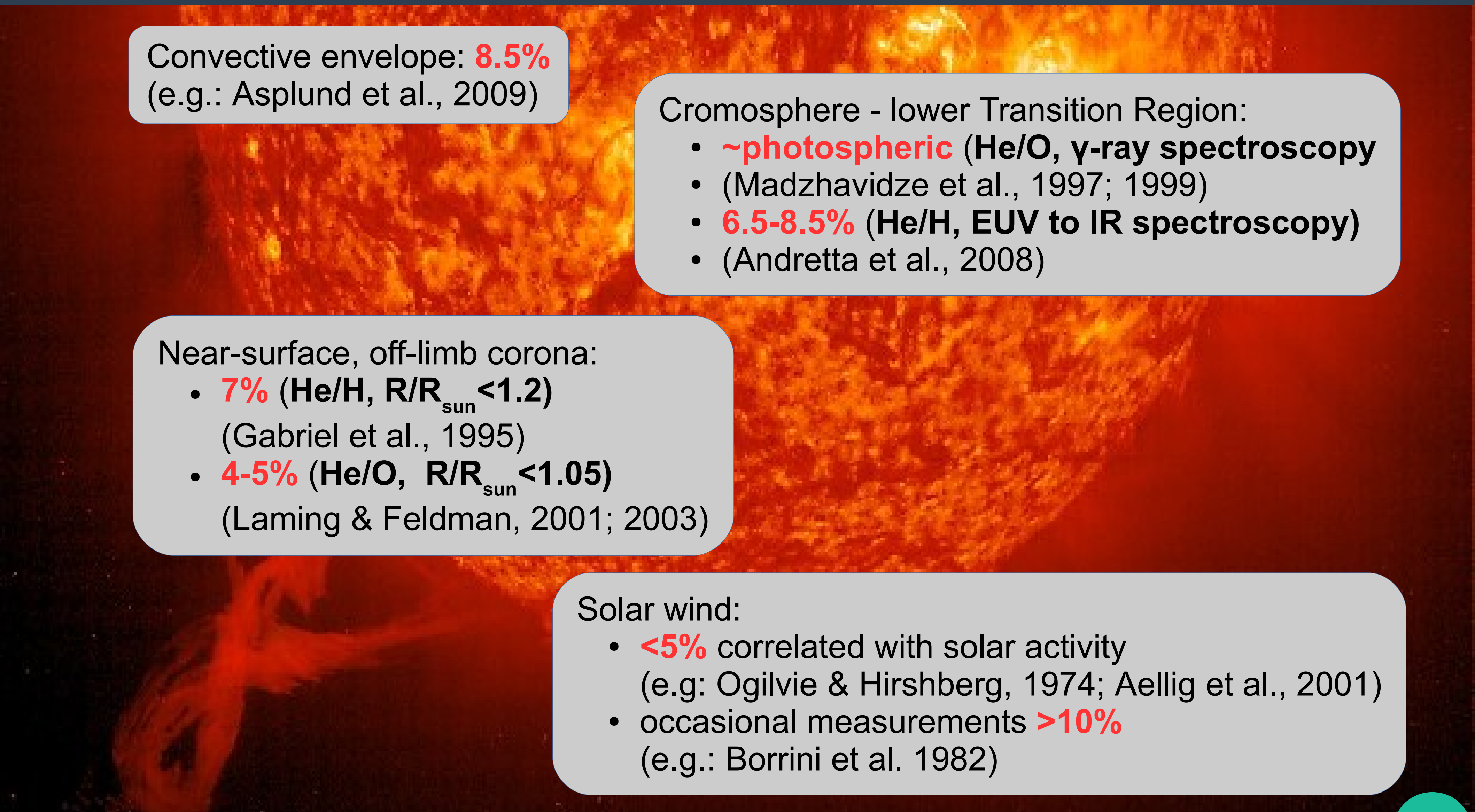
Helium abundance in the corona with joint Metis/EUI observations

V. Andretta (INAF/OAC)
F. Auchère (IAS)
S. Parenti (IAS)
D. Spadaro (INAF/OACt)

Helium abundance measurements



Convective envelope: **8.5%**
(e.g.: Asplund et al., 2009)

Cromosphere - lower Transition Region:

- **~photospheric** (**He/O, γ-ray spectroscopy**
- (Madzhavidze et al., 1997; 1999)
- **6.5-8.5%** (**He/H, EUV to IR spectroscopy)**
- (Andretta et al., 2008)

Near-surface, off-limb corona:

- **7%** (**He/H, R/R_{sun}<1.2)**
  (Gabriel et al., 1995)
- **4-5%** (**He/O, R/R_{sun}<1.05)**
  (Laming & Feldman, 2001; 2003)

Solar wind:

- **<5%** correlated with solar activity
  (e.g: Ogilvie & Hirshberg, 1974; Aellig et al., 2001)
- occasional measurements **>10%**
  (e.g.: Borrini et al. 1982)

Helium abundance: what we know

Compared to its value in the solar convective envelope, the **helium abundance in the in-situ measurements** of the fast and slow solar wind has long been known to be depleted relative to hydrogen, with occasional, transient exceptions.

In the **slow solar wind**, the degree of depletion has been shown to depend upon the wind speed and the level of solar activity.

Measurements of the helium abundance can therefore provide useful constrains on the mechanisms for the release, heating, and acceleration of the solar wind, in particular of the slow solar wind, and allow identification of its source regions.

Helium abundance in the corona

Pergamon

Adv. Space Res. Vol. 15, No. 7, pp. (7)63–(7)67, 1995

0273–1177/95 $9.50 + 0.00

0273–1177(94)00020–4

SPACELAB 2 MEASUREMENT OF THE SOLAR CORONAL HELIUM ABUNDANCE

A. H. Gabriel,* J. L. Culhane,** B. E. Patchett,***
E. R. Breeveld,** J. Lang,*** J. H. Parkinson,**
J. Payne*** and K. Norman**

** Institut d'Astrophysique Spatiale, Universitie Paris XI, 91405 Orsay Cedex, France*
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**** Rutherford Appleton Laboratory, Chilton, Didcot, Oxon OX11 0QX, U.K.*

ABSTRACT

The abundance of helium relative to hydrogen has been measured with the "Coronal Helium Abundance Spacelab Experiment" (CHASE) from the space shuttle Challenger in 1985. Previous solar measurements have proved difficult due to the temperature-sensitivity of the electron excitation rates for the observed lines. In this approach scattered Lyman Alpha (Lyα) radiation of helium and hydrogen formed in the corona were measured with a grazing-incidence spectrometer and compared with the intensity of the illuminating flux from the solar chromosphere. The abundance ratio by number of atoms was found to be 0.070 with an uncertainty of 0.011. Scattered light in the telescope is the main source of error.

INTRODUCTION

The collisional excitation rates in the temperature region of He line formation are unusually sensitive to temperature. This leads to significant error in the deduced abundances. Lines produced by photon impact excitaton eliminate the temperature sensitivity. The effect used was first observed during a total solar eclipse where the Lyα line was observed as the brightest line in neutral hydrogen illuminated by the very intense chromospheric Lyα radiation (Gabriel 1971). Calculations (Patchett et al 1981) showed that the only other line similarly dominated by resonance fluorescence in the inner corona below 1.3 $R_\odot$ is He II Lyα at 30.4 nm. Regarding the chromospheric emission of the two lines as light sources, the coronal emission of

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$<1.3\ R_{Sun}$

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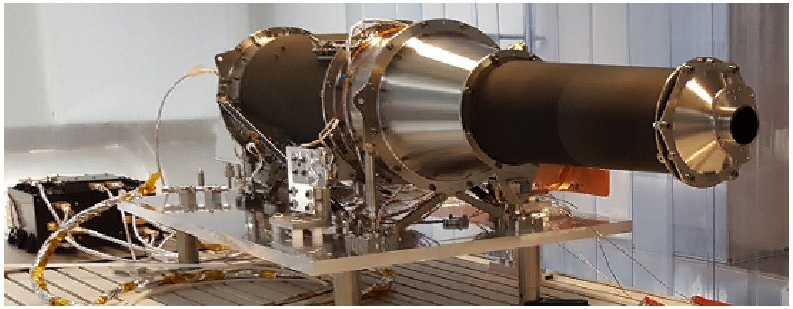
What Solar Orbiter can measure

Metis

Corona in the range $R/R_{Sun} > 1.6°$

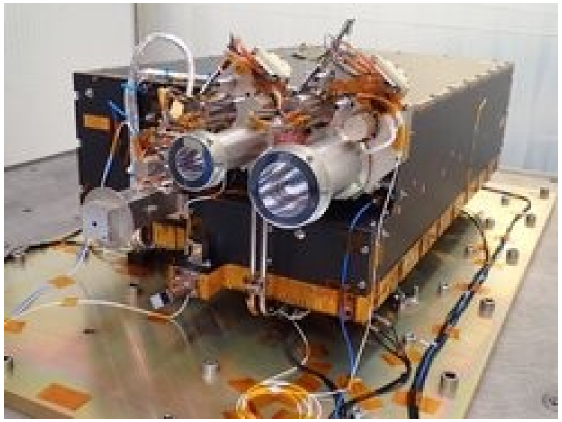
- **H I 1216 Å (Ly-α)**, narrow-band imaging
- Visibile-light, broad-band polarized (pB) imaging



