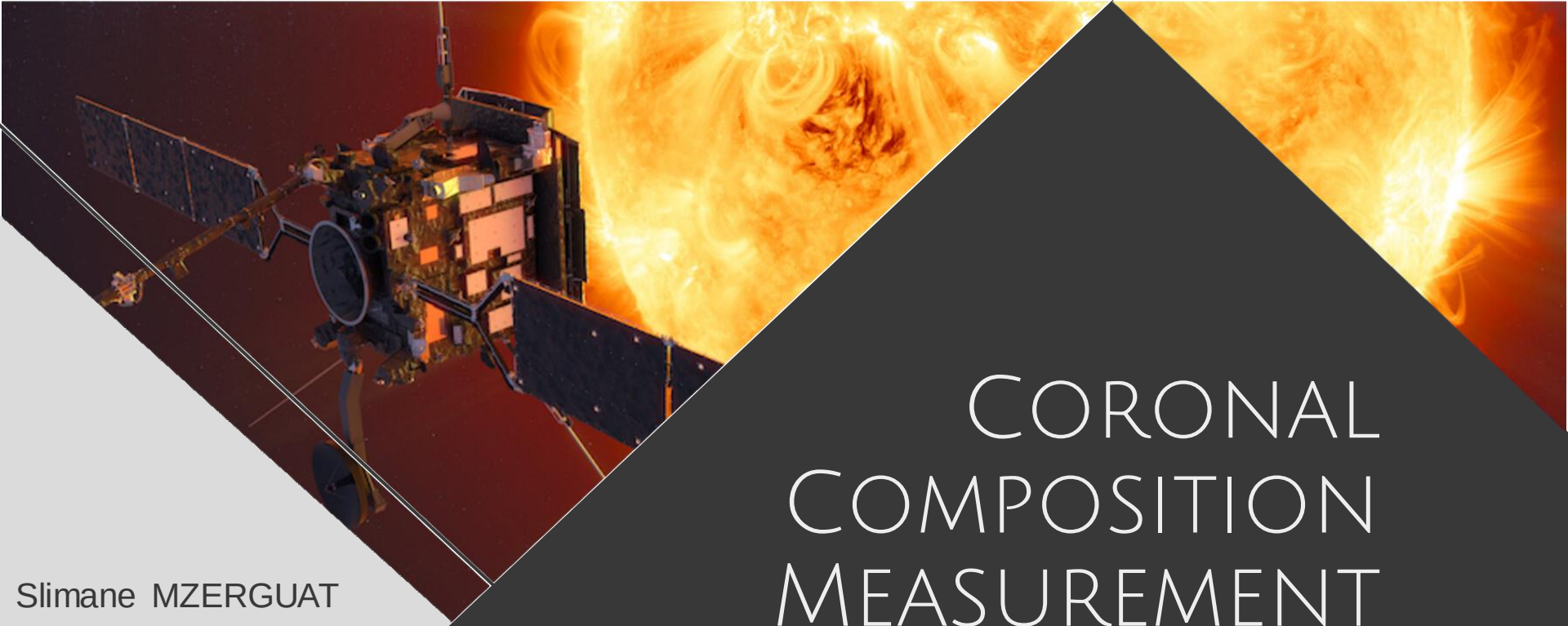


Coronal Composition Measurement

A multi-instrumental analysis including Solar Orbiter/SPICE

Slimane MZERGUAT

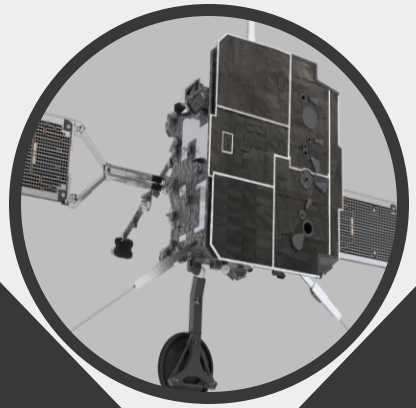
Eric BUCHLIN
Miho JANVIER

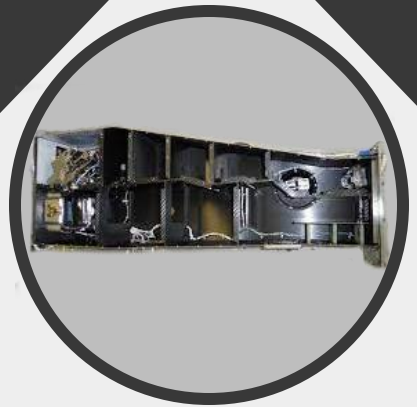
Institut d'Astrophysique Spatiale (IAS),
France

PNST 2024

SOLAR ORBITER

Joint ESA-NASA mission, explores the Sun's magnetic fields, solar wind, and inner heliosphere, orbiting as close as **60 solar radii**. Equipped with **10 instruments**.





SPICE

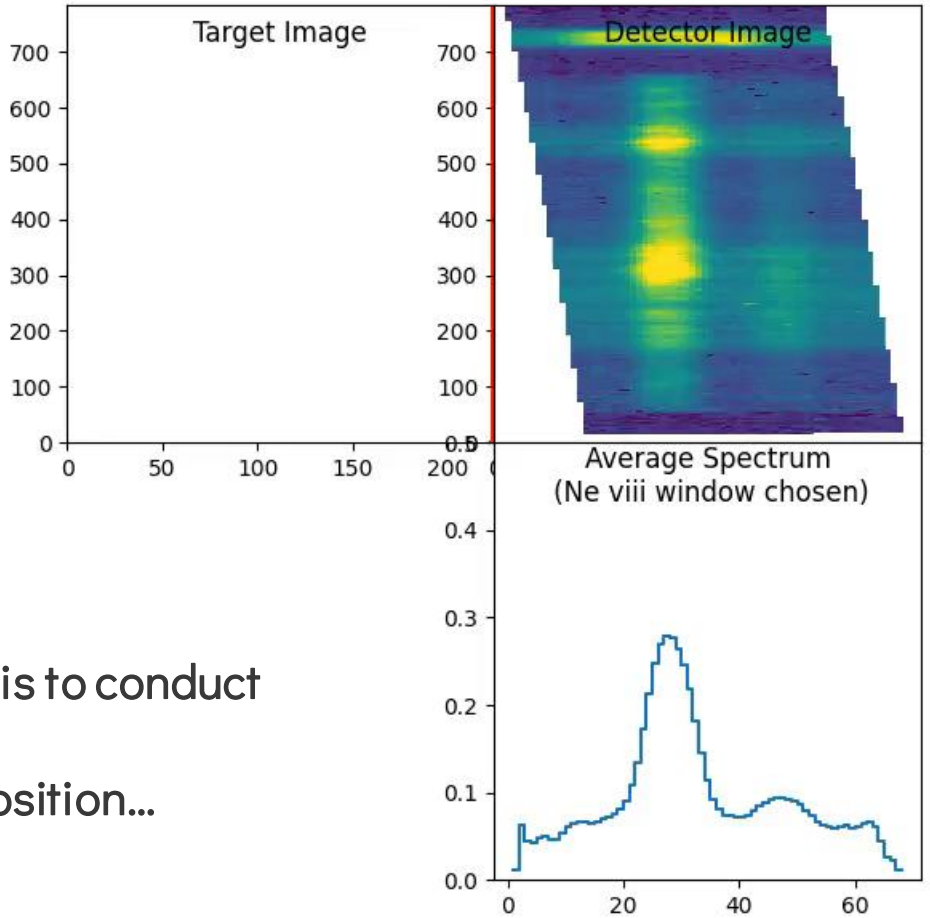
SPICE (Spectral Imaging of the Coronal Environment) captures **EUV spectra**, providing data for plasma diagnostics from **upper chromosphere to lower corona**

SPICE INSTRUMENT

One data cube
⇒ 1 image is a set of N exposures along x direction. (can be time consuming)

⇒ 3 axes (spatial directions + spectral direction).

⇒ discrete spectral windows.



The main task for SPICE instrument is to conduct plasma diagnostics:
Temperature, Doppler, Composition...

SPICE OBSERVATIONS

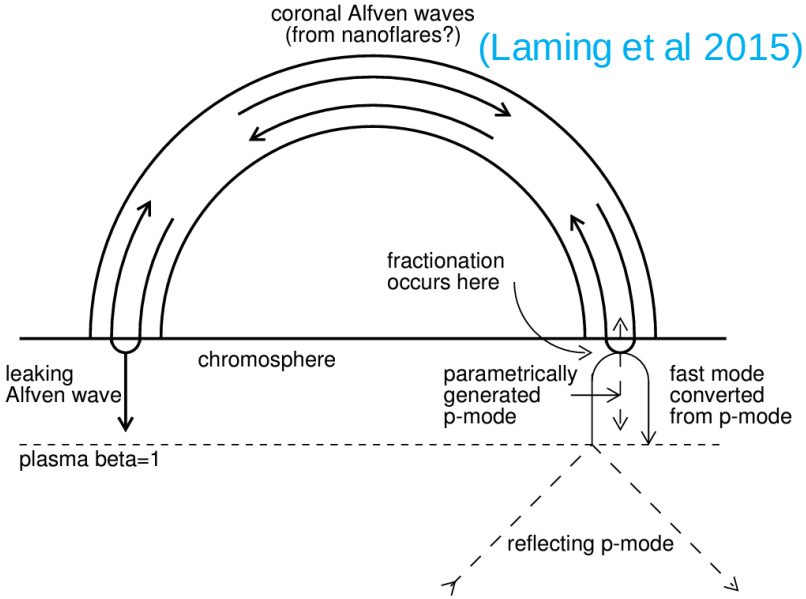
The main task for SPICE Instrument is to conduct plasma diagnostics:
Temperature, Doppler, Composition

why Composition :

- Needed to fully describe plasma evolution.
- A tracer of the **source region** of the solar wind.
- Linked to different physical processes: Wave propagation and absorption, reconnection…

SPICE COMPOSITION

Composition



"FIP bias" : abundance bias as a function of the elements' First ionization potential.

