

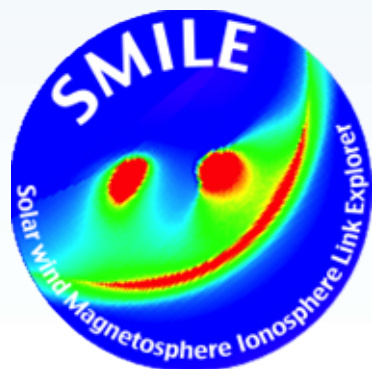


The SMILE mission:

A novel way to study solar-terrestrial interactions

Graziella Branduardi-Raymont
UCL – MSSL

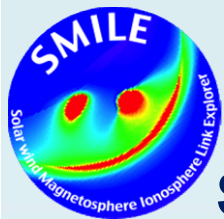
Chi Wang
CAS – NSSC



and the SMILE collaboration
(ESA, CAS and European, Canadian, USA, China institutions)



EGU2020 “Sharing Geoscience Online” – Session ST2.1



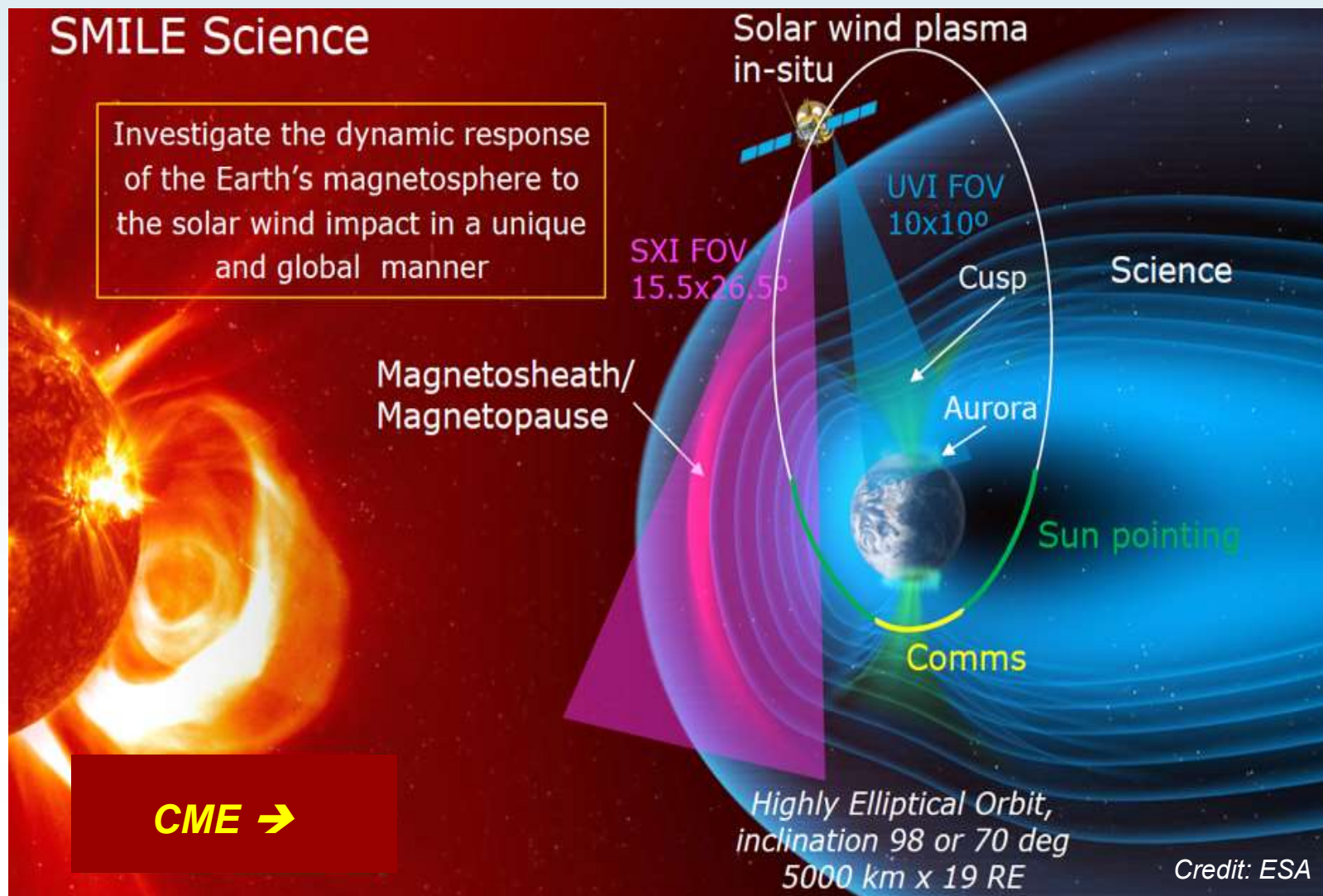
SMILE

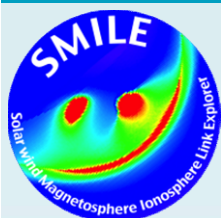


Solar wind Magnetosphere Ionosphere Link Explorer

SMILE Science

Investigate the dynamic response of the Earth's magnetosphere to the solar wind impact in a unique and global manner

