THE ABUNDANCES OF CARBON, NITROGEN AND OXYGEN IN THE ATMOSPHERES OF METALLIC - LINE STARS

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ABSTRACT. The abundances of carbon, nitrogen and oxigen in the atmospheres of ten metallic - line stars were analysed on the basis of the observations carried out with the CCD array implementing the model atmosphere technique. It has been found that oxygen and nitrogen abundances are 0.5 dex lower than that of the Sun, and carbon - by 0.7 dex. The observed anomalies are compared with the predicted values.

The data on the C, N and 0 abundances in the atmospheres of chemically peculiar stars are rather scanty. Over a long period of time the most authoritative and ample investigation belonged to Sargent and Searle (1962). They studied 20 peculiar and 3 normal A stars and determined the oxygen abundance by using the measurements of the equivalent width of IR blend 0I λ 7772-7775 A. The authors have drawn a conclusion that oxygen is underabundant (from 8 to 100 times) in the atmospheres of the investigated stars. Praderie (1968) has determined the 0 and N abundances using the lines of the IR region in the atmospheres of five metallic-line stars. As was noted by Sargent and Searle (1962), the 0 abundance was determined by the equivalent widths of blends 0I λ 7772-7775 A and λ 8446 A. The N abundance was found by line NI λ 8660.2 A which, as it has been noted later by Lambert et al.(1982), might be blended by the S line. Following the comprehensive investigations of the chemical composition of the metallic-line star atmospheres, carried out by Smith (1971), we can make a conclusion, that the carbon is underabundant by 0.5 - 0.8 dex. In the recent investigation of Laster and Lane (1981) on the abundance of light elements in the atmospheres of 4 metallic - line stars it has been found, that the carbon abundance is 3 - 6 times lower than that of the Sun, and the nitrogen abundance is twice as small.

The obstacle to the detailed study of carbon abundance and especially that of nitrogen and oxygen is related to the fact, that the majority of non-blended lines of these elements are lying in the red and infrared spectral regions and to the necessity to make the analysis of the lines with relatively small eguivalent width (sf. below). The photographic technique, being as a rule of low spectral resolution, permitted us to determine the equivalent widths of the blend λ 7772-7775 A as in the case of neutral oxygen. Owing to the implementation of modern types of light detectors the high quality observational material became available.

An example of such investigation was reported by Lambert et al.1982 for C, N and 0 abundance determination in the atmospheres of α Lyr and α CMa. Using the Reticon detector, the spectral regions of 100 A were registered with a spectral resolution of 0.1- 0.3 A. The signal-to-noise ratio was about 900. The measured equivalent widths were analysed by the model atmospheres assuming the LTE effect.

As it has been noted by Lambert et al. (1982), this assumption might be the cause of significant systematic errors. Starting from the works of Kohl (1964) and Raimers (1969) according to the detailed analysis of the atmospheres of Sirius and δ Del correspondingly, it has been found, that the analysis of the IR triplet lines 0I λ 7772 - 7775 A leads to the overestimated values of log ε , if compared with the analysis of the visual spectral region. The published non-LTE calculations (Baschek et al., 1977) for the atom 0I in the atmospheres of A stars showed, that the LTE deviations affect the lines of 1, 2 and 3 multiplets, but as far as the multiplet 10 is concerned, the effect, in question, is small.

Our observations were carried out at the 2.6-m telescope of the Crimean Astrophysical Observatory with the CCD array supplied by the Helsinki University (Finland). The spectra were registered in Coude focus of the spectrograph with an inverse dispersion of 3 A/mm. The time of one exposure was about 15-40 minutes. The spectral resolution was of the order of 0.15 A. The observational material was obtained with the signal-to-noise ratio from 30 to 100. The interval of 30 A was registered simultaneously. The list of the investigated stars together with the parameters of their atmospheres is given in Table 1.

