Introduction to EUI data

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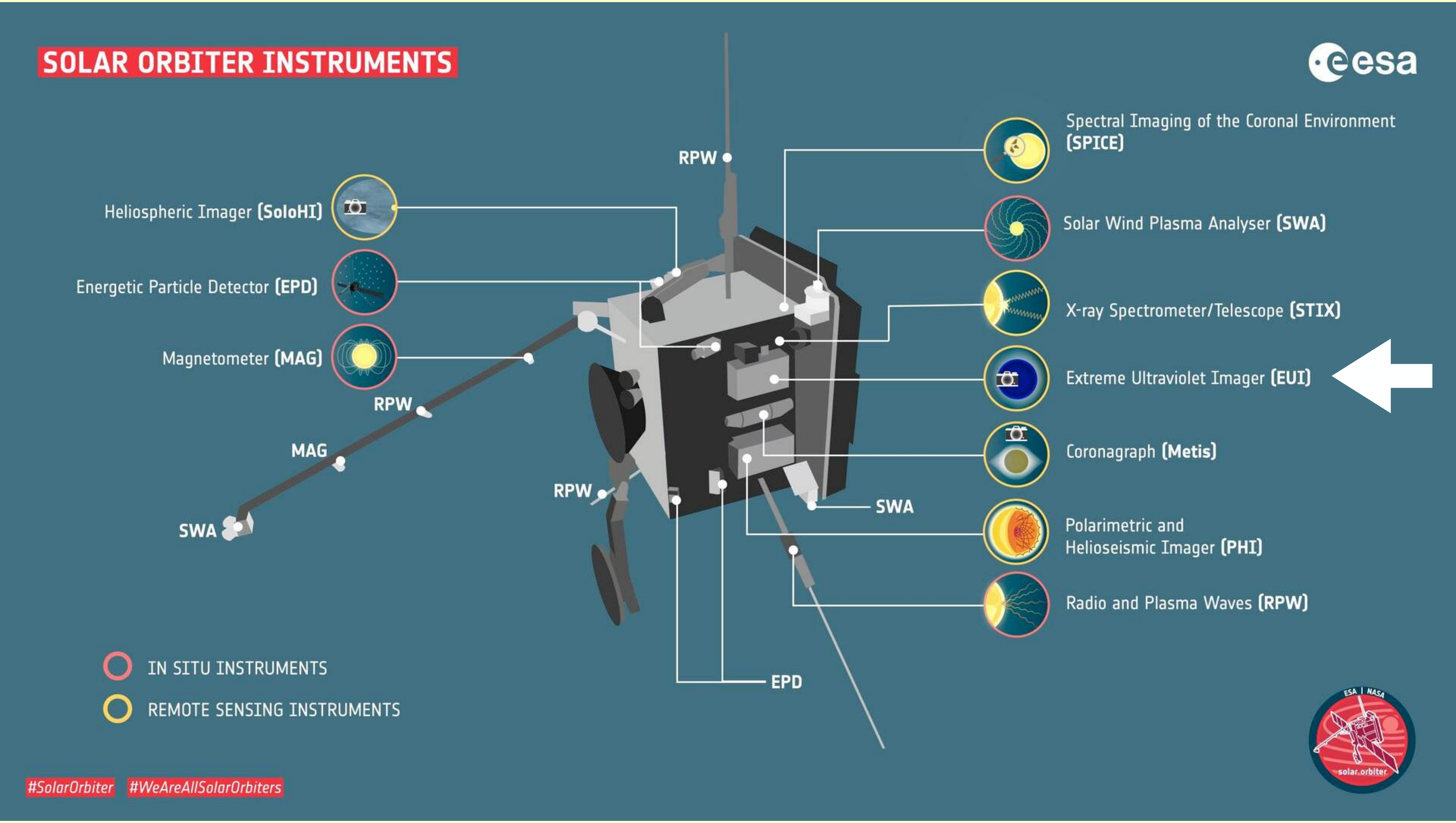
Davos, 14.03.2023

Introduction to EUI data - plan

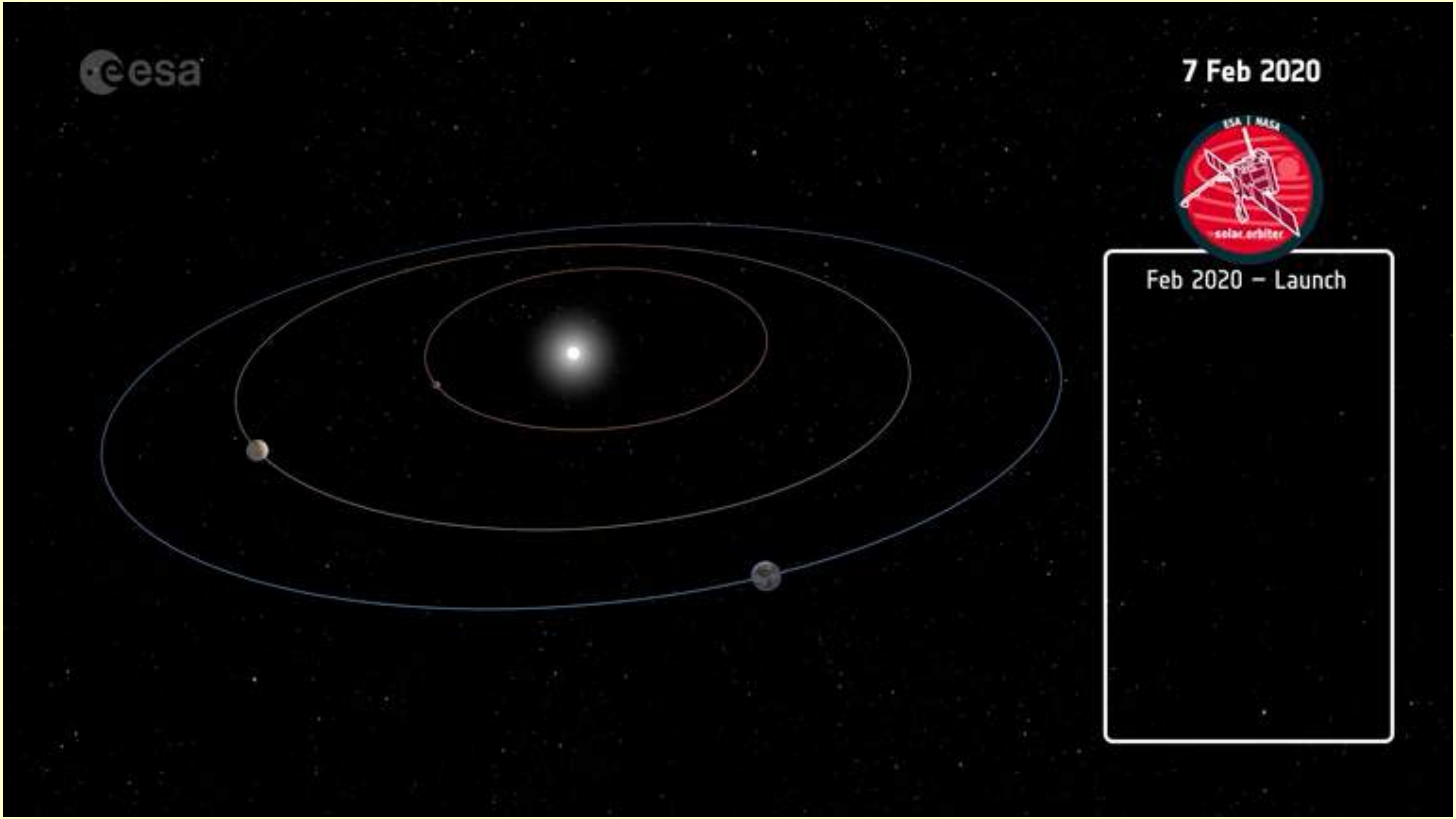
- **Remote-sensing observations with Solar Orbiter**
  - **Instrument EUI**
  - **Data access**
  - **Python**
  - **IDL**
- **Data analysis**

Solar Orbiter -intro



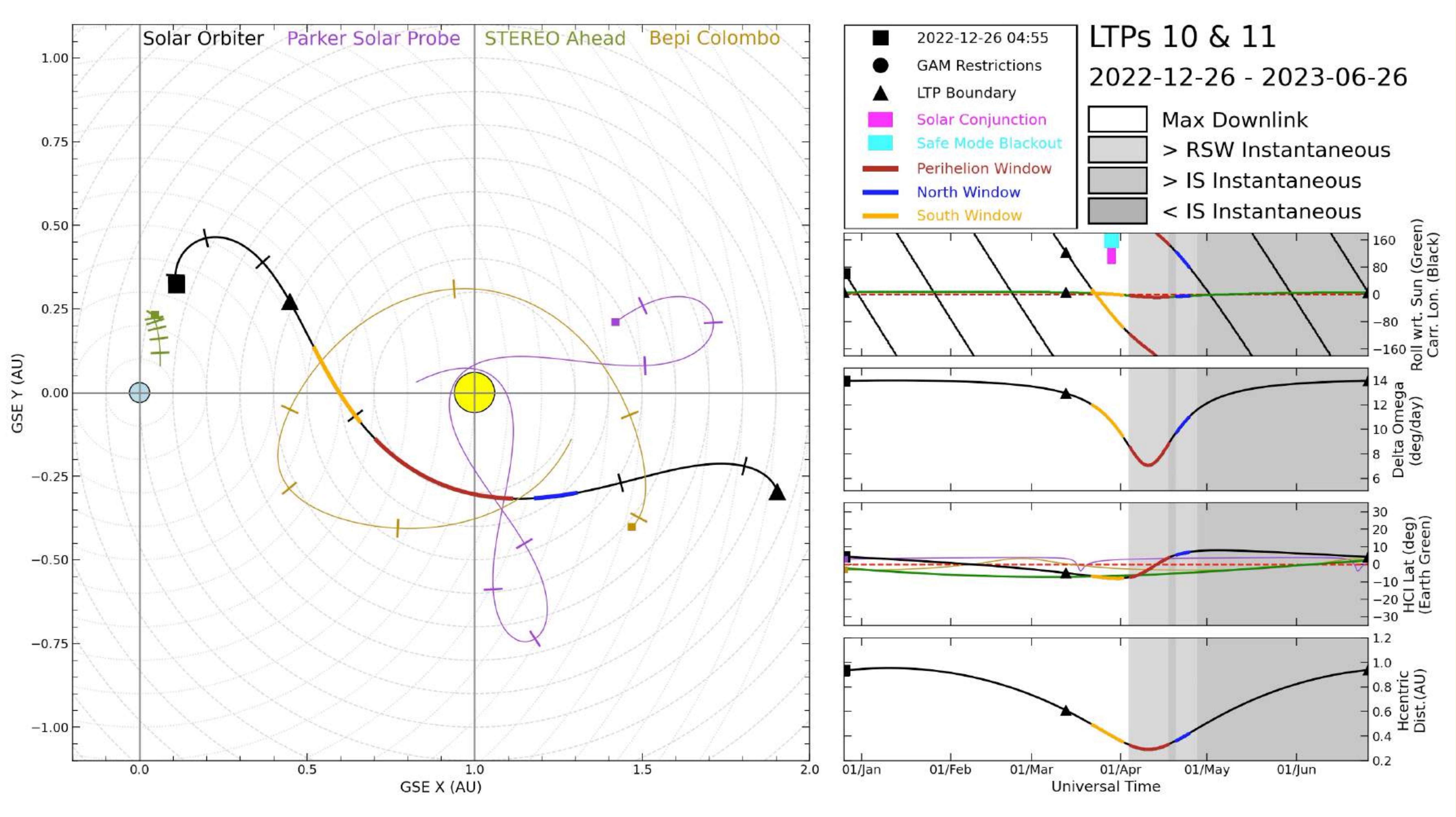
ESA

Orbit



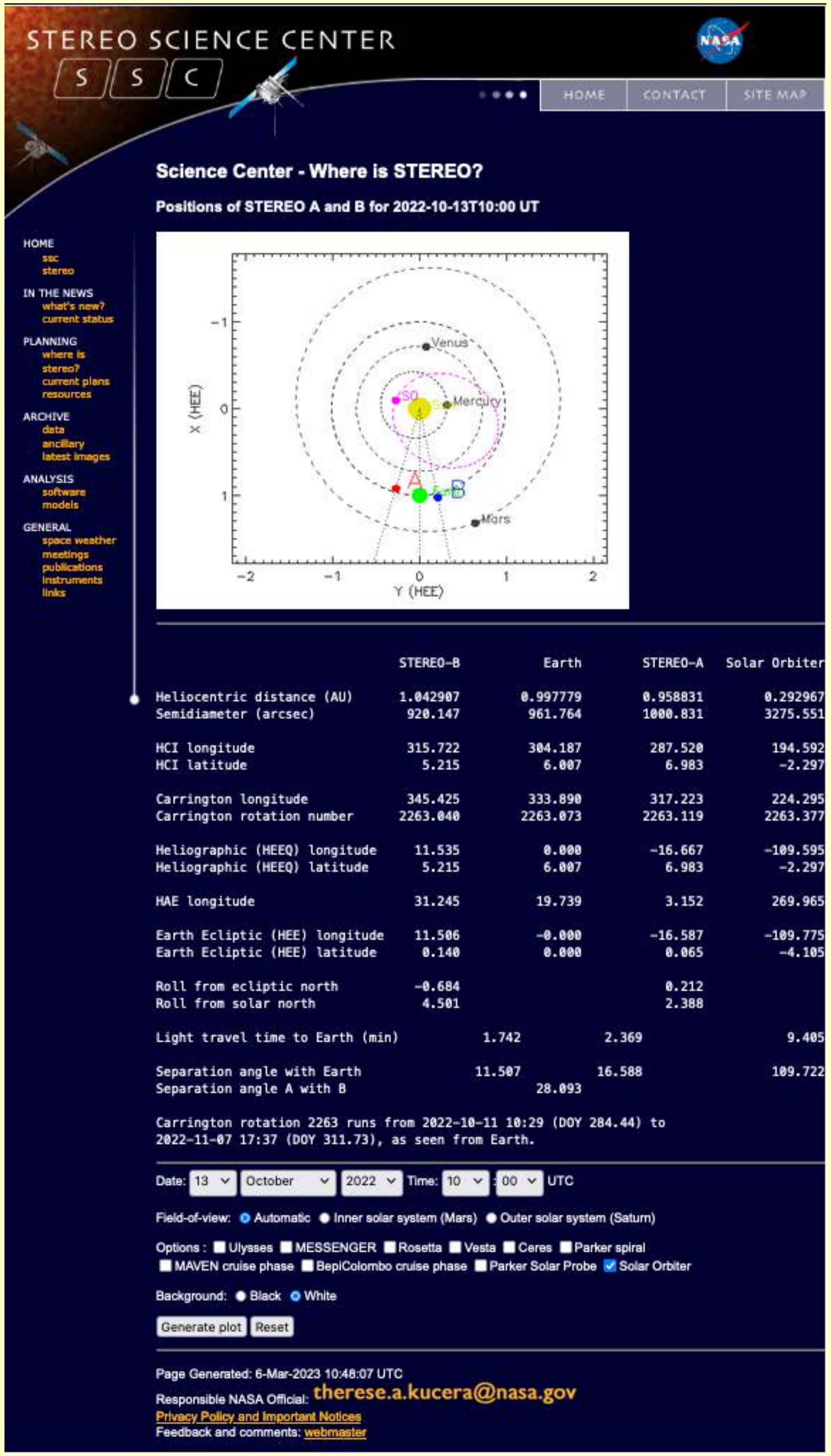
- **Remote sensing windows -2 times per year**

Orbit details



https://issues.cosmos.esa.int/solarorbiterwiki/display/SOSP/Science+Planning

Orbit position



STEREO SCIENCE CENTER

SSC

HOME CONTACT SITE MAP

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Science Center - Where is STEREO?

Positions of STEREO A and B for 2022-10-13T10:00 UT

	STEREO-B	Earth	STEREO-A	Solar Orbiter
Heliocentric distance (AU)	1.042907	0.997779	0.958831	0.292967
Semidiameter (arcsec)	920.147	961.764	1000.831	3275.551
HCI longitude	315.722	304.187	287.520	194.592
HCI latitude	5.215	6.007	6.983	-2.297
Carrington longitude	345.425	333.890	317.223	224.295
Carrington rotation number	2263.040	2263.073	2263.119	2263.377
Heliographic (HEEQ) longitude	11.535	0.000	-16.667	-109.595
Heliographic (HEEQ) latitude	5.215	6.007	6.983	-2.297
HAE longitude	31.245	19.739	3.152	269.965
Earth Ecliptic (HEE) longitude	11.506	-0.000	-16.587	-109.775
Earth Ecliptic (HEE) latitude	0.140	0.000	0.065	-4.105
Roll from ecliptic north	-0.684		0.212	
Roll from solar north	4.501		2.388	
Light travel time to Earth (min)	1.742		2.369	9.405
Separation angle with Earth	11.507		16.588	109.722
Separation angle A with B		28.093		

Carrington rotation 2263 runs from 2022-10-11 10:29 (DOY 284.44) to 2022-11-07 17:37 (DOY 311.73), as seen from Earth.

