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Can stabilization and symmetry breakings give rise to life in the process of the universe evolution?

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Research Article

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Abstract

Biogenesis can be understood as the final process of the Universe's evolution, from Planck scale down to nuclear scale to atomic scale to molecular scale, then finally to bioscale, with the breaking of relevant symmetries at every step. By assuming the simplest definition of life, that life is just a molecular system which can reproduce itself (auto-reproducing molecular system – ARMS) and has such kinetic ability (kineto-molecular system), at least for its microscopic level, as to respond actively to its surrounding environments, we tried to explain the origin of life, taking the final step of the Universe evolution. We found a few clues for the origin of life, such as: (1) As the Universe expands and gets extremely cold, biogenesis can take place by ARMS, new level of stabilization may be achievable only at 'locally cold places' (LCPs), such as comets. (2) There must be the parity breaking in the bioscale stabilization process, which can be violated spontaneously, or dynamically by the van der Waals forces possible only at LCPs. (3) The rule of bioparity breaking is universal within the biohorizon. So we will find, e.g. only left-handed amino acids in all living beings dwelling within our Galaxy. (4) The idea of biogenesis through the bioscale stabilization in the evolution of the Universe looks very consistent with Panspermia hypothesis and supports it by providing a viable answer for life's origin at such LCPs.

Introduction

The evolution of the Universe (Hawking 1996) from the big-bang to the present day can be understood to be a collapse of larger symmetries to smaller ones, as the Universe expands. Symmetries that existed in early Universe were violated, one by one, with the expansion of the Universe, evolving from energy to matter, nucleons to atoms and so on. A large gauge symmetry like E(8) → SO(10) collapses to the standard model (Glashow 1961; Weinberg 1967; Salam 1968) of SU(3)XSU(2)XU(1) at the electroweak scale: It is the collapse of symmetries from a perfect big symmetry to smaller symmetries. Symmetries of the early Universe at high-energy scale were broken one by one with the evolution of the Universe (e.g. CP (charge conjugation and parity inversion) symmetry violation, spontaneous symmetry breaking of the vacuum, etc.), energy becomes matter, massless particles become massive and materials that have a simple structure become more complex. Starting from the big-bang through inflation, the Universe expanded to create a world of matter from energy, then nucleons–electrons recombined into neutral atoms, then from stars to a Galaxy then to Galaxy clusters – finally to the present day Universe. According to cosmology, the origin of matter may well be understood through baryogenesis, which explains the process of matter generation from pure energy through multiple symmetry breakings associated with cosmic expansion after the big-bang. Russian nuclear-particle physicist Sakharov proposed that three conditions are required to satisfy for the baryogenesis (Sakharov 1991):

1. Baryon number violation,
2. CP symmetry violation,
3. thermal inequilibrium in the process of the Universe evolution.

These three conditions can bring out our matter world from pure energy by breaking matter–antimatter symmetry, creating the world of the cosmic particles and structures that are currently observed.

On the other hand, the Miller–Urey experiment (Miller & Urey 1959) of the 1950s is being reproduced from a molecular biology perspective, but even the definition of life is throwing many new questions from the life's uncertain point of view. What is the definition of life? Is it just accidentally made from a mixture of organic acid? Currently, many similar experiments are underway as an advanced method of the Miller–Urey experiment. We would like to ask a few fundamental questions, which may be intrinsically connected to the evolution of the Universe: How can the evolution of the Universe be linked to the origin of life (Prigogine 1977; Piran *et al.* 2016; Takeuchi *et al.* 2017], which may break out at almost end of the Universe evolutionary process? What is the principle behind the origin and the evolution of life? What kind of symmetry breakings can lead to the origin of life? Physicists have already studied systematically and have come to understand the physics laws for the evolution of non-living matter (the Universe), which is already well understood in the principles of 'symmetry collapse' and 'stabilization cross-over'. Here we would like to extend the principles to the understanding of living matter (life). We will try to find the conditions of life generation, corresponding to the Sakharov's three conditions of baryogenesis. Through such convergent methodology, we can deduce many important questions: Is life present only on Earth? Or does it exist in all possible circumstellar habitable planetary zones of the Universe? Do aliens exist? Does life evolve in the expansion of the Universe, with the collapse of symmetry, inevitably as a natural phenomenon? Or was it deliberately created by a divine being? Or has it been created by chance in myriad possibilities?

