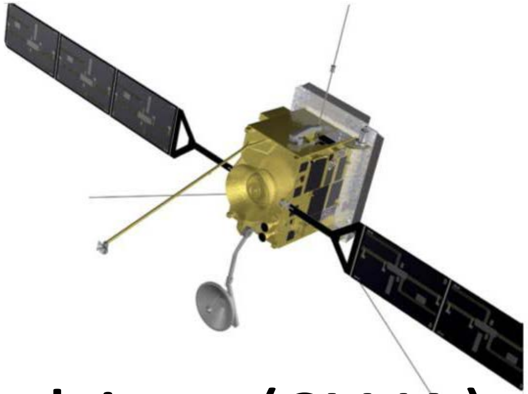

Solar Orbiter (SWA) parte eliosferica

[1]Roberto Bruno

on behalf of

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2) UniAq, L'Aquila , Italy
3) UniCal, Cosenza , Italy
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5) INAF-OATo, Torino , Italy
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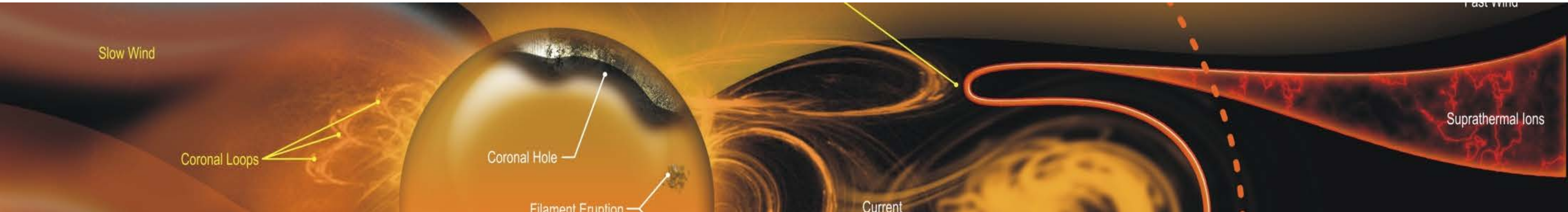
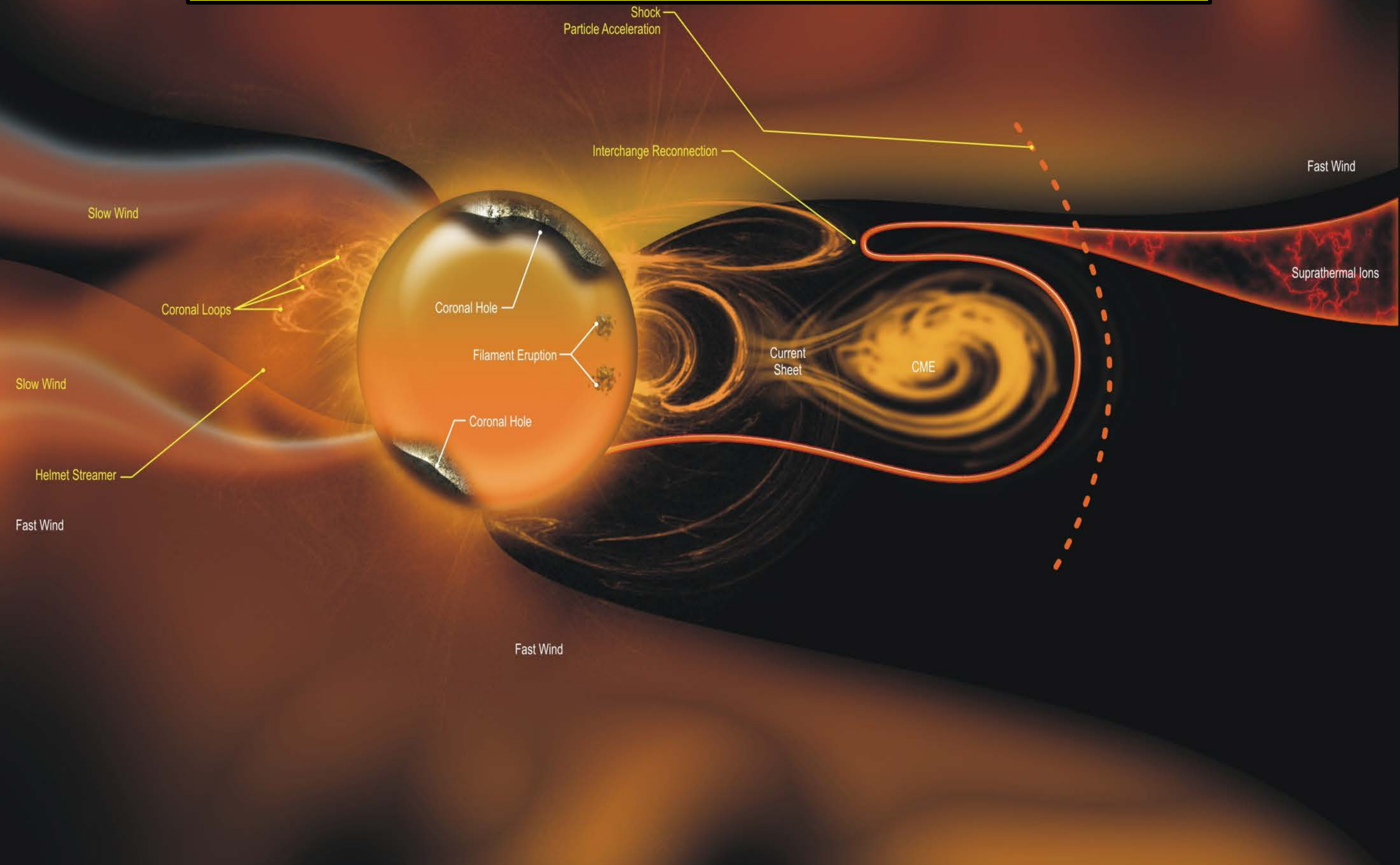
*) in quiescenza

Sole e Sistema Solare
Giornata in memoria di Angioletta Coradini
Roma 30 Ottobre 2012



