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Article

Life Origin in the Milky Way Galaxy: II. Scanning for Habitable Stellar Systems on Behalf of Future Space Missions

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Abstract: The possibility of the life origin in the stellar systems, located at a distance of $\sim$ 200 pc from the solar system, was investigated. The stars, in the spectrums of which C (carbon), O (oxygen), N (nitrogen), and P (phosphorus) are found, are called DNA–stars. Based on stellar abundances a new method for searching for habitable exoplanets has been developed and a list of 48 DNA–stars in the solar neighborhood, on which life is possible, has been defined. The quota of DNA–stars is equal 1.3% of the total amount of Hypatia Stellar Catalog. Only three DNA–stars out of selected 48 stars belong to the spectral class as our Sun (G2V). The closest to the solar system is the DNA-star with the number HIP 15510, which belongs to the G8V class and is 6 pc away from the solar system. Nine DNA–stars, which have the highest chemical similarity with solar spectrum, were identified. It is identified that one of these nine stars, HIP 24681, has six planets.

Keywords: Interstellar Mission; Habitability; Stellar Abundance; Hypatia Stellar Catalog; DNA-star

1. Introduction

The problem of the existence of life forms outside the solar system has long been of interest to humanity. In the last decade with progress in astronomy and astronautics, new methods to study remote exoplanets have appeared. The number of known exoplanets has been increasing exponentially for 25 years, and now their number reaches $\sim$ 4900 exoplanets. Details about different exoplanet investigation projects could be found in the NASA Exoplanet Archive [1] and the references cited in this resource.

Currently the number of confirmed exoplanets discovered by Kepler mission is equal to 2707 and the Kepler project candidates yet to be confirmed is 2058. A similar ratio of the amount of confirmed to the candidate for K2 and TESS projects are equal to 477/1024 and 176/3475. Note that there are 11 fundamental methods, which using in exoplanet investigations, the major contributions are being to the Transit and Radial Velocity methods, (76.6 %) and (18.6, %), correspondently. Statistic as of the now is given in Table 1. The total amount of discovered exoplanets is equal to 4903 pcs.

In this study, we are interested inhabitable planets, so we will be looking for exoplanets those that fall into the *habitable zone*. Quite often, the *habitable zone* is defined as the area of the exoplanets, in which one of the next expressions is right:

$$180 < \quad T_{exo} \quad < 310\,\mathrm{K} \qquad (1)$$
$$0.25 < \quad I_{exo} \quad < 2.2 \qquad (2)$$

where T_{exo} is equilibrium exoplanet temperature and I_{exo} – exoplanet insulation value in the Earth flux. Note that the achievements in exoplanet habitability, the research methods and plans for the future are represented in reviews [2], [3], [4], [5], [6], [7].

Table 1. The amounts of exoplanets discovered by different methods.

Discovery Method	Amount of exoplanets in pcs.	in %
Astrometry	1	0.02
Imaging	57	1.16
Radial Velocity	912	18.60
Transit	3755	76.59
Transit timing variations	22	0.45
Eclipse timing variations	16	0.33
Microlensing	121	2.47
Pulsar timing variations	7	0.14
Pulsation timing variations	2	0.04
Orbital brightness modulations	9	0.18
Disk Kinematics	1	0.02
All Exoplanets	4903	100

The Exoplanet Archive [1] allows to estimating quickly the amount of exoplanets, for which the condition (Equation 1 or 2) is satisfied. The results of the calculations are shown in Table 2. At the moment, the total number of confirmed exoplanets in the *habitable zone* is 88. Most of these prospective habitable planets have size compared with the size of Neptune.

Table 2. The amount of exoplanets in the *"habitable zone"* for different exoplanet sizes.

Exoplanet radius range, in $R_\oplus$		Amount of exoplanets in the Habitable Zone; Equilibrium Temperature between 180 and 310, in K		Amount of all exoplanets	
		confirmed	confirmed and candidate	confirmed	confirmed and candidate
≤ 1.25	Earth size	7	24	13	924
$1.25 — 2$	super Earth size	25	100	805	1365
$2 — 6$	Neptune size	47	199	1311	1838
$6 — 15$	Jupiter size	9	28	152	316
> 15	Larder	0	10	21	157
	Total[a]	88	361	2302	4600

[a] At present not all exoplanets have their sizes are confirmed, so the total number of about 4600 in Table 2 is slightly less than the number indicated in Table 1

This study suggested a new method for finding life in the remote star systems. As it is known, all biological species on Earth have a unique DNA code (Deoxyribonucleic Acid), which determines the full diversity of biological species. The DNA includes the following elements, namely: C (carbon), O (oxygen), N (nitrogen), and P (phosphorus). The synthesis of Na (natrium), Mg (magnesium), S (sulfur), K (potassium), Fe (iron), Co (cobalt), Cu (copper), Zn (zinc), Ca (calcium), Mn (manganese), and Mo (molybdenum), which regulating growth and development of the elementary biological forms, is also required.

