

X-RAY OBSERVATIONS OF THE YOUNG OPEN CLUSTER BLANCO 1. THE XMM-NEWTON VIEW

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ABSTRACT

We present the analysis of a 50 ks XMM-Newton observation of the young, metal-rich open cluster Blanco 1. In the sum of EPIC MOS 1, MOS 2 and pn data we have detected 190 X-ray sources, 36 of them having as cluster member as optical counterparts. We have analyzed the X-ray spectra and time variability of the light curves of the cluster sources. Coronal spectra of solar mass stars are characterized by two thermal components at 0.3 and 1.0 keV, with comparable emission measure. One late-A type member shows a coronal spectrum remarkably different from that of solar-type members, thus suggesting an intrinsic difference in the corona production mechanism. The X-ray luminosity distribution of M-type stars suggests a difference with respect to that of coeval, less metal rich Pleiades M-type stars. Short time scale variability is commonly detected in Blanco 1 star coronae, with M-type stars being more variable than G-type stars. Flare-like events are common but smooth modulations in solar mass stars are also detected. Detailed analysis of two subsequent flares observed in a solar-like cluster star allows us to infer the geometric size and morphology of the coronal structure underlying the flares. An arcade composed of tens of small loops is a likely description of the flaring structure, with possibly the same structure responsible for both flares. On the 6-yr time scale of a comparison with previous ROSAT-HRI observations there is no evidence of an analog of the 11-yr solar cycle. Thus any variability resulting from stellar cycles, if present in young and active stars, must have a lower amplitude (or different cycle periods) than observed for the Sun.

Key words: X-ray: stars – Stars: activity – Stars: flare — Open clusters and associations: individual: Blanco 1

1. INTRODUCTION

Blanco 1 is a young open cluster with age similar to the Pleiades (~ 100 Myr) and high metallicity ($[\text{Fe}/\text{H}] = +0.23$, Edvardsson et al., 1995). Its distance from the galactic plane is larger than the scale height of open cluster systems thus suggesting a peculiar origin. These properties make Blanco 1 an interesting target for studying the X-ray activity in young, metal rich stars. The cluster is sparse

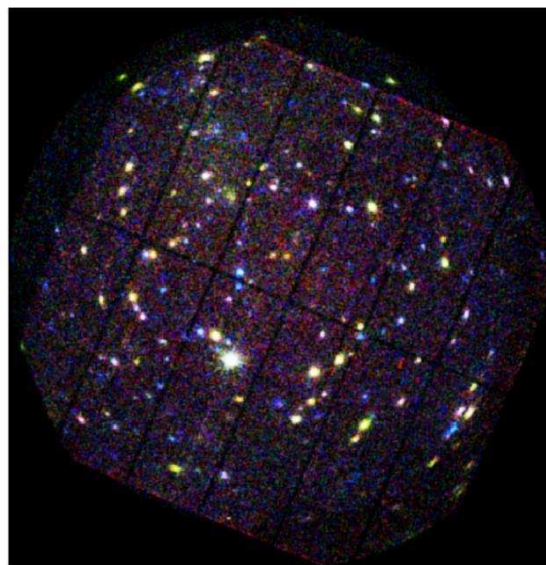


Figure 1. Summed image of EPIC MOS 1, MOS 2 and pn data. The colors in the electronic version code the following bands: red 0.3–0.7 keV; green 0.7–1.5 keV, blue 1.5–4.5 keV. Blanco 1 stars are yellow-green sources. Since the cluster is at high galactic latitude, several extragalactic sources are present. They are bluish sources because of their harder spectrum.

and it is composed of ~ 210 stars (Panagi & O'Dell, 1997), at a distance of ~ 250 pc. We present a X-ray study of Blanco 1 based on XMM-Newton observations.

