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Plasma Concept of the Origin of Life under Meteorite Impact in the Process of Earth Formation and Mass Accumulation

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Abstract: ***An original Plasma Concept of the origin of simplest forms of living matter during the expansion of the plasma forming in the process of a hypervelocity meteorite impact onto the Earth surface is proposed. The concept uses the fact that meteorite bodies were the main contributors to the accumulation of the Earth mass. The feasibility of the concept is confirmed by the results of direct impact experiments and experiments with laser modeling of hypervelocity impact processes involving the generation of plasma identical to impact one. It is shown that during the adiabatic explosive expansion and cooling of the plasma the conditions form that ensure the possibility of stochastic synthesis of simplest and complex molecular structures including those with chirality. Constant unidirectional ring-shaped magnetic field is shown to form in the process of the impact plasma expansion, and that this field interacts with the UV radiation of the plasma to form local physical chiral medium causing moderate breaking of mirror symmetry of enantiomers synthesized in the plasma with the predominant formation of L amino acids and D sugars. At the final stage of this expansion the impact plasma reached both anomalously high catalytic activity and the peak rate of plasma processes, making possible the assembly and ordering of high-molecular structures that could contribute to achieving enantioenrichment or even enantiopurity with the growth of the characteristic size of the plasma region. The earlier proposed protoviroid – a hypothetical virus-like organism – is used as the model of the most primitive living being. The mass of the protoviroid, which consisted of 300 nucleotides and 100 amino acids, did not exceed 100 kDa. The estimates obtained showed that the crust- and meteorite-material plasma processed during the accumulation of the nominal Earth mass could ensure no less than 1047 statistical trials required for the synthesis of a "correct" sequence of a protoviroid monomers. It is also shown conclusively, based on experimental results, that abiogenous processes accompanying the expansion of meteorite plasma and crater formation satisfied all the requirements needed to ensure the emergence of a protoviroid and formation of a medium allowing the survival of the first living being in the geological history of the Earth.***

Keywords: life origin; meteorite impact; plasma; breaking mirror symmetry; homochirality; enantiopurity; stochastic synthesis; statistical sampling

I. INTRODUCTION

A. Main requirements for the origin of life conditions

The presence of life is the greatest wealth of our planet. Since ancient times humankind was interested in the problem of the origin and evolution of extremely rich and immense Earth's biosphere. However, the first meaningful and fruitful searches for the origin of life date back only to about 170 years ago when Louis Pasteur found in 1848 that molecular foundation of life is chiral and asymmetric [1]. Further long-lasting studies of the organization of the most primitive forms of living matter and of the environment and processes ensuring the existence of life and its evolutionary development proved to be fruitful and made it possible to find natural abiogenous processes necessary for the origin of life on Earth. It was shown in the studies [2-5] that the origin of life cannot be explained based on chemical reactions in the processes of statistical trials of monomers. It was shown, based on the results of these and many other key studies carried out by subsequent generations of outstanding researchers that the processes of the origin of life are extremely complex and in some cases defy explanation because of the lack of necessary knowledge about many natural processes associated with the «Eternal Problem» (see [6]). This is why natural mechanisms of the emergence of living matter could not be found for many years. However, the existence of life on Earth and the possibility to detailed study it allowed to biologists to reach a consensus. It was shown that the composition and properties of the natural environment where life could presumably have originated must have been, with only a few exceptions, identical to the properties of the environment where representatives of primitive forms of inexhaustible terrestrial biosphere lived and evolved [7-9].

According to results of the studies and consensus reached by most of leading researchers, the environment where life originated must have had the form of local chiral physical medium ensuring:

1) Stochastic synthesis of chiral molecules – amino acids and sugars with moderate breaking of mirror symmetry
2) Formation of a local chiral physical field with the chirality "sign" coincident with that of the chirality sign of bioorganic matter
3) Formation of enantiopure medium
4) Possibility of realization of at least 1035 statistical trials
5) Formation of a survival medium with the presence of water and moderate temperatures above water melting point

Hereafter, for the sake of brevity, the above requirements are referred to as «The Main requirements» (asymmetry, enantiopurity, trials, and survival).

The chirality related problems proved to be the most difficult ones because in the first half of the 19th century no natural mechanisms were known that could produce chiral environments, and the same was true for the processes resulting in the breaking of mirror symmetry, as well as for the mechanisms and media ensuring the emergence of enantioenrichment. Thus the effect of a chiral composition on the processes of matrix oligomerization was studied experimentally in [10,11] and it was shown that life can emerge only in enantiopure medium.

For the first simplest living beings to survive at the initial stage of their emergence, natural environment had also to provide not only suitable temperature and the necessary amount of water, but also the presence of simple organic molecules required for metabolism of the first living species.

The main problems with the attempts to develop a plausible scenario of the origin of life were due to the processes of symmetry breaking.

The authors of the groundbreaking and well-known study [12] dedicated to the laws of mirror symmetry breaking of bioorganic world in a chemical medium shown that the 170-years long search did not make it possible to explain when and under what conditions the symmetry breaking occurred that was necessary for the emergence of life, and what factors ensured that such events actually occurred. It was also not clear what factors determined the chirality "sign" of the biosphere – was it due to some cause or was it a mere random event.

The search for a natural environment where life could have emerged included media in all of four known states of matter. Particular attention among them was also given to the little studied plasma medium, which at first sight appears to be not very suitable for the emergence of life. However, promising results of many experiments aimed at searching for mechanisms of the origination of life in atmospheric (lightning) discharges proposed by Miller and Urey [13] latter turned out to be delusive. In these experiments no symmetry breaking was observed in chemical substances synthesized in the plasma. Without this life could not have come into being. It was also experimentally demonstrated [14] that for the same reasons life could not originate in the cold ionospheric plasma either.

Numerous experiments demonstrated that almost all organic compounds necessary for the emergence and evolution of life could have been synthesized in plasma media of various nature. However, without the breaking of mirror symmetry of amino acids and sugars this proved to be insufficient for the origination of life.

The lack of reasonable answers to numerous questions regarding the nature of possible mechanisms of the origination of life in chemical processes meant that the chemical environment of the Earth, as well as the chemical processes that occur in it could not have provided a suitable solution for this extremely important problem.

A long series of many failed attempts to find an environment and natural mechanisms capable of producing a primitive form of living matter led to significant stagnation, and many researchers reconsidered their approach to the problem of the origination of life. To overcome the arising difficulties, hypothetical structures with «primary selectivity» have been proposed [15]. Koonin [16] considered the possibility of the origination of life beyond our Universe or Multiverse. So far, these innovations could not resolve the crucial problems including that of the place of formation of living matter. Most of the biologists believe that life originated on Earth. During this period there was also another concept stating that life could have originated and exist beyond the Earth. There was a large amount of material evidence suggesting that carbon compounds, amino acids, sugars, lipids, porphyrins, purine, pyrimidine, and nitrogenous bases, and nucleotides, i.e., compounds many among which are needed for the origination of life, have been found in carbonaceous chondrites [17-19]. Along with the above molecular structures reliable breaking of mirror symmetry was observed in chondrules of carbonaceous chondrites with the enantiomeric excess of L amino acids [20,21] and D sugars [22] whose "sign" coincided with that of bioorganic breaking of mirror symmetry.

The results of studies involving finding and investigation of the so-called "organized elements" or structures resembling microorganism casts continue to arouse keen interest among the research community. None of the researchers could prove the biogeneous nature of the compounds found in meteorite bodies.

It became clear that to solve the above problems of the origination of life outside the Earth it is necessary at least to know how life could originate on the Earth. To find natural environment, mechanisms, molecular structures where life emerged, a reasonable and well-justified approach was suggested. The idea was to use the features found when studying primitive forms of living beings of the terrestrial biota as markers for searching for processes of the emergence of life [9]. This approach made it possible to gain understanding that the environment for the origin of life must have ensured without fail the fulfillment of the «Main requirements» under natural conditions irrespectively of the physical state of the environment. And it is only in this case that after innumerable trials it could be counted on the possibility of the origin of the first being under natural conditions.

In this paper the Plasma Concept is proposed, where it was shown that all conditions listed in the "Main requirements" are reliably fulfilled in the plasma medium of a meteorite impact. Therefore the «Main requirements» can be used as a criterion determining the direction of further studies of the problem of origination of life. The results presented below were obtained experimentally within the framework of the development of the Plasma Concept of the origin of life. They for the first time put the long-awaited clarity into the problem considered, in particular, in what processes, where, and when enantiomeric excess could emerge and enantiopure environment formed without which life could not originate on the Earth.

B. Plasma Concept

In the early 2000-s the original concept of the origin of life in the plasma of a hypervelocity meteorite impact was proposed at the Space Research Institute of the Russian Academy of Sciences [23-30]. The main aim of the new concept was to search for such natural abiogeneous plasma processes in nonliving nature, which could provide an environment and mechanisms capable of leading to the emergence of simplest forms of living matter.

It was proposed, in the case of finding the sought-for natural phenomena, to carry out comprehensive experimental studies confirming the possibility, capability, and feasibility of the processes and mechanisms found. It was also necessary to obtain proofs that the processes and molecular structures found would with certainty lead to the emergence of life.

From the very beginning of the work on the new concept it was found that plasma processes generated during an impact have important advantages over other natural processes proposed earlier for solving the problem of the origin of life. These advantages were due to the fact that in the case of a meteorite falling onto the Earth the impact plasma formed always, spontaneously, with no extra conditions or preconditions. The processes of plasma formation occurred necessarily and entirely with the fulfillment of practically all the necessary requirements ensuring the emergence of living matter.

At the initial stage of the development of the Plasma Concept a paper was considered [31] (reviewed in [32]), where it was experimentally shown that laser plasma during its expansion forms toroidal, unidirectional, constant magnetic field with a strength of 100 to 200 kG. A detailed analysis of the properties of magnetic fields of laser and impact plasma showed that because of high degree of similarity between these processes magnetic field could also be conclusively generated during impact. This fact allowed the authors of [26] to make an important conclusion that physical fields in inner regions of the impact plasma are "true" chiral fields [33]. In this case the effect of these fields on the products of synthesis should have resulted in the breaking of their mirror symmetry. Impact plasma formed in the isolated region, which displaced completely the local atmosphere, e.g., the Earth's atmosphere, if present. Plasma formed in the process of each individual impact, which could have ensured the synthesis and breaking of the symmetry of chiral amino acids and sugars and other, non-chiral structures of organic compounds (OC) required for the formation of proteins, nucleotides, and DNA/RNA structures. The experimental results described below and obtained in the process of the development of the Plasma Concept have demonstrated conclusively that during adiabatic expansion and cooling of the hot plasma generated by the meteorite impact the conditions developed that ensured the complication of molecular structures synthesized during the impact and increase of their mass in the processes of self-assembly and ordering. Anomalously high rate of plasma processes and high catalytic activity of plasma also contributed to such behavior. This was accompanied by the formation of the local chiral physical medium, which could resulted in a moderate enantiomeric excess of amino acids and sugars. It was shown that the polarity of the chirality "sign" of the enantiomers of amino acids and sugars synthesized in the impact plasma coincided in "sign" with that of bioorganic matter. Another result of greatest importance was the fact that all the natural plasma processes mentioned above ensured the formation of a medium, where the first living beings could emerge and evolve. The processes of impact plasma formation were reproduced and experimentally studied in laboratory conditions. Such experiments allowed to identify conclusively the physical processes required for the emergence of life without any problems or inconsistencies.

These studies showed that non-stationary and irreversible physical (plasma) process forms during adiabatic expansion of hyper-velocity impact plasma. Matter in this medium is in the fourth, i.e., plasma, state, which is far from the thermodynamic branch of equilibrium. Hot plasma is known to undoubtedly have extremely high catalytic activity and high reaction rates of plasma processes, and also a broad spectrum of plasma instabilities arising in the medium. The emerging medium also has other unique natural properties ensuring the synthesis of monomers of molecular structures including the chiral ones. The expansion in the case of the use of synthesized monomers is then accompanied by self-assembly and complication of new molecular compounds whose substantial ordering could result in the formation of enantiopure medium.

