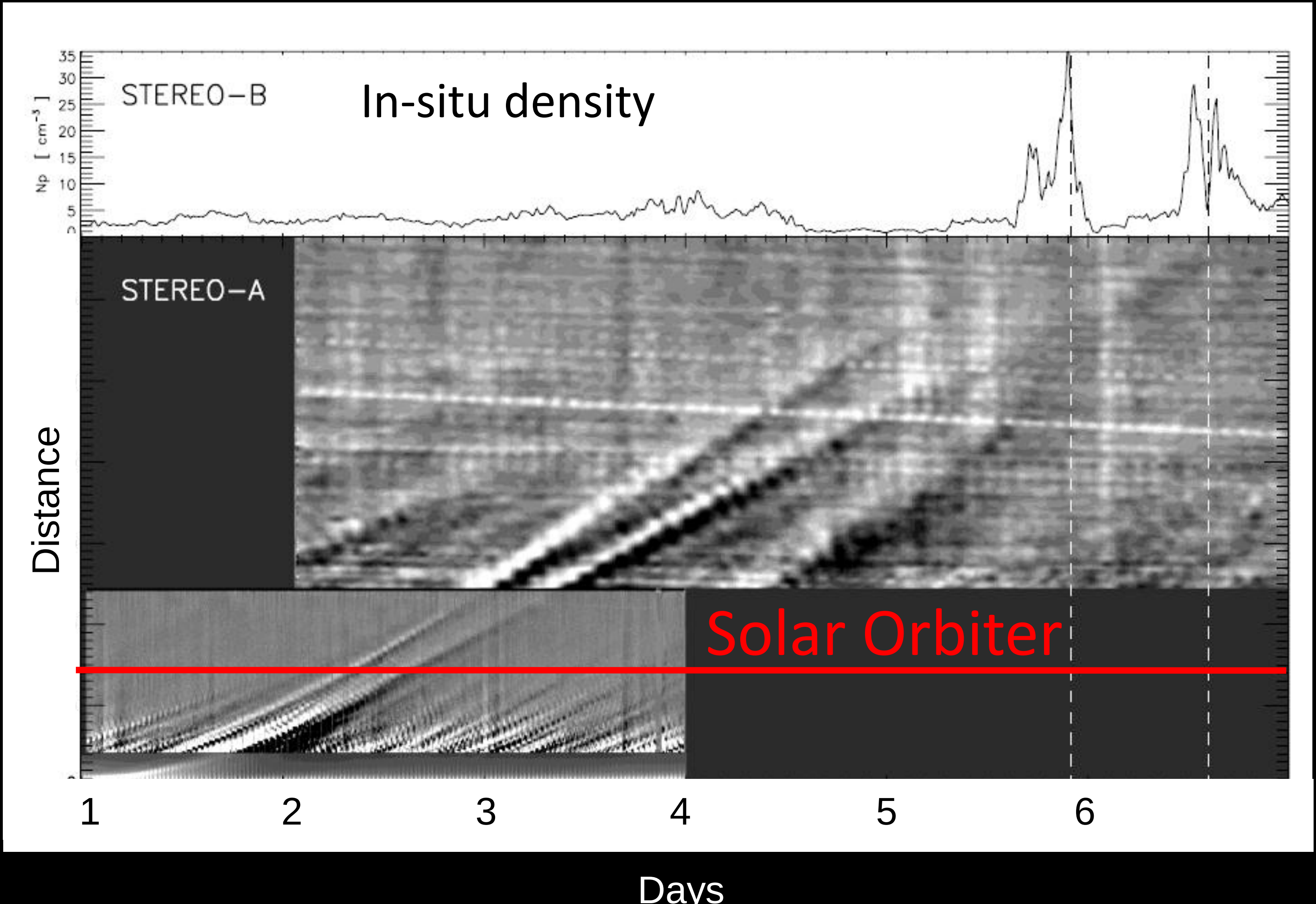
Solar Orbiter

Exploring the Sun-heliosphere connection

Tim Horbury, Imperial College London

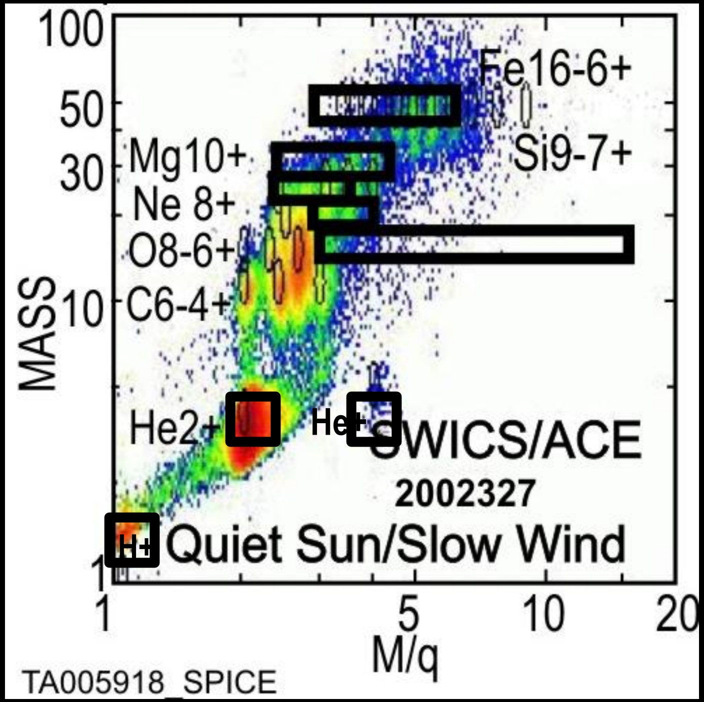
The need for near-Sun observations



Linking Sun and the solar wind

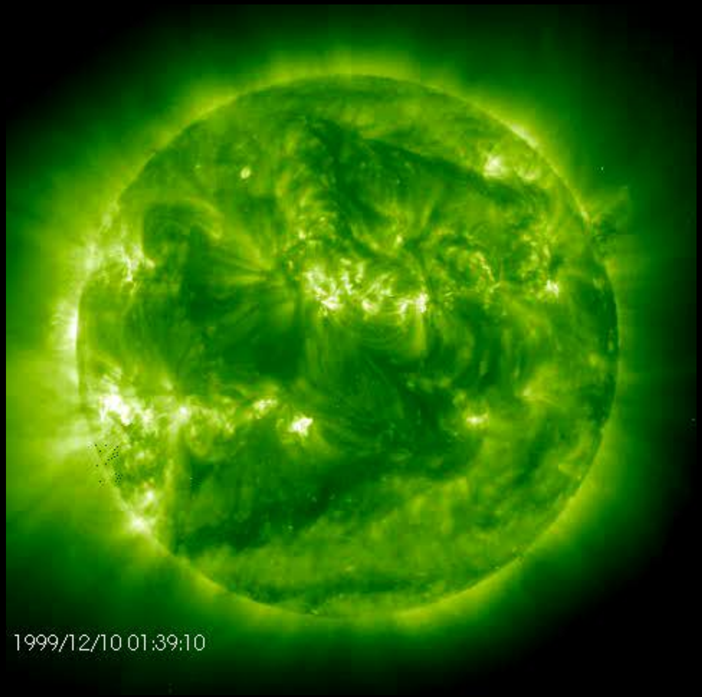
- We need to measure the same parameter on the Sun and in space to make the link
  - Heavy ion charge states and composition
  - Magnetic polarity
  - Energetic particles

