Solar Orbiter

Exploring the Sun-Heliosphere Connection

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European Space Agency

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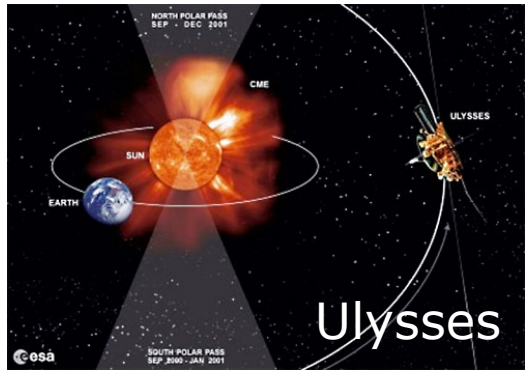
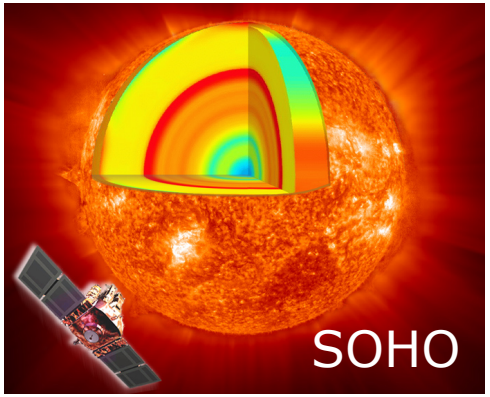
Solar Orbiter

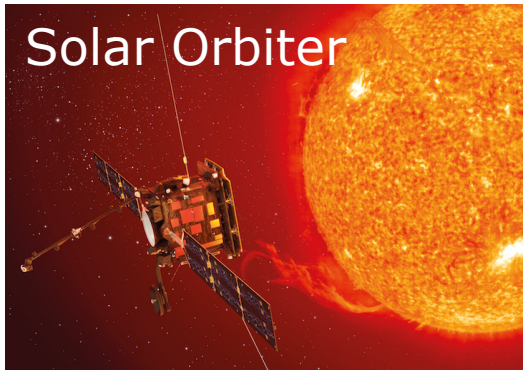
- First medium-class mission of ESA's Cosmic Vision 2015-2025 programme, implemented jointly with NASA
- Dedicated payload of 10 remote-sensing and in-situ instruments measuring from the photosphere into the solar wind





Talk Outline

- Science Objectives
- Mission Overview
- Spacecraft & Payload
- Science Operations & Synergies



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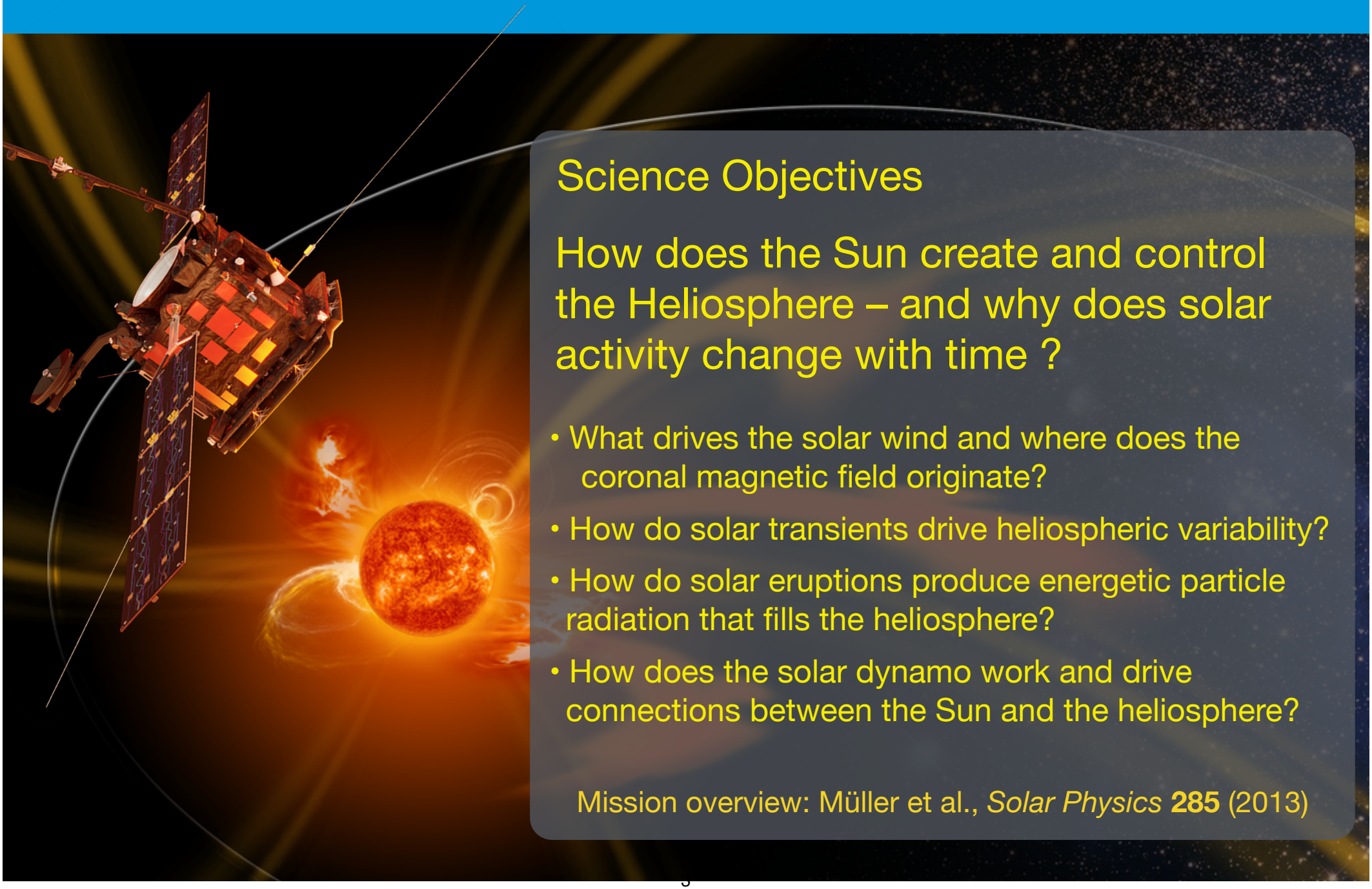

Science Objectives

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

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

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

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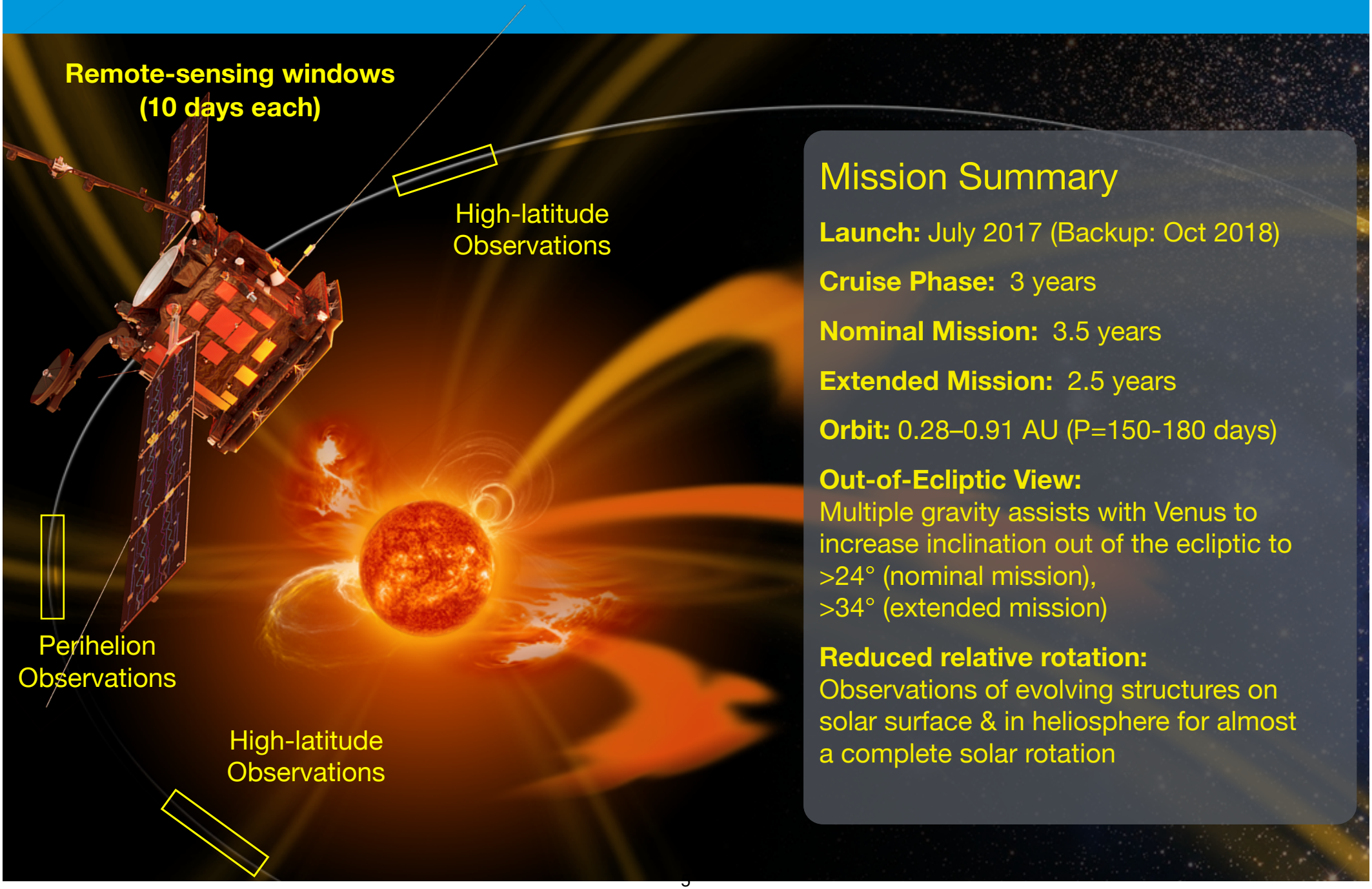