2. THE OBSERVATION AND SOURCE DETECTION

The observation has been obtained during orbit nr. 0461 of XMM-Newton with the EPIC camera and the *Medium* filter. The nominal exposure time was 50 ks, and only a segment of 0.75 ks has been discarded because of high background rate. The sum of EPIC MOS 1, MOS 2 and pn images is shown in Fig. 1.

Source detection has been performed in the 0.3–5.0 keV band on the sum of MOS 1, 2 and pn data with PWXDETECT code, based on wavelet transform analysis and developed at the INAF-Osservatorio Astronomico of

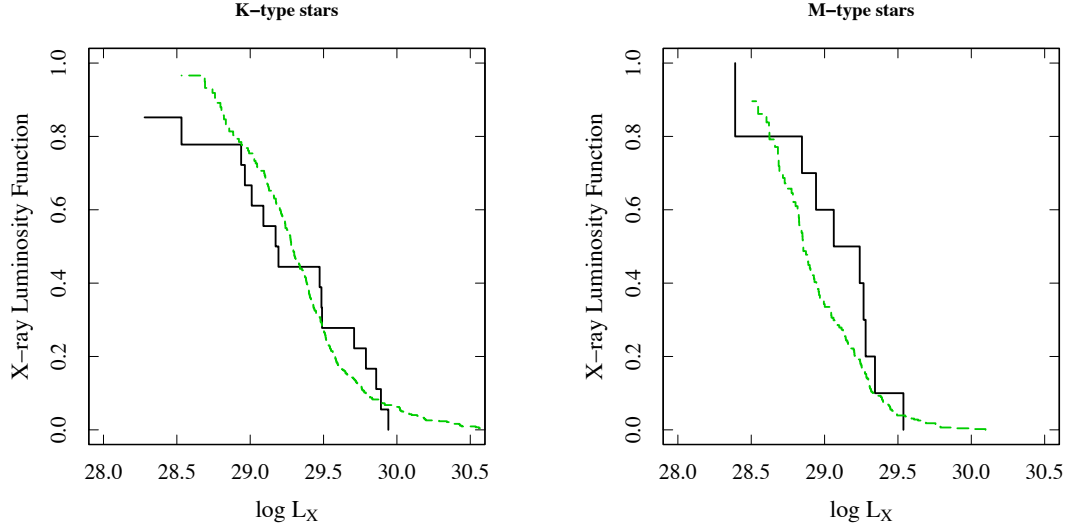


Figure 2. Kaplan-Meier estimators of X-ray Luminosity Distributions for dK stars (left panel) and dM stars (right panel) in Blanco 1 cluster (solid line) and Pleiades (dashed line).

Palermo. We have detected 190 sources, 36 of them among cluster members. All dF and dG stars in the field of view and 80% and 90% of dK and dM stars, respectively, have been detected. For dK and dM stars of Blanco 1 – the largest spectral type subsamples – Kaplan-Meier estimators of the X-ray Luminosity Distributions stars have been calculated and compared to those of Pleiades (Micela et al. 1999). Blanco 1 dM stars are marginally more luminous than Pleiades ones (see Fig. 2).

3. SPECTRA OF STELLAR CORONAE

The spectra of the six cluster sources with more than 1000 counts have been analyzed with global fitting technique. Spectra of dG and dK stars are well described with 2 thermal components: $T_{cool} \sim 0.3$ keV and $T_{hot} \sim 1$ keV. The spectrum of the only A-late type star (Fig. 3) has a different shape, consistent with a 1-T model at ~ 0.6 keV and suggesting an origin of the X-ray emission of this star different from that of later type stars.

4. X-RAY TIME VARIABILITY

Short time scales. We have found that 14 out of 36 detected stars are variable at a confidence level of 99% accordingly to the Kolmogorov-Smirnov test on unbinned arrival photon times. M-type stars are more variable than G- and K-type stars. Variable source light curves present often flares, especially in the lowest mass star cases (see top row in Fig. 4). In some cases a secondary pulse is observed after the first one, suggesting a sort of triggering

mechanism (e.g. top left curve in Fig. 4). In other cases, mainly in solar mass stars, smooth variations are observed (curves in the bottom row of Fig. 4).

