DEEP CHANDRA X-RAY VIEW OF THE CYGNUS OB2 YOUNG GLOBULAR CLUSTER

J. F. Albacete Colombo*, G. Micela, E. Flaccomio, S. Sciortino & F. Damiani

INAF - Osservatorio Astronomico di Palermo (OAPA), Piazza del Parlamento 1 (90134), Palermo, Italy.

ABSTRACT

A deep (97.7 ksec) *Chandra*/ACIS observation of the Cygnus OB2 (Cyg OB2) young 'globular' cluster yields 1003 X-ray sources within the 17'×17' FOV. Correlation with the 2MASS catalog (∼4800 objects in the FOV) results in 766 identifications, 25 of which with OB stars. The typical X-ray spectra of our sources have median energy $\overline{E}_{\rm x} \sim 2.0$ keV, while OB stars appear to be softer ($\overline{E}_{\rm x}$∼1.4 eV). NIR color-magnitude diagrams, [K vs. H-K] and [J vs. J-K], indicate that most X-ray sources have $\overline{Av}$∼5 mag and masses between 0.6 to 3 $M_\odot$. The NIR color-color [J-H vs. H-K] diagram shows that few (∼5%) X-ray sources are located in the CTTS locus. Fits of absorbed isothermal models to the X-ray spectra result in distributions of $N_{\rm H}$ and kT peaking at 2.0×10^{22} cm^{-2} and 1.5 keV respectively, with higher $N_{\rm H}$ values often associated with higher kTs. Absorbed and un-absorbed X-ray luminosities are 1.3×10^{30} and 4.3×10^{30}ergs/sec, respectively, mapping typical of X-ray emission from low mass stars (LMSs). Hard (more absorbed) X-ray sources appear more variable than softer ones. OB stars have $L_{\rm x}/L_{\rm bol}$ in the 10^{-7}-10^{-6} range.

Key words: Globular clusters and OB associations: individual (Cygnus OB2): X-rays: stars.

1. INTRODUCTION

The Cygnus OB2 young "globular" cluster represents one of the largest concentration of low mass stars (0.5 - 3 $M_\odot$), also containing some of the most massive stars of the galaxy (Cyg OB2 N° 5, 8, 9 and 12). The interstellar extinction toward this region ranges from 4 to 15 mag (Comeron et al., 2002), therefore optical and near-IR studies may seriously underestimate the low mass stellar population. X-ray luminosity of low mass Pre-Main Sequence (PMS) stars ($L_x \sim 10^{29}$-10^{31} erg s^{-1}) is much higher with respect to older field stars. We use deep (∼97.7 ks) *Chandra* X-ray imaging[1] (Fig.1), and data from the 2MASS NIR database, to select an unbiased member sample, to characterize the X-ray emission of low- and high mass stars, to investigate common IR and X-ray properties of Cygnus OB2 stellar members.

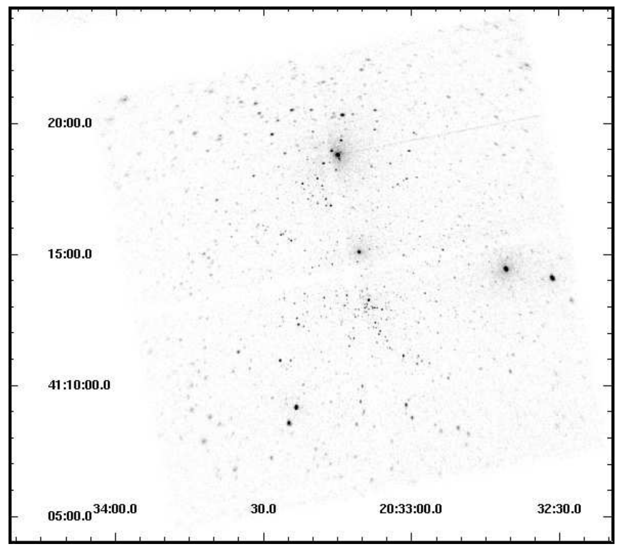

Figure 1. Chandra X-ray image of Cyg OB2. In the electronic version[1], colors refer to different energy bands.

2. X-RAY DETECTION AND CROSS-ID

Source detection was performed with the *PWDetect* code (Damiani et al., 1997). After manual rejection of spurious detections we finally accepted 1003 X-ray sources. X-ray properties of sources were derived using the Acis-Extract (AE) code (Broos et al., 2002).

X-ray sources were cross-identified with the 2MASS catalog (∼ 4800 sources in the FOV). Due to the off-axis dependence of the *Chandra* PSF, as well as to the source crowding at the field center, cross-identification were performed with an off-axis dependent radius: 1.0, 1.5, 2.1 and 2.7 arcsec for off-axis 0-2, 2-4', 4-7' and > 7', respectively. We cross-identify a total of 766 sources in the entire observed field.

