CHEMICAL COMPOSITION OF ATMOSPHERES OF COOL GIANT STARS

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ABSTRACT. Results of determination of abundances of chemical elements in the atmospheres of 57 giant stars of the oxygen sequence of the Galactic disk are given. A brief survey of findings is presented making it possible to draw conclusion on evolution of abundances of chemical elements in the atmospheres of cool stars at the transition stages from the main sequence (MS) to that of the red giant (FRGB), from the upper boundary of a giant branch to the horizontal one, and eventually, at the stage of asymptotic giant branch (AGB). The rate of stellar evolution, efficiency of mixing depends on initial mass of the stars and primordial chemical composition of the progenitor matter.

Key words: Stars: abundances, giant, evolution, nucleosynthesis.

One of the problems of modern astrophysics is the testing of theories of nucleosynthesis and stellar evolution, chemical and dynamical evolution of the Galaxy based upon data of abundances of chemical elements in various objects of the Galaxy. Particularly, it is necessary to know most precisely about the abundance of chemical elements and their isotopes in the atmospheres of stars of different masses which have proceeded through one or another stage of evolution. For such investigation the most convenient object are cool stars – giants and supergiants. This is the fact that these are the brightest objects of stellar population in the Galaxy and their spectra contain a great number of absorption and/or emission lines of various chemical elements and their compounds are detected (even for stars with extreme iron deficiency).

According to the present concepts of the stellar evolution theory, the duration of stay of the star at a certain stage (at a certain locus at the HR diagram) is essentially dependent of its mass, initial chemical composition and nucleosynthesis processes. The belonging of stars to various population types of the Galaxy, to different types of clusters and dynamic groups gives an excellent possibility of tracing the evolution of chemical composition of their atmospheres depending on their age and composition of progenitor matter. The evolution of stars with different masses and various chemical composition occurs according to various scenarios.

In this paper we shall consider results of investigation of chemical composition in the atmospheres of cool giant stars of the oxygen sequence of the Galaxy disk, which have been obtained at the Astronomical Observatory of the Odessa State University.

On the initiative of Director of the Observatory V.P.Tsessevich, in 1966 I and my colleague V.A.Pozigun manufactured an IR–spectrometer on the basis of photomultiplier RCA 7102. The photomultiplier was purchased by V.P.Tsessevich during his scientific trip to Harvard Observatory. Owing to this, my research interest came to studying cool giant stars, which have maximum radiation in this region.

Giant stars in the Galaxy disk are at various stages of evolution – the first and subsequent giant branches (FRGB and other), blue and red parts of the horizontal branch (BHB and RHB), the asymptotic giant branch (AGB), the post–asymptotic giant branch (post–AGB) and in the region HR diagram penetrating into each other. If the theory of stellar evolution pertaining to the mix of their atmospheres with products of nucleosynthesis is true, their abundances with their known fundamental characteristics stars can provide information about evolutionary status of stars, that is of its mass and chemical composition of progenitor matter (Sweigart et al. 1989).

The simplest interpretation of classification of stellar spectra made it necessary to suggest a difference between chemical compositions in the atmospheres of cool giant stars. There are stars with excess or deficiency of elements of iron group, with various ratio of abundances of carbon and oxygen, elements with even and odd Z, with excess or deficiency of the s-process elements etc.

A great number of works have been published recently on the determination of abundances in the atmospheres of stars, and therefore, other fundamental characteristics by using the spectra with a high signal-noise ratio (S/N $<$ 300) and the method of model atmospheres. We shall consider in brief the survey of results given in literature. The readers are referred to survey (Gehren 1988) wherein this problem is presented in detail.

Stars of the main sequence (MS) of the Galaxy disk in the solar neighborhood have the following elemental abundances of CNO – group relative to the Sun : [C/H] = –0.23, [N/H] = 0.38 , [O/H] = –0.03, where $[A_i/H] = \log(A_i/H)^* - \log(A/H)^{\odot}$, where log A_i is the abundance in the scale of log $A_H = 12.0$. The ratio of abundances of isotopes ^{12}C and ^{13}C ranges from 10 to 50 (the average value $^{12}C/^{13}C = 22.5$) whereas that of $^{12}C/^{13}C$ for the solar atmosphere approximates 90.

