Solar Orbiter

Exploring the Sun-Heliosphere Connection

Update

Louise Harra (EUI co-PI)
many slides from Daniel Müller! ESA project scientist

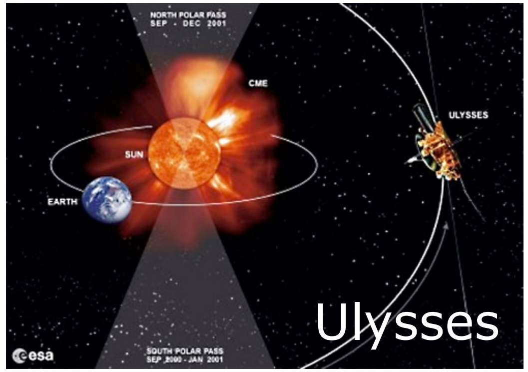
www.esa.int

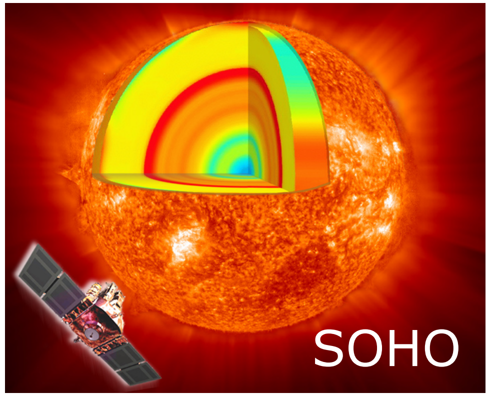
European Space Agency

Solar Orbiter
Exploring the Sun-Heliosphere Connection

Solar Orbiter

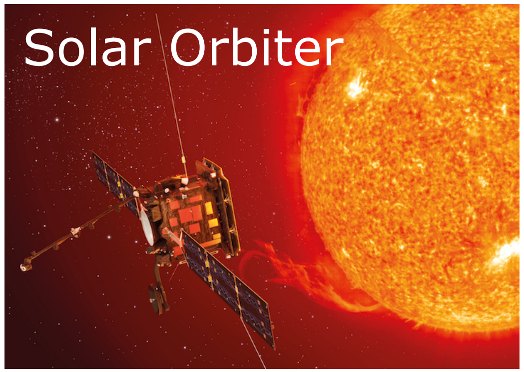
- First medium-class mission of ESA's Cosmic Vision 2015-2025 programme, implemented jointly with NASA
- Comprehensive payload suite of 10 remote-sensing and in-situ instruments measuring from the photosphere into the solar wind





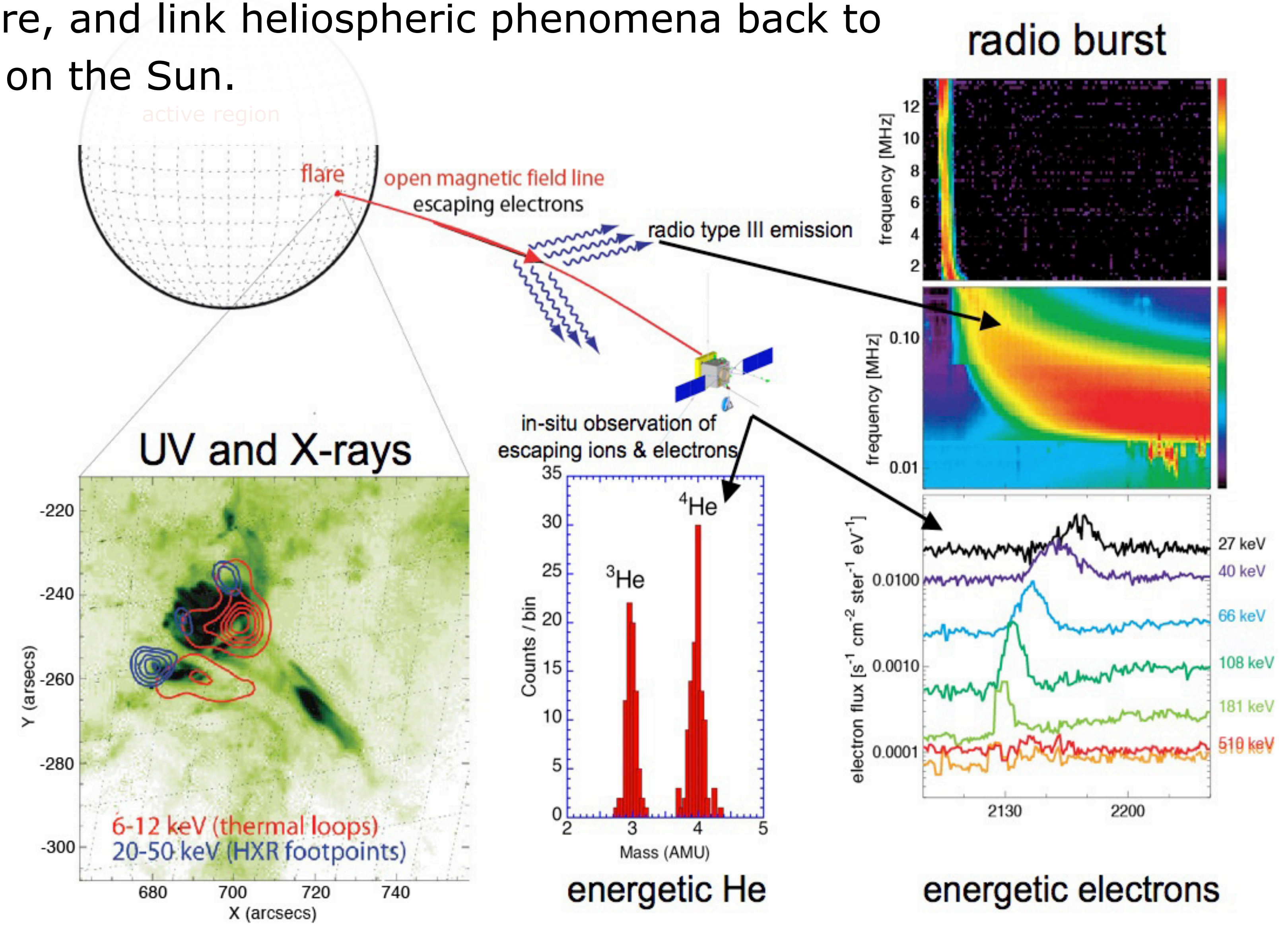
Overarching Science Question

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



What will Solar Orbiter do?