- Elements with Low FIP (LF) (<10 eV) are more enhanced (2 times or more) compared with High FIP elements
- Measured in the solar wind as well as in the corona
- See poster (Alixis P.Rouillard, Nicolas Poirier)

SPICE COMPOSITION

Composition ⬅ FIP bias

LCR method: Linear Combination Ratio

A new method for reconstructing elemental abundances using a set of lines from Low FIP (LF) elements and another from High FIP (HF) elements.

Method assumptions:

- Transparent plasma (doesn't work in filaments)
- LF and HF combinations of lines have close contribution functions

(Zambrana Prado et.al 2019)

SPICE COMPOSITION

Composition ⬅ FIP Bias ⬅ LCR methods

SAFFRON: Spectral Analysis, Fitting Framework, Reduction Of Noise.

- A local pipeline for fitting SPICE L2 data and providing plasma diagnostics.
  - Automatic initial parameter generator.
  - Denoising
  - Despiking (Cosmics…)
  - Convolution (for increasing signal power)
  - Fitting and error estimation … etc.

SPICE COMPOSITION

Composition ⬅ FIP Bias ⬅ LCR methods ⬅ SAFFRON

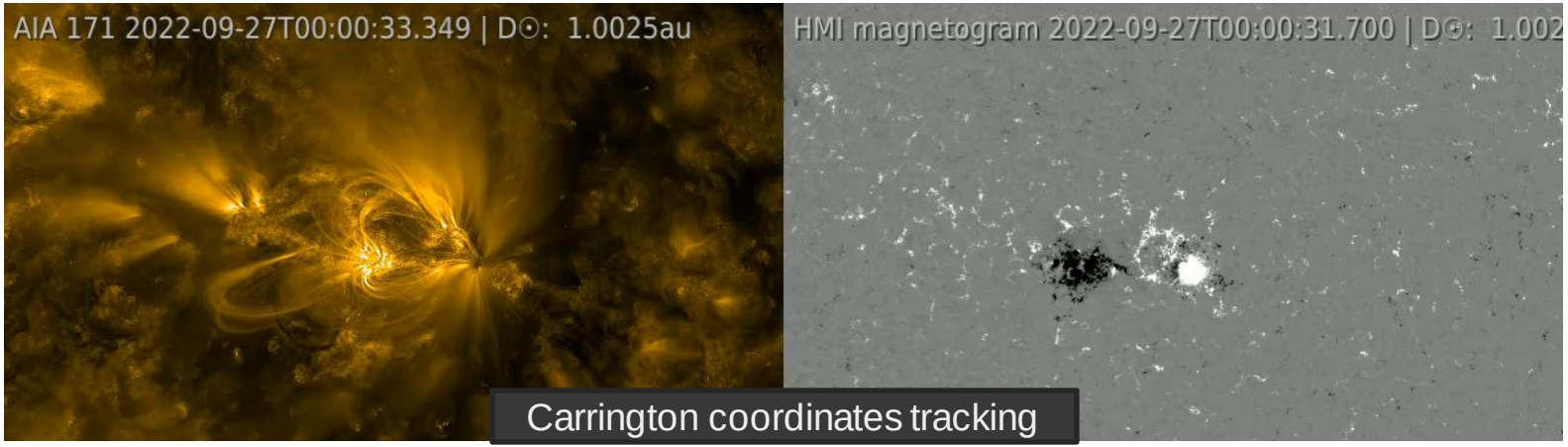
SAFFRON : Spectral Analysis, Fitting Framework, Reduction Of Noise.

- A local pipeline for fitting SPICE L2 data and providing plasma diagnostics.
  - Automatic initial parameter generator.
  - Denoising
  - Despiking (Cosmics…)
  - Convolution (for increasing signal power)
  - Fitting and error estimation … etc.

