XMM-Newton observations of the Cyg OB2 association*

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Abstract: We present the first results of an observing campaign of the Cyg OB2 association with the *XMM-Newton* observatory. The brightest OB-type stars exhibit rather hard spectra suggesting that at least part of their X-ray emission arises in a wind-wind interaction. The EPIC images reveal a large number of fainter X-ray sources most of which are probably low-mass pre-main sequence stars belonging to Cyg OB2.

1 Introduction

The Cyg OB2 association is one of the richest and most massive young open clusters known in our Galaxy. These properties make it an ideal target for observations over a broad range of wavelengths from the radio to the γ-ray domain. Optical studies (e.g. Massey & Thompson 1991) are hampered by the heavy and patchy absorption by dense molecular clouds. A far more complete census of the cluster population can be obtained in the near infrared: Knödlseder (2000) analysed 2MASS data of Cyg OB2 finding that the cluster probably harbours about 2600 ± 400 OB stars among which 120 ± 20 O-stars. He accordingly suggested that Cyg OB2 could be a young globular cluster. Four cluster members have been extensively studied in the radio domain. Three of them are non-thermal radio emitters (Cyg OB2 #5, #8a and #9, see e.g. Waldron et al. 1998 and references therein), whilst the fourth one (Cyg OB2 #12) could be one of the most luminous stars in our Galaxy. At the other end of the electromagnetic spectrum, the error box of the unidentified *EGRET* γ-ray source 3EG J2033+4118 overlaps to a large extent with the cluster (Romero et al. 1999, Rauw 2004). Finally, X-ray emission from Cyg OB2 was discovered serendipitously when *EINSTEIN* was pointed at Cyg X-3 (Harnden et al. 1979). This was actually the first report of X-ray emission from OB stars. Since then, Cyg OB2 has been observed by every major X-ray satellite.

Here, we present the very first results of an observing campaign with the EPIC instruments onboard *XMM-Newton*.

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2 *XMM-Newton* observations of Cyg OB2

Four pointings centered on Cyg OB2 #8a and separated by 10 days each were obtained in October - November 2004. The raw data were processed with SAS version 6.0. After rejecting some bad time intervals affected by high background events (so-called soft-proton flares), the remaining total exposure time was 75 ksec. A few stray-light features (due to singly reflected photons) from Cyg X-3 are visible in the lower right corner of the images. However, they do not affect the most interesting part of the field of view. The SAS routines detected a total of 221 sources in the combined EPIC images (outside the region affected by the stray-light) with fluxes down to $2 \times 10^{-14}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$. The EPIC spectra of the brightest X-ray sources were analysed with the `xspec` software. The spectra and the light curve of Cyg OB2 #8a are discussed by De Becker & Rauw (these proceedings) and we will not repeat this analysis here.

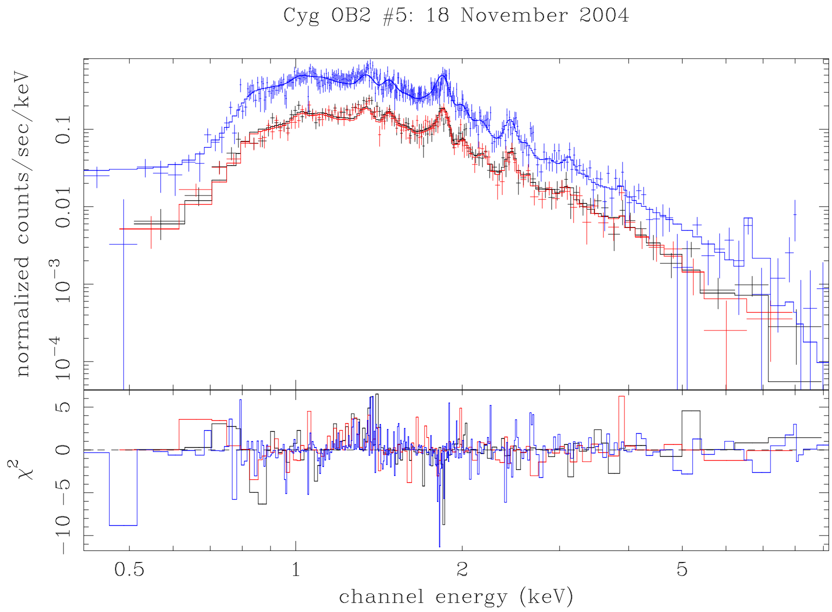

Figure 1: EPIC spectra of Cyg OB2 #5 as observed on 18 November 2004. The data were fitted with an absorbed two temperature optically-thin thermal plasma model (see text).

2.1 Cyg OB2 #5

Cyg OB2 #5 (= BD+40° 4220) is in fact a multiple system consisting (at least) of a short-period colliding wind binary (O6-7 Ia + Ofpe/WN9, Rauw et al. 1999) and a third visual component (most probably a B star, Contreras et al. 1997). The EPIC spectra of this source are well fitted with an absorbed two-temperature thermal plasma model (Fig. 1). In addition to the absorption by the neutral interstellar medium, we included a wind absorption model computed following the technique of Nazé et al. (2004). While the lower temperature of the fit ($kT_1 = 0.63 \pm 0.01$ keV) is quite typical of the intrinsic X-ray emission of early-type stars, the second component is much hotter ($kT_2 = 1.7 \pm 0.2$ keV) and arises most probably in a wind interaction zone. In fact, this multiple system most probably harbours several potential wind-wind collision regions. Unfortunately, the four observations of this system do not provide a good coverage of the 6.6 day orbital period of the close binary system, so that we presently cannot make any statement about the existence or absence of a phase-locked variability.

