X-RAY SURVEY OF THE PLEIADES: 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 (10^3 - 10^4 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 ($\Delta E/E$) 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 14^m. (Hertzsprung, 1947).

The exposure time of the observation sets a detection treshold 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.

A. Maeder and A. Renzini (eds.), Observational Tests of the Stellar Evolution Theory, 101–104.

TABLE 1

X-ray Source #	L_x [ergs/sec] 10^{29}	Counterpart Hz II #	Sp	m_v	B - V	Note●
1E 0340.9+2404	7.2	193	G7†*	11.29	+0.81	
1E 0341.1+2406	6.3	263	G8*	11.54	+0.88	
1E 0341.3+2356	19.0	303	G9†*	10.48	+0.89	
1E 0341.4+2437	18.0	320	G5*	11.04	+0.88	
1E 0341.5+2425	9.3	345	G8*	11.65	+0.85	
1E 0342.2+2419	5.5	563	B6*	4.31	-0.11	19 TAU
1E 0342.6+2355	6.6	708	G0*	10.13	+0.62	
1E 0342.6+2408	6.0	686	K2†*	13.62	+1.04	f v
1E 0342.7+2403	4.2	761	G1*	10.55	+0.67	
1E 0342.7+2428	8.1	727	F9*	9.70	+0.55	v
1E 0343.3+2402	4.4	956	F0†*	7.96	+0.32	d
1E 0343.3+2347	8.1	980	B6IV*	4.18	-0.06	23 TAU
1E 0343.5+2416	8.7	1032	G8*	11.34	+0.86	v
1E 0343.6+2411	5.1	1100	K3*	12.16	+1.15	f
1E 0343.7+2426	4.3	1122	F4*	9.29	+0.46	
1E 0344.4+2426	14.0	1384	A2*	7.66	+0.21	
1E 0344.6+2413	7.5					

● 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).
* Spectral types based on spectroscopic data (Mendoza, 1956; Wilson, 1963; Herbig, 1962; Kraft & Greenstein, 1969).

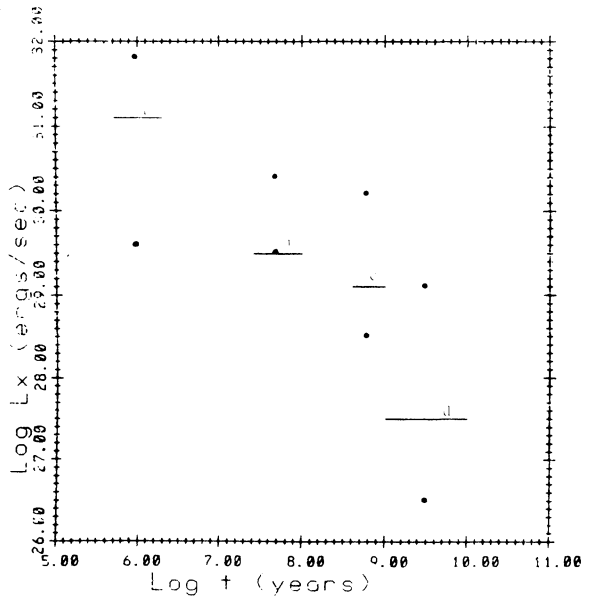

Fig. 1 - Dependence of median X-ray luminosity from age for different samples of G stars : a) pre-main sequence stars (Ku & Chanan, 1979; Feigelson & De Campli, 1981); b) main sequence G stars in the Pleiades (present work); c) main sequence G stars in the Hyades (Stern et al., 1981); d) local disk population 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 treshold for each group.

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distance < 3%, and a sistematic 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 = $10^{6.5}$ °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 $10^{29.5}$ 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 $L_x \propto \tau^{-\beta}$, β is of the order of 1. The absence of sources identified with M stars, except perhaps the one source without optical counterpart‡, 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.

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‡ The optical catalog is complet to $m_V < 14^m$, 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 14^{th} 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.

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