Exploration

Expanding Earth Hypothesis and Pre-Cambrian Earth

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Abstract

In this article I continue to develop the TGD version of the Expanding Earth hypothesis. The key topics are more detailed views of the pre-Cambrian biology, geology, and thermal evolution and of what happened in the Cambrian explosion induced by the increase of the radius of Earth by factor 2. 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. The 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.

1 Introduction

In this article I continue to develop the TGD version of the Expanding Earth hypothesis [4]. 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 [10, 7, 14].

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.

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There would have been no large 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.

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 [14].

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 [2] (`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 [10, 7] 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 [14].

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 [13].

   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 [14] 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.

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 mono-cellulars (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 [3].

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 [13, 12].

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 [12]. 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 [6, 9, 8, 11].

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 [1, 5]?

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