Date: 13 October 2022 Time: 10 : 00 UTC

Field-of-view: Automatic Inner solar system (Mars) Outer solar system (Saturn)

Options: Ulysses MESSENGER Rosetta Vesta Ceres Parker spiral MAVEN cruise phase BepiColombo cruise phase Parker Solar Probe Solar Orbiter

Background: Black White

Generate plot Reset

Page Generated: 6-Mar-2023 10:48:07 UTC

Responsible NASA Official: therese.a.kucera@nasa.gov

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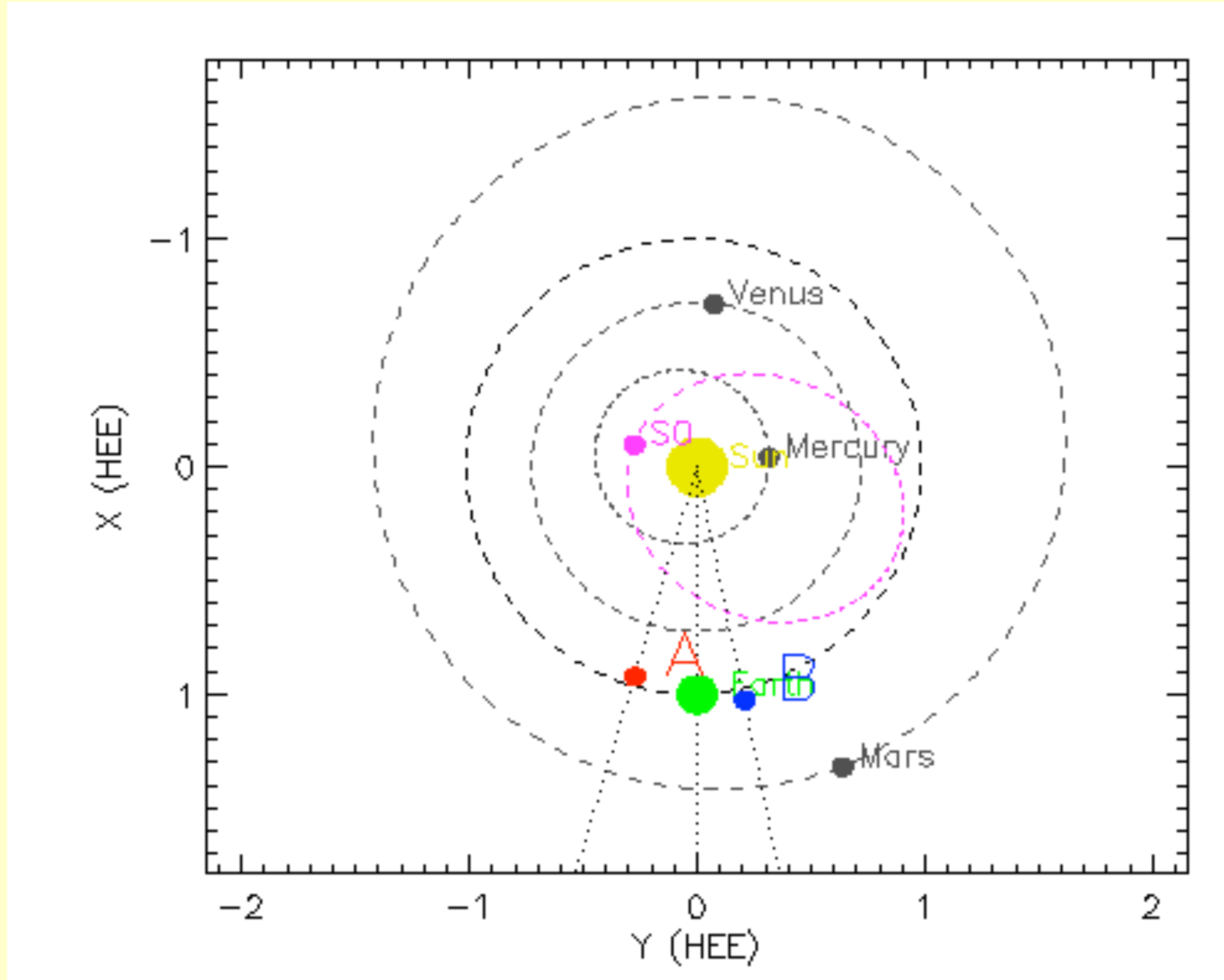
Feedback and comments: webmaster



https://stereo-ssc.nascom.nasa.gov/where.shtml

Orbit impact

- **Solar Orbiter distance to Sun**

  -0.29 AU to 1.1 AU

- **Angular size of structures**

  -at 1 AU: 1 arcsec = 726 km

  -at 0.3 AU: 1 arcsec = 218 km

- **Separation angle with Earth**

- **Inclination respect to the planetary plane**

EUI -Extreme Ultraviolet Imager

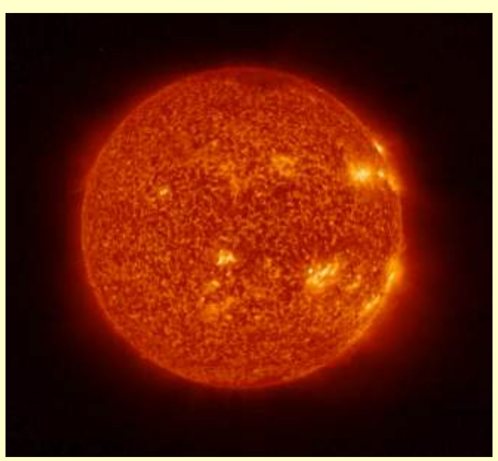
EUI data

EUI

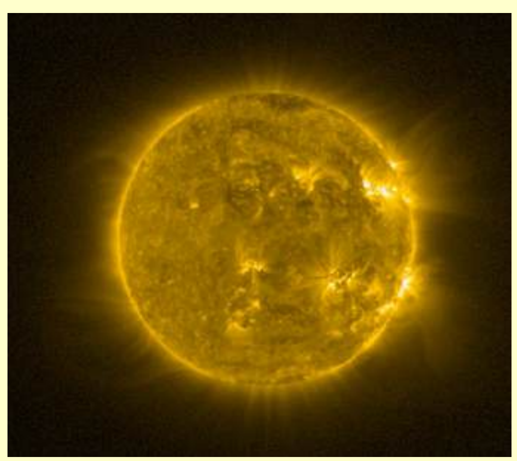
Full Solar Imager (FSI)

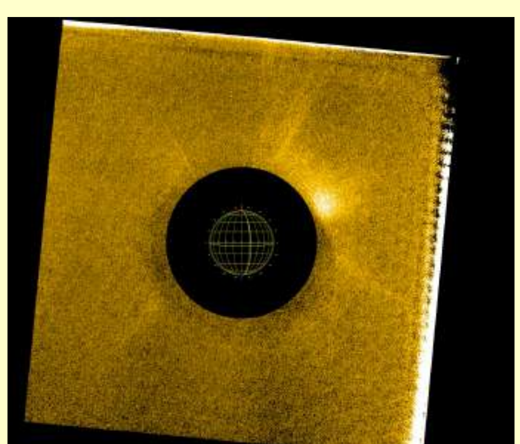
High-Resolution Imager

FSI 304

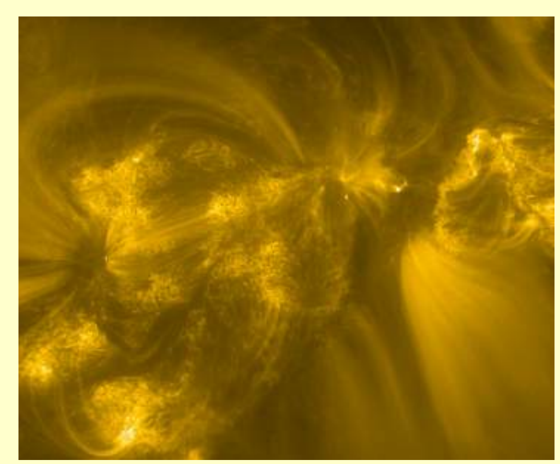


FSI 174

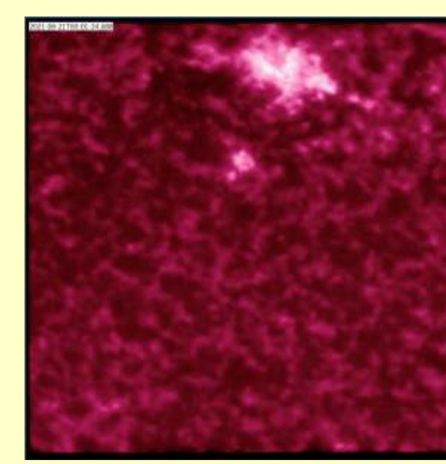




HRI 174

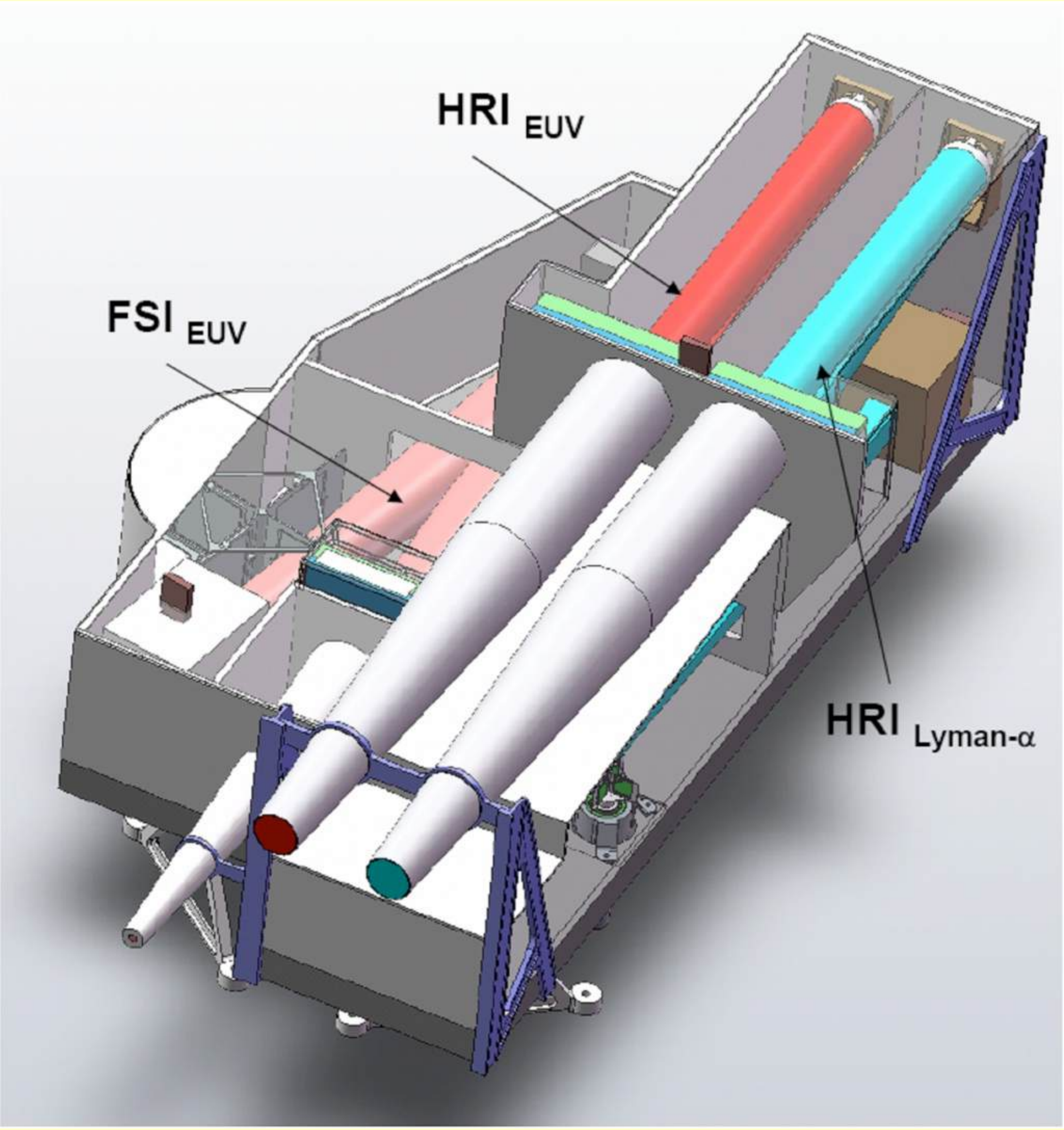


HRI 1216 (Ly-alpha)

