Science objectives in METIS re-scoped configuration

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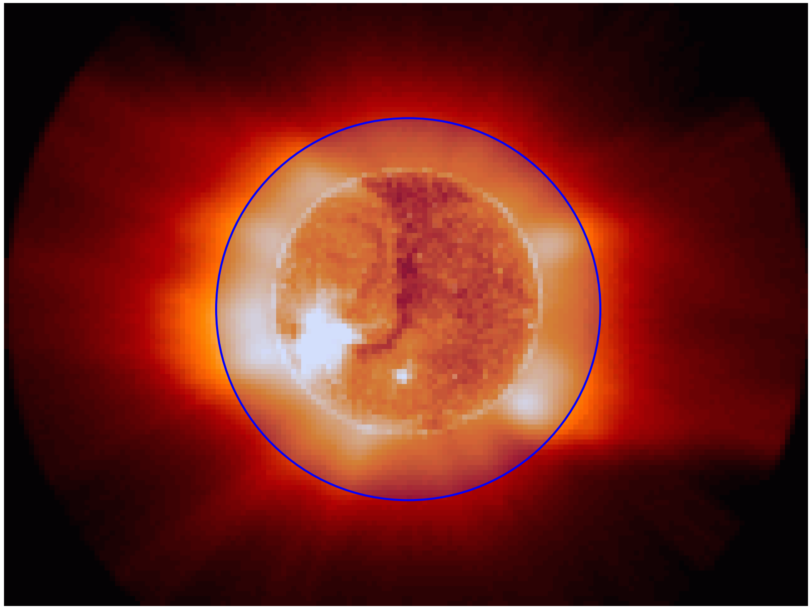
- METIS INSTRUMENT-

Conceived to perform off-limb and near-Sun coronagraphy

Imaging annular FoV:
1.5° -2.9° from disk center



Diagnostics of the structure and dynamics of the full corona from 1.5 to 3.0 $R_{\odot}$, at minimum perihelion (0.28 AU), and from 1.7 to 3.5 $R_{\odot}$, at maximum perihelion (0.32 AU). Crucial in linking the solar atmosphere phenomena to their evolution in the inner heliosphere.

Unprecedented temporal coverage and spatial resolution: down to about 4000 km.

- METIS -

Off-limb and near-Sun coronagraphy

For the first time:

•simultaneous imaging of the full corona in polarized visible light (580-640 nm) and narrow-band ultraviolet H I Ly α (121.6 nm)

Complete characterization of the most important plasma components of the corona and the solar wind, i.e., electrons and protons – density, outflow velocity,…

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CONTRIBUTION TO ADDRESS SOME OF THE MAJOR OPEN ISSUES OF THE PHYSICS OF THE SOLAR CORONA

(see the doc METIS-OACT-RPT-001 – METIS Scientific Performances Report)

1. - Origins and acceleration of the solar wind streams

2. - Sources of the solar energetic particles (SEP)

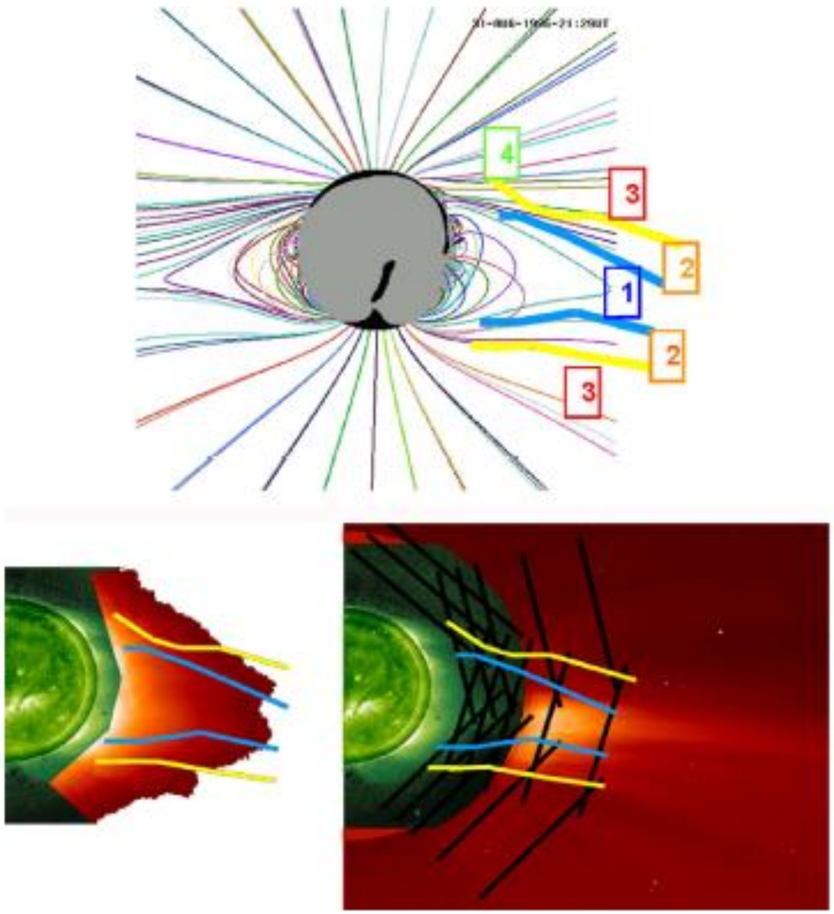
3. - Origin and early propagation of coronal mass ejections (CME)

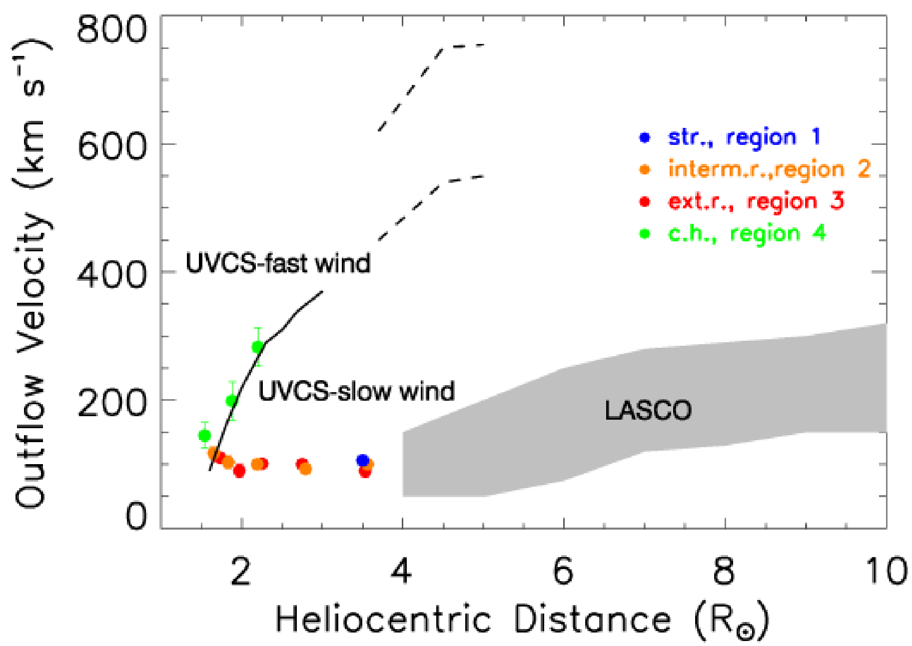
* Crucial questions in the field of coronal and solar wind physics *

