4
The Catalysis Project: On the Possibility of Purposeful Expansion of Intelligent Life in the Galaxy

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Abstract

The article deals with the possibility of expansion of biological life, intelligence and modern culture in the Galaxy in the autocatalytic mode using modern and promising technical means. It is proposed to accelerate biogenesis in protoplanetary disks by introducing biocatalysts into them by groups of simple probes with solar sails. The subsequent placement of groups of simple probes with solar sails, used as information carriers is proposed on the periphery of formed exoplanet system.

Keywords: *intelligent life, culture, catalysis, biocatalysts, protoplanetary disk, exoplanets, solar sails, space civilizations, METI, information carriers, evolution.*

The prospects for the further development of intelligent life in the Universe, including modern humanity and its possible subsequent forms, depend to a large extent on the average density of life spread in general and intelligent life in particular, *i.e.*, formally in the scale of the Galaxy – on the values of the factors f_l, f_i, f_c of the well-known Drake equation:

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L,$$

where N is the number of cosmic civilizations in our galaxy with which communication might be possible;

R^* is the number of stars formed per year in the Galaxy;

f_p is the fraction of stars with planetary systems;

n_e is the average number of planets that might support life per star with planetary system;

f_l is the fraction of suitable planets on which life actually appears;

f_i is the fraction of life bearing planets on which intelligent life emerges;

f_c is the fraction of civilizations that develop a technology that releases detectable signs of their existence into space;

L is the average length of time such civilizations release detectable signals into space.

A number of authors (Panov 2013 and others) substantiate the possibility of a qualitative transition to higher forms of organization of matter in comparison with the concept of 'intelligent life' when a certain density of CCs and rather intense interaction between them is reached. The forms of such an organization can be different – from the formation of a single 'galactic cultural field' (*Ibid.*) to the localization of CCs in artificial star clusters and the subsequent intergalactic interaction between them (Novoseltsev 2017b).

However, the existing estimates derived analytically based on the forecast of the values of certain factors of the Drake equation in its various forms, or on any other models, present quite pessimistic expectations of CCs' prevalence. The average distances between existing CCs can be of the order of tens of kiloparsecs (Anchordoqui *et al.* 2017), which excludes any real interaction between them.

This evaluation may change with the transition from a natural science paradigm to an engineering paradigm, presupposing practical activity of CCs, even if they are small and significantly remote in space and time, in a purposeful transformation of the environment. It is important that for a significant influence on the distribution of highly organized forms of matter, for individual CCs such activity as a whole should be of altruistic nature, because its results are manifested in time intervals of a geological or cosmological scale, far exceeding the planning horizon for any pragmatic problems. However, as will be shown below, such activities can also have a certain pragmatic meaning for both the CC and its individual representatives.

As a typical example of such a modern program of artificial panspermia, it is possible to consider, first of all, the Genesis Project by Prof. Gros from the Institute of Theoretical Physics at Goethe University (Frankfurt, Germany) (Gros 2016). The project involves sending some complex automatic probes equipped with power plants, specialized artificial intelligence and equipment for biological synthesis to detectable Earth-like exoplanets. It is assumed that by achieving the destination point, these probes perform a detailed analysis of the environment and using methods of synthetic biology create biological species optimal for the colonization of exoplanets. As a main propulsion system, Gros suggests using laser sail, similar to those being developed for high-speed ultralight probes for Breakthrough Starshot project, and possibly using the same starting infrastructure, and version of 'magnetic sail' (magsail) as a braking device (Gros 2017).

The implementation of the project in the presented form, however, seems unlikely. One of the issues, of course, is the solution by artificial intelligence of Gros's probes, not only technical and biological-ecological, but also ethical tasks. If the artificial intelligence of the probe incorrectly interprets the information about the state of the environment of the chosen as the target exoplanet, it may depress or completely destroy the autochthonous protobiosphere by artificially created invasive species. But a much more likely scenario, taking into account the history of modern practical astronautics, is a series of avalanche-like technical failures that increase during a long flight, as a result of which the probes will be inoperable by the end of the flight. It should be noted that at present there are no powerful energy sources with the necessary resource of several tens of thousands of years, including radioisotope generators. A very limited selection of potential targets is an issue: for all the prospects of synthetic biology, the possibility of creating a complex developed biosphere, and especially of the emergence of potentially intelligent species on such planets of the Solar system with a solid rocky surface as Mercury and Venus, and also most open exoplanets such as 'Earth' and 'super-Earth', seems to be unlikely.

