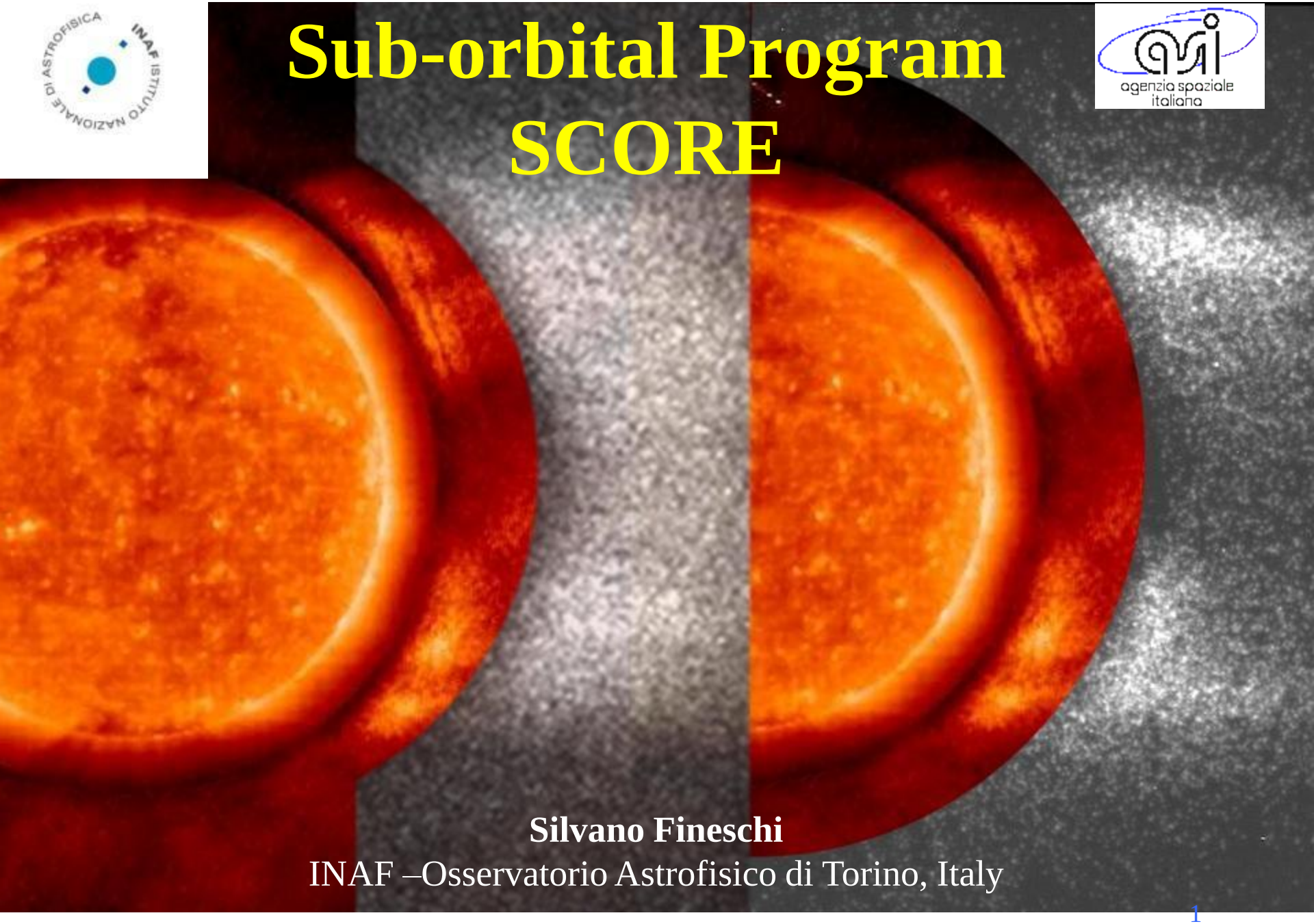
Sub-orbital Program SCORE



Silvano Fineschi
INAF –Osservatorio Astrofisico di Torino, Italy

“Esplorazione Sistema Solare” Contratto ASI 2007-2010

Angioletta Coradini
Ester Antonucci

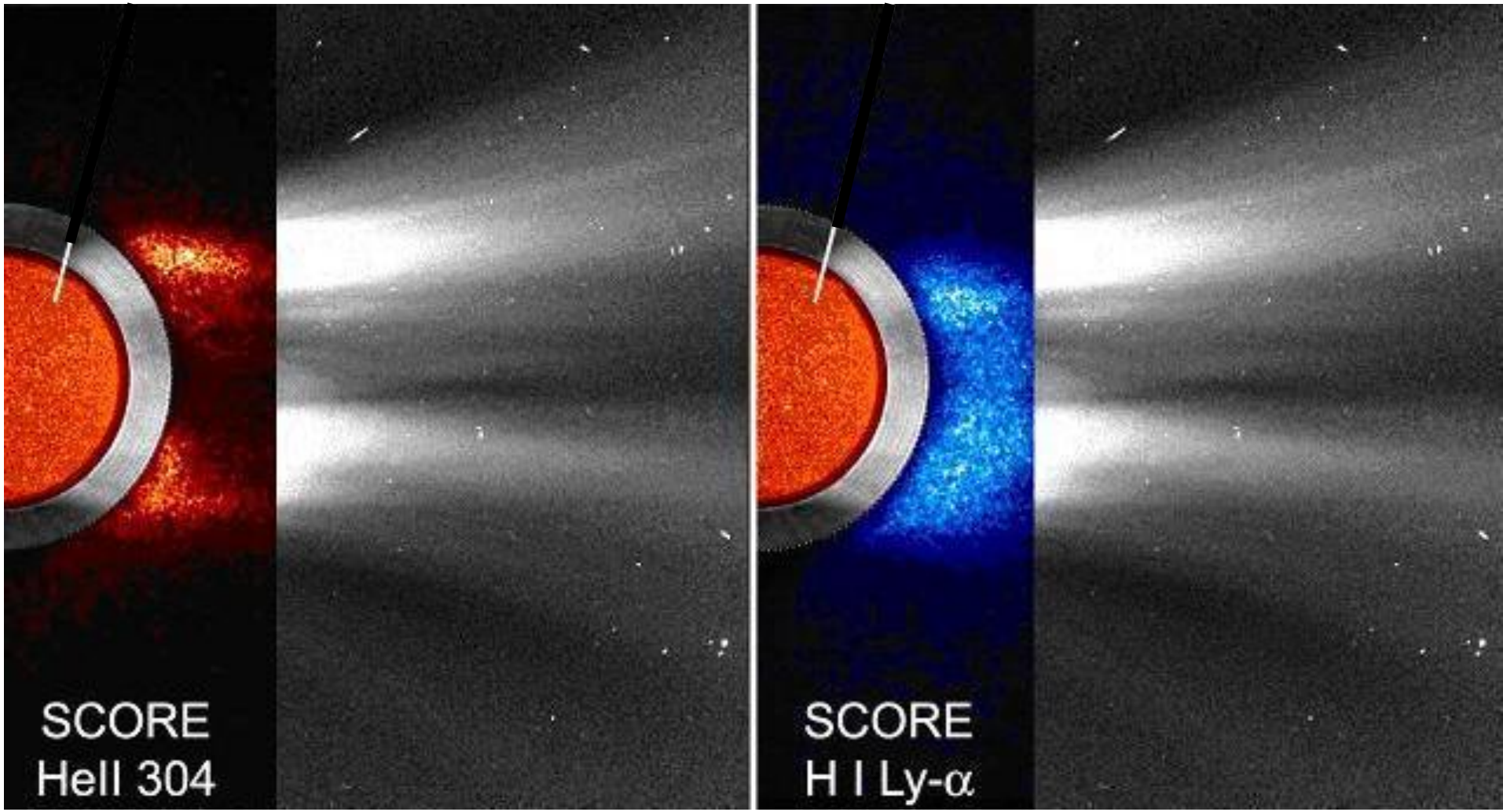
Contratto ASI n. I/015/07/0

Studio Esplorazione Sistema Solare
Contratto ASI n. I/015/07/0

- TASK 2400 – **'Esperimenti di laboratorio'** (E. Antonucci)
  - Sub Task 02410 Sviluppo di ottiche per spettroscopia ad immagini UV e Vis. (S. Fineschi)
  - Sub Task 02420 Sviluppo e realizzazione di prototipi di coating ottici nell'UV (P. Nicolosi)
  - Sub Task 02440 Impianto di calibrazione e validazione di coronografi spaziali (S. Fineschi)
-

Sub-orbital Program

SCORE:
Sounding-rocket Coronagraphic Experiment



The Role of He in the Solar Corona

- Multi-fluid simulations attribute the near constancy of the solar wind hydrogen flux to a regulatory role played by helium in the corona (Geiss et al. 1970; Bürgi 1992; Hansteen et al. 1994,1997).

