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Orbital solutions for the 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 20.53 d spectroscopic binary first reported by Pickering in 1890. Its orbital elements were determined by Vogel in 1901. The redetermination of the orbital elements for these two binaries used the spectrum disentangling computer code KOREL (Hadrava 1995, 1997). We present revised orbital elements based on new electronic spectra taken at the Ondřejov Observatory between 1994 and 2003.

Keywords. Methods: numerical, binaries: spectroscopic

1. Introduction

The computer code `KOREL` for Fourier spectral disentangling (developed by Hadrava 1995, 1997) provides a powerful tool for determining orbital elements of binary or multiple (up to five components) stars as well as for 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 the quadruple system of o And (Budovičová *et al.* 2004).

The purpose of this study is to check the usefulness and the applicability of this method using well known bright multiple stars as benchmark tests. We start with two binary stars, Mizar and α Dra (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 Reticon or CCD detectors. Spectra obtained by these detectors cover the range $\lambda\lambda$6300-6700. Selected spectral lines used for obtaining an orbital solution are listed in Table 1. Some of these lines are blends of several neighbouring lines and only the strongest component is listed.

2. Working with the `KOREL` code

Orbital parameters are determined from a time series of observed spectra at different orbital phases. It is an iterative process, starting from an initial estimate of the orbital parameters and radial velocities.

The first step in 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

Table 1. Selected spectral lines

Line	Mizar A	α Dra
Si II λ6347	$\star$	$\star$
Si II λ6371	$\star$	$\star$
Fe I λ6400	$\star$	
Fe II λ6433	$\star$	$\star$
Fe II λ6456	$\star$	
H I λ6562	$\star$	$\star$
Fe I λ6678	$\star$	

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 can be taken from a solution of radial velocity curves measured in the standard way or from the literature 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 process of orbital solution to values calculated from the annual motion of the Earth and the coordinates of the star. These lines serve as an independent measure of the stability of the detector (cf. Horn *et al.* 1996).

The input for the `PREKOR` code are the stellar coordinates (right ascension, declination, and equinox) and coordinates of the observatory. This code also allows the selection of narrow spectral regions be decomposed in the `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. They should also be decomposed from the spectra, so that the final solution is free from the telluric lines.

Once we have everything prepared we run the `KOREL` code for finding a solution for 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 the parameters simultaneously only at the end to improve the final solution. It means that we first converge the epoch T and semiamplitude K_1 (and the mass-ratio q in the case of two-component spectroscopic binaries). The eccentricity e and the periastron longitude ω are allowed to converge in the next step. The line strengths do 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 accessible for spectral disentangling.

3. 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-type stars. Its binarity has been first reported by Pickering (1890). The first spectroscopic elements were determined by Vogel (1901), who measured the relative radial velocity between the components. The period was 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. The first interferometric measurements were reported by Pease (1927). Recent interferometric obser-

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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
$K_1(\mathrm{km{\cdot}s^{-1}})$	69.1	68.85 ± 0.02
$K_2(\mathrm{km{\cdot}s^{-1}})$	67.2	65.51 ± 0.4
M_2/M_1	1.03 ± 0.07	1.051 ± 0.006

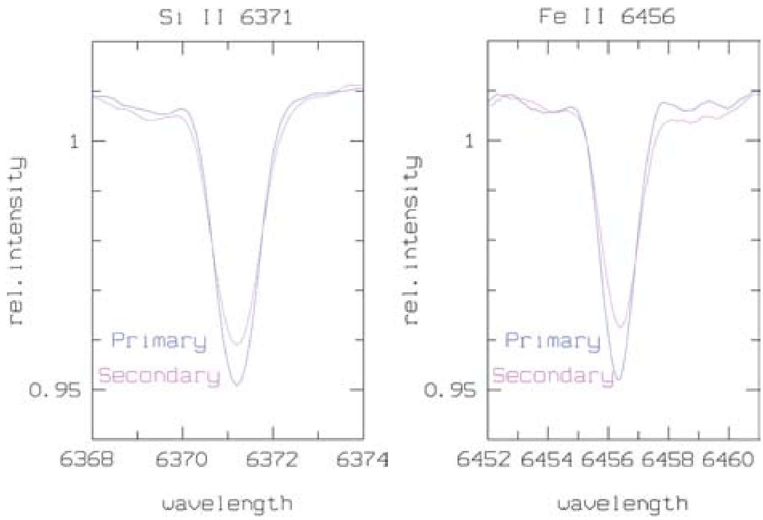

Figure 1. The decomposed spectra of Mizar A (Si II and Fe II).

vations 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. Figure 1 shows an example of the decomposed spectra of both binary components in the Si II (λ6371) and the Fe II (λ6456) spectral regions.

4. α Dra

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 A. Changes in radial velocities of this star have been first reported by Campbell & Curtis (1903) and Frost (1906). The 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 from selected spectral lines (Reticon + CCD). The mean values of the orbital elements are listed in Table 3. Figure 2 shows a radial velocity curve of the first component as one of the results obtained from the KOREL code.

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Table 3. Orbital elements of α Dra.

	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
$K_1(\mathrm{km \cdot s^{-1}})$	49.7 ± 0.3	49.5 ± 0.1

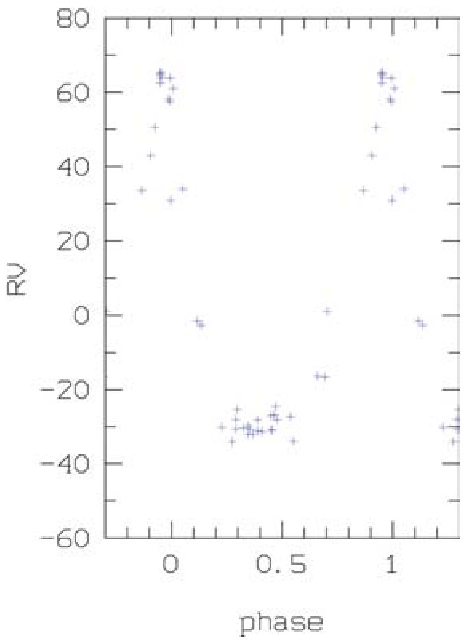

Figure 2. Computed radial velocities of α Dra.

5. Summary

⋆ The method of spectrum disentangling is very powerful and enables one to decompose the spectra of individual stars in multiple stellar systems.

⋆ The derived orbital elements for Mizar A and α Dra are in a good agreement with those published in literature.

⋆ The 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.

⋆ We obtained a very good orbital solution for α Dra. The second component has not been found yet. A search for the secondary component is still in progress.

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