Plasma medium and the processes that occur in it and have such unique properties were first discovered experimentally, described, and for the first time used in the origin of life scenario exactly within the Plasma Concept. Among the greatest advantages of the Plasma Concept was also the availability by that time of an abundance of data about the properties of impact processes during the formation of the Earth and detailed information about the properties of the impact crater formation [34].

The difficulties with this concept was that the accumulation of the Earth mass was accompanied by an increase in the mass of falling meteorites to levels, which did not make it possible to understand the consequences of these impacts. The estimates made in terms of the Plasma Concept proposed here showed that for a local chiral physical field to form that is required for moderate breaking of the mirror symmetry of enantiomers – amino acids and sugars – certain conditions have to be fulfilled. Thus the target of the meteorite impact has to be semi-infinite and thick and the plasma expansion mode has to be free, three-dimensional, and adiabatic. The meteorite should not punch the target through because otherwise the plasma moving away from the backside of the target may have compensated the asymmetry of the expansion and prevent the formation of the local chiral physical medium without which life could not emerge.

II. METHODOLOGIES OF IMPACT PROCESSES STUDIES

A number of original techniques and measurement instruments were used for in-depth study of impact processes and plasma media arising in nature. The following plasma techniques and instruments were utilized in our experimental studies:

1) Laboratory simulation of the impact process using nanosecond laser pulse ensuring plasma motion in the free expansion mode. A Nd:YAG laser produced a pulse with a duration of several ns at a wavelength of 1.06 μm with a power density of 109W/cm2 [35,36]
2) Direct impact experiments under laboratory conditions reproducing the natural process of the formation of impact plasma. In this case the impact was produced by a light-gas gun and 2—3-mm impactors: up to 20 such impactors were accelerated to a velocity of 7 km/s [30]
3) Use of mass-spectrometry and chromatography techniques to determine the elemental and isotopic composition of samples and products of synthesis, which included LASMA laser time-of-flight mass-spectrometer, MALDI TOF-TOF Bruker Autoflex Speed mass-spectrometer, Hewlett Packard 5890 gas chromatograph interfaced to a Hewlett Packard 5972 mass selective detector (with chiral column for detection of enantiomers), and Orbitrap, or orbital ion trap mass-analyzer [30,35,36]

The use of the above techniques and instruments made it possible to achieve substantial progress in obtaining experimental results for confirming of appearance of important components of possible progenitors of the biosphere.

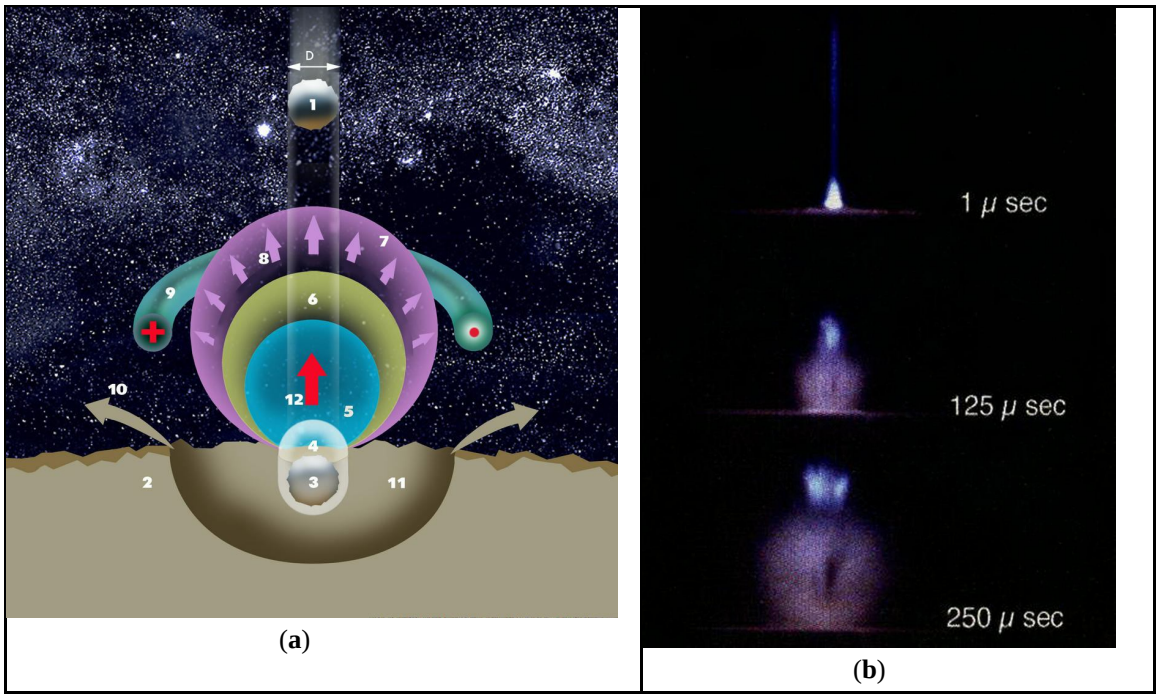
III. INVESTIGATION OF IMPACT PROCESSES AND IMPACT SIMULATION

A. Expansion of the impact plasma and symmetry breaking

With a meteorite reaching the velocity of 5-7 km/s [37,38] explosive expansion of both an impactor and a target matter occurs. A 10^9 W/cm^2 strong laser pulse [39] also results in the explosive expansion of the target matter. In both cases matter transforms into the plasma state. Hence both impact and laser plasma are typically accompanied by a plasma ejection. Adiabatic expansion of hot plasma results in its fast cooling. As it is shown in Figure 1, the process of the plasma expansion in the case of a high velocity impact begins at the time when the impactor touches the target and fully ends 100—200 μs in the case of a 1—2 mm diameter impactor, its density 2-5 g/cm3, and impact velocity of 7 km/s. The expansion velocity for laser plasma is approximately the same for a 1—5-ns laser pulse at 1.06 μm within a ~50-μm diameter focus spot and a power density of 10^9 W/cm^2. According to results of numerical simulations of the formation of the Popigay crater, the plasma expansion resulting from an impact of a ~8-km diameter meteorite moving at a velocity of 15 km/s lasts ~200 s [40].

The expansion-away of the impact plasma (like that of a laser plasma) is directed to the upper hemisphere (see Figure 1). Plasma motion generates a toroidal magnetic field. The interaction of the plasma UV radiation with this magnetic field generates levorotatory circularly polarized radiation (LRCPR).

According to results of experiments in [41], this radiation leads to photolysis of D amino acids and this how the predominance of L-amino acids is achieved. Such influence probably also results in moderate breaking of the mirror symmetry of sugars with the predominance of D-enantiomers [22]. These processes determine the chirality "sign" of the environment and, providing the control field, should ensure as a result of the further ordering of the medium it must achieve the state of enantiopurity.



(**a**) (**b**)

Figure 1. Plasma expansion in vacuum: (a) Schematic sketch of the main physical domains, electromagnetic fields, and characteristic sizes of the plasma torch during its expansion-away in vacuum. Plasma is generated by a hypervelocity impact of a body of diameter D. The formation and expansion-away of plasma precedes the ejection of ground material of the target from the intermediate crater of diameter 5D and depth 2—3D. 1 — Meteorite; 2 — target; 3 — the plasma-formation domain; 4 — the hot spot; 5 — zone of expansion beginning; 6 — zone of hot electrons; 7 — zone of ion-beam formation; 8 — electric-field vectors; 9 — ring-shaped magnetic field; 10 — direction of the target matter ejection; 11 — transitional crater; and 12 — vector of axial magnetic field; (b) Stages of expansion of the impact plasma, when the impactor moves from the top vertically downwards. The separation of the plasma component from the dust component and the occurrence of plasma strata in the form of individual globules are clearly visible, i. e. the plasma is not homogenous, but is structured. Reprinted from [28] with permission.

B. Emergence of enantiopurity

Enantiopurity is the crucial property of the environment where life can emerge and therefore it is the extreme level of ordering of the local chiral physical medium where all enantiomers of amino acids and sugars are represented by L- and D-enantiomers, respectively. It is shown below that this behavior is observed in the process of successive ordering of the chiral medium with the increase of the characteristic size of the plasma formation without the use of enzymes. As it was pointed out above, on the brink of the emergence of life the environment meant for its origination should be homochiral [10-11].

There are different hypotheses concerning the origin of enantiopurity including those based on synergetic approach and associated with the formation of dissipative structures and bifurcations [42]. They were initially proposed to describe chemical processes of explosive burning.

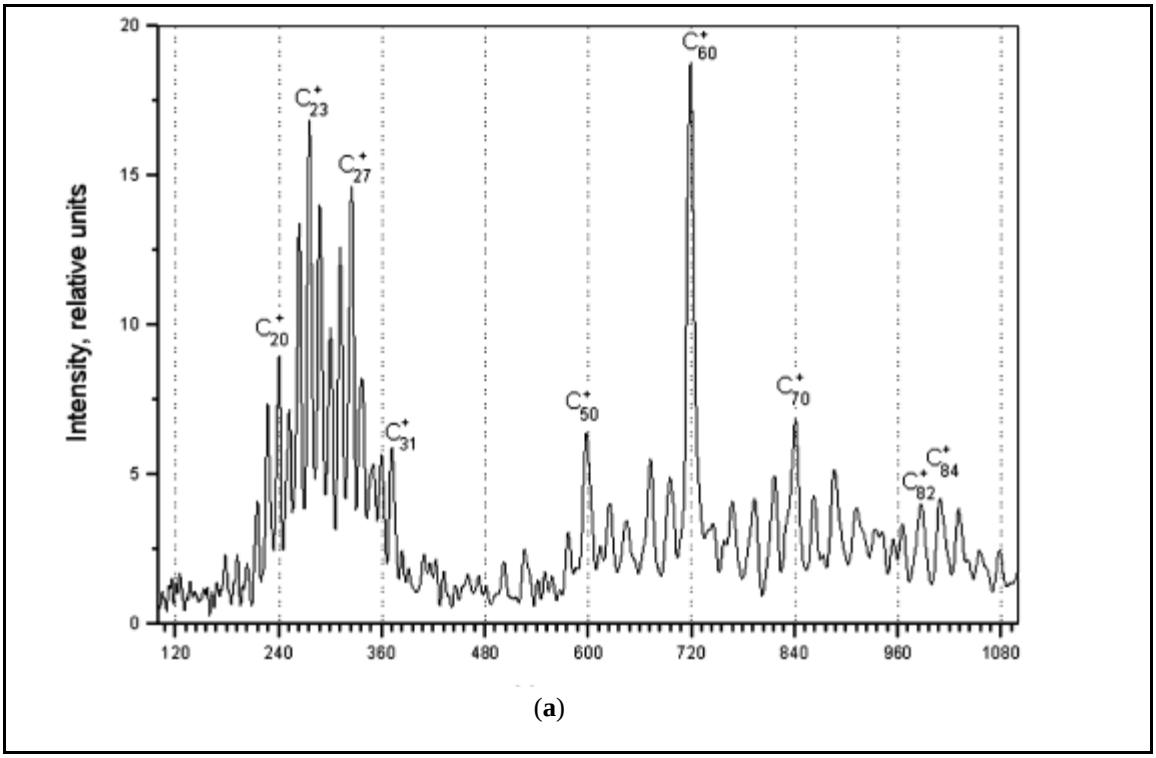
Note that impact event has no natural analogs in terms of basic physical properties, in particular, the impact power density, characteristic size of the emerging plasma formation, extremely high catalytic activity of the medium, high rate of plasma processes, and the final effect. Therefore during the development of the Plasma Concept the plasma processes were created and experimentally studied that were so far not considered in connection with the problem of the origin of life and self-ordering of matter. That is why the applicability of the synergetic approach, which was earlier developed for chemical media, to plasma media is by no means evident and requires further studies.

