

SMESE: A Small Explorer for Solar Eruptions

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Abstract

The Small Explorer for Solar Eruptions (SMESE) mission is a microsatellite proposed by France and China. The payload of SMESE consists of three packages: LYOT (a Lyman α imager and a Lyman α coronagraph), DESIR (an Infra-Red Telescope working at 35–80 and 100–250 μm), and HEBS (a High-Energy Burst Spectrometer working in X- and γ -rays).

The status of research on flares and coronal mass ejections is briefly reviewed in the context of on-going missions such as SOHO, TRACE and RHESSI. The scientific objectives and the profile of the mission are described. With a launch around 2012–2013, SMESE will provide a unique tool for detecting and understanding eruptions (flares and coronal mass ejections) close to the maximum phase of activity.

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1. Introduction

Solar flares and coronal mass ejections (CMEs) are the two most violent eruptions on the Sun. Solar flares are usually manifested by a local explosion, tracing the sudden heating of plasma and the acceleration of electrons and ions to high energies. CMEs form in a global explosion, causing the ejections of large-scale magnetic structures and huge masses out of the corona. Both of them are driven by instabilities of the magnetic field in the solar atmosphere, which involve basic processes of plasma-magnetic field interaction in the universe. Flares and CMEs are also the main sources of serious disturbance for the interplane-

tary environment, spacecraft, technology, and possibly for human beings.

The joint study of these two explosive phenomena requires a dedicated instrumentation that addresses the issues of flare/CME initiation, energy transport and release. This is the aim of SMESE, a mission which combines a disk and corona UV imager (called LYOT), an Infra-Red Telescope (called DESIR), and a hard X- and γ -ray spectrometer (called HEBS). Their combination gives access to thermal and kinetic processes along with particles acceleration (up to very high energies) and the impact of these non-thermal particles on the Sun.

In Section 2, we provide the general present scientific context for the proposed mission. In Section 3, we present the scientific objectives of the SMESE mission, first the global ones and then the detailed objectives of the three proposed instruments. In Section 4, we briefly describe the

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SMESE mission and its novel instrumentation which addresses the above-mentioned scientific objectives. We finally draw a brief conclusion in Section 5.

2. The scientific context

2.1. Solar flares

Solar flares have different spatial scales, from microflares to huge two-ribbon flares, and different time-scales, from tens of seconds to many hours with a total energy of 10^{26} – 10^{32} ergs (see e.g. Tandberg-Hanssen and Emslie, 1988; Priest and Forbes, 2002). The flaring atmosphere, mainly in the corona, can be heated to 10^7 – 10^8 K. They also have various morphologies, but two-ribbon flares and compact flares are the two basic configurations. In the initial stage of a typical large two-ribbon flare, a prominence and sometimes an overlying coronal arcade erupt outwards, and they leave behind an arcade of rising soft X-ray (SXR) loops with separating H α and UV ribbons at their feet. The intensity of the SXR emission begins to rise slowly at first and then continues to rise rapidly in phase with the H α emission over a hundred of seconds or so: a phase called impulsive. Later, both emissions decline slowly during a gradual phase over a period of several hours. During a typical large flare (e.g. Miller et al., 1997), a wide range of emission is produced at different wavelengths, including microwaves (due to gyrosynchrotron emission from spiralling electrons), hard X-ray and γ -ray continuum (due to bremsstrahlung from sub-relativistic and relativistic electrons), low-frequency radio (from plasma radiation), SXR (due to thermal bremsstrahlung continuum and atomic lines), visible and EUV emission (from hot thermal plasma, e.g. Fig. 1), γ -ray lines (due to

the interaction of MeV ions with ambient nuclei) and γ -ray continuum greater than 10 MeV (due to the decay of pions). During the impulsive phase, the hard X-ray, γ -ray, and radio emissions rise and decay much more rapidly than SXR, UV, and visible emissions.