Mission Summary

Launch: July 2017 (Backup: Oct 2018)

Cruise Phase: 3 years

Nominal Mission: 3.5 years

Extended Mission: 2.5 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), >34° (extended mission)

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

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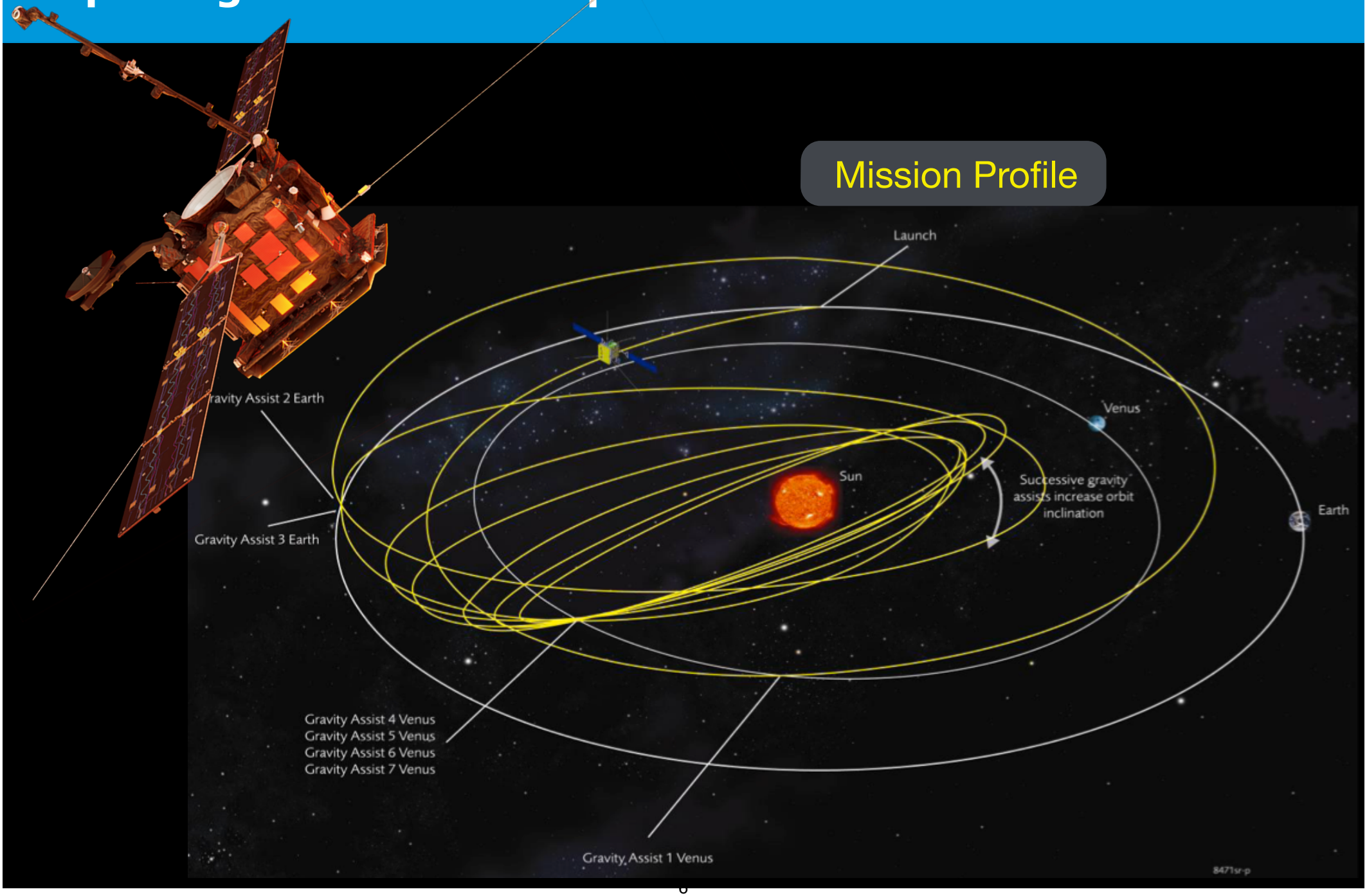
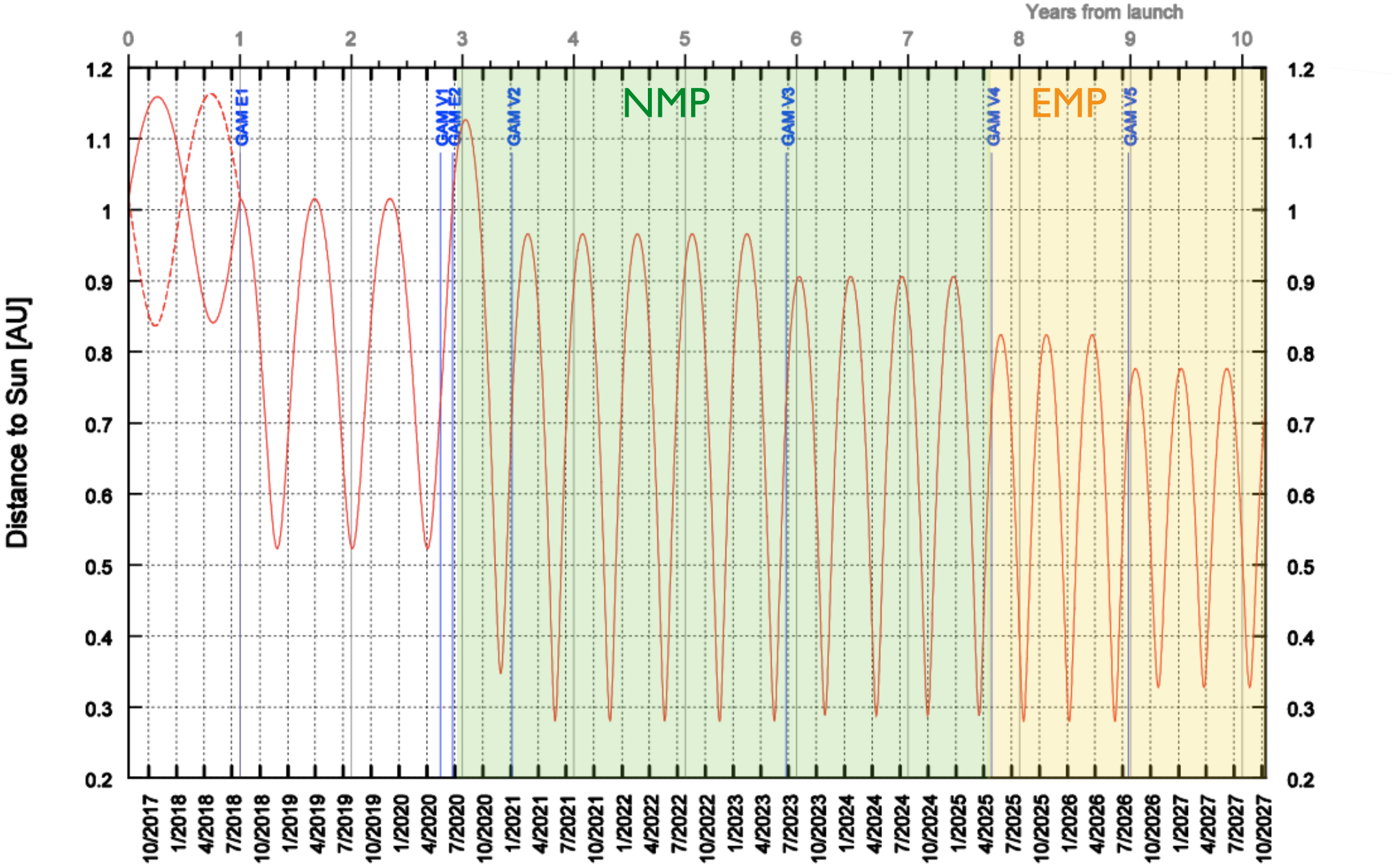
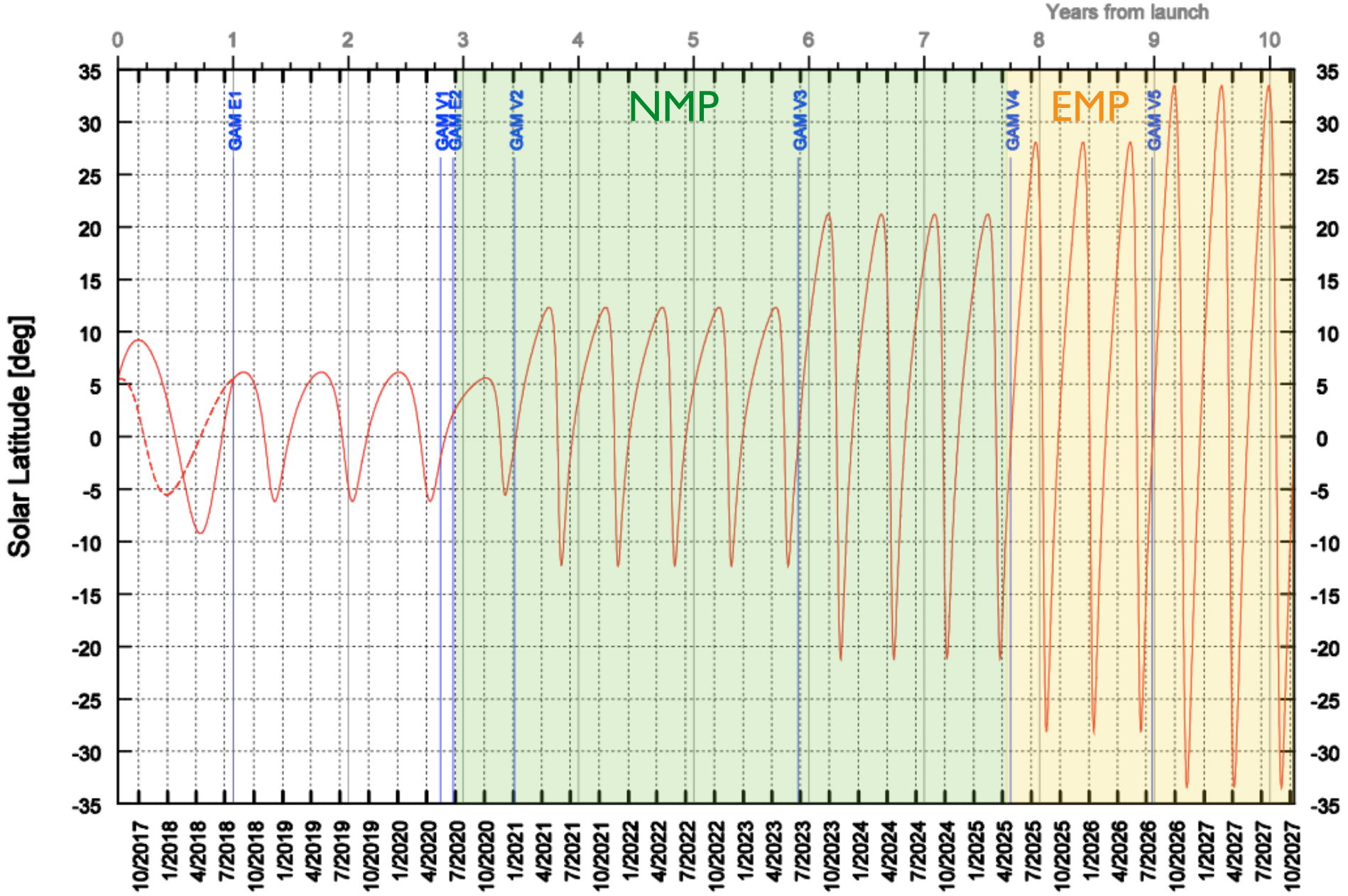


