

HIGH RESOLUTION SPECTROSCOPY OF RECENTLY DISCOVERED CHROMOSPHERICALLY ACTIVE BINARY STARS

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ABSTRACT

During last years (1999-2004) we have carried out a spectroscopic survey of young single late-type active stars possible members of young stellar kinematic groups, in order to study the kinematic and spectroscopic properties of these groups of stars. One of the results of this survey is the detection of a set of active stars showing noticeable radial velocity variations. Multiwavelength optical observations have allowed us to determine precise radial velocities by cross correlation with radial velocity standard and then to confirm or dismiss the binarity. In addition, we have obtained information about orbital solution and about the activity of the chromosphere of these active binary systems using the information provided for several optical spectroscopic features (from the Ca II H & K to Ca II IRT lines) that are formed at different heights in the chromosphere. The chromospheric contribution in these lines has been determined using the spectral subtraction technique.

Rotational velocities ($v \sin i$) and lithium (Li I λ 6707.8) equivalent widths were determined too. In this contribution we have made an exhaustive study of two spectroscopic binary systems, BD+11 2052A and BD+39 2587 with are both members of a visual binary. We have obtained an orbital solution, with a high eccentricity for both systems and studied the chromosphere emission.

Key words: Stars: activity – binaries: chromospheres – spectroscopic: BD+11 2052A – BD+39 2587

1. INTRODUCTION

This is a continuation of our ongoing project of multi-wavelength optical observations aimed at studying the chromosphere of active binary systems using the information provided for several optical spectroscopic features that are formed at different heights in the chromosphere (see Montes et al. 1997, Paper I; Montes et al. 1998, Paper II; Montes et al. 2000, Paper III; Gálvez et al. 2002, Paper IV).

Activity-rotation and activity-age relationships have been found in many studies of late-type stars. The rotation rate moderates the dynamo mechanism which generates and amplifies the magnetic fields in the convective zone,

but there is a further relationship between rotation and age. Rotation rates declines with age because stars lose angular momentum through the coupling of the magnetic field and stellar mass loss, and thus there is an indirect trend of decreasing activity with increasing age. Chromospherically active binaries (CAB) are detached binary systems with cool components characterized by strong chromospheric, transition region, and coronal activity.

We use high resolution echelle spectroscopy to determine radial velocities and confirmed a new binary, and we develop the activity study in order to better understand these activity-rotation and activity-age relationships.

We focus here in the new selected chromospherically active binaries BD+11 2052A and BD+39 2587.

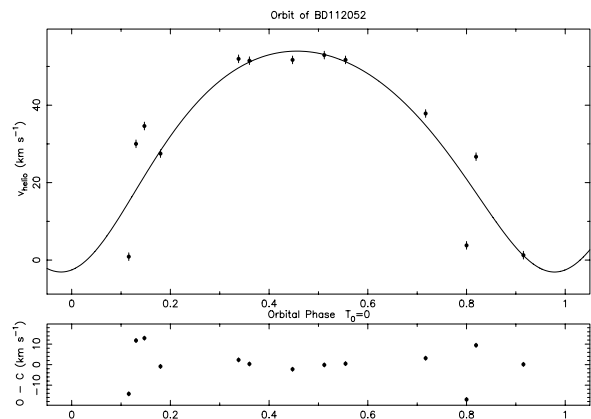


Figure 1. Radial velocity data and fit vs the orbital phase for BD+11 2052A. (9 data from ours, 2 from Strassmeier et al. 2000 and 3 from Custipoto et al. 1999). The solid curves represent a minimum χ^2 fit orbit solution.

2. OBSERVATIONS AND DATA REDUCTION

2.1. OBSERVATION RUN

The spectroscopic observations of these binaries were obtained from 29 March to 7 April 2004 using the 2.2m Telescope at the German Spanish Astronomical Observatory (CAHA) in Almeria (Spain), with the Fibre Optics Cassegrain Echelle Spectrometer (FOCES) (Pfeiffer

Table 1. Orbital solution of BD+11 2052A.

