Combined coronal observations of streamer belt with Metis and EUI instruments on Solar Orbiter

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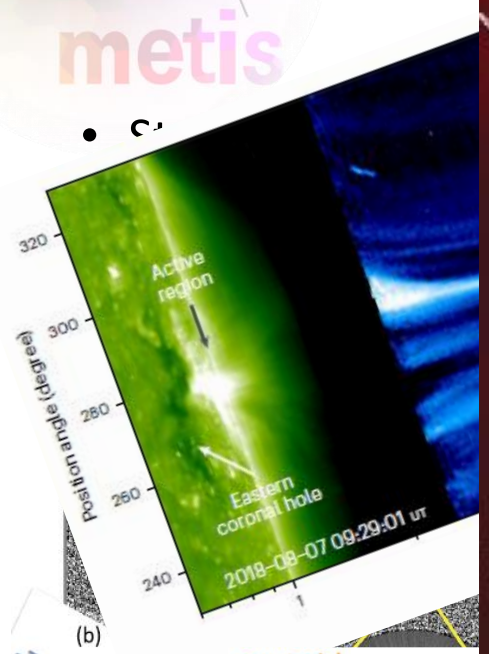
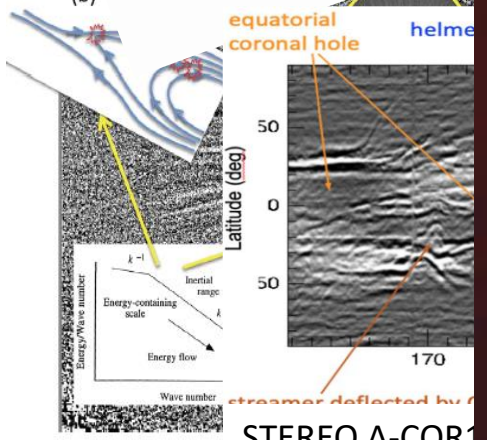
Motivation

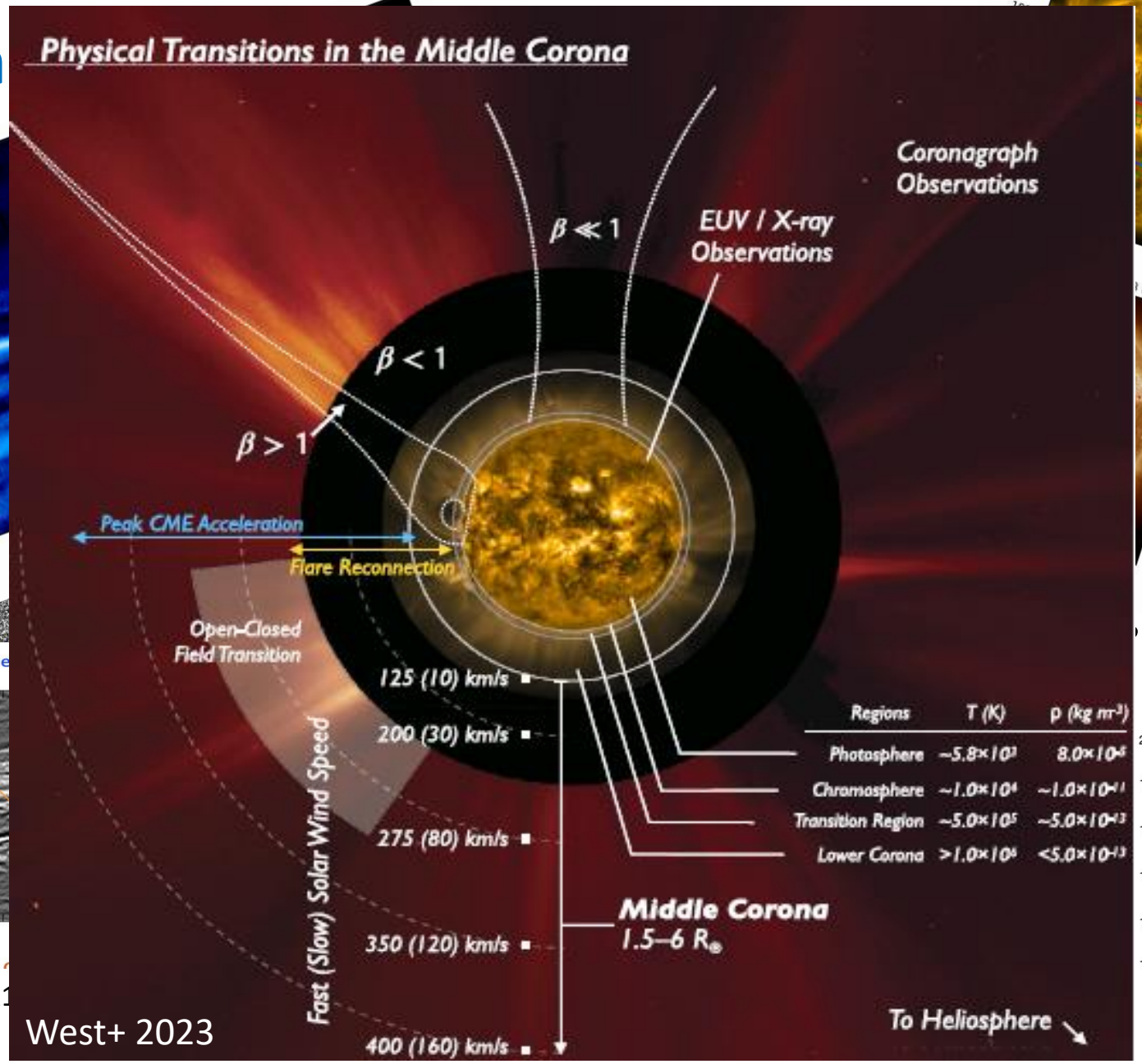
metis

- C

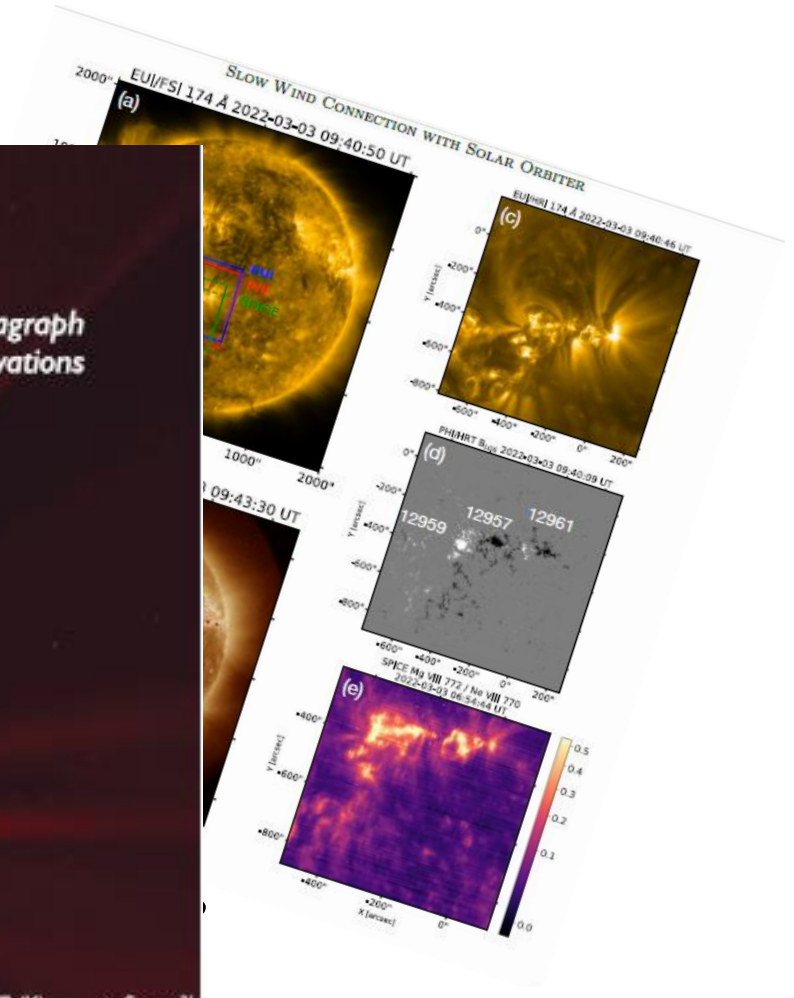




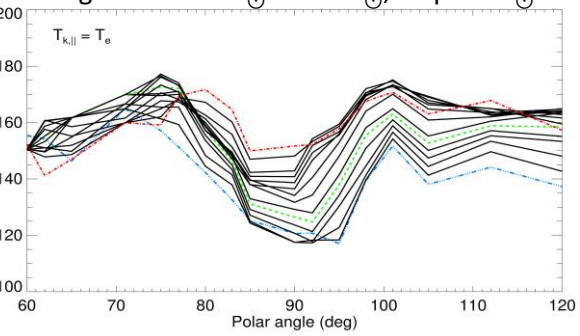
STEREO A-COR1



West+ 2023



Range: from 4.0 $R_\odot$ to 6.8 $R_\odot$, step 0.2 $R_\odot$



Abbo, Ofman, Antiochos, Hansteen, Harra, Ko, Lapenta, Li, Riley, Strachan, von Steiger, Wang 2016, SSRv

EUI disk/coronagraphic observations

Table 1. Summary of the FSI coronagraph mode campaigns.