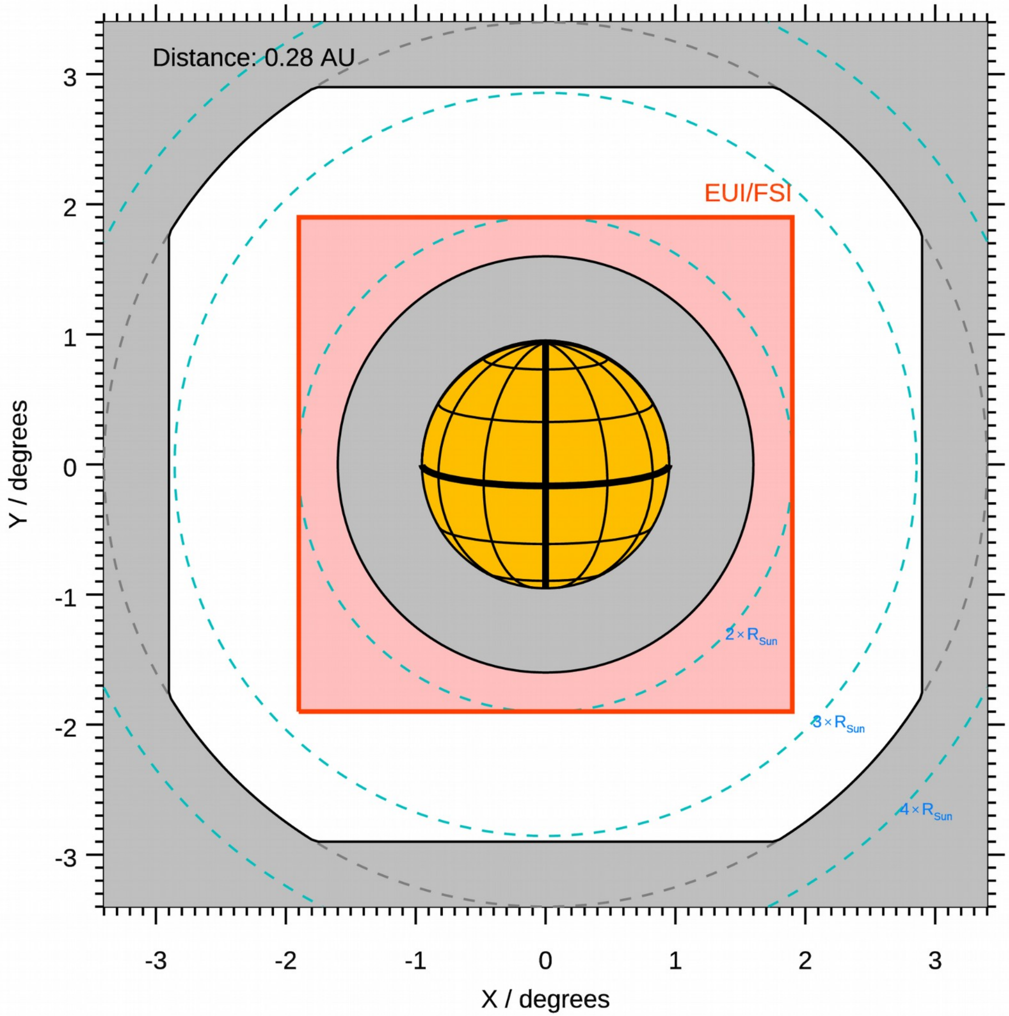
EUI/FSI

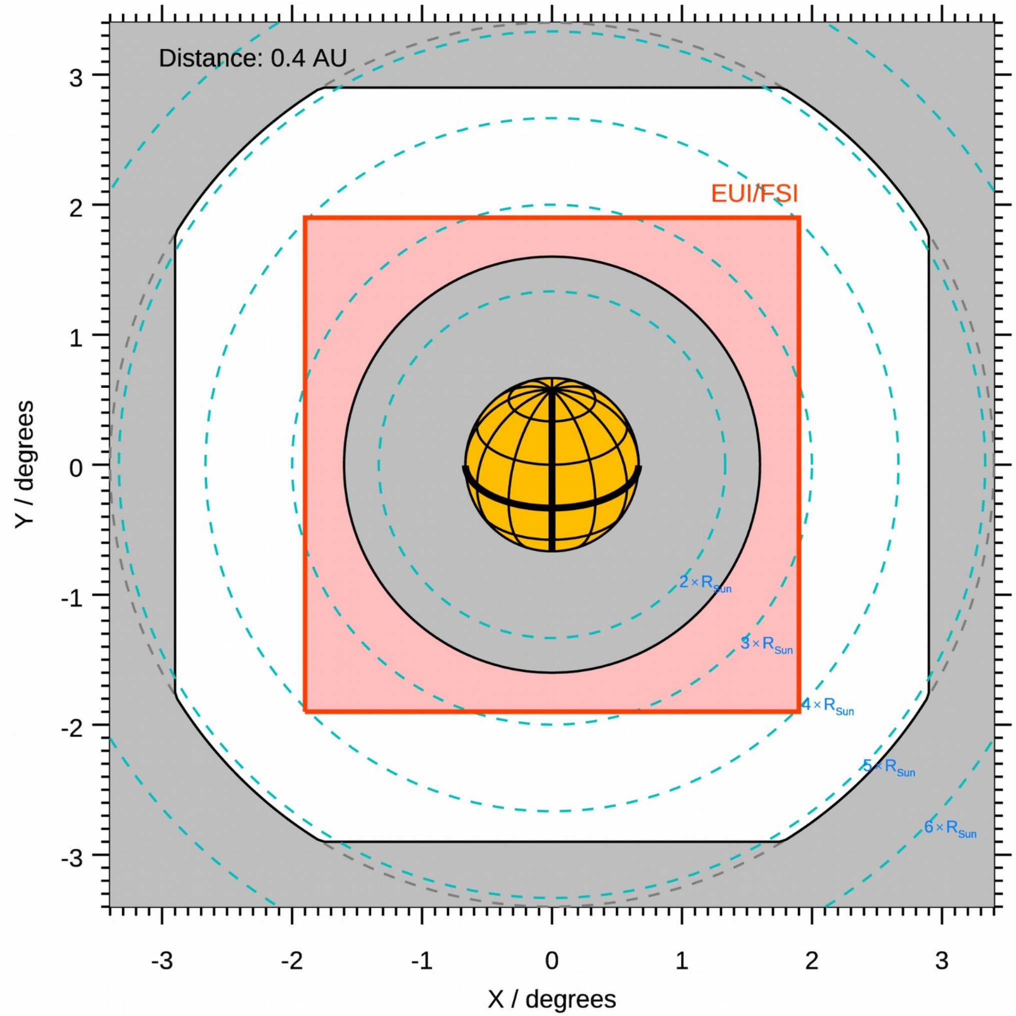
Corona in the range $R/R_{sun} < 3.8°$

- **He II 304 Å**, narrow-band imaging
- 174 Å narrow-band imaging

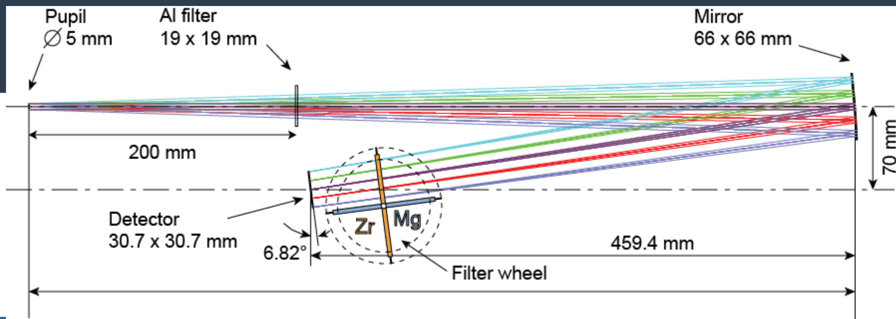


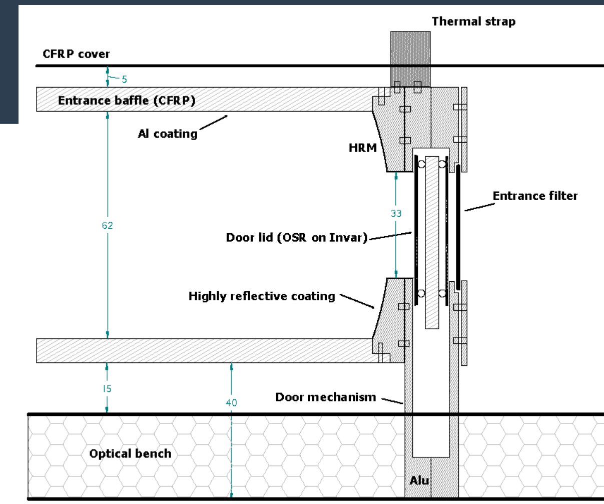
Metis and EUI Field of View

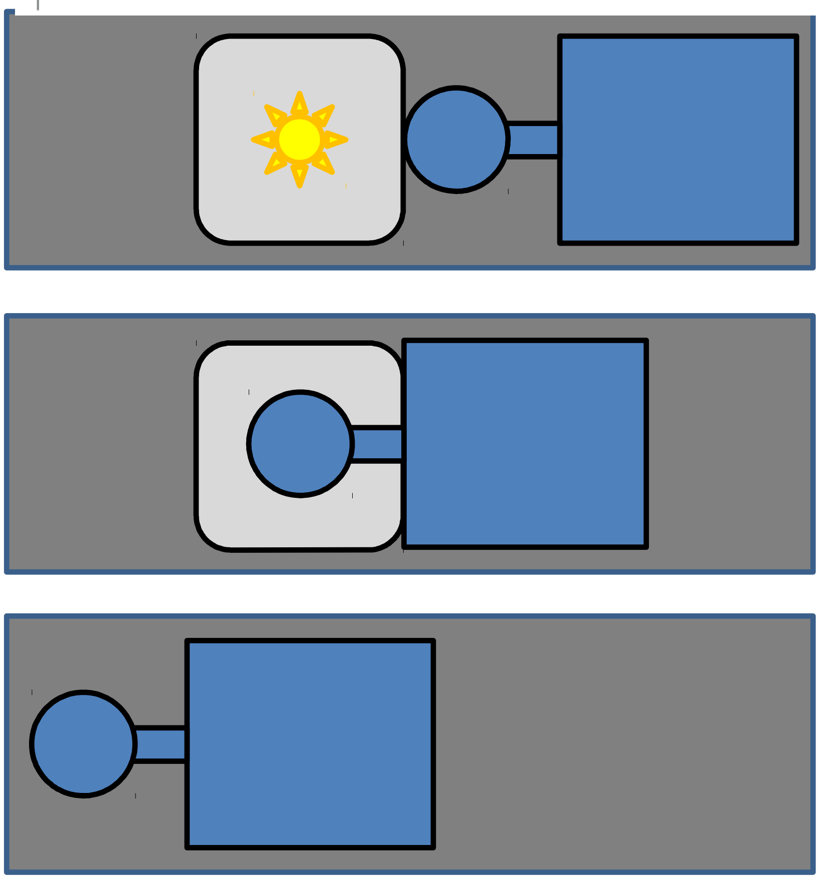




EUI: Using an occulting disk...







Open

Occulter

Closed

... on the door

- Simple occulter design OK @ 174 & 304
- Door modifications are implemented
- Limited number of operations
  - Campaign mode
  - Only when far from the Sun (>0.4 A.U.)