4. - Study of Sun-grazing comets (in addition)

Open Issue 1:

Identifying solar wind streams: slow and fast





Abbo et al. 2009

Open Issue 1 (cont' d):

- **Measurement of the electron density (VL polarized emission) and the solar wind outward expansion velocity**

Doppler dimming technique applied to the resonantly scattered component of the H I Ly α emission line

$$I_r/I_{VL} = \text{constant } R(T)D(v)$$

D(v) - Doppler dimming term

Evaluation of flow velocity (Noci, personal communication)

-Global maps of the outflow velocity of the H component Identification of fast and slow wind streams

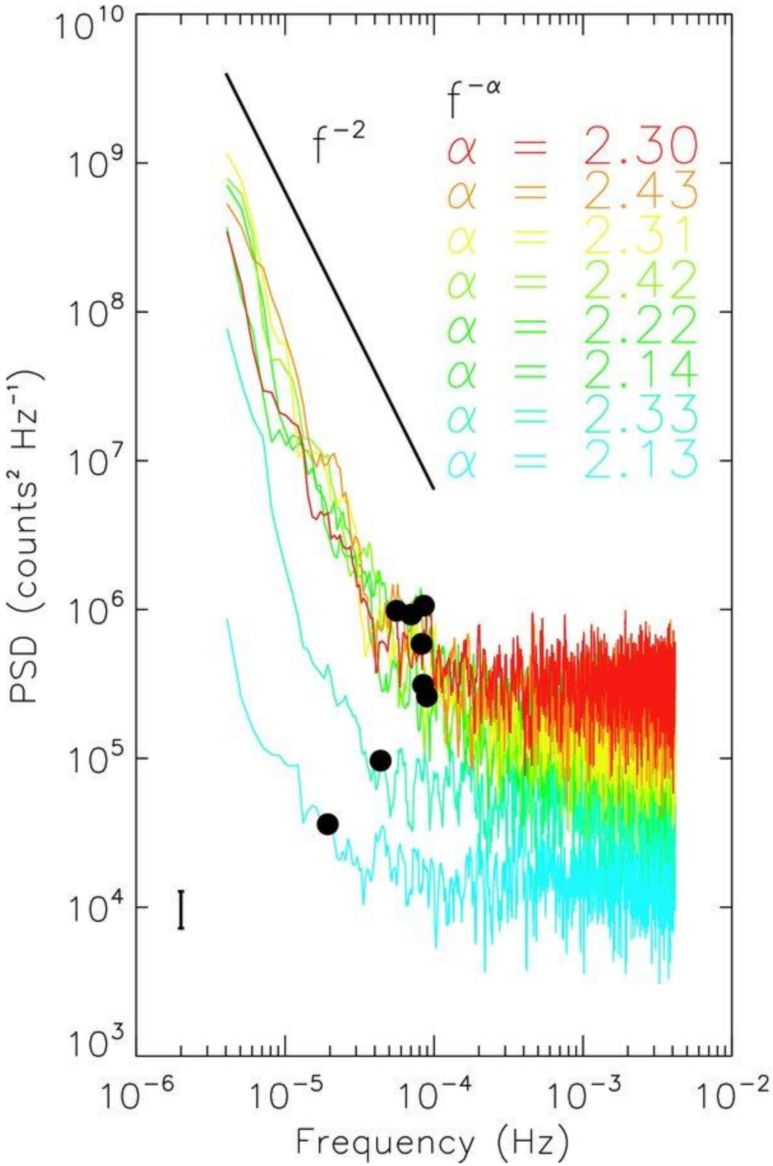
Open Issue 1 (cont’d):

- identifying the energy deposition mechanism in the solar wind streams

  - locating the energy deposition: wind acceleration (maximum coronal expansion velocity gradient) and deposition rate (density, velocity, acceleration)

  - determine the nature of coronal density and velocity fluctuations

Coronal fluctuations recently found in the outer layers of the solar atmophere



H I Ly-α intensity fluctuations from UVCS/SOHO data (Telloni et al. 2009)
- - - - see also Bemporad et al. 2008

- **Key to understand the transfer of energy from the inner layers to the regions where the solar wind is accelerated**

High spatial resolution and temporal cadence observations of UV and VL coronal brightness

Quasi co-rotational vantage point: opportunity to isolate fluctuations arising from the rotation from those due to propagation of waves and/or inhomogeneities

Open Issue 1 (cont’d):

- relationship of fluctuations with the global maps of the H outflow velocity, as well as with morphology and evolution of the magnetic coronal structures

→

useful information for understanding the transfer of energy to the outflowing solar wind plasma

Open Issue 1 (cont'd):

•assessing the role of coronal magnetic topology in controlling the wind outflow velocity

Interrelation of solar wind acceleration region and magnetic topology of flux tubes (degree of expansion): modulation of the wind physical parameters ($v_{outflow}$, deposition level)?

