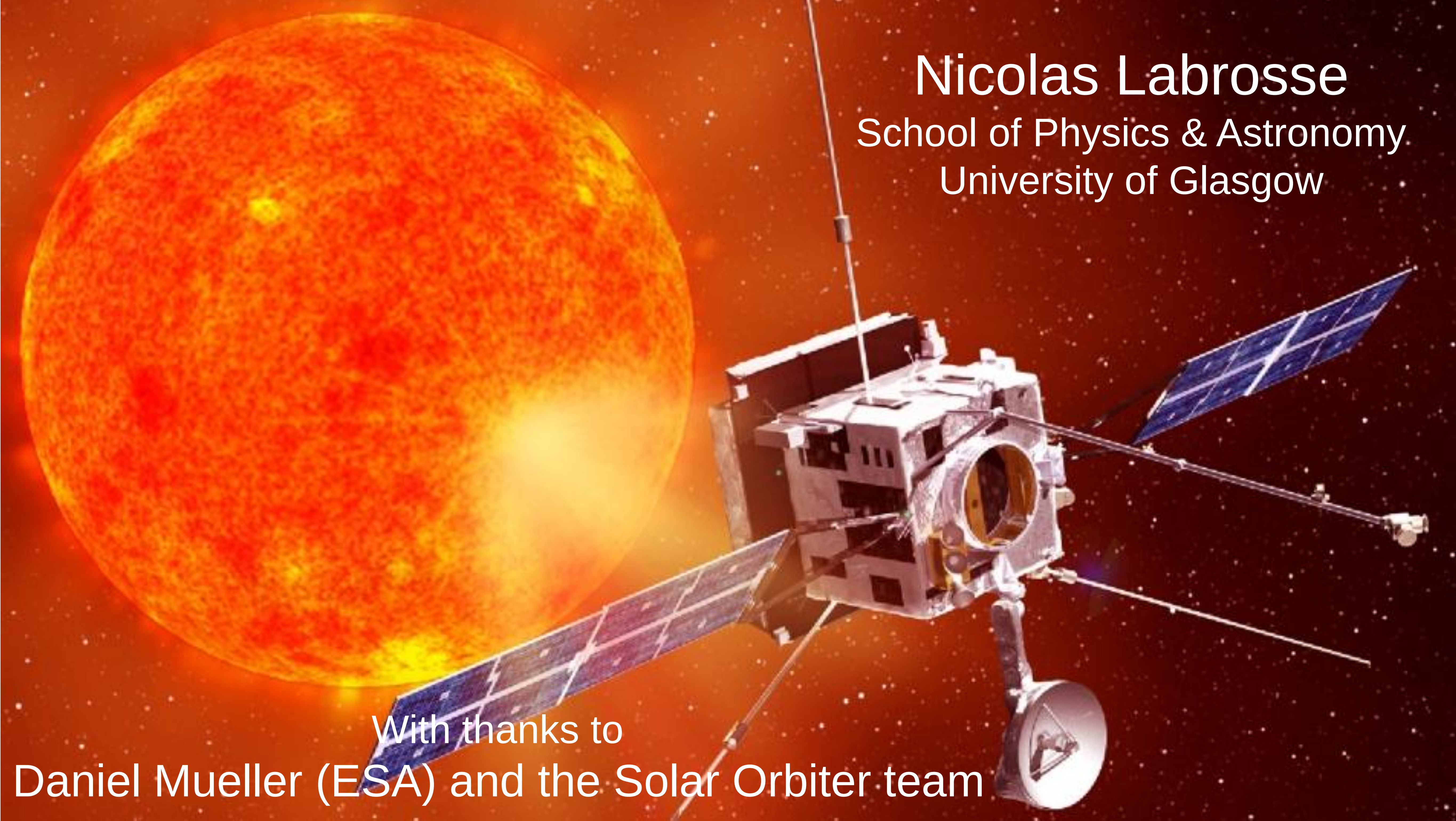
Solar Orbiter

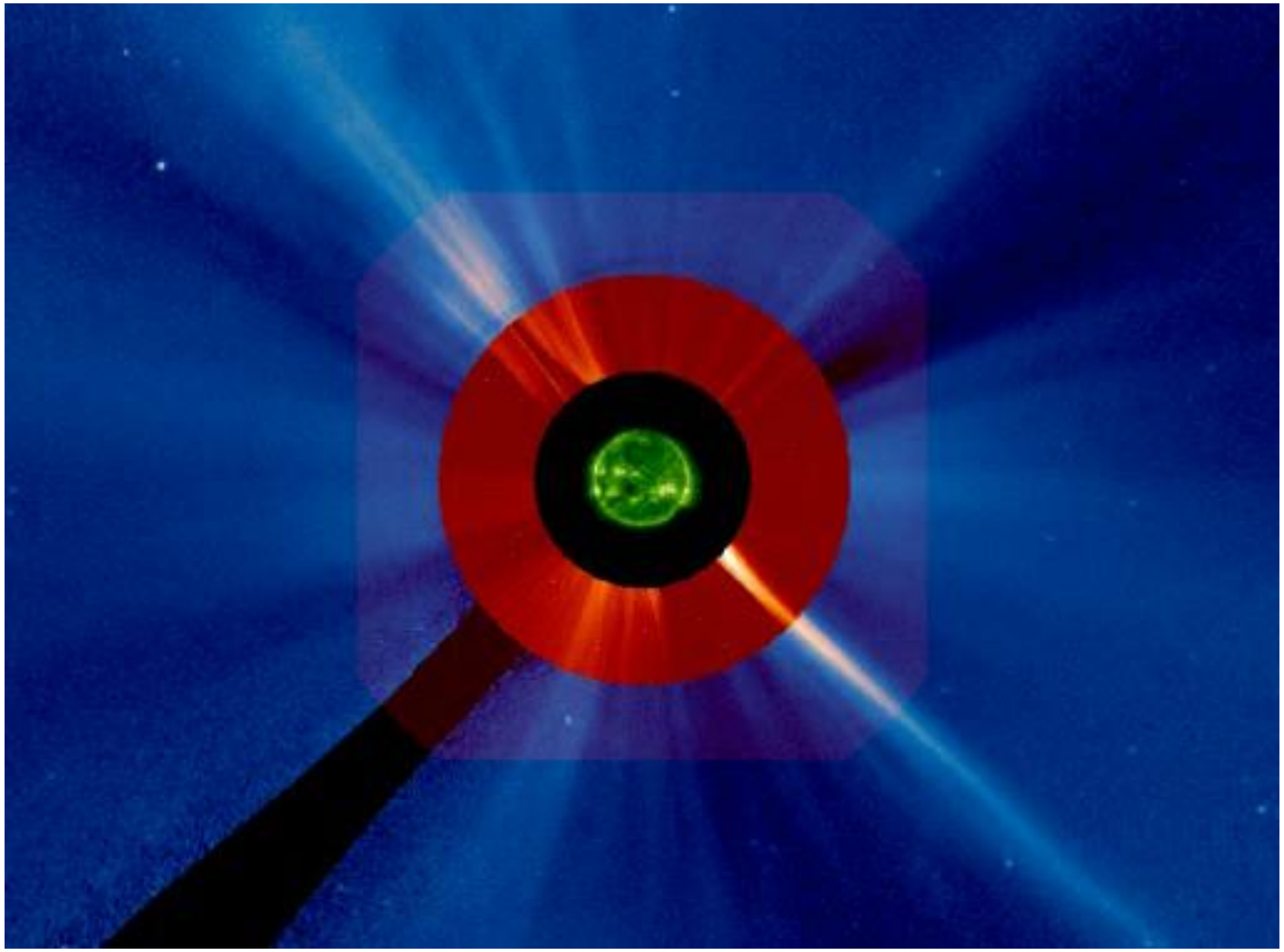
Exploring the Sun-heliosphere connection



Nicolas Labrosse
School of Physics & Astronomy
University of Glasgow

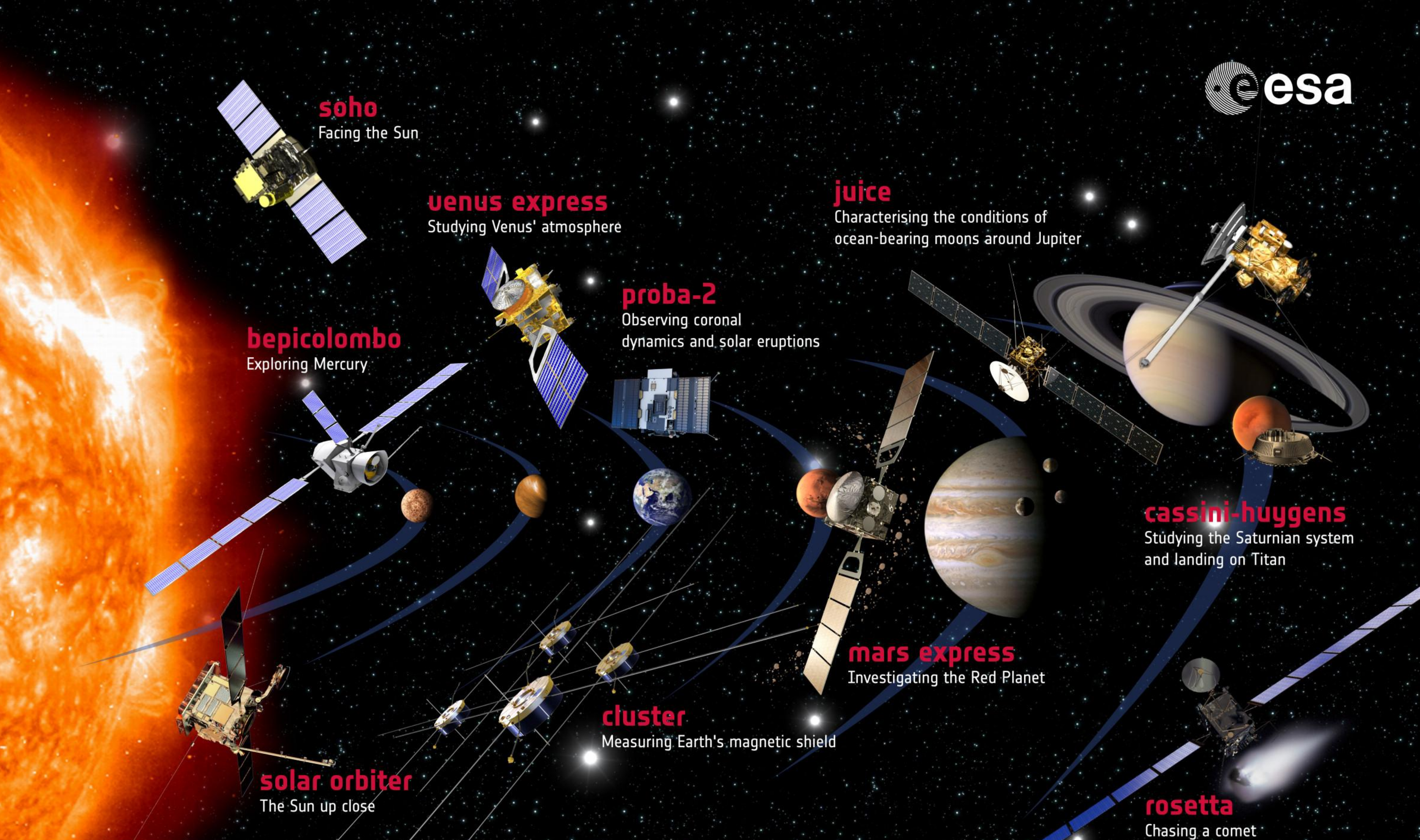
With thanks to
Daniel Mueller (ESA) and the Solar Orbiter team

Solar corona, wind and magnetic activity: an intimate connection to form a dynamic heliosphere