Observational context

It all started with an active region…

AR13110
Facing earth between 27-09-2022 and 05-10-2022

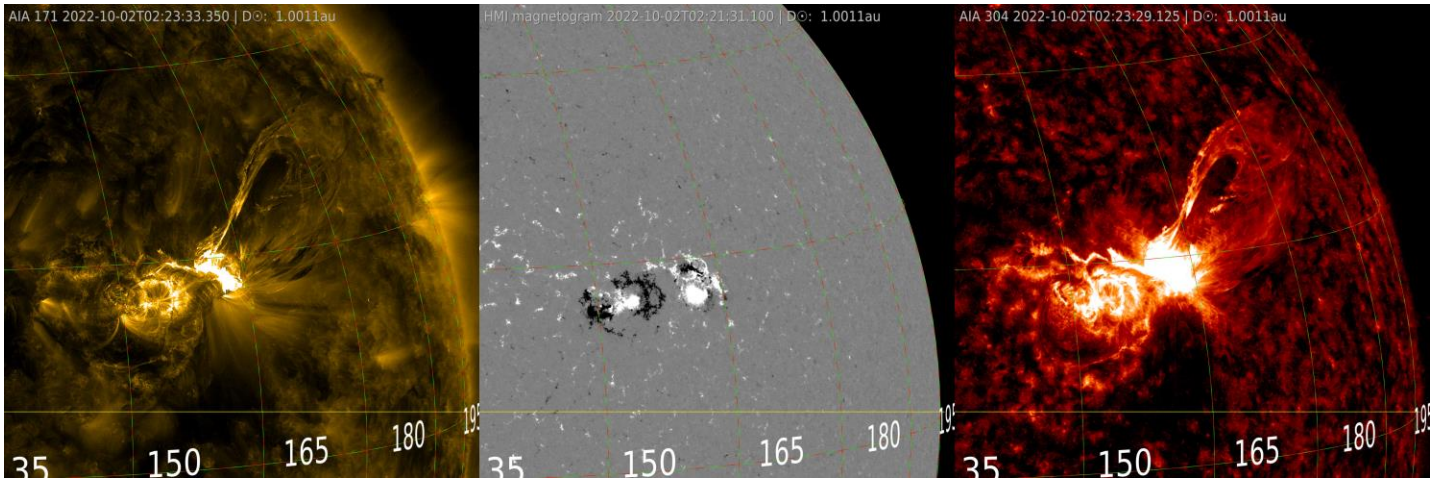


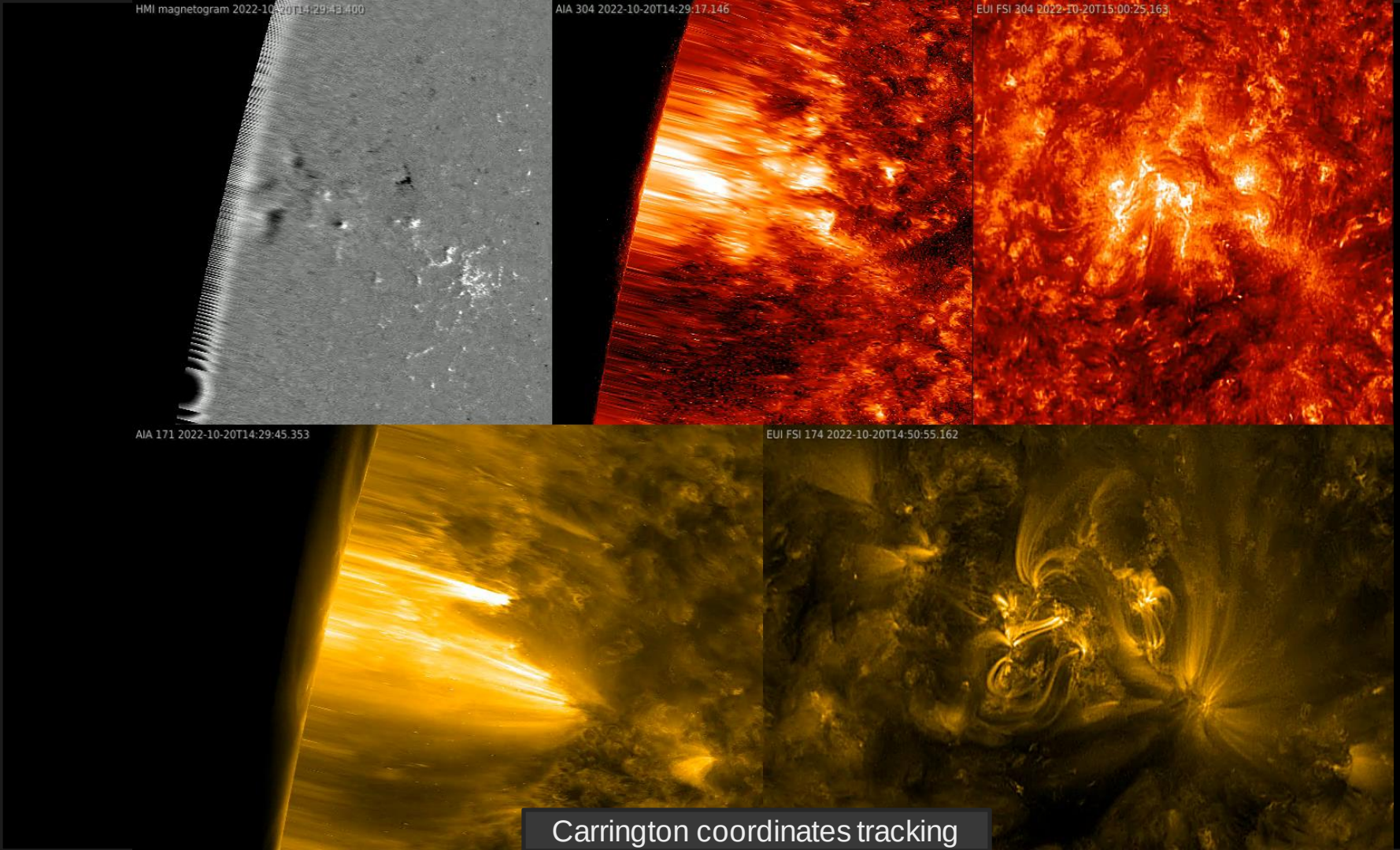
Observational context

Multiple events on AR13110

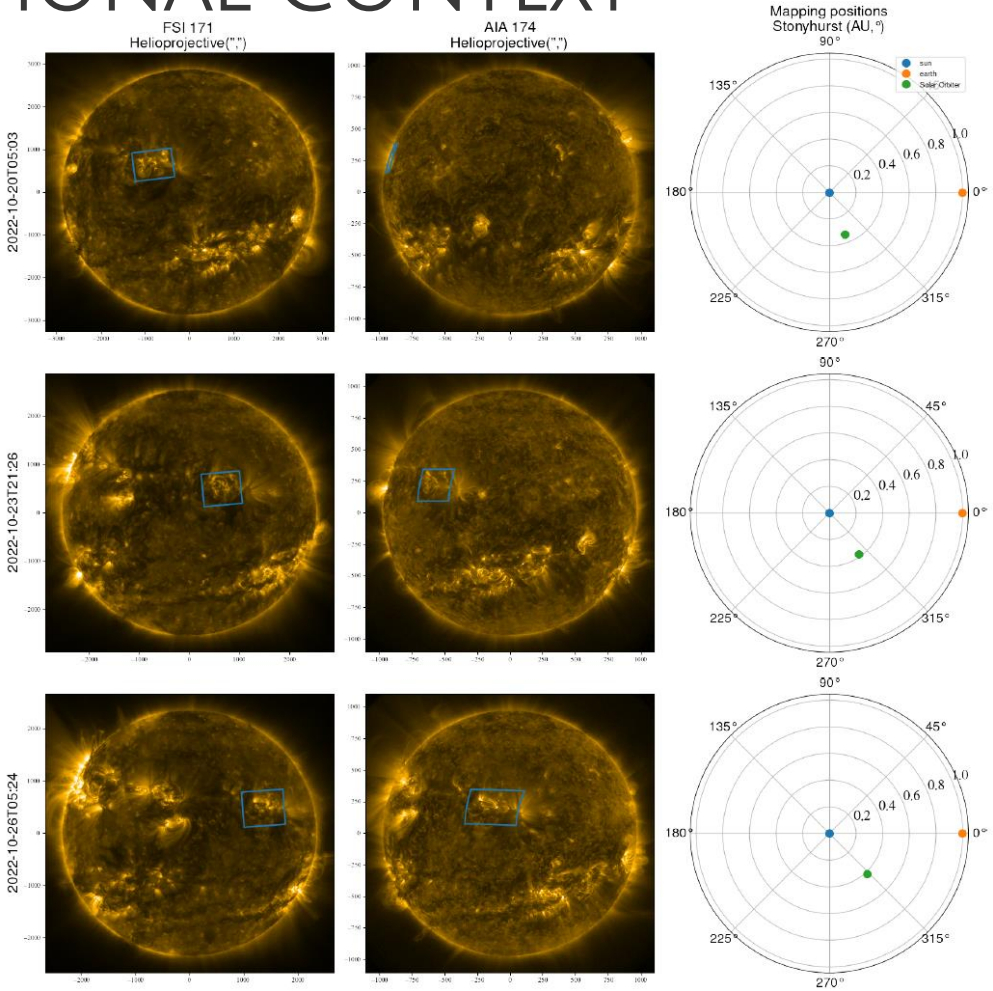
X1.0 flare on 2-10-2022, peak at 20:25 UTC.
M5.86 flare on 1-10-2022, peak at 20:10 UTC.
CME on 2-10-2022 around 02:00 UTC.

Good target for
AR decaying study
SOOP: AR long term tracking

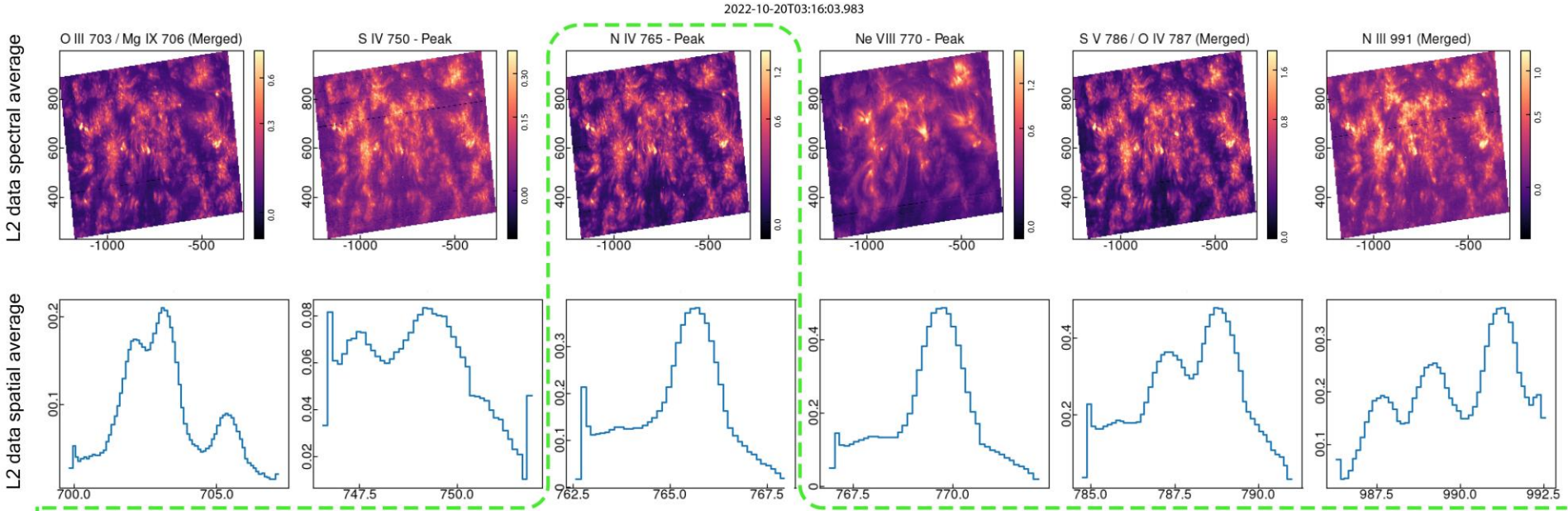



HMI magnetogram 2022-10-20T14:29:43.400
AIA 304 2022-10-20T14:29:17.146
EUI FSI 304 2022-10-20T15:00:25.163
AIA 171 2022-10-20T14:29:45.353
EUI FSI 174 2022-10-20T14:50:55.162
Carrington coordinates tracking

