CHEMICAL COMPOSITION OF APPROXIMATELY EQUAL MASS Hg-Mn COMPONENTS OF THE SB2 SYSTEM 46 Draconis

V.V.Tsymbal[1], O.P.Kotchoukhov[1], D.L.Lambert[2], V.L.Khokhlova[2]
[1] Simferopol State University, Simferopol
[2] Department of Astronomy, University of Texas at Austin, Austin
[3] Institute of Astronomy, Russian Academy of Sciences, Moscow

ABSTRACT. We report results of the most complete up to date elemental abundance analysis of approximately equal mass Hg-Mn components of chemically-peculiar SB2 system 46 Dra. The high-dispersion S/N≥200 CCD spectrum were obtained with the echelle spectrograph of the McDonald Observatory 2.7-m reflector. Lines in the wide spectral region of 3800-9000 Åwere identified and the chemical composition of each component was determined for 25 elements. Chemical anomalies of both components are found to be roughly similar: He, C, N, O and Al deficiency, nearly normal abundance of iron-peak elements, large excesses of P, Mn, Ga, Sr, Y, Zr, Ba, Pt, Au and Hg which show a common trend with atomic number. However we found significant abundance differences between the components especially for Ne, Al, S, V, Mn, Ni, Ga, Sr, Zr and Pt.

Key words: Stars: Abundances: 46 Dra

1. Introduction

In recent years the number of studies of Hg-Mn type stars in binary systems have increased considerably. Such stars is of particular interest because duplicity makes it possible to obtain solid data on such fundamental properties as masses and radii as well as on the evolutionary status of these stars. Of special interest is a comparative abundance analysis of SB2 components, because it is crucial in testing the hypotheses of the origin of chemical anomalies. Still more promising would be studies of chemical peculiarities in a binary system consisting of components of equal mass, because in that case one could expect both stars to be formed from the same parent matter and to follow a common evolutionary path. Will they have the same chemical composition? Thus, to provide tests for the theories which attempt to explain chemical anomalies one should study subtle differences in the chemical composition of the stars in binary CP systems with equal mass components. 46 Dra provides so far unique laboratory for such purposes due to the small rotatinal velocities of both components (Vsin i≤5km/s) and a mass ratio M_a/M_b=1.12 (Adelman et. al. 1997). Only eclipsing binary system AR Aur (Khokhlova et. al. 1995) has so similar components, but rotational velocities of 23km/s resulting in considerable line blending makes it difficult to obtain a full set of AR Aur A and B abundances. Other known double-lined binaries with Hg-Mn primaries such as HR 4072 (Adelman 1994), X Lup (Wahlgren et. al. 1994) and 112 Her (Ryabchikova et. al. 1996) have much higher M_a/M_b ratios and effective temperature difference between the components of dissimilar peculiarity classes is greater than 1400 K. Thus, among all these systems 46 Dra is of worth studying. Chemical composition of 46 Dra was obtained earlier by Conti (1970) and Guthrie (1984). The most detailed among the previous studies was done by Adelman et.al. (1997, hereafter ARD) using Reticon spectra with S/N=200. ARD obtained light ratio L_a/L_b=1.7 and found solution for the atmospheric parameters of the components using spectrophotomety (Adelman&Pyper 1979), H-gamma profile synthesis, and ionization equ-

Table 1. Known physical parameters of SB2 system 46 Dra.

	46 Dra A	46 Dra B
T_{eff}	11700	11100
lg g	4.0	4.1
[M/H]	+0.2	+0.2
He/H	0.01	0.017
L_a/L_b	1.7	
M_a/M_b	1.12	
R_a/R_b	1.23	
P,d	9.81073(4)	
T_o, JD	2440003.128(32)	
e	0.200(6)	
$K_a, km/s$	26.01(17)	
$K_b, km/s$	29.12(18)	
$\gamma, km/s$	-27.88(9)	

ilibruum condition for FeI and FeII lines. A metallicity of +0.2 dex was assumed for both components.

Table 1 lists atmospheric parameters of 46 Dra dtermined by ARD as well as orbital elements obtained by Aikman (1976) and refined by ARD.