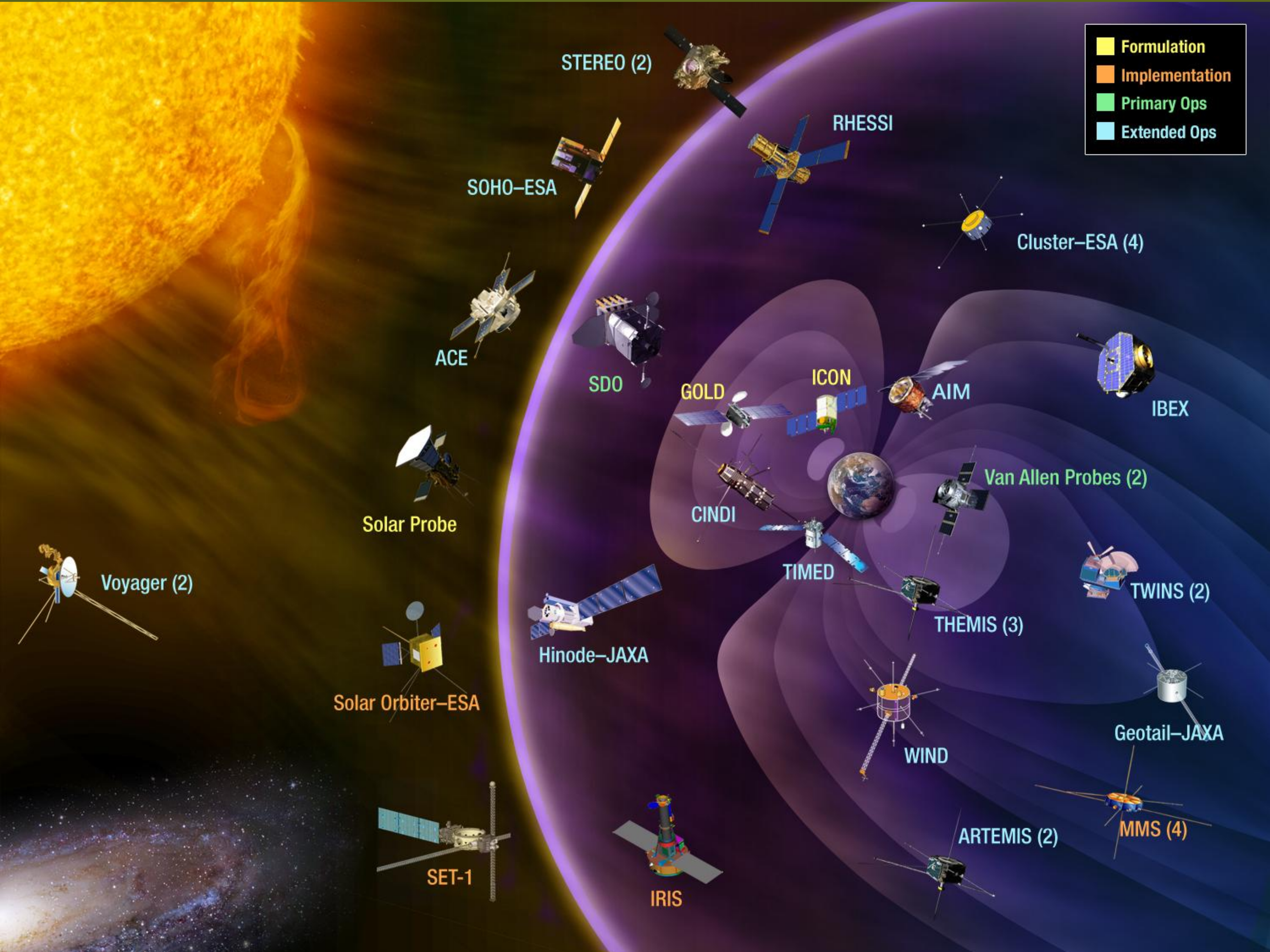
Why study the Sun-heliosphere connection?

- Addresses some fundamental questions:
  - "How does the solar system work?"
  - "What are the fundamental physical laws of the Universe?"
- Study plasma phenomena which occur throughout the Universe
  - Shocks, particle acceleration, magnetic reconnection, turbulence, etc.
- Solar wind and energetic particles directly affect life on Earth
- Impact on space and ground-based assets



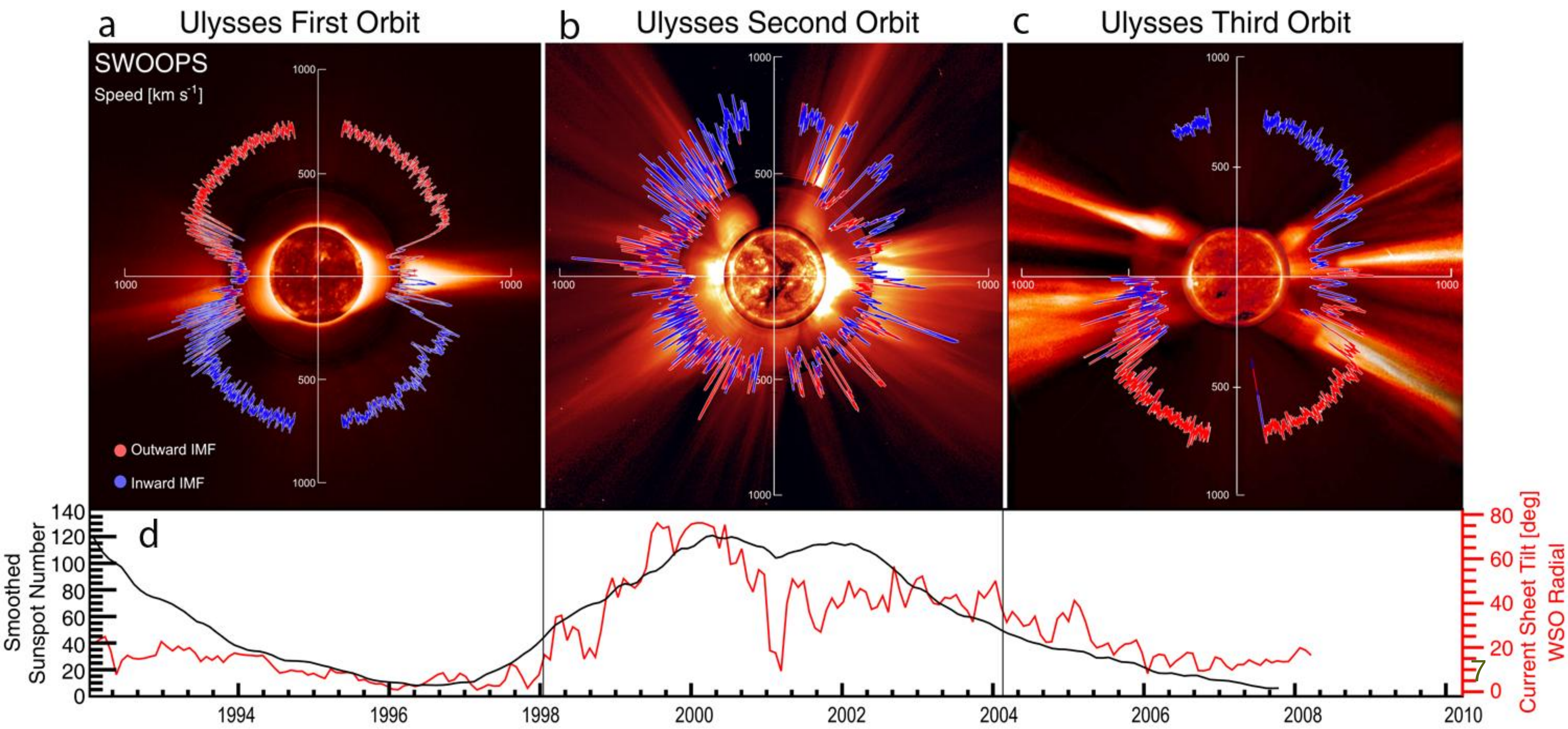
→ ESA'S FLEET IN THE SOLAR SYSTEM

The Solar System is a natural laboratory that allows scientists to explore the nature of the Sun, the planets and their moons, as well as comets and asteroids. ESA's missions have transformed our view of the celestial neighbourhood, visiting Mars, Venus, and Saturn's moon Titan, and providing new insight into how the Sun interacts with Earth and its neighbours. The Solar System is the result of 4.6 billion years of formation and evolution. Studying how it appears now allows us to unlock the mysteries of its past and to predict how the various bodies will change in the future.



Formulation
Implementation
Primary Ops
Extended Ops
STEREO (2)
RHESSI
SOHO–ESA
Cluster–ESA (4)
ACE
SDO
GOLD
ICON
AIM
IBEX
Solar Probe
CINDI
Van Allen Probes (2)
TIMED
Voyager (2)
TWINS (2)
THEMIS (3)
Hinode–JAXA
Solar Orbiter–ESA
Geotail–JAXA
WIND
ARTEMIS (2)
MMS (4)
SET-1
IRIS

How does the Sun create and control the Heliosphere – and why does solar activity change with time ?



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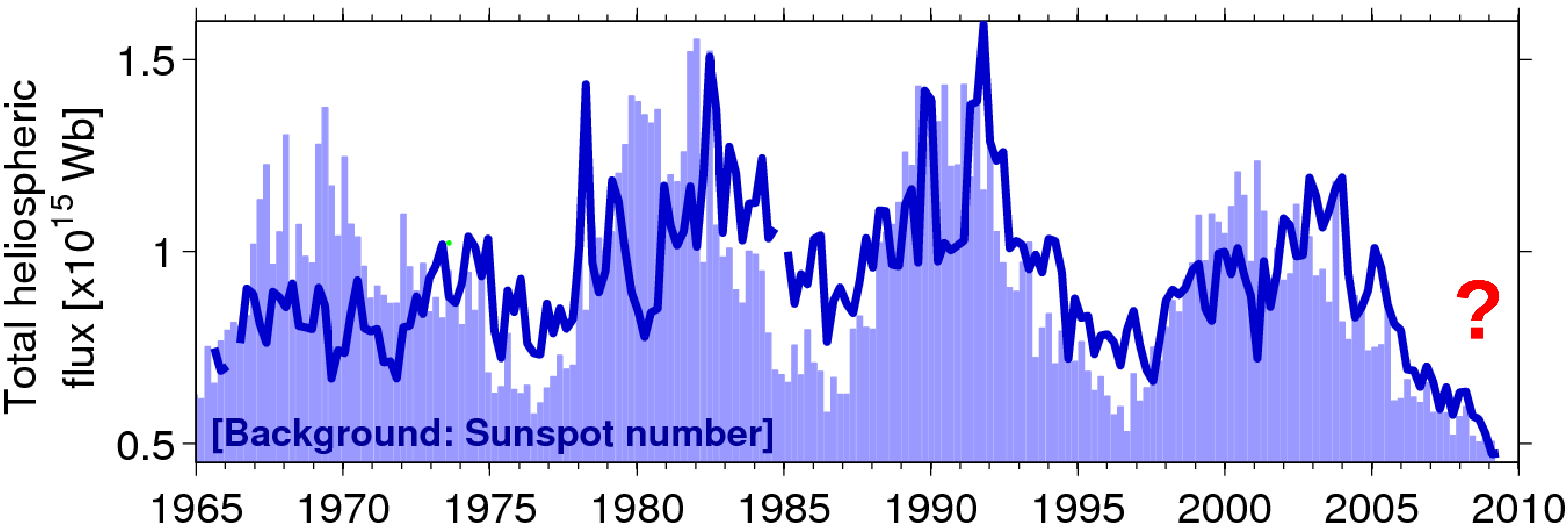

(From M. Owens, University of Reading.)

How does the Sun create and control the Heliosphere?

Q1) How and where do the solar wind plasma and magnetic field originate in the corona?

Q2) How do solar transients drive heliospheric variability?

Q3) How do solar eruptions produce energetic particle radiation that fills the heliosphere?

Q4) How does the solar dynamo work and drive connections between the Sun and the heliosphere?

