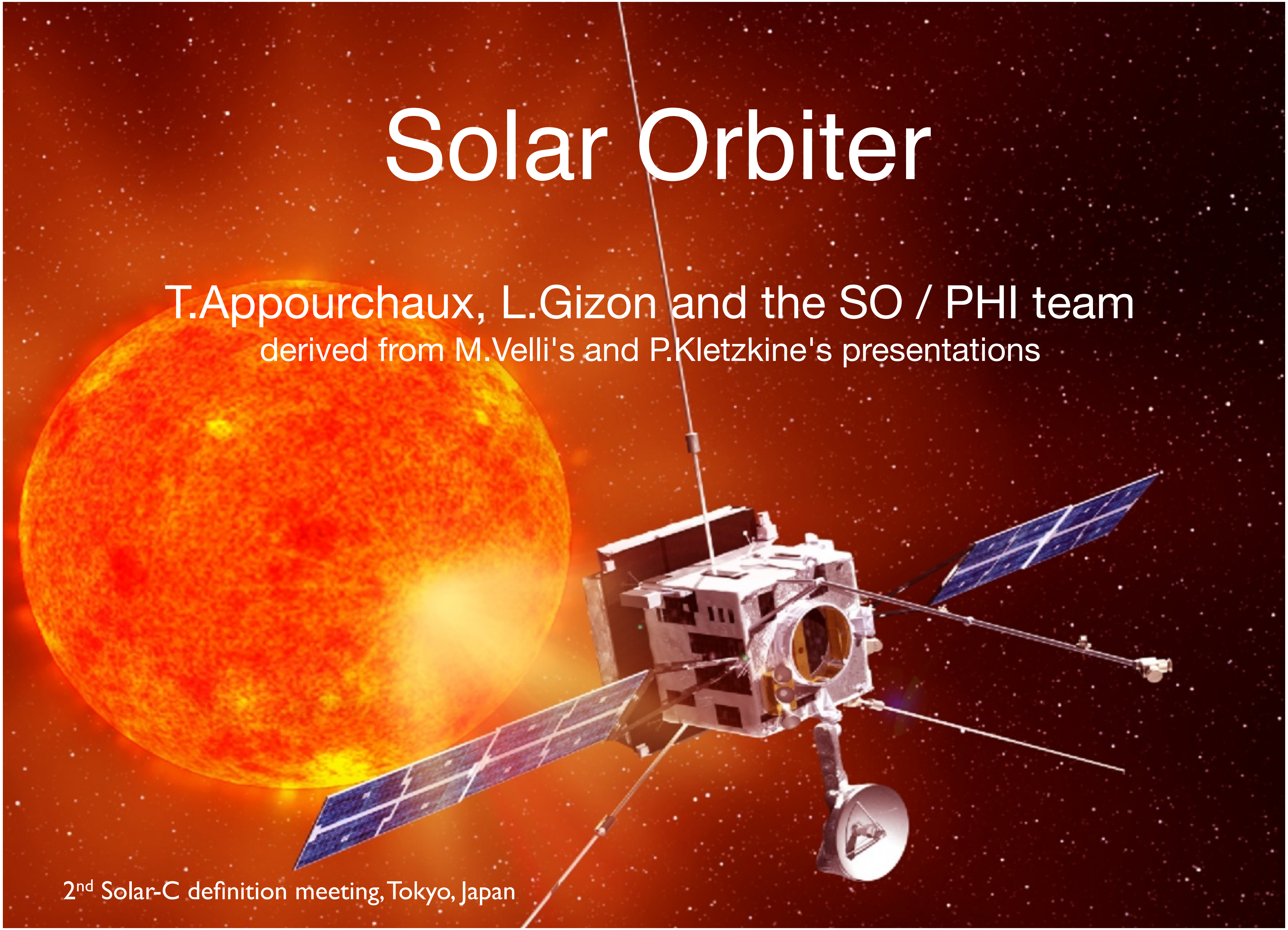
Solar Orbiter

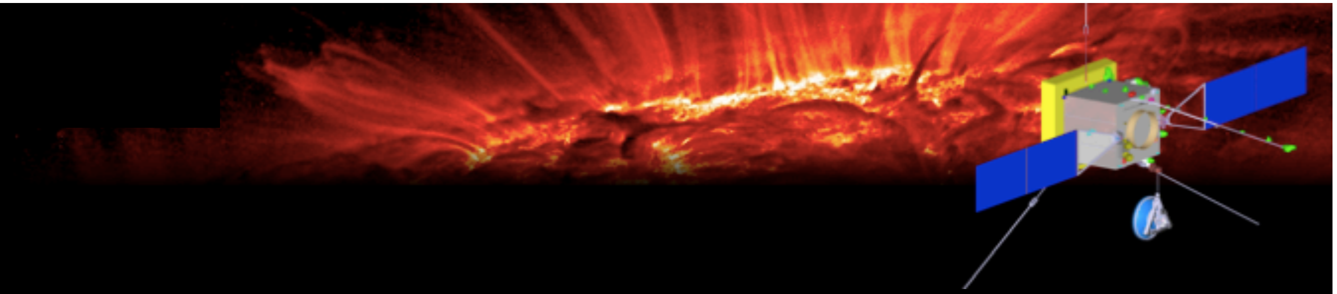
T.Appourchaux, L.Gizon and the SO / PHI team

derived from M.Velli's and P.Kletzkine's presentations



2nd Solar-C definition meeting, Tokyo, Japan

Content



- Science Objectives of Solar Orbiter
- Solar Orbiter mission and status
- Helioseismology, magnetic fields and PHI
- Solar Orbiter complementarity with other missions
- Conclusion