Start date (UT)	End date (UT)	Channel	Exposure	Cadence	Sun distance	Separation angle Earth	Separation angle STEREO A
2021 Sep. 9 00:42	2021 Sep. 9 09:30	17.4 nm	640 s	11 min	0.60 au	65°	24°
2021 Nov. 1 00:42	2021 Nov. 3 23:42	17.4 nm	1000 s	30 min	0.83 au	2°	36°
2021 Nov. 4 00:12	2021 Nov. 4 21:12	30.4 nm	1000 s	30 min	0.84 au	2°	36°
2022 Feb. 8 04:15	2022 Feb. 8 07:45	17.4 nm	1000 s	30 min	0.79 au	19°	16°
2022 Mar. 7 16:00	2022 Mar. 7 19:30	17.4 nm	1000 s	30 min	0.50 au	3°	33°
2022 Dec. 5 04:00	2023 Jan. 1 22:15	17.4 nm	1000 s	30 min	0.83 au–0.95 au	16°–22°	4°–9°

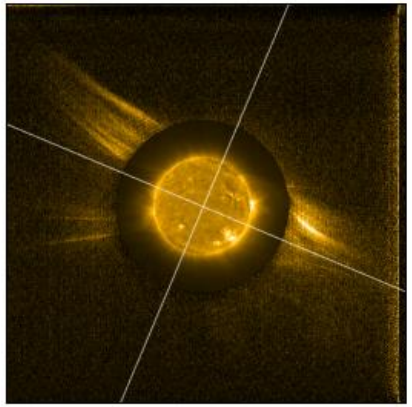


Fig. 6. Composite of FSI 17.4 nm images taken in disk mode (below 1.81 $R_\odot$, 2021 September 8 at 23:55 UT) and coronagraphic mode (September 9 at 00:42:03 UT). As in all subsequent figures, the axes of the helio-projective coordinate system are plotted to materialize the roll angle of the spacecraft.

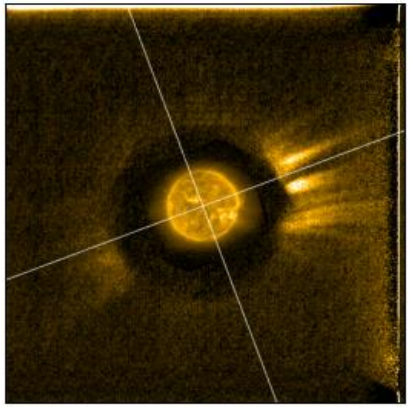
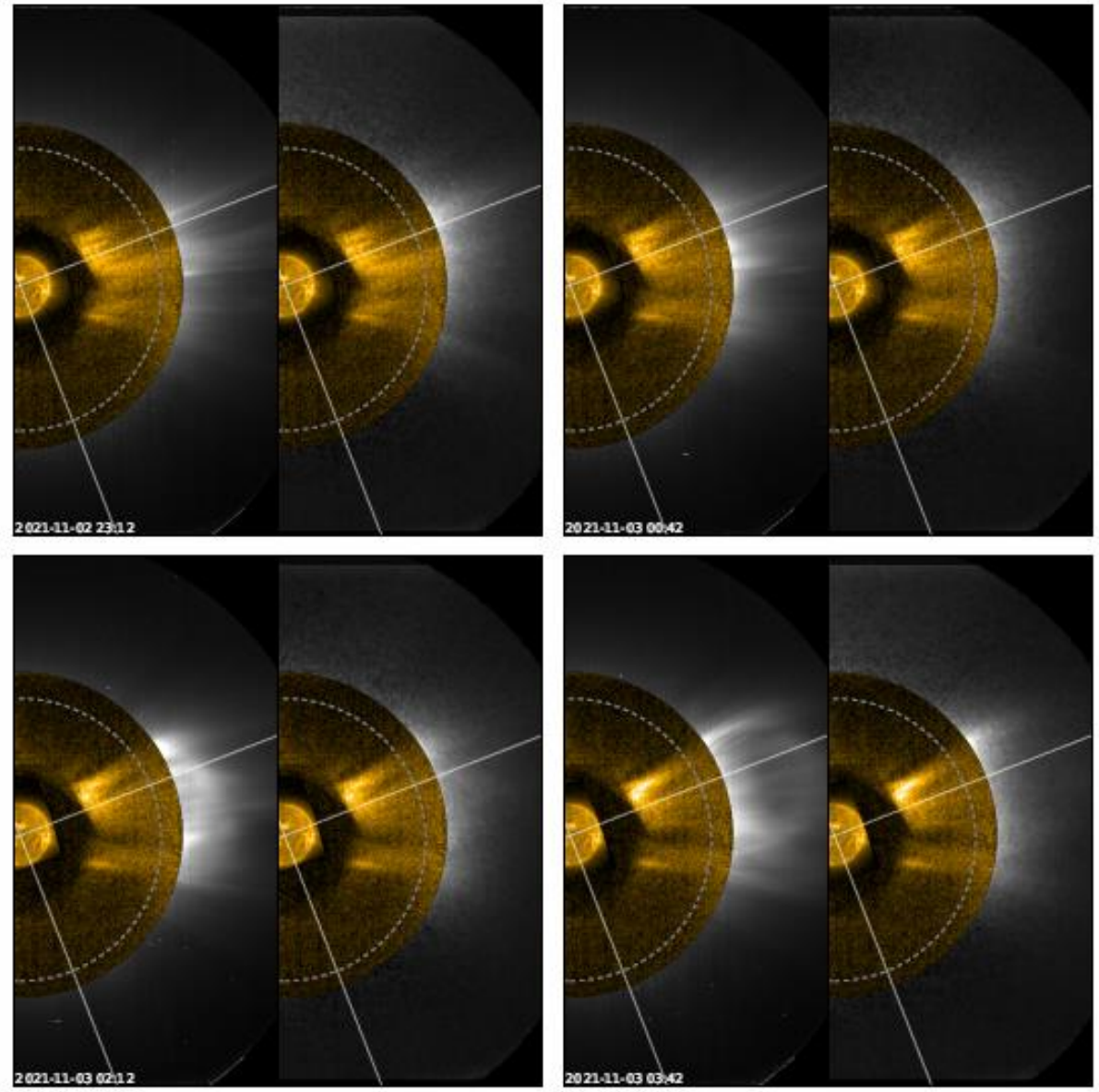


Fig. 7. Composite of a SWAP 17.4 nm image (below 2 $R_\odot$, 2021 November 1 at 10:43 UT) with an FSI 17.4 nm image in coronagraphic mode (10:42 UT).



Auchère+ 2023

Combined Metis and EUI observations on March 2021

Metis and EUI observations

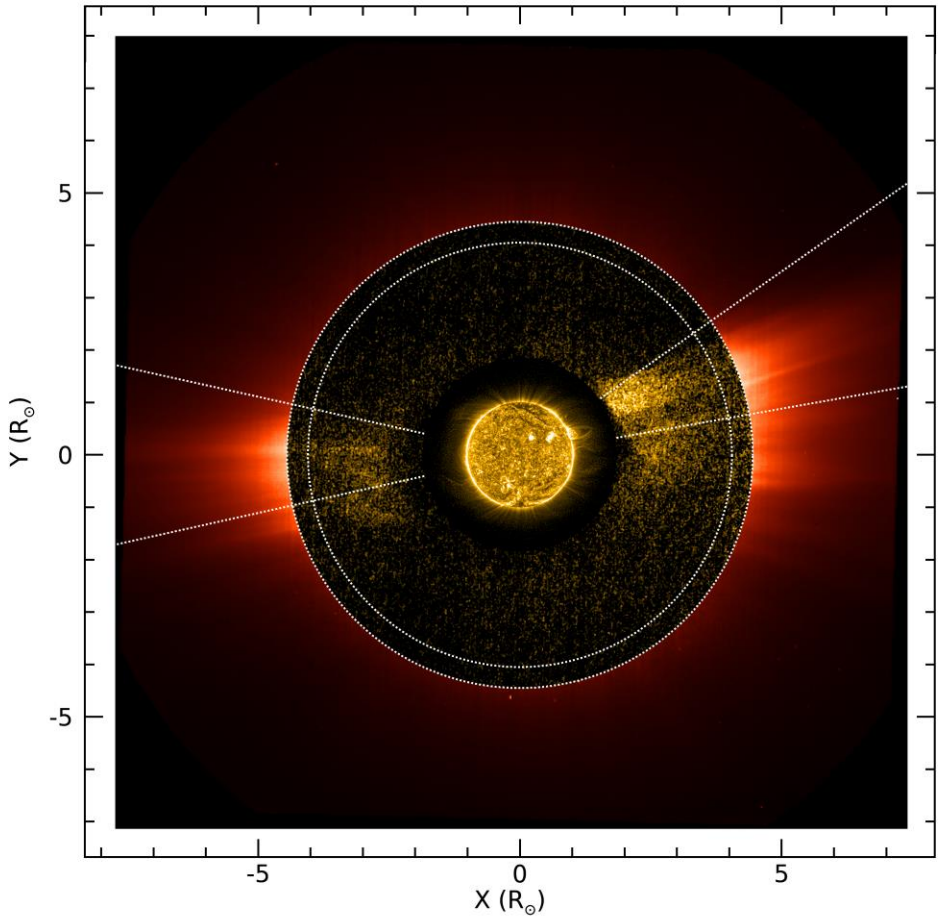
Analysis of the images acquired by Metis and EUI on 21 March 2021

- Metis LT-CONFIG observations → polarised VL emission in the range 580-640 nm + UV HI Lyman-α (121.6 nm) → *study of the evolution of the large-scale corona*
- Special EUI/FSI174 observations carried out with an occulting disc on the door mechanism in front of the entrance filter → *exploration of the fainter corona further away from the solar surface*