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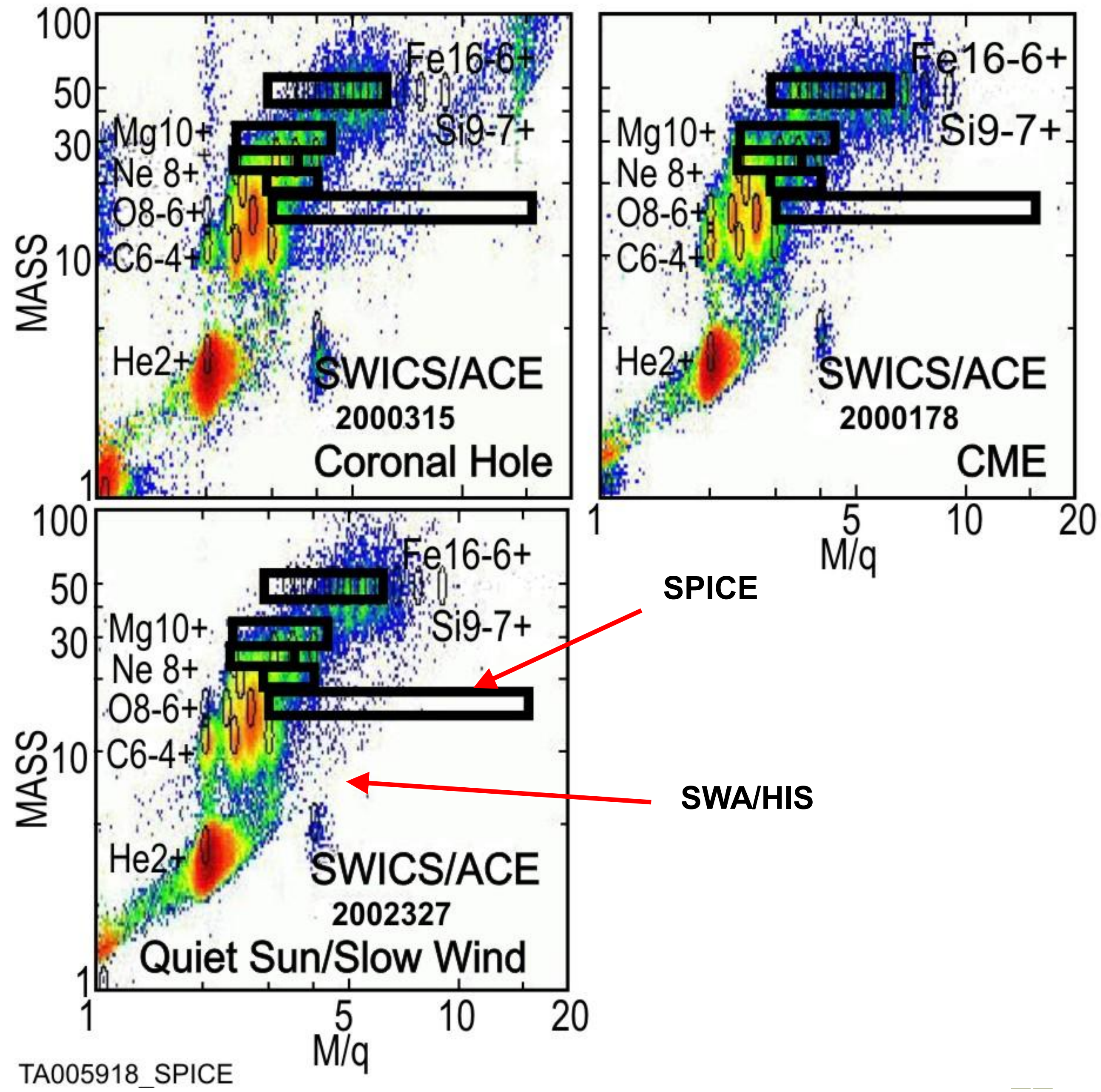
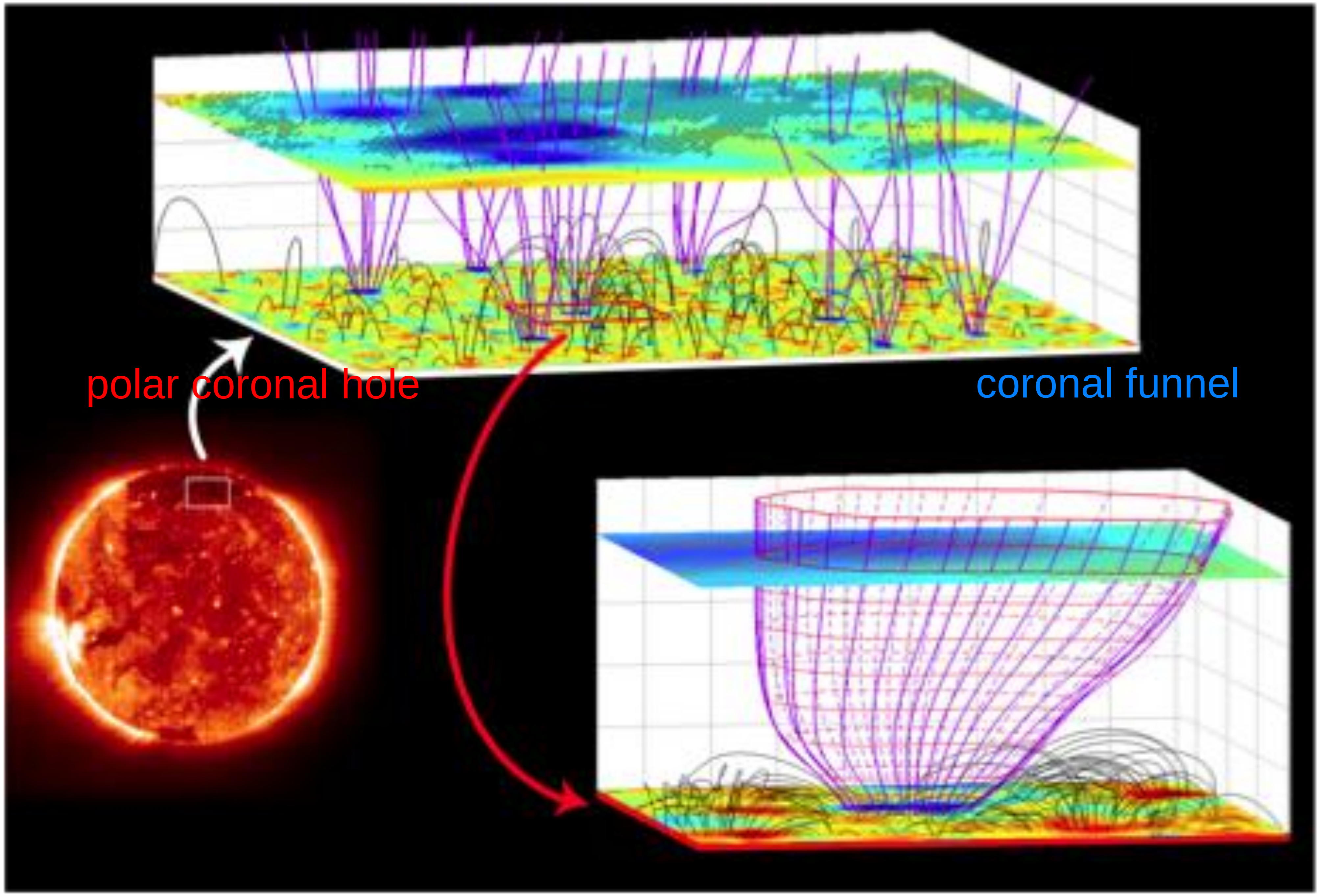
Linking in-situ and remote-sensing observations

- Correlation between remote-sensing and in-situ composition measurements is fundamental
  - Heavy ion charge states and composition
  - Magnetic polarity
  - Energetic particles

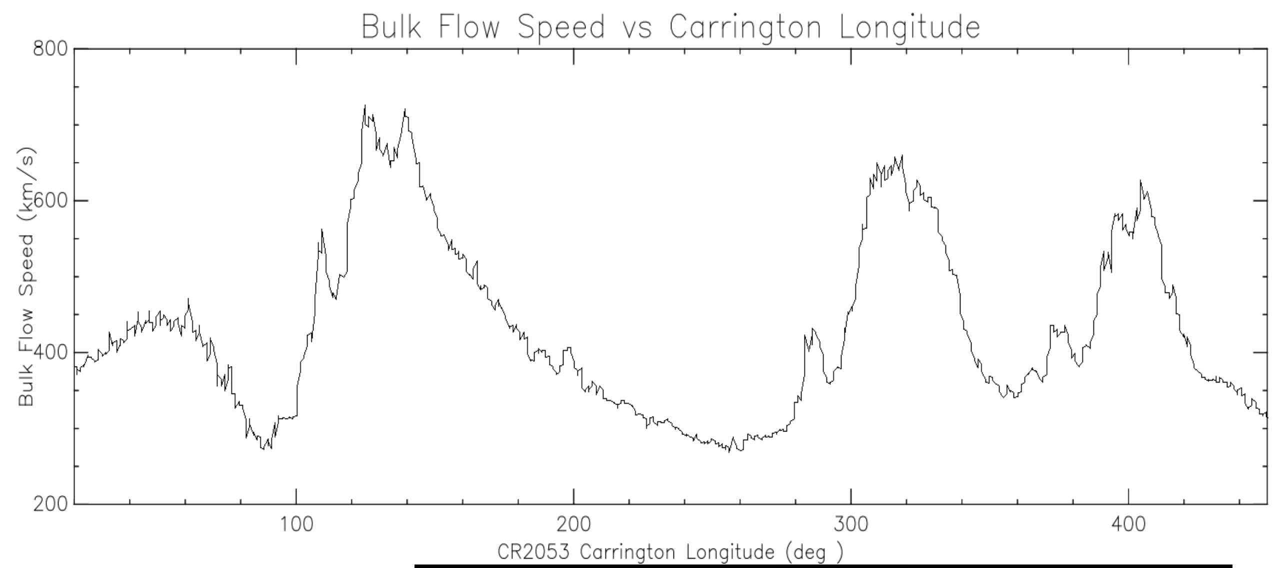


What are the source regions of the solar wind and heliospheric magnetic field?



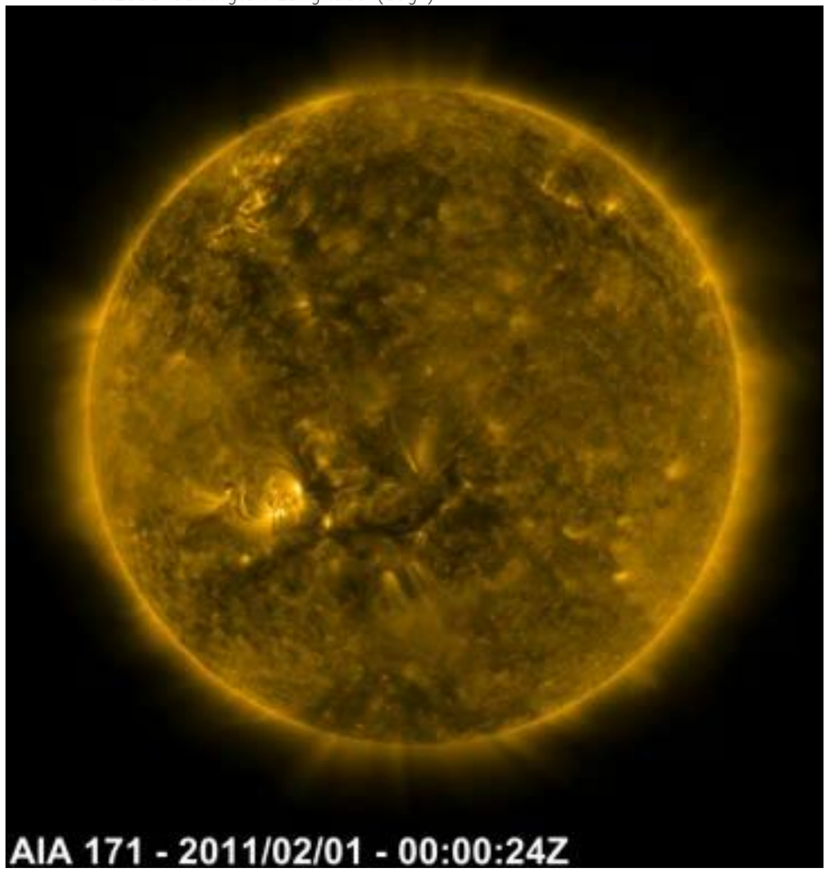
Tu, Zhou, Marsch *et al.*, *Science* 2005

Disentangling Space/Time Structures



•…requires viewing a given region for more than an active region growth time (~ 10 days)

• **Multiple sources of slow solar wind** – active regions are one source. Identifying the source directly in the wind by the time it gets to 1 AU is extremely challenging and can only be done on a statistical basis.



Understanding the detailed physical processes can only be achieved by getting closer.