Also considered are other possible scenarios of the breaking of mirror symmetry, in particular, in hydrothermal systems exposed to circularly polarized radiation in the process of a supernova explosion, and in the case of the interaction of nitrogen atoms with neutrino [43-46]. However, the above exotic mechanisms require rather specific conditions and additional studies.
The results of impact experiments obtained in the process of our work on the Plasma Concept proved to be more realistic [28,29].

Thus for the enantiopure medium to form in the impact process the following conditions should be fulfilled:

1) Synthesis of chiral compounds – amino acids and sugars in the process of the plasma expansion
2) The breaking of mirror symmetry of these compounds in local chiral physical fields arising in laser plasma – in order to ensure the self-assembly and buildup of their mass
3) Ordering of molecular structures arising spontaneously because of the high catalytic activity of plasma processes

In the absence of extremely high level of catalytic activity and extremely high rates of reactions characteristic for plasma medium one could hardly expect attaining the level of ordering required to achieve enantiopurity. To experimentally find out the nature of the origin of enantiopurity, experiments were conducted involving the simulation of impact using a laser. In experiments on laser modeling of the impact plasma IR lasers operating in the pulsed q switching and free expansion mode were used. These lasers operating at the 1.06 μm wavelength and emitting 0.3 to 0.8 ns long pulses produced a power density of ~10^9 W/cm^2 for a focal spot diameter ranging from 50 to 1500 μm [27-29].
High degree of similarity between impact and laser plasma was proved repeatedly in experiments involving the development of important onboard instruments. This in the process of the development and calibration of original onboard PUMA dust-impact mass spectrometers designed for studying the composition of dust components of the comet tail in the VEGA experiment - all results were based on the assumption of similarity between laser and impact plasma [47,48]. Furthermore, the mass spectra obtained both in experiments on modeling an impact with laser exposure and in impact experiments proved to have identical ion composition (Figure A1) [27,49]. It was found in above experiments that the increase of the characteristic size of the plasma formation resulting from the increase of the laser focal spot diameter from 50 to 1500 μm brought about the increase of the mass and extent of the polymer structures synthesized in the plasma. Thus, as it is evident from Figures 2 and 3 in the case of the laser focal spot diameter of up to 1500 μm, fullerenes and their onion-shaped analogs, acetylene hydrocarbons and dendrites were recorded quite conclusively. The probability of the process of self-assembly and spontaneous ordering of similar structures ranged from 10^{-3} to 10^{-4}. Note that although these requirements were fulfilled in laboratory experiments with low probability for laboratory time scale, they nevertheless proved to be quite acceptable for cosmic scales.



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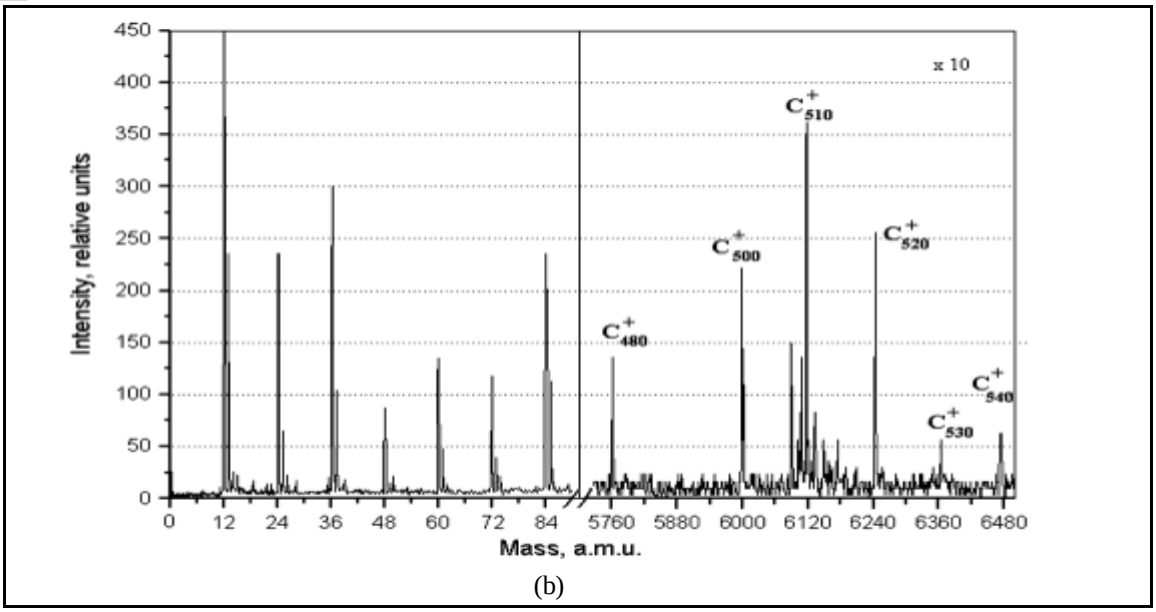

(b)

Figure 2. Mass-spectra of fullerenes synthesized in laser plasma. (a) Mass spectrum of fullerenes and their fragments. The spectrum was obtained in laboratory experiments with spot diameter dL=1.5-2 mm and power density WL ~108 W/cm2. Peaks corresponding to masses from 19 to 31 C with step 1C with high probability may be referred to individual fragments of fullerenes, as well as 50, 60, 70, and 82–84 C mass peaks with 2 C step to the fullerenes itself; (b) Fragments of mass spectrum of giant fullerenes. Typical spectra of carbon and hydrocarbon structures were obtained with the dL=1.5-2 mm and WL ~108W/cm2. Mass peaks containing from 480 to 540 C atoms correspond to the typical mass of "onion"-like fullerenes, representing enclosed each into other quasi-spheres, with following quantities of C: 60, 240, 540, 960, etc. Mass peaks at 12–96 a.m.u. represent carbon and hydrocarbon ion radicals. Reprinted from [27] with permission.

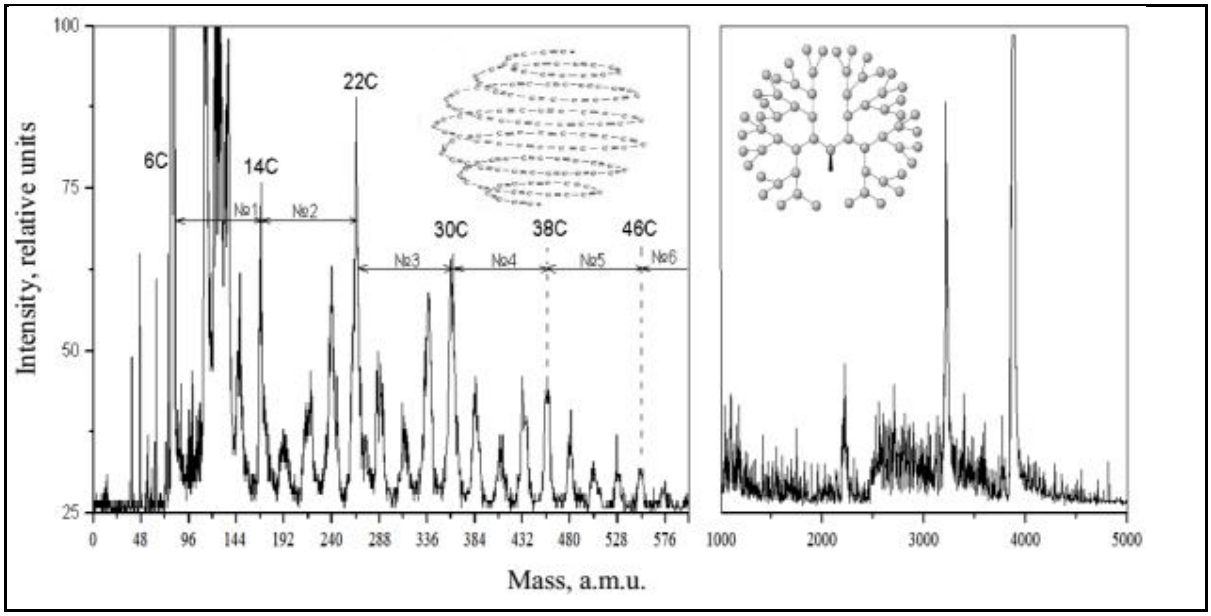

Figure 3. Mass-spectrum obtained by subjecting a carbon and 15NH415NO3 mix to laser radiation with a spot diameter of 1.5-2mm. The spectrum consists of four fragments with significant orderliness. The areas of linear-chain carbons (from 36 to 72 a.m.u.), amino acids (from 96 to 144 a.m.u.), acetylene carbons (from 168 to 576 a.m.u.), and dendrites (giant peaks located at 2200, 3200 and 3900 a.m.u.) are clearly visible. The insets show the estimated structure of synthesized molecules - acetylene carbons and fifth generation homolysine dendrimer. All spectra presented in Figures 2 and 3 were obtained in the course of a single experiment, i.e. all of these substances were synthesized simultaneously. Reprinted with changes from [30] with permission.

In case of a laser focal spot diameter of 1500 μm the maximum mass of fourth-order amino-acid dendrimers synthesized in the plasma has reached 3900 a.m.u.

Note that the rate of self-assembly of this structure in the plasma medium was about 3 10^{-6} s, whereas the rate of self-assembly of the same compound in a chemical medium was 600 s [50-53]. Thus the rate of self-assembly of a dendrite in the plasma medium proved to be 10^{8}-10^{9} times higher than in the chemical medium.

The observed super high assembly rate of the above structures is due to the high catalytic activity of the plasma medium. This property of the plasma medium is of crucial importance for subsequent fast assembly of polymers from monomers of chiral compounds synthesized in plasma in the absence of enzymes.

There are conclusive data that transferring Alanine racemate into the state of L-enantiopurity requires an energy of 5.7×10^{-7} J/mole·K [54]. Furthermore, according to the results of computations [55], transfer of carbynes into fullerenes is accompanied with an entropy decrease of 3.692 J/mole·K. The observed decrease of entropy in this case is indicative of a significant ordering of the system. As it was demonstrated in [56], a transition of a medium consisting of H, N, and O into polypyridylphenylene dendrimers is also accompanied with a decrease of entropy, which is also indicative of the ordering of the system. These results demonstrate that in impact-simulating experiments in the processes of self-assembly of fullerenes and dendrimers the increase of the mass of OC's is also accompanied by their complication and ordering.

The estimates based on the change of entropy depending on the size of the plasma formation, which also take into account the energy required for transferring Alanine racemate into enantiopure state, showed that natural physical processes could by a large margin have ensured the attainment of enantiopurity with the increase of the focal diameter of the laser spot from 1500 μm to 15 cm, and the increase of the impactor diameter to 5 cm. In this case the volume of the plasma formation region due to combined contributions of an impactor and crust matter increases by at least 6×10^{13} μm^3 (approximately corresponding to a 4—5-cm diameter spherical impactor), which is sufficient for the synthesis of substances with masses comparable to that of the protoviroid – the hypothetical simplest living being similar to a virus and having an atomic mass of no less than 100 kDa (see Section 4.1). More complete information about results of calibration experiments is presented in Figure 3.

To confirm laser modeling results of an impact, we performed a series of impact experiments, which confirmed our assumptions that impact and laser plasma are practically identical formations.

C. Impact experiments: synthesis and symmetry breaking of amino acids and assembly of short peptides

Experiment [30] used impactors with characteristic sizes of 2-3 mm. The most important results were obtained in direct impact experiments reproducing the physics of a meteorite impact in its entirety. In these experiments light-gas gun was used that allowed impactors to be accelerated to 7 km/s. Impactors had the form of diamond crystals made of ^{13}C isotope. Such isotopic label decreased the $^{12}C/^{13}C$ isotopic ratio from the natural value of 89.33 down to ~1 thereby making it possible to identify amino acids, which were synthesized beyond all doubt in the impact plasma. The multilayered target consisted of a mix of ^{12}C and ammonium nitrite powder (containing H, O, and N) and was reinforced with steel plates.

