X-RAY SOURCES ASSOCIATED WITH YOUNG STELLAR CLUSTERS IN CANIS MAJOR R1

G. Rojas[1,2], J. Gregorio-Hetem[1], N. Grosso[2] and T. Montmerle[2]

[1] Instituto de Astronomia, Geofisica e Ciências Atmosféricas, Universidade de São Paulo
Rua do Matão, 1226 - 05508-900 - São Paulo - SP – Brasil
[2] Laboratoire d'Astrophysique, Observatoire de Grenoble - BP 53, F-38041 Grenoble Cedex 9 – France

ABSTRACT

We present X-ray observations of Canis Major R1 molecular cloud performed with XMM-Newton EPIC camera, and supplemented with Chandra ACIS-S archival data. We have detected 135 X-ray sources in this region, confirming the presence of several individual faint sources, not resolved by our previous ROSAT PSPC observations. More than 60 sources are associated with stellar clusters embedded in the reflection nebulae BRC27 and VDB92. We present here the X-ray sources detected by XMM-Newton and Chandra, mainly T Tauri and Herbig Ae/Be stars.

1. INTRODUCTION

Canis Major (CMa) R1 is a moderately distant (d ~ 1 kpc) star forming region associated to S296, a long arc-shaped emission nebulosity. This nebula coincides with the boundary of an expanding neutral hydrogen shell, which have led Herbst & Assousa (1977) to suggest that a supernova explosion may have induced the star formation in the area.

In particular, two stellar clusters in BRC 27, a bright-rimmed cloud (Sugitani et al. 1991), and the reflection nebula VDB92 (van den Bergh 1966) are found at the outer edge of S296. Soares & Bica (2002, 2003) have studied near-IR data of the stars embedded in these clusters. Based on colour-magnitude diagrams, they estimated ages of 1.5 Myr for BRC27, and 5-7 Myr for VDB92.

Therefore, CMa R1 is a very interesting, yet poorly studied star forming region where only the more massive members are known. X-ray observations not only improve the population census down to solar-like stars; they can also help to ellucidate whether or not the star formation was triggered by a supernova explosion.

Table 1: X-ray Observations of CMa R1 Region.

Detector	Net Exposure (kiloseconds)	Field Area (arcmin^2)	Sources Detected
ROSAT PSPC	20	3600	61
XMM EPIC/MOS	3	780	61
Chandra ACIS-S	31	150	83

2. CMA R1 IN X-RAYS

Back in the 1990's, our group observed the CMa R1 region in X-rays with ROSAT PSPC (Gregorio-Hetem et al. 2003). An extended feature was detected, very precisely located on top of the optical diffuse feature, argued to be, as discussed before, an old supernova remnant. Since the PSF of the PSPC image is very degraded towards the edge of the ROSAT field, the nature of the extended emission was unclear from these data: it could be due to unresolved stellar clusters or a truly diffuse emission.

Zinnecker & Preibisch (1994) observed Z CMa in CMa R1, during their survey of Herbig Ae/Be stars. A cluster of X-ray sources is visible in this archival data. However, due to the limited sensitivity and angular resolution of ROSAT, a diffuse component emission at a low level cannot be rejected.

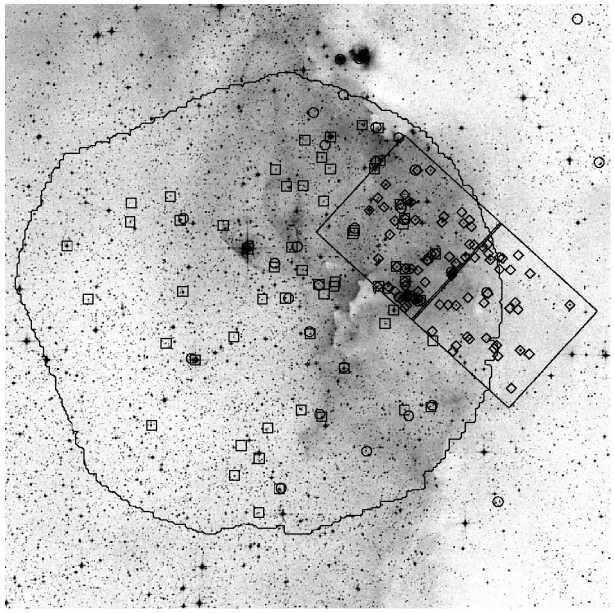

Fig. 1: DSS-2 Red Image of the CMa R1 Region. The large round area is the XMM-Newton EPIC field of view, and the two squares at the right are the locations of Chandra's ACIS-S CCDs #6 and #7. Open squares, triangles and circles indicate X-ray sources detected by XMM, Chandra and ROSAT, respectively.

In order to quantify the contribution of a possible extended X-ray emission and to improve the young stellar population census, our team performed a XMM-Newton EPIC observation centered on the cluster mentioned above. The observation was heavily affected by flaring background during ~ 90% of the allocated time, preventing us to use PN data. Neverthless, a total of 61 X-ray sources were detected in this observation. XMM data was reduced using SAS 6.5 routines.