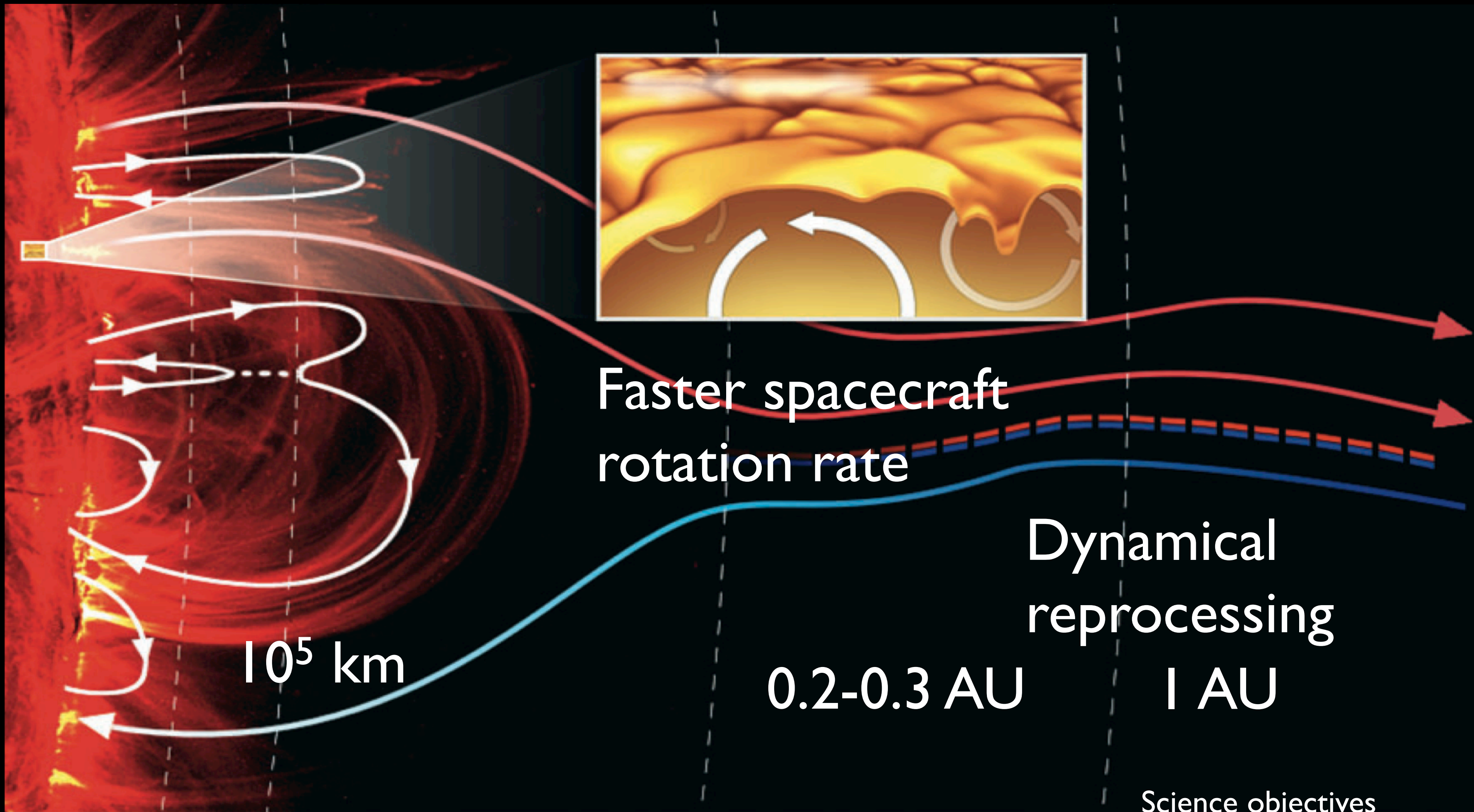
Why study the Sun-Heliosphere connection?

To answer ***How does the solar system work?*** ESA's Cosmic Vision Q2.

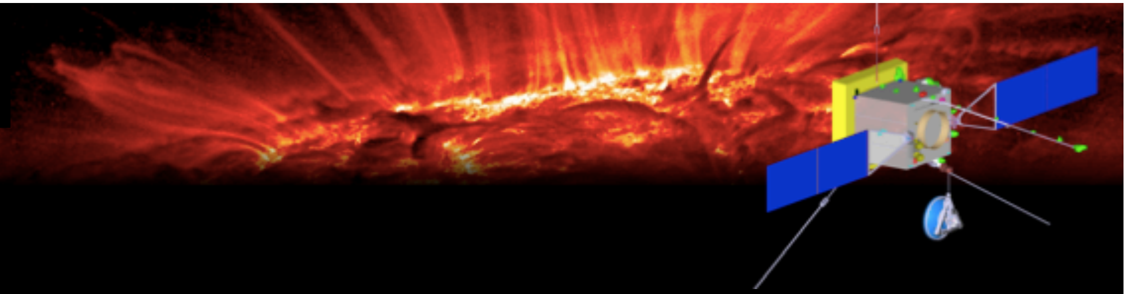
Sun's magnetized atmosphere and wind ***define planetary space environments*** (CV Q1)

It is the site of universal phenomena which can be studied and understood in detail (CV Q3):
magnetic reconnection, collisionless shocks, turbulence and collective nonlinear effects and energetic particle acceleration

Solar Orbiter in short



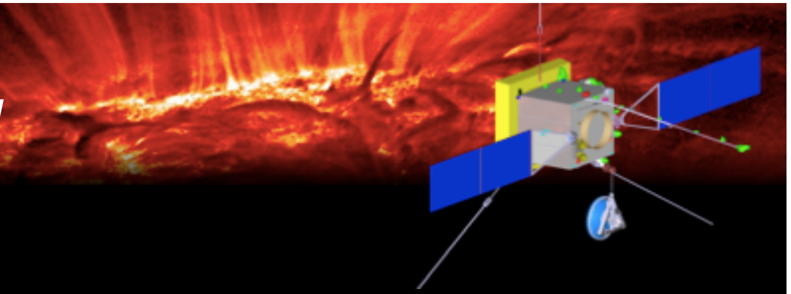
Solar Orbiter Mission



- Solar Orbiter is the logical and timely next step after Ulysses and SOHO, combining remote sensing and in-situ experiments.