The energy of solar flares comes from magnetic energy through reconnection, during which the magnetic energy is dissipated and converted to the non-thermal, thermal, and kinetic energy (Priest and Forbes, 2000). Recent multi-wavelength observations explored the possibility of detecting both the site and the current sheet (CS) related to the magnetic reconnection (e.g. Lin et al., 2005). The released energy can be transported both to interplanetary space and the solar lower atmosphere through different mechanisms, such as non-thermal particles, radiation, heat conduction, and waves (e.g. Tandberg-Hanssen and Emslie, 1988; Fang et al., 1993; Veronig et al., 2002). The energy transport to the lower solar atmosphere results in the heating of the chromosphere and even the photosphere, providing chromospheric condensation and evaporation, and then the heated plasma rises up and fills the flaring loop, causing the increase of SXR emission (Gan et al., 1991, 1993).

If magnetic energy conversion by two-dimensional magnetic reconnection is relatively well understood, in three dimensions we are only starting to understand the complexity of the magnetic topology and the involved dynamics. How the dynamics lead to particle acceleration is even less understood. Particle acceleration in flares may in principle occur in a variety of ways (such as stochastic acceleration by MHD turbulence, direct electric field acceleration at the reconnection site, or diffusive shock acceleration at the shock fronts that are produced during the flare). However, which of these processes is most important for the acceleration of the energetic particles and what is the relationship among the thermal, non-thermal, and kinetic energies remains a mystery. The eruption of the prominence often occurs *before* the flare: see, for instance, the well-documented case of the Bastille Day flare (July 14, 2000; e.g. Aulanier et al., 2000). When the prominence (and the whole CME body) erupts, it stretches the CS underneath, and when the current sheet length-to-width ratio exceeds a critical value, reconnection starts which is then observed as the flare (by radiation signatures of accelerated particles and heated plasma). But what happens when no prominence eruption occurs, as in compact flares? Moreover, there are still open questions such as: are non-relativistic, relativistic electrons and ions accelerated by a single process or different ones? What are the lower and higher energy cutoff of accelerated electrons and ions?

2.2. Coronal mass ejections (CMEs)

CMEs are large-scale ejections of mass and magnetic flux from the low corona into interplanetary space (see e.g. Webb et al., 1994; Forbes, 2000; Aschwanden, 2004; Zhang and Low, 2005). Measurements from coronagraphs

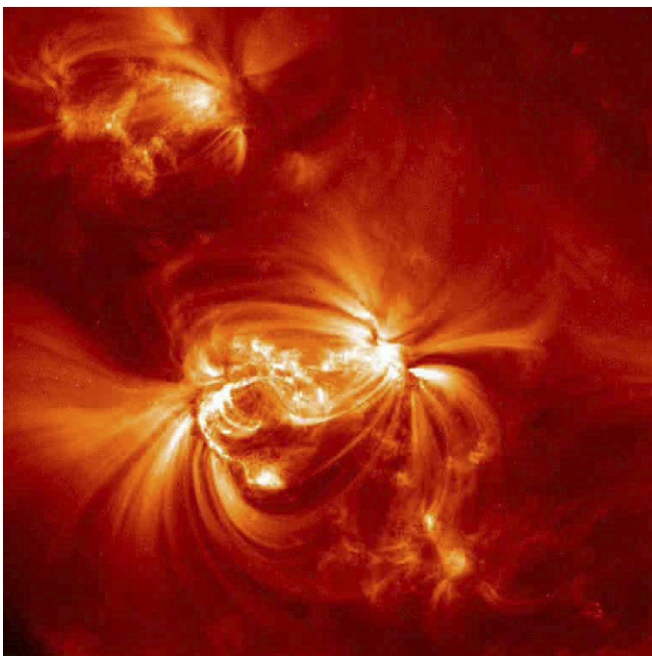


Fig. 1. Post-flare-loops as observed with TRACE.

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