Evidence for phase-locked X-ray variations from the colliding wind massive binary Cyg OB2 #8A*

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Abstract: We report on preliminary results of a multi-observatory investigation of the X-ray emission from the massive colliding wind binary Cyg OB2 #8A (O6If + O5.5III(f)). On the basis of our new *XMM-Newton*-EPIC observations, along with archive *ASCA*-SIS and *ROSAT*-PSPC data, we show strong evidence for a significant phase-locked variability of the X-ray emission from Cyg OB2 #8A with the period of 21.9 days determined by De Becker et al. (2004). These results lend further support to the colliding wind scenario that was already suggested by optical data (De Becker & Rauw 2005). We briefly discuss the behaviour of the X-ray emission from this binary system as a function of phase in the context of the colliding wind scenario.

1 Introduction

Cyg OB2 #8A is a binary system with a period of about 21.9 days, and an eccentricity of 0.24 (De Becker et al. 2004). Optical data strongly suggest that the winds of the two stars (O6If + O5.5III(f)) interact (De Becker & Rauw 2005). Another particularity of this system is that it is known to be a non-thermal radio emitter displaying a phase-locked modulation of its radio flux (see Ronny Blomme's contribution, this conference). These variations lend further support to the idea that binarity is a necessary condition to observe non-thermal radio emission from massive stars (see Sven Van Loo's contribution). This system is also expected to give rise to modulations of its X-ray emission correlated with its orbital motion. For this reason, we investigated its X-ray behaviour using new *XMM-Newton* and archive *ASCA* and *ROSAT* data.

2 Data description and analysis

2.1 *XMM-Newton*-EPIC

We obtained 4 pointings (∼ 20 ks each) centered on Cyg OB2 #8A with a time separation of about 10 days (end of 2004). A significant soft protons contamination of the fourth observation

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[*] Based on data obtained with *XMM-Newton*.

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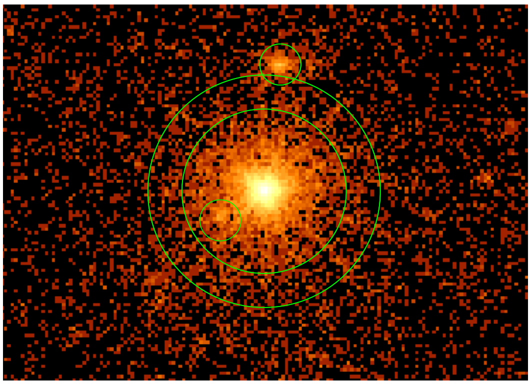

Figure 1: EPIC-MOS1 X-ray image of Cyg OB2 #8A. The source (inner circle) and background (annulus) regions are shown. Close point sources were rejected from the source and background regions (small circles). The North is up and the East is on the left.

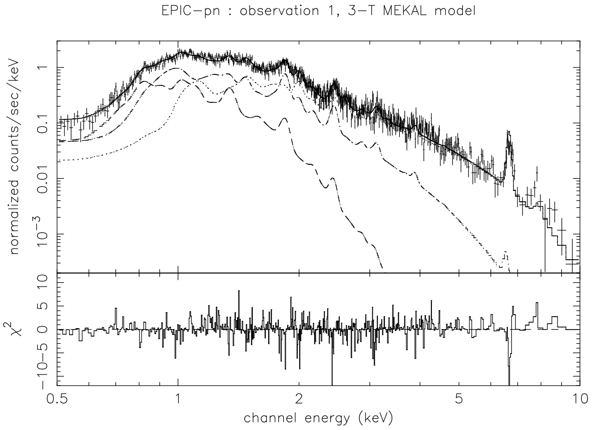

Figure 2: EPIC-pn spectrum of Cyg OB2 #8A for Obs. 1. The spectrum is fitted with a three-component thermal model, including ISM (neutral) and local (ionized) absorption components. The typical plasma temperatures are about 3, 9, and 20 MK respectively for the three emission components. The strong Fe K blend at about 6.7 keV argues in favor of the thermal nature of the hard part of the spectrum (see De Becker et al. 2005).

reduced its effective duration to ∼ 10 ks but Cyg OB2 #8A is bright enough in X-rays to produce a high quality EPIC spectrum in only 10 ks. No significant pile-up was detected despite of the brightness of our target. The spectrum of Cyg OB2 #8A was extracted within a 60 arcsec radius circular region, and the background events were selected within an annulus centered on the source (see Fig.1).

Good quality spectra were obtained and analysed with the XSPEC software (see Fig. 2 for EPIC-pn). Best-fits were obtained using a three-component thermal model (`mekal` model, see Kaastra 1992). The results we obtained for the four observations were very consistent, with a slight variation of the temperature of the hard component (for details, see De Becker et al. 2005). The presence of a thermal component with a very high characteristic temperature (∼ 20 MK), the very high X-ray luminosity (about a factor 10 overluminous as compared to that expected for a single star of identical L_{bol}), and the strong variability of the X-ray flux (see Sect. 3 and 4) argue strongly in favor of a colliding wind scenario.

2.2 *ASCA*-SIS

The Cyg OB2 region was observed with the *ASCA* satellite in April 1993 (Kitamoto & Mukai 1996), with an exposure time of ∼ 30 ks. We retrieved the data and analysed them with the XSELECT package to obtain spectra between 0.5 and 10.0 keV and derive an X-ray luminosity for Cyg OB2 #8A. The characteristic temperatures derived for a 3-T model are similar to those obtained for *XMM-Newton* data.