July 2017 Launch: Solar Distance



July 2017 Launch: Solar Latitude



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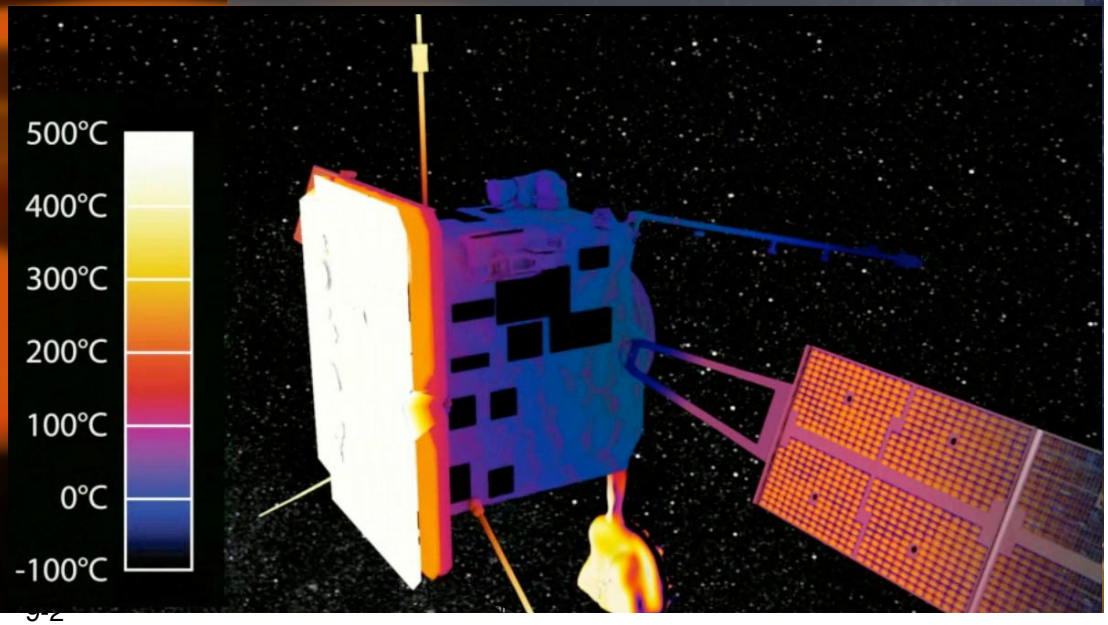
The Spacecraft

