Scanning for habitable stellar systems on behalf of future interstellar missions

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Abstract

In this study, terrestrial and solar abundances were compared with stellar abundances of stars allocated in the ~ 200 pc solar neighborhood. To study the dynamics of processes occurring in these stars, it introduces a concept of ensemble-averaged stellar reactor. According to the effective temperature value, four stellar classes are identified, for which the correlation coefficients and standard deviation are counted. The statement about the possibility of transferring heavy elements, synthesized by stars, at a great distance in the cosmos has been refuted thoroughly. There is no invariance of element distributions on neighboring stars and in solar system. It is shown that the chemical elements are mainly synthesized inside each star reactor. The theory of the buoyancy of elements is generalized to stars. The stars explosion causes are suggested, and a physical explanation of the critical Chandrasekhar limit's existence is offered. It was suggested that stars are over-heated due to the shift parameters of the nuclear processes occurring inside the stars, which leads to the synthesis of transuranium elements, to the achievement of a critical nuclear mass, and then to star explosion. Based on chemical abundances, a list of stars, on which the origin of life is possible, is defined.

Theories of stellar nucleogenesis

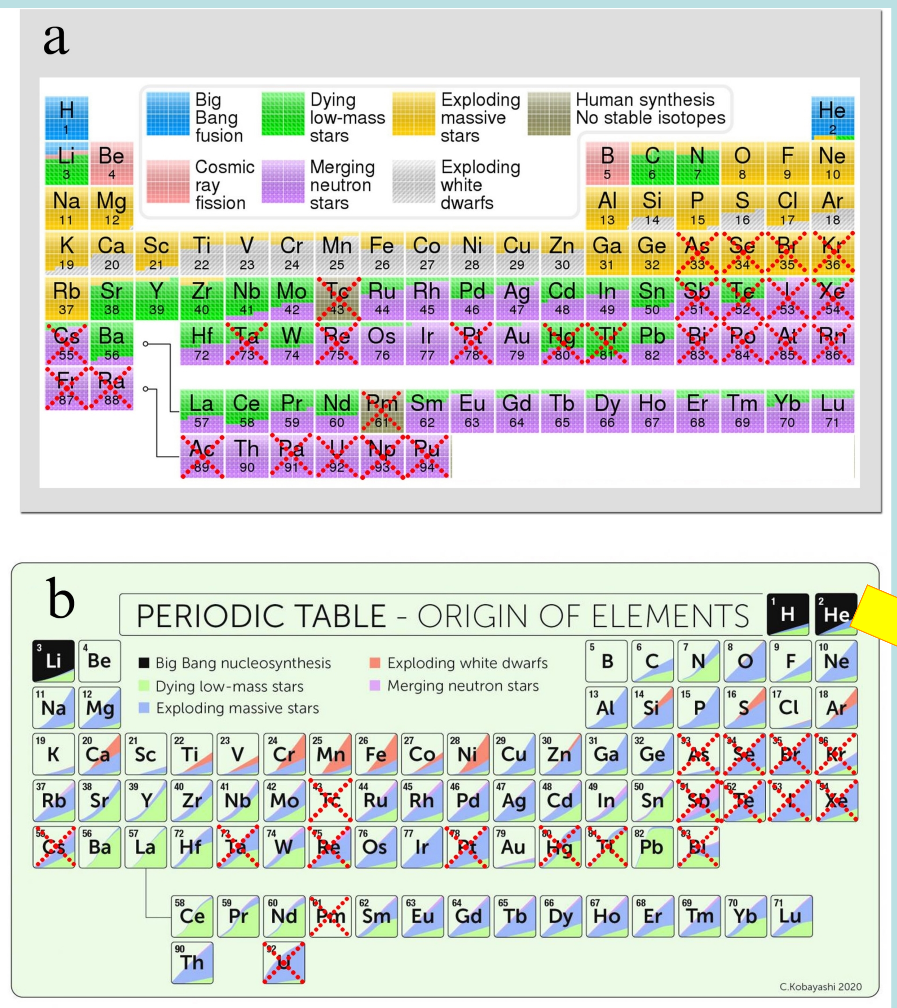

Figure 1. Two standard periodic tables, showing the origins of each chemical element. (a) – periodic tables according to B²FH model (adapted from Wikipedia); (b) – K²L model (Artwork: Sahm Keily). The red crosswise marks the elements which could not be recorded in the solar photosphere spectrum.