UVCS observations of the slow coronal wind (Antonucci et al. 2005)

- global maps of outflow velocity and coronal density
- quasi co-rotation: intrinsic evolution of magnetic topology

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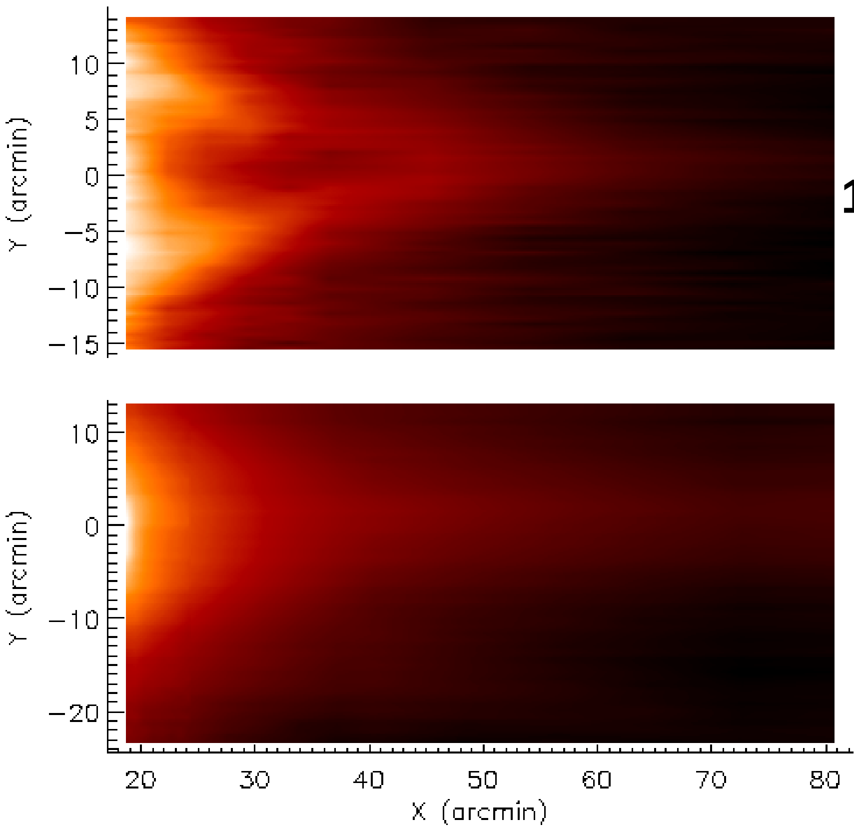
- **identifying the slow wind source regions**

UVCS/SOHO maps



O VI 1032 Å

H I Lyα

Test of the different hypotheses on the slow wind origin

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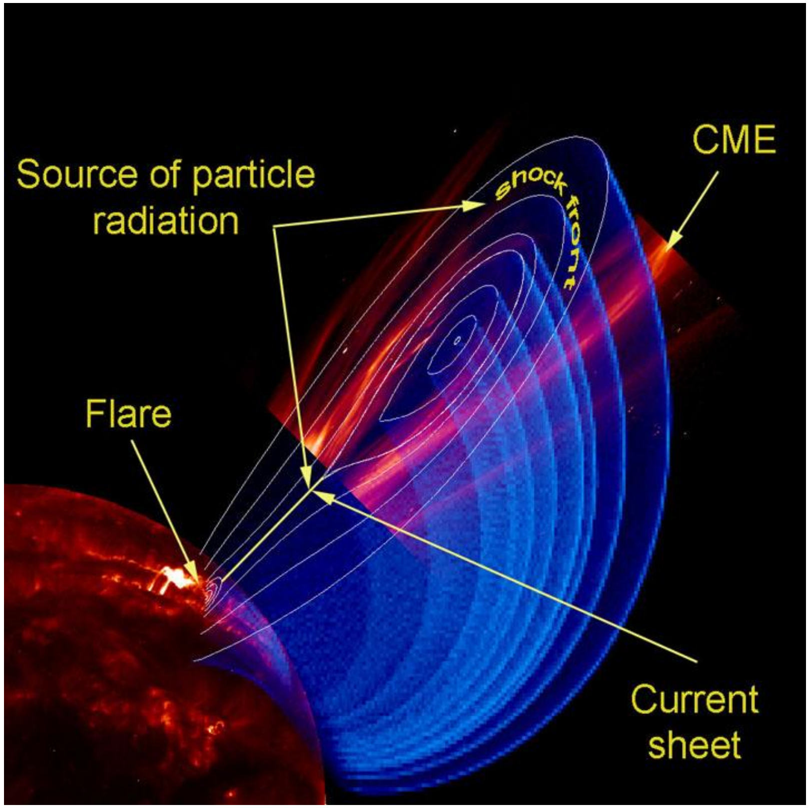
- **e^- density maps**
- **velocity maps of H**
- **streamer borders**
- **open field lines separating sub-streamers**

Open Issue 2:

• identifying the events giving rise to SEP produced by CMEs

- characterizing their associated shocks as they traverse the corona



Determine the key shock parameters and their evolution as the ejected mass propagates outward.

Timing of type II radio bursts…

Global maps of electron density and outflow velocity of the H component

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Path of the shock front where particles can be accelerated

Open Issue 3:
Origin and early evolution of CMEs

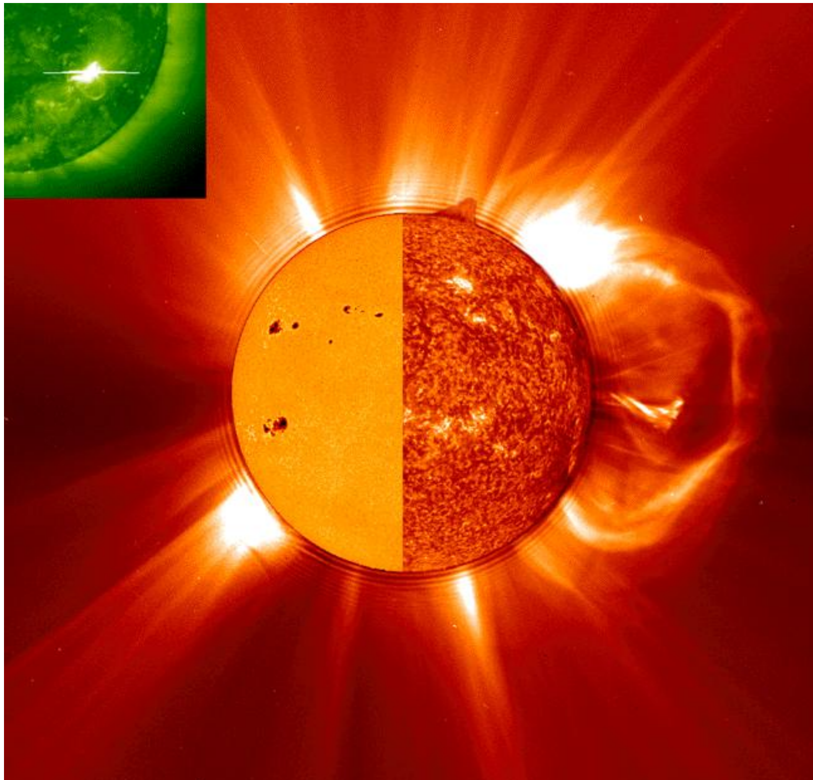
• **identification of the mechanism driving the abrupt eruption of coronal mass**

- where does the CME material come from?