Three-axis stabilized spacecraft, Sun pointing

- Closest Sun encounter: 0.28 AU
- Heat shield to protect spacecraft and payload



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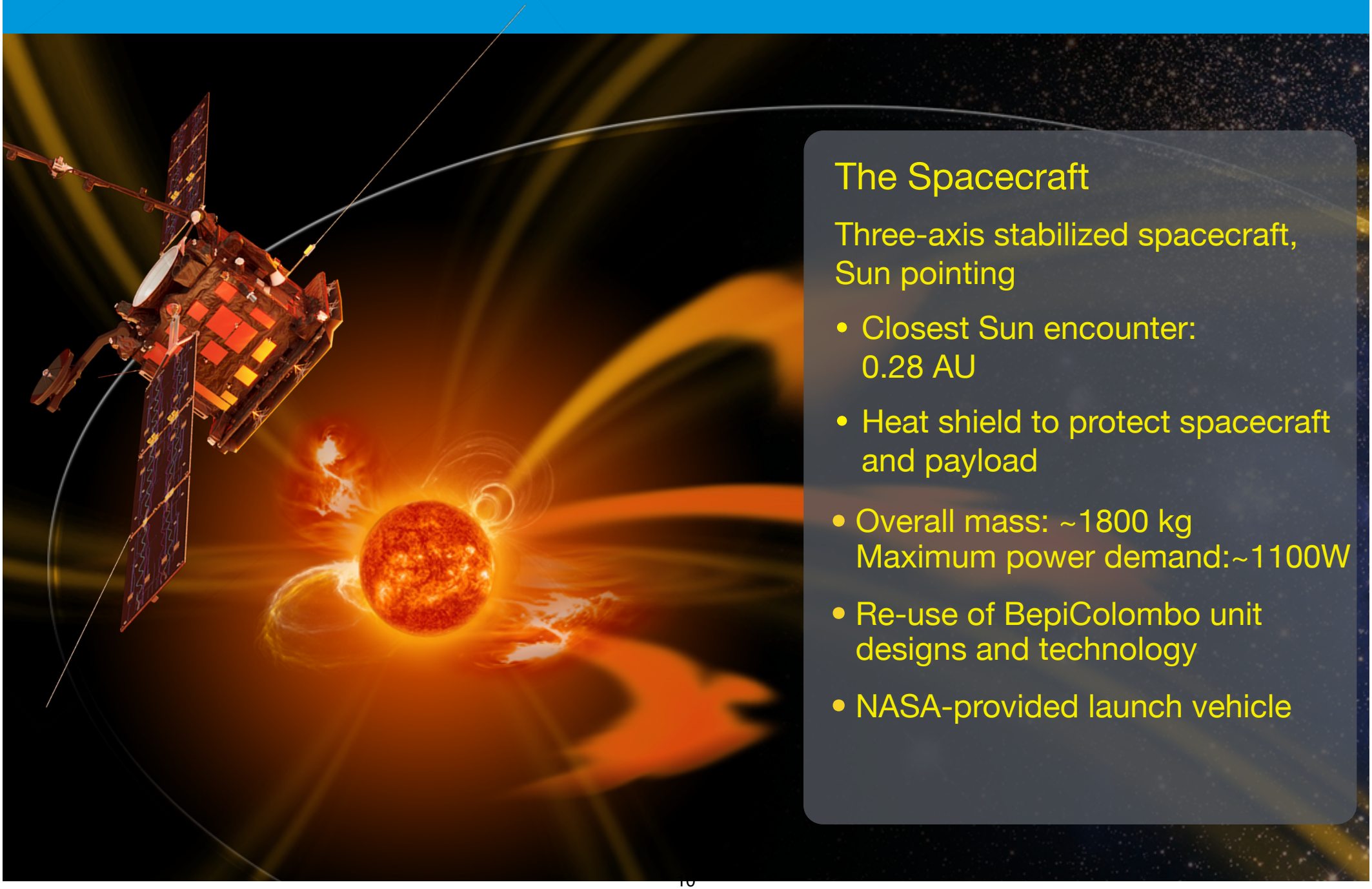
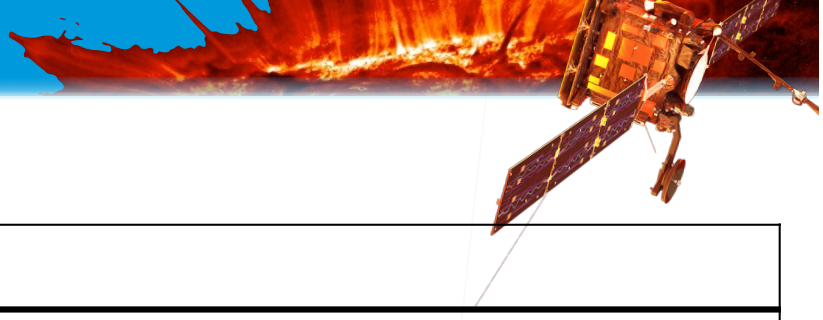


The Spacecraft

Three-axis stabilized spacecraft, Sun pointing

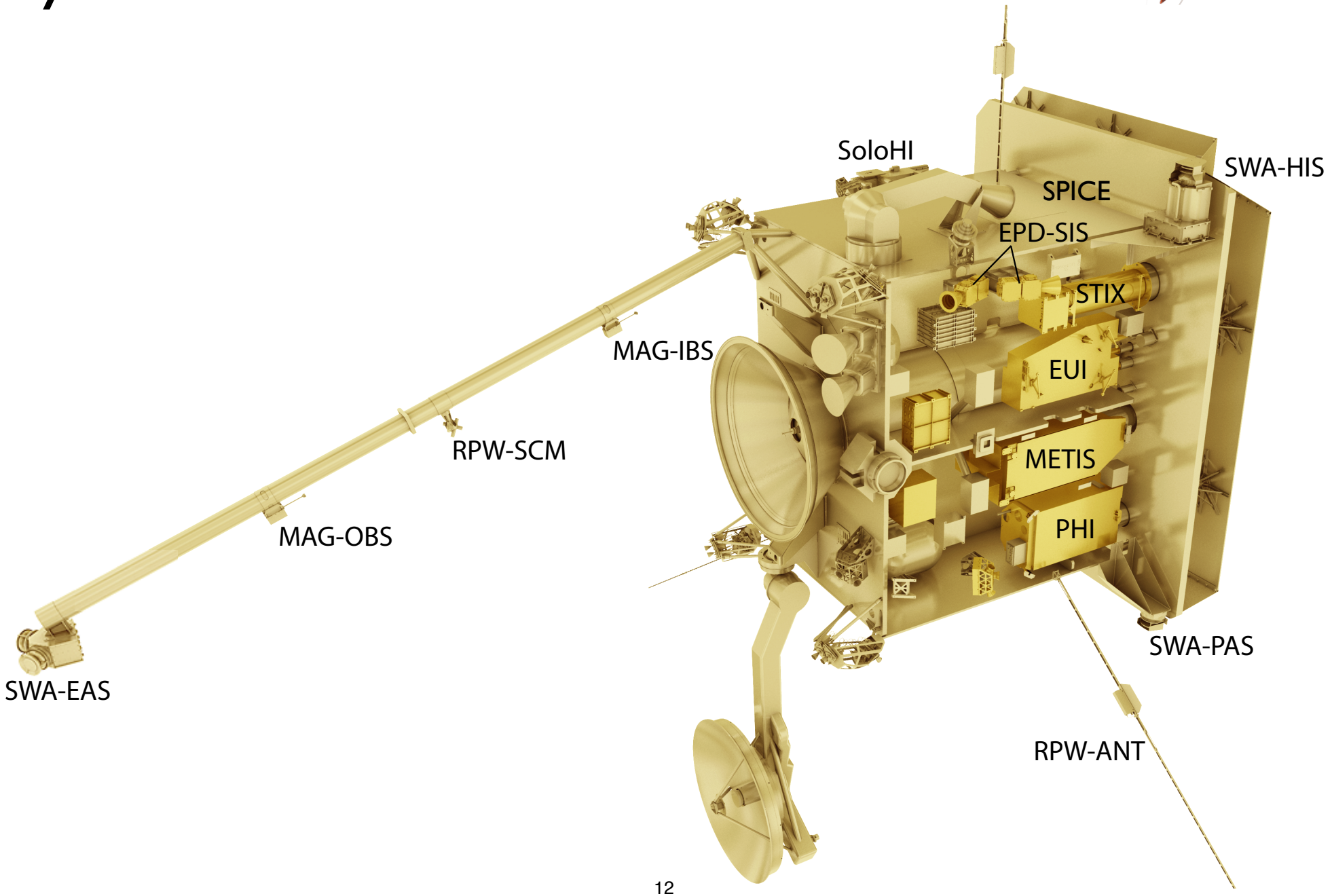
- Closest Sun encounter: 0.28 AU
- Heat shield to protect spacecraft and payload
- Overall mass: ~1800 kg
  Maximum power demand:~1100W
- Re-use of BepiColombo unit designs and technology
- NASA-provided launch vehicle



