A brief introduction to the SMESE mission

C. Wang[1], C. Fang[2], W. Gan[3], J. Prado[4], G. Trottet[5], J. Vial[6], Y. Yan[7], F. Auchere[6], J. Chang[2] and G. Molodij[5]

[1] Center for Space Science and Applied Research, Chinese Academy of Sciences, China
[2] Nanjing University, China
[3] Purple Mountain Observatory, Chinese Academy of Sciences, China
[4] Centre National d'Etudes spatiales, France
[5] Laboratoire d'etudes Spatiales et d' Instrumentation en Astrophysique, Observatoire de Paris, France
[6] Institut d' Astrophysique Spatiale, France
[7] National Astronomical Observatory, Chinese Academy of Sciences, China

Abstract. Small Exploration for Solar Eruptions (SMESE) is a joint mission between France and China to investigate the two main types of eruption events on the Sun: Coronal Mass Ejections (CME) and solar flares, and their relationship. SMESE will provide a set of unprecedented and complementary measurements including Ly-alpha imager, Ly-alpha coronagraph, EUV imager, Detection of Solar Infra red radiation, Hard X-ray/gamma ray spectrometry. SMESE aims to study, among others, the CME triggering mechanism and its acceleration in the corona, the particle acceleration by CME and solar flare, the physical association of the CME and solar flare etc. SMESE will be launched in the next solar maximum between 2010-2012.

Index Terms. Coronal mass ejections, solar flares, space mission.

1. Introduction

The solar corona is the seat of variability which involves basic processes of plasma-magnetic field interaction in the universe, while also being a source of disturbances for spacecraft, technology, and possibly for human beings.

Explosive energy conversion in the corona has two major types of manifestation: coronal mass ejections (CMEs) reveal the ejection of large-scale magnetic structures out of the corona, while solar flares trace the sudden heating of coronal plasma and the acceleration of electrons and ions to high, sometimes relativistic, energies. Both are basically driven by instabilities of the magnetic field in the corona. While space borne and ground-based instrument brought new insight into the physics of flares and CMEs, they suffered from three shortcomings: (1) a low cadence of imaging observations (SOHO: 12 min) and a gap between corona and disk observations, which restricts our ability to study the dynamics of mass ejections; (2) access to electromagnetic emission from a limited range of particle energies, which leaves the question unanswered up to which energies the Sun is able to accelerate particles, (3) the lack of simultaneous observations of flares and CMEs in a wide range of energies/wavelengths.

In an attempt to better investigate the two types of solar eruption events on the Sun (CME and solar flare) and their relationship, Small Exploration for Solar Eruption (SMESE) has been joint by French and Chinese scientists, and the Chinese part has been recently approved by CNSA to proceed with Phase-A study.

2. Scientific objectives

SMESE aims at providing a well-defined novel instrumentation to answer specific questions left open by the highly successful Solar and Heliospheric Observatory (SOHO) (Bonnet and Felici, 1997) and The Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) (Lin et al., 2002) missions to their ground-based companion instruments:

1. What triggers CMEs and how are they accelerated in the low corona and out of the corona into the helosphere?

2. How are CMEs and solar flares related? More specifically, how does the Sun decide to partition energy between large-scale mass motion, small-scale heating, and particle acceleration?

3. How does the Sun accelerate particles to relativistic energies? Are relativistic electrons, ions of low and high energies accelerated by the same mechanism? And what are the highest energies to which charged particles can be accelerated in the solar corona?

4. How do radiation, conduction and energetic particles participate in the transport of energy in the solar atmosphere?

SMESE is a small explorer mission which will provide a set of unprecedented and complementary measurements to address the above questions. It will be the first combined imaging of the solar disk and corona in Ly α with sufficiently high time resolution to trace the development of CMEs in the low corona, and with a sensitivity several orders of magnitude higher than previous space borne coronagraphs. It will be the first ever measurements of solar flares in the far infrared, where most energetic electron and positrons that the Sun is able to accelerate are expected to be seen through their synchrotron emission. It will attain hard X-ray/gamma ray spectrometry at the highest energies ever with a solar dedicated instrument to study the most energetic electrons and nuclear processes in the Sun's atmosphere.