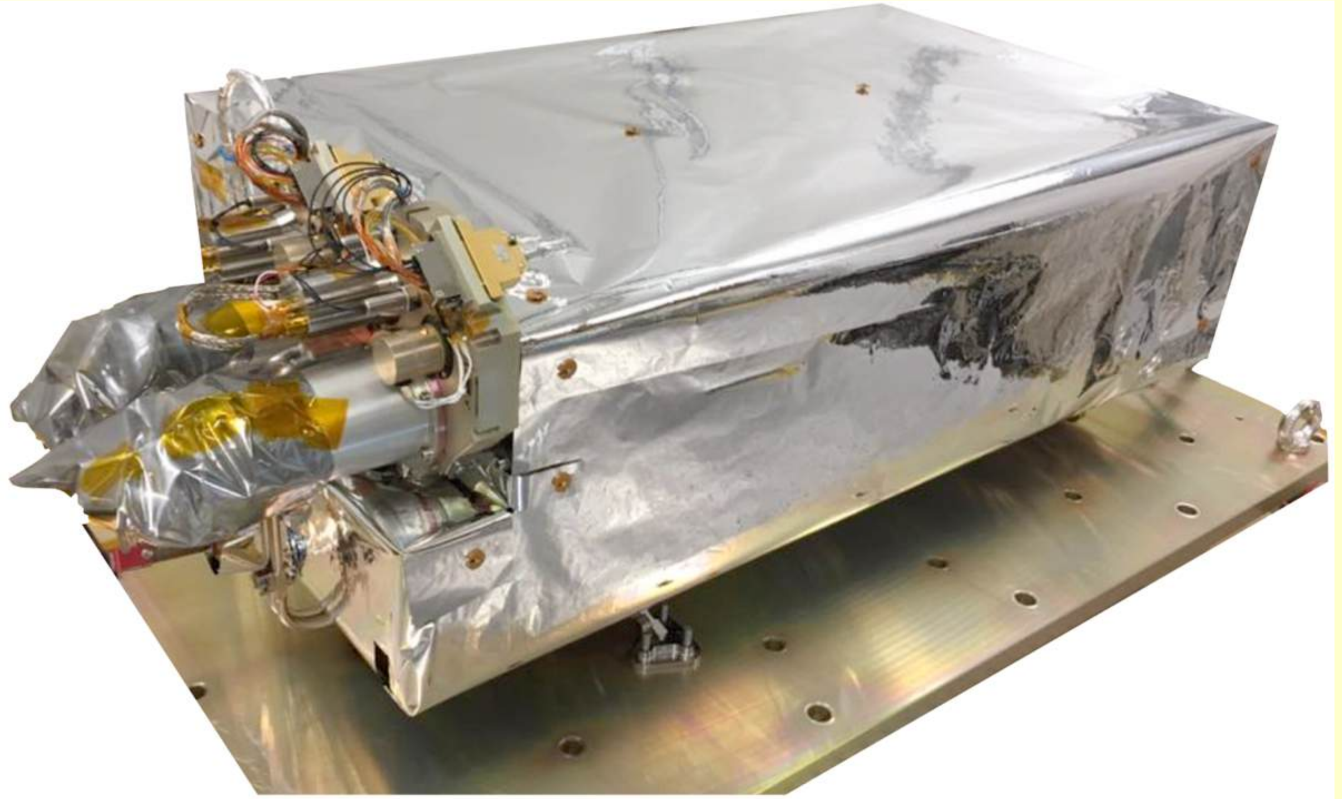


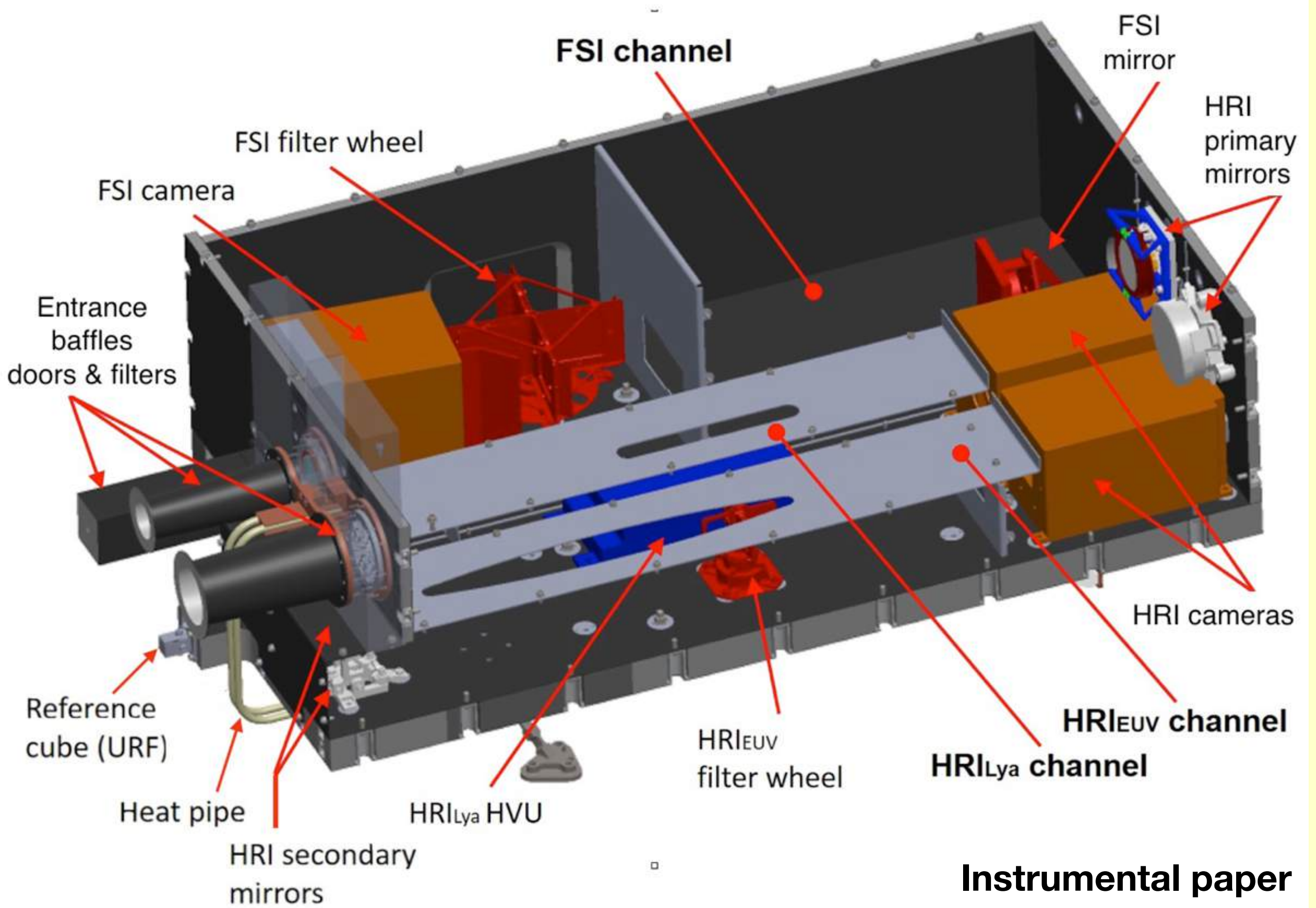
EUI data

- **EUI instrument**



MPS, Goettingen





Instrumental paper

Temperature response function

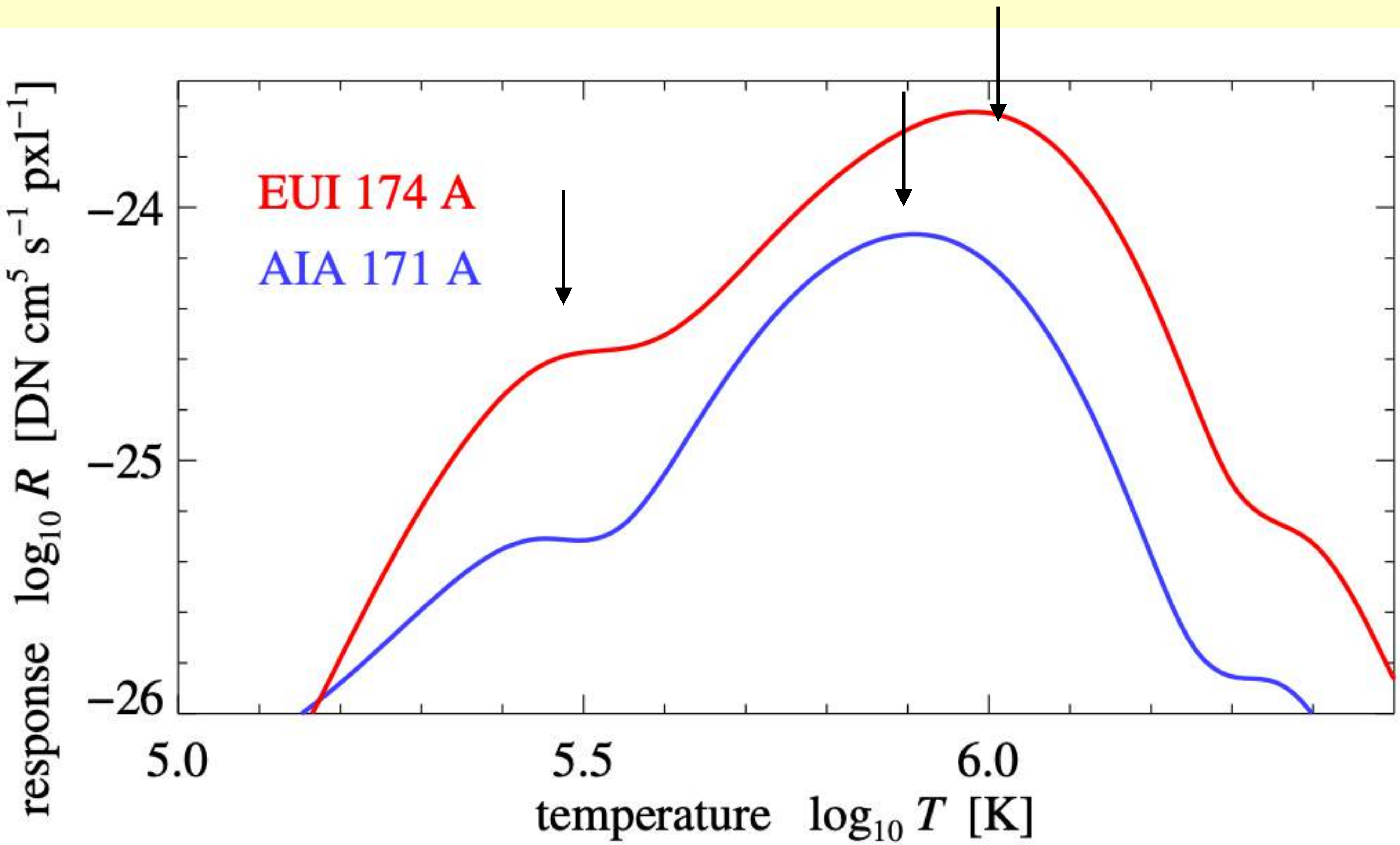
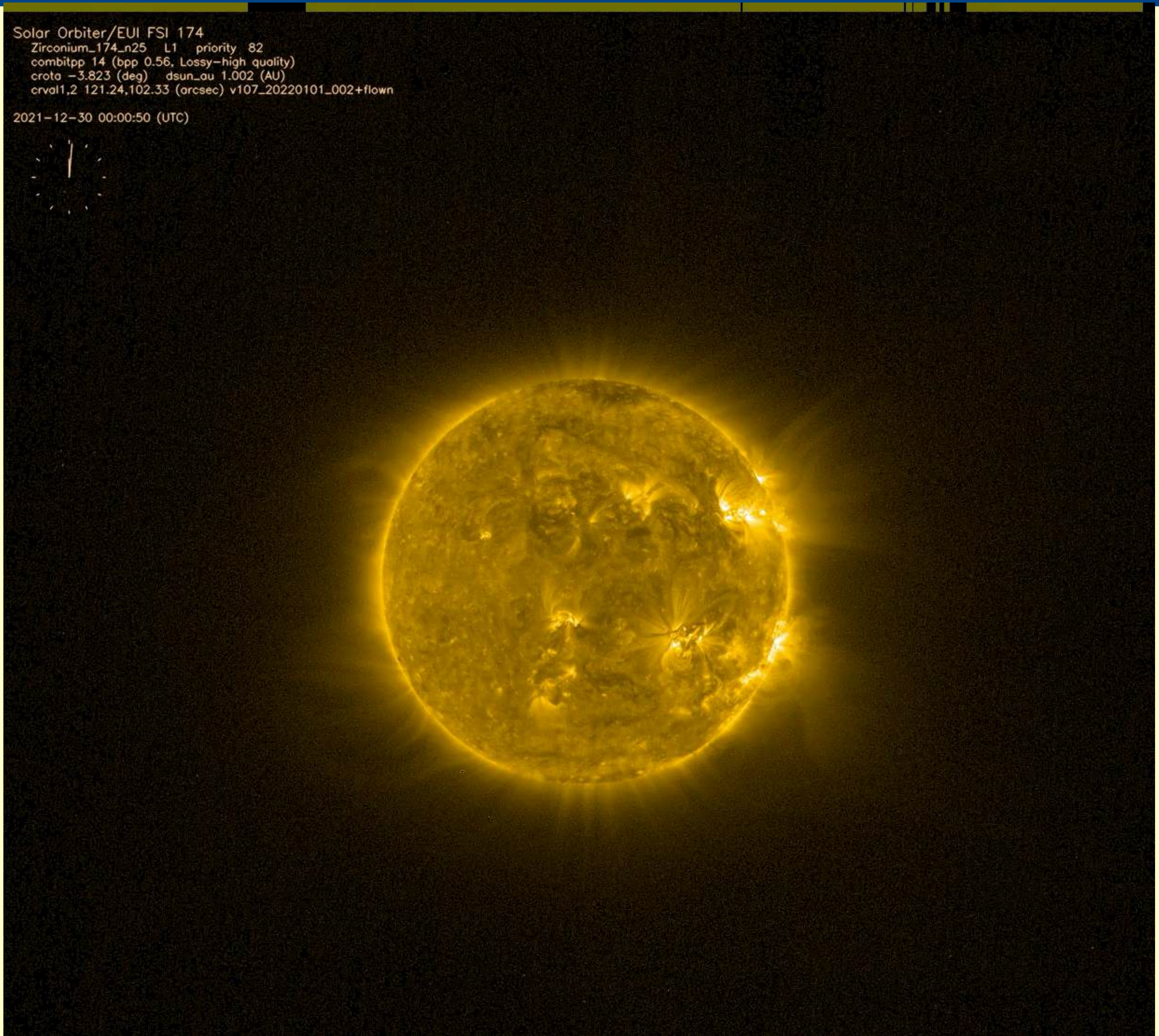


Fig. 1. Temperature response (or contribution) function $R(T, n)$. The red line shows the response for the EUI channel at 174 Å, the blue line the one for AIA at 171 Å. Both responses are shown here for a density of $n = 10^9\,\mathrm{cm}^{-3}$ which is typical for coronal loops. The radiative losses (per volume) in the respective band are given by $n^2 R$. See Sect. 2.2.

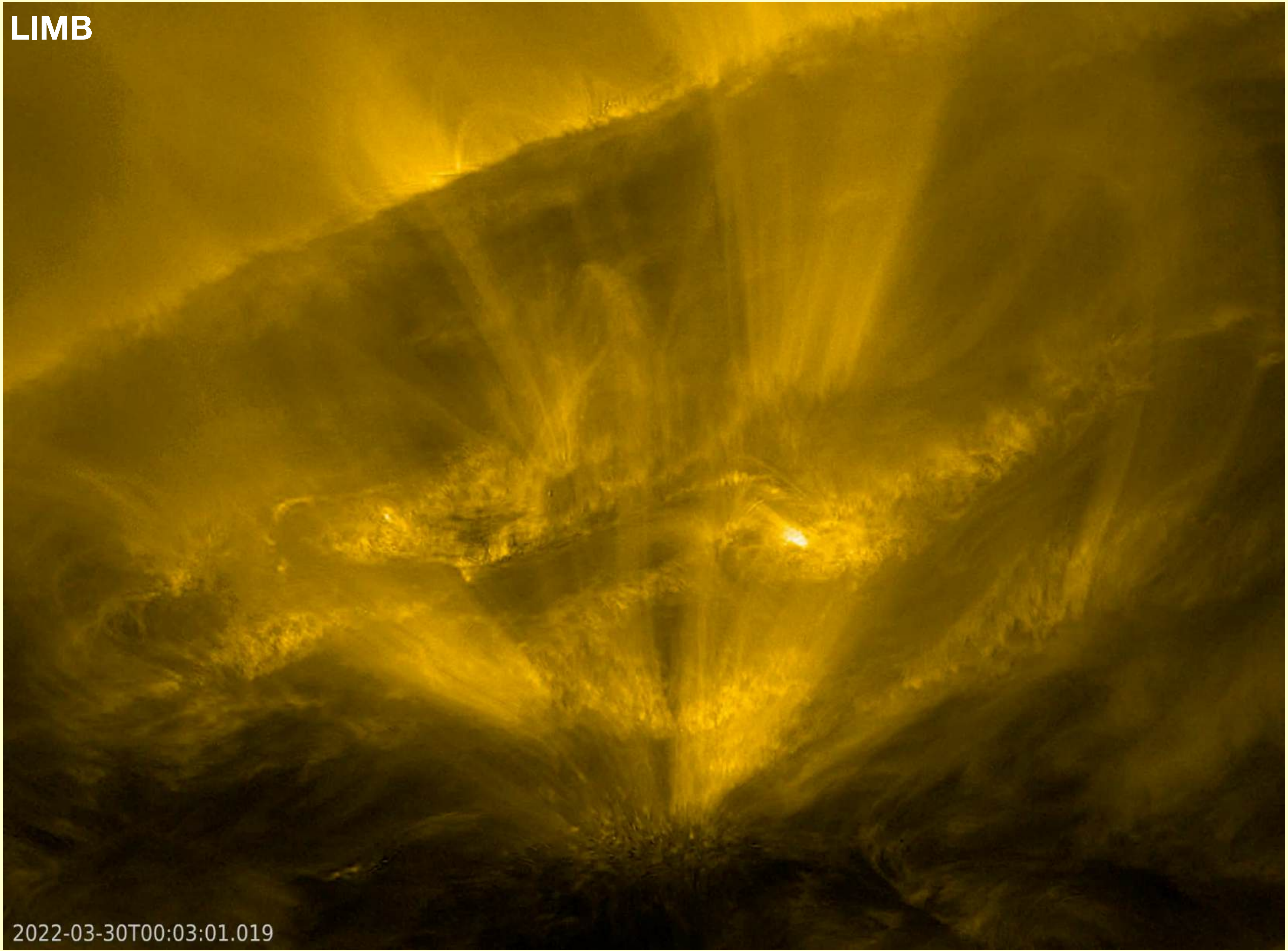
EUI/FSI 174


Solar Orbiter/EUI FSI 174
Zirconium_174_n25 L1 priority 82
combitpp 14 (bpp 0.56, Lossy-high quality)
crota -3.823 (deg) dsun_au 1.002 (AU)
crval1,2 121.24,102.33 (arcsec) v107_20220101_002+flown
2021-12-30 00:00:50 (UTC)

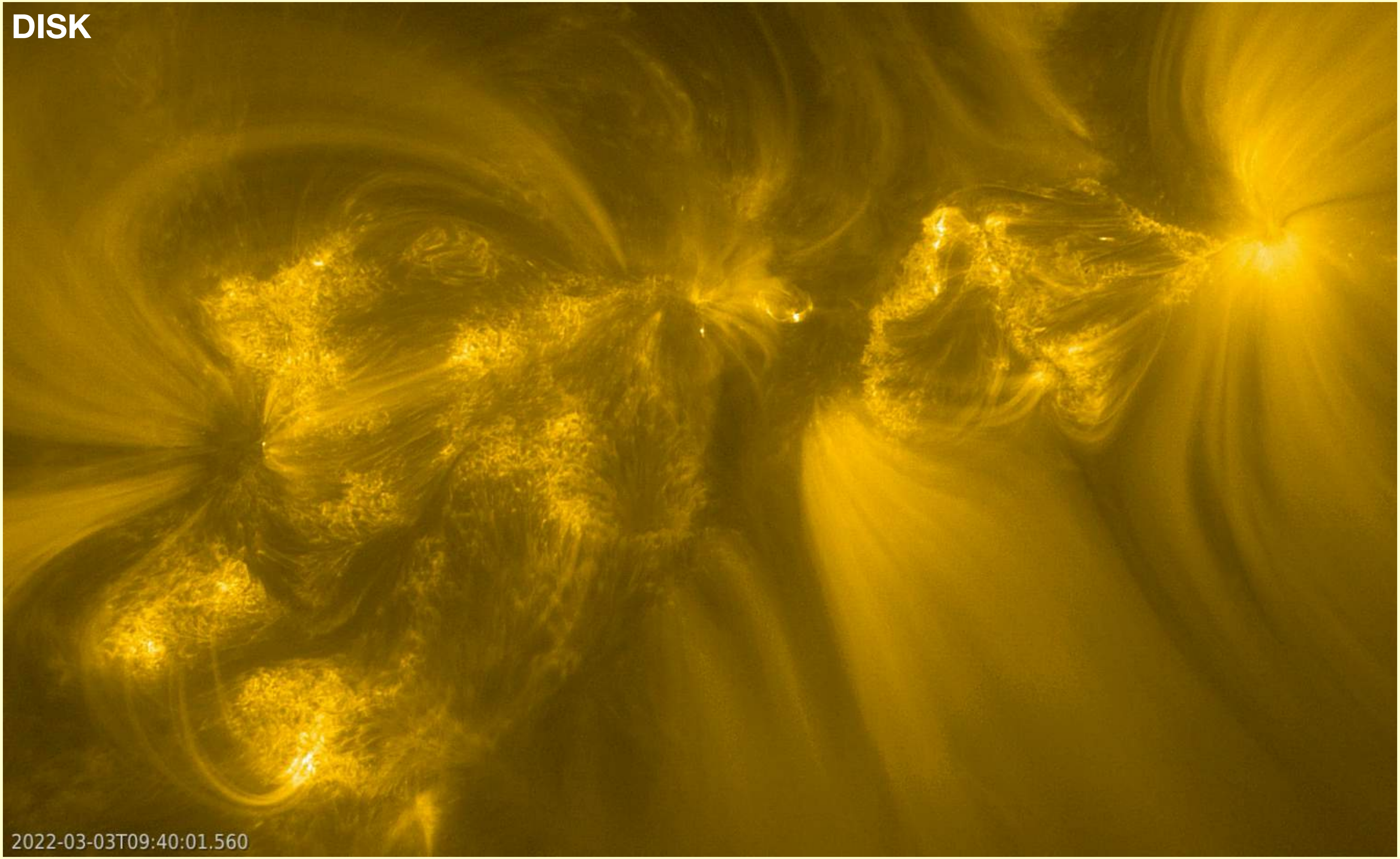
EUI/FSI 304


Solar Orbiter/EUI FSI 304
Magnesium_304_n4 L1 priority 80
combitpp 14 (bpp 0.56, Lossy-strong)
crota -3.823 (deg) dsun_au 1.002 (AU)
crval1,2 121.23,102.52 (arcsec) v107_20220101_002+flown
2021-12-30 00:00:20 (UTC)

