Orbital solution of A–type binaries α Dra and Mizar A using spectrum disentangling

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Abstract: The single–lined 51.420d spectroscopic binary α Dra (HD 123299, Thuban, spectral type A0 III) is a slightly metal poor star. First orbital elements were obtained by Harper in 1907. Mizar A (HD 116656, spectral type A2 V) is a double–lined 20.53d spectroscopic binary first reported by Pickering (1890). Its orbital elements were determined by Vogel in 1901. Redetermination of orbital elements for these two binaries has been performed by means of the spectrum disentangling using a computer code KOREL developed by Hadrava (1995, 1997). We present revised orbital elements based on new electronic spectra taken at the Ondřejov Observatory between 1994 and 2003.

Introduction

The computer code KOREL (developed by Hadrava 1995, 1997) provides a powerful method for a determining orbital elements of binary or multiple (up to five components) stars as well as for a decomposing composite spectra of multiple systems into individual ones. The code is also able to decompose the telluric lines from the components of the stellar system. This method has been applied to studies of selected stellar systems by a number of authors. Recently, it has been applied to a study of the Be star 66 Oph (Štefl et al. 2004) and quadruple system of o And (Budovičová et al. 2004).

The aim of this study is to check the usefullness and applicability of this method using well known bright multiple stars as benchmark tests. We start with two binary stars – Mizar and Thuban – that have been observed with the 2–m telescope at Ondřejov Observatory between 1994 and 2003.

The observations were performed with the Ondřejov 2–m telescope coudé spectrograph equipped with the Reticon or CCD detectors.

Spectra obtained by these detectors cover range from 6300 Å to 6700 Å. Selected spectral lines used for obtaining an orbital solution are listed in Table 1. Some of these lines are blends of several neibouring lines and only the strongest component is listed.

Table 1. Selected spectral lines

Line	Mizar A	Thuban
Si II 6347 Å	⋆	⋆
Si II 6371 Å	⋆	⋆
Fe I 6400 Å	⋆	
Fe II 6433 Å	⋆	⋆
Fe II 6456 Å	⋆	
H I 6562 Å	⋆	⋆
Fe I 6678 Å	⋆	

Working with the `KOREL` code

Orbital parameters are determined from a time series of observed spectra. It is an iterative process, starting from an initial estimate of the orbital parameters.

The first step of using the `KOREL` code is setting the initial estimates of orbital parameters of the system (period P, time of periastron passage T, eccentricity e, periastron longitude ω, the radial velocity amplitude of the component with the lowest index K_1, and the mass ratio of the components $q = M_2/M_1$) which should be solved.

The initial values of parameters are from a solution of radial velocity curves measured in the standard way or they are simply taken from literature or catalogs if they are known. In addition, the `KOREL` code enables us to make use of terrestrial lines when they are present in observed spectra. Terrestrial lines are considered as a third component of the stellar system and their orbital parameters are fixed during the whole proccess of orbital solution. These lines serve as an independent measure of the stability of the detector (cf. Horn et al. 1996). These parameters are computed by a `PREKOR` code, which is used for preparing data to the `KOREL` code. The input of `PREKOR` code are stellar coordinates (right ascension, declination, and equinox) of the star and coordinates of the observatory. This code also allows to choose the narrow regions, which will be decomposed in `KOREL` code.

After setting these initial orbital parameters we fix them to compute line strengths. This step is important for treating terrestrial lines in spectra, which play a useful role in the calculations. Once we have everything prepared we run the `KOREL` code for finding a solution of the epoch T, which is set close to the time of observations. Simultaneously with solving for the epoch we can also improve the line strengths.

It is generally recommended to converge the most important parameters first, with the less important parameters fixed, and to converge all parameters simultaneously only at the end to improve the final solution. It means that we converge first the epoch T and semiamplitude K_1 (and the mass–ratio q in the case of two–component spectroscopic binaries). Eccentricity e and periastron longitude ω are allowed to converge in the next step. The line strengths not need to be converged at every step. The period P needs to be determined in advance, mostly on the basis of old data not accesible for spectral disentangling.

