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

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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 $E_\text{med} \sim 2.0$ keV, while OB stars appear to be softer ($E_\text{med} \sim 1.4$ eV). NIR color-magnitude diagrams, [K vs. H-K] and [J vs. J-K], indicate that most X-ray sources have $A_V \sim 5$ 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 $N_\text{H}$ and $kT$ peaking at $2.0 \times 10^{22}$ cm$^{-2}$ and 1.5 keV respectively, with higher $N_\text{H}$ values often associated with higher $kTs$. Absorbed and un-absorbed X-ray luminosities are $1.3 \times 10^{30}$ and $4.3 \times 10^{30}$ 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 $L_x/L_{bol}$ 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.

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.
3. X-RAY PROPERTIES OF CYG OB2 SOURCES

The X-ray median energy ($\langle E_x \rangle$) distribution of the 1003 detected sources peaks at $\approx 2.0$ keV, while OB stars appear to be softer ($\langle E_x \rangle \approx 1.4$ keV). Non-identified X-ray sources show a wider $\langle E_x \rangle$ 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 $2.0^{+2.0}_{-1.0}$ $\times 10^{22}$ cm$^{-2}$, while the $kT$s distribution peaks at $1.5^{+0.2}_{-0.2}$ keV. Absorbed X-ray luminosity ($L_x$) ranges from $2.0^{+3.0}_{-1.5} \times 10^{30}$ to $2.2^{+5.0}_{-1.5} \times 10^{32}$ erg s$^{-1}$, while un-absorbed luminosities ($L^0_x$) ranges up to $6.7 \times 10^{33}$ erg s$^{-1}$. The lower $L^0_x$ values are typical of LMSs in the quiescent state, while the higher $L^0_x$ 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 $\langle E_x \rangle$ of the sources. OB stars do not vary significantly within the $\sim 97$ 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 $L_x/L_{bol} \sim 2 \times 10^{-7}$, 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 $\sim 5$% 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.

ACKNOWLEDGMENTS


REFERENCES

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

$^2$http://www.astropa.unipa.it/~facundo/proceedings/2mass-xray.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 $\langle E_x \rangle$ of the source.