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



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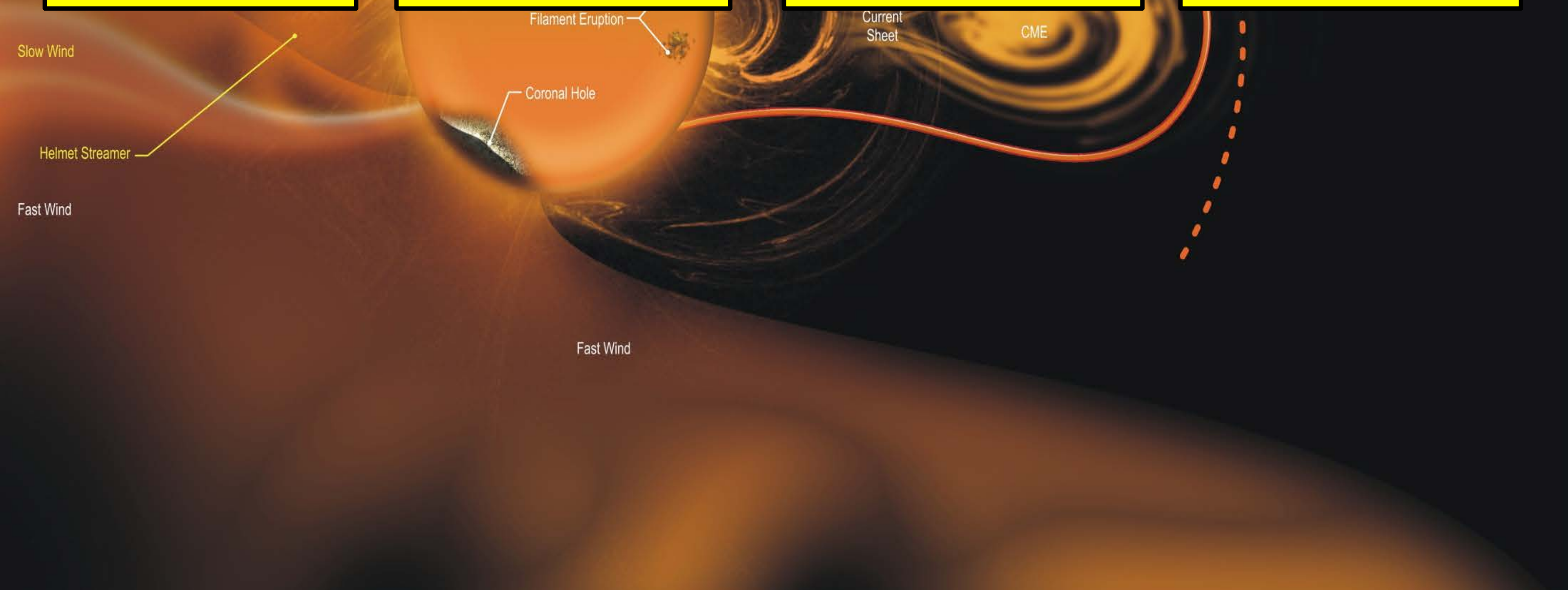
Solar orbiter objectives from the ASR

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

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?



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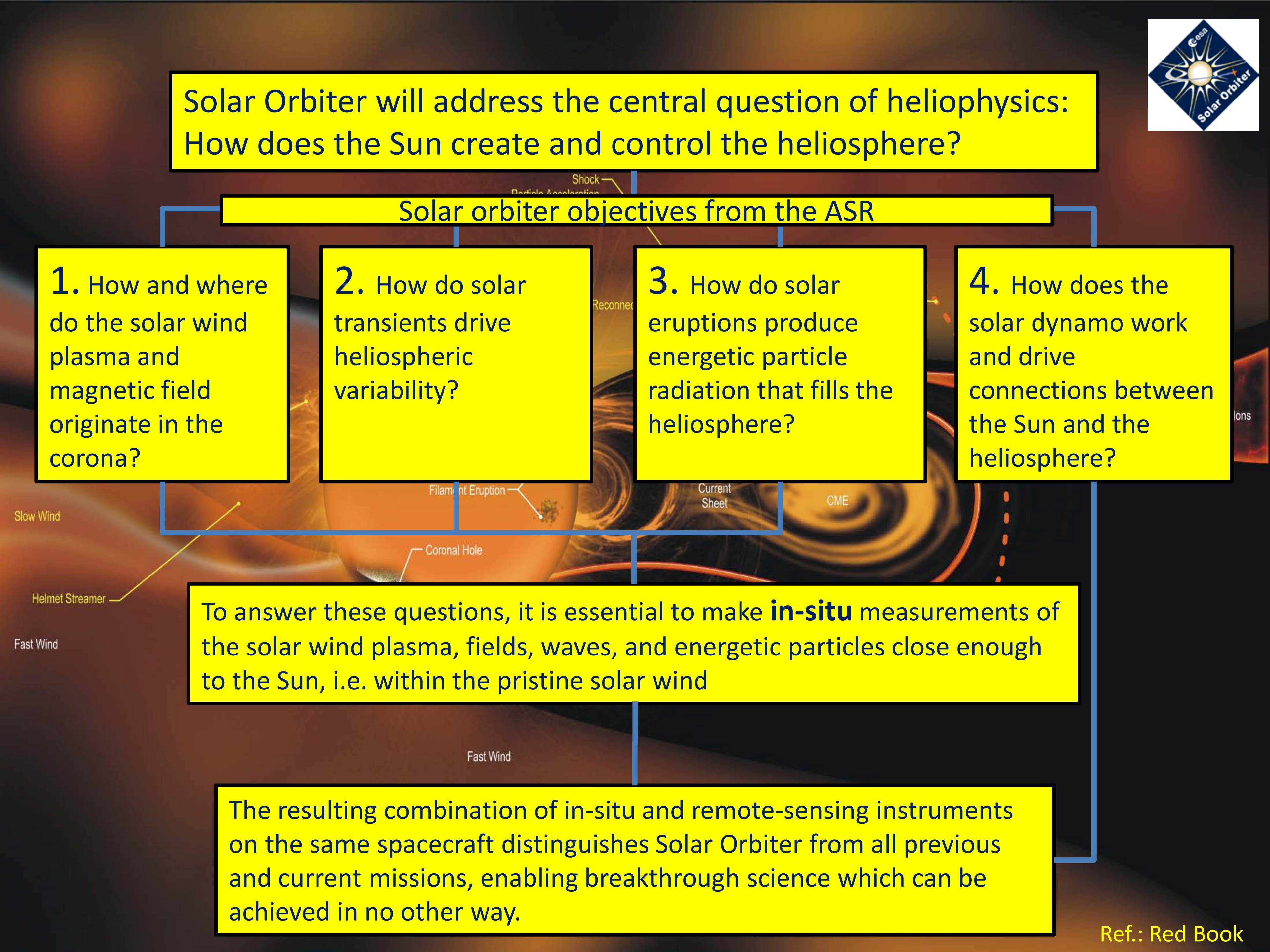
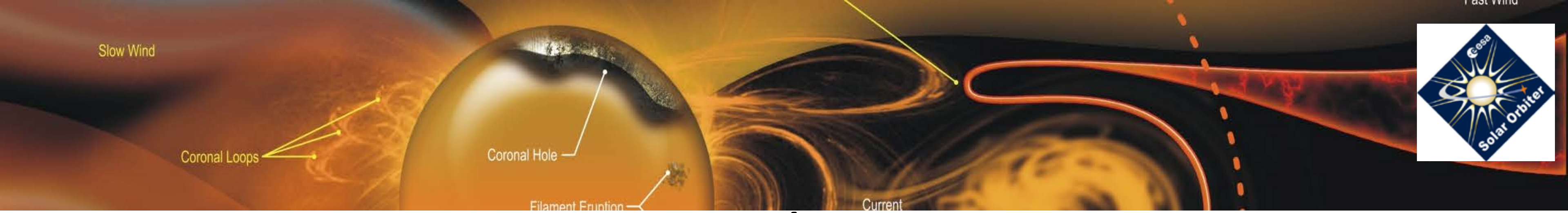
To answer these questions, it is essential to make **in-situ** measurements of the solar wind plasma, fields, waves, and energetic particles close enough to the Sun, i.e. within the pristine solar wind

The resulting combination of in-situ and remote-sensing instruments on the same spacecraft distinguishes Solar Orbiter from all previous and current missions, enabling breakthrough science which can be achieved in no other way.