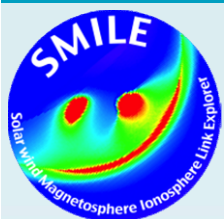




SMILE mission and instruments

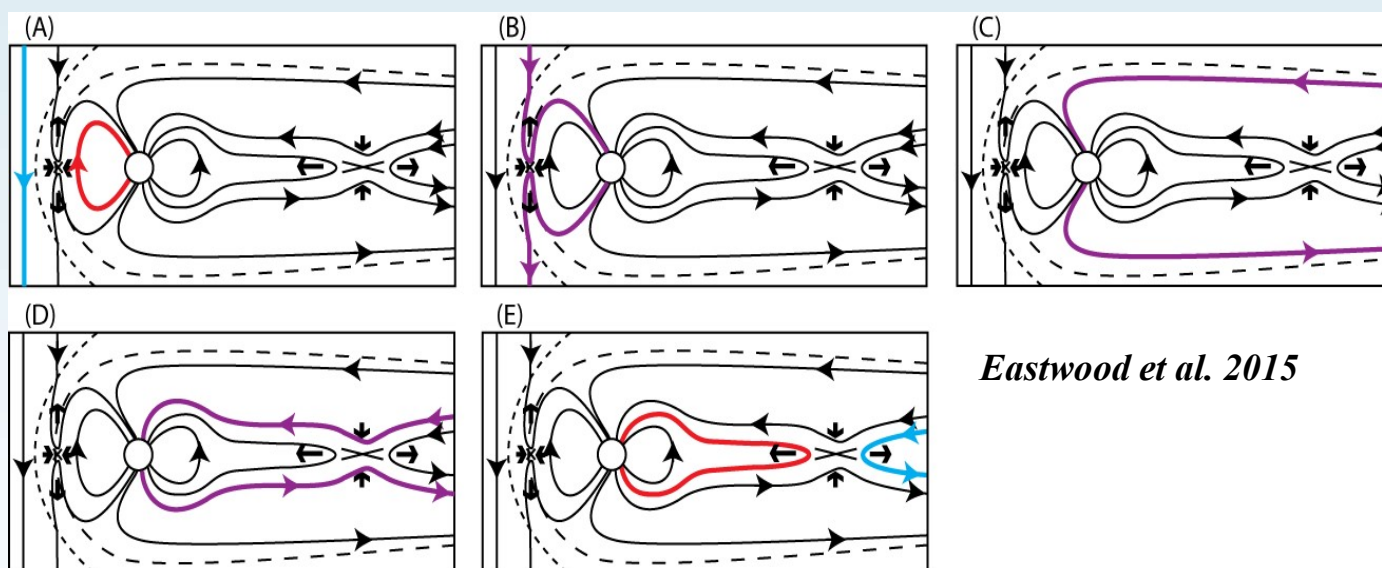


- SMILE is a joint scientific mission, from inception to launch and operations, by the **European Space Agency** and the **Chinese Academy of Sciences**, it is under development and due for launch at the end of 2023
- SMILE will investigate the dynamic response of geospace to the solar wind impact, exploring the **full chain of events that drive Space Weather**
- SMILE combines **X-ray imaging** of the dayside magnetosheath and the cusps (with the Soft X-ray Imager, **SXI**), simultaneous **UV imaging** of the Northern aurora (UltraViolet Imager, **UVI**) and in situ monitoring of the **solar wind** and **magnetosheath** conditions (Light Ion Analyser, **LIA**, and **MAG**netometer) from a very elliptical orbit

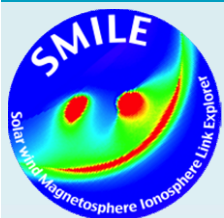


SMILE scientific motivations

Study the full chain of events that drive Sun-Earth relations



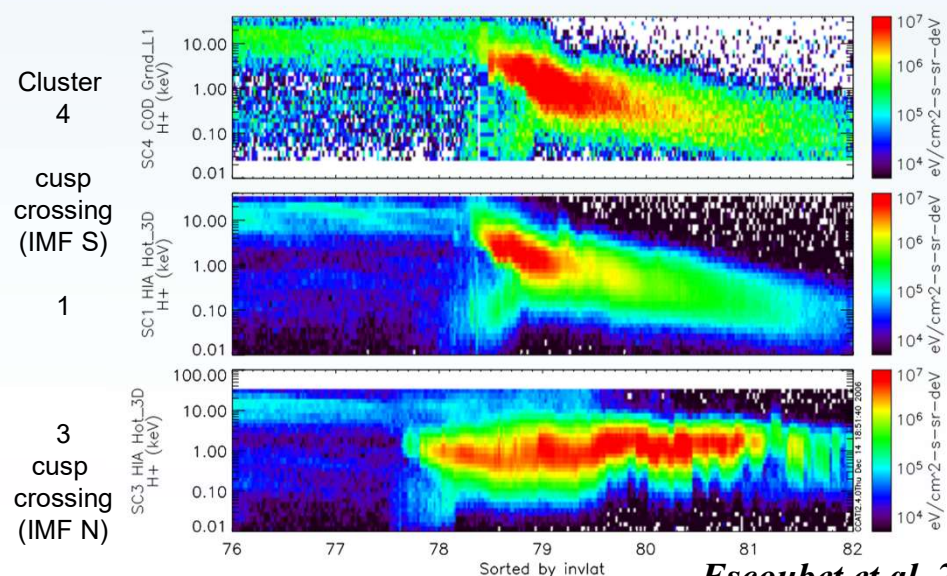
- Structure and dynamics of the magnetosphere mainly controlled by **magnetic reconnection**: Basic theory of magnetospheric circulation well known, **microscale** explored by many in situ measurements
- Reality of how complex interaction takes place on **a global scale**, and **how it evolves**, still not understood
- SMILE can answer questions which help **distinguishing modes of interaction**



SMILE scientific motivations

What are the fundamental modes of the dayside solar wind / magnetosphere interaction?

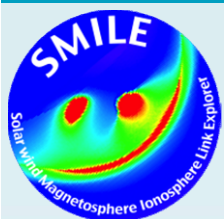
- When/where is **reconnection** steady/transient/bursty, patchy or global?
- Dependent on solar wind parameters or intrinsic instabilities?
- Component or anti-parallel
- Role of the magnetospheric cusps in solar wind/magnetosphere coupling



Ion energy decreases towards pole for IMF S, and vice versa

Cusps expands poleward after IMF turns N

Escoubet et al. 2008



SMILE scientific motivations

What defines the substorm cycle?

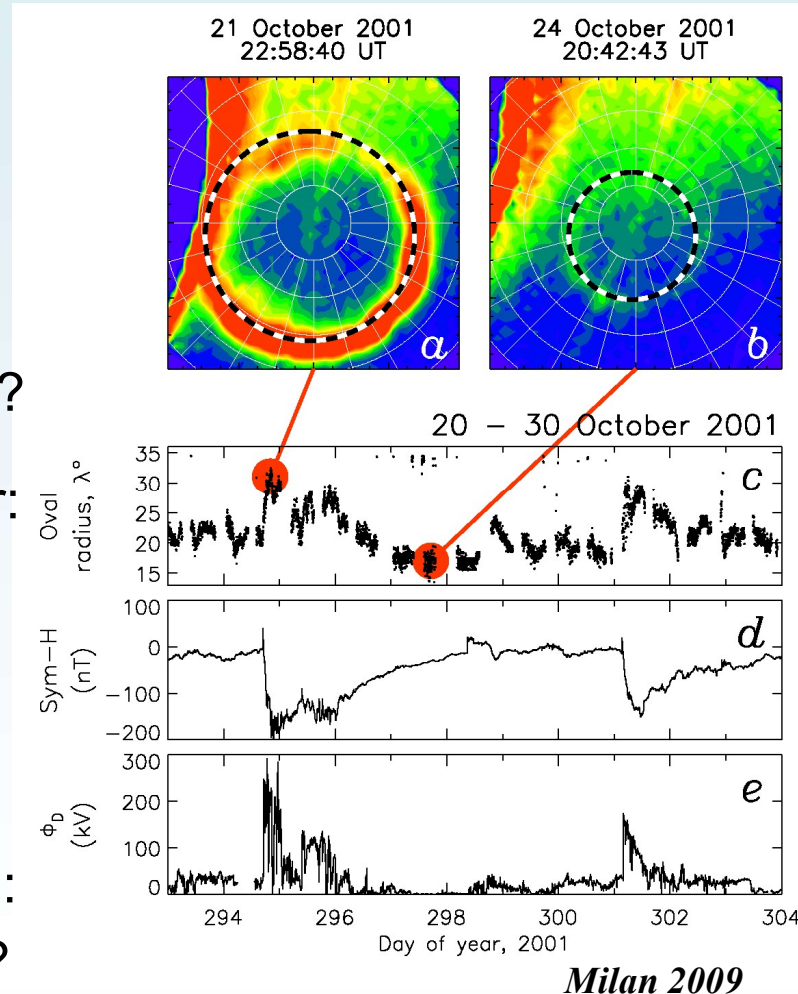
- Auroral oval responds to changes in magnetospheric or solar wind conditions: IMF orientation, dynamic pressure triggers?
- Other modes of magnetospheric behaviour: e.g. saw-tooth events, auroral beads

How do CME-driven storms arise?