Long time scales. The comparison of L_X in 0.1-2.4 keV bandpass measured with ROSAT-HRI in 1996 (Micela et al. 1999, Pillitteri et al. 2003) and XMM-Newton shows that variations are within a factor two (Fig. 5). In the Sun, the variations in a similar band and time scale are expected to be a factor ~ 10 because of the presence of the 11-yr cycle (Micela & Marino 2003). Our result suggests that (if any) analogs of solar cycles in young Blanco 1 stars should be different by variability amplitude and/or cycle period. The lack of analogs of solar cycles has been also reported in the 140 Myr young stars of the open cluster NGC 2516, by analyzing a series of XMM-Newton observations at distance of 20 months Pillitteri et al. (2004) and the younger stars (20 Myr) of IC 2391 open cluster (Marino et al., 2004, these proceedings).

5. FLARES AND CORONAL STRUCTURES

Two flares have been observed in the G-late type star ZS 76. The light curve shows the two impulses at a time distance of ~ 15 ks, both with e-folding decay time of ~ 1.5 ks (cf. top right panel in Fig. 4). Through time resolved spectroscopy of the two flares we have estimated the size of the flaring loops with the method presented in Reale et al. (1997) and Reale & Micela (1998) which is based on hydrodynamical models and extensive numerical simulations of flare events. Spectrum best fit parameters of

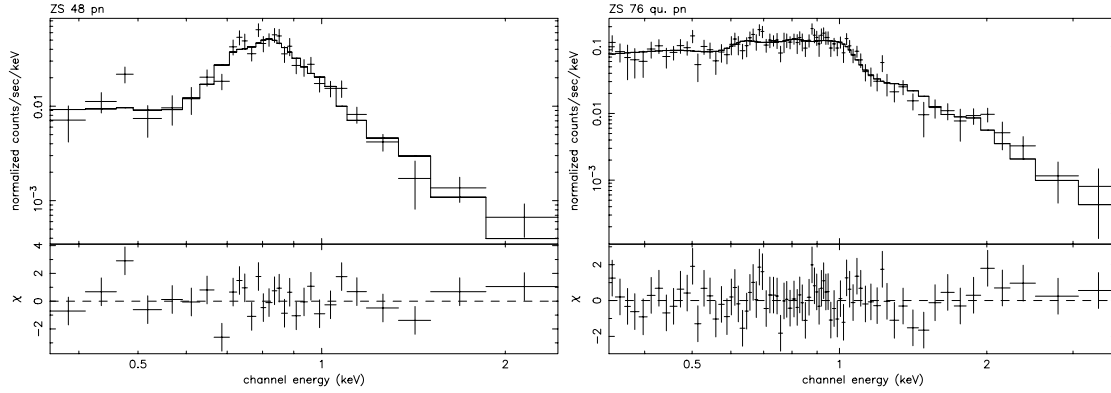


Figure 3. X-ray spectra of two cluster stars: ZS 48 (spectral type: A9, left panel) and ZS 76 (spectral type: G9, quiescent X-ray spectrum, right panel).

