X-RAY OBSERVATIONS OF THE YOUNG OPEN CLUSTER ζ SCULPTORIS

G. MICELA[1], S. SCIORTINO[1], F. FAVATA[2], R. PALLAVICINI[1], J. PYE[3]

[1] *Istituto e Osservatorio Astronomico di Palermo, Italy*

[2] *European Space Agency, Astrophysics Division, Noordwijk, The Netherlands*

[3] *Department of Physics and Astronomy, Leicester University, UK*

ABSTRACT. We present preliminary results from two deep HRI ROSAT exposures on the ζ Sculptoris open cluster. This cluster, younger than the Pleiades, has photometric indicators that seem to imply a metal-poor cluster. On the contrary detailed analysis of high resolution spectroscopic observations results in a metal abundance higher than the solar value. Furthermore many cluster members show chromospheric emission typical of young stars. X-ray observations reveal a high number of X-ray sources consistent with the young age of the cluster. The time sampling of the pointings allow us to study the variability of the sources on time scales from hours to 6 months - 1 year.

1. Introduction

ζ Sculptoris (Blanco 1) is an open cluster somewhat younger than the Pleiades ($\sim$ 50–70 Myr). In the most complete study of this cluster, de Epstein & Epstein (1985) have obtained photographic photometry of about 1500 stars down to $m_V \sim 16.5$ (corresponding to the late dK cluster members). Spectral types are available down to early G members and are missing for redder stars. From the analysis of the derived colour-magnitude (CM) diagram de Epstein & Epstein (1985) conclude that about 150 of the stars in their study belong to the cluster main sequence and deduce a distance modulus of 6.9 (i.e. a distance of 240 pc) and a color excess E(B-V) = 0.013. ζ Sculptoris is also one of the few open clusters at high galactic latitude, whose formation mechanism is unclear.

In the last few years several detailed studies of ζ Sculptoris have been conducted. These works show, interestingly, that while photometric indicators such as m_1 or $U-B$ seem to imply a metal-poor cluster (de Epstein and Epstein, 1985; Westerlund et al. 1988), the detailed analysis of high resolution spectroscopic observations (Edvardsson et al. 1995) results, on the contrary, in a metal abundance [Fe/H]=+0.23, about 70% higher than the solar value. Panagi et al. (1994) have presented spectroscopic observations of a sizeable fraction of cluster members, covering the whole bandpass from the Ca II(H,K) region to the Ca II(IR) triplet. These authors find a high mean Ca II surface flux consistent with that of other young clusters and deduce the presence of a high degree of surface inhomogeneity, implying intense magnetic activity on young stars. Lithium observations indicate that ζ Sculptoris has an age similar to that of the young cluster α Persei (Panagi et al. 1994, Panagi & O'Dell 1997).

2. Analysis of the x-ray images

We have obtained 2 deep HRI observations pointed toward the central part of the ζ Sculptoris cluster. One of the two images (hereafter Field 1) has been observed in three distinct segments 6 months apart.

The HRI data have been analyzed adopting a wavelet trasform detection algorithm (Damiani et al. 1997a,b) specifically tuned for the characteristics of the HRI detector (Damiani et al. 1997c) that allows the efficient detection of weak sources in crowded fields even in presence of spatially variable background and provides source intensity, probability of existence and extension. In the present work the detection algorithm acceptance threshold, determined through extensive simulations, has been chosen so to have no-more than one predicted spurious source for each HRI image.

Sources have been searched in Field 2 and in each of the three segments making the entire Field 1 observation. Before proceeding with the analysis of the summed Field 1 observation, we have searched for possible inconsistencies of the aspect determination among the three segments, since this is a well known problem affecting the ROSAT HRI observations (Briel et al. 1996). Using as reference coordinate system that of the optical positions of the cluster members, we have identified the likey counterparts of X-ray sources in each of the three segments and have found a misplacement up to 12" among the three segments. The adopted identification radius has been chosen equal to 20" to account for uncertainties in X-ray (and optical) positions. After proper positional registration of the three segments we have summed them and have searched for sources in the deeper image so obtained for Field 1. Sources in Field 1 and 2 have been cross-matched with a list of known cluster members and with a list of other objects in the surveyed region adopting a positional matching radius of 20". As a result of this analysis we have found 129 X-ray sources, 40% of which are identified either with known cluster members or with other catalogued objects.

We have computed the expected number of extragalactic sources in our fields, using the sensitivity maps obtained by the wavelet algorithm with a spatial resolution of 10"x10". We have estimated the number of expected extragalactic sources for a hydrogen column $N_H = 2\ 10^{20}$ cm^{-2}, obtained interpolating data from Stark et al. (1992), and a power law spectrum with a photon index ranging between 1 and 2. The total number of expected extragalactic sources in our survey ranges between 13.6 and 19.1, depending on the assumed spectrum, if we use the log(N)-log(S) of Branduardi-Raymont et al. (1994), and between 15.4 and 21.5 with the log(N)-log(S) of Hasinger et al. (1993).

The conversion factor from HRI count rates to flux (in the 0.1-2.4 keV bandpass) is 3.2 10^{-11} erg cm^{-2} cnt^{-1}. It has been derived assuming a single temperature Raymond-Smith model for an optically-thin plasma with a temperature of 1 keV, appropriate for describing the emission from young active coronal emitters, and a hydrogen column density Log (N_H) = 20, as deduced from the mean measured E(B-V). In deducing X-ray luminosities for cluster members we have adopted the distance of 240 pc.