- identification of the driving mechanism(s):
  main source of flux injection
  restructuring of the global corona
  total transport of mass and magnetic fluxes
  out of the Sun during transient events

- coronal observations extended
  down to 1.6 solar radii

- full sequence of a CME:
  pre-eruption, eruption, propagation,
  reconfiguration of the solar corona



Origin and early evolution of CMEs

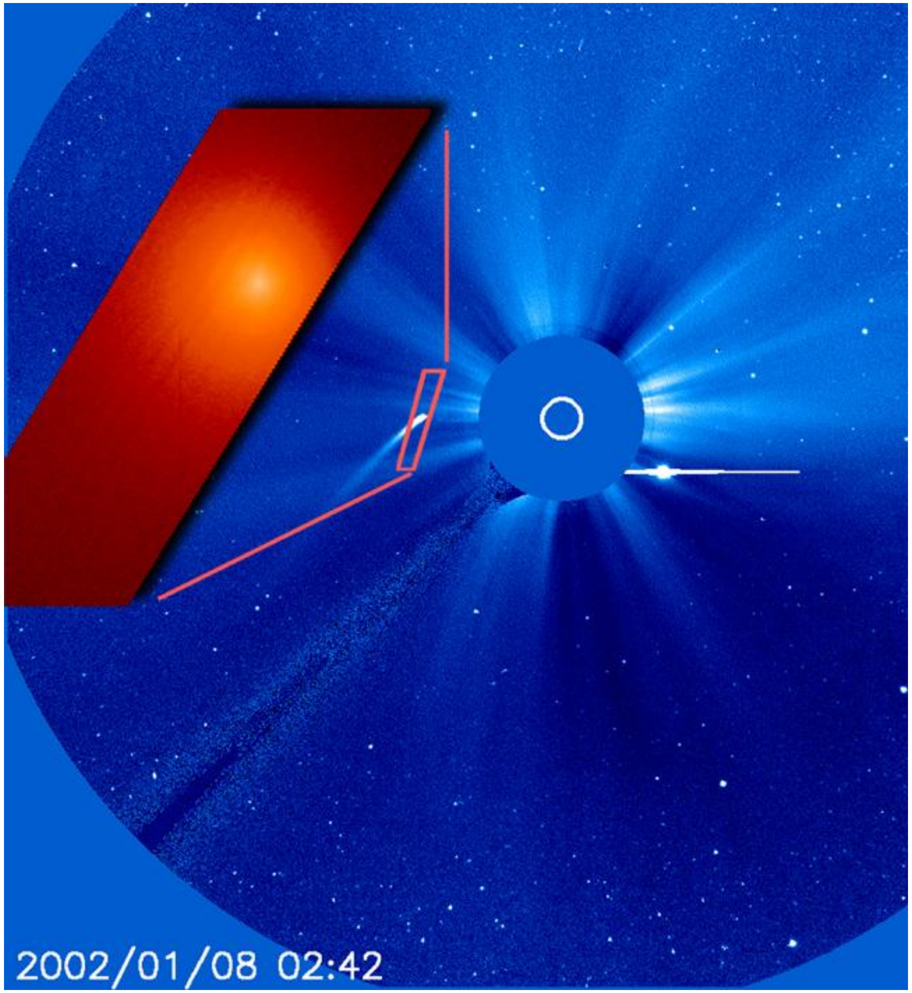
- directionality of the plasma erupted from the Sun: geo-effectiveness

- out-of-ecliptic vantage point: longitudinal structure and distribution of expanding CMEs

• understanding the evolution of the global corona (e.g., streamer belt) in response to different phenomena, varying from:
  - moderate episodic heating to
  - disruptive CMEs

longitudinal distribution and evolution of electron density
total mass and magnetic flux injection into the heliosphere

Sun-grazing comets



UVCS observations of Sun-grazers:

high cometary emission in the H I Ly α line –

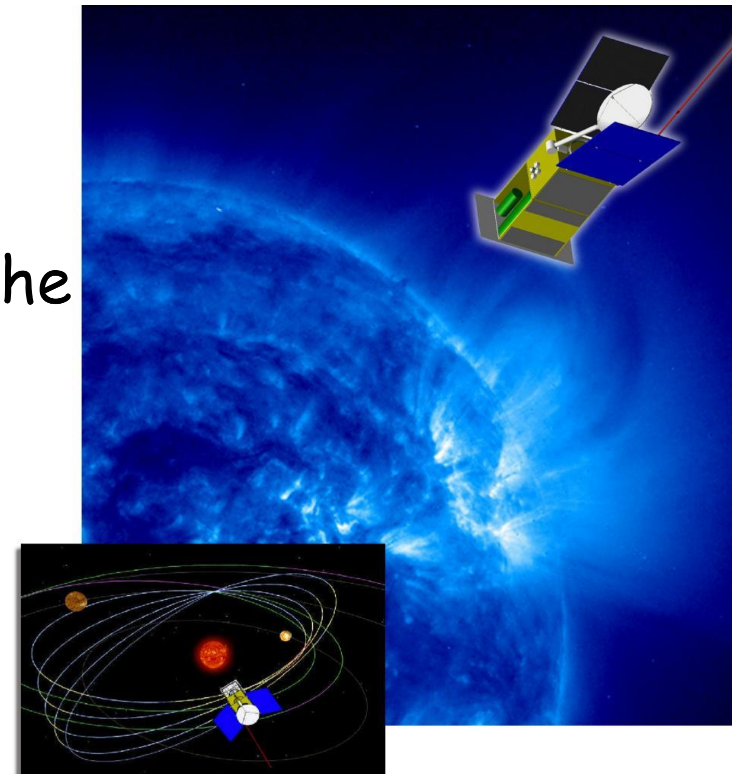
radiative excitation of neutral H atoms from the water outgassed from the cometary nucleus –

monitor the evolution of the cometary emission along its trajectory close to the Sun –

estimate of:

- **outgassing rate**
- **local coronal electron density**
- **size of the cometary nucleus**
- **nucleus fragmentation**

The *Solar Orbiter mission profile* offers unique opportunities and new perspectives that can help to fulfil the science targets of METIS



- exploring the inner regions of the Solar System
- study the Sun from a close-up point of view (up to 0.28 UA)
- quasi-corotation with the Sun
- provide images of the polar regions of the Sun from heliolatitudes up to 34°

METIS Instrument Performance	
CORONAL IMAGING	
Avg. Instrumental Stray Light (B_{corona}/B_{disk})	VL<10^{-9} UV<10^{-7}
Wavelength range:	VL: 580-640 nm UV: 121.6±10 nm
Spatial Resolution	20 arcsec
Field-of-view	1.5°-2.9°annular off-limb corona

Table 1: METIS instrument performances (for information only)

Traceability Matrix

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Table 1 Traceability Matrix

Notes:

1) **FOV:** =FE_!G>FQ_!$- - * /$&!) ,, G/9 <!+) &) - $!