Table 1.

star	T_e	log g	ξ_t, $\frac{km}{s}$	log ε (El)			
				C	N	O	Ca
16 Ori	7900	4.35	6.0	7.72		8.50	5.45
15 Vul	8100	3.5	4.8	8.30		8.35	6.22
81 Tau	8100	4.1	6.5			8.72	6.13
γ Gem	9300	3.4	2.0	8.34	7.39	8.67	6.58
68 Tau	9300	3.75	4.0	8.03	7.55	8.44	6.52
η Oph	9300	4.2	3.0			8.26	6.18
θ Leo	9400	3.6	2.6	8.05	7.49	8.55	6.14
43 Peg	9800	3.8	3.5	7.89		8.38	6.47
τ UMa	7400	4.05	6.0	7.62	7.59	8.32	5.41
ξ^1 Lyr	7650	3.5	5.0			8.19	5.66

The majority of them were studied by model atmosphere technique (Lyubimkov et al., 1983). For the stars τ UHa and ξ^1 Lyr the atmospheric parameters were evaluated by using the same technique adopting the data obtained by Smith (1973) and Praderie (1968), correspondingly. Table 1 also presents the basic results of the calculations. The oxygen abundance was determined by two lines of 10 multiplet (λ 6156.78 A and λ 6158.19 A), being less sensitive to the non-LTE effects. CaI λ 6162.17 A line, encounted in the registered region, has been also measured. The carbon abundance determination is based on the analysis of CI. λ 5052.15 A line. Let us note that in the spectra of 81 Tau and ξ^1 Lyr, having high enough values of v sin i, this carbon line is blended by the iron line.

In our analysis the oscillator strengths for the investigated lines were adopted from the paper (Lambert et al., 1982) and the data on damping constants - from (6ehlich, 1969).

Fig. 1 shows the obtained results versus the effective temperature of the star. The data from Table 1 were completed with the results for 63 Tau and α CMa (Hundt, 1972; Lambert et al., 1982 correspondingly).

They have been obtained by the same lines, as the data from Table 1. The data on C, N and 0 element abundances in the atmosphere of the sun were published by Lambert (1978), and Ca - by Smith (1981). In Fig. i solar values are indicated by stroke lines. It is obviously that the oxygen abundance in the atmospheres of metallic-line stars is lower by O.5 dex with respect to the Sun, and the carbon abundance - by 0.7 dex. Me can conclude that the anomalies of these elements are only slightly temperature dependent. The dependence similar to that described earlier by Lyubimkov et al. (1983) for calcium, is nicely pronounced in the observations of λ 6162.17 A CaI line (Fig. 1).

The nitrogen abundance was determined only for 4 stars by the lines of 1 multiplet: λ8683.38, λ 8686.13 and λ 8703.24 A. On the average, this element turned out to be underabundant by O.5 dex. It is noteworthy, since by Lambert et al. (1982) the nitrogen was referred as overabundant in the atmosphere of Sirius.

It seems plausible to compare the observed anomalies of carbon, nitrogen and oxygen directly with the predictions of the diffuse theory of element separation in the atmospheres of chemically peculiar stars. According to Lambert et al. (1982) and Michaud et al. (1976) the abundance of any element can be described as follows:

$$\log \varepsilon \, (El) = \log \varepsilon \, (El)_0 + \log E,$$

where $\log \varepsilon (El)_0$ is the abundance of the element at the absence of diffusion. As follows from Lambert at al.(1982), for the star with M=2.6 $M_\odot$, the value log E equals to -0.5, -0.2 and -1.0 for C, N and 0, correspondingly. Four of the investigated stars have the mass equal or close to 2.6 $M_{\odot}$. Unfortunately, for two of them, 15 Vul and 43 Peg, only the carbon and oxygen abundances have been determined.