Evolution of the Universe: symmetry breakings and stabilization processes

We would like to ask a few fundamental questions, which may be intrinsically connected to the evolution of the Universe: How can the evolution of the Universe be linked to the origin of life, which may break out at almost end of the Universe evolutionary process? What kind of symmetry breakings can lead to the origin of life? We intend to explore the conditions for the creation of life. When the Universe becomes very complex and globally cold at almost end of the Universe evolution, at such a place, where matter is gravitationally accumulated, life may have started as a natural process of the Universe evolution, and we want to explore the conditions for the process, so-called biogenesis process. We will try to find the conditions of life generation, corresponding to the Sakharov's three conditions of baryogenesis. When those conditions are all satisfied, can life be created naturally and automatically? The conditions for the biogenesis may be intrinsically connected to the stabilization process of matter world as well as to the symmetry breaking, as the Universe expands and gets cold.

Nuclear stabilization – nucleosynthesis

As the Universe expands and cools down, the gravitationally accumulated matter undergoes various stages of stabilization and becomes successively complex after the elementary constituents fuse together as a part of stabilization process. There are three pronounced stabilization stages in the evolution of the material Universe, which are very well studied. At the nuclear scale (∼1 GeV, about $O(0.1–1)$ second after the big-bang for the big-bang nucleosynthesis) through nuclear interactions (strong and weak forces), so-called nucleosynthesis (e.g. big-bang nucleosynthesis, stellar nucleosynthesis and supernova nucleosynthesis through nuclear fusion), which creates new heavy atomic nuclei from pre-existing light protons and neutrons. The average binding energy (http://hyperphysics.phy-astr.gsu.edu/hbase/NucEne/nucbin.html) per nucleon for all naturally occurring isotopes as a function of the number of nucleons in nucleus clearly shows this nuclear stabilization process. This binding nuclear energy is negative with respect to the total energy of the particles pulled apart; therefore, the nucleosynthesis is a stabilization process at the nuclear scale. It peaks and becomes flat at around Fe^{56}, and as the number of nucleons further increases, those heavier nuclei become unstable and decay naturally via nuclear fission. We will call this change of modes between nuclear fusion and fission as a stabilization cross-over, and particularly for this as the nucleosynthesis stabilization cross-over. So Ni^{62} and Fe^{56} are very common metals in the planetary core.

Atomic stabilization – atomic recombination

As the Universe expands even more and gets even cooler (about 400 000 years after the big-bang), electrons and nucleons became bound to form electrically neutral atoms, called the big-bang atomic recombination, at the atomic scale (∼keV – eV scale) through electromagnetic interactions, which makes atoms energetically more stable: e.g. an electron and a proton bind together become a hydrogen atom by releasing 13.6 eV. The atomic ionization energy (https://www.thoughtco.com/ionization-energy-and-trend-604538) as a function of atomic number, which is a measure of this atomic stabilization process, exhibits the following trends: The ionization energy for the first column of the periodic table (the alkali metals, Li, Na, Rb, Cs, Fr, …) decreases as the atomic number increases. The tendencies progress to the last column of the periodic table (the noble gases, He, Ne, Ar, Xe, Ra, …). Note that the maximum ionization energy for each row diminishes as one progresses from row 1 to row 7 in a given column. We find again the *flattening* of the stabilization, as atoms become heavier and heavier, in the atomic scale recombination stabilization process.

