characteristic value serving as a signature for life. Any sedimentary rocks that formed before life appeared on Earth would have the high C-13 ratio of a volcanic origin. The discovery of rocks with the same C-13 ratio that serve as a signature of life support the view that very primitive microbial life existed already at that time. One can consider the possibility that very primitive life forms existed at the surface of Earth. Second possibility is that they leaked from underground oceans. Also in Mars there is evidence for the presence of water and it could have indeed leaked from underground water reservoirs.

3.3.8 Anomalously high rates of tectonic plate motion and the TGD view of Cambrian explosion

The popular Arstechnica article (see this) tells that the motion between plates was surprisingly fast. The rate of the tectonic motion as relative rate for the distance increase between plates was surprisingly fast: even about 4 times the recent one.

The TGD view of expanding Earth relies on the prediction of cosmic expansion as a sequence of fast periods of expansion for astrophysical objects.

1. The model predicts that the tectonic plates were created in rather fast radial expansion of Earth: radius increased by a factor 2. Cracks giving rise plates were formed because rock is not flexible material.

2. The model explains the Cambrian explosion: advanced photosynthesising multicellulars emerged from underground oceans as the oxygenated water bursted to the surface. The TGD view of dark matter allows to circumvent the obvious objections against the model and conforms with the recent surprising findings [L18] (see this) and this).

3. The fast radial expansion caused a fast increase of the distances between plates. The velocity v of this recession would have been $v = dR/dt \times \Delta\Phi$, where $\Delta\Phi$ is the angular distance between the plates and dR/dt is the radial expansion rate.

   The duration of Cambrian Explosion was roughly $\Delta T = 30$ million years. Using Earth radius $R = 6,371$ km, one obtains the estimate $dR/dt = R/\Delta T \simeq 20$ cm/year. v is obtained from this by multiplying with $\Delta\Phi < \pi$. The largest rate mentioned in the popular article is $v = 64$ cm/year. The order of magnitude is correct and the rate would have been higher than the average during the fastest periods.

   The estimate for v must involve a large enough angle $\Delta\Phi$ and a long enough time period so that $\Delta\Phi$ is expected to be a considerable fraction of π. For $\Delta\Phi$ slightly below π, the estimate is exact but this is probably an accident.

4. Note that the predicted contribution to v is always positive and could provide a test for the TGD view.

A fascinating, and admittedly frightening, question, which just now occurred to me, is whether the Cambrian explosion was gravitational expansion analogous to cosmic expansion in which the metric (!) distances between points doubled! This would have required the scaling of the induced metric by a factor about 4. Could this make sense or does it kill the basic idea?

1. In zero energy ontology (ZEO), light-cone proper time a serves in the role of the cosmic scale factor of either half-cone of the causal diamond (CD) having interpretation as empty cosmology. "Big" state function reductions (BSFRs), serving as TGD counterparts of the ordinary SFRs, change the arrow of time and a pair of BSFRs would be behind quantum tunnelling in the TGD Universe.

   In the TGD framework quantum coherence and BSFRs are possible even in astrophysical scales. Could the increase of the radius of Earth be quantum tunnelling be realized as a pair of BSFRs.

2. Can one imagine a local "mini" Big Bang for the CD inside which Earth's space-time surface belongs and a scaling of light-cone proper time a by a factor 2 in astrophysical quantum quantum tunnelling? The value of the light-cone proper time a, characterizing the cosmotemporal position of Earth in a double BSFR, would have increased by factor 2. The spatial scaling by a factor 2 conforms with the p-adic length scale hypothesis stating that p-adic length scales coming as powers of 2 are of special importance.

3. One can try to form a more quantitative view of the situation. Note that the size scale of the initial CD before explosion would be $T/2$, where T is the distance between the tips of the CD would be about 30 million years. The Cambrian explosion occurred about $T_i = 540$ million years ago. If T_i corresponds to the cm of CD, the future tip of the initial CD would be at 570 million years. CD size would be scaled by factor 2 and the end of the cm of CD would correspond to $T_f = 570$ million years.

   The quantum average space-time surface would be replaced by a new one in double BSFR and would be modified already 60 million years before T_f. This time would correspond to 630 million years. As explained, some multicellular plant fossils have been found with an age of about 600 million years. Could this replacement of geometric past explain them?