Solar Orbiter is a mission designed to observe the Sun and the heliosphere, and link heliospheric phenomena back to their sources on the Sun.



Solar Orbiter
Exploring the Sun-Heliosphere Connection

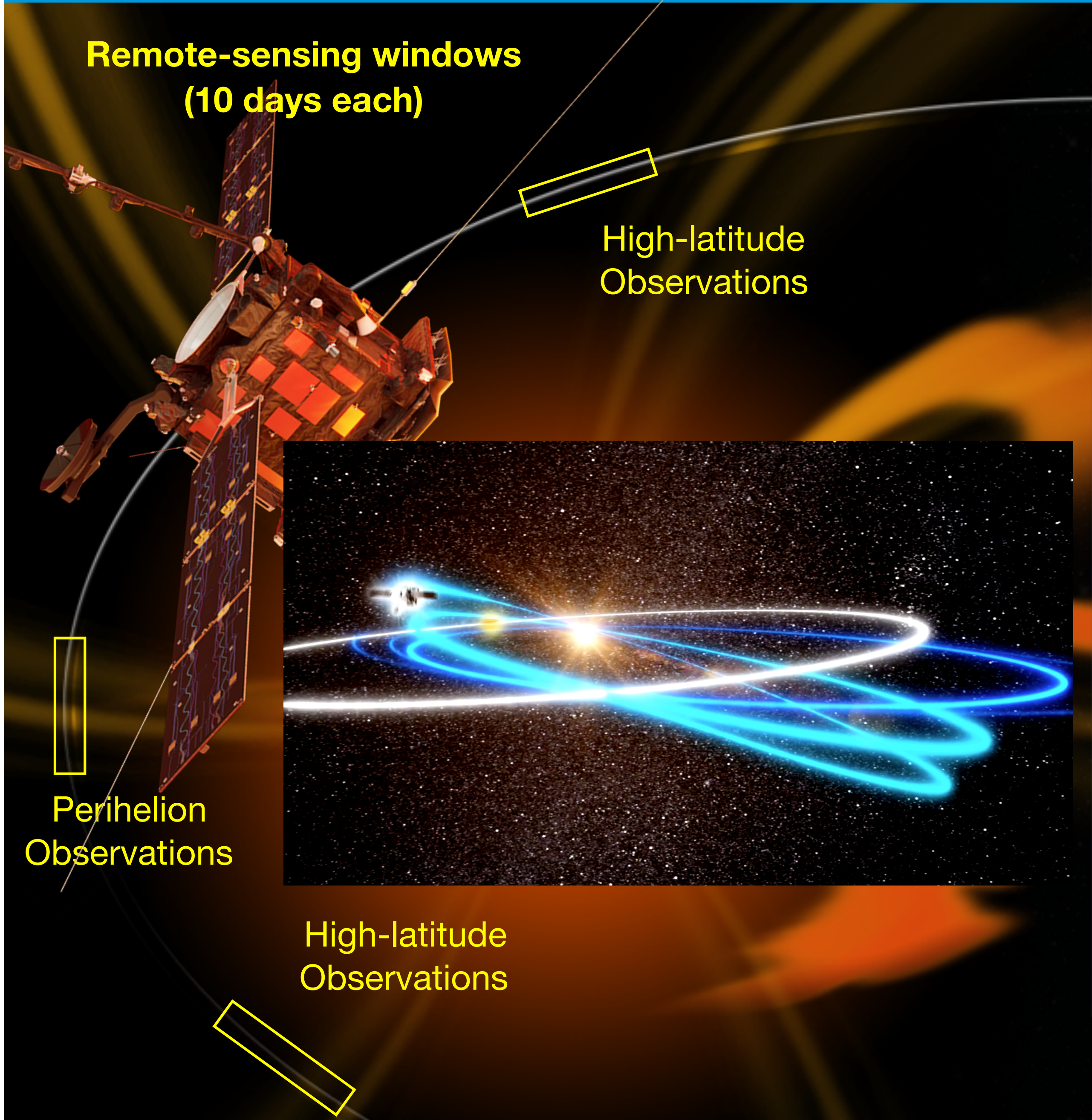
Science Objectives

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

1. What drives the solar wind and where does the coronal magnetic field originate?
2. How do solar transients drive heliospheric variability?
3. How do solar eruptions produce energetic particle radiation that fills the heliosphere?
4. How does the solar dynamo work and drive connections between the Sun and the heliosphere?

