New colliding wind massive binaries

M. De Becker & G. Rauw

Institut d'Astrophysique et de Géophysique, Université de Liège, 17, Allée du 6 Août, B5c, B-4000 Sart Tilman, Belgium

Abstract. We report on the recent discovery of two new massive binary systems: WR 20a and Cyg OB2 #8A. For both systems, we briefly present the orbital solutions and we discuss the strong phase-locked line profile variability of the Hα and HeII λ 4686 lines for WR 20a, and the HeII λ 4686 line in the case of Cyg OB2 #8A. In both cases, we show that the profile variability reveals a signature of a wind interaction. The prospects for future high-energy observations are also discussed.

1. Introduction

Colliding wind binaries are known to present signatures of their wind interaction in different wavelength domains. For instance, the line profile variability analysis in the optical band of HD 149404 revealed an obvious wind interaction zone (Rauw et al. 2001). Moreover, such colliding wind binaries can display an additional X-ray emission due to the plasma heated in the interaction zone (Stevens et al. 1992). Consequently, when new massive binary systems are discovered, a straightforward question worth to be asked is: do we detect any evidence for a wind interaction?

WR 20a (Rauw et al. 2004) and Cyg OB2 #8A (De Becker et al. 2004a) were recently discovered to be binaries with periods of about 3.7 and 21.9 d respectively. The spectral analysis revealed that the two components of WR 20a are likely WN6ha stars, and that the spectral types of the two components of Cyg OB2 #8A are most probably O6If and O5.5III(f) respectively for the primary and the secondary.

The cases of WR 20a and Cyg OB2 #8A will be presented respectively in Sect. 2 and Sect. 3. For each system, we will first briefly present the obital solution, before discussing the line profile variability in the optical domain and some prospects for future high-energy observations. Finally, our general conclusions will we given in Sect. 4.

2. WR 20a

2.1. Orbital solution

WR 20a was observed with the EMMI instrument mounted on the NTT in La Silla. We measured the radial velocity (RV) of the Hγ, HeII λ 4542, NV λ 4604, NV λ 4620, NIV λ 4058 and Hδ lines, and used the averaged RV to compute the orbital solution (Rauw et al. 2004).

We found that the orbit is most probably circular, with an orbital period of 3.675 ± 0.030 d. The most striking property of this system is the fact that it consists of two almost identical stars with the largest masses ever measured in a binary system. Indeed, the minimum masses derived by Rauw et al. (2004) were of about 70.7 and 68.8 $M_\odot$ for the primary and the secondary respectively. This result was confirmed by Bonanos et al. (2004) through photometric observations in the *I* band. These authors obtained an inclination angle of 74.5°, yielding masses of about 83 and 82 $M_\odot$ for the primary and the secondary.

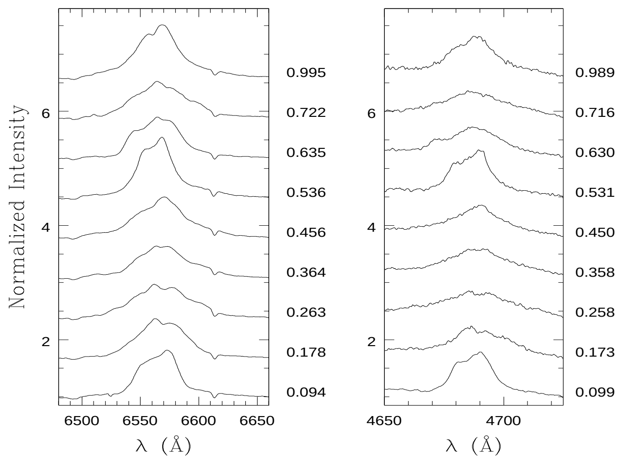

Figure 1. Phase-locked profile variability of the Hα (left) and HeII λ 4686 (right) lines. The phases are quoted beside each profile (Rauw et al. 2004, in preparation).