3.3.9 Does the existence of an underground ocean floor at the mantle-core boundary relate to underground life?

The popular article published in Futurism discussed an unexpected observation by the group led by Samantha Hansen published in Science [D1]. The mantle-core boundary in the Earth's interior contains a layer that looks like the crust of Earth in the sense that the seismic perturbations

propagating through it have an ultralow velocity. There are mountains many times higher than Himalaya! How is this possible? Is this possible in standard physics?

The answer of the article to this question is based on the idea that subduction for continental plates implies that part of them sinks down because they are denser than the surrounding material and gradually gather to form a second sea floor at the mantle-core boundary. To me this idea looks rather plausible but need not be correct.

My first reaction was the question whether this second sea floor could be a genuine seafloor, the seafloor of an underground ocean! Could new physics predicted by TGD make this possible?

1. The basic prediction of the Expanding Earth hypothesis [L18] explaining Cambrian Explosion is that life evolved in underground oceans and bursted to the surface as the radius of Earth increased by factor 2 in a rapid expansion lasting about 30 million years (cosmic expansion would occurred as rapid jerks for astrophysical objects). During the last weeks several strange findings removing the most obvious objections against this vision have emerged.

2. Could these mountains at the core-mantle boundary correspond to mountains of underground ocean floor?

Could the underground oceans have existed and carried life? Could they reside even in the extremely hostile environement at the mantle-core boundary?

1. Underground oceans near the mantle-core boundary boundary could be imagined as a porous structure having water inside pores. Such structures are very common and if Earth's crust is formed from meteorites the water would be present from the beginning. Even biological matter is analogous to porous structure. When stone is heated it becomes a porous structure. Maybe the enormous heat flux from the core could cause porosity. In accordance with the standard vision of self-organization, this could be understood as complexity developing induced by a constant heat flux. Self-organization takes place at boundaries.

2. It is known that huge reservoirs of water exist underground. The boundary between upper and lower mantle at a depth of about 500 km contains a porous structure carrying water (see this). If the size of the pores is large enough, considerably above cell size, advanced multicellulars could evolve in the underground oceans.

It is easy to invent lethal objections in the standard physics framework.

1. The temperature and pressure increase as one goes towards the core. The temperature of pores should be around 40 C for life to survive. Also the pressure should be normal.

2. Consider the crust first. The temperature reaches the values in the range 100-600 C at the crust-mantle boundary. The temperature increase is about 30 C per kilometer in the upper part of the crust and would be about 30 C at the depth of 1 km if it is 0 C at the surface. The underground water reservoirs should not be at depths much larger than 1 km if the standard physics applies and the largest depths would be possible near the poles.

3. In the underground ocean at the boundary of the upper and lower mantle at a depth of about 500 km, the temperature and pressure are quite too high. Temperature of the surrounding solid material varies from 500 K at the lower boundary of the crust to 1200 K at the boundary of upper and lower mantle. Densities would be several times higher than the normal density of water.

4. Temperature at the mantle-core boundary is about 3000 -4500 K and pressure 1.3 trillion times the atmospheric pressure. The density of mantle is by factor about 5-6 higher than the density of crust so that the pressure is really huge since water and solid matter are almost incompressible. Water in ordinary form cannot exist in this kind of environment if standard physics applies.

Could underground oceans allow some exotic phase of water at physiological temperature around 40 C and normal pressure? This is not possible for the water of standard physics. But the water in living matter is not normal!

1. The phase of water discovered by Pollack [?, ?] called fifth phase of water by Pollack himself (also the term "ordered water" is used). Pollack proposed it to be fundamental for life. Gel phases would represent a basic example of this water.

   This phase of water plays a key role in the TGD based model of living matter. The model identifies dark matter based as phases of ordinary matter with non-standard values of Planck constant. The gravitational Planck constant indeed has huge values.

2. The underground life faces the same problem as the biological cell at the surface of Earth: how to isolate itself from the environment. The high temperatures and pressures make the problem orders of magnitudes more challenging. The fifth phase of water surrounding the system could provide the solution in the case of cell membrane and DNA double strand: develop a layer consisting of the fifth phase of water which thermally shields the volume of the ordinary water from the environment at a different temperature.