- Helium does not couple as strongly to the gravitational and pressure gradients in the corona as hydrogen. Instead helium is reliant on Coulomb collisions with protons.

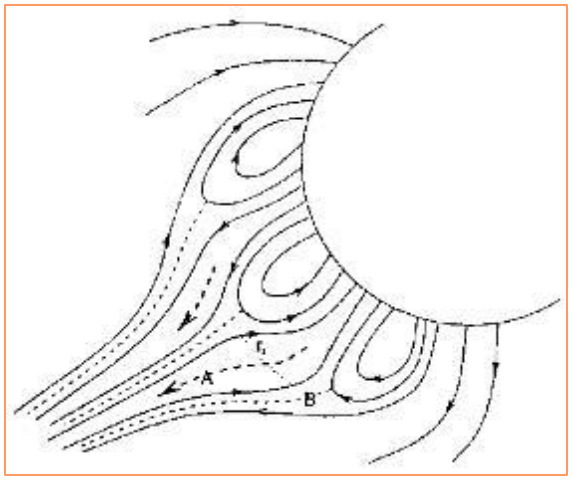
- Helium may enter cyclotron resonance with cascading turbulent Alfve´nic fluctuations in the corona (UVCS)

Questions
(a few of the many …)

- Where and how are high-frequency (10-10 kHz) coronal MHD waves generated? (e.g., UVCS)

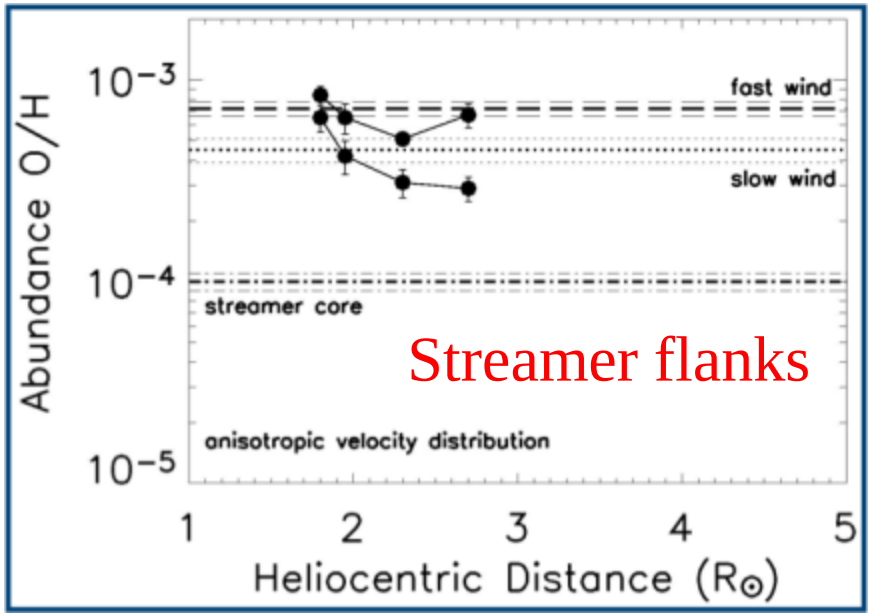
- What is the apportionment of energy flux dissipated into p+ and He^{2+} ?

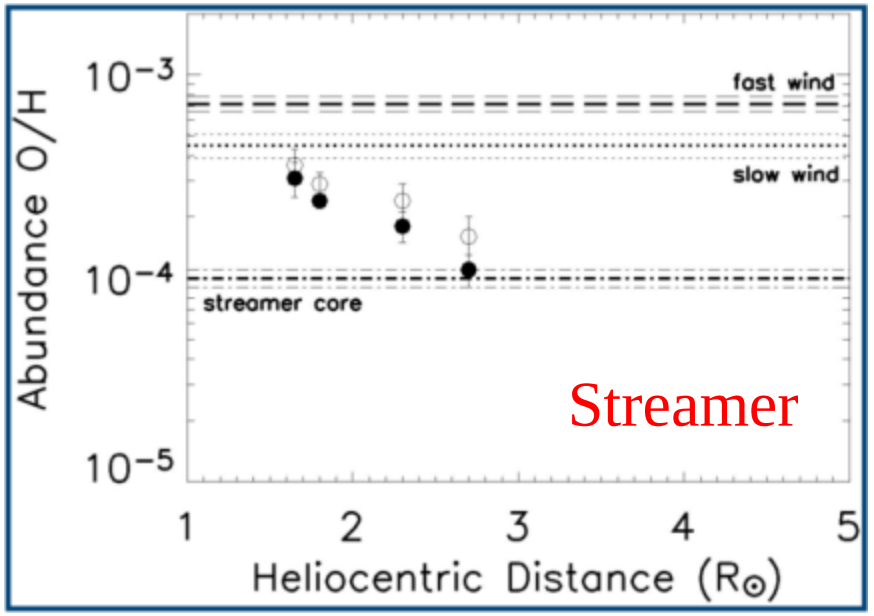
- What are the sources of fast and slow solar wind?



Slow Solar Wind Origin

(Noci 1996)





(Antonucci 2006)

HERSCHEL Payload

(HElium Resonance Scattering in Corona & HELiosphere)

NASA/ASI sounding-rocket payload: P.I. : J.D. Moses (US NRL)

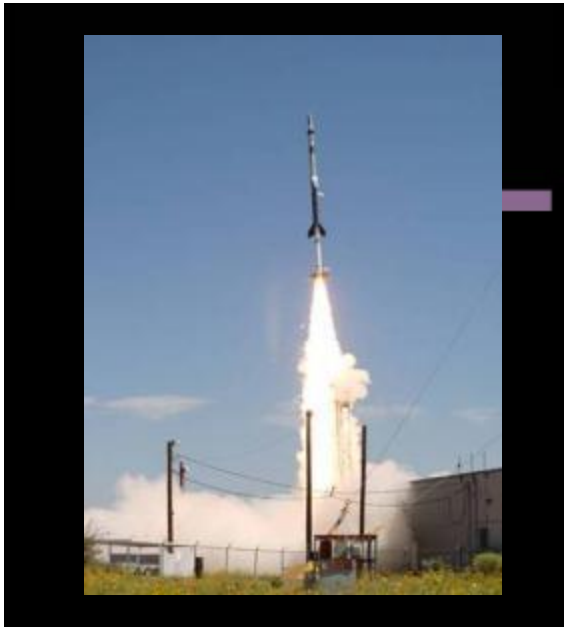
- **Selected in 2003 – NASA Living With a Star Program**
  Targeted Research & Technology

SCORE (Sounding-rocket CORonagraphic Experiment)

P.I.: E. Antonucci; Proj. Sci.: S. Fineschi; Instr. Sci. M. Romoli

- **Italian Space Agency (ASI) Italy**
- **INAF – Osservatorio Astronomico Torino**
- **Universita' di Firenze**
- **Universita' di Pavia**

- **HeCor Inst. Astrophys. Spatiale – France &NRL**
- **HEIT (HERSCHEL EUV Imager Tel.) US NRL**
- **Launched: 14 September 2009**



