Spectroscopic Monitoring of β CMi in the 21-st Century

By: Larkin Folsom, Anatoly S. Miroshnichenko, Stephen Danford, Sergey V. Zharikov, Carl J. Sawicki

Folsom, L., Miroshnichenko, A. S., Danford, S., Zharikov, S. V., Sawicki, C. J. (2016). Spectroscopic Monitoring of β CMi in the 21-st Century. *ASP Conference Series*, 506, 319.

Abstract:

We report the results of high-resolution spectroscopic observations obtained in 2000–2014. The goals of the program were to search for signs of binarity, which was suspected in several studies long ago but not confirmed by more recent data. We have measured parameters of some emission and absorption lines and studied their trends on different time scales. Implications for the circumstellar disk properties and the system binarity are discussed.

Keywords: Astronomy | Binary stars | Be stars | Circumstellar disk

Article:

1. Introduction

The mechanisms through which Be stars form, maintain, and disperse their circumstellar disks are not well understood. Therefore, careful study of these objects over long time periods is necessary. One possible explanation for the formation of a Be star is that it has a secondary component which facilitated a spin up of the primary. For this project we study the temporal behavior of β Canis Minoris (HR 2845, B8 Ve).

Binarity may be revealed through detection of periodic variations of the spectral line radial velocity (e.g., Bjorkman et al. (2002) for π Aquarii and Nemravová et al. (2012) for γ Cassiopeae) or V/R peak intensity (e.g., Zharikov et al. 2013, for π Aquarii). Binarity of β CMi was first suspected by Struve (1925). Jarad et al. (1989) reported detection of regular radial velocity variations with a period of 218 days based on ∼30 spectrograms that cover nearly two cycles. Chini et al. (2012) suspect binarity based on 12 high-resolution spectra. Nevertheless, most other studies (e.g., Wheelwright et al. 2012) failed to detect any evidence of a secondary companion.

We measured the wavelength and intensity of the violet (V) and red (R) peaks in the Hα profile and their ratio (V/R). Radial velocity of the He I 4471 Å and Mg II 4481 Å lines were measured as well. We analyzed temporal variations of the measured quantities and tried to find

periodic variations due to the presence of a secondary companion through Fourier analysis. Previous studies of β CMi have been inconclusive in this regard. For this reason, spectra obtained during the last 14 years were examined.

2. Observations

Most spectra of β CMi were obtained with the 0.81m telescope of the Three College Observatory (TCO) located near Greensboro, NC, U.S.A. (66 échelle spectra, December 2011 – May 2014, spectral range 4250–7800 Å, spectral resolving power R ∼ 10000), and the 1m telescope of the Ritter Observatory of the University of Toledo (87 échelle spectra, 2000– 2007, 5300–6700 Å, R ∼ 26000). Seventy two spectra were retrieved from the BeSS database (http://basebe.obspm.fr, mostly long-slit spectra around the Hα line, 2007–2014, R = 10000–20000). Additionally several échelle spectra were taken at 2m class telescopes at the Observatoire of Haute Provence, France (ELODIE archive, Moultaka et al. 2004), the San Pedro Martir Observatory in Baja California (Mexico), and the McDonald Observatory (TX, U.S.A.) with R = 20000–60000.

3. Results and Discussion

The Hα line intensity has been relatively stable during the entire period of our observations (2000–2014). The line peak intensity varied between 1.7 and 1.9 the continuum intensity. Nevertheless, the V/R variations in the Hα line are noticeable. The V/R ratio was found to range from ∼0.98 to ∼1.04 (see Fig. 1). We carefully checked for the presence of telluric lines contaminating the peak intensity. In case of a strong contamination, the spectra were removed from the dataset (no more than 5% of the entire dataset). The remaining spectra were analyzed for periodic variations using the periodogram method developed by Scargle (1982). The results are shown in Fig. 2. The two significant peaks in the power spectrum correspond to the periods of 182.83 days (half year) and 368.23 days (nearly a year). The second peak is wide and most likely due to the availability of the star for observations. The first peak seems to be real which is supported by a nearly sinusoidal phase curve.

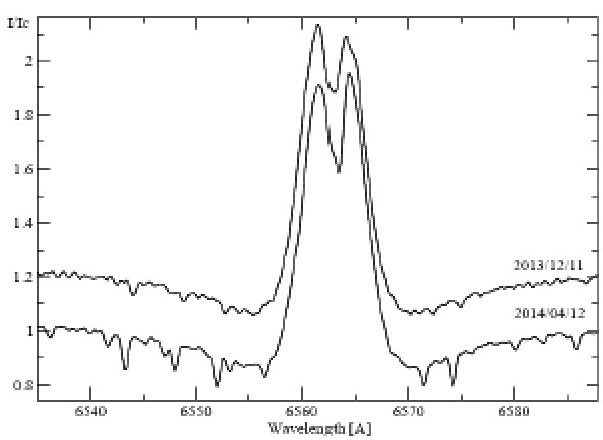

Figure 1. Examples of the Hα line profiles with different V/R ratios in the spectrum of β CMi. The spectra shown were obtained at TCO and are labeled with the observing dates. Wavelengths are heliocentric, intensity is normalized to the nearby continuum.