N.B.: Early design. Door is now rotating

What Solar Orbiter can measure

Metis diagnostics

- **UV**: H I 1216 Å
- **VL**: Electron density *(simultaneous)*

<u>Also:</u>

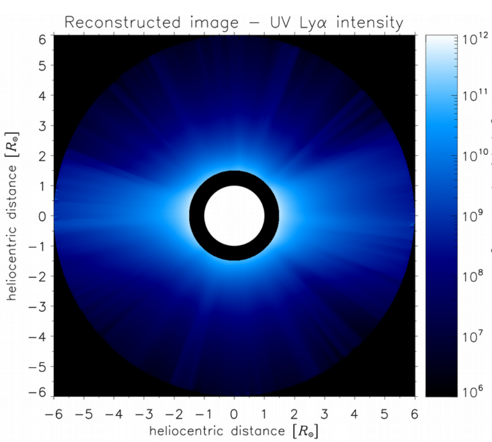
- **UV**: Radial velocity

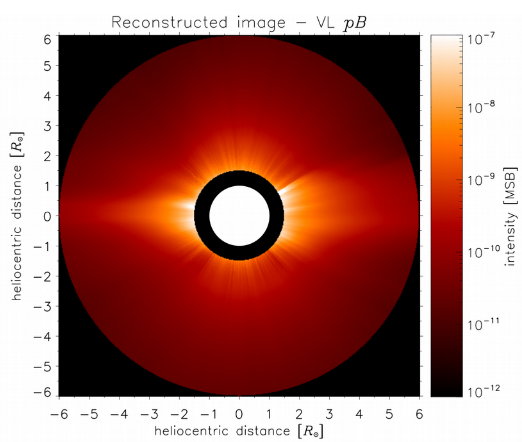
EUI/FSI diagnostics

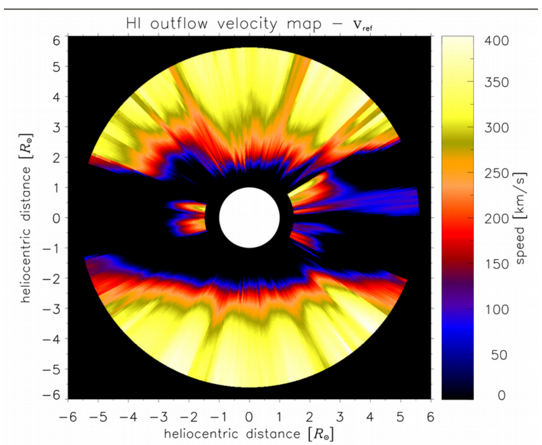
- **EUI FSI304**: He II 304 Å

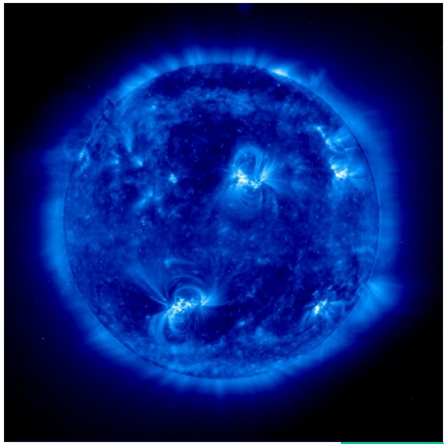
<u>Also:</u>

- **EUI FSI174**: Emission Measure at ~10^6 K *(quasi-simultaneous)*









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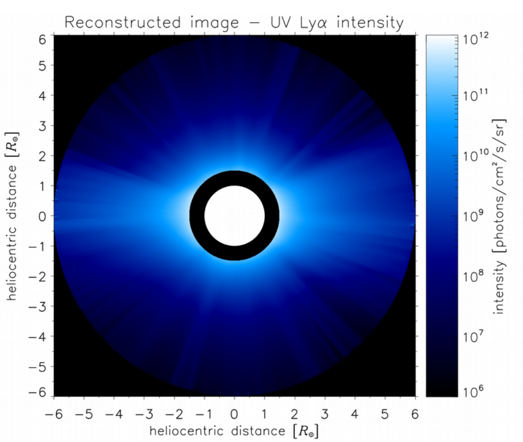

