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X-ray properties of NGC 2516 open cluster

A. Marino[1], I. Pillitteri[1], G. Micela[2], and G. Peres[1]

[1] Dipartimento di Scienze Fisiche & Astronomiche, Sez. di Astronomia, Università di Palermo, Piazza del Parlamento 1, 90134 Palermo, Italy
[2] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, 90134 Palermo, Italy e-mail: marino@.astropa.unipa.it

Abstract. We present the results of a study of X-ray properties of the NGC 2516, obtained with a series of XMM-Newton observations. Deep X-ray photometry has been obtained by summing up six EPIC observations, for a total of 105 ks, thus increasing the sensitivity in the X-ray band in this region by a factor 5 with respect to all previous surveys. Coronal spectra of solar mass stars are generally well described by one or two plasma thermal model, with typical temperatures ranging in 0.5-2.0 keV interval. We have studied the X-ray luminosity functions for different spectral types, confirming that G-M type stars are statistically less luminous than stars in the coeval Pleiades. Analysis of X-ray light-curves shows that only a small fraction of cluster members are variable on short time scales. X-ray variations are also studied on longer time scales.

Key words. X-ray: stars – Stars: activity – Stars: early-type – Stars: late-type – Open clusters and associations: individual: NGC 2516

1. Introduction

Open clusters, providing large, chemically homogeneous, and well dated samples of stars, are ideal laboratories to study coronal emitters. NGC 2516, also called the "Southern Pleiades", is a rich and young open cluster in the constellation of Carina, observed several times with XMM-Newton observatory. At a distance of ∼ 387 pc (Jeffries et al. 1997), the cluster contains about 1300 known members spanning all spectral types so enabling the study of different processes driving the X-ray emission from stars of different internal structure. NGC 2516 was observed with ROSAT (Dachs & Hummel 1996; Jeffries et al. 1997; Micela et al. 2000) and Chandra (Harnden et al. 2001; Damiani et al. 2003; Wolk et al. 2004). The observations discussed in this paper have been obtained with XMM-Newton, and their sum permits to obtain the deepest sensitivity in the X-ray band of the cluster.

Send offprint requests to: A. Marino

2. Observations and data analysis

The cluster has been observed many times with XMM-Newton during the first two years of calibration operations. We used data from six EPIC observations, spanning 19 months with exposure times, screened to exclude high background, ranging from 6 ks to ∼ 20 ks each. The data have been processed using the XMM-Newton Science Analysis System 6.0.0. Sources detection and X-ray photometry for the sum of all the MOS and pn exposures,

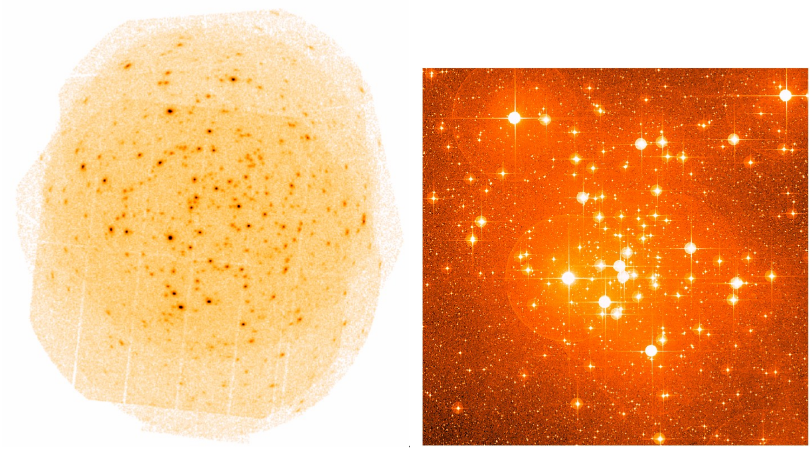

Fig. 1. On the left: MOS1 + MOS2 + pn X-ray images of the six EPIC observations. On the right: the optical image of NGC 2516.

as well as for single MOS and pn exposures, have been obtained in the 0.3 - 5.5 keV bandpass using the Wavelet Detection code developed at the INAF - Osservatorio Astronomico di Palermo (Damiani et al. 1997a,b). In the summed data set, we have detected 431 X-ray sources, 235 identified with cluster members of all spectral types. The two images in Fig. 1 show the sum of the X-ray image of EPIC fields and the corresponding optical image of the cluster.