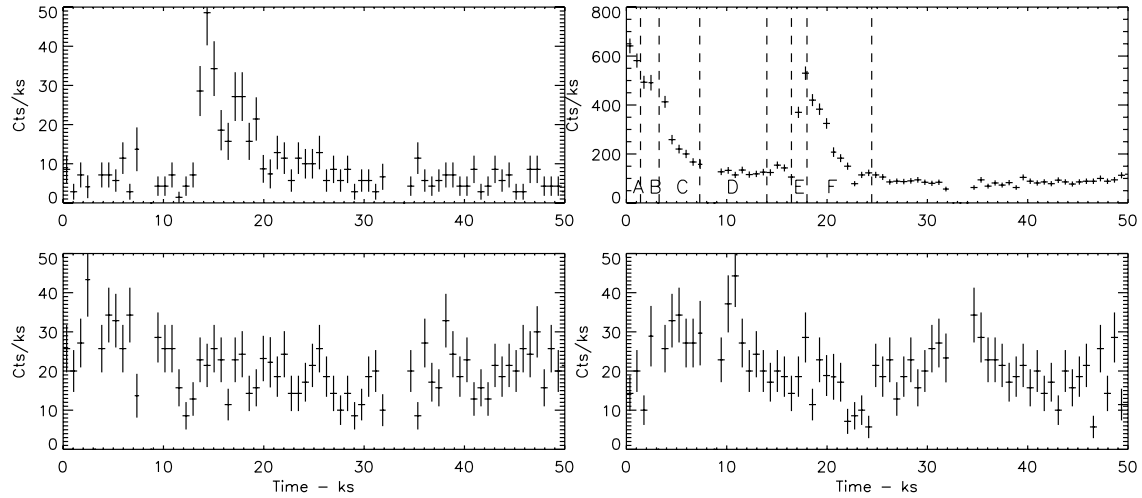


Figure 4. Examples of X-ray light curves of Blanco 1 stars: flares in the top row, smooth variations in the bottom row.

the two flares and the properties of the flaring structures are reported in Table 1 and 2. The large emission measure at the flare peaks and the density estimates from Rosner, Tucker and Vaiana (1978) scaling laws lead to conclude that an arcade of 20–30 of identical loops rather than a single loop has been ignited. The arcade possibly hosted both flares. A simplified scenario is shown in Fig. 6.

6. SUMMARY

We have presented the analysis of a 50 ks XMM-Newton observation of the young, metal rich open cluster Blanco 1. X-ray spectra of solar mass stars are described with 2-T

models (temperatures: $kT = 0.3$ and 1.0 keV). One A-late type star shows a different spectrum shape, described by 1-T model at 0.6 keV. Variability on short time scales is more frequent in M-type stars than in G-type stars. Comparison with previous ROSAT data does not evidence variability amplitudes similar to those expected by 11-yr solar cycle. From the detailed study of two flares in a cluster member we infer that an arcade composed of a few tens of small loops could be the likely flaring region.

REFERENCES

Edvardsson, B., Pettersson, B., Kharrazi, M., & Westerlund,

Table 1. Spectral fitting parameters for each temporal segment of the flares in the star ZS76. In parentheses the 10% and 90% error ranges are reported.

Flare 1	Segment	log kT (K)	log EM (cm ⁻³)	χ^2 (dof)	P($\chi > \chi_0$)
	A	7.57 (7.48 – 7.71)	53.92 (53.86 – 53.98)	0.90 (32)	63%
	B	7.41 (7.34 – 7.52)	53.68 (53.62 – 53.74)	0.96 (30)	53%
	C	7.37 (7.26 – 7.54)	53.42 (53.30 – 53.50)	0.85 (32)	71%
	D	7.30 (7.15 – 7.50)	53.26 (53.10 – 53.34)	0.80 (33)	75%
Flare 2	Segment	log kT (K)	log EM (cm ⁻³)	χ^2 (dof)	P($\chi > \chi_0$)
	E	7.48 (7.38 – 7.58)	53.62 (53.54 – 53.68)	0.78 (24)	76%
	F	7.06 –	53.02 (52.92 – 53.08)	1.00 (32)	46%

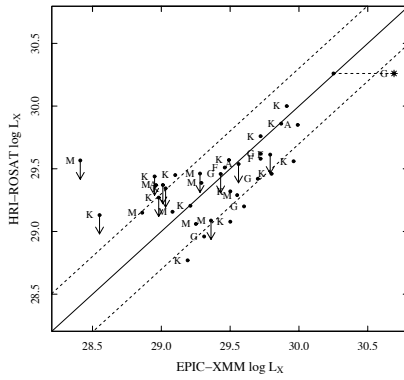


Figure 5. Scatter plot of X-ray luminosities in the ROSAT band (0.1–2.4 keV) of Blanco 1 stars as measured by EPIC XMM-Newton and ROSAT-HRI.