2.2. Line profile variability

We analysed time series of the Hα and HeII λ 4686 lines (see Fig. 1). We see that both lines display similar profile changes, suggesting that they are formed in the same regions. At phases near conjunction (0.0 and 0.5), we observe a narrow double-peaked profile with some excess emission on the red part. At phases close to quadrature (0.25 and 0.75), the profile is broader with possibly more than two peaks. These observations suggest that some emission is produced in addition to that of the two individual stars. This is compatible with a fraction of the emission arising from a wind interaction zone.

Can we derive the shape of this interaction zone? To answer this question, we have to consider several points resulting from our analysis. First, the winds have most probably similar strengths. The interaction zone should thus be roughly symmetrical about the centre of mass of the system. Second, the equivalent widths corrected for the variations of the continuum of the Hα line present a minimum at phases about 0.05 - 0.10 before conjunctions. This suggests a partial occultation of the emission region at those phases. Third, with the large orbital speed expected for such a close binary system, large Coriolis forces are able to strongly deflect the interaction zone. Finally, from Doppler tomographic analysis, we find that the peak of the emission is located at a phase

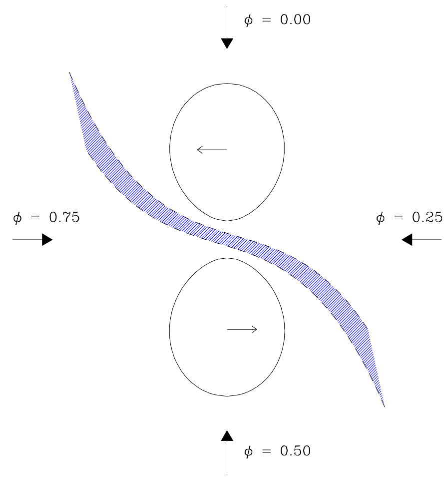

Figure 2. Schematic view of a possible interaction process in WR 20a. The direction of the line of sight is projected on the orbital plane for the phases of conjunction. The peaks of the Hα and HeII λ 4686 emission probably arise in the shaded areas (preliminary result).

shift of about 0.25 compared to the orbital motion of the two stars. Considering all these indications, we propose the preliminary schematic representation shown in Fig. 2 for the interaction zone (for details see Rauw et al. 2004, in preparation).

2.3. High-energy observations

As the winds of the components of WR 20a are probably colliding, we can expect to detect a signature of this wind interaction in the X-ray domain. The plasma heated by this collision is indeed likely to produce a significant thermal X-ray emission.

WR 20a was detected with *ROSAT*. The analysis of archive data reveals a High Resolution Imager (HRI) count rate of $(2.3 \pm 0.5) \times 10^{-3}\,\mathrm{cts\,s^{-1}}$. The HRI image indicates that the X-ray source associated with WR 20a lies at about $40''$ from a somewhat brighter source at the core of the Westerlund 2 open cluster. Assuming an optically thin thermal plasma model with a temperature of 1 keV, an interstellar medium column density $\mathrm{N_H} = 10^{22}\,\mathrm{cm^{-2}}$, and using the HRI count rate to derive a normalization factor, we obtain a flux for WR 20a of about $4.9 \times 10^{-13}\,\mathrm{erg\,s^{-1}}$. New X-ray observations with a good spatial and spectral resolution are needed to constrain the X-ray production of the binary. Folding the above model through the response matrices of the instruments on board the *XMM-Newton* satellite, we expect EPIC-pn and EPIC-MOS count rates of about 0.05 and $0.02\,\mathrm{cts\,s^{-1}}$ respectively.