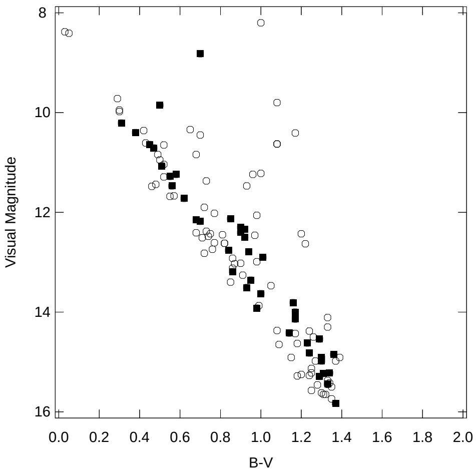

Fig. 1. Color-magnitude diagram for ζ Sculptoris likely members in the X-ray observed region. Filled symbols indicate stars identified with X-ray sources

3. X-Ray activity among the ζ Sculptoris members

In Fig. 1 we show the CM diagram for the ζ Sculptoris likely members falling in the surveyed region. The filled symbols indicate the stars that have been identified with X-ray sources. The cluster members that we have looked at but not detected in X-rays are 81. Notice that X-ray emission is common over the entire range of spectral types.

The scatter plot of L_X vs. B-V for the detected stars is shown in Fig. 2. The solid horizontal lines indicate the median Log (L_X) for the Pleiades (Micela et al. 1996) for the 0.3-0.5, 0.5-0.8, 0.8-1.45, $>$ 1.45 B-V ranges corresponding to the early dF, dF7-G9, dK0-9, dM0-5 spectral types, respectively. The extremes of the solid vertical lines indicate the 10% and 90% range of the Pleiades Log (L_X) Maximum Likelihood distribution function. For comparison we show with dashed lines the same information for the α Per open cluster (Randich et al. 1996). It is worth to notice: i) the large spread of L_X for each spectral type, similar to that seen in the Pleiades; ii) the lack of information for dM stars due to the limiting magnitude of the optical reference catalogue.

4. X-ray variability

Field 1 has been observed in three different time segments $\sim$ 6 months apart. This circumstance allows us to explore X-ray variability on this time scale. Indeed for some sources, variability of the mean activity level is observed from one segment to the other.

We have looked in detail to the light curves of all these sources and only for one source the high level observed in Dec 1995 seems to be due exclusively to a large flare with an amplitude of a factor $\sim$ 30. This source is not identified with known stars, and is likely a low mass cluster member. For all the remaining sources, the variations of the activity level seem to be due to slower events, and there is no evidence of variability within a single segment of observation. The variability can be simply due to a variation

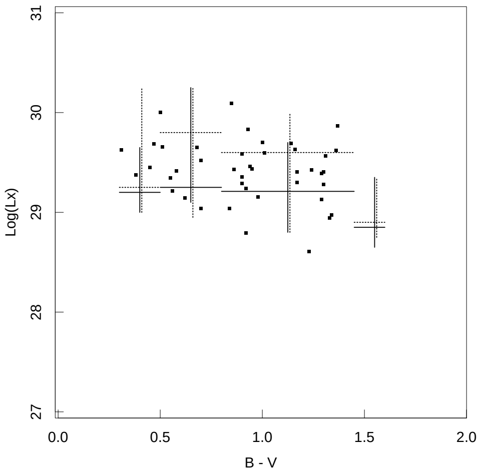

Fig. 2. Scatter plot of L_X vs. B-V for ζ Sculptoris likely members detected in x-ray. The solid horizontal lines indicate the median Log (L_X) for the Pleiades, while he dashed lines indicate the median for the α Per cluster

of the number of the active regions making up the stellar corona. Most of the variable sources identified with cluster members are typically of spectral type K.

References

Branduardi-Raymont G., Mason, K. O., Warwick R. S., et al.: 1994, *Mon. Not. R. Astr. Soc.* **270**, 947

Briel U. G., Aschenbach B., Hasinger G., et al.: 1996, The ROSAT Users' Handbook

Damiani F., Maggio A., Micela G., Sciortino S.: 1997a, *Astrophys. J.* **483**, 350

Damiani F., Maggio A., Micela G., Sciortino S.: 1997b, *Astrophys. J.* **483**, 370

Damiani F., et al.: 1997c, in preparation

Edvardsson B., Pettersson B., Kharrazi M., & Westerlund B.: 1995, *Astron. Astrophys.* **293**, 75

de Epstein A. E., & Epstein I.: 1985, *Astron. J.* **90**, 1211

Hasinger G., Burg R., Giacconi R., et al.: 1993, *Astron. Astrophys.* **275**, 1

Micela, G., Sciortino, S., Kashyap., V., Harnden, F. R., Jr. & Rosner, R.: 1996, *Astrophys. J. Suppl.* **102**, 75

Panagi P. M., O'Dell M. A., Collier Cameron A., & Robinson R. D.: 1994, *Astron. Astrophys.* **292**, 439

Panagi P. M., O'Dell M. A.: 1996, *Astron. Astrophys. Suppl. Ser.* **121**, 213

Randich S., Schmitt J.H.M.M., Prosser C. F., Stauffer J. R.: 1996, *Astron. Astrophys.* **305**, 785

Stark A. A., et al. 1992, *Astrophys. J. Suppl.* **79**, 77

Westerlund B., Garnier R., Lundgren K., Pettersson B., Breysacher J.: 1988, *Astron. Astrophys.* **76**, 101