3. The negatively charged exclusion zones (EZs) generated in the Pollack effect as protons go to magnetic flux tubes as dark protons realizing the dark genetic code, are also able to get rid of various impurities in their interiors. This violates second law in its standard form and suggests that the arrow of time at the magnetic body of EZ controlling its dynamics has a non-standard arrow of time and induces an effective change of the arrow of time for ordinary biomater for long periods of time. This would isolate the system also chemically from the environment.

4. As a matter of fact, it has been discovered that ordinary water in air develops a thin molecular layer at its surface. This layer is neither water or ice and the identification as the fifth phase of water would be suggestive [L14]. This layer could also work at nanoscales and reduce the freezing temperature of the lattice water in materials like concrete to about -70 C. The mechanism could be essentially thermal isolation.

Could thermal isolation work also in high temperature environments, where underground life had to survive?

1. Could the darkness of the ordered water make possible a situation in which the interactions of the water inside pores with the hot high pressure environment are very weak and heat and matter are not transferred between the solid environment and water. Thermal equilibrium would be established very slowly and the temperature could and pressure could be much lower than otherwise for very long periods.

2. Magnetic bodies would carry the dark matter relevant for the biocontrol and would be shielded from the hot environment. They would be gradually heated and this would lead to biological death as it does in ordinary biology according to TGD. Zero energy ontology would however come in rescue and the change of arrow of time would reverse heating to cooling!

3. The unpaired and their chemically non-inert valence electrons of biologically important ions should be dark and reside at the flux tubes associated with very long dark valence bonds. This would generate long range quantum coherence. This would explain why living matter contains these ions although thermal ionization is not possible at physiological temperatures. Also the protons of hydrogen bonds would be dark. Only the chemically inert full electron shells would remain and the system would remain and since be effectively thermally isolated from the hot environment.

   As a matter of fact, electrolytes involve ions and the mechanism of ionization is not actually understood and TGD suggest a mechanism of ionization based on the generation of dark valence electrons and dark protons [L15, L8].

While preparing this text, I learned that the standard view of Cambrian explosion has a problem with the Cambrian ocean temperature.

1. If the oceans existed (not clear in the TGD framework before the Cambrian explosion!), their temperatures should have been around 60 C. Marine invertebrates do not however survive above 38 C.

2. Isotopic estimates for Cambrian phosphatic brachiopods [I4] (see) assuming no post-Cambrian O^{18} isotopic depletion relative to the recent concentration suggests that the temperatures of Cambrian oceans were in the range 35-41 C. This range is above the recent range 27-35 C. Assuming a O^{18} depletion of -3 promille of the early Cambrian sea water relative today, one can get Cambrian temperatures around 30 degrees.

3. The problem now is that the underground oceans should have been very near to the surface (unless one assumes the TGD inspired thermal insulation hypothesis). Faint Sun paradox comes to rescue here. The luminosity of the Sun should have been 30 per cent lower than now so that the temperature at the surface of Earth should have been below the freezing point. This has motivated the snowball Earth hypothesis. The paradox disappears if life evolved in the underground oceans in a warmer environment. The temperature deduced from the O^{18} fraction of fossils should be that for the underground ocean. Furthermore, the faint Sun makes it possible for the underground oceans to be located below 1 km depth without assuming the thermal insulation hypothesis.

4. What could have caused the O^{18} depletion of the Cambrian phosphatic brachiopods? A possible explanation is that there were non-oxygenated water reservoirs (presumably in a form of ice) at the surface of Earth and the oxygenated underground water was mixed with this water. Also the surface of Mars, to which the surface of Earth before the Cambrian explosion is analogous, contains some water.

To conclude, I am not suggesting that life developed at the mantle-core boundary: this might be quite too science-fictive an idea. Pole regions of the crust are the most conservative candidate for the seat of underground oceans. It is quite enough for the purposes of the Expanding Earth model that it developed in underground water reservoirs at depths of a few kilometers. Also in this case the thermal and chemical isolation from the environment could have played a key role. An interesting question is whether the critical temperature range 30-40 C of life could fix the depth for the underground oceans in which life most probably evolved.

3.4 A possible mechanism of radiative energy transfer from the Earth's core to underground oceans near the surface of Earth

The recent observations [D1] strongly suggest that there is an ancient seabed on top of the Earth's core, and there are also mountains with a height of about 10 km. The proposed model, in which convection moves the sea floor to the region above the mantle, is probably correct.