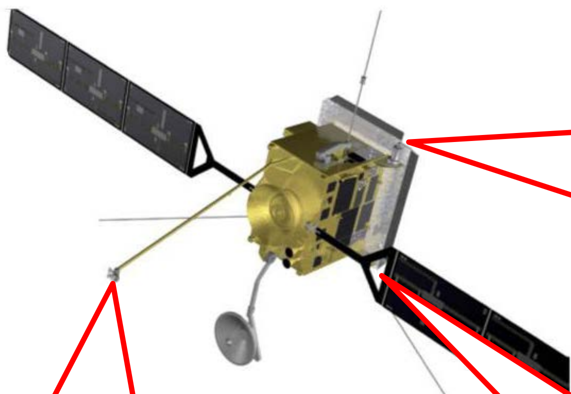
Ref.: Red Book



Instruments and measurements

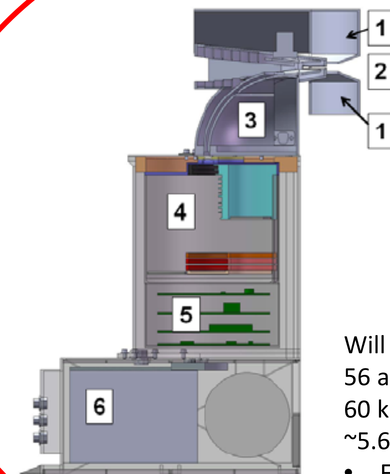
Investigation	Measurements
Solar Wind Analyzer (SWA)	Solar wind ion and electron bulk properties, ion composition (1eV- 5 keV electrons; 0.2 - 100 keV/q ions)
Energetic Particle Detector (EPD)	Composition, timing, and distribution functions of suprathermal and energetic particles (8 keV/n – 200 MeV/n ions; 20-700 keV electrons)
Magnetometer (MAG)	DC vector magnetic fields (0 – 64 Hz)
Radio & Plasma Waves (RPW)	AC electric and magnetic fields (~DC – 20 MHz)
Polarimetric and Helioseismic Imager (PHI)	Vector magnetic field and line-of-sight velocity in the photosphere
EUV Imager (EUI)	Full-disk EUV and high-resolution EUV and Lyman-α imaging of the solar atmosphere
Spectral Imaging of the Coronal Environment (SPICE)	EUV spectroscopy of the solar disk and corona
X-ray Spectrometer Telescope (STIX)	Solar thermal and non-thermal X-ray emission (4 – 150 keV)
Coronagraph (METIS/COR)	Visible, UV and EUV imaging of the solar corona
Heliospheric Imager (SolOHI)	White-light imaging of the extended corona

The SWA Plasma Suite



HIS

SwRI (TX)
CoPI-ship

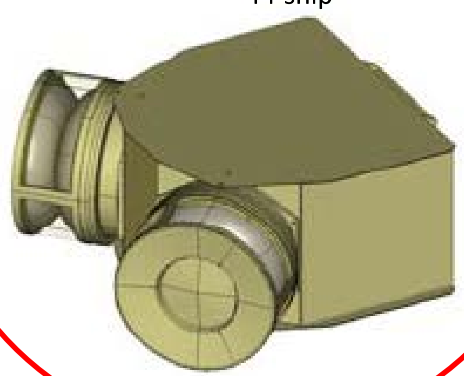


Will measure mass in the range 2-56 amu/q, energy in the range 0.5 – 60 keV/q, pixel FoV 6°x 6°, ΔE/E ~5.6%

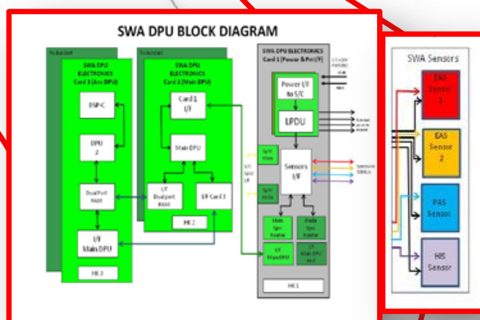
- Full 3-D distribution in 5 min in NM
- 30 s for heavy ions or 3 s for alphas in BM

EAS

UCL-MSSL
PI-ship



energy range from ~1 eV to ~5 keV with ΔE/E ~12%
pixel FoV 11.25º x 3° - 8°
Full 3D VDF each 1 sec
Moments of the electron distribution at 4s
2-D pitch angle distributions at 1/8 s (BM)



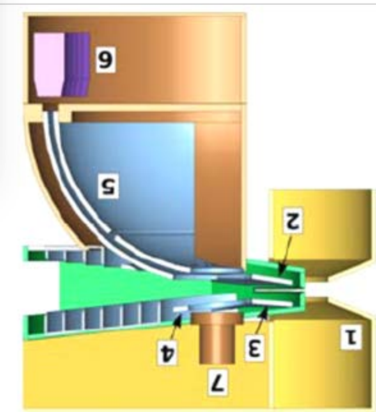
Performs: power distr. from s/c, commanding, data handling and data compression functions for all of the sensors. Produced by AMDL srl

DPU

INAF-IAPS
CoPI-ship

PAS

CNRS-IRAP
CoPI-ship



energy range 0.2 – 20 keV/q, with ΔE/E ~5% and pixel FoV 6°x 5°
Full 3D VDF each 1 sec
Moments of the proton distribution at 4s
Reduced 3-D distributions at 1/54 s (BM)

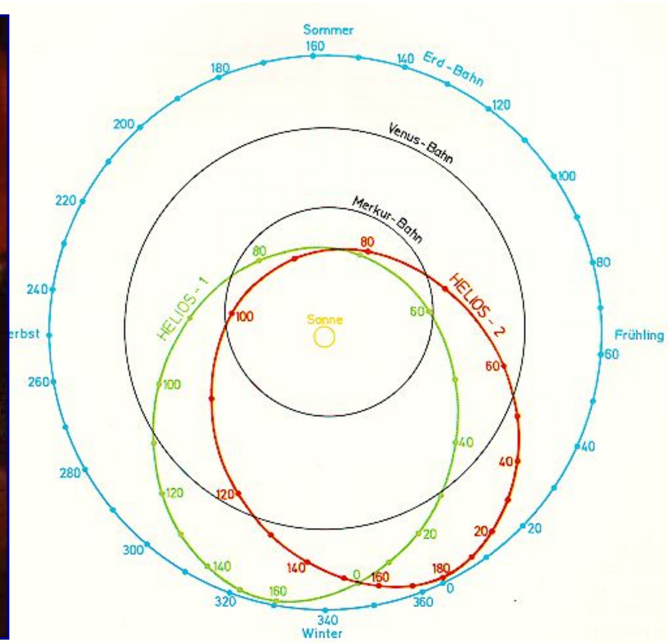
SWA will address fundamental and still unanswered questions in space plasma physics like solar(stellar) wind acceleration and plasma heating

- *PAS*: kinetic and fluid properties of the bulk solar wind plasma and dominant physical processes (e.g.: wave-particle interactions, origin and dissipation of turbulence, etc)

- *HIS*: 3D VDF of minor ions for the first time in the Heliosphere (temperature anisotropy and differential heating mechanism); ion composition as a key to link the Sun with the Heliosphere

- *EAS*: kinetic evolution of solar wind electrons with distance from the Sun; magnetic connectivity of solar wind regions

Most of our knowledge about solar wind plasma and magnetic field in the inner heliosphere is due to Helios 1/2



- Two spacecraft, launched in <u>1974 & 1975</u>
- ecliptic orbit, perihelium @ 0.29AU
- Plasma measurements: protons(+alphas) and electrons
- <u>No composition</u>
- Slow plasma sampling, VDF in 81(40.5) sec
- Low phase space resolution
- <u>NO imaging</u>

SolO-SWA represents an enormous quality leap with respect to plasma measurements performed by Helios

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Solar orbiter objectives from the ASR

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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?