B²FH model - Burbidge, E.M., Burbidge, G.R., Fowler, W.A. and Hoyle, F. (1957) Synthesis of the Elements in Stars. Reviews of Modern Physics, 29, 547-650.

K²L model - Kobayashi, C., Karakas, A.I. and Lugaro, M. (2020) The Origin of Elements from Carbon to Uranium. The Astrophysical Journal, 900, 179.

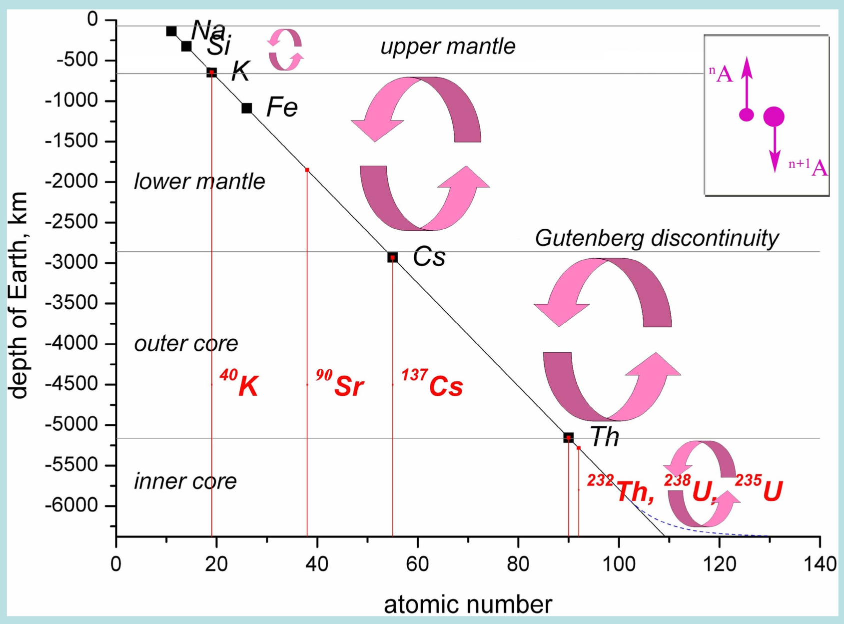

Figure 7. The scheme of terrestrial nuclear reactor ("*cold*" planet) is presented. The linear distribution of the chemical elements inside the Earth at the non-perturbed state of natural terrestrial reactor, according buoyancy theory, is drawn. The red lines show the basic fuel elements, such as ^{40}K, ^{232}Th, ^{235}U, ^{238}U and major products of decay such as ^{137}Cs and ^{90}Sr. The red circular arrows show the shallow convection processes inside the Earth. The Sr decay level is degenerated in the "cold" planet. On plate: the buoyancy theory principal: the heavy element ^{n+1}A sinks down; the light element ^{n}A floats up.

