SMILE – X-ray imaging of the Sun-Earth connection

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Introduction

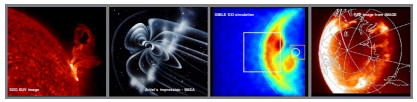
The Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) is a novel self-standing mission which is being jointly developed by ESA and the Chinese Academy of Sciences (CAS).

It will observe the solar wind-magnetosphere coupling by acquiring X-ray images of the magnetosheath and polar cusps, UV images of global auroral distributions and by making simultaneous in situ solar wind/magnetosheath plasma and magnetic field measurements.

Remote sensing of dayside magnetosheath and the cusps with X-ray imaging is now possible thanks to the relatively recent discovery of solar wind charge exchange (SWCX) X-ray emission, first observed at comets, and subsequently found to occur in the vicinity of the Earth's magnetosphere.

In particular, SMILE will address the following specific science questions:

- What are the fundamental modes of the dayside solar wind/magnetosphere interaction?
- What defines the magnetospheric substorm cycle?
- How do CME-driven storms arise and what is their relationship to substorms?

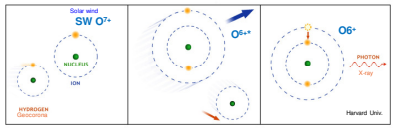


Mission summary

- 3-axis stabilized spacecraft
- Orbit: 1.8x20 R_E geocentric distance, 70-90 deg. inclination, 51 h period
- Payload: Mass 55 kg, including
  - SXI (Soft X-ray Imager) – Wide field lobster-eye 0.2-5 keV X-ray imager. CCD detectors. 15 x 27 degree FOV
  - UVI (UV Imager) – Four mirror imager in the range 160-180 nm. CMOS detector
  - LIA (Light Ion Analyser) – Top-hat analyser for detection of protons and alphas. Energy range 50 eV-20 keV.
  - MAG (Magnetometer) – Flux-gate magnetometer with two sensors on a 2.5m boom
  - Regions of interest:
    - 41 h around apogee over North pole
- Telemetry: X-band, 65.5 Mbps
- Ground station network: Troll 7.3m, possibly Kourou 15m, Sanya 12m
- Launch 2021, with Soyuz dual launch or Vega C.

X-ray imaging of the magnetosphere

Example of the
Solar Wind Charge eXchange (SWCX) process

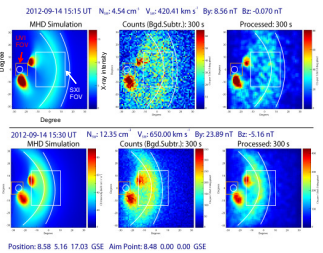


1. A highly ionised solar wind ion O7+ interacts with an hydrogen atom from the Earth's geocorona (left panel).
2. The O7+ picks-up the electron from the H atom and becomes O6+ in an excited state (middle panel).
3. The O6+ emits a soft X-ray and relaxes to a more stable state (right panel)

MHD and SXI simulations

Typical solar wind

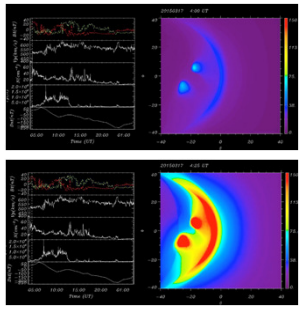
After inter-planetary shock



Storm 17 March 2015 MHD simulation

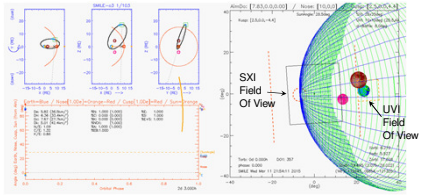
04:00 UT
N=15 cm-3
V= 410 km/s

04:25 UT
N=50 cm-3
V= 510 km/s



Mission

Instrument pointing simulations



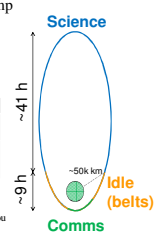
Data acquisition and dump

Baseline: 5000 x 120000 km HEO; orbit duration: ~51 h
- ~ 41 h science operations (SXI & UVI)
- LIA & MAG observing entire orbit

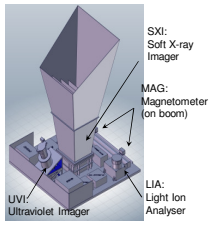
- Science data volume dominated by imagers

	SXI	UVI	LIA	MAG
Data rate (kbps)	120	17.6 – 840	12 – 48	6
Data volume (GBytes per orbit)	2.5	1.15	0.654	0.14

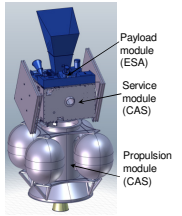
- Estimated downlink time: ~10 min
  - X-band, 65.5 Mbps
  - Ground station network: Troll 7.3m, possibly Kourou 15m, Sanya 12m



Payload module



Spacecraft with propulsion



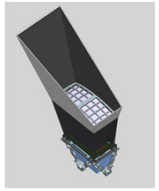
ESA-China collaboration:

ESA responsibilities:
- Payload module (science TM)
- Launch (shared Soyuz, Vega or other launcher)
- Ground station and Science operations

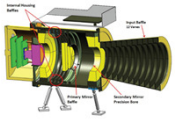
China responsibilities:
- Service module (power, pointing, commanding)
- Propulsion module
- Light Ion Analyser and Magnetometer
- Ground station, Spacecraft and Science operations

Instruments

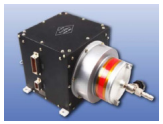
- SXI: Soft X-ray Imager
  - Wide field lobster-eye 0.2-5 keV X-ray imager.
  - Two large CCD detectors (PLATO-like).
  - 15 x 27 degree FOV.
  - Science regions: magnetosheath, polar cusps
  - PI: S. Sembay, Leicester, UK



- UVI: UV Imager
  - Four mirror imager
  - Wavelength:160-180 nm.
  - CMOS detector. Coated mirrors
  - Science regions: dayside and nightside auroras
  - PI: E. Donovan, Calgary, Canada



- LIA: Light Ion Analyser
  - Top-hat analyser for p and α, density, velocity and temperature
  - Energy range: 50 eV - 20 keV
  - FOV : 360° and up to +/-45°
  - Science regions: solar wind, magnetosheath, magnetosphere
  - PI: L. Dai, NSSC, CAS, China



- MAG: Magnetometer
  - Flux-gate magnetometer for magnetic field strength and direction
  - 2.5 m boom, sensors separated by 0.8-1 m
  - Science regions: solar wind, magnetosheath, magnetosphere
  - PI: L. Li, NSSC, CAS, China

Conclusions

- SMILE will trace and link the processes driving solar wind injection in the magnetosphere with those acting on the charged particles precipitating into the cusps and the aurora
- **SMILE transforms magnetospheric X-rays from an 'unwanted background' in X-ray astrophysical observations to a diagnostic tool for the study of solar-terrestrial interactions**
- Outreach: Great interest for novel magnetosphere imaging
- Cooperation with China: SMILE is a showcase, building on Double Star experience

http://www.mssl.ucl.ac.uk/SMILE/