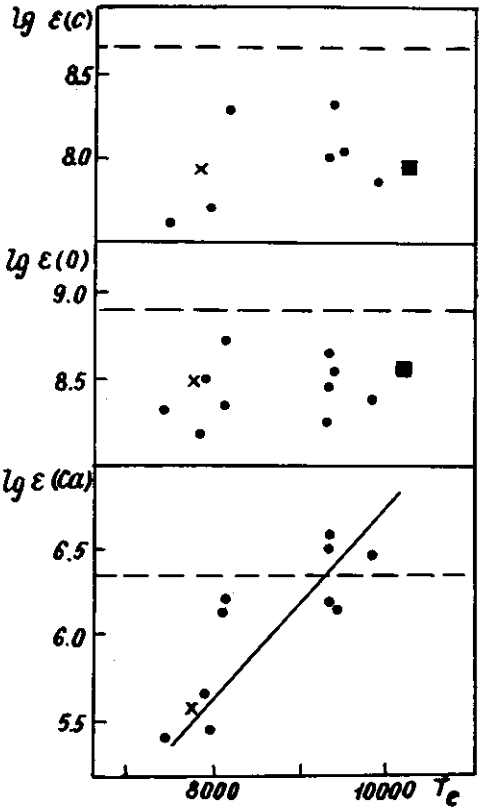

Fig. 1: The abundances of C, O and Ca versus the effective temperature of the star. Solar values are indicated by stroke lines, data for 63 Tau and α CMa - by crosses and squares, correspondingly.

From the analysis of Table 2 it eight seem that there exists a good agreement between the predicted theoretical and observational data: the abundance of all the three elements is lower with respect to the solar one; the nitrogen deficit is lower, than that of carbon and oxygen. However, the ratios of these element abundances differ significantly. It eight be due to the fact that the theory predicts greater value of oxygen deficit, that it follows from the observations.

Table 2.

	$\log E(C)$	$\log E(N)$	$\log(O)$	$\log\frac{E(N)}{E(C)}$	$\log\frac{E(C)}{E(O)}$
4 Am-stars	-0.6	-0.5	-0.5	+0.1	-0.1
diffusion	-0.5	-0.2	-1.0	+0.3	+0.5

The anomalous abundances of carbon, oxygen and nitrogen in the stellar atmospheres eight be observed in the case of stellar enrichment by the CNO-cycle products (Caughlan, 196S) in course of the reaction the overabundance of nitrogen occurs relative to C and 0. The total abundance of the three elements during the reaction cycle must be the same. According to our determinations it equals to 8.85, 8.62 and 8.70 for the stars τ Gem, 68 Tau and θ Leo, respectively, and is significantly lower than the solar value 9.15.

It is known, that the matter of atmospheres in the case of giants of late spectral classes on the stage of mixing is enriched by the products of the CNO-cycle. In the course of the investigation of 32 giants of the spectral class G8 - K5 (Lambert et al., 1981), it has been stated, that the carbon abundance is in the deficit in the atmospheres of these stars, whereas the nitrogen is overabundant, and the oxygen abundance is close to the solar value. The total composition of CNO correlates with the iron abundance and differs from the solar one by no more than 0.4 dex. The value C + N + 0 = -0.4 is reached for the stars with the iron abundance lower by 0.4-0.5 dex with respect to the solar value. Thus, if we suppose that the carbon and oxygen deficit in atmospheres of the metallic - line stars is determined by resolving these elements into nitrogen as a result of the CNO-cycle, then the total abundance of the three elements would have been more properly attributed to the stars with metal deficit.

CONCLUSION.

Herewithin we discuss briefly the results of carbon, nitrogen and oxygen abundances in the atmospheres of ten metallic - line stars. The detailed description of the observational data is published by Savanov (1986). It has been found that the abundances of the three elements are lower in respect to the Sun. The results obtained while analysing the eguivalent widths can be improved by analysing the observational material with the synthetic spectrum technique. Such improvement is especially important for the nitrogen line investigations due to blending.

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