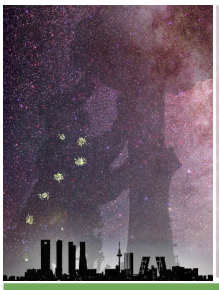

Flare Frequency In The Young Stellar Cluster Trumpler 16

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Abstract

Studies of the solar corona have found evidences of high-frequency, low-energy flaring that would be enough to explain the heating of stellar corona. Using a maximum likelihood algorithm, we characterized the variability of our sample stars and obtained their flare frequency and energy distribution. The selection of stars with infrared excesses has been using an independent extinction index. We detected 129 flares in the 1035 X-ray sources of Trumpler 16. Energy distribution can be described as a power-law of index α = 1.84 ± 0.01. Approximately 11.8% of the stars with a proto-planetary disk showed flare activity during the 88.4 ks exposure observation (and 14.3% of the stars without disks). The flare energy distribution suggests that micro-flaring may play an important roll in coronal heating, although it would not be the unique process. We compared our results with those obtained from Chandra observations of the Cygnus OB2 association and the Orion Nebula Cluster.

Observations

Trumpler 16 and Cygnus OB2 were observed with the ACIS detector on-board the *Chandra X-ray Observatory* (CXO).

	Trumpler 16	Cygnus OB2	ONC
Date	2008 August 31	2006 January 16	2003 January
Instrument	ACIS-I	ACIS-I	ACIS-I
Mode	VERY FAINT	VERY FAINT	VERY FAINT
RA	$10^h44^m47.93^s$	$23^h33^m12.20^s$	$5^h35^m16.80^s$
Dec	-59°43'54.21''	41°15'00.07''	5°23'39.84'
Exposure (ks)	88.4	97.7	838

Table 1: Main data for the observations.

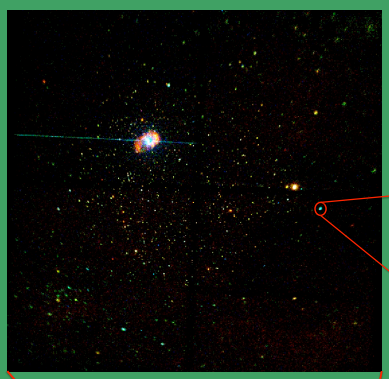


Figure 1: *Bottom:* Optical image of Trumpler 16. *Top:* X-ray image of Trumpler 16 (FOV of Chandra image).

Variability

The maximum likelihood block (MLB) method divides the source's light curve in blocks with constant signal and classifies the blocks into three different levels according with their emission: *Characteristic level, Elevated level,* and *Very Elevated level* (Wolk et al. 2005, Caramazza et al. 2007).

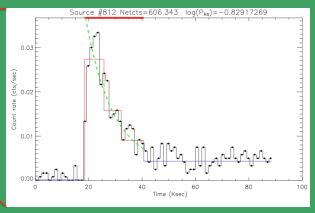


Figure 2: light curve of a flaring Trumpler 16 X-ray source. The red line represents the elevated and very elevated blocks and the blue line represents the characteristic level. The green line indicates an exponential fit for the decay phase.

The measure of the time variation in the count rate, the derivative, help us to define a flare, that is a group of non-characteristic levels beginning with a block for which the ratio between the derivative and characteristic level is above a threshold, here set to $10^{-4.2}$ s^{-1}.

Results

• FLARE FREQUENCY

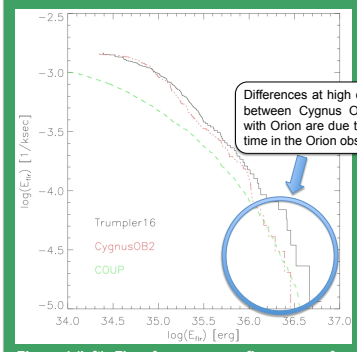
	Trumpler 16	Cygnus OB2	Orion
Sources	997	976	1613
Flares	128	147	1388
Exposure Time	88.4	99.7	838
Flare Frequency	1 in 675 ks	1 in 685 ks	1 in 974 ks

Table 3: Flare frequency of stars in Trumpler 16 compared with those of the Cygnus OB2 and Orion regions.

• FLARE ENERGY DISTRIBUTION

Studies of the solar corona have found solid evidences of small-scale continuous flaring. The flare energy distribution was found to follow a power law:

$$\frac{dN}{dE} \propto E^{-\alpha} \quad \Rightarrow \quad \log N(>E_{flr}) \propto \beta \cdot \log(E_{flr}) + C^{nt} \quad were \quad \beta = \alpha - 1$$



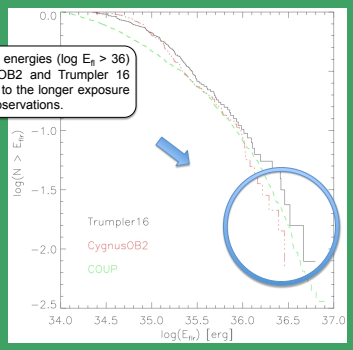


Figure 4 (left): Flare frequency vs. flare energy for the three regions and Figure 5 (right): Cumulative distribution of flare energies for the three regions.

The best match for the power-law index determined from Fig. 4 and Fig. 5 (in the energy range $35.1 < \log E_{fl} < 36.0$) is

β = 0.84 ± 0.1

=> α = 1.84 for Trumpler 16

Region	Slope (α)
Trumpler 16	1.84
Cygnus OB2	2.10
Orion (COUP)	2.05*
Taurus	2.40

Table 4: The power-law index in regions studied to date. *When the Orion exposure is divided into 100 ks segments, α = 1.90, more similar to the value for Tr 16.

• RELATIONSHIP DISK-FLARE

We selected stars with circumstellar disk using an extinction-independent index (Damiani et al. 2006):

$$Q_{ABCD} = (A-B)-(C-D) \times E_{A-B}/E_{C-D}$$

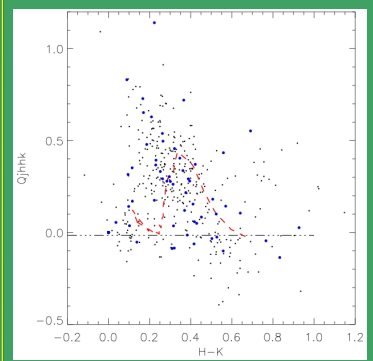
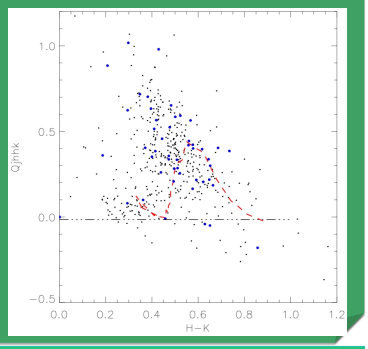


Figure 6 (Left) and 7 (Right): Index Q_{jhhk} vs. (H-K) for Trumpler 16 (left) and Cygnus OB2 (right). The red line is the main sequence, the black dashed line is the limit for the reddened objects. Blue circles represent flaring stars.

	Flaring stars with disk	Flaring stars without disk
	Percentage of stars	
Trumpler 16	11.8 %	14.3 %
Cygnus OB2	9.6 %	10.5 %
	Flare energy (erg·s^{-1})	
Trumpler 16	$1.52 \cdot 10^{36}$	$4.24 \cdot 10^{35}$
Cygnus OB2	$1.21 \cdot 10^{35}$	$3.78 \cdot 10^{35}$

Table 5: Comparison between the flaring star with and without disk.



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