*Mission overview: Müller et al., Solar Physics **285** (2013)*

Solar Orbiter
Exploring the Sun-Heliosphere Connection



Mission Summary

Launch: Feb 2019 / Feb 2020 back-up

Cruise Phase: 2.8 / 1.8 years

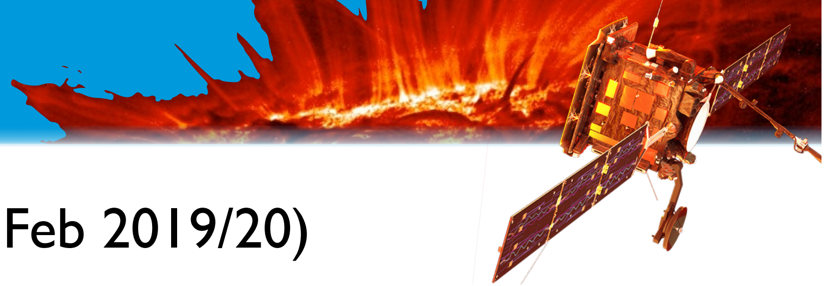
Nominal Mission: 4 years

Extended Mission: 3.5 years

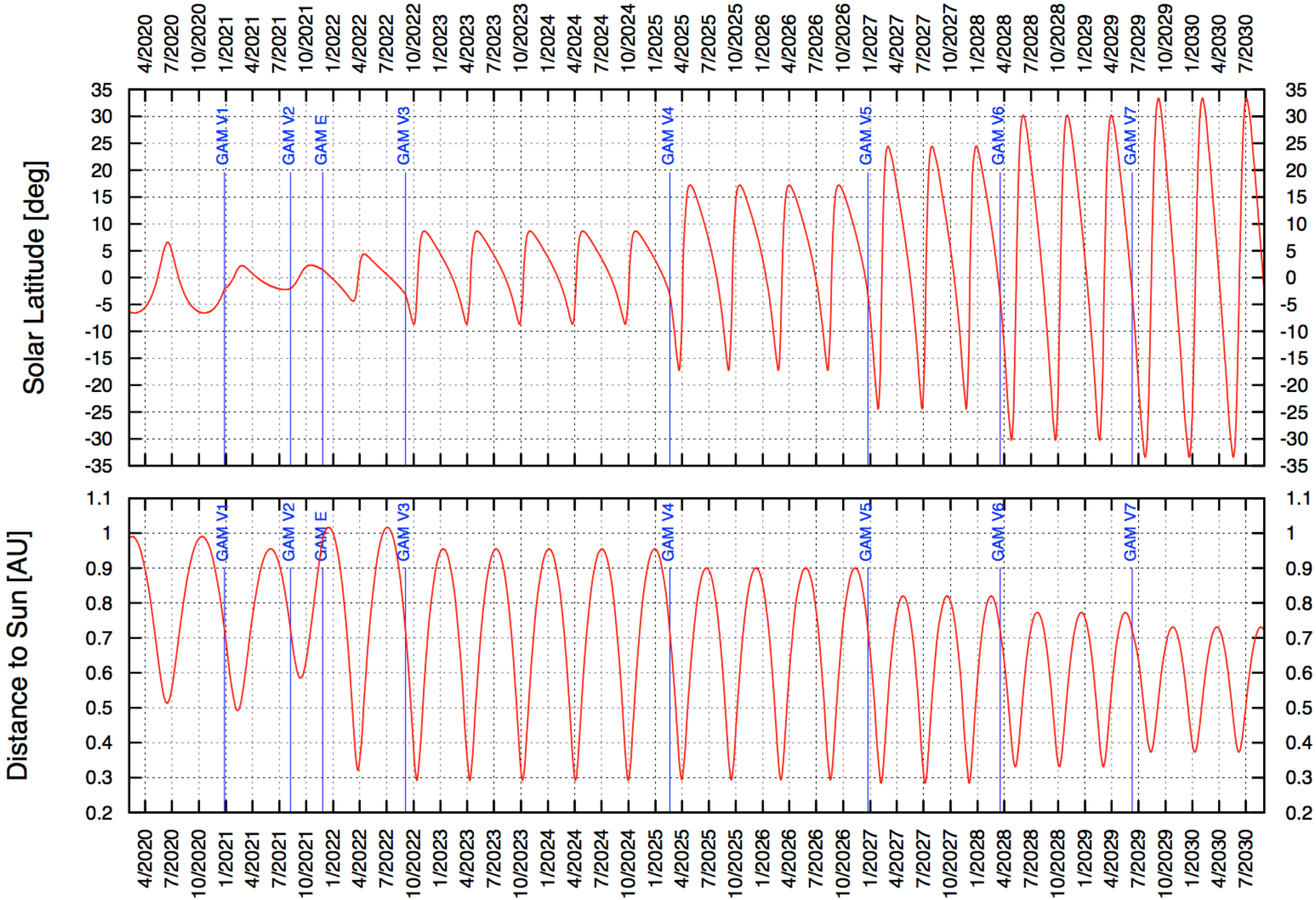
Orbit: 0.28–0.91 AU (P=150-180 days)

Out-of-Ecliptic View:
Multiple gravity assists with Venus to increase inclination out of the ecliptic to >24° (nominal mission), >33° (extended mission)

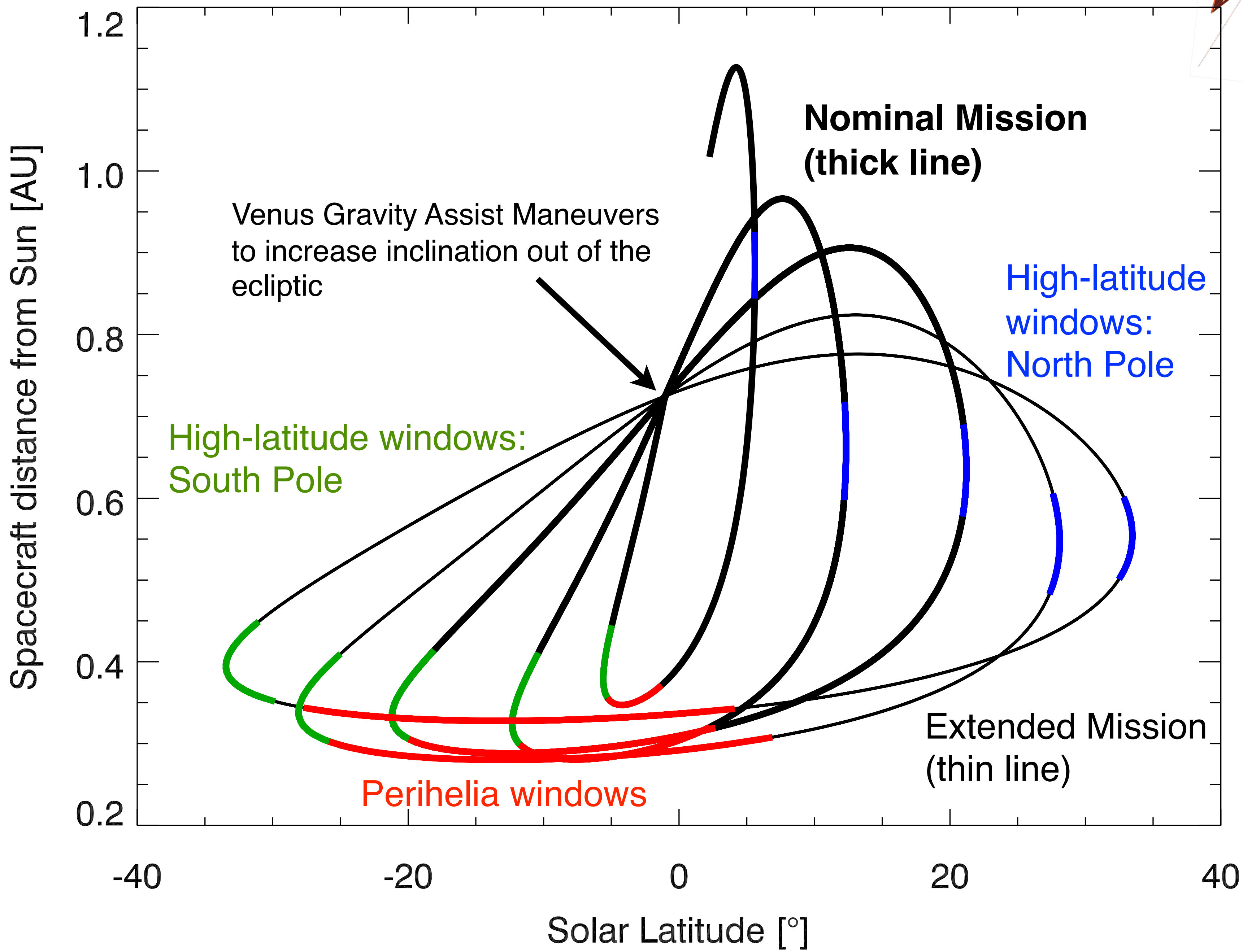
Reduced relative rotation:
Observations of evolving structures on solar surface & in heliosphere for almost a complete solar rotation