SCORE Science

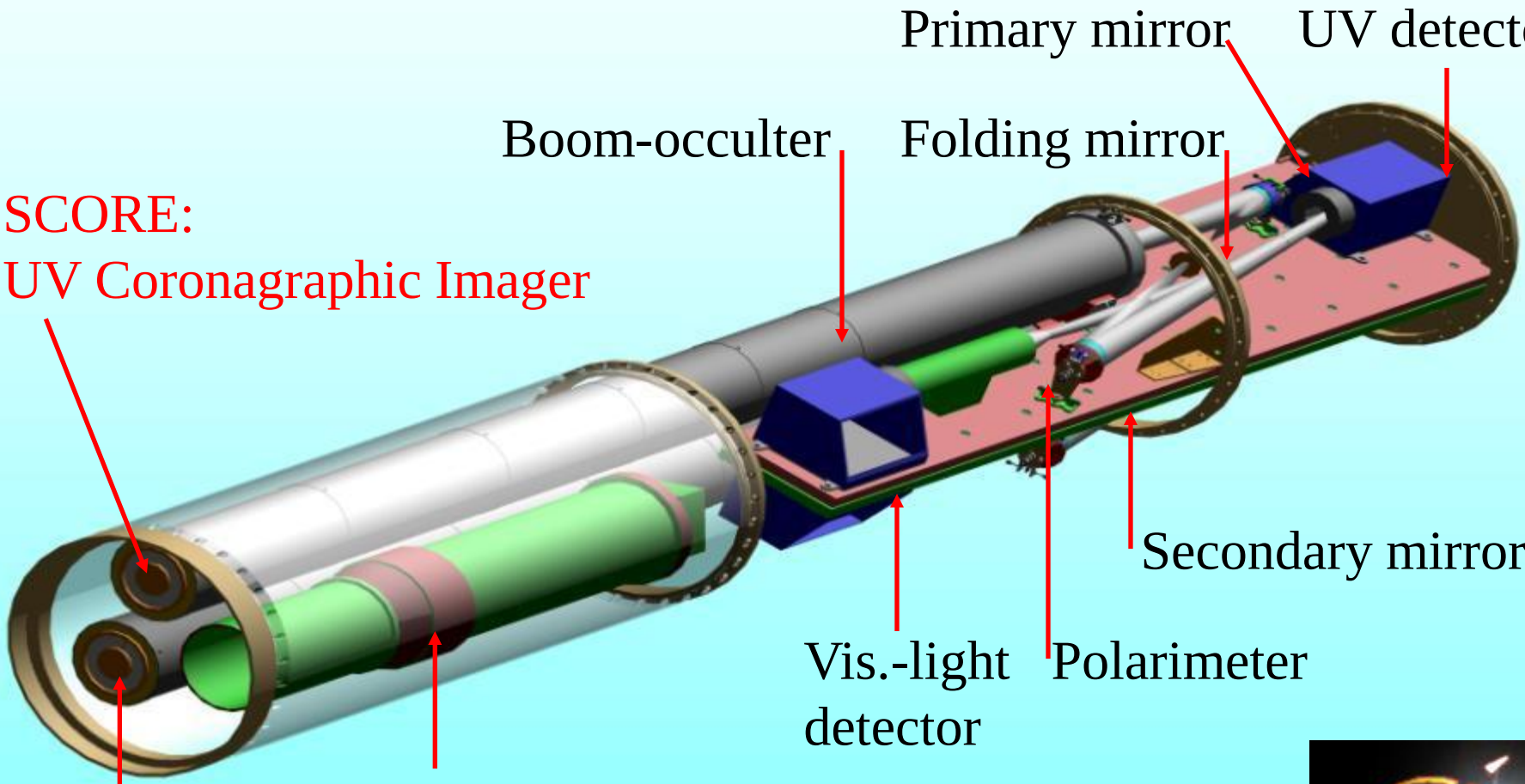
- **Full Imaging of the extended corona (1.5 – 3.5 Ro) in EUV (30.4 nm), UV (121.6 nm), and visible light**

⇓

- **Helium absolute abundance in corona (i. e., He/H)**

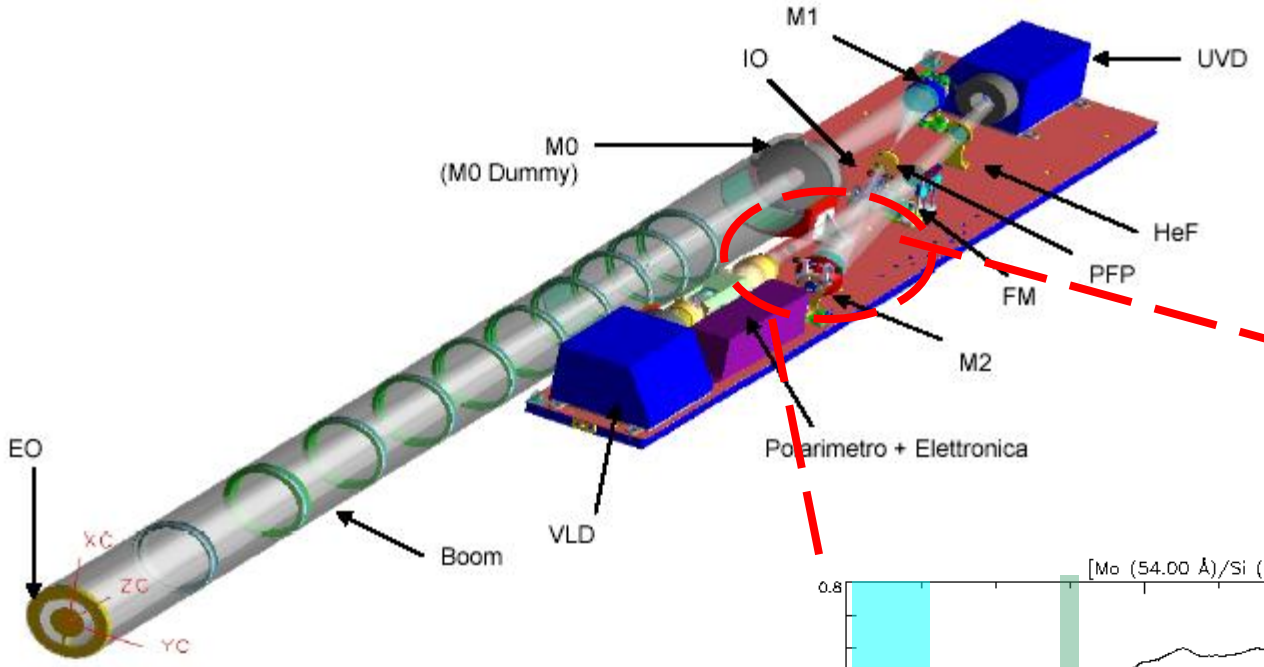
- **Density distribution in corona of H^0, He^+, and e^-**

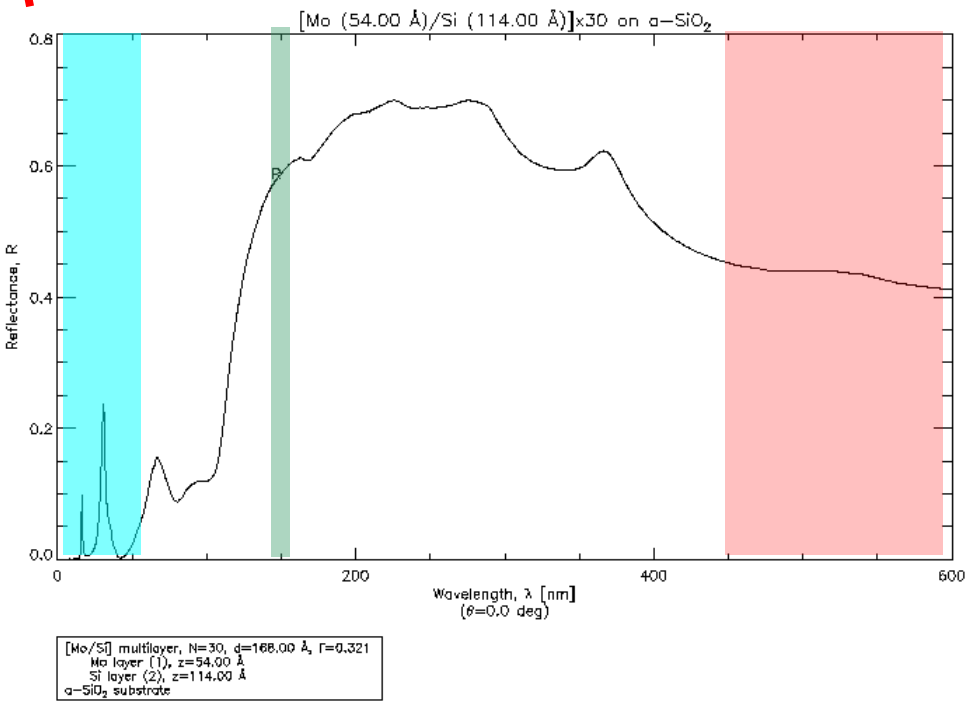
Sounding-Rocket Coronagraphic Experiment