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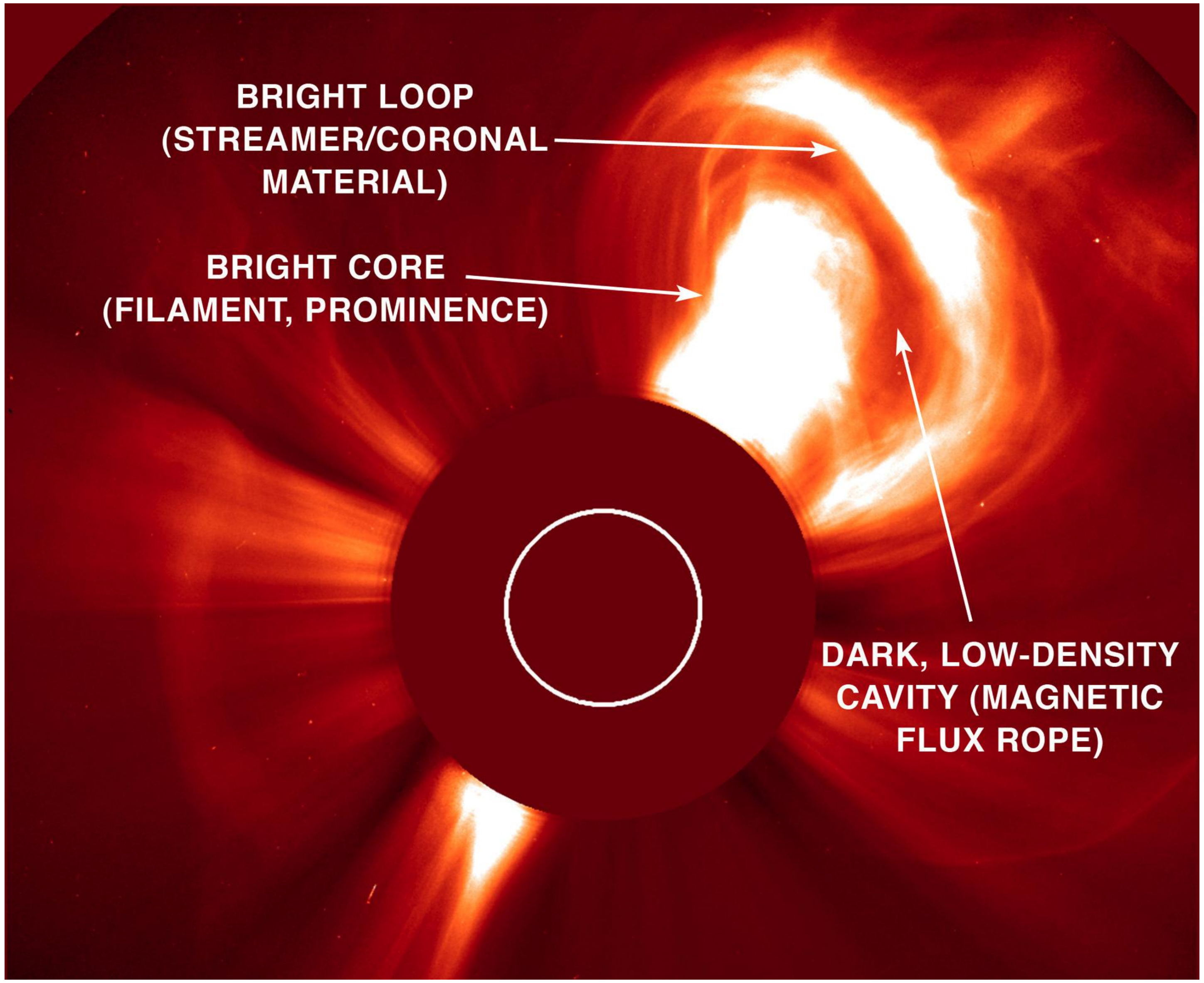
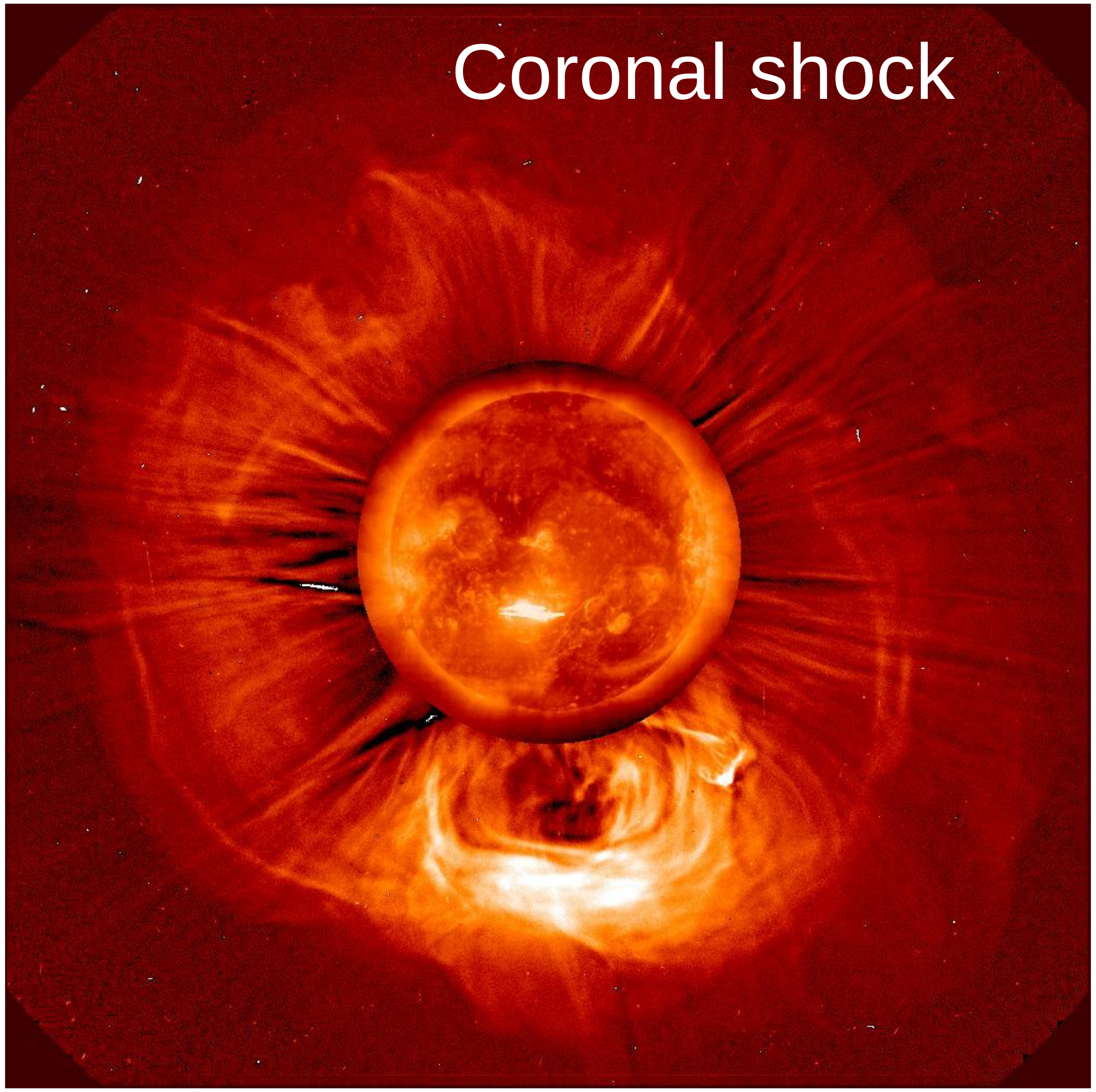
How do coronal mass ejections (CMEs) evolve through the corona and inner heliosphere?





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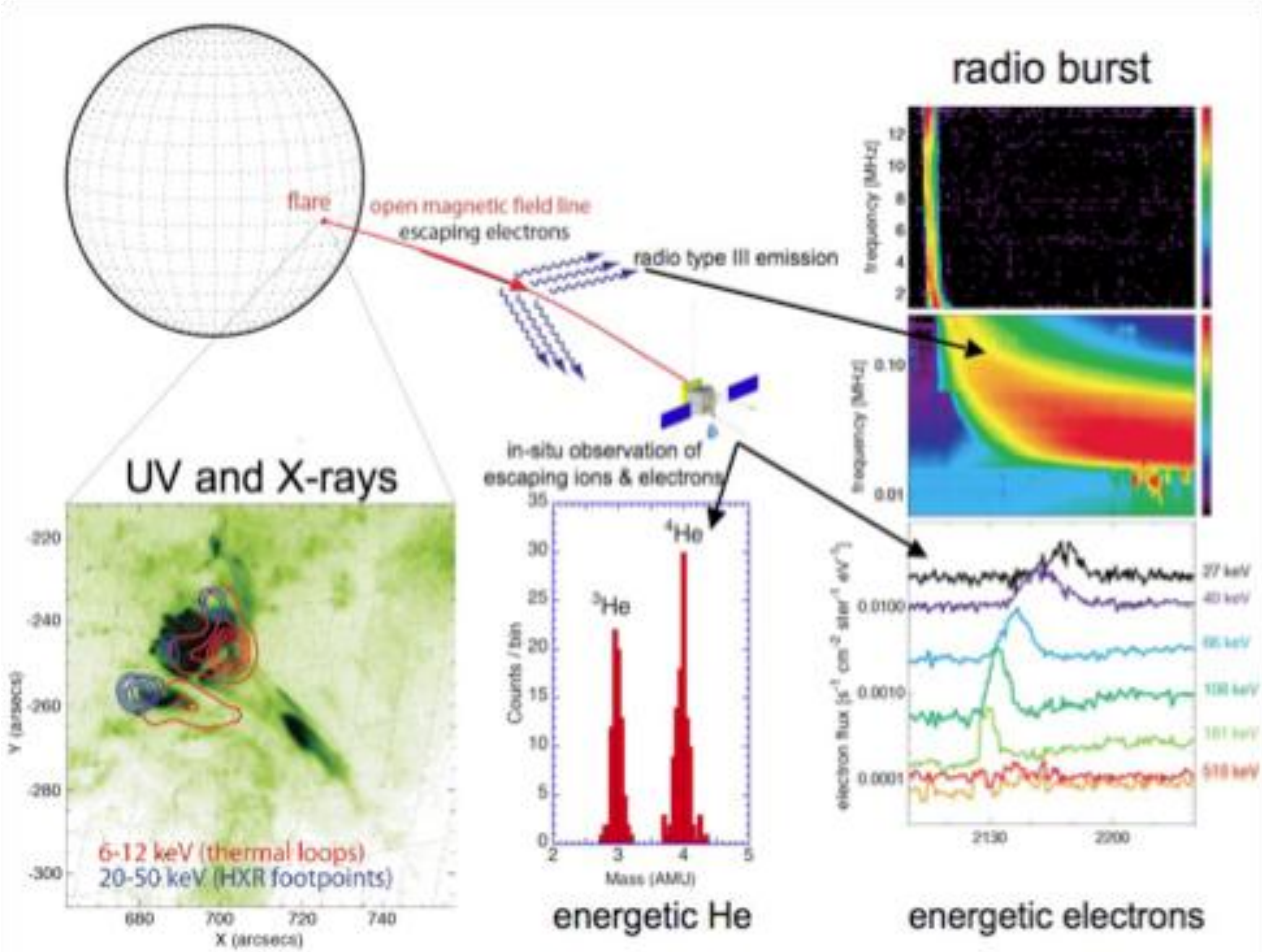
How and where are energetic particles accelerated?



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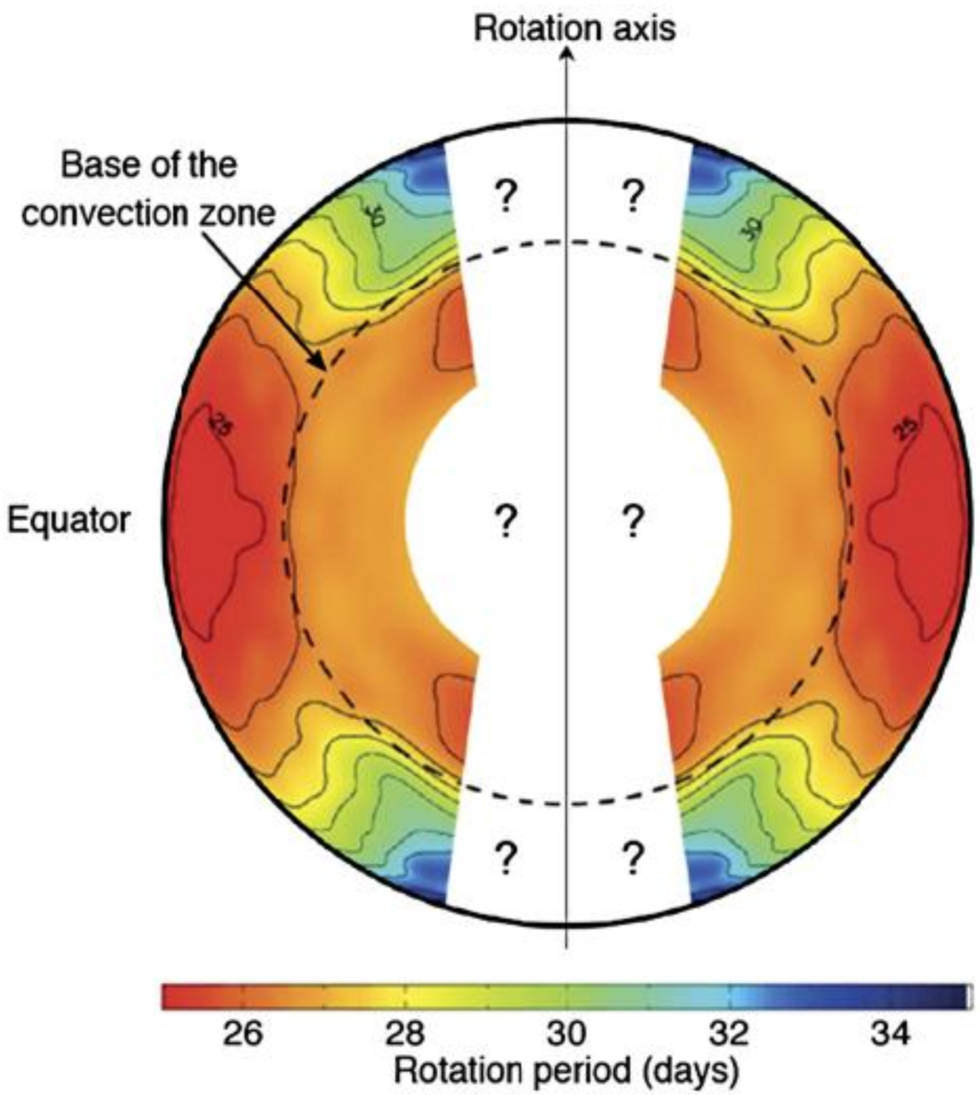
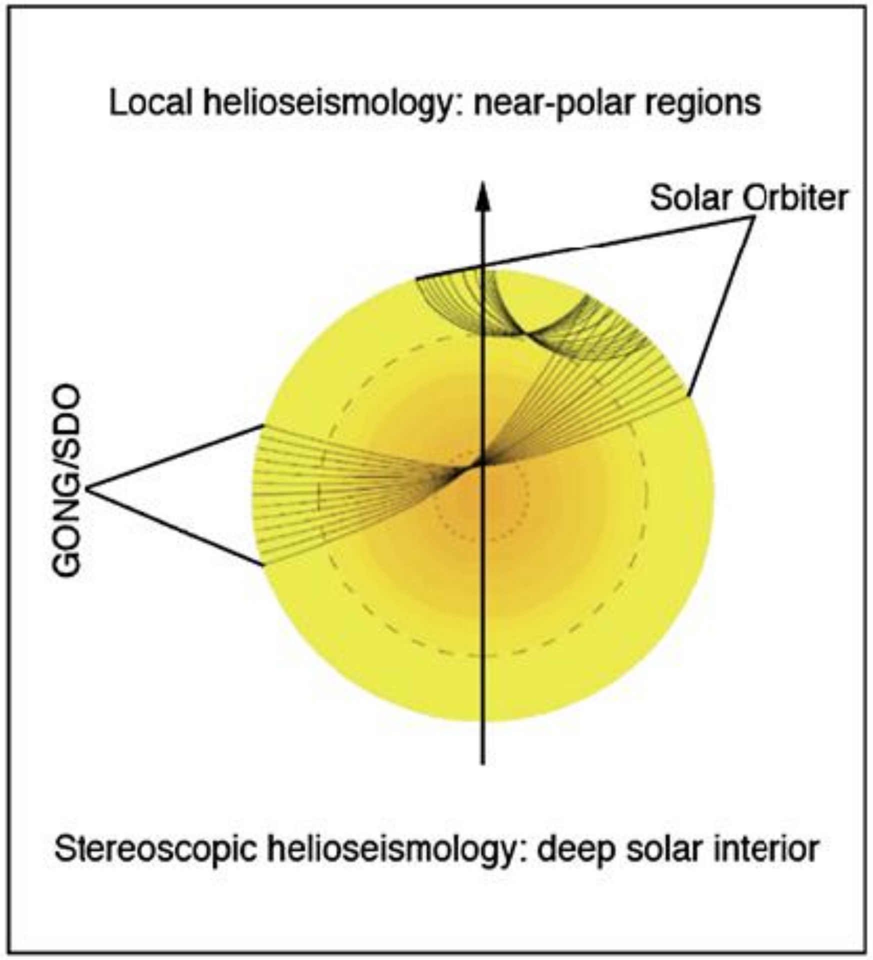
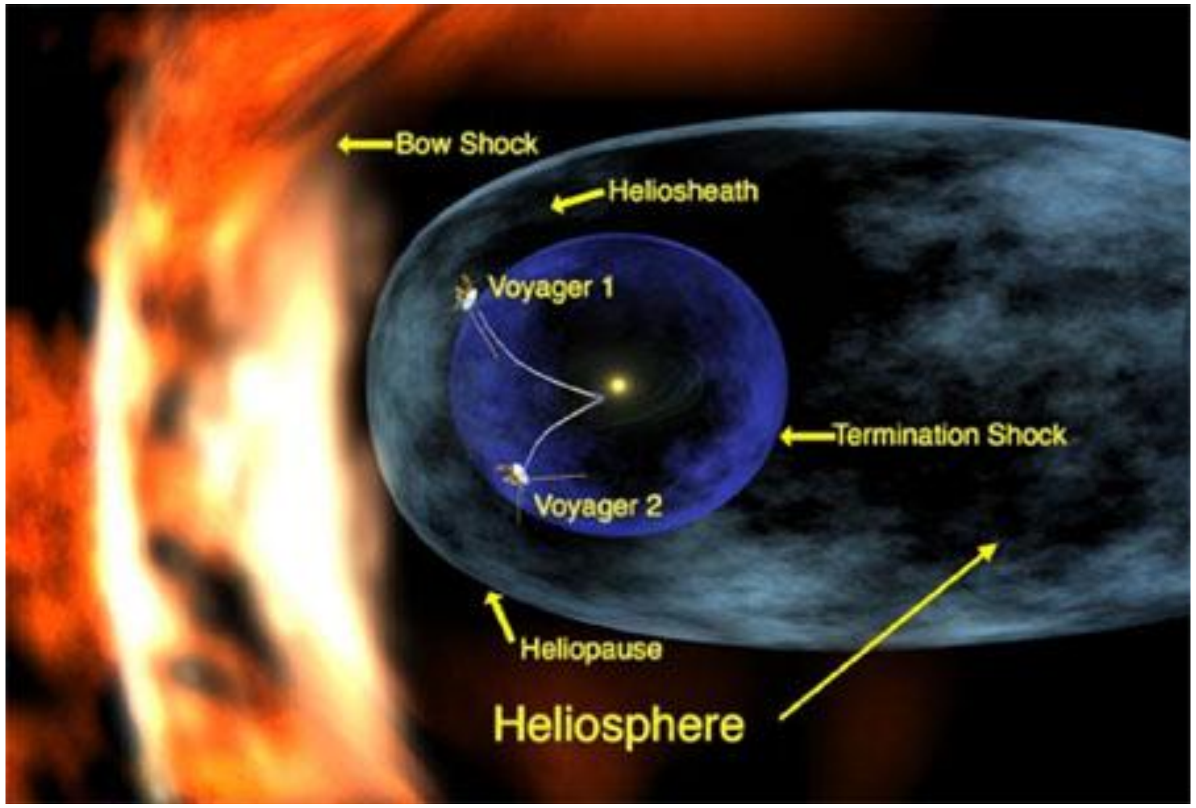
How is magnetic flux transported to and reprocessed at high solar latitude?