2) The lossless compression factor (preserving full resolution, i.e. 20" in the VL channel) is assumed to be 5. For a ~2 degradation in resolution (i.e. 40" in the VL channel) the compression factor is assumed to be 10

3) The exposure times in the tables (case A1) refer to the range of heliocentric distances 1.9 - 2.5 $R_{\odot}$ at a S/C - Sun distance of 0.28 AU. For different S/C - Sun distances, the exposure times will have to be adjusted taking into account changes in the geometry of the target relative to optical instrumental properties such as the vignetting function, for example.

4) The exposure times for the VL channel take into account that to obtain pB images four polarized images will normally be taken.

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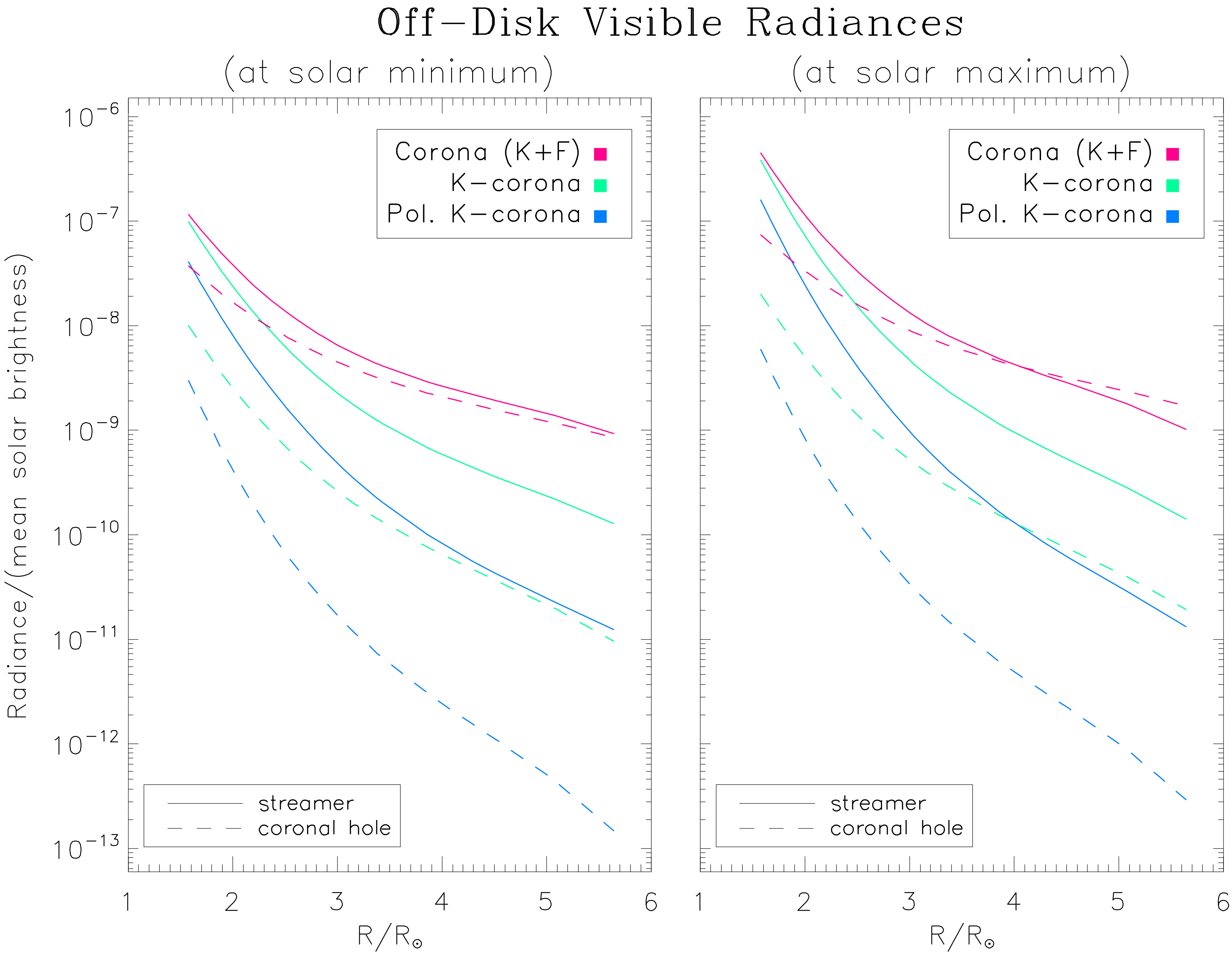
- Evaluation of scientific performances and revision of the Traceability Matrix: what to do

- Available coronal radiances (METIS-OACT-TNO-004)