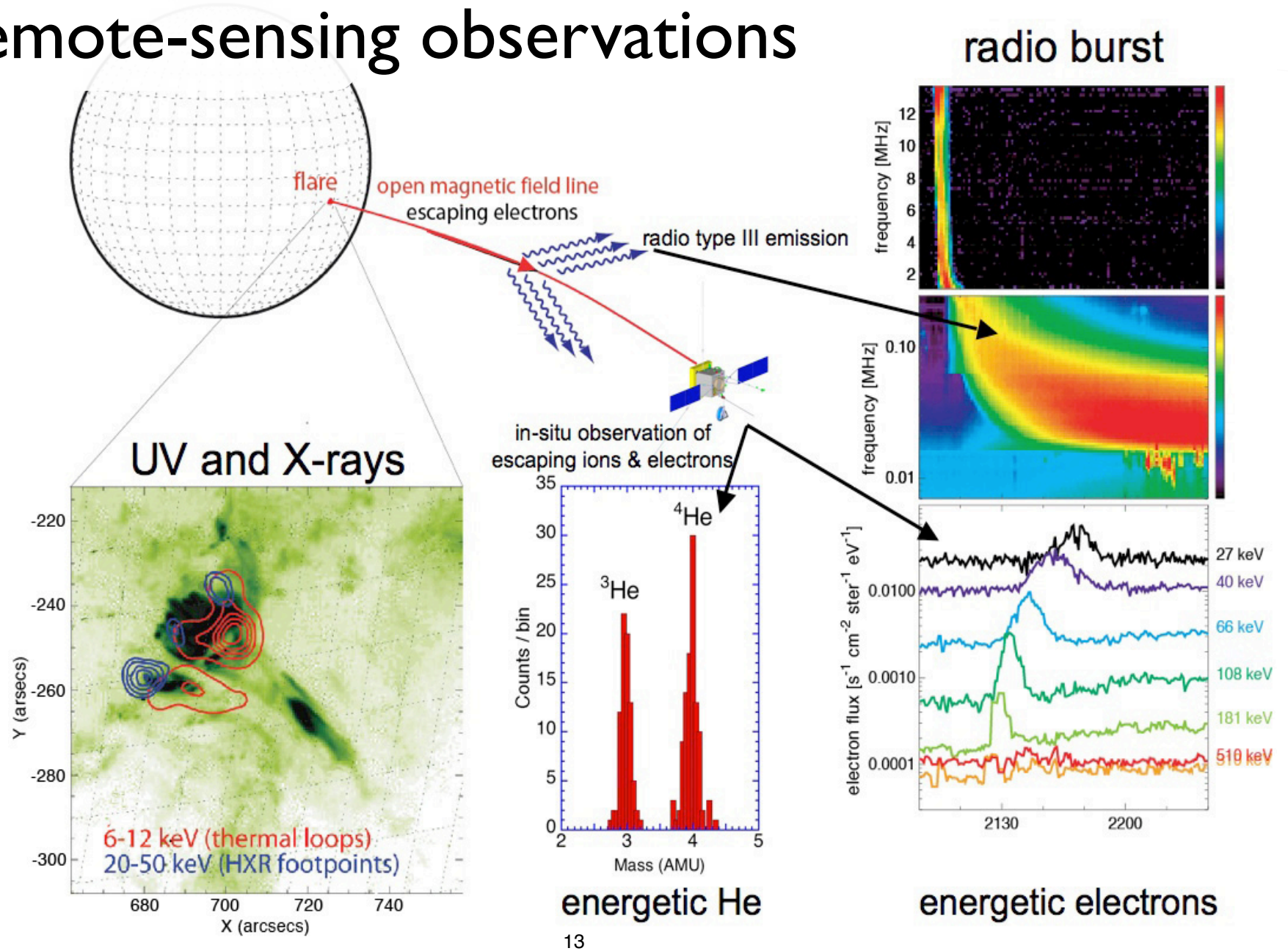
Payload

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 EUV imaging of the on-disk corona
METIS	Coronagraph	E. Antonucci	Visible and (E)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	European-led facility instrument	EUV 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

Payload Accommodation

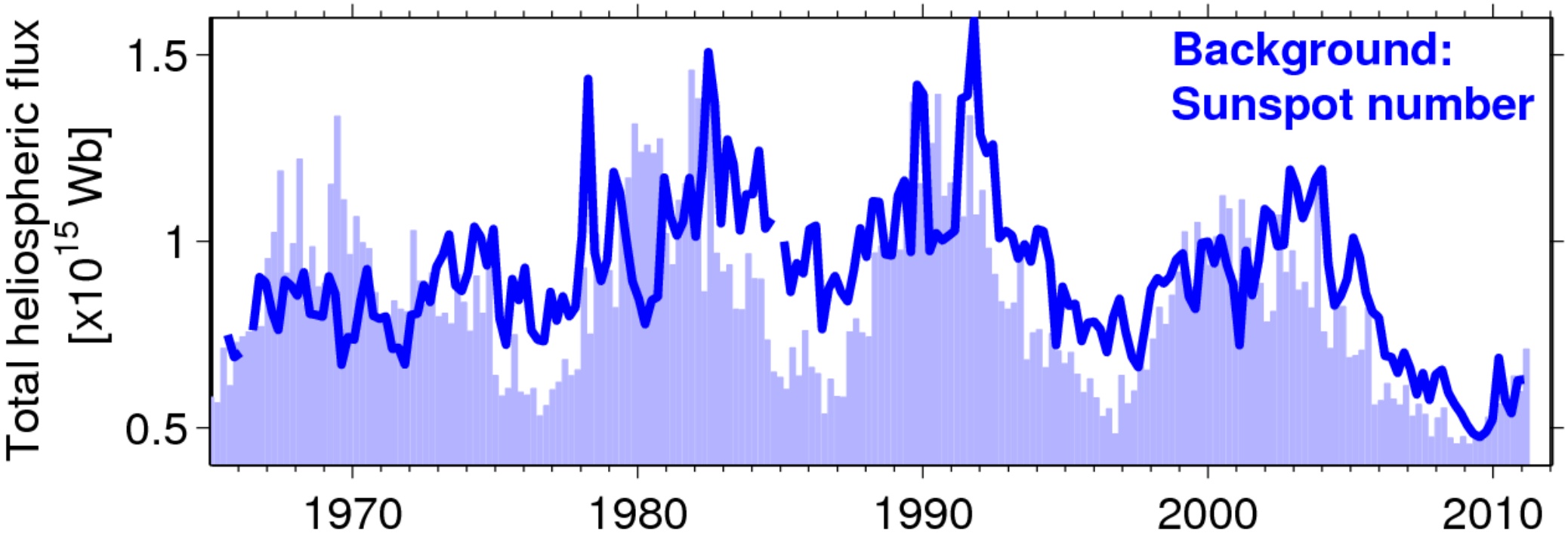


Solar Orbiter = Linking in-situ and remote-sensing observations



Solar Orbiter Science Focus:

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



Courtesy M. Owens (U. of Reading)

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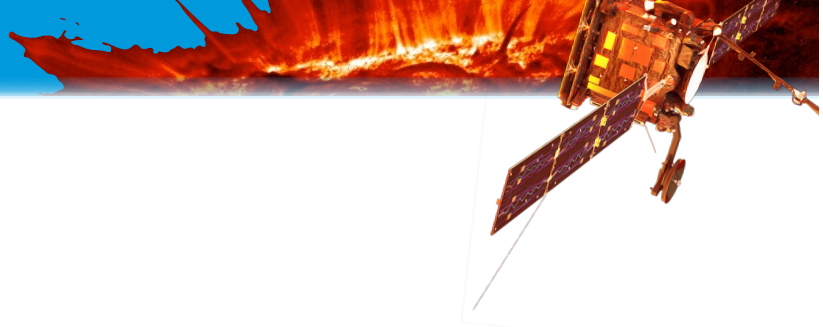