Molecular stabilization – molecular compound

Once the Universe expands even further and becomes globally very cold, at the molecular scale (∼eV – sub eV scale) through ionic and covalent bond interactions, atoms bind together to (organic and inorganic) molecules, to macromolecules such as polymers, to be more stabilized to lower energy scale. From the study of molecular bond dissociation energy (http://www.chemguide.co.uk/physical/energetics/bondenthalpies.html), it is clear that as the molecules become heavier, the dissociation energy becomes smaller and smaller due to the increasing effective average distance between the constituent molecules. Note that the nuclear reaction, due to strong Coulomb repulsion, needs very energetic nucleons to fuse together, which makes the nuclear reaction possible only at the core of stars or the core of supernovas or at very early Universe after the big-bang. Chemical reactions also require (chemical, electrical or radiation) catalysts to overcome Coulomb blockade, to make the reaction easier. However, the blockade of the molecular reactions is much weaker compared with the atomic or nuclear repulsion, and even becomes further weaker as molecules get heavier.

We find here a very important tendency from the nucleosynthesis, atomic recombination and molecular compound as the Universe expands and gets cold and colder, that the matter fuses together at each scale to be more stable, and become heavier constituents, however, emitting less and less energy and with weaker and weaker blockade to overcome. We conclude this section that the evolution of the Universe, especially for matter world, is in short via 'symmetry collapses' and 'stabilization processes to lower scale'. In the next section, we want to apply those two inherent essences of the Universe evolution to the generation of life, i.e. biogenesis at the macromolecular scale.

Biogenesis in the evolution of the Universe

Auto-reproducing molecular system in bioscale stabilization process

We would like to ask a question which may be fundamentally connected to the biogenesis: As the Universe expands even much further and gets very cold globally to the scales below the molecular bond, at the places where bits of gravitationally accumulated matter exist, e.g. comets, meteors, deep outer planets, what kind of stabilization will break out at those places? No more stabilization after the molecular bond? Or another stabilization with a new approach? We learned in the previous section that as the Universe expands and gets cold and colder, *the matter fuses together at each scale to be more stable, and become heavier and heavier, however, emitting less and less energy and with weaker and weaker blockade to overcome.* May be that the stabilization process can go on further down to lower energy scale, lower than the molecular scale at places, where gravitationally accumulated matter condensed to fuse further. Condensed such that the average distance among assembled molecular subunits becomes ~ $O(0.1–1)$ nanometre, van der Waals forces take over the stabilization process, and molecules fuse to macromolecules, supramolecules and biomolecules.

However, as the Universe expands and gets extremely cold (<100 K), such stabilization process must eventually meet cross-over (bioscale stabilization cross-over, similar to the nucleosynthesis stabilization cross-over), i.e. no more stabilization with such a fusing, due to previously explained tendency – getting heavier and heavier, emitting less and less energy to be more stabilized, i.e. eventually almost no stabilization ever. *At this critical moment*, biogenesis can take place by auto-reproducing molecular system (ARMS), *not by fusing to heavier composites but by reproducing itself, new level of stabilization may be achievable at such locally cold places (LCPs).*[1] So the final step of the Universe evolution for the material world from this point of view is the self-replicating molecular system, i.e. ARMS. This view of the Universe evolution predicts the existence of life inevitably everywhere, possibly every planetary system, not just on Earth by chance.

We describe the ARMS stabilization process here schematically:

- B, C: organic molecules; D, d, δ: catalysts; ΔΓ, δγ, δγ’: energy release
- $B + C + D \rightarrow A(=BC) + D + \Delta\Gamma$ (A = BC: synthesized biomolecule with energy release ΔΓ)
- $B + C + d \rightarrow A + d + \delta\gamma$ (almost no blockade d~0, almost no energy release δγ~0 near the bioscale stabilization)
- Approaching to the extreme stabilization cross-over: $A + (B + C) + \delta \rightarrow 2A + \delta + \delta\gamma'$ (δ~0 and δγ’~0)
- $A + (B + C) \rightarrow 2A + \delta\gamma'$ (self-catalyst or no catalyst due to δ→0)
- $A + (B + C) \leftrightarrow 2A$ (chemical equilibrium due to δγ’→0)
- $A + (B + C) \rightarrow 2A$ (inequilibrium process due to the Universe expansion or environmental effects; A ≡ ARM)