How do they relate to substorms?

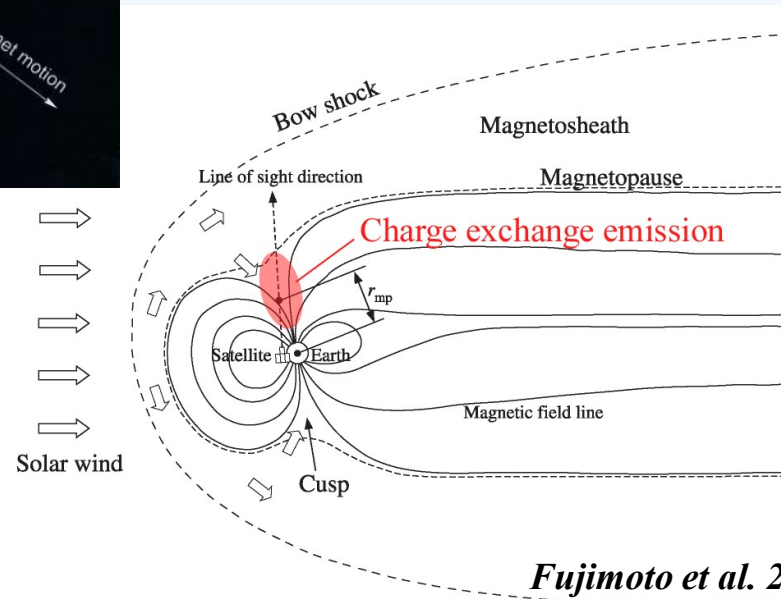
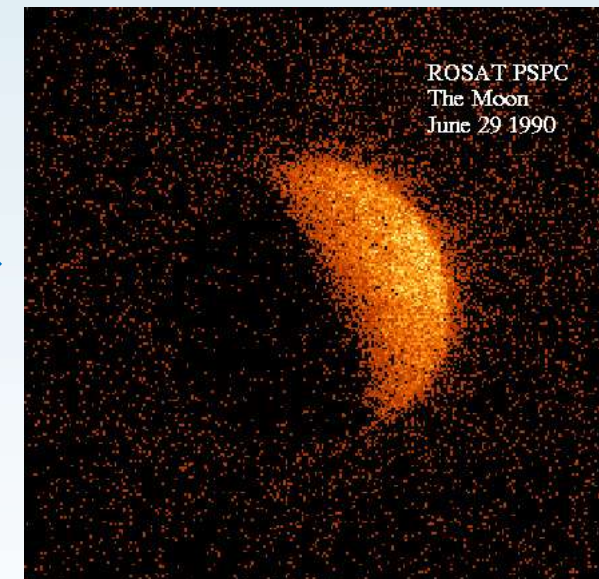
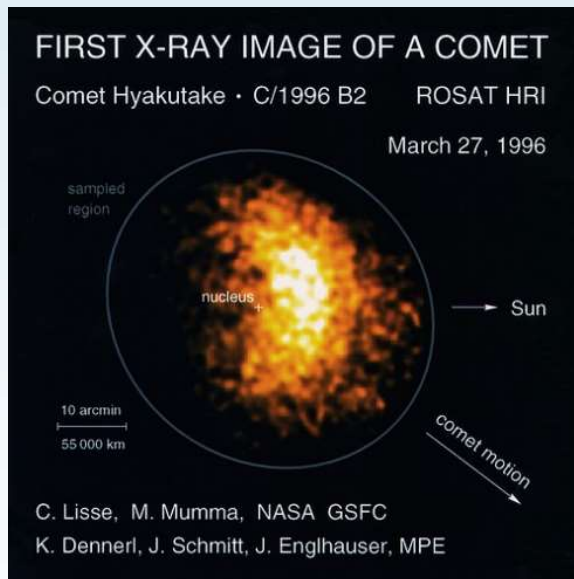
- Fast solar wind and long intervals of S IMF: Is solar wind driving the only storm trigger?

- Relation storm – substorm? How do storms end? Space weather relevance

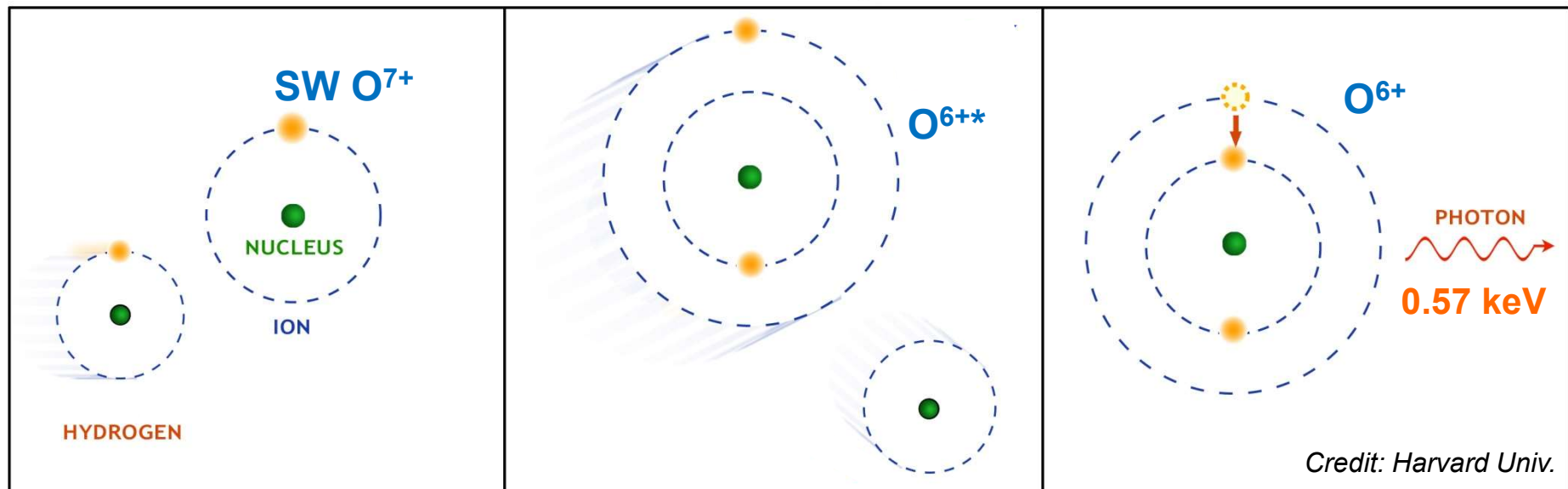


Solar Wind Charge eXchange (SWCX) X-rays

The atomic process that explains the bright X-ray emission of **comets** and the **variable soft X-ray background** in X-ray observations of the cosmos

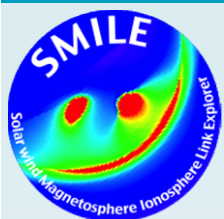


Solar Wind Charge eXchange (SWCX)



$$P_X = \alpha n_{sw} n_n \langle g \rangle \text{ eV cm}^{-3} \text{ s}^{-1}$$

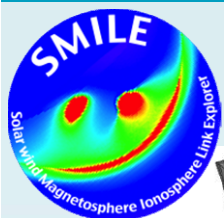
X-ray emission proportional to density of solar wind ions and neutrals, hence brightest in the dayside magnetosheath and the cusps