INAF-Turin Observatory, U. Florence, U. Pavia, NRL

SCORE

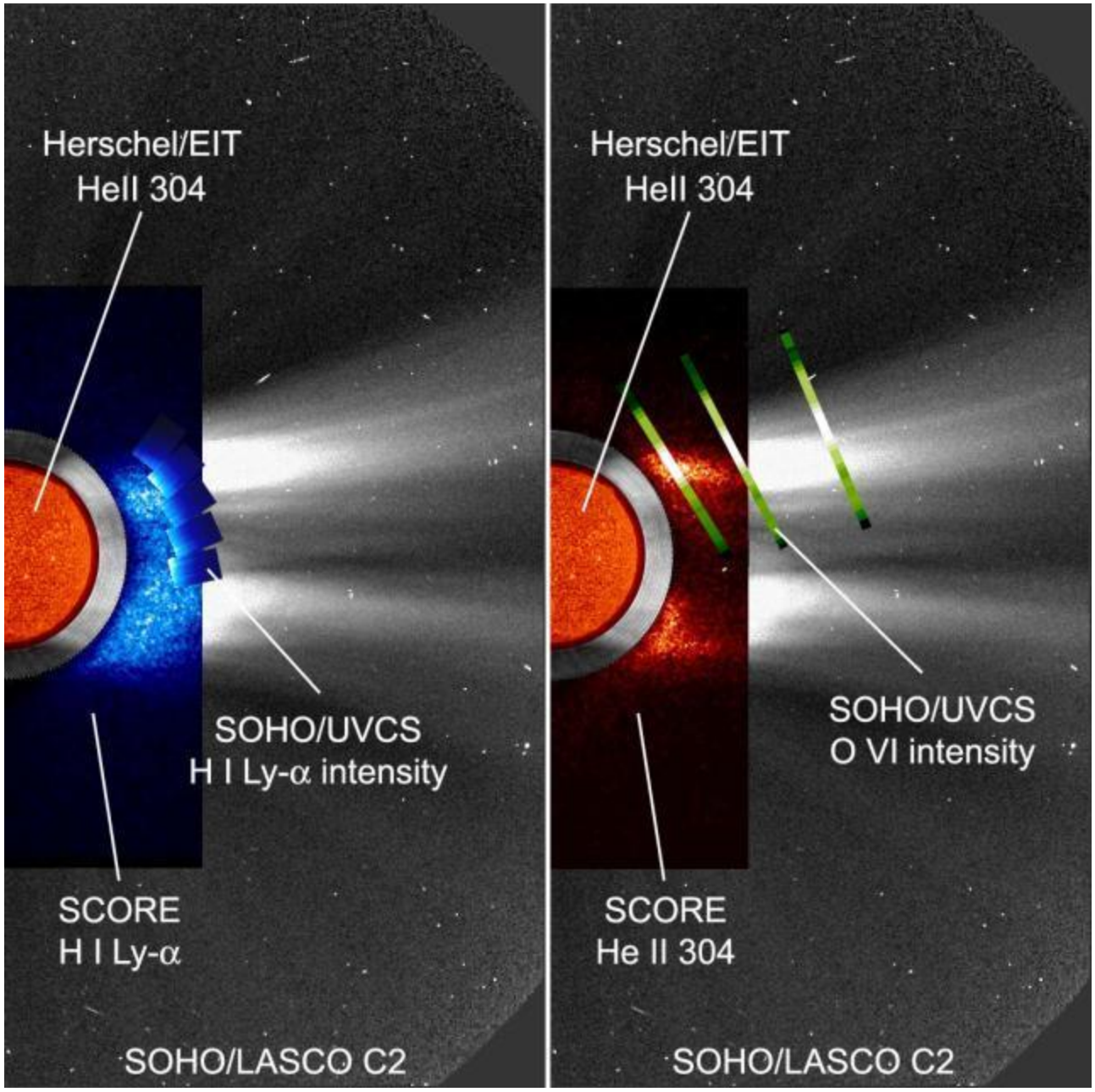




3-wavelength bands in 1 telescope optics

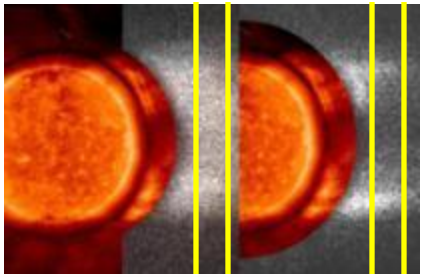
(ASI-ESS07 subtask 2420)

First Observation of coronal He^{+} &H^{0}



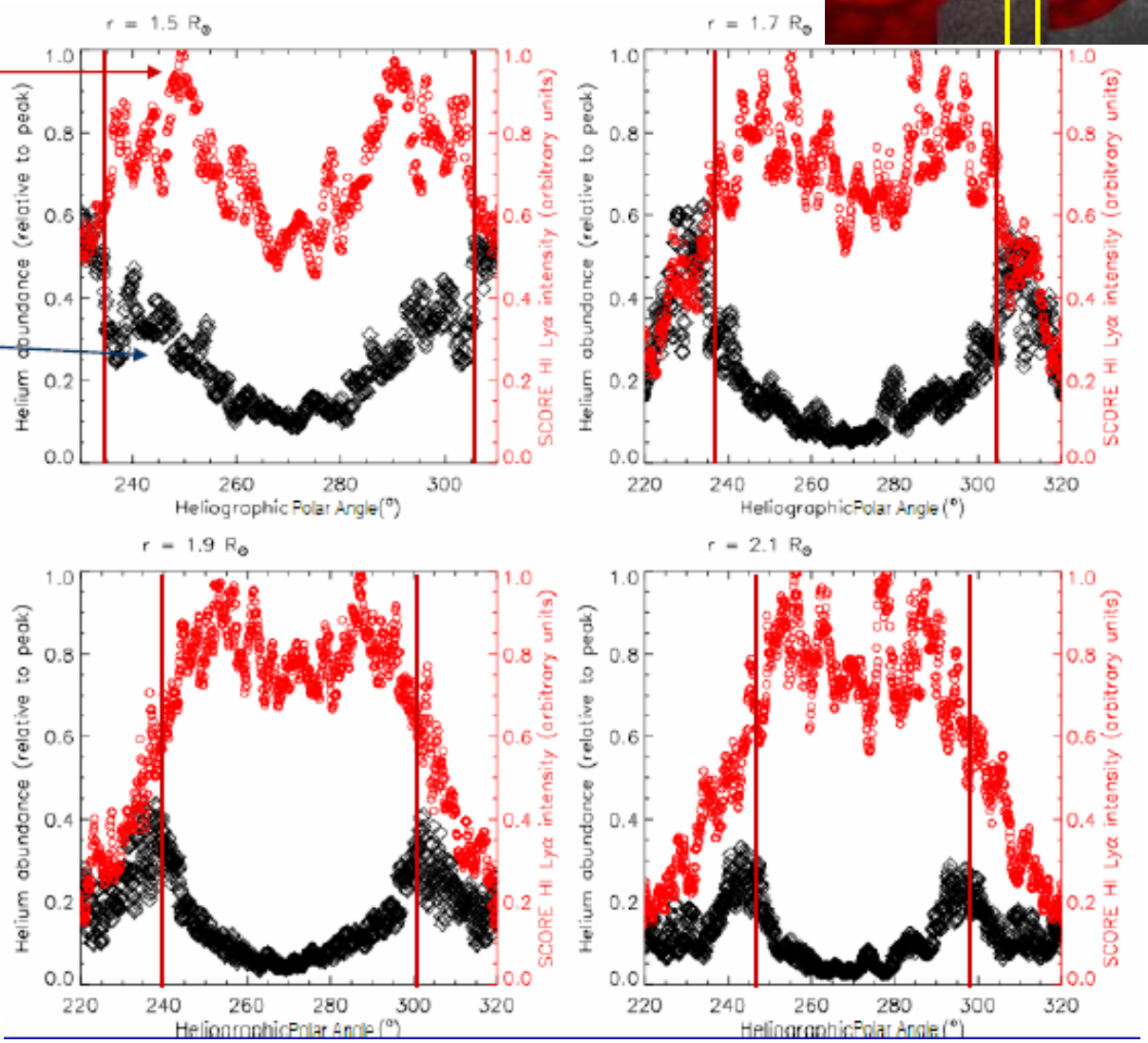
SCORE & SOHO/ UVCS, LASCO coordinated observations

He Abundance Enhancement Peaks at Boundary Between Streamer and Polar Coronal Holes



Hydrogen Ly-α Intensity
(Boundary of streamer defined as 1/e drop in intensity)