The results of this experiment are presented in Figures 4 and A2 and according to these data the following processes and features were observed during the plasma expansion:

1) Synthesis of Glycine, Alanine, and Serine with the breaking of the mirror symmetry of L-Alanine with 1.15 excess over D-Alanine (found in SIM mode)
2) Assembly of short peptide with a mass of 300 a.m.u. and consisting of same amino acids
3) Assembly of a polymer structure with a mass of up to 1300 a.m.u. and with mass peaks 28 and 16 a.m.u. apart formed by C, H, O, and N
4) The Glycine to Alanine mass-peak amplitude ratio was 12 and coincided with the results obtained earlier in impact experiments [57,58], however, no symmetry breaking was found in those experiments
5) The polarity of the Alanine chirality "sign" coincided with the corresponding bioorganic polarity and was not random but determined by the polarity of the physical chiral fields of the impact plasma

This was the first experiment that involved finding the possibility of the breaking of mirror symmetry of amino acids and the possibility of the synthesis of short protein in this medium. It was also found for the first time that the choice of the polarity "sign" of the chirality of bioorganic world was not random – all these results are of great importance. The experiments were carried out under high purity conditions and 13C markers showed that they were contaminant free.

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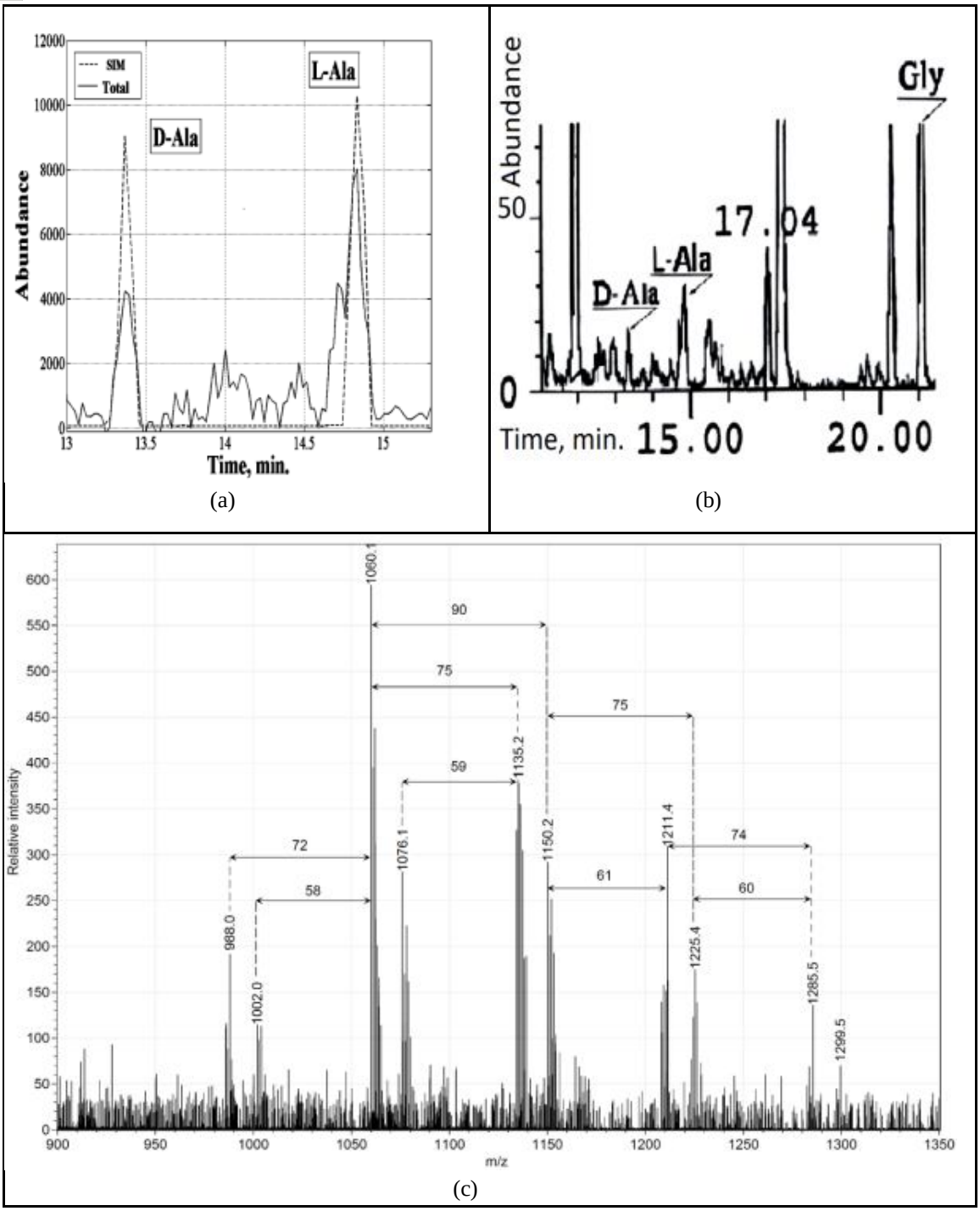

Figure 4. Organic substances synthesized in impact experiment: (a) Section of the total ion and SIM chromatograms of amino acids extracted from the impact sample (N-trifluoroacetyl, isopropyl esters), with the retention times for D-Ala and L-Ala at 13.3 s and 14.7 s, respectively, derived from SIM mode measurements. Comparison of chromatograms in SIM mode and total ion mode to verify the retention times for D-Ala and L-Ala. In SIM mode the mass 140 a.m.u. was used for D-Ala and L-Ala. Processed data are presented; (b) Original (unprocessed) plot for the chromatograms presented in Figure 4a; (c) Mass spectrum recorded with the MALDI TOF/TOF instrument in positive ion mode. It shows a section of the mass spectrum of OC's with a molecular mass around 1300 a.m.u. The arrangement of groups of peaks 1 amu apart is periodic with the periods corresponding to the masses of glycine, alanine, serine and their fragments. The fine structure of a group of mass peaks is presented in Appendix B. Reprinted from [30] with permission.

D. Impact experiments: synthesis of RNA/DNA

Direct impact experiments aimed at finding the possibility of the synthesis of molecular structures associated with sugars, nucleotides, and progenitors of RNA/DNA structures are important extension of impact experiments [59,60].

To investigate this problem of prime importance using an impact experiment, P was introduced to the target in the form of ammonium dihydrogen phosphate (ADP) in addition to C, H, O, and N. Impact compression of up to 790 GPa was produced by wolfram impactors and ensured total atomization and ionization of the target and impactor matter.

Because of the spectral noise caused by relatively high yield of phosphoric acid ions we could confidently detect only the mass peak of glucose (Figure A3). This noise prevented the detection of the breaking of the mirror symmetry of this compound. It is important that trace amounts of some other, equally interesting molecular structures, such as ribose and maltose, were also detected in the spectra obtained.

As is evident from Figure 5, the results of the same experiments showed conclusively that the monomeric structural unit synthesized in the impact plasma had the form of orthophosphoric acid (Figure A4) with polymerization degree from n = 2 to n = 25 and empirical formula $(H_3O_4P)_n$.

The possibility of stochastic synthesis of such a polymer shown in Figure 5 in the impact plasma is of special interest because this structure proved to be a close analog of the backbone of the reactive center of the synthesis of DNA/RNA nucleotides ensuring their preliminary covalent bonding with purine of pyrimidine bases. It is also possible that primary nucleic acids were represented in the form of poly orthophosphate chain with a sterically axial arrangement of nitrogenous bases.

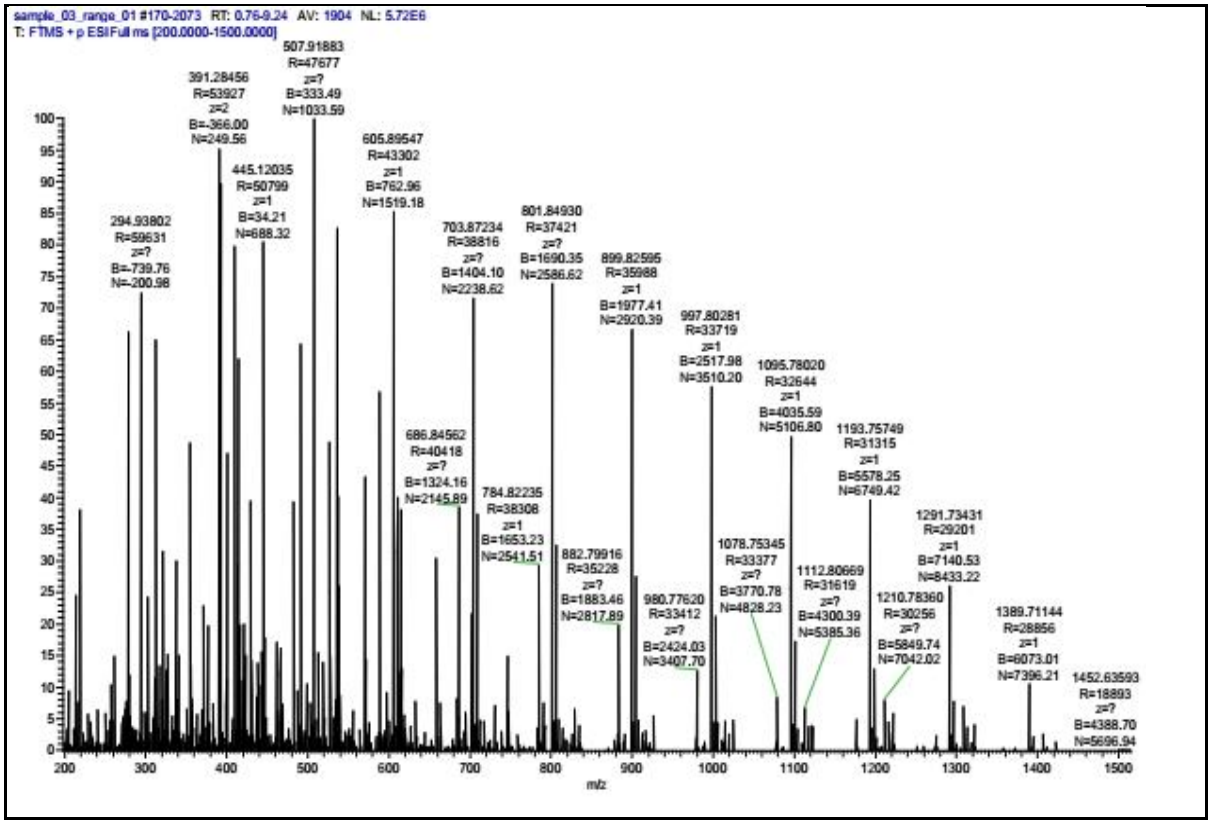

Figure 5. Mass spectrum obtained as a result of an impact experiment with tungsten impactors and a target containing C, H, O, N, and P. The mass spectrum is interpreted as the mass spectrum of poly orthophosphate.

Thus the results of plasma experiments presented above obtained in experiments on laser simulation of an impact and the results obtained in direct impact experiments show that the most important requirements put earlier by the biological community to the environment and processes and considered to be necessary for the emergence of life are easily and without inconsistencies completely fulfilled in the plasma medium. Furthermore, in the case of increased characteristic size of the plasma formation region these processes may also ensure the synthesis of protoviroid-like molecular structures.

E. Identity of Impact Mechanism of Enantiomers Synthesis in Nature

The studies of amino acids in chondrules of Murchison meteorite carried out in [20] showed for the first time that abiogenously synthesized L-Alanine found in Murchison meteorite and synthesized 4.563 billion years ago [61] has a factor of 1.17 excess over D-Alanine. A comparison of the data obtained in direct impact experiments [30] with those obtained from an analysis of chondrules [20] showed the coincidence or similarity of the following properties: identical amino acids, the same "sign" of their chirality, and very similar degrees of symmetry braking. The characteristic sizes of chondrules also coincided with those of their artificial analogs. Such a strong similarity of the results cannot be accidental and is indicative of the identity of the underlying initial processes or of the fact that chondrules could have formed in impact processes ~4.5 billion years ago, possibly even before the Earth began to form. This conclusion is consistent with the current hypothesis that amino acids in chondrules formed in the processes of impact melting and are the oldest celestial bodies with close to the solar composition [62].