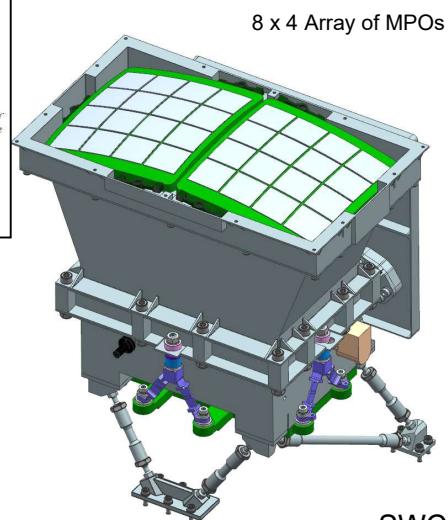
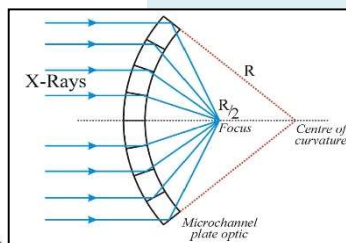
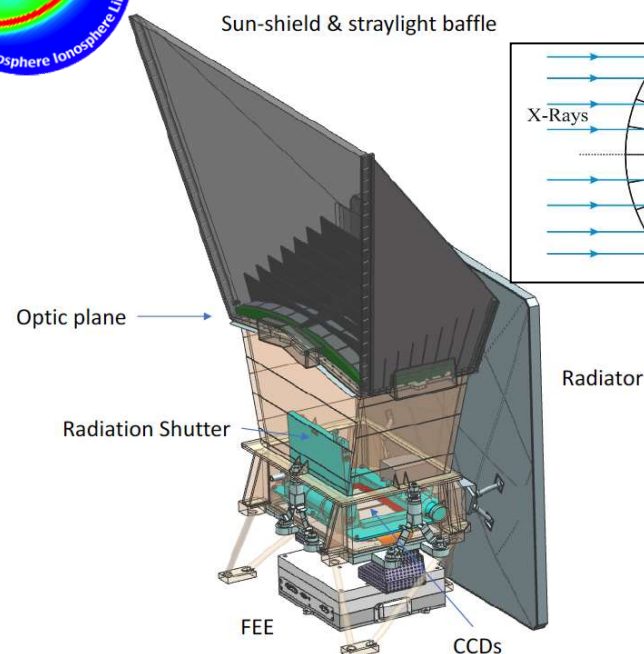
How we got to SMILE



- X-rays from the magnetosphere: from 'noise' to **diagnostic tool** of geospace
- Early concept missions: MagEX (*Sembay et al. 2008; Collier et al. 2009*) and STORM (*Kuntz et al. 2008; Sibeck et al. 2011; Collier et al. 2015*) proposed to NASA; AXIOM and AXIOM-C (*B-R et al. 2010, 2012*) to ESA
- Lobster eye optic: DXL/STORM flights (*Thomas et al. 2013, Collier et al. 2015*)
- Concept has **matured substantially** → SMILE **chosen** in June 2015 for **joint ESA - CAS mission**, **selected** in Nov. 2015 and **adopted** into the ESA Cosmic Vision programme in March 2019, with launch expected at end 2023



SMILE Soft X-ray Imager (SXI)



Lobster-eye Micropore Optic

Ultra-wide field of view
~16° x 26°

Focal length 30 cm

Optic Mass < 1kg

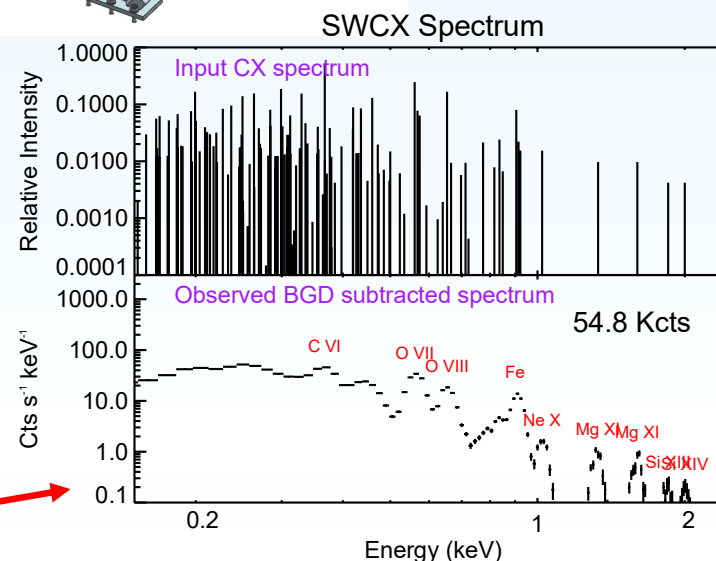
Instrument ~36 kg

CCD Detector Plane

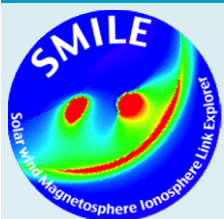
Photon counting: Photon lists with ~4 s time resolution