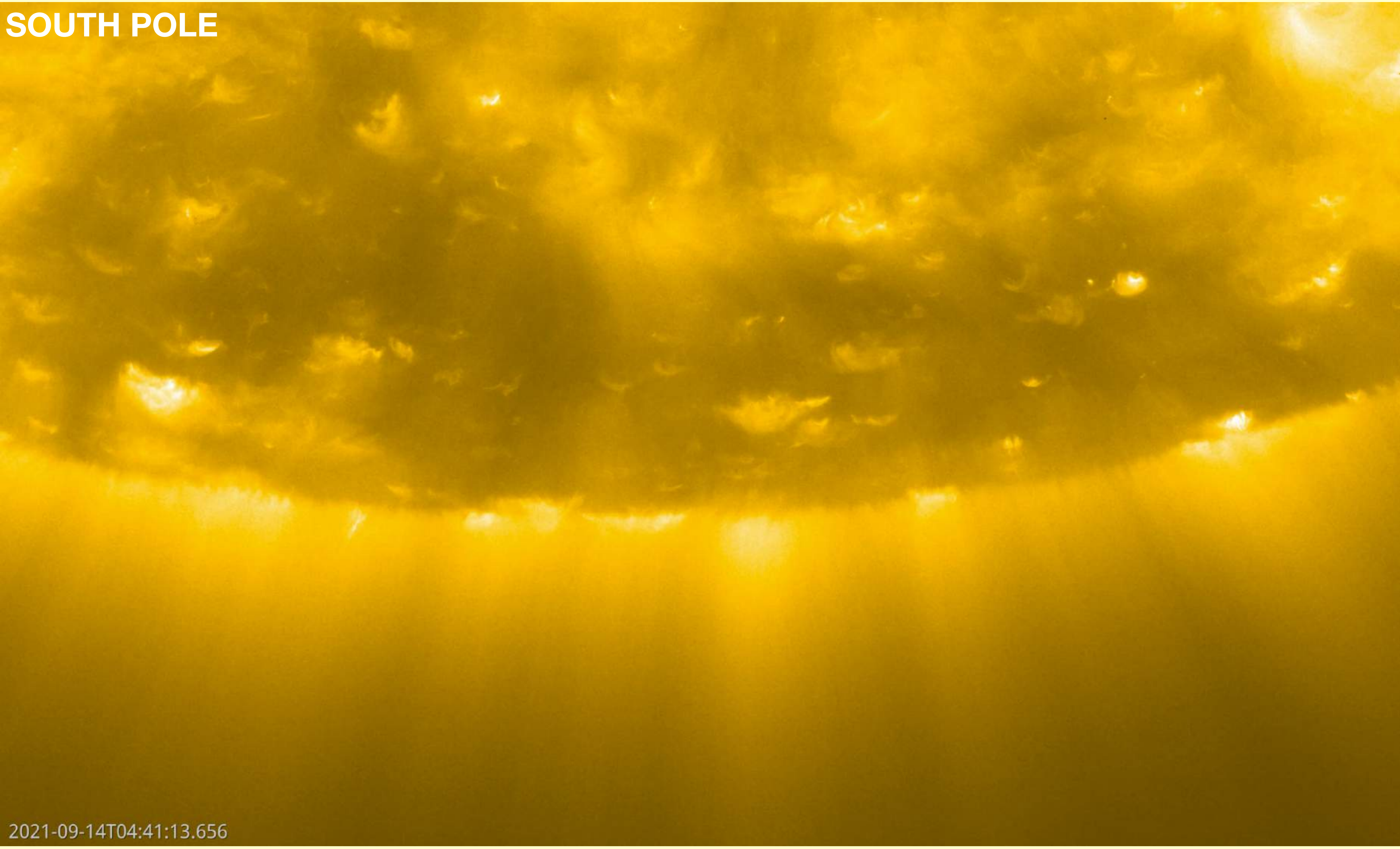
EUI/HRI 174



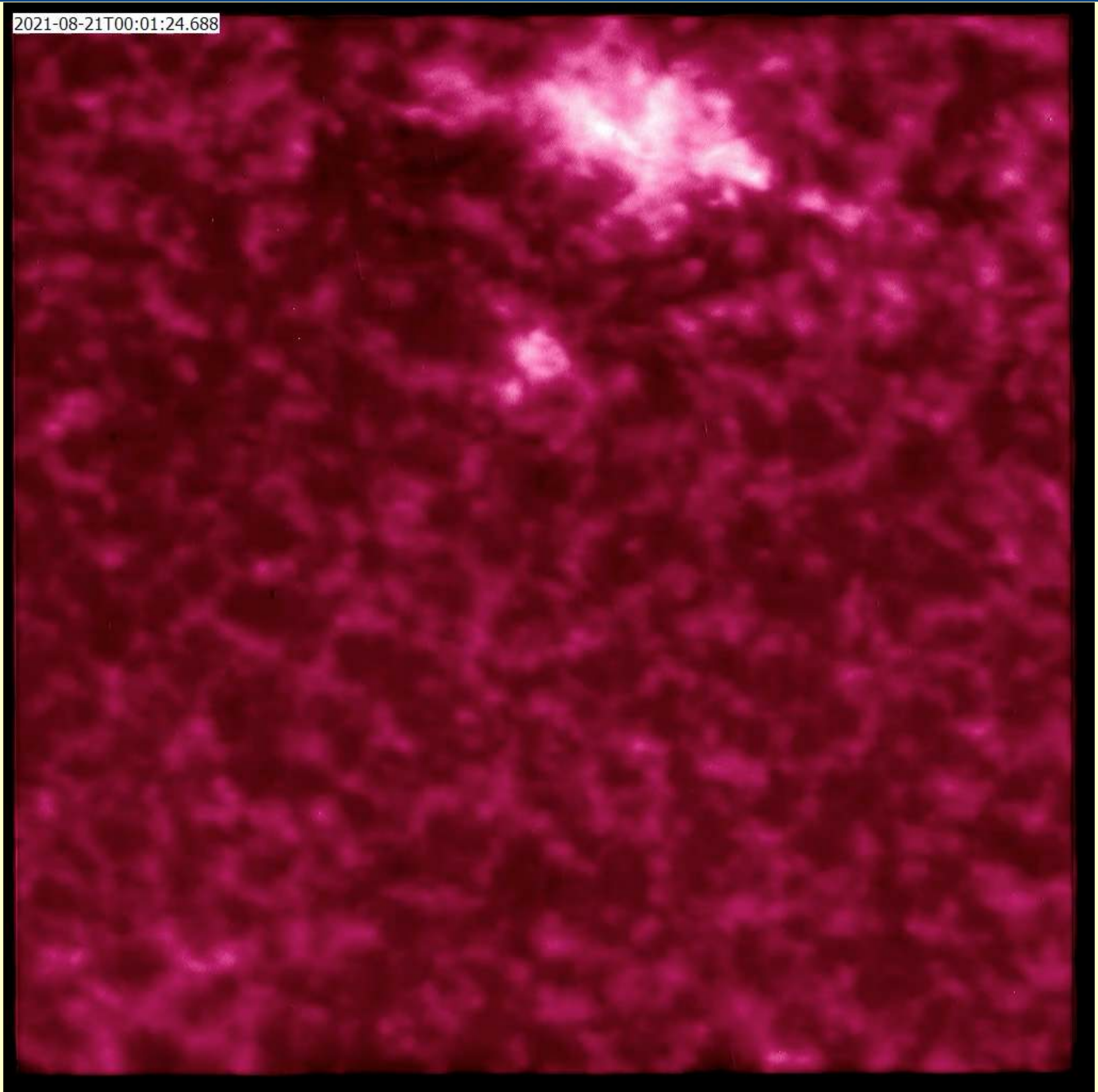
EUI/HRI 174



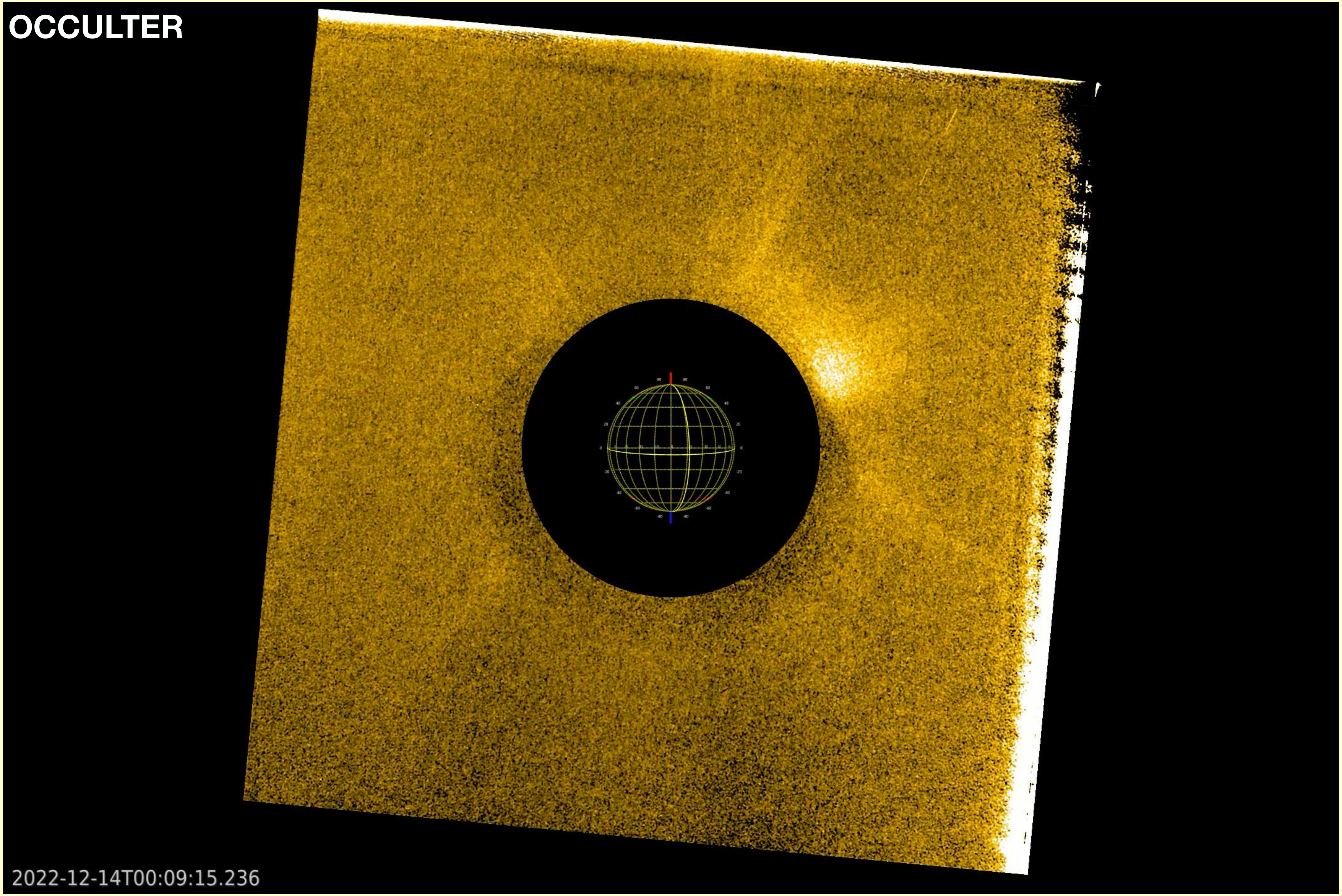
EUI/HRI 174



EUI/HRI 1216



EUI/FSI 174 - occulter



Overview of EUI data

Astronomy & Astrophysics manuscript no. main
January 16, 2023

First Perihelion of EUI on the Solar Orbiter mission

D. Berghmans[1] ⋆, P. Antolin[2], F. Auchère[3], R. Aznar Cuadrado[4], K. Barczynski[5,6], L. P. Chitta[4], S. Gissot[1], L. Harra[5,6], Z. Huang[4], M. Janvier[7,3], E. Kraaikamp[1], D. M. Long[8], S. Mandal[4], M. Mierla[1], S. Parenti[3,1], H. Peter[4], L. Rodriguez[1], U. Schühle[4], P. J. Smith[8], S. K. Solanki[4], K. Stegen[1], L. Teriaca[4], C. Verbeeck[1], M. J. West[9], A. N. Zhukov[1,10], T. Appourchaux[3], G. Aulanier[11,12], E. Buchlin[3], F. Delmotte[13], J. M. Gilles[14], M. Haberreiter[5], J.-P. Halain[14,7], K. Heerlein[4], J.-F. Hochedez[15,16], M. Gyo[5], S. Poedts[17,18], and P. Rochus[14]

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4 Max Planck Institute for Solar System Research, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany
5 Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center, 7260, Davos Dorf, Switzerland
6 ETH Zürich, Institute for Particle Physics and Astrophysics , Wolfgang-Pauli-Strasse 27, 8093 Zürich
7 European Space Agency, ESTEC, Keplerlaan 1, PO Box 299, NL-2200 AG Noordwijk, The Netherlands
8 UCL-Mullard Space Science Laboratory, Holmbury St. Mary, Dorking, Surrey, RH5 6NT, UK
9 Southwest Research Institute, 1050 Walnut Street, Suite 300, Boulder, CO 80302, USA
10 Skobeltsyn Institute of Nuclear Physics, Moscow State University, 119992 Moscow, Russia
11 Sorbonne Université, Observatoire de Paris - PSL, École Polytechnique, Institut Polytechnique de Paris, CNRS, Laboratoire de physique des plasmas (LPP), 4 place Jussieu, F-75005 Paris, France
12 Rosseland Centre for Solar Physics, University of Oslo, P.O. Box 1029, Blindern, NO-0315 Oslo, Norway
13 Laboratoire Charles Fabry, Institut d'Optique Graduate School, Université Paris-Saclay, 91127 Palaiseau Cedex, France
14 Centre Spatial de Liège, Université de Liège, Av. du Pré-Aily B29, 4031 Angleur, Belgium
15 AESTER INCOGNITO, 75008 Paris, France
16 LATMOS, CNRS - UVSQ - Sorbonne Université, 78280, Guyancourt, France
17 Centre for mathematical Plasma Astrophysics, KU Leuven, 3001 Leuven, Belgium
18 Institute of Physics, University of Maria Curie-Skłodowska, Pl. M. Curie-Skłodowskiej 5, 20-031 Lublin, Poland

Received ; accepted

ABSTRACT

Context. The Extreme Ultraviolet Imager (EUI), onboard Solar Orbiter consists of three telescopes: the two High Resolution Imagers in EUV (HRI_{EUV}) and in Lyman-α (HRI_{Lya}), and the Full Sun Imager (FSI). Solar Orbiter/EUI started its Nominal Mission Phase on 2021 November 27.
Aims. EUI images from the largest scales in the extended corona off limb, down to the smallest features at the base of the corona and chromosphere. EUI is therefore a key instrument for the connection science that is at the heart of the Solar Orbiter mission science goals.
Methods. The highest resolution on the Sun is achieved when Solar Orbiter passes through the perihelion part of its orbit. On 2022 March 26, Solar Orbiter reached for the first time a distance to the Sun close to 0.3 au. No other coronal EUV imager has been this close to the Sun.
Results. We review the EUI data sets obtained during the period 2022 March-April, when Solar Orbiter quickly moved from alignment with the Earth (2022 March 6), to perihelion (2022 March 26), to quadrature with the Earth (2022 March 29). We highlight the first observational results in these unique data sets and we report on the in-flight instrument performance.
Conclusions. EUI has obtained the highest resolution images ever of the solar corona in the quiet Sun and polar coronal holes. Several active regions were imaged at unprecedented cadences and sequence durations. We identify in this paper a broad range of features that require deeper studies. Both FSI and HRI_{EUV} operate at design specifications but HRI_{Lya} suffered from performance issues near perihelion. We conclude emphasising the EUI open data policy and encouraging further detailed analysis of the events highlighted in this paper.

Key words. Sun: UV radiation – Sun: transition region – Sun: corona – Instrumentation: high angular resolution

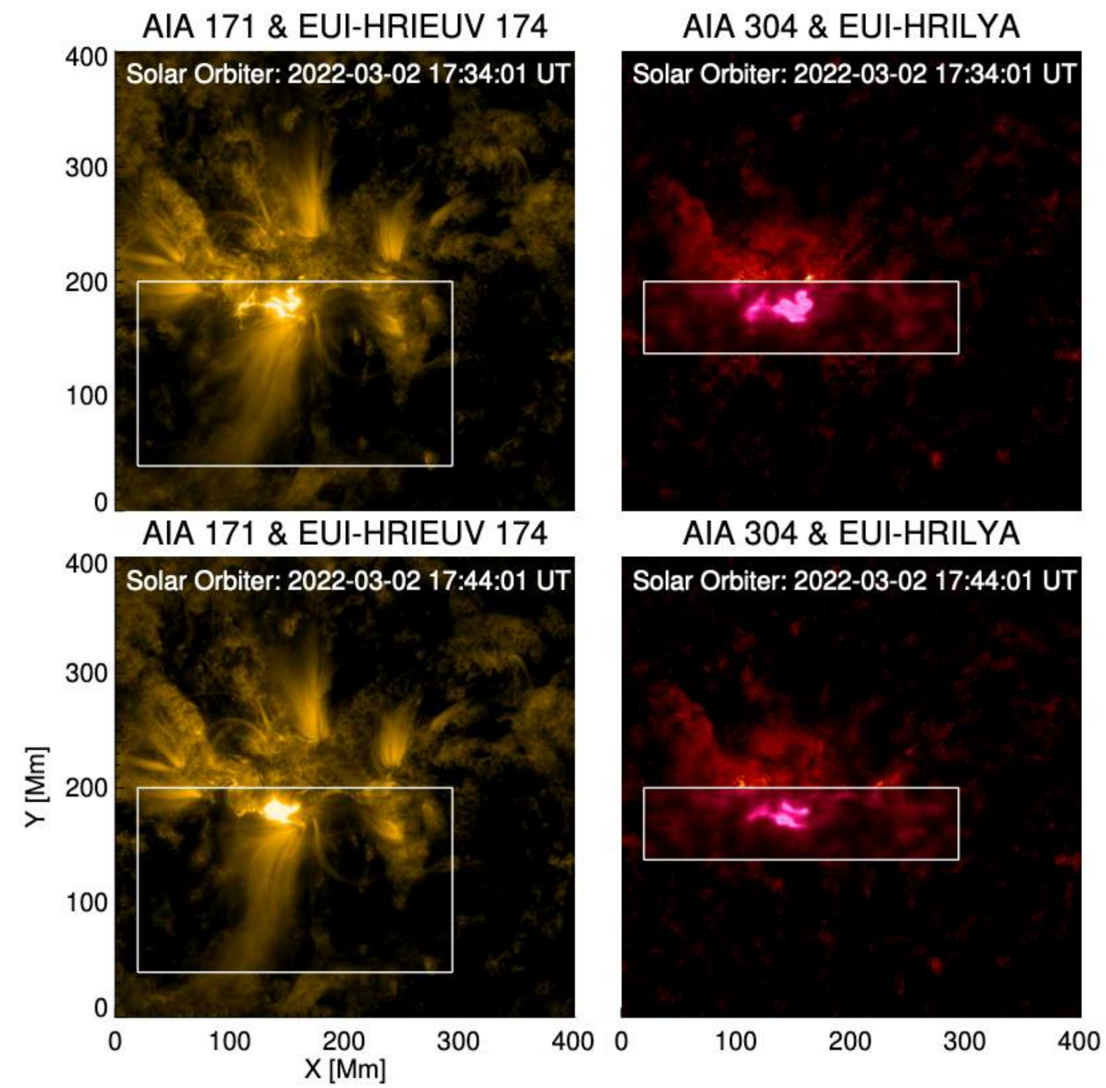
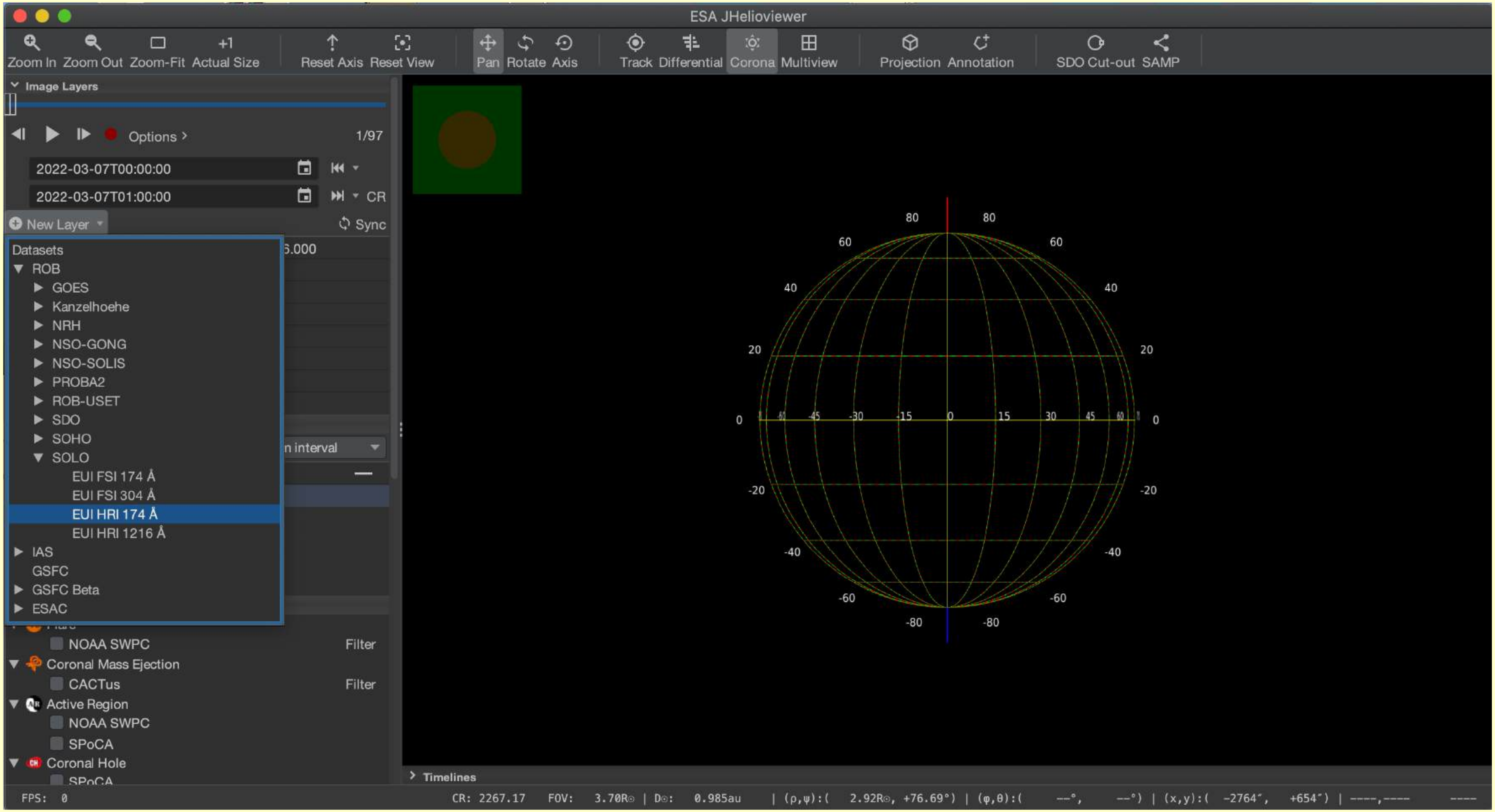


Fig. 12. M2 flare on 2022 March 2. Left hand side panels: combination of AIA 17.1 nm images and HRI_{EUV} 17.4 nm, the latter being shown within the white box (only few seconds apart). Right hand side panels: Same, but for the combination of AIA 30.4 nm and HRI_{Lya} images. The bottom row is taken 10 min later than the top row images. The white boxes delineate the boundaries of the areas showing data from EUI-HRIs. See Sect. 3.1.9.