This finding combined with the discovery of the so-called superionic ice [D2], which could exist above the Earth's core, allows to develop a proposal for a mechanism of metabolic energy transfer from the Earth's core to the underground oceans near the surface of Earth. This would make possible the development of photosynthesizing life forms in underground oceans. The generalization of the Pollack effect [I5, L1, I8, I6] would play a key role in the mechanism.

3.4.1 Ultralow velocity zones

The following abstract of the article (see this) published by a group led by Dr. Samantha Hansen [D1] gives an overall view of what has been observed.

Ultralow velocity zones (ULVZs) are the most anomalous structures within the Earth's interior; however, given the wide range of associated characteristics (thickness and composition) reported by previous studies, the origins of ULVZs have been debated for decades. Using a recently developed seismic analysis approach, we find widespread, variable ULVZs along the core-mantle boundary (CMB) beneath a largely unsampled portion of the Southern Hemisphere. Our study region is not beneath current or recent subduction zones, but our mantle convection simulations demonstrate how heterogeneous accumulations of previously subducted materials could form on the CMB and explain our seismic observations. We further show that subducted materials can be globally distributed throughout the lowermost mantle with variable concentrations. These subducted materials,

advected along the CMB, can provide an explanation for the distribution and range of reported ULVZ properties.

So called S waves (see this) are transversal acoustic waves caused by the shear force parallel to the propagation. This force is proportional to viscosity and is negligible in liquids but much larger in solid phase waves reflected at mantle-core boundary. The core of Earth is in a liquid phase. Therefore sound waves from the surface of Earth are reflected back at the mantle-core boundary.

This makes it possible to deduce information from the structure of the mantle-core boundary and it has turned out that it has a highly complex structure. First of all, these waves propagate very slowly. This allows us to conclude that there is a relatively thin layer with a high density, which could consist of the same material as the seabed. This layer contains mountains with heights of order 10 km.

The TGD inspired view of the evolution life, inspired by the Cambrian Explosion and TGD based view of cosmology, is that photosynthesizing life evolved in underground oceans and that the expansion of the Earth radius by about factor 2 bursted these oceans to the surface of Earth in Cambrian Explosion [L2, L9, L5, L18, L17].

Could the ancient seabed above the mantle be assigned to the ocean immediately above the mantle? This is not possible. The existence of an underground ocean immediately above the mantle is impossible due to the high pressure and temperature so that the convection remains the natural explanation for the presence of seabed.

The second objection is that life in the underground oceans is not possible because solar energy needed by photosynthesis is not available. How could photosynthesis have developed in the underground oceans? The key observation is that energies of the photons of thermal radiation coming from the core are of the same order as the metabolic energy currency with nominal value of .5 eV: could this radiation have served as a source of metabolic energy.

How would this energy be transferred? The Pollack effect [I5, L1, I8, I6] and its reversal, whose TGD based understanding [L1, L16, L21, L23, L22] has increased considerably during this year, could provide a fast energy transfer mechanism, but in its standard form the Pollack effect requires liquid water. Could the so-called superionic ice [D2], which has been speculated to be found even near the mantle of Earth, make possible the analogy of the Pollack effect?

3.4.2 Ordinary water cannot survive near mantle

Although it is obvious that ordinary liquid water cannot exist at temperatures and pressures prevailing near the mantle, it is useful to look at the situation more quantitatively.

In mechanical equilibrium, pressure gradient and the gravitational force, expressible in terms of the gradient of gravitational potential, cancel each other in good approximation. One can estimate the change of pressure as $\Delta p = \rho\Delta\Phi_{gr} = \rho GM\Delta(\frac{1}{R})$. The equation of state allows an estimate for ΔT.

Pressure is estimated to increase from 100 MPa at the surface of the Earth to 139 GPa above the mantle, that is by a factor 1000. Temperature, converted to thermal energy $E = kT$, is estimated to increase from .03 eV$\rightarrow$ to 0.42 eV. The increase is by a factor of 10. Ordinary water cannot survive in this kind of environment so that underground water is possible only sufficiently near to the surface of Earth.