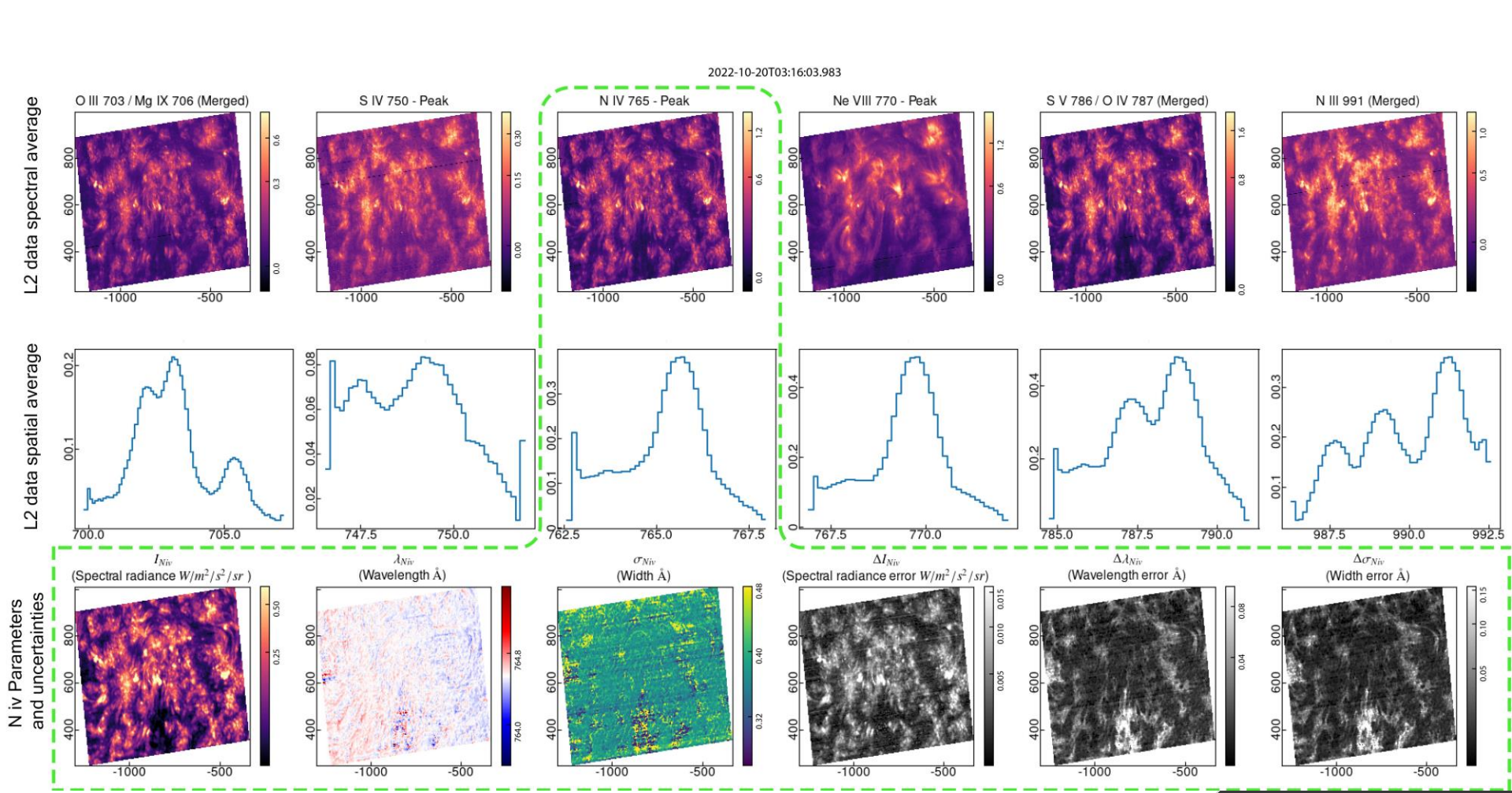
Observational Context

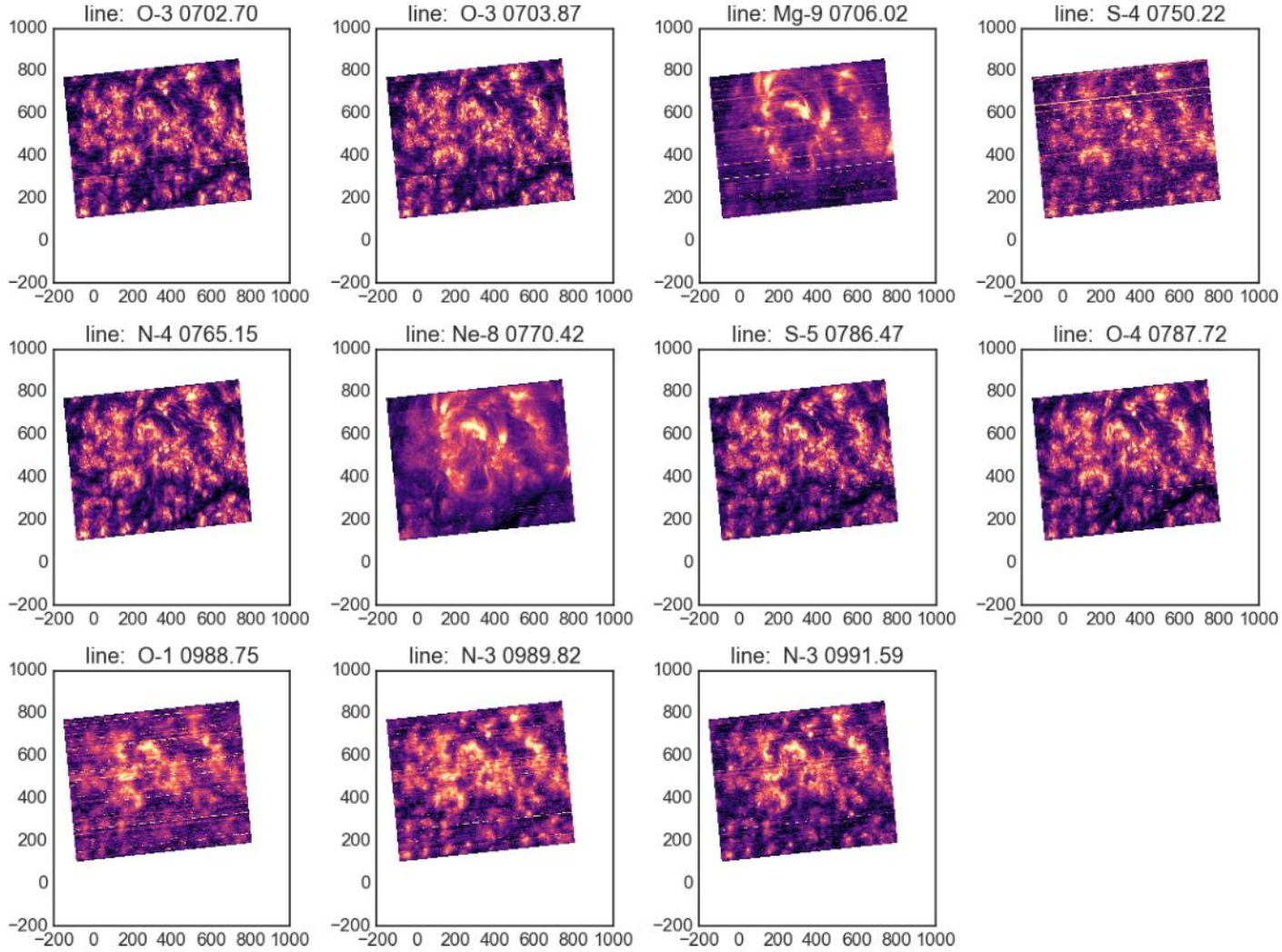


SPICE DATA

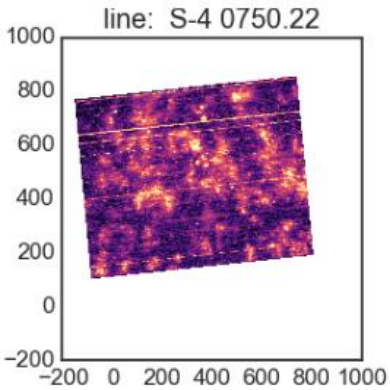


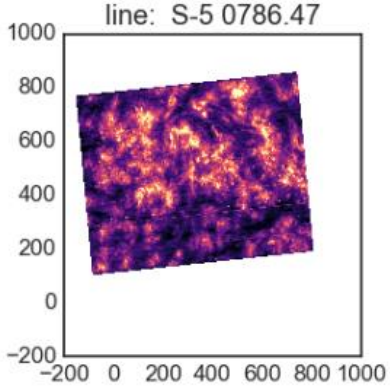
O III-(702.33Å & 702.89Å & 702.82Å), O III-(703.87Å), Mg IX-(706.02Å)	S IV-(748.40Å), Mg IX-(749.54Å), S IV-(750.22Å)	N IV-(765.15Å)	Ne VIII-(770.42Å)	S V-(786.47Å), O IV-(787.72Å)	Na VI-(988.65Å), O I-(988.75 Å), N III-(989.82Å), N III-(991.59Å)


2022-10-20T03:16:03.983
L2 data spectral average
L2 data spatial average
N iv Parameters and uncertainties
O III 703 / Mg IX 706 (Merged)
S IV 750 - Peak
N IV 765 - Peak
Ne VIII 770 - Peak
S V 786 / O IV 787 (Merged)
N III 991 (Merged)
I_{Niv} (Spectral radiance $W/m^2/s^2/sr$)
λ_{Niv} (Wavelength Å)
σ_{Niv} (Width Å)
ΔI_{Niv} (Spectral radiance error $W/m^2/s^2/sr$)
$\Delta\lambda_{Niv}$ (Wavelength error Å)
$\Delta\sigma_{Niv}$ (Width error Å)

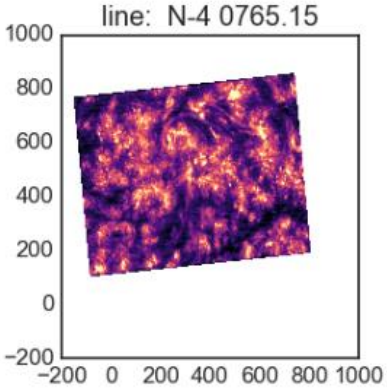

line: O-3 0702.70
line: O-3 0703.87
line: Mg-9 0706.02
line: S-4 0750.22
line: N-4 0765.15
line: Ne-8 0770.42
line: S-5 0786.47
line: O-4 0787.72
line: O-1 0988.75
line: N-3 0989.82
line: N-3 0991.59
1000
800
600
400
200
0
−200
−200 0 200 400 600 800 1000