- Solar Orbiter carries a dedicated payload of **10 selected remote-sensing and in-situ instruments** measuring from the photosphere into the solar wind.

How does the Sun create and control the Heliosphere ?



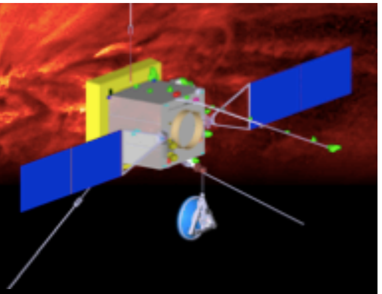
Q1) How and where do the solar wind plasma and magnetic field originate in the corona?

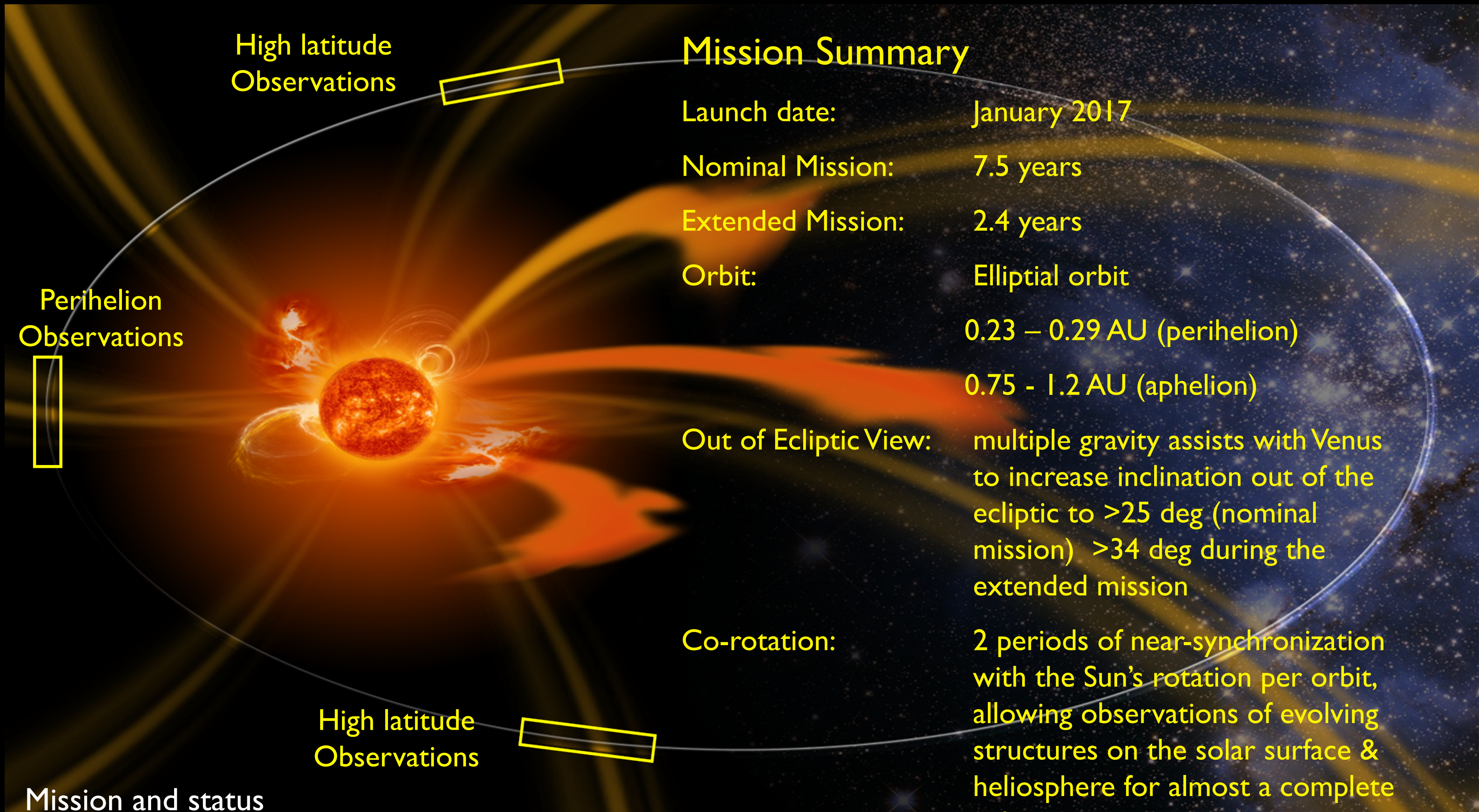
Q2) How do solar transients drive heliospheric variability?

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?

Solar Orbiter Mission Overview

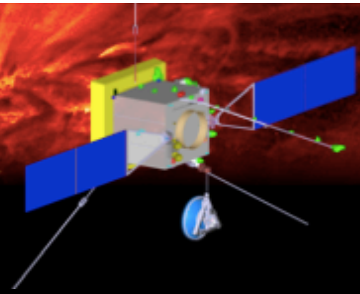




Mission Summary

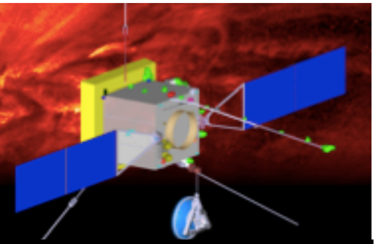
Launch date:	January 2017
Nominal Mission:	7.5 years
Extended Mission:	2.4 years
Orbit:	Elliptial orbit
	0.23 – 0.29 AU (perihelion)
	0.75 - 1.2 AU (aphelion)
Out of Ecliptic View:	multiple gravity assists with Venus to increase inclination out of the ecliptic to >25 deg (nominal mission) >34 deg during the extended mission
Co-rotation:	2 periods of near-synchronization with the Sun's rotation per orbit, allowing observations of evolving structures on the solar surface & heliosphere for almost a complete solar rotation