2. Observations and spectrum reduction

In this study we analysed spectrum of 46 Dra obtained with the echelle spectrograph of the 2.7-m McDonald Obsevatory telescope using a CCD detector (Tull et. al. 1995). The spectrum were obtained in May 1996 during an observation run held by prof. D.L.Lambert with participation of V.L.Khokhlova. 61 spectral order covered the wavelength region of 3600-9800 A with the spectral resolution of 60000. The typical signal-to-noise ratio was S/N$\geq$200. Initial spectrum reduction was done in the University of Texas by V.Wolff and V.L.Khokhlova with the KPNO-IRAF package. Further reduction and calculations were conducted in the Simferopol University by V.V.Tsymbal and O.P.Kotchoukhov using DECH20 code (Galazutdinov 1994) and STARSP package (Tsymbal 1996). Since spectral orders with Balmer lines were too short and flat fielding during the initial reduction was not perfect enough we refused from the atmospheric parameters refinement and assumed parameters obtained by ARD with modern analytic technique and observational data. Julian dates for our observations, radial velocities for both components of 46 Dra and phases calculated with the ephemerides given in Table 1 are listed in Table 2.

Since our spectrum covered a wide wavelength range didn't accessible in previous studies we paid much attention to careful spectral lines identification and equivalent widths measurement in order to refine abundances for the elements that were poorly studied earlier or obtain abundances for the species weren't studied at all. We didn't study numerous transitions of Zr and some iron-peak elements (Ti, Cr, Mn and Fe) because their abundances were obtained fairly accurate by ARD who identified many lines of these elements. We performed line identification in spectrum obtained at different phases so atmospheric lines which were not shifting with phase were excluded easily. Equivalent widths were measured mainly in the spectra obtained at the phase of 0.067 when spectral lines of the components were of the best separation. Gaussian profiles were fitted through the metal lines with DECH20 code. A linear regression comparisons of our equivalent widths (in mA) with those measured in other studies are given be the following relations:

$$W(\text{Conti 1970}) = 0.855W + 7.973;$$
$$W(\text{Guthrie 1984}) = 0.993W + 1.795;$$
$$W(\text{ARD}) = 0.943W + 0.238.$$

3. Abundance analysis

In spectral line identification and chemical composition determination spectrum synthesis technique was used extensively. We performed spectral synthesis with BINARY code which is specially adapted for SB2 composite spectrum synthesis. This code is a part of STARSP package written by V.V.Tsymbal and based on Kurucz's (1993) programs and data.

Table 2. Observational data for 46 Dra.

JD 2450000+	Phase	$V_r(p)$,km/s	$V_r(s)$,km/s	$\gamma, km/s$
206.9465	0.067	-58.23	+1.77	-29.92
207.9427	0.169	-41.57	-16.57	-29.78
208.9331	0.270	-24.92	-36.92	-30.58

In addition to HeI lines we used spectral sythesis in determination of Ga abundance from GaII 6334 feature which is severly affected by the hyperfine structure broadening (Lanz et. al. 1993) and in coarse estimation of Hg isotope mixture from HgII 3984 feature. The main body of abundances was obtained with traditional equivalent widths technique using WIDTH9 code. Instead of a widespread equivalent widths correction procedure employed for SB2 spectral analysis we directly calculate equivalent width of a spectral line in a composite spectra using the following formula

$$W_a = \int \frac{F_\lambda^A + S \cdot F_\lambda^B}{F_c^A + S \cdot F_c^B} d\lambda,$$