Mizar A

Mizar A (ζ UMa A, 79 UMa A, HD 116656, HR 5054) is a double–lined spectroscopic binary consisting of two similar A stars. Its binarity has been first reported by Pickering (1890). First spectroscopic elements were detemined by Vogel (1901), who measured the relative radial velocity between the components. He found the values of the period to be 20.6 days and the eccentricity 0.502. The most recent spectroscopic elements were determined more than 40 years ago by Fehrenbach & Prevot (1961).

Mizar A was also subject to a number of interferometric observations. First interferometric measurements were reported by Pease (1927). Recent interferometric observations were performed by Hummel et al. (1998), who also presented the most recent complete set of orbital parameters.

We ran the `KOREL` code for selected spectral lines available in our Reticon spectra to obtain orbital parameters. Then we calculated mean values of orbital elements together with the errors. The results are listed in Table 2.

Figures 1 and 2 show an example of decomposed spectra of both components in this binary in Si II (6371 Å) and Fe II (6456 Å) spectral lines.

Table 2. Orbital elements of Mizar A

	Hummel et al. (1998)	`KOREL` code
$P(d)$	20.53835 ± 0.00005	20.53835 ± 0.00001
T_0	47637.07 ± 0.02	49114.81 ± 0.06
e	0.5354 ± 0.0025	0.542 ± 0.004
ω(deg)	104.3 ± 0.3	104.16 ± 0.05
K_1(km·s^{-1})	69.1	68.85 ± 0.02
K_2(km·s^{-1})	67.2	65.51 ± 0.4
M_2/M_1	1.03 ± 0.07	1.051 ± 0.006

Figure 1. Decomposed spectra of Mizar A (Si II)