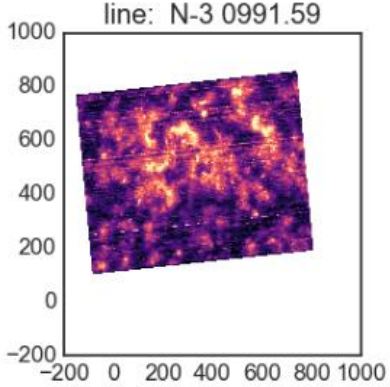
SPICE DATA





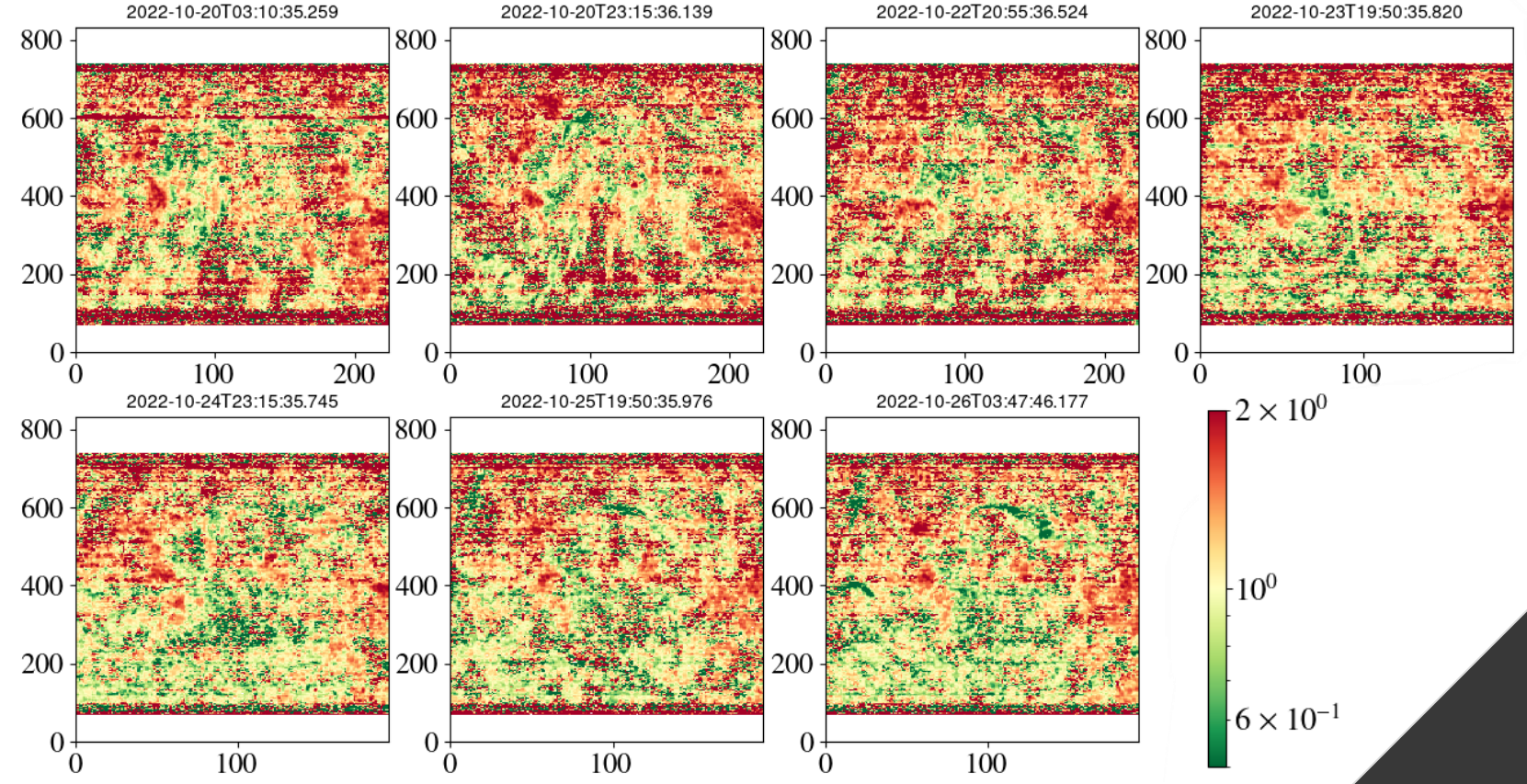
Low FIP lines



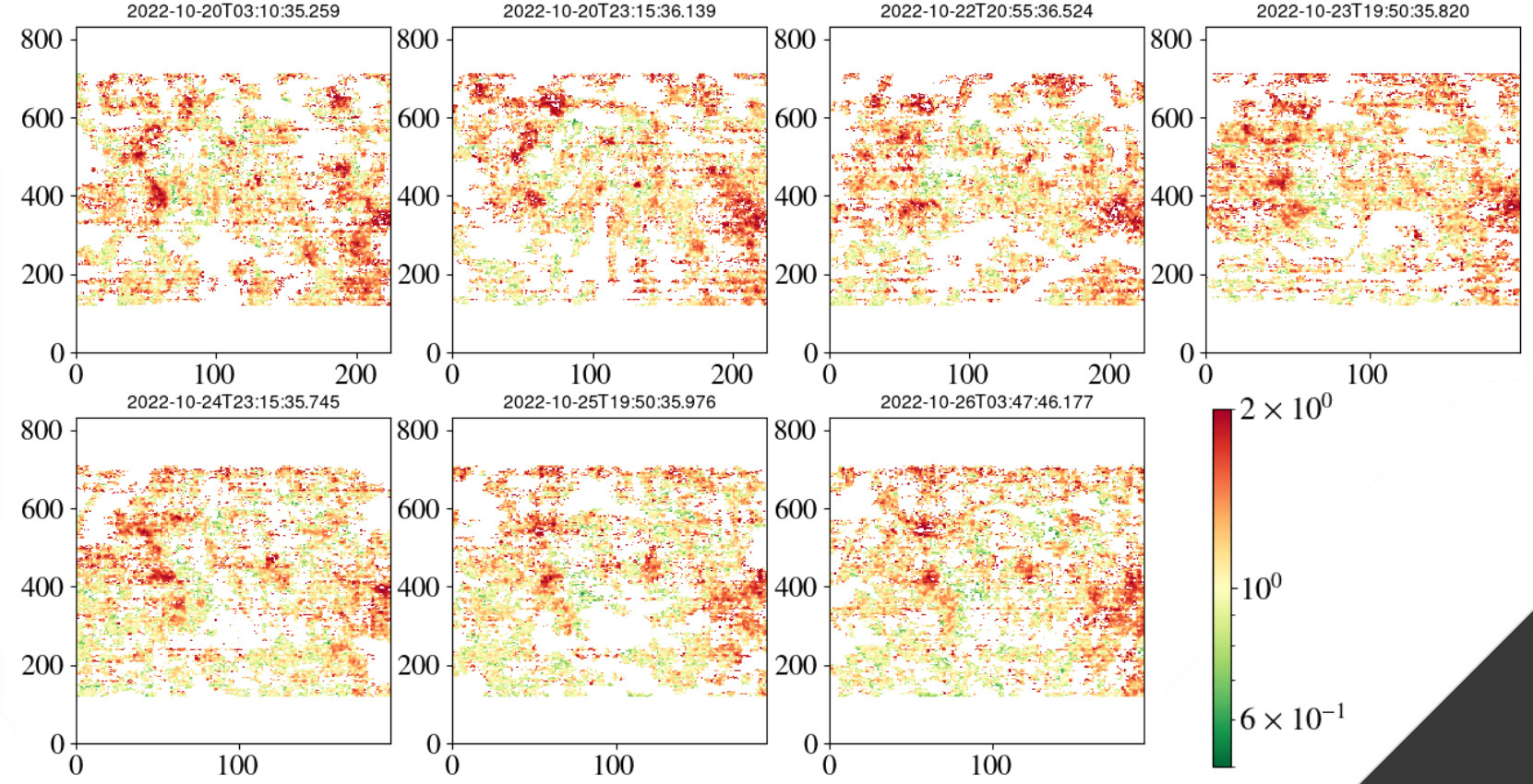


High FIP lines

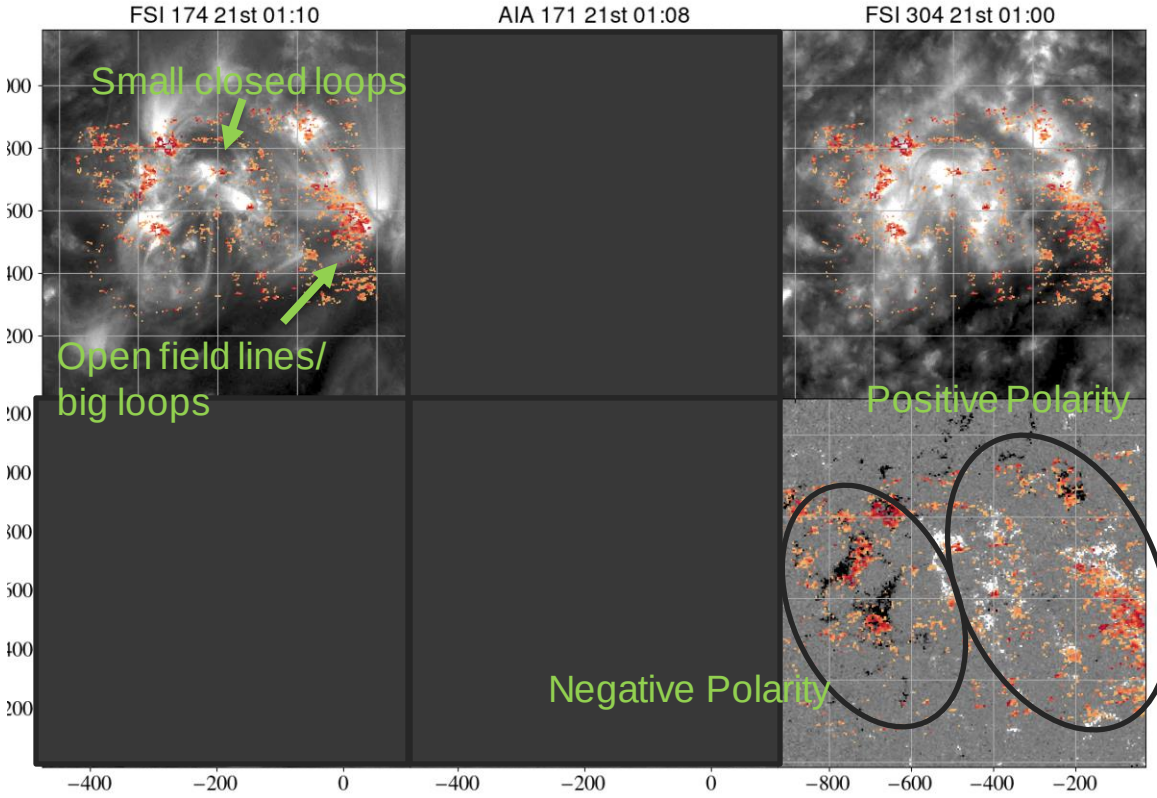
Composition Maps (Raw Results)