| Element | Value | Uncertainty | Units |
|-------------------|-----------|-------------|--------------------|
| P_{orb} | 4.8122 | 0.0001 | days |
| T_{conj} | 49650.424 | 0.0000 | HJD |
| ω | 191.1938 | 0.8477 | degrees |
| e | 0.1756 | 0.0180 | |
| $K(*)$ | 28.5237 | 0.9630 | km s^{-1} |
| γ | 30.3529 | 0.3285 | km s^{-1} |
| $a_1 \sin i$ | 1.9490 | 0.0092 | 10^6 km |
| $a_2 \sin i$ | 2.0545 | 0.0134 | 10^6 km |
| $a(*) \sin i$ | 1.8582 | 0.0630 | 10^6 km |
| " | 0.01242 | | AU |
| " | 2.6698 | | R_{\odot} |
| $f(M)$ | 0.0110399 | 0.0011234 | M_{\odot} |

et al. 1998). During this observing run, a 2048x2048 pixel 150μ Site#1d15 CCD detector was used. The spectrograph set up was chosen to cover the Ca H & K (3933 and 3962 Å, H α (6563 Å and Ca II IRT (8498, 8542, 8662 Å lines. The wavelength range covers from 3720 to 10850 Å in 100 orders. The reciprocal dispersion ranges from 0.04 to 0.13 Å/pixel and the spectral resolution, determined as the FWHM of the arc comparison lines, ranges from 0.08 to 0.35 Å.

2.2. RADIAL VELOCITIES

Heliocentric radial velocities of the principal components have been determined by using the cross-correlation technique. The spectra of the program stars were cross-correlated order by order, using the routine fxcor in IRAF, against spectra of radial velocity standards of similar spectral types. The radial velocity of the primary component of both spectroscopic binaries is derived from the position of the cross-correlation peak.

2.3. CHROMOSPHERIC EMISSION LINES

The chromospheric contribution in the different optical chromospheric activity indicators has been determined using the spectral subtraction technique Montes et al. (1995; 1997; 1998). The synthesized spectrum was constructed using the program STARMOD developed at Penn State (Barden 1985). We have obtained the subtracted spectra for all the optical indicators (Ca II IRT, H α , H β , H γ , H δ and H & K Ca lines). The profiles of the H α , and Ca II IRT (λ 8498, λ 8542) lines are plotted in Figure 2, 3, 5 and 6. For each observation we have plotted the observed spectrum (solid-line) and the synthesized spectrum (dashed-line) in the left panel and the subtracted spectrum (dotted line) in the right panel.

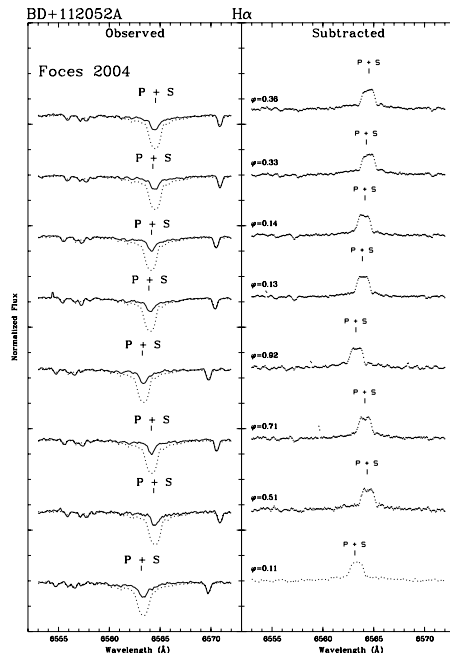


Figure 2. Spectra of BD+11 2052A in the H α line region. The observed spectrum (solid-line) and the synthesized spectrum (dashed-line) are plotted in the left panel and the subtracted spectrum (dotted line) in the right panel.

3. BD+11 2052A (SAO 98614)

This spectroscopic binary system belongs to the visual binary system BD+11 2052A and B. We have studied both components and observed the spectral features variations.

We have found that the B component of this system, BD+11 2052B, have a constant radial velocity. We have measured a value of $27.07 \pm 0.04 \text{ km/s}$ for radial velocity that is in agreement with the value given by Strassmeier et al. (2000), indicating that this component is a single star. Analyzing the spectra we have found emission lines filling the absorption lines in H α and Ca IRT, that indicate certain level of activity.

For the A component of this system, BD+11 2052A, we have measured 9 different values of radial velocity, confirming its binary nature. With these new values adding to two from Strassmeier et al. (2000) and three from Cutispoto et al. (1999), we have obtained the orbital solution. The results shows a eccentric orbit with a period of 4.812 days. See Fig 1 and the orbital parameters listed in Table 1.

