THE X-RAY FLARE OF π' UMA : TEMPERATURE AND EMISSION MEASURE

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ABSTRACT. *An X-ray flare from the star π^1 UMA has been observed by EXOSAT on January 31, 1984. The data were collected using the Low Energy Experiment and the Medium Energy Experiment, sensitive to the spectral bands 0.04 - 2 Kev and 1-20 Kev (Landini et al. 1986).*
The temperature and emission measure variations during the flare are deduced under the isothermal assumption. Using a parametrized profile of the differential emission measure, wich is controlled by the conductive flux via the temperature gradient, the comparison with the observed data gives some insight on a " mean loop" model and its power supply.

1. INTRODUCTION

π' UMA (HD 72905) is a solar like star (G0 V) which has been observed with EXOSAT as part of a program devoted to the study of the X-Ray emission from coronae of late type stars (Pallavicini et al. 1988). On January 31,1984 around 16 U.T. a large increase in the counting rate has been measured both by the low energy detector (LE) with the 3 Lexan filter and by the medium energy (ME) detector. A detailed discussion of the data and an isothermal interpretation of the observations have already been given (Landini et al. 1986). Here attention is put to estimate the time evolution of the temperature and emission measure and to evaluate a "mean" model of the flare in ţ ɜrm of a stationary loop.

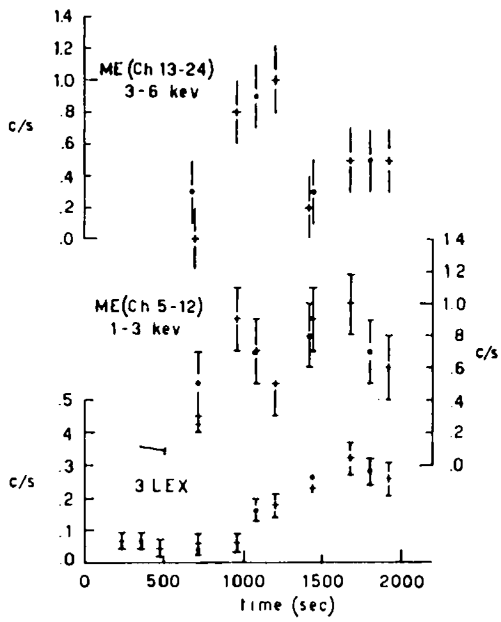

fig.1: *Time history of EXOSAT observation of flare from π' UMa. Starting time t=0 correspond to $15^h\ 43^m\ 20^s$ U.T. of January 31, 1984. Flux data are counts/sec at the earth. Dots indicate data averaged over 240 sec; cross: data averaged over 360 sec.*

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2. THE TIME EVOLUTION OF TEMPERATURE AND EMISSION MEASURE.

Due to the very low counting rate, ME data have been binned in two larger energy intervals concerning channels 5 to 12 (1.1-3 Kev) and 13 to 24 (3-6 Kev). Fig 1 shows the ligth curve of the event measured in the two ME bands and in the 3 Lexan filter (0.04-2 Kev), after background subtraction. Data have been averaged over 240 sec. and 360 sec.; both are shown in the figure.

Since the counting statistics is rather poor and the data concern only three energy bands, the analysis has been developed assuming that the main contribution to the emission come from the quasi isothermal region which is the coronal part of the loop. The power emitted by unit emission measure from the flare plasma has been evalutated in the temperature interval 4.3 < log T< 8.0 and filtered through the effective area of the detectors. By means of this information it is easy to evaluate the emission measure which produces the observed count rate for any temperature from each detector.