Solar Orbiter will use local helioseismology to determine the currently unknown properties of the solar interior below the poles.

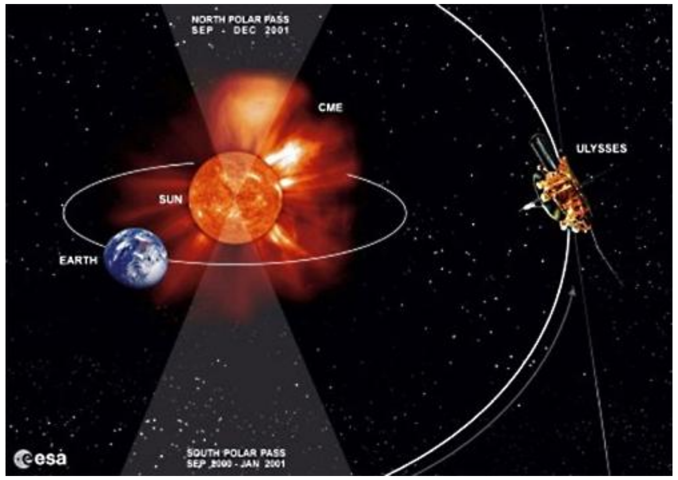
Solar Orbiter – The mission to understand how the Sun creates and controls the Heliosphere

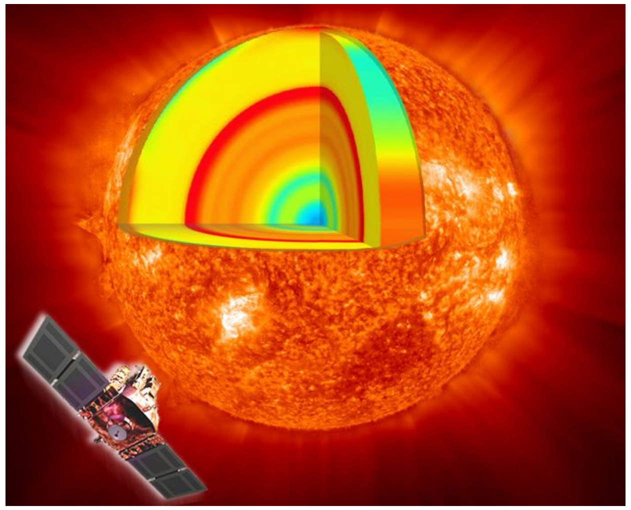


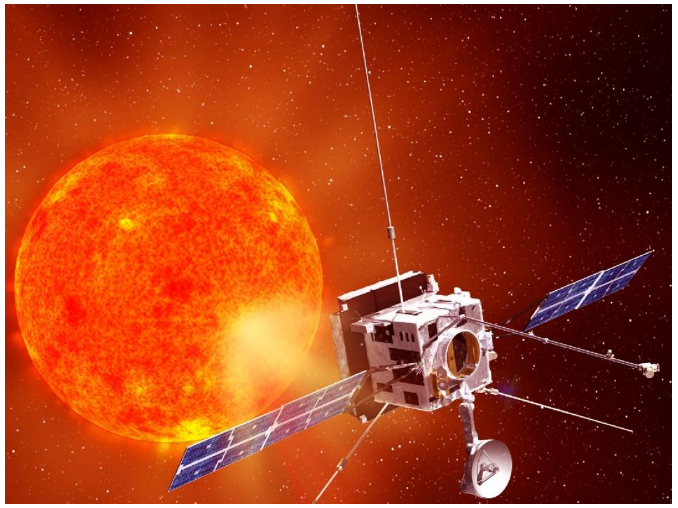
The Mission

- Combines remote sensing and in-situ experiments.

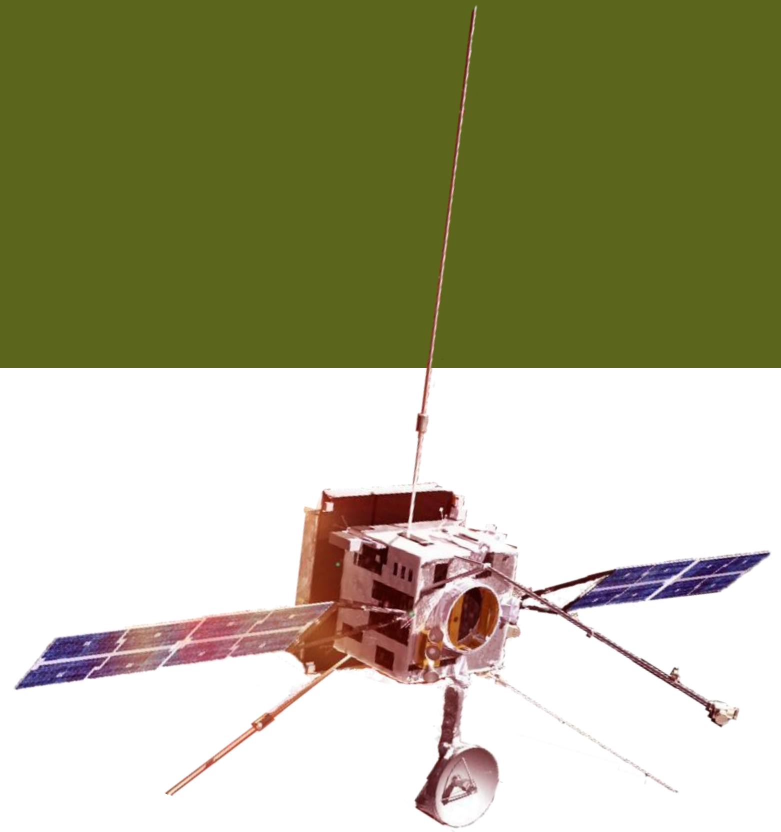
- Dedicated payload of 10 selected remote-sensing and in-situ instruments measuring from the photosphere into the solar wind.







What is required?



- Close to the Sun
- Out of the ecliptic
- Long duration observations of the same region
- Remote measurements of the Sun and corona
- In situ measurements of fields and particles

- It is this unique combination provided by Solar Orbiter that makes it possible to address the question of how the Sun creates and controls the heliosphere

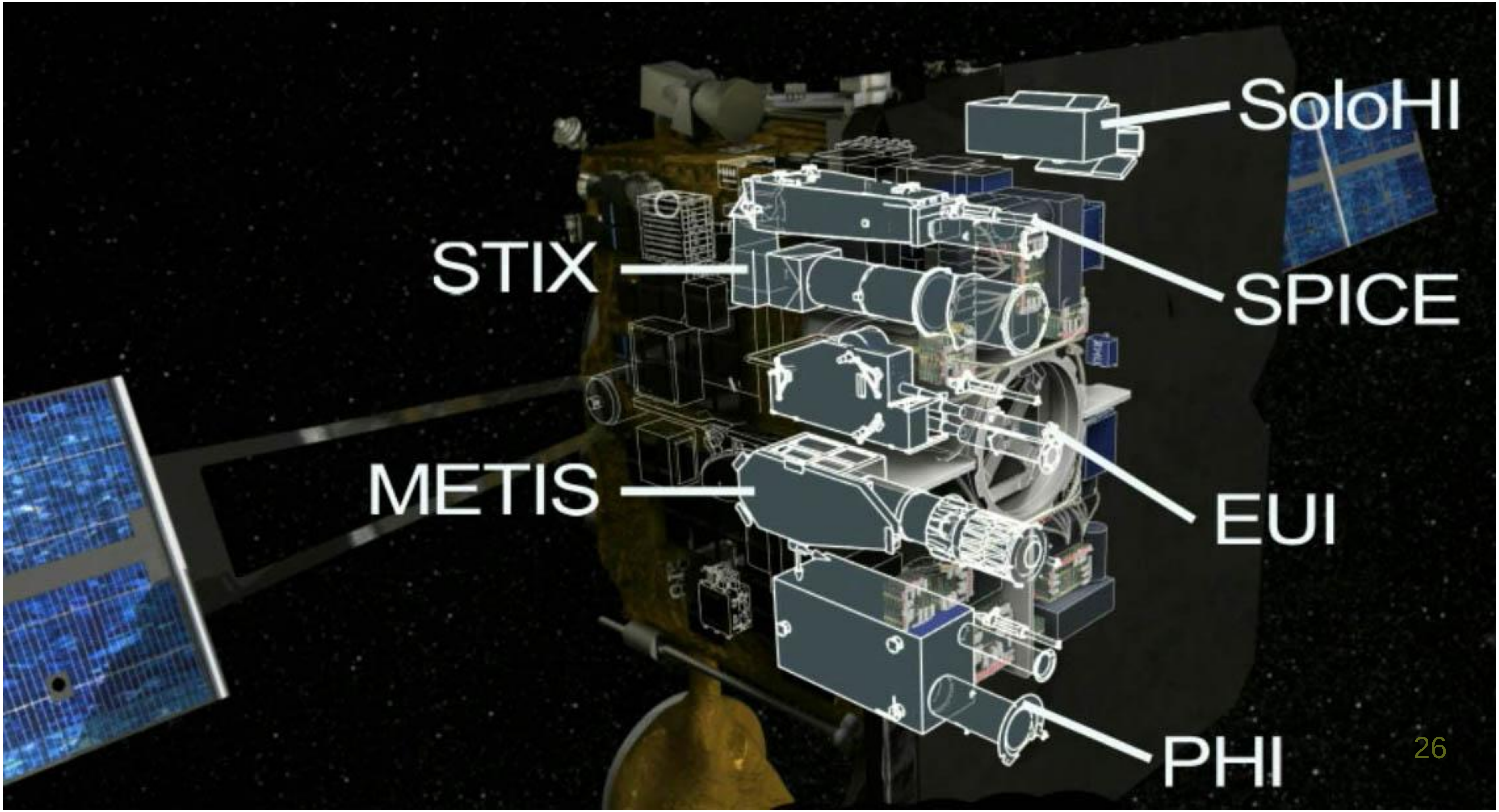
Payload

In situ instruments			
SWA	Solar wind analyser	Chris Owen, UK	Sampling protons, electrons and heavy ions in the solar wind
EPD	Energetic particle detector	Javier Rodriguez-Pacheco, Spain	Measuring timing and distribution functions of accelerated energetic particles
MAG	Magnetometer	Tim Horbury, UK	High-precision measurements of the heliospheric magnetic field
RPW	Radio and plasma wave analyser	Milan Maksimovic, France	Studying local electromagnetic and electrostatic waves and solar radio bursts