- Solar Orbiter will make all of these measurements with both remote sensing and in situ instruments

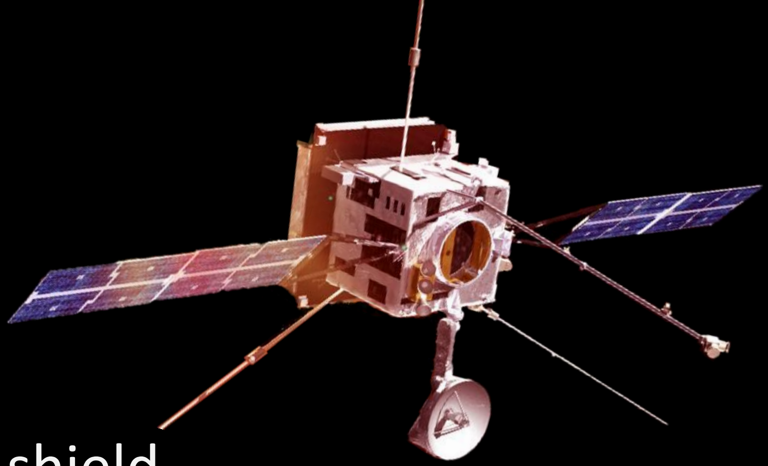


Solar Orbiter science questions

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

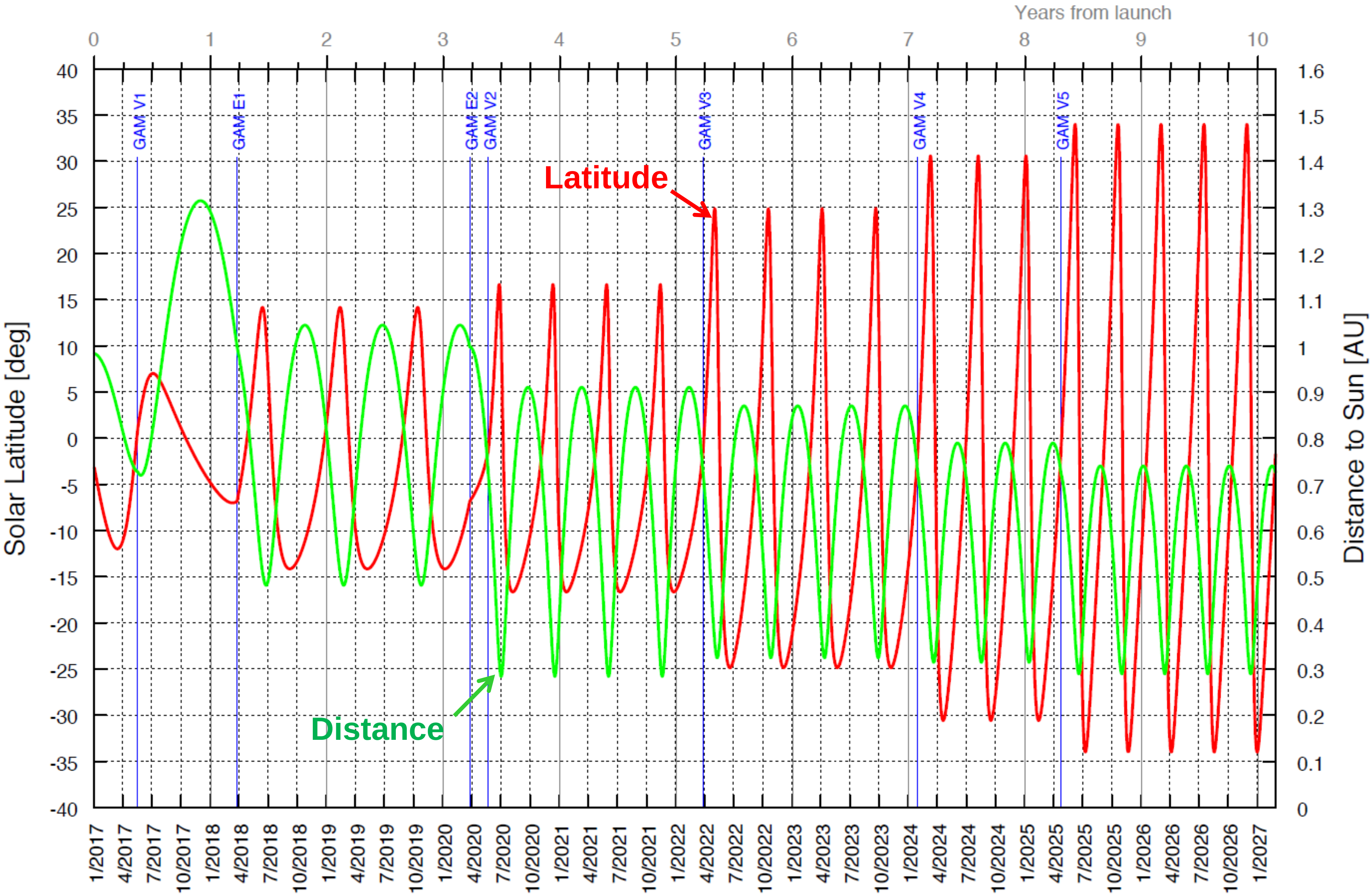


Mission overview



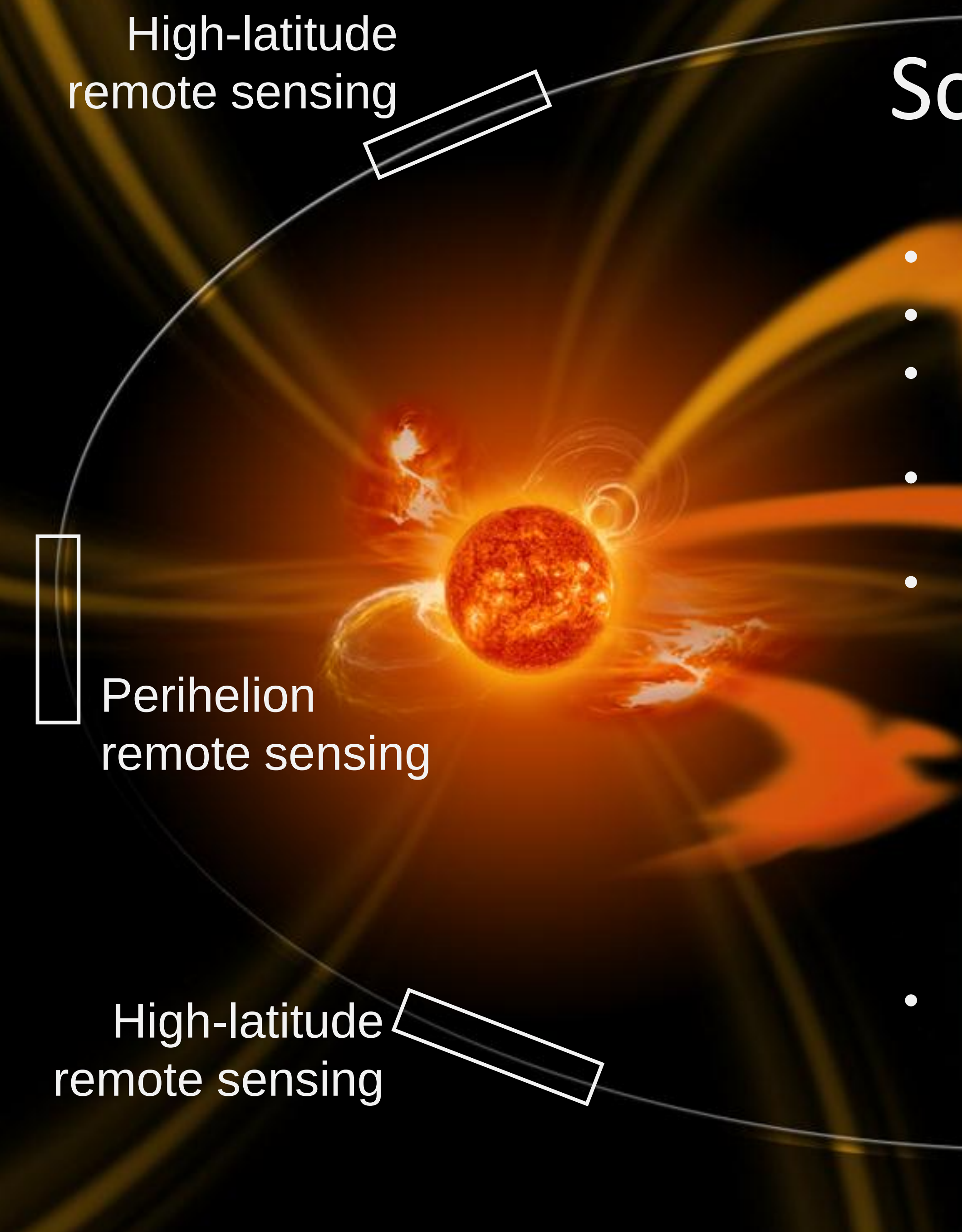
- Sun-pointing spacecraft with heat shield
- Carefully optimised payload of ten remote sensing and in situ instruments
- Launch: January 2017
- Cruise 3 years; nominal mission 3.5 years; 2.5 year extended
- Minimum perihelion: 0.28 AU
- Fast perihelion motion: solar features visible for almost complete rotation
- Out of ecliptic: first good view of solar poles

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
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**



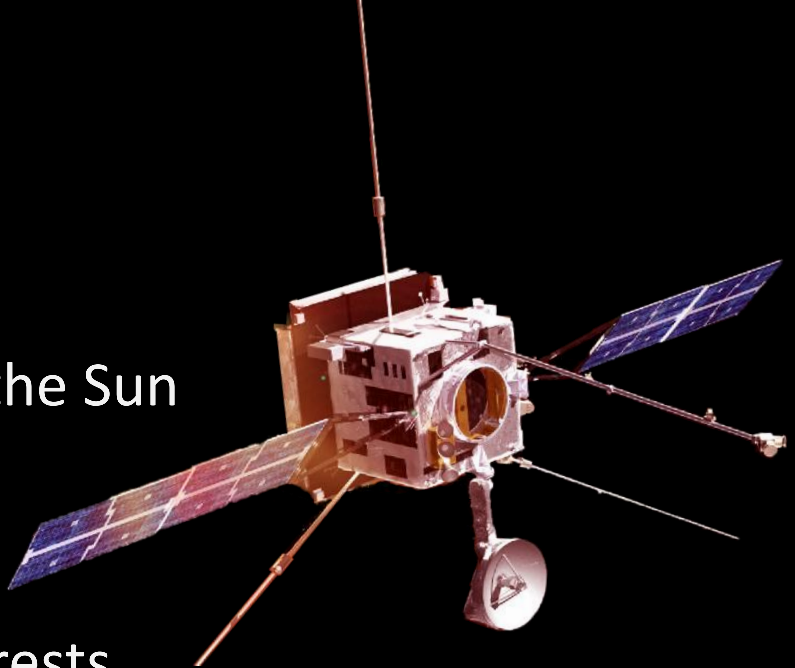
Years from launch
0
1
2
3
4
5
6
7
8
9
10
Solar Latitude [deg]
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
Distance to Sun [AU]