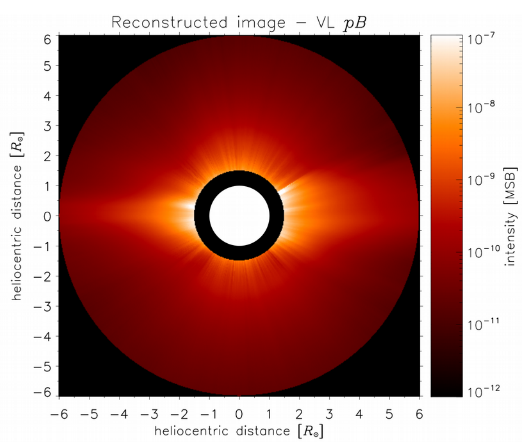

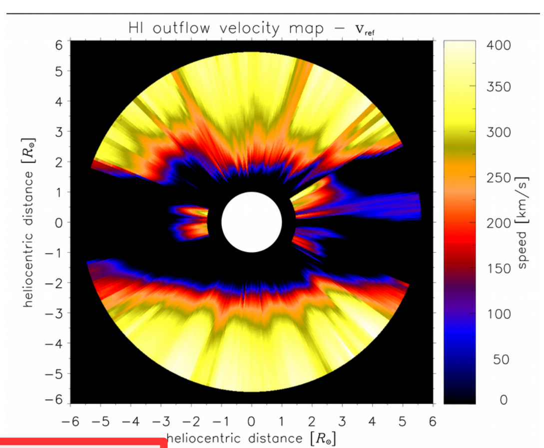

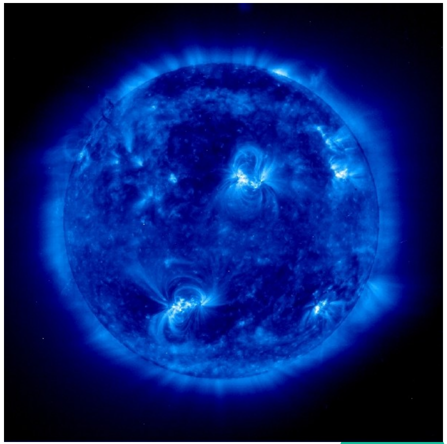

Dolei et al., 2018, A&A 612, A84

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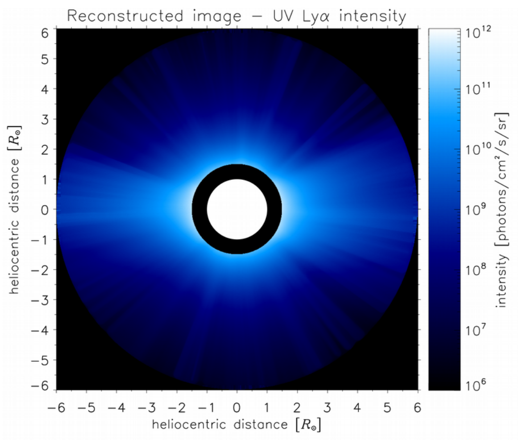
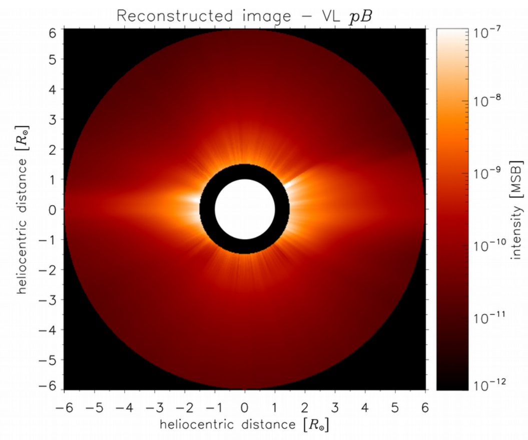
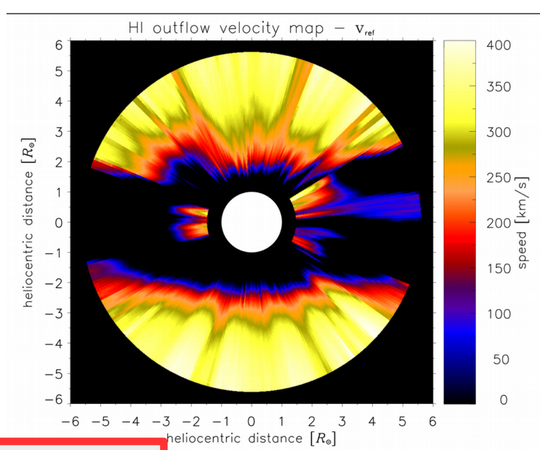
Also:

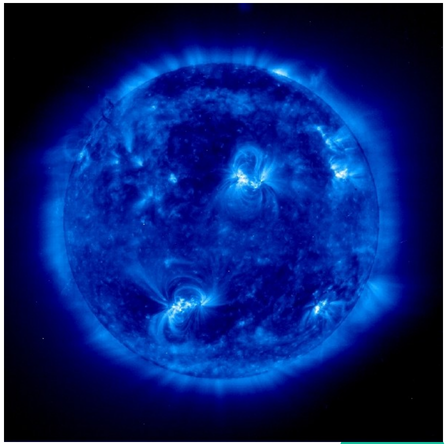
tial

Complete characterization of the properties and dynamics of the main components of the solar wind: Electrons, hydrogen and protons, and <u>helium</u>



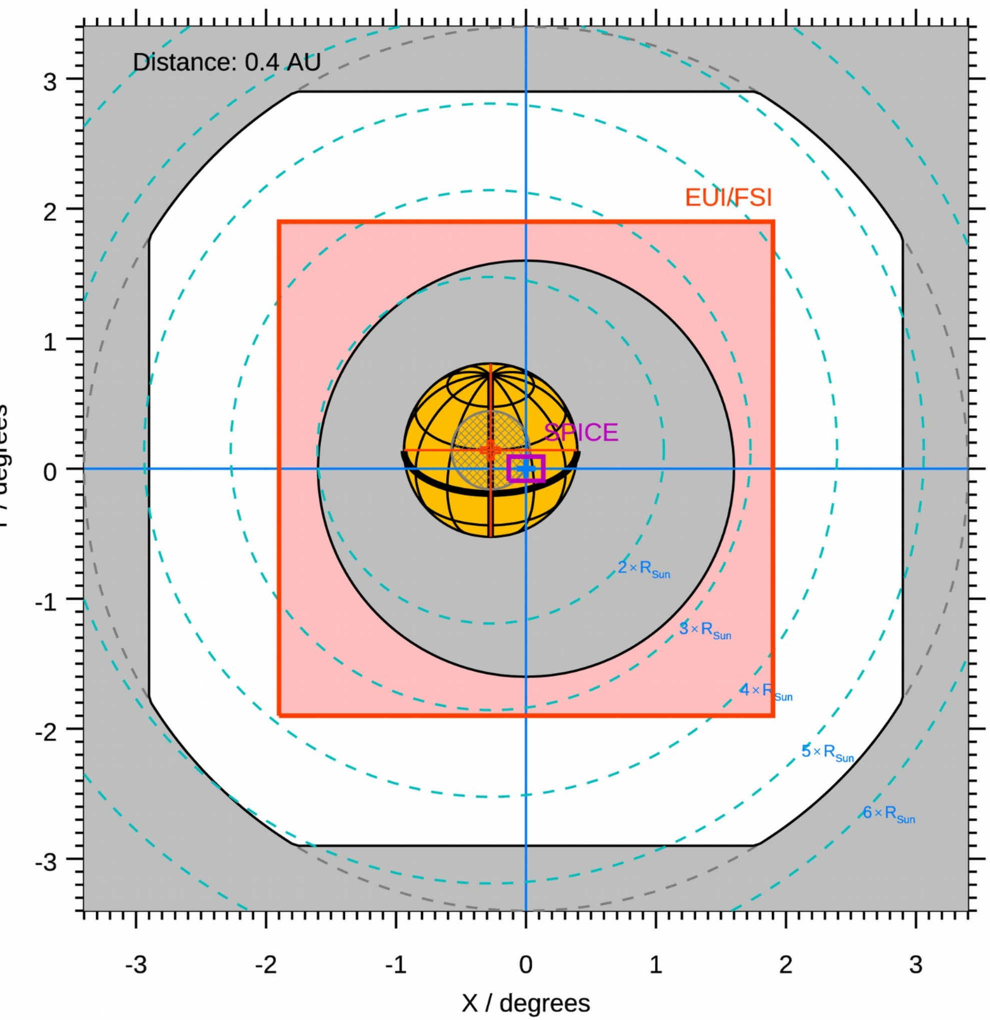






Dolei et al., 2018, A&A 612, A84

Adding SPICE to the recipe ...



SPICE Composition (FIP) map *(being updated)*:

Profiles:

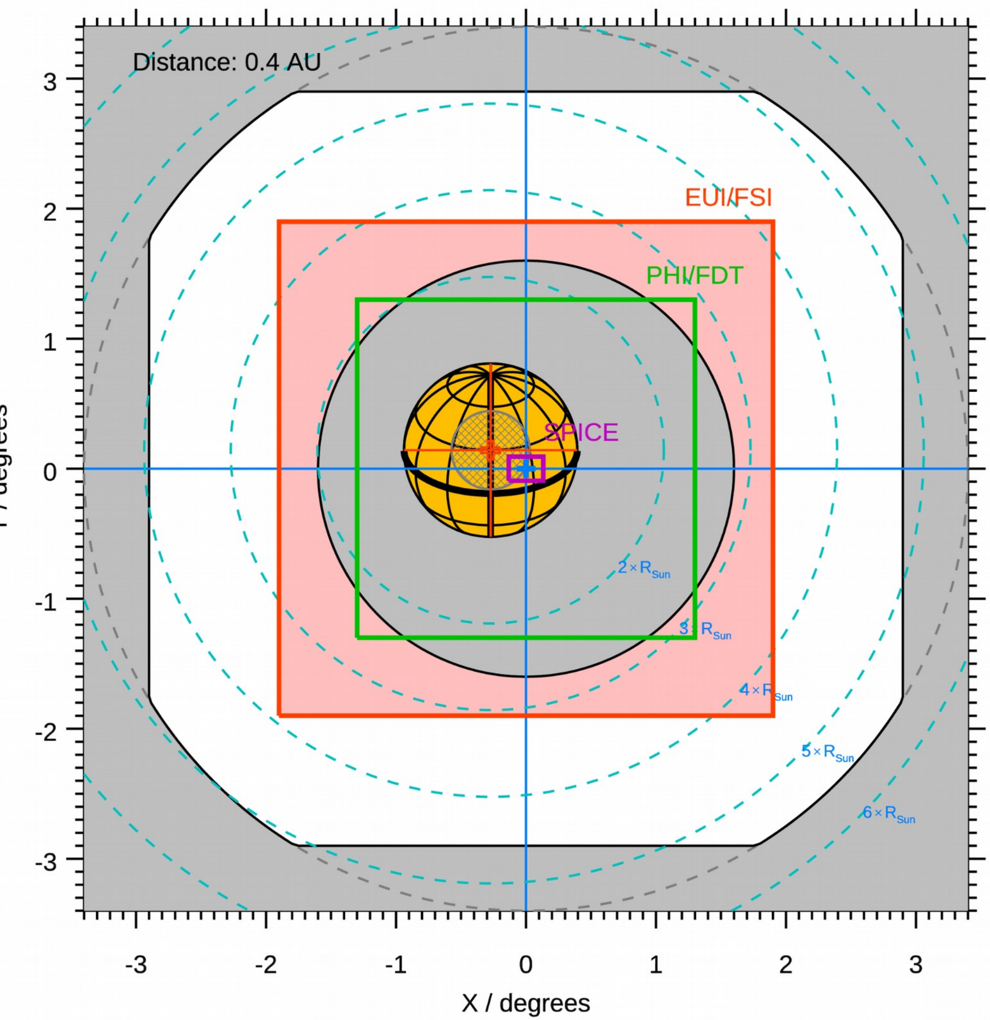
- **Mg VIII 78.23 nm *(TBC)***
- **Mg IX 70.6 nm**
- **Ne VIII 77.04 nm**
- **S V+O IV 78.65+78.7 nm**

Total intensity:

- **O VI 103.6-103.7**

Raster: 4” slit, 16x11’ *(TBC)*

... and PHI, and more ...



