CHEMICAL COMPOSITION OF THE ATMOSPHERES OF THREE GIANTS IN HYADES

T.V.Mishenina, N.S.Komarov, L.E.Kantsen

Abstract. The abundances and physical conditions in the atmospheres of three Hyades giants have been investigated by using the high-dispersion (5.6 A/mm) spectra obtained at the 6-m telescope of the Special Astrophysical Observatory. The empirical analysis of the deviations from LTE for the Fe lines with the low and high excitation potentials showed the slight differences within the limits of the determination errors. The abundances of 22 chemical elements the atmospheres of the K-giants derived by the method of the model atmospheres differ from the solar one. Underabundance of O and overabundance of Na of about 0.5 dex and of elements after Y of about 0.2 dex are established.

Key Words : Stars: late giants, chemical composition

The investigation of the chemical composition of the Hyades stars nearest to the Sun [distance modulus m-M = 3.3 (Kholopov, 1981)] covers a wide range of astrophysical problems: a more precise definition of an initial main sequence, the refinement of a scale of the galactic distances, the testing the theory of the nucleosynthesis and of the star formation, of the presence of the overshooting etc. In this Paper, we present the results of the investigation of three Hyades giant-stars. Table 1 contains a list of the stars and their characteristics (Komarov et al.,1979): HD number, stellar name, V-stellar magnitude, B-V - color index, SP - spectral type, π " -parallax. δ Tau star is a spectro- scopic binary, an assumed component is a late M - subtype dwarf (Griffin and Gunn, 1977). The estimation of the mass of the Hyades giant-stars from the tracks of Paczynski (1970) gives the value $M \sim 2M_\odot$ where $M_\odot$ is the Solar mass. By using the expression of Masevich and Tutukov (1988):

$$T = 7.6 \cdot 10^{9} \, \frac{1 + 30\,Z}{(M/M_\odot)^{3.7}} \cdot \left(\frac{0.23}{Y}\right)^{1.6} \text{ years},$$

where Y,Z are the abundances of helium and heavy elements, one may determine the age, when a giant-star with a mass 2 reaches the peak of giants branch: $T = 9.3 \cdot 10^{8}$ years (Kholopov, 1981).

Table 1. Characteristics of the giant-stars in the Hyades cluster

HD	Star	V	B-V	Sp	π "
27371	γ Tau	3.64	0.99	KO III	0.023
27697	δ Tau	3.76	0.98	KO III	0.016
28305	ε Tau	3.54	1.02	KO III	0.018

The analysis of the chemical composition of the Hyades stars made by different authors has shown, that the metallicities [Fe/H] obtained from the spectrophotometric and photometric observations of the stars are different, the latter being by 0.1-0.2 dex higher than the spectrophotometric ones. Commonly, the spectrophotometric determination of [Fe/H] gives the values of 0.1-0.3 dex, the photometric one gives 0.2-0.3 dex, the reticon observations yield 0.2 dex (Branch et al.,1980). The aim of our investigations is to solve the problem on the abundances in the atmospheres of γ Tau , δ Tau , ε Tau - stars based upon the analysis of the spectrograms with high spectral resolution obtained at the 6-m telescope of the Special Astrophysical Observatory. The spectrograms of the giant-stars were obtained in 1984 by V.G.Klochkova, V.E.Panchuk and I.F.Bikmaev at the first camera of MSSP BTA on the Kodak 103aF - plates within the wavelengths from 5300 to 6700 A with the dispersion 5.6 A/mm. It was possible to obtain such a material only due to the reconstruction of the first camera of MSSP (Gajour et al.,1986). The spectrogram recording was made by a using the microphotometer at SAO in direct intensities.