Berghmans et al. 2023

Data access

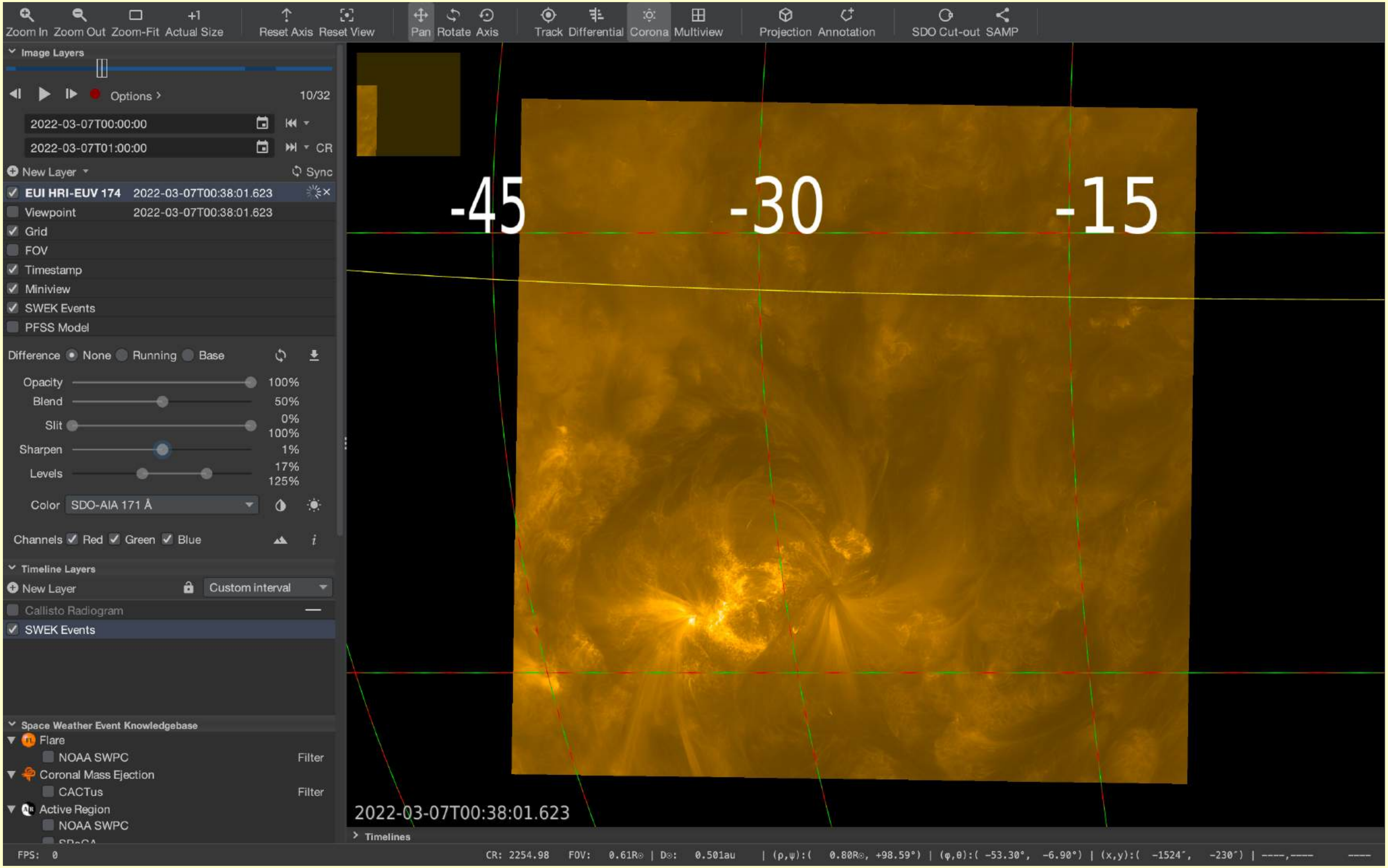
EUI Instrument



Access to EUI data with JHeliovover:

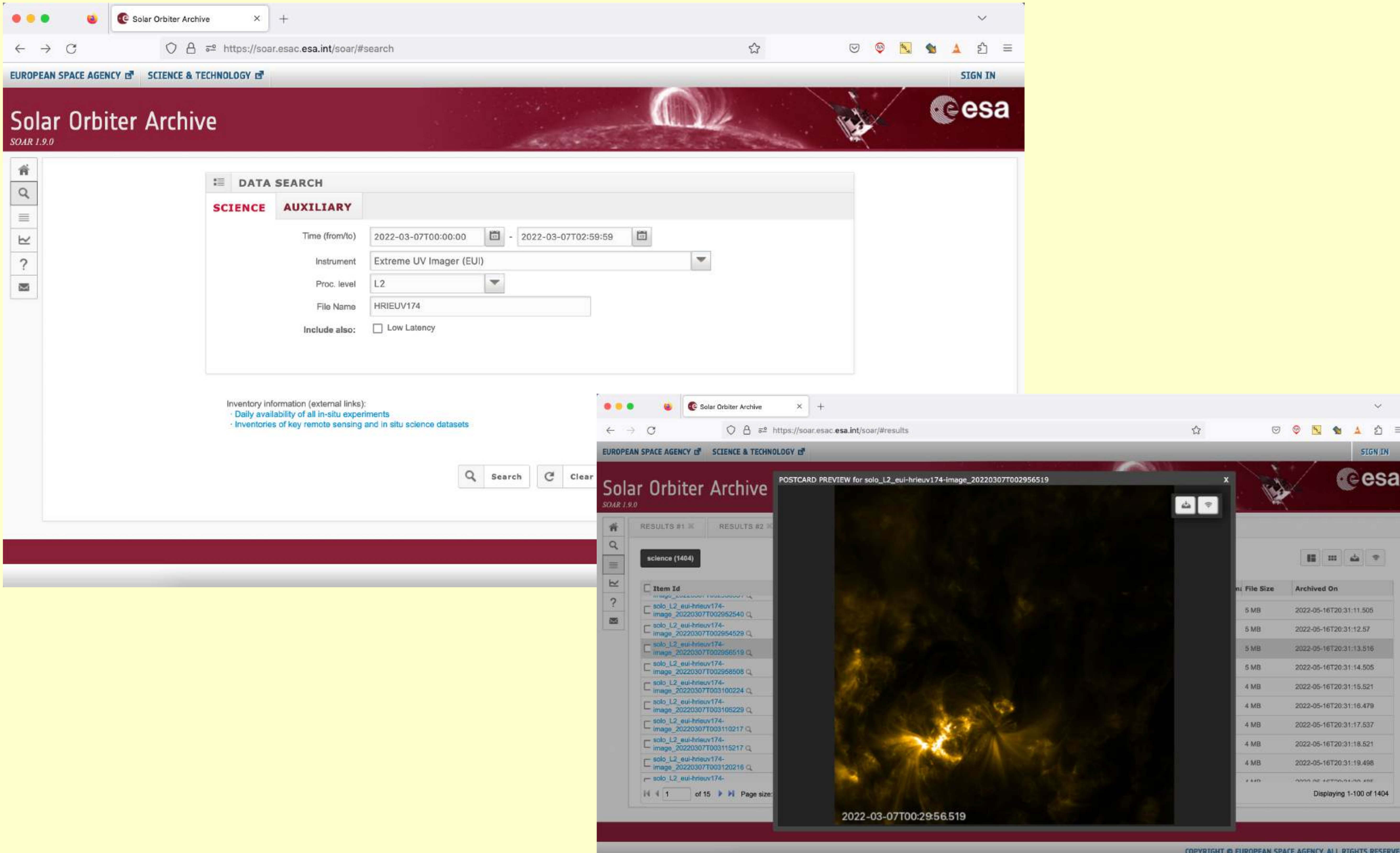
Image Layers -> New Layer -> Datasets -> ROB -> SOLO -> EUI channels

EUI Instrument



Data sources (all SO instruments)

- **Solar Orbiter Archive: https://soar.esac.esa.int/soar/#search**



Data sources (only EUI)

Royal Observatory of Belgium

SolO/EUI Data Release 6.0 2023-01

DOI:	https://doi.org/10.24414/z818-4163
Title:	SolO/EUI Data Release 6.0 2023-01
Published:	2023
Publisher:	Royal Observatory of Belgium (ROB)
Data Availability:	http://sidc.be/EUI/data/releases/202301_release_6.0
Creators:	Kraaikamp Emil, Gissot Samuel, Stegen Koen, Verbeeck Francis, Mampaey Benjamin, Auchere Frederic, Berghmans David (Principal Investigator)
Contributors:	Rochus Pierre, Harra Louise, Schuehle Udo, Long David, Aznar Cuadrado Regina, Buchlin Eric, Halain Jean-Philippe, Jacques Lionel, Mierla Marilena, Nicula Bogdan, Parenti Susanna, Rodriguez Luciano, Smith Phil, Teriaca Luca, Zhukov Andrei.
Description:	The Extreme Ultraviolet Imager (EUI) is part of the remote sensing instrument package of the ESA/NASA Solar Orbiter mission. The EUI consists of three telescopes, the Full Sun Imager (FSI) and two High Resolution Imagers (HRILYA, HRIEUV), which are optimised to image in Lyman-α and EUV (17.4 nm, 30.4 nm). The 3 telescopes together provide a coverage from chromosphere up to corona with both high resolution and with a wide field of view. EUI scientific data consists of calibrated and raw data images acquired by the three EUI telescopes. Following the orbit profile of Solar Orbiter, the data coverage, imaging cadence and effective spatial resolution of the EUI data are very variable. "SolO/EUI data release 6.0" was initially released with the Solar Orbiter/EUI data up till mid 2023 January. Later data will be included a-posteriori in this release as long as the software (including calibration) remains stable that generates the science data products. See the User Manual associated with this release for more technical details.
Dates:	Time range of observations: [2020-03-03 , open] (to be appended with later incoming data) Date of DOI mining: 2023-01-05

https://www.astro.oma.be/doi/ROB-SIDC-SolO_EUI-DataRelease6.0_2023-01.html

Data sources (only EUI)

- **Royal Observatory Belgium: https://www.sidc.be/EUI/data/**

Index of /EUI/data

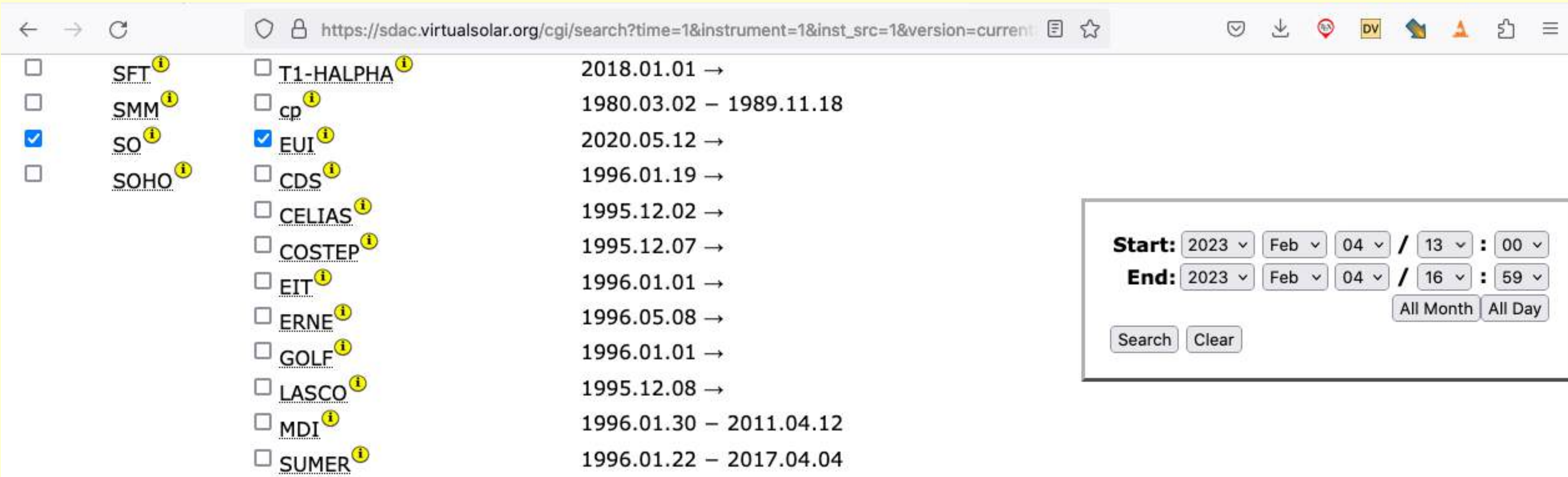
https://www.sidc.be/EUI/data/

Index of /EUI/data

Name	Last modified	Size	Description
Parent Directory		-	
L1/	2022-09-20 17:28	-	Current Level 1 released data
L2/	2022-06-21 15:08	-	Current Level 2 released data
L3/	2022-04-14 14:10	-	Current Level 3 released data
lastDayFSI/	2023-02-01 00:14	-	
latest_release_notes.html	2022-05-02 11:57	14K	
movie/	2022-05-18 13:31	-	
presentation/	2023-02-01 14:54	-	
releases/	2022-04-29 09:19	-	Current and past released data

Apache/2.4.41 (Ubuntu) Server at www.sidc.be Port 443

Data sources (VSO)

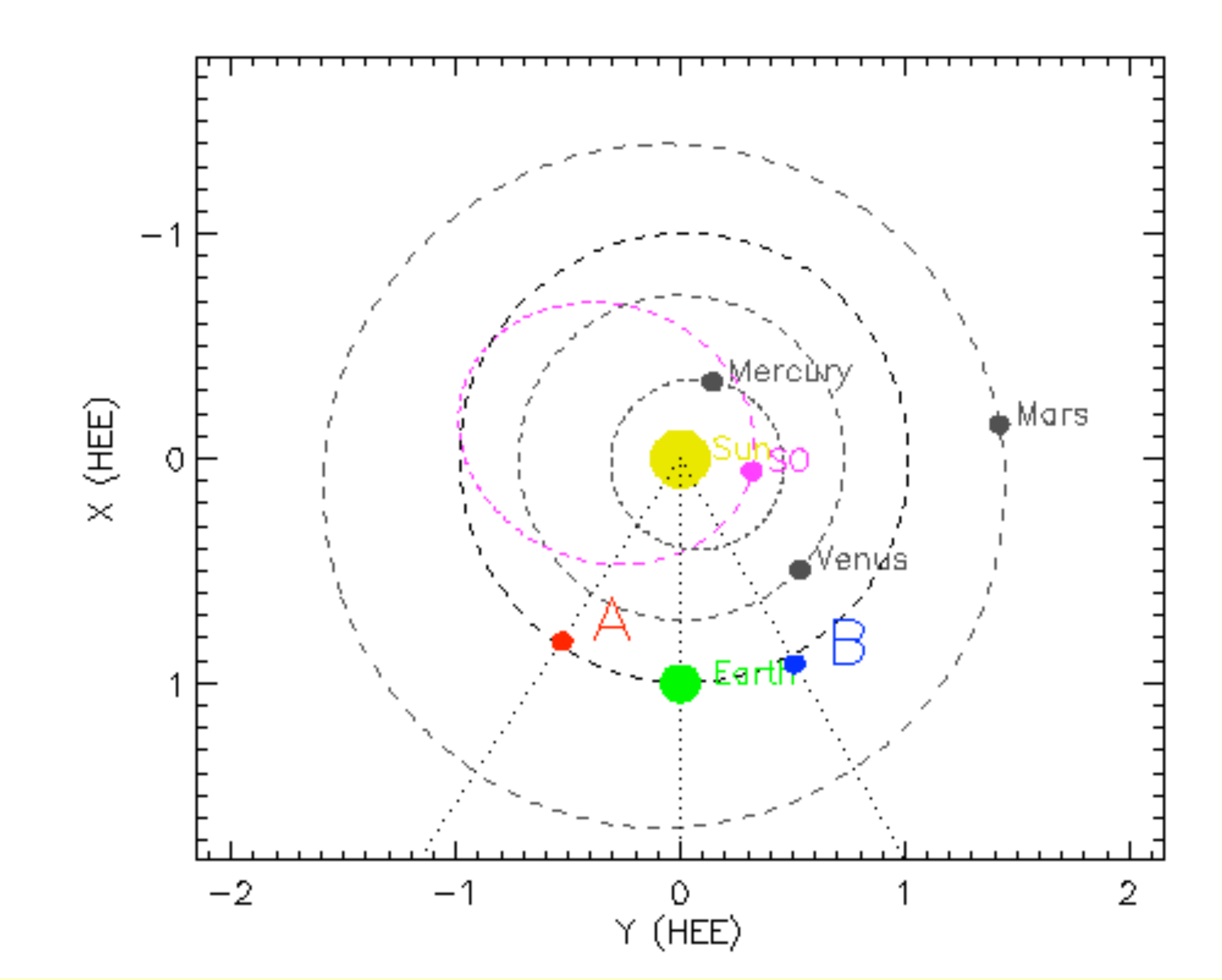


Header data -time

DATE-BEG= '2022-03-27T21:29:10.252' / [UTC] start time of observation
DATE-AVG= '2022-03-27T21:29:11.652' / [UTC] average time of observation

EAR_TDEL= 336.2593777137113 / [s] Time(Sun to Earth) - Time(Sun to S/C)
SUN_TIME= 161.7059410133145 / [s] Time(Sun to S/C)

DATE_EAR= '2022-03-27T21:34:47.911' / [UTC] start time of observation Earth
DATE_SUN= '2022-03-27T21:26:29.946' / [UTC] start time of observation Sun



Heliocentric distance (AU): 0.324

Separation angle with Earth: 80.438

Python

Data analysis with Python

- **Introduction -reading data**

  https://github.com/SolarOrbiterWorkshop/solo8_tutorials/blob/main/EUI_tutorial/1_introduction.ipynb

- **SQLite database and euiprep**

  https://github.com/SolarOrbiterWorkshop/solo8_tutorials/blob/main/EUI_tutorial/2_sqlite_euiprep.ipynb