SOOP:

`L_FULL_HRES_MCAD_Coronal_He_Abundance`

PHI Default mode *(TBC)*:

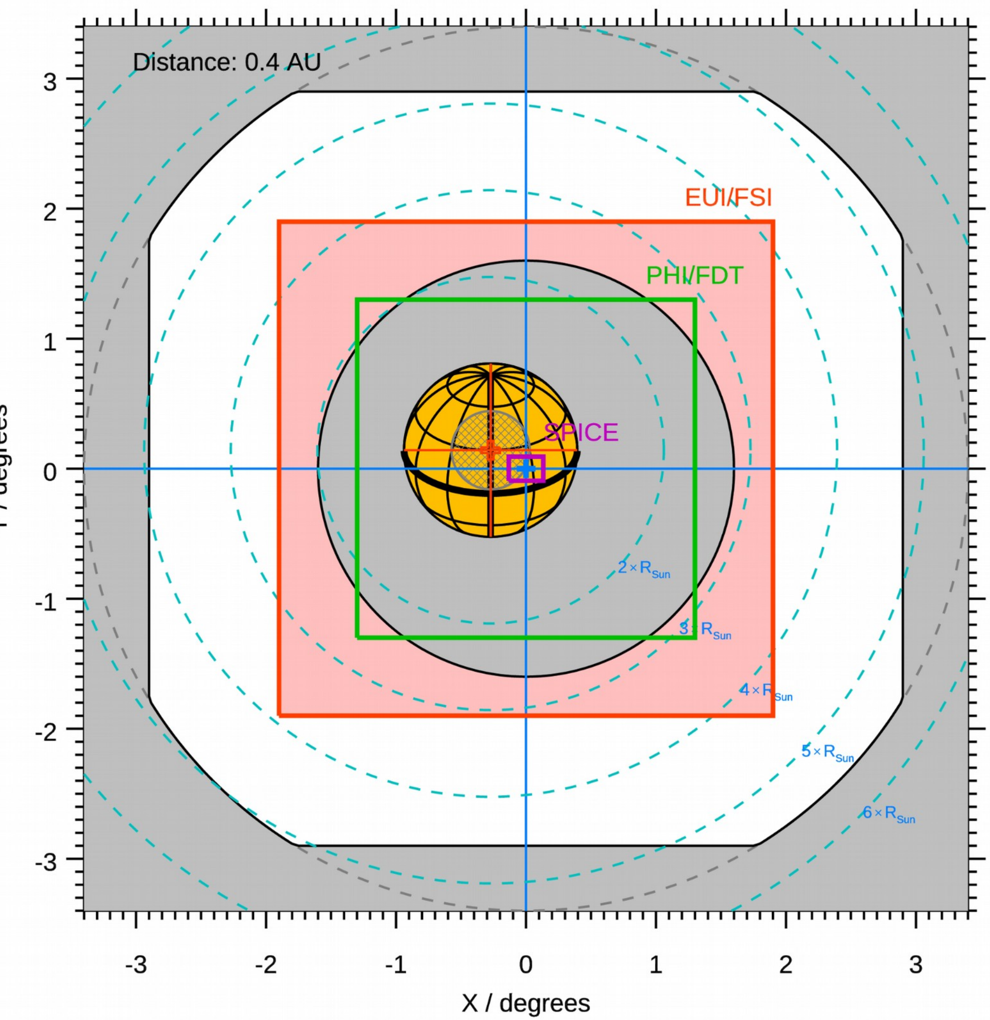
PHI_synoptic_FDT_4

(► coronal extrapolations)

SWA

(► α/p density ratio)

... and PHI, and more ...



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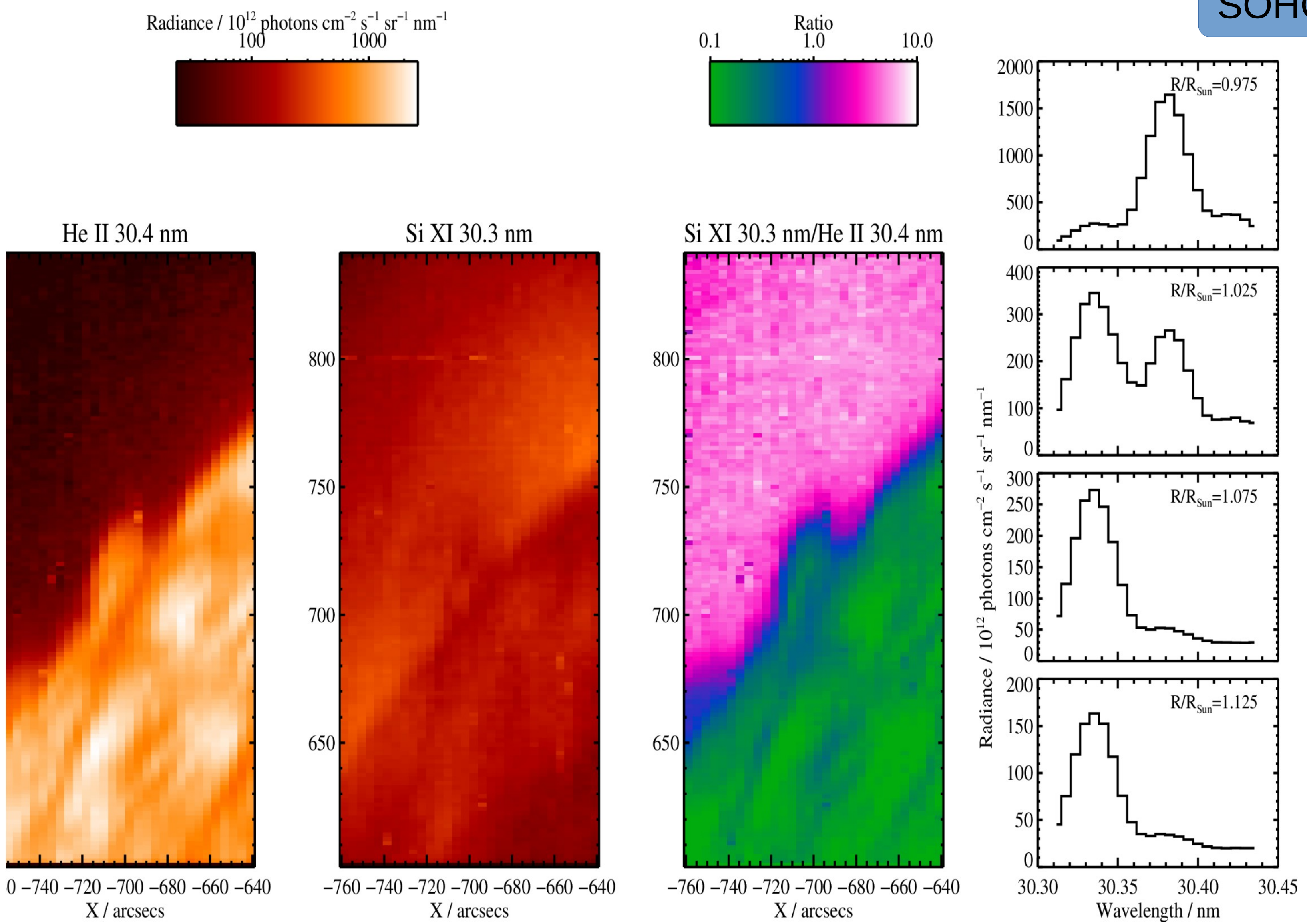
Ground based support, e.g.:

DKIST:

(► He I 10830, B_{cor}, N_e)