As it is known, the stellar abundance is defined by local synthesis, called a self–enriched process, and by transferring elements from other remote stars. These two processes can be described by Equations 3 and 4:

$$A_{star} = A^s_{star}(t_e) + A_T(t_e, t_T) \quad (3)$$

$$A_T(t_e, t_T) = \sum_{i=1}^{n} \alpha(t_T) \cdot A_i(t_e)) \quad (4)$$

where A_{star} is actual abundance, A^s_{star} – the self–enriched process at star evolution, A_T – the elements, obtained from remote stars, and $\alpha(t_T)$ is space scattering coefficient.

According to the older B^{2}FH model [8] and the newest K^{2}L models [9], necessary elements for life origin, are synthesized on different stars, in other words $A_T \gg A^s_{star}$. In other words, according to the B^{2}FH and K^{2}L models, the solar reactor is weak and can synthesize mainly hydrogen and helium. The heavy elements were transferd to solar system from different sources such as exploding one or more massive stars, and white dwarfs, and dying single low mass stars or merging neutron stars. It is important to notice that the synthesis of various elements on different stars made it impossible to raise biological forms on these stars.

Moreover, the author is surprised to discover that the transfer equation is absent in the chemical models of galaxies (GCE). The error is visible even in the name of models of Galactic Chemical Evolution (GCE), so these models are not models of Galactic Chemical Transport (GCT). For fastidious or evil opponents, the appendix contains the simplest task for translating a textbook. This problem has no solution within the framework of modern astrophysics.

Further, in previous work [10], this problem was solved by the self-enriched process, i.e. the first term in the Equation 3 is prevail, $A_T \ll A^s_{star}$. In [10], it was shown that in addition to well-known processes of slow neutron capture (s–process) and rapid neutron capture (r-–process), there is a new synthesis process in the overheated stars (h–process). The detailed analysis of the spatial distribution of overheated stars, in which an effective stellar temperature are more than 6500 K and the heavy elements are synthesized at the h–process, was carried out in [11].

In other words, most of the elements found in the solar system were synthesized in our solar system at a certain point of its evolution, and were not imported from outside. Due to localization of self–enriched process it is pointless to look for life in that stellar system whose reactor has not synthesized the elements necessary for life origin. Simply put, the astronomers look at those stars where it is easier for them to record remote planets instead of at those stars in which the probability of finding life is higher. The new technique to find habited exoplanets has more prospects than the standard method for determining exoplanets using traditional astronomy methods, see Table 1.

The goal of the study is to find an answer to the following question: In which stellar systems is it necessary to look for signs of life?

2. Materials and Methods

2.1. Biochemical criteria for searching for signs of life on remote stars

Recently, much attention has been paid to exoplanets' study and the possibility of contacts with other extraterrestrial civilizations. At the moment, the criterion of the temperature comfort for biological species, based on the analysis of the exoplanet distance from a star, is often applied to search for extraterrestrial civilizations. This study proposes another way to search, based on the chemical abundance studied above.

As it is known, all biological species on Earth have a unique DNA code (Deoxyribonucleic Acid), which determines the full diversity of biological species. The DNA is a set of four nucleotide ACGT: A — (adenine, $C_5H_5N_5$), C -— (cytosine, $C_4H_5N_3O$), G — (guanine, $C_5H_5N_5O$) and T — (thymine, $C_5H_6N_2O_2$). In RNA thymine nucleotide is

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replaced by U — (uracil, $C_4H_4N_2O_2$). The DNA has two helixes, which covalently linked to a phosphodiester backbone $PO4^-$ (H_3PO_4).

Thus, a star system must occur, except hydrogen, which is present in all stars, other basic elements, such as C, N, O, and P. The stars, in which spectrum it was presented together C, N, O, and P elements, below will be called DNA–stars. Note that the term DNA–star was introduced years ago to label a viral test, so please could not be confused with DNA–star, used in this study.

