X-ray spectrometers on-board Aditya-L1 for solar flare studies

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Aditya-L1 mission will carry two high-spectral resolution X-ray spectrometers to study solar flares. The soft X-ray spectrometer will cover the energy range from 1 to 30 keV, while the hard X-ray spectrometer will cover from 10 to 150 keV. These two instruments together will provide opportunities to study the plasma parameters during solar flares as well as acceleration mechanisms of energetic particles during the flaring time.

Keywords: Coronal heating, solar flares, X-ray spectrometers.

Introduction

SOLAR flares were first observed by Carrington and Hodgson in 1859 as a sudden increase of brightness for a few minutes on the solar atmosphere. Flares have then been observed regularly in the hydrogen alpha line originating in the chromosphere. The complex nature of structures like different source sizes, associated plasma ejections and Morton waves have been reported. Radio observations during the flaring time indicated that the flares not only heat up the plasma, but also accelerate electrons which produce these radio emissions. In late 1950s when space observations were feasible, flares were well observed in X-ray energies. It has been realized from these observations that a sizeable portion of the flare energy is emitted in hard X-rays. Gamma-ray emissions are also seen during solar flares, making it a phenomenon observed in all wavebands (Figure 1)[1]. It is now understood that although the flaring phenomenon is initiated in the corona, energy is deposited by the flare in all layers of the solar atmosphere (corona, chromosphere and photosphere).

Though solar flares are observed in all energy bands, X-ray energies provide the best observations due to high temperatures generated during the flares. Solar flares are

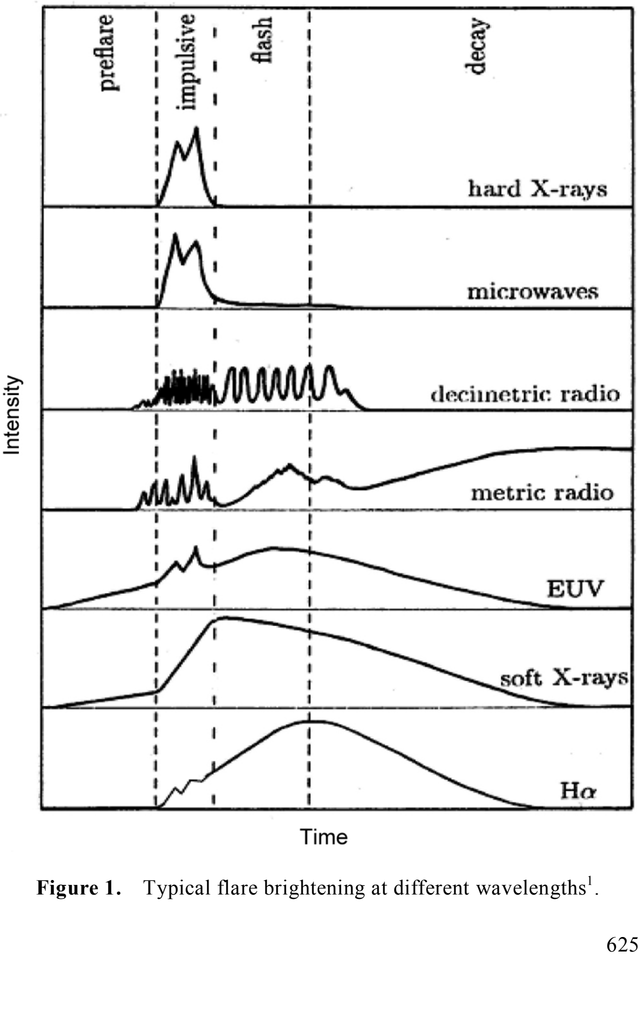

Figure 1. Typical flare brightening at different wavelengths[1].

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classified as A, B, C, M and X by their brightening in the soft X-ray band, with the X-class flare having an energy range 10^{-4} Wm^{-2} (X1) to 10^{-3} Wm^{-2} (X10) with M1 flux smaller by an order to X1 flux, and so on.

Two solar spectrometers covering soft (1 to 30 keV) and hard (10 to 150 keV) X-ray bands will be flown on Aditya-L1 mission to study solar flares and their dynamics.

Overall science objectives

The two X-ray spectrometers covering the energy band from 1 to 150 keV will allow us to carry out the following science objectives: (i) Study of heating mechanisms during the flare[2]. (ii) Quantitative measure of flare energies by measuring the temperature of the plasma (thermal energy) and also studying the acceleration of particles (non-thermal energy)[2]. (iii) Coronal abundance during flare evolution[3]. (iv) Precursor phase activities possibly related to reconnection mechanisms[4]. (v) Time variation of spectral parameters as well as quasi-periodic oscillations, especially seen in hard X-ray energy[5]. (vi) Association of flare and Coronal Mass Ejections (CMEs)[6]. (vii) Prominence eruption and flare trigger[7].