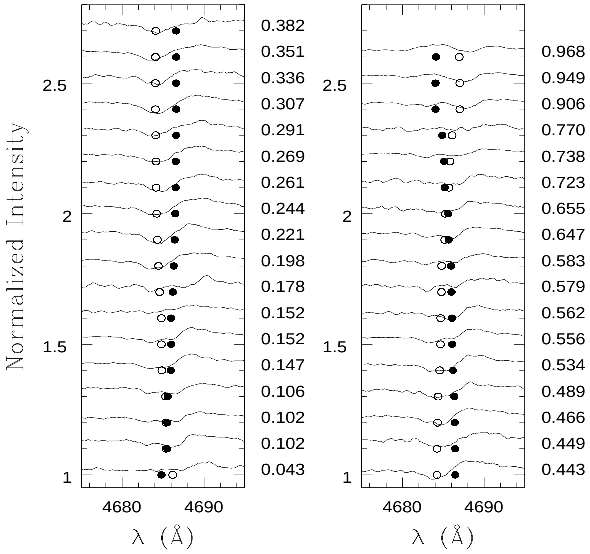

Figure 3. Phase-locked profile variability of the HeII λ 4686 line. The phases are quoted beside each profile. The filled and open circles stand respectively for the position of the primary and secondary line centroids as expected from the orbital solution of De Becker et al. (2004a).

3. Cyg OB2 #8A

3.1. Orbital solution

We obtained a time series of 35 spectra at the Observatoire de Haute-Provence (France). Our analysis of the RVs measured on the HeI λ 4471 line revealed that this star is an eccentric binary ($e = 0.24 \pm 0.04$) with a period of 21.908 ± 0.040 d (De Becker et al. 2004a).

3.2. Line profile variability

The HeII λ 4686 line undergoes a strong phase-locked variability, as can be seen in Fig. 3. We find that most of the time, the profile attributed to the primary displays a P-Cygni shape. The profile of the secondary seems most probably to be in absorption. Most of the variability can be explained by the blend of the two lines due to the orbital motion. However, we observe also some deviations from a P-Cygni profile for the primary (e.g. phases close to 0.95). We propose that these deviations may be due to the alteration of the line emission region by a wind-wind interaction.

3.3. High-energy observations

Cyg OB2 #8A has been observed by several X-ray satellites (*Einstein*, *ROSAT*, *ASCA*, *Chandra*) over the past 35 years. The analysis of the archive *ASCA*-SIS data (De Becker 2001) with thermal models reveals characteristic temperatures of about 0.7 and 1.7 keV. The latter temperature is compatible with the one expected for a plasma heated by a wind-wind collision.

To investigate the X-ray emission from this system, we obtained observing time with the *XMM-Newton* satellite. Four pointings will be taken to monitor the X-ray variability attributed to binarity. This will also help to characterize the nature (thermal vs. non-thermal) of the hard part of the spectrum. Our results will be confronted to archive data to obtain an X-ray light curve emission.

Another probable consequence of the wind interaction is the generation of non-thermal emission. Cyg OB2 #8A is a known non-thermal radio emitter (see e.g. Waldron et al. 1998). The population of relativistic electrons responsible for the radio synchrotron emission could in principle also produce hard X-rays and γ-rays through Inverse Compton scattering of UV photons. This scenario was investigated to evaluate the possible contribution of Cyg OB2 #8A to the unidentified EGRET source 3EG J2033+4118, estimated to be about 10 % (De Becker et al. 2004b). Forthcoming observations with the *INTEGRAL* satellite will help to constrain the properties of the high-energy non-thermal emission from Cyg OB2 #8A, and from other massive stars in the Cyg OB2 region.

4. Conclusions

We report on new results concerning two recently discovered binary systems, i.e. WR 20a and Cyg OB2 #8A. We investigated the line profile variability exhibited by the Hα and HeII λ 4686 lines in the case of WR 20a, and the HeII λ 4686 line in the case of Cyg OB2 #8A. Our analysis unveils a probable wind interaction signature for both systems.

These results suggest promising prospects for future high-energy investigations. One can indeed expect a significant thermal X-ray emission to be produced by the plasma heated by the wind-wind collision of both systems. In the case of Cyg OB2 #8A, the collision zone is also expected to be responsible for the non-thermal radio emission observed in the radio domain. We note that the binarity of Cyg OB2 #8A lends further support to the binary scenario to explain the non-thermal emission from massive stars (see Van Loo, these proceedings). Future high energy observations (*XMM-Newton*, *INTEGRAL*) will aim at investigating a possible non-thermal emission in the high-energy domain.

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