SOLI INVICTO

INAF
ISTITUTO NAZIONALE DI ASTROFISICA

PROBA-3/ASPIICS Coronagraph

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Audizione RSN-3 Sessione 8

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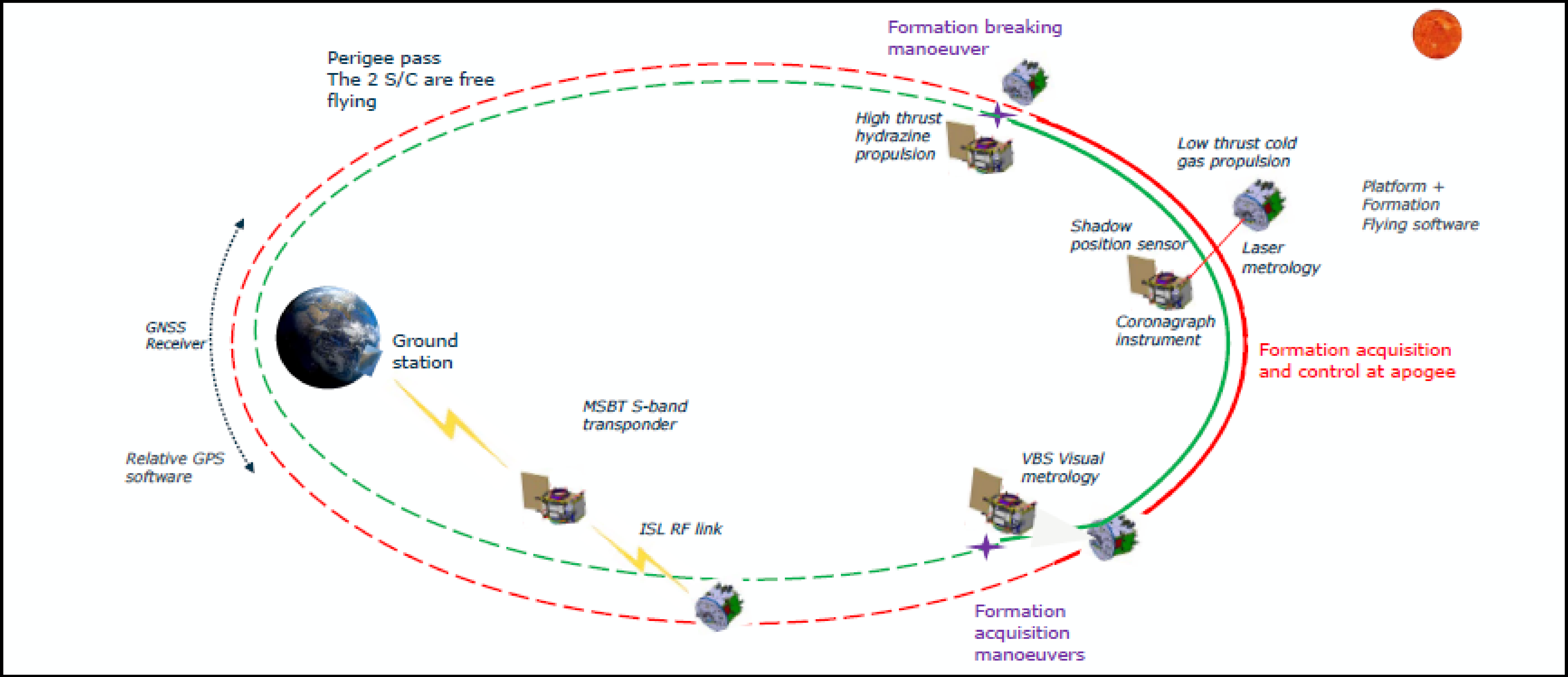
Heliophysics in a nutshell

- Heliophysics is the science that unites all of the linked phenomena in the region of the cosmos influenced by the Sun:
  - ✴ solar physics,
  - ✴ space physics
  - ✴ heliospheric physics,
  - ✴ physics of planetary magnetospheres, etc.
- Objects under study:
  - ✴ Sun and its corona,
  - ✴ solar wind,
  - ✴ solar cosmic rays,
  - ✴ plasma environment of planets.
- Measurements performed:
  - ✴ remote-sensing measurements,
  - ✴ in situ measurements.

(movie courtesy B. Nicula & the JHelioviewer team at ROB)

ESA PROBA-3: 1st Formation-flying Mission Technology Demonstrator



A coronagraph with the external occulter on one spacecraft and the optical instrument on the other spacecraft at ~150 meters from the first one.

Relative transverse positioning accuracy: ±1.5 mm

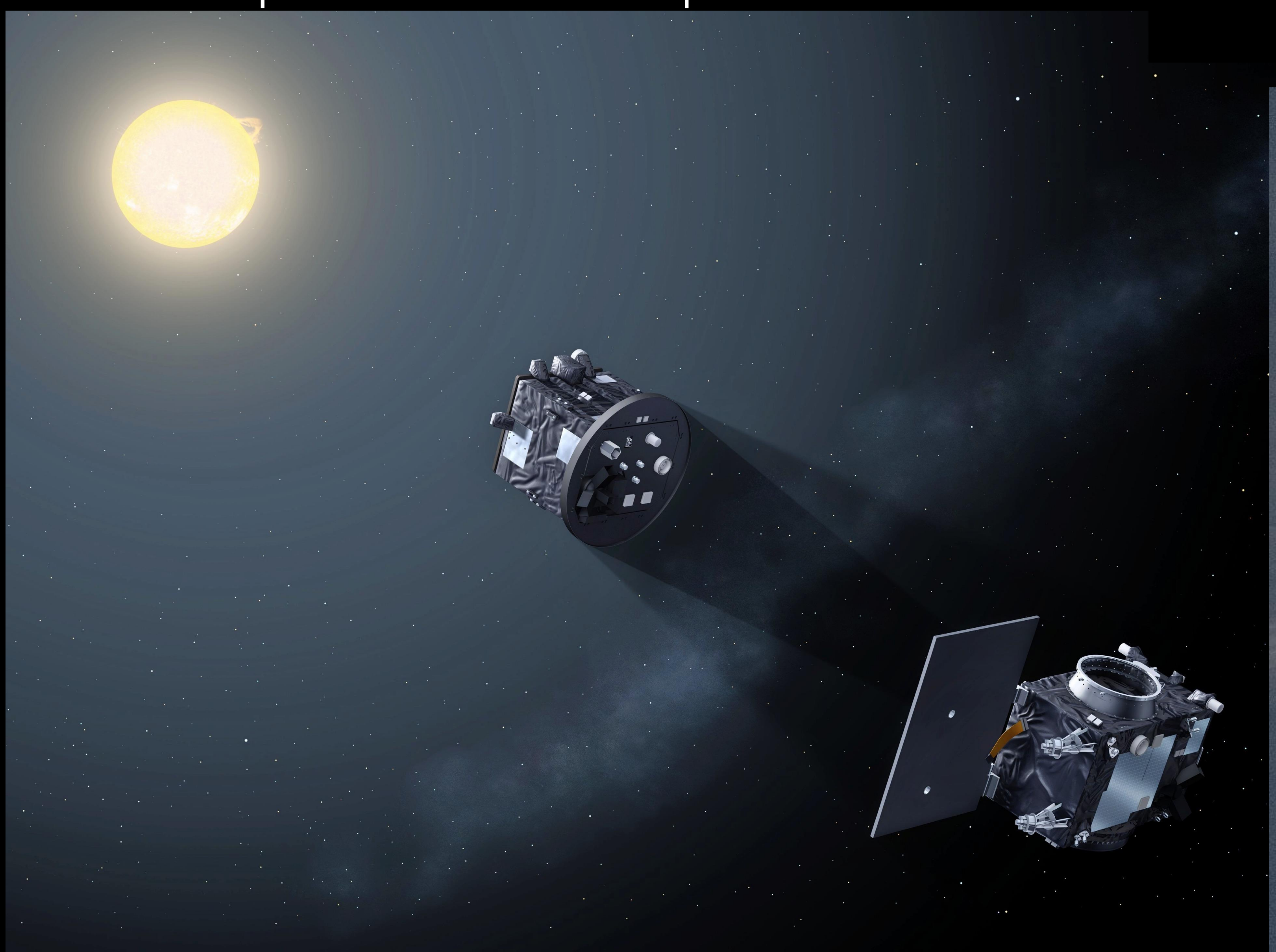
PROBA-3 Development Timeline

- 2005 Technological Mission concept study
- 2009 Phase A studies - “Startiger”
- 2012 Phase B
- 2014 Phases C/D/E1 (change of industrial organisation)
- 2018 System CDR
- 2017 Mission of opportunity adoption by the ESA Science Programme.
- 2021 ASPIICS delivery to PROBA-3 S/C
- 2023 June Launch
- 2023 + 6 months End of commissioning
- 2025 End of nominal mission

