Solar Orbiter
Exploring the Sun-heliosphere connection

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

polar coronal hole

coronal funnel
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.
How does the Sun create and control the Heliosphere?

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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

<table>
<thead>
<tr>
<th>In situ instruments</th>
<th>Description</th>
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</thead>
</table>
| **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

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Description</th>
<th>Scientist</th>
<th>Location/Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHI</td>
<td>Polarimetric and heliospheric imager</td>
<td>Sami Solanki</td>
<td>Germany, Full-disc and high-resolution visible light imaging of the Sun</td>
</tr>
<tr>
<td>EUI</td>
<td>Extreme ultraviolet imager</td>
<td>Pierre Rochus</td>
<td>Belgium, Studying fine-scale processes and large-scale eruptions</td>
</tr>
<tr>
<td>STIX</td>
<td>Spectrometer/telescope for imaging X-rays</td>
<td>Arnold Benz</td>
<td>Switzerland, Studying hot plasmas and accelerated electrons</td>
</tr>
<tr>
<td>METIS</td>
<td>Multi-element telescope for imaging and spectroscopy</td>
<td>Ester Antonucci</td>
<td>Italy, High-resolution UV and extreme UV coronagraphy</td>
</tr>
<tr>
<td>SoloHI</td>
<td>Solar Orbiter heliospheric imager</td>
<td>Russ Howard</td>
<td>US, Observing light scattered by the solar wind over a wide field of view</td>
</tr>
<tr>
<td>SPICE</td>
<td>Spectral imaging of the coronal environment</td>
<td>Facility instrument, ESA provided</td>
<td>Spectroscopy on the solar disc and corona</td>
</tr>
</tbody>
</table>
Remote-sensing Instruments
In-situ Instruments
In-situ Boom-mounted Instruments
Spacecraft Temperatures
Gravity Assist Manoeuvres for a complex orbit
Observation Modes

Nominal Observation Mode:
Perihelion ± 5 Days

Nominal Observation Mode:
Max. Southern Latitude ± 5 Days

Nominal Observation Mode:
Max. Northern Latitude ± 5 Days

Low Data Rate Observation Mode:
Rest of Orbit
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
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
ESA's Solar Orbiter mission

Courtesy Equinox Graphics
The orbit

Launch

Closest Perihelion at 0.284 AU
The orbit