- **Aligning data and attempt to fix HRI EUV pointing**

  https://github.com/SolarOrbiterWorkshop/solo8_tutorials/blob/main/EUI_tutorial/3_alignment_b.ipynb

- **HRI EUV in more details**

  https://github.com/SolarOrbiterWorkshop/solo8_tutorials/blob/main/EUI_tutorial/4_euv_mosaic.ipynb

Reading and downloading data

https://github.com/SolarOrbiterWorkshop/solo8_tutorials/blob/main/EUI_tutorial/1_introduction.ipynb

Task 1 -Plot map

```
>>> import matplotlib.pyplot as plt
>>> from astropy.visualization import ImageNormalize, SqrtStretch, PowerStretch
>>> import sunpy.map
>>> import sunpy_soar
>>> from sunpy.net import Fido
>>> import sunpy.net.attrs as a
>>> import numpy as np
>>> instrument = a.Instrument('EUI')
>>> time = a.Time('2022-03-06 18:0:00', '2022-03-06 18:10:00')
>>> level = a.Level(2)
>>> product = a.soar.Product('EUI-HRILYA1216-IMAGE')
>>> result = Fido.search(instrument & time & level & product)
>>> print(result)
```

```
Results from 1 Provider:

10 Results from the SOARClient:

Instrument     Data product      Level        Start time               End time         Filesize
                                                                                          Mbyte
---------- -------------------- ----- ----------------------- ----------------------- --------
       EUI EUI-HRILYA1216-IMAGE    L2 2022-03-06 18:00:30.287 2022-03-06 18:00:35.287    1.437
       EUI EUI-HRILYA1216-IMAGE    L2 2022-03-06 18:01:30.287 2022-03-06 18:01:35.287     1.44
       EUI EUI-HRILYA1216-IMAGE    L2 2022-03-06 18:02:30.287 2022-03-06 18:02:35.287    1.261
       EUI EUI-HRILYA1216-IMAGE    L2 2022-03-06 18:03:30.287 2022-03-06 18:03:35.287    1.449
       EUI EUI-HRILYA1216-IMAGE    L2 2022-03-06 18:04:30.287 2022-03-06 18:04:35.287    1.452
       EUI EUI-HRILYA1216-IMAGE    L2 2022-03-06 18:05:30.287 2022-03-06 18:05:35.287    1.449
       EUI EUI-HRILYA1216-IMAGE    L2 2022-03-06 18:06:30.288 2022-03-06 18:06:35.288    1.443
       EUI EUI-HRILYA1216-IMAGE    L2 2022-03-06 18:07:30.288 2022-03-06 18:07:35.288     1.44
       EUI EUI-HRILYA1216-IMAGE    L2 2022-03-06 18:08:30.288 2022-03-06 18:08:35.288    1.426
       EUI EUI-HRILYA1216-IMAGE    L2 2022-03-06 18:09:30.288 2022-03-06 18:09:35.288    1.423

>>>
```

Map plotting

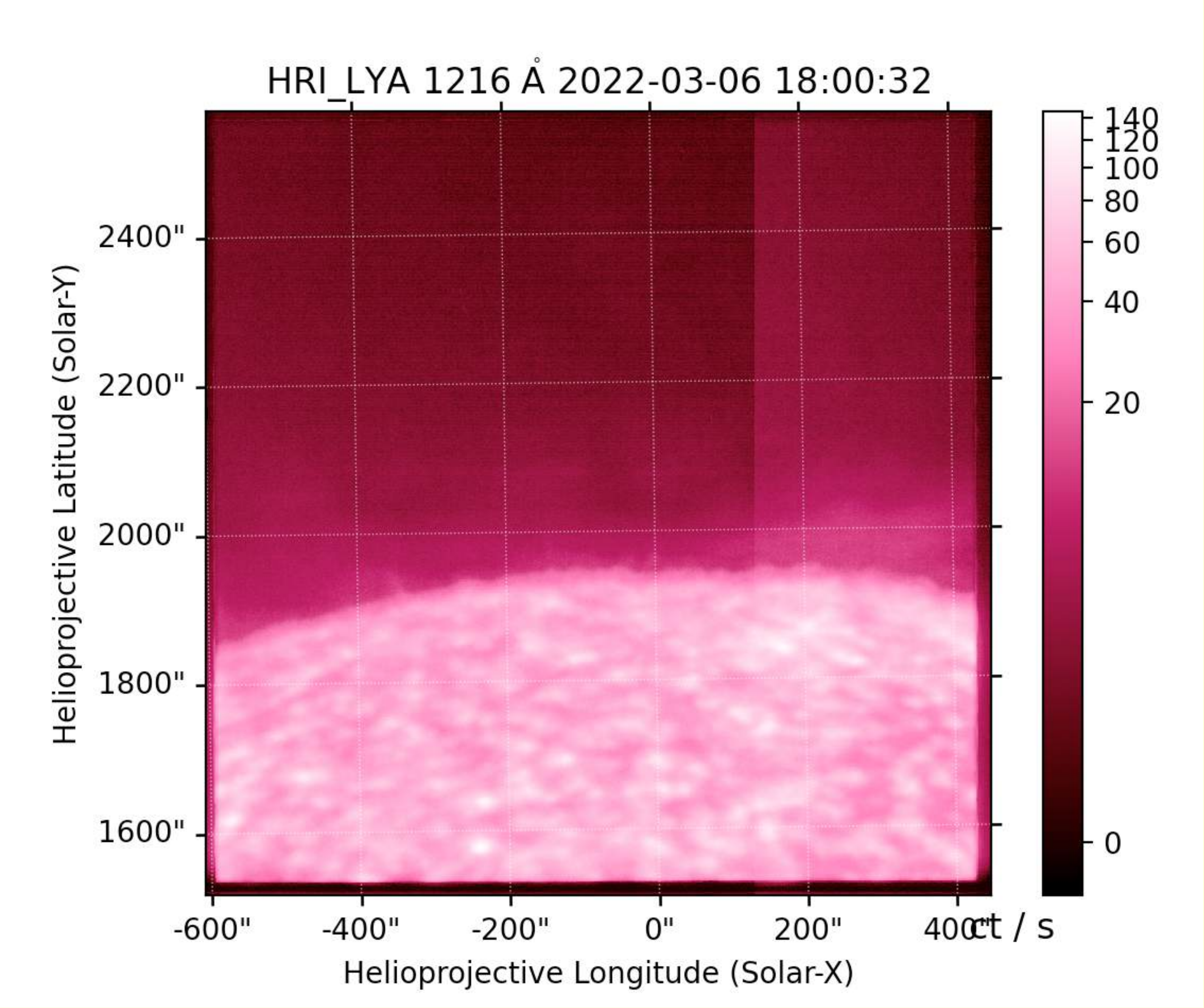
Reading data

```
>>> files = Fido.fetch(result)
Files Downloaded: 100%|████████████████████████████████████| 10/10 [00:00<00:00, 19.13file/s]
```

Download data

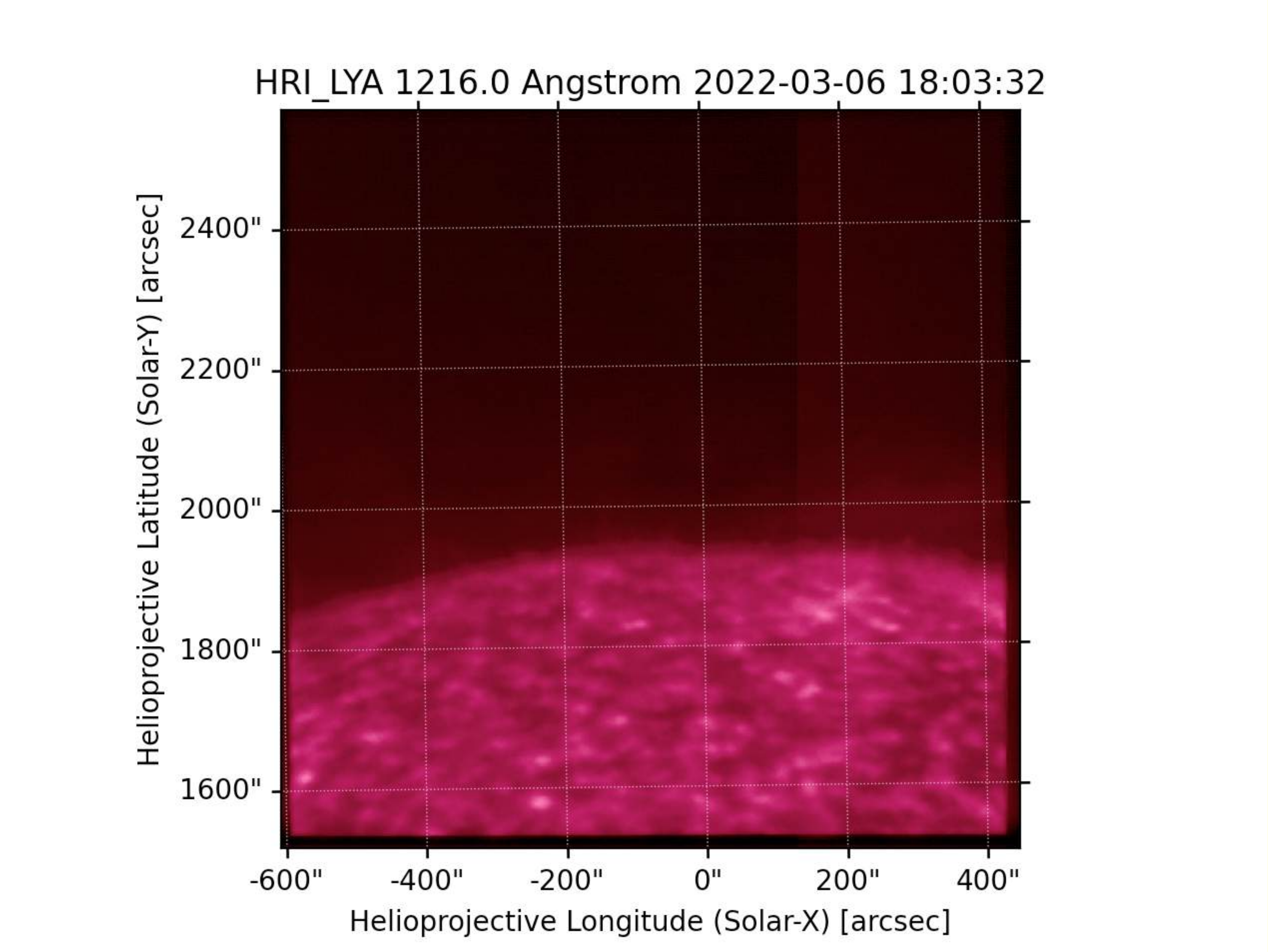
```
>>> map = sunpy.map.Map(files[0])
>>> map.peek()
```

Plot map



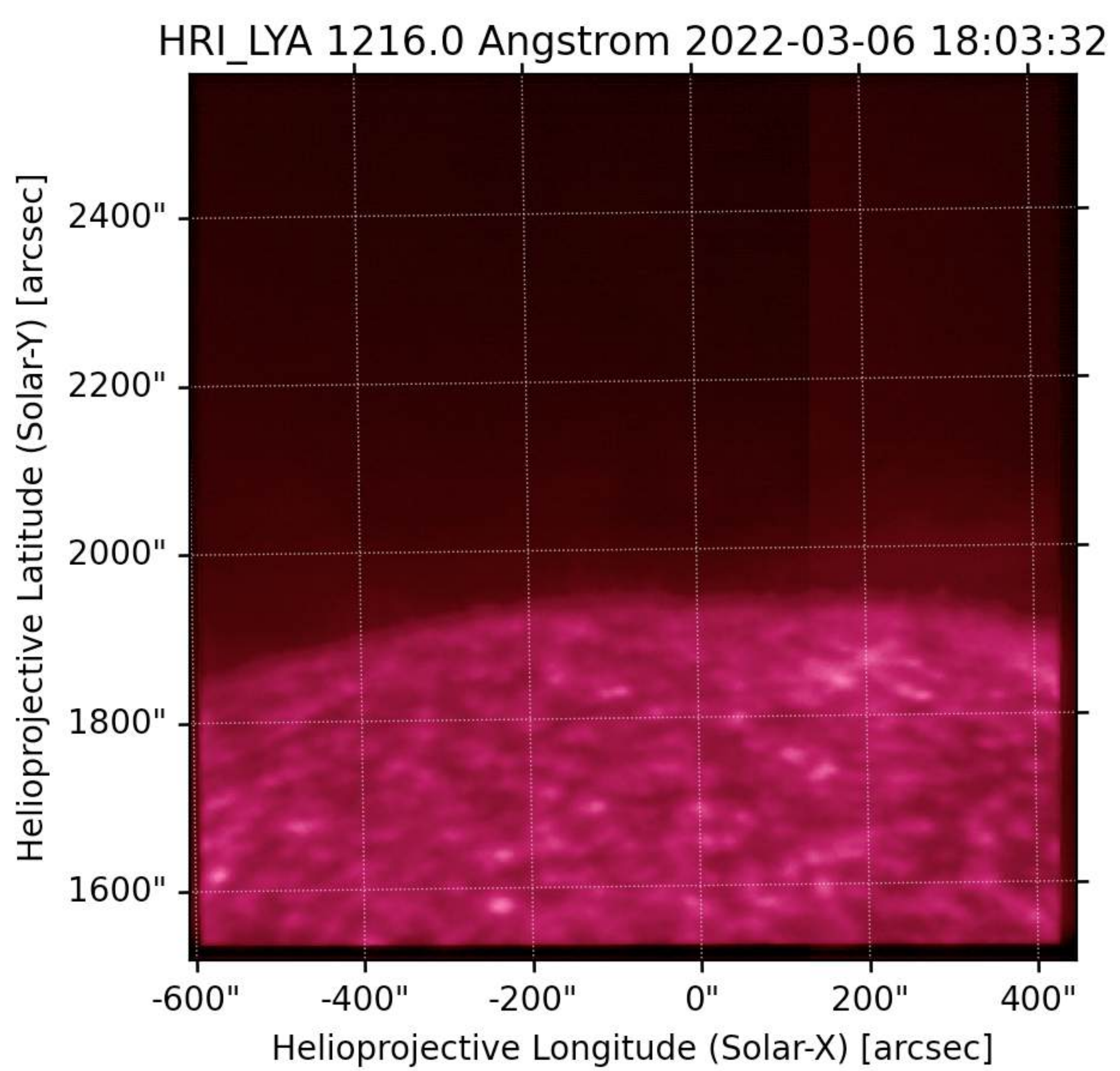
Animation


```
>>> sequence = sunpy.map.Map(files, sequence=True)
>>> for each_map in sequence:
...     each_map.plot_settings['norm'] = ImageNormalize(vmin=0, vmax=300, stretch=SqrtStretch())
...
>>> plt.figure()
<Figure size 640x480 with 0 Axes>
>>> ani = sequence.plot()
>>> plt.show()
```



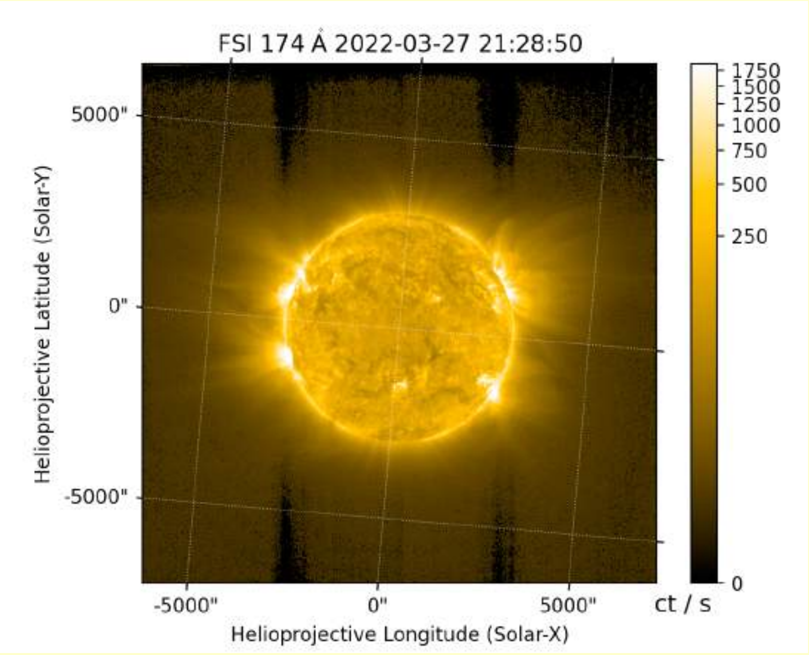
Animation


```
>>> sequence = sunpy.map.Map(files, sequence=True)
>>> for each_map in sequence:
...     each_map.plot_settings['norm'] = ImageNormalize(vmin=0, vmax=300, stretch=SqrtStretch())
...
>>> plt.figure()
<Figure size 640x480 with 0 Axes>
>>> ani = sequence.plot()
>>> plt.show()
```