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
GAM V1
GAM E1
GAM E2
GAM V2
GAM V3
GAM V4
GAM V5
Latitude
Distance
1/2017
4/2017
7/2017
10/2017
1/2018
4/2018
7/2018
10/2018
1/2019
4/2019
7/2019
10/2019
1/2020
4/2020
7/2020
10/2020
1/2021
4/2021
7/2021
10/2021
1/2022
4/2022
7/2022
10/2022
1/2023
4/2023
7/2023
10/2023
1/2024
4/2024
7/2024
10/2024
1/2025
4/2025
7/2025
10/2025
1/2026
4/2026
7/2026
10/2026
1/2027

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
  - Spacecraft pointing to regions of interest
  - Requires careful planning
- Autonomous burst mode triggers for unpredictable events

Summary



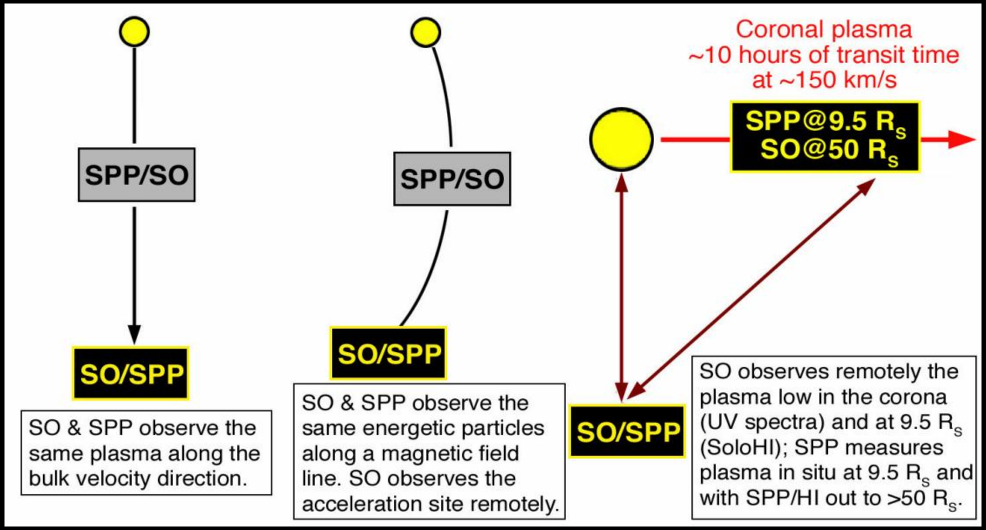
- Solar Orbiter is Europe’s mission to the Sun
- Major UK involvement
  - Excellent fit with UK science interests
  - 2 UK-led instruments, 2 major contribution
  - Astrium UK is prime contractor
- Get involved ***now*** to make sure your science interests are captured in the mission planning
- Solar Orbiter workshop, Bruges, 10-14 September 2012
- www.solarorbiter.org