where $F_\lambda^{A,B}$ and $F_c^{A,B}$ are monochromatic fluxes in a spectral line and continuum respectively computed with model atmospheres adopted and $S=(R_b/R_a)^2$. Therefore our method doesn't require obtaining equivalent width correction coefficient and determining its wavelength dependance. All model atmospheres that we used were generated with Kurucz's ATLAS9 code and OPDF tables (Kurucz 1993). We paid particular attention to the choosing of iteration cutoff criterion. Since integral fluxes 1% error cutoff leads to significant errors in elemental abundances especially for those derived from strong lines, we continue iterations till temperature's error decreases to 1% in every atmospheric layer. Besides in model atmosphere calculations it is important to account for He defficiency. In our study we used models generated with real He abundances obtained by ARD. Accounting for He deficiency changes FeI/FeII ratio, therefore one can suspect "ionization equilibruum" method of atmospheric parameters refinement to be sensible to He abundance. Full results of our line-spectrum analysis with equivalent widths measured, abundances derived and atomic data for each identified line will be published elsewhere. Compares our abundances with those of ARD are of good agreement and discrepancies rarely achieve 0.3 dex.

4. Discussion

The summary of chemical composition anomalies for both components of 46 Dra is shown on Fig.1a. Components' abundances look very similar except of small discrepancies for Ne, Al, S, V, Ni and Zr, and significant abundance differences for Mn, Ga, Sr and Pt. In addition we found significant difference for the mercury's isotopic composition: in the primary's atmosphere nearly all (85%) the Hg is in the form of the 202Hg isotope, but in the secondary the haviest stable isotope 204Hg dominates reaching 81% from all the Hg abundance. The secondary's Hg isotopic mixture resembles those of another Hg-Mn component of a SB2 system-X Lup (Guthrie 1984). It is interesting to compare abundances determined for the components of 46 Dra with those of similar SB2 system AR Aur (Khokhlova et. al. 1995). Both SB2 systems have approximately equal mass main sequince components of spectral class near B9V and rotation synchronized with the orbital motion. So it it natural to suggest 46 Dra and AR Aur to have the similar evolutionary history. Fig.1a and b show that chemical compositions of 46 Dra A and B are much alike than those of AR Aur components. But in both cases the same elements show abundance differences between the components: Al and Ni deficiency, Mn, Sr and Y overabundance are different for the components in both systems. As for heavy elements like Ba, Pt and Hg they behave very different in 46 Dra and AR Aur: the latter has much