As previously explained, the governing interaction would be van der Waals interactions (Dzyaloshinskii *et al.* 1961) in the macromolecular scale. We also learned from the stabilization tendency, the Coulomb blockade becomes weaker and weaker, so the ARMS stabilization process may not need any catalyst at all, or even ARM itself can be the self-catalyst to speed up the process (Ricardo & Szostak 2009). Recently Horowitz and England (Horowitz & England 2017) simulated that a chemical mixture, if it continually absorbs energy from its environment, can exhibit inequilibrium stabilization – this founding may support the last step of the ARMS stabilization shown above. As an additional supporting evidence, here we add quotes from the article ‘Ribose and related sugars from ultraviolet irradiation of interstellar ice analogs’ of Science (2016) (Meinert *et al.* 2016):‘…We empirically simulated this process in the laboratory at low temperature ($T = 78$ K) and low pressure ($p = 107$ mbar) …. ‘We observe an autocatalytic reaction.’ … ‘In this experimental frame, precursors of both proteins (amino acids) and genetic material (sugars and their derivatives) are produced in large amounts so that if delivered from meteorites in the Earth environment, their coevolution may be considered one of the standing issues in prebiotic chemistry.’

Note that the ARMS can be generated only at such LCPs, however, not at early Earth’s hot organic soup, neither at hot waters around undersea volcanic eruptions, nor at warm water underneath the Mars surface, even though small amounts of non-living organic materials can be found in the water reservoir. This may hint at the idea of Panspermia.

What kind of macromolecules can be the candidates of ARMS? Can DNA (deoxyribonucleic acid) or RNA (ribonucleic acid) or even PNA (peptide nucleic acid) or similar entity be such candidates of the ARMS? The followings are the quotes from the article, ‘The Dimeric Proto-Ribosome: Structural Details and Possible Implications on the Origin of Life’ (Agmon 2009): … ‘A symmetric pocket-like entity, composed of two L-shaped RNA units, encircles the peptide synthesis site within the contemporary ribosome. This entity was suggested to be the vestige of a dimeric proto-ribosome, which could have formed spontaneously in the prebiotic world, catalyzing non-coded peptide bond formation and elongation. … By catalyzing the production of random peptide chains, the proto-ribosome could have enabled the formation of primary enzymes, launching a process of co-evolution of the translation apparatus and the proteins, thus presenting an alternative to the RNA world hypothesis.’ Detailed thermos-dynamical study of the ARMS stabilization cross-over is under way (Kim 2018).

Bioparity violation in the ARMS stabilization process and kineto-molecular system

There must be a symmetry breaking in the ARMS stabilization process, i.e. violation of chirality (parity, mirror symmetry), which can be violated dynamically by the van der Waals forces or just spontaneously, because there are left-handed and right-handed amino acids in nature, but the amino acids present in living organisms exist only with left-handed. Parity is a global discrete symmetry, and physicists have already seen its maximal violation at the nuclear scale, through the parity violation of the weak interaction, theoretically proposed by Lee and Yang (Lee & Yang 1956), and experimentally confirmed (Friedman & Telegdi 1957; Garwin *et al.* 1957; Wu *et al.* 1957) from Cobalt’s β decays.

How the bioscale parity violation can be generated? One possible answer would be the spontaneous breaking within a bubble of the Universe expansion. This idea of spontaneous breaking is a kind of random breaking as the Universe cools down, chosen to be more stable solution. If the bioparity violation is spontaneous,

[1]We introduce a new terminology ‘locally cold place’ as a place of gravitationally accumulated matter, which is at very low temperature because of residing in either the globally cold empty space/vacuum or the very cold regions in a planetary system such as the outer planets or comets (when passing around outer planets) or interstellar dusts.

the rule of breaking is universal within the biohorizon[2], which could be at least a few billion light years' radius sphere, because only a few hundred million years divide the formation of the Earth and the appearance of the first forms of life in the Earth. Then we will find only left-handed amino acid in living matter from out of the Earth within our Galaxy.