In addition, studing spectral clasification and emission lines, we have obtained a good fit between observed and synthetic spectra by using a G8V component but there is the possibility of certain secondary contribution to the spectra, showing a good fitting a 0.78 contribution of a G8V and 0.22 contribution of a K5V stars. Chromospheric

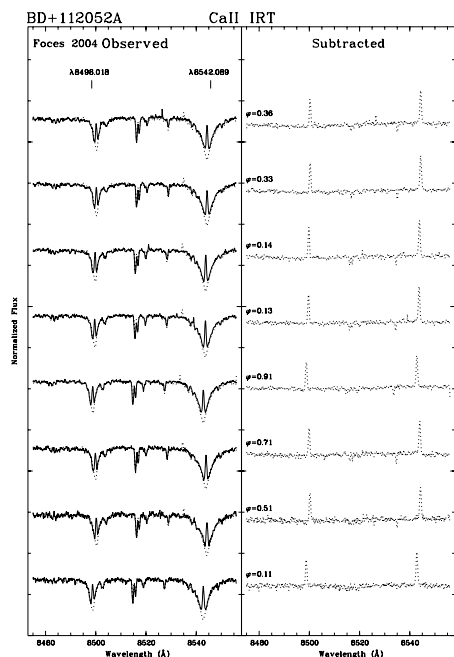


Figure 3. Observed and Subtracted spectra in the region of the Ca II IRT (8498, 8542 Å) lines for BD+11 2052A, as in figures of H α . An excess emission from the primary (P) and secondary (S) components is detected.

emission lines are observed in the subtracted spectra. The H α line is completely filled by emission (Fig 2), and a clear excess emission in the Ca II IRT lines is detected (Fig 3). It is a young star with a lithium (Li I λ 6707.8) equivalent width is about 131 mÅ

4. BD+39 2687 (SAO 63275)

As visual BD+11 2052 system, BD+39 2687 belongs to another visual binary system. For the A component of this system, BD+39 2586 (HD 112733), we have measured a value of -4.62 ± 06 km/s for the radial velocity that is in agreement with Strassmeier et al. (2000), indicating that this component is a single star. Chromospheric emission lines are not detected in the spectra indicating that it is an inactive star.

The B component of the visual binary (BD+392587, SAO 63275) is a single lined spectroscopic binary (SB1), but as we can observe the chromospheric emission lines of both components, the secondary radial velocities have been measured with the variations in the wavelength between primary and secondary emission lines. The orbital solution has been obtained using 10 new data from our run and one from the literature (Strassmeier et al. 2000). The results show a very eccentric orbit ($e = 0.3$) with a 6.72 days

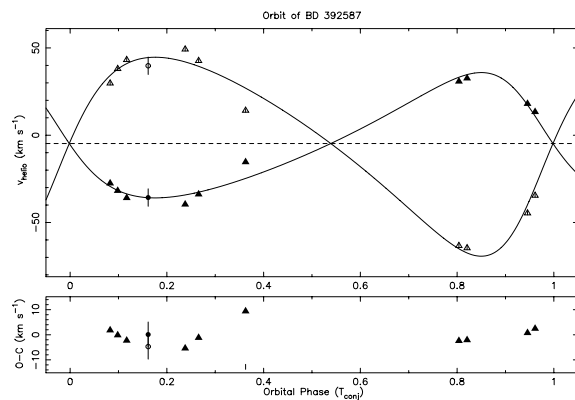


Figure 4. Radial velocity data and fit vs the orbital phase for BD+39 2587. Solid symbols represent the primary and open symbols represent the secondary (triangles for Our data and circles for Strassmeier et al. 2000). The solid curves represent a minimum χ^2 fit orbit solution.

of period. See Fig 4 and the orbital parameters listed in Table 2.