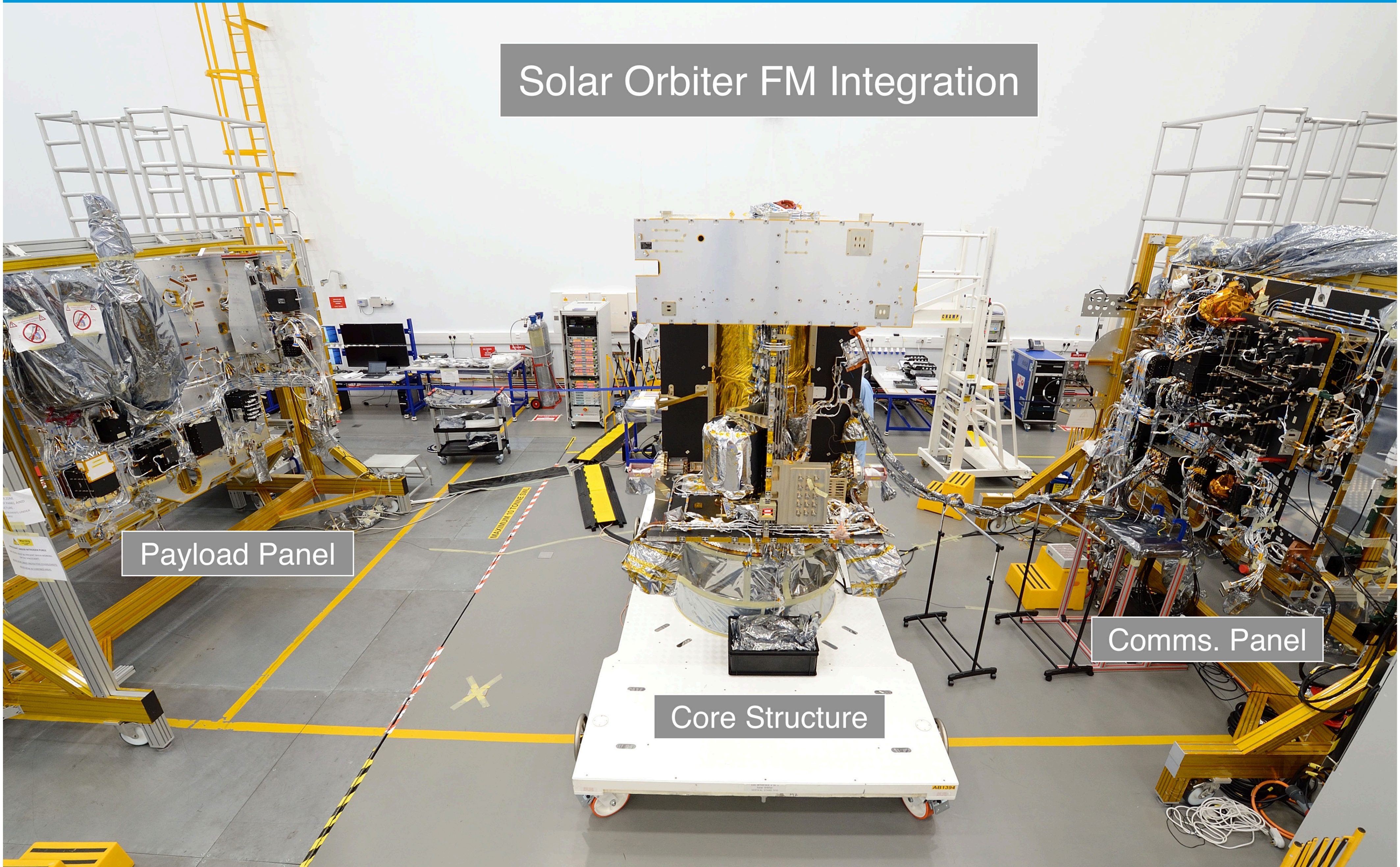
Solar Latitude & Distance (for launch in Feb 2019/20)