High QE in soft X-rays
~90% at 500 eV

Medium energy resolution
~50 eV FWHM at 500 eV



PI S. Sembay, Univ. of Leicester, UK

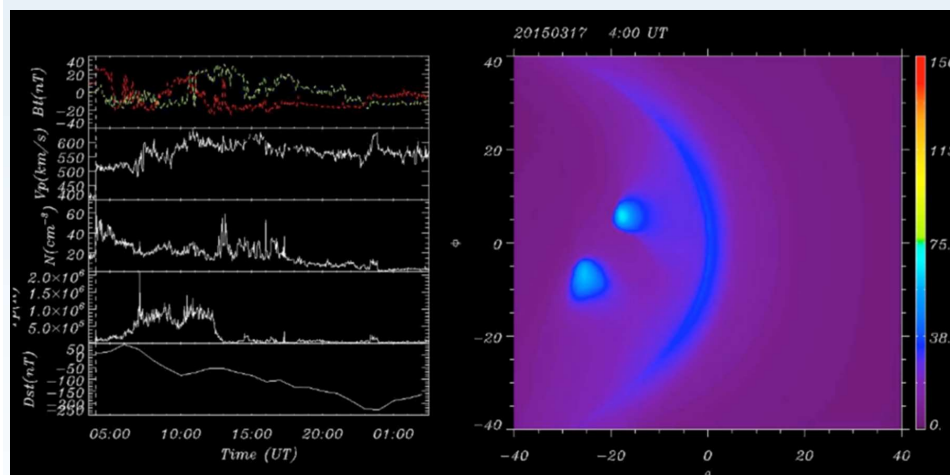


17th March 2015 storm event

Before storm: 04 UT, $N=15 \text{ cm}^{-3}$, $V= 410 \text{ km/s}$

Solar wind input

X-ray emissivity line-of-sight integrated

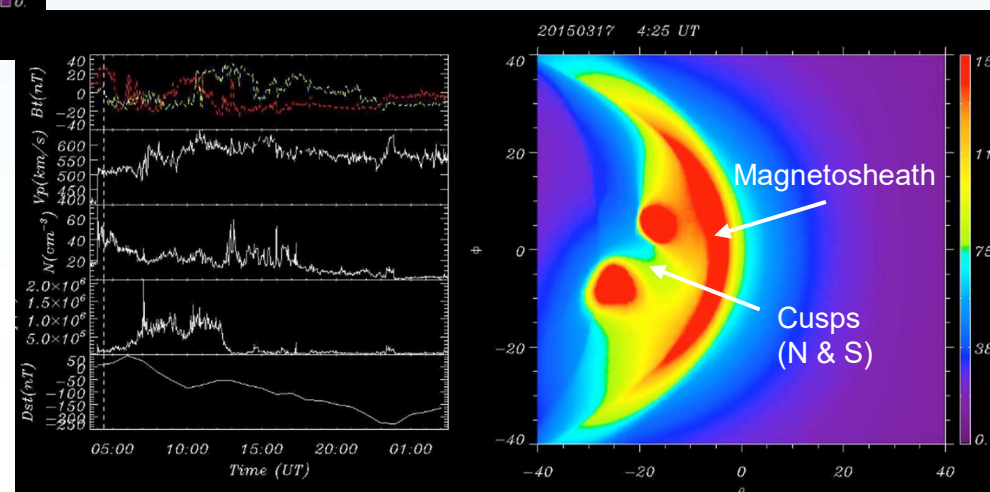


**Predicted SWCX X-ray emissivity
from MHD simulation**

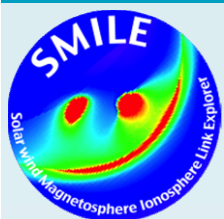
During storm: 04:25 UT, $N=50 \text{ cm}^{-3}$, $V= 510 \text{ km/s}$

Solar wind input

X-ray emissivity I-o-s integrated



T. Sun, NSSC, CAS, China

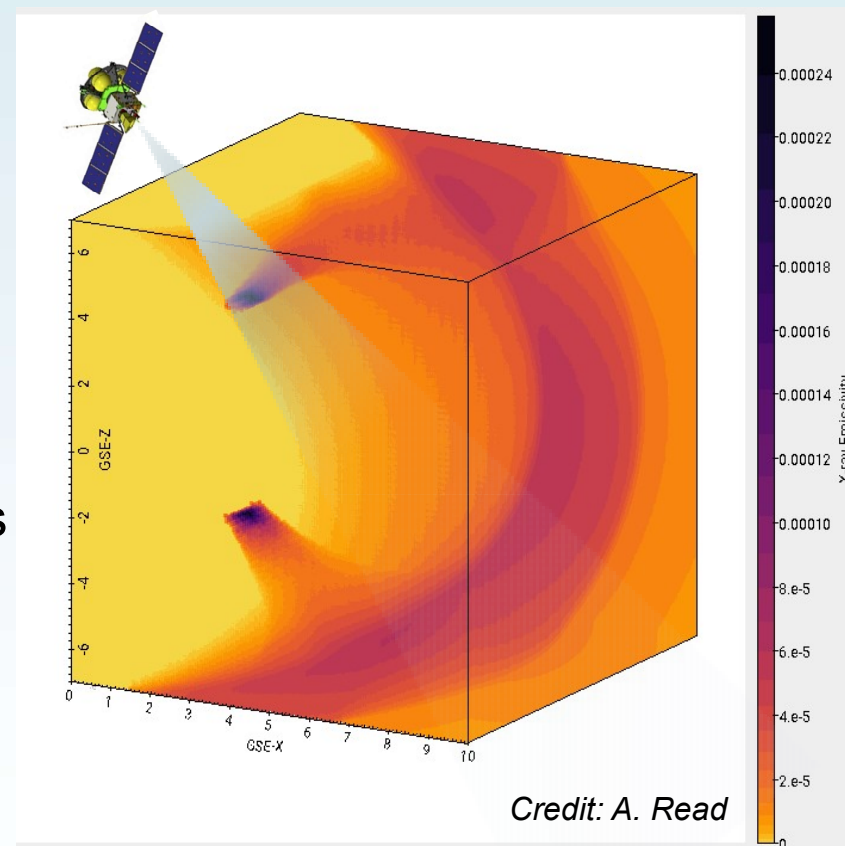
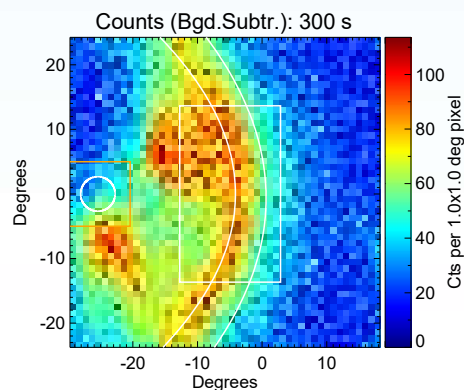
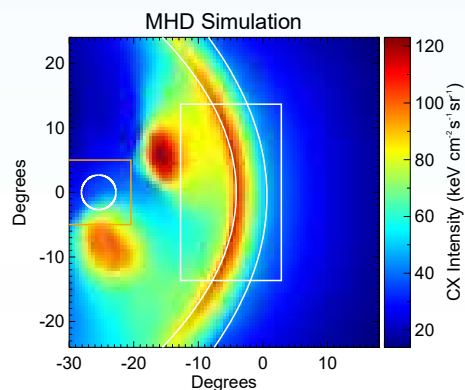


From X-ray emissivity to observed counts

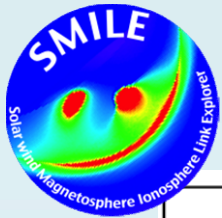
Detectable X-ray emission
calculated by integrating
along the line of sight
through the modelled
X-ray emissivity cube