Could one imagine a phase of water allowing the analog of Pollack effect so that the transformation of protons to dark protons at the gravitational MB could make it possible to transfer metabolic energy to the higher heights, where underground liquid water can exist. This would have made possible the development of photosynthesizing life and would also solve the "faint Sun" paradox (`https://rb.gy/mfhavz`) [L18] meaning that the solar energy feed was not enough for the metabolic needs of life at the surface of Earth.

3.4.3 Pollack effect for superionic water and metabolic energy feed from the core of Earth

Superionic ice [D2] (see this and this) existing at extreme pressures. The density of superionic ice is slightly less than 4 times the density of ordinary ice. In superionic ice O^{2-} ions form a lattice whereas H^+ ions float freely. This phase is conductor with H^+ ions serving as charge

carriers. Superionic ice is proposed to appear in the mantles of giant planets such as Uranus and Neptune and in [**?**]he possibility that it could occur in the Earth's mantle was considered.

Could water appear as superionic ice above the Earth's core and allow Pollack effect and its reversal so that gravitational flux tubes would carry dark protons. Could dark photons emitted in the reverse Polack effect transfer the energy along gravitational flux tubes to the underground oceans near the surface of the Earth?

Let's assume that there exists superionic ice above the mantle.

1. Could the radiation from the core kick part of the protons of the superionic water to the gravitational magnetic body? The gravitational binding energy of protons at the surface of Earth is about .5 eV and now roughly by a factor 4 larger, that is 2 eV, at the top of the mantle. At the gravitational magnetic flux tubes the reduction of gravitational binding energy is therefore below 2 eV. The temperature of the core corresponds to the metabolic energy currency of about .4 eV so that the radiation could have played the same role as the solar radiation in photosynthesis.

2. If the reverse Pollack effect occurs, dark photons are emitted and they propagate to the MBs of water volumes near the surface of Earth and could provide energy for photosynthesis. Also time reversal can occur for the water near the surface of Earth and the proton can gain the energy required by darkness by emitting a negative energy dark photon propagating to the MB near the mantle. I have called this mechanism remote metabolism or quantum credict card and asked whether it could play a key role also in the ordinary biology.

3. If the temperatures of the lower part of the mantle and the core are the same, the energy input from the core could feed protons to gravitational MB, maintain the superionic water phase and compensate for the energy loss due to the reverse Pollack effect. The transfer of energy near the earth's surface would take place at the speed of light and dissipation would be very small.

4. The number of ordinary-to-dark transitions of protons per unit time determines the energy flow to the MB and the energy flow to the uppermost layers of the mantle. In a steady state, this flow must be the same as the radiative heat flow from the core. This transfer rate is determined by the rate for the photon absorptions kicking protons to the MB. The energy flow of energy coming as radiation is proportional to T^4.

3.5 Did the proposed Expansion of Earth during Cambrian Explosion lead to the formation of Moon?

The discussions related to the Expanding Earth hypothesis stimulated interesting questions. How planets and Moons would have been born in TGD-based astrophysics and could the formation of Moon relate to the Expanding Earth hypothesis explaining also Cambrian Explosion [L18] and whether the gradual growth of Moon's orbit might relate to it?

During the last year, I wrote two articles about the birth of stars and planets and also Moons in TGD Universe last year [L19, L20].

The first basic idea is the fractality of TGD-based cosmology, which follows from the TGD view of space-time as a 4-D surface in $H = M^4 \times CP_2$. Another key idea is the replacement of a smooth continuous expansion with a sequence of fast explosions.

1. The scaled down versios of Big Bang would occur on different scales. For example, a star would produce shells of mass ejected in an explosion that would condense into planets.

2. The planets could also do the same and this would lead to the birth of shells, from these the rings would be born and from these the Moons would be born.

There are many theories about the formation of the Moon. One of them is that for about 4.5 Gy years ago a planet christened as Theia (see this) and having a mass about the mass of Mars collided with Earth and was evaporated in the process, and that the vapour condensed to form Moon. 10-30 percent of Theia's mass formed Moon which is roughly 1 per cent of the mass of Earth and 70-90 per cent of mass contributed to the mass of Earth: this makes less than 10 per

cent of the mass of the Earth. This would have led to the increase of the radius of the Earth and the rough estimate gives that the radius increased by a factor 2. Expanding Earth hypothesis in turn proposes that the radius of Earth increased in Cambrian explosion by factor 2.

