Chemical composition in the components of the visual binary system BD+40^0 175: rare-earth elements

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Abstract. Preliminary results of abundance analysis for rare-earth and some other elements in the atmospheres of components of the visual binary system BD +40°175 are presented. The spectra were obtained with the 6 m telescope. Both the stars have significant overabundances of rare-earth elements, typical for cool CP stars.

1. Introduction

BD + 40°175 (SAO 36713) is a visual binary with a 3.7 arcsecond separation of its components. The brightness of BD + 40°175A is m_V = 9.5 and BD + 40°175B is fainter by = $0.^m4$. Bidelman (1985) classified BD +40°175 as a CP star with SrCrEu anomalies on the basis of objective prism spectra. Babel & North (1997), using the ELODIE echelle spectrograph on the Haute-Provence 1.9 m telescope and the cross-correlation technique, found a strong and variable magnetic field. The mean surface field of BD + 40°175A varied from 12.7 to 22.3 kG.

Elkin (1999) obtained new spectra of both components of BD + 40° 175 with the 6 m telescope using a circular polarisation analyzer. These observations proved the presence of a strong effective magnetic field B_e in the A component. Moreover, it was found that the second component is also a magnetic star. Spectra of both the components of BD + 40° 175 indicate an anomalous chemical composition. The lines of rare-earth elements are very strong, which is common for magnetic CP stars.

In this contribution, the preliminary results of abundance analysis of both components of BD + 40°175, mainly of rare-earth elements, are presented.

2. Observations

The spectroscopic observations of the studied stars were obtained with camera 2 of the Main Stellar Spectrograph of BTA. Four spectra covering the spectral region of 4460 - 4620 ÅÅ and one of 4320 - 4490 ÅÅ were secured for each component of BD + 40° 175. The MIDAS system was used during the observations and further reduction together with the DECH software package (Galazutdinov, 1992). A detailed description of data reduction can be found in Elkin (1999) and Romanyuk et al. (1998). The spectra were obtained with a circular polarisation analyzer. Using this device the two spectra circularly polarized in opposite directions are obtained simultaneously. By means of co-addition, these two spectra result in a "normal" spectrum, like that obtained without an analyzer. As no variations of spectral lines were found, the four spectra of both components in the interval of 4460 - 4620 ÅÅ were co-added again to gain better S/N ratio.

3. Determination of T_{eff} and log g

The effective temperature of BD + 40°175A was determined by Babel & North (1997). They used the profiles of H_γ and H_β and found a value of T_{eff} = 7100 ± 400 K.

We used H_γ profiles for T_{eff} determination. A comparison of the observed profile with the profile computed with the SYNSPEC code (Hubeny et al., 1995, Krtička, 1998) and Kurucz's (1993) models with enhanced metals resulted in a value of T_{eff} = 8000 ± 400 K and log g = 4.0. This value of T_{eff} is larger than that by Babel & North (1997). The secondary component is somewhat cooler, T_{eff} = 7500 ± 400 K and log g = 4.0. As there are no other independent spectroscopic and photometric determinations of T_{eff}, we used the values from our spectroscopy for abundance determination for the sake of having consistent values for both the components.

4. Abundance determination

As chemical elements in the atmospheres of magnetic CP stars are in most cases distributed inhomogeneously due to the presence of magnetic field, the best method for abundance determination is their surface

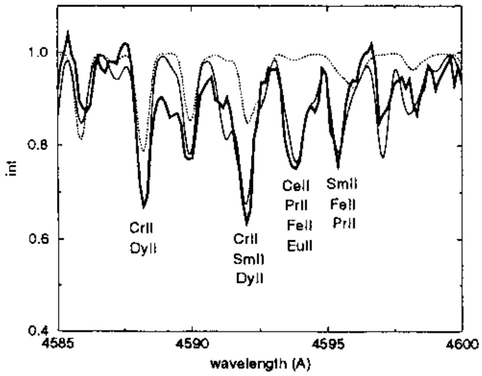

Figure 1: *Spectrum of* BD + 40°175*A*. *Bold line: the observed spectrum, thin line: synthetic spectrum with abundances from Table 1, dashed line: synthetic spectrum with solar abundances.*

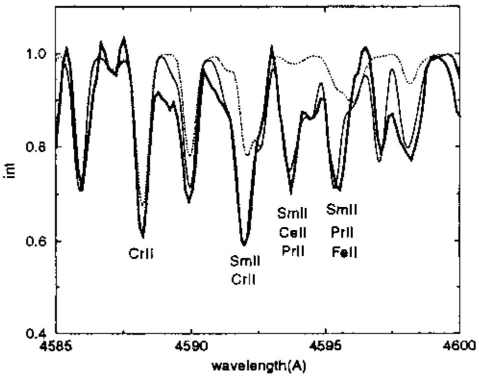

Figure 2: *The same as in Fig. 1, but for* BD+40°175*B*.