Solar Reactor and Solar Abundances

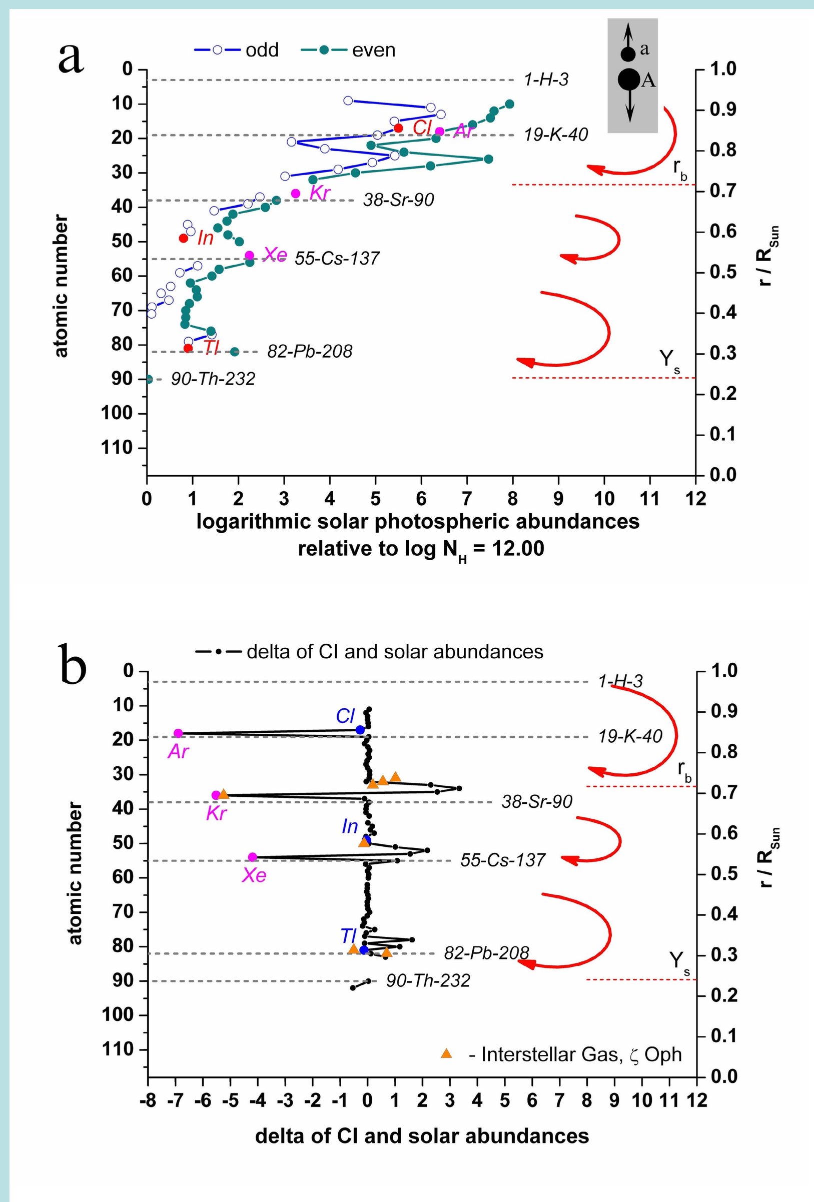

Figure 6. (a) – The logarithmic solar abundances of elements in the solar photosphere are shown. In grey plate the theory of buoyancy schematically is shown: the light elements flow up and heavy elements sink down. (b) – The delta of CI carbonaceous chondrites logarithmic abundance (Lodders, 2010) [and solar photosphere abundance (Scott et al, 2014a), (Scott et al, 2014b), (Grevesse et al, 2015) [4], [5], [6] was presented. The indirect photospheric estimates have been used for the noble gases: Ar, Kr, Xe (magenta color). Abundances chlorine Cl, indium In, thallium Tl, obtained from sunspot spectrums, were presented as blue points. All values were calibrated to log NH = 12. The red arrows demonstrated convection processes determined by helioseismological methods (rb, Ys). The delta between interstellar gas abundances (ζ–Oph) and CI meteorites was presented in Figure 6b by orange triangles (Cardelli, 1994).