The continuum was plotted from intensities peaks. In order to identify the lines, a synthetic spectrum was used, which was calculated by using the SYNT (Tsymbal, 1980) computer code for the wavelength range $\lambda\lambda$ 5300-6700 A. For the computations, we used model of the atmosphere (Bell et al., 1978) with the parameters: effective temperature T_{eff} = 5000 K, logarithm of gravity log=3.0, solar abundances. To specify the absorption lines identification, the Solar Atlas (Moore et al.,1966) was used as well as the Catalogue of equivalent widths W_λ of the lines in the spectra of K-M-giants created at the Odessa Astronomical Observatory by V.F.Karamysh et al. The selection of the unblended and least blended lines was made with the account of the spectrogram resolution (0.15-0.20) and possible errors of the oscillator strengths in Kurucz-Peytremann's(1975) list used for the calculation of the synthetic spectra. The equivalent widths W_λ in the spectra of the examined stars were determined according to the 'log W_λ - R_λ' - relation from the residual intensity R_λ. This relation has been derived from the unblended lines. The values of W_λ determined in the present paper and that from the spectral material with a dispersion of 15A/mm (Mishenina, 1985) correspond to the value of the correlation coefficient about 0.98 (Mishenina et al.,1987). Let us consider briefly the selection of the parameters of the model atmospheres, which were used for the determination of the chemical composition of the atmospheres of the investigated stars. The effective temperature was determined by using the several methods:

a) from the scales of the effective temperatures: from the scale (Ridgway et al.,1980) constructed by using the direct radii measurements, it was found that T_{eff} =4800 K; from the scale (Burnashov, 1983) constructed mainly from the results of the absolute stellar spectrophotometry, it is established that T_{eff} = 5000 K;

b) the color indices B-V selfconsistent with the models of atmospheres (Bell et al., 1978) give the lowest values of T_{eff} = 4700 K;

c) in assuming the photosphere radiation to be the Planck's one in atomic lines and molecular bands, most absorption-free, at the spectral bands with $\lambda\lambda$ 4600, 6100 and 7550 A, the temperatures obtained are 5050 K;

d) the effective temperature determined by using the method of the spectral indices (Burnashov, 1983) is about 4930-4940; Motrich (1990) has obtained the value 5020- 5025 K;

e) the effective temperature determined by using the method of the photometric indices applied to the results of Geneva photometry is equal to 4930$\pm$15 K (Korotina et al.,1988).

The gravity of the studied stars is determined as follows:

a) from the bolometric stellar magnitude found by using the bolometric corrections (Burnashov, 1983) and the belonging of stars to the cluster, the value is obtained log g = 2.6-2.7;

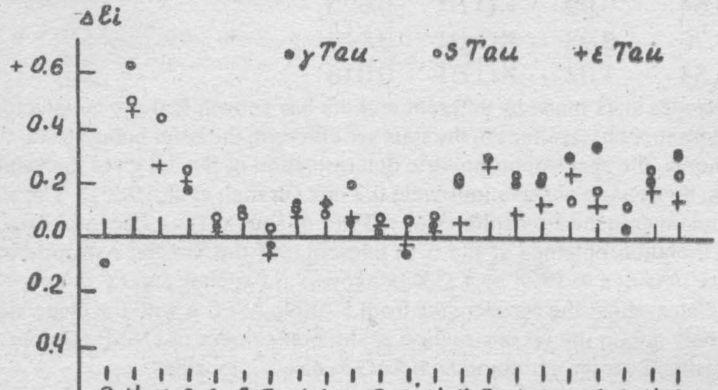
b) from the spectral indices (Burnashov, 1983) log g = 2.9-0.09; from the paper (Motrich, 1990), log g = 2.6-0.03;

c) from the photometric indices (Korotina et al., 1988), log g = 2.6-0.04;

d) from the condition of the ionization equilibrium for the lines of neutral iron (Mishenina et al., 1986) log g = 2.7-0.1 (D=15A/mm) and for the lines of neutral iron and titanium in the present work, log g = 2.83-0.4 and 2.8-0.1, respectively. Taking into account the mentioned above values, the computations of the abundances were made for the model with T_{eff} = 5000 K, log g= 2.25 and 3.0 and with solar abundance, for two values of the turbulent velocities V_t = 1.6 and 1.8 km/s. The more detailed data on the choice of the model parameters and the turbulent velocity one may find in Mishenina et al.(1986). The oscillators' strengths log gf are mainly taken from Gurtovenko and Kostyk (1980), Kostyk (1982), Perekhod (1988) and, in some cases, from Kurucz and Peytremann (1975), Boyarchuk and Boyarchuk (1981).