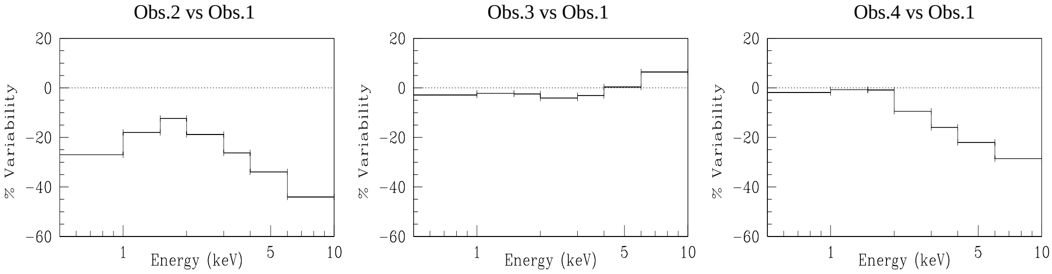

Figure 3: Relative X-ray variability of Cyg OB2 #8A between 0.5 and 10.0 keV as observed with EPIC-pn. The fluxes in all energy bands were determined on the basis of the 3-T thermal model. A negative (resp. positive) value of the percentage stands for a decrease (resp. increase) of the flux of an observation (2, 3, or 4) as compared to the first one.

2.3 *ROSAT*-PSPC

Two ROSAT observations of Cyg OB2 #8A were found in the archives: (i) one from 1991 April 21, and (ii) one resulting from a series of pointings executed between 1993 April 29 and 1993 May 5. The 1993 data set was split into its four individual main exposures of about 3-4 ks each. All spectra were fitted with thermal models. We obtained characteristic plasma temperatures of about 6-7 MK.

3 Variations from *XMM-Newton* data

On the basis of the best-fit 3-T model, we estimated the X-ray fluxes in several energy bands, between 0.5 and 10.0 keV. We used the first observation as a reference, and we compared the fluxes obtained in all energy bands to evaluate the variability level (see Fig. 3). On the basis of these results, the variability can be discussed in the context of the colliding wind scenario. Accordingly, the X-ray flux can vary for two main reasons:

- a variation of the absorption along the line of sight (mainly in the soft part of the EPIC spectrum).
- the eccentricity, likely to cause the physical conditions of the collision zone to change with orbital phase (mainly the hard part of the spectrum).

From Obs. 1 to Obs. 2, the X-ray fluxes decrease in all energy bands. This can be explained by the fact that we compare fluxes obtained respectively close to apastron and periastron ((i)absorption increases, and (ii) the separation decreases, leading to a lower pre-shock temperature). No significant differences are observed between Obs. 1 and Obs. 3. This is not unexpected as they fall at similar orbital phases (see Fig. 4). Obs. 4 presents a strong decrease of the X-ray flux in the hard part of the spectrum. However, the soft part remains steady as compared to Obs. 1. This suggests that the absorption conditions are similar during Obs. 1 and Obs. 4. Identical trends are observed either with fluxes or count rates, for EPIC-MOS and EPIC-pn, therefore lending strong support to these results.

4 Phase-locked variations

We first folded the 3-T model obtained for the first *XMM-Newton* observation with the response matrices of the *ASCA*-SIS and *ROSAT*-PSPC instruments, and we determined the count rate

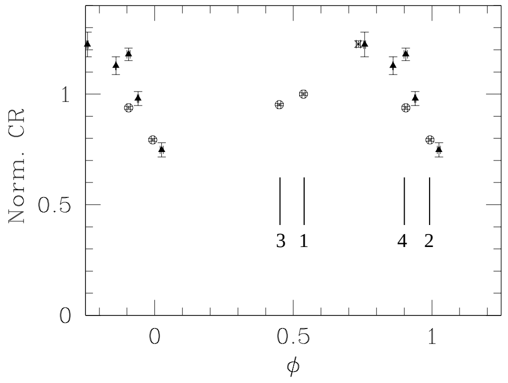

Figure 4: Phase folded X-ray light curve of Cyg OB2 #8A. The equivalent normalized count rates of *XMM-Newton*-EPIC (open circles), *ASCA*-SIS (cross) and *ROSAT*-PSPC (filled triangles) are plotted. According to the ephemeris determined by De Becker et al. (2004), apastron and periastron fall respectively at phases 0.5 and 0.0. The four *XMM-Newton* points are individually labelled (see De Becker et al. 2005).

of the faked spectra. We then compared the observed count rates to the faked ones, and normalized them relative to that of the first *XMM-Newton* observation. We finally folded all the count rates with the ephemeris determined by De Becker et al. (2004) and we obtained the X-ray light curve plotted in Fig. 4, where the count rate of the first *XMM-Newton* observation is equal to 1. The reasonable agreement between the counts rates obtained with the various instruments at different epochs strongly argues in favor of a phase-locked variability on the orbital period of 21.908 days determined by De Becker et al. (2004).

5 Summary and conclusions

On the basis of four new *XMM-Newton* observations and of archive *ASCA* and *ROSAT* data, we investigated the properties of the X-ray emission of Cyg OB2 #8A. The spectrum between 0.5 and 10.0 keV is fitted with a three-component thermal model, with characteristic plasma temperatures of about 3, 9 and 20 MK.

We detected a significant variability ($\sim$ 20%) of the X-ray flux, and our multi-observatory investigation shows clearly that the variations are phase-locked. These results provide strong evidence that the X-ray emission from Cyg OB2 #8A is strongly dominated by the colliding wind interaction.

Acknowledgements

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