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A look into the behaviour of BF Cygni after 2009

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Abstract. The last active phase of the eclipsing symbiotic binary BF Cygni began in 2006 and continues up to now. In 2009 Balmer satellite components indicating a bipolar collimated outflow with a variable velocity and intensity appeared in the spectrum. In this contribution we will examine the spectral behaviour of the system with emphasis on its burst during 2017. The satellite components of some lines indicating collimated ejection from the system disappeared for some time during the optical maximum and appeared again. The data are interpreted in the framework of the model of collimated stellar wind.
Key words: binaries: symbiotic – stars: mass-loss – stars: individual: BF Cyg

1. Introduction

BF Cyg is an eclipsing binary with an orbital period of 757.2 days (Fekel et al., 2001), whose eclipses (orbital minima) are observed well in both quiescence and outbursts (Skopal et al., 2015). The last active phase of BF Cyg began in 2006 and continues up to now. During this period its light is modulated by the orbital motion and shows photometric minima with a variable depth and shape. The residual of the depth of the first five minima is examined in a number of articles of Tomov et al. (2015, 2017, 2019); Tomov & Tomova (2018) and is interpreted in the framework of the model of the collimated stellar wind for Z And (Tomov et al., 2014).

In 2009 a collimated bipolar ejection of material from the system was observed for the first time (Skopal, Tomov & Tomova, 2013). The profile of the Balmer lines transformed – satellite emission components, located approximately symmetrically to the central emission, appeared. From that moment on, these satellite components are present in the spectrum, sometimes both emission components are present, and at other times only the red one (see Fig. 1, where our observations of the Hβ line up to and including 2016 are presented). In 2015 and 2017 during the development of a new activity were observed 1-mag bursts with gradual fading to the pre-outburst level lasting for about 1 year (Shchurova et al., 2019). Skopal et al. (2017) noted that around mid-February 2017 BF Cyg is around its peak brightness of the burst and the line spectrum was dominated by hydrogen lines with a sharp absorption at about $-70\,\mathrm{km\,s^{-1}}$, and before the maximum the Balmer lines were accompanied by satellite emissions at about -400 and $+200\,\mathrm{km\,s^{-1}}$.

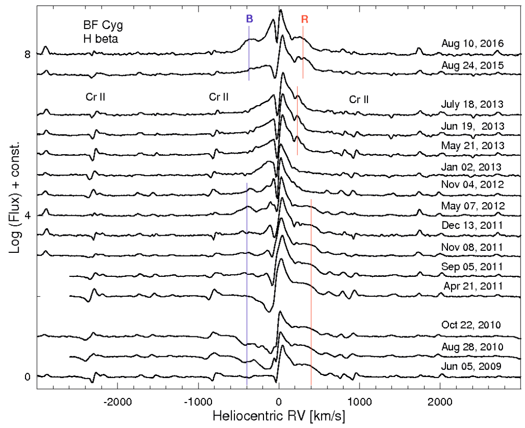

Figure 1. The spectral evolution of Hβ line, June 2009 – August 2016

We observed the system with a high resolution at the end of 2016, during the burst in 2017 and in September 2018 after the orbital minimum as well. Aim of our investigation is to analyse the profiles of some visual lines in the spectrum, to trace their evolution and to consider the changes of the mechanism of loss of mass of the outbursting compact object. Here we introduce preliminary results of our investigation.

2. Observations

The system BF Cyg was observed with the ESpeRo Echelle spectrograph (Bonev et al., 2017) of the 2m RCC telescope of the National Astronomical Observatory Rozhen, Bulgaria. The spectral resolution was ~30 000. The spectra were reduced by means of IRAF (Tody, 1993). In our study we considered only the lines in the ranges of Hβ, HeI $\lambda\,4922$ Å, HeI $\lambda\,5016$ Å, FeII $\lambda\,5169$ Å.

3. Spectral behaviour

3.1. The Hβ line

Our spectra from Dec. 11, 2016 and Sept. 02, 2018 showed a Hβ line consisting from two-peaks central emission component and a narrow absorption with $RV = -10, -15\,\mathrm{km\,s^{-1}}$ (see Fig. 2). Clearly visible emission components were present on both sides of the central component of the 2016 spectrum. These emission components were not visible in the 2017 spectra, which showed a rather broad emission component, diminished by broad blue absorption, in some cases up to about $-500\,\mathrm{km\,s^{-1}}$. It reached up to about $-370\,\mathrm{km\,s^{-1}}$ in 2018. The presence of such components in the profile indicates a mass outflow from the outbursting compact object. We approximated the profile of the Hβ line with different number of Gauss functions. At first the central component was approximated and its contribution was subtracted from the emission in the area of the satellite components, in order to determine their parameters more precisely. Each satellite component of the Dec. 2016 profile was approximated with one Gaussian (see Fig. 2). Using the parameters from the approximation and the orbital inclination, $i = 75°$, and assuming that the bipolar outflow is perpendicular to the orbital plane, its opening angle was calculated $\theta = 10\overset{\circ}{.}2 \pm 0\overset{\circ}{.}3$. This value is comparable to that obtained by Skopal, Tomov & Tomova (2013), $\theta = 15\overset{\circ}{.}2 \pm 1\overset{\circ}{.}5$, for the period 2009–2012.