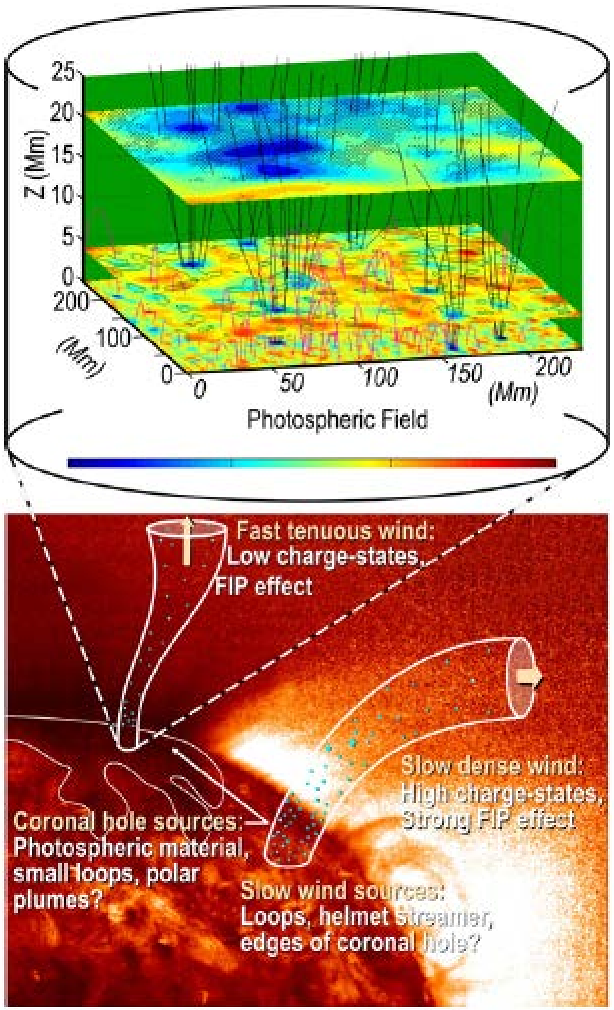
In particular:

1) What are the source regions of the solar wind and the heliospheric magnetic field?

2) What mechanisms heat and accelerate the solar wind?

3) What are the sources of turbulence in the solar wind and how does it evolve?

❑ Origin of fast and slow wind



Fast Wind origin:

❑ Current idea:

directly from the complex magnetic structure at the base of photospheric flux tubes, at the basis of coronal holes, expanding in to the cromosphere and corona.

■ Observations of low FIP enhancement by *SWA* in fast wind and in small coronal loops and spicules is the key to unravel the origin of fast wind.

Slow Wind origin:

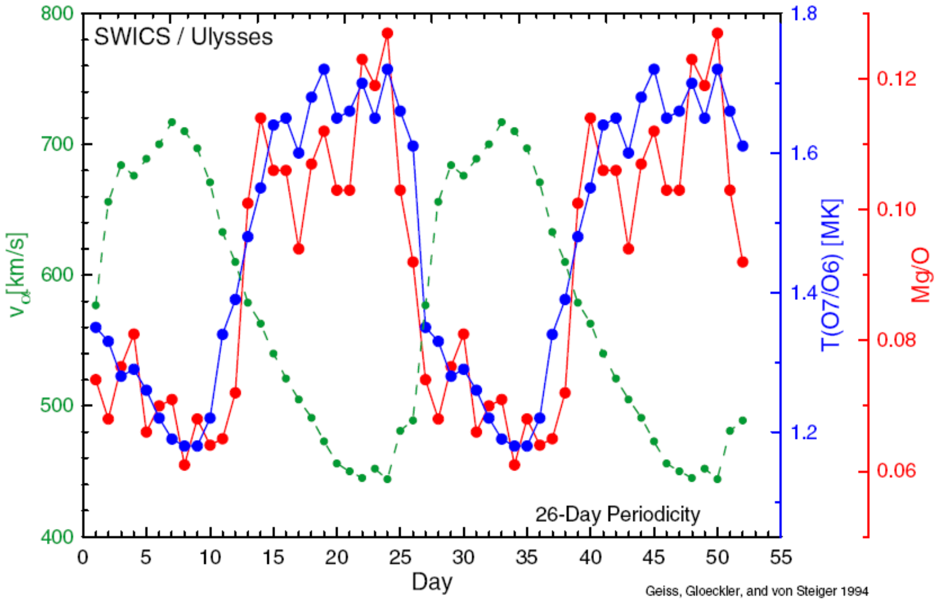
❑ Current idea:

from the edges of overexpanding coronal holes or from coronal loops outside of coronal holes via reconnection events which free loop material.

■ Observations of elemental composition and charge state by *SWA* is the key.

SWA will allow to associate definitively in-situ observations with the morphology of the corona

- elemental and charge state composition will not change during wind expansion
- Possibility to identify small scale boundaries



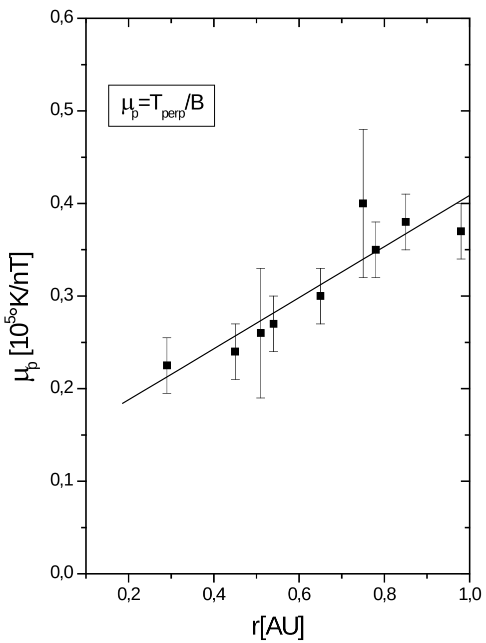
In particular:

- Slow wind has higher oxygen freeze-in temperature
- Slow wind has higher FIP effect (enrichment of Mg/O, Mg has a lower FIP wrt O)