Solar Orbiter Mission status



- Payload selected back in 2008
- Preliminary Payload review held in end 2009-beg. 2010
- Solar Orbiter down selected in February 2010, together with EUCLID and Plato (SPICA having a special status) for Phase A/B1
- Two missions to be selected in mid-2011
- Start of Phase B1: early 2011
- Likely start of Phase B2/C/D: mid-2011

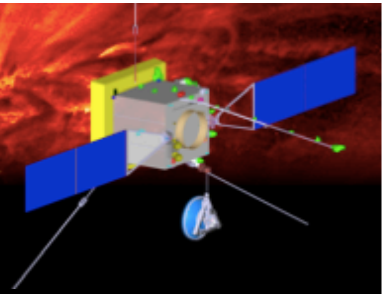
Solar Orbiter Payload



Investigation	*Collaboration*	*Measurement*
Solar Wind Analyzer (SWA) PI C. Owen, UK	UK, I, F, Japan, D, CH, USA	SW ion & electron bulk properties, ion composition (1eV- 5 keV electrons; 0.2 - 100 keV/q ions)
Energetic Particle Detector (EPD) J. Rodríguez-Pacheco, Spain	Spain, D, FI, GR, CH, F, Slovakia, USA	Composition, timing, distribution functions of suprathermal - energetic particles
Magnetometer (MAG) T. Horbury, UK	UK, A, I, H, D, F, E, DK, USA	DC vector magnetic fields (0 – 64 Hz)
Radio & Plasma Waves (RPW) M. Maksimovic, France	France, SE, CZ, NO, UK, A, D, GR, AU, I, H, FI, Russia	AC electric and magnetic fields (~DC – 20 MHz)
Polarimetric and Helioseismic Imager (PHI) S. Solanki, Germany	Germany, E, F, SE, NO, CH, AU, USA	Vector magnetic field and line-of-sight velocity in the photosphere
EUV Imager (EUI) P. Rochus, Belgium	Belgium, UK, F, D, USA	Full-disk EUV and high-resolution EUV and Lyman-α imaging of the solar atmosphere
Spectral Imaging of the Coronal Environment (SPICE) D. Hassler, USA	USA, UK, D, F, N	EUV spectroscopy of the solar disk and corona
X-ray Spectrometer Telescope (STIX) A. Benz, Switzerland	Switzerland, PL, D, CZ, IRE, A, UK, F, USA	Solar thermal and non-thermal x-ray emission (4 – 150 keV)
Coronagraph (METIS/COR) E. Antonucci, Italy	Italy, CK,F, D, GR, USA	Visible, UV and EUV imaging of the solar corona
Heliospheric Imager (SolOHI) R. Howard, USA	USA, Belgium, UK, Germany	White-light imaging of the extended corona

Mission and status

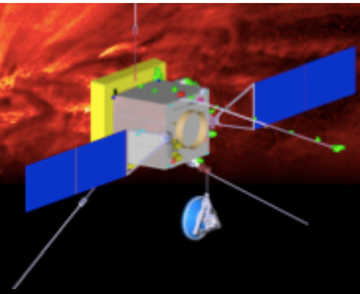
Q4) How does the solar dynamo work and drive the connections between the Sun and the heliosphere?



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

4.2) What are the properties of the magnetic field at high solar latitudes?

4.3) How does the solar dynamo work?