→ SXI_SIM produces expected count maps

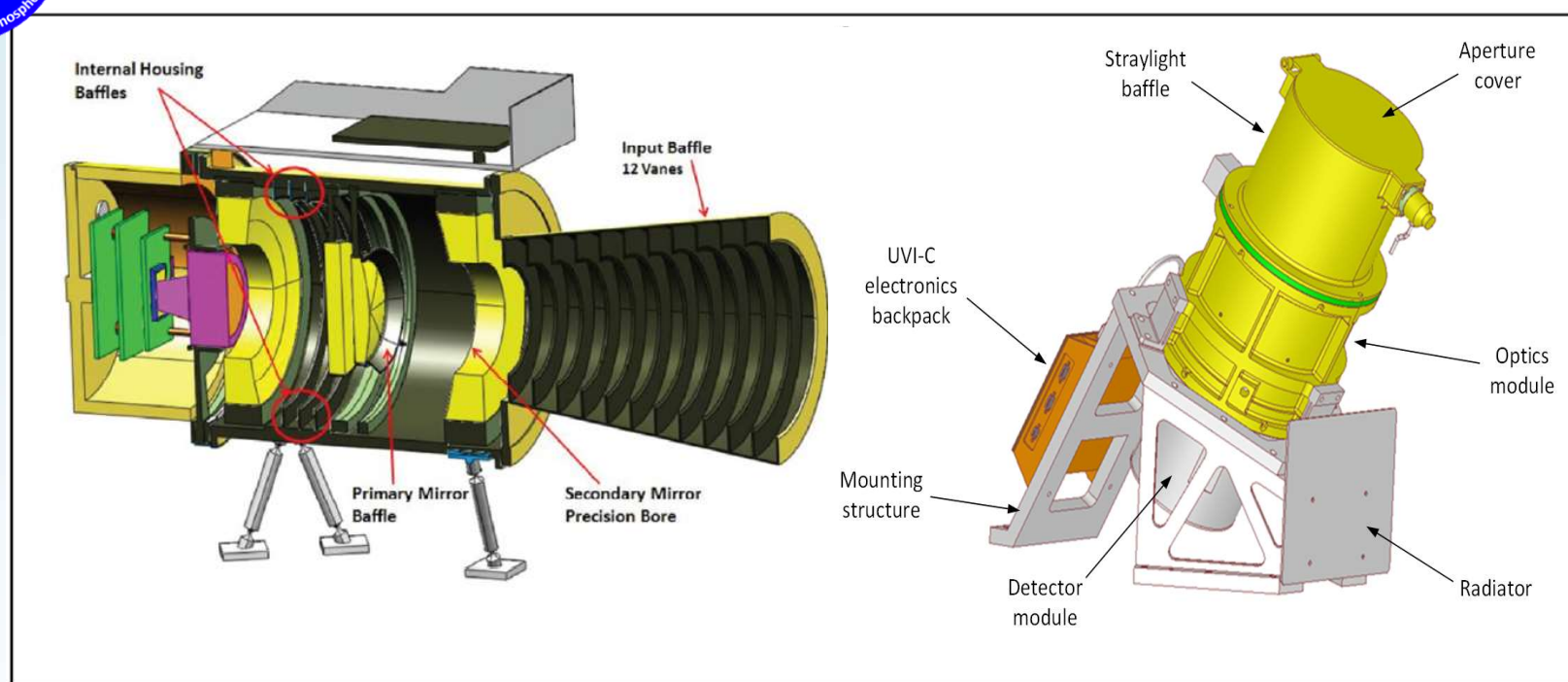
140912_IMF_turning_larger_alpha_o3_1905
 N_{sw} : 22.69 cm⁻³ V_{sw} : 623.14 km s⁻¹ B_y : 7.89 nT B_z : 14.87 nT
 Position: 8.58 5.16 17.03 GSE
 Aim Point: 8.48 0.00 0.00 GSE



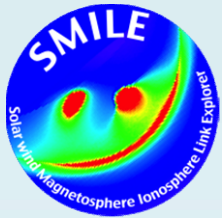
→ SXI performance study confirms
SMILE science requirements are
satisfied



SMILE UltraViolet Imager (UVI)

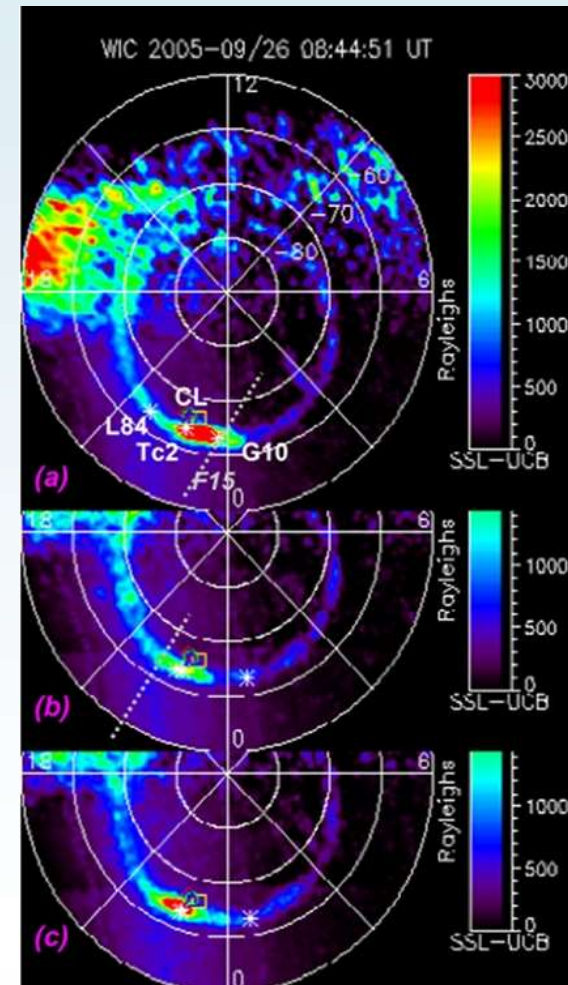
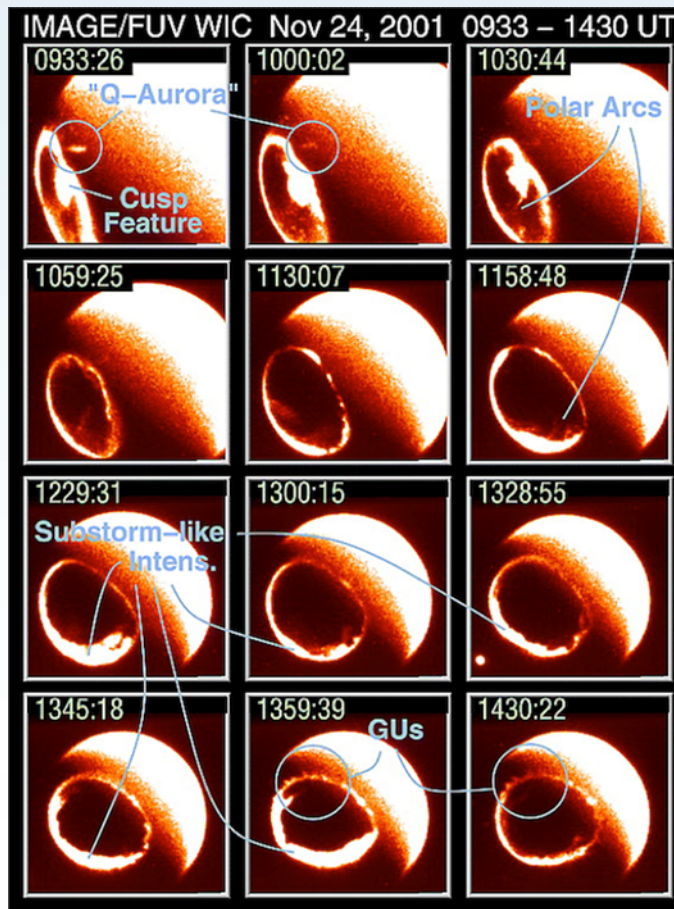


- Four mirror reflective UV imager of whole northern aurora at high spatial and temporal resolution
- UV bandpass (155-175 nm) achieved coating optical & detector surfaces
- Image intensifier detector (photocathode → MCP → phosphor → CMOS sensor)