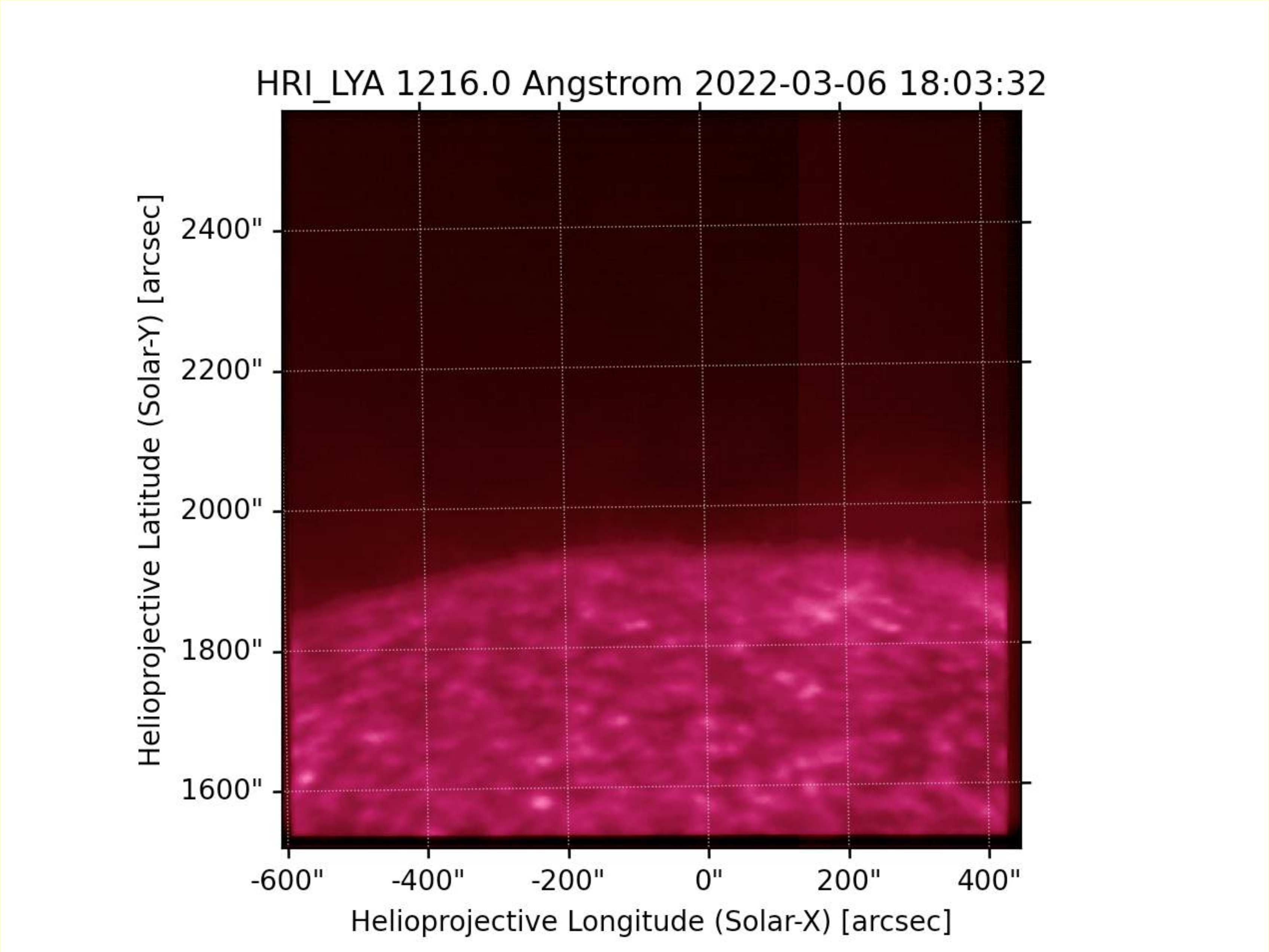
FSI

```
>>> time = a.Time('2022-03-27 21:24:00', '2022-03-27 21:34:00')
>>> level = a.Level(2)
>>> product = a.soar.Product('EUI-FSI174-IMAGE')
>>> result = Fido.search(instrument & time & level & product)
>>> result
<sunpy.net.fido_factory.UnifiedResponse object at 0x123f0e6a0>
Results from 1 Provider:

1 Results from the SOARClient:

Instrument   Data product   Level        Start time               End time            Filesize
                                                                                        Mbyte
---------- ---------------- ----- ----------------------- ----------------------- --------
       EUI EUI-FSI174-IMAGE    L2 2022-03-27 21:28:45.245 2022-03-27 21:28:55.245    5.881


>>> files = Fido.fetch(result)
Files Downloaded: 100%|████████████████████████████████████████████████████| 1/1 [00:00<00:00,  3.57file/s]
>>> amap = sunpy.map.Map(files)
>>> amap.plot_settings['norm'] = ImageNormalize(vmin=0, vmax=np.percentile(amap.data,99.9), stretch=PowerStr
etch(0.2))
>>> amap.peek()
```



Animation

```
>>> sequence = sunpy.map.Map(files, sequence=True)
>>> for each_map in sequence:
...     each_map.plot_settings['norm'] = ImageNormalize(vmin=0, vmax=300, stretch=SqrtStretch())
...
>>> plt.figure()
<Figure size 640x480 with 0 Axes>
>>> ani = sequence.plot()
>>> plt.show()
```



IDL

Reading data with IDL

See: “Introduction to EUI data analysis with IDL” by KB

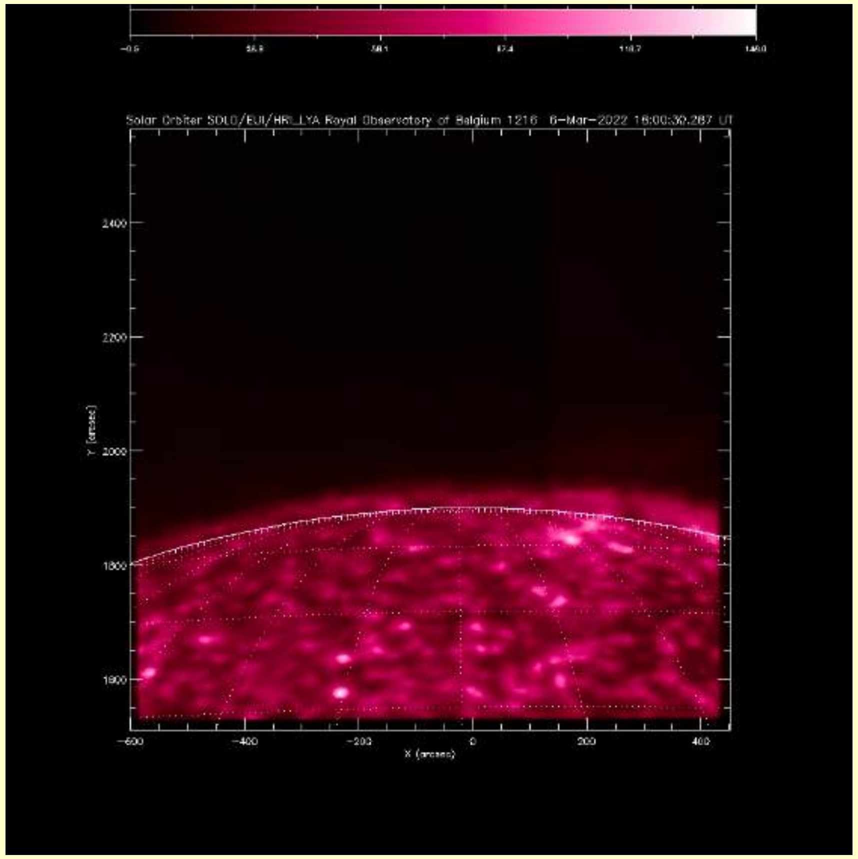
Retrieving and looking at data

HRI LYA

```
IDL> a = vso_search(date='2022/03/06T18:00-2022/03/06T18:10', inst='eui', wave='1216 Angstrom') ; select data
Records Returned : SDAC_SO : 20/20
IDL> a=a[WHERE(a.info EQ 'L2')]    ;define the data level
IDL> print_struct, a  ;print data structure
# DETECTOR INSTRUMENT SOURCE PROVIDER INFO  PHYSOBS                                 FILEID      SIZE  EXPTIME    DARK  ECLIPSE  PERCENTD  URL
GETINFO
0          EUI   SO  SDAC_SO  L2  intensity  data/so/eui/L2/2022/03/06/solo_L2_eui-hrilya1216-image_20220306T180030287_V01.fits   1403.   5.000   0   0   0.000
1          EUI   SO  SDAC_SO  L2  intensity  data/so/eui/L2/2022/03/06/solo_L2_eui-hrilya1216-image_20220306T180130287_V01.fits   1406.   5.000   0   0   0.000
2          EUI   SO  SDAC_SO  L2  intensity  data/so/eui/L2/2022/03/06/solo_L2_eui-hrilya1216-image_20220306T180230287_V01.fits   1232.   5.000   0   0   0.000
3          EUI   SO  SDAC_SO  L2  intensity  data/so/eui/L2/2022/03/06/solo_L2_eui-hrilya1216-image_20220306T180330287_V01.fits   1415.   5.000   0   0   0.000
4          EUI   SO  SDAC_SO  L2  intensity  data/so/eui/L2/2022/03/06/solo_L2_eui-hrilya1216-image_20220306T180430287_V01.fits   1418.   5.000   0   0   0.000
5          EUI   SO  SDAC_SO  L2  intensity  data/so/eui/L2/2022/03/06/solo_L2_eui-hrilya1216-image_20220306T180530287_V01.fits   1415.   5.000   0   0   0.000
6          EUI   SO  SDAC_SO  L2  intensity  data/so/eui/L2/2022/03/06/solo_L2_eui-hrilya1216-image_20220306T180630288_V01.fits   1409.   5.000   0   0   0.000
7          EUI   SO  SDAC_SO  L2  intensity  data/so/eui/L2/2022/03/06/solo_L2_eui-hrilya1216-image_20220306T180730288_V01.fits   1406.   5.000   0   0   0.000
8          EUI   SO  SDAC_SO  L2  intensity  data/so/eui/L2/2022/03/06/solo_L2_eui-hrilya1216-image_20220306T180830288_V01.fits   1392.   5.000   0   0   0.000
9          EUI   SO  SDAC_SO  L2  intensity  data/so/eui/L2/2022/03/06/solo_L2_eui-hrilya1216-image_20220306T180930288_V01.fits   1389.   5.000   0   0   0.000
IDL>
IDL> b = vso_get( a ) ;download data
% VSO_GET: This will download 10 file(s)
1 : https://vso1.nascom.nasa.gov/data/so/eui/L2/2022/03/06/solo_L2_eui-hrilya1216-image_20220306T180030287_V01.fits
% SOCK_GET_MAIN: 1437120 bytes of solo_L2_eui-hrilya1216-image_20220306T180030287_V01.fits copied in 1.36 seconds.
2 : https://vso1.nascom.nasa.gov/data/so/eui/L2/2022/03/06/solo_L2_eui-hrilya1216-image_20220306T180130287_V01.fits
% SOCK_GET_MAIN: 1440000 bytes of solo_L2_eui-hrilya1216-image_20220306T180130287_V01.fits copied in 1.31 seconds.
```

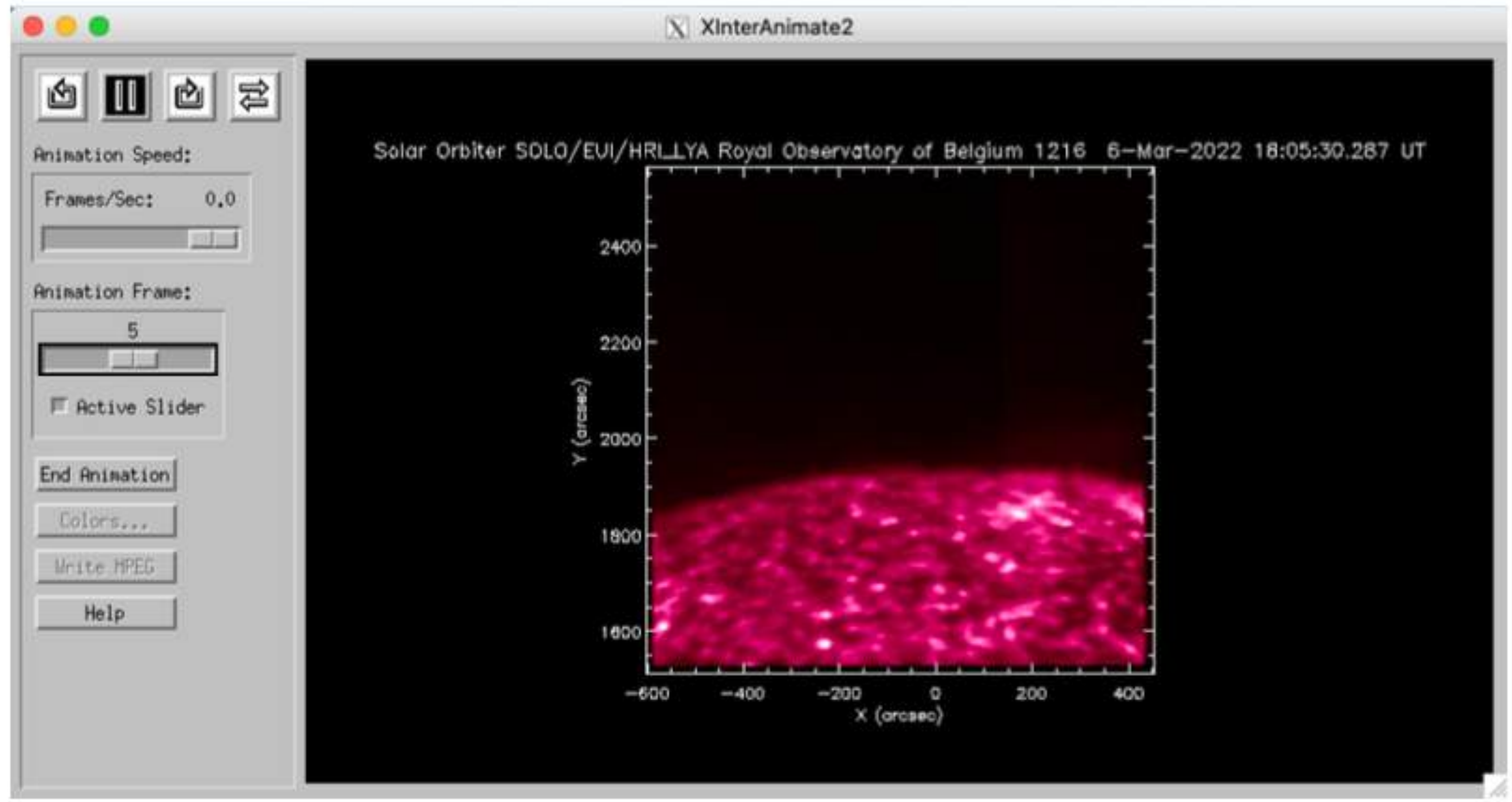
Ploting map with IDL


```
IDL> file_list=file_search('*.fits')      ; search for downloaded data
IDL> fits2map, file_list, map_hri1216, /USE_WCS ;read fits file to SSW maps,  /USE_WCS -the maps use WCS coordinate system
IDL>
IDL> ; HRILYA color Table
IDL> ; Starting from the "red temperature" color table in IDL, we add a bit of blue to make it violet
IDL> loadct, 3, rgb_table=rgb        ; 3= red temperature
IDL> factor=indgen(256)/256.
IDL> r=rgb[*,0]
IDL> g=rgb[*,1]
IDL> b=rgb[*,0]*factor
IDL> b=bytscl(b)
IDL> tvlct, r,g,b                    ; optional
IDL>
IDL> device, retain=2
IDL> window, 0, xs=900, ys=900
IDL> plot_map, map_hri1216[0], /cbar, /grid, /limb, GRID_SPACING=10 ; create HRI1216 maps with limb and grid, the grid spacing is equal 10 deg
IDL>write_png, 'map_hri1216_0.png', TVRD(/TRUE) ;save window to .png file
```



Animation with IDL

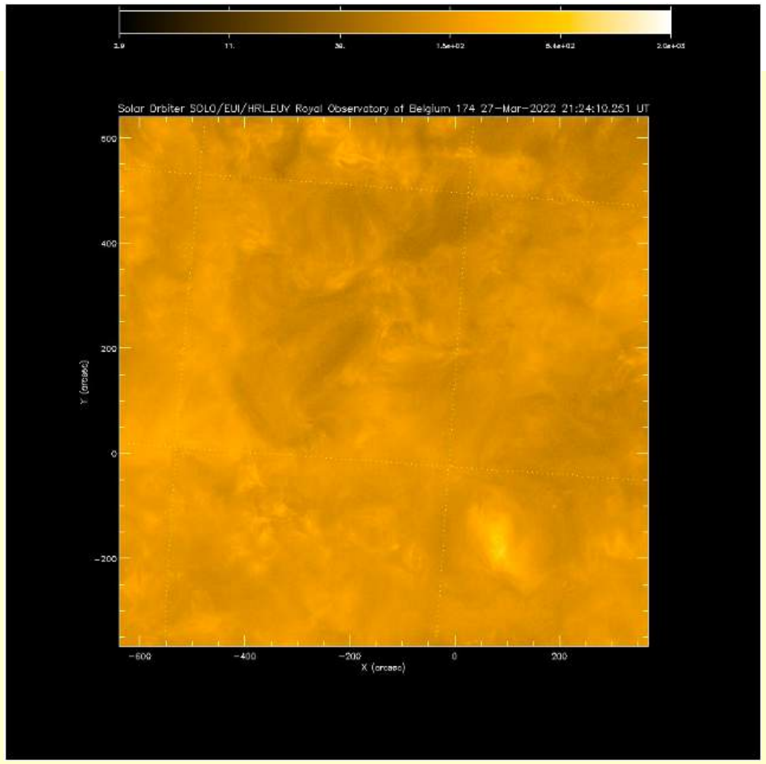
IDL>movie_map, map_hri1216, dmin=0, dmax=120 ;generate animation with defined intensity range 0-120 DN/s



Ploting map with IDL -HRI 174

HRI EUV

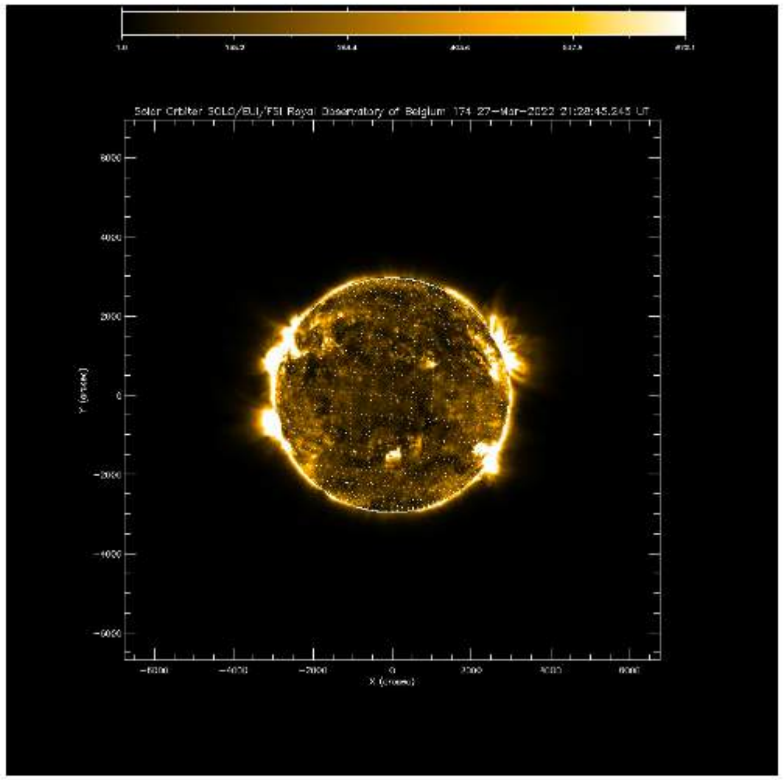
```
IDL>
IDL> a = vso_search(date='2022/03/27T21:24-2022/03/27T21:50', inst='eui', wave='174 Angstrom') ; select data
Records Returned : SDAC_SO : 58/58
IDL> a=a[WHERE(STRMATCH(a.FILEID, '*solo_L2_eui-hrieuv174*', /FOLD_CASE) EQ 1.0)]    ;define the data level
IDL>
IDL> print_struct, a  ;print data structure
 # DETECTOR INSTRUMENT SOURCE PROVIDER INFO   PHYSOBS                                   FILEID     SIZE   EXPTIME    DARK   ECLIPSE  PERCENTD URL
GETINFO
 0           EUI    SO   SDAC_SO   L2  intensity  data/so/eui/L2/2022/03/27/solo_L2_eui-hrieuv174-image_20220327T212410251_V01.fits   6112.   2.800   0   0   0.000
 1           EUI    SO   SDAC_SO   L2  intensity  data/so/eui/L2/2022/03/27/solo_L2_eui-hrieuv174-image_20220327T212510251_V01.fits   6308.   2.800   0   0   0.000
 ...
24           EUI    SO   SDAC_SO   L2  intensity  data/so/eui/L2/2022/03/27/solo_L2_eui-hrieuv174-image_20220327T214810254_V01.fits   6429.   2.800   0   0   0.000
25           EUI    SO   SDAC_SO   L2  intensity  data/so/eui/L2/2022/03/27/solo_L2_eui-hrieuv174-image_20220327T214910254_V01.fits   6008.   2.800   0   0   0.000

IDL> b = vso_get( a ) ;download data
IDL> file_list=file_search('*solo_L2_eui-hrieuv174*.fits')      ; search for downloaded data
IDL> fits2map, file_list, map_hri174, /USE_WCS
IDL> aia_lct,wave=171,/load
IDL> device, retain=2
IDL>
IDL> window, 0, xs=900, ys=900
IDL> plot_map, map_hri174[0], /cbar, /grid, GRID_SPACING=10,dmin=0, dmax=2000.0, /log ; create HRI174 maps with grid, the grid spacing is equal 10 deg;
IDL> WRITE_PNG, 'map_hri174_0.png', TVRD(/TRUE) ;save window to .png file
```



