X-ray variability in Rosat observations of M stars

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Abstract.

We present preliminary results of a systematic analysis of X-ray light curves of the PSPC pointed observations of M stars, contained in the CNS3 catalog. A large fraction of the sample stars show significant variations, regardless of the quiescent activity level. Variability is observed at all time scales we have explored, and the variations in X-ray luminosity are well related to variations in the hardness ratio of the spectra.

We discuss the possible effect of variability on the spread observed in the X-ray luminosity function of M stars.

1. The Observations

We have analyzed the X-ray light curves of all M stars, listed in the CNS3 catalog, detected in the ROSAT PSPC pointed observations and available in the public archive. Among them we have selected all the stars detected with more than 40 counts and with off-axis angle $\leq$ 48 arcmin. Our sample consists of 53 stars, for a total of 74 distinct observations. The number of counts of each source is evaluated in a circular region centered on the average position of the observed photons in the (0.1-2.4) keV range and with radius R (arcsec) ranging from 2' for sources on the axis of the telescope and 5' for the sources at large off-axis. The background is measured in an annulus, centered on the same centroid, with internal radius R+25 arcsec and the external one R+50 arcsec. In some cases we have made "pie cuts" to exclude the contribution of nearby intense sources.

2. Time variability in Rosat observations

We have applied the Kolmogorov-Smirnov test to all the stars of our sample. The results are reported in Tab. 1. Variability is present on many time scales and does not seem to depend on the activity level. Figs. 1a,b,c show examples of light curves of stars with very different average X-ray luminosity: from 3×10^{27} (Gl 866) to 3×10^{29} erg/sec (Gl 490). In most cases we cannot derive the characteristics of the variability because of the temporal gaps inside each observation.

We have assumed that the minimum luminosity observed for the i-th star corresponds to its quiescent level $L_{i,Q}$. Fig. 2 shows the normalized cumulative distribution of amplitude variability (solid line) i.e. of $L_{i,j}/L_{i,Q}$, where $L_{i,j}$ is