Nevertheless, the issue can be solved. Thus, the author proposed the Catalysis project, focused on the use of the most simple and reliable technical solutions on the basis of modern technologies and materials (Novoseltsev 2017a). The project assumes a purposeful assistance to the mass emergence of life, including potentially intelligent life, and the preservation and distribution of information materials about contemporary culture (METI) in the more distant future than is provided for by the Genesis project, at the time interval of the order of several billion years, not on existing, but the emerging exoplanets.

It is supposed to use as the main technical means the simplest spacecrafts with solar sails, as the most reliable propulsion systems, not involving the use of onboard energy sources. The launch of space vehicles is possible using existing rocket and space technology.

The first stage of the project implementation involves sending to known stable stars (presumably of spectral classes K and F) with distinct protoplanetary disks of a group of 'seeder' probes. The main task of the 'seeder' probes is the delivery to the protoplanetary disks of sets of biocatalysts that promote intensive prebiological synthesis of complex organic compounds (probably, including early primitive forms of RNA and DNA capable of self-replication) in the matter of the protoplanetary disk. In the absence of reliable prediction of the evolution of the protoplanetary disk, the optimum strategy for the project is the *r*-strategy – the use of large groups of probes with the widest possible set of biocatalysts for the parallel implementation of various biogenesis scenarios.

Due to the low thermal stability of biocatalysts for 'seeder probes with solar sails, the possibility of additional acceleration using laser radiation' (Lubin 2016) or 'start with a large acceleration from near-Solar orbits with low perihelion is excluded' (Matloff and Mallove 1981). When choosing potential targets at a distance of up to 100 light-years, this results in increase in the flight time to several million years, which is not crucial in comparison with the overall duration of the project of the order of billions of years, but imposes corresponding demands on design solutions that involve the use of the simplest high-resource analog devices, integrated in the construction.

Thus, for the reasons of radiation resistance the working surface of the sail should not be made from traditional metallized polymer films such as Mylar (Derbes *et al.* 2003), but from metal foil, a single-layer aluminum or multi-layer with an aluminum reflective coating. Sailing control is possible due to varying of its geometry when changing the degree of heating, by using integrated web slings made of materials with TiNi shape memory. It should be noted that the implementation of 'self-controlling' of sail without using any specialized equipment is probably one of the most complex technical problems of the project.

The most important tasks of the distribution of biocatalysts are to ensure the maximum area of their contact with the gas-dust environment of the protoplanetary disk and to exclude their shedding during the flight. In this case, it seems reasonable to place the biocatalysts on the back (non-reflective) surface of the solar sail, facing towards the target. For this purpose, a nanostructured material is proposed to be applied to the sail material in the form of a forest of carbon nanotubes – Vertically Aligned carbon NanoTube Array (VANTA). A typical representative of such materials is the commercial material Vantablack produced by the British company Surrey NanoSystems Limited. These materials on the metal substrate have sufficient adhesion, mechanical and temperature resistance for the application in outer space (Theocharous *et al.* 2014). Biocatalysts are located inside the nanotubes. Due to the high ability of these materials to absorb infrared radiation and a large surface area, this design allows not only to actively adsorb and condense water vapor from the gas-dust environment in a protoplanetary disk, but also to keep water inside the nanotubes in the liquid state when the 'seeder' probe is behind the formal 'ice border' of the emerging exoplanetary system, thus expanding the potential 'habitat zone'.

Due to the extremely low reflectivity of VANTA-type materials , as well as the weakening and scattering of starlight by a protoplanetary disc, the deceleration of the probe due to the solar sail effect (from the surface with the application of biocatalysts) is ineffective. With a relatively small intrinsic speed of the probe, the braking manoeuvre is possible near the target at a combination of gravitational deceleration and aerodynamic braking of a large sail in the gas-dust environment of a protoplanetary disk, with a restriction in the degree of aerodynamic heating determined by the thermal stability of biocatalysts.

It is expected that there will be the drift of the 'seeder' probes, aimed at the star by the side of the sail with the applied biocatalysts, in the matter of the protoplanetary disc to the regions of the 'dust traps', where exoplanets are formed (Gonzalez *et al.* 2017). It is assumed that as a result, by the time of the destruction of the probes, the process of self-replication of complex organic compounds in the areas of the emerging exoplanets and their satellites becomes irreversible and autocatalytic. So, as a result of the first stage of the Catalysis project, the prebiological stage of the evolution of all celestial bodies of the formed exoplanetary system, the physical conditions of which allow the existence of any forms of protein life, is reduced from an interval of about 1.5 billion years for the Earth (Panov 2013) to several million years, and the probability of developing of complex biospheres in each of the emerging exoplanetary systems approaches unity. This corresponds to a correction of coefficient f_l in the Drake equation and indirectly – a correction of coefficient f_i, although the nature of the relationship between them is not obvious.