The identity of the initial processes ensures that identical results are obtained and allows joint reduction of the data together with those obtained by analyzing chondrules produced in a meteorite impact. This approach improves substantially the reliability of the research results. The results obtained are especially valuable because they made it possible for the first time to trace the entire transformation of amino acids in the impact plasma from their synthesis, symmetry breaking to the formation of proteins, which were also synthesized for the first time in impact processes. Further progress required performing similar studies involving the synthesis of sugars, nucleotides, and DNA/RNA structures. Such an impact experiment whose results are presented in the previous section was successfully performed. However, as we pointed out above, we could not determine the chirality "sign" of sugars.

In the following paper of Cooper and Rios [22], which was published almost simultaneously with paper [30] on the synthesis of amino acids in impact plasma, relieved us from the need to engage in similar very complex studies to search for the chirality sign of sugars in the plasma torch and in chondrules. Cooper and Rios [22] reported finding enantiomers of sugars with maximum excess ratio of D-enantiomers over L-enantiomers, which was as high as 6.4 in some of the cases as is evident from the data presented in Figure 6.

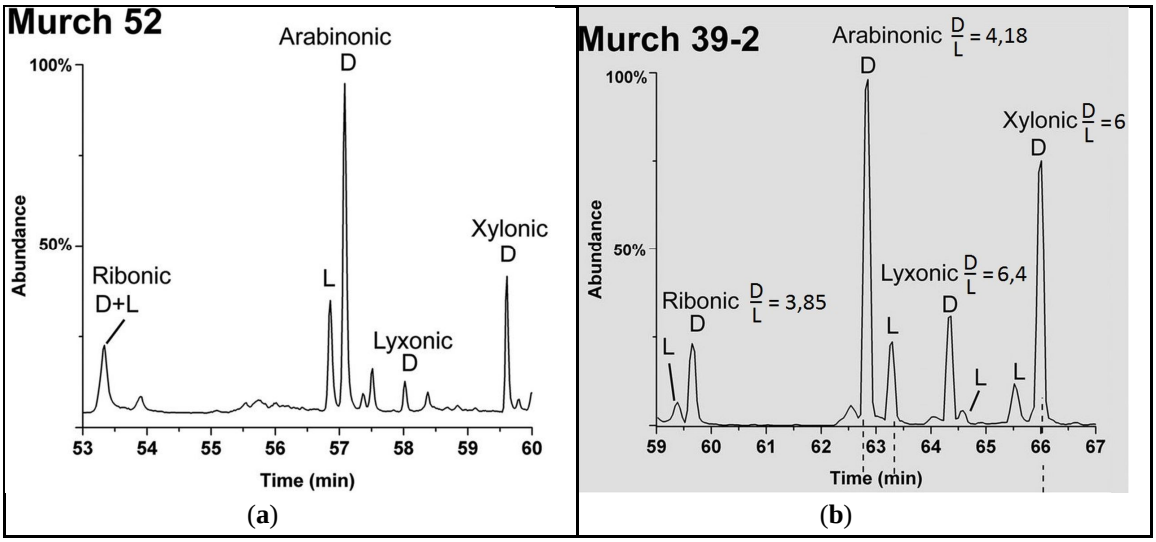

Figure 6. Mass spectra of sugars found in chondrules of the Murchison meteorite. Unlike the situation with amino acids, the symmetry breaking of 5 and 6 carbon sugars with D-enantiomer excess ratios as high as 6.4 (Lixonic) can be considered to be significant. The results of these measurements indicate that sugars in the samples considered are not far from enantiopurity and can be found in the process of the analysis of new Murchison meteorite samples: (a) Data from Murch 52 sample; (b) Data from Murch 39-2 sample. Reprinted with changes from [22] with permission.

The experimentally established identity of the processes occurring in impact experiments and during the formation of chondrules lead to a conclusion that enantiomers of sugars in the Murchison meteorite should have also been synthesized in a process similar to meteorite impact. A comparison of the amino acid enantiomer ratio (L/D = 1.15) obtained in the impact experiment (see Section 3.3) and the sugar enantiomer ratio (D/L = 6.4) measured in the chondrules of the Murchison meteorite bear information of great importance about the nature of the formation of enantiopurity, characteristic sizes of natural impactors that synthesized chondrules ~4.5 billion years ago, and about the nature of the symmetry breaking.

Thus with increasing absolute value of the enantiomer ratio the medium progressively approaches the homochiral state and once this state is achieved the enantiomer ratio becomes infinite. However, because of the complete lack of information as to what radiation causes the breaking of mirror symmetry of sugars and given that we know conclusively how the symmetry of amino acids is broken, it can be assumed that LRCPR, which inevitably forms in the impact plasma and ensures the photolysis of D amino acids in the case of sugars should destroy L sugars exclusively. And, finally, we should bear in mind that the increase of the characteristic size of impactors brings about the increase of the degree of ordering arising in the plasma medium that forms in the impact and the medium attains enantiopurity.

Thus it was demonstrated that enantiopurity can, in principle, develop, and propose experimentally found natural mechanisms of self-assembly and ordering of molecular structures and the properties of the medium that ensure the synthesis of molecular structures with extreme ordering.

It was found experimentally that the degree of ordering depends on the characteristic size of an impactor or plasma formation. An important feature of the mechanisms and processes found is the close genetic link between the processes of the formation of enantiopurity and the processes of the formation of a chiral medium and synthesis of enantiomers. This result is of great importance because it uncovers the fundamentals of the physical processes of the formation of enantiopurity. In this respect they are of considerable importance because finding just an enantiopure medium whose form is familiar to us, may be not too interesting.

In this connection it is appropriate to recall that the finding of the effect of mirror symmetry breaking in carbonaceous chondrites has remained with satisfactory explanation for 25 years. Only now, in consequence of the results obtained in the process of the development of the Plasma Concept, a satisfactory mechanism for the formation of chondrules was proposed, which is associated with the impact process identical to meteorite impact. There is every reason to believe that enantiopure medium will possibly be found in carbonaceous chondrites, perhaps even in the Murchison meteorite, because it will be too difficult to find under laboratory conditions. This is due to the fact that technical limitations of light-gas guns currently do not allow substantial increase of impactor masses without which it is practically impossible to achieve enantiopurity. However, this problem can be addressed in the near future within the framework of the “Head impact” low-ionosphere experiment proposed by Managadze and Eismont [63], where two retired ballistic missiles moving on a head collision course could provide the required impact velocity, impactor mass and size.

IV. POSSIBILITY OF THE PROTOVIROID SYNTHESIS IN THE IMPACT PLASMA

A. Protoviroid – the progenitor of the biosphere

One of the main requirements to the origin of life conditions is that they must ensure a significant number of statistical trials. To estimate the number of trials provided by the plasma concept it is necessary to know the size and mass of the first living beings - self-replicating macromolecules - that formed on Earth. However, currently there is no consensus of opinion regarding the nature of the first organism – the progenitor of modern biota.

Currently, the dominating hypothesis of the origin of life is the RNA world hypothesis: Gilbert [64] and many other authors believe that the first living organisms were made of RNA. The advocates of this hypothesis usually do not propose any particular model for the first living beings.

An alternative hypothesis (progene hypothesis) [65,66] assumes a certain structure and a certain emergence scheme of the first living organism, which consists of the following: it is either a bimolecular system consisting of a polynucleotide gene, which includes ~300 nucleotides and a polypeptide, and having the form of processive polymerase consisting of ~100 amino acids. By its nature this being is similar to a virus and designated as protoviroid (Protoviroidum primum). Protoviroid forms not from mononucleotides and mono amino acids, but rather from triplet structures named progenes: NpNpNp~pX~Aa, where N - nucleotide; p - phosphate; X - bifunctional agent, e.g., ribose; Aa - amino acid, and ~ - macroenergic bond. The molecular masses of progene and protoviroid are ~ 1 kDa and ~ 100 kDa, respectively.

The progene formation mechanism gives a clue to the complex issue of primordial selections of substances for constructing the first living organism, and to an even more complex problem of the origin of the primitive genetic code. Protoviroid originates in lipidic vesicles as a result of progene combinatorics as an extremely rare event, it proliferates via a unified replication-transcription-translation (RTT) mechanism based on progenies and because of its capability of Darwinian evolution. Protoviroid needs nothing for it to originate and proliferate (it even does not need a ribosome) except progenes and conditions under which these progenes originate. Further evolution of protoviroids proceeds via duplication of genes. The general scheme of the evolution of protoviroids includes «monogenic protoviroid -> polygenic protoviroid -> polygenomic cell». Subsequent evolution of polygenomic cells results in the development of a biota formation consistent with the present-day biota including the emergence of present-day types of cells and viruses.

Thus the hypothesis of A. Altshtein pointed the way that was fundamentally different from the RNA world idea. Academician A.S. Spirin, who himself advocates the idea of the RNA world, characterized the progene hypothesis as "clever and attractive" [67] because the properties needed to ensure replication and formation of the simplest genetic code were incorporated into the protoviroid structure even before its "vitalization". In accordance with these properties the protoviroid was adopted as the model of the first living being, the progenitor of biota [65], because it could originate under abiogenic conditions on the early Earth. However, for life to emerge the protoviroid had to ensure the breaking of the mirror symmetry of enantiomers and be enantiopure. Thus the hypothesis of A. Altshtein indicates the way that is fundamentally different from the RNA world idea.

To address this problem, A. Altshtein proposed a scheme where the development of enantiopurity in the process of the formation of progenes was facilitated by steric interactions between an amino acid and a dinucleotide, as well as by prebiological selection of "correct" monomer sequences, which at the same time prevented further development of "wrong" sequences. However, the major weakness of the proposed scheme of the enantiopurity emergence was the complete lack of experimental evidence supporting the feasibility of this process in nature. It is notable that protoviroid, which was adopted as a working model, fitted quite well into the plasma concept, which had its own, well justified physical mechanism of the symmetry breaking for enantiomers that were synthesized in the plasma and used for the enantiopurity origination. A combination of such macromolecular structure with unique, hitherto unknown properties of the impact plasma could, in extremely rare cases, ensure the development of structures capable of replication and transferring these properties to subsequent generations via a very simple genetic code. To produce this extremely rare sequence of monomers needed for the emergence of the capability to replicate, the medium must ensure the occurrence of at least 10^{30}-10^{35} statistical trials. It is important that the experimental part of this study demonstrated conclusively that plasma processes of a meteorite impact ensured the fulfillment of the "Main requirements" needed for the emergence of the simplest forms of living matter and a protoviroid in particular. And, possibly, not only of a protoviroid.

In this connection of considerable interest is the possibility of the synthesis of other important biological molecules, e.g., precursors of ribosomes, in the impact plasma. Thus it can hardly be ruled out that a protoribosome – a molecular structure consisting of ribosome RNAs and proteins – may form in the process of yet another stochastic synthesis of molecular structures in the impact plasma. Many researchers seriously doubted the possibility of abiogenous synthesis of ribosomes under the conditions of nonliving matter because of the complex chemical structure and large molecular mass of these substances. That is why a hypothesis was put forward suggesting that ribosomes may have begun to form gradually and much later, after the development of the first living organisms, and this could substantially facilitate the increase of their mass and complication of their molecular structure.