3. Spectral analysis and L_x distribution functions

The spectra of G, K and M type stars are well described with one or two thermal components (at $kT_1 \sim 0.5$ keV and $kT_2 \sim 2.0$ keV), similar to coronae of stars in other clusters, as Pleiades (Briggs & Pye 2003), Blanco1 (Pillitteri et al. 2004), IC 2391 (Marino et al. 2005), etc.

For F to M spectral types, we have constructed the Kaplan-Meyer estimators (Feigelson & Nelson 1985) of the distribution of L_x (see Fig. 2), which gives the fraction of stars with L_x greater than a certain value taking into account the upper limits. Fig. 2 also shows by comparison the distributions of the Pleiades. Altough contamination by less active field stars could be present among upper limits, G, K and M stars in NGC 2516 are significantly less luminous than those of the Pleiades; a possible explanation is a lower rotational rate in the NGC 2516 stars with respect to Pleiades and/or an older age.

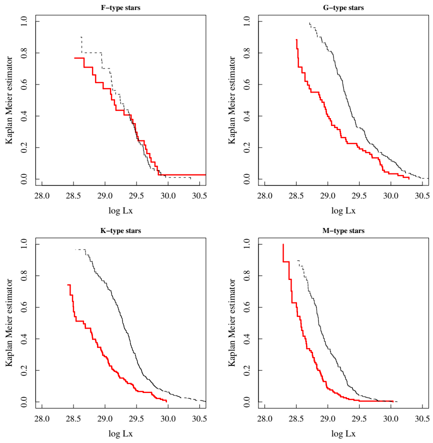

Fig. 2. Cumulative distribution of X-ray luminosities of NGC 2516 stars for various spectral types, evaluated with Kaplan Meyer estimators (thick lines, Pillitteri et al. (2005)), and the distributions of Pleiades (thin lines, Micela et al. (1999)).

4. Timing analysis

Variability on short-time scale is not very common among NGC 2516 members (Fig. 3) likely

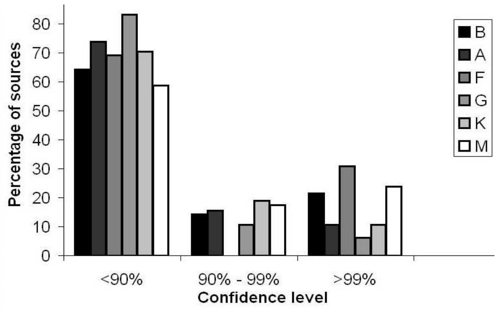

Fig. 3. Results of the K-S test for member stars of different spectral type.

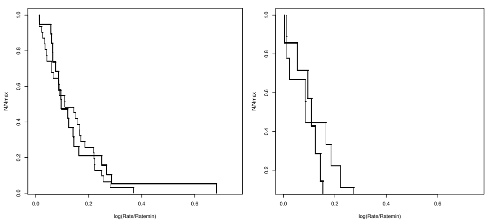

Fig. 4. The Time XAD for dF7-dK2 (left) and dK3-dM (right) on short ($\leq$ 1 day, Obs. 4-5, 2-6, thin line) and long ($\sim$ 17 months, Obs. 1-3, thick line) time scales.

because the poor statistics. The Kolmogorov-Smirnov test applied to the X-ray photon time series shows that only a small fraction (12%) of the members of NGC 2516 are variable with a confidence level $\geq$99%, with a maximum fraction of 30% among F stars.

4.1. Time X-ray distribution functions

Since the six individual observations are spread in 19 months we may study variability properties at different time scales comparing observations taken at different time distance. We derived the Time Amplitude X-ray luminosity Distribution function (Time XAD) for the dF7-dK2 (0.5 $\leq$B-V$\leq$0.99) and dK3-dM (B-V >0.9) as in Marino et al. (2003). Time XAD yields the fraction of time that a star spends with a flux higher, by a given factor, than its minimum value; and is constructed taking for each star the ratio between the count rate of the subsample of observations and the minimum one. In Fig. 4 the Time XAD on short (< 1 day) time scales for dF7-dK2 (on the left) and dK3-dM (on the right) stars is compared with that one on long (17 months) time scales. In order to explore the presence of long time scale amplitudes variations, we selected only the stars variable with confidence level < 99%. Both the dF7-dK2 and dK3-dM distributions, on short and long time scale appear very alike, indicating that long-term variations, if exist, must be of much less amplitude than those on short time scales.

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