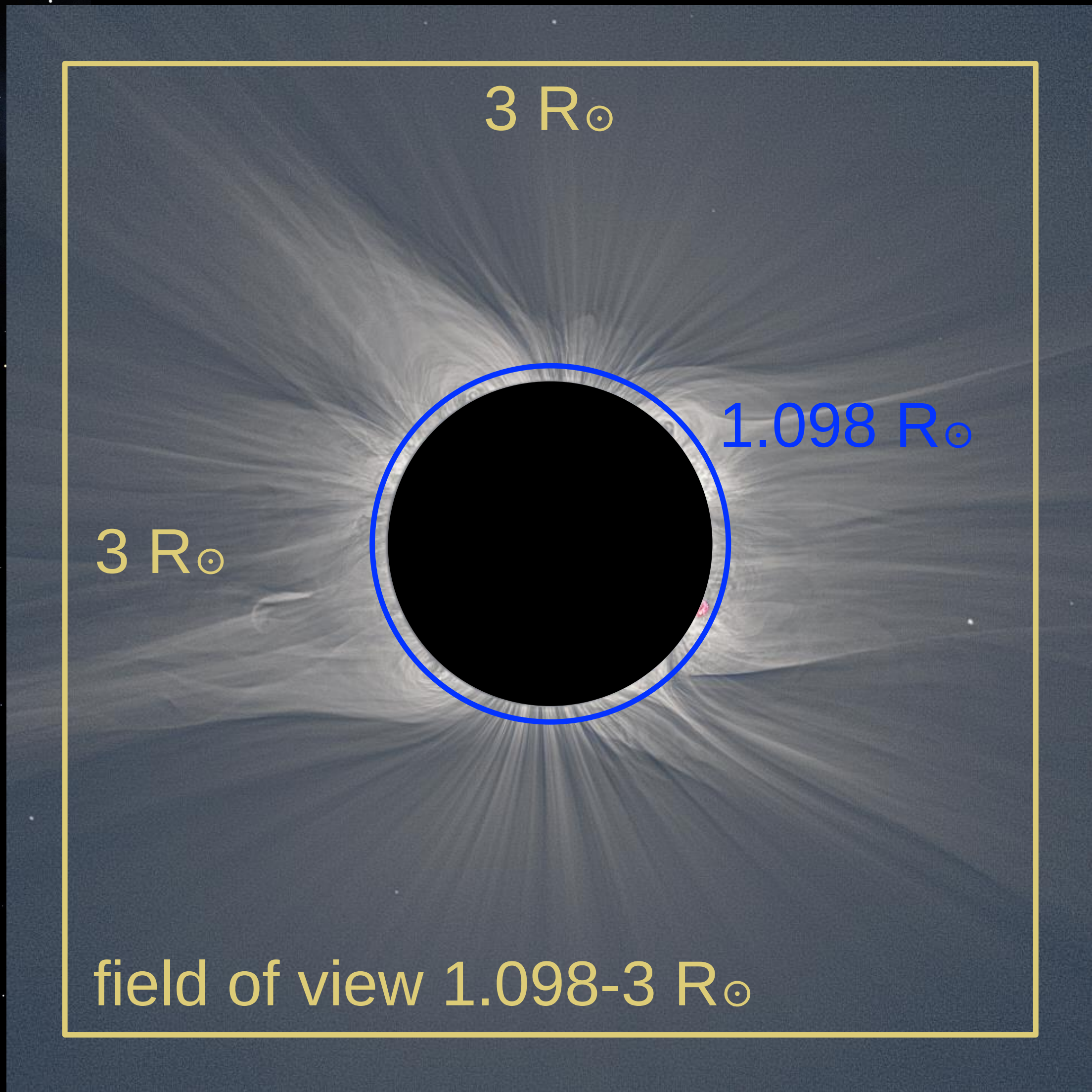
  - INAF involved since Phase A (“Startiger”) 2009

PROBA-3/ASPIICS: the ultimate coronagraph!

- The formation flying will be maintained over 6 hours in every 20-hour orbit: *around a factor 100 improvement* in the duration of uninterrupted observations in comparison with a total eclipse.
- PROBA-3 will observe the corona two orbits per week on average: *around a factor 50 improvement* in the occurrence rate in comparison with a total eclipse.

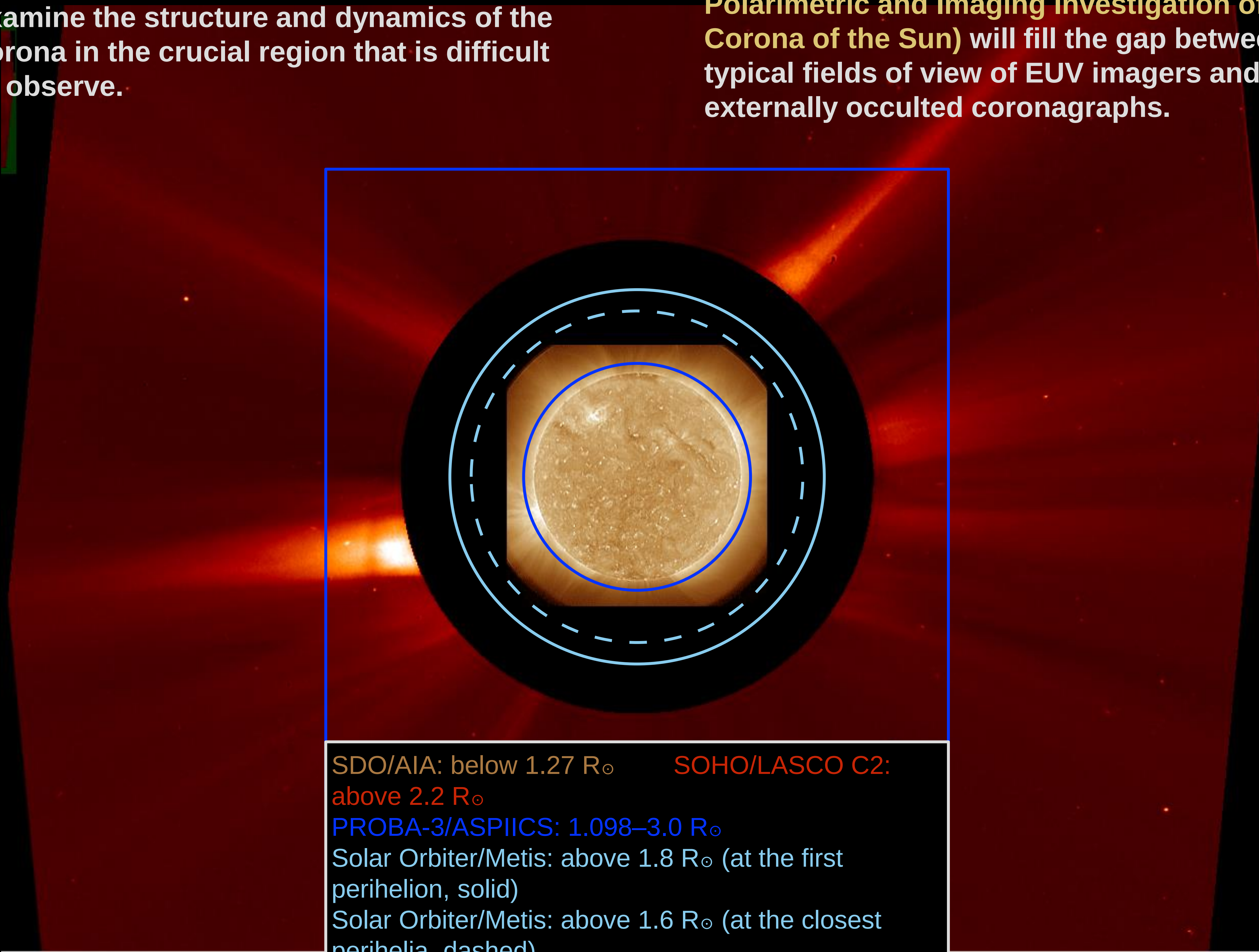


- 6 spectral channels:
  - white light (5350-5650 Å),
  - 3 polarized white light,
  - Fe XIV passband at 5304 Å.
  - He I D3 passband at 5877 Å.
- 2048x2048 pixels (2.8 arc sec per pixel)
- 60 s nominal synoptic cadence
  - 2 s using a quarter of the field of view.

