

# Temporal Characteristics of Solar Flare of 14 July 2004



## Physics

**KEYWORDS :** Solar flare, SOXS, Multi thermal plasma

Ravindra M. Jadav

Gujarat Arts and Science College, Ahmedabad – 380006.

### ABSTRACT

*We have analyzed here an M class solar flare occurred on 14 July 2004 and detected by SOXS onboard GSAT-2. We have also plotted 4-25 keV energy range at sub keV resolution. Spectro-temporal evolution of this flare suggests that this is a multi-thermal plasma which is a combination of thermal and non-thermal components. The plasma in the solar flare is heated at different temperatures (multi-thermal plasma), and therefore the emission measure varies as a function of the temperature.*

### 1. Introduction

Solar flares are complex transient excitation of solar atmosphere above magnetically active regions of the surface involving enhanced thermal and radio emissions, soft & hard x-rays, cosmic rays and plasma ejection.

During the sudden and brief outbursts, electrons and protons are accelerated to nearly the speed of light. Protons and helium nuclei are thrown down into the chromosphere, causing intense heating there. High-speed electrons and protons are also hurled out into interplanetary space where they can threaten astronauts and satellites. Shock waves can be produced during the sudden, violent release of flare energy, ejecting masses of hot coronal gas into interplanetary space. Some of the intense radiation and energetic particle emission reaches the Earth where they can adversely affect humans.

The key to understanding and predicting solar flares is the structure of the magnetic field around sunspots. If this structure becomes twisted and sheared then magnetic field lines can cross and reconnect with the explosive release of energy. Solar flares are always located near sunspots and occur more often when sunspots are most numerous. This does not mean that sunspots cause solar flares, but it does suggest that solar flares are energized by the powerful magnetism associated with sunspots. When these magnetic fields in a solar active region become contorted, they want to release their pent-up energy, and when they do it is often in the form of a solar flare. This energy is suddenly and explosively released at higher levels in the solar atmosphere just above sunspots. Since solar flares are very hot, they emit the bulk of their energy at X-ray wavelengths.

### 2. Instrumentation

Solar low energy detector (SLD) of Solar x-ray spectrometer (SOXS) onboard Indian geostationary satellite GSAT-2 aims to study high energy and temporal resolution x-ray spectra from solar flares. The SLD comprises of two semiconductor devices, Silicon PIN detector for 4-25 keV and Cadmium Zinc Telluride (CZT) detector for 4-56 keV energy range. Both detectors have 100 ms temporal resolution characteristics, which make them most appropriate for solar flare research.

The X-ray energy spectrum from a typical large solar flare is dominated by soft X-ray line and thermal (free-free) bremsstrahlung emission at  $\epsilon \approx 1-20$  keV, and collisional bremsstrahlung of non-thermal electrons at  $\epsilon \approx 20-1000$  keV (Jain et al. 2000a, 2000b; 2005). The measurements of soft X-ray flux before and during the flare provide a wonderful opportunity to study the soft X-ray characteristics of active region

### 3. Method and Analysis:

We use the OSPEX (Object Spectral Executive) software package inside SolarSoft to analyse the data. The OSPEX is an object-oriented interface for X-ray spectral analysis of solar data. Through this software, the user reads and displays the input data, selects

and subtracts background, selects time intervals of interest, selects a combination of photon flux model components to describe the data, and fits those components to the spectrum in each time interval selected. During the fitting process, the response matrix is used to convert the photon model to the model counts to compare with the input count data.

### Solar Flare data: 14 July 2004

KeV Range	PT (Hrs)	PT (min)	PT (sec)	Peak Value
4 – 5 KeV	5	23	8	8600.55
5 – 6 KeV	5	22	57	22149.5
6 – 7 KeV	5	22	55	43504.3
7 – 8 KeV	5	23	4	20884.4
8 – 9 KeV	5	22	37	11830.7
9 – 10 KeV	5	22	22	6540.41
10 – 11 KeV	5	22	47	4076.36
11 – 12 KeV	5	22	55	2830.75
12 – 13 KeV	5	23	3	1979.04
13 – 14 KeV	5	22	48	1563.01
14 – 15 KeV	5	22	54	895.944
15 – 16 KeV	5	22	23	665.628
16 – 17 KeV	5	22	21	384.36
17 – 18 KeV	5	22	44	262.747
18 – 19 KeV	5	22	58	196.135
19 – 20 KeV	5	22	7	142.187
20 – 21 KeV	5	22	30	104.718
21 – 22 KeV	5	22	18	90.9829
22 – 23 KeV	5	22	9	83.2428
23 – 24 KeV	5	22	8	89.9673
24 – 25 KeV	5	22	33	77.9435
6.2 – 7.2 KeV	5	23	2	43946.8
7.5 – 8.5 KeV	5	22	37	15718.2

**Table 1: Peak count and time at various sub keV energy bands for 14 July 2004 solar flare.**

On 14 July 2004, an M class flare occurred and detected by SOXS. To analyse this flare its raw data is used which is available on soxs website in binary format. Data extraction is done using IDL, OSPEX which may give light curves of desired energy bands. We chose each KeV resolution and generated data files for each KeV band for this flare.

Using IDL and OSPEX data for each KeV range i.e. 4-5 KeV, 5-6 KeV ... 24-25 KeV is extracted for each flare. Table 1 shows peak value and time for each keV band. As we may see from table that the count value is highest at 6-7 keV range.