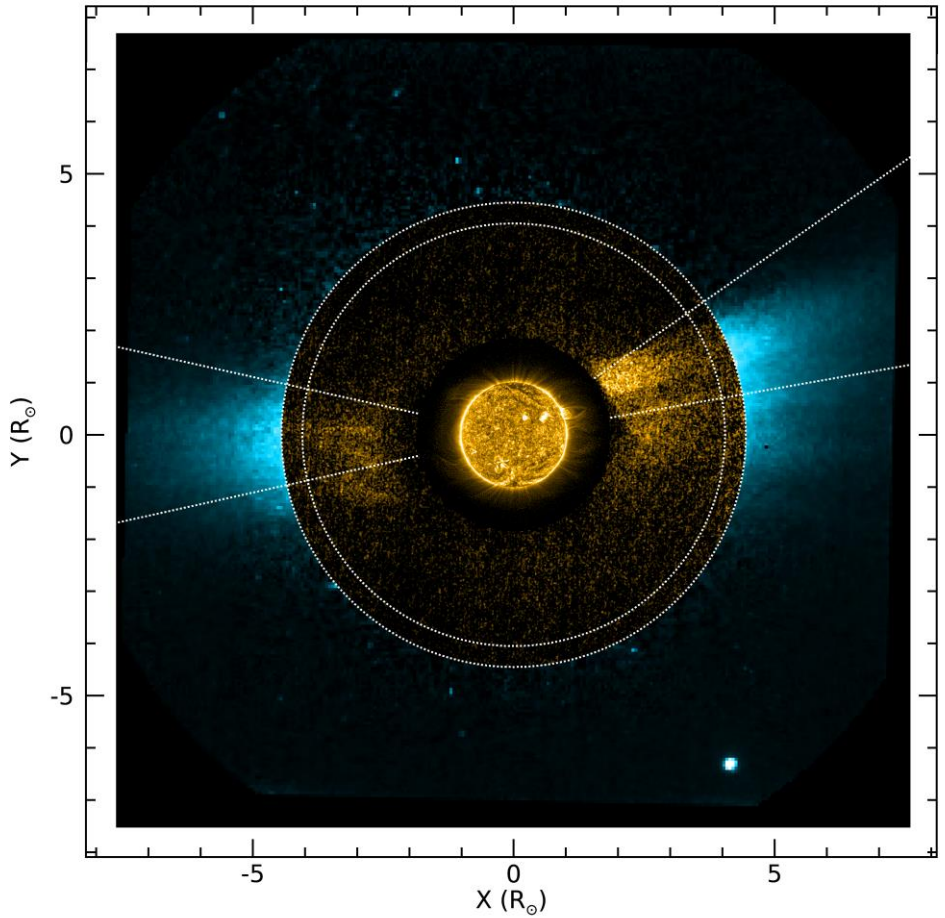
Metis and EUI observations

21 March 2021
0.68 AU helio-distance
Metis FOV ~ 4-7 $R_\odot$ EUI FOV ~ from limb to >4.5 $R_\odot$

Metis pB + FSI 17.4 nm

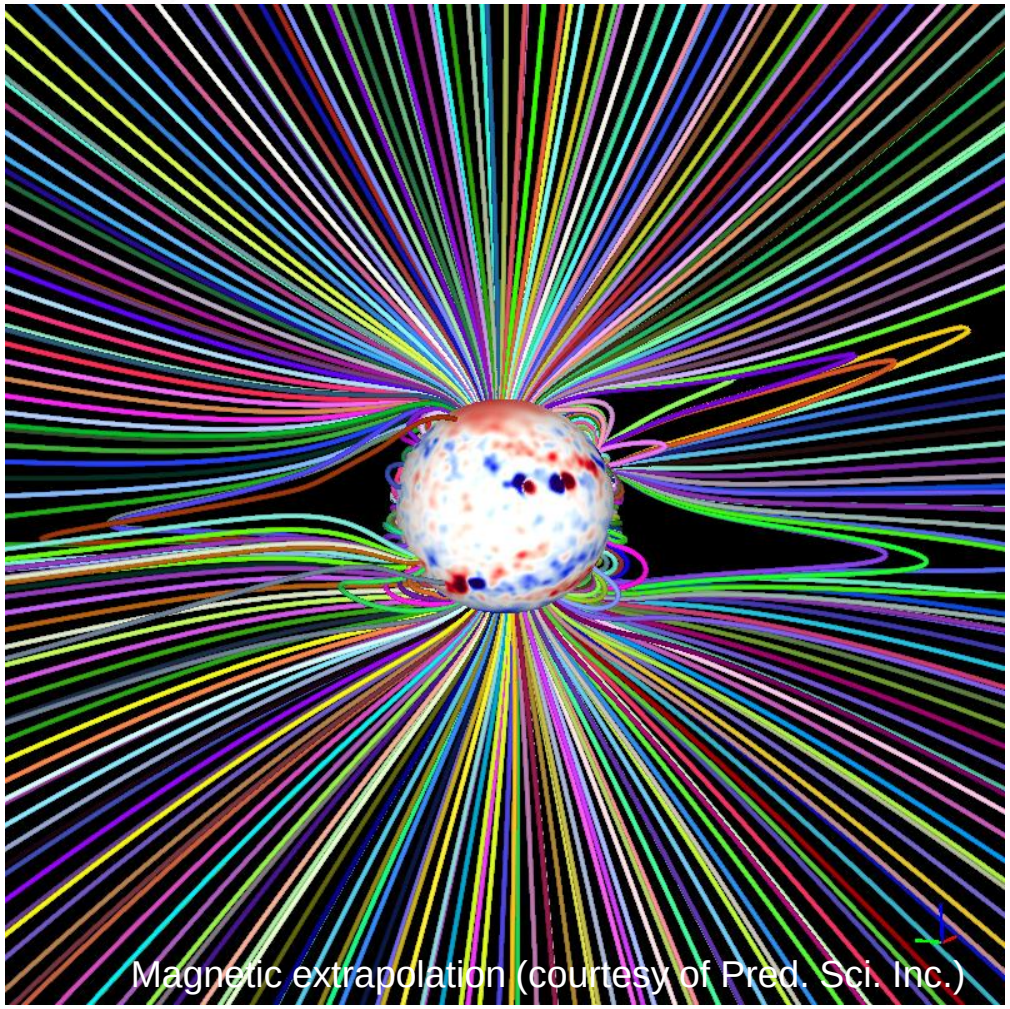


Metis UV Lyman-α + FSI 17.4 nm

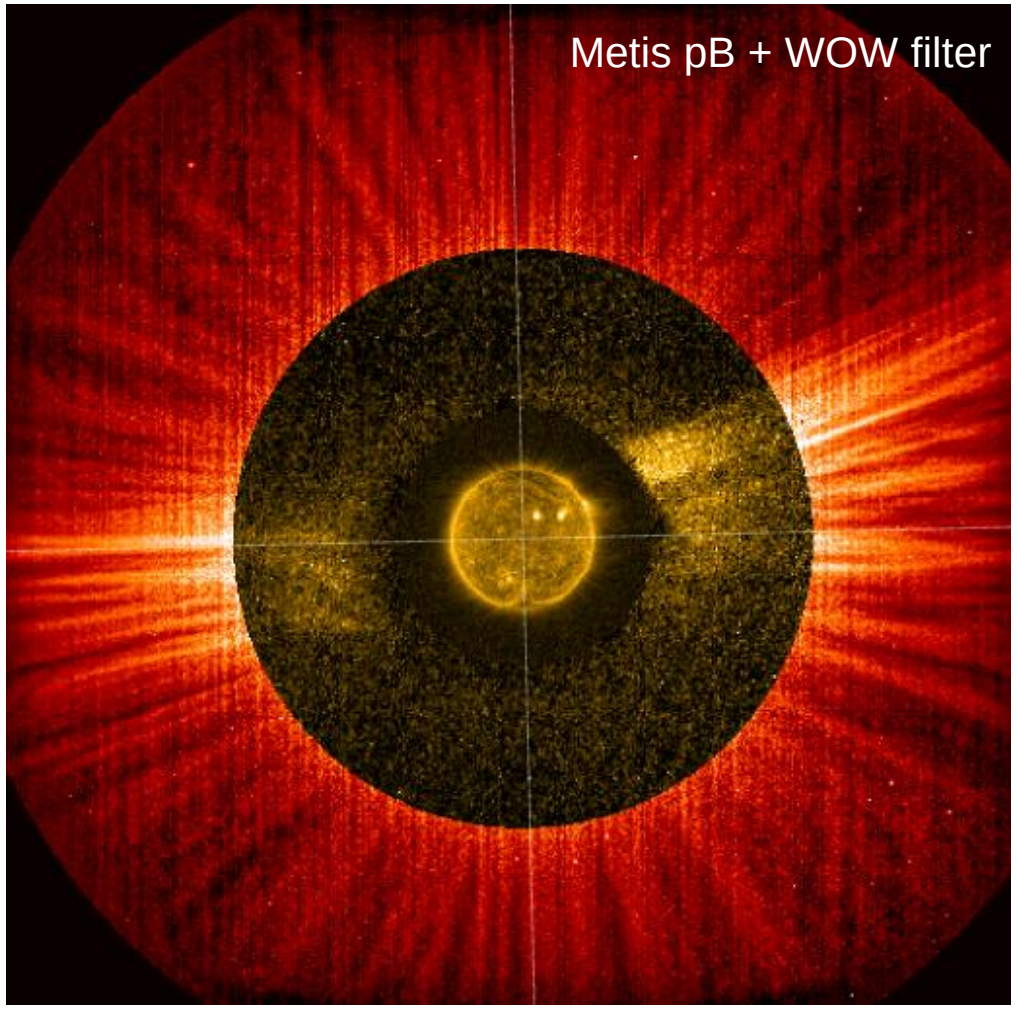


Magnetic topology and coronal structures

21 March 2021
0.68 AU helio-distance
Metis FOV ~ 4-7 $R_\odot$ EUI FOV ~ from limb to >4.5 $R_\odot$



Magnetic extrapolation (courtesy of Pred. Sci. Inc.)



