THE COOL GIANT STARS AND CHEMICAL EVOLUTION OF GALAXY

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ABSTRACT. The fundamental characteristics and abundances of cool giant stars is discussed. The possible evolution of nuclides in process evolution of Galaxy was very shortly described.

Key words: Cool giant stars, evolution of stars

Introduction.

The main goal of modern astrophysics is the determination of abundances in atmospheres of stars, in particularly, in atmospheres of cool giant and supergiant stars. Spectra of these stars contain great number of atomic and molecular lines of absorption which are formed at various optical depths of their atmospheres. This gives a possibility to study the structure and parameters of atmospheres of G,K,M - giant and supergiant stars belonging to various Populations of Galaxy. This is necessary for testing theories of evolution of stars and of nuclides. Really stars of Galaxy Disk, and possible Halo, are product of subsequent generation of stars through interstellar medium. The interstellar medium was formed of matter proceeded of stars' nuclear synthesis and so was enriched by products of various nuclear processes. According to the modern concept of theory the time of evolution of the stars' being at the certain locus essentially depends on its mass, initial abundances and on nuclear processes. Cool giant and supergiant stars have been leaving from early epoch of the origin of Galaxy up till now and contain the records of abundances of elements and their isotopes in different epoch of evolution of Galaxy. The determination of abundances in their atmospheres can give information about chemical evolution of Galaxy.

"Standard" abundances of elements and isotopes.

The sources of information about evolution nuclides in process of evolution of Galaxy are their abundances and their distribution from number of proton - Z, or number of neutron - N, or of mass number - A=N+Z. They have been received with using the earths' crust, meteorites, solar atmosphere (photosphere, chromosphere, corona), solar wind, interstellar medium, planetary nebulae, galaxies, quasars, cosmic rays.

In Table 1 are tabulated "cosmic", "normal", "standard" abundance of elements Anders & Grevesse (1989) - $\log \epsilon_{st}$ and values abundance of elements in atmosphere of Sun - $\log \epsilon_{\odot}$. The izotopic abundances (nuclides) for the solar system determined from meteorites are presented in Table 2. These ratios can be determined in the atmospheres of cool giant stars.

The curve of distribution of abundances have characteristics: their values exponentially decrease with the growth of mass number up to A=100 and then a considerably slowing down; large fluctuations in abundance of light elements; presence of peaks in distribution of abundances with certain mass numbers. These peculiarities must be explained by the theory of initial formation and evolution of all nuclides. The analysis of abundances in stellar atmospheres show on their descrepances (for example, stars of population I and II of our Galaxy, stars of type R CrB, peculiar & metallic-line stars, carbon stars etc). It should be noted that chemical composition of interstellar gas in H II-regions around nearly forming stars and planetary nebulae (objects were formed at later stage of evolution of stars) is close to that of the solar system. Moreover, the abundances in other galaxies and quasars (the oldest objects of the Universe) differs slightly from the solar one. All this must be explained by one theory of evolution of abundances of chemical elements and their isotopes. A great compilation arises due to a small number of stable isotopes among multitude of unstable isotopes. Therefore, the distribution of abundance of nuclides must be changed as a result of radioactive decay which may differ under these or other conditions (up to decay absence). This should be especially taken into account in analysis of abundances of meteorites, unevolved and evolved stars and etc. The atmospheres of unevolved stars do not contain the products of stellar nucleosynthesis. On the contrary the atmospheres of evolved stars can be diluted with products of stellar nucleosynthesis and be different from the abundances of progenitory matter.

Fundamental characteristics of cool giant stars, model atmospheres and their evolution status.

We shall mainly dwell upon the results of determination of abundances and of fundamental characteristics of cool giant stars. It is evident that during evolution of stars their abundances can be essentially change. So the peculiarity of stars says about their the advanced stage of evolution.

The information about atmospheres of giant stars is a key to the solution of many problems on the evolution of stars and stellar systems, formation of nuclides with mass more then mass of H, enrichment of star atmospheres by heavy and light elements and isotopes. However, here we come across a paradox - the presence of a tremendous number of atomic and molecular lines of absorption permits to determine abundance of many nuclides and, unfortunately, at the same time these mainly hinder both the investigations of parameters of atmospheres of cool giant stars and the construction of mathematical model of atmospheres of stars.

