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High resolution spectroscopy of the triple system 20 Leo

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Abstract. 20 Leo is a spectroscopic triple system composed of 3 very similar stars, one of which seems to be a δ Sct star. Observations at high spectral and high time resolution have been obtained at the Observatoire de Haute Provence with the ELODIE spectrograph on the 1.9-m telescope. The spectra were taken during 7 nights in 2003 January and cover the whole optical domain from 3900 to 6800 Å. We used a Fourier transform technique recently developed by P. Hadrava to disentangle the combined spectrum. Application of the method allows the derivation of radial velocities at all orbital phases (even at phases of complete blending), as well as individual spectra for each component. From these computations we deduced more accurate individual radial velocities and improved orbital parameters describing the motion of the inner binary. Model atmospheres were used to analyze each individual spectrum and determine stellar fundamental parameters of the three components such as effective temperature, surface gravity and projected rotation velocity.

1. Introduction

The vast majority of stars, irrespective of their spectral type, belong to binary or multiple systems. The frequency of binaries is estimated to be at least 60% in the Solar neighbourhood (Duquennoy & Mayor 1991), but this is still an underestimate of the true binary frequency. It is therefore not surprising to detect variable stars among the components of a double or a multiple star. In the present work, we are dealing with the hierarchical triple system 20 Leo (HR 3889, HD 85040). It is composed of 3 very similar stars: one component of the wide system (B) is a probable a δ Sct star while the other two form a close spectroscopic binary (components Aa and Ab). The orbital period of the Aa,b

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system is 4.15 d and the orbital period of the visual AB pair is about 200 yr (Fekel & Bopp 1977). Our main objective is to perform a detailed study of the pulsational behaviour of the variable component in the system. As the result of a recent photometric multi-site campaign, multiple pulsation frequencies were detected (Lampens et al. 2003). For the same purpose a full spectroscopic analysis of the multiple system was deemed necessary.

2. Observations

High-resolution spectroscopic observations of the 20 Leo system were carried out during 7 nights from 2003 January 3 – 15 at the Observatoire de Haute Provence (OHP). The spectra were obtained with the ELODIE echelle spectrograph (Baranne et al. 1996) attached to the 1.9-m telescope with an average resolving power of about 42 000 and a spectral range from 3906 Å to 6811 Å. Observations were made continuously during several hours each night with a 6-min exposure time. This provided us with 246 spectra with a signal-to-noise ratio per pixel ranging from 50 to 160. Data reduction (order extraction, wavelength calibration, etc.) was done automatically after each exposure with the INTERTACOS pipeline.

3. Spectrum disentangling

3.1. Adopted method

In a partly unresolved triple system such as 20 Leo, the spectra of the three components are merged which makes any careful analysis very difficult. We adopted the spectrum disentangling method introduced by Hadrava (1995, see references therein) and applied in his KOREL computer code, to obtain the individual contribution of each component. KOREL assumes that the observed spectrum is composed of n ($n = 3$ in our case) time-independent intrinsic spectra moving relatively to each other, and it fits the Fourier transform of the composite spectrum observed at different orbital phases by a least squares method.

3.2. Orbital parameters and radial velocities

The disentangling procedure provides us not only with the individual spectrum of each star, but also with orbital parameters and radial velocities, even at phases where all the components are completely blended. We selected, in all of our 246 spectra, 5 different spectral regions containing in total about 50 to 60 atomic transitions as input data for KOREL. During the fitting procedure, 5 parameters were used to describe the orbit of the close binary system (A) and were defined as free parameters, while the longitude of periastron was kept fixed. The final values of these parameters are as follows: $P = 4.14675$ d, $T_0 =$ JD2442094.07, $e = 0.00$, $K_{\rm Aa} = 100.72\,{\rm km\,s^{-1}}$, and $q = 1.0$, where P is the orbital period, T_0 is the time of periastron passage, e is the eccentricity, $K_{\rm Aa}$ is the amplitude in radial velocity of the Aa component and q is the mass ratio. As the period of the visual binary (AB) is too long compared to the time coverage of our observations, its orbital parameters were kept fixed ($P = 200$ yr; $K_{\rm A} = 7.13\,{\rm km\,s^{-1}}$; $K_{\rm B} = 11.90\,{\rm km\,s^{-1}}$) in a way that the KOREL radial velocities should be coherent