Additionally, we retrieved Chandra ACIS-S archival data (Obs. ID #3751) around the star Z CMa. These additional data accounted for 83 X-ray sources, where 60 sources were not detected by the XMM observation. Chandra data was reduced with CIAO 3.2 routines. Fig. 1 shows an optical image of CMa R1, the area covered by the X-ray observations, and the sources detected.

3. RESULTS AND DISCUSSION

Of a total of 61 X-ray sources detected by XMM and 83 by Chandra, 95% and 72%, respectively have 2MASS near-IR counterparts. We have built color-color and color-magnitude diagrams of the X-ray counterparts in order to identify candidates with infrared excess. Nearly half of the sources show intrinsic infrared excesses. Comparison with theoretical pre-main sequence evolutionary models (Fig. 2) indicates that the sources are younger than 10 Myrs and the masses range from 0.4 to 10 $M_{\odot}$.

Analysis of X-ray spectra were only possible for the brightest Chandra sources. We have performed spectral fitting using XSPEC 11.3. An impulsive flare (Fig. 3) was observed for one object.

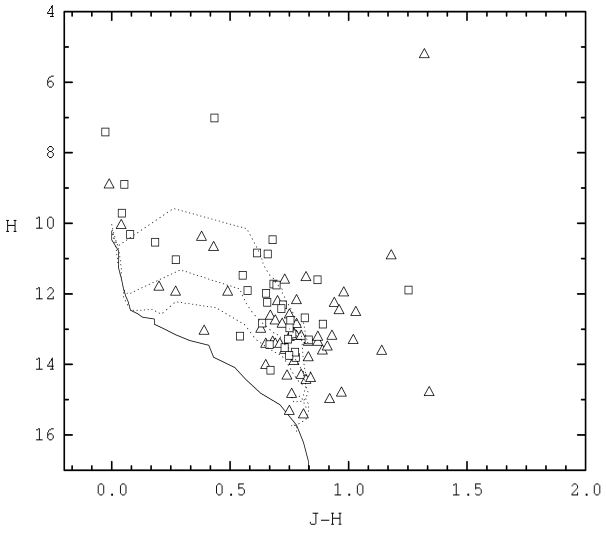

Fig. 2: Color-magnitude diagram for the X-ray sources with 2MASS counterparts. Symbols are the same of Fig. 1. ZAMS (solid line) and isochrones for 1, 5 and 10 Myrs (dotted lines) from Siess et al. (2000).

Regarding the extended emission issue, no signal of it was detected on the Chandra image. We therefore conclude that the extended feature detected on our previous ROSAT image was due to unresolved point sources. However, this does not rule out the supernova-induced star formation scenario, since the detection of a faint diffuse emission would require a longer (~100 ksec) exposure.

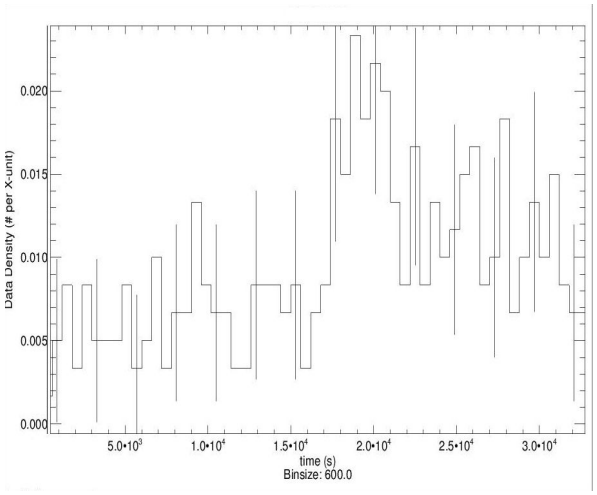

Fig. 3: X-ray background subtracted light curve for the source associated with the star 2MASS 07035575-1129315.

4. SUMMARY AND CONCLUSIONS

Using XMM-Newton observations and Chandra archival data, we have identified a total of 135 X-ray sources in the CMa R1 star forming region. 87% of the sources have 2MASS counterparts. The color-magnitude diagram indicates that nearly half of the young stars candidates have infrared excesses.

5. REFERENCES

Gregorio-Hetem, J., Montmerle, T., Marciotto, E. R.. 2003 in O*pen Issues in Local Star Formation*, eds. J. Lépine, J. Gregorio-Hetem, Kluwer

Herbst, W. & Assousa, G. E. 1977, ApJ, 217, 473

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

Soares, J. B. & Bica, E. 2002, A&A, 388, 172

Soares, J. B. & Bica, E. 2003, A&A, 404, 217

Sugitani, K, Fukui, Y., Ogura, K. 1991, ApJS, 77, 59

v an den Bergh, S. 1966, AJ, 71, 990

Zinnecker, H. & Preibisch, T. 1994, A&A 292, 152