Problem: Si XI 303 Contribution to the EUI 304 band

SOHO/CDS spectra



Andretta et al., 2012, Sol. Phys. 279, 53

Ratio Si XI 303/He II 304

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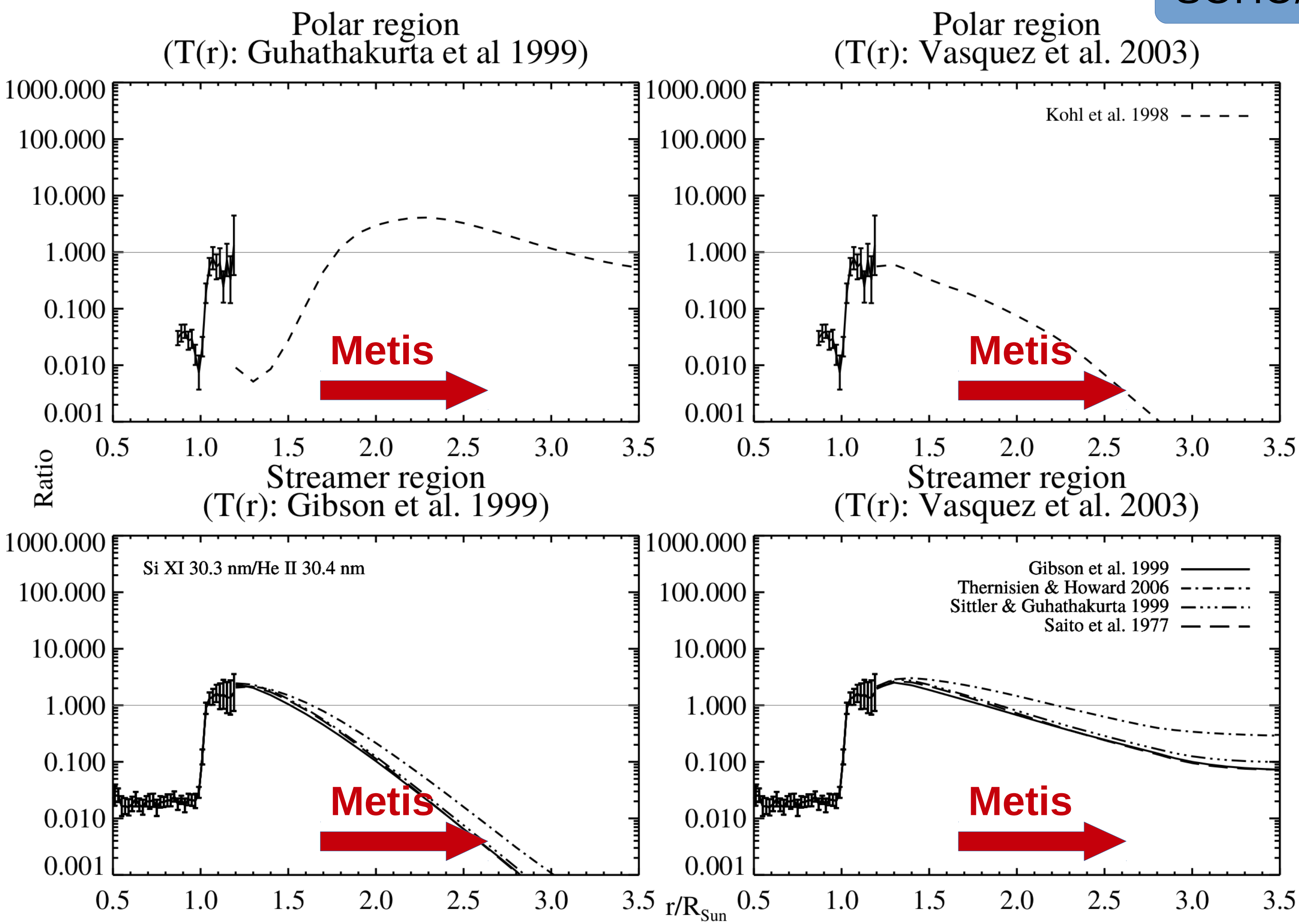
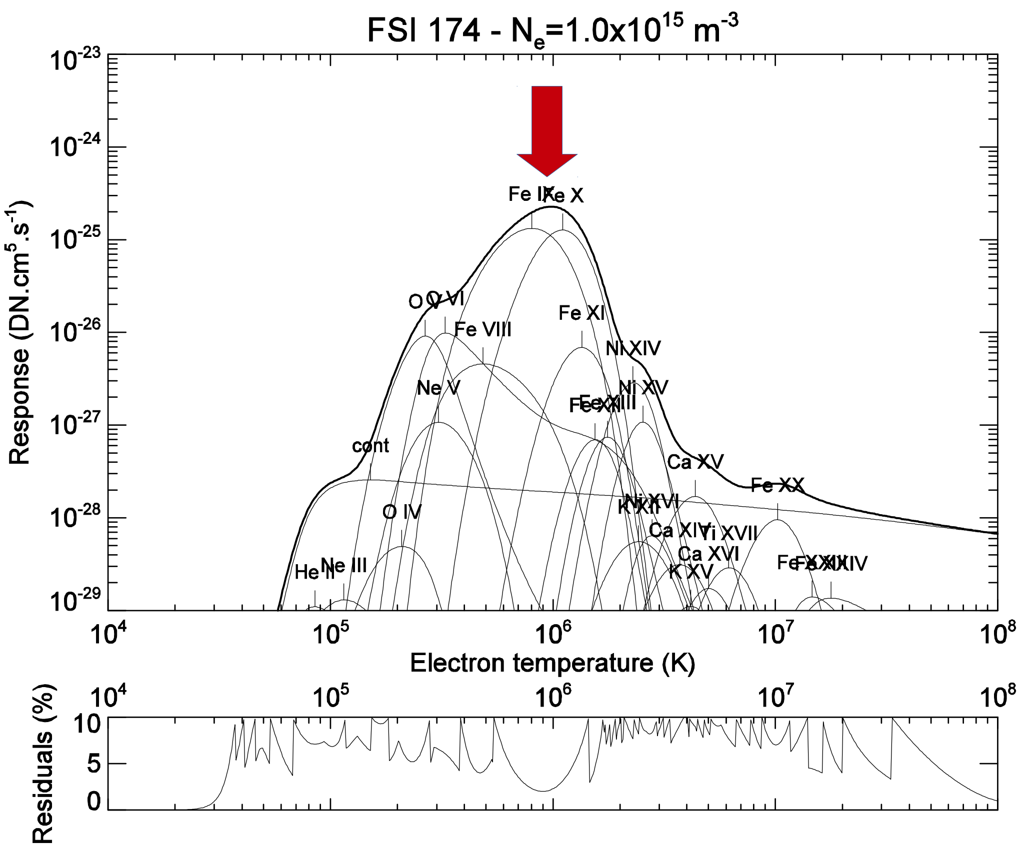
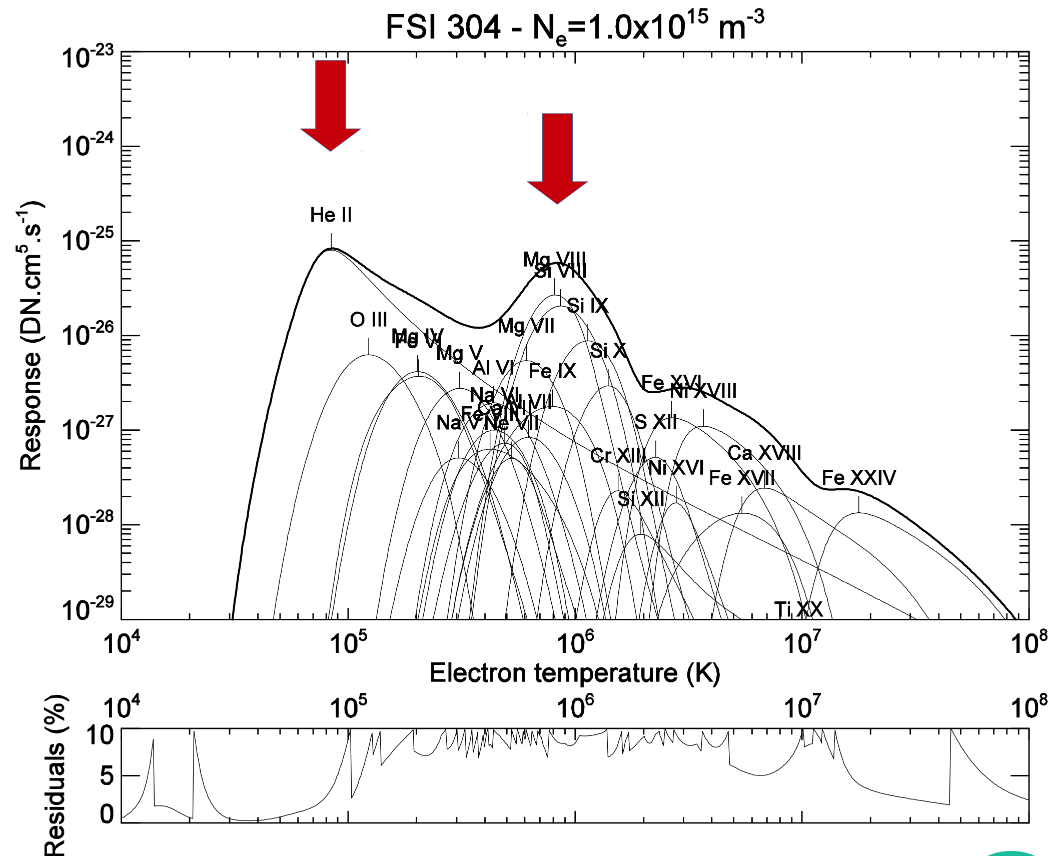


