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Constraints on Extraterrestrial Civilizations

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Abstract
Using new results for observations of extrasolar planets, we present some constraints on the number of extraterrestrial civilizations in the Galaxy and in the Universe. We discuss the habitable zones around extrasolar host stars with planetary systems in the harsh environment of migrating planets and belts of asteroids. Further, we critically investigate the well-known equations which claim to be able to calculate the number of civilizations in the Galaxy. We conclude that intelligent life is very rare in our Galaxy, since an emerging of intelligence is not a final product of biological evolution. Despite high rates of evolution and/or large time scales. One reason for this is the action of the principle of natural selection which contains no finalism.
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I. INTRODUCTION

Since the discovery of the extrasolar planets (Mayor and Queloz, 1995; Marcy et al., 1999), the question of the number of technological civilizations outside the Solar system is becoming increasingly interesting. Estimations of the number of civilizations in the Galaxy vary enormously. Some investigations conclude that the number is very small (Hart, 1975), while others found a very large number of civilizations (Shklovskii and Sagan, 1966; von Hoerner, 1978; Goldsmith and Owen, 1980). In next section, we summarize the role of liquid water in connection with the habitable zone, where life-supporting liquid water may be favorable. Then we present some constraints for the existence of extraterrestrial intelligent life from the viewpoint of the biological evolution. Here, we emphasize the fundamental role of the principle of natural selection. The new idea of this study is that equation (1) (”Green Bank Formula”) is analyzed critically from the standpoint of the biology of evolution. For complementary literature the reader is referred to textbooks by e. g. Strassmeier (1997, section 12).

II. CONSTRAINTS FOR THE LIFE AND HABITABLE ZONES

2.1 The most abundant chemical elements in the Galaxy

The ten most abundant chemical elements in the Solar system are H, He, O, C, Ne, Fe, N, Si, Mg and S (Arnett 1996). This distribution is valid for the interstellar matter and field B stars in the Galaxy (Snow and Witt 1996). The sequence of abundance of chemical elements given above led to the recognition that life on terrestrial planets evolves on the basis on (liquid) water and CO_2. Further, oxygen-, carbon-, nitrogen- and iron-bearing molecules should be important species for the evolution of life. An evolution of life on the basis of Si- and S-bearing molecules seems highly improbably, at least in the solar neighborhood.

2.2 The habitable zones around host stars

A criterion which defines a region around stars conducive to the development of life is the habitable zone. We refer to some earlier investigations of Hart (1979), Kasting et al. (1993) and Gehman et al. (1996). The habitable zone is determined as the width around a host star enabling earth-like planets can support liquid water at its surface. The inner and outer edges of a habitable zone are defined by the loss of water (e. g. by photolysis) and by the formation of clouds (e. g. the formation of CO_2 clouds), respectively. The latter process is able to increase the albedo of the planet. Some numerical results are e. g. 0.95 to $1.15AU$ for our sun[1]. Gehman et al. (1996) have presented habitable zones in some observed extrasolar planetary systems. They consider the possible existence of habitable earth-like planets in four of observed systems (see e. g. Marcy et al., 1999, Table 1). The investigations concludes that the planetary systems 51 Peg, 70 Vir, ρ^1 Cnc and 47 UMa may have life-bearing planets, since they show habitable zones ranging numerically in the region of 0.4 to $3AU$

[1] $1AU = 150 \times 10^6$ km

for 51 Peg, 0.36 to 2.7AU for 70 Vir, 0.31 to 2.7AU for ρ^1 Cnc and 0.41 to 3.1AU for 47 UMa. All of them have host stars of spectral type G0V to G8V.

An example of a (rocky?) planet which harbors in its habitable zone is the planet Kepler-22b with a mass of $m_p = 2.38M_E$ orbiting a G-type main sequence star (Borucki et al. 2012), M_E is the mass of the Earth. The surface temperature of the planet was estimated as 262K which is in the range of 255K of the Earth. From the theory of the Kuiper belt (Kenyon and Luu 1998), a formation of belts of asteroids in extrasolar systems should be taken into account. An absence of a screen makes a harsh environment unavoidable.