Eventually, the molecular structure of ribosomes was established and it was suggested that ribosomes in today's living organisms may have formed from a very simple RNA molecule – a protoribosome – which could catalyze the combination of two amino acids. All other building blocks of the ribosome were added successively to the protoribosome without disrupting its structure and gradually enhancing the efficiency of its operation. This history is also of considerable interest because the synthesis of a protoribosome could also occur in an inorganic nature. This possibility is evidenced by the fact that the molecular mass or protoviroid is close to that of protoribosome, and also by the close similarity of their structural properties. In 2009 Bokov and Steinberg [68] demonstrated experimentally that with protoribosome present all other building blocks of ribosomes could be added to it without disrupting the structure of the ribosome, and gradually enhancing its efficiency bringing it to its nominal level. The possibility of abiogeneous synthesis of protoribosome considered above is consistent with the impact-triggered plasma synthesis and therefore the synthesis of protoribosome could be successfully realized in natural impact processes on the early Earth. This is evidenced by the results of laboratory studies, which demonstrated that in impacts with impactors of 4–5 cm diameter it is possible to synthesize a structure that corresponds in mass and in complexity to the protoviroid as well as to the protoribosome. Study of this process and investigation of other models of the first living beings have great importance and could clarify nature of the first self-replicating macromolecules - progenitors of the biosphere.

B. Statistical Trials

The available data made it possible to estimate the number of statistical trials for a protoviroid to form during the period of the Earth formation. As it is well known, the Earth formed over 100 million years ago and has accumulated mass mostly as a result of meteorite impacts. It is also known that during this time impact processes consumed energy of about 10^{39} erg [34]. A sizable part of this energy was spent for the processes ensuring the origin of life. It is also known that in the case of a hypervelocity impact the entire matter of the meteorite and the crust matter in the amount of 10% to 100% of the volume of the intermediate crater transformed into molten state and about 5 to 10 % of the total mass of the matter involved in impact processes was spent for generating the plasma formation.

Hence during 10^8 years - the time required for the accumulation of the nominal mass of our planet – the entire meteorite matter and a significant part of the matter of the emergent crater was subjected to plasma processing. Given that the carbon abundance in the Earth crust is no less than 200 ppm, about 10^{25} grams of carbon may have undergone plasma processing [69]. Note, however, that we still do not know the carbon abundance in the Earth in the process of its formation.

Note that to guarantee the generation of shock plasma, it was necessary for meteorites to accelerate in the gravitational field of the Earth to velocities of 5 km/s or higher. Such velocity could have been provided if the mass of the swelling Earth was comparable to that of Mars and reached ~6×10^{26} g or 0.1 of the nominal Earth mass. However, in this case it would be appropriate to exclude the mass of the planet from further considerations.

After decreasing the mass of the planet by 10% the inferred value should be multiplied by a factor of 10^3, because, as is well known, the total area of terrestrial craters is greater than the Earth surface by about the same factor [34]. At the same time, one must take into account the fact that for small impactors only ~5% of the mass taking part in the impact is molten and only ~1% is transformed into the plasma state. For large impactors the part of the mass transformed into the plasma state is significantly higher.

Given these corrections, the total effective mass of the Earth matter subjected to plasma processing was $6\times10^{27} \times 10^3/10^2 = 6\times10^{28}$ g. Recall that the mass of the protoviroid is 10^5 a.m.u. or 6×10^{-19} g. In this case plasma processing could result in the formation of at least $N = 6\times10^{28}/6\times10^{-19} = 10^{47}$ individual regions potentially fulfilling the requirement of the above number of statistical trials needed for the synthesis of at least one “correct” sequence of nucleotides, which could ensure replication. Note that, as it was shown above, no more than 10^{35} statistical trials are sufficient for stochastic synthesis of a protoviroid.

V. SURVIVAL ENVIRONMENT AND SYNTHESIS OF WATER

A. *Required Properties of the Survival Environment*

Of major interest are the required main properties of the environment for protoviroid and determination of the possibility of the presence of such an environment at different stages of the Earth formation.

Protoviroid, which forms in the impact plasma, is genetically linked to the impact crater. It is in the crater that its life may began, which emerged in the process of this particular impact. As a result of impact heating the matter of geological rocks residing in the crater in the form of large monolithic fragments and their melting together with well ground material are ejected into the upper hemisphere and settle down onto the crust surface adjacent to the crater. The crater formation process is accompanied by the formation of slowly setting dense dust clouds, which could protect products of synthesis against ultraviolet radiation. The close link between the impact plasma and impact crater ensures that practically all products of plasma synthesis including the protoviroid that formed in the plasma are preserved in different parts of the crater.

Water is the key substance needed for the survival of the protoviroid after its formation because it is water that delivers admixtures of biogenic elements and chemical compounds and molecular structures dissolved in it to the protoviroid. According to [65], the temperature range of the survival environment should not go beyond the interval from ~ 0 to 30 °C.

Finding natural mechanisms of the synthesis of water to ensure the survival of the protoviroid in natural processes corresponding to the plasma concept became the crucial task at the final stage of the decades long elaboration of the problem of the emergence of living matter. In this connection, some of the natural mechanisms of the synthesis of water, which could have worked on the early Earth and which are considered below, are proposed and experimentally studied.

B. *Synthesis of Water Driven by Solar-Wind Ions*

Managadze et al. [70] demonstrated experimentally under laboratory conditions the possibility of the synthesis of water as a result of the interaction of the solar wind with oxides of the lunar surface. SiO_2 powder and olivine were used to simulate lunar surface matter employed deuterium ions instead of hydrogen ions to distinguish them from terrestrial water. In these experiments the experimentally measured water yield for the present-day solar wind was ~10^{-3}.

According to the nebular hypothesis and the results of [34], protoviroid could have originated only 15-17 million years after the influence of the solar wind onto the Earth’s germ. Until this time, the Earth had insufficient mass to accelerate meteorites to a velocity required to generate full-blown plasma ejecta where a protoviroid could form. Therefore by the time a protoviroid appeared the germ of the Earth had already a reserve of water formed as a result of the effect of the solar wind over a time period of 17 million years.

Given all the factors mentioned above, the average thickness of the water layer at the surface of the Earth germ could be as large as ~4 μm, which should have been sufficient for the survival of the protoviroid.

Greenwood et al. [71] published results of recent studies of the process of the synthesis of water on the Earth. The authors showed experimentally that oxygen isotopic ratios in lunar rock samples and in the samples retrieved from the Earth ocean floor coincided to within 3×10^{-7} % and differed from the corresponding ratios for the matter of asteroids and comets. According to their estimates, asteroid and comet water made up for 5 to 30% of the total amount of the "Earth water". These results strikingly illustrated the fact that water on Earth was mostly of "local origin" and that is was unlikely to have been preserved on the germs of the planets that have undergone strong heating and impact cataclysms.

Therefore a hypothesis arose that the Earth began to form far from the Sun, which could prevent excessive heating of the surface of the planet. Note, however, that there are other natural factors that could neutralize the mechanism of the synthesis of water driven by the interaction of solar-wind ions with oxides. These factors could contribute to significantly reduce the access of solar wind to the Earth surface and they must have become substantially more intense with the growth of the Earth. Here two well-known factors are meant: the first one – the ever intensifying magnetic field of the germ of the Earth, which was capable of reducing the ion flux to the Earth, and the second factor associated with the formation of the neutral atmosphere, which was also capable of suppressing the flux of solar-wind ions. Currently, material evidence has been found indicating that the Earth's magnetic field originated 400 million years earlier than previously believed [72]. If magnetic field existed during the first several dozen million years of the formation of the Earth the synthesis of water driven by the interaction of solar wind with oxides and in the absence of the atmosphere should have "died out". In this connection, it became necessary to search for a new natural mechanism of the synthesis of water capable of providing the survival zone for the protoviroid.

C. Synthesis of Water in Impact Processes

Water could be synthesized in pulsed processes occurring during the meteorite impact onto the Earth surface containing oxides, hydrides, - like many other molecular structures could have formed in the process of stochastic synthesis (see Sections 3 and 4). The major advantage of water, which could be synthesized in the impact plasma, should be that such water could be synthesized in the same environment as the protoviroid. In this connection, there were no problems with transporting water to the region where the protoviroid could have originated. Experimental studies of the proposed impact mechanism of the synthesis of water were performed in the process of impact-simulating experiments and are shown in Figure 7. In these experiments the plasma environment of an impact was generated by exposing a target consisting of a mechanical mix of TiH_2 and SrO to a laser radiation.

In these experiments the synthesis of water was observed in ~10% cases of exposure, whereas the water yield was equal to ~1% of the mass of the substance subjected to plasma processing. Note, however, that we performed the experiment with TiH_2 and SrO, whereas the efficiency of the synthesis of water could differ significantly in the case of the use of other compounds. Furthermore, laser simulation reproduced the processes that occur in plasma, but did not reproduce processes of the formation of the crater and the target. It was demonstrated that the water synthesis mechanism described here can, in principle, be realized, however, estimating the quantity of water synthesized under real conditions requires further investigation.

In view of the uncertainty of the quantity of water synthesized in impact processes, some extra sources of water were looked for.

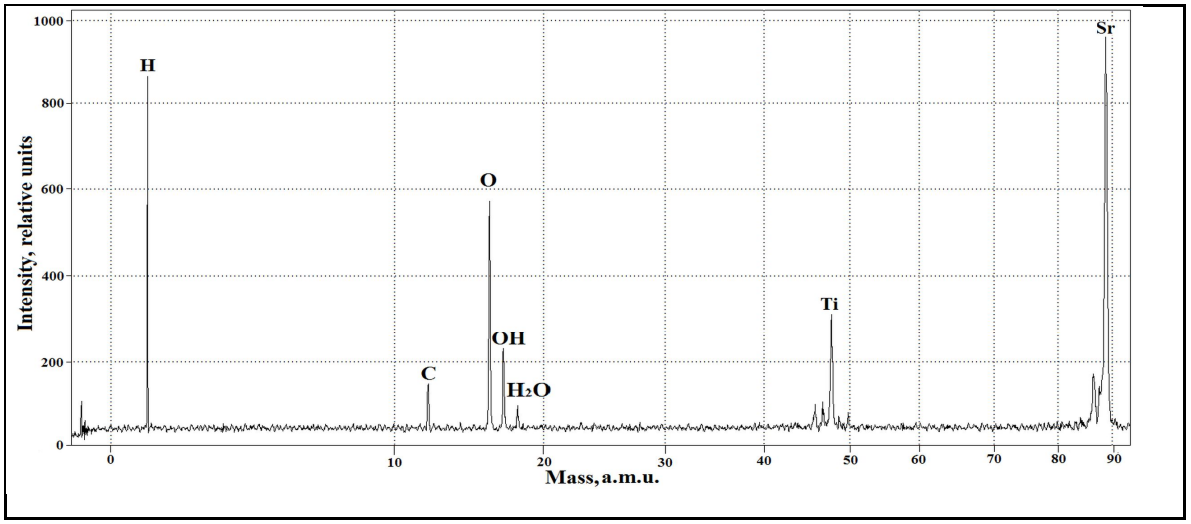

Figure 7. H_2O (M=18) and OH (M=17) synthesized in the process of the simulation of a meteorite impact by exposing a mechanical mixture of SrO and TiH_2 powder to laser radiation.

D. Thermal Processes of the Formation of Water

Other important properties of the impact effect increasing the water yield include substantial heating of the region located around the intermediate crater inside which the temperature of minerals can be as high as 1500 K. The temperature distribution at the final stage of the crater formation corresponds to the distribution of heated rock fragments over the entire surface of the resulting crater after its collapse.

Assuming that the early Earth began to form in cool regions of the Solar system far from the Sun [71], the abundance of ice at the surface of the young Earth combined with a meteorite impact could with high probability contribute to the formation of water. In the event just described of greatest importance is the impact, which could hit the ice surface or the permafrost zone, and the energy of this impact would bring about ice melting and formation of water. In the case considered it is important that because of the low heat conductivity of the rocks highly ground in the impact the impact zone could cool slowly. The crater cooling time can be computed using the following formula

$t \sim D2/\sigma$,

where D - the meteorite diameter in cm; σ - the average heat conductivity of rocks, which is equal to 10^{-2} Kcal/cm·s·K ([74]. See also [28,29]), which shows that for a 10-km diameter meteorite this time is about 10 million years.

Currently it is impossible to predict what can happen during this time period in the life of a protoviroid in the case of its survival.