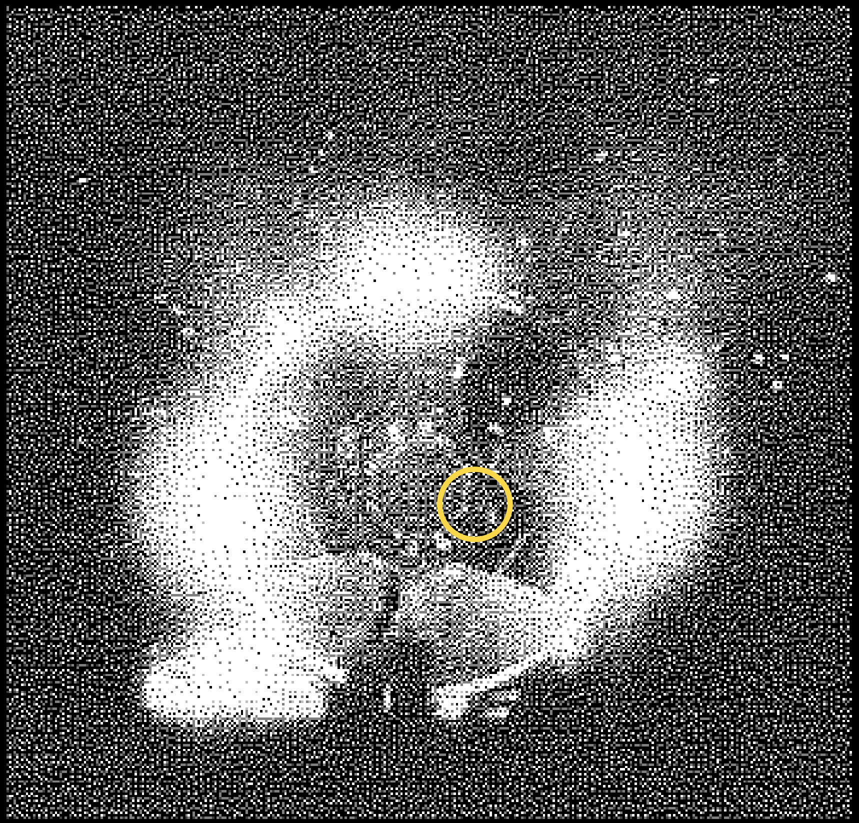


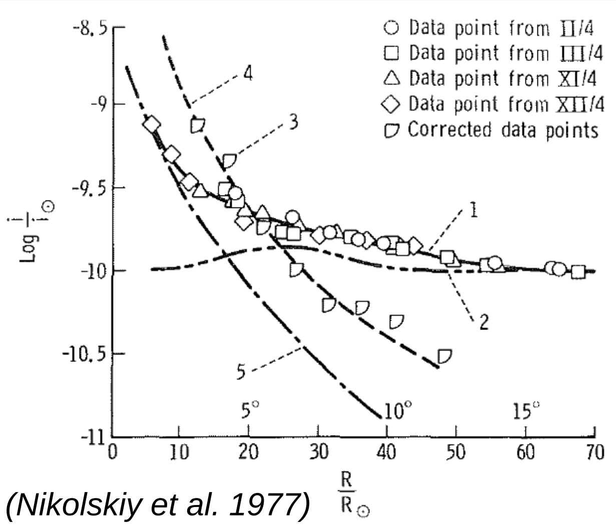
The PROBA-3/ASPIICS coronagraph will examine the structure and dynamics of the corona in the crucial region that is difficult to observe.

ASPIICS (Association of Spacecraft for Polarimetric and Imaging Investigation of the Corona of the Sun) will fill the gap between the typical fields of view of EUV imagers and externally occulted coronagraphs.



Observing solar corona using formation flying: Apollo-Soyuz Test Project (1975)

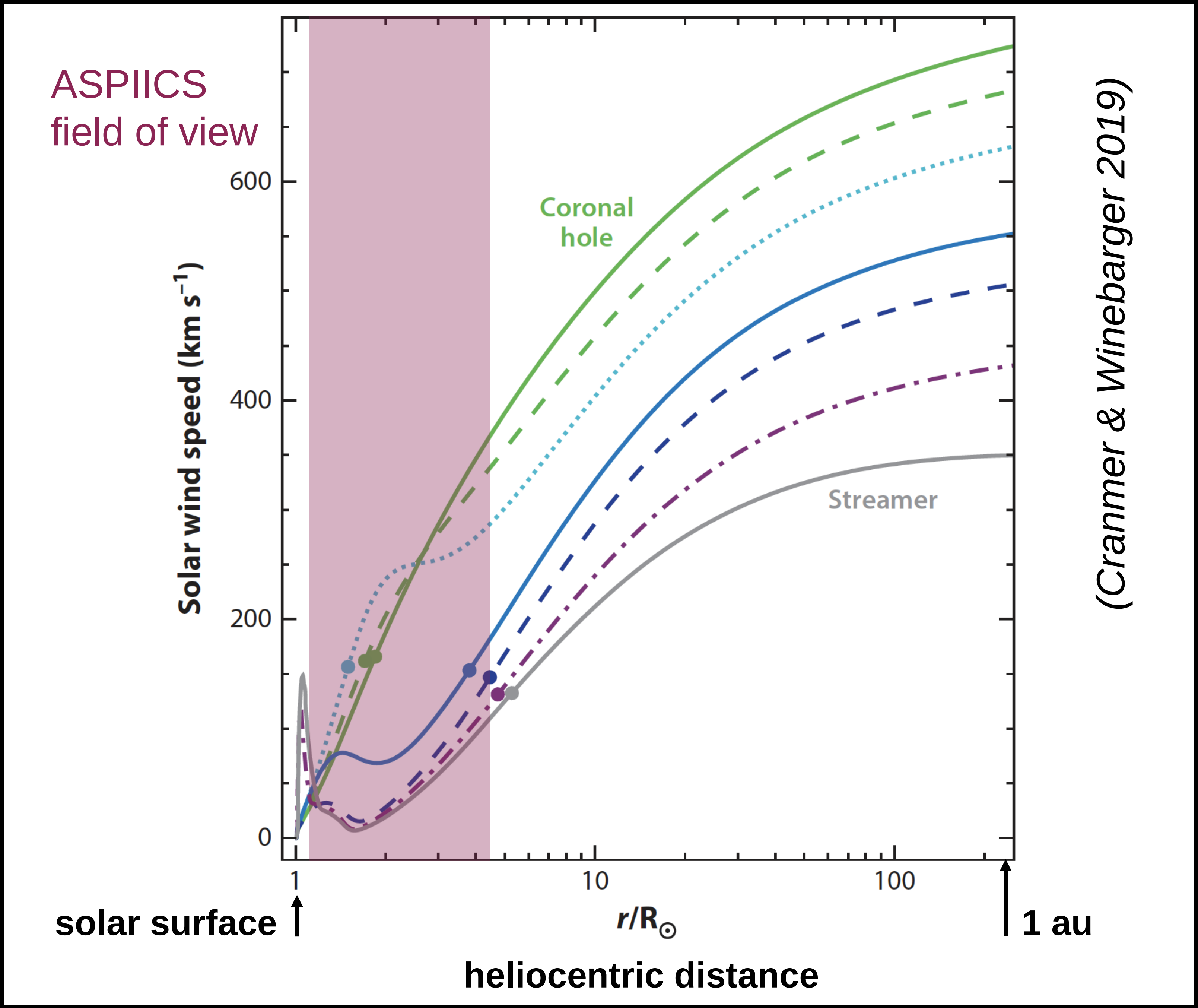


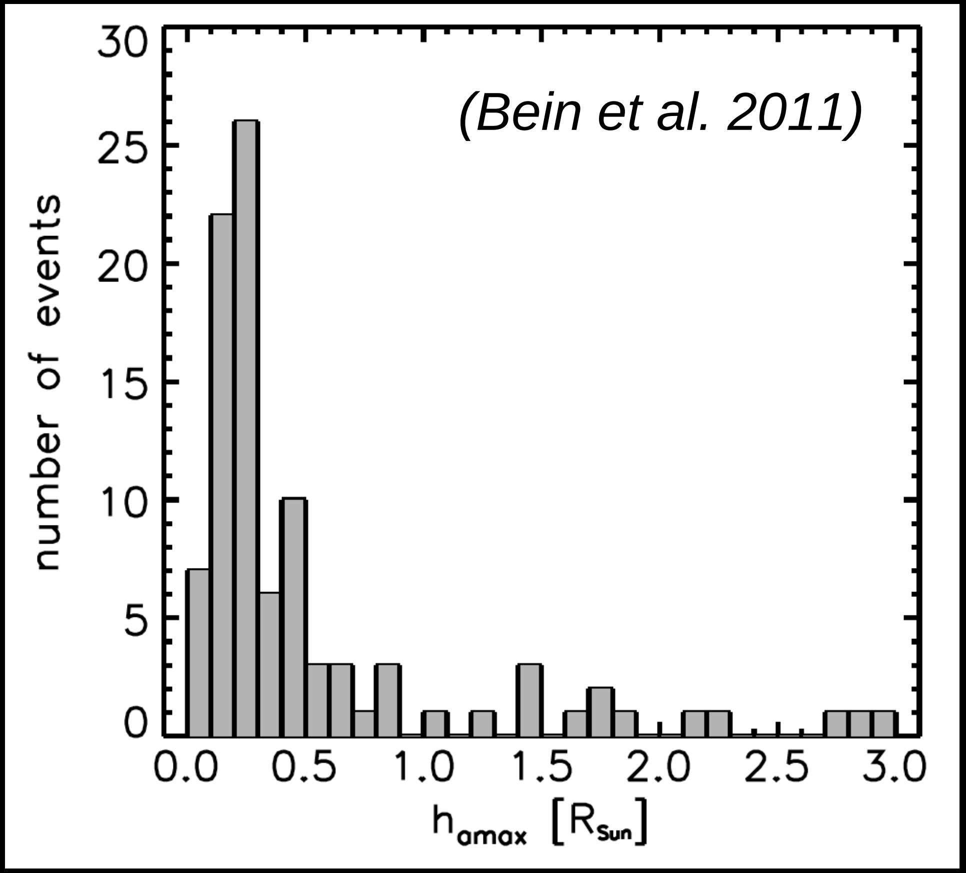


(Nikolskiy et al. 1977)

First formation flying coronagraphic experiment: images taken by the crew of Soyuz with Apollo occulting the Sun.