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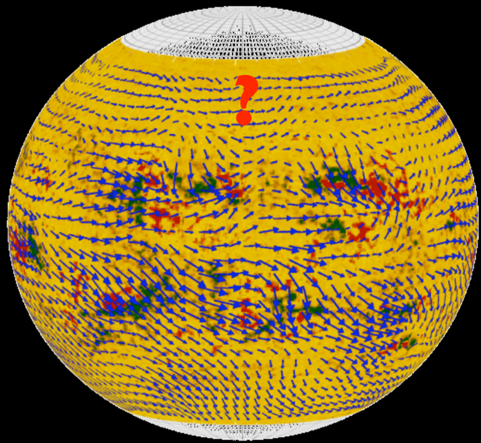
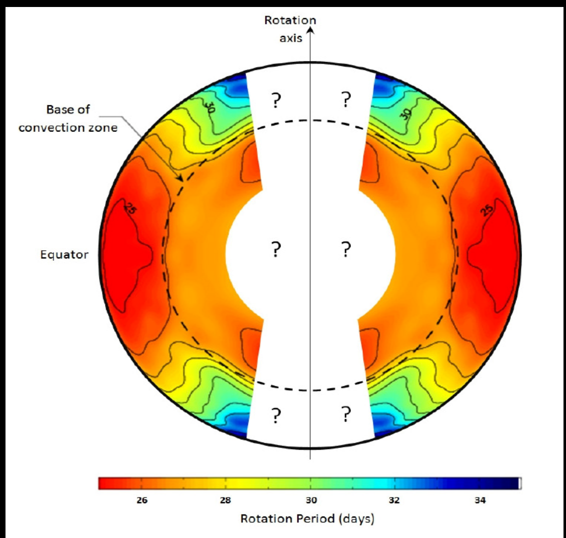
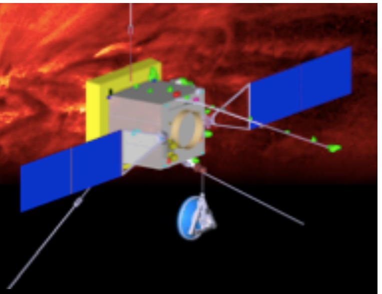
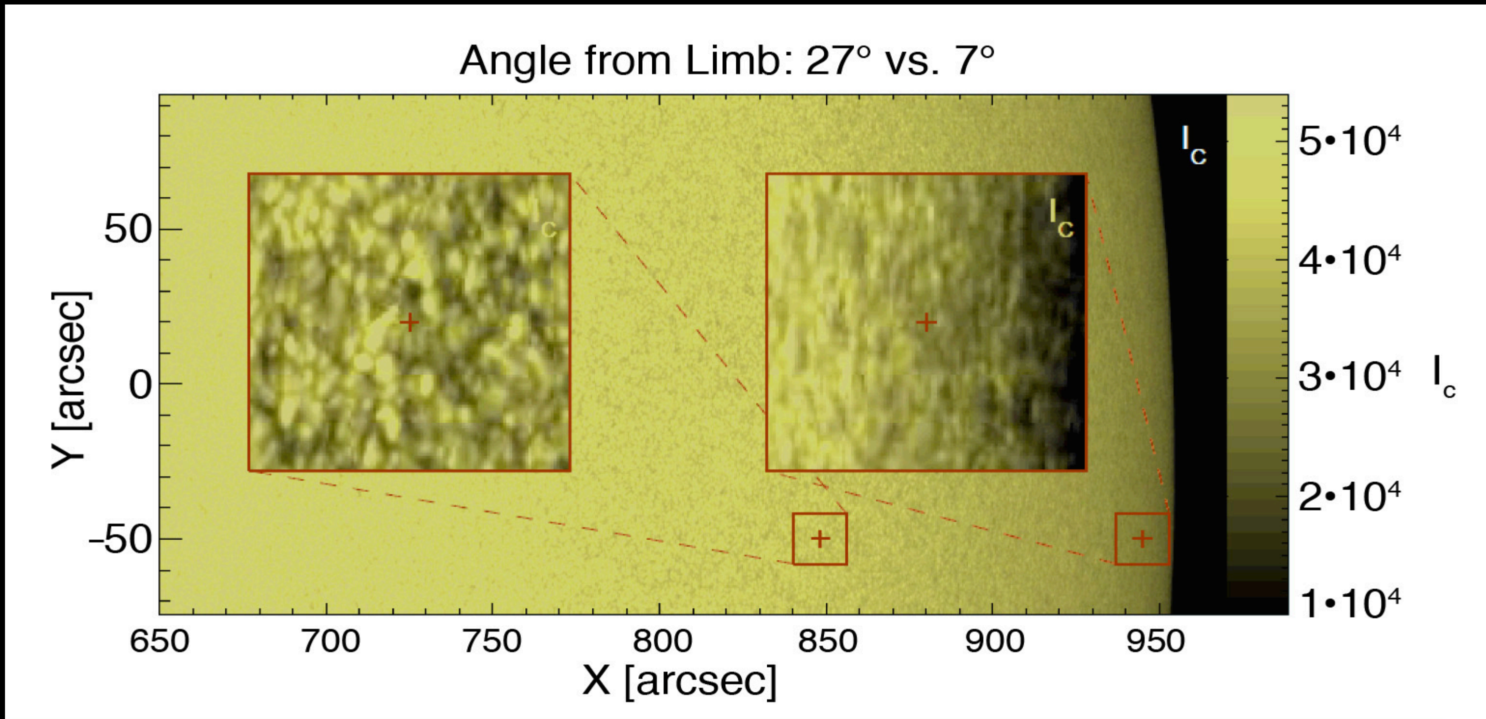




- Detect flows at and below the solar surface, in particular at high latitudes
- Most important flows are:
  - Differential rotation
  - Meridional circulation

4.2) *What are the properties of magnetic fields at high solar latitudes?*

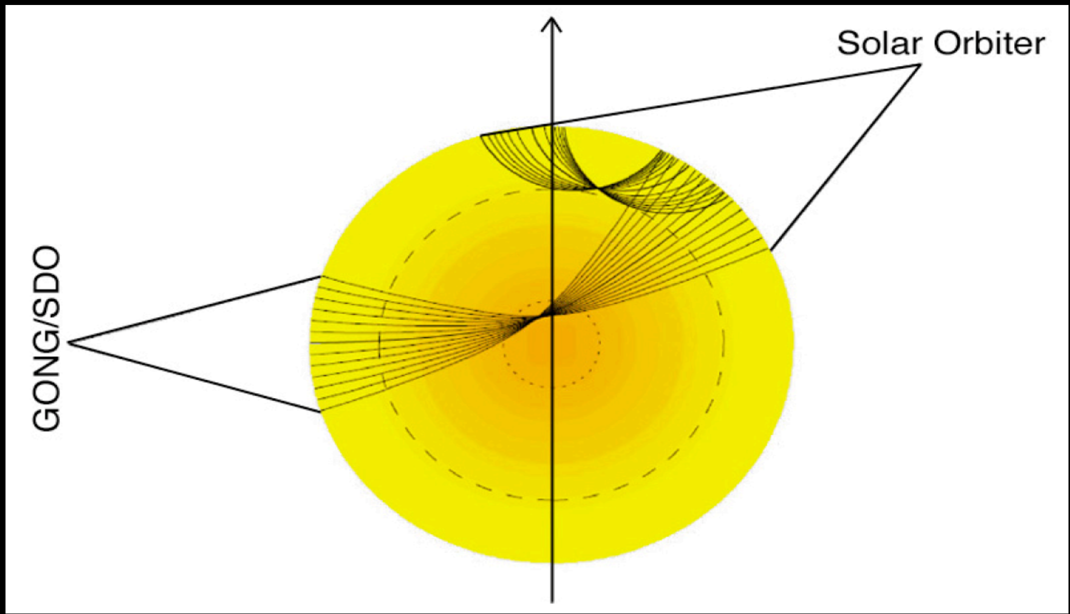




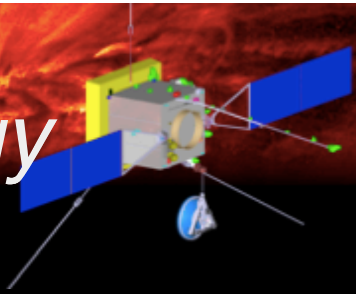
At 27° magnetic measurement is far improved. Granulation tracking can now follow large-scale flows.

4.3) How does the solar dynamo work?

- SO can probe the tachocline at low / medium latitudes
- Solar-cycle variations at high latitudes
- Joint observations with SDO, GONG (long time series) : probe deep interior; very high potential with Plan-A !