The impact heating forms a unique medium with exceptional properties, which is capable of developing its “own” local zone providing water for the impact zone for the emergence of life irrespectively of what conditions existed in this medium before the impact. Hence the impact effect contributes to the formation of processes beginning with the development of a local chiral medium and the synthesis of enantiomers to the development of enantiopurity satisfying all the «Main requirements» without exception.

VI. CONCLUSIONS

170 years ago Louis Pasteur found that life is chiral and asymmetric, however, so far no natural media and mechanism have been found, which would reproduce the conditions ensuring the formation of L-amino acids and D-sugars, and where enantiopurity would be achieved as the main requirement.

To address the difficulties associated with understanding of the nature of symmetry breaking and development of enantiopure medium, the Plasma Concept was proposed according to which all processes required for the emergence of life could occur in the plasma medium of a meteorite impact.

It was shown that a meteorite impact is capable of explaining the required number of statistical trials and creating a medium for the survival and evolution of the simplest forms of living matter. It was shown experimentally during the development of the Plasma Concept when reproducing an impact to a full scale and simulation of impact processes that in the impact plasma the “Main requirements” are fulfilled and understanding is achieved of the underlying mechanisms required for the development of the main mechanisms needed for the emergence and survival of the first living beings. In particular, from the development of asymmetry and until the emergence of the survival environment.

It was shown in the proposed Plasma Concept that:

1) Asymmetric expansion of the impact plasma solely into the upper hemisphere results in the formation of a constant unidirectional ring-shaped magnetic field, which interacts with the plasma UV radiation generating levorotatory circularly polarized radiation. At the same time stochastic synthesis of chiral molecules – amino acids and sugars whose enantiomers (D amino acids and L sugars) undergo photolysis – occurs in the impact plasma. Therefore L amino acids and D sugars end up in excess. This results in the formation of a local chiral physical field whose chirality “sign” coincides with that of bioorganic field and acts as the control field in the process of the formation of the enantiopure medium;

2) It was demonstrated during the development of the Plasma Concept that a factor of 103 increase of the characteristic size of the impact-produced plasma formation resulted in achieving the highest catalytic activity of the medium and the rate of plasma processes increased by a factor of 108-109 compared to a chemical medium. The increase of the effective size of the impactor brought about, with a probability of 10-3 – 10-4, the formation, via self-assembly and complication, of new macromolecular structures from monomers synthesized in the plasma. Having reached the limiting ordering levels, these macromolecular structures formed the chiral medium, which could have attained enantiopurity;

3) It was shown that during the accumulation of the nominal Earth mass the effective mass of the Earth crust, which was subjected to plasma processing, could amount to several Earth masses and, because of the small mass of the protoviroid the total number of statistical trials could have reached 1047;

4) It was shown that impact processes capable of bringing about the formation of a protoviroid could have been guaranteed at meteorite impact velocities of 5-7 km/s and, beginning with this time instant of and until the end of the meteorite bombardment water in the amount required for the survival and evolutionary development of the protoviroid (in case it is born) could have been present at the surface of the Earth;
5) A comparison of impact experiments results with results of the measurements of the composition of chondrules in carbonaceous chondrites showed that the formation mechanism of chondrules operates with high confidence in impact processes and that these processes are identical. This conclusion made it possible to perform a joint analysis of impact experiments data and those of the chondrule composition measurements. The results of a comparison of findings of the excess of L amino acids in impact experiments with the data obtained in findings of the excess of D sugars in chondrules of carbonaceous chondrites after their joint analysis were recognized as material evidence supporting the viability of the Plasma Concept;
6) Thus the impact plasma forms in non-equilibrium and irreversible physical (plasma) processes far from the thermodynamic branch of equilibrium. In the case of the use of synthesized monomers this conclusion ensures self-assembly and complication of the new molecular compounds whose significant ordering may end up in the formation of a enantiopure environment;
7) Life in meteorite impact processes may emerge with confidence in any space region if an impactor moving at a velocity of no less than 5 km/s hits a thick semi infinite target providing conditions for its survival. Life so emerged could have been only of terrestrial type.

It should be especially pointed out that this is the first study to uncover the physics of the process of the formation of electromagnetic fields bringing about the breaking of symmetry and emergence of enantiopurity. Plasma medium and the processes therein with such unique properties were for the first time found experimentally and described in the process of the development of the Plasma Concept, and it is the first time that these processes are used to explore the origin of life.

The Plasma Concept of the origin of life is sound and thoroughly elaborated; it is based on the results having reliable experimental validation, and found to be realizable under natural conditions.

The Plasma Concept with high probability and confidence indicates the reliable path to origination of life taking into account abiogenous synthesis of chiral molecular structures and the process of symmetry breaking in extremely complex natural processes of the ordering of matter. The soundness of the plasma concept also follows from the fact that it is free of the inconsistencies and problems considered above, which are typical for a chemical medium. It follows from the results presented above that when it formed, the protoviroid could have begun its life at large depths in the Earth crust, and that it could have got there during rock motion in the process of the collapse of an impact crater. However, protoviroid could also find itself at the surface, covered with a coating of dense dust clouds. Conditions for the formation of a protoviroid emerged relatively early, about 17 million years after the beginning of the formation of our planet. The gravitational field of the Earth, which then reached the nominal mass of the present-day Mars, could accelerate meteorites to velocities required for the fulfillment of the “Main requirements”, maintaining these conditions until the Earth ran out of meteorite bodies in its vicinity. This is consistent with the data indicating that much more complex life forms than protoviroid already existed in the Earth ~4 billion years ago [74-76]. And it would be quite justified in the future to call the life that originated in meteorite impact processes a terrestrial type.

VII. ACKNOWLEDGMENTS

A. Leonid Kelner

At the time of this paper to be in the final stages of its preparedness for a publication, Dr. George Managadze unexpectedly passed away. During intense discussions of the final version of this paper between myself and Dr. Managadze we considered various options for its publication and the final format of this paper. To a large extent this paper was a culmination of the contract between Fenix Technology International and NASA Goddard Space Research Center under the title “Organic Synthesis in Hypervelocity Impacts.” We are grateful to Dr. W. Brinckerhoff of the NASA Goddard Center for continuous support of this work and his valuable advise and contributions to make this project possible. This research was partially funded by a NASA contract.

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Appendix A

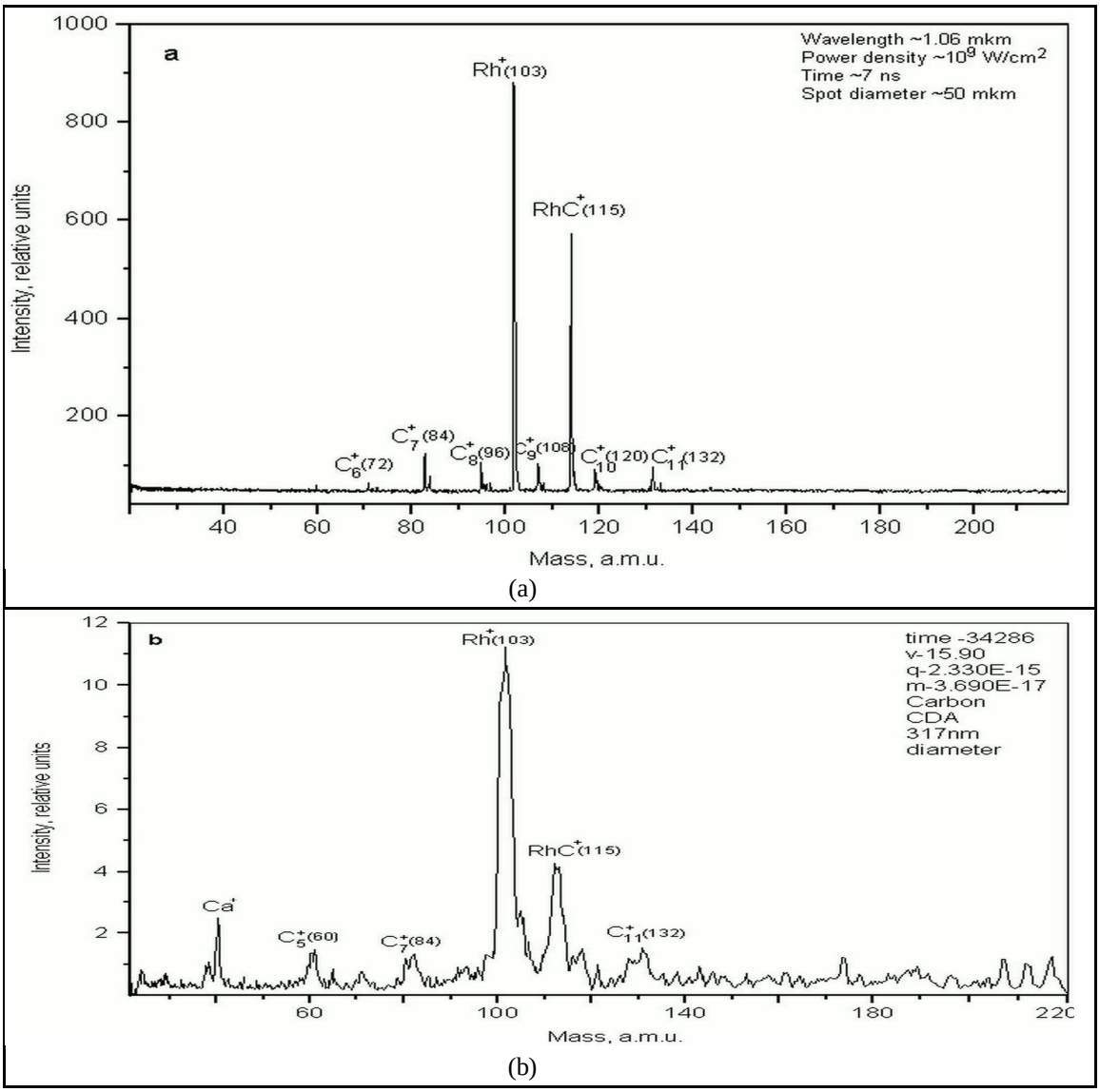

Figure A1. Comparison between mass spectra from laser modeling of hypervelocity impact and those obtained in the dust-impact experiments. Spectra were obtained: (a) under the impact of laser radiation on the target made of pure C and Rh mechanical mixture with the laser wavelength 1.06 mm and W ~109 W/cm2; (b) in dust-impact experiments using the dust particle accelerator with the impact of carbon particles (weight 3.7×1014 g, diameter 317 nm and velocity 16 km/s) on the pure Rh target. This ensured the identity of chemical composition of initial components. Reprinted from [27] with permission.