Why are observations of the inner solar corona so important?

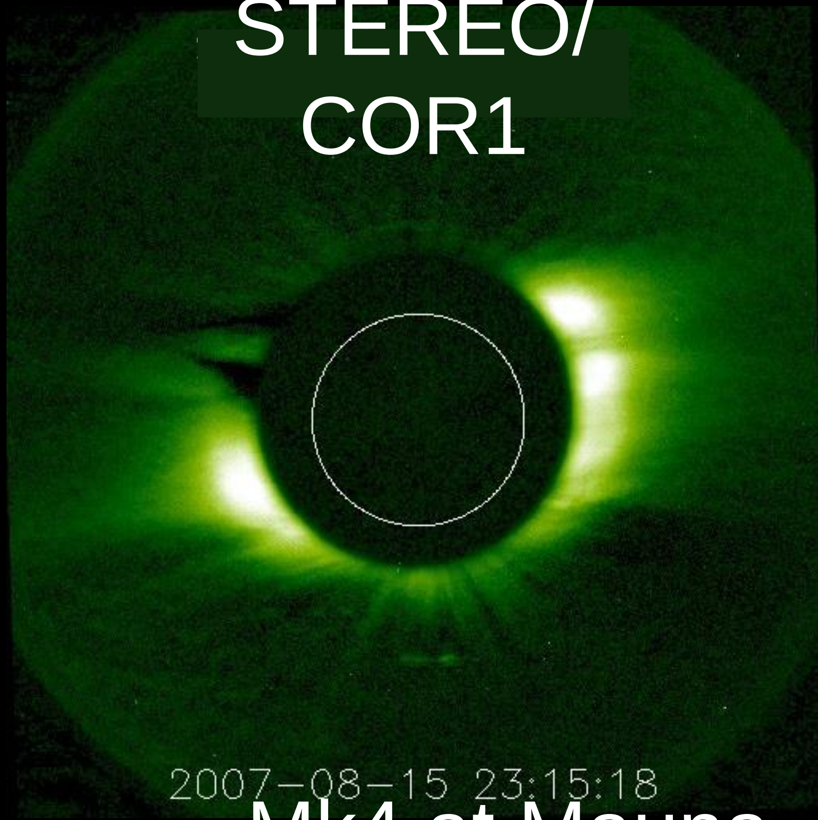


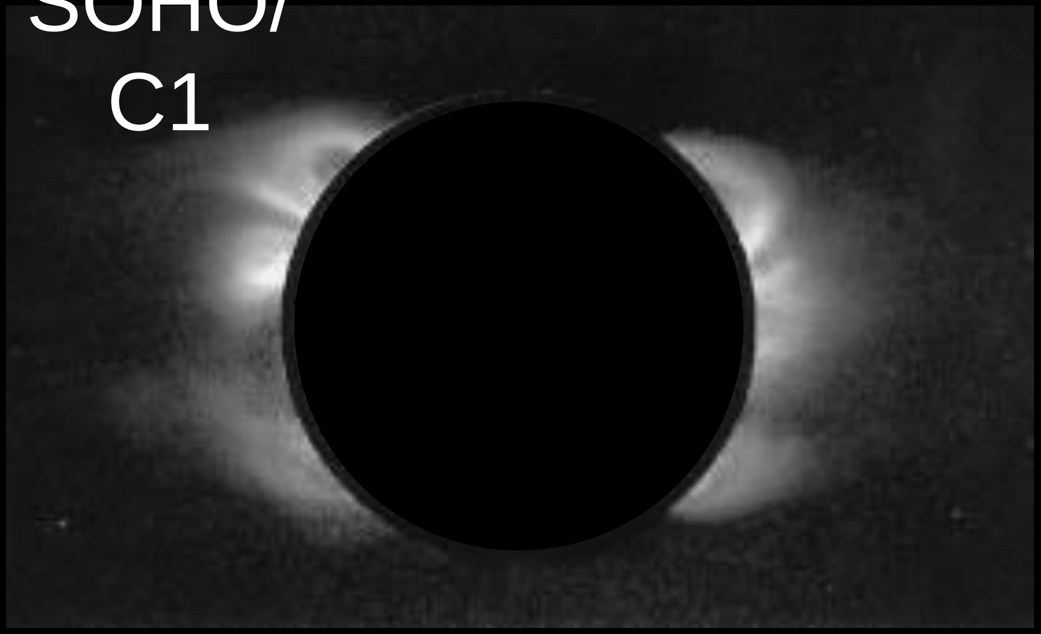


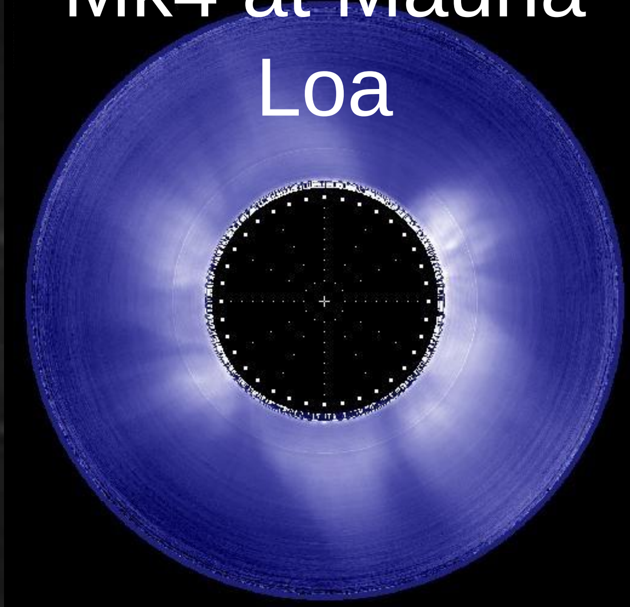
- Simulations show important acceleration of the solar wind (to supersonic velocities) around 2-3 R⊙ from the center of the Sun.
- The peak acceleration of coronal mass ejections (CMEs) also occurs in this region.

Why wasn't the inner corona observed in much detail before?

- A short answer: straylight
- Straylight in coronagraphs is very difficult to suppress when the corona below 2 $R_\odot$ is observed.
- High straylight means that signal-to-noise ratio, the contrast of small-scale features, and the effective spatial resolution become low.