Binary Be stars with weak Balmer emission lines show V/R variations in the Hα line that are phase-locked with the orbital period (e.g., Zharikov et al. 2013). This is why we suspect that the period we found is the orbital period of the β CMi binary system. The nearly sinusoidal shape of the V/R phase curve (see right panel of Fig. 2) may indicate that the orbit is circular. This is typical for binary systems with a Be primary and a non-degenerate secondary companion. Our result for the period is additionally supported by a provisional relationship between the largest equivalent width of the variable Hα line of late B–type binary Be stars and their orbital periods (Miroshnichenko 2014).

The period of 218.498 days found by Jarad et al. (1989), who used the cross-correlation method for non-hydrogen lines in the spectral range 3700–4700 Å, is not confirmed by our data. This result is based on only ∼30 photographic spectra obtained over a period of ∼450 days. These authors found that the orbit is very eccentric (e = 0.48 ± 0.11), which implies a component mass ratio of 1.4–2.0 if the the disk inclination angle ranges from 50° to 90° with respect to the line of sight. The latter, if true, suggests that some spectral lines of the secondary component may be detectable. We have not detected them so far.

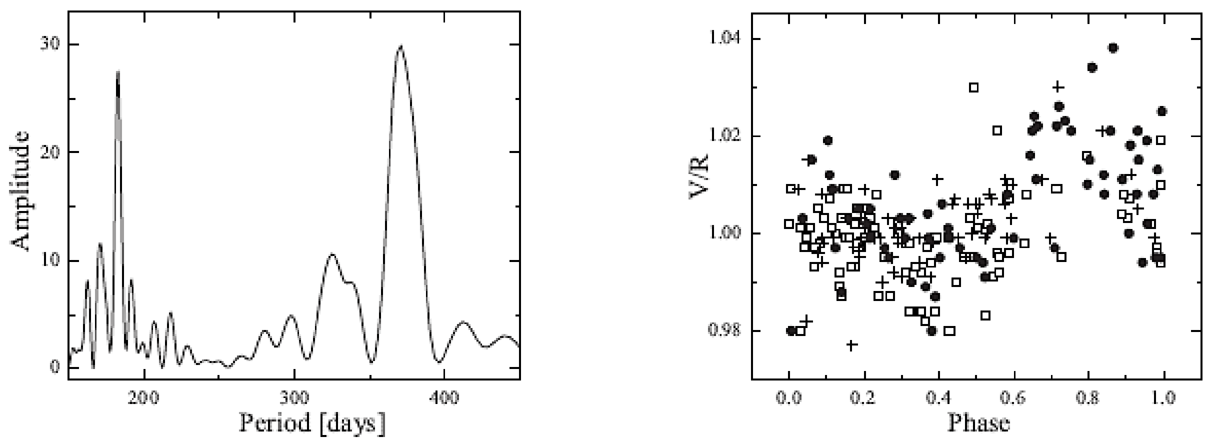

Figure 2. Left panel: Fourier power spectrum of the V/R variations measured in the Hα line. Right Panel: The V/R variations folded with the 182.83-day period. Symbols: filled circles – TCO data, open squares – Ritter Observatory data, pluses – amateur and other observatories data.

Neither the radial velocity of the H_ line nor the broad absorption lines of He I 4471 Å and Mg II 4481 Å seem to show periodic variations. The absorption lines are broad and very shallow (Peak intensity of only 5% of that in the continuum) due to the star’s fast rotation. Also, less than 1/3 of our spectra contain these lines.

4. Conclusions and Future Work

Our preliminary study of over 200 spectra of β CMi obtained in 2000–2014 shows that the object may be a binary system on a circular orbit with a period of 182.83 days. We will continue monitoring the system to look for more evidence of its binarity. In particular, we will try to detect and measure parameters of faint absorption lines to search for periodic radial velocity variations and traces of the secondary component. We will also try to observe the object for a longer period of time during one year. The observing season 2013–2014 lasted for 6 months which is very close to the detected period. A longer season will allow us to check if this period is real.

Acknowledgments. L. F. and A. M. acknowledge travel support from the University of North Carolina at Greensboro and its Department of Physics and Astronomy. S. Z. acknowledges PAPIIT grants IN–100614 and CONACyT grants 151858 and CAR 208512 for resources provided toward this research. We used the SIMBAD database operated by CDS, Strasbourg, France, as well as the BeSS database, operated at LESIA Observatoire de Meudon, France: http://basebe.obspm.fr.

References

Bjorkman, K.S., Miroshnichenko, A.S., McDavid, D., & Pogrosheva, T.M. 2002, ApJ, 573, 812

Chini, R., Hoffmeister, V.H., Nasseri, A., et al. 2012, MNRAS, 424, 1925

Jarad, M.M., Hilditch, R.W., & Skillen, I. 1989, MNRAS, 238, 1085

Miroshnichenko, A.S. 2014, in Bright Emissaries: Be Stars as Messangers of Star–Disk Physics, ASP Conf., Ser., (This volume)

Moultaka, J., Ilovaisky, S.A., Prugniel, P., & Soubiran, C. 2004, PASP, 116, 693

Nemravová, J., Harmanec, P., Koubský, P., et al. 2012, A&A, 537, A59

Scargle, J.D. 1982, ApJ, 263, 835

Struve, O. 1925, ApJ, 62, 434

Wheelwright, H.E., Bjorkman, J.E., Oudmaijer, R.D., et al. 2012, MNRAS, 423, L11

Zharikov, S.V., Miroshnichenko, A.S., Pollmann, E., et al. 2013, A&A, 560, A30