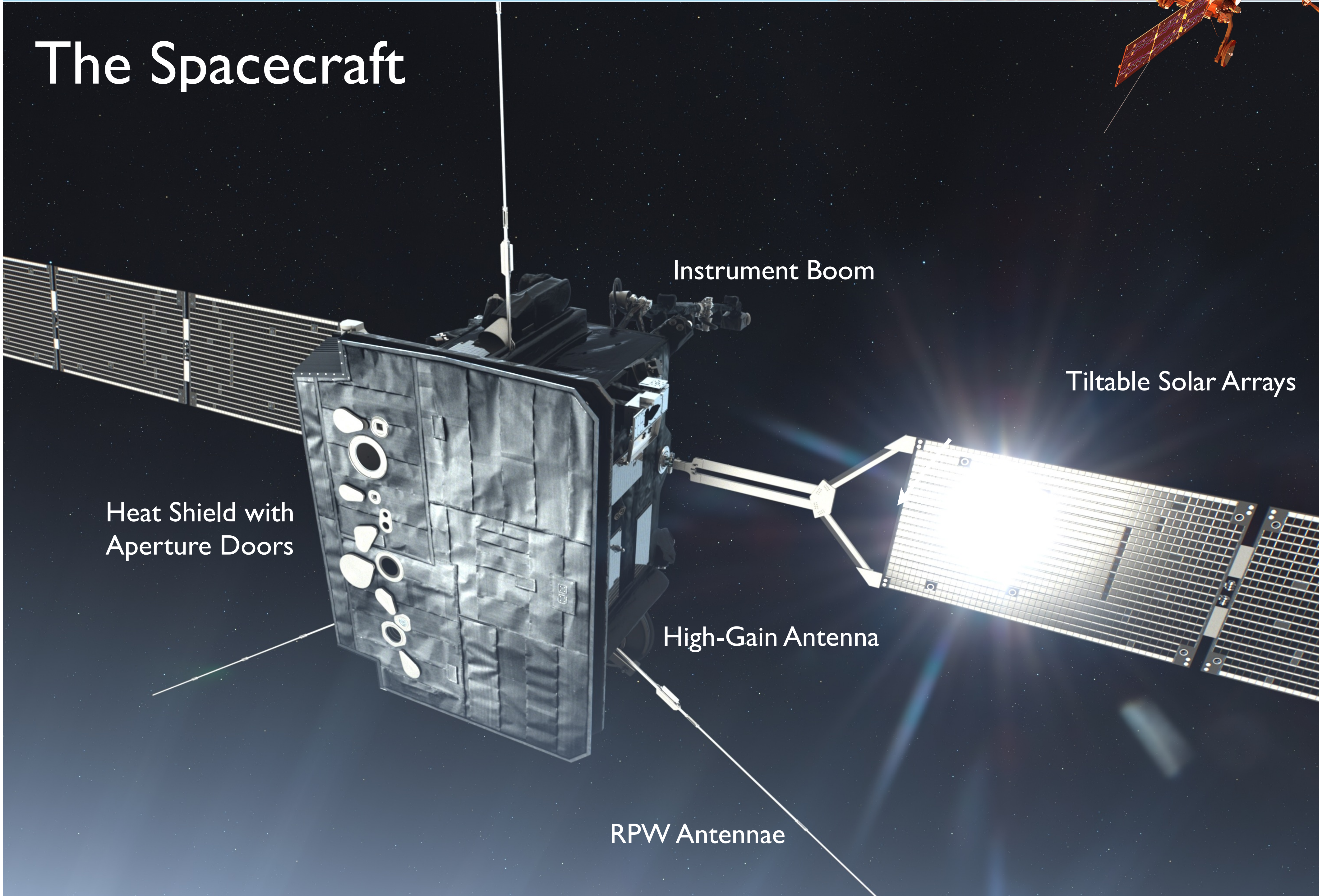
Default Remote-Sensing Windows: 3x10 days/orbit

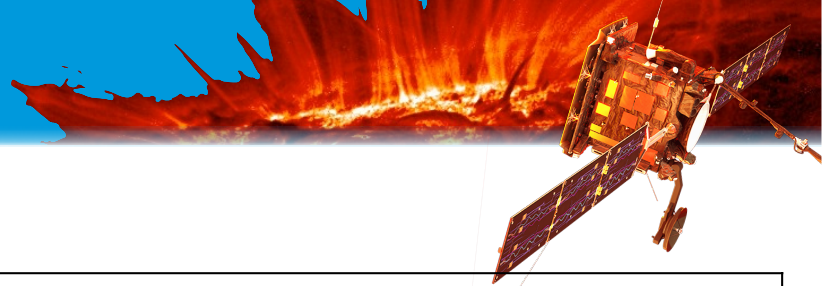


Solar Orbiter Flight Model Integration (Sep 2017)



The Spacecraft

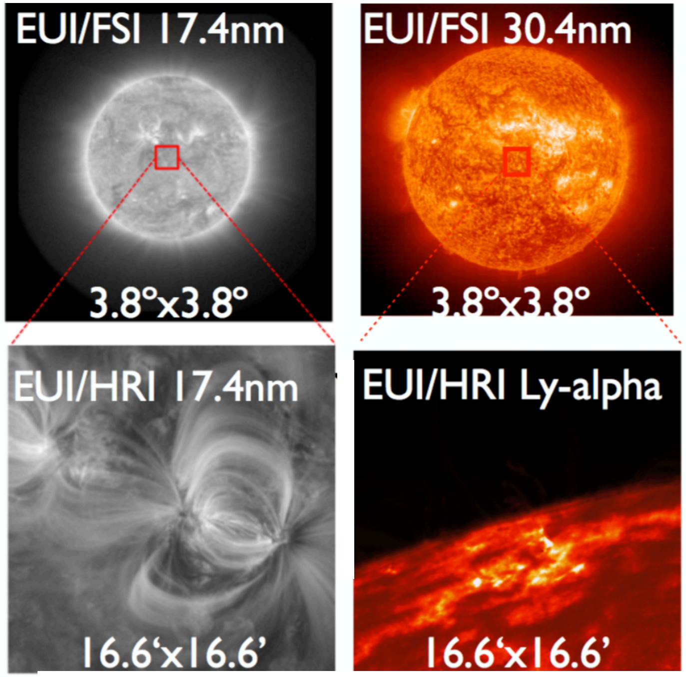


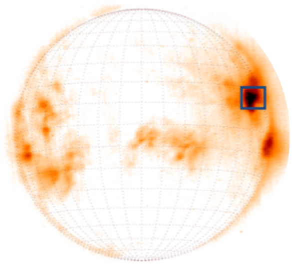


Payload

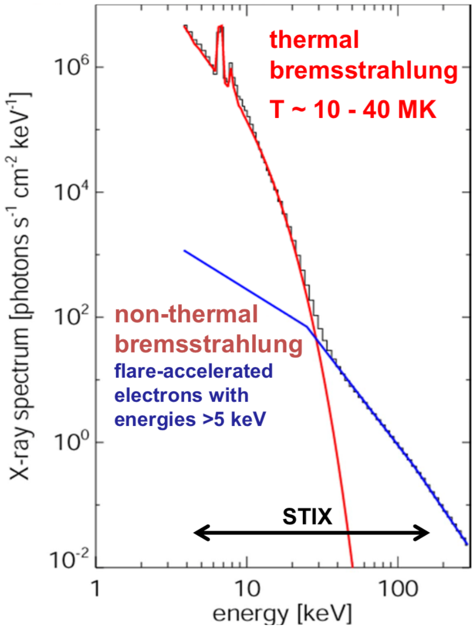
In-Situ Instruments			
EPD	Energetic Particle Detector	J. Rodríguez-Pacheco	Composition, timing and distribution functions of energetic particles
MAG	Magnetometer	T. Horbury	High-precision measurements of the heliospheric magnetic field
RPW	Radio & Plasma Waves	M. Maksimovic	Electromagnetic and electrostatic waves, magnetic and electric fields at high time resolution
SWA	Solar Wind Analyser	C. Owen	Sampling protons, electrons and heavy ions in the solar wind
Remote-Sensing Instruments			
EUI	Extreme Ultraviolet Imager	P. Rochus	High-resolution and full-disk (E)UV imaging of the on-disk corona
METIS	Coronagraph	E. Antonucci	Visible and UV Imaging of the off-disk corona
PHI	Polarimetric & Helioseismic Imager	S. Solanki	High-resolution vector magnetic field, line-of-sight velocity in photosphere, visible imaging
SoloHI	Heliospheric Imager	R. Howard	Wide-field visible imaging of the solar off-disk corona
SPICE	Spectral Imaging of the Coronal Environment	ESA facility instrument	EUV imaging spectroscopy of the solar disk and near-Sun corona
STIX	Spectrometer/Telescope for Imaging X-rays	S. Krucker	Imaging spectroscopy of solar X-ray emission