Back up slides

Links to Solar Probe Plus

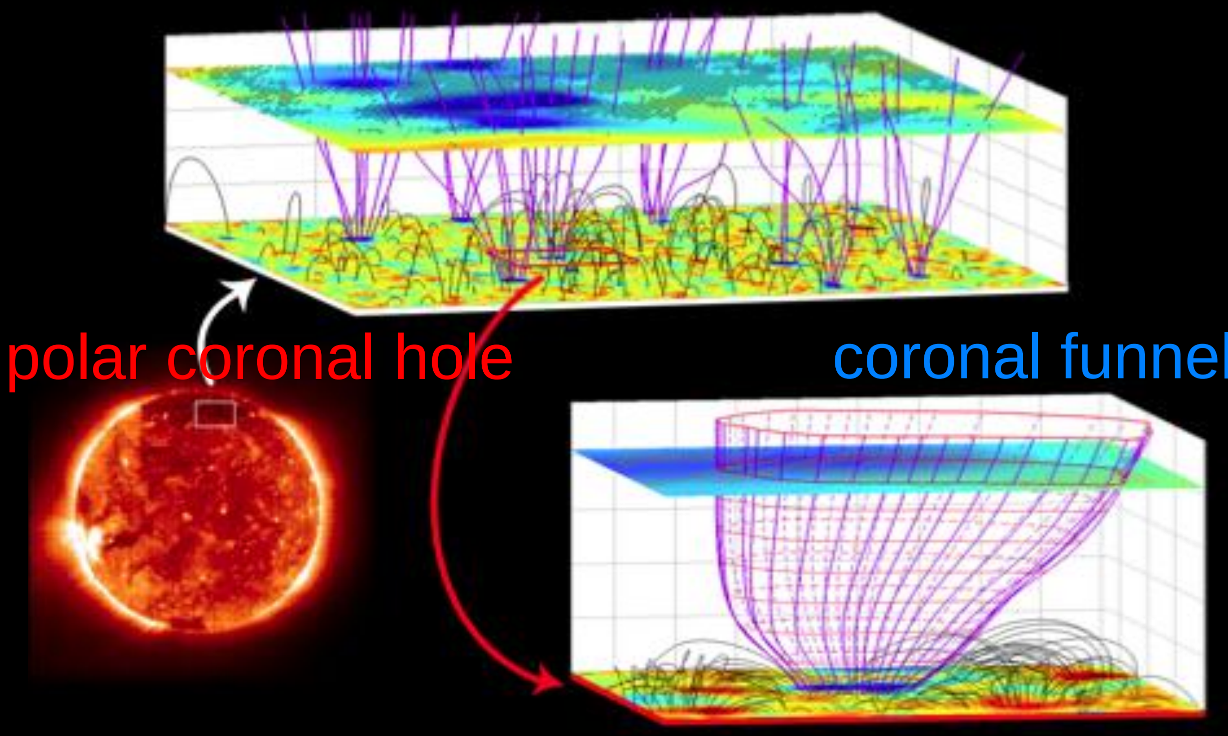
- Many conjunctions will occur between Solar Orbiter and Solar Probe Plus
  - Extends science return from both msisions

- Solar Probe Plus is not required for any Solar Orbiter science goal



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

- Solar wind is variable and structured
- Originates in complex magnetic “carpet”
- Small scale transient jets are common



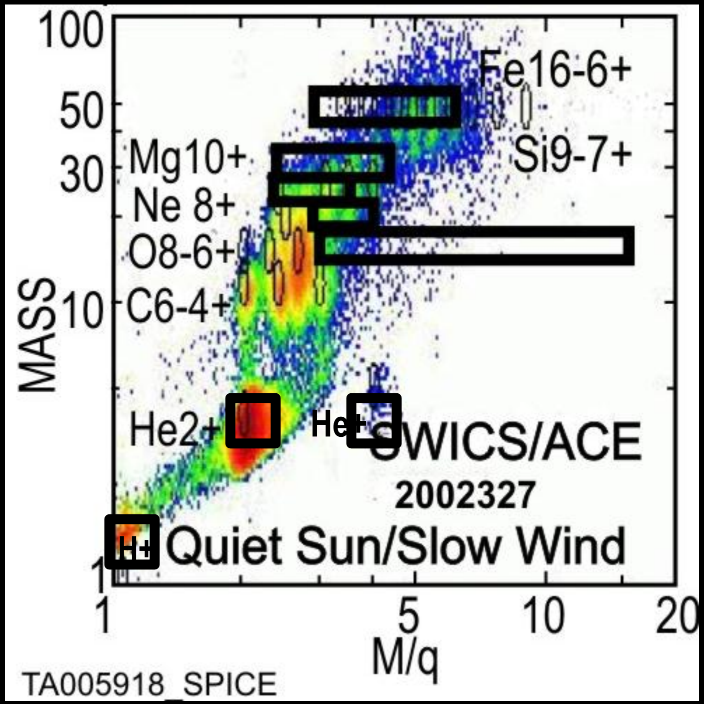
Tu, Zhou, Marsch et al., Science 2005

- Solar Orbiter will measure the spatial and temporal variability of the solar source and solar wind in unprecedented detail