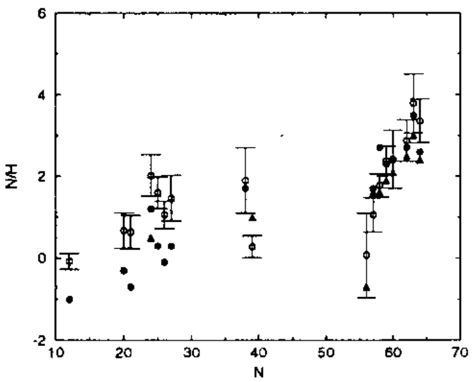

Figure 3: *Comparison of our results and the mean abundances for cool CP stars: filled circles —* BD + 40°175*A*, *filled triangles —* BD + 40°175*B*, *open circles with error bars — mean values (Adelman, 1973).*

mapping. This requires spectra of high spectral resolution and high S/N ratio, which is not the case with our spectra. For this reason we decided to use classical model atmosphere analysis. SYNSPEC code (Hubeny et al., 1995, Krtička, 1998) with Kurucz's (1993) ATLAS9 models and VALD database (Piskunov et al., 1995, Kupkaet al., 1999 and Ryabchikova et al., 1999) were used in our abundance determination.

Magnetic fields in the atmospheres of CP stars cause intensification of spectral lines. If there is no correction made for the magnetic field, the resulting abundances of elements will be of a higher value (Hensberge & De Loore, 1974). A simple method for such a correction was used by many authors (see for example Kupka et al., 1996). They introduced an additional microturbulent velocity ξ_{mag} [km/s] term, which is propotional to the magnetic field and to the Lande factor of the spectral line:

$$\xi_{mag} = 4.66 \times 10^{-13} \times c \times \lambda \times g_{eff} \times B, \qquad (1)$$

where c is the speed of light in km/s, λ is the wavelength in ÅÅ, g_{eff} is the Lande factor and B is the mean surface magnetic field in gauss. Such a correction, however, can only be used in the case of relatively weak magnetic fields.

Both the components of BD+ 40° 175 have strong magnetic fields. The resolution of our spectra does not allow us to see the Zeeman splitting of spectral lines, but their profiles are affected by it. It would therefore be useful to compute synthetic profiles for each individual spectral line with its particular Zeeman pattern. This work will be done later. In this paper we present our results obtained with the use of term ξ_{mag}

As the observed surface magnetic field of BD + 40°175A reached values over 12 kG, it was unsuitable to use formula (1). When applied, a corresponding ξ_{turb} turned out to be more than 8 km/s, which led to very strong metallic lines in the synthetic spectrum. We had to reduce the abundances of metals significantly to fit the observed spectrum. There is no reason for this, as generally metals are overabundant in magnetic CP stars. Therefore we used a value of microturbulent velocity ξ_{turb} == 2 km/s and no additional magnetic intensification was taken into account. Even in this case some of the metallic lines show underabundances.

There is no determination of the surface magnetic field for BD + 40°175B, but according to Elkin's (1999) determination of B^e we can estimate the value

Table 1:

Elem.	BD + 40° 175A	BD + 40° 175B	mean*
Mg	-1.0	⊙	−0.08 ± 0.19
Ca	-0.3	⊙	+0.68 ± 0.43
Sc	-0.7	⊙	+0.64 ± 0.41
Cr	+1.2	+0.5	+2.02 ± 0.51
Mn	+0.3	⊙	+1.60 ± 0.38
Fe	-0.1	⊙	+1.06 ± 0.33
Co	+0.3	⊙	+1.47 ± 0.56
Sr	+1.7	⊙	+1.90 ± 0.80
Y	⊙	+1.0	+0.28 ± 0.27
Ba	⊙	-0.7	+0.07 ± 1.03
La	+1.7	+1.6	+1.06 ± 0.42
Ce	+2.7	+1.6	+1.78 ± 0.29
Pr	+2.3	+1.9	+2.38 ± 0.36
Nd	+2.4	+2.1	+2.42 ± 0.71
Sm	+2.7	+2.5	+2.88 ± 0.51
Eu	+3.5	+3.0	+3.79 ± 0.72
Gd	+2.6	+2.4	+3.36 ± 0.54
Dy	+1.7	⊙	–

⊙ – solar values, * – Adelman (1973)

of B^s to be 5-6 kG. Using the term ξ_{mag} from formula (1) we derived the value of ξ_{turb} =4 km/s for the secondary component of BD + 40° 175.

As follows from Figs. 1 and 2, the spectra are very complex with a lot of blends. Since we focused our effort on rare-earth elements, we chose the interval 4585 - 4600 ÅÅ with dominating rare-earth lines and relatively weak lines of other metals to demonstrate our results. In Table 1 our results (the [N/H] abundances in units of the solar values) are compared with those given by Adelman (1973) as mean values for a sample of cool CP stars.

As follows from Table 1, both components of BD + 40° 175 are CP stars with significant overabundances of rare-earth elements. In the A component Eu is the most overabundant element (by 3.5 dex), Ce, Pr, Nd, Sm and Gd are overabundant by 2 - 3 dex and Cr, Sr, La, and Dy by 1 - 2 dex. Some of the elements are deficient in the A component. The most underabundant elements are Mg and Sc. In the B component we found slightly lower overabundances, again Eu being the most overabundant. With the exception of Ba no underabundances were found.

Our results for rare-earth elements are in general agreement with the mean values for cool magnetic CP stars given by Adelman (1973). The underabundances found in BD + 40° 175A for the other elements (especially for Mg and Sc) are common in cool CP stars. More realistic abundances, however, could be derived only by taking account of Zeeman splitting in the strong magnetic field.

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