New data about giant stars are obtained at the Astronomical Observatory of Odessa State University, and namely, the temperature, gravity, microturbulent velocity, radius, mass and total luminosity.

According to the data of Komarov et al. (1996) parameters of cool giant stars in oxygen sequence of field of Galaxy disk up till now being in the solar neighbourhood (in the spectral interval from G to M) for temperature range from 2500 to 5500K, for gravity from 0.00 to 3.00 dex, for metallicity from -0.7 to 0.4 dex. The luminosity of stars are markedly varied from spectral type (by the order of a value), radii vary from 5 to 30$R_\odot$, whereas masses - from 0.7 to 1.4$M_\odot$. Mean values metallicities within spectral types G0-K0, K0-K5 and M0-M4 are equal to -0.20, -0.07 and -0.20dex respectively. Cool giant stars in solar neighbourhood of Galaxy disk at the increase of metallicity are shifted towards higher temperatures and larger luminosities. Masses of cool giant stars belonging to open clusters and moving groups range from 2 to 3$M_\odot$! It is likely to show that *field stars* have already passed the stage of belonging to a certain group of stars and refer to the Population of the old Galaxy disk.

One impressive result discovered by us should be emphasized: the age of majority cool giant stars of Galaxy field can be compared with that of the oldest objects of Galaxy - globular clusters (15×10^9). We finded also two flares in formation of stars that determine the various number of giant stars in certain spectral tapes accordingly their metallicity.

The model of atmosphere of cool giant star can be calculated after determining of fundamental characteristics of star and by usual simplified assumptions. We must underline that are not model atmospheres adequate to the structure of the real stars even when unknown processes in their atmospheres are absent.

Table 1. The "standard" and "solar" abundances of elements.

Z	El	$\lg \epsilon_{st}$	$\lg\epsilon_\odot$	Z	El	$\lg\epsilon_{st}$	$\lg\epsilon_\odot$
1	H	12.00		44	Ru	1.82	
2	He	10.99		45	Rh	1.09	
3	Li	3.31	1.16	46	Pd	1.70	
4	Be	1.42	1.15	47	Ag	1.24	0.94:
5	B	2.88	2.53	48	Cd	1.76	
6	C	8.60		49	In	0.82	1.66:
7	N	8.00		50	Sn	2.14	2.0
8	O	8.86		51	Sb	1.04	
9	F	4.48		52	Te	2.24	
10	Ne	8.09		53	I	1.51	
11	Na	6.31		54	Xe	2.23	
12	Mg	7.58		55	Cs	1.12	
13	Al	6.48		56	Ba	2.21	2.13
14	Si	7.55		57	La	1.20	
15	P	5.57	5.45	58	Ce	1.61	
16	S	7.27		59	Pr	0.78	
17	Cl	5.27	5.5	60	Nd	1.47	
18	Ar	6.56		62	Sm	0.97	
19	K	5.13		63	Eu	0.54	
20	Ca	6.34		64	Gd	1.07	
21	Sc	3.09		65	Tb	0.33	
22	Ti	4.93		66	Dy	1.15	
23	V	4.02		67	Ho	0.50	0.26:
24	Cr	5.68		68	Er	0.95	
25	Mn	5.53	5.39	69	Tm	0.13	0.29
26	Fe	7.51		70	Yb	0.95	
27	Co	4.91		71	Lu	0.12	0.76:
28	Ni	6.25		72	Hf	0.73	0.88
29	Cu	4.27		73	Ta	0.13	
30	Zn	4.65		74	W	0.68	1.11:
31	Ga	3.13	2.88	75	Re	0.27	
32	Ge	3.63		76	Os	1.38	
33	As	2.37		77	Ir	1.37	
34	Se	3.35		78	Pt	1.68	
35	Br	2.63		79	Au	0.83	1.01:
36	Kr	3.23		80	Hg	1.09	
37	Rb	2.40		81	Tl	0.82	
38	Sr	2.93		82	Pb	2.05	
39	Y	2.22		83	Bi	0.71	<1.9:
40	Zr	2.61		90	Th	0.08	0.23
41	Nb	1.40		92	U	-0.49	<-0.47
42	Mo	1.96					

Table 2. The abundances of nuclides.