In particular, we want:

- To follow the evolution of CMEs from the pre-event configuration in the corona, that we identify with combined and quasi-contiguous disk imaging and coronagraphic observations, through the first 2.5 solar radii above the photosphere, tracking different features with a cadence better than 30 seconds and thereby evaluating the speed and acceleration in regions where earlier coronagraphic observations show that the man acceleration occurs.
- To track the detailed time profiles of the hard X-ray, gamma-ray and far infrared emission with sub-second cadence, to evaluate the fundamental acceleration times of electrons and ions up to relativistic energies. The far infrared observations will have the capability to localize the sources, and the context imaging in EUV and especially Ly α wavelengths will serve to identify the coronal magnetic field structures where the particles propagate, and where they were accelerated.
- To infer the spectra of energetic particles from suprathermal to relativistic energies, as a stringent constraint for the acceleration processes at work.
- To probe the thermal radiation from the 10 million K plasma in the coronal at moderately hard X-ray energies, and form the chromosphere at several thousands of K in the far infrared continuum, to trance the energy transport during flares and identify the physical processes at work.
- To use particle acceleration and energy transport inferred form the hard X-ray, gamma-ray and far infrared diagnostics as a key for understanding all processes of explosive energy conversion in the solar atmosphere, namely the coronal magnetic field evolution traced by the imagers.

The SMESE mission will greatly contribute to the International Living with a Star program and will be a forerunner component of space weather research. As a matter of fact, it will provide the only coronagraph support for the Solar Dynamics Observatory mission and possibly the Solar-B mission in operations around 2010. With its cadenced and continuous disk and out-of-limb observations, it will provide a unique survey of the source and propagation of CMEs. It will provide unique observational tools for the prediction of both flares and CMEs, since other spacecraft available then (such as SDO, Solar-B, STEREO) has no payloads working in X-rays, gamma-rays, and far infrared radiations.

3. The SMESE payload

SMESE consists of three packages:

(1) LYOT

LYOT (Lyman alpha Imaging Orbiting Telescope) is a suite of two imagers and a coronagraph. It provides the first combined imaging of the solar disk and corona in Ly α. The Ly α imager has a field of view up to 1.1 solar radii and a spatial resolution up to 1 arcsec. The EUV imager observed the solar disc up to 1.4 solar radii in the 19.5 nm Fe XII band, with a resolution up to 1 arcsec. Similar images are obtained every 12 minutes by EIT on SOHO. Ly α images of the solar corona are obtained by a coronagraph observing between 1.15 and 2.5 solar radii with a resolution of 2.7 arcsec. Ideally, we want to repeat Gabriel's eclipse observations (Gabriel, et al., 1971), very close to the limb, but more frequently.

(2) DESIR

An Infra-red imager called DESIR (Detection of Solar Infrared Radiation). It will perform the first-ever measurements of solar flares in the far-infrared, where the most energetic electron and positrons that the Sun is able to accelerate are expected to be seen through their synchrotron emission. DESIR will explore the electromagnetic emission in a region between cm-mm and white light where three frequency decades remain unexplored in flares.

(3) HEBS

A High Energy Burst Spectrometer called HEBS-X and HEBS –gamma. It will perform hard X-ray and gamma-ray spectrometry at the highest energies ever attained (up to 600 MeV) with a solar –dedicated instrument and it will enable the study of the most energetic electrons and nuclear processes in the solar atmosphere.

There are total 3 packages (6 instruments) in the SMESE payload. The SMESE instrumentation including their wavelength/energy range, field of view, spatial resolution and time resolution is summarized in Table 1, and the payload resources including estimated weight, size, power and telemetry rate are give in Table 2.

Table 1. SMESE Payload

	Wavelength / Energy	Field of View	Spatial resolution	Time resolution
LYOT: Ly α Imager	121.6 nm	Full Disk	1 arcsec	30s
LYOT: Ly α Imager	121.6 nm	>5 solar radii	2.5 arsec	2 min
LYOT: EUV imager	19.5 nm	Full Disk	1 arcsec	30 s
DESIR: Detection of Solar Infra red Radiation	35 and 150 µm	Full Disk	50 arcsec at 35µm	100 ms
HEBS: HEBS-X	10-500 keV	Full Disk	Full Disk	1s down to 32 ms
HEBS HEBS-G	100 keV- 10 MeV 10 MeV - 600 MeV	Full Disk	Full Disk	1s down to 32 ms

Table 2. Payload Characteristics

	Mass (kg)	Volume (cm^3)	Power (W)	Telemetry
LYOT:	27	58000	39	28 G/day
DESIR	10	20000	10	2 G/day
HEBS	20	23000	18	1 G/day
ECU (computer +mass memory)	4	4000	4	
TM/TC package	2	2000	2	
Structure	12			
Total	75	107000	73	31G/day

4. The SMESE characteristics

Spacecraft

The spacecraft platform for SMESE will be one of the MYRIADE family, developed by CNES and already flight proven (DEMETER, PARASOL, ESSAIM). A very similar project in terms of platform requirements, PICARD, is presently in preparation at CNES. PICARD is to be launched in 2008. The similarities and differences between the requirements for SMESE compared to PICARD are summarized in Table 3.