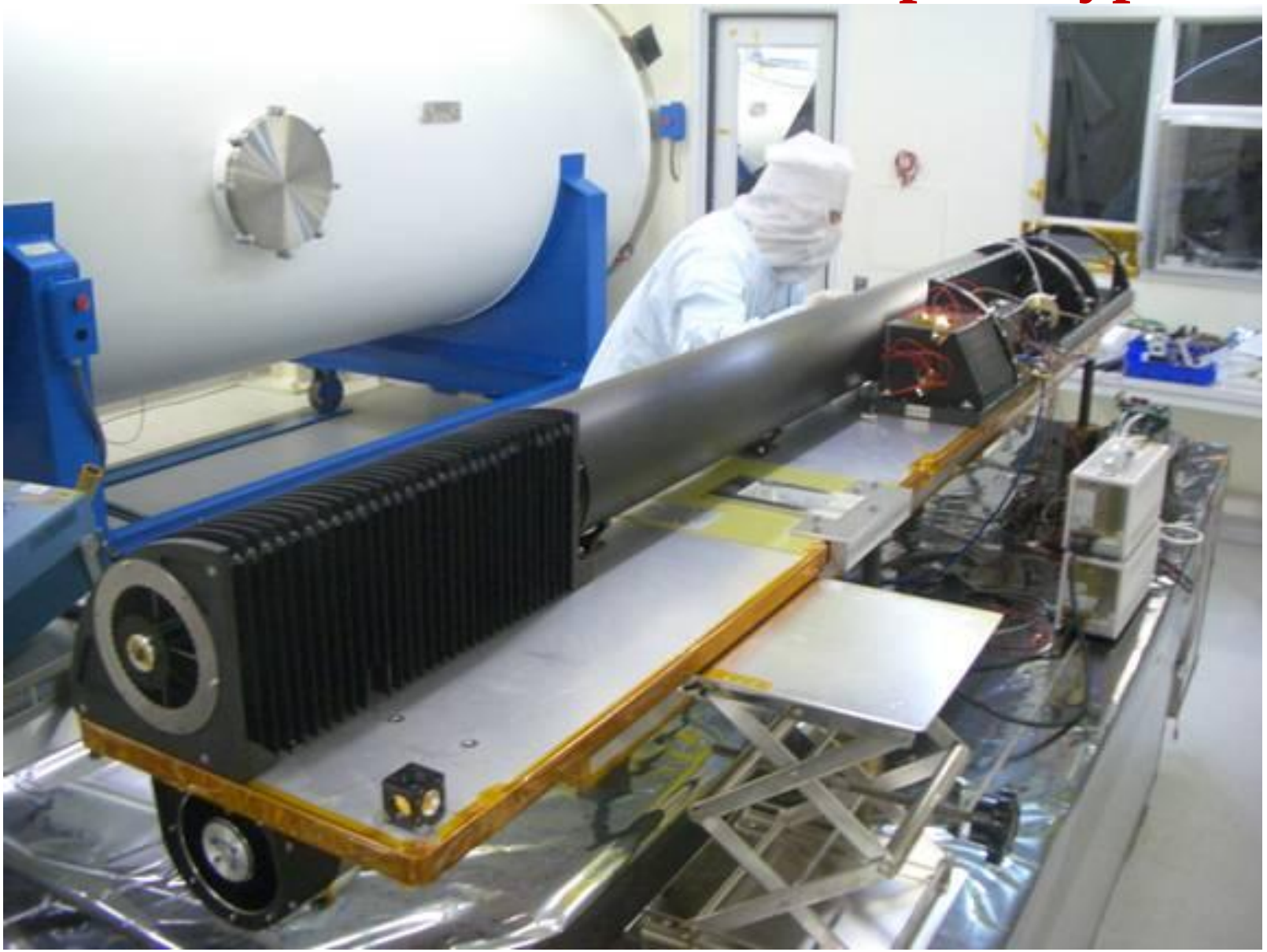
Relative He Abundance



The He abundance distribution might be:

1) Stagnation of helium ions in the slow wind region close to the boundary (Antonucci, 2006);
2) Coulomb friction in the slow wind (Fineschi, Ofman et al. 2002).

SCORE: METIS sub-orbital prototype



OPSys (Optical Payoad Systems) Facility

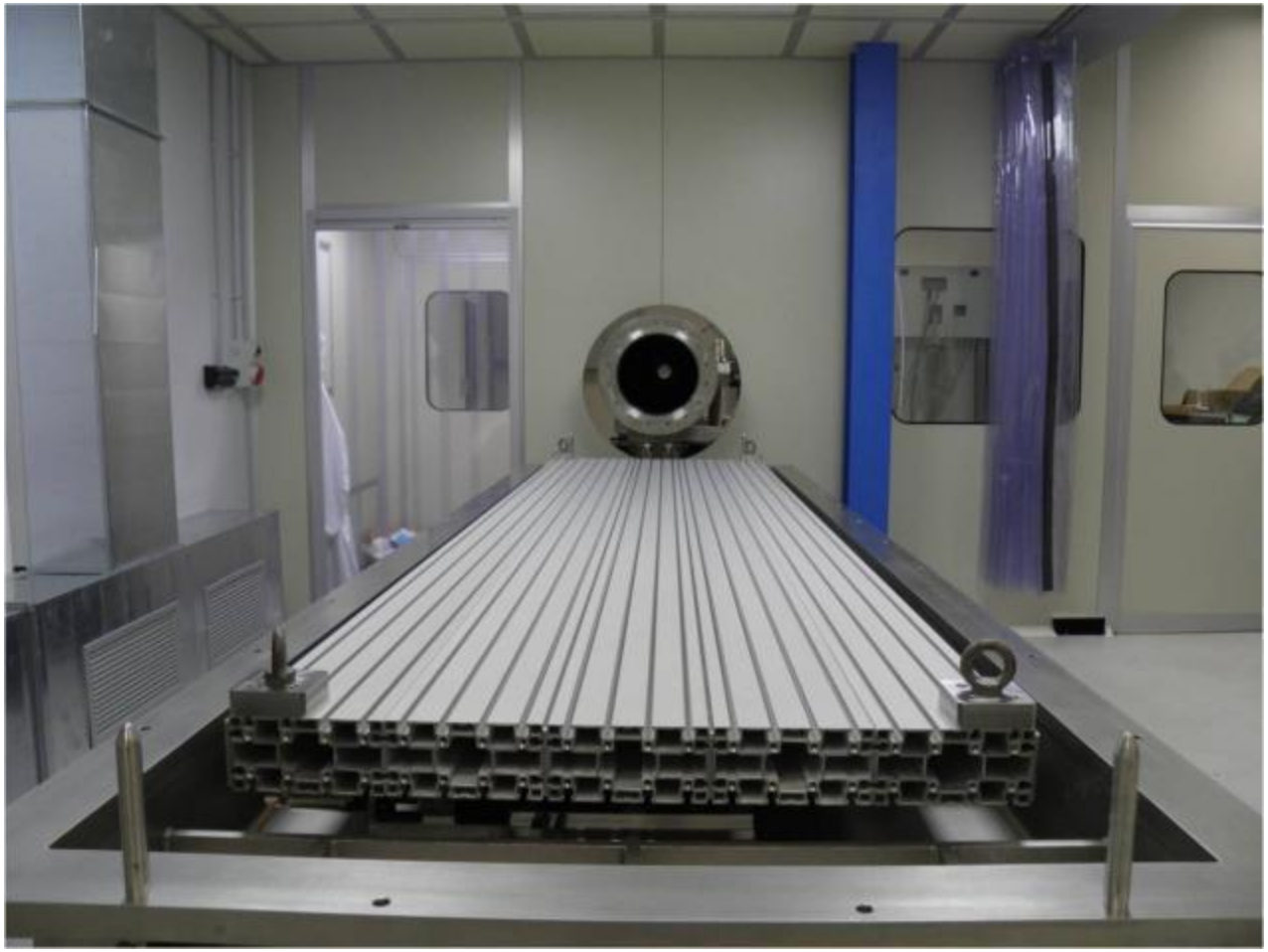
(Regione Piemonte 2006; ASI-ESS/07 subtask 2440)

SCORE Integration & Turin OPSys Facility

Dimensione esterne camera a vuoto (sez. semicircolare) (1080x4000x880) mm^3

- Sezione pompe: Ø 400 mm, L = 1850 mm
- Sez. raccordo e sorgenti: Ø 400 mm, L = 2550mm + Ø 600 mm, L = 2050 mm