Linking Sun and the solar wind

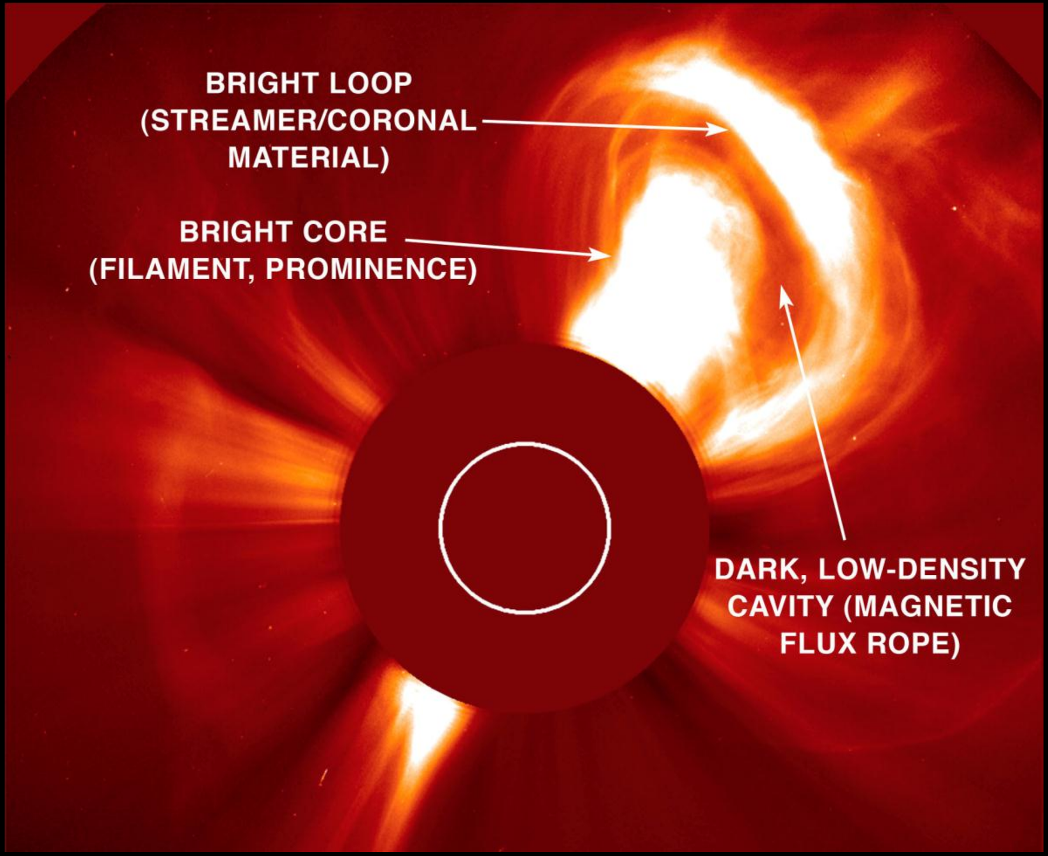
- We need to measure the same parameter on the Sun and in space to make the link
  - Heavy ion charge states and composition
  - Magnetic polarity
  - Energetic particles

- Solar Orbiter will make all of these measurements with both remote sensing and in situ instruments

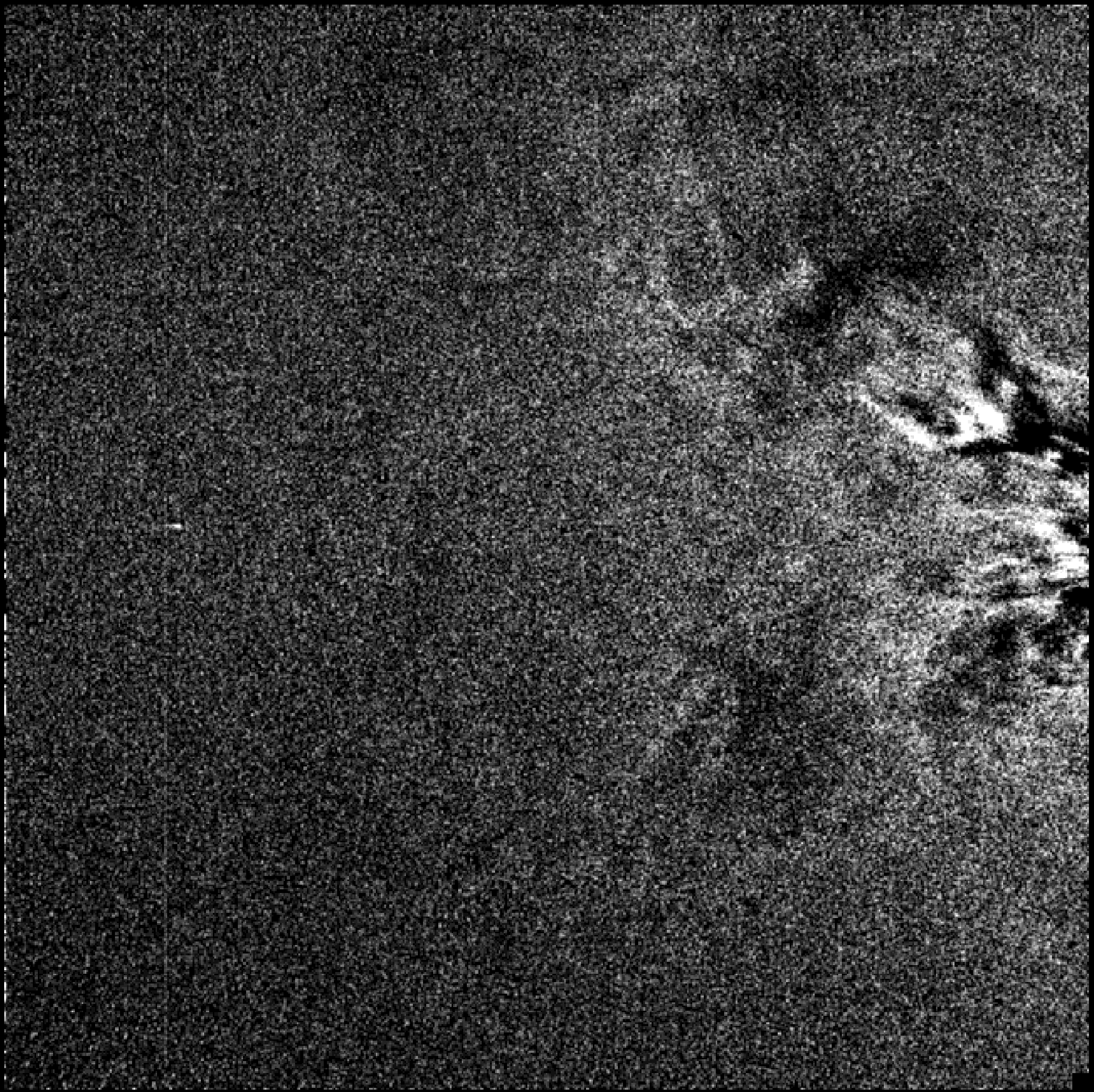


How do solar transients drive heliospheric variability?