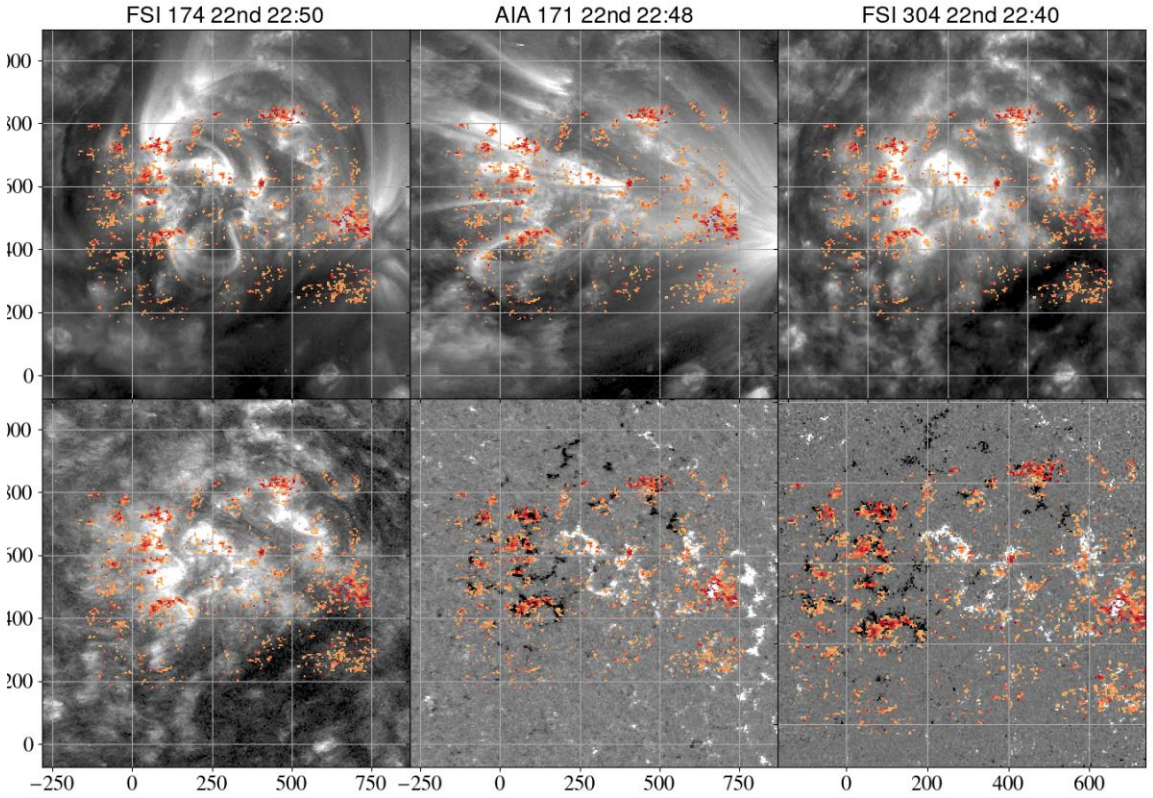
Composition Maps (Clean Results)



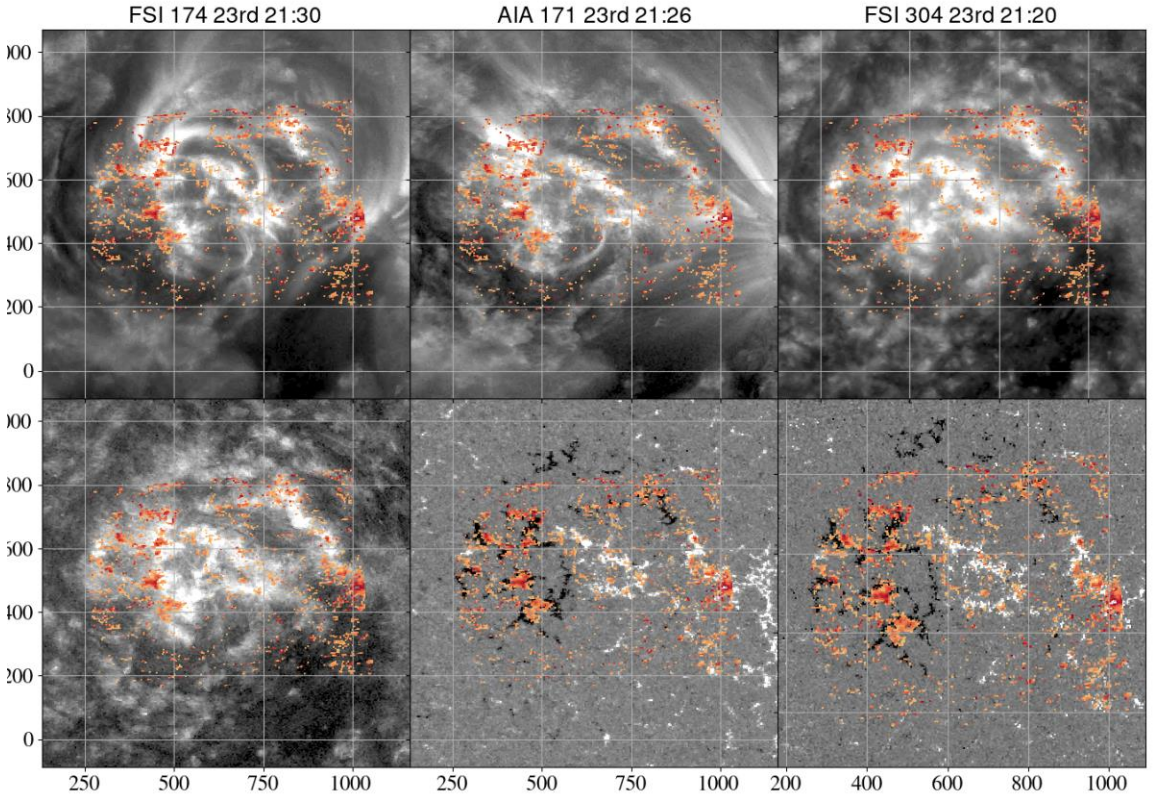
Co-aligning FIP Maps with images



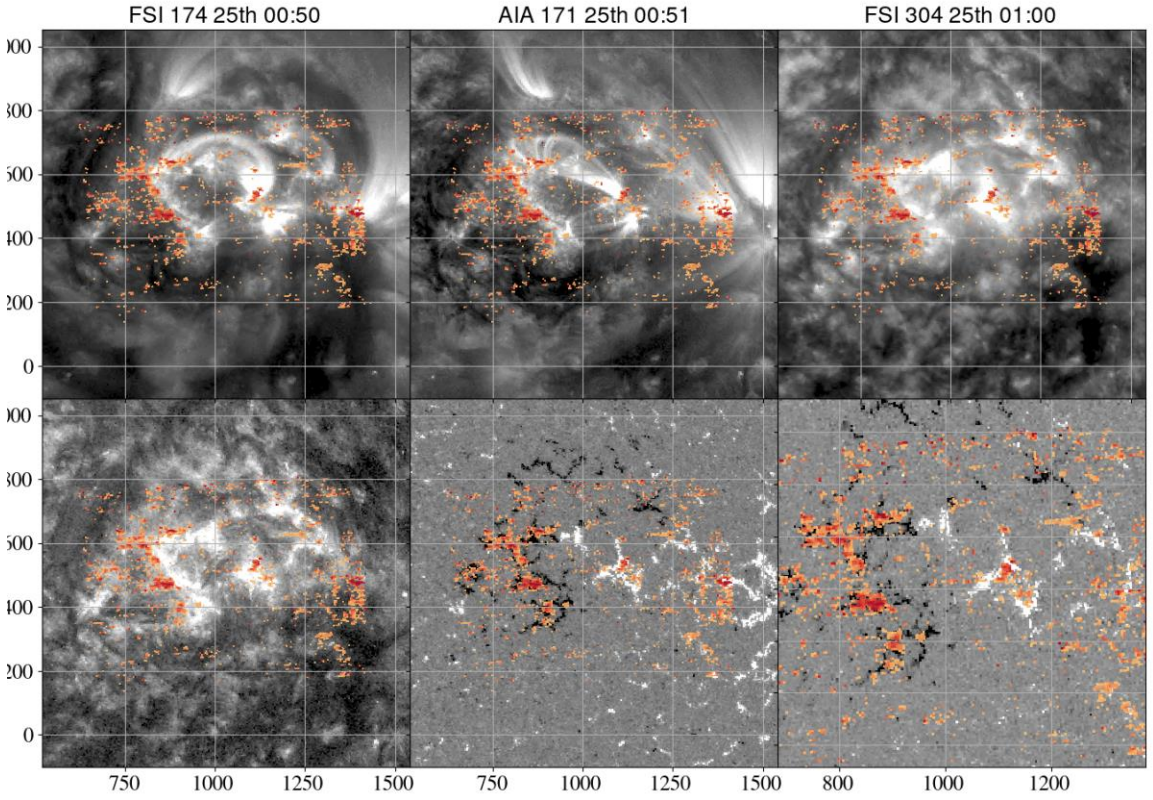
Helioprojective Coordinates (Solar Orbiter)