Progenitors of G – M giant stars are the F – G dwarf stars with masses ranging from $0.8 < M/M_{\odot} < 3.0$. Therefore, in their atmospheres the products of nucleosynthesis can be expected. Virtually, for 4 and 2 giant stars of the Hyades and Praesepe clusters the current ratio C/N = 0.9 whereas for the sun (C/N) = 4.8, but for dwarf-stars of Hyades it was found to be $C/N = (C/N)_{\odot}$.

In the work by Kjaergaard et al. (1982) it was obtained that C/N = 2.3, i.e. the nitrogen abundance was found to enhance while that of carbon to decrease, incidentally, for metal deficient stars and for those with masses $< 1M_{\odot}$ the ratio $(C/N)^* = (C/N)^{\odot}$, whereas $(N/Fe)^* > (N/Fe)^{\odot}$ and $(C/Fe)^* < (C/Fe)^{\odot}$ for all the giants. At the same time the total abundance of C, N, O elements for dwarf stars and giant stars of Hyades cluster is nearly identical. It is characteristic of the atmospheres of giant stars to be carbon poor, nitrogen rich at the constant oxygen abundance as compared to the abundance of these elements in the atmospheres of dwarf stars. The abundance of chemical elements obtained for the atmospheres of field giant stars is in good agreement with that of dwarf stars in the metallicity range region $-2.4 < [Fe/H] < 0.35$, while elements of the $\alpha-$ process are overabundant in the atmospheres of metal deficient stars and while Na and Al are underabundant relative to elements $\alpha-$ process (Gratton et al. 1987). It should be noted that formal excess of some elements relative to the solar abundance can result from either hyperfine structure of atomic lines or isotopic shift.

Therefore, in determining elemental abundance it is necessary to carefully analyze the structure of a lower level of every absorption line, otherwise we can several times overestimate the elemental abundance. In the case of isotopic shift it is necessary to take into account the abundance of table isotopes of a certain chemical element. For the elements of iron group the isotopic shift is unlikely to occur since isotopes ^{52}Cr, ^{55}Mn, ^{56}Fe, ^{59}Co, ^{58}Ni are primarily observed. For elements with odd Z the hyperfine structure of atomic levels is probable. Abundance ratios of isotopes of elements C, O, Ng, Al, Si, Ca, Ti, Zr can differ from those of the Earth and give information on thermonuclear process resulting from the addition of $\alpha-$ particles and neutrons.

For sustaining the structure of a red giant the absence of full mixing between outer and inner layers is of importance. However, as was shown above, the $^{12}C/^{13}C$ isotopic ratio for giant-stars is considerably less than that of the Earth (the Sun). Of particular interest are metal-poor red giants with [Fe/H] < –2 which are likely to be stars with low mass ($M < 0.8M_{\odot}$), to have originated from a cloud with mass 10^5 – 10^6 $M_{\odot}$. Massive stars of short lifetimes supply the cloud with different metals and products of the CNO–cycle. Variations in intensity bands of CN, CH and NH indicate that red giants originated from progenitor matter with various ratio of nucleosynthesis products. In this respect, rather illustrative is the Cas A object – a remnant of the supernova flared up approximately 300 year ago. The clouds is found with a primary oxygen abundance ([H/O] = –3.7, [He/O] < –1.9 and [C/O] < –2.1). Lines of S, Ar and Ca elements are visible. This means that the star is at the evolutionary presupernova stage, has layer structure, and thicknesses of corresponding layers depend on initial mass of the star.

The determination of elemental abundances in the atmospheres of cool stars is to a greater extent associated with the problem of determining fundamental characteristics, i.e. effective temperatures T_{eff}, on gravities on the surface (g), metallicities ([Fe/H]), microturbulent velocities [V], with that of calculation of model atmospheres adequate to the structure of atmospheres of real stars, with that of determining the physical – chemical radiation and collision parameters of atoms and molecules (Ridgway et al. 1980, Komarov et al. 1985, Korotina et al. 1992).