- How are substructures of coronal mass ejections related to interplanetary transients?
- How are CMEs processed as they travel from the Sun?
- Solar Orbiter will image CMEs and measure their evolution in the inner heliosphere

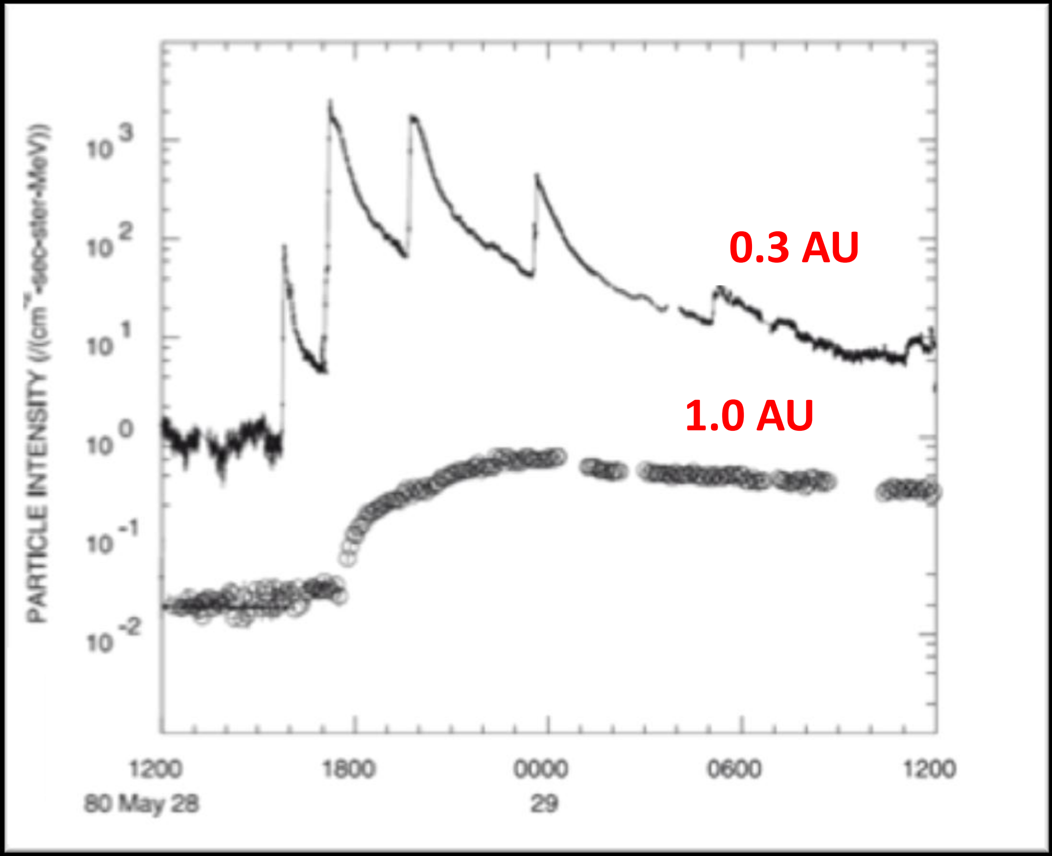


Coronal mass ejections in space



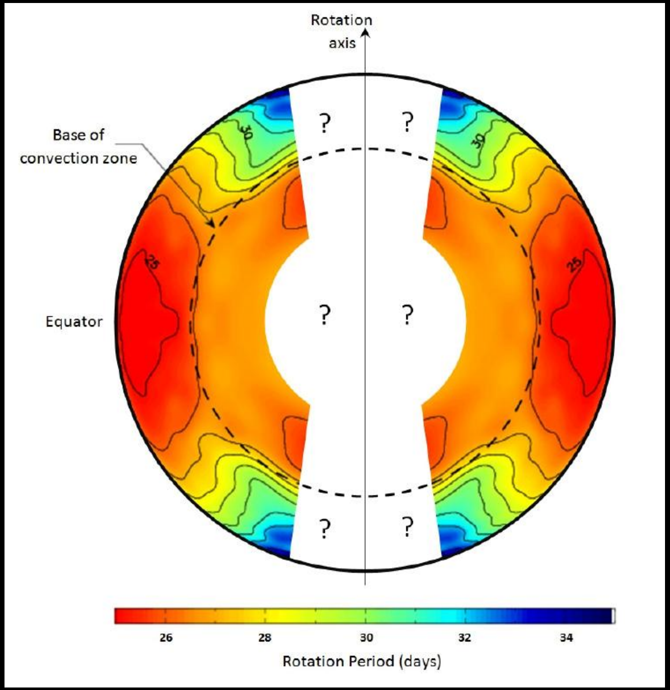
How do solar eruptions produce energetic particle radiation?

- Around 10% of coronal mass ejection energy is in accelerated particles
- Understanding release and transport mechanisms requires going close to the Sun
- Solar Orbiter will measure energetic particles within a mean free path of their acceleration site

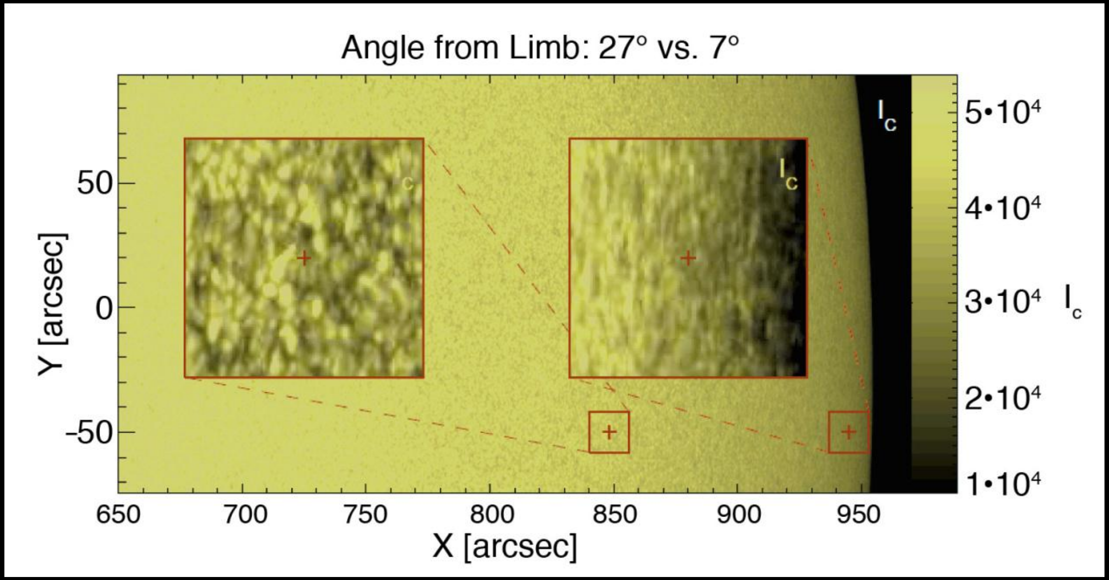


How does the solar dynamo work?