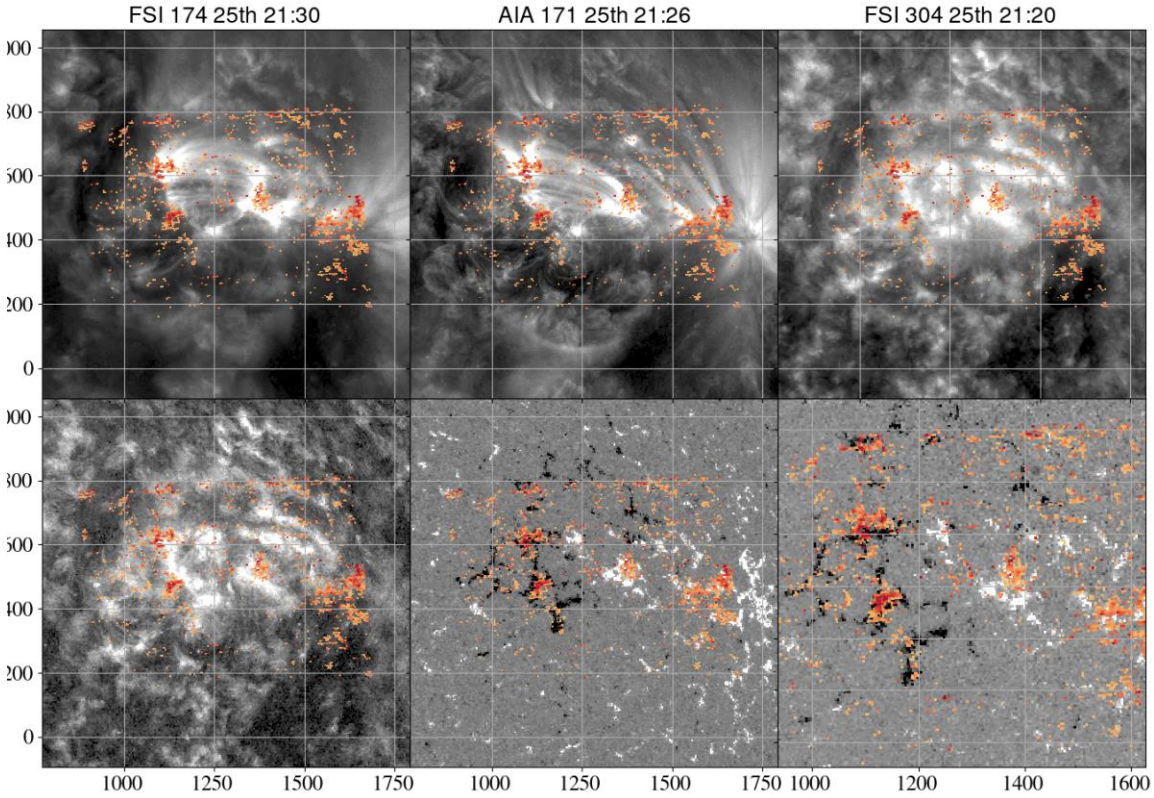
Helioprojective Coordinates (Solar Orbiter)



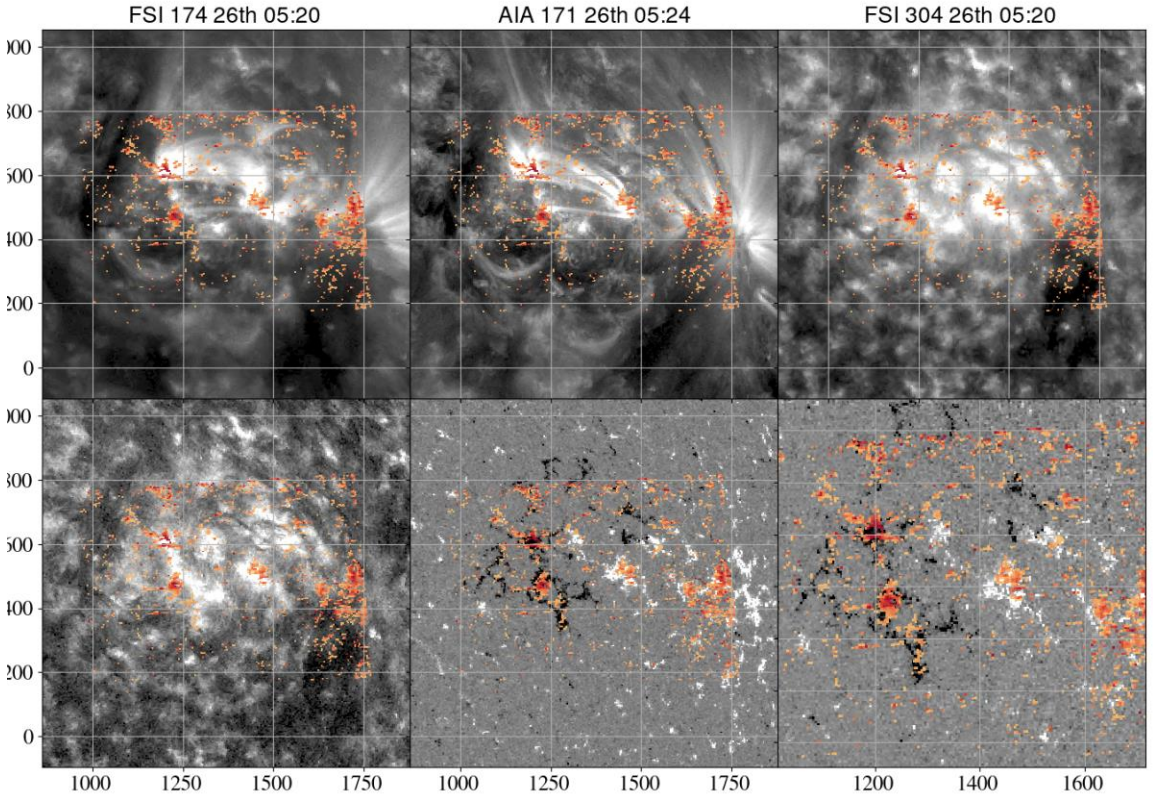
Helioprojective Coordinates (Solar Orbiter)



Helioprojective Coordinates (Solar Orbiter)



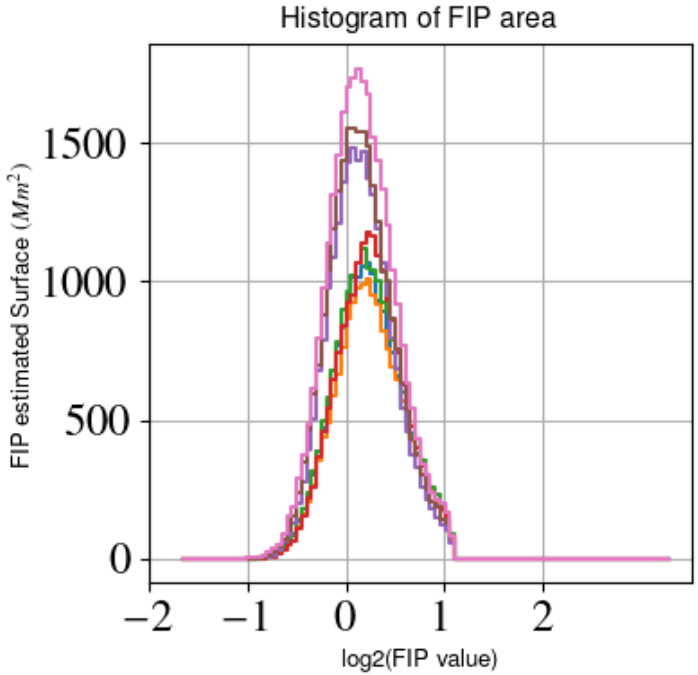
Helioprojective Coordinates (Solar Orbiter)

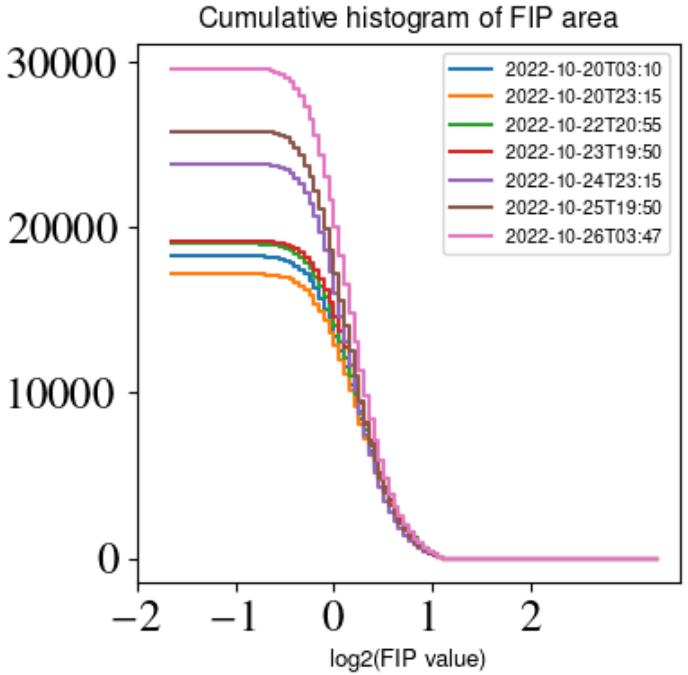


Helioprojective Coordinates (Solar Orbiter)