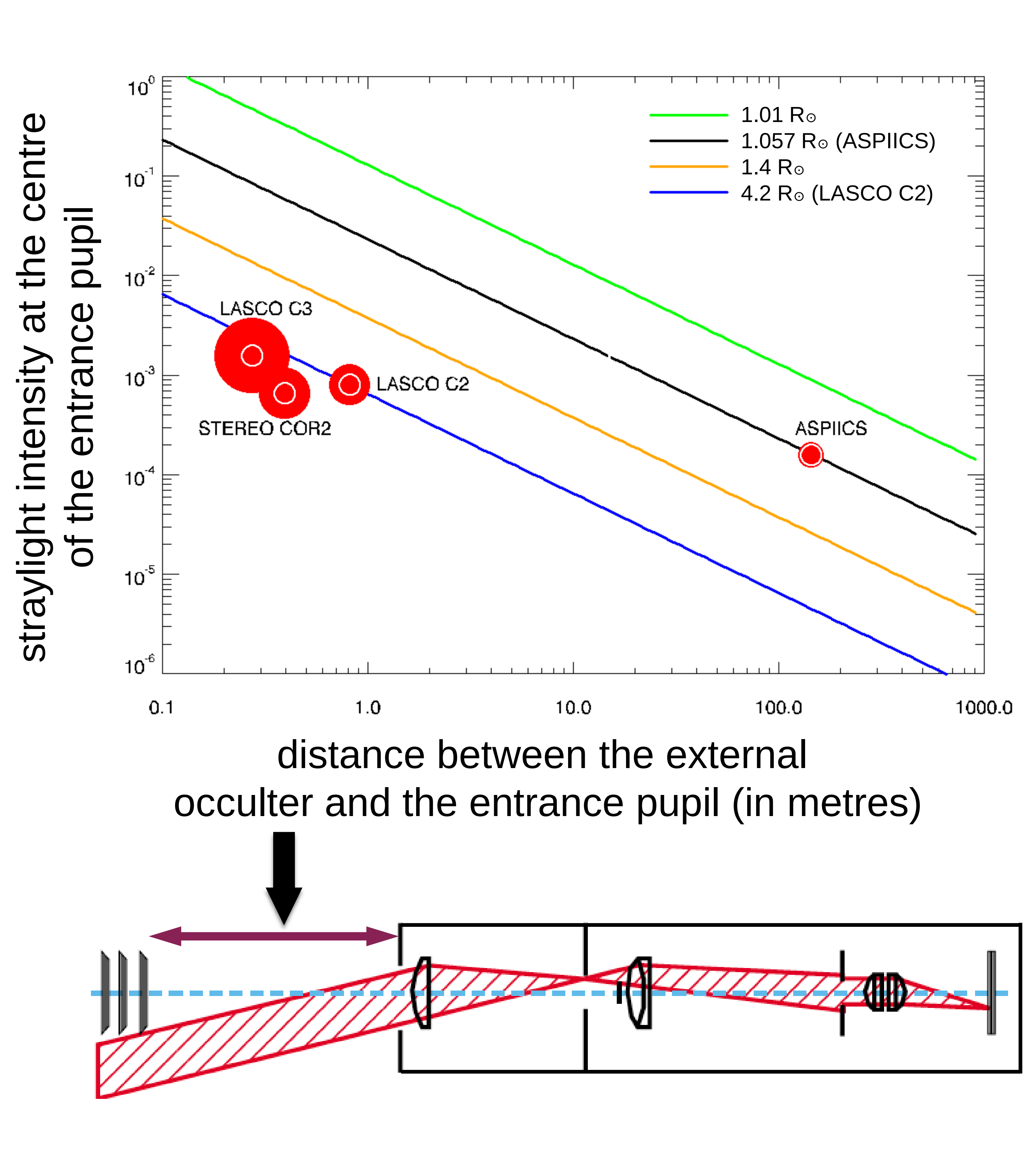




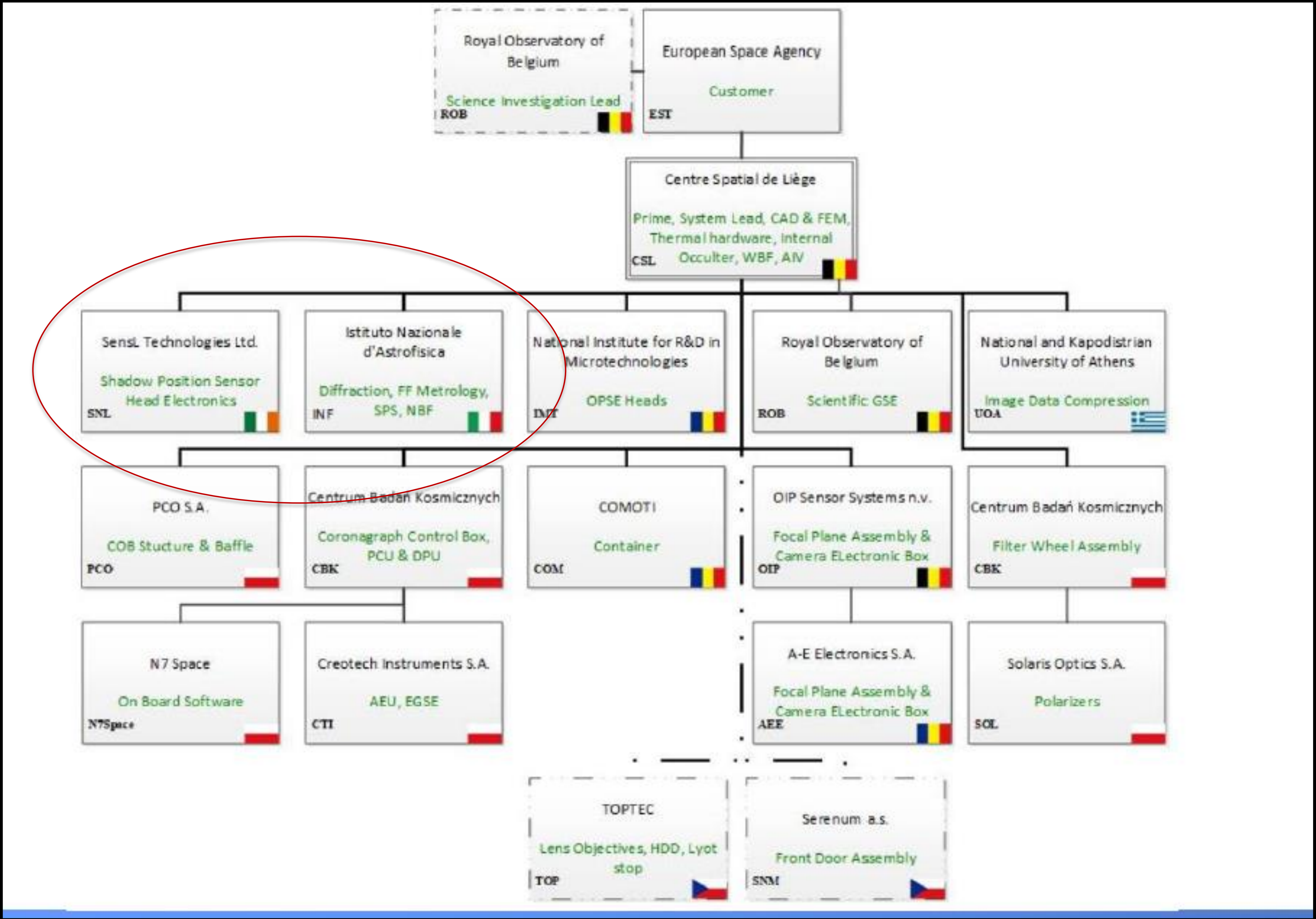


Why will PROBA-3/ASPIICS do the job?

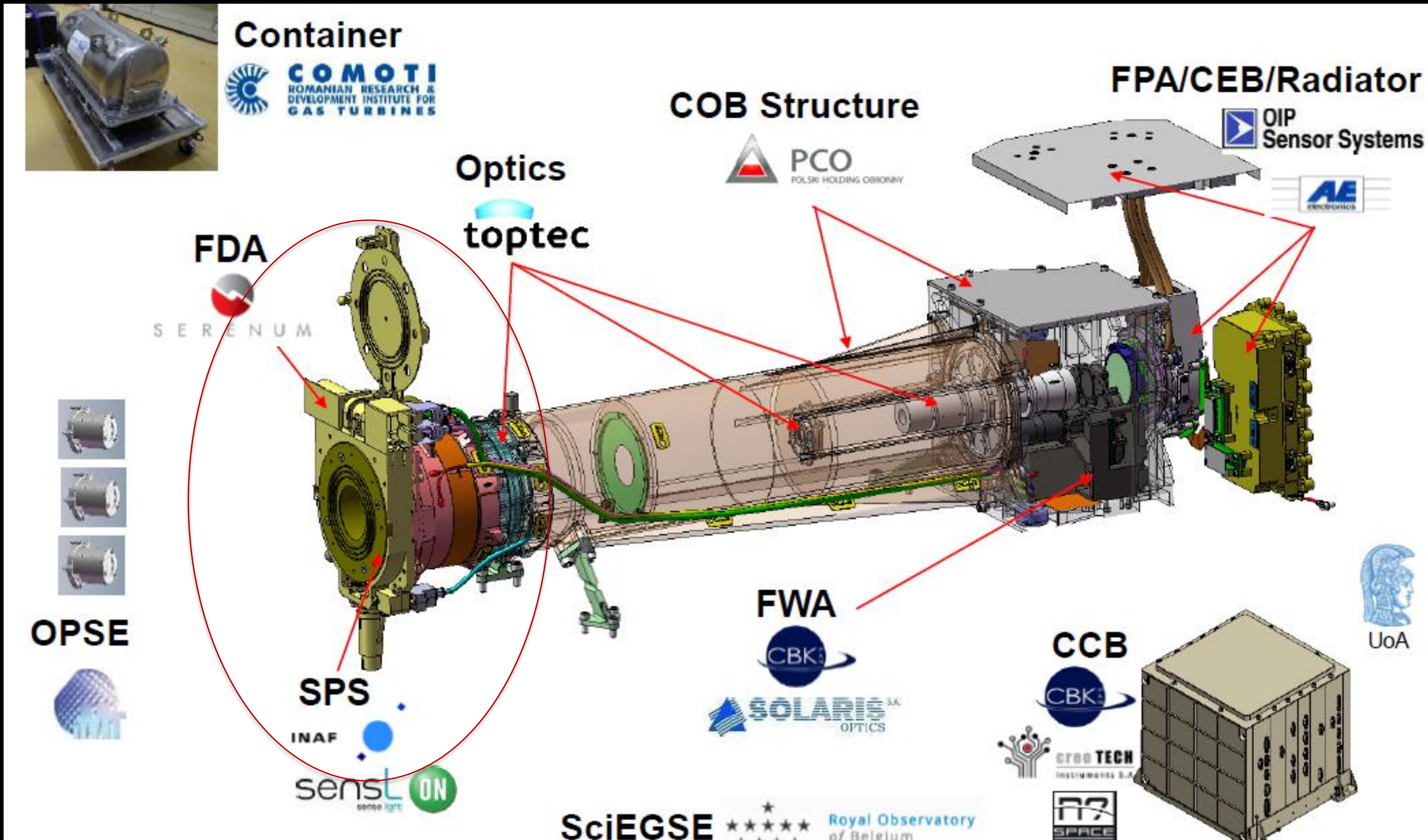
- The straylight critically depends on the distance between the external occulter and the entrance pupil.
- In ASPIICS, this distance is around two orders of magnitude larger than that in any other coronagraph built so far.
- This increase of distance allows in the same time:
  - to reduce the position of the inner edge of the field of view from 2.2 R⊙ (LASCO C2) to 1.098 R⊙ (ASPIICS),
  - to have the straylight 5 times lower than that in other coronagraphs.