Biological species such as bacteria, algae, and plants can use light from the star to obtain energy, but they also need a growth medium and some microelements. The bulk growth medium for cyanobacteria propagation contains is next: $NaNO_3$ (1.5), $K_2HPO_4 \times 3\,H_2O$ (0.051), $MgSO_4 \times 7\,H_2O$ (0.075), $CaCl_2 \times 2\,H_2O$ (0.036), Na_2CO_3 (0.02), $FeCl_3 \times 6\,H_2O$ (0.003), in grams per 1 liter [12]. The several microelements involved in the biological process of regulation also must be added: H_3BO_3 (2.86), $MnCl_2 \times 4\,H_2O$ (1.81), $Co(NO_3)_2 \times 6\,H_2O$ (0.0444), $CuSO_4 \times 5\,H_2O$ (0.079), $ZnSO_4 \times 7\,H_2O$ (0.222), $Na_2MoO_4 \times 2\,H_2O$ (0.39), in milligrams per 1 liter. Thus, except for C, N, O, and P, in the stellar spectrum, such elements as Na, Mg, S, K, Fe, Co, Cu, Zn, Ca, Mn, and Mo are desirable.

Biochemical criteria for searching for life on remote stellar system is presence in the stellar spectrum the chemical elements necessary for the origin of life.

2.2. Stellar Abundances in the Solar Neighborhood

In this work for future interstellar missions, the stellar abundance in the solar neighborhood was detailed analyzed. The data is accessible on the site of Hypatia Stellar Catalog (below HSC) by [13]. This dataset includes stellar names, spectral type, and distance from Sun, position, and the elemental abundances for stars in ~ 200 pc solar neighborhood.

The position of the HSC stars is determined in Cartesian geocentric XYZ—coordinates from the Sun and is described by the following relations:

$$
\begin{aligned}
X &= d \cdot \cos(des) \cdot \cos(ra) \\
Y &= d \cdot \cos(des) \cdot \sin(ra) \\
Z &= d \cdot \sin(des)
\end{aligned}
\tag{5}
$$

where ra is right ascension and dec – declination from Hipparcos (J2000) and d – the distance from Sun in pc.

In the HSC catalog, the abundance of chemical elements is defined as the deviation from the distribution in the Sun, normalized according to data of [14] and referred to the H content. Therefore the stellar abundances are measured in relative units [element/H] looks like:

$$
\log(\mathrm{n}_{element}/\mathrm{n}_{\mathrm{H}})(\mathrm{star}) - \log(\mathrm{n}_{element}/\mathrm{n}_{\mathrm{H}})(\mathrm{solar})
$$

The database is updated continuously; currently, it contains information about 3757 stars and about 43 chemical elements. Note that the number of chemical elements registered in the spectra of stars and presented in the HSC dataset may differ for different stars. A detailed description of these data can be found in [15], [16]. For comparison, please also see the CATSUP database, which is a catalog of 951 solar neighborhood stars within 30 pc in [17].

3. Results

The statistical values of abundances of C, N, O, and P in stellar spectrums are summarized in Table 3.

It turned out that phosphorus was found only in the 86 cases of the 3757 HSC stars. That is only 2.3% of stars contain phosphorus. Also, phosphorus has only been detected in stars of the RT2 stellar group ($5600 < T < 6500K$) [10]. Therefore phosphorus is the main limiting element. In the HSC catalog, there is no distinction between ND (Not Detected)

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Table 3. The amount of HCS stars, in which spectrum was specified by the chemical elements that are demanded for DNA creation.

Elements	Amount of stars pcs.	%
C	3217	85.6
O	3107	82.7
N	1044	27.8
P	86	2.3
C, N, O and P (DNA–stars)	48	1.3
C, N, O and P (class G2V)	3	0.08
similar to Earth abundances	9	0.24
Total amount of stars	3757	100

and NS (Not Studying). Of course, it is impossible to draw an unambiguous conclusion from a negative signal; in other words, phosphorus can be determined on some stars during further experiments.

Moreover, some researchers forgot about the fourth element of DNA and did not include phosphorus in the mandatory list for searching for habitable systems. In 2011 the first chemical evolution study was performed [18]. In this study P I line at 1.06 μm was used, and phosphorus in the spectrum of ~ 20 FGK dwarfs was measured. Later in [19] the phosphorus abundances in spectrums of 12 Hyades stars and 9 field stars were reported. However, due to only Fe, Si, and P abundances being listed in [19], it is problematic to include these stars in our evaluation of the definition of DNA–stars. The delay in research phosphorus abundances undoubtedly deforms statistics on DNA–stars. To highlight the importance of the registration of phosphorus in the spectrum of remote stars, the concept of DNA stars (with C, O, N and P) has been introduced.