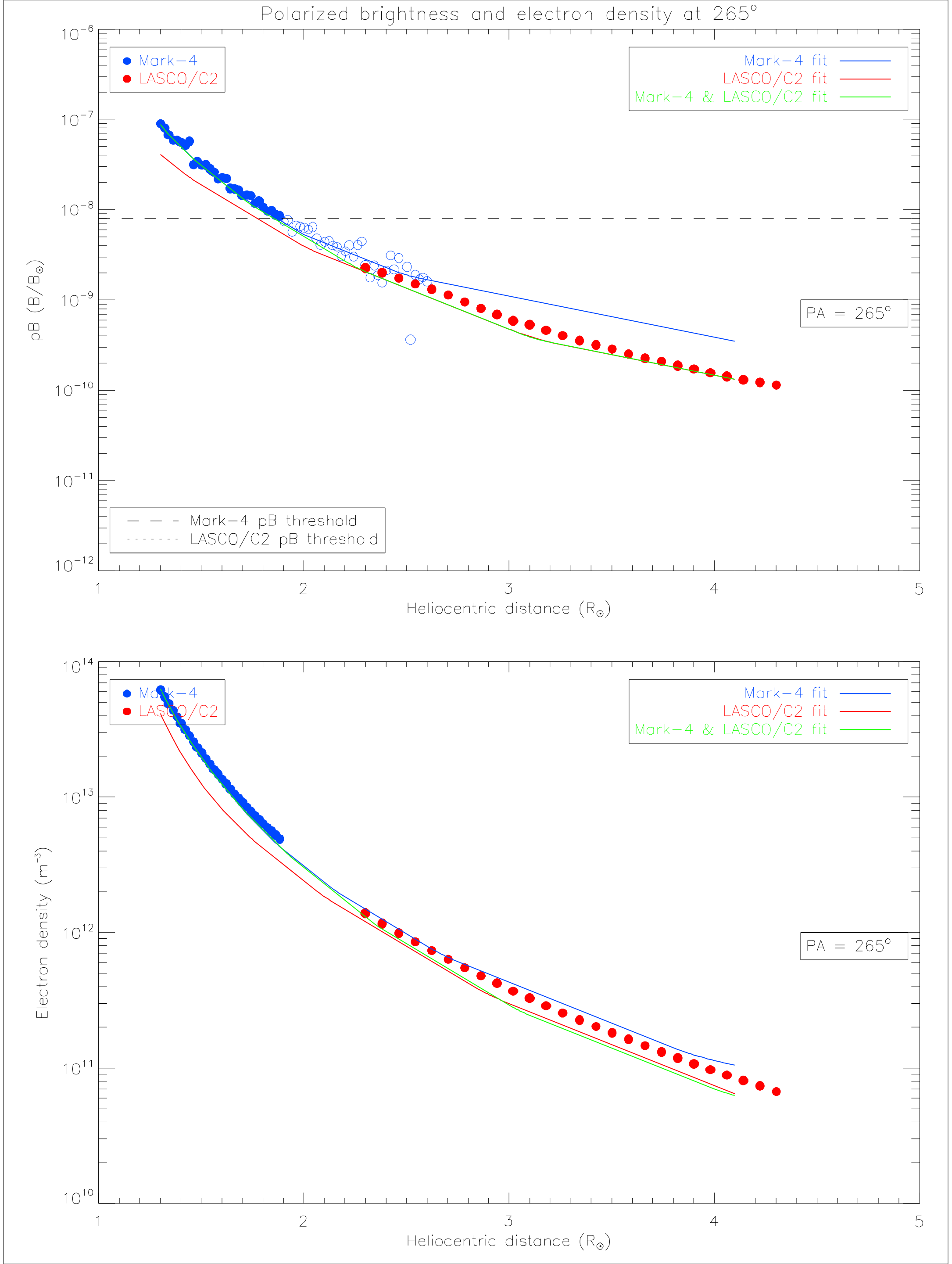
- Instrument configuration and optical performances (METIS-OATO-SPE-006)

- Estimated count rates for the observations of coronal structures and transients at different S/C-Sun distances, in different phases of the solar activity cycle

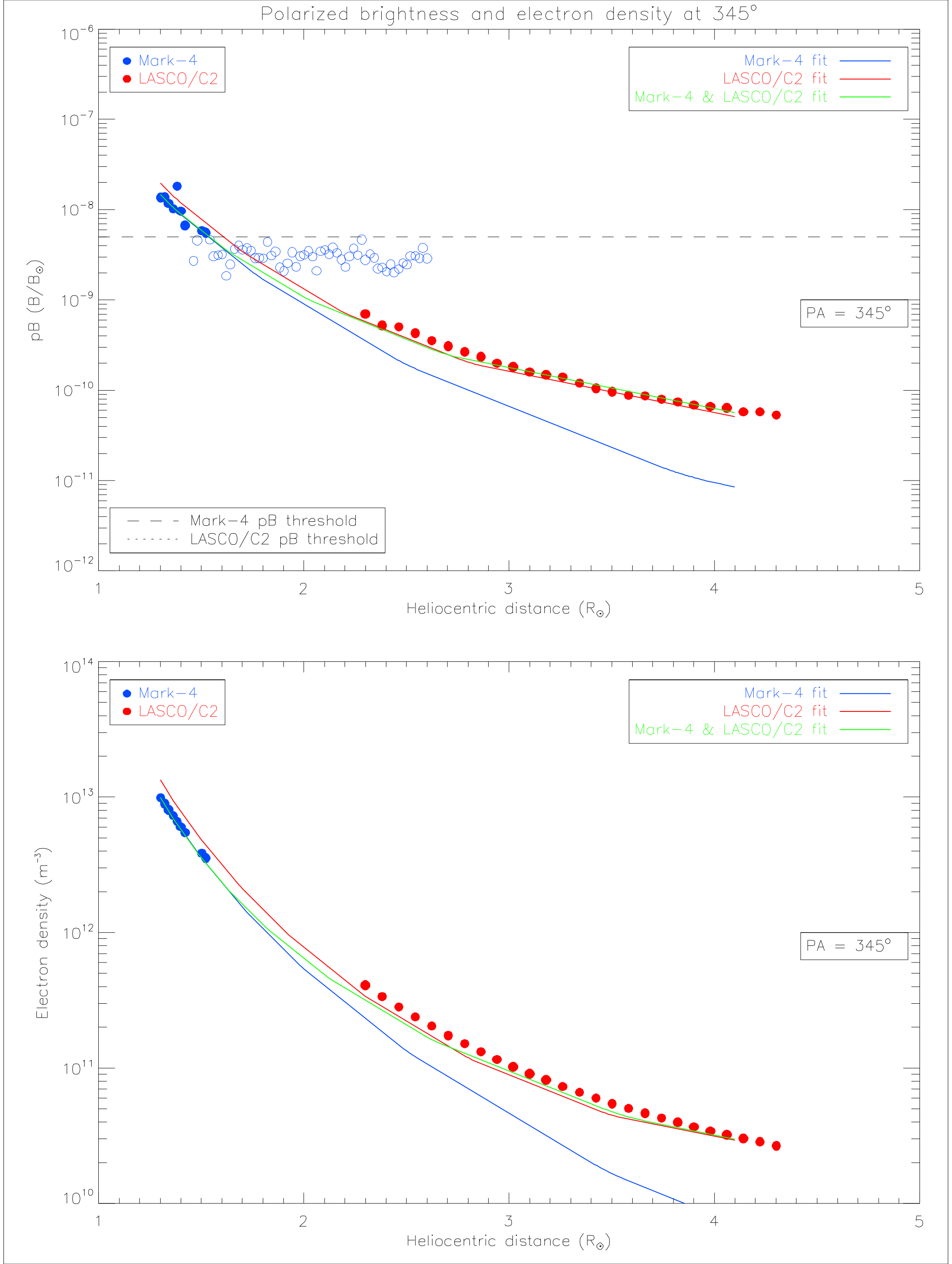
- Exposure times, cadence, duration, spatial resolution, etc., required for the various observing programs (modes) driven by the science objectives and questions