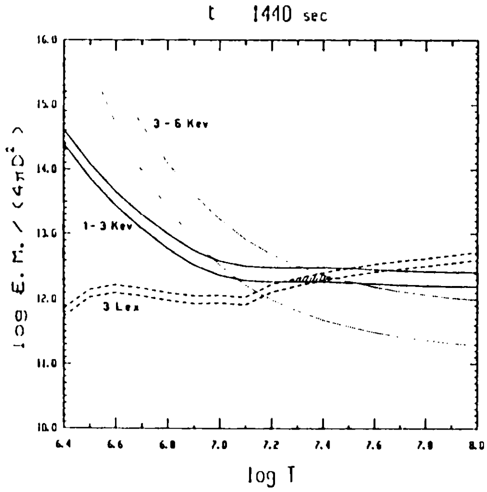

fig.2: *Isothermal analysis; the dashed region shows the temperature and emission measure which satisfy the signals ± errors from all three detectors. Any temperature larger than 3.10^7 °K is a solution. Data at time 1440 sec from the beginning of the event.*

Fig.2 show an example of the procedure applied to data at time 1440 sec. For each energy band, the signal ± the error is used to generate the " *strip* " in the diagram which shows the emission measure versus temperature, compatible with the observation. If the three " *strips* " identify a common region in the diagram, this is the region of the solutions which satisfy all the three observations within the uncertainties.

In fig.3 the temperature and emission measure is plotted as a function of time. For comparison the dotted line shows an example of the time profile of the temperature for a solar flare observed by the SOLRAD satellite using similar spectral bands (Landini and Monsignori Fossi 1979). A typical decay time of about 600 sec. is obtained both in π' UMA and the Sun but the temperature of π' UMA is about twince the solar one. The emission measure remains almost costant all over the flare after a sharp increase in the early phase. Also this time evolution is very similar to the solar case apart from the fact that the "typical" solar emission measures are about 10^{49}-10^{50} cm^{-3}, more than two orders of magnitude lower than the π' UMA flare.

Decay times of several hundred seconds require electron densities of the order of $10^{12}cm^{-3}$, if the radiation is the main cooling mechanism; this number density and the observed temperature claims for pressure very near to 10^4 dyne cm^{-2}.

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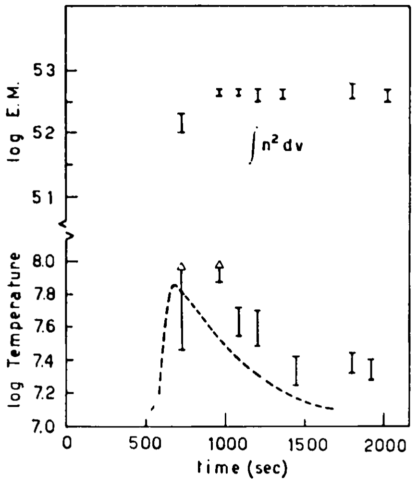

fig.3: *Temperature and emission measure time evolution for the flare of π' UMa on January 31, 1984 at 16 U.T.; e-folding time decay is of the order of 600 sec; temperature evolution for a solar flare (September 3, 1976) is shown for comparison.*

3. A "MEAN" LOOP MODEL OF THE FLARE.

To have some insigth in the "mean" model for the loop, attention has been put on the part of the event where temperature seems to be stabilized ($t \geq 900$ sec). The count rates of ME bands and 3Lexan filter have been integrated and used to evaluate a multi-temperature loop model following a semi-empirical approach which proved to be useful for solar active regions (Monsignori Fossi and Landini,1988).

The following parametric form is assumed for the conductive flux:

$$F = F_o e^{-T_o / T} (T / T_c)^{\beta} [1 - (T / T_c)^{0.5}]^{1/2} = F_o \; f (T, T_c , T_o, \beta)$$

the differential emission measure is therefore:

$$S n^2 (dh / dT) = (p_o^2 S / (4k^2 F_o)) \; (A T^{0..5} / f) \qquad (A = 10^{-6})$$

if costant pressure p_o and cross section S and completely ionized conduction are assumed. The parametrized differential emission measure is used to generate simulated emission for proper selection of the parameters T_o, β, T_c($\equiv$ maximum temperature in the loop). A best χ^2 fit procedure is used to estimate the parameters T_o, β, T_c and (p_o^2S/F_o), which allow agreement between observed and predicted emission.