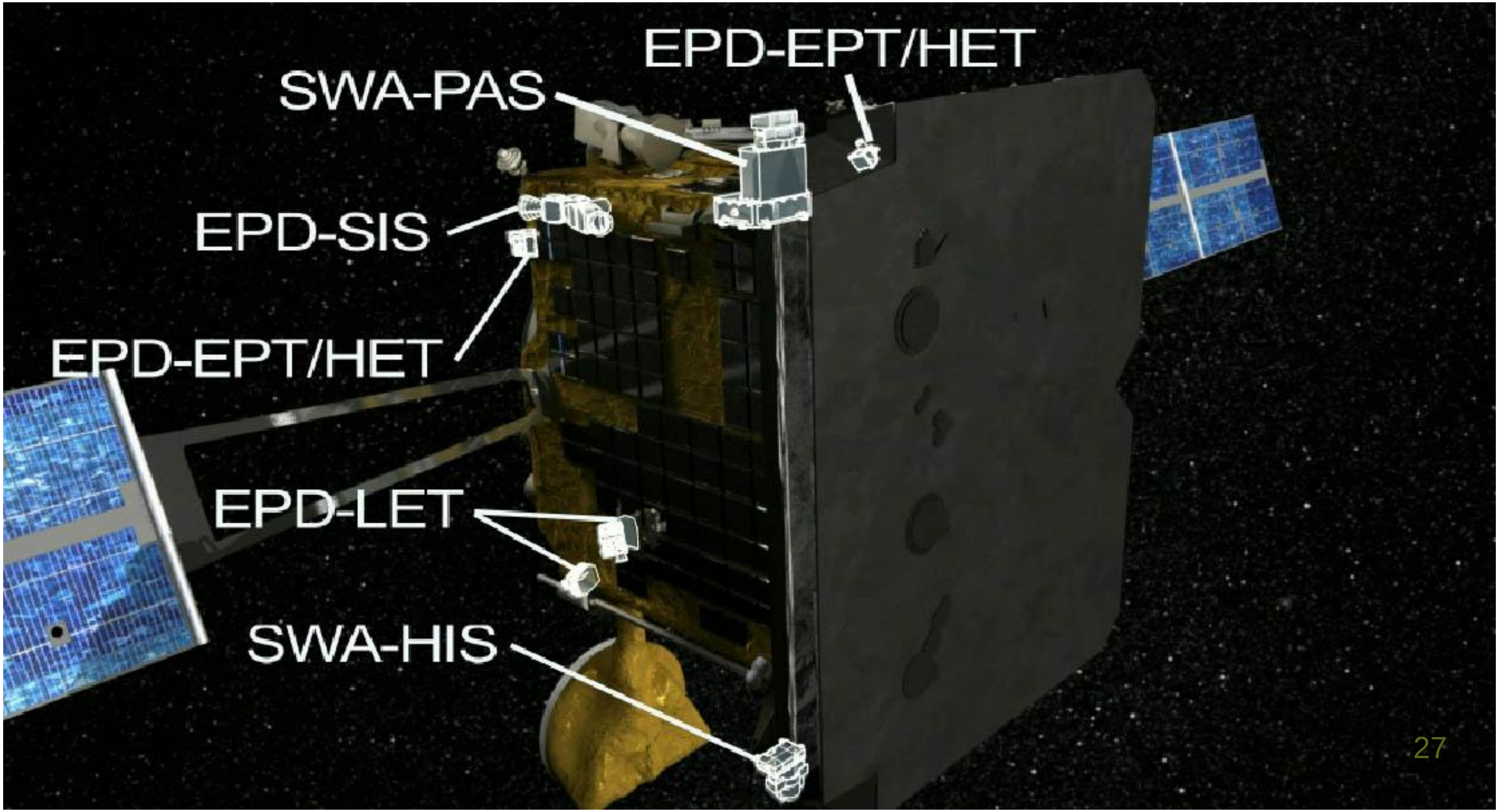
Payload

Remote sensing instruments			
PHI	Polarimetric and heliospheric imager	Sami Solanki, Germany	Full-disc and high-resolution visible light imaging of the Sun
EUI	Extreme ultraviolet imager	Pierre Rochus, Belgium	Studying fine-scale processes and large-scale eruptions
STIX	Spectrometer/telescope for imaging X-rays	Arnold Benz, Switzerland	Studying hot plasmas and accelerated electrons
METIS	Multi-element telescope for imaging and spectroscopy	Ester Antonucci, Italy	High-resolution UV and extreme UV coronagraphy
SoloHI	Solar Orbiter heliospheric imager	Russ Howard, US	Observing light scattered by the solar wind over a wide field of view
SPICE	Spectral imaging of the coronal environment	Facility instrument, ESA provided	Spectroscopy on the solar disc and corona