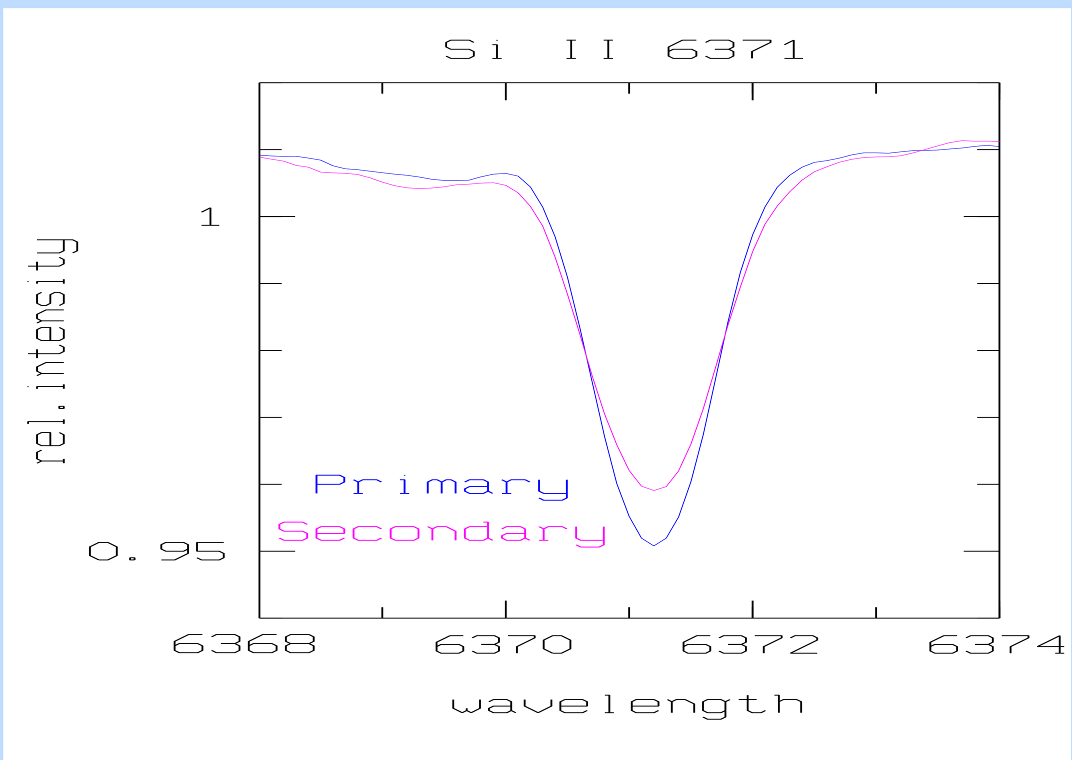
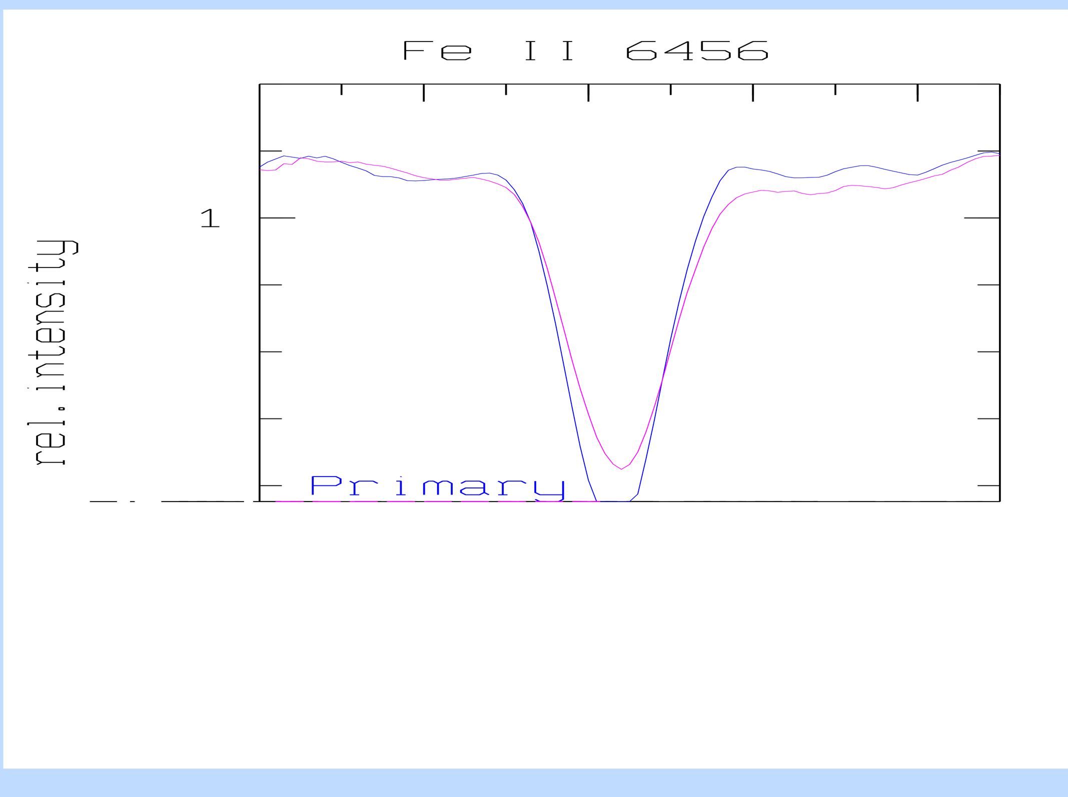


Figure 2. Decomposed spectra of Mizar A (Fe II)