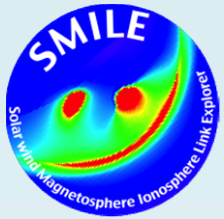


SMILE UVI targets the Earth's North aurora

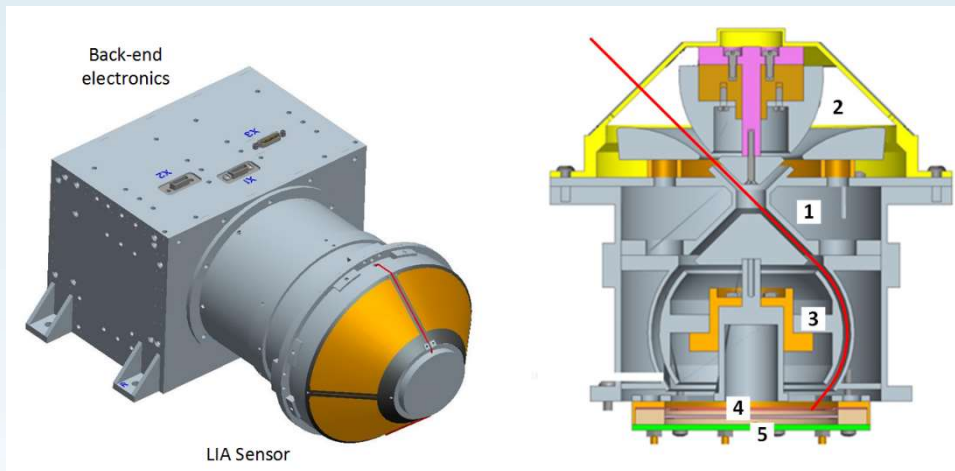
SMILE UVI will observe the Earth's **northern auroral oval** like the IMAGE satellite did



Credit: IMAGE/NASA/GSFC



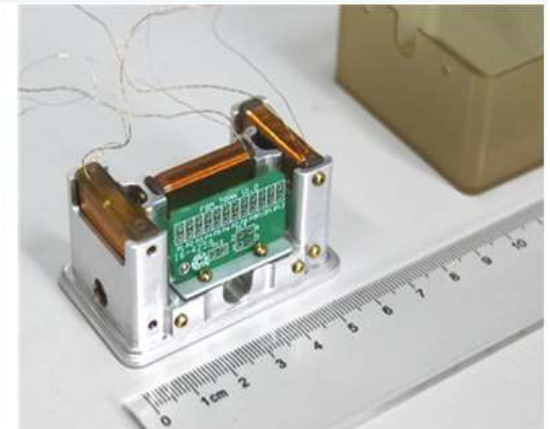
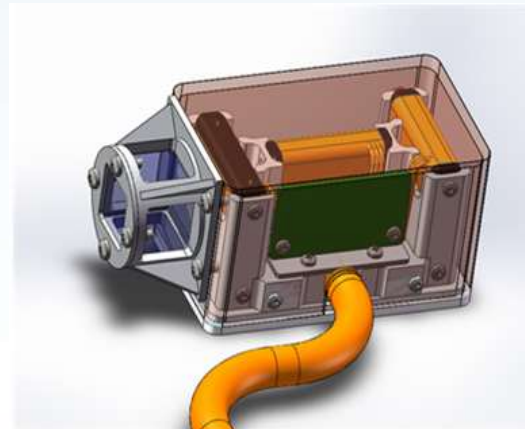
SMILE Light Ion Analyser (LIA) & MAGnetometer (MAG)



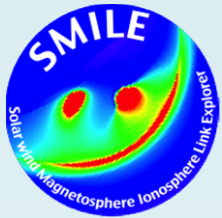
- Fluxgate magnetometer for magnetic field strength & direction
- 3 m boom, two sensors

- Top-hat analyser for p and α density, velocity and temperature
- Energy range: 50 eV - 20 keV
- FOV : 360° (azimuth) and up to 90° (elevation)

PI L. Dai, NSSC, CAS, China

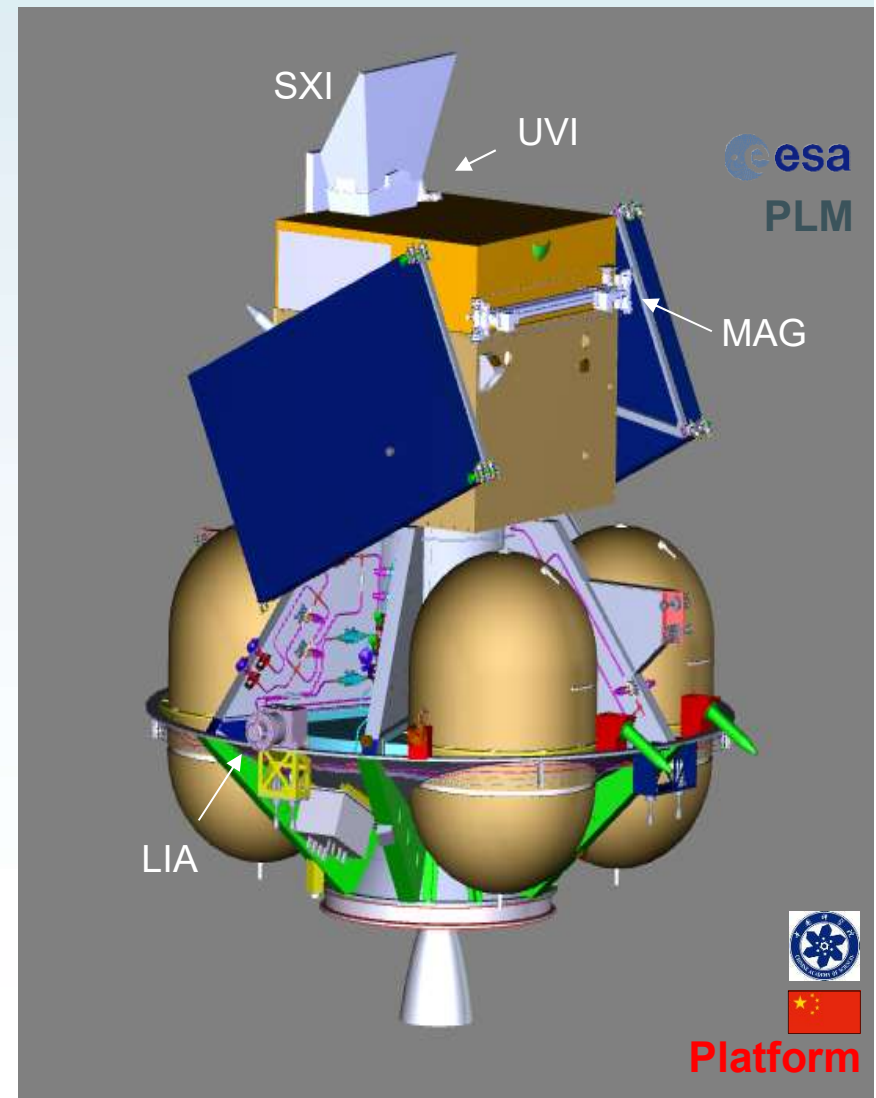


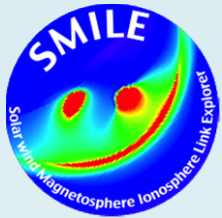
PI L. Li, NSSC, CAS, China



SMILE shares of responsibilities

- **ESA** provides the Payload Module, launcher, AIT facilities for spacecraft integration and testing; ESA member states/Canada provide instruments
- **CAS** provides the Propulsion Module, Service Module, Spacecraft Prime, Mission Operations (with contribution by ESA), Chinese instruments