PROBA-3/ASPIICS Industrial Organization

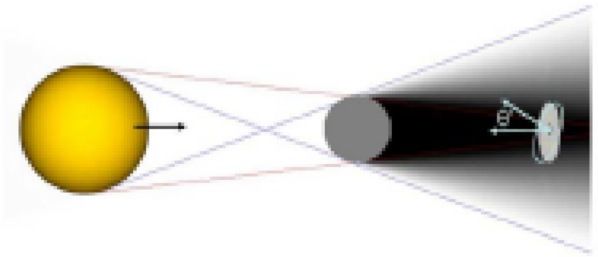


ASPIICS Overview



Italy's Contribution to PROBA-3/ASPIICS: Formation-flying Metrology System

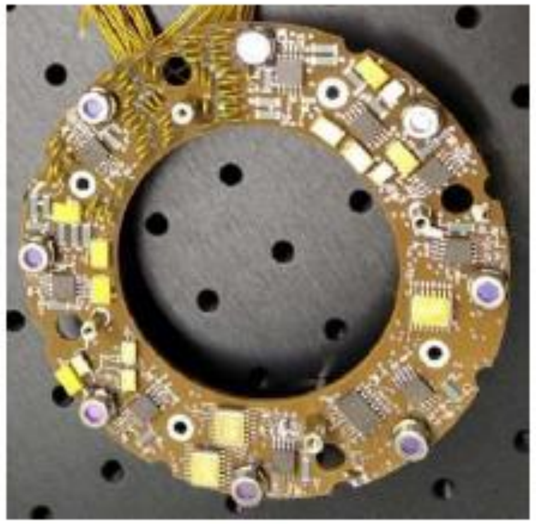
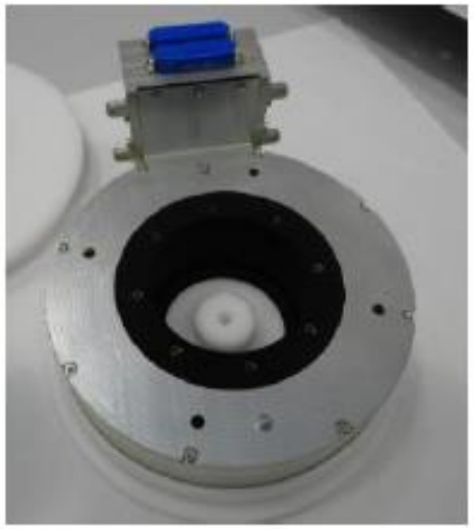
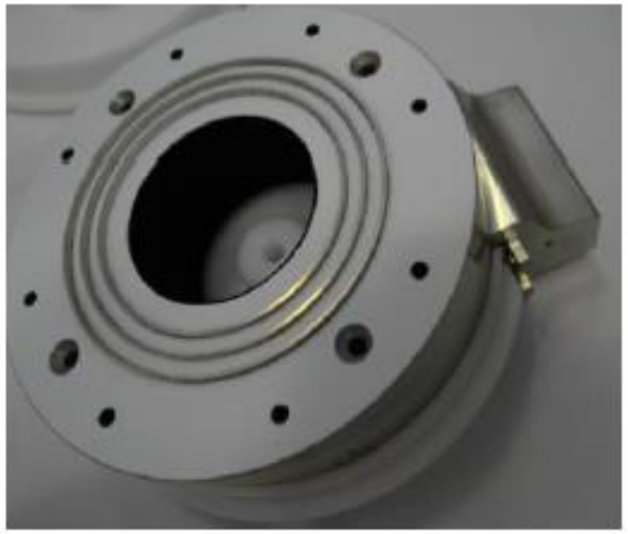
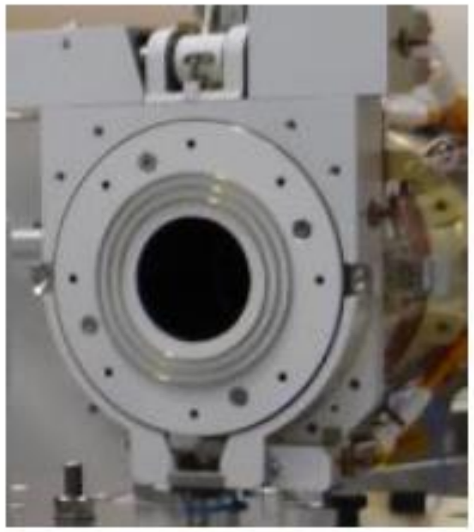
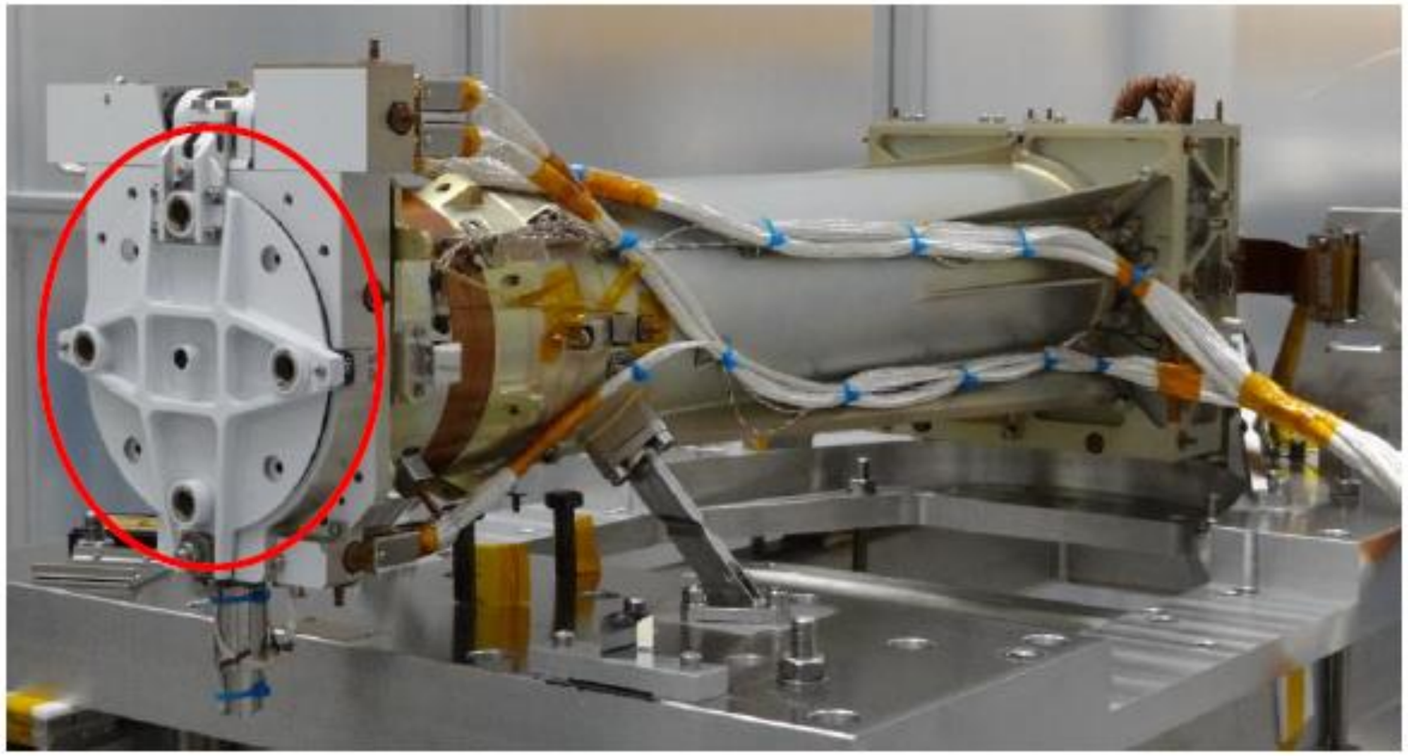
- Shadow Position Sensor (SPS)
  - 8 photodiodes surrounding the coronagraph pupil
  - On-board algorithm for position estimation with respect to shadow