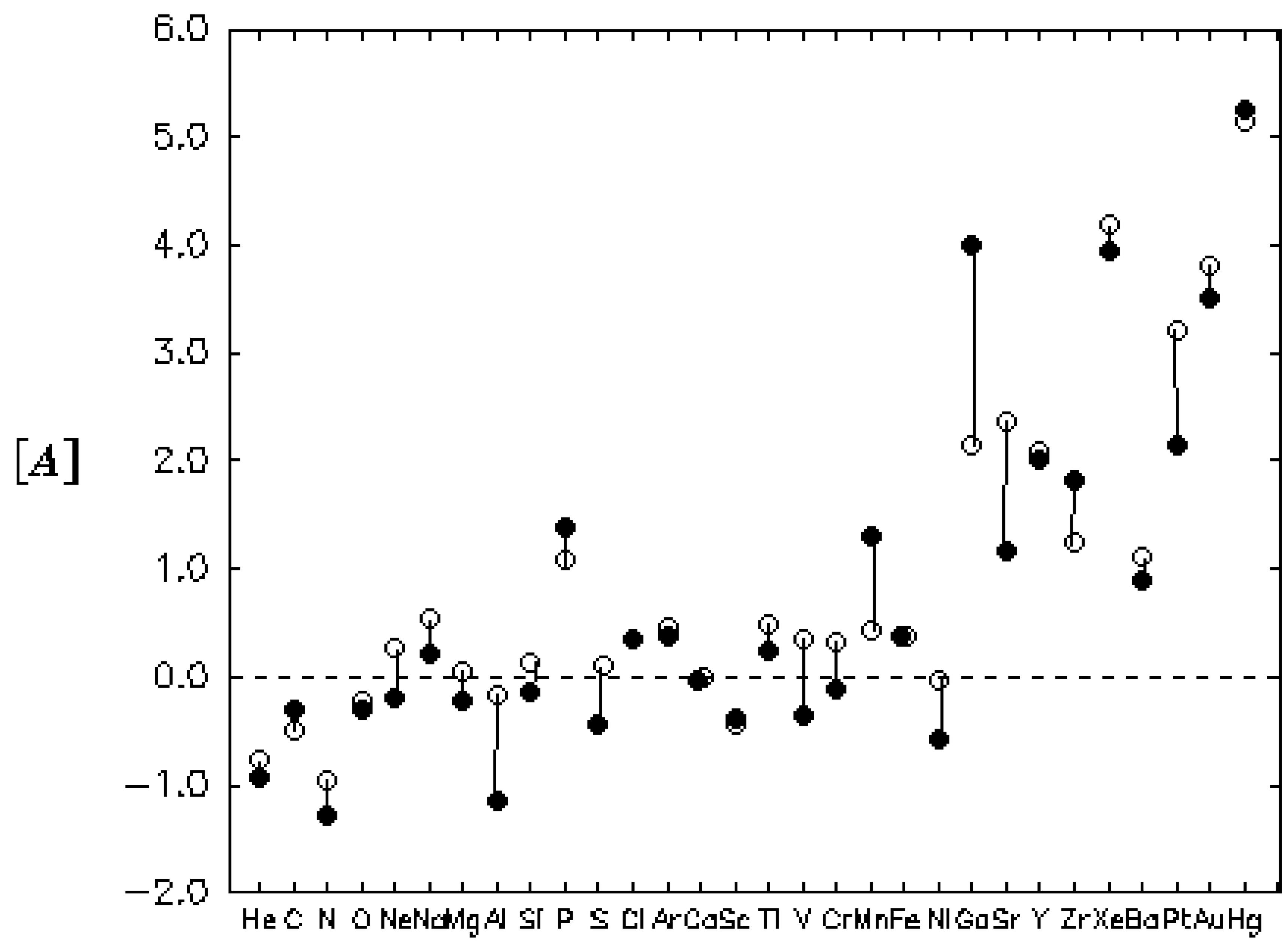

Fig. 1a. Abundances derived for 46 Dra A (filled circles) and B (open circles) The solar abundance is indicated by a horizontal dashed line.