In order to have enough data, the following channel binning has been used for the ME:

0.89 - 1.81 keV	$1.07 \; 10^{-1} \pm 0.95 \; 10^{-1}$	c/s
1.81 - 2.52 keV	$2.39 \; 10^{-1} \pm 0.69 \; 10^{-1}$	c/s
2.52 - 3.49 keV	$2.37 \; 10^{-1} \pm 0.73 \; 10^{-1}$	c/s
3.49 - 5.00 keV	$2.02 \; 10^{-1} \pm 1.02 \; 10^{-1}$	c/s
5.00 - 6.31 keV	$8.55 \; 10^{-2} \pm 8.00 \; 10^{-2}$	c/s
3 Lexan	$2.30 \; 10^{-1} \pm 0.21 \; 10^{-1}$	c/s

The following results are obtained with a reduced χ^2 less than 1: $\log T_o = 5.6$, $\log T_c = 7.5$, $\beta = 0$.

From the parametric form of the conductive flux it is possible to evaluate in each point of the loop the conductive energy and the enthalpy flux for reasonable low value of the velocity v_o at the base of the loop. By proper selection of the loop cross section S, the loop length and base velocity v_o, the

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energy balance between radiative losses, conductive energy and divergence of the enthalpy flux may be investigated and indication of the distribution of the power supply along the loop may be obtained.

An example of this procedure is shown in fig 4. In this case the cross section, the length and the base velocity have been selected in order to obtain energy balance for pressure slightly smaller than 10^4 dyne cm^{-2} as appears to be required by radiative decay times.

The temperature profile along the loop may be also obtained by integration of the conductive flux along the temperature once the length is known.

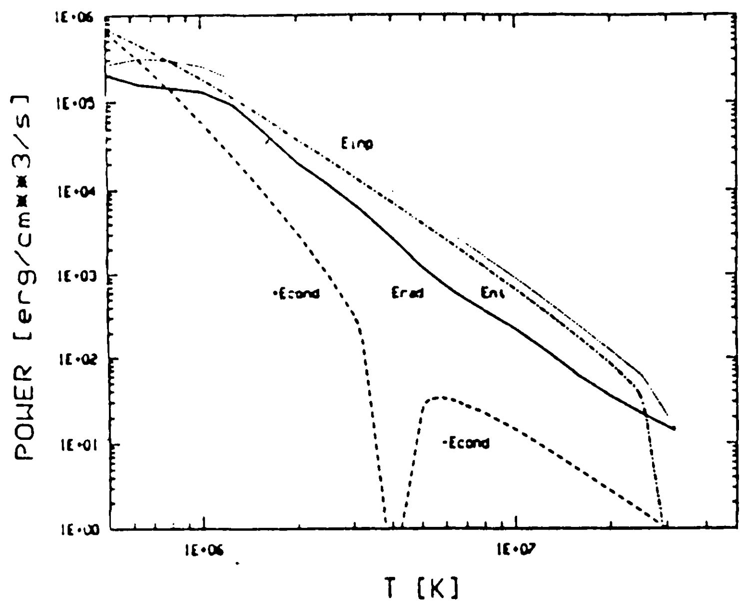

Fig.4: *The energy balance for L= 10^{10} cm, S = 1.7 10^{18} cm^2 and base velocity vo = 3. 10^4 cm/sec. The coronal region of the loop must be heated by an energy supply which decays according to a power law proportional to $T^{-2.5}$ ($n^{2.5}$). The aspect ratio [loop radius/semi-length] is 0.07. Values have been selected in order to obtain coronal number density compatibles with the radiative decay time.*

4.CONCLUSIONS

The time evolution of temperature and emission measure for the flare of π' UMA has similar decay times of those observed for the Sun (~ 600 sec) but attains temperature twice higher and emission measures almost two order of magnitude larger.

The use of a "semiempirical" model of the differential emission distributions inside a costant cross section and costant pressure loop, permits the evaluation of the loop length and temperature profile and allows to investigate the energy balance.

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