Metis and EUI observations - emission properties

Metis polarised VL

↓

Thomson scattering of photospheric radiation

↓

$$pB = \int_{l.o.s.} f(n_e)\, ds$$

Metis UV Lyman-α

↓

Mainly resonant scattering of chromospheric Lyman-α

↓

$$I = \int_{l.o.s.} f(n_e, T_e, T_k, I_\odot, v_w)\, ds$$

EUI FSI 174 Å

↓

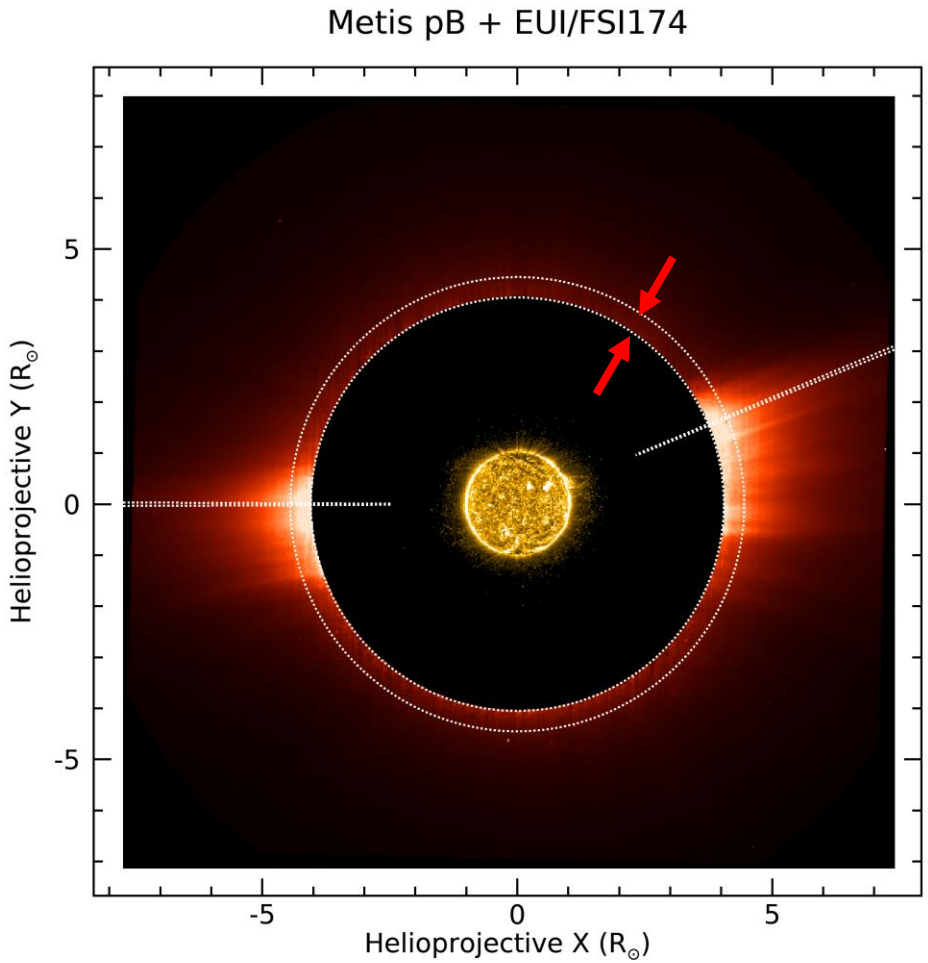
Mainly collisional excitation of Fe IX/X

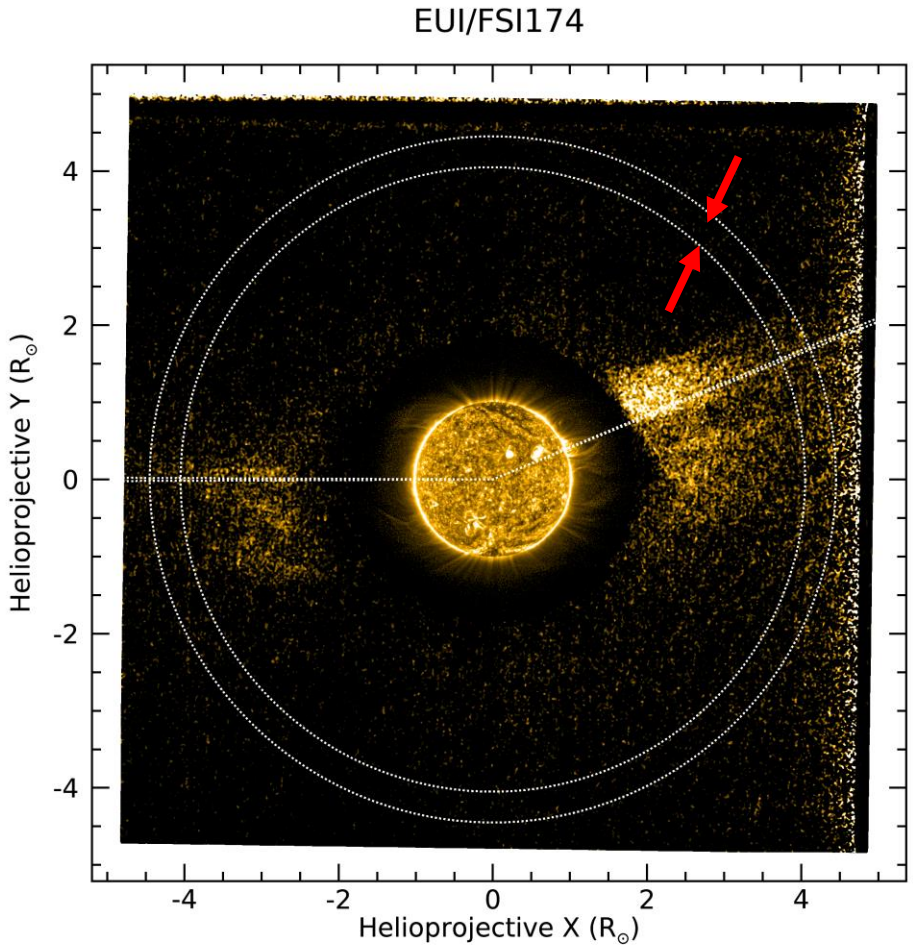
↓

$$I = \int_{l.o.s.} f(n_e^2, T_e)\, ds$$

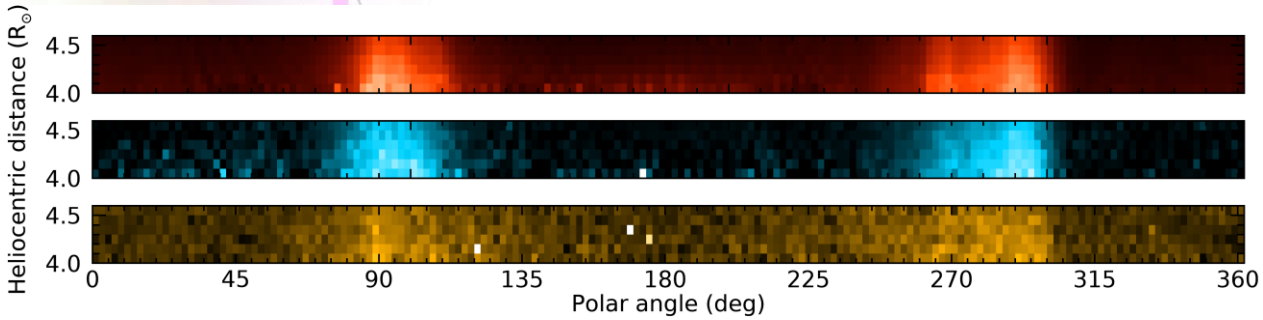
Metis and EUI observations

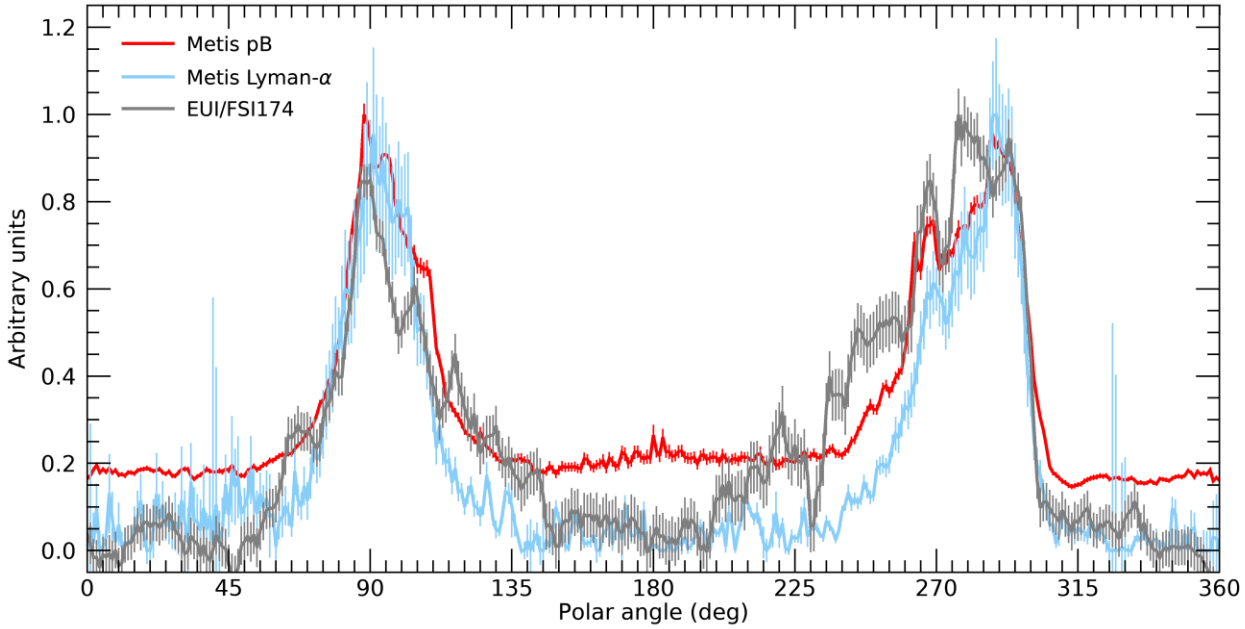
FOVs overlapping between ~4.05-4.45 $R_\odot$