The value of microturbulent velocity V_t in the first approximation was estimated from the curve of growth for absorption lines Fe I. The value V_t was revised by the method of model atmospheres by means of calculation of abundance log A_{Fe}. The correlation between log A_{Fe} and W_λ was found, and the value V_t was selected when there was no correlation between log A_{Fe} and W_λ. The influence of rotation and macroturbulence on the profile of absorption lines was taken into account by the convolution of a synthetic spectrum with the apparatus function of a spectral device. It is suggested that broadening of a profile of the line due to rotation and macroturbulence are small as compared to those caused by the apparatus function of the device.

For cool stars it is difficult to select relatively pure absorption lines by taking no account of a synthetic spectrum and its convolution with the apparatus function of the device as the apparatus function of a spectral device. The apparatus function of a spectral device was taken the Gaussian with a half–width equal to spectral resolution. For selecting pure and weakly blended absorption lines the calculation of synthetic spectra were carried out. The model atmospheres was taken from the grid (Bell et al. 1978) with parameters T_{eff}, log g, [Fe/H] corresponding to K0 III and K5 III stars, but namely (5000, 3.00, 0.0) and (4000, 1.50, 0.0), respectively.

The same stars γ Tau, δ Tau, ϵ Tau clusters of Hyades, α Tau, γ Sge their parameters and chemical composition were found from spectrograms with reciprocal dispersion not worse than 5.6 Å/mm with the wavelength range 5360 – 6700 Å. In the same detail chemical composition of stars BS 3427 and BS 3428 of open cluster Praesepe was investigated (Komarov et al. 1985ab, 1992, Mishenina et al. 1986, Gopka et al. 1990ab).

In analyzing results of chemical abundances in the atmospheres of cool giant stars of oxygen sequence it is necessary to take into account the belonging of stars to various stages of star formation (Korotina et al. 1989, 1992) and their evolutions on different ascending branches of giant stars, horizontal branches of giant it this or that transition, and asymptotic branches of giants. It is related to our possibility of only rough estimating field stars' mass and in even such assumption there arises a question on reliability of the results. We check the evolutionary status of a star from it position in the HR diagram but at the same locus of HR diagram can be located stars proceeding different stages of evolution affected by distinctions in masses and initial chemical composition of protostar matter. The best position of stars seemed to be those belonging to the open clusters or dynamical groups because of a possibility of estimating there age. But here we come across a paradox. As is known from (Korotina et al. 1989, 1992), the relative quantity of stars of G5 III – K0 III spectral types with a "standard" chemical composition must be small but that of stars in K2 III – K5 III range with "standard" chemical composition is predominant. However, in the most nearby open Hyades and Praesepe clusters the K0 III giant stars have "standard" abundance (except for same elements C, O, Na) whereas in the most well studied dynamical group the α Boo star (K2 IIIp) is certain to be metal–deficient. In the analysis and comparisons of results obtained by the various authors the abundances should be given relative to hydrogen in the same star rather than relative to abundance in the solar atmospheres. From our data the abundances in atmospheres of 57 giant stars belonging to the disk of Galaxy are obtained.

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PHOTOMETRIC STUDY OF A NEW X–RAY SOURCE – THE ECLIPSING POLAR RXJ 2107.9–0518

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ABSTRACT. The object RXJ 2107.9–0518 was discovered as a soft X–ray source at the space observatory ROSAT in 1990. Its X–ray spectrum is characteristic to the systems of the AM Her type thus the object was suspected to be a polar. The first photometric study of this object were obtained in 1992 independently at two observatories: in August–October by Schwope et al. at the 90–cm ESO telescope and in November–December by us at the 50-cm telescope of the Crimean Astrophysical Observatory.

Our photometry confirmed the preliminary classification of this source as a polar with an orbital period of 125 minutes. The eclipses were detected with a duration of nearly 10 minutes and with depth $\geq 3.5^m$. It was found that the eclipsed emission source is shifted in respect to the line of centers at 32°. The morphology of the light curves is consistent with two active magnetic poles the power of which changes with time similar to BY Cam.

Key words: Stars: Cataclysmic Variables; Polars.