Photons 1

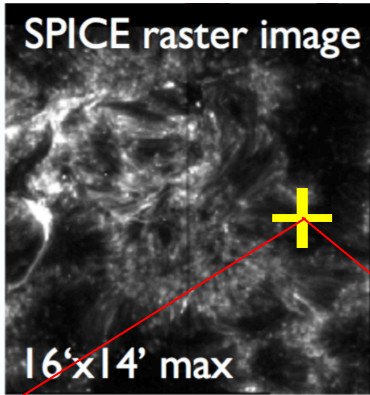


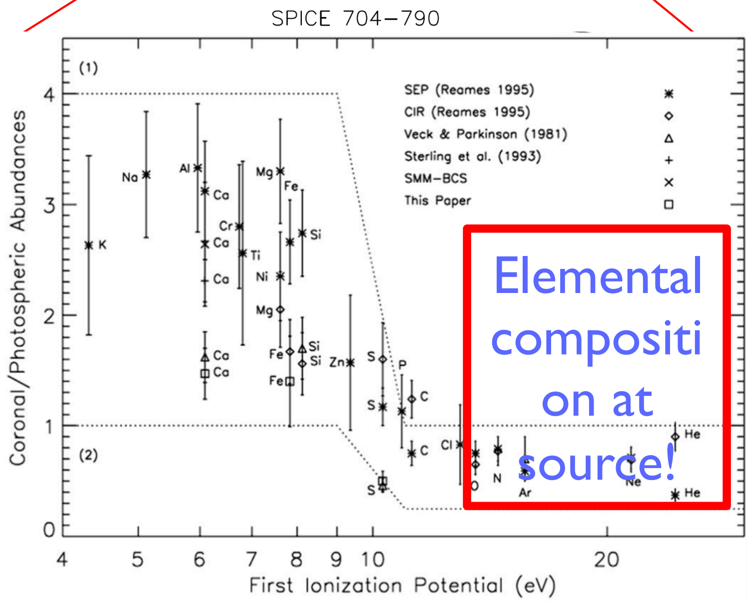


STIX imaging



STIX spectra



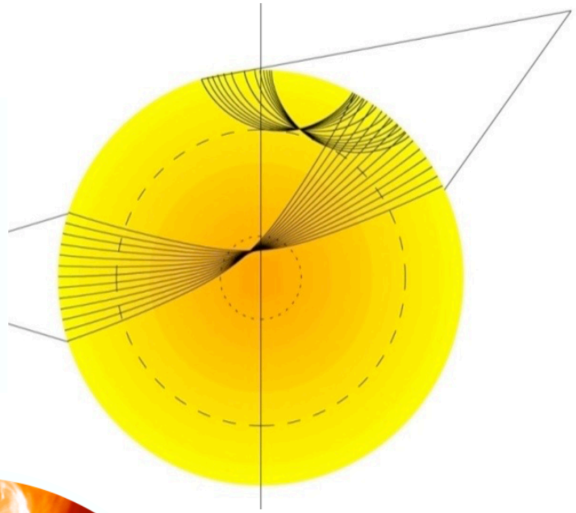


Elemental composition at source!

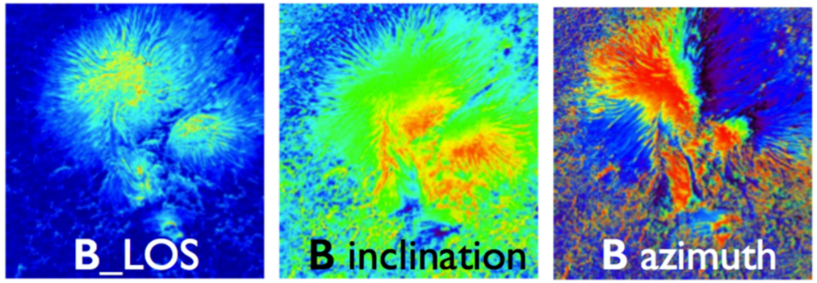
Photons 2

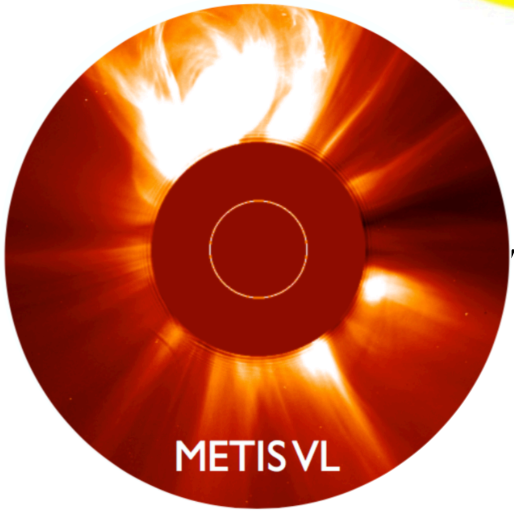
+ similar images across the entire visible hemisphere