*e-mail: facundo@astropa.unipa.it

[1]http://www.astropa.unipa.it/∼facundo/proceedings/CygOB2_acis.tif

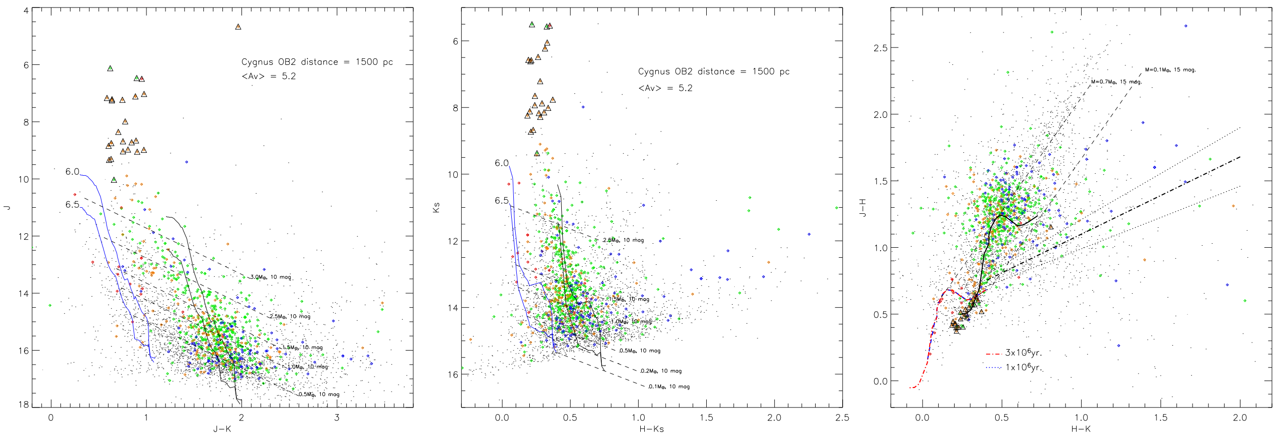

Figure 2. Color-magnitude and color-color diagrams of IR sources (small dots) and X-ray - 2MASS cross-identified sources (solid fill dots). X-ray detected OB stars are flagged with open black triangles. Therefore Siess et al. (2002) Isochrones of 1 and 3 Myr are shown, both unabsorbed and the absorbed by A_v=5.2. Note the small number of sources along the T-tauri loci in the right panel. In the electronic version[2] *colors refer to the $\overline{E}_x$ of the source.*

3. X-RAY PROPERTIES OF CYG OB2 SOURCES

The X-ray median energy ($\overline{E}_x$) distribution of the 1003 detected sources peaks at ≈2.0 keV, while OB stars appears to be softer ($\overline{E}_x$≈1.4 keV). Non-identified X-ray sources show a wider $\overline{E}_x$ distribution, suggesting a variety of X-ray emission processes and/or different intrinsically absorption values.

We extracted X-ray spectra from the 1003 sources with more than 20 X-ray photons. We fit spectra using an absorbed (WABS) thermal model (APEC). We find that the N_H distribution peaks at $2.0^{2.1}_{1.8}\times10^{22}$ cm^{-2}, while the kTs distribution peaks at $1.5^{1.7}_{1.3}$ keV. Absorbed X-ray luminosity (L_x) ranges from $2.0^{2.3}_{1.9}\times10^{30}$ to $2.2^{2.6}_{1.9}\times10^{32}$ erg s^{-1}, while un-absorbed luminosities (L_x^0) ranges up to 6.7×10^{33} erg s^{-1}. The lower L_x^0 values are typical of LMSs in the quiescent state, while the higher L_x^0 could be produced by flare activity, as well as by OB stars.

We also studied source variability using the Kolmogorov-Smirnov (KS) test. The function of variable stars is seen to increase with the $\overline{E}_x$ of the sources. OB stars do not vary significantly within the ∼97 ks of the observation.

The positions of OB stars in the L_x vs. L_{bol} diagram are in rough agreement with the known relation L_x/L_{bol} $\sim2\times10^{-7}$, but some O-type stars of luminosity classes I and III show excesses.

4. IR PROPERTIES OF CYG OB2 MEMBERS

According to the K_s vs. H-K_s and J vs. J-K_s (CM) diagrams, (Fig. 2: left and center), we find a visual extinction (A_v) of about 5 magnitudes as representative value for Cyg OB2 members (see the electronic color version)[2]. About 68 % of the cross-identified X-ray sources lie between the 1.5 and the 0.5 solar mass tracks, whereas 25 of detected OB stars clearly appears in the upper part of the CM diagram. Surprisingly, the J-H vs. H-K_s color-color diagram (Fig. 2: right) shows that the CTTS locus (Meyer, 1997) is almost empty, with only about ∼ 5% of the total 2MASS - X-ray source sample. Hard X-ray sources are widely scattered at the highest extinction values, suggesting the presence of additional absorption material. Unidentified X-ray sources may be related to very LMSs and/or deeply embedded Class I and/or eventually Class 0 YSOs.

[2]http://www.astropa.unipa.it/∼facundo/proceedings/2mass-xray.tif

ACKNOWLEDGMENTS

J.F.A.C acknowledges support by the Marie Curie Fellowship Contract No. MTKD-CT-2004-002769 of the project "*The Influence of Stellar High Energy Radiation on Planetary Atmospheres*", and the host institution INAF - *Osservatorio Astronomico di Palermo* (OAPA).

REFERENCES

Broos P. et at. 2002, Penn, State University.

Comerón F. et al. 2002, A&A, 389, 874.

Damiani F., Maggio A., Micela G., Sciortino S. 1997, ApJ, 483, 370.

Hanson, M.M. 2003, ApJ, 597, 957.

Meyer M.R., Calvet N., Hillenbrand L.A. 1997, AJ, 114, 288.

Siess L., Dufour E., Forestini M. 2000, A&A, 358, 593.