Alternative answer would be the dynamical bioparity violation in the process of ARMS stabilization by the van der Waals forces. Interactions between permanent charges, dipoles, multipoles of van der Waals forces are anisotropic, depending on the relative orientation of the molecules, becoming attractive or repulsive. However, as being so weak interactions, this electrostatic van der Waals forces are temperature-dependent (Dzyaloshinskii *et al.* 1961): When in random thermal motion as in liquid or gas state, the resultant forces are averaged out to be negligible. Therefore, at around room temperature, only the induced or dispersive van der Waals forces are important because those induced and dispersive van der Waals forces are always attractive, isotropic, irrespective of orientation. Hence, if temperature becomes much colder than room temperature (<100 K), which we previously have assumed for the ARMS stabilization process, the van der Waals forces between macromolecular subunits become anisotropic, resulting to generate dynamical bioparity violation in those stabilization processes (Kim 2018). It means that the ARMS stabilization process at the macromolecular scale at such LCPs can generate dynamically the bioparity violation, so that only left-handed amino acids exist in living organisms of the Earth. In case of this dynamical bioparity violation, the rule of breaking is universal within the biohorizon, too. We will find only left-handed amino acids in living matter from out of the Earth within our Galaxy, and aliens from far away galaxies might have right-handed amino acids. There is one possible caveat: Here we do not consider any environmental effects after the ARMS stabilization process, which is intrinsically connected to the evolutionary process, such that once the first catalytic biomolecules were present, the prevalence of one of the two forms (left or right) would be expected by the tendency of similar amino acids to polymerize together (Yin *et al.* 2015).

Once the bioparity is violated, the biomolecules can have directional property, viewing back and forth differently, by transforming rotational anisotropy to translational direction. Therefore, the bioparity violated biomolecules can have kinetic ability – ARMS becomes kineto-molecular system (KMS) (Nobel Chemistry Lecture by Jean-Pierre Sauvage 2016). The ARMS can move in principle if there is some external energy source, e.g. chemical, Solar energy, etc.

Panspermia – LCPs and locally hot places

From macromolecules to life, there are quite a few proposals (Agmon 2009; Ricardo & Szostak 2009): DNA first, RNA first, PNA first or metabolism first, etc. However, because only a few hundred million years separate the appearance of early life forms on the Earth and the formation of the Earth, it has been suggested that the very first organisms on our Earth may be visitors from outside – the idea of Panspermia (http://www.panspermia-theory.com/). Panspermia hypothesis states that life exists throughout the Universe, is spread by comets, meteoroids and other debris, and that the microscopic forms of life are able to survive the extreme conditions of space. Panspermia hypothesis, however, does not give any answer for the origin of life, but only ascribe it to another celestial object.

We would like to apply the idea of Panspermia to the biogenesis of ARMS in the process of the Universe evolution, together with the regular oscillatory motion of comets in a planetary system. To give more elaborated explanation, we now introduce two simple concepts: the LCPs and locally hot places (LHPs). LCPs have been already introduced for the places of the ARMS stabilization. Newly introduced LHPs are the places like circumstellar habitable planetary zone in a planetary system, so-called Goldilocks planets. Once the microscopic life forms of ARMS happen to arrive to cozy and warm environments of circumstellar habitable planetary zone, the ARMS special ability of self-reproduction and self-kinetic motility may propel the status of ARMS to a certain direction, possibly to the evolution of life by responding to environments, with some external energy supply such as Solar energy. The idea of biogenesis through ARMS stabilization process in the evolution of the Universe looks very consistent with Panspermia proposition, supporting the proposition by providing a viable answer for life's origin.