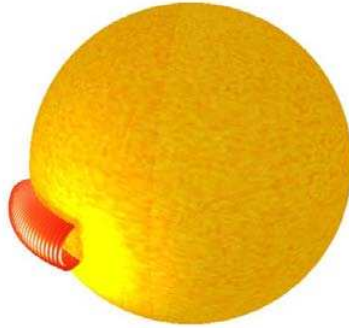


Figure 6. Sketch of the flaring arcade on the star ZS 76.

- B. 1995, A&A, 293, 75
 Micela, G., Sciortino, S., Harnden, F. R., Kashyap, V., Rosner, R., Prosser, C. F., Damiani, F., Stauffer, J., & Caillault, J.-P., A&A, 341, 751
 Micela, G., Sciortino, S., Favata, F., Pallavicini, R., & Pye, J. 1999, A&A, 344, 83
 Micela, G. & Marino, A. 2003, A&A, 404, 637

Table 2. Parameters derived for flares 1 and 2 from spectral fitting and from loop scaling laws. The uncertainty range of T_{max} is derived from the values in Table 1.

	Flare 1	Flare 2
τ_{LC} (ks)	1.4 ± 0.2	1.5 ± 0.2
$\zeta^{(1)}$	0.8 ± 0.2	~ 1.3
$T_{max}^{(2)}$ (10 ⁶ K)	66 (52 – 95)	52 (40 – 68)
L (10 ⁹ cm)	8 ± 4	~ 13
$L_X^{(3)}$ (10 ³⁰ ergs/sec)	9.8	9.2
$E_{tot}^{(4)}$ (10 ³⁴ ergs)	1.4	1.4
$p^{(5)}$ (10 ³ dyn/cm ²)	14	4
$n_e^{(6)}$ (10 ¹¹ cm ⁻³)	8	4
$V^{(7)}$ (10 ³⁰ cm ³)	1.3	2.6
$E_H^{(8)}$ (10 ³¹ erg/s)	5.3	1.6
$N_{loop}^{(9)}$	~ 30	~ 20

¹ Slope of the decay in the n-T diagram

² Estimated loop maximum temperature at the flare peak

³ X-ray luminosity at the flare peak (0.3 - 5 keV band)

⁴ Total emitted energy

⁵ Maximum pressure of the flaring loop estimated from the loop scaling laws Rosner et al. (1978)

⁶ Particle density at the location of the loop maximum temperature estimated from loop scaling laws Rosner et al. (1978)

⁷ Volume of the flaring region estimated from the maximum emission measure and from the estimated density

⁸ Maximum heating rate estimated from the loop scaling laws Rosner et al. (1978) and assuming the volume V

⁹ Number of loops filling the flare volume, assuming an aspect $r/L = 0.1$ for a single loop.

- Panagi, P. M. & O'Dell, M. A. 1997, A&AS, 121, 213
 Pillitteri, I., Micela, G., Sciortino, S., & Favata, F. 2003, A&A, 399, 919
 Pillitteri, I., Micela, G., Marino, A. & Sciortino, S. 2004, Mem. Societa Astronomica Italiana, 75, 440
 Pillitteri, I., Micela, G., Sciortino, S., Damiani, F. & Harnden, F. R. Jr. 2003, A&A, 421, 175
 Reale, F., Betta, R., Peres, G., Serio, S., & McTiernan, J. 1997, A&A, 325, 782
 Reale, F. & Micela, G. 1998, A&A, 334, 1028
 Rosner, R., Tucker, W. H., & Vaiana, G. S. 1978, ApJ, 220, 643