Solar Orbiter science planning

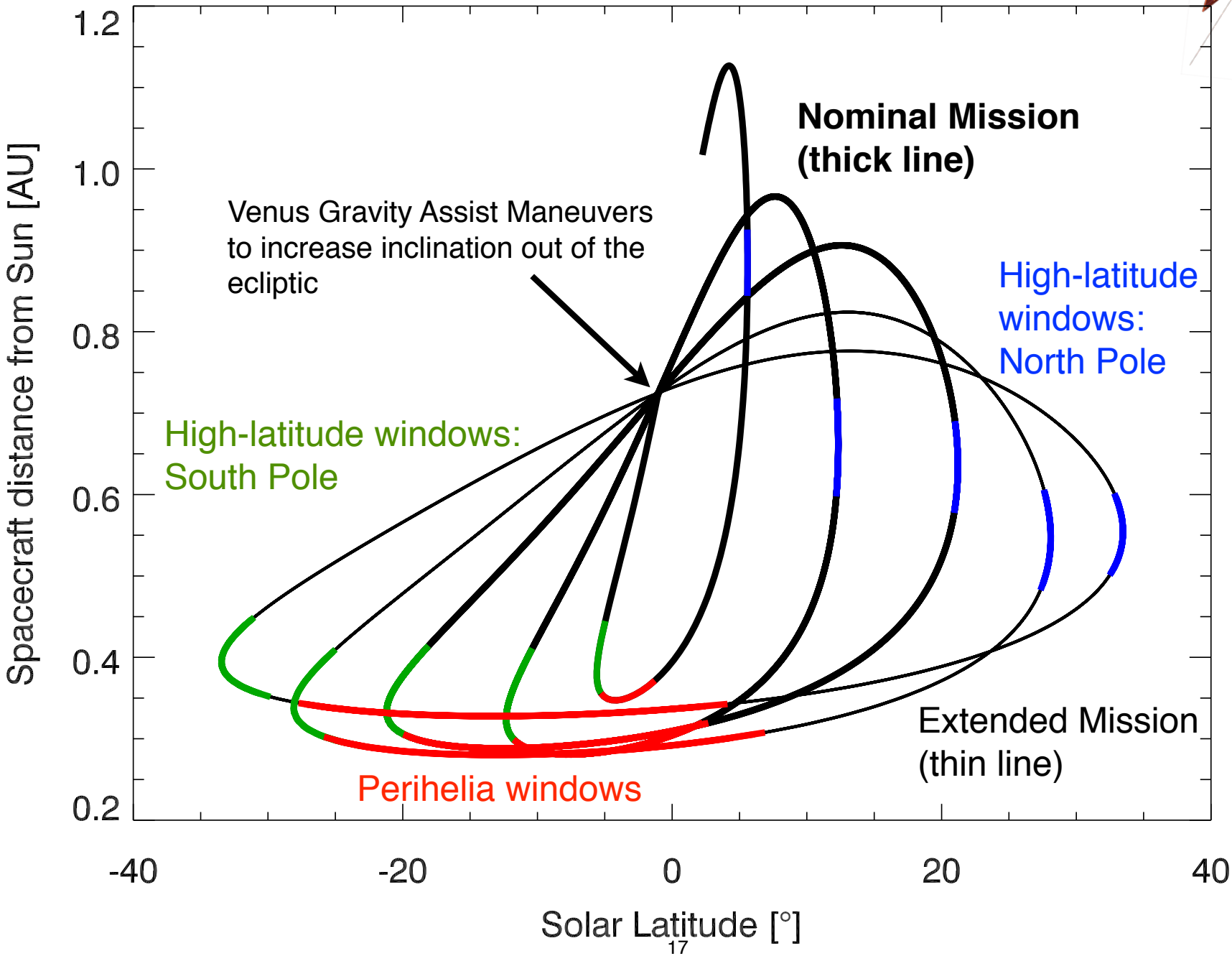
- Most missions have Long-Term, Medium-Term, Short-Term Plan
- Solar Orbiter also implements

  Mission Level Planning:
  - science goals depend on coordinated observations during opportunity windows along mission trajectory
  - variable downlink & limited space onboard
  - restrictions on RS observation time, TM and EMC noise

  Very Short Term Planning:
  - high-resolution FOVs require fine-pointing to target
  - changing solar activity imposes pointing updates
  - short turn-around for data selection & calibration updates

    ⇨ requires low-latency (=quicklook) data

Remote-Sensing Observing Windows



Solar Orbiter data return

- Continuous in-situ measurements, intermittent remote-sensing data
- Coordinated science campaigns ⇨ linked data products
- TM constraints ⇨ data resolution and cadence varies
- Strongly varying latencies in data retrieval, up to 6 months
  - minimal set of 'Low-Latency data' downlinked daily (10MB/day low-resolution, subfields, highly-compressed, …)
  - science datasets might come down at varying times
- RS FOVs and spatial resolution vary along the orbit

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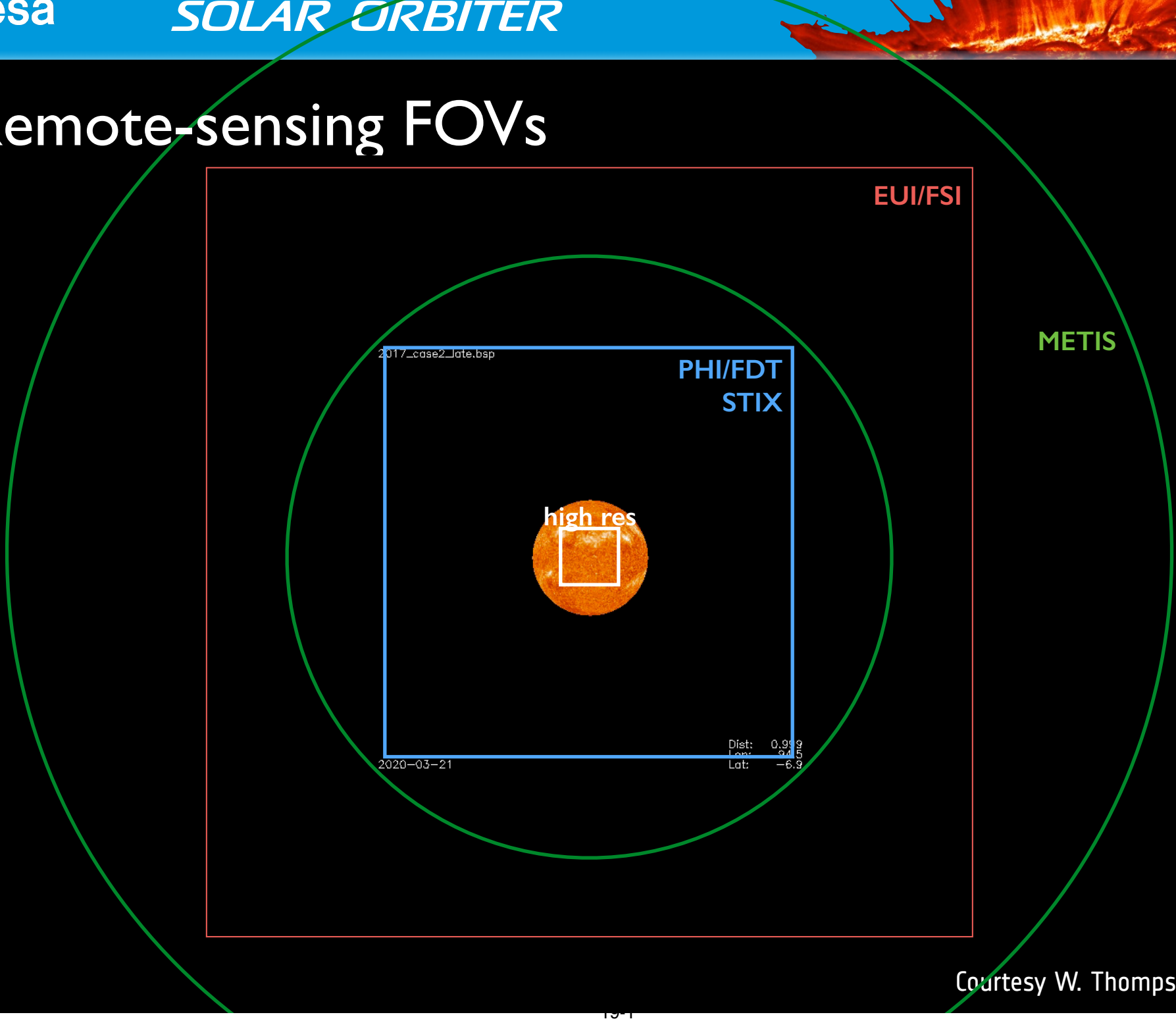
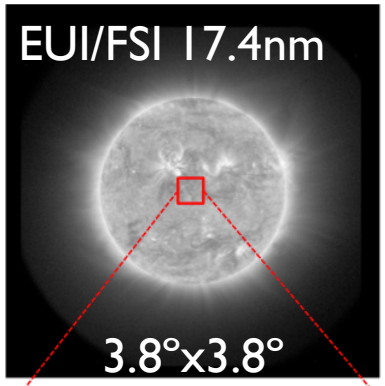
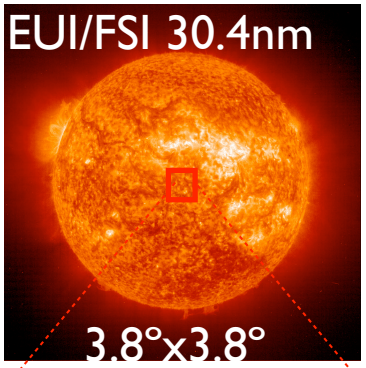
very different from Solar missions like SOHO, SDO !