We note that comets[3] are very useful tool to explain the Panspermia proposition because they regularly oscillate between LCPs and LHPs. As is well known, comet Halley passes every 76 years around the Sun, with much elongated elliptical track from deep outer planetary space to the Goldilocks zone, the Earth and the Mars. Comets are like a pendulum, to bring the ARMS to circumstellar habitable planetary zone regularly, back and forth between LCPs and LHPs. Finally, organic molecules, including polycyclic aromatic hydrocarbons, have been recently detected (Fernandez 2006) in significant quantities in comets, leading to the speculation that comets or other debris could have brought to our Earth the precursors of life or the life itself.

Three conditions for biogenesis and conclusion

By summarizing the previous section, we derived the required conditions for the origin of life in the Universe:

1. ARMS, as the self-replicating biomolecules, at LCPs, which predict the existence of life possibly every planetary system, not just on Earth by chance.
2. Bioparity violation in the ARMS stabilization process at LCPs, which makes the ARMS to be a KMS to respond to environments.
3. Panspermia proposition with regular oscillatory motion of comets in a planetary system, which connect regularly the ARMS of LCPs to LHPs.

We have assumed, for the simplest definition of life, that life is just a molecular system which can reproduce itself, and has such kinetic ability, at least for its microscopic level, responding actively to its surrounding environments. We have tried to explain the origin of life (biogenesis) taking the final step of the evolution of the Universe, as the Universe expands and gets cold, with the bioscale stabilization cross-over and the violation of chiral symmetry (parity, mirror symmetry), finally with Panspermia hypothesis. This was possible only because of the stabilization tendency, that as the Universe expands and gets cold, the matter fuses together at each

[2]Biohorizon is the boundary of that region of our Universe, which is causally connected to the Earth as far as the natural laws of biogenesis are concerned.

[3]Due to Kepler's second law (i.e. a line between the Sun and the planet sweeps equal area in equal time interval), comets stay during almost all of their life span at LCPs and pass regularly around LHPs only very short time interval.

scale to be more stable, and become heavier and heavier, however, emitting less and less energy. We have attempted to understand the origin of life through the fusion of physics and biology beyond the analytic methods of modern biology. As is well known, each of above three conditions of the biogenesis has been intensely investigated by astrobiologists, molecular biologists, biochemists, biophysicists, SETI (https://www.seti.org/) scientists and Breakthrough Initiative (https://breakthroughinitiatives.org/), not as a whole convergently, but as each subject divergently and analytically.

We have tried to find answers for such questions:

Is life only on Earth? Or does it exist in all possible circumstellar habitable planetary zones of the Universe? Do aliens exist? Does life evolve in the expansion of the Universe, with the collapse of symmetry, inevitably as a natural phenomenon? Or was it deliberately created by a divine being? Or has it been created by chance in myriad possibilities? What are the meanings of the organisms found in meteors, possibly in comets? Is parity violated in bioscale? and so on.

Then we have found some clues for those questions, such as:

As the Universe expands and gets extremely cold, biogenesis can take place by ARMS, not by fusing to heavier composites but by reproducing itself, new level of stabilization may be achievable only at such LCPs, like comets, deep outer planets, etc., however, not at early Earth's hot organic soup, neither at hot waters around undersea volcanic eruptions, nor at warm water reservoir underneath the Mars surface, etc., even though non-living organic materials could be found in those water. There must be the bioparity breaking in the biostabilization process, which can be violated spontaneously, or dynamically by the van der Waals forces only possible at such LCPs; and the rule of bioparity breaking is universal within the biohorizon. So we will find only left-handed amino acids in living matter from out of the Earth within our Galaxy, and aliens may have different handedness for their flesh's DNA only from galaxies far away. The idea of biogenesis through the biostabilization process in the evolution of the Universe looks very consistent with Panspermia proposition, supporting the proposition by providing a viable answer for life's origin.

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