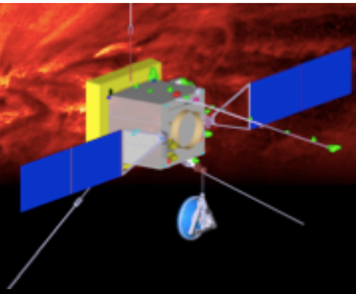


SO/PHI: Polarimetry and helioseismology



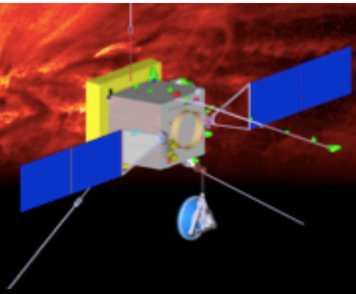
- *Provide B to EUV imagers and spectrometer (linkage science)*
- *First proper view of magnetic and velocity field at the poles*
- *Stereoscopic helioseismology to probe the deep interior*
- *Stereoscopy of the photosphere*
- *Provide magnetic context for Solar Probe plus*
- *S/C ressources: 30 kg, 31 W, 20 kbps*

SO/PHI instrument concept

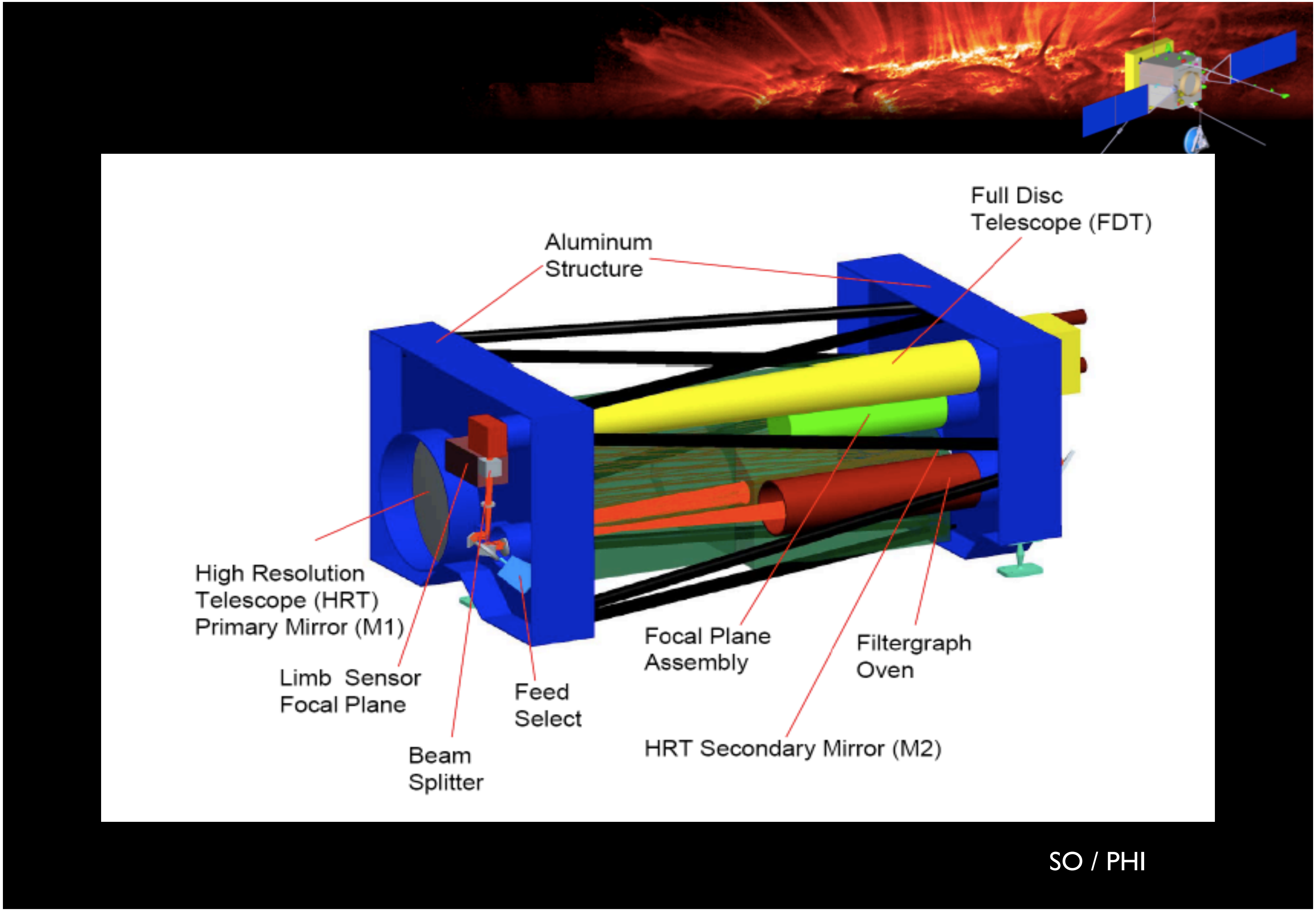


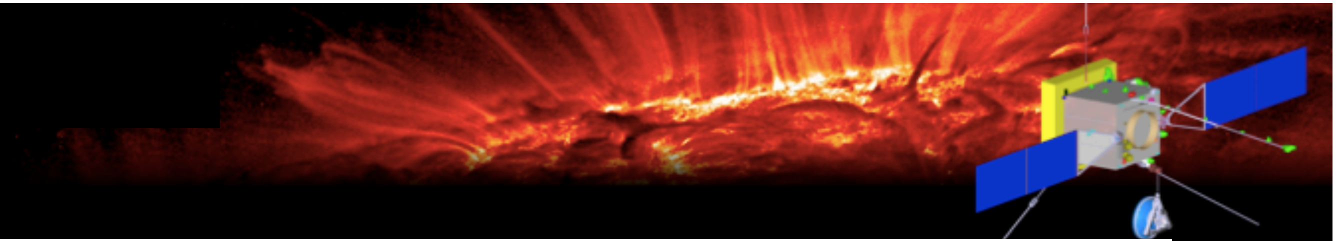
- Solar radial velocity and vector magnetic field (absorption line)
- High Resolution Telescope (HRT):
  - ✓ FOV: 16.8 arcmin, 1" arcsec resolution (0.5" pixel, 95 kms at 0.28 AU)
- Full Disk Telescope (FDT):
  - ✓ FOV: 2.6 deg, 9.3" arcsec resolution (4.6" pixel, 930 kms at 0.28 AU)
- FDT and HRT used in sequence on different part of the orbit