2.2 Cyg OB2 #9

This O5 If star is a variable non-thermal radio emitter (see also the contributions by Van Loo and by Blomme in these proceedings). Although the non-thermal emission is strongly believed to arise in a wind interaction zone, no spectroscopic evidence for binarity has been reported so far. As for Cyg OB2 #5 , the EPIC spectra are rather well fitted by an absorbed 2-T thermal plasma model (see Fig. 2). While the lower temperature ($kT_1 = 0.63 \pm 0.03$ keV) is again rather typical for O-type stars, the second temperature reaches $kT_2 = 2.4$ keV which corresponds by far to the hottest plasma in the O-type stars of Cyg OB2. This feature is quite consistent with a colliding wind scenario in a binary system where the winds reach their terminal velocities before they collide.

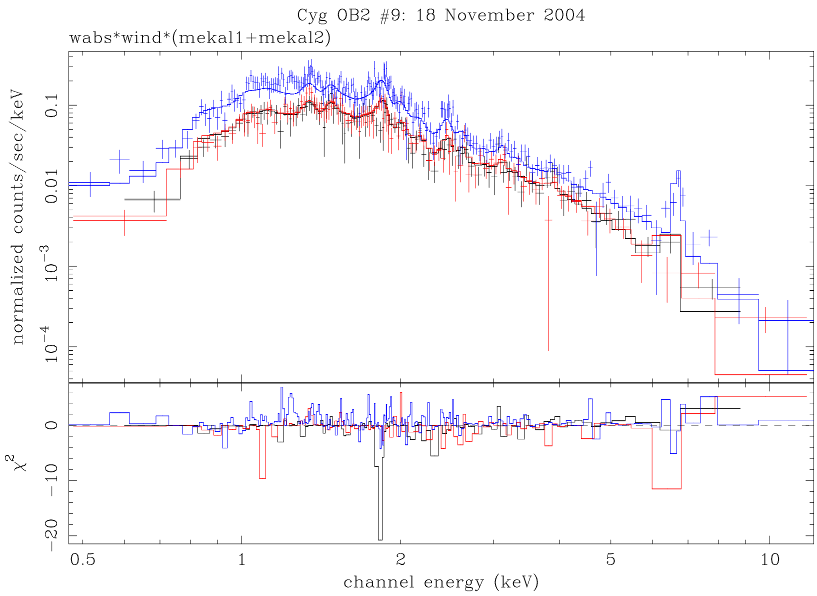

Figure 2: Same as Fig. 1 but for Cyg OB2 #9. Note the prominent Fe K line at 6.6 keV.

2.3 Cyg OB2 #12

The spectral type of this star is rather ill-defined and is probably variable. However, most investigations agree that Cyg OB2 #12 is an extremely luminous B supergiant that could be related to the LBV phenomenon. The EPIC spectra are well fitted with a thermal plasma model with $kT_1 = 0.73 \pm 0.16$ and $kT_2 = 1.8 \pm 0.4$ keV. The latter temperature is surprisingly high given the fact that the wind of the star is rather slow (~ 150 km s^{-1}, Klochkova & Chentsov 2004). Kolchkova & Chentsov presented evidence for a line radial velocity gradient that they interpreted as an indication for infall of matter. However, even assuming head-on collisions of two flows, each at a velocity of 150 km s^{-1}, the post-shock temperature would not be sufficient to account for the hard X-ray spectrum. Therefore, the most likely scenario seems again to be a colliding wind binary where the wind of the companion would have to be much faster.

2.4 Secondary sources

We have cross-correlated the positions of our 221 X-ray sources with the 2MASS point source catalogue. We found near-IR counterparts for 185 of them. Among these, there are 15 known

O-type stars. Beside these early-type objects, most X-ray sources have rather faint near-IR counterparts ($K > 11$). Their location in a $(J-K,\ K)$ colour-magnitude diagram (Fig. 3) suggests that they actually belong to Cyg OB2 and could be low-mass pre-main sequence stars. This latter interpretation is also supported by the flaring activity of some of these secondary sources. Evidence for an active star formation process in Cyg OB2 was already reported based on *IRAS* observations (e.g. Parthasarathy et al. 1992). The *XMM-Newton* results will help to shed more light on the star formation history of this extremely interesting cluster.

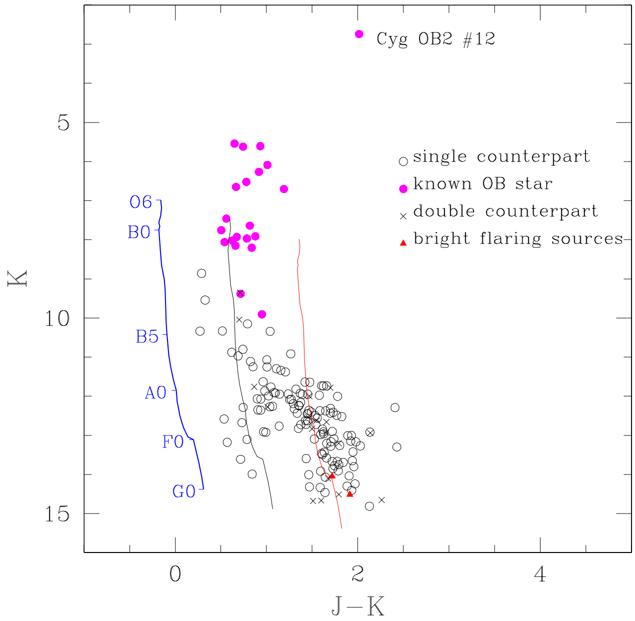

Figure 3: Near-IR colour-magnitude diagram of the 2MASS counterparts of the X-ray sources in Cyg OB2. The location of the main-sequence is shown for three different values of the reddening: from left to right, $A_V = 0$, 5 and 10 mag.

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