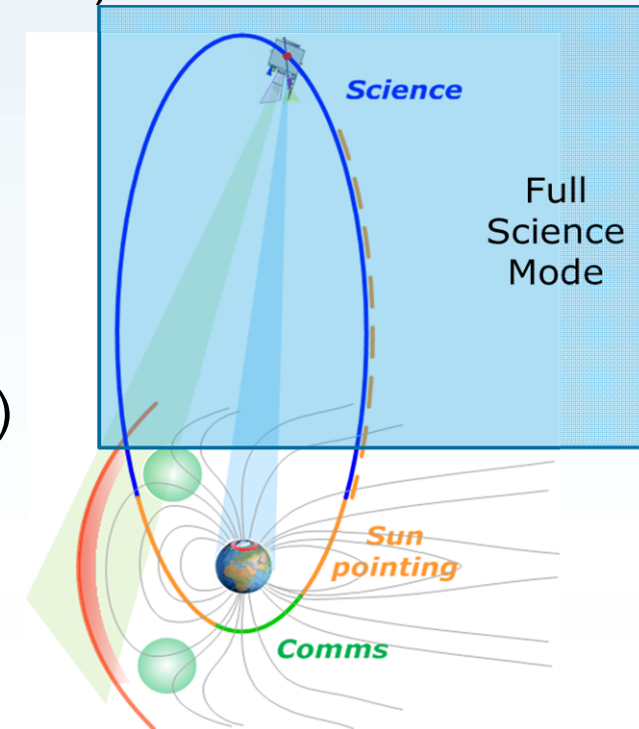
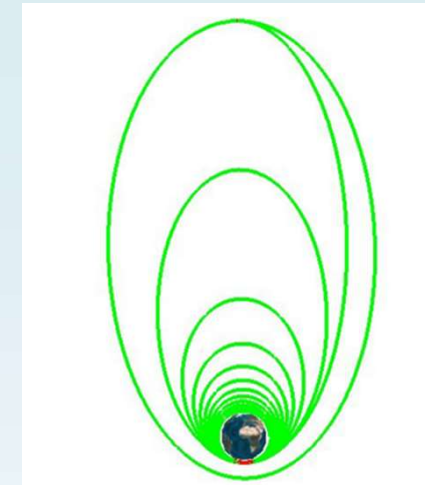


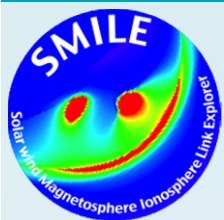
SMILE orbit

Baseline: ~ 5000 km x 120,000 km HEO,
51 hr orbit (40 hr SXI and UVI science operations)

Launch (2023): **Vega-C** (single passenger, ~70° incl.)
or **Ariane 6** (dual launch into SSO 700 km,
98° incl.), both from Kourou

Ground stations: Troll (Antarctica, baseline, ESA)
and Sanya (China, support, CAS)





Data Formats
WG

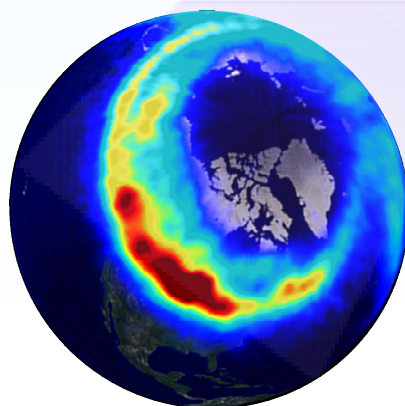


In Situ
WG

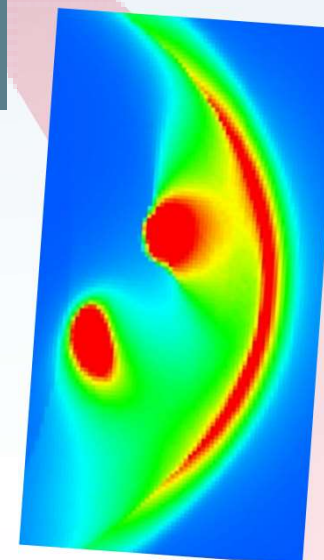
SMILE Working Groups

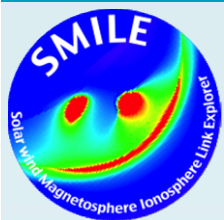
Ground Based &
Additional
Science WG

Modelling WG



Outreach
WG

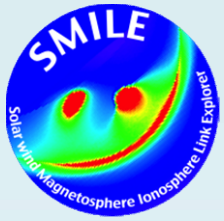




SMILE Consortium meeting # 7

13-15/5/2019, Xi'an, China





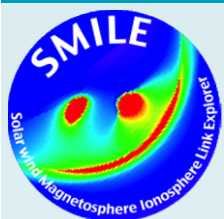
SMILE Consortium meeting # 8

European Space Astronomy Centre, Spain

18-20/11/2019

SMILE SWT14 @ESAC





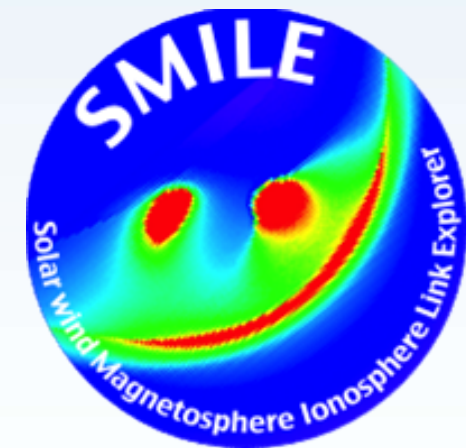
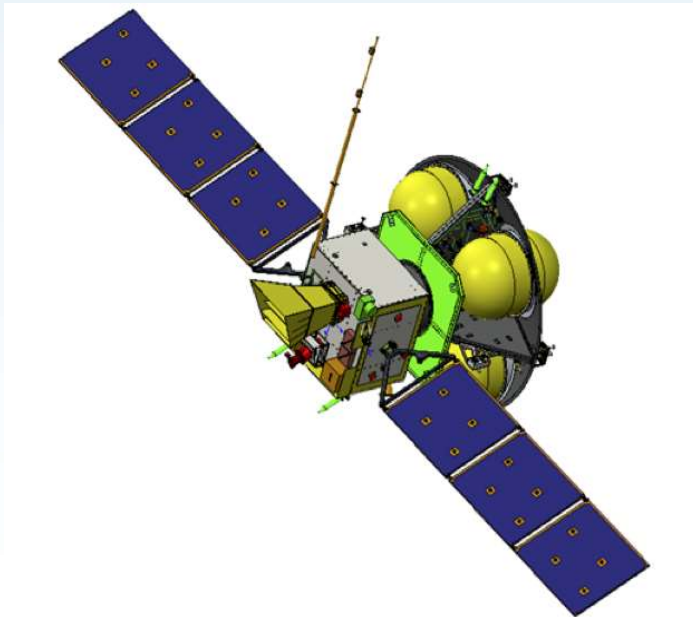
SMILE impact



- X-rays from the magnetosphere: from ‘unwanted background’ for X-ray astrophysical observatories to **diagnostic tool of Sun-Earth relationships**
- SMILE will provide direct **scientific input** to the studies of space weather by providing the remote sensing measurements needed to **validate global models** of solar wind-magnetosphere interactions
- **Outreach**: Images and movies will captivate public to science (magnetic field) so far invisible
- **Cooperation with China**: SMILE is a showcase, building on Double Star



Thank you!



<http://sci.esa.int/smile/>

<http://english.cssar.cas.cn/smile/>

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