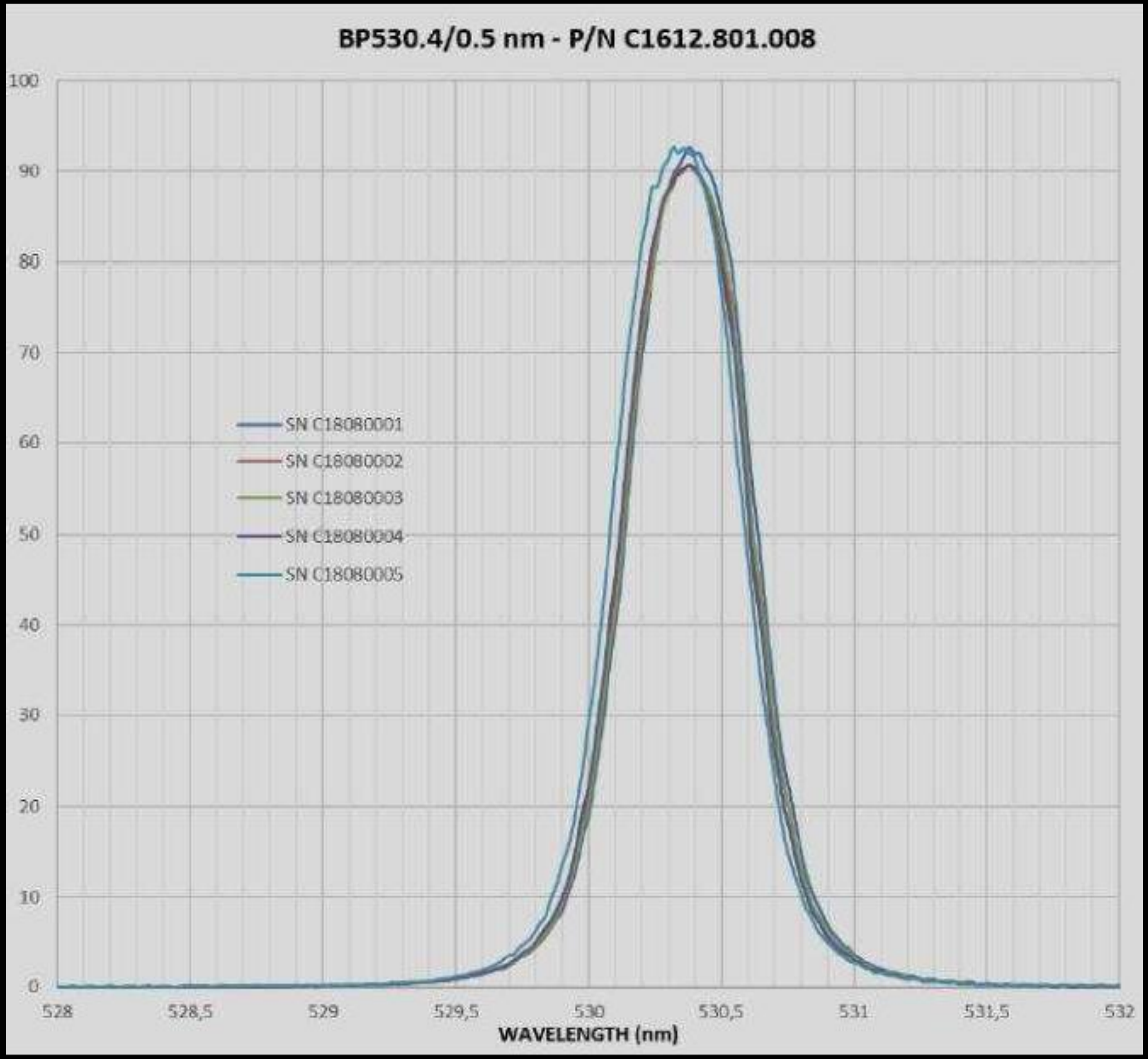
- SPS: 8 SiPM (Silicon PhotoMultiplier) assembled, together with the control electronics, within a mechanical flange installed in front of the ASPIICS telescope
- SPS will monitor the symmetry of the shadow generated by the occulter on the ASPIICS's pupil plane
- A specialized algorithm will measure with a high accuracy (<0,5mm) any displacement of the shadow with respect to the telescope reference system

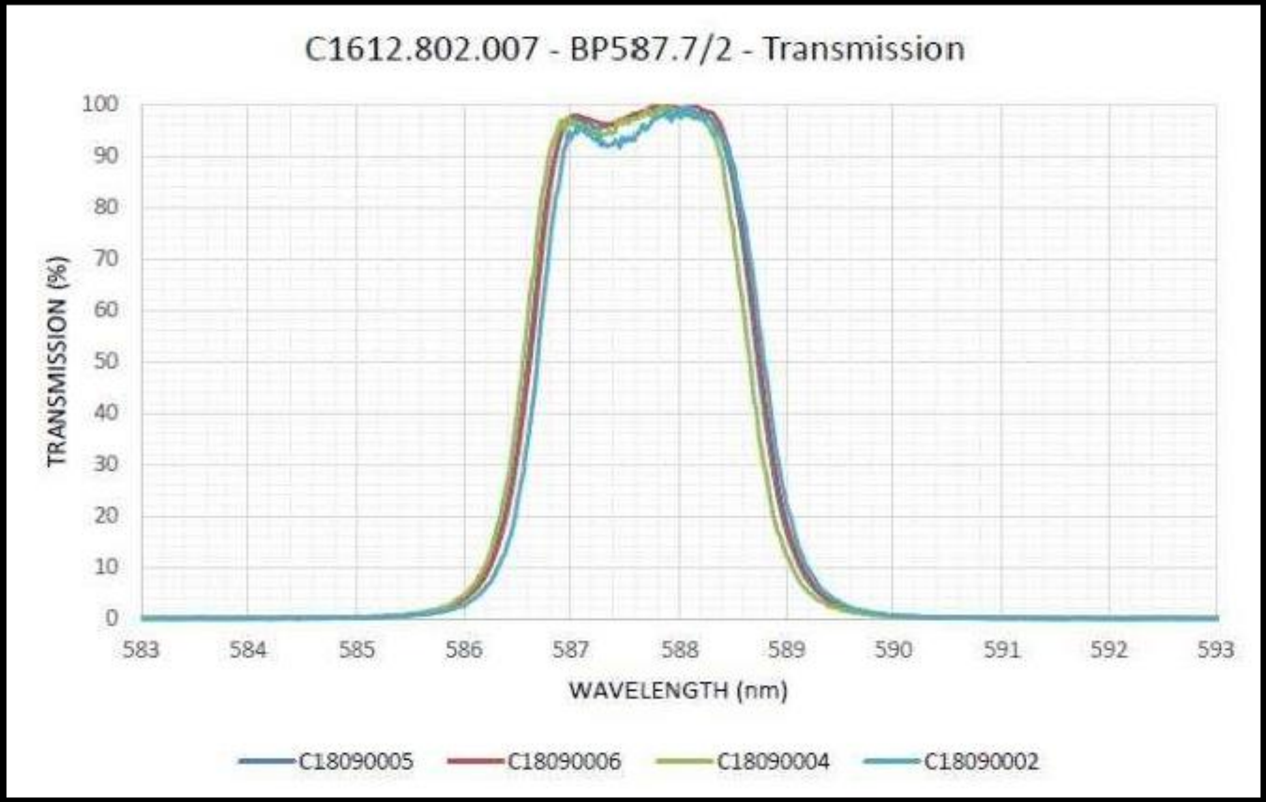
INAF Shadow Positioning Sensors and formation-flying for ASPIICS/PROBA-3