The Cambrian explosion is also an explosion. The composition of the Moon is known to be the same as that of the Earth (see this). The crazy question that comes to mind (I can already hear my colleague's laughter in my ears) is whether the Moon was born this way in the Cambrian explosion about .5 Gy ago (instead of 4.5 Gy ago). This of course does not exclude the possibility that Moon was formed in a similar explosion for 4.5 billion years ago.

Can the Cambrian option be ruled out by comparing the ages of the Earth's Moon? Radiometric age determinations give the matter making up the Earth and the Moon (not the Earth or the Moon itself!!) age estimates of 4.543 Gy and 4.46 Gy. The age difference is 80 million years.

1. The age of the material composing Moon has been deduced from the radioactive decay of Zirconium and in the latest determination the estimate increased by 40 million years (see this). This inaccuracy is of the same order as the difference in the ages of the substances! So can the Moon consiste of matter, which has the same radio-active age as the Earth?

   One can also critically ask why the Moon's and Earth's matter would be of different ages when the composition is the same? The most natural explanation would that the substance is the same and therefore of the same age.

2. Radioactive age determinations would therefore not rule out the hypothesis of the formation of the Moon in the Cambrian explosion. In such an explosion, a layer with a thickness of about 6 km would have been thrown out and taken with it both the life on the surface and the fossils if there were any! .5 billion years old fossils would be products of underground life!

Is there any empirical evidence that the age of the Moon *cannot* be on the order of .5 billion years. Is there any evidence for the explosive origin of the Moon? Could one compare Theia hypothesis and the two variants of TGD proposal? Could the dynamics of the Moon-Earth system help here?

1. It is known that the distance of the Moon from the Earth increases slowly: $v = 3.78$ cm per year (see this). Could the recent rate for the increase of the orbital radius be interpreted in terms of cosmic expansion? The Hubble constant is about $H = 70$ km/sMpc, where parsec (pc) is 3.26 ly. This gives for the cosmic recession velocity of Moon $v(now) = HR \simeq 2.8$ cm/y. This is 74 per cent of the observed velocity of increase for the orbital radius. This suggests that the velocity due to the explosion has gradually decreased and is approaching the cosmic recession velocity (, which increases linearly with the distance: this effect has been observed but surprisingly, has not been interpreted in terms of the cosmic recession velocity!).

   Could the deviation $v - v(now)$ be a remnant of the rapid increase in the orbital radius associated with the Cambrian explosion?

2. If Moon was born in about .5 billion years ago and the velocity would have been *constant* $v = 3.78$ cm/y, the Moon would have reached a distance of about 1.9×10^7 m, which is about $2.97R_E$ (three Earth radii) from the Earth and conserably smaller than $R = 60R_E$ so that the speed should have been significantly faster at the beginning.

3. If the Moon was born in such an explosion 4.5 Gy ago, the same rough estimate assuming constant velocity $v = 3.78$ cm/y would give for the distance of the Moon $R = 26.7R_E$, $R_E = 6,357$ km. This is roughly by a factor 1/2 smaller than the recent distance $R = 60R_E$ of the Moon. This option looks more reasonable than the Cambrian option.

   Cosmic expansion cannot explain the increase of the Moon's orbital radius. One would have $dR/dt = HR$ giving the estimate $R(t) = R_E exp(v(now)t/R)$ and $R(now) = eR_E$, which is much smaller than $R = 60R_E$.

4. Could Theia hypothesis explain the growth of the distance of the Moon's to its recent in terms of the recoil momentum gained by the evaporated fragment giving rise to the Moon?

This should have made the orbit elliptic. The orbit of the Moon is slightly elliptic: the eccentricity is .055 (see this). One should also understand the mechanism, which distributed the remaining matter evenly along the surface of the Earth.

What is intriguing from the TGD point of view is that the radius of Earth could have increased by a factor 2 in the collision with Theia. This would explain the findings motivating the Expanding Earth hypothesis if the continents were formed already in the collision with the Theia.

How quickly did the ejected crust condense to form the Moon? Surprisingly, this can happen very quickly. It is estimated that the Moon could have been born within hours after the impact of Thea (see this)!

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