Andretta et al., 2012, Sol. Phys. 279, 53

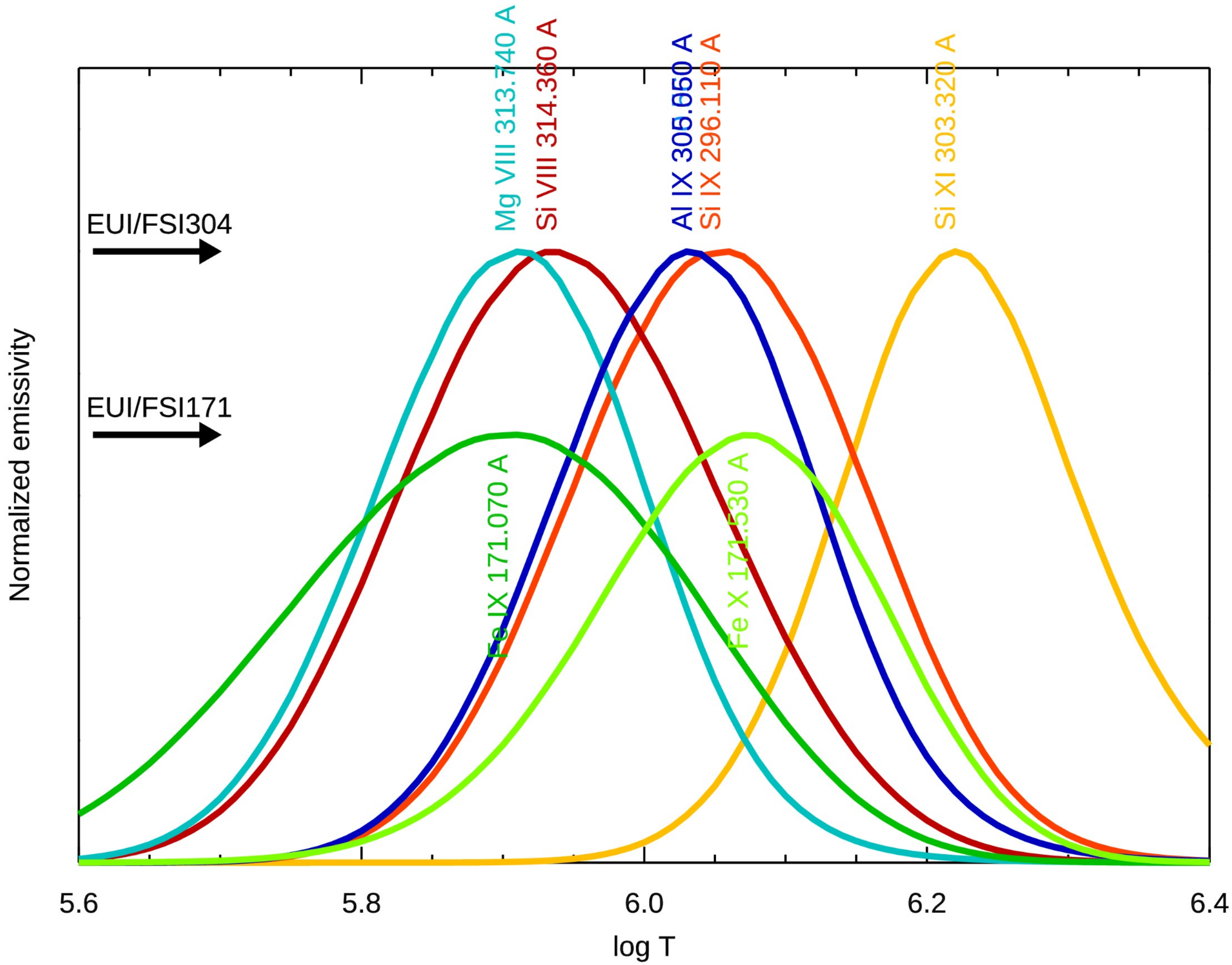
EUI/FSI Spectral Response

Since EUI/FSI is a single bounce design, the spectral response is quite wide and several lines other than Si XI can contribute as much, especially Mg VIII and Si VIII lines. These are cool and may actually pick up at large distances in the corona.



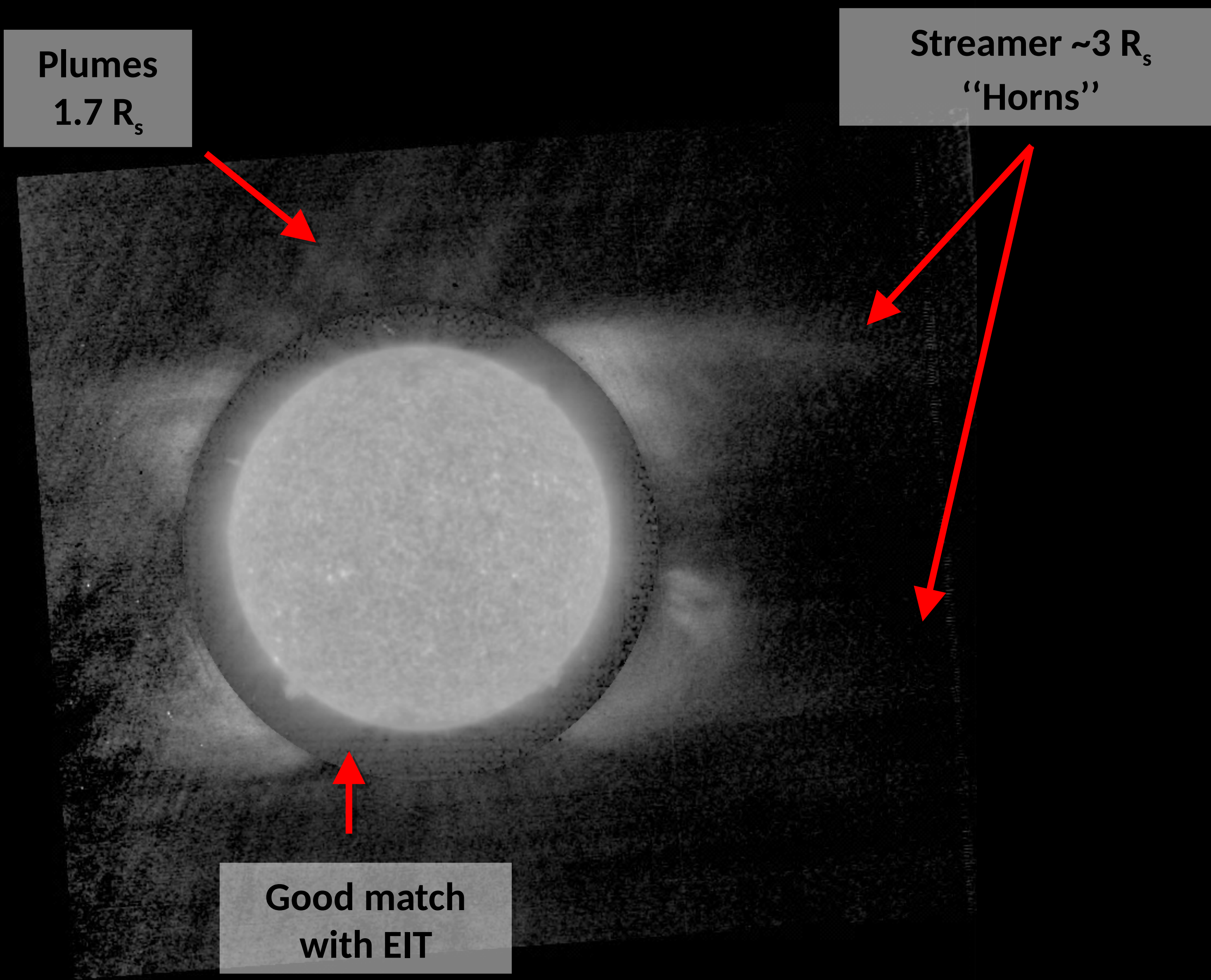


Constraints from EUI/FSI174?