Thuban

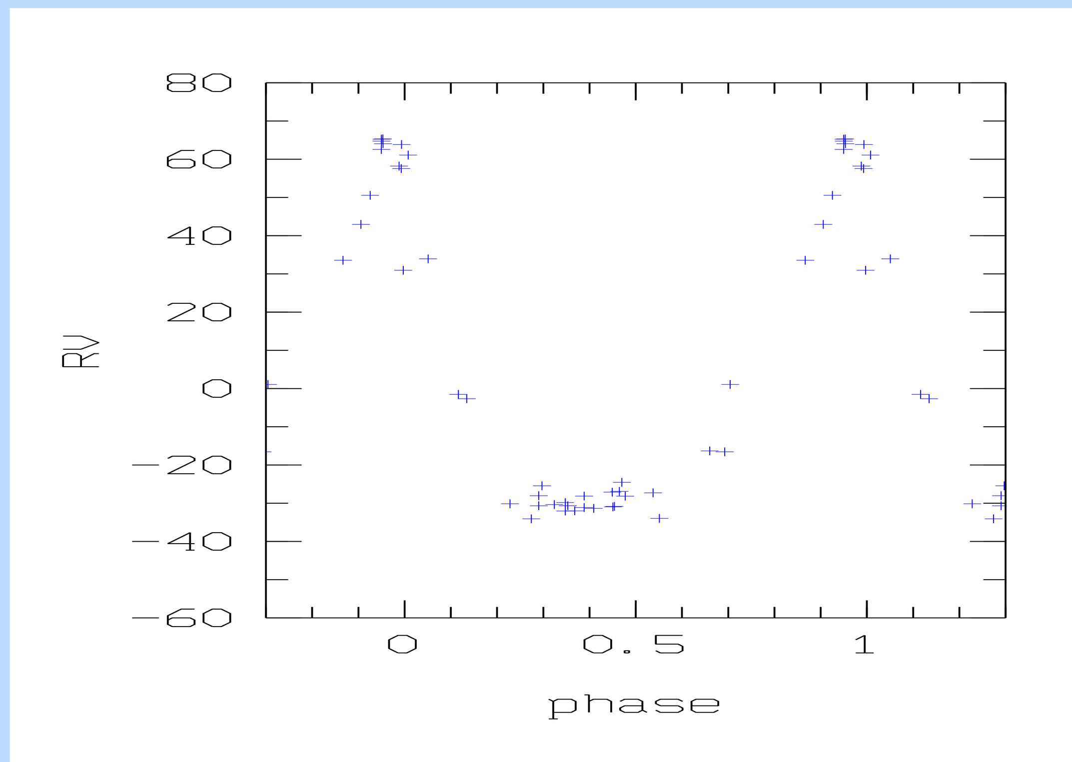
α Dra (Thuban, 11 Dra, HD 123299, HR 5291) is a single–lined chemically peculiar spectroscopic binary. The spectroscopic orbit was determined more frequently than for Mizar. Changes in radial velocities of this star have been first reported by Campbell & Curtis (1903) and Frost (1906). First orbital parameters were obtained by Harper (1907, 1910). The period was corrected to the value of 51.41 days by Harper (1935).

An orbital solution was found for selected spectral lines (Reticon + CCD). Mean values of orbital elements are listed in Table 3. Figure 3 shows a radial velocity curve of the first component as one of the results obtained from the `KOREL` code.

Table 3. Orbital elements of Thuban

	Elst et al. (1983)	`KOREL` code
$P(d)$	51.4167 (fixed)	51.406 ± 0.003
T_0	45117.3748 ± 0.0849	50156.48 ± 0.02
e	0.400 ± 0.006	0.413 ± 0.004
ω(deg)	23.20 ± 0.79	23.77 ± 0.06
K_1(km·s^{-1})	49.7 ± 0.3	49.5 ± 0.1

Figure 3. Computed radial velocities of Thuban (Hα)



Summary

- ⋆ The method of spectrum disentangling is very powerful method. It enables to solve the orbital parameters as well as decompose spectra of individual stars in multiple stellar systems.
- ⋆ Derived orbital elements for Mizar A nad Thuban are in a good agreement with those published in literature.
- ⋆ Decomposed spectra of Mizar A show that both components of this binary are nearly of the same spectral type. This was also confirmed in previous studies.
- ⋆ In the case of Thuban, we obtained a very good orbital solution. This binary is more complicated because of its spectroscopic binarity. The second component has not been found in the spectra yet. Search for the secondary component is still in progress.

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