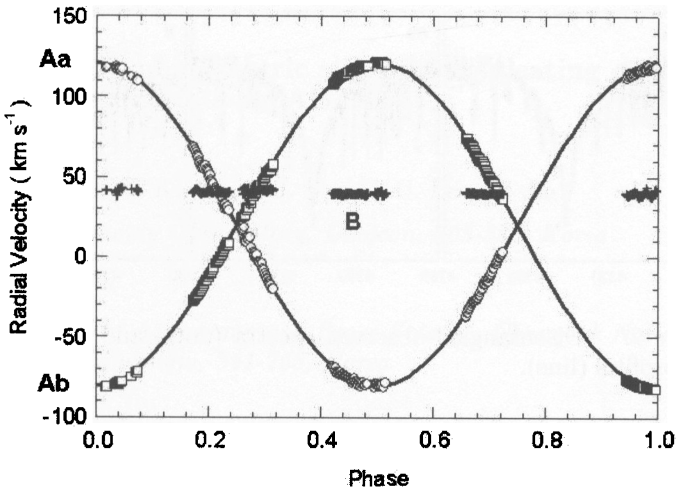

Figure 1. Radial velocities derived by KOREL for components Aa (white disks), Ab (white squares) and B (crosses).

with those directly measured on the cross-correlation functions provided by the INTERTACOS pipeline.

4. Stellar parameters

About 12 unblended spectral lines were selected in the final disentangled spectra to determine the projected rotation velocity of each component using a Fourier transform technique (Smith & Gray, 1976). Effective temperatures were estimated by fitting the individual Hα and Hγ lines with theoretical line profiles computed using the SYNSPEC (Hubeny & Lanz 1995) program together with the LTE model atmospheres of Kurucz (1993; see the black line in Fig. 2). The contribution of each component to the total flux and its intrinsic luminosity have been estimated using the line depth of the saturated Ca K line. We then estimated their superficial gravity from their mass and radius interpolated in the theoretical evolutionary tracks of Schaller et al. (1992). Our derived fundamental parameters for each component are given in Table 1.

Table 1. Derived Fundamental Parameters

Star	Aa	Ab	B
$T_{\rm eff}$	7470 K	7390 K	7590 K
$\log g$	3.8	3.8	3.8
$V \sin i$	$42 \pm 2\,{\rm km\,s^{-1}}$	$28 \pm 2\,{\rm km\,s^{-1}}$	$31 \pm 3{\rm km\,s^{-1}}$

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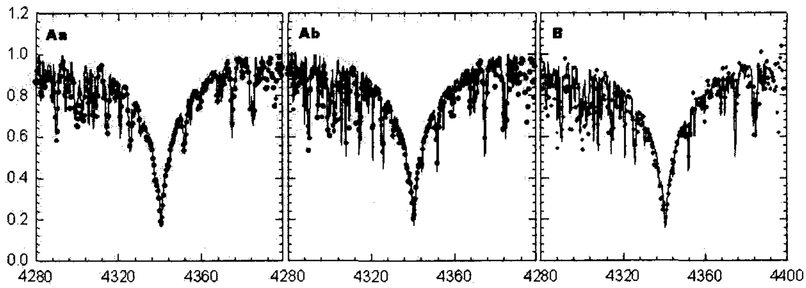

Figure 2. Disentangled observed spectra (dots) and theoretical Hγ line profiles (line).

5. Discussion and perspectives

Presently, our spectroscopic observations cover about 40% of the close binary's orbital period (Fig. 1) and confirm the suggestion made by Fekel & Bopp (1977) that component B is the pulsating star. Our results show that all three components have similar fundamental parameters. A full analysis of their atmospheric chemical compositions has still to be completed in order to study their relative abundance pattern and their possible similarities or differences. Our radial velocity measurements clearly show that the visual binary (AB) is close to periastron passage. We are therefore presently acquiring new radial velocity measurements for the system. In combination with existing speckle data, we will then be able to put new constraints on the secular orbit that could allow a direct mass determination of the pulsating component.

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