The next (the second) stage of Catalysis project involves the correction of the coefficient f_c in the Drake equation and represents one of the forms of METI. It involves sending to the same targets to which the 'seeder' probes were sent earlier, some groups of 'keeper' probes carrying a database on modern culture on board. The implementation of this stage is based on the assumption that the most valuable information for any active CC is information of an 'exohumanitarian' nature (*Ibid.*), and the value of information does not decrease over time.

As the origin of hypothetical CCs as potential information recipients is possible for several billion years after the first stage of the Catalysis project has been launched, the low speed of the 'keeper' probes, which simplifies both their launch and braking, is also not crucial in terms of the timing project. This also makes it reasonable to use classical solar sails. The braking process is somewhat different for the 'keeper' probes. It is also a combination of gravitational and aerodynamic braking. However, the necessity to preserve information for several billion years imposes specific requirements. After a brief touch of the outer edge of the protoplanetary disk with low density and the initial decrease in velocity for gravitational capture, the 'keeper' must move to a stable closed but distant from the star orbit, which should minimize its radiation and dust erosion throughout the storage period. It is assumed that the regular geometric shape of the sail and its high reflectivity should facilitate the subsequent identification of the 'preserver' by the hypothetical CCs of the exoplanetary system, one or several, which resulted from the implementation of the first phase.

A separate issue is the data carrier with such a long resource. Previously, there were discussed various data carriers for the purposes of METI or 'time capsules' for a period of up to 1 billion years (Guzman *et al.* 2016), but not for several billion years in conditions of continuous radiation load. In this case, such promising data carriers as artificial DNA, which require massive radiation protection, are excluded. It is advisable to record information directly in the sail material by means of scanning tunneling microscopy. At the same time, the density of stable recording is of the order of 10^{22} bit/kg with the reserve of

1,000 atoms/bit (Rose and Wright 2004; Surdin 2007), which makes it possible to ensure the safety of information not due to inhibition of a data carrier by a layer of matter several meters thick unacceptable for reasons of mass characteristics of probes, but due to its multiple preservation on the surface of the sail. All the cultural information accumulated by the beginning of the 2000s can be recorded by a similar method on a data carrier with a mass of less than 1 g (Surdin 2007). Multiple redundancy of sail capacity when recording in similar way allows the location of not only general information on its surface but also data of numerous separate individuals, including the results of full genome sequencing and an array of personal information (memories). The latter in fact represents one of the forms of the so-called 'digital immortality' and provides to a hypothetical CC as the addressee of information the possibility of more or less reliable modeling of the personalities of individuals for a more reliable interpretation of data of an 'exohumanitarian' nature.

An interesting question is that of the possible influence of the information of 'keepers' on the development of hypothetical CCs that arose as a result of the first stage of the project. Paradoxically, obtaining such information requires a higher level of technological development than sending it. An object similar to a 'keeper' probe can be detected at the outskirts of an exoplanetary system of CC with a development level slightly higher than current one, during the systematic cataloging of small objects of an exoplanetary system as a part of an Asteroid Threat Mitigation program. But reading the information presupposes sending to the 'keeper' the probe with equipment for scanning tunneling microscopy, its deceleration and approaching with the 'keeper' with high accuracy, and then non-destructive scanning of the surface of a large-sized object which is several billion years old, followed by filtering of interference inevitably resulting from damage of data by radiation, micrometeoritic and dust erosion. The latter is far beyond the modern technical capabilities. CC, which has such a potential for a long time, is rather stable, and the obtained information is not capable of having any noticeable negative, destabilizing influence on its development, but it will be successfully integrated into the autochthonous culture of the CC, formed during the evolution.

On the other hand, in a similar way, the existing modern culture can be spread and continue in the composition of the cultures of the formed CCs.

After the completion of the second stage of the Catalysis project, the situation with the distribution of the CCs in the Galaxy can radically change in comparison with the modern one. If as a result of the project more than one CC appear (the multiplication factor is more than 1), which is possible with a rather large number of targets and sent to them 'seeder' probes, the process of diffusion of intelligent life in the Galaxy can become autocatalytic and irreversible. Any predictions about the possible values of the parameter L, like the other coefficients of the Drake equation, are quite speculative, but it can be assumed that at least some 'secondary' CCs will last long enough and reach a rather high level of scientific and technological development, in order to discover and use the surviving 'keepers'. After 'keepers' are detected, CCs will have access not only to the most important in terms of the worldview information about their own origins, but also information about all targets of the Catalysis project and, consequently, a possible location of other CCs of this generation, as well as proposed by the organizers of the project the common standards of communication by electromagnetic (radio, optical) communication channels. SETI problem in the current definition will not be relevant for them. The combination of more CCs of comparable level of development, smaller distances between them and common communication standards may be a sufficient condition for the formation of such a form of self-organization of matter as a 'galactic cultural field' that is more highly organized than single CCs (Panov 2013).