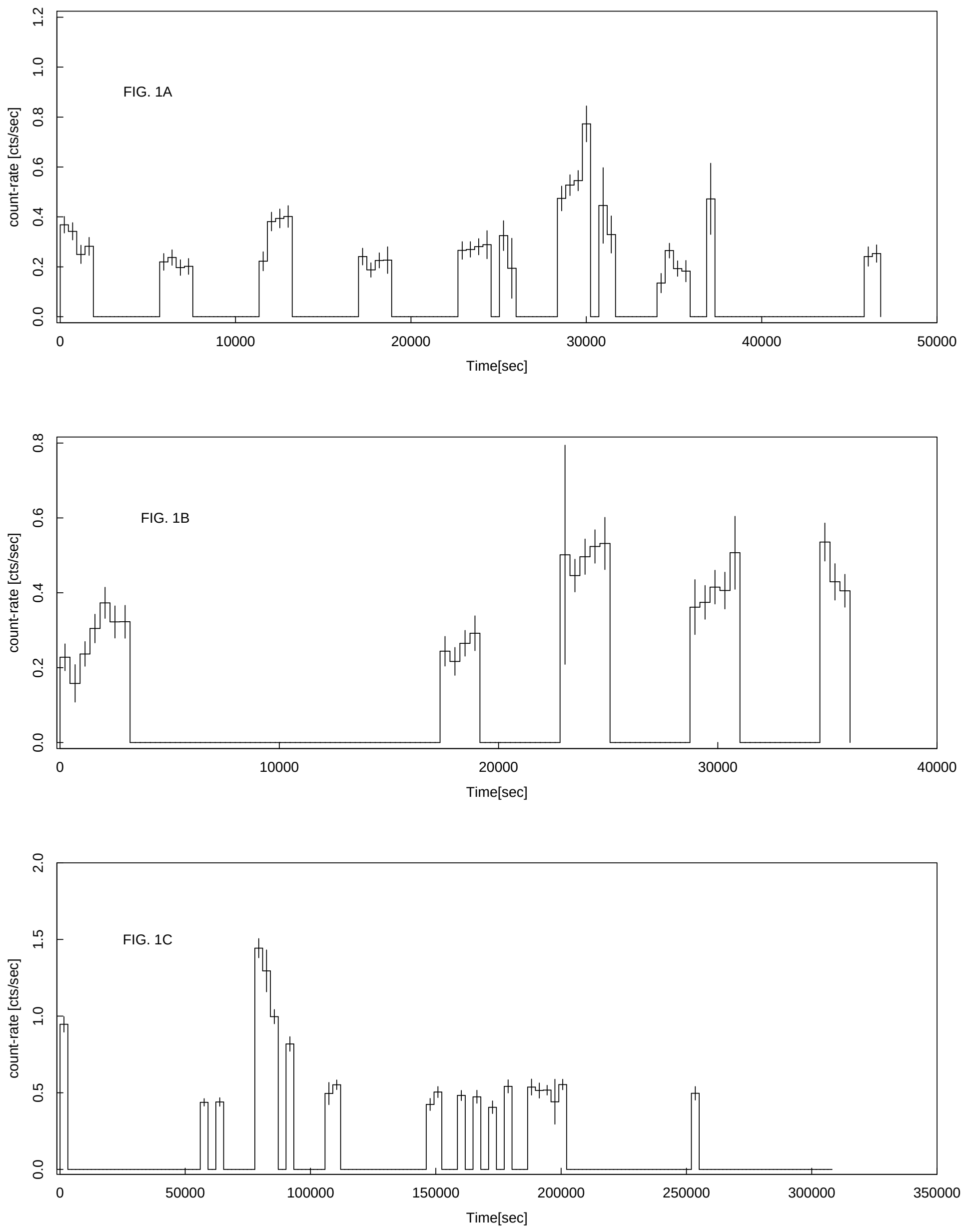

Figure 1. Examples of light curves of stars with very different average X-ray luminosity: In panel 1A we present Gl 866 with $L_x = 3 \times 10^{27}$, in panel 1B, GJ 1207 with $L_x = 3 \times 10^{28}$, and in panel 1C, Gl 490 with $L_x = 3 \times 10^{29}$

Table 1. Results of the K-S test

Number of observations	Confidence level[1]
39	$\geq$99%
5	95%-99%
7	90%-95%
23	$\leq$90%

[1] Confidence level for the rejection of the constant source hypothesis from the K-S test.

the X-ray luminosity of source i during the observing time j.
For comparison we report in figure the analogous distributions for ρ Oph (IPC data, Montmerle et al. 1983, dotted line) and for the Sun in the (2-10) Å range (dashed line, Drake 1971). We note that both distributions are similar to that of our dM stars.
Comparing the range of the X-ray luminosity function of M stars (Barbera et al. 1993, Schmitt et al. 1995) and that of our amplitude distribution function, we see that the variability on time scale less than a few years may account for only a small fraction of the spread observed in the luminosity function.

3. X-ray spectra and luminosity

We have computed the spectral hardness ratio as:

$$HR = \frac{H-S}{H+S}$$

where S is the sum of photon counts over the pulse height channels between 11 and 41 (0.11-0.42 keV), and H the sum of those between 42 and 247 (0.42-2.4 keV). To derive the conversion factor from count rate to flux we have generated 40 single-temperature spectra in the (0.1-1) keV range, and computed the hardness ratio for each of them.

We have determined the count rate, flux, luminosity, and HR in different time intervals of the relevant observations. Fig. 3 shows the scatter plot of L_x vs. HR for the stars of our sample. Asterisks represents stars with only one time interval available. In the other cases, different symbols represent different stars. For most stars, data points tend to occur along different lines, all with similar slope.