It should be noted that planetary systems like our Solar system are very rare: 3% to 5% of all planetary systems show Sun-like stars with Jupiter-like planets with orbital periods of 2000 days and parameters of $e = 0$ and $a = 5.2AU$ (Wittenmyer et al. 2011). Numerically, Maher and Stevenson (1988) give us some values of impact rates of asteroids. They have calculated the impact rates of asteroids for the early earth: e. g. 4.2 x $10^9 y$ ago every 50.000y one impact hit the earth with the consequence of a global sterilization. An impact every 500y can lead to a climate trauma. The asteroids are thought to be 50 – 75 km in diameter. Without screening any earth-like planet is for a long time subjected to large impact rates of asteroids. In this case the planet is e. g. not able to build up a layer of ozone against the letal UV radiation. Livio (1999) concludes that a shadowing of life (e. g. the eukaryotes) against the letal UV radiation has lasted 1.6 x $10^9 y$ for the early earth.

Previous to the discovery of planets in very small orbits, it was predicted that Jupiter-type planets would form at or outside 3 – 5AU (Boss 1995). But searches for extrasolar planets have yielded the result that many of giant planets orbits within 0.1AU of their parent stars.These close-in planets are called "hot Jupiters". An explanation for this effect may be that the hot Jupiters were formed farther out ($\sim 3 - 5AU$) and then migrated to their current state ($\sim 0.1AU$).

In order for a terrestrial planet in its habitable zone coexist with hot Jupiters, the terrestrial planet must survive the inward gas giant migration. The fraction of terrestrial planets that survive a migration ranges between 15% – 40% (Raymond et al. 2006; Thommes & Murray 2006; Mandell et al. 2007).

Meanwhile some Mid-infrared imagers are able to detect nearby terrestrial exoplanets (Quanz et al. 2015). By indirect methods with the NASA Kepler mission 4981 exoplanets are confirmed[2]. M-stars are of high interest, because around 80% of all stars are belong to this type. A high amount of them is within a distance of $\sim 6pc$ of the Sun. Some examples are the small planet around Proxima Cen with a distance of 1.3pc (Anglada-Esudé et al. 2016), Lalande 21185 at a distance of 2.5pc (Diaz et al. 2019) or the Teegarden's star at a distance of 3.8pc (Zechmeister et al. 2019).

III. CONSTRAINTS FOR EXTRASOLAR INTELLIGENCEFROM THE BIOLOGY OF EVOLUTION: THE IMPORTANT ROLE OF THE PRINCIPLE OF THE NATURAL SELECTION

Let us present some constraints for the formation of extrasolar intelligence and civilizations from the viewpoint of biology and the evolution of species. From the theory of evolution of species, it is well known that the natural selection works in such a way that it rewards an actual success of a population. lt works on variations present in a population. This has a very important consequence: if some populations of species succeed on long time scale, the selection favors production of a large amount of a variation of those species (in German: hohe Variationsbreite). As a consequence, many of animals of this type are formed in the course of evolution. The reader can find an example in Fig.1 of Pilbeam (1984).

Mammals of the order of primates are rewarded by natural selection by a large amount of species of the same kind (order), as they have attributes which favor them in special environments compared to other species. The large amount of species given above can be explained in another way: natural selection has rewarded success by high rates of evolution.

From Fig.1 of Pilbeam (1084) we conclude that in short time scale (4.5 x $10^7 y$) a large amount of species of the same order is formed. The same is true for other animals which show a high rate of evolution. On the other hand, it is well known that several lines of evolution show no progress over a very lang time scale ($\sim 10^9 y$), e. g. some prokaryotes. Nevertheless, they have survived to this day. Prokaryotes are very resistant to harsh environments and ability is rewarded by natural selection. Other examples are the lungfishes and the Echinodermata. Both of these being very old species. The former population has an age of $10^8 y$ (Mayr, 1991), the latter an age of 4 x $10^8 y$. Both show a low rate of evolution. They have not changed morphologically, although they had enough time. In summary, the evolution of species is never aligned to the future in that evolution goes to form some ultimate objectives like intelligent species, despite high rates of evolution and/or long-time scales. The evolution is of the kind of rigid opportunism: natural selection rewards any success: this can be e. g. lungs, blood-circulation, egg-laying or brain-evolution. Under the aspect of natural selection, all of

[2] Exoplanet Orbit Database: http://exoplanet.eu/

these successes are of equal standard, which explains the rigid opportunism mentioned above. The selection is never teleological nor determined by any law (Mayr, 1995).