In order to compare the abundances in the stellar atmospheres with the solar ones, the chemical composition of the solar atmosphere was calculated with the same atomic line parameters as for the investigated stars. The model of the solar atmosphere HSRM (Kurucz, 1970) was used, the equivalent widths W_λ were taken from Moore et al.(1966). The calculations of the abundance of the chemical elements in the atmospheres of the stars and the Sun were made by using the WIDTH-6 computer code.

At Figure 1, the distribution of the abundance of the chemical elements corresponding to log g = 2.8 is shown for the investigated stars in respect to the Sun. While comparing these results with that of Nomoto and others (Branch et.al.1980), one may see, that the chemical composition of Hyades giant-stars is related to their origin from the interstellar medium enriched by the different contributions of the heavy metals due to the explosions of the Type-I and Type-II Supernovae.



For the purpose of a more detailed investigation of the physical conditions in the atmospheres of cool stars, it is of interest to study the non-LTE case.

For one of the investigated stars, we made earlier an empirical analysis from the lines of neutral iron (Mishenina, 1987). In the work there were used 15 lines with $\chi \leq 3.5$ eV and 90 lines with $\chi > 3.5$eV. The values of the iron abundance log determined from the lines with high and low excitation potential are practically coinciding. In the present work, the list of neutral iron lines in the atmospheres of α, δ and ε Tau is enlarged. The results are shown in Table 2, where logE_{Fe} (lg g) - is the iron abundance determined from the different values of log g =2.25 and 3.0 for the lines with high and low excitation potential of low level.

Table 2. Results of non-LTE analysis.

	$\chi \leq 3.5$			$\chi > 3.5$		
	γ Tau	δ Tau	ε Tau	γ Tau	δ Tau	ε Tau
lgE_{Fe} (2.25)	4.41	4.44	4.41	4.47	4.45	4.44
lgE_{Fe} (3.0)	4.37	4.39	4.36	4.44	4.41	4.40

With the increasing number of lines with $\chi \leq 3.5$, some difference in the abundance for the lines with low and high excitation potential is noticed in case of γ Tau, which ranges within the determination error; the differences are at minimum in the case of δ Tau and ε Tau stars. In the analysis of the atmospheres of the K-giants from the given observational material and using the Bell models (Bell et al.,1978) and the work on the equivalent line widths, the usage of the LTE-assumption is quite justified. In order to detect a finer non-LTE effect, a higher resolution ($\Delta\lambda < 0.1$) and the analysis of line profiles are needed.

The precision of abundances determination constitutes 0.20 dex from the iron lines and other elements represented by the numerous lines, and not higher than 0.5 dex for the elements represented by one or two lines. To increase the number of lines and the reliability of elements' abundances determination after the iron peak, we have investigated all the lines of these elements found by the different authors in the spectra of the late-type stars. In spite of the fact, that in the spectra of the K-giants there are identified about 160 lines of the elements starting with yttrium, only 21 lines remained after the careful analysis. The difference in the solar abundance determination in the case of the neodymium amounts to the unit value from the separate lines that may be due to the poor precision of oscillators' strength determination or equivalent widths of these lines in the solar spectrum ($\lambda_1 = 5431.52$, $\log E_{\lambda_1} = -10.51$, $\lambda_2 = 5442.26$, $\log E_{\lambda_2} = -9.57$).

The abundance of the elements' in the atmospheres of the Hyades K-giants is nearly solar. The oxygen deficiency, excess of sodium by ~ 0.5 dex and of the elements starting with yttrium by 0.2 dex have been found.

The authors express their thanks to the colleagues of the SAO (Russian Academy of Sciences) V.G.Klochkova, E.A.Panchuk and I.F.Bikmaev.

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