❑ Origin and dissipation of turbulence

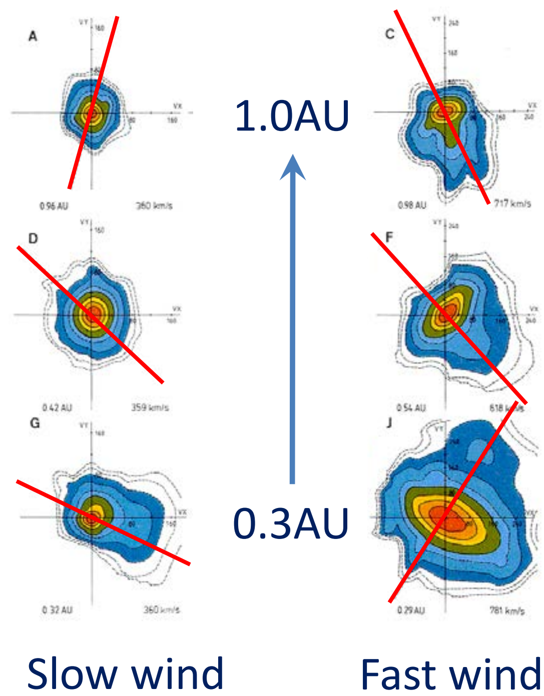
SWA will help to understand fundamental kinetic aspects:

- Fast wind does not expand adiabatically

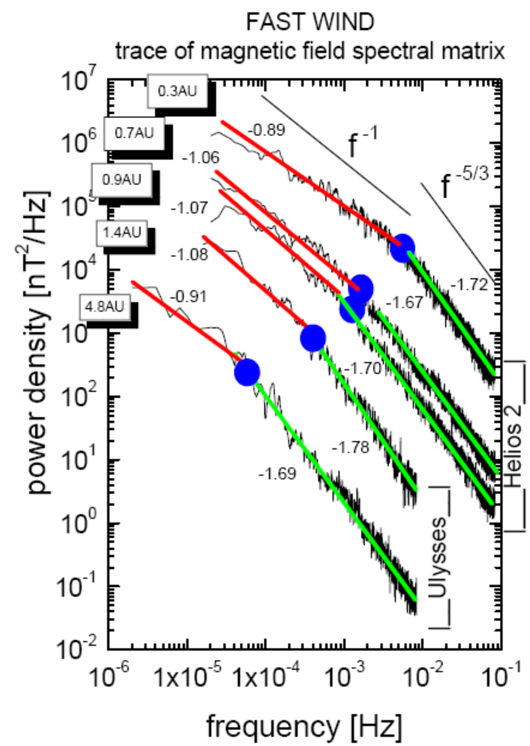


First adiabatic invariant in fast wind

- Differencial heating perpendicular to local B



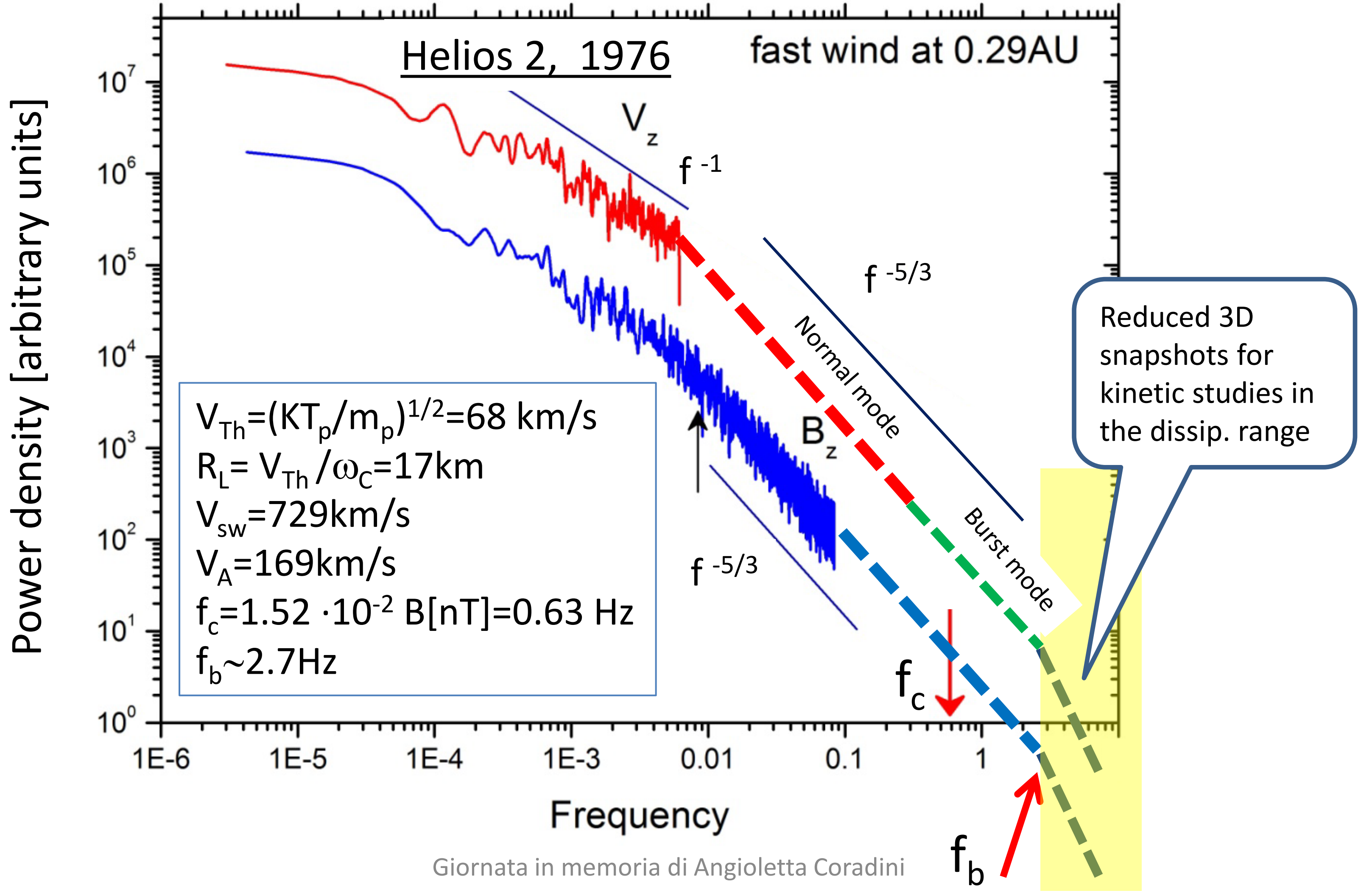
- Non-linear interactions in Alfvénic turbulence



Helios observations

SWA will allow:

- Plasma sampling three orders of magnitude faster than Helios.
- First time exploration of the dissipation range



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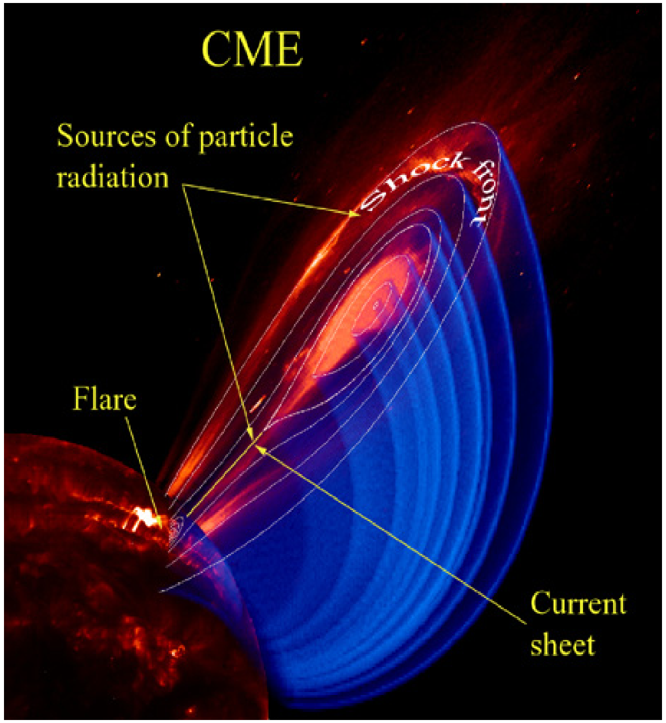
In particular:

1) *How do Coronal Mass Ejections (CMEs) evolve through the corona and inner heliosphere?*

2) *How and where do shocks form in the corona and inner heliosphere?*

Ref.: Red Book

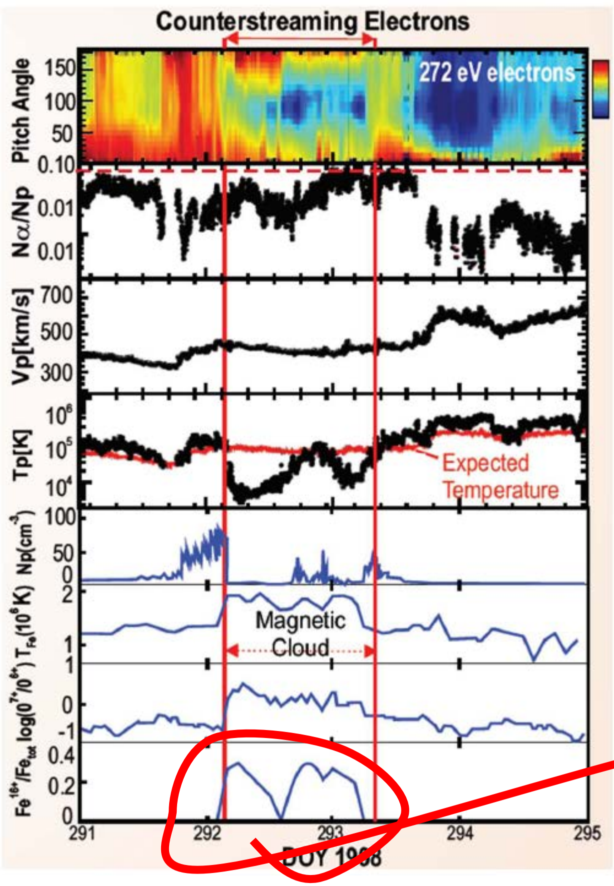
heavy ions composition and counterstreaming electrons from *SWA* will help to identify the source regions of CME's.



SWA measurements of:

- electron pitch angle distribution,
- alpha/proton ratio,
- freeze-in temperature (e.g. O),
- O and Fe charge state ratios

will identify links between coronal sources of CME's and their in-situ counterparts (ICME's) heavy ions composition and counterstreaming electrons from *SWA* will help to identify the source regions of CME's.



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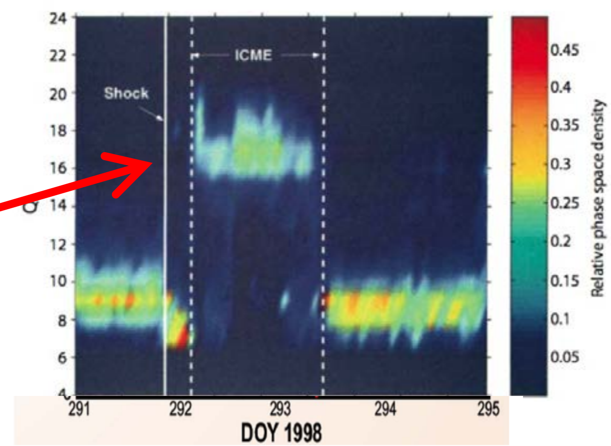
Sharp edges



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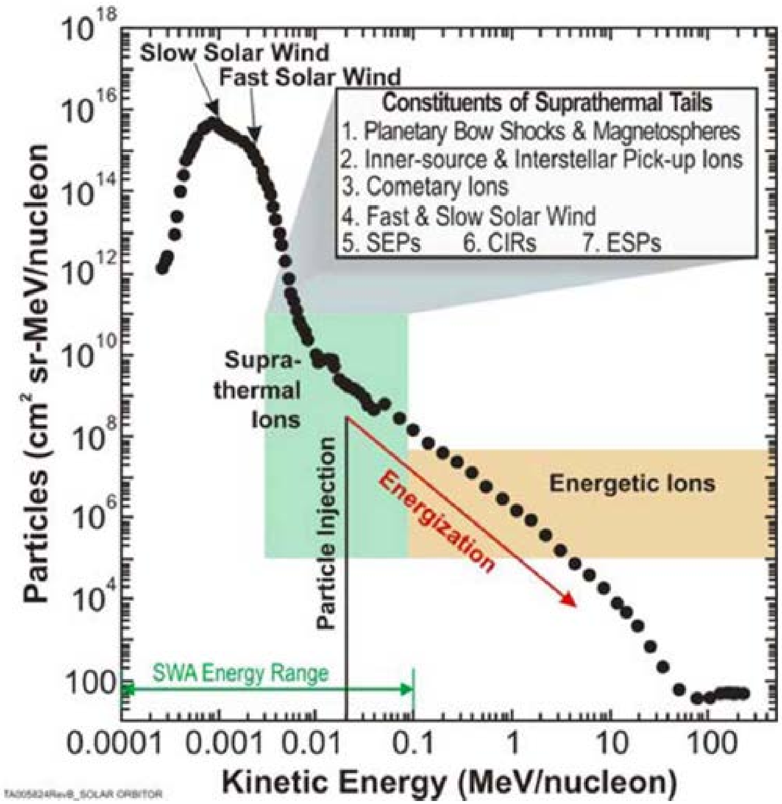
In particular:

1) How and where are energetic particles accelerated at the sun?

2) How are energetic particles released from their sources and distributed in space and time?

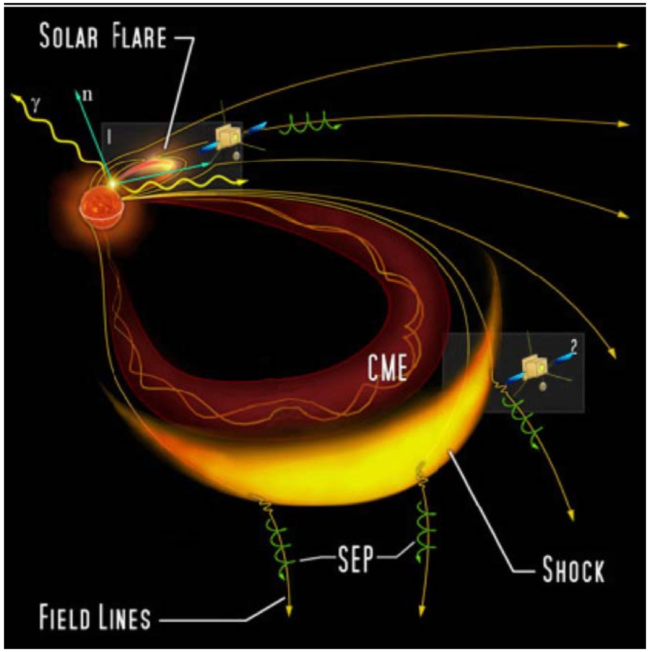
3) What are the seed populations for energetic particles?