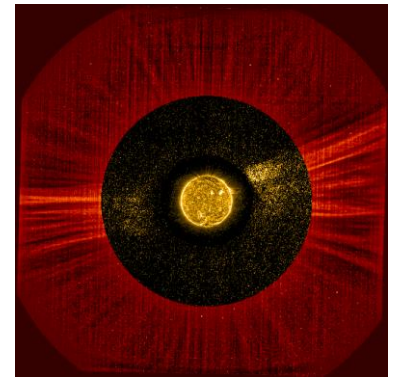


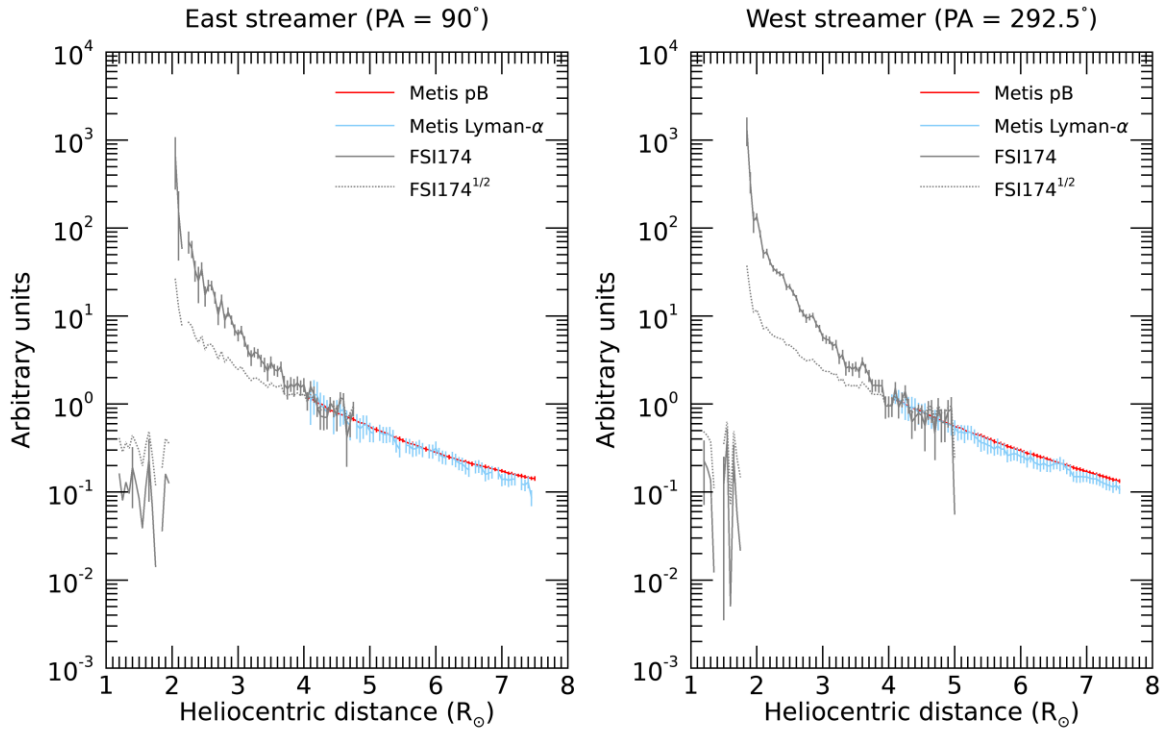
Metis and EUI observations





Metis and FSI174 latitudinal profiles obtained by averaging the data in the overlapping region. The profiles are normalised to their maximum value.

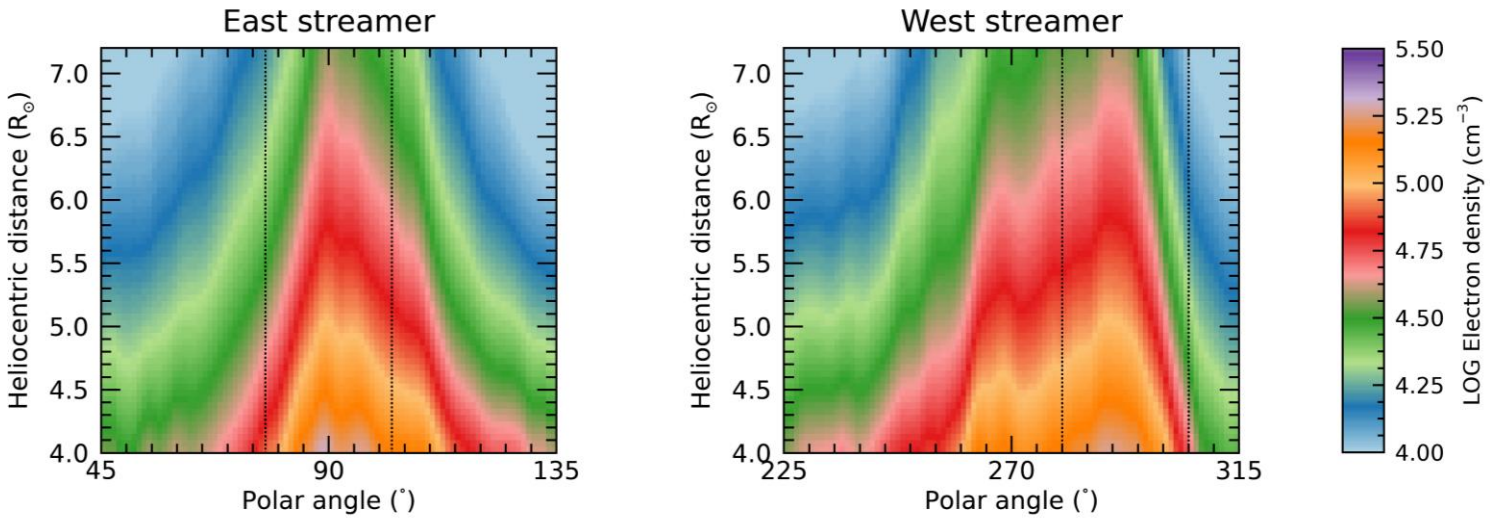


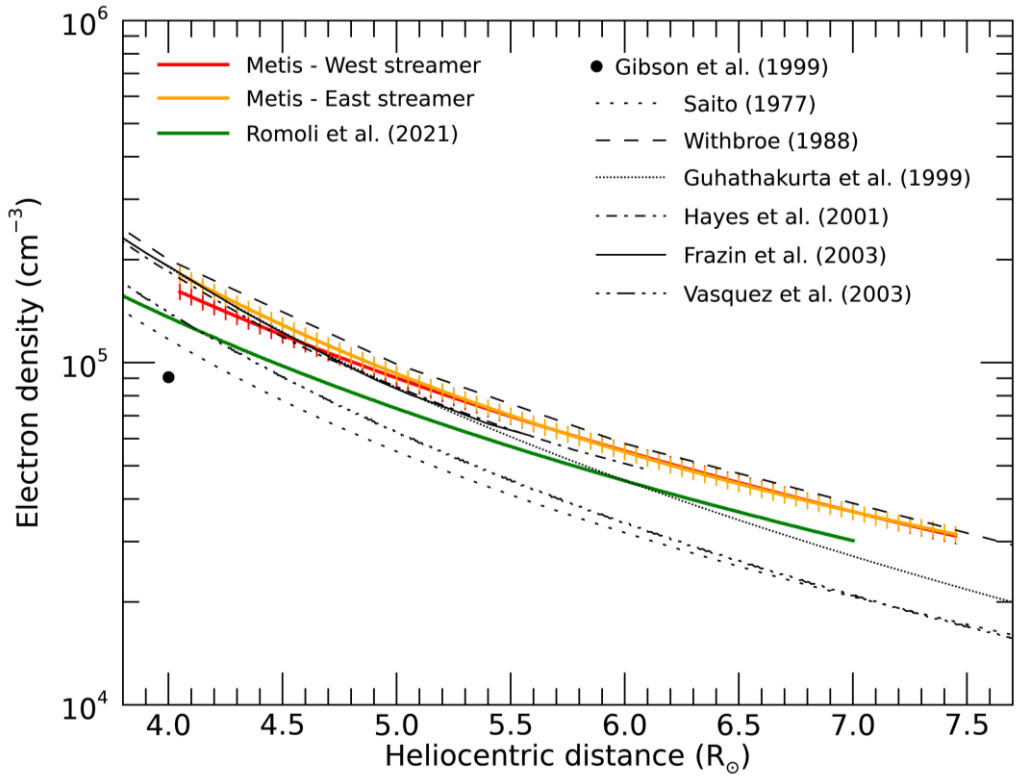


Radial profiles at PA = 90° and 292.5°, normalised to the overlapping-region values.