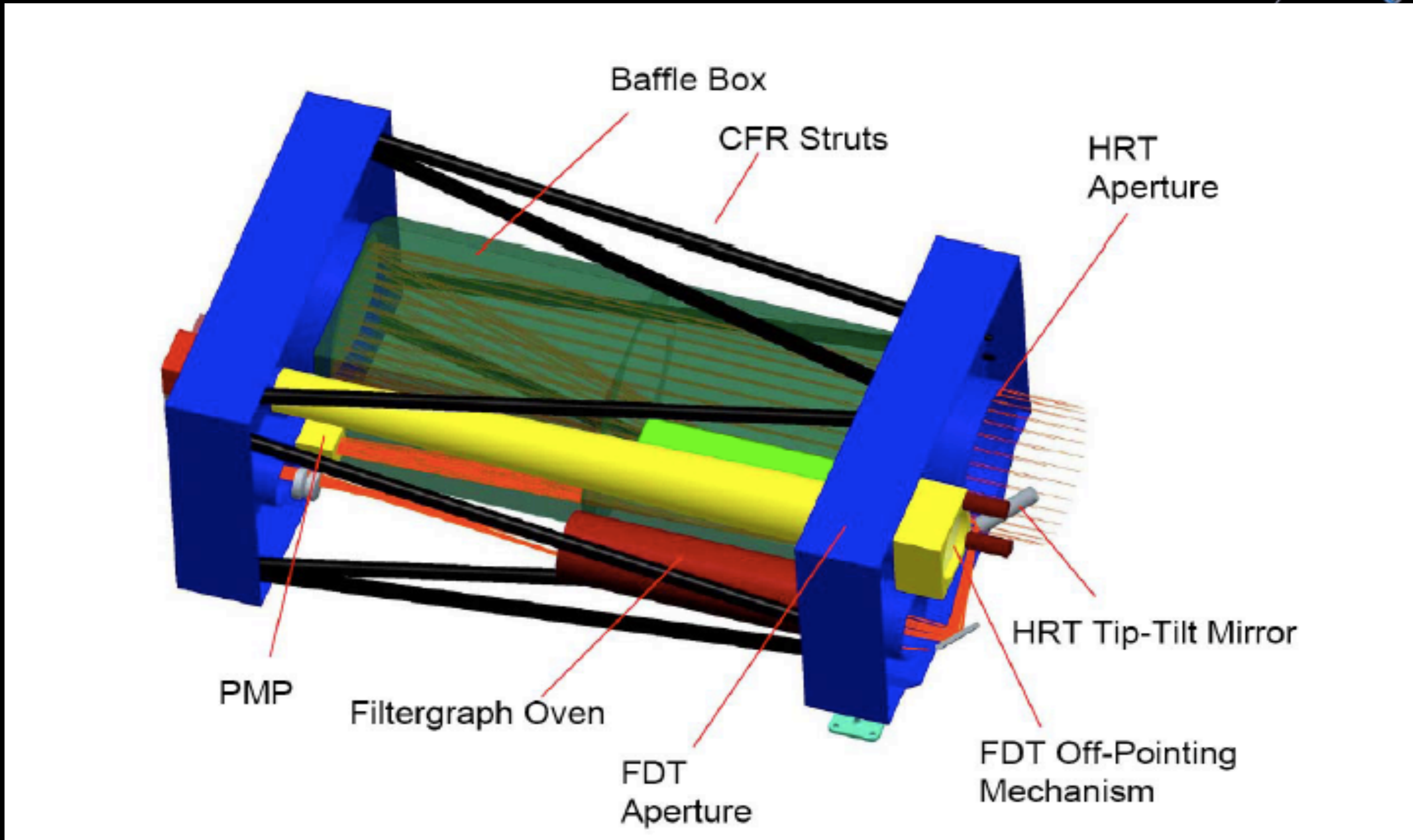
SO/PHI sub-systems



- *Entrance window (14-cm diameter)*
- *HRT / FDT*
- *Off-pointing mechanisms*
- *Image Stabilization System (to 0.02 arcsec rms)*
- *Polarization Modulation Package*
- *Feed select (HRT or FDT)*
- *Filtergraph (Fabry-Perot)*
- *Focal Plane Assembly*
- *E-box*

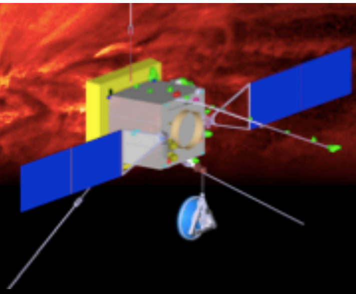

Full Disc
Telescope (FDT)
Aluminum
Structure
High Resolution
Telescope (HRT)
Primary Mirror (M1)
Limb Sensor
Focal Plane
Beam
Splitter
Feed
Select
Focal Plane
Assembly
Filtergraph
Oven
HRT Secondary Mirror (M2)