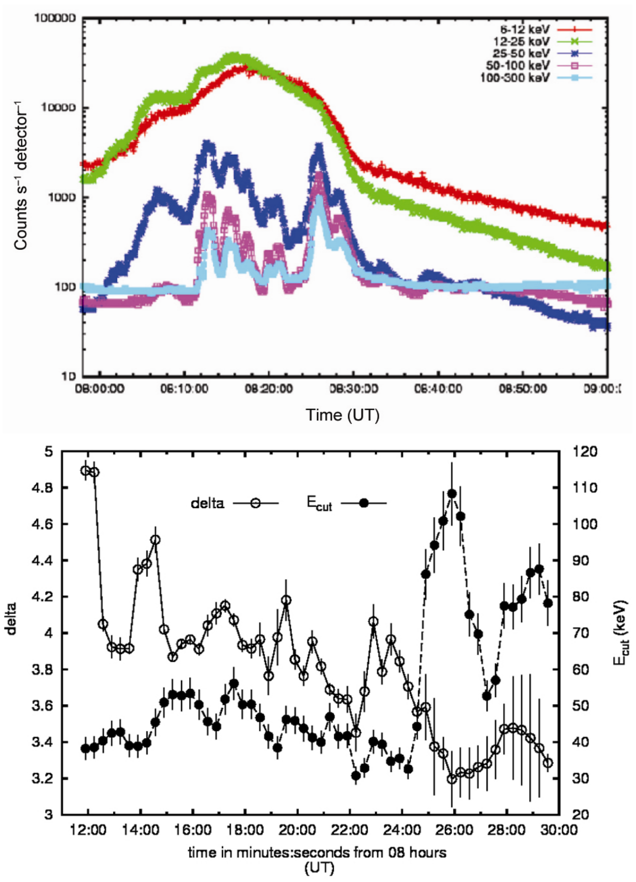

Figure 2. (Top) Light curve of X1 class flare of 19 January 2005 showing pulsations during the impulsive phase. (Bottom) Temporal variation of low-energy cut-off of the hard X-ray emitting electron distribution and its spectral index.

A typical X1 class flare and the spectral parameters of the hard X-ray (HXR) emitting electrons[8] have been studied and plotted in Figure 2 as the flare evolves over time.

Solar Low Energy X-ray Spectrometer

Solar Low Energy X-ray Spectrometer (SoLEXS) will cover the energy band from 1 to 30 keV with a spectral resolution of <4% (i.e. <250 eV at 6 keV). This energy band will help in obtaining the thermal energy of the flares. To cover the large class of flares, from A- to X-class, SoLEXS will carry two identical detectors with different apertures. The large area aperture will cater to small flares (A- to C-class), while the small aperture will observe intense flares (other classes).

SoLEXS is configured as two packages, viz. detector package and electronics package (Figure 3). The detector package carries the two detectors and the associated high voltage power supply along with charge sensitive preamplifiers. The electronics package carries the required processing and power electronics to cater to the instrument.

SoLEXS will also carry an on-board calibration source for the gain calibration over time to obtain high spectral quality for its data. With its on-board processing, SoLEXS will provide spectra with 1 s cadence during a flare. A flare trigger using the count rate threshold is implemented to operate this instrument in quiet as well as flare mode. This flare trigger is also provided as a hardware line to the SUIT instrument on-board Aditya-L1. Currently, the engineering model of SoLEXS (both the packages) is being integrated to test for its performance[9].

High Energy L1 Orbiting X-ray Spectrometer

High Energy L1 Orbiting X-ray Spectrometer (HEL1OS) is a high-energy X-ray spectrometer (10 to 150 keV) for studying the impulsive phase of solar flares. HEL1OS aims to take advantage of the location of the spacecraft at Sun–Earth L1 in order to obtain uninterrupted observations

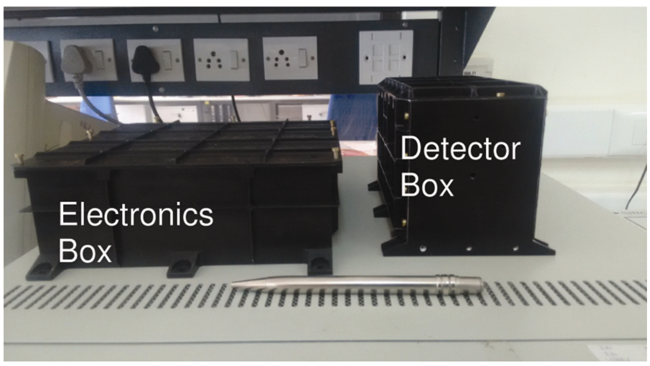

Figure 3. Solar low energy X-ray spectrometer engineering model.

Figure 4. Engineering model of the HEL1OS payload.

of the short-lived impulsive phase of solar flares. This energy band helps identify the non-thermal energy release during the flares.

HEL1OS is being developed with two different types of detectors[10]: CZT and CdTe. The CZT detector is a state-of-the-art, near-room-temperature device. In order to achieve a total geometric area of 32 sq. cm, two such detectors (16 sq. cm per detector) are used to cover the energy range 20 to 150 keV and operate in the temperature range 5°C to 20°C. The individual detectors are pixelated with 256 pixels, with pixel dimension 2.46 mm × 2.46 mm. The CdTe detector, which has better resolution at lower energies, is used for detailed spectroscopic studies from 10 to 40 keV, and operates in the temperature range –35°C to –25°C. The overall geometric area of 0.5 sq. cm will be achieved using two CdTe detectors, each with an area of 0.25 sq. cm. The field-of-view of the instrument has been constrained to 6° × 6° using a stainless steel mesh-type collimator.

At present, the engineering model of HEL1OS is under development (Figure 4). All electronics cards (front-end electronics with detectors mounted, processing electronics and power conditioning electronics) are fabricated and populated; electrical testing and performance verification with detectors is underway.

Summary

Solar flares in X-rays have been studied in detail using the RHESSI mission for the last several years, albeit with low spectral resolution. The X-ray instruments on-board Aditya-L1 will provide a large energy coverage (1 to 150 keV) with a spectral resolution better than of RHESSI providing opportunities to study coronal abundances, break energy shift for different classes of flares, separation of thermal and non-thermal energies, etc. These two instruments will also carry out flare–CME studies in combination with coronagraph and also prominence–flare–CME relations with SUIT and coronagraph. Aditya-L1 being at Sun–Earth L1 point provides us with a unique opportunity to study the flare phenomenon continuously in X-rays without any data gap, like in previous missions.

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