Launch

SMESE will be launched in the next solar maximum between 2010-2012. A launch by a DNIEPR launcher form the Russian company KOSMOTRAS as a prime customer is the baseline choice. A piggy back launch with a Chinese Long March rocket could also be envisioned, provided the CNES delivered hardware can comply with the ITAR regulation.

Operations

The SMESE platform being very similar to PICARD, the Satellite Control Centre will be located in the CNES premises in Toulouse. The Mission Control Centre will be located in France (CNES or scientific laboratory). The programming of the instruments will be based on a weekly sequence of commands that will be prepared by the scientific teams in France and China and transmitted to the Mission Control Centre. The raw data will be made available to the French and Chinese scientific teams through the Mission Control Centre. At lease two receiving ground stations are planned for the SMESE telemetry reception, on in France (3.4 meter diameter dish), one in China (11 meter dish). The telecommands will be uploaded from a CNES station.

Responsibilities

The organization scheme also will be very similar the one of PICARD, where on the French side, CNES and the scientific institutes will be responsible for providing:

- the overall system specifications
- the MYRIADE platform
- part of the instrumental payload (LYOT and DESIR instruments)
- the launch
- part of the ground segment (Satellite Control Centre, Mission Control Centre, at least on TM antenna, the TC antenna)

while China will provide:

- part of the instrumental payload (X and gamma spectrometers)
- one ground station for receiving the telemetry (X band)
- Payload Onboard Data Processing Unit (including a ~30 Gbits mass storage)
- One of the ground data analysis centers.

The provision by China of additional items (e.g. the X band system) will be investigated during the assessment study.

Management

A Science Definition Team has been set up (10 scientists including from ESA and one from NASA) during the definition phase. During the development stages, it will keep a regular view over the SMESE project to ensure that the initial scientific goals are satisfied. It will also liaise with ground or space project.

Mission profile

The SMESE mission profile is summarized in Table 3.

Table 3. SMESE Mission Profile

Item	Specification
Orbit	Dawn/dusk heliosynchronous
Orbit Control	In the 650-750 km range
Total P/L Mass	75 kg
Attitude	Sun pointed, solar panel tilted by 45°/ecliptic
Nominal Attitude Modes	Sun pointing
Pointing accuracy provided by the platform alone	0.1°
Pointing available for the Payload	0.01°
Power available for the Payload	90 to 120 W, depending on the season
Data per day	31 G
Telemetry rate	>16 Mb/s
Telecommand	S band
Telemetry	X band
Mission duration	2 years minimum
Launcher	DNIEPR

5. Conclusions

SMESE should bring new and complementary information on eruptive solar phenomena through a compact and innovative payload. The SMESE Phase A will start in March 2006 and will extend into the beginning of 2007. The objective is to have SMESE launched during the next solar maximum (2010-2012).

Acknowledgments. We thank all of the French and Chinese team members involved in the preparation of the SMESE mission, especially N. Zhang, H.Li, M.S. Cai, Y.P. Li, T. Ma (PMO), Y. Dai, P.F. Chen, M.D. Ding (NJU), J. Wu, H.X. Sun, X. M. Chen (CSSAR), J.X. Wang (NAOC), A. Semery (LESIA), M. Berthe, and F. Rouesnel (IAS).

References

R. M. Bonnet and F. Felici, "Overview of the SOHO Mission," *Adv. Space. Res.* vol. 20, pp. 2207-2218, 1997.

R. P. Lin, B.R. Dennis and A. O. Benz (eds.), "The Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI)- Mission description and early results", *Solar Phys* , vol. 210, pp. 1-456, 2002.

A. H. Gabriel et al., "Rocket Observations of the Ultraviolet Solar Spectrum during the total eclipse of 1970, March 7", *Astrophys. J.*, vol. 169, p. 595, 1971.