Z	Nuc	A	logϵ_{iz}	Z	Nuc	A	logϵ_{iz}
1	H	1	12.00	20	Ca	43	3.53
		2	7.22			44	4.69
2	He	3	7.08			46	1.89
		4	10.99			48	3.64
3	Li	6	2.22	22	Ti	46	3.85
		7	3.31			47	3.82
5	B	10	1.83			48	4.82
		11	2.43			49	3.70
6	C	12	8.60			50	3.68
		13	6,67	26	Fe	54	6.29
7	N	14	8.00			56	7.50
		15	5.51			57	5.87
8	O	16	8.84			58	5.05
		17	5.41	28	Ni	58	6.09
		18	6.15			60	5.67
12	Mg	24	7.50			61	4.33
		25	6.60			62	4.82
		26	6.65			64	4.29
14	Si	28	7.55	40	Zr	90	2.37
		29	6.24			91	1.71
		30	6.07			92	1.89
20	Ca	40	6.36			94	1.90
		42	4.18			96	1.11

The abundances in atmospheres of cool giant stars.

Cool dwarf stars - stars of main sequence (MS) - of Galaxy disk have the abundances of elements of CNO-group near to the solar ones, and namely, [C/H]=-0.03±0.1,[N/H]=0.02±0.1 and [O/H]=0.00±0.1. At the same time abundances of metals-group can vary from 0.3 to -0.7dex. The mean level of metallicity can change for various open clusters. No distinct dependence upon the age is found. The atmospheres of stars of MS in the spectral region from F to early K have abundances elements from C to Sc in limits from 0.08 to -0.04.

Progenitors of cool giant stars of G-M spectral types are dwarf stars of F-K spectral types. Is the progenitory matter in atmospheres of giant stars diluted with products of nuclear synthesis? Indeed, the average ratio abundances is equal C/N=0.9 for open clusters of the Hyades and Praesepes (Mishenina et al., 1991, Komarov & Basak, 1992) while for the Sun C/N=4.8. The average value C/N=2.3 is obtained for cool giant stars of Galaxy field. That means the abundance N grows while abundance C decrease. It should be noted that theory of evolution of single star predicts ratio C/N=2.0 after mixing. Light elements Li,Be and B are easily destructed at low temperatures (nearly from 2×10^6 to 5×10^6) that must decrease abundance of these elements in atmospheres of giant stars especially of Li. These nuclides cannot be formed during the stellar evolution (during the processes of nuclear synthesis), except may be ^{7}Li. However, abundance of ^{7}Li in some giant stars exceeds the cosmological abundance! Abundance ^{7}Li in meteorites and in the solar atmosphere differs by nearly two orders. Now it is necessary to determine the abundances of these elements in atmospheres of oldest Galaxy stars with big deficiency of metals. The ratio of izotopes ^{12}C/^{13}C for atmospheres of cool giant stars are much less than the solar (terrestrial) one. Ratios of abundances of nuclides due to circulations, He-flares, deeply penetrating convection and mass loss can be changed in the stellar atmospheres. The ratio ^{12}C/^{13}C in atmospheres of these stars can vary from 4 to 40. The values ^{12}C/^{13}C from 20 to 30 range for the stars with $M > 2M_\odot$. This ratio swiftly decrease for stars with more little mass according to observations and that contradicts to the theory. To explain this effect it is necessary to suppose unknown mechanism of mixing. During further evolution of stars with $M < 1.5M_\odot$ they proceed in sequence of spectral types M-MS-S-SC-C (R or N). This sequence is caused by the variation in ratio C/O.