Appendix B

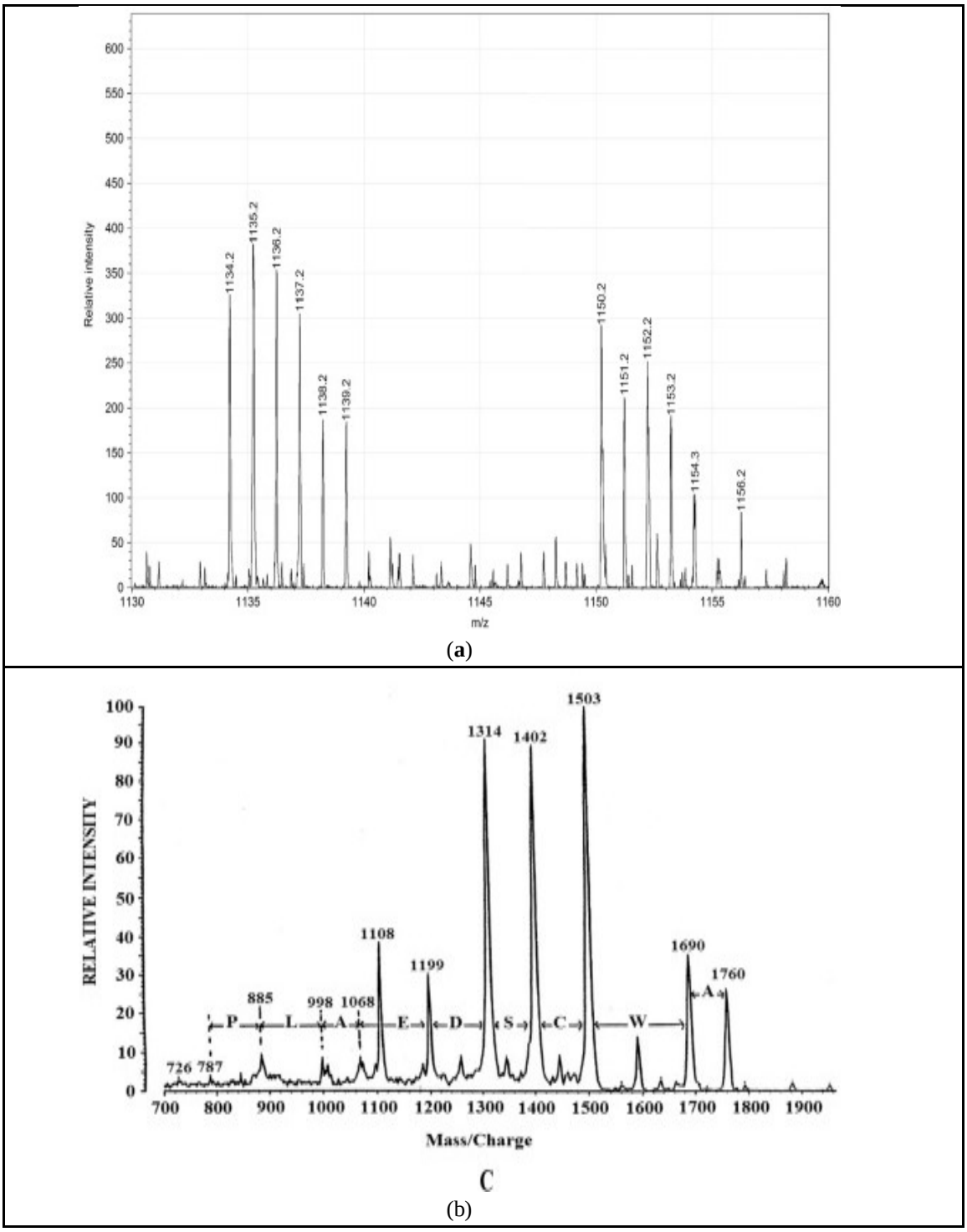

Figure A2. Organic substances synthesized in impact experiment: (a) Mass spectrum recorded with the MALDI TOF/TOF instrument in positive ion mode. It shows the fine structure of a group of mass peaks (presented in Figure 4c), which depends on the number of carbon atoms in the amino acids forming the protein; (b) For comparison, MALDI-TOF mass spectrum of an artificial polypeptide with a molecular weight of 1800 a.m.u., which includes 17 protein amino acids (AWCSDEALPPGSPRCDG). Reprinted from [30,77] with permission.

Appendix C

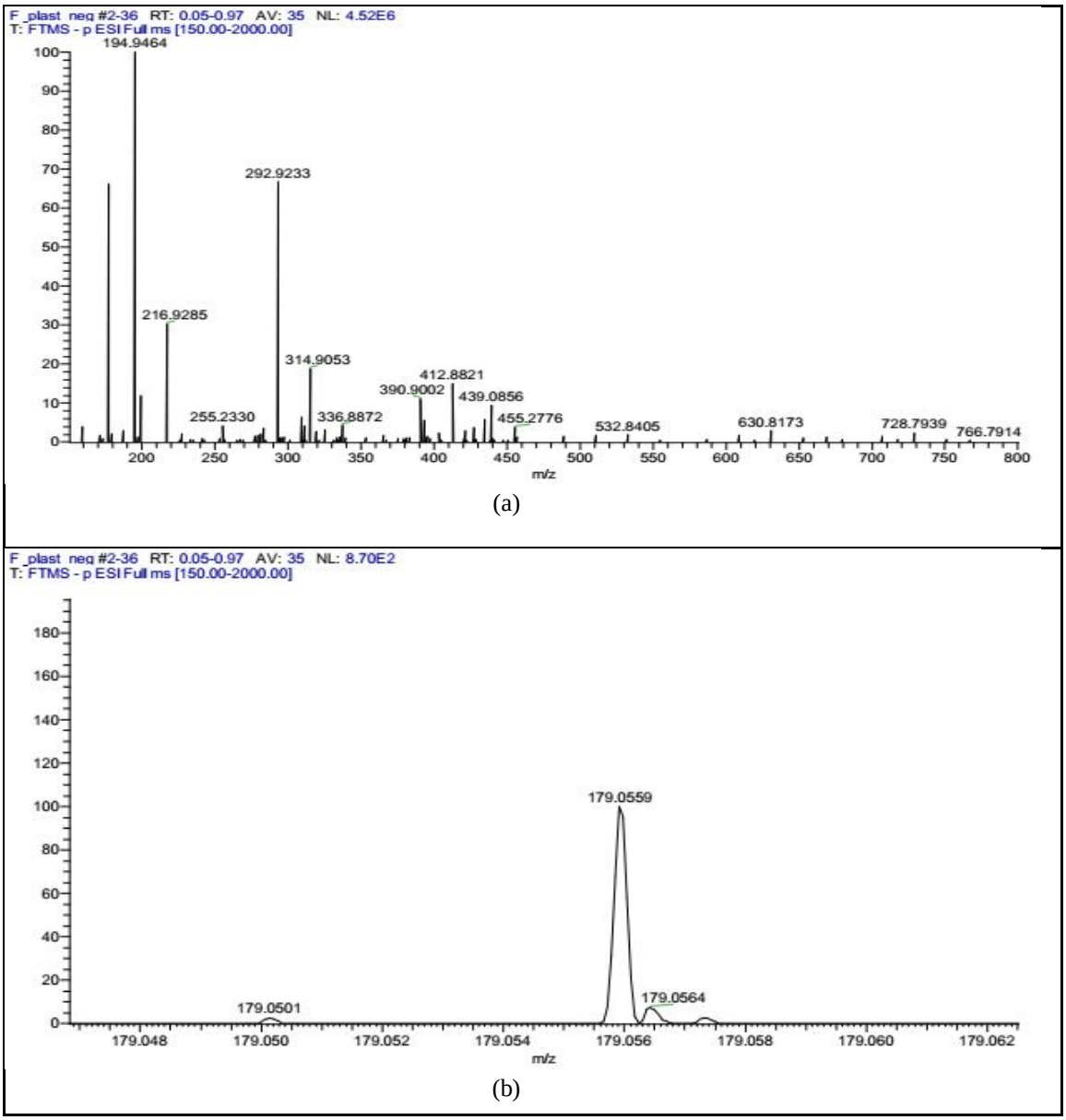

Figure A3. Mass spectrum (electrospray, negative ions) obtained as a result of an impact experiment with tungsten impactors and a target containing C, H, O, N, and P: (a) Full spectrum; (b) Enlarged mass spectrum region with a peak, the exact mass of which corresponds to the deprotonated glucose molecule.

Appendix D

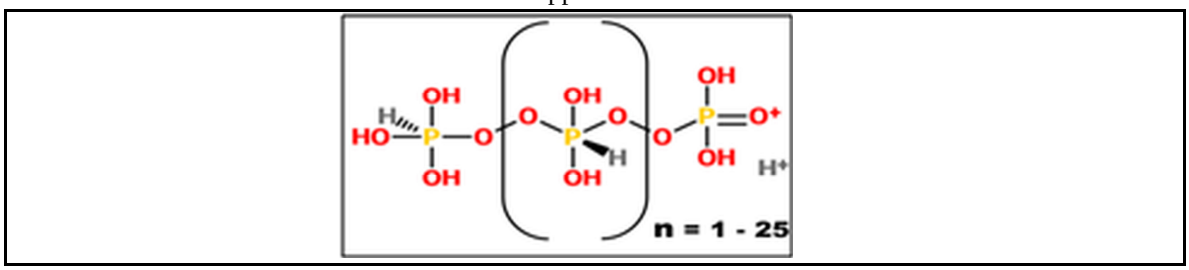

Figure A4. Structure of the poly orthophosphate monomer found in frontal mass-spectrometry analysis. M= 97.97 a.m.u.

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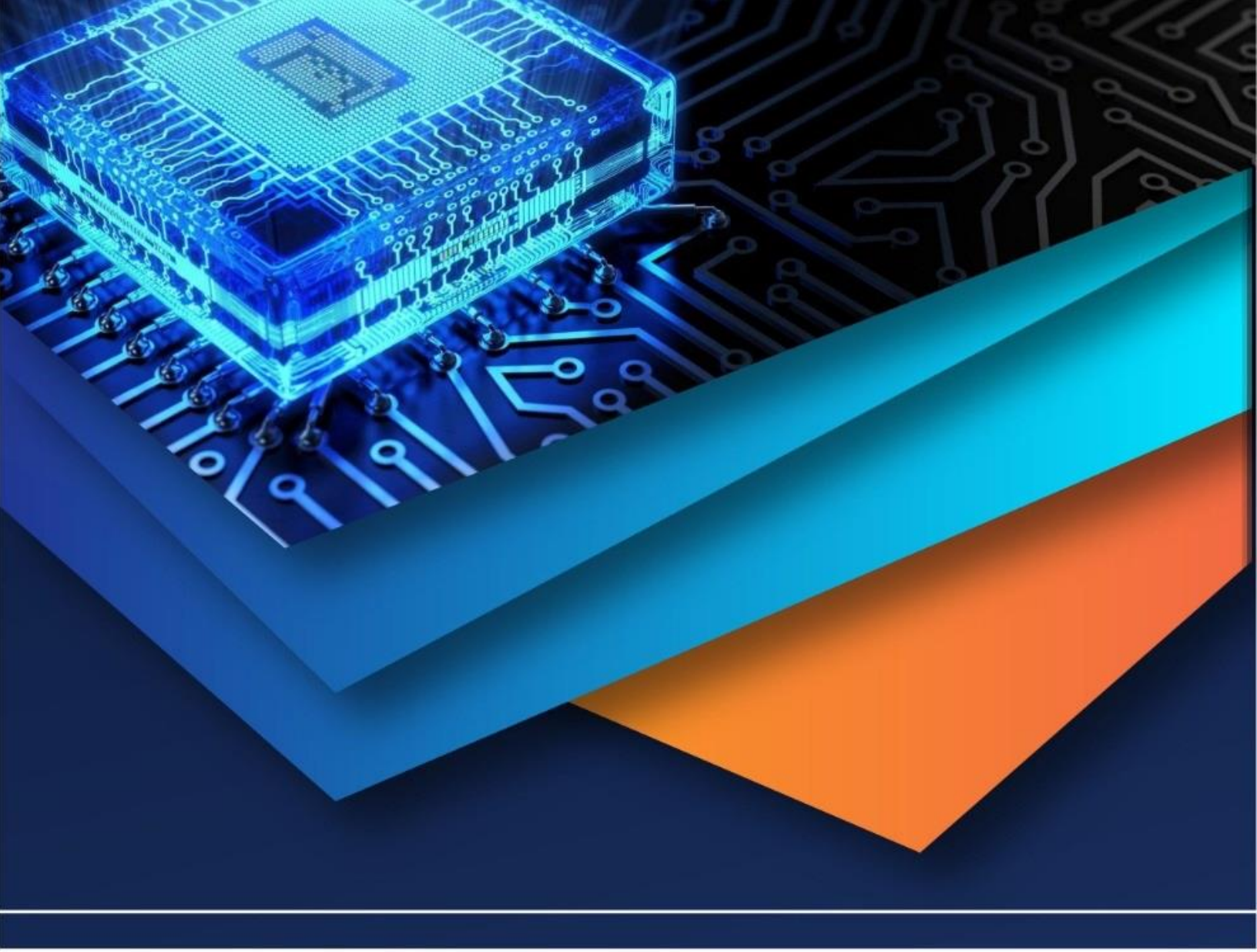

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