4. Long term variability

A number of stars in our sample have been observed with the EINSTEIN/IPC, allowing the analysis of possible variability on a time scale comparable with that of the solar cycle.

Fig. 4 shows the scatter plot of Log(L_x) measured with the PSPC (one value for each observational time interval) versus Log(L_x) measured with the IPC

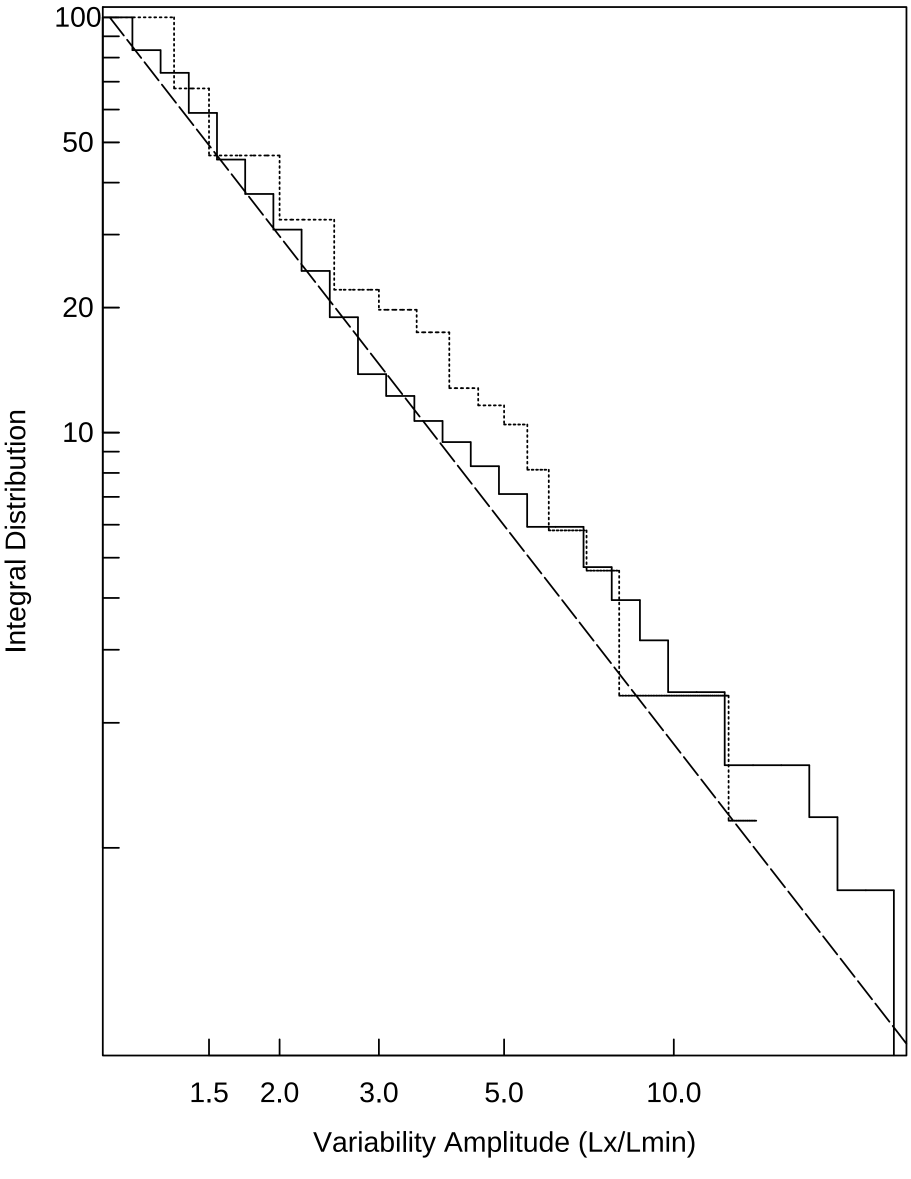

Figure 2. Normalized cumulative distribution of amplitude variability (solid line). For comparison we report in figure the analogous distributions for ρ Oph (IPC data, Montmerle et al. 1983, dotted line) and for the Sun in the (2-10) Å range (dashed line, Drake 1971)