In several studies Simpson (1964, 1974) ruled out any prevalence of humanoids and finalism in the evolution of species. He pointed out that slight changes in the earlier parts of history would have profund cumulative effects on all descendent organism through the succeeding millions of generations. This conclusion, in connection with the action of natural selection given above, is very important for the evolution of species on extraterrestrial planets. Fig.1 of Pilbeam (1984) shows an impressive example of the high degree of variability of the order of primates for which the selection has worked. Despite a high rate of evolution, the number of species with high intelligence is very low. Mayr (1985) does not preclude the existence of intelligent life on other planets evolved from other mammals than primates. But the improbability of formation of high intelligence is proved very well by the fact that millions of phylectic lineages have failed an elaboration of the brain and the cortex. From 10^9 animals only a single one was able to do this. From all species that have populated the earth (5 x 10^{10}) from the origin of life (3.5 x $10^9 y$ ago), only one species was able to develop high intelligence.

IV. THE EVOLUTION OF SPECIES: NO RANDOM PROCESS

In the earlier years of research into extraterrestrial intelligent life, some scientists believed that the number of technological civilizations in the Galaxy can be calculated by random processes. Shklovskii and Sagan (1966) present the well-known equation for the number of technological civilizations in the Galaxy (Drake, 1961)

$$N=N_s \times f_p \times n_e \times f_l \times f_i \times f_c \quad (1)$$

N_s is the number of stars in the Galaxy, f_p the fraction of stars with planetary systems, n_e the mean number of planets in each planetary system with enviroments conducive for the formation of life, f_l the fraction of such planets on which the formation of life actually develops, f_i the fraction of those planets on which intelligent life evolves, and f_c means the fraction of such intelligent species that have built up a technological civilization. The authors found a large number of civilizations in the Galaxy which range between 5 x 10^4 to 10^6. Although some parameters of equation (1) are well defined, it is not admissible to calculate the number of extraterrestrial civilizations by random processes as given in equation (1).

The number of stars in the disk of our Galaxy is 3.4 x 10^{11} (Scheffer and Elsässer 1992). Catanzarite and Shao (2011) estimate 1% – 3% of stars like the Sun to have Earth analog planets, based on the Kepler data of 2011. Studies from Kepler mission indicate that about 16.5% of stars have at least one Earth-size planet with orbital periods up to 85 days (Fressin et al. 2013, see also the NASA experiment from March 2014 (Gelino and Kane 2014)). We prefer a lower limit of $f_p \geq 0.1$ from Marcy and Butler (2000). The number of n_e is today unknown, because the technique used at present is not capable of detection planets with earthlike masses. On the other hand, a calculation of f_l, f_i and f_c e. g. via a random process is highly questionable. We have shown in the former section that the evolution of species is triggered by the action of natural selection. Due to the extreme diversity of life, calculating e. g. f_i by random processes is not permissible as the natural selection works on extraterrestrial planets under conditions which highly differ from those on the Earth. From the biological point of view we emphasize the causal chain responsible for the existence of the present species and their present number of 3 x 10^7 on the earth (Mayr 1988) it is well known that from the beginning of the era of Precambrian (6 x $10^8 y$ ago) until the era of Pliocene ($10^4 y$ ago), 17 heavy fauna catastrophes (extinctions) have destroyed a large number of species (Stanley 1988). Therefore, the evolution of species on the earth depends on a sharp sequence of causative events since a time scale of at least 6.5 x $10^8 y$.

In summary, it is not possible to calculate fractions like f_i, f_c and the number N by random processes as given by equation (1): the equation (1) is false and is to be ruled out.

V. CONCLUSION

The fraction f_p of stars with planetary systems may be very large. On the other hand, intelligent life and technological civilizations are very rare in our Galaxy, since the emergence of intelligence is not a product of the principle of natural selection; the natural selection contains no finalism for forming intelligent life: natural selection works by way of rigid opportunism on variations of populations of species only. Furthermore, 99% of new formed species died out with any significant evolution (Mayr 1988). As a consequence thereof, the number of intelligent species remains extremly low. A fact well known from the history of life on the earth.

Observations seems to confirm that the number of technological civilizations in the disk of our Galaxy is very low (Horowitz and Sagan 1993). Recently, some new investigations for the Big Ear Wow from 1977 were done (Gray and Marvel 2001; Gray and Ellingsen 2002).

No unusual spectral features, no unusual spectral indices and no temperal variations are observed. A radio signal to the nearest spiral galaxy M31 will have a time scale of 2.4 x $10^6 y$ when we accept a distance of

725*kpc* (Hodge 1991). On the other hand, a signal from M31 would never be detected by any receiver: from Lyne and Graham-Smith (2012) 2000 pulsars are known in our Galaxy. M31 contains a large amount of pulsars, although never observed (Lyne and Graham-Smith 2012). If pulsars of M31 with their large reservoir of energy are unable to contact our Galaxy, no technological civilization in M31 will ever be able to do so.

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