Earth view



Solar Orbiter view

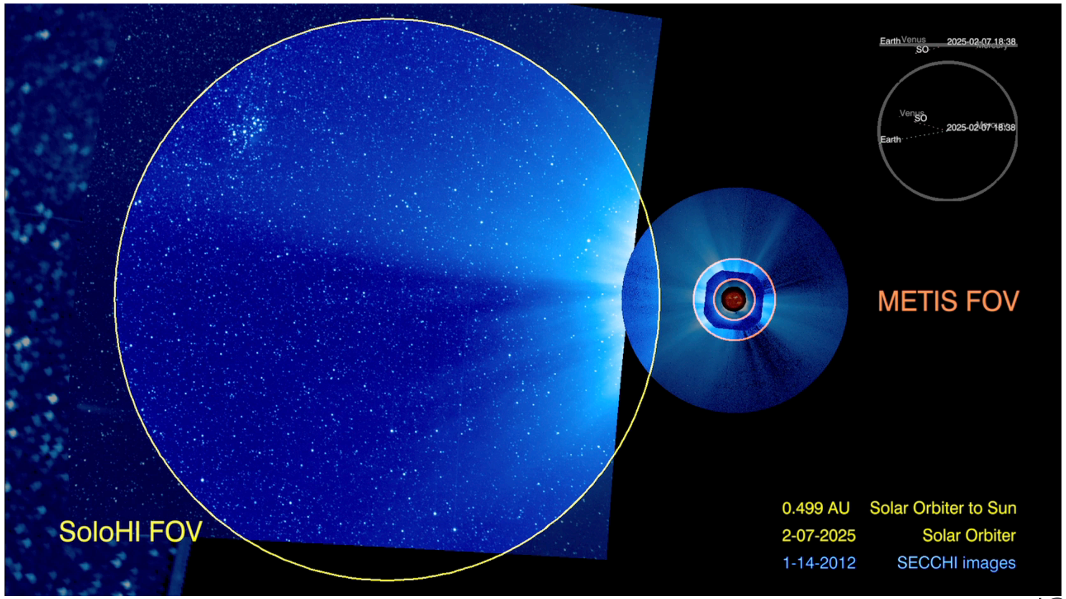




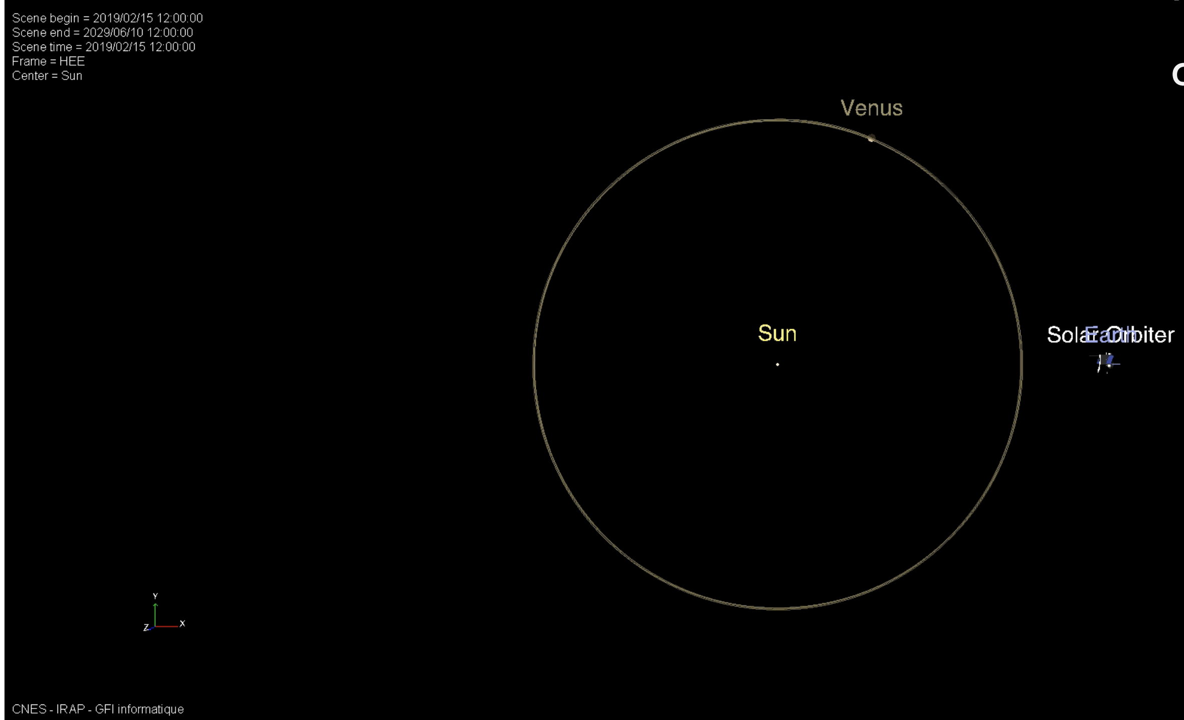
UV (HI 121.6 ± 5 nm

VL (580 – 640 nm) polarised light

Combination also gives solar wind speed *via* Doppler dimming

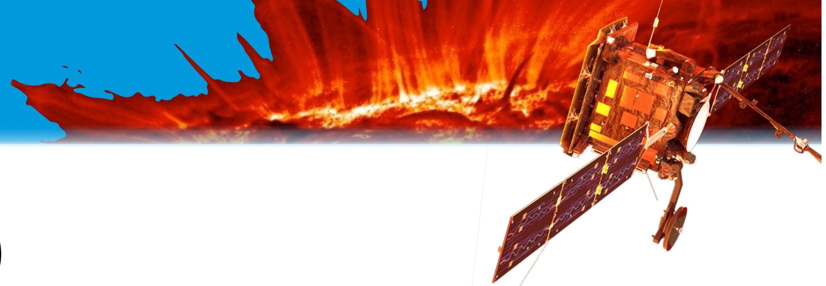


Effects of Solar Orbiter’s trajectory: geometry



Trajectory for launch in February 2019 in HEE coordinates
(Feb 2020 just skips one year of ‘parking orbit’)

- Non-Earth-synchronised orbit means *many* different observation opportunities
  - Geometric alignments with Sun-Earth line (conjunctions)
  - Quadrature with Earth
  - Parker-spiral alignments with Earth
  - Alignments with Parker Solar Probe *(unplannable until both launched)*
  - Other opportunities you can think of…



The Science Activity Plan (SAP)

- Strategic plan covering the science we're going to do and when over the whole mission, written by the Science Working Team (Lead: Y. Zouganelis)
- How?
  1. Definition of detailed science objectives.
  2. Group sub-objectives that require similar observations together. Define a SOOP (Solar Orbiter Observing Plan) that includes a collection of instruments and modes.
  3. Examine the trajectories to find the best opportunities for each SOOP. Define the SOOP scheduling strategy.
  4. Schedule all SOOPs within a given trajectory and simulate the high-level plan against mission constraints.