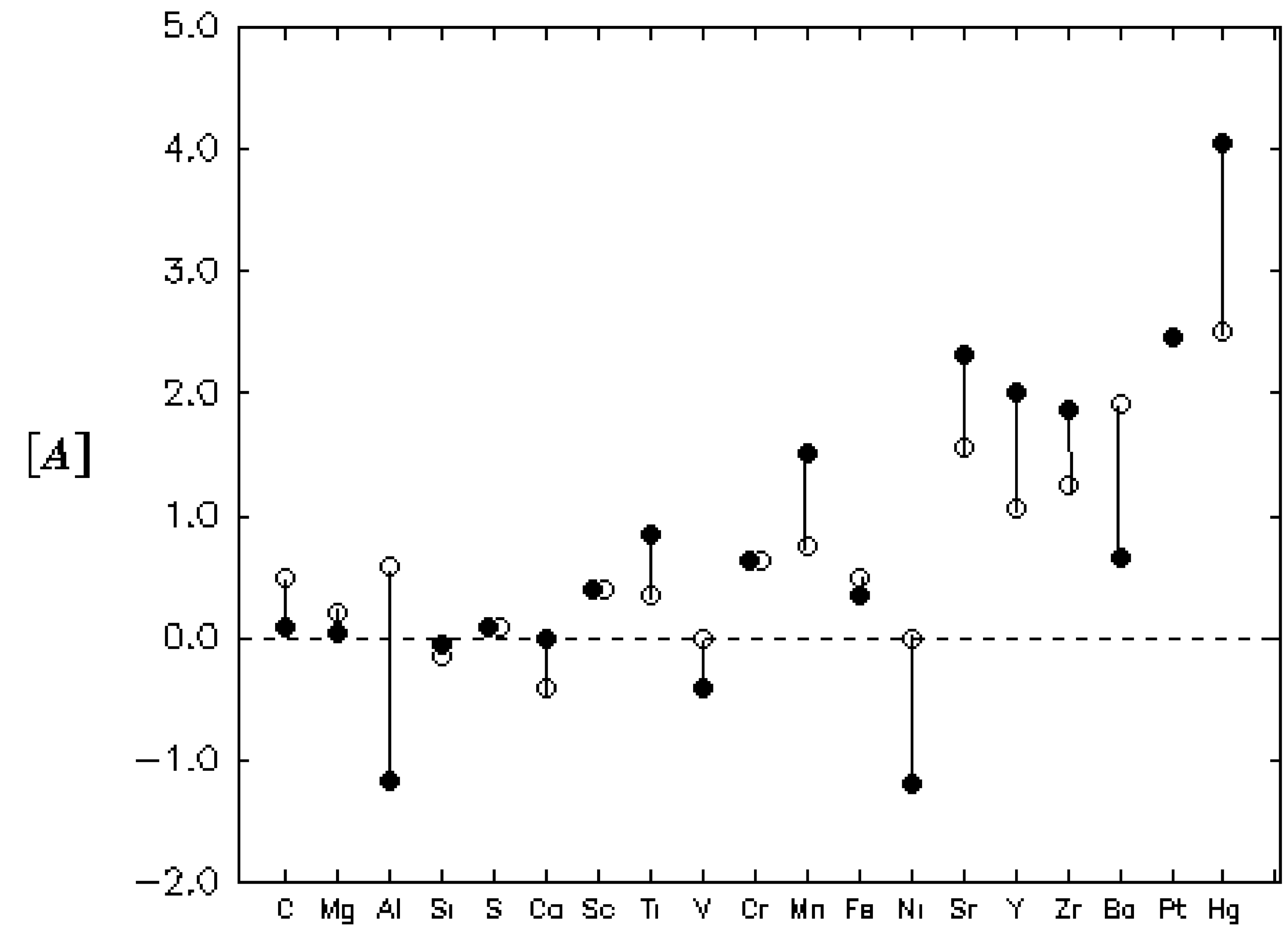

Fig. 1b. The same as in Fig.2a but for AR Aur A and B (Khokhlova et. al. 1995).

higher discrepancies of these elements than the former. Detailed investigation of other SB2 systems with approximately equal mass CP components is necessary in order to specify the time and origin of chemical anomalies appearance.

Acknowledgements. In conclusion we would like to acknowledge T.A.Ryabchikova and other authors of ARD study for the possibility of using their results and data before publication.

References:

Adelman S.J.: 1994, *Mon. Not. Roy. Astron. Soc.,* **266**,97.

Adelman S.J., Ryabchikova T.A., Davidova E.S.: 1997, *Mon. Not. Roy. Astron. Soc.,* (in press)

Adelman S.J., Pyper D.M.: 1979, *Astron. J.* **84**, 1603.

Aikman G.C.L.: 1976 *Publ. Dominion. Astrophys. Obs.,* **14**, 379.

Galazutdinov G.: 1994 *Preprint of Special Astrophys. Obs. RAS.,*

Guthrie B.N.G.: 1984 *Mon. Not. Roy. Astron. Soc.,* **206**, 85.

Conti P.S. 1970 *Astron. Astrophys.,* **7**, 213.

Kurucz R.L. 1993 *CD-roms Smithsonian Astrophys. Obs.*

Lanz T., Artru M.C., Didelon P., Mathys G.: 1993 *Astron. Astrophys.,* **272**, 465.

Ryabchikova T.A., Zakharova L.A., Adelman S.J. 1996 *Mon. Not. Roy. Astron. Soc.,* **283**, 1115.

Tull R.G., McQueen P.J.,Sneden Ch., Lambert D.L.: 1995 *PASP.,* **107**, 251.

Khokhlova V.L., Zverko Yu., Ziznovskij I., Griffin R.E.M.: 1995 *Astronomy Letters,* **21**, No 6, 818.

Tsymbal V.V.: 1996 *Model Atmospheres and Stellar Spectra. ASP Conf. Ser. / Eds S.J. Adelman, W.W. Weiss.,* **108**, 198.

Wahlgren G.A., Adelman S.J., Robinson R.D.: 1994 *Astrophys. J.,* **434**, 349.