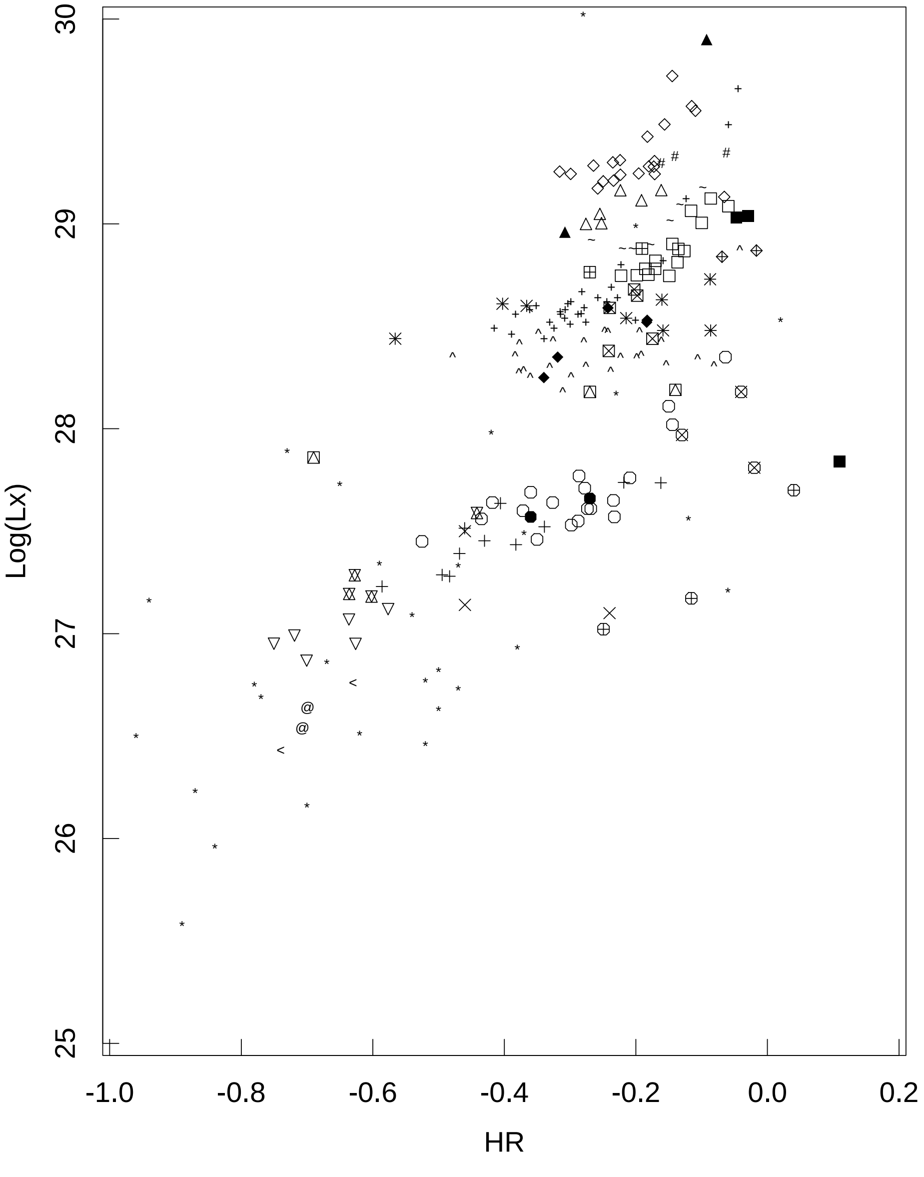

Figure 3. Scatter plot of L_x vs. HR for the stars of our sample. Asterisks represents stars with only one time interval available. In the other cases, different symbols represent different stars. For most stars, data points tend to occur along different lines, all with similar slope.