Various flare related parameters have been identified for this flare. For e.g. start time of a flare is identified as the least time at which the counts crosses the value of average background value plus thrice standard deviation. Peak flux during a flare is the time at which the counts reaches maximum value during flare unless there are more than two points giving a spike before the visible peak. In later case, the spike will be the first peak and the visible peak shall be second peak. Take any such peak, where more three data points contribute, as consecutive peak.

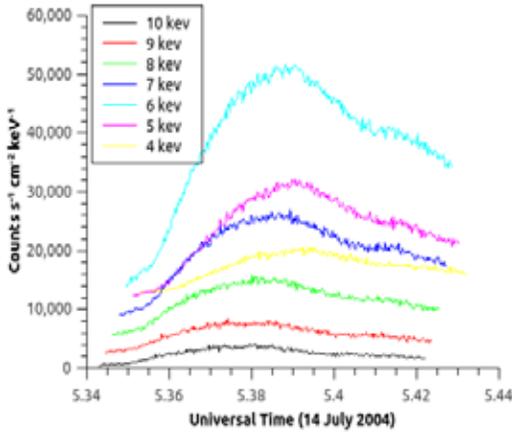


Figure 1: Counts vs time plot for 14 July 2004 solar flare for 4 – 10 keV energy.

Peak time is taken when the flux reaches at peak. Flare end time is taken when at the value after start time at which consecutive 05 count values go below average background plus thrice standard deviation. In case when the post flare phase is seen as quiet period but the values are more than pre flare ground, than take end time as the time when the flare mode levels off. Rise Time is taken at the time between start time and peak time whereas decay time is the time between peak time and end time. Finally impulsiveness indicative of how fast is flare is ejected from the sun is taken as the ratio between peak flux and rise time.

Each curve in Figure 1 is made up of counts at various times for any 1 keV energy band. As shown in figure 1, the highest value of counts is in 6-7 keV energy range however at all energy bands the peak time is almost same within few seconds range. Figure 2-3 are similar curve plots for 11-17 keV, and 18-24 keV respectively. Figure 4 is for 62 keV and 72 keV plots for relatively higher energy bands.

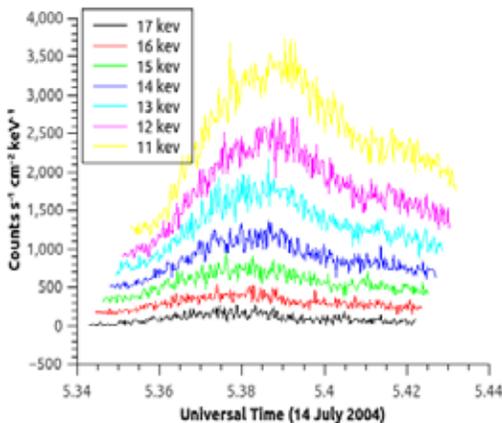


Figure 2: Counts vs time plot for 14 July 2004 solar flare for 11 – 17 keV energy.

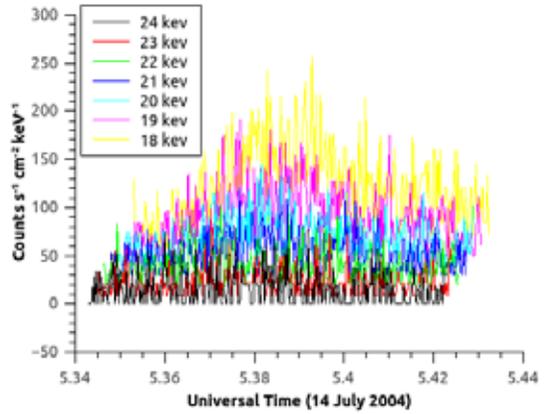


Figure 3: Counts vs time plot for 14 July 2004 solar flare for 18 – 24 keV energy.

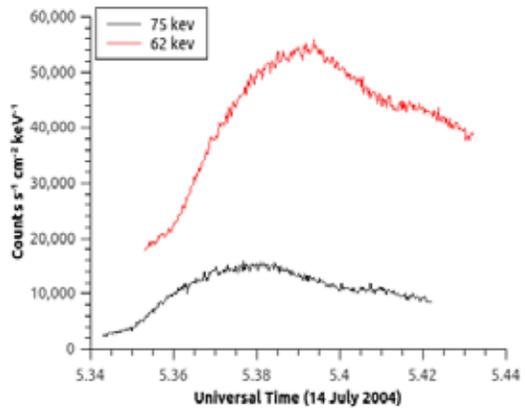


Figure 4: Counts vs time plot for 14 July 2004 solar flare for 62 and 75 keV energy.

**4. Discussion and conclusion:**

We have analyzed here an M class solar flare occurred on 14 July 2004 and detected by SOXS onboard GSAT-2. We have also plotted 4-25 keV energy range at sub keV resolution. Spectro-temporal evolution of this flare suggests that this is a multi-thermal plasma which is a combination of thermal and non-thermal components. The plasma in the solar flare is heated at different temperatures (multi-thermal plasma), and therefore the emission measure varies as a function of the temperature, emphasizes the crucial need to study X-ray spectra with improved energy and temporal resolution (Aschwanden, 2007, 2008). There are strong indications that, in many flares the non-thermal component contains a substantial fraction of the total energy (Jain et al., 2000, 2005; Gan et al., 2001; Lin et al., 2002). The flare-accelerated 10-100 keV electrons appear to contain a significant fraction around 10-50% of the total energy, indicating that particle acceleration and energy release processes are intimately linked.

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