Indications that FeX line is mainly produced by collisional excitation

Electron density from Metis polarised VL



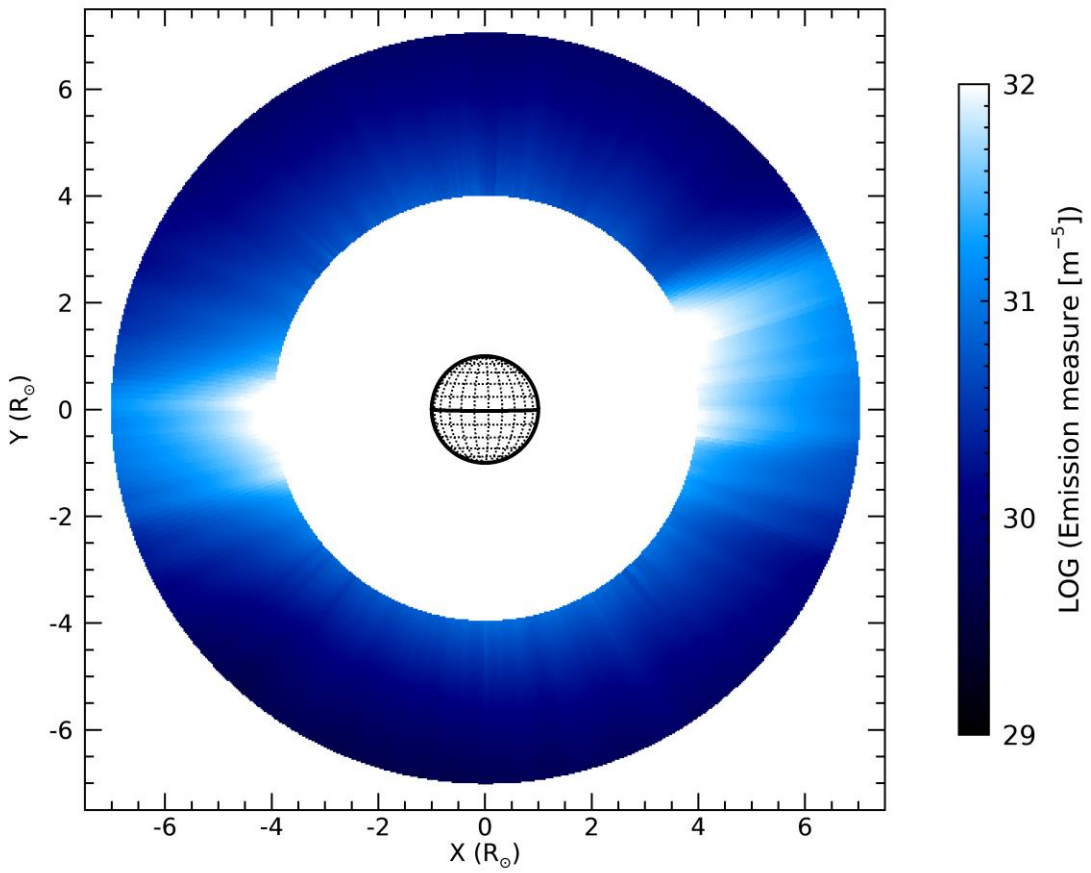


Electron density maps derived from Metis pB data in the two regions surrounding the equatorial streamers.
The thin vertical lines mark the region where Metis pB data are averaged to get the radial profiles.

Emission measure from Metis

$$\mathrm{EM} = \int_0^{+\infty} \xi(T_e)\, d\log T_e = \int_0^{\infty} n_e^2\, ds.$$

Computed by considering a l.o.s. of ±10 solar radii



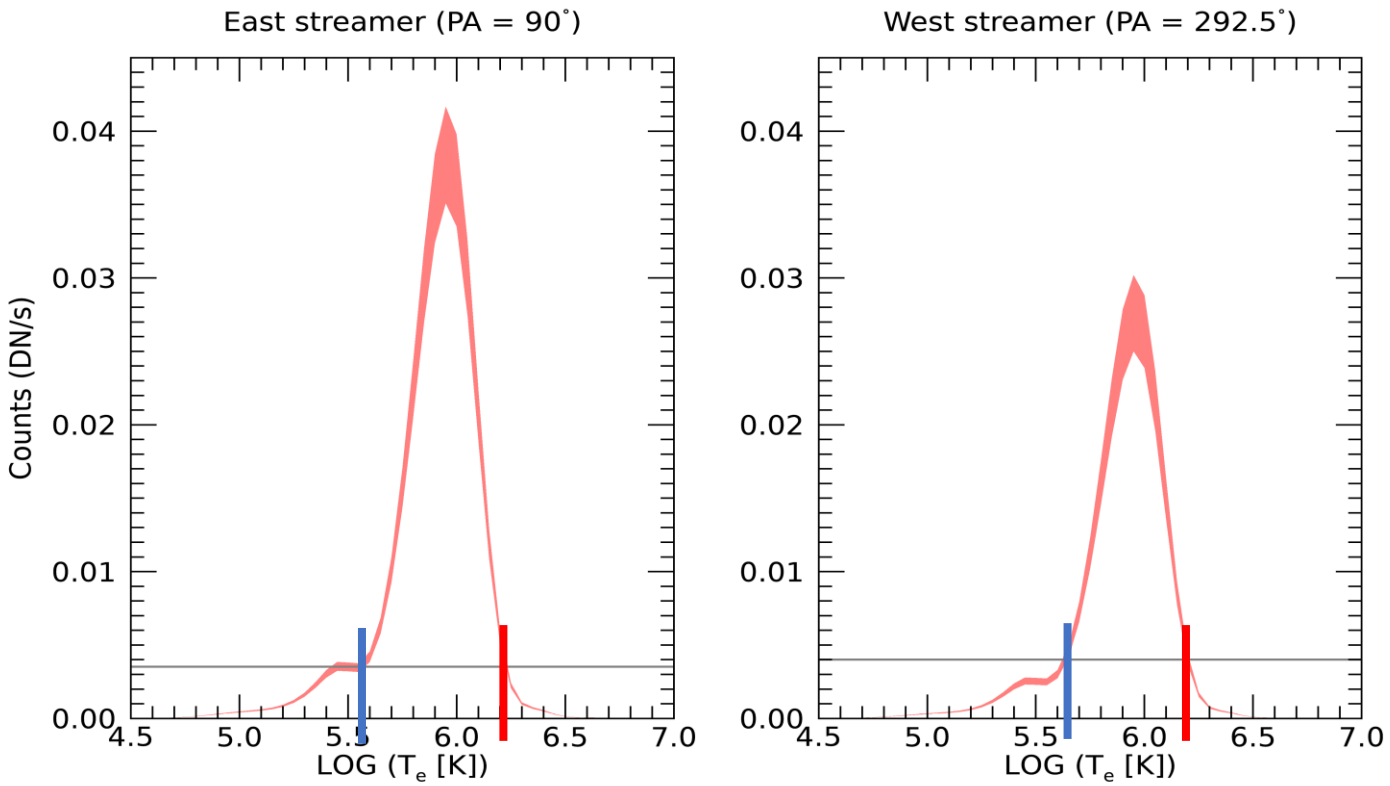
Expected FSI 174 counts from Metis EM

We calculated the response functions in the FSI 17.4 nm passband, $R(n_e, T_e)$, by using the CHIANTI atomic database (Dere et al. 1997; Del Zanna et al. 2021) for n_e between 10^2-10^{12} cm^{-3} and T_e between 10^4-10^8 K.

The corresponding number of counts detected by FSI per unit time is given by:

$$C_{FSI} = \frac{1}{4\pi}\int_{\infty} R(n_e, T_e)\, n_e^2\, ds \approx \frac{1}{4\pi} R(T_e)\, EM$$

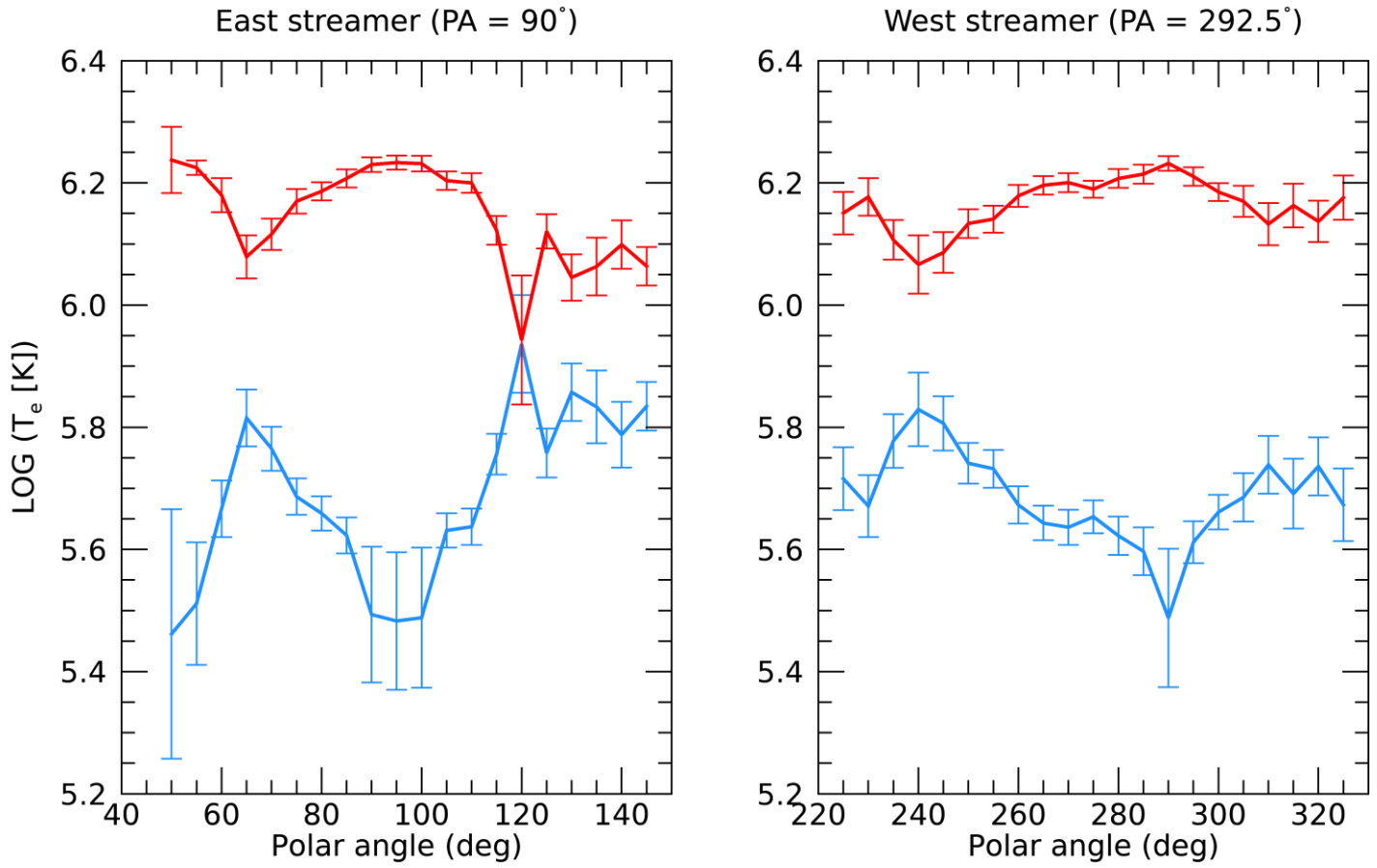
Comparison expected and measured FSI counts
→ 'cold' and 'hot' solutions



Electron temperature results from Metis EM

T_e (in logarithmic scale) as a function of polar angle across the streamers as derived from the intersections between the counts computed by the emission measure with the measured counts of FSI, in the overlapping region between Metis and EUI.