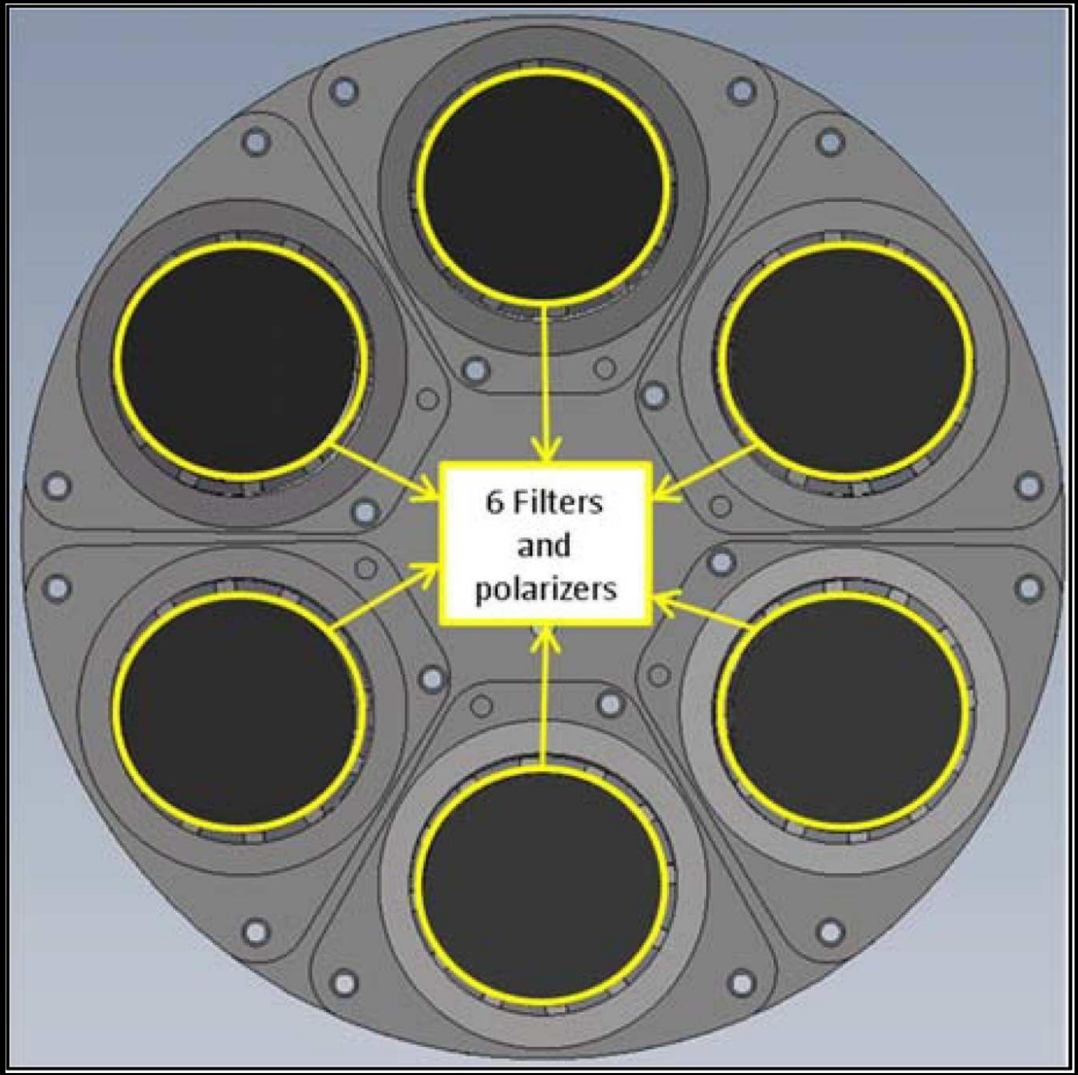
SPS FM successfully tested (FFT) and baked-out

INAF-Filters for ASPIICS





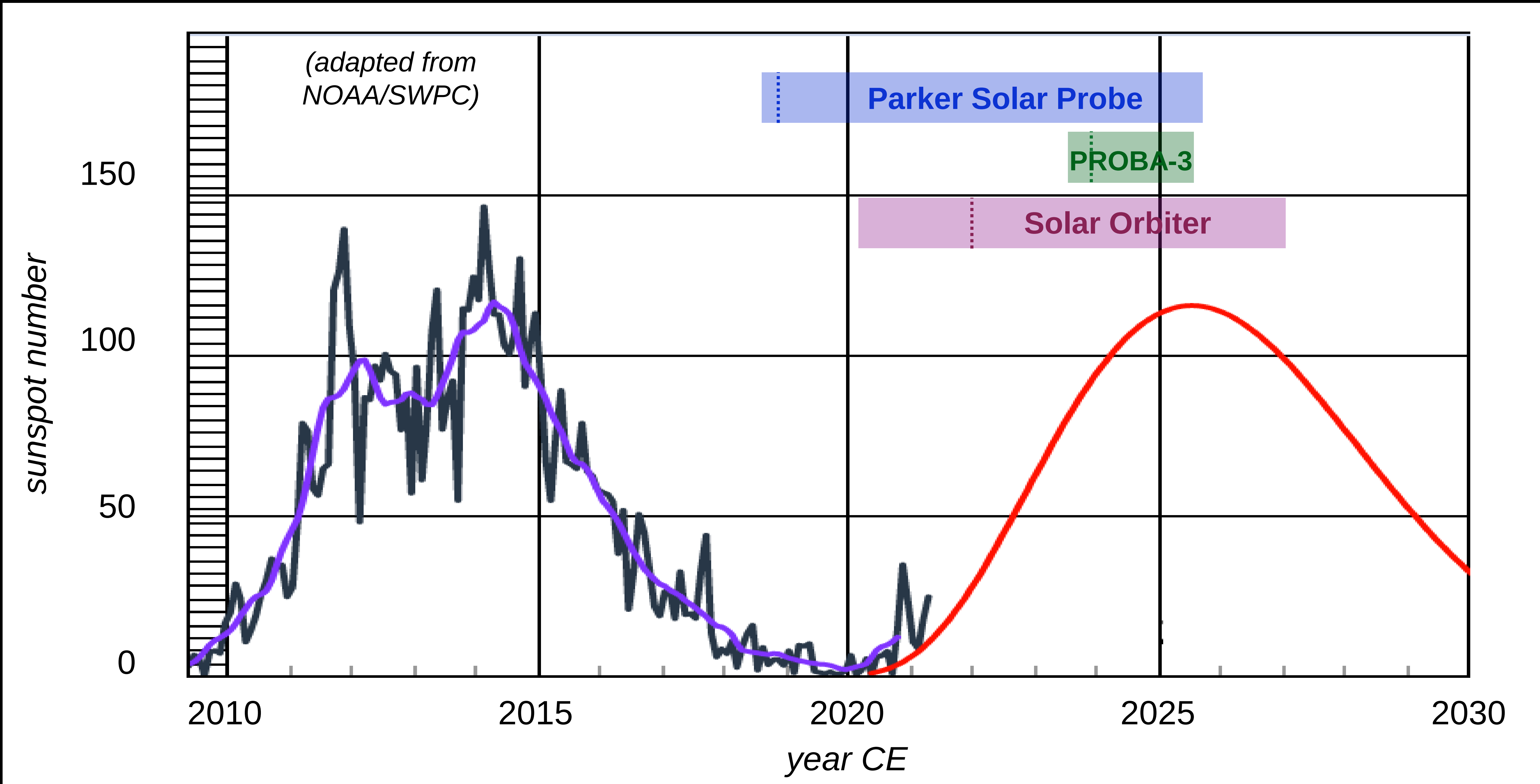


BP filter 530.4/0.6 nm

BP filter 587.7/2 nm

ASPIICS Calibration in the INAF Optical Payload Systems (OPSys) Facility

PROBA-3 in synergy with other missions with INAF participation



ASPIICS Team & INAF Leadership

ASPIICS Team

- INAF – Turin Astrophysical Obs. (**Lead-C-I Silvano Fineschi**)
- INAF – Capodimonte Astronomical Observatory, Naples
- INAF – Catania Astrophysical Observatory
- University of Florence

15. Team Summary

15. Personale INAF coinvolto

Numero di partecipanti INAF al progetto: 15

Struttura	Nfte	N0	TI 21	TI 22	TI 23	TD 21	TD 22	TD 23	Nex	Extra
O.A. TORINO	11	0	1.70	1.90	2.00	0	0	0	0	0.00
O.A. CAPODIMONTE	1	0	0.10	0.10	0.10	0	0	0	0	0.00
O.A. CATANIA	2	0	0.35	0.45	0.45	0	0	0	0	0.00
Totali	14	0	**2.15**	**2.45**	**2.55**	**0.00**	**0.00**	**0.00**	0	**0.00**

16. Personale Associato INAF coinvolto

Numero di partecipanti Associati INAF: 2

#	Struttura	TI 2021	TI 2022	TI 2023	TD 2021	TD 2022	TD 2023	Extra
1	NASA/GSFC	0	0	0	0.10	0.10	0.10	0.00
2	Università degli Studi di Firenze	0.10	0.10	0.10	0	0	0	0.00
	Totali	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.00**

Criticalità

- **Finanziamento ESA solo fino al commissioning:**
  2023 Giugno + 6 mesi
- **Finanziamento per i due anni di operazioni**
  scientifiche (2023-2025) – da acquisire
- **Possibile inclusione delle operazioni di ASPIICS/PROBA-3 nel rinnovo del contratto ASI (2022-2025) per le operazioni di Metis-Solar Orbiter?**


Thank you
for your attention!