Is a B[e] Star V2028 Cyg a Binary?

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V2028 Cyg shows a B[e] phenomenon. Due to the presence of both cool (K7III) and hot (B4III) component in the spectra, it is supposed to be a binary. Our modelling of the time variability of Hα line bisectors shows, however, that this hybrid spectrum can originate in one star, which is surrounded by a disc.

Introduction

V2028 Cyg is a star showing B[e] phenomenon, i. e. lines from the forbidden transitions are present in its spectra. This is a sign of very extended circumstellar envelope. Due to this reason, the nature of this object is unknown. The determination of the stellar parameters is very uncertain, since the commonly used synthetic spectra are not applicable. Therefore we focused on a study of time dependencies of the spectral features. Our aim was also to specify better the role of the binarity in this system. The spectrum of V2028 Cyg is very atypical among stars with B[e] phenomenon, since it is composed of two kinds of spectra – K7III and hot B4III (Zickgraf 2001; Bergner et al. 1995).

We obtained a series of 88 spectra (Polster et al. 2010, 2011a, b) from the Ondřejov 2 m telescope in the spectral range around Hα (R $\sim$ 12500). These data were used for the description of the spectral-line variability. The time dependencies of equivalent width (EW), line intensities, radial velocities and bisectors (positions of the line centre in different highs, Gray 2005) of the Hα line were modelled.

Modelling

In order to narrow the set of possible geometries, we constructed a numerical **model** based on these **assumptions**:

– Gaussian emission (absorption) profile

– optically thin media (+ very simple absorption); resulting profile = sum of Gaussian profiles along the line-of-sight

– the grid respects the velocity gradient

– parameters of hot star from Zickgraf (2001) – $M_\star \sim 7.5\,M_\odot$, $R_\star \sim 7\,R_\odot$

– if a compact object is included, it is represented as a white dwarf with $M_\star \sim 1\,M_\odot$ and $R_\star \sim 10^{-2}\,R_\odot$

Such model is too simple for the B[e] star description, however, it can be used in this case. We do not derive the parameters of the system, but we only compare the relative time variations of certain quantities – equivalent width, line intensities, and line bisectors.

Based on the previous works, we **investigated** following **geometries**:

– a disc with a spot, an arm, an oscillating arm ($\equiv$ stellar wind focused by a close compact companion)

– a symbiotic star

– cool star with a wind + hot compact companion (a possible disc around it)

– pulsations

– a disc with a dust ring (Fig. 3)

Our **observations** defined following **restrictions** on V2028 Cyg model:

– line profile shape – a redwards shifted peak

– radial velocities and bisectors have a different behaviour in the wings and peak

– |EW| is correlated with the maximum of relative flux

– |EW| is anti-correlated with the radial velocity of the wings (RV_{wings})

	asymmetric line profile	radial velocity of the wings and peak	$\lvert EW\rvert = f(I)$	$\lvert EW\rvert = f(RV_{wings})$
disc + spot	+ / –	–	–	–
disc + arm	+ / –	–	–	–
disc + oscillating arm	+	–	–	–
stellar pulsations	+	–	–	–
symbiotic star	+	–	–	–
cool star with the wind + hot star	+	+	–	–
disc + dust ring	+	+	+	+

Table 1: Matching of the investigated models with observed properties.

Results

The line-profile shape is possible to fit by all the models, however, the observed time dependencies agreed only with a star surrounded by a gaseous disc with a dust ring (Tab. 1). The best fit is plotted in the Fig. 1. The disc with a dust ring must obscure a significant part of the disc itself (Fig. 3), otherwise the dependencies will be broken.

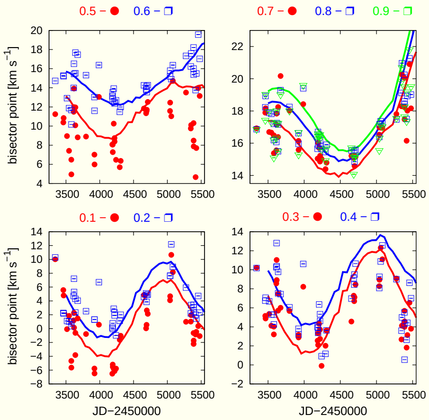

Figure 1: Time dependencies of the Hα bisectors. Measured points are fitted by the best simulation (the disc containing a dust ring). The line bisectors are plotted for the relative highs 0.1 (wings) – 0.9 (peak).

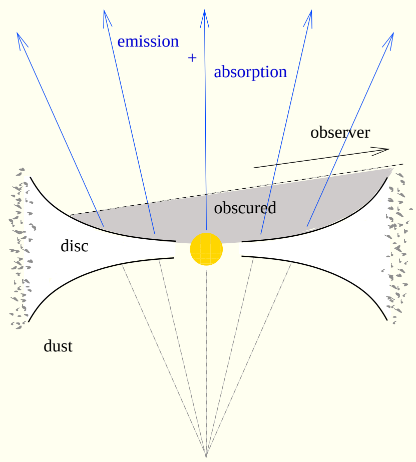

Figure 3: Sketch of the best fitted model explaining all the observed properties.

In order to verify this hypothesis, we compare the radial velocities measurements of the Hα line and the absorption K component (Fig. 2). The double-Gaussian method (Schneider & Young 1980) was used for the Hα wings and the position of the absorption lines of the K spectra was found by Gaussian fitting. Both measurements were confirmed by independent methods (profile mirroring, cross-correlation). A similar trend is possible to see in the Fig. 2. This supports the hypothesis of the geometrically thick disc. However, the accuracy of our measurements is low. There still remains the possibility, that the trend in the radial velocities is coincidental and V2028 Cyg is a binary. Considering the previous (Zickgraf 2001) and our observations, the orbital period of the system in this case must be larger than 25 years.

Discussion and conclusion

The resulting model of the disc with the dust ring (Fig. 3) implies an alternative explanation of the two component spectra of V2028 Cyg. The spectrum with features of a hot star originates in the internal part of the disc and wind region. The outer parts of the disc, which we see edge-on, have low temperature close to the dust condensation value. These conditions allow to form an absorption spectrum of the K type.

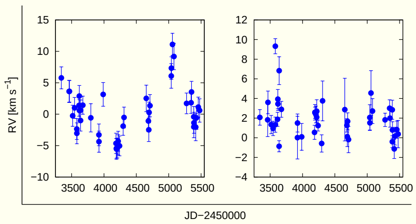

Figure 2: Radial velocity of the Hα wings (left panel) and the absorption K component (right panel).

Acknowlegements

This research is supported by grants 205/09/P476 (GA ČR), 205/08/H005 (GA ČR), MUNI/A/0968/2009, and projects MSM0021620860 (MŠMT ČR) and AV0Z10030501 (AV ČR).

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Poster presented at IAU Symposium 282: From Interacting Binaries to Exoplanets: Essential Modeling Tools, Tatranská Lomnica, Slovakia, July 18 – 22, 2011