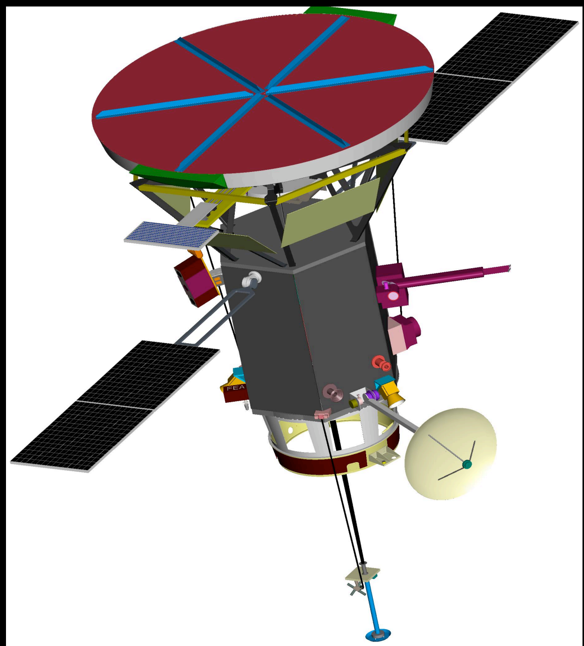
Baffle Box
CFR Struts
HRT
Aperture
HRT Tip-Tilt Mirror
PMP
Filtergraph Oven
FDT
Aperture
FDT Off-Pointing
Mechanism

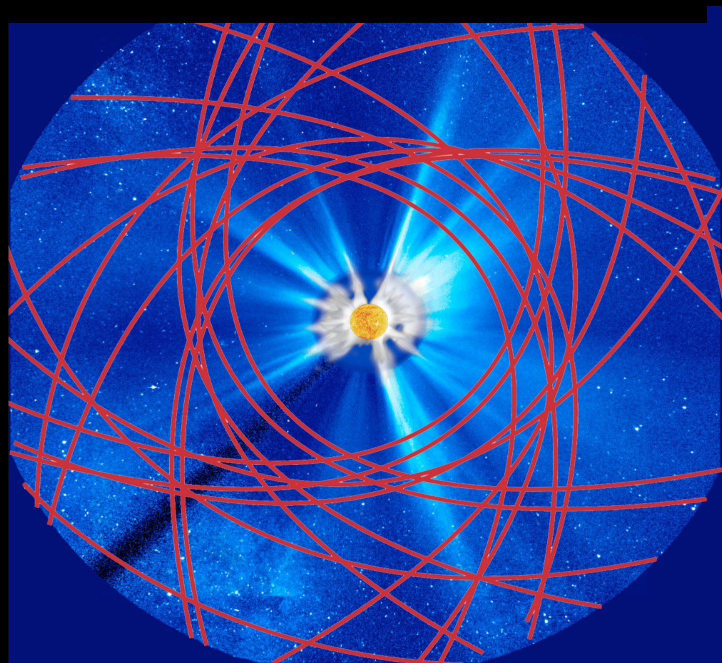
Potential Synergy with Other Missions: Solar Probe Plus



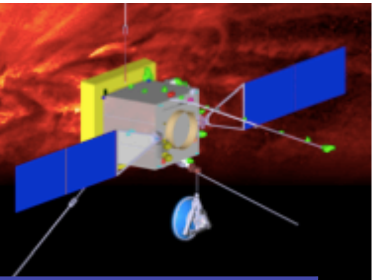
Joint NASA-ESA Solar Orbiter -
Solar Probe Assessment ‘09

Enhanced science from mutual context / alignments





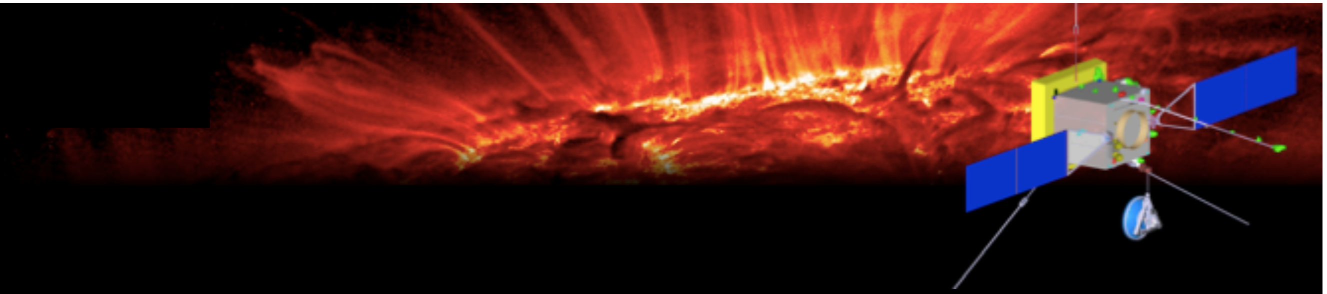
Solar Orbiter complementarity



Mission	Instruments	Velocity	Magnetic field	Resolution (kms)	Inclination (deg)	Minimum distance (AU)	Duration above 30 deg per orbit (days)
SOHO	SOI	Yes	Longitudinal	3000	7	0.92	0
	GOLF	Yes	Longitudinal	None	7	0.92	0
Hinode	BFI	Yes	Vector	140	7	0.97	0
	NFI	Yes	Vector	210	7	0.97	0
SDO	HMI	Yes	Vector	750	7	0.97	0
SOLO	PHI (HRT)	Yes	Vector	190	35	0.28	~15 (perihelie)
	PHI (FDT)	Yes	Vector	1800	35	0.28	~40
	MAG	N/A	Yes	N/A	35	0.28	~40
Plan-A	DSI	Yes	Vector	750	> 40	1	150
Solar probe +	In-situ	N/A	Yes	N/A	3.4	0.04	0

- *High resolution velocity and magnetic field of the poles with SO / PHI*
- *Solar Orbiter has both in-situ and remote sensing instruments*
- *Ideal for linking with any in-situ only mission or remote-sensing only mission*

Conclusion



Solar Orbiter answers the Cosmic Vision question "How does the solar system work?" :

- *Exemplified by the theme of Sun-Heliosphere Connection: Solar Orbiter will reveal how the Sun creates and drives the heliosphere.*
- *The selected payload is optimized to answer the most fundamental science questions of solar and heliospheric physics*
- *Solar Orbiter will be launched in 2017, in synergy with Solar Probe Plus, and hopefully Plan-A*
- *Plan-A ideal for 3-D stereoscopic helioseismology !*