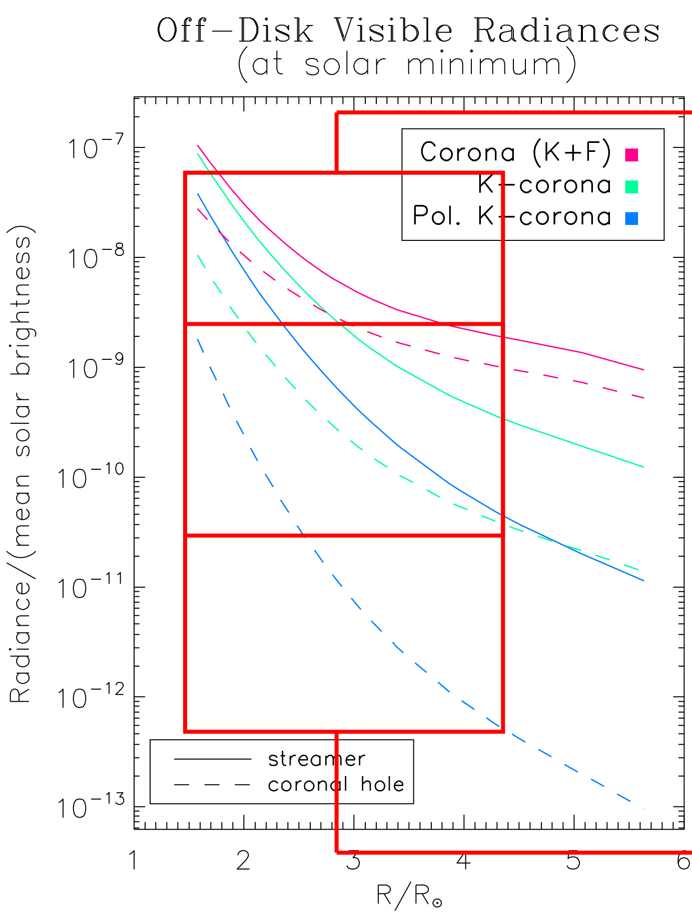
Off−Disk Visible Radiances
(at solar minimum)
(at solar maximum)
Radiance/(mean solar brightness)
Corona (K+F)
K−corona
Pol. K−corona
streamer
coronal hole
R/R⊙

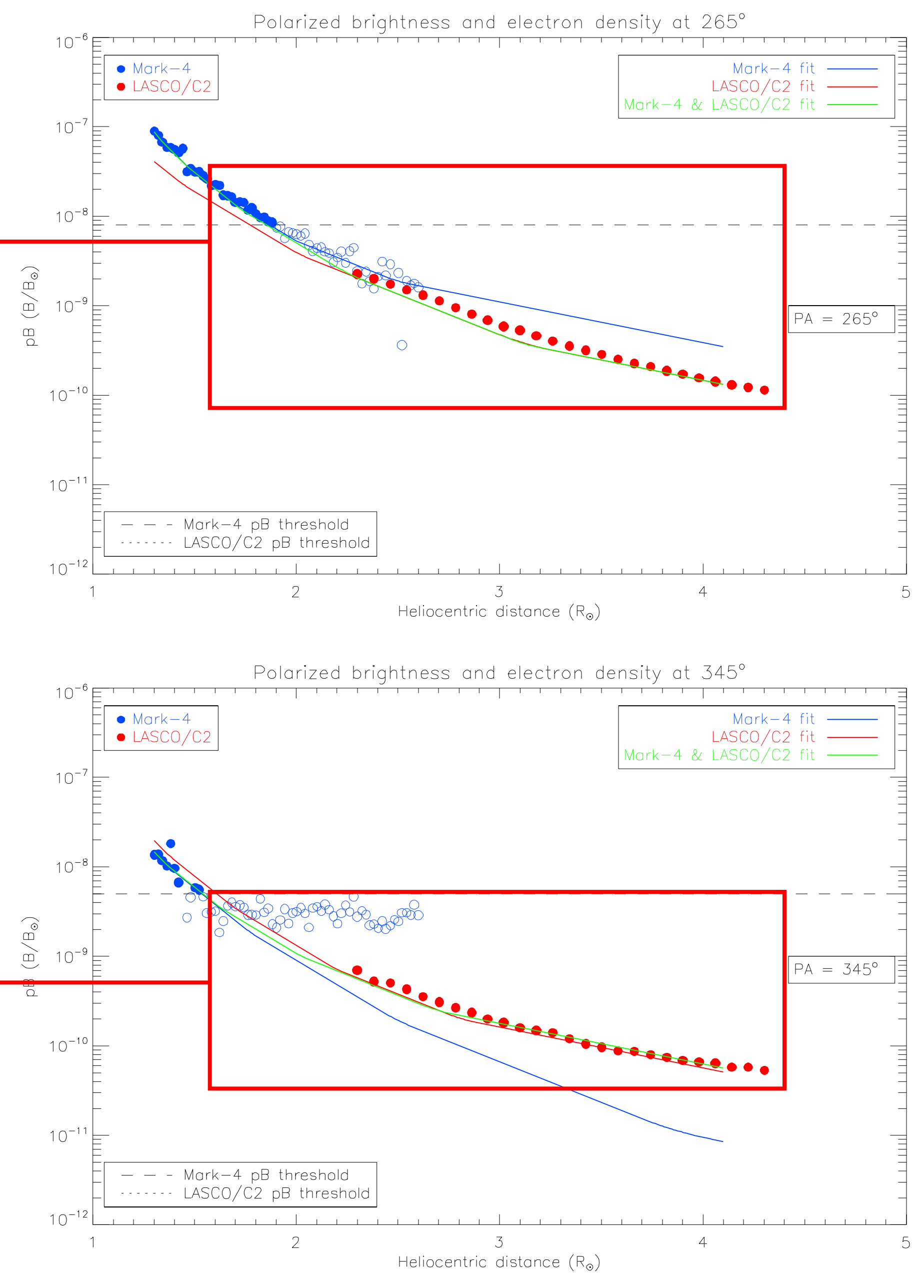


Polarized brightness and electron density at 265°
Mark-4
LASCO/C2
Mark-4 fit
LASCO/C2 fit
Mark-4 & LASCO/C2 fit
PA = 265°
Mark-4 pB threshold
LASCO/C2 pB threshold
pB (B/B⊙)
Heliocentric distance (R⊙)
Mark-4
LASCO/C2
Mark-4 fit
LASCO/C2 fit
Mark-4 & LASCO/C2 fit
PA = 265°
Electron density (m⁻³)
Heliocentric distance (R⊙)