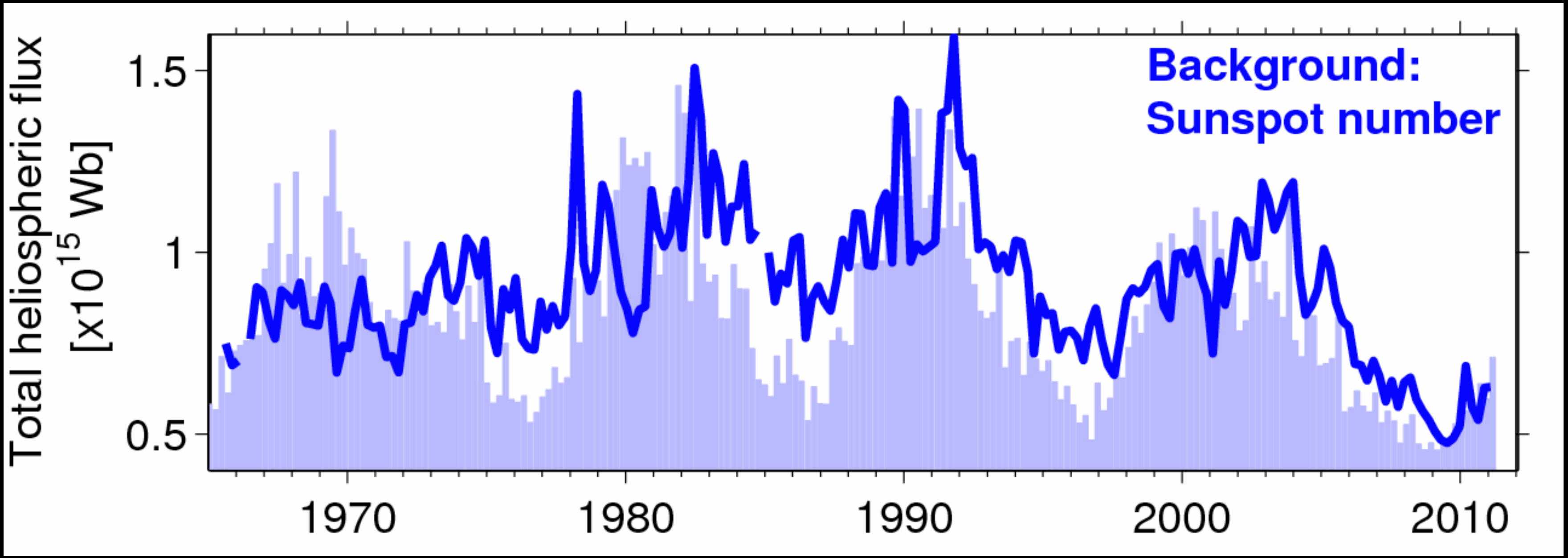
- The unexplored poles are central to the operation of the Sun's dynamo



- Solar Orbiter will provide the first accurate measurements of polar flows and magnetic fields



The Sun has changed



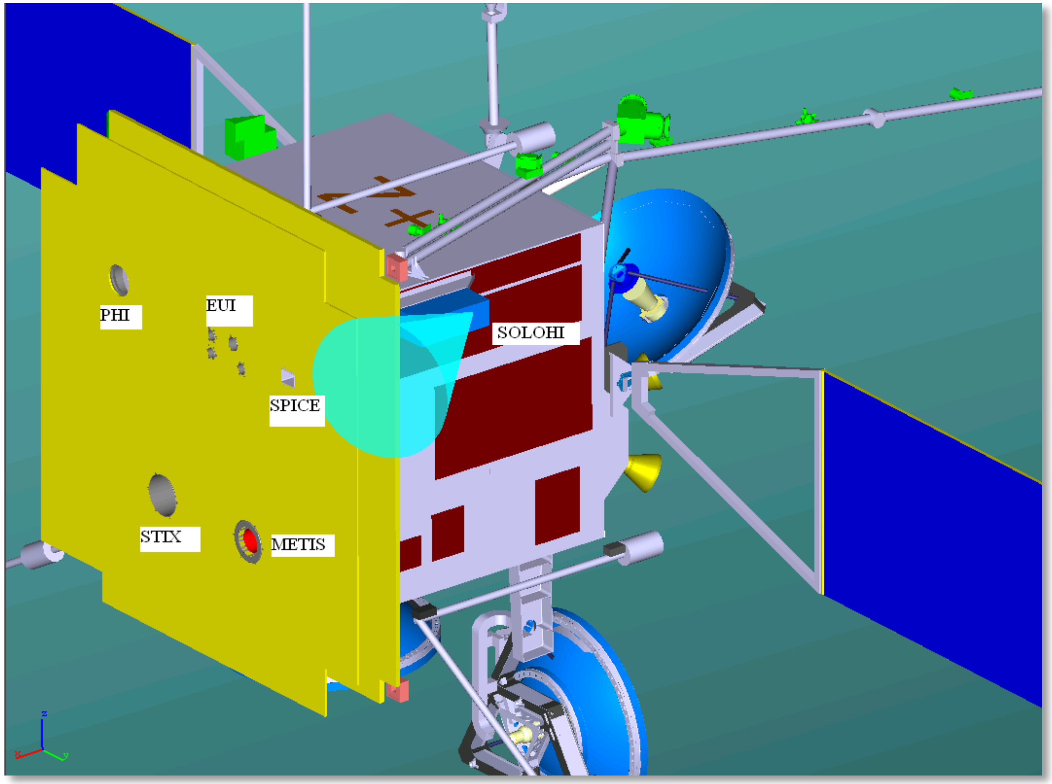
Europe's close encounter mission to the Sun

- Travel close to the Sun: 60 solar radii (0.28 AU)
- Observe solar regions for extended periods
- Travel to over 30° latitude, observing the Sun's polar regions
- Carry both in situ and remote sensing instruments