Ploting map with IDL -FSI 174

FSI 174 EUV

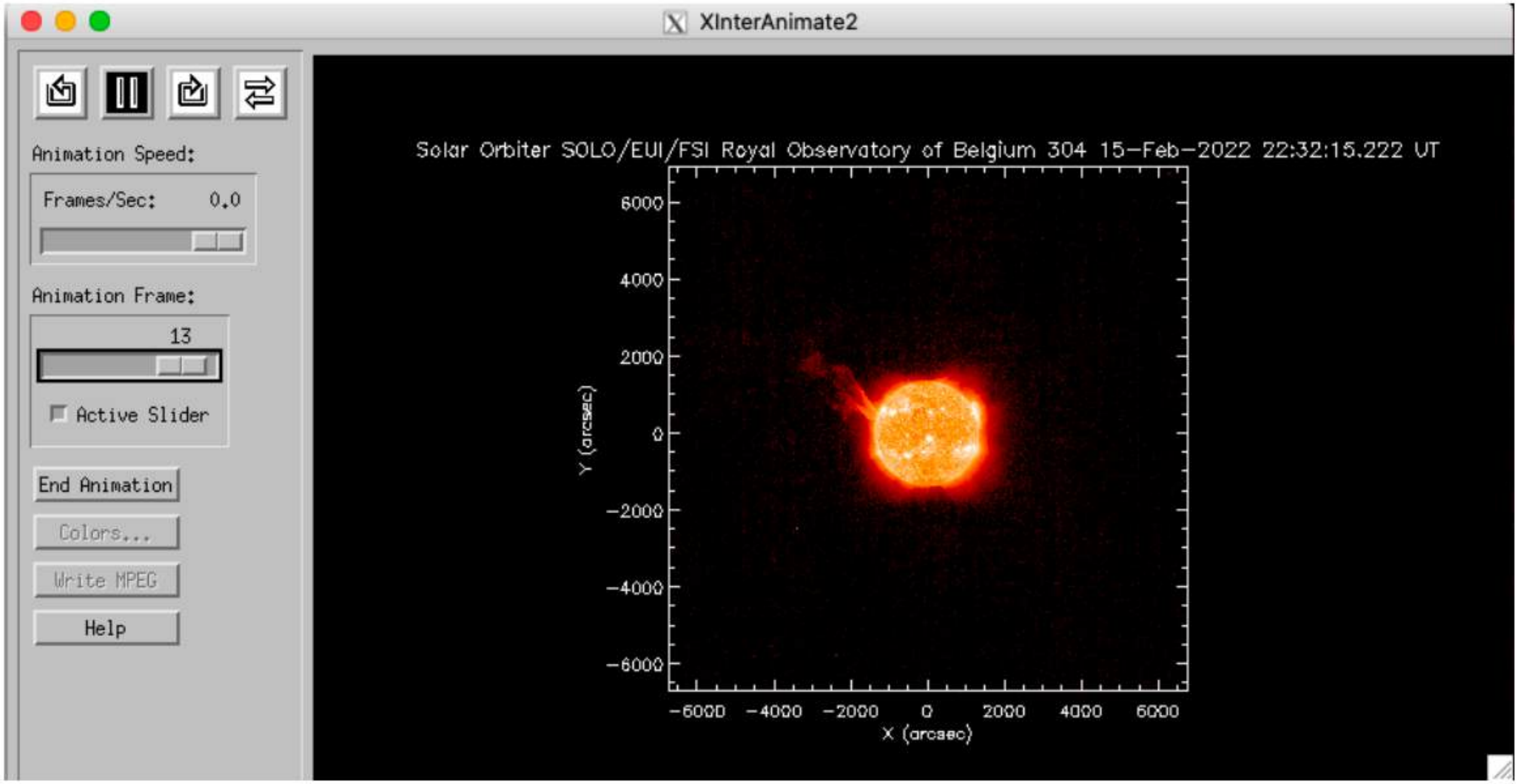
```
IDL>a = vso_search(date='2022/03/27T21:24-2022/03/27T21:34', inst='eui', wave='174 Angstrom') ; select data
IDL> a=a[WHERE(STRMATCH(a.FILEID, '*solo_L2_eui-fsi174*', /FOLD_CASE) EQ 1.0)]    ;define the data level
IDL> b = vso_get(a) ;download data
IDL> file_list=file_search('*solo_L2_eui-fsi174*.fits')
IDL> fits2map, file_list, map_fsi174, /USE_WCS
IDL> aia_lct,wave=171,/load
IDL> device, retain=2
IDL> window, 0, xs=900, ys=900
IDL> plot_map, map_fsi174[0], /cbar, /grid, /limb, GRID_SPACING=10.0, dmin=1.0, dmax=percentiles(map_fsi174[0].data,value=[0.99]), square_scale=1.0 ; create fsi174 maps with limb and grid, the grid spacing is equal 10 deg;
```



Animation with IDL - FSI 304

FSI 304 EUV

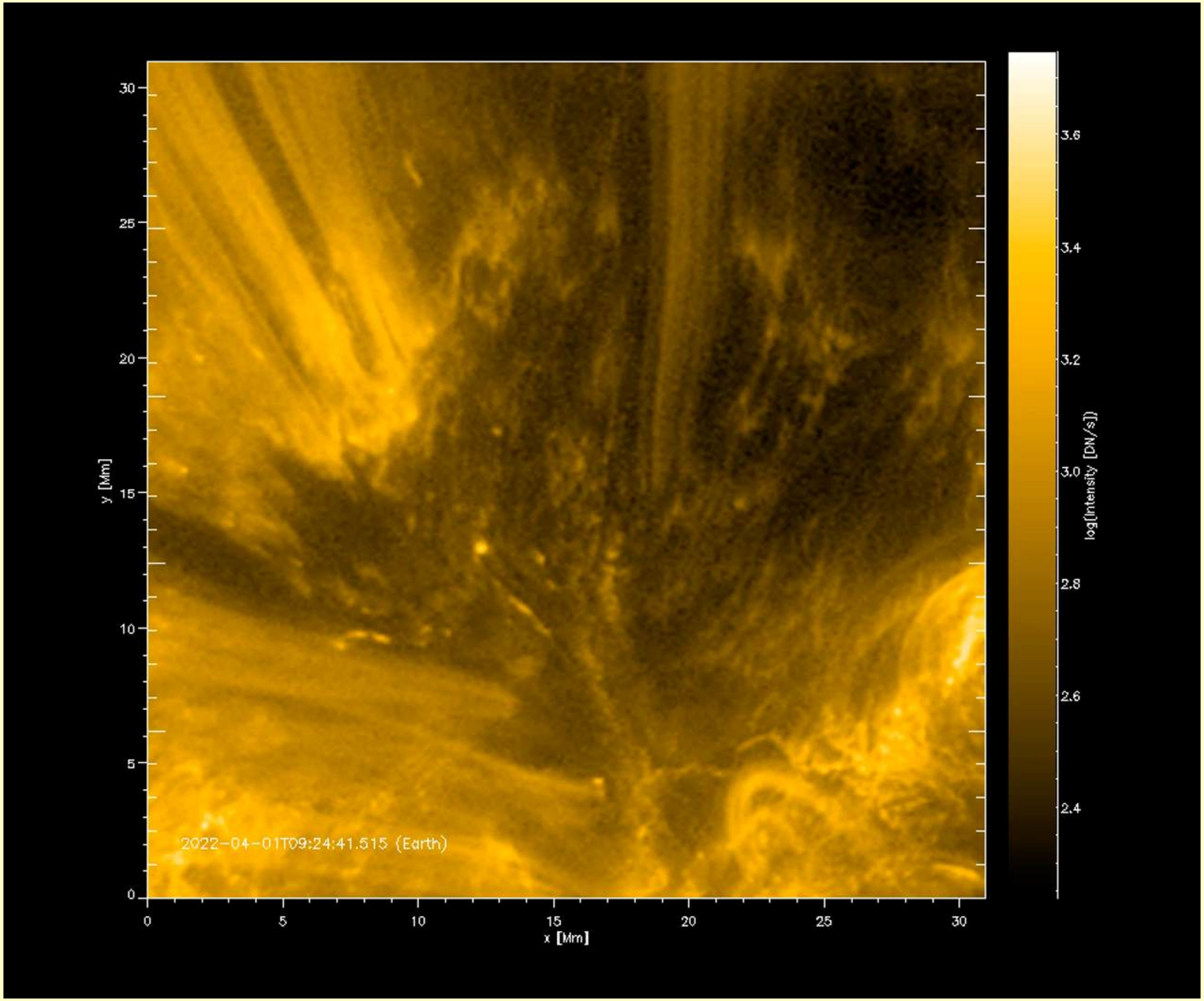
```
IDL> a = vso_search(date='2022/02/15T22:00-2022/02/15T22:34', inst='eui', wave='304 Angstrom') ; select data
Records Returned : SDAC_SO : 28/28
IDL> a=a[WHERE(STRMATCH(a.FILEID, '*solo_L2_eui-fsi304*', /FOLD_CASE) EQ 1.0)]    ;define the data level
IDL> b = vso_get(a) ;download data
IDL> file_list=file_search('*solo_L2_eui-fsi304*.fits')    ; search for downloaded data
IDL> fits2map, file_list, map_fsi304, /USE_WCS
IDL> aia_lct,wave=304,/load
IDL> aia_lct,wave=304,/load
IDL> movie_map, map_fsi304, dmin=0, dmax=300, /log
```



Data analysis

Data alignment

- **problem with co-alignment of high-resolution data**



Stereoscopic view I

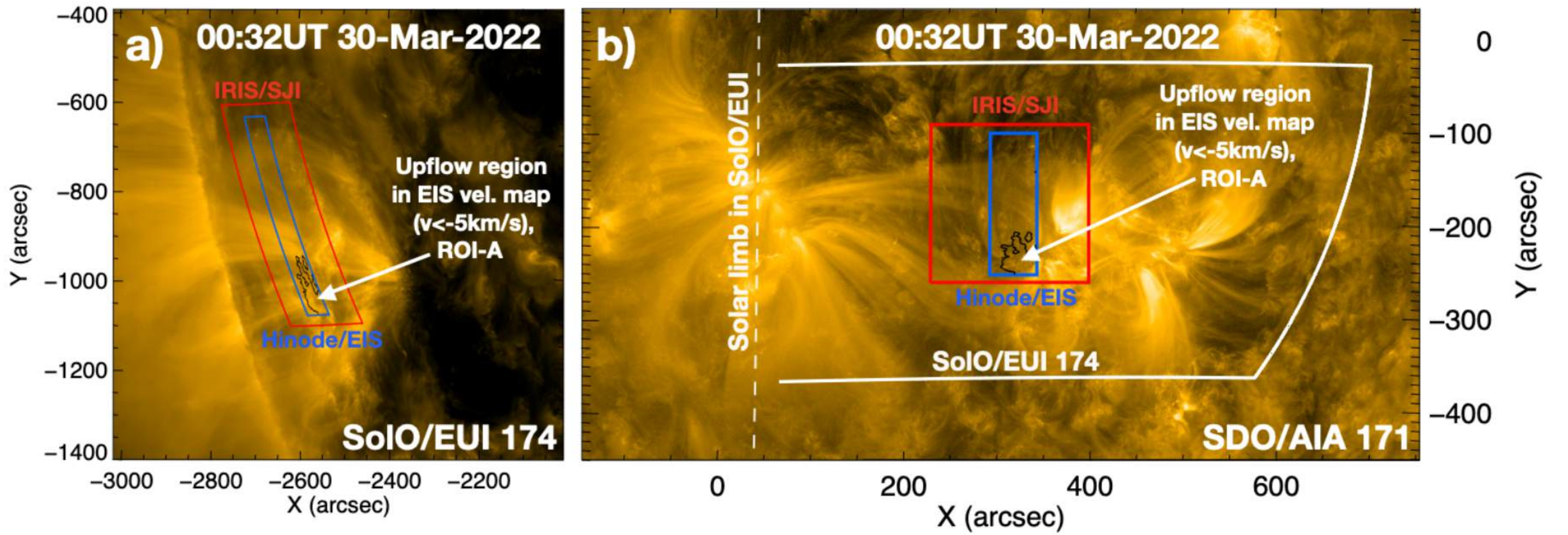


Fig. 1. Overview of the active region observations from Solar Orbiter/Extreme Ultaviolet Imager (EUI) and HRI_{EUV} telescope at 174 Å (a) and AIA 171 Å (b). The IRIS/SJI and Hinode/EIS FOVs are marked with red and blue boxes, respectively. The black contour highlights the ROI-A that spatially corresponds to the Hinode/EIS upflow region defined in Fig. 2. In panel (b), the white line presents the solar disk limb position from panel (a) computed with the WCS_LIMB solar software routine and then transformed into the SDO/AIA view. The limb observed in EUI/FSI 174 Å (panel a) is marked by a dashed line in the 171 Å map (panel b).

Barczynski et al. 2023

https://hesperia.gsfc.nasa.gov/ssw/gen/idl/wcs/wcs_tutorial.pdf

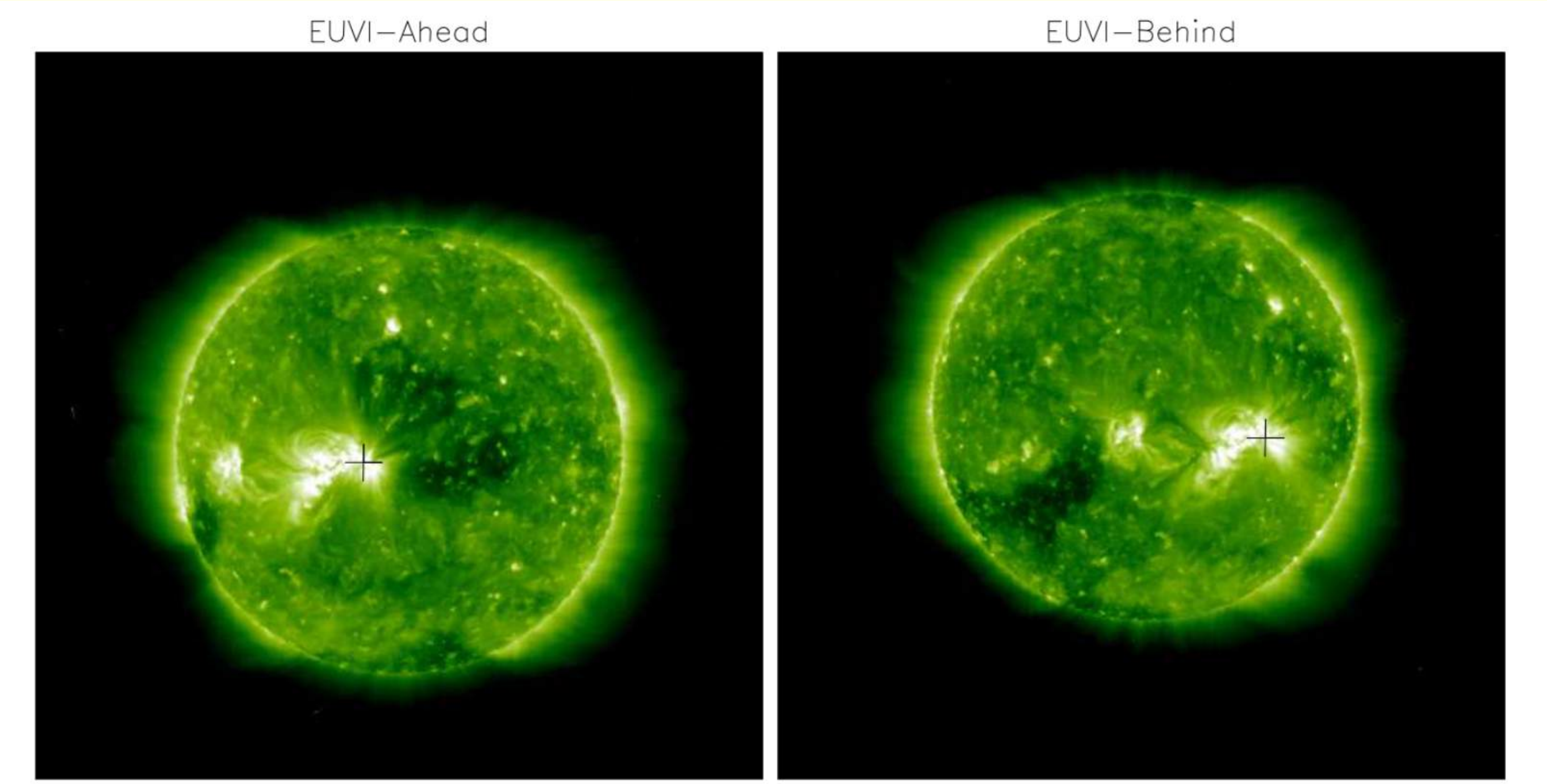
Stereoscopic view II

4.1 Example: Comparing observations from different viewpoints

Figure 5 demonstrates the use of the WCS conversion routines to convert pixel positions on a STEREO-A image into the equivalent position on a STEREO-B image. This is done by using heliographic coordinates as an intermediate step. The commands used were:

```
wcs_a = fitshead2wcs(header_a)
wcs_b = fitshead2wcs(header_b)
coord_a = wcs_get_coord(wcs_a, pixel_a)
wcs_convert_from_coord, wcs_a, coord_a, 'HG', hgln, hglt
wcs_convert_diff_rot, wcs_a, wcs_b, hgln, hglt
wcs_convert_to_coord, wcs_b, coord_b, 'HG', hgln, hglt
pixel_b = wcs_get_pixel(wcs_b, coord_b)
```

Note the use of the routine WCS_CONVERT_DIFF_ROT to take into account any difference in time between the two observations. (This example was taken from Thompson and Wei (2010).)



https://hesperia.gsfc.nasa.gov/ssw/gen/idl/wcs/wcs_tutorial.pdf

Thank you for your attention!

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