In this study, we reported that it was found only 48 DNA stars which is 1.3% of the studied array of HSC stars. The referenced DNA–stars are shown in Figure 1a and Figure 1b in the Right Ascension and Declination coordinate system (J2000), see grey points in both Figures.

In this work, it was found that from 48 DNA–stars, only three stars belong to the G2V spectral class, namely HIP 20800 (66.85293, 46.85315), HIP 35209 (109.15178, 1.87877), and HIP 42356 (129.53545, 26.04898), see blue stars in Figure 1a. These stars are located at a distance from the Sun of 30.25, 41.74, and 44.35 pc, correspondingly. These stars' masses are equal to 1.03, 1.08, and 1.06$M_{\odot}$ and radiuses –- 1.29, 1.25, 1.23$R_{\odot}$.

The nearest star to Sun from 48 DNA–stars is the star HIP 15510 (49.98189, -43.0698), located at a distance of 6 pc and belonging to the G8V spectral class (5433.8 K), see magenta star in Figure 1a. Also, it is known, Sun belongs to the G2V spectral class.

We also select DNA–stars, which have abundances similar to the solar system. The parameters of these stars are following: C, N, O, and P abundances are not Null, and Δ abundances are less than 0.2 and above than -0.2. Below, such stars are called T–starts. The RANK of T–stars was determined as the total account of elemental abundances from Li to U, which does not have value in the range of (-0.2, 02) of Earth abundance, normalized by [14]. The position of T–stars was shown in Figure 1b as red stars. The properties of 9 T–stars, which were high RANK, are presented in Table 4. The abundances of life origin elements for selected T–stars are presented in Table 5. The most similar to Sun in the chemical composition are the following stars: HIP 42356 (5910 K, G2V), HIP 48423 (5673 K, G5), HIP 24681 (5879 K, G0), HIP 16852 (5991 K, F9IV/V), HIP 108859 (6091 K, F9V), HIP 47592 (6165 K, F8V), HIP 96895 (5790 K, G1.5V), and HIP 64150 (5748 K, G3IV). The spectrums of these stars have a different number of registered elements, so their mutual rating may change as new information becomes available.

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Currently, the properties of the planets are known only for one HIP 24681 (alternative name HD 34445) of the selected T–stars, which above are presented in Table 4. These planetary properties can be obtained from the Catalog of Nearby Exoplanets database [20] and are also available via the HSC website. The period of rotation, planet mass, and distance have resulted in Table 6.