(averaged on the IPC observation, Barbera e al. (1993)). Given the difference of the two instruments and all the difficulties in cross calibrating the spectral responses, we do not consider as significant any variability within a factor two, i.e. inside the region of the plot enclosed by the lines. It is clear from the figure that the mean X-ray luminosity has changed by more than a factor two for only $\sim 20\%$ of the sample, consistently with the distribution in Fig. 2 obtained from PSPC data.

It is worth noting that PSPC data of each star span typically less than one year, whereas Fig. 4 addresses variability on a time scale of approximately a decade. The comparison between figs. 3 and 4 suggests a lack of evidence of long time variability (on time scale of order of ten years) in stars of our sample.

References

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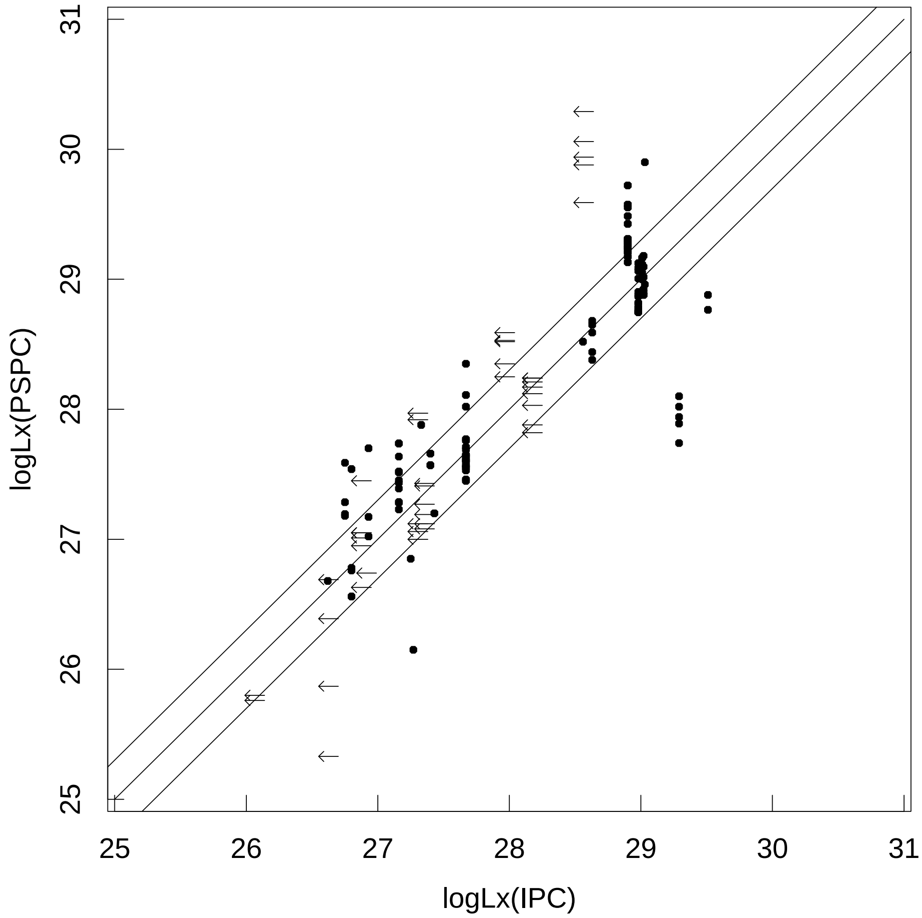

Figure 4. Scatter plot of $\mathrm{Log}(L_x)$ measured with the PSPC (one value for each observational time interval) versus $\mathrm{Log}(L_x)$ measured with the IPC (averaged on the IPC observation, Barbera e al. (1993)).