- *Study how the Sun links into space*

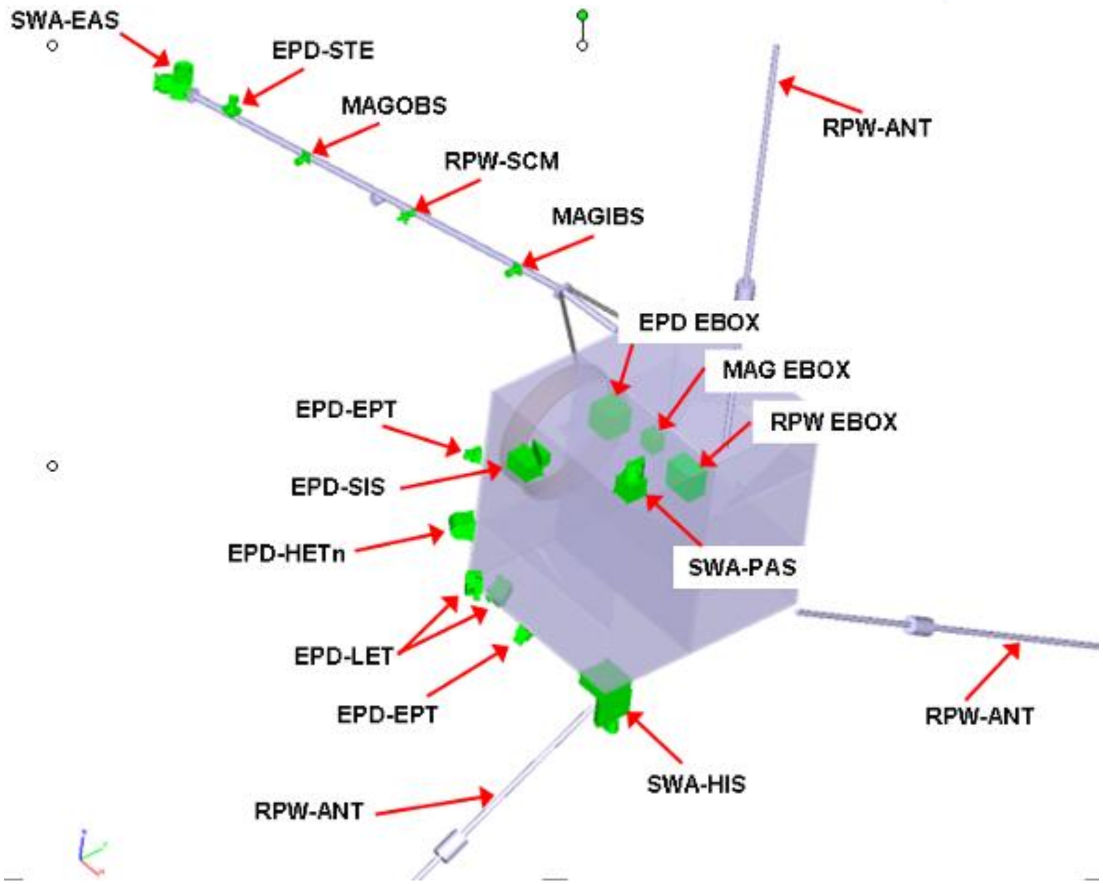
Solar Orbiter spacecraft

- 3-axis stabilised, Sun-pointing
- Heat shield at front
- Solar panels rotate to reduce solar flux
- Imaging instruments have holes in heat shield
- Boom in shadow for magnetometer, search coil, SWA electron sensor



Solar Orbiter spacecraft: in situ

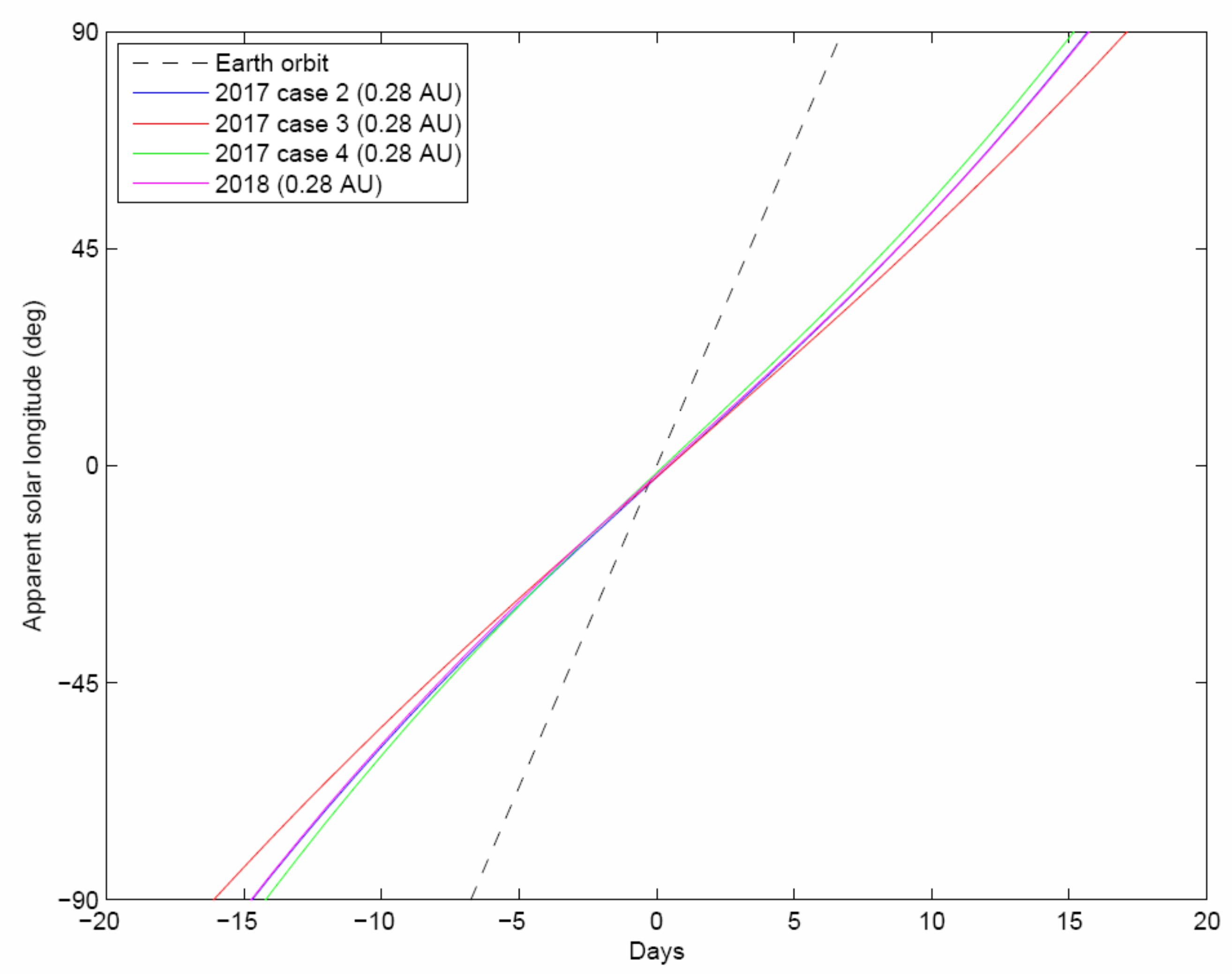
- Particle instruments have multiple sensors to allow wide field of view
- Boom in shadow for magnetometer, search coil, electron sensor



Time line

- January-June 2012: instrument Preliminary Design Reviews
- Sapcecraft PDR
- Early 2013: instrument Critical Design Reviews
- January 2015: instrument deliveries
- January 2017: launch

Feature motion



Orbit statistics

Case	2017 case 2	2017 case 3	2017 case 4	2018
Days above 20 deg	1504	1670	1620	1471
Days above 25 deg	660	884	796	657
Days above 30 deg	239	441	398	237
Days within 0.25 AU	0	0	0	0
Days within 0.3 AU	111	147	138	97
Days within 0.4 AU	765	732	828	758
Days within 0.5 AU	1593	1539	1586	1566
First time <0.3 AU	2020 day 173	2020 day 236	2020 day 180	2022 day 20
First time >20 deg	2020 day 109	2021 day 285	2022 day 115	2023 day 321
Days features visible	28	30	26	28