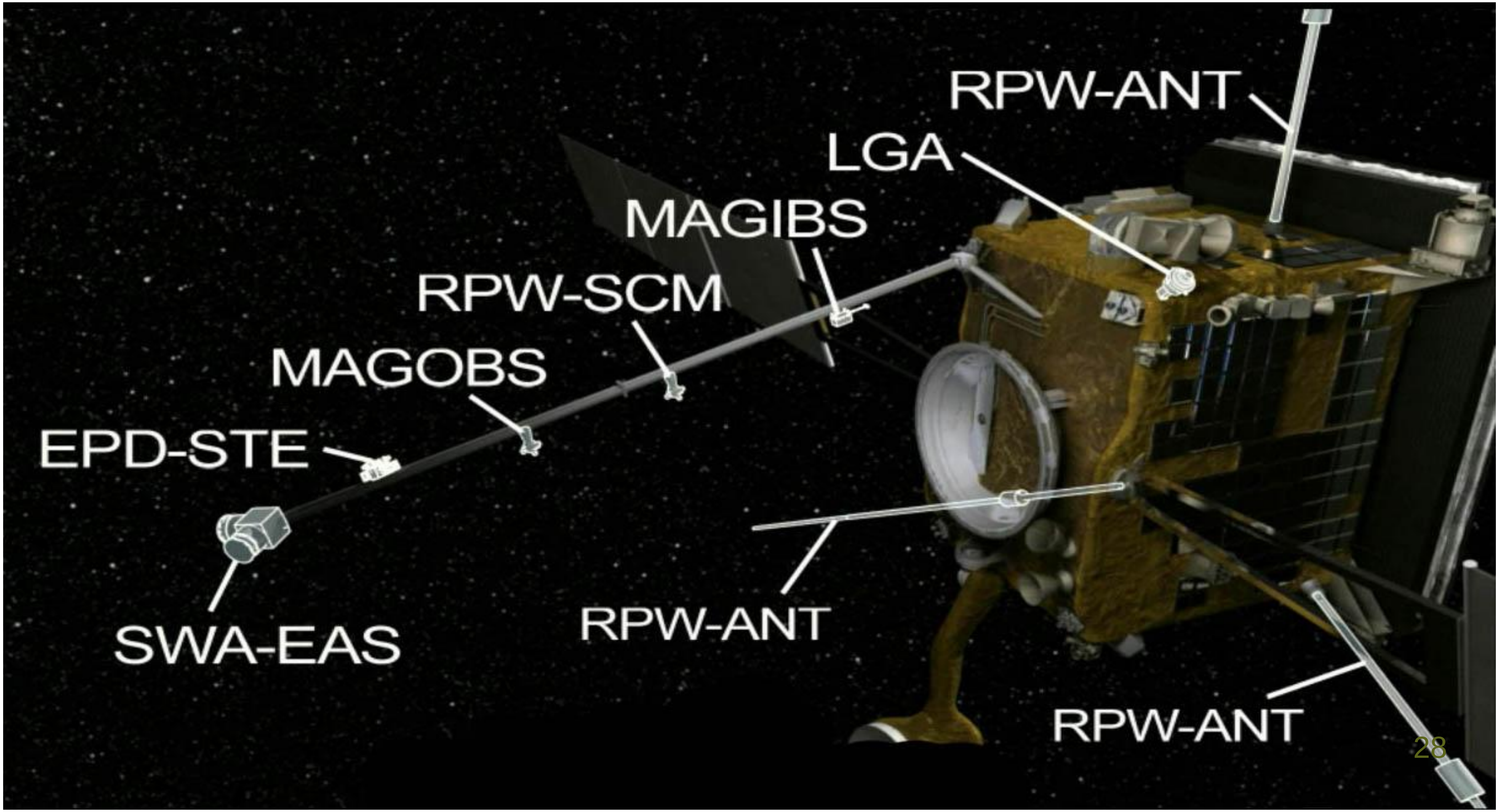
Remote-sensing Instruments



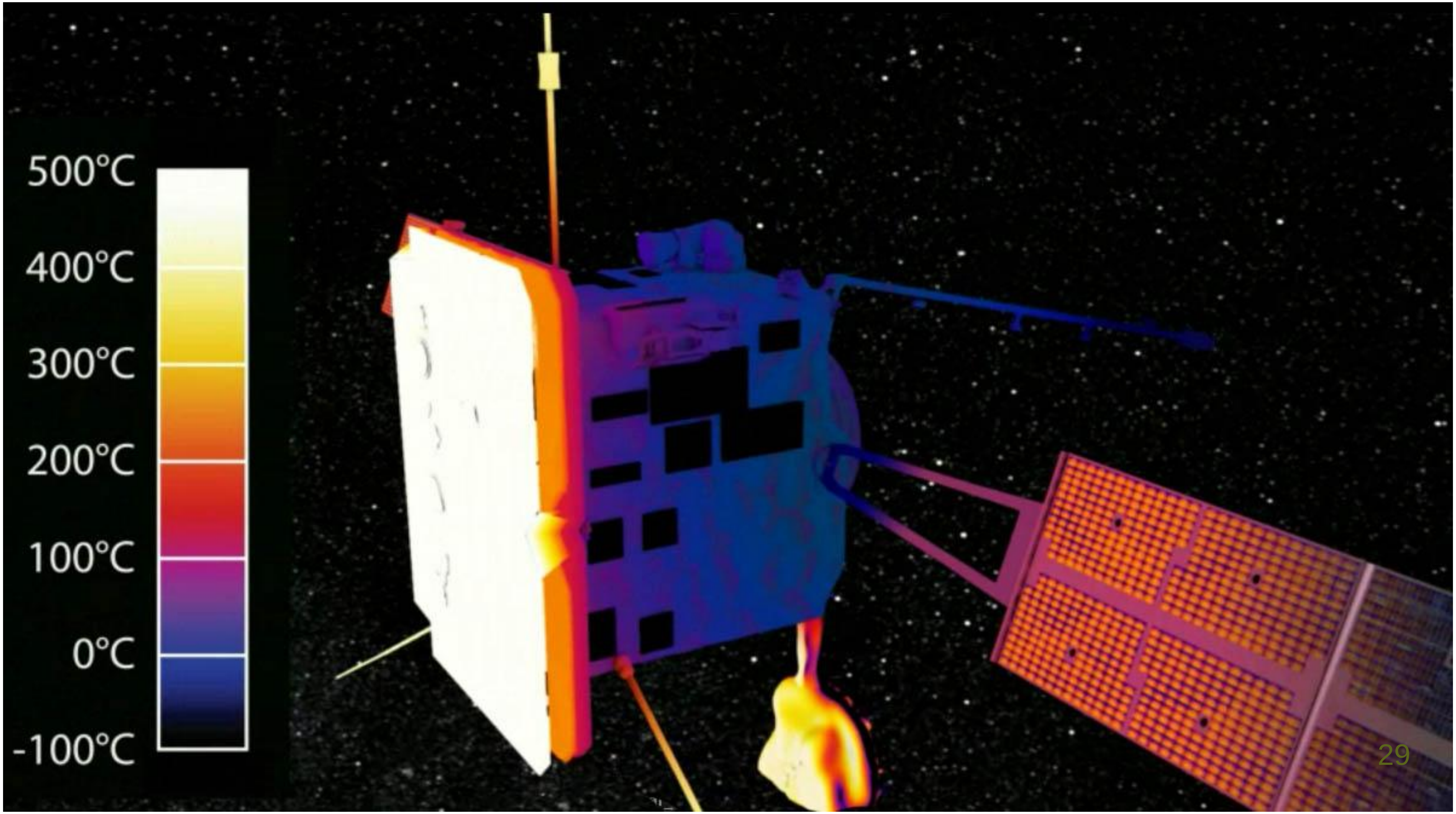
In-situ Instruments



In-situ Boom-mounted Instruments

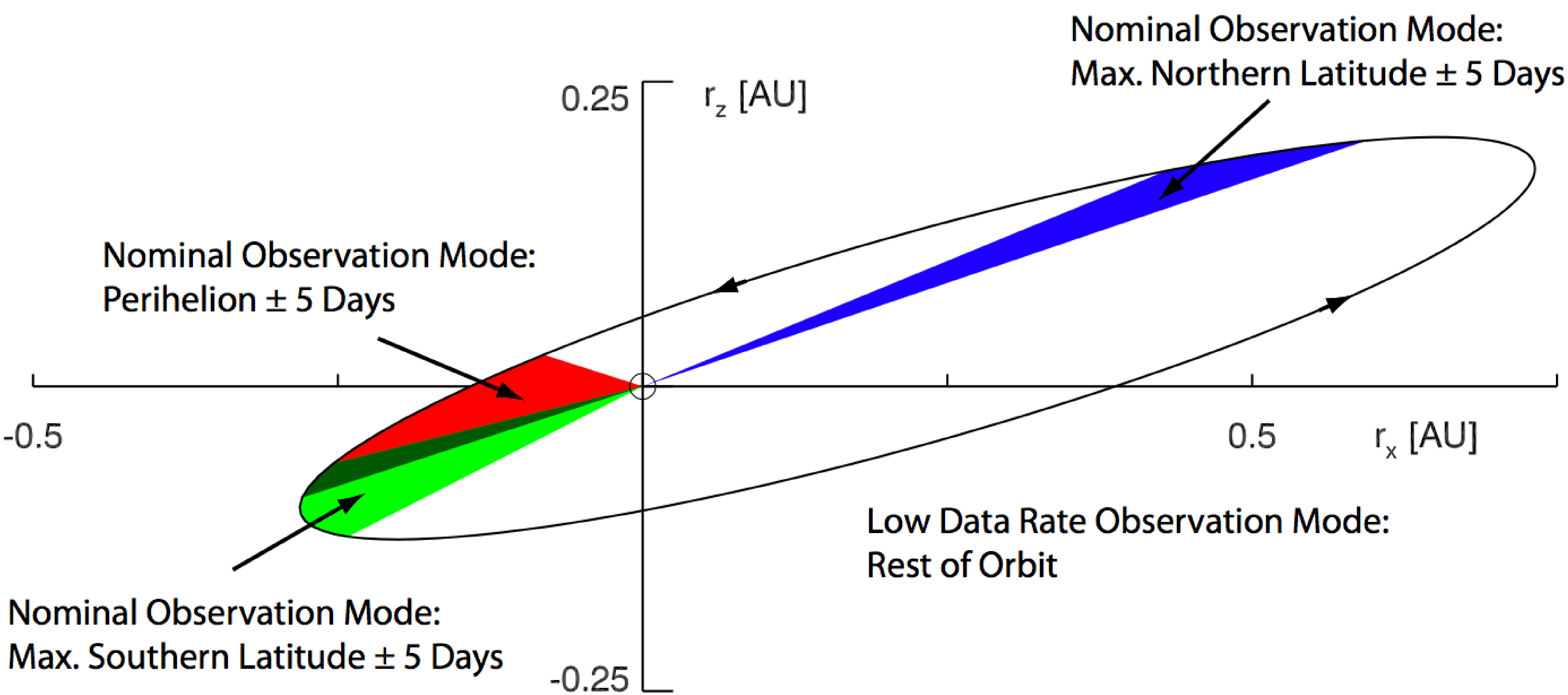


Spacecraft Temperatures



Gravity Assist Manoeuvres for a complex orbit

Observation Modes



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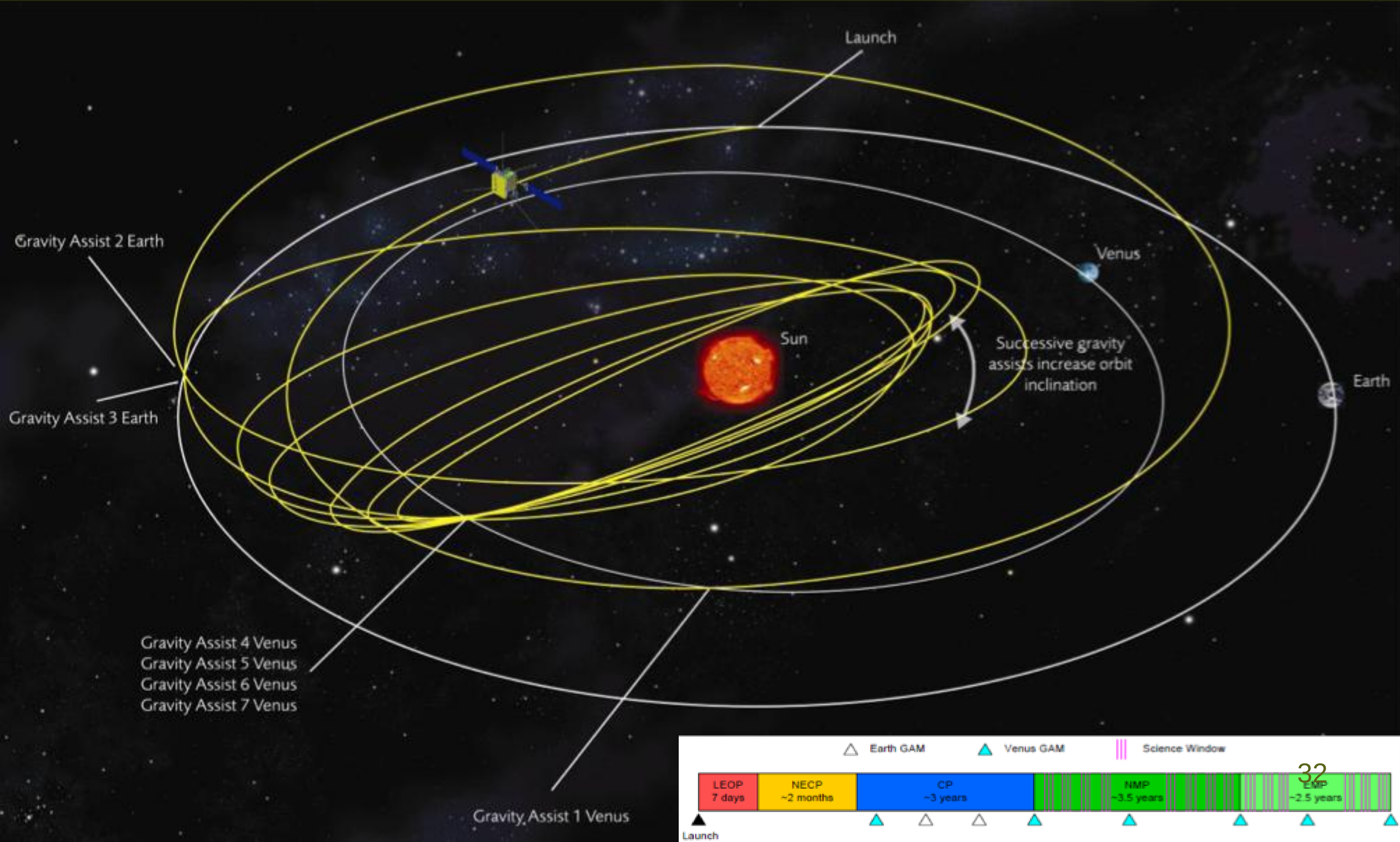
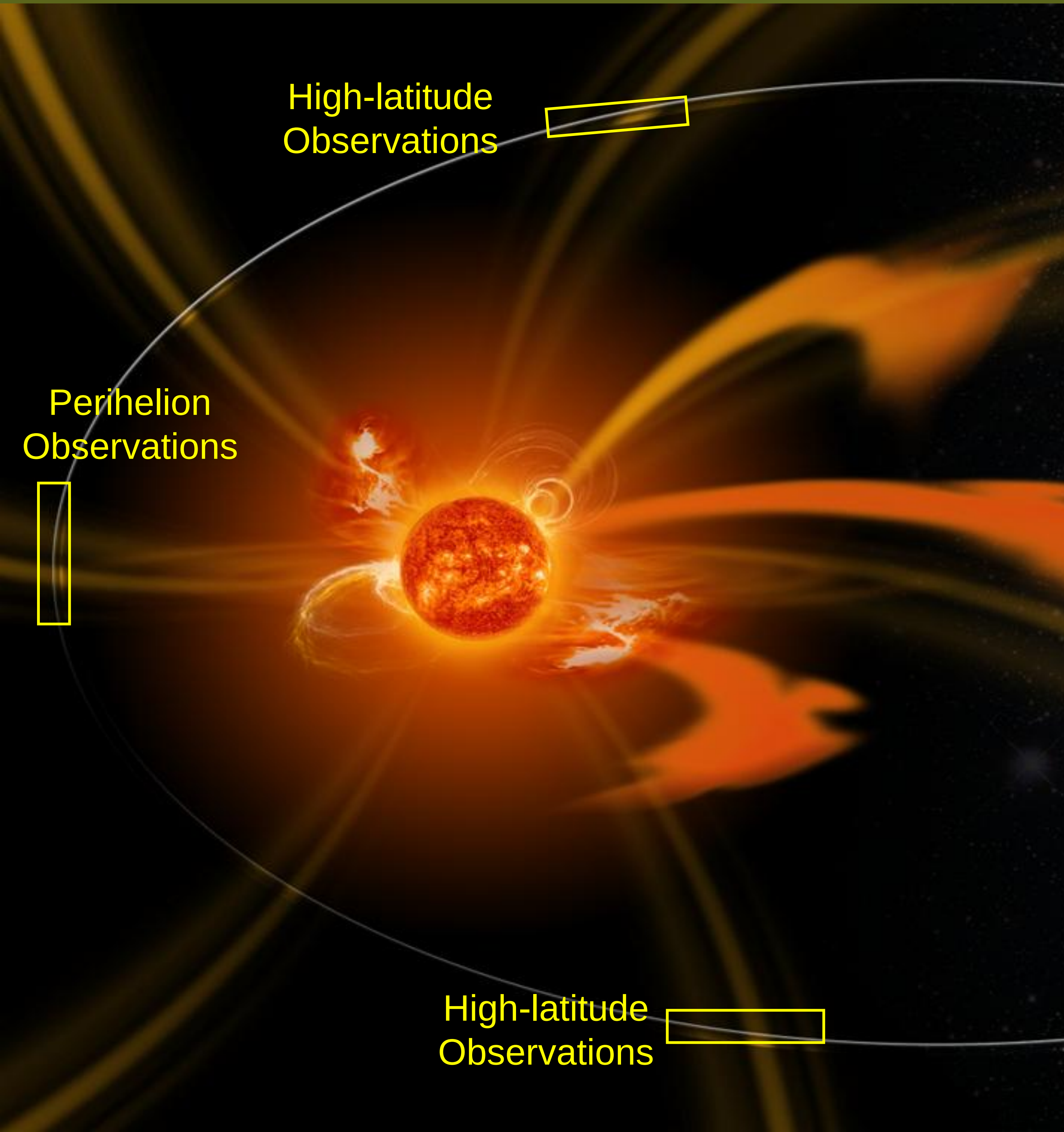




Science windows:

Orbit: 150-168 days

In situ instruments on at all times

Three science "windows" of 10 days each

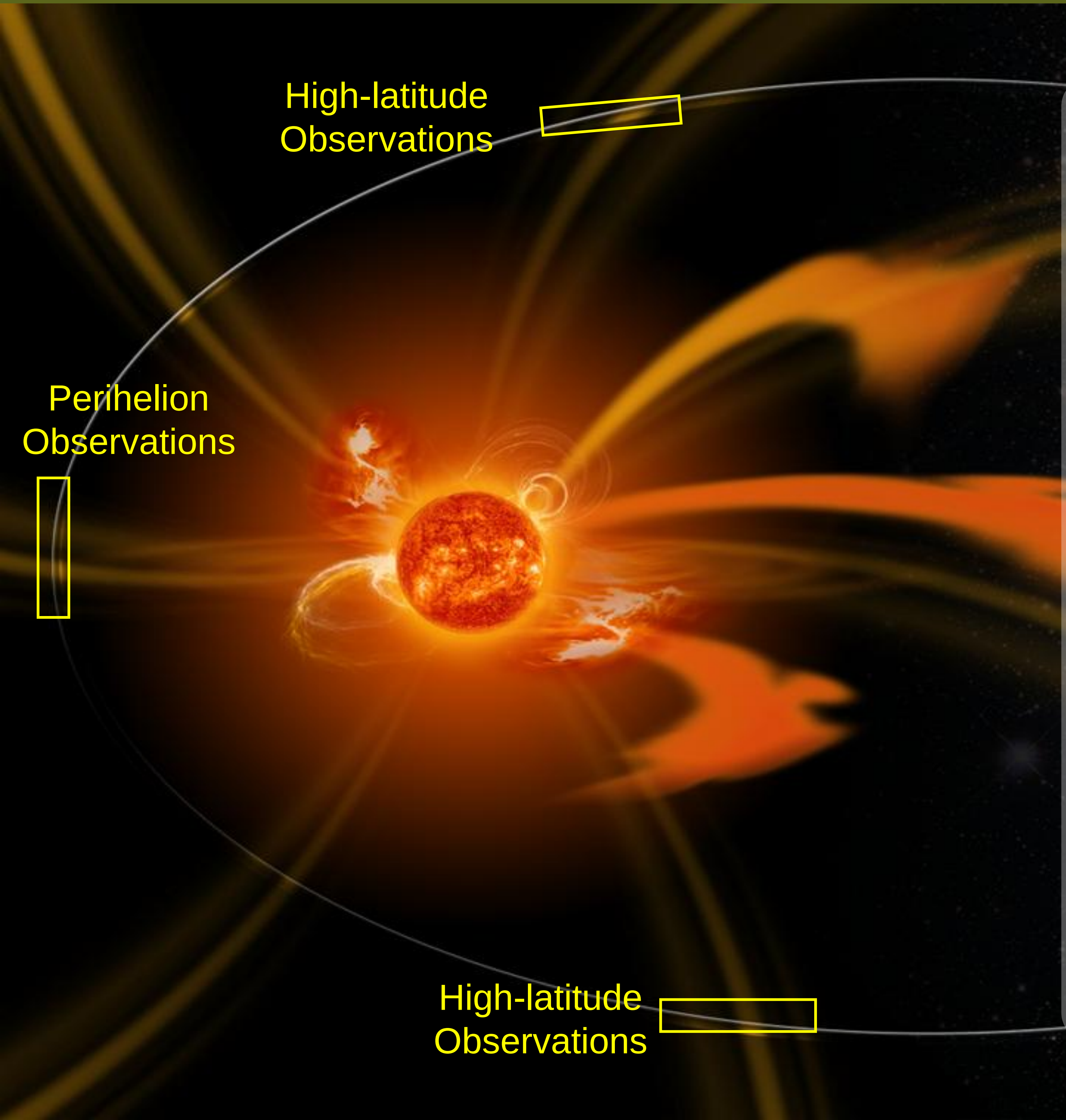
All remote sensing instruments operational