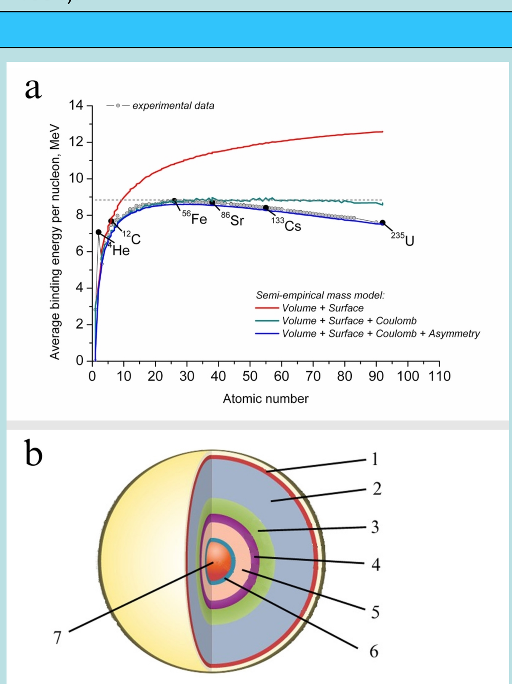

Figure 4. (a) – The nuclear binding energy per nucleon for stable nuclei in terms of mass number was presented by points (B/A vs Z); (b) – The standard astrophysical "onion" model for pre-collapsed massive star (M > 10 M☉). Abundances for such stars are next: 1 – upper hydrogen; 2 – hydrogen and helium fusion; 3 – helium fusion; 4 – carbon, oxygen fusion; 5 – magnesium, neon, oxygen fusion; 6 – silicon, sulfur fusion; 7 – nickel and iron core.

Problems of Terrestrial and Solar Nucleosynthesis

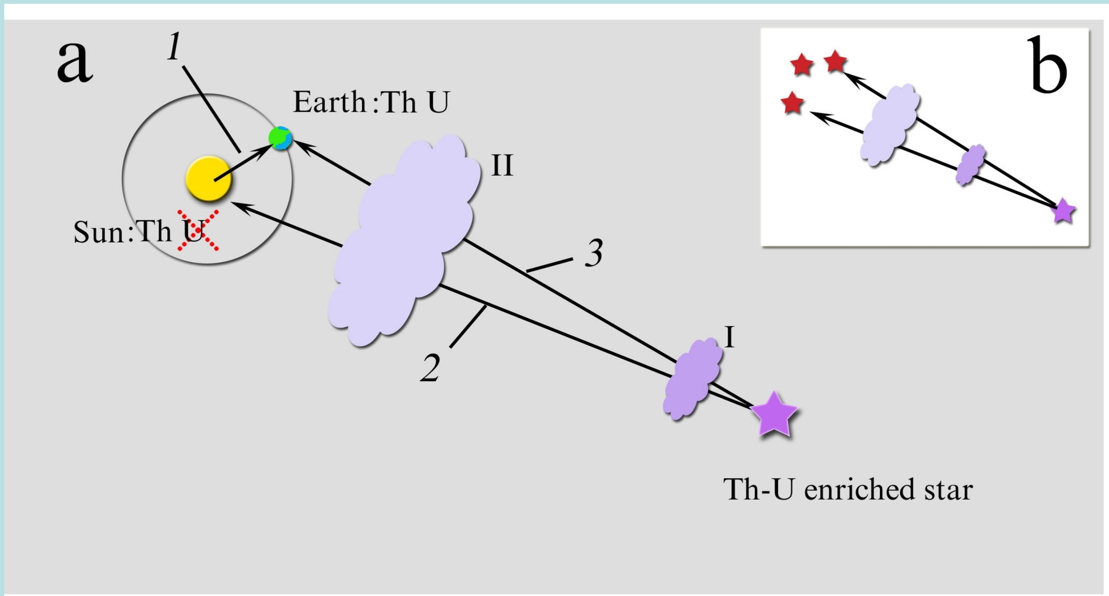

Figure 5. (a) – The scheme illustrates a problem of the Th-U nucleosynthesis from the Th-U enriched star, nearest to the Earth. The nearest single neutron star is allocated at the distance of 167 pc from our solar system. Clouds I and II demonstrated reducing concentrations at the propagation in space; (b) – property of invariance of isotopes for a group of neighborhood stars is shown on a plate

There are four major lacks in the B²FH and K²L theories:

✓ The invariance of element distributions in the solar system is not recorded;
✓ The invariance of element distributions on the neighborhood stars also is not recorded;
✓ It is absence super mega-enriched stars, called in this study as a donor-stars;
✓ It is absent significant quantity of heavy traces in the interstellar space.