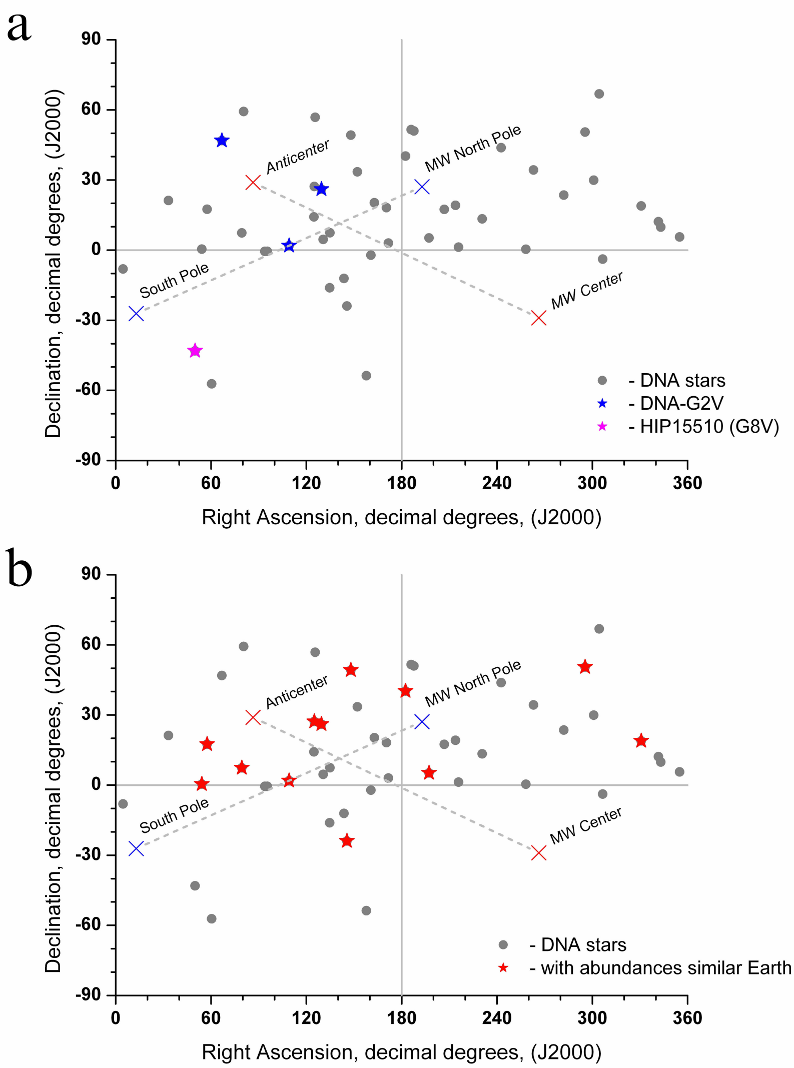

Figure 1. (a) — Three stars belong to the G2V spectral class and the star, closest to the solar system, which belongs to the G8V class, were shown by blue and purple colors; (b) —- Twelve T–stars, which have abundances similar to the solar system, were presented. On both figures as background, the 48 DNA stars, in the spectrum of which C, N, O and P elements were found, is drawn by grey color.

4. Discussion and some remarks

1. The development of the new conception of an ensemble-averaged stellar reactor (EASR), the generalizing theory of the buoyancy of elements and isotopes to stars, definition of self-–enriched stellar mechanism and discovered a new nucleogenesis mechanism, called a hot–process, in [10] allowed to carry out this study.

2. From the comparison of the B^2FH and K^2L models with terrestrial and solar element abundance, it follows that the existence of a set of elements, which was found on Earth,

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Table 4. The stellar property of 9 T–stars, which have abundances similar to Earth. For selection, the next filter was used: C, N, O, and P abundances are not Null, and < 0.2 and > -0.2 of Earth abundance, normalized by [14]. The minimum abundance RANK corresponds to the best coincidence of stellar saturation to saturation of solar system; see STable 5.

	Stellar property								
Number	1	2	3	4	5[a]	6	7	8	9
HIP Name	59280	48423	64150	96895	24681	42356	16852	108859	47592
Temp, K	5409	5673	5748	5790	5879	5910	5991	6091	6165
Radius, $R_\odot$	0.90	0.93	1.10	1.25	1.46	1.23		1.19	1.25
Ra	182.41	148.07	197.21	295.45	79.42	129.54	4.22	330.79	145.56
Declination	40.25	49.19	5.21	50.53	7.35	26.05	0.40	18.88	-23.92
Distance, pc	25.09	33.17	26.36	21.14	46.09	44.35	13.96	48.30	14.81
Spectrum	G8IV/V	G5	G3IV	G1.5V	G0	G2V	F9IV/V	F9V	F8V
RANK	16	2	7	7	3	1	6	6	6

[a] Currently, planet properties are known only for one star, namely HIP 24681

Table 5. The abundances of life origin elements for nine selected stars. The RANK is a total account of total elementary abundances, which does not have value in the range of (0.2, 02) of Earth abundance.

	Element abundance								
Number	1	2	3	4	5[a]	6	7	8	9
HIP Name	59280	48423	64150	96895	24681	42356	16852	108859	47592
C	0.10	0.07	0.10	0.15	0.19	0.16	0.06	0.03	0.08
N	0.01	-0.02	-0.01	0.09	0.07	0.12	0.05	-0.09	-0.07
O	-0.08	0.04	0.04	0.10	0.13	0.10	0.02	0.04	0.06
P	0.19	0.08	0.11	0.07	0.05	0.15	-0.08	0.01	0.08
Na	0.10	-0.09	0.02	0.10	0.07	0.06	-0.05	-0.05	-0.05
Mg	0.16	0.01	0.08	0.18	0.15	0.13	0.05	0.12	0.06
S	0.32	0.13	0.04	0.10	0.05	0.12	-0.03	-0.07	-0.09
K	0.11	0.06	0.17	0.11	0.15	0.17	0.16	-0.06	
Ca	0.21	0.20	0.08	0.13	0.16	0.20	0.00	0.11	0.01
Ca_{II}	0.35	0.24	0.17	0.35	0.17	0.30	0.07	0.29	0.07
Fe	0.20	0.17	0.08	0.12	0.16	0.16	-0.01	0.06	0.00
Mn	0.11	-0.01	-0.02	0.00	0.09	0.06	-0.16	-0.14	-0.17
Co	0.34		0.09	0.14	0.31		0.00	0.08	0.01
Cu	0.21		0.05	0.00	0.04		-0.24	-0.16	-0.23
Zn	0.05		-0.04	0.02	0.01	0.10	-0.10	-0.17	-0.19
Mo				0.10					
RANK	16	2	7	7	3	1	6	6	6