SWA: composition and energy of suprathermal ions

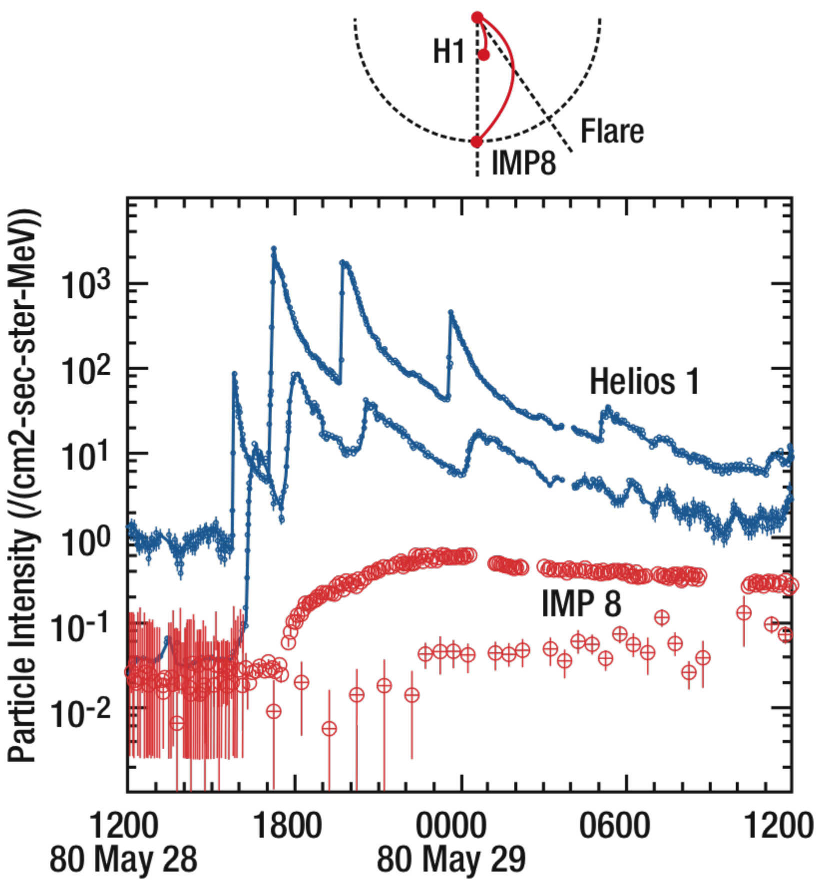


❑ Solar Energetic Particles (SEP) might be accelerated directly out of the solar wind suprathermal tail by a stochastic process (1st order Fermi) associated with the shock wave disturbance.

■ Comparison between SWA suprathermal composition near the shock and that of energetic particles by EPD will shed light on the role of shocks in generating SEP's



Moreover, being closer to the sun is of fundamental importance



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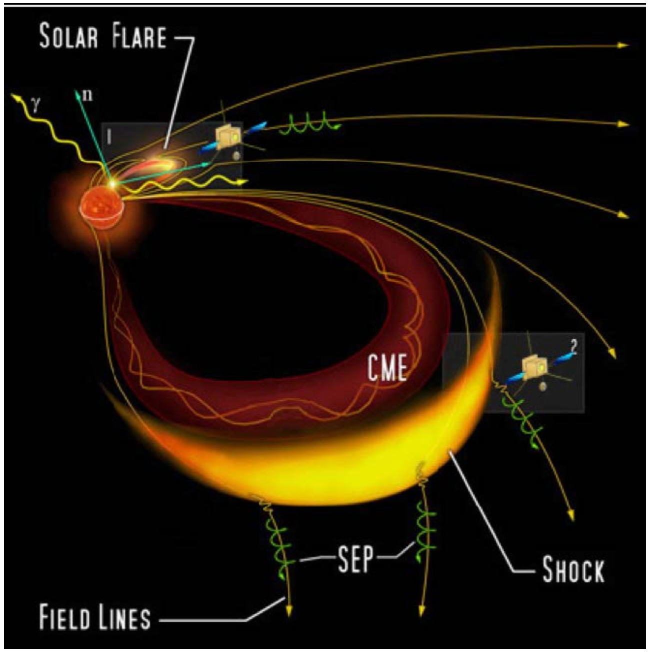
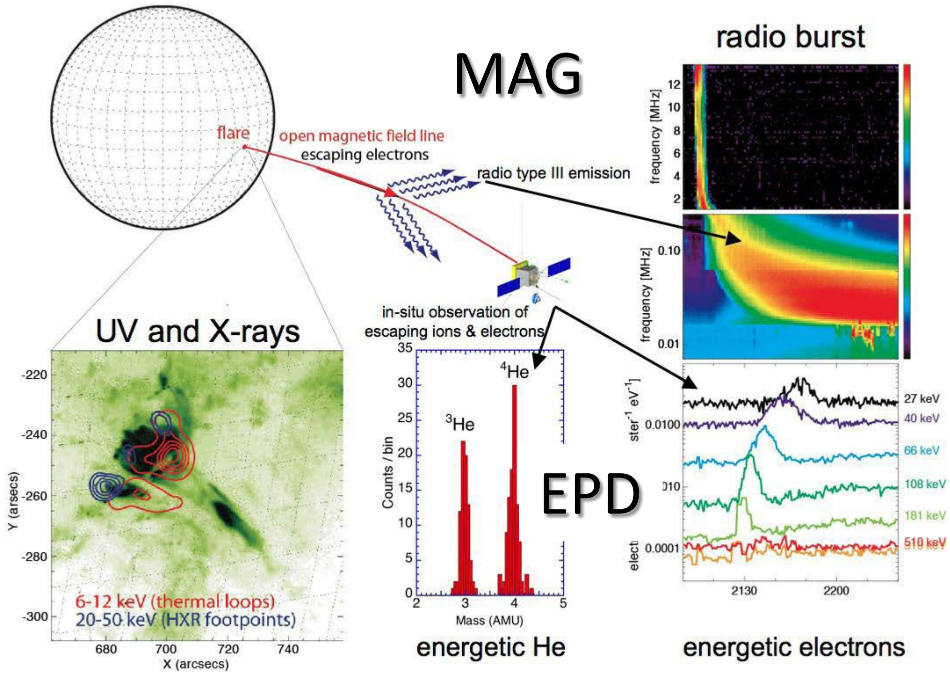


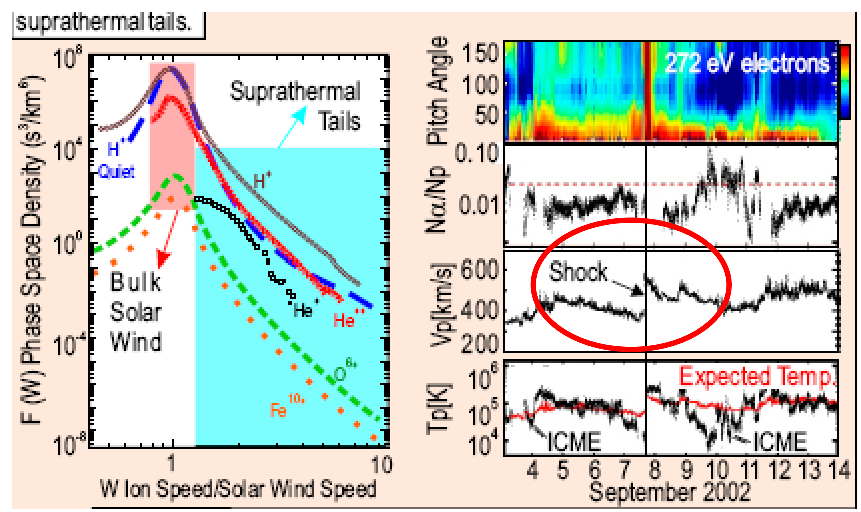
Coordination efforts within the In-Situ Working Group



