X-RAY SURVEY OF THE PLEIADIES: DEPENDENCE OF X-RAY LUMINOSITY ON STELLAR AGE

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The study of X-ray emission of stellar clusters, allows to decouple the influence of some individual stellar parameters, as initial conditions, composition and age, on the stellar X-ray luminosity function.

In order to be studied in the soft X-ray band, a cluster must be sufficiently near for its stars to be detected in "normal" observations times (10³ - 10⁴ sec); this means that the cluster must have a maximum distance ≤ 150 pcs. The clusters which meet this requirement are only a few, namely: the Hyades, Ursa Major, Coma and the Pleiades.

A detailed study on the central region of the Hyades has been done by Stern et al. (1981). They have detected X-ray emission above a threshold of 10⁻²⁸.⁵ ergs/sec from ~ 50% of the cluster stars. The median X-ray luminosity for dwarfs G Hyades stars resulted to be ~ 30 times the luminosity of the Sun which is ~ 1 order of magnitude older. Since the Pleiades are even younger than Hyades, a survey of this cluster can improve our knowledge of the dependence between X-ray luminosity and stellar age.

We report here preliminary results from an Einstein X-ray survey of the Pleiades. We have analysed, using the standard Einstein Observatory software a 1° x 1° exposure centered over one of the more luminous stars of the cluster (20 TAU, [B7-III]), taken with Imaging Proportional Counter (IPC) (Giacconi et al., 1979) which is sensitive to X-rays in the energy band .15 - 4.0 KeV with a energetic resolution (ΔE/E) of ~ 1 at 1.0 KeV and a spatial resolution of ~ 1°.

This field contains ~ 62 cluster members out of a total of ~ 270 stars with magnitude lower than 14m. (Hertzsprung, 1947).

The exposure time of the observation sets a detection threshold of ~ 10⁻²⁹.⁵ ergs/sec. With this threshold we have detected 17 distinct X-ray sources; 16 sources are identified with a cluster stars within a distance less than 1°. The probability of a chance identification is ≤ 2.10⁻³. X-ray emission from 2 (out of 8) B stars, 1 (out of 9) A star, 3 (out of 6) F stars, 8 (out of 19) G stars, 2 (out of 20) K stars has been detected. The brightest X-ray sources is Hz 303‡ (spectral type G1), which has Log L_X ~ 30.3.

We give in Table 1 the X-ray luminosities, together with the optical properties, of the detected sources.

The estimated error on the values of the X-ray luminosity is ~ 40% compounded by a statistical error ranging from 10 % to 30%, sistematic errors in instrument calibration < 20% (Harnden et al., 1979), error in the individual cluster member

‡ In the following will use the numeration of Hertzsprung, 1947.

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<table>
<thead>
<tr>
<th>X-ray Source #</th>
<th>$L_X$ [ergs/sec]</th>
<th>Counterpart Hz II #</th>
<th>Sp</th>
<th>$m_V$</th>
<th>$B - V$</th>
<th>Note*</th>
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<td>1E 0340.9+2404</td>
<td>7.2</td>
<td>193</td>
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</table>

* v indicates variable star, f flare star, d binary system.
† Spectral type determined from B-V values (Johnson & Mitchell, 1958; Jones, 1973; Landolt, 1979; Stauffer, 1980) corrected for reddening, using as mean E(B-V)=0.04 (Crawford & Perry, 1976).

Fig. 1 - Dependence of median X-ray luminosity from age for different samples of G stars: a) pre-main sequence stars (Ku & Chanan, 1979; Feigelson & De Campill, 1981); b) main sequence G stars in the Pleiades (present work); c) main sequence G stars in the Hyades (Stern et al., 1981); d) local disk population G dwarfs (Vaiana et al., 1981; Topka et al., 1981; Rosner et al., 1981). Solid line indicates the median value and the error bar represents the uncertainty in age determination. The range of observed luminosities is indicated by •: the lower limit is always fixed by the best detection threshold for each group.
distance < 3\%, and a systematic error in converting counts to flux < 20\% due to the assumed hydrogen column density and source temperature \(N_H = 10^{20.3}\) atoms/cm\(^2\), \(T = 10^{5.6}\) °K).

Only 5 stars (~ 3\% of the stars with comparable limiting magnitude) in the Hyades survey have been detected as X-ray sources with a luminosity above the threshold for the present Pleiades survey. Since the Pleiades are ~ 1 order of magnitude younger than the Hyades, this different behaviour can be attributed to the age difference of the two clusters.

Since have been detected in X-rays ~ 42\% of dwarfs G the value of the median of the X-ray luminosity function is not far from \(10^{26.5}\) ergs/sec. We have plotted in figure 1 this value together with the median of the X-ray luminosity of T Tauri stars, of main sequence G stars in the Hyades, of local disk population G dwarfs. This plot provide evidence of a dependence of the level of the X-ray emission for G stars from stellar age. Fitting a relationship of the type \(L_x \propto \tau^\beta\), \(\beta\) is of the order of 1. The absence of sources identified with M stars, except perhaps the one source without optical counterpart\(\dagger\), may indicate a dependence of X-ray luminosity from age more complex than a simple law of monotonic decrease for all spectral types. In fact, in the nearby sample, the median X-ray luminosity of M stars is higher than that of G stars, while in the Pleiades the upper limit to the X-ray luminosity of M stars is lower than the median luminosity of G stars.

We acknowledge the support of Ministero Pubblica Istruzione, Piano Spaziale Nazionale and CRRNSM.

REFERENCES


\(\dagger\) The optical catalog is complete to \(m_V < 14\), i.e. to late K stars.
DISCUSSION

Richer: Did you detect any X-ray sources that were not visible as stars on the plates? Did you detect the supposed white dwarf member of the Pleiades in the X-ray region?

Micela et al: One of the X-ray source detected in our X-ray observation is not identified with a Pleiades member. However, the published optical catalogue is complete until 14th magnitude (i.e. late-K main sequence stars). The nature of the unidentified X-ray source should be object of more detailed investigation to clear if we are looking at an M main-sequence star belonging to the cluster, or a field star or an object of different nature.