[a] Currently, planet properties are known only for one star, namely HIP 24681

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Table 6. The planet properties of the HIP 24681 star, sorted by semi major axis values

Planet letter	Planet period (in days)	Planet mass (in Jupiter mass)	Orbital eccentricity	Semi major axis (in AU)
e	49.175	0.053	0.09	0.269
d	117.87	0.097	0.027	0.482
c	214.67	0.168	0.036	0.718
f	676.8	0.119	0.031	1.543
b	1049	0.82	0.27	2.07
g	5700	0.38	0.032	6.36

can not be provided by a single source: such as, exploding one massive star or white dwarf, or dying a single low mass star, or merging two neutron stars. Also, to provide a full abundance of chemical elements in the solar spectrum, different types of stars located around our Sun had to blow up together, which is a low–probability event.

3. In the B^2FH model, the frequency of neutron star collisions raised doubts. According to the K^2L model, the neutron star collisions do not create the quantity of chemical elements than previously assumed. In addition to the common lacks of these models, related to the element transfer in space, each model has individual defects. The K^2L mode can not explain the amount of such elements as Cl, K, Sc, As, and Au creating new astronomical *mystery*. In summary, we can conclude: the new K^2L mode did not solve the previous B^2FH model's problems.

4. During propagation in interstellar space the concentration of element abundances will rapidly decrease with the donor star's distance. At uniform spherical 3D expansion, the decrease will occur as $\sim 1/r^2$, and at cylindrical 2D expansion the concentration will decrease as $\sim 1/r$. Thus, for receiving one gram of Th and U on Earth, it is required that the donor star has a colossal value of transuranic elements, i.e., this case the donor–star must entirely consist of thorium or uranium. But such stars have not been found in our galaxy.

5. It is possible to write that according to the HCS, in this part of the Milky Way Galaxy, within 80—100 pc away from the Sun, the probability of meeting aliens or registering a signal sent by them is not too high. Based on the chemical abundances, a list of stars on which the origin of life is possible is defined. Note that earlier in [21] it was investigated the influence of the galaxy on mass extinctions. Therefore, there is not only one problem of life origin on the remote stars, but also other problem of preservation and revival of wise life forms under our galaxy regular oppressive influence.

5. Conclusions

In this study, the possibility of the life origin in other star systems, located at a distance of ~ 200 *pc* from the solar system, was investigated. For the origin of life the synthesis of chemical elements, such as C, N, O and P, which are necessary for the formation of DNA and biological organisms, are important. The stars, in spectrums of which these elements are presented, are called DNA–stars.

Based on the chemical compounds, a new method for searching for habitable star systems has been developed and a list of 48 DNA–stars in the solar neighborhood, on which life is possible, has been determined. These stars make up only 1.3 % of the total amount of studied stars. Moreover, only three stars out of the selected 48 stars belong to the same spectral class as our Sun (G2V). The closest to the solar system is the DNA star with the number HIP 15510 from the Hypatia Stellar Catalog (HSC). This star belongs to the G8V spectral class and is 6 pc away from the solar system. Finally, nine stars, which have the highest chemical similarity with our solar spectrum, were identified (Table 4). Further of these nine stars, as it is currently known, only one HIP 24681 has six planets (Table 6).

This star belongs to the spectral class G0, has an effective temperature of 5879 K, and is allocated at a distance of 46.09 pc from the Sun.

At the moment, we can only express the hope that in the future the planetary properties of not only the remaining 8 stars with a high–affinity rank but all the remaining 47 DNA–stars, allocated in the neighborhood of the solar system, will be investigated.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A The simple task for GCE models verifications]

> "The solar reactor is weak and can synthesize mainly hydrogen and helium. According to B^2FH and K^2L models, the thorium can be synthesized in neutron stars (NS), which have a strong reactor. The nearest NS is RX J1856.5 − 3754, which is allocated at 167 pc from Sun. In the solar system was recorded 1 gram of thorium.
>
> How much of thorium has produced the NS donor-star?"

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