

Observing the solar corona with the Extreme Ultraviolet Imager (EUI) on Solar Orbiter

David Berghmans
Royal Observatory of Belgium



Observing the *solar corona* with the
Extreme Ultraviolet Imager (EUI) on Solar Orbiter

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Svalbard, Norway 2015 April 20

© Thanakrit Santikunaporn



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Composite by Christian Lockwood



$$P = P_0 \exp\left(-\frac{z}{H}\right)$$