The nuclides of s-process can be synthesized only in the entrails of giant and supergiant stars with $M > 1.5M_\odot$. It is shown ,that atmospheres of giant stars of field of the Galaxy disk in spectral range G-K with solar metallicity have almost solar abundances of elements of s-process. Gopka and Komarov (1990), Gopka et al.(1990) have shown that the atmosphere of α Tau have "solar" abundances of Fe and elements s-process, whereas for α Boo these elements exhibit the same deficiency relatively to their abundance in the atmosphere of Sun. The abundances of nuclides of the s,r-processes in atmospheres of giant stars of the Galaxy Halo must be deficient with respect to the solar abundances because nuclides of Fe are primordial nuclei for s,r-processes. This is confirmed by observations and treatments of spectra of giant stars belonging to the globular clusters. The evolution of elemental abundances in atmospheres of cool giant stars belonging to the first or second branches of giants remains unknown. This is associated with our insufficient knowledge of processes in outer layers of these stars. It is enough to say that in region of spectral type K are stars of various types - "solar" and "nonsolar" types. Conditional character of such a division is clear enough.

The abundances of the atmospheres of cool giant stars belonging to the galactic disk in neighbourhood of Sun are in a fair agreement with ones for dwarf stars in the interval of metallicity from -2.4 to 0.35 dex. Whereas the elements of α-process are overabundant for metal deficient stars and odd-elements Na, Al are deficient relatively to elements of α-process (Edvardson et al., 1993). It is noted that the overabundance Na in atmospheres of giant stars from 0.3 to 0.8 dex has been found by Komarov et al. (1985). It is correlating with luminosities of stars (and namely with gravities) - the larger stellar luminosity conform to greater Na-excess. This correlation is due to dependence of luminosity of stars upon its mass or its age.

We can be sure that abundances of elements and their izotopes of stars of oxygen sequence in the galactic disk are different for groups of stars accordingly their formation and their being in various ascending branches, or their being in the horizontal branch, or their being in the asymptotic branch. Now the age of single star cannot be determined only upon their location on the HR-diagram. Some supplementary criterion for the age or mass is needed. Such criterion may be parameter of the activity of chromosphere (in particular level of emission in H,K Ca II and H,K Mg II lines). The position of stars belonging to open clusters and moving groups would seem to be better because there is a possibility to estimate their age. But here we come across paradox! As is stated by Komarov et al. (1996) a relative number of stars with "standard" abundances for spectral types G5 III-K0 III must be small whereas the relative number of stars in the spectral region K2 III-K5 III prevails. However, in the closest open cluster of Hyades the giant stars (spectral type K0 III) have "standard" abundance for almost all elements (excepting some elements, for example, carbon, oxygen, sodium) while in the best studied moving group Boo of star α Boo have deficient of all elements. The stars of galactic disk have been formed since on 10^9 years. However, we and Edvardson et al. (1993) have found of the stars with ages comparable with that of globular clusters. It is necessary to take into account that even oldest stars with metallicity from -1.5 to -3.5 dex have the ratios of abundances of heavy elements approximately in the same proportion as for the Sun. Now the under- and/or over-abundances in these or those elements or their izotopes must be found.

References

Anders E., Grevese N.: 1989, *Geochim. Cosmochim. Acta*, **53**, 197.

Edvardson B., Andersen J., Gustafsson B. et al: 1993, *Astron. Astrophys.*, **275**, 101

Gopka V.F., Komarov N.S., Mishenina T.V., Yuschenko A.V.: 1990, *Astron. Zh*, **67**, 1204.

Gopka V.F., Komarov N.S.: 1990, *Astron. Zh.*, **67**, 1211.

Komarov N.S., Mishenina T.V., Motrich V.D.: 1985, *Astron.Zh.*, **62**, 738.

Komarov N.S., Basak N.Y.: 1992, *Astron. Astrophys. Trans.*, **3**, 179.

Komarov N.S., Korotina K.V., Shevchuk T.V.: 1996, *Kinematika i Fizika Nebesnych Tel*, **12**, 3.

Mishenina T.V., Komarov N,S., Kantsen L.E.: 1991, *Izv. SAO, Astrof. Issl.*, **31**, 82.