In the event that at least some 'secondary' CCs, using the information obtained from the 'keepers', implement their own versions of the Catalysis project, the intensity of the process of diffusion of intelligent life in the Galaxy will increase significantly. By this time (several billion years from now), the number of stars with protoplanetary disks and the emerging exoplanets in the Galaxy may increase by an order of magnitude (Behroozi and Peeples 2015), and the distances between them will correspondingly decrease. In addition, the number of such emerging exoplanetary systems in 4.5 billion years from now, will increase significantly during the merger of the Galaxy and the Andromeda Nebula (Cox and Loeb 2008). In the future, rather closely spaced CCs of subsequent generations can realize more intensive forms of interaction and joint astroengineering activity, for example, the formation of inhabited artificial star clusters with the possibility of exchanging information over electromagnetic communication channels during months and interstellar flights during the years (Novoseltsev 2017a, 2017b).

Here one can note the pragmatic aspect of the project. In addition to the potential commercialization of a number of technical solutions for 'seeder' and 'keeper' probes, such as solar sail technology, biocatalysis, high-resource materials and ultra-high-density data carriers, the Catalysis project can be considered as the most realistic in terms of the used technical means and the least resource-intensive scenario of self-replication of modern culture, including the personal data of its individual members, to other biological carriers which are optimal for their living environment, its enrichment by the cultural achievements of other CCs and in perspective – to expand to the borders of the Galaxy, as well as the most achievable in the materialistic paradigm variant of immortality.

When considering the Catalysis project in retrospective there inevitably arises the most important question of both scientific and worldview nature: can the biological life known to us in the Solar system and the modern civilization be the result of a similar project realized in the remote past by a hypothetical

CC? Despite the speculative nature of most estimates and the lack of data, the answer to this question with a probability close to unity is negative.

Until recently there have been no signs of the existence of a CC in the Galaxy, which already had sufficient scientific and technical potential for the realization of such a project several billion years ago. Moreover, there were no signs of the existence of such a CC in the past, although a number of possible relevant markers were identified and methods for their registration were suggested (Stevens *et al.* 2015). According to some estimates, 8–10 billion years ago, *i.e.*, in the period of possible birth of life, capable of leading to the emergence of such a CC in the course of development, the conditions in the Galaxy as a whole were unfavorable for most life forms due to the high background radiation due to the activity of the Galactic core (Balbi and Tombesi 2017).

But the basic argument against such an assumption is a rather long period of prebiological development of the Earth which lasted about 1.5 billion years, as well as the practical absence (or, with optimistic assumptions, localization in marginal ecological niches) of life forms at other objects of the Solar system. Some reduction of the known by the geological evidence prebiological development of the Earth in regards to the calculated values can be explained by the development of the initial stages of biogenesis in the Galactic environment before the formation of the Earth (Panov 2013). As mentioned above, the main objective of the first phase of the project is to reduce the duration of the periods of biogenesis to a few million years, and the maximum spread of well-adapted to the environment forms of life in the exoplanetary systems. Thus, the discussion of the Catalysis project makes sense only in the context of planning the activities of modern civilization for the foreseeable future.

In conclusion, one should argue the feasibility of implementation of the Catalysis project in the nearest future and allocation of resources in the presence of other large-scale projects with much closer planning horizons (*e.g.*, human colonization and the possible subsequent terraforming of Mars and other planets and satellites of the Solar system).

At such a low density of the CCs distribution in the Galaxy (Anchordoqui *et al.* 2017), any of them, including, of course, modern humankind, represents a significant and irreplaceable value. At the same time, the existence of modern humankind has been and continues to be subjected to catastrophic risks of varying degrees, from partial degradation to complete destruction, against the background of irresistible natural, and in the 20th – 21st centuries also increasingly important anthropogenic factors (Turchin 2010). A number of authors noted a nonlinear aggravation of processes that carry potential risks in the 21st century (Panov 2013 and others). In this context, the Catalysis project, which is an extended version of 'time capsule', if implemented, sufficiently provides an opportunity for practical indestructibility of modern culture, even under the most pessimistic scenarios and its subsequent large-scale development.

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