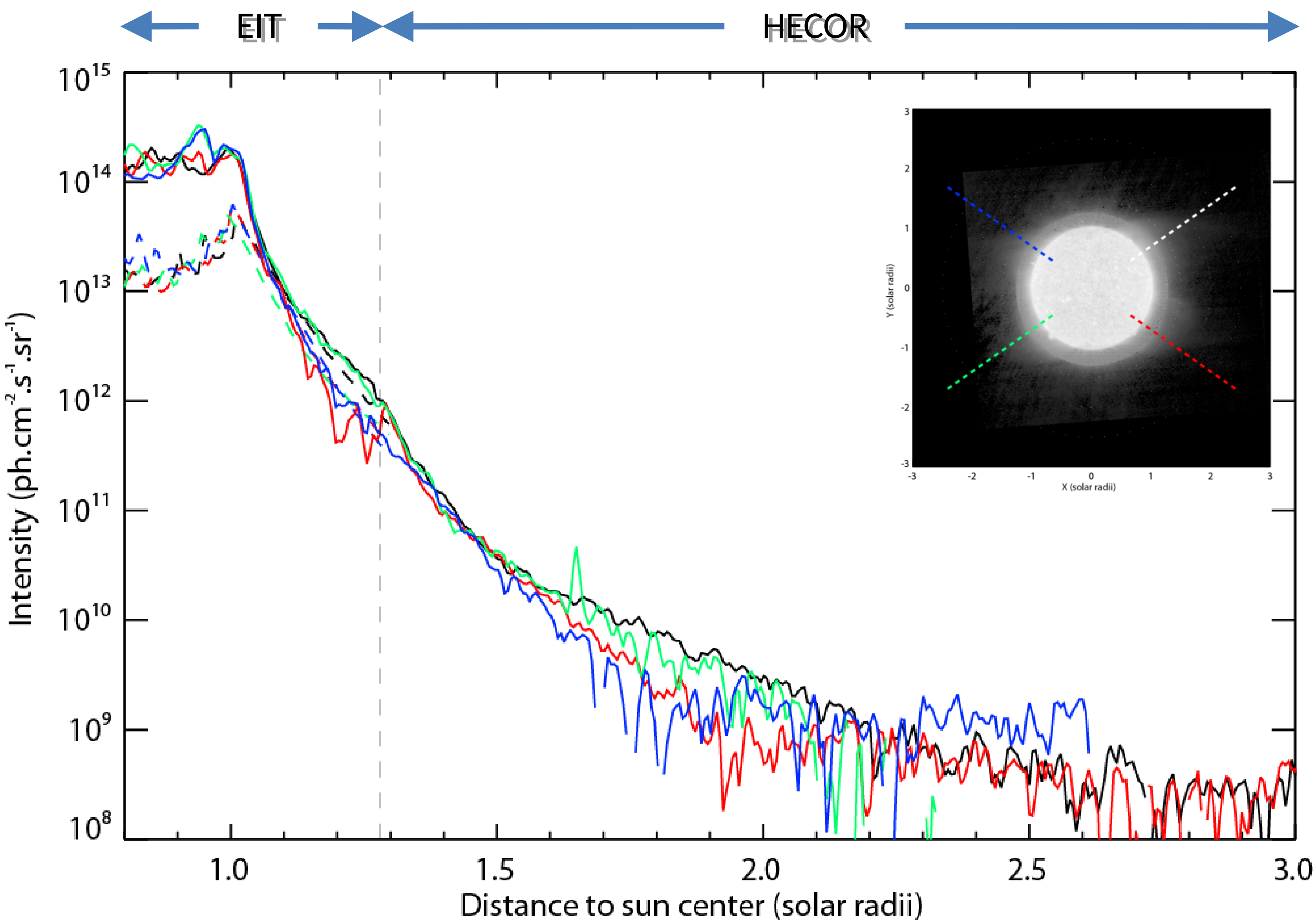


Additional Material

HECOR + EIT composite



Evidence for resonant scattering



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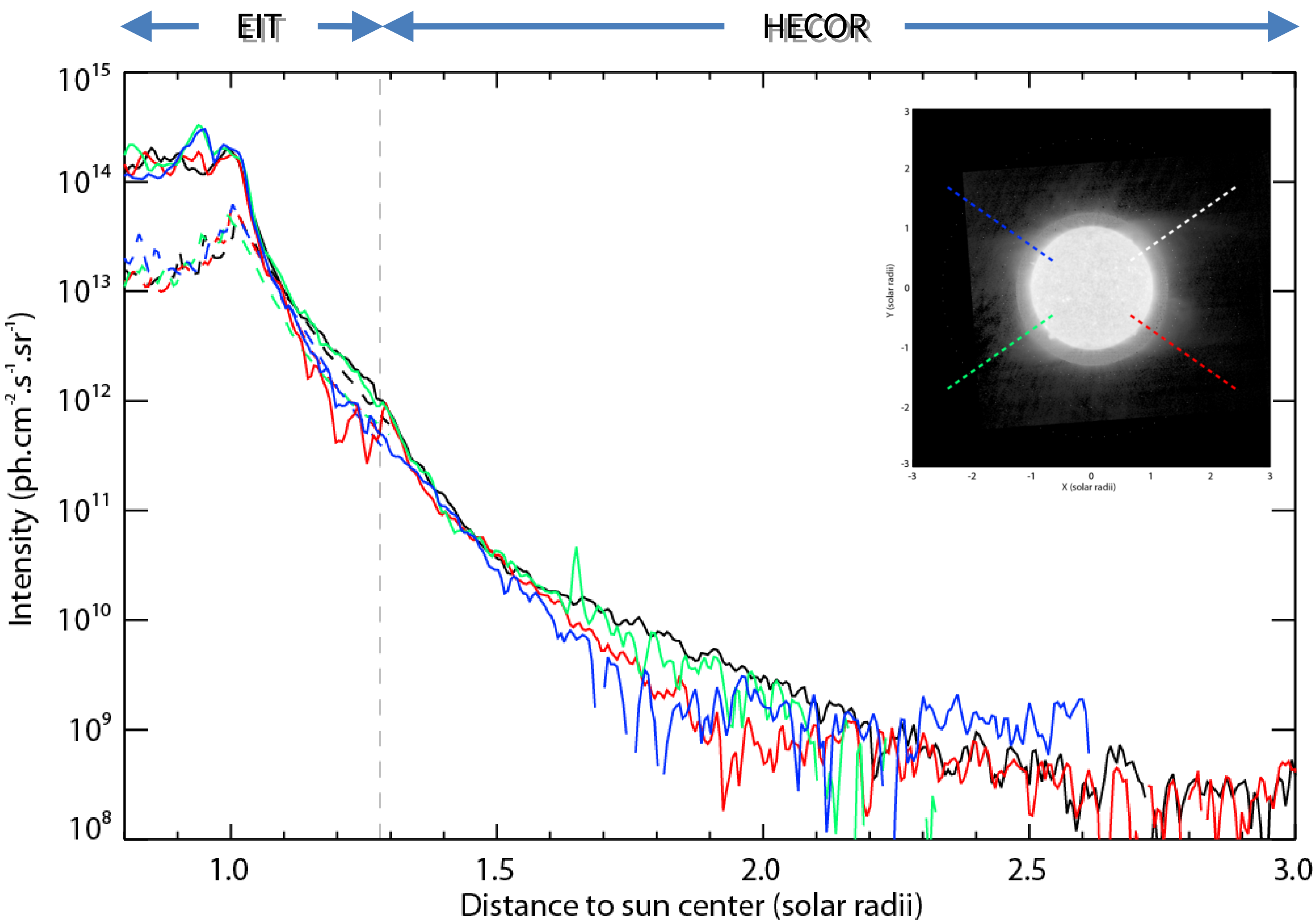

Expected signal

30.4 nm corona: ~10^8 photon.cm^{-2}.s^{-1}.sr^{-1} @ 3 Rs

HeCOR 1.7×10^{-10} DN.$photon^{-1}$.cm^2.sr
FSI 5×10^{-13} DN.$photon^{-1}$.cm^2.sr

x340 → small pupil & two filters in FSI

Bin 4x4 → x16
Exposure time x20 → 2400 seconds (20 minutes)

Resonant scattering → brighter corona during maximum of activity

Detection of Helium up to 3 Rs possible in 20 minutes

DKIST coronal observations

DKIST coronal diagnostics during early operations

- Emphasis on bright line observations with greatest magnetic field sensitivity.
- Corresponding peak temperature coverage: 1 to 1.6 MK
- Filter availability can be expanded in the future.

Maximum FOV: 2.8 arcmin   -- Coordinated Operations

DL-NIRSP Spectropolarimetry

Fe XI λ7892   ; Log(T) ~ 6.13
Fe XIII λ10747 ; Log(T) ~ 6.22
Fe XIII λ10797 ; Log(T) ~ 6.22
He I λ10830 ; Log(T) ~ 4*
Si X λ14300 ; Log(T) ~ 6.13

VBI Imaging

Fe XI λ7892   ; Log(T) ~ 6.13

VISP Spectropolarimetry

Various lines: 380 to 900 nm
Including FeXIV 5303, FeX 6375,
(green + yellow lines)

Maximum FOV: 5 arcmin

Cryo-NIRSP Spectropolar.

Fe XIII λ10747 ; Log(T) ~ 6.22
Fe XIII λ10797 ; Log(T) ~ 6.22
He I λ10830 ; Log(T) ~ 4*
Si X λ14300 ; Log(T) ~ 6.13
Si IX λ39350 ; Log(T) ~ 6.04

Cryo-NIRSP Context Imager

Fe XIII λ10747 ; Log(T) ~ 6.22
He I λ10830 ; Log(T) ~ 4*
Si IX λ39340 ; Log(T) ~ 6.04

5