AN ANALYSIS OF X-RAY FLARES IN PLEIADES STARS

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In the assumption that stellar flares, in analogy to many solar flares, occur in coronal magnetic loops (see Serio 1995), Reale et al. (1995) have devised a method, calibrated with extensive hydrodynamics modeling, to derive quantitative constraints on loop length (L) and the characteristic time scale of heating (τ_{ht}) from quantities observed during the decay phase. We have applied this method to flares observed in the Pleiades. This work is based on those on solar flares by Serio et al. (1991) and Jackimiec et al. (1992) which showed that the *Slope* of the curve traced by flares in the density-temperature (n-T) plane during the decay depends only on the presence of significant heating during the decay (i.e. with e-folding time, τ_{ht}, at least, comparable to the loop thermodynamic decay time, τ_{tdh}). The resulting diagnostics has been succesfully applied to flares observed with SMM (Sylwester et al. 1993). Reale et al. (1993) have extended this modeling to stellar cases analyzing the dependence from gravity, g, and shown that the *Slope* in the (n-T) diagram depends also on the ratio of loop length, L, and pressure scale height $H = 2kT/g\mu$. The time evolution of soft X-ray flare spectra is non-parametrically described in terms of Spectral Shape Indexes (SSI) computed projecting the time resolved spectra observed during flare decay along a set of principal component axes derived from the analysis of a sample of spectra of hydrostatic loop models. For the ROSAT PSPC the value of the 1^{st} SSI explains most of the variance among template loop spectra and is directly related to the *effective* (i.e. as measured by the detector) temperature of coronal plasma. The same data allow also to compute the intensity decay time, τ_{lc}. This is the other

Name	Sp	R_* $[10^{10}]$ (cm)	τ_{lc} $[10^3]$ (sec)	T_{max} $[10^7]$ (K)	EM_{peak} (cm^{-3})	E_{Flare} (erg)	L (10^{10} cm)	H	Heating during Decay Phase & $\tau_{heating}(sec)$
Hz 892	(K0)	5.92	2.8	9.6	1.9 (54)	5.5 (34)	5	42	May Be [$\sim$ 2000]
Hz 1100	K3	5.43	10	3.7	2.5 (53)	2.9 (34)	17	16	No [$<<$10000]
Hz 1516	(K7)	4.87	5	8.2	1.9 (54)	9.6 (34)	2	32	Yes [$\sim$ 5000]
Hz 2411	M3/M4e	2.78	13	6.3	3.2 (52)	4.1 (33)	$<$ 20	17	?
AD Leo	dM3.5e	2.78	0.6	2.5	8.9 (51)	7.7 (31)	0.6	7	May Be [$\sim$ 600]

quantity required to characterize flare properties, given that loop emission intensity scales approximately with the square of plasma density. Hence, in the stellar context the (n-T) plane is replaced by an equivalent plane of **observable** quantities, namely 1^{st} SSI, and (Cnt Rate)$^{0.5}$. The same model flare data points allow also to define two analytical curves in the (τ_{lc}/τ_{tdh}-$Slope$) plane, one for $L/H << 1$ and the other when $L/H \sim 1$, from which one can estimate L with an uncertainty of about 30%.

We have inspected the X-ray light curves of all detected stars in the 4 PSPC images toward the Pleiades clusters (cf. Stauffer et al. 1994; Micela et al. 1996), identifying 3 Pleiades stars and one Hyades star (Hz 2411) showing intense flares with coverage of the flare decay phase appropriate for the outlined analysis method. To this sample we have added for comparison a flare seen on AD Leo, a nearby dMe star. The light curves of sample stars have been subdivided in few segments and background-subtracted spectra have been accumulated in each of them. Given the intensity of Pleiades stars we have been able to collect only hundreds of counts per segment (typical for any PSPC observation of young nearby open clusters). The temperature at the top of the flaring loop has been computed scaling the fitted single-temperature Raymond-Smith model at the observed flare maximum and is adopted to estimate the pressure scale height, H. Relevant data for sample stars are summarized in the table together with the main result of our analysis that reveals the occurrence of substantial heating during the decay phase of the flare on Hz 1516. A more extensive report of these results will be presented by Sciortino et al. (1995).

References

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