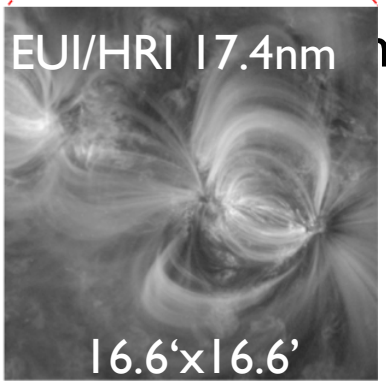
Remote-sensing FOVs

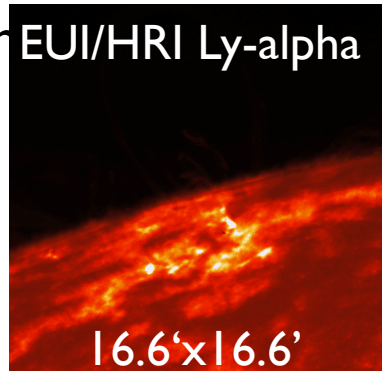


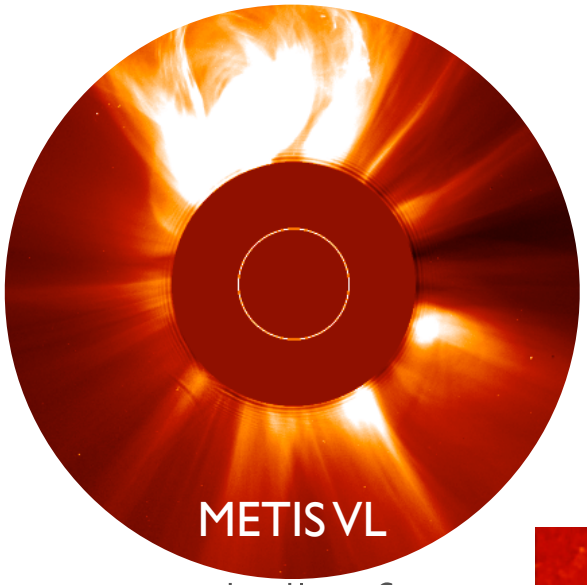
Courtesy W. Thompson (GSFC)



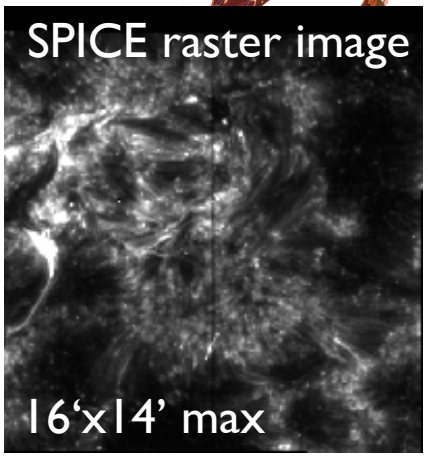


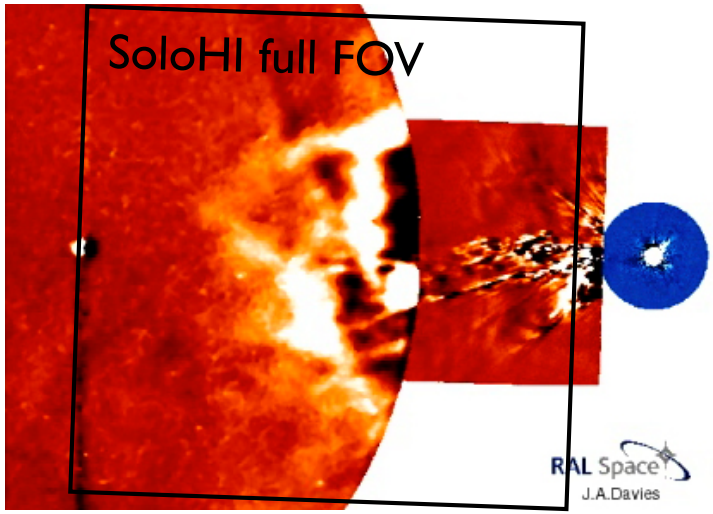




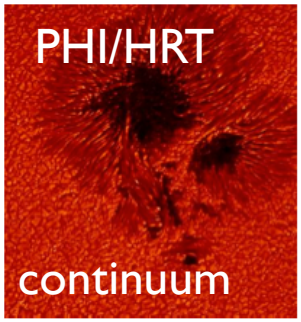


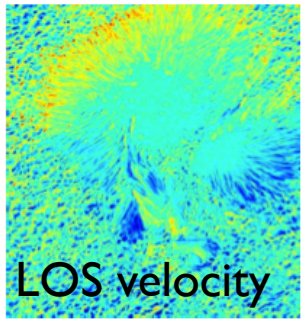
+ similar for Ly-alpha

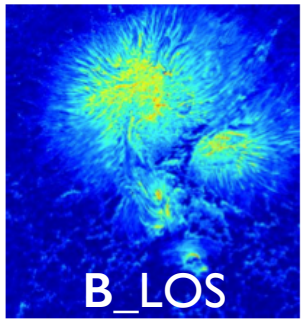


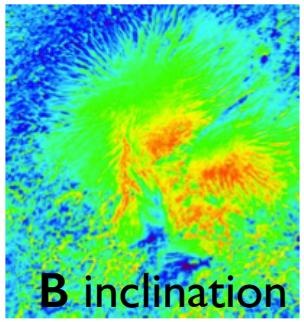


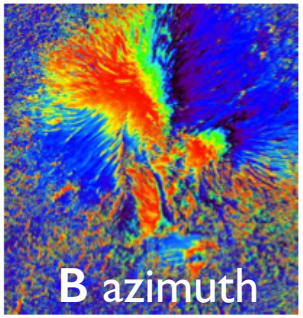
All images in FITS format + WCS
Resolution varies along the orbit





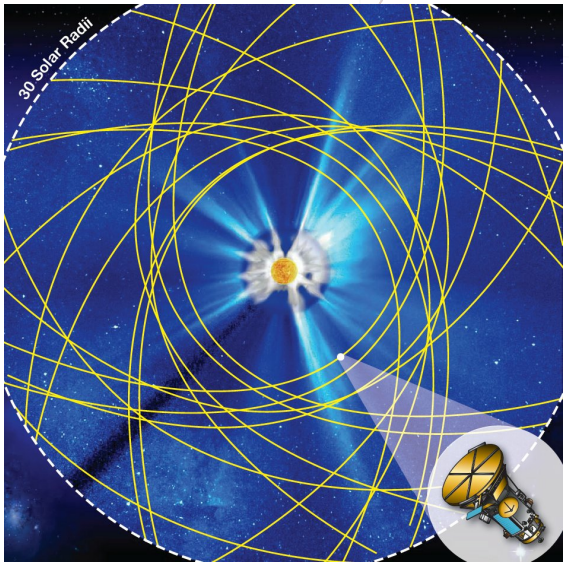






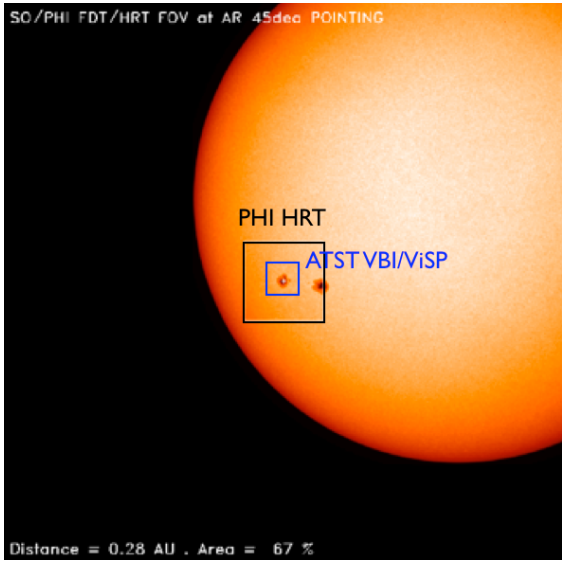
+ similar images for PHI/FDT

Synergy between Solar Orbiter and other Observatories



<u>Solar Orbiter:</u>
+ unique orbit (solar distance, inclination, longitude)
+ comprehensive payload suite
- limited telemetry due to orbital characteristics