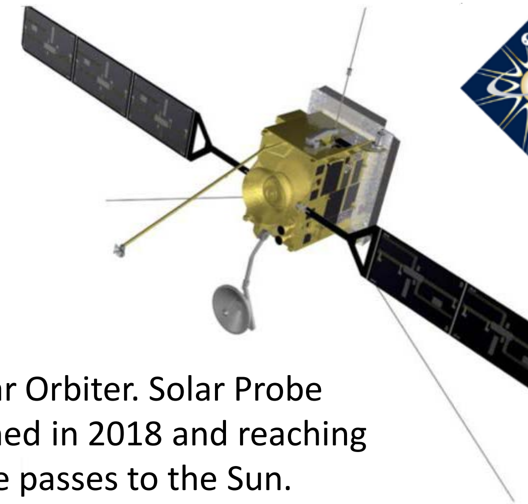
RPW

EUI and STIX

SWA



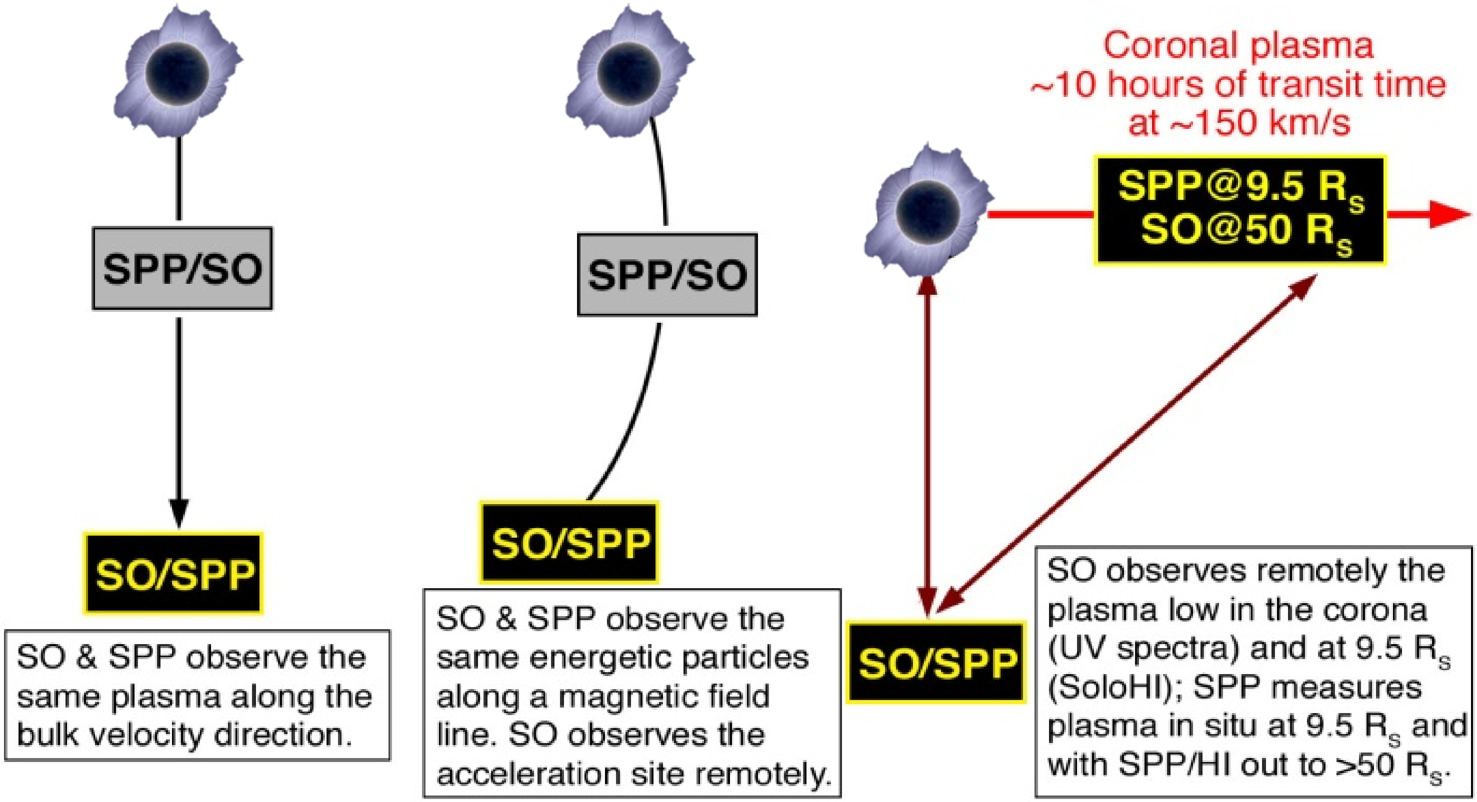
- EUI and STIX observe flare west side
- RPW observe type III radio emissions
- EPD might observe escaping energetic ions & e^-
- RPW would observe local Lagmuir waves
- SWA is then allerted for possible shock wave arrival



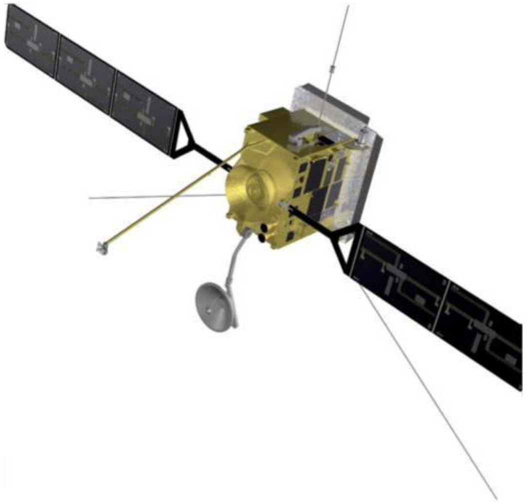
Synergy with SPP

Solar Probe Plus

The NASA Solar Probe Plus mission is highly complementary to Solar Orbiter. Solar Probe Plus is a ~7 year mission to approach the Sun, planned to be launched in 2018 and reaching a 9.5 R_s x 0.7 AU orbit with an 88-day period resulting in many close passes to the Sun.



conclusions



- SolO will answer fundamental questions relevant to both solar and stellar plasma physics

- SolO will investigate kinetic and fluid properties of the bulk solar wind plasma and dominant physical processes (e.g.: wave-particle interactions, origin and dissipation of turbulence, particles acceleration, etc)

- SolO is a discovery mission. There has never been a mission like this in the inner heliosphere (remote & in-situ packages @ 0.28AU, quasi corotation, high latitude)

- Launch in 2017 … 43 years after Helios!