Problem of habitable stellar systems

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, O, N, and P. In this study it was entered the new concept of DNA-stars, in which spectrums were recorded together C, O, N, and P elements. The possibility of synthesis of Na, Mg, S, K, Fe, Co, Cu, Zn, Ca, Mn and Mo, regulating growth and development of the elementary biological forms is also discussed.

The synthesis of different elements on different stars made it impossible to create biological forms on these stars.

The goal of the study is to find an answer to the next two questions:

✓ How are the chemical elements necessary for the origin of life synthesized on stars?
✓ In which stellar systems it is necessary to look for signs of life?

Table 2 Different approaches to investigation of stellar nucleogenesys.

Stellar Enriched Process is :	
Nuclear Fusion (self–enriched process)	this study
Nuclear Fusion (in donor star) + Interstellar Transfer* (from donor star to acceptor star)	B²FH and K²L

*- The transfer equation in the GCE models is *mistical* lacking.

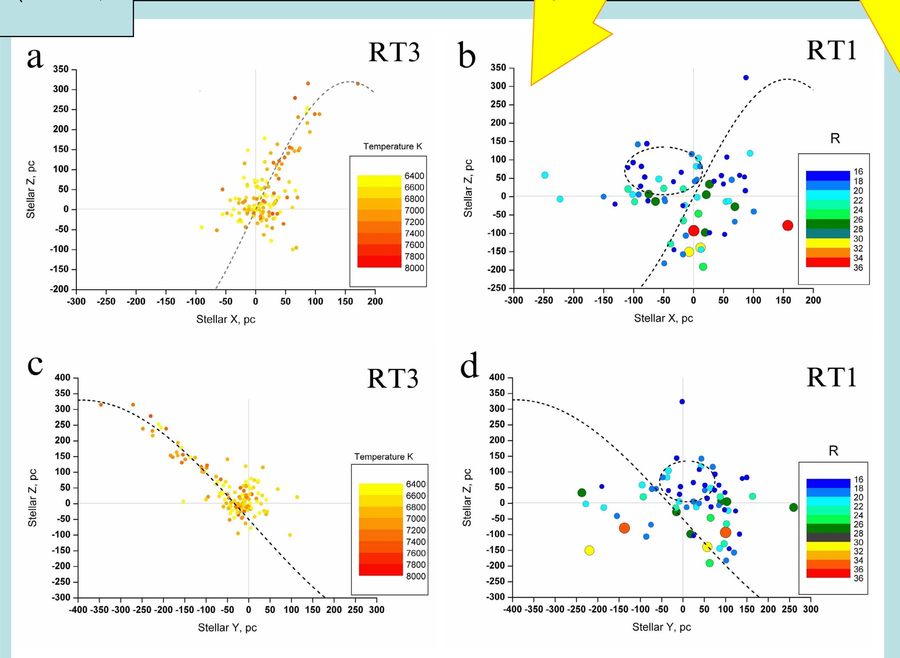

Figure 15. (a) – Spatial distribution of RT3 stars in Cartesian geocentric XZ-coordinate system with additional temperature color gradation at T > 6500 K; (b) – Spatial distribution of RT1 stellar group in XZ-coordinate system with additional color gradation at stellar radius R > 16 Ro. In (c) and (d) similar spatial distributions were presented but in the YZ-coordinate system.

The Ensemble-Averaged Stellar Reactor

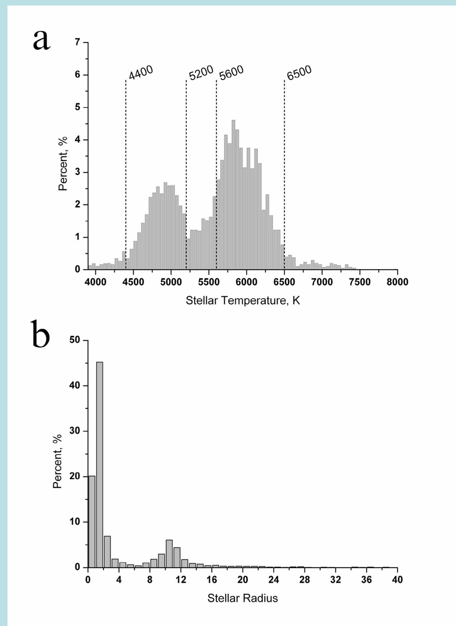

Figure 2. The statistic distributions of a stellar radius, and stellar effective temperature for stars within 300 pc neighborhood of Solar System.