Observing strategies based on science targets

Active regions, coronal hole boundaries, flares, high speed wind, polar structures

Autonomous burst mode triggers for unpredictable events

Telemetry and mass memory tailored to return planned instrument data volumes



Summary

Launch Date: January 2017

Cruise Phase: 3 years

Nominal Mission: 3.5 years

Extended Mission: 2.5 years

Orbit:

0.28 – 0.30 AU (perihelion)

0.75 - 1.2 AU (aphelion)

Out-of-Ecliptic View:
Multiple gravity assists with Venus to increase inclination out of the ecliptic to >25˚ (nominal mission), >33˚ (extended mission)

Reduced relative rotation:
Observations of evolving structures on the solar surface & heliosphere for almost a complete solar rotation

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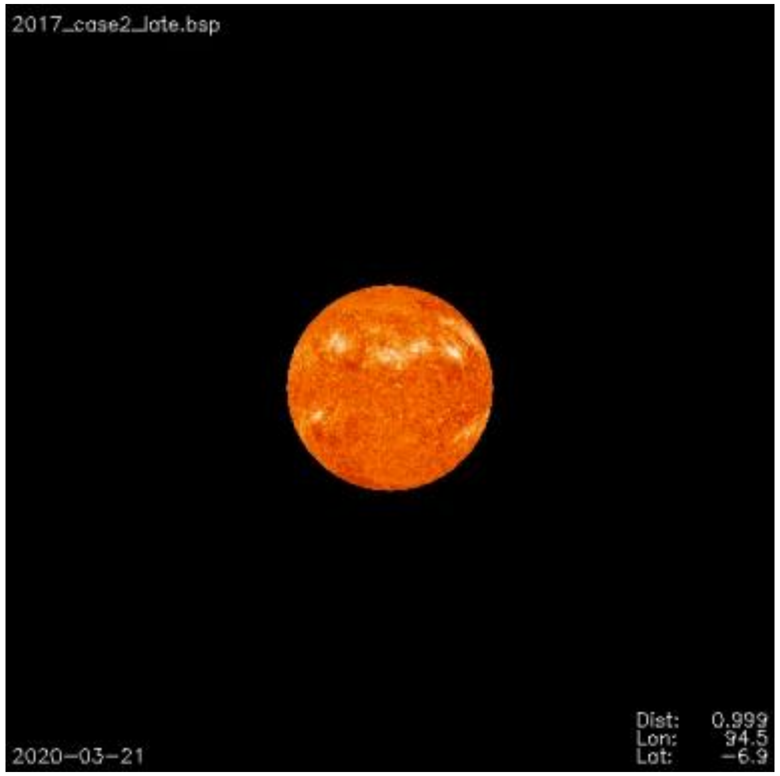
Solar Orbiter and the Glasgow A&A group

- Co-Investigators on three of Solar Orbiter's instruments
  - STIX: Spectrometer/ telescope for imaging X-rays
  - EUI: Extreme Ultraviolet Imager
  - RPW: Radio and Plasma Wave analyser

A&A Group on a trip to the Sun

Posted on December 14, 2011 by Iain Hannah

The European Space Agency has selected the Solar Orbiter Mission as one of its next two missions to fly. Several members of the A&A group are Co-Investigators on Solar Orbiter instruments, in particular on the STIX X-ray imager. The group's involvement with Solar Orbiter and STIX continues a long history of pioneering research in solar physics (dating back to the first Regius Chair in 1760) and solar X-rays in particular – a heritage which includes Co-I-ship on NASA's award-winning RHESSI mission. With an expected launch date of 2017, the Solar Orbiter carries several instruments deep into the inner solar system to co-rotate with the Sun, imaging activity on its surface and sampling its magnetic field and solar wind.

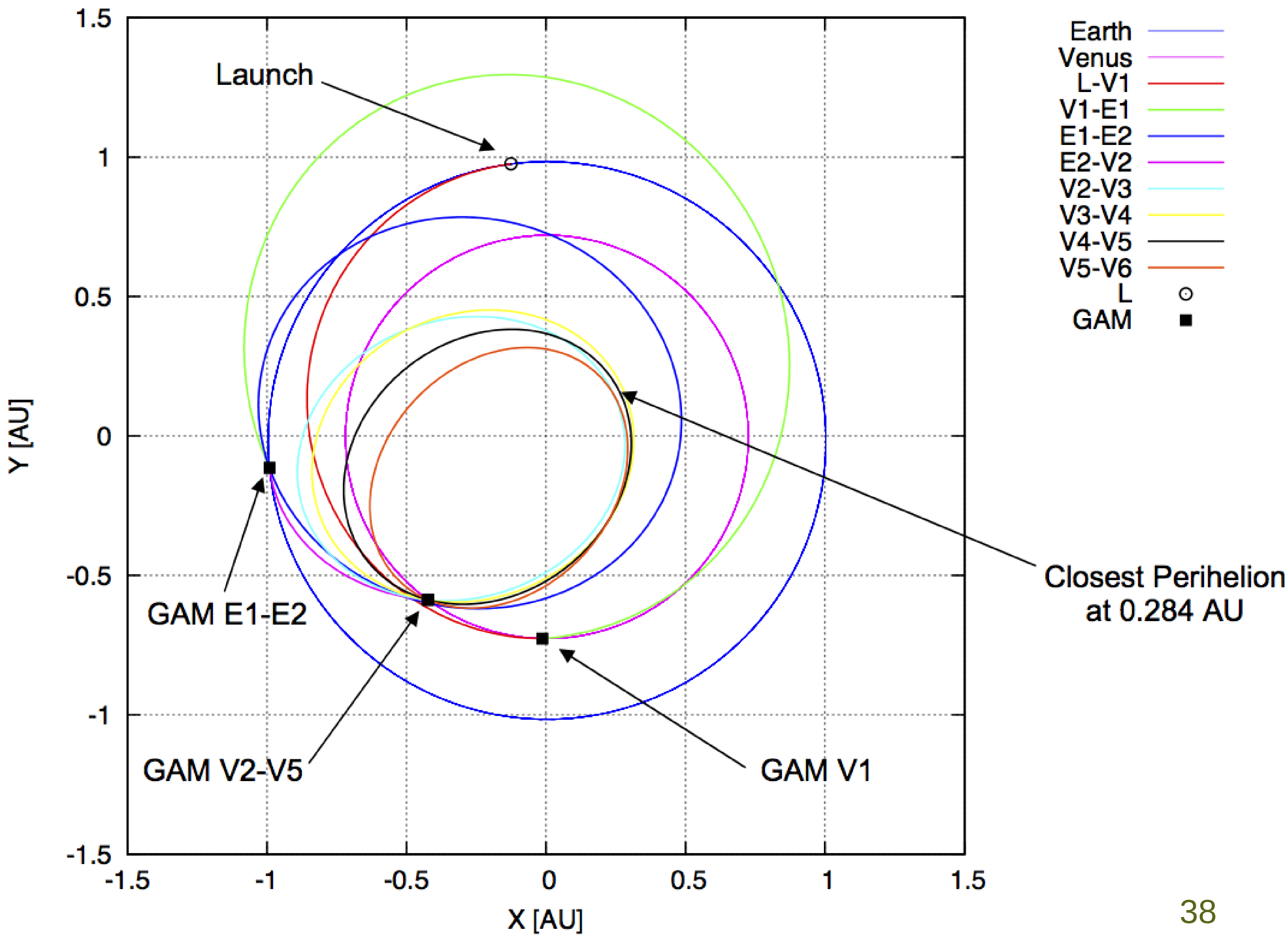


Courtesy W. Thompson

ESA's Solar Orbiter mission

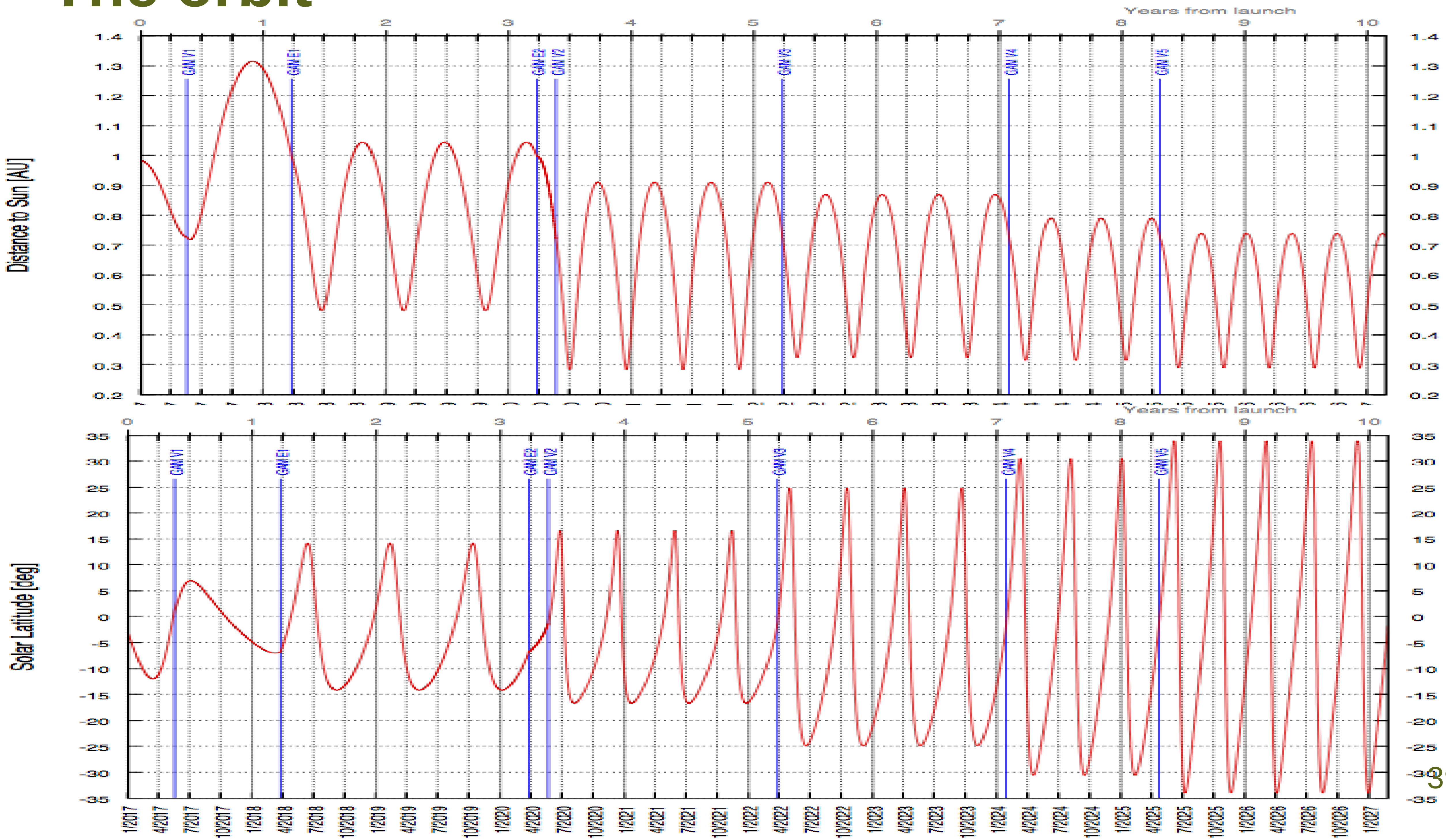
Courtesy Equinox Graphics

The orbit



Earth
Venus
L-V1
V1-E1
E1-E2
E2-V2
V2-V3
V3-V4
V4-V5
V5-V6
L
GAM
Launch
Closest Perihelion at 0.284 AU
GAM E1-E2
GAM V2-V5
GAM V1
X [AU]
Y [AU]
1.5
1
0.5
0
-0.5
-1
-1.5

The orbit


Years from launch
Distance to Sun [AU]
GAM V1
GAM E1
GAM E2
GAM V2
GAM V3
GAM V4
GAM V5
Solar Latitude [deg]