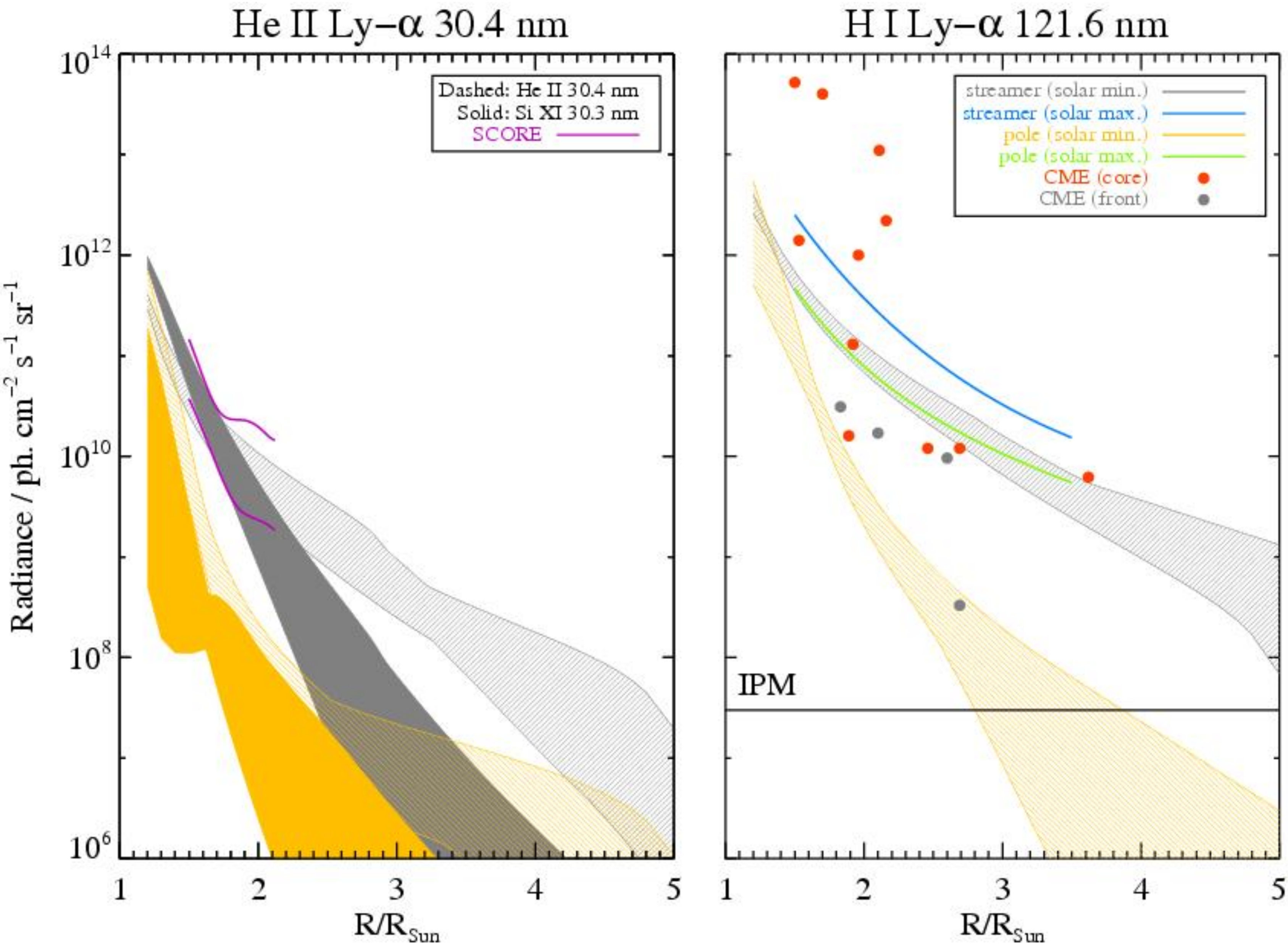


Polarized brightness and electron density at 345°
Mark−4
LASCO/C2
Mark−4 fit
LASCO/C2 fit
Mark−4 & LASCO/C2 fit
PA = 345°
Mark−4 pB threshold
LASCO/C2 pB threshold
pB (B/B⊙)
Heliocentric distance (R⊙)
Electron density (m⁻³)





Different radial variation of percentage of polarization



He II Ly−α 30.4 nm
H I Ly−α 121.6 nm
Dashed: He II 30.4 nm
Solid: Si XI 30.3 nm
SCORE
streamer (solar min.)
streamer (solar max.)
pole (solar min.)
pole (solar max.)
CME (core)
CME (front)
IPM
Radiance / ph. cm^{-2} s^{-1} sr^{-1}
10^{14}
10^{12}
10^{10}
10^{8}
10^{6}
1
2
3
4
5
R/R$_{Sun}$

METIS & ESA

Solar Orbiter Remote Sensing Working Group

Chair: Valentin Martinez Pillet

Members: representatives of the instruments

- **EUI**
- **PHI**
- **SPICE**
- **STIX**
- **HI**
- **METIS (D. Spadaro, S. Fineschi, V. Andretta)**

The RSWG will merge with the Science Operations Working Group (SOWG)

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Solar Orbiter Remote Sensing Working Group

Activities:

- Doc on <u>instruments commissioning and calibration</u>
  - Requests and plans of each instrument
  - Comments from the Mission Team, boundary cond’s
  - Development in progress within the RSWG
  - Consolidated plan (baseline for calibration and operations) for each instruments, according to resources and constraints, at the CDR
- Doc on <u>instruments operations</u>
  - Operations of the RS instruments during three encounter periods in the nominal mission phase
  - RS instrument flags and expected triggered reactions

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Solar Orbiter Remote Sensing Working Group

Activities (cont.):

•Doc on instruments operations (cont.)

- **Various combined operation modes (coordination of RS instruments)**
- **Requirement on co-alignment of the FoVs of instruments with high spatial resolution modes (EUI, PHI and SPICE)**

•Definition of pointing strategy for remote-sensing windows: "pre-cursor" observations to be acquired prior to the nominal science windows, in order to define the S/C fine pointing (EUI, PHI and SPICE); discussion with SWT and SOWG in London (Feb. 2013)