Table 2. Orbital solution of BD+39 2587.

| Element | Value | Uncertainty | Units |
|-------------------|------------|-------------|--------------|
| P_{orb} | 6.7231 | 0.0000 | days |
| T_{conj} | 51097.0156 | 0.0098 | HJD |
| ω | 64.2469 | 0.9664 | degrees |
| e | 0.3051 | 0.0025 | |
| K_1 | 35.9049 | 0.2404 | km s $^{-1}$ |
| K_2 | 57.0066 | 0.5565 | km s $^{-1}$ |
| γ | -4.7654 | 0.0607 | km s $^{-1}$ |
| $q = M_1/M_2$ | 1.5877 | 0.0113 | |
| $a_1 \sin i$ | 3.1611 | 0.0213 | 10^6 km |
| $a_2 \sin i$ | 5.0189 | 0.0492 | 10^6 km |
| $a \sin i$ | 8.1801 | 0.0536 | 10^6 km |
| " | 0.05468 | | AU |
| " | 11.7530 | | R_{\odot} |
| $M_1 \sin^3 i$ | 0.2961 | 0.0060 | M_{\odot} |
| $M_2 \sin^3 i$ | 0.1865 | 0.0039 | M_{\odot} |
| $f(M)$ | 0.0278473 | 0.0005638 | M_{\odot} |

We have obtained a good fit between observed and synthetic spectra by using a G8V primary component with 89 % of contribution to the spectra and a M0V secondary component with the 11% of contribution. This result is in agreement with the literature classification of the primary component and the relation of masses derived from the orbital solution. Emission lines are observed in the

subtracted spectra, show $H\alpha$ almost completely filled by emission for primary component and always in emission above the continuum for the secondary (Fig 5), and excess emission (strong for primary component and lower for secondary) in the Ca II IRT lines (Fig 6). The rest chromospheric indicators ($H\delta$, $H\beta$, $H\gamma$ and H & K Ca lines) presents excess emission from both components too. Lithium ($\text{Li I } \lambda 6707.8$) equivalent width is about 104 mÅ

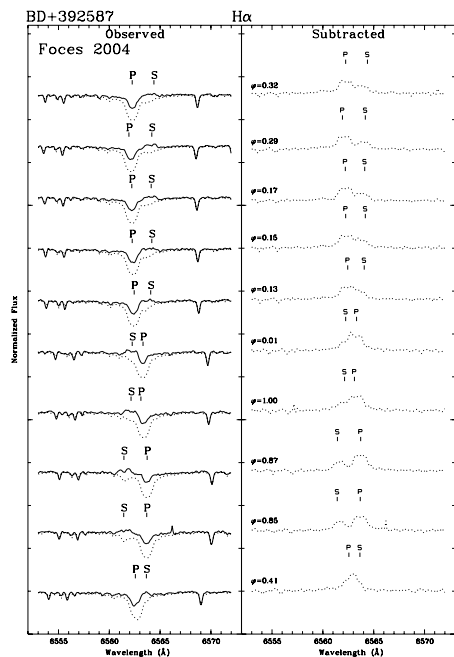


Figure 5. Spectra of BD+39 2587 in the $H\alpha$ line region. The observed spectrum (solid-line) and the synthesized spectrum (dashed-line) are plotted in the left panel and the subtracted spectrum (dotted line) in the right panel. The position of the $H\alpha$ line for the primary (P) and secondary (S) components are marked with short vertical lines.

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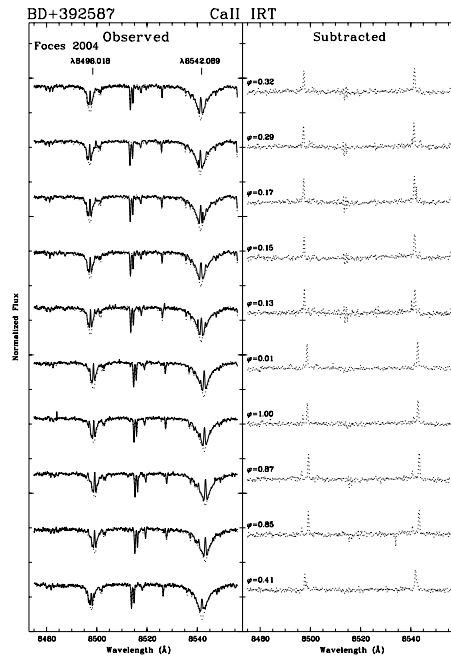


Figure 6. Observed and Subtracted spectra in the region of the Ca II IRT (8498, 8542 Å) lines for BD+39 2587, as in figures of $H\alpha$. An excess emission from the primary (P) and secondary (S) components is detected.

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