- Opening of the tests section with optical bench in clean area ISO 5/6

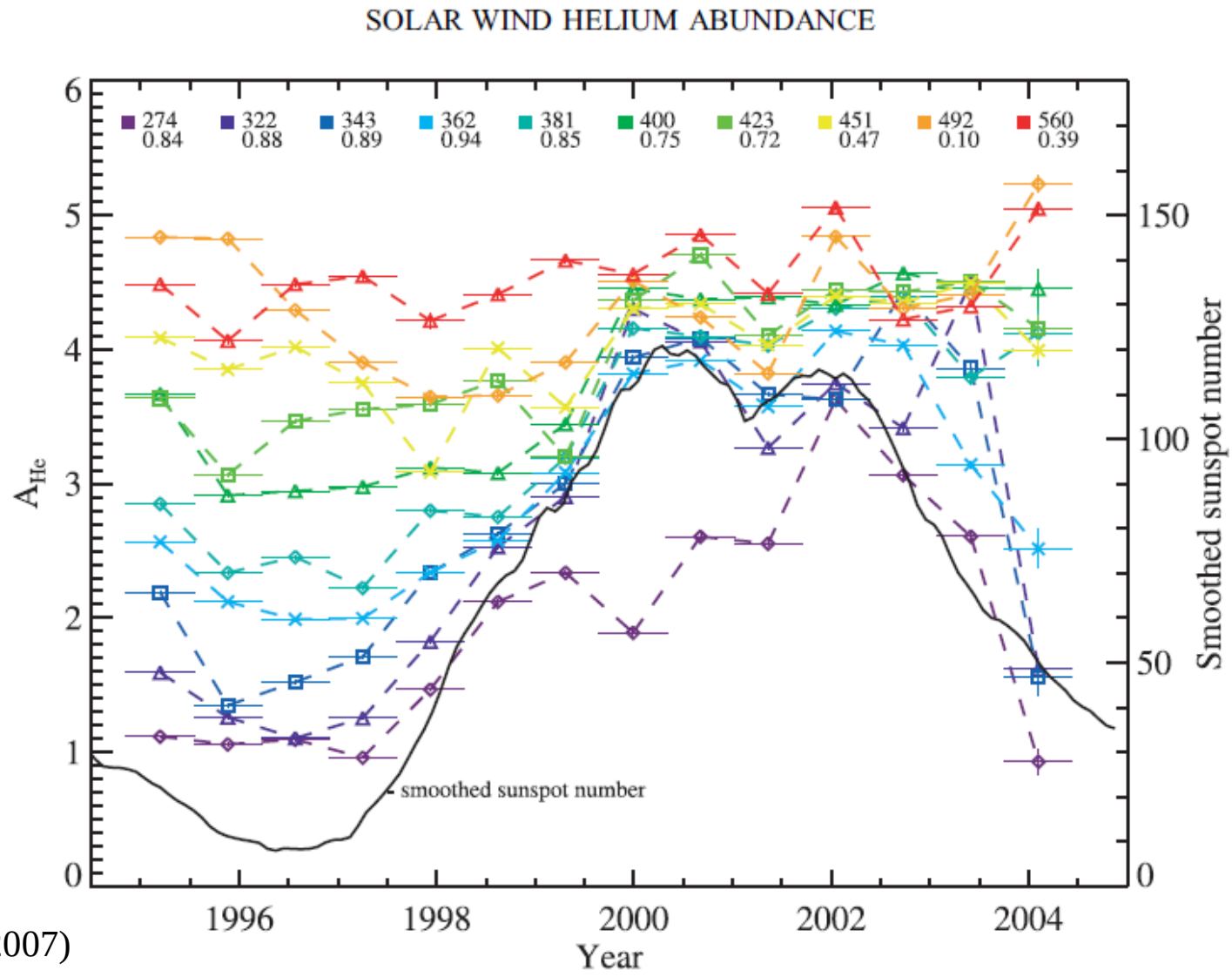


- Motorized vacuum optical bench

Continuation and Follow-ups of the Sub-orbital Program

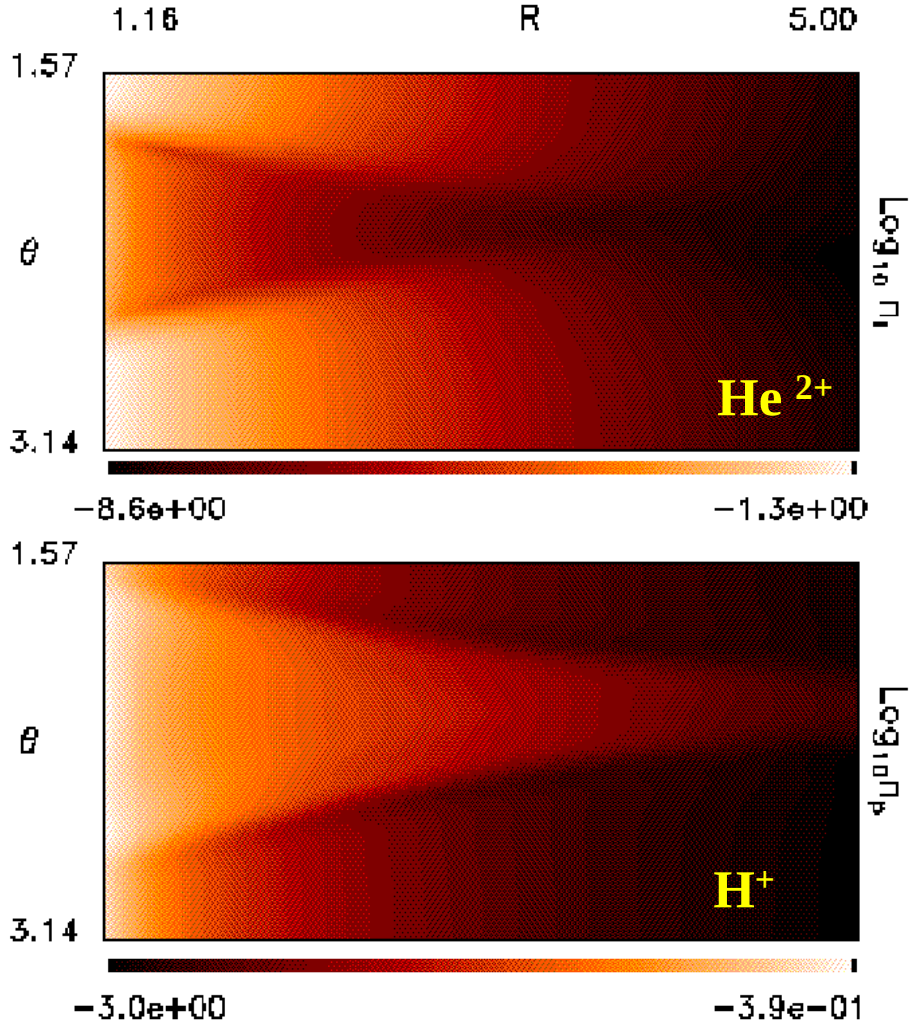
- Proposal HERSCHEL re-flight submitted in 2012 in response to NASA-ROSES 12
- Proposal baloon flight with LC Lyot filter submitted in 2012 in response to NASA-ROSES 12
- OPSys sun-simulator: external occulters optimization.
- Solar Orbiter METIS – Multi-Element Telescope for Imaging and Spectroscopy (3-wavelength coronagraph)

“in-situ” He abundance in slow solar wind is strongly correlated with solar activity



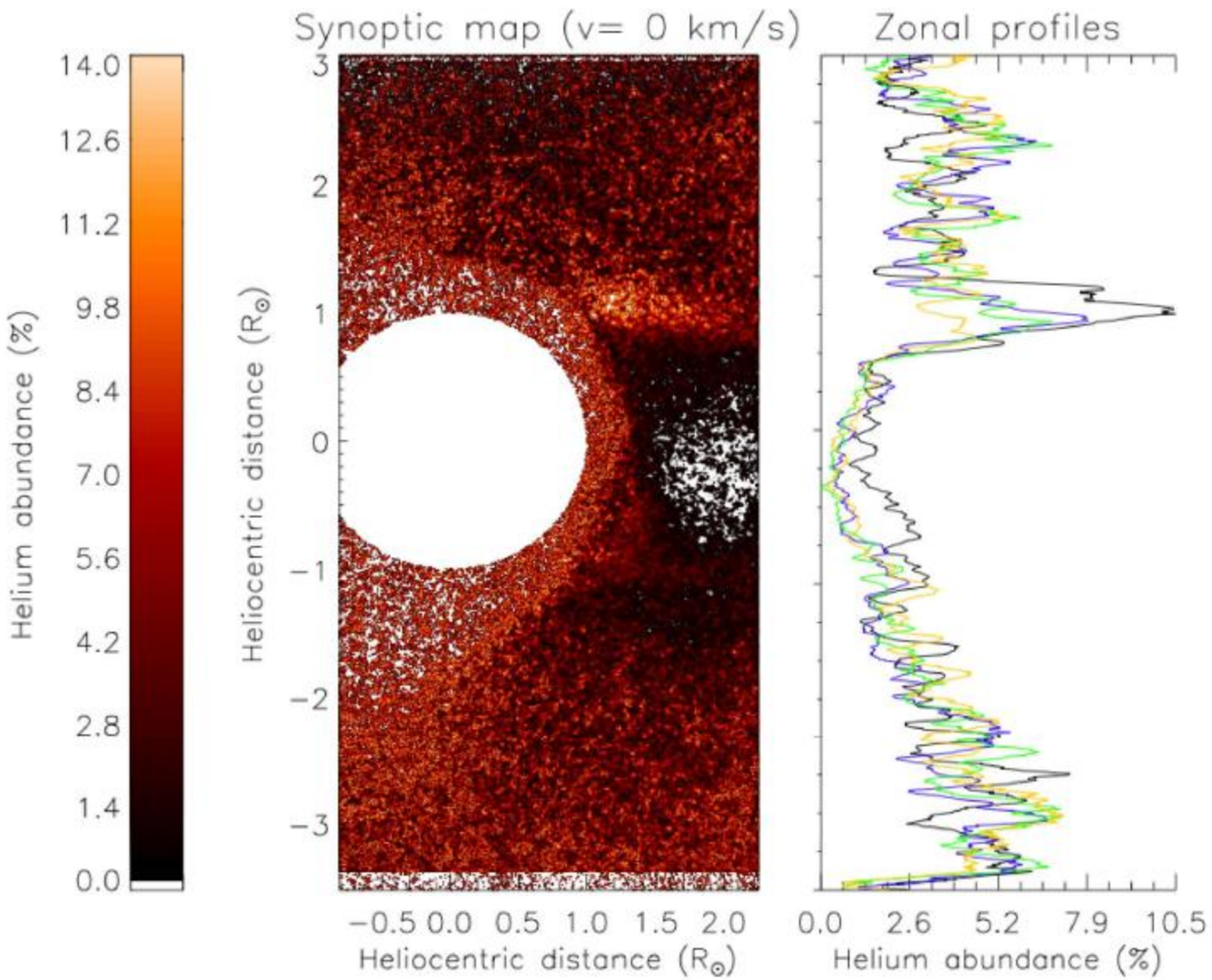
Kasper (2007)