The **blue** curve represents the first solution (named cold) and the **red** curve represents the second solution (named hot).



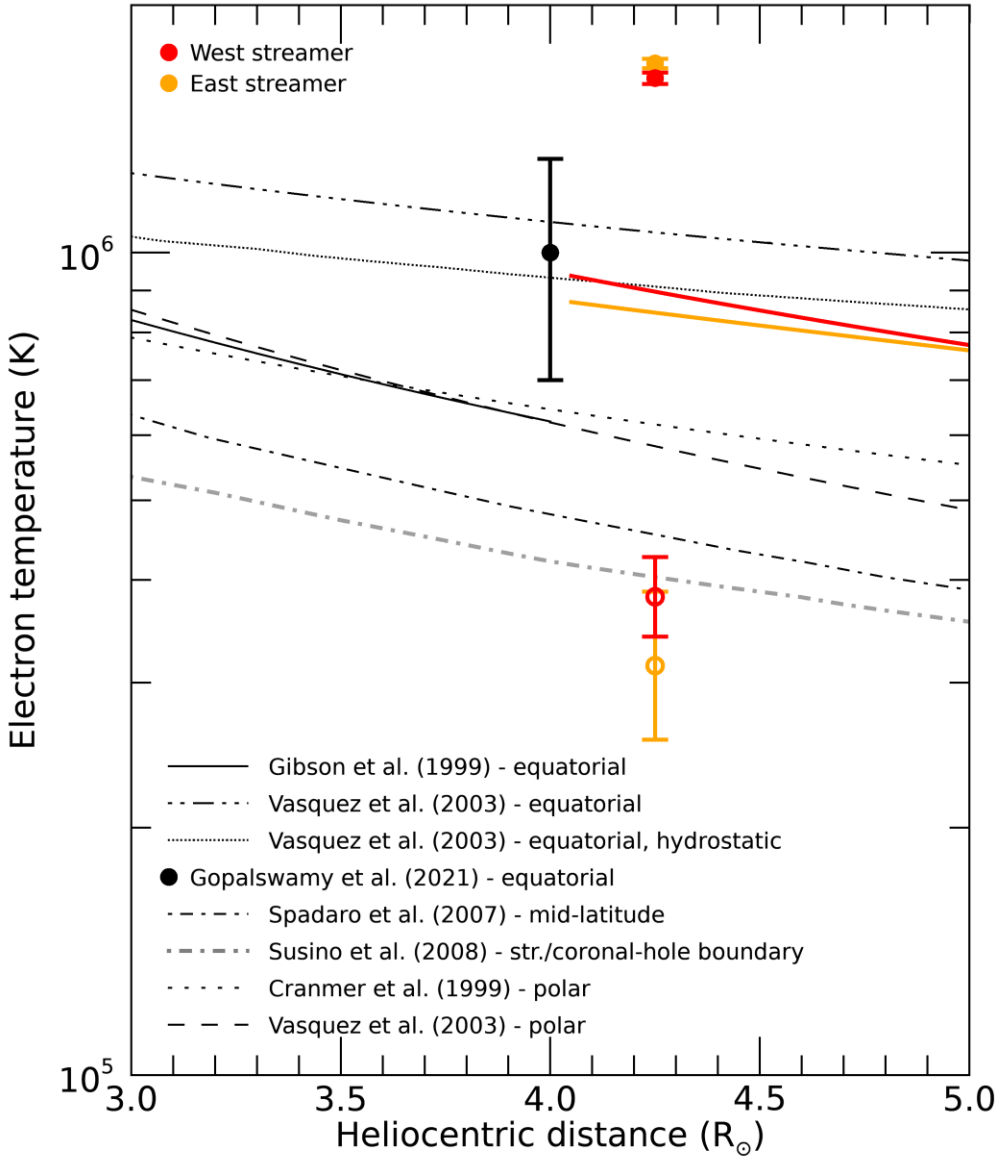
Electron temperature results from Metis

T_e derived for the West (red) and East (orange) streamers observed on March 21, 2021, with two different methods:

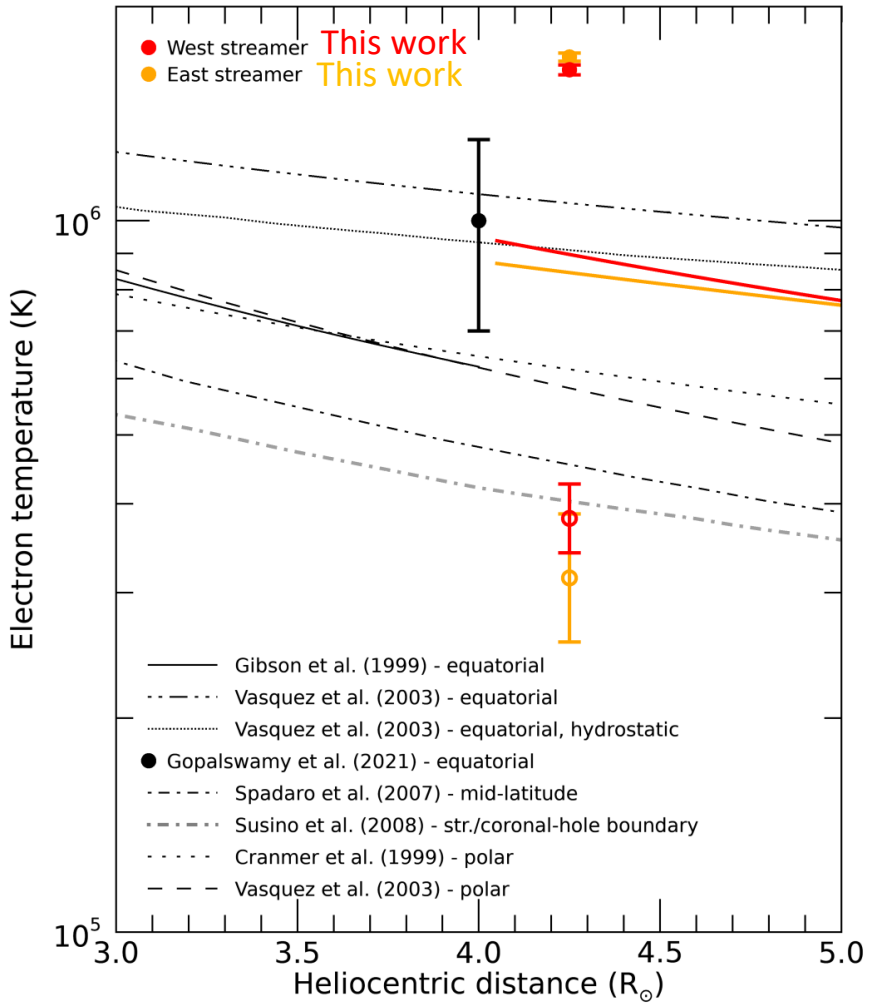
(1) inversion of the electron density profiles derived from Metis pB data assuming hydrostatic equilibrium (thick lines)

(2) comparison between the Fe IX/Fe X 17.4 nm intensities measured by FSI and expected in the FSI passband at 4.25 $R_\odot$, given the emission-measure distribution obtained from Metis visible-light data (open circles: cold solution; filled circles: hot solution)

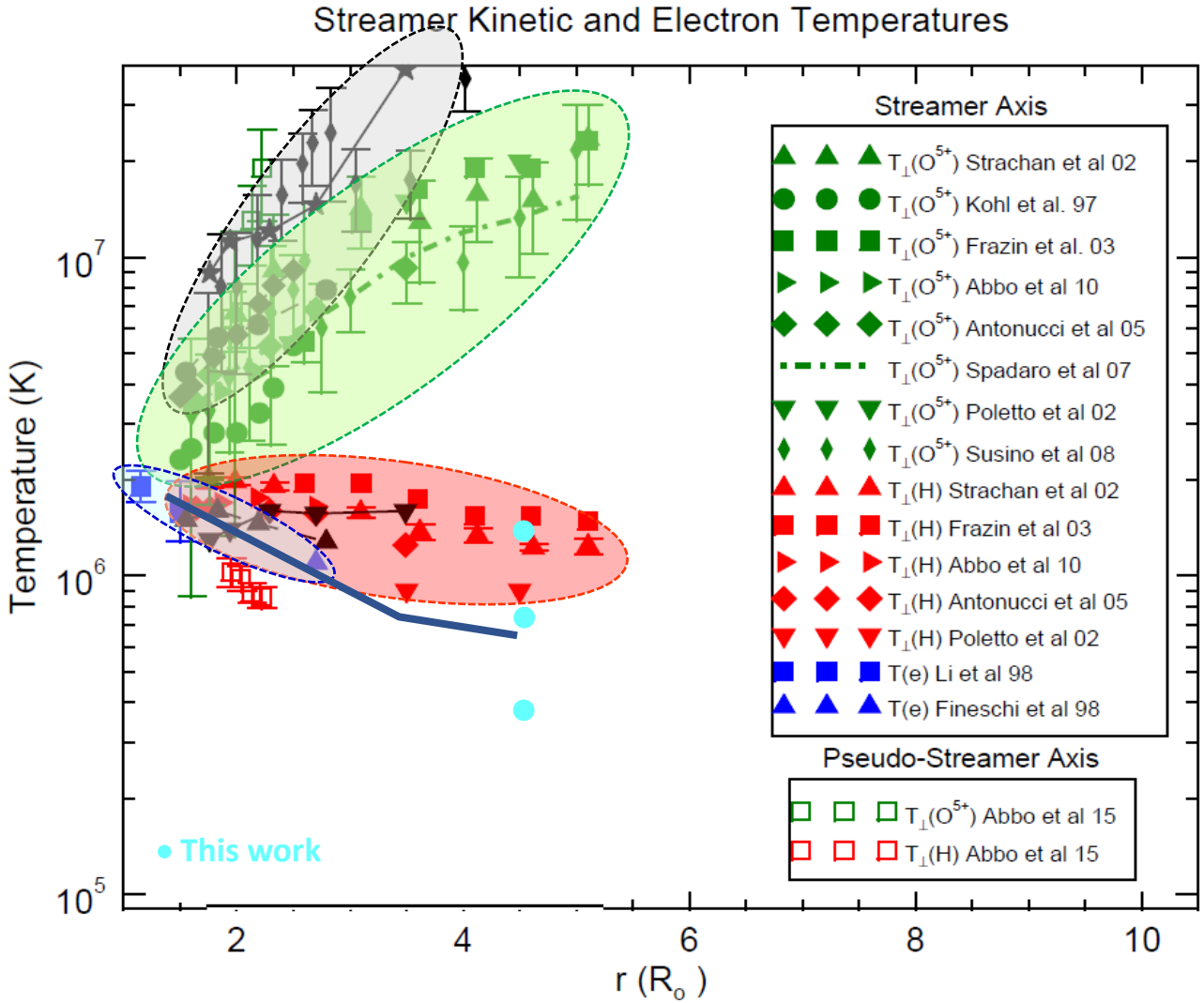
The inferred values are compared with some literature T_e profiles for equatorial/mid-latitude streamers and polar regions, as indicated in the plot legend.