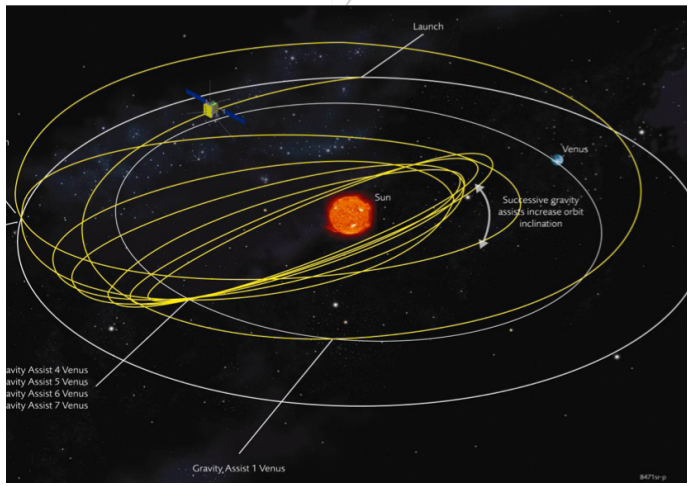
<u>Solar Probe Plus:</u>
+ unique orbit (min. perihelion ≈10 R_{Sun})
- payload mass constrained by orbital characteristics, mostly in-situ instrumentation



<u>Near-Earth assets:</u>
+ much higher data return (SDO, DKIST)
- limited to Sun-Earth line

→ Depending on orbit, Solar Orbiter remote-sensing data can be complemented either by high-res/high-cadence **co-spatial** data from other observatories or data with **additional spatial coverage**, e.g. for helioseismology

Data analysis challenges for Solar Orbiter

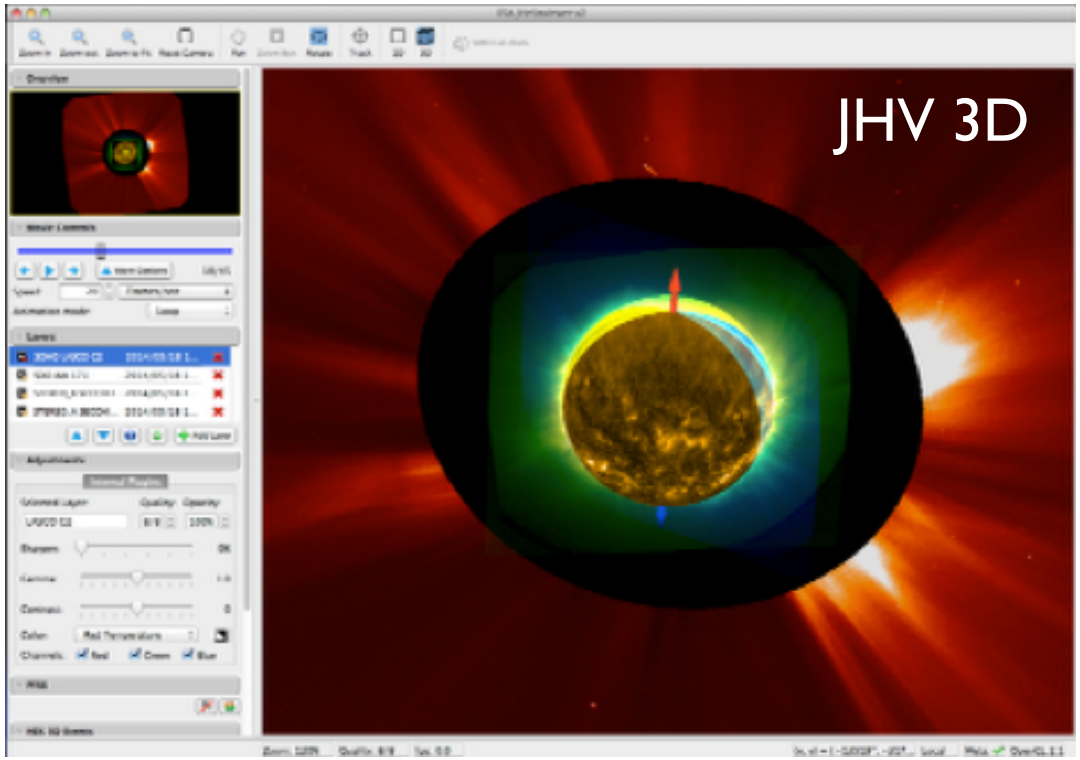


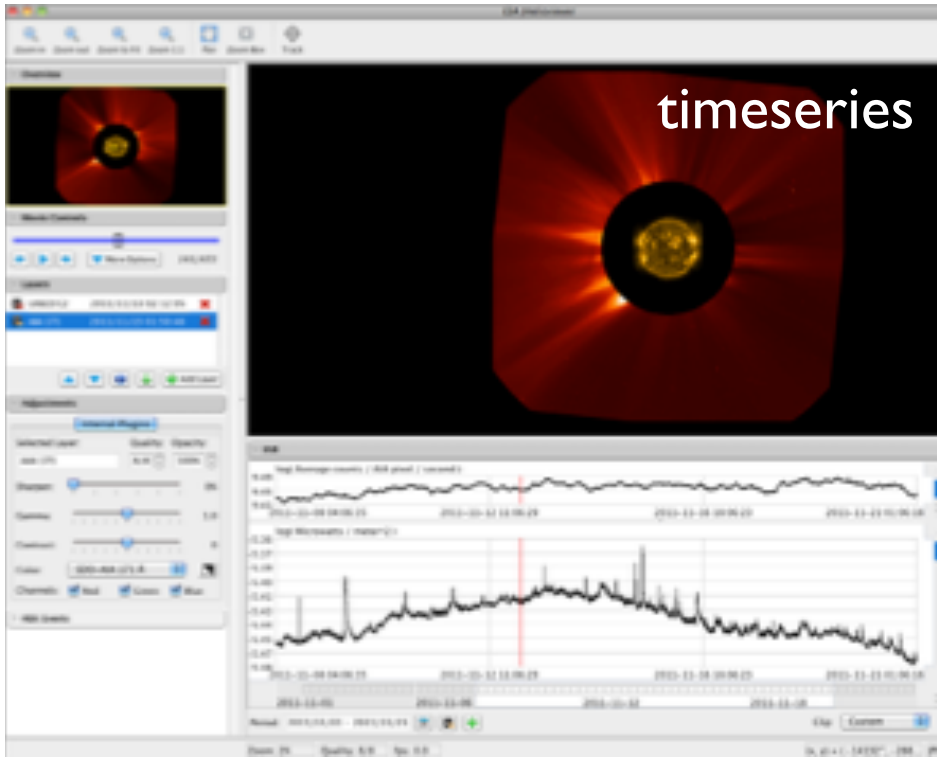
- Connect in-situ and remote-sensing data
  ⇨ 3D time-dependent data representation
- Assimilate data into models
- Combine Solar Orbiter data with data from other missions
  ⇨ Need to jointly display data from different viewpoints
  ⇨ Transform between coordinate systems
  ⇨ Coordinate information in metadata (WCS)

Data browsing & analysis: ongoing efforts

- Modelling and Data Analysis Working Group *(Alexis Rouillard)*
  ⇨ SO metadata standard, Modelling, Analysis SW

- JHelioviewer development





Summary

- Solar Orbiter will address a central question of heliophysics: How does the Sun create and control the heliosphere?

- Solar Orbiter will perform
  - In-situ measurements of the solar wind plasma, fields, waves and energetic particles as close as 0.28 AU from the Sun
  - Simultaneous high-resolution imaging and spectroscopic observations of the Sun in and out of the ecliptic plane (up to 34°).
- The combination of in-situ and remote-sensing instruments, together with the new, inner-heliospheric perspective, distinguishes Solar Orbiter from all previous and current missions, enabling new science which can be achieved in no other way.
- Solar Orbiter has unique synergies with Solar Probe Plus, DKIST and other new observatories.

Solar Orbiter Heat Shield STM being lowered into Large Space Simulator at ESTEC