→ trajectory dependent

SAPs

https://issues.cosmos.esa.int/solarorbiterwiki/display/SOSP

Solar Orbiter Confluence   Spaces   Log in

- File lists
- Getting started
- MOC Documents
- SOC Documents
- SOC Presentations
- Solar Orbiter SPICE Kernels
- SOWG
- Modelling and Data Analysis Working
- Low Latency Pipeline Engineering
- EMC
- Orbit Plots
- Instruments: observables, modes anc
- **SAP-related work**
  - Solar Orbiter detailed science obje
  - SOOP pages
  - General Planning strategy for first
  - Planning periods Option E (LTP/M
- In Situ Working Group
- Remote Sensing Working Group
- Instrument-Specific Pages
- Software Development Collaboration:
- Meeting notes

Pages / Solar Orbiter SOC Public

SAP-related work

Created by Anik De Groof, last modified by Yannis Zouganelis on Jul 10, 2017

The latest version (v0.1, 10 July 2017) of the full SAP document can be downloaded here.

N.B.: The individual Confluence pages might contain more recent information than the full SAP document.

- Solar Orbiter detailed science objectives
  - Objective 1: What drives the solar wind and where does the heliospheric magnetic field originate?
    - 1.1 What are the source regions of the solar wind and heliospheric magnetic field?
      - 1.1.1 Source regions of the fast solar wind
        - 1.1.1.1 Low FIP fast wind origins
        - 1.1.1.2 Origin of the small-scale X-ray and UV jets in polar coronal holes
      - 1.1.2 Source regions of the slow solar wind
        - 1.1.2.1 Does slow wind originate from the over-expanded edges of coronal holes?
        - 1.1.2.2 Does slow and intermediate solar wind originate from coronal loops outside of coronal holes?
        - 1.1.2.3 Abundance of minor ions as a function of height in the corona as indicator of slow or fast wind
        - 1.1.2.4 Study of density fluctuations in the extended corona as a function of the outflow velocity of the solar wind while evolving in the heliosphere
        - 1.1.2.5 Structure and evolution of streamers
        - 1.1.2.6 Disentangle the spatial and temporal variability of the slow wind
        - 1.1.2.7 Trace streamer blobs and other structures through the outer corona and the heliosphere.
        - 1.1.2.8 Determine the velocity, acceleration profile and the mass of the transient slow wind flows
      - 1.1.3 Source regions of the heliospheric magnetic field
        - 1.1.3.1 Full characterization of photospheric magnetic fields and find structures
        - 1.1.3.2 How does the Sun's magnetic field link into space?
          - 1.1.3.2.1 How does the Sun's magnetic field change over time?
          - 1.1.3.2.2 How is the heliospheric current sheet (HCS) related to coronal structure?
          - 1.1.3.2.3 How does the heliospheric magnetic field disconnect from the Sun?
        - 1.1.3.3 What is the distribution of the open magnetic flux?
      - 1.1.4 Transverse themes
        - 1.1.4.1 Reconnection
          - 1.1.4.1.1 Interchange reconnection between open and closed field lines and its role in slow wind generation

EUI SOOP for Filament Observations

Having examined the currently proposed Solar Orbiter Observing Proposals (SOOPs) there does not appear to have been much consideration for observations of filaments. Therefore the following draft SOOP has been created to try and fill this gap.

Proposed SOOP Coordinators

Name: R_BOTH_HRES_HCAD_Filaments
Jack Jenkins, Lidia van Driel-Gesztelyi, David Long, Susanna Parenti

Description

High resolution observations of Filaments (AR or QS) to study structure and dynamics. SOOP supports both high and low cadence, depending on structural or dynamic aims. Perihelion preferred. Can potentially be used in quadrature with Earth for coordinated observations with DKIST and other Earth-based observatories/instruments.
Pointing requirements: Preferably run on disk center, may be pointed off-limb (without Metis)
Default SOOP duration: 1 hour (TBC)
Triggers: Disabled

Instrument	Mode	Comment
EUI	HRI in highest spatial resolution. EUV & LYA Quiet Sun modes (Q) or EUV & LYA Active Region modes (A), HIGH-MID CADENCE: 10-60 second. FOV: Full (no rebinning). FSI Synoptic observations.	Will limit telemetry for entire orbit, therefore recommended to only run for 1 hour.
PHI	PHI science mode 2 (FDT or HRT)	Observations used for context and extrapolations. In event that DKIST co-observations are unavailable, PHI HRT will be required.
SPICE	A modified SPICE Dynamics mode, exposure times should be adapted for good S/N ratio in quiet Sun. H-Ly beta line, with additional lines both above and below the Ly-alpha head.	Centre of raster at centre of EUI provided that filament is at centre of EUI FOV

new input by
Jack Jenkins

4.5 How are coronal and heliospheric phenomena related to the solar dynamo?

(contacts: Louise Harra & Lidia van Driel-Gesztelyi)

Explore the fine structure of the polar coronal holes and find clues whether or not there are signatures of a local dynamo besides the global dynamo there. Tsuneta et al. (2008, ApJ 688, 1374) using Hinode/SOT found many strong (1 kG) magnetic concentrations with vertically oriented fields, which were fanning out with height, and ubiquitous transient horizontal fields in between. The 1-kG patches were coherently unipolar and their polarity was consistent with the dominant magnetic polarity of the polar region. Their size showed a tendency to increase with latitude. The lifetime of these kG patches (5-15 hr) was found to be longer than that of magnetic concentrations in the quiet sun. Dacie et al. (2016, A&A, 596, A69; 2017, A&A 606, A34) showed that the magnetic field distribution, as represented by the slope of a power-law, evolves in active regions from their emergence through the decay phase ending in a quiet-sun state in such way, which is consistent with magnetic flux being reprocessed by (super)granular convective cells. The reprocessing is breaking down larger flux concentrations, making the negative power-law slope steeper with time. Carrying out such analysis in polar coronal holes will reveal how different the magnetic fields in polar areas are from lower-latitude quiet-sun and coronal-hole areas, in particular concerning the importance of magnetic field reprocessing by convective flows, an important element of the local dynamo.

The particular magnetic field distribution in polar coronal holes implies that there should be difference in the behavior and activity in the atmosphere from those of the lower-latitude regions. Harra et al. (2015, Solar Phys., 290, 3203)

Community Involvement

Solar Orbiter will be discussed at the annual missions forum.

STFC provided some travel funds for the community to attend meetings. This has been used for SO meeting (Granada), MADAWG, helioseismology session. Gherardo Valori and Paolo Pagnano will attend the next MADAWG.

We have had one UK solar orbiter working group meeting - an all day meeting to discuss science (end of 2016)

The next SO international science meeting will be in Belfast ~2020.