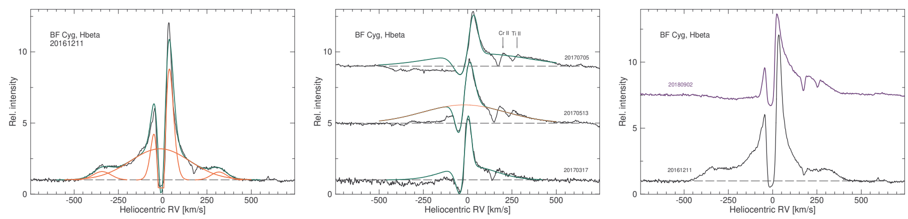

Figure 2. *Left and middle panel:* Approximation of Hβ line. Observed spectra are in black. Gaussians of components are in orange. Resulting curves approximating the observed spectra are in green. The satellite components are seen on the left panel. *Right panel:* Comparison of the profiles before and after the burst.

We applied the same approach to the 2017 spectra but we were unable to find confident presence of the red satellite emission component there. CrII and TiII lines are present over the red wing of the Hβ line, show strong P Cyg profile in this period and influence the red wing intensity. The red wing of the Hβ line in March and May 2017 is well approximated by a broad emission component (Fig. 2, middle). In July 2017 a weak red satellite emission is probably present, but we were unable to separate it from the rest of the emission of the Hβ wing. In addition, a multicomponent blue absorption up to about $-500\,\mathrm{km\,s^{-1}}$ is present in the Hβ profile on this date. Therefore we can not conclude that the satellite components are present in the Hβ line during our observations in 2017, but rather a broad emission component of wind, whose blue part is diminished by P Cyg absorption.

The satellite components are probably present in the Hβ line in the spectrum of Sept. 2018. A red emission and a blue absorption components have been fitted on this spectrum, but these fits have large error and are not reliable.

3.2. The FeII 42 lines

The FeII 42 lines are presented in Fig. 3. The Hβ and FeII 42 lines show the same characteristics – a narrow P Cyg absorption, broad red emission and broad blue absorption, but different velocities – lower for the lines of FeII 42. This shows that the loss of mass which is observed in Hβ, is observed also in FeII 42 lines.

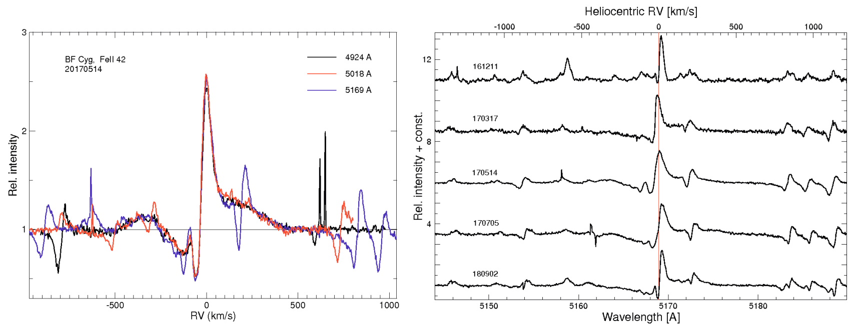

Figure 3. *Left panel:* Example of FeII 42 line profiles. A broad red emission and a broad blue absorption components are visible. The narrow P Cyg absorption is also present. An additional emission on the short wavelengths side of the blue absorption component is seen on this date, as well. *Right panel:* Evolution of the FeII 42 5169 Å line in our spectra during Dec. 2016 – Sept. 2018.

4. Conclusion

We present preliminary results from our study of the Hβ and FeII 42 line profiles before, during and after the burst in 2017. These lines contained clearly visible components indicating mass-outflow from the system. Based on approximation of the Hβ line profile we can not conclude that the satellite components are present in the 2017 observations, but rather a broad emission component of wind, whose blue part is diminished by P Cyg absorption. In Sept. 2018 the satellite components are probably restored.

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