FIP Histogram

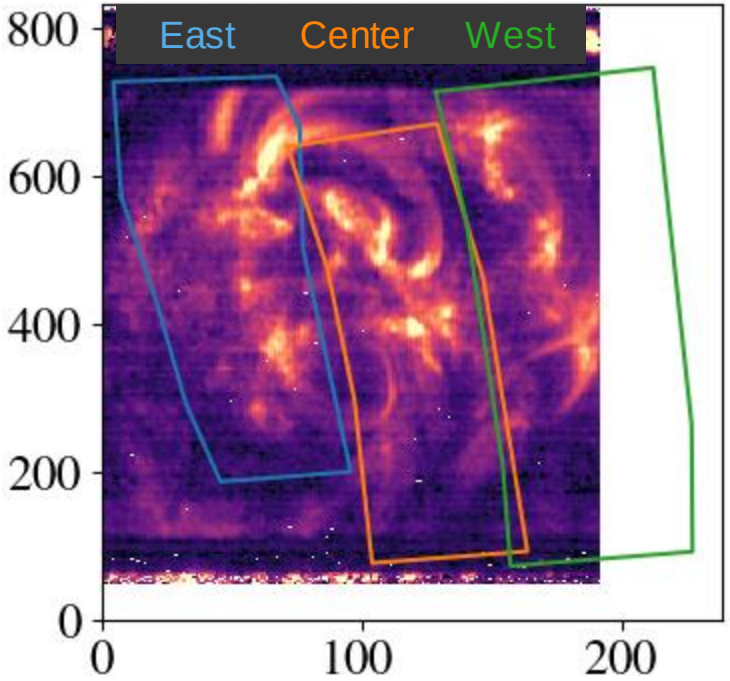
- Histogram of FIP surface
- Total histogram integral ∝ distance from the Sun
- A shift from FIP=1 in part because low snr pixels have been eliminated



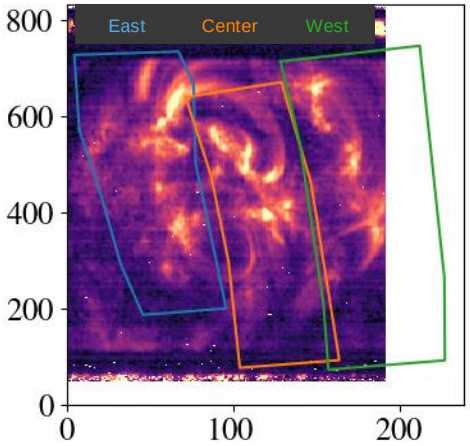


LOCAL ANALYSIS

- Selecting 3 distinct regions based on the loop footpoint sets

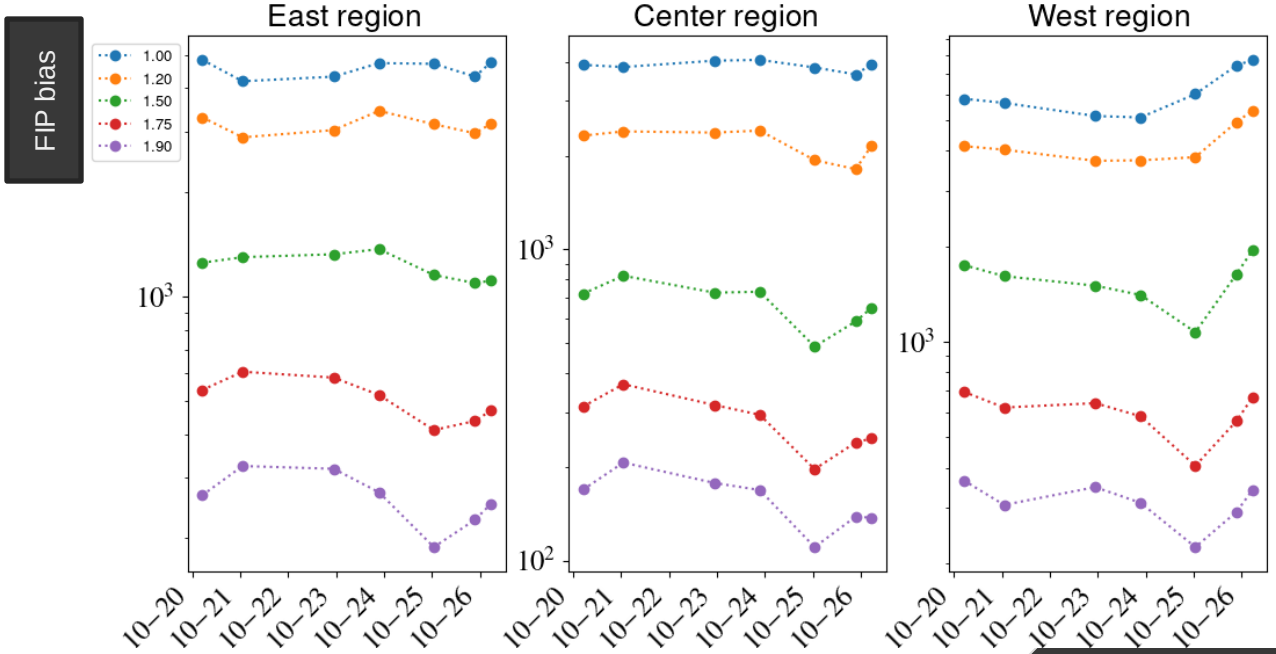


LOCAL ANALYSIS



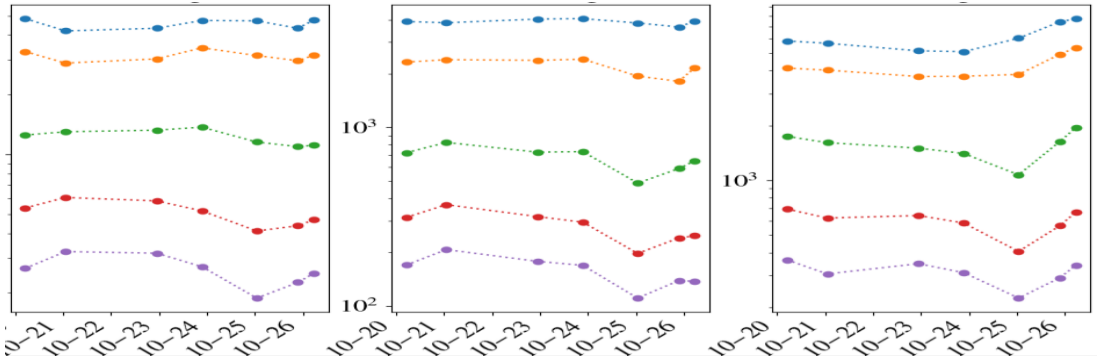
- High FIP bias increase variation around 25-10
- Increase of FIP bias above 1 in the west region
- The overall high FIP bias is increased in the closed loops regions (East, Center) between 21 and 23

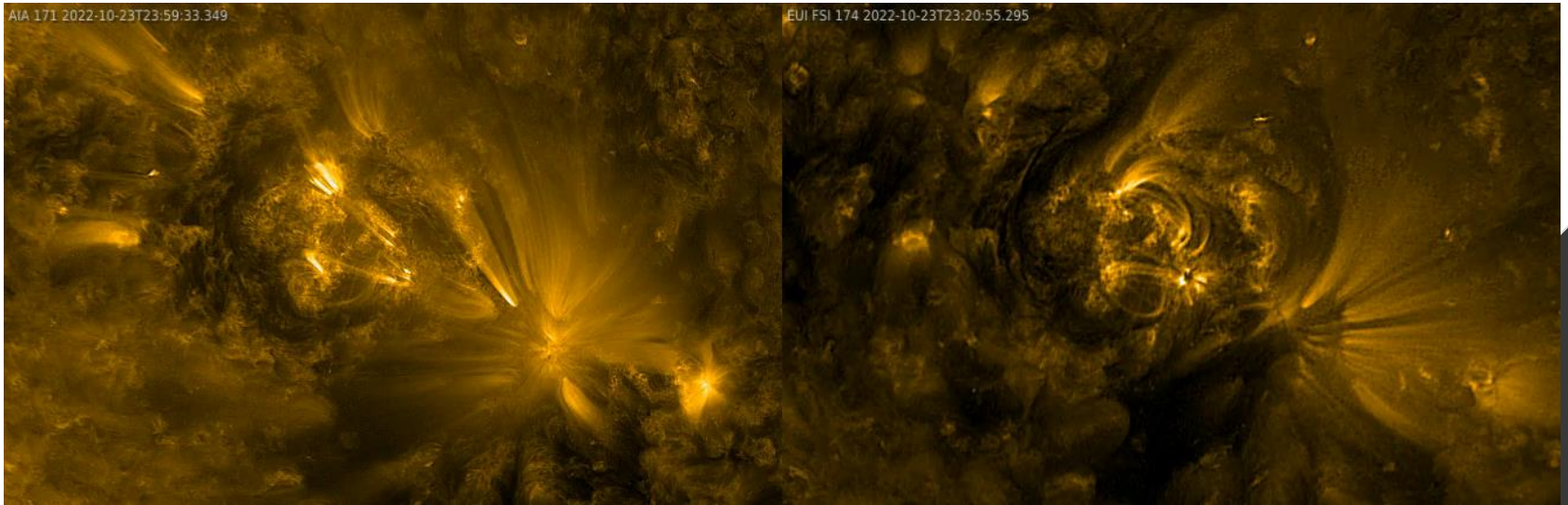
Area (Mm^2) evolution with time for pixels above some FIP bias values



Conclusion

- Current Hypothesis: Strong change in the magnetic structure between October 24 and 25.





What Next...

- We are going to analyze Hinode /EIS observations and include them for a coverage of compositions in the mid corona. (Observations available starting from 20-10-2024)
- Comparing sulfur abundance with the theoretical predications under different magnetic configurations.
- Using the magnetogram for magnetic extrapolations

- SAFFRON will be applied for the other observation campaigns. 10-2023, 04-2024 including in-situ measurements from SO, PSP.