Slow wind



2.D MHD model, quadrupolar global B (Fineschi & Ofman, 2002)

HERSCHEL 2009 flight (Moses, Antonucci, Fineschi, Romoli et al., 2010)


Synoptic map (v= 0 km/s)
Zonal profiles
Helium abundance (%)
14.0
12.6
11.2
9.8
8.4
7.0
5.6
4.2
2.8
1.4
0.0
Heliocentric distance (R⊙)
3
2
1
0
−1
−2
−3
−0.5 0.0 0.5 1.0 1.5 2.0
Heliocentric distance (R⊙)
0.0 2.6 5.2 7.9 10.5
Helium abundance (%)

SCORE: METIS sub-orbital prototype

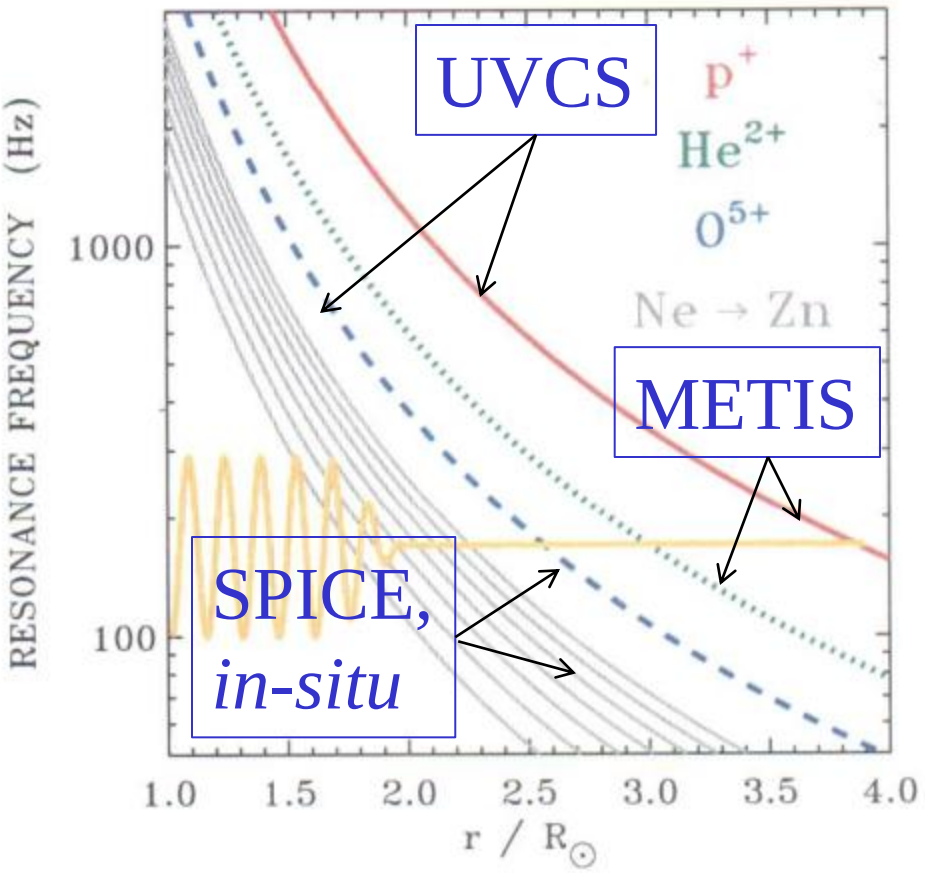
INAF-Turin Observatory, U. Florence, U. Pavia, NRL

Where and how are coronal waves generated?

It is well known that Alfvén waves are damped when their frequencies equal the local cyclotron frequencies of positive ions (proportional to magnetic field strength and q_{ion}/m_{ion}). [e.g., Cranmer et al. 1999, *Ap. J.*, 518, 937]

Since the magnetic field strength must decrease with height, waves propagating out from the base of the corona are resonant first with heavy, low abundance ions, then with lighter, more abundant ions. ⟶

New theoretical analysis shows that there exist a large number of ions (neon to zinc) that can totally damp out waves coming from very near the Sun BEFORE they can become resonant with any of the ions observed spectroscopically!



The most natural explanation is that there is an extended source of "replenishment" of the fluctuation power (i.e., gradual wave growth) high in coronal holes.

(by MHD turbulent cascade, plasma micro-instabilities)

What is the p+/He^{2+} apportionment of energy flux

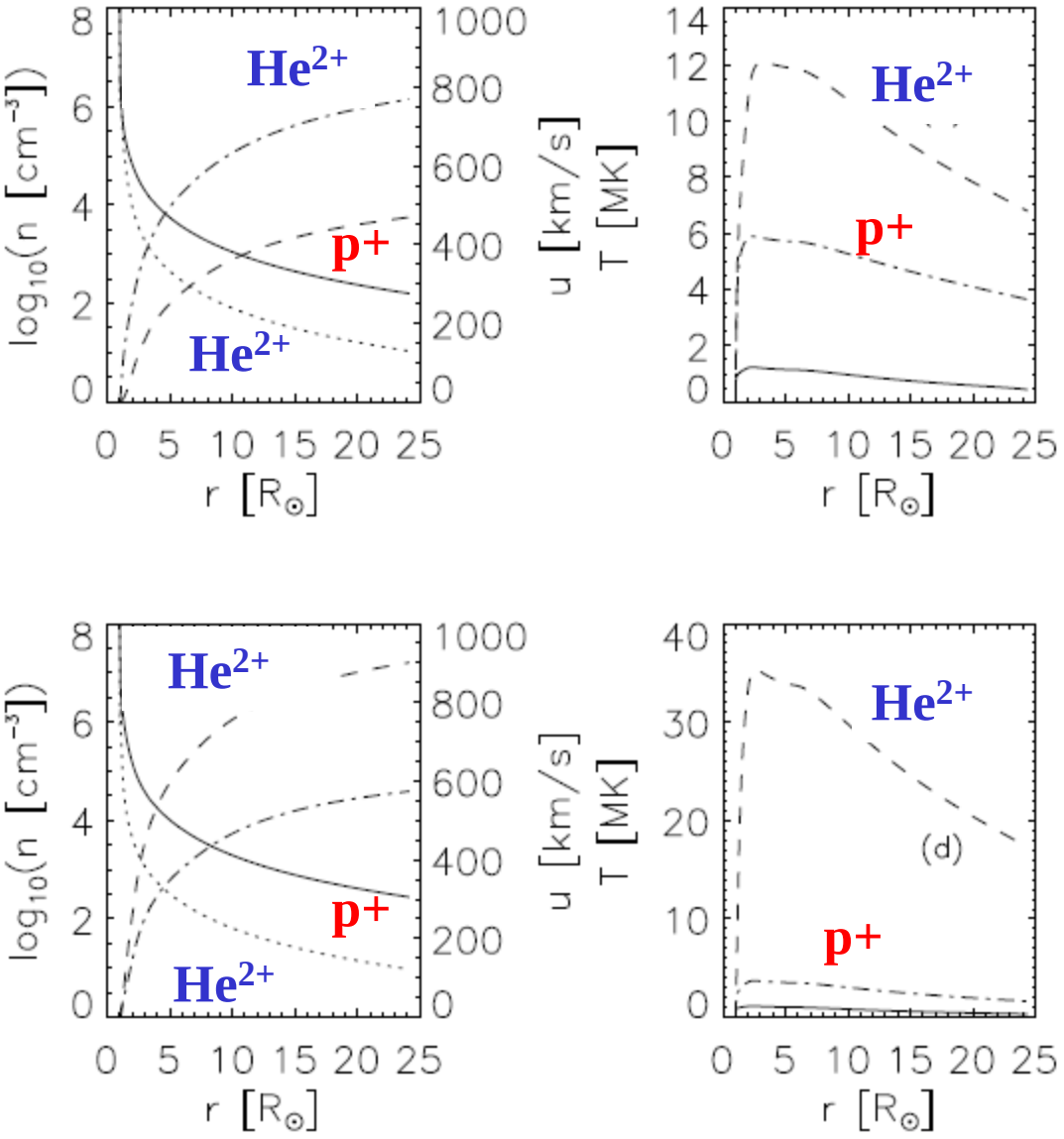
- Top row:

75% p+; 15% He^{2+}

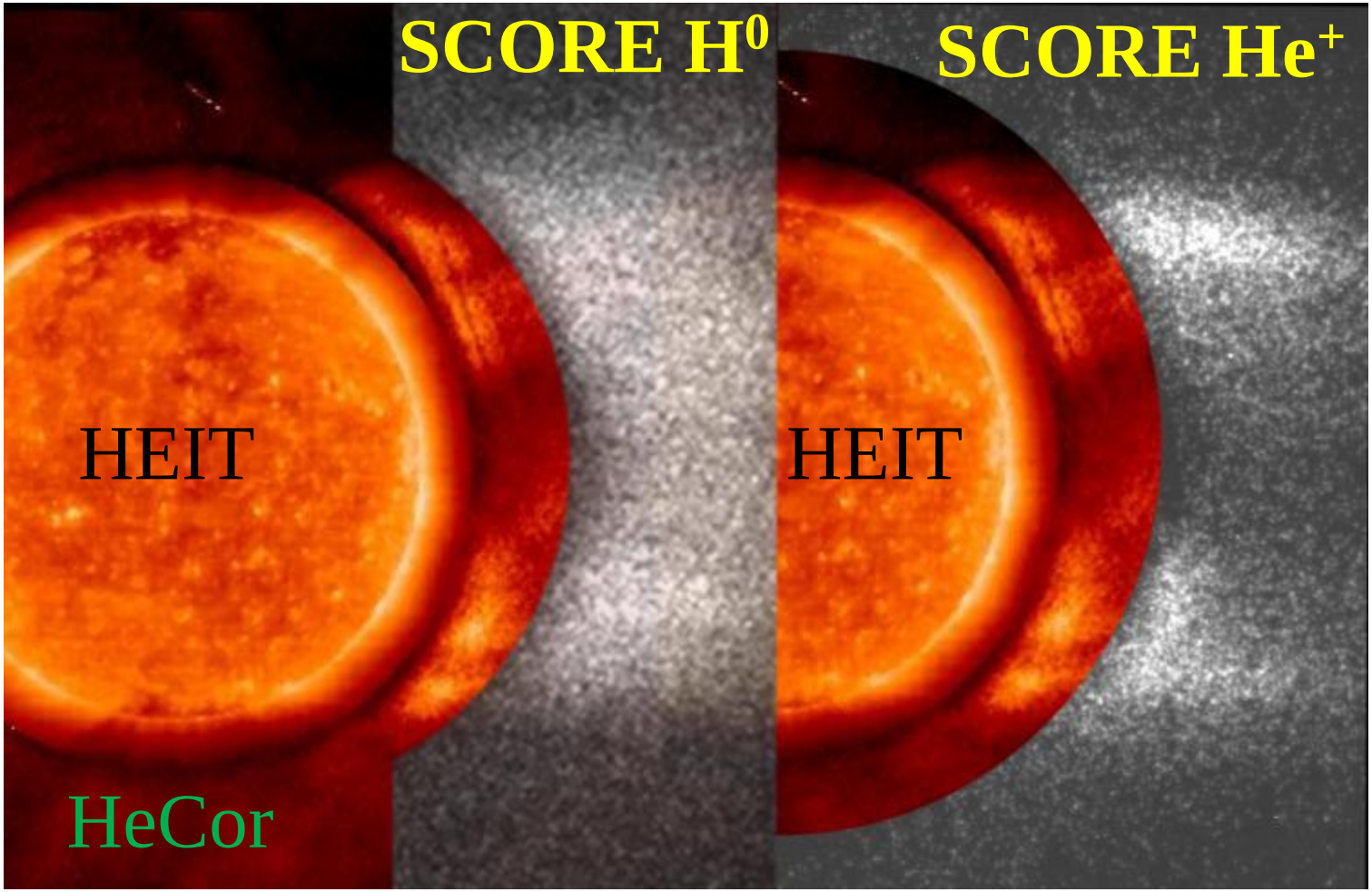
- Bottom row:

55% p+; 35% He^{2+}

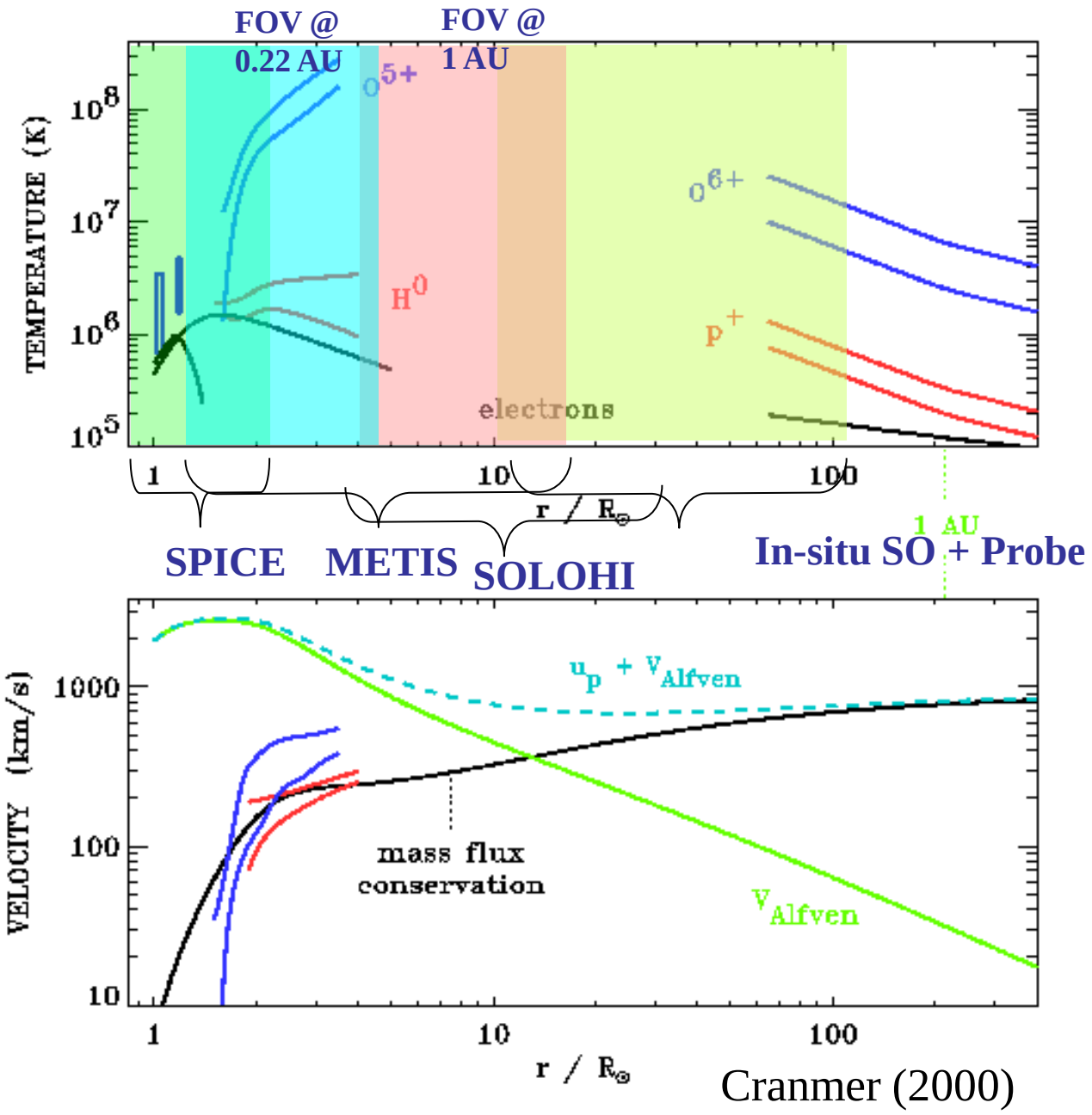
(Hansteen & Leer, 1997)



METIS Capabilities: He^{+}/H^{0}



Physical Parameters of the Fast Solar Wind & Heliosphere



Cranmer (2000)

Conclusions

- Imaging of coronal e^-, H^0, He^+ addresses the Solar Orbiter coronal science goals (solar wind acceleration, origin, etc.)

- METIS observations bridge the coronal regions comprised between the photosphere (SO-PHI), chromosphere, TR (EUI, SPICE) and heliosphere (SOLOHI, Probe+)