Electron temperature results from Metis



Abbo, Susino,+ submitted, Fig.8



Abbo+ 2016, Fig.3 adapted by L. Strachan and myself

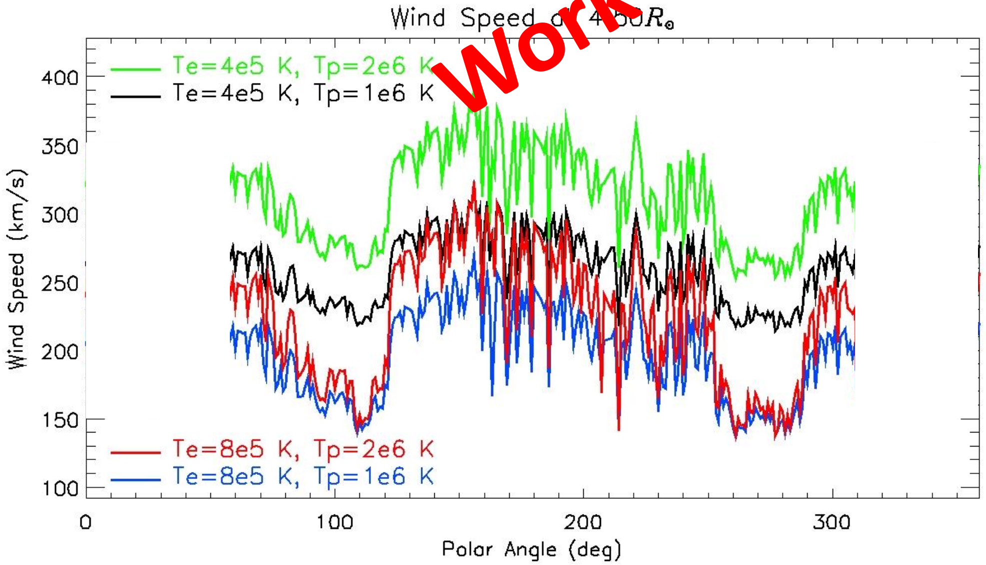
T_e from PSP/FILEDS data (Moncuquet+ 2020): 3.5×10^5 K at 36 $R_\odot$ (0.17 au) and of 2.3×10^5 K at 64 $R_\odot$ (0.3 au)

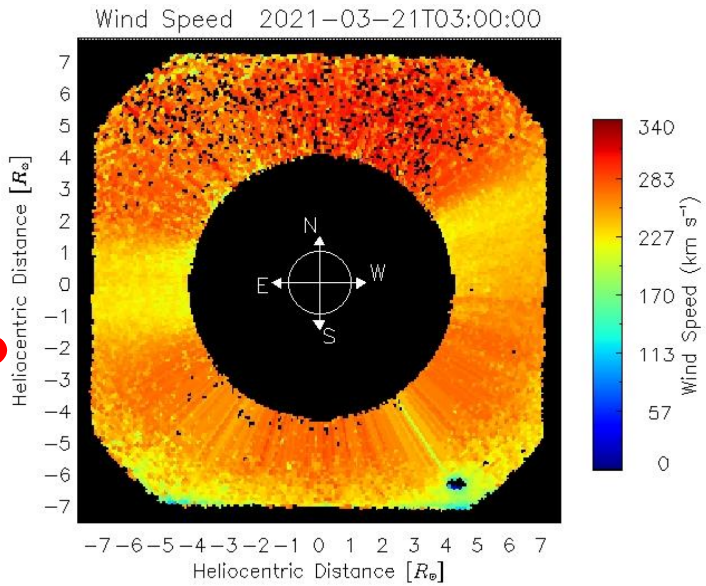
Solar wind velocity from Metis data

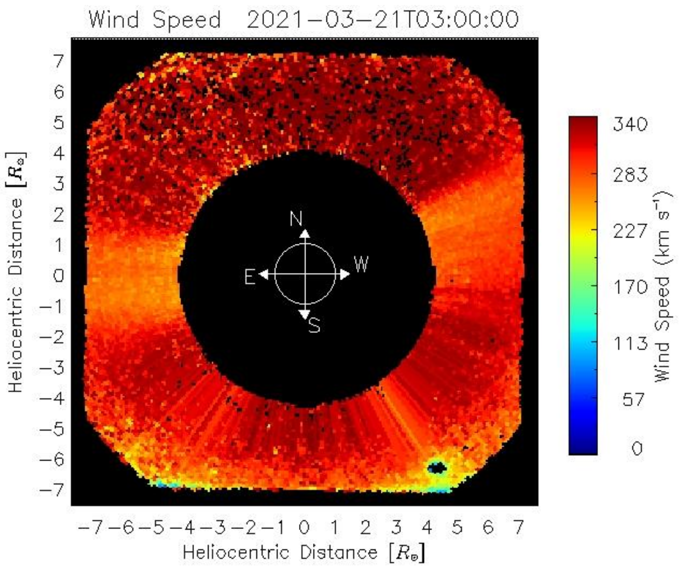
4 outflow velocity maps

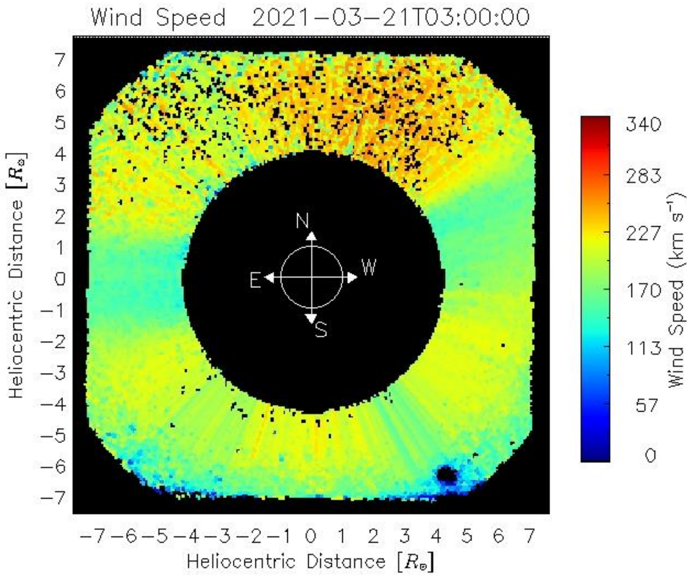
Te = 4.e5 K, Tp = 1.e6 K
Te = 4.e5 K, Tp = 2.e6 K
Te = 8.e5 K, Tp = 1.e6 K
Te = 8.e5 K, Tp = 2.e6 K

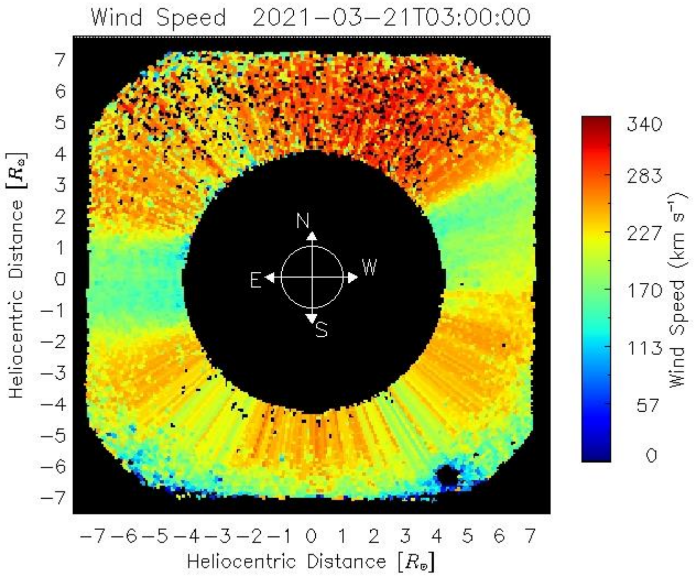
Work in progress











Discussion on the results

Analysis of the images acquired by Metis and EUI on 21 March 2021

- This observation is a good opportunity to test the potential of combining measurements from Metis and EUI to infer a model of a coronal streamer
- The possibility to constrain electron density, electron temperature and outflow velocity
- Plan future combined observations by using the occulting disc of EUI for studying the boundary between streamer and coronal hole and the density fluctuations with high frequency observations when SolO is at a heliodistance >0.4 au (also for the inflows/outflows topic)

Abbo, Susino, Auchère, Parenti, et al., A&A, under review

THANK YOU FOR YOUR ATTENTION

GRAZIE PER L'ATTENZIONE!

http://metis.oato.inaf.it/
https://www.esa.int/Science_Exploration/Space_Science/Solar_Orbiter/
#SolarOrbiter
#Metis Coronagraph - Solar Orbiter
#TheSunUpClose #WeAreAllSolarOrbiters