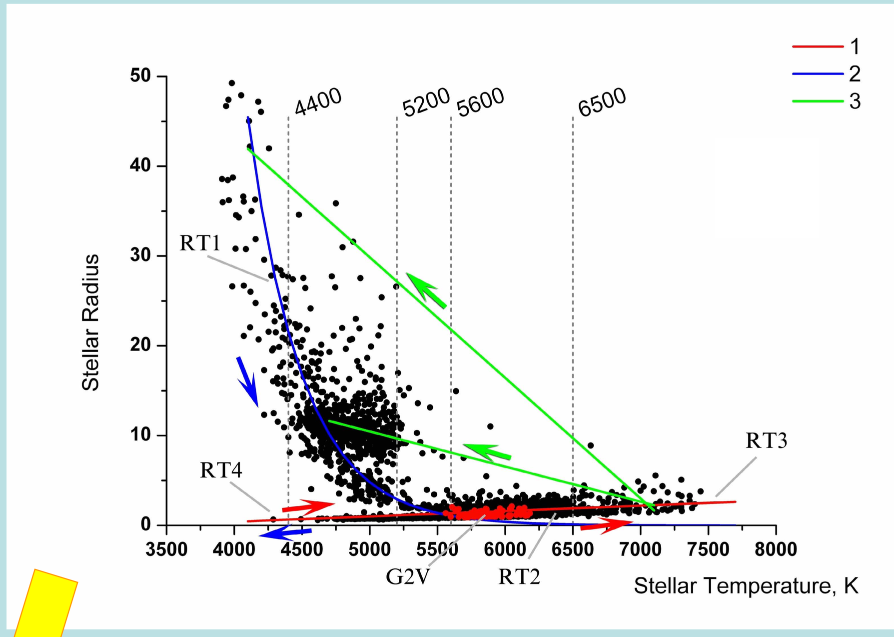

Figure 3. The scheme of working of the thermal nuclear engine, which is providing generation of heat and a variety of chemical elements in the Universe, it is designated by arrows (1–2–3). The stars from Hypatia Stellar Catalog (HSC), belonging to the G2V spectral class, are drawn as red points. The studying ranges were marked as RT1 – RT2 – RT3 – RT4 sites.

Table 3 The amount of synthesis and degradation processes of chemical elements which were recorded in this study. R is the correlation factor on RT diagram between abundance and effective stellar temperature. The table includes only statistically significant values with $|R| > 0.12$ and amount stars, $N > 10$. The amount of studying cases, in which it was recorded in the stellar spectrums the element in the ionization state, is marked in brackets.

Name	Amount of processes: Synthesis $R > 0$	Amount of processes: Degradation $R < 0$	Total amount
RT1	9 (3)	28 (9)	37
RT2	14 (1)	7 (2)	21
RT3	28 (6)	6 (3)	34
RT4*	3 (0)	13 (6)	16

*- On RT4 site the generalized star nuclear reactor can work in both directions, both at the origin of new stars and at dying low-mass stars. Therefore element synthesis is also possible at dying low-mass stars, i.e. at the $R < 0$.

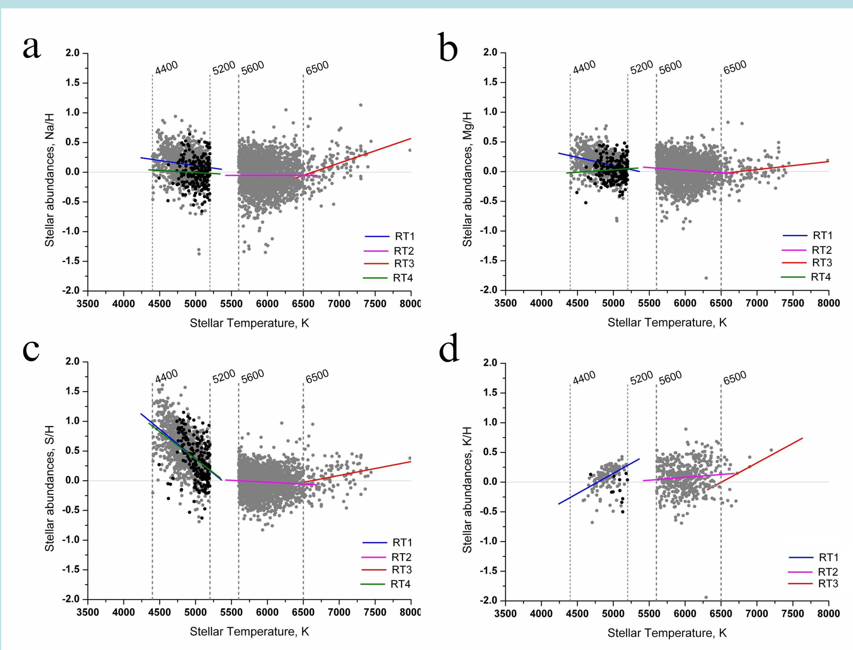

Figure 9. The linear regressions for Na, Mg, S, and K abundances for RT1–RT4 stellar groups were presented in Figures (a), (b), (c), and (d).

Periodic Tables for RT1–RT4 Groups

Figure 7. The periodic tables of stellar abundances for RT1–RT4 stellar group are presented. **Margin color** indicates an element that is synthesized in the specified RT group, i.e. indicate element that has the statistically significant positive slope in the linear regression abundance of effective stellar temperature. **Blue color** indicates an element which has a statistically significant negative slope. **Green color** corresponds to an element with a statistical none significant value or has not been present in the selected RT group. **White color** marks a chemical element which does not present in the Hypatia Stellar Catalog (HSC). In Figures, the label "II" after element name is presented the abundance of ionized state of an element.

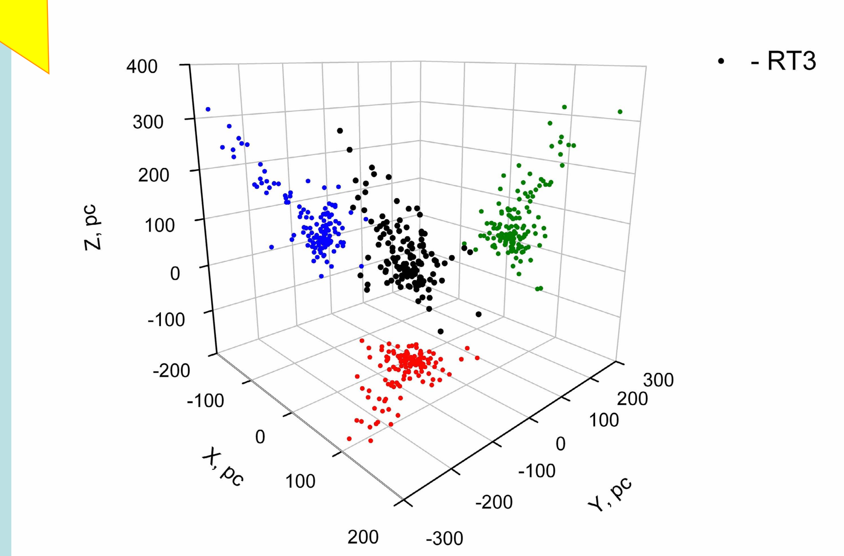

Figure 14. The spatial distribution of "hot" stars from RT3 stellar group, but in Cartesian geocentric XYZ-coordinates with additional color plane projections. Blue points are projected on YZ, red points – on XY, and green – on XZ planes.

DNA-stars

Table 4 The amount of HCS stars, in which spectrum was specified by the chemical elements that are demanded DNA creation.

Elements	Amount of stars: pcs.	Amount of stars: %
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

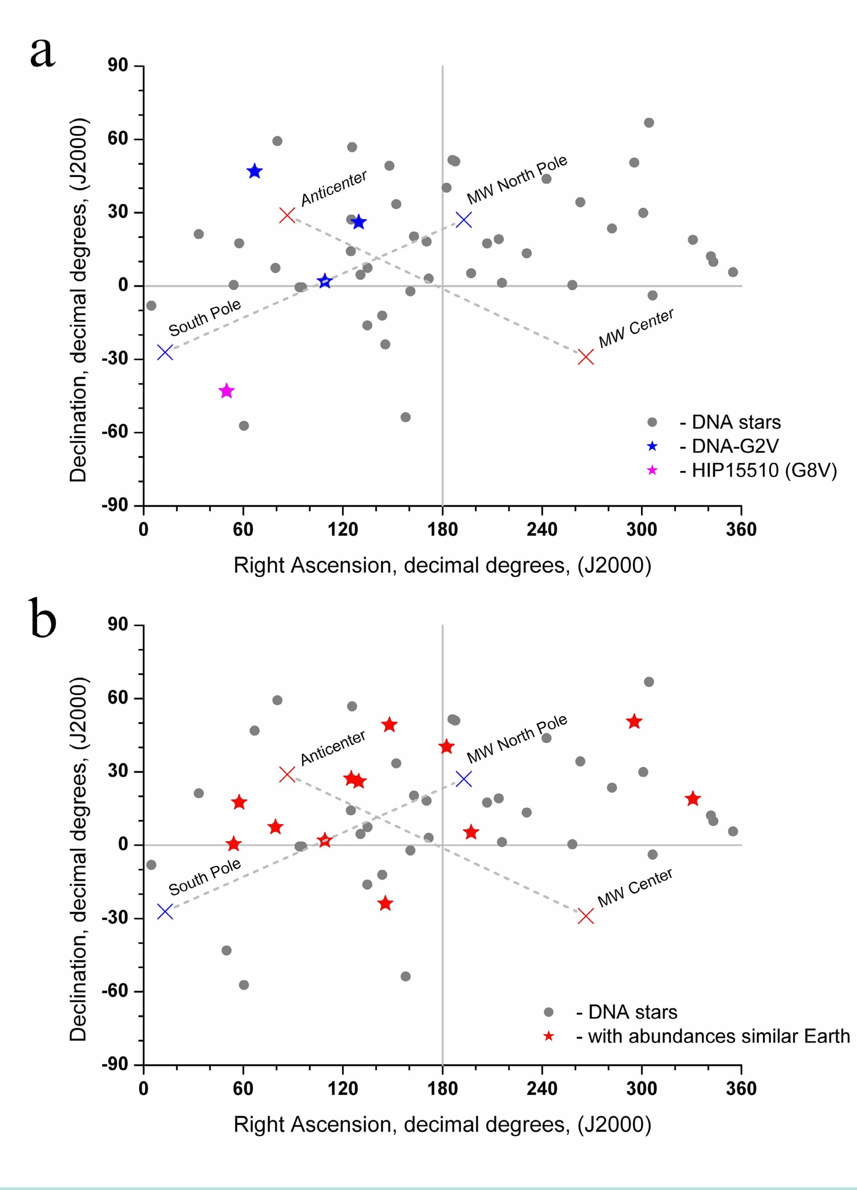

Figure 12. (a) – Three stars belong to the G2V spectral class and the star, closest to the solar system, which belongs to the G8V class, were shown by blue and purple colors; (b) – Twelve T-stars, which have abundances similar to the Earth abundances, were presented. On both figures as background, the 48 DNA stars, in the spectrum of which C, N, O and P elements were found, is drawn by grey color.

Safronov, A.N. (2016) "The Basic Principles of Creation of Habitable Planets around Stars in the Milky Way Galaxy" // International Journal of Astronomy and Astrophysics, 6, 512-554,
Safronov A. N., A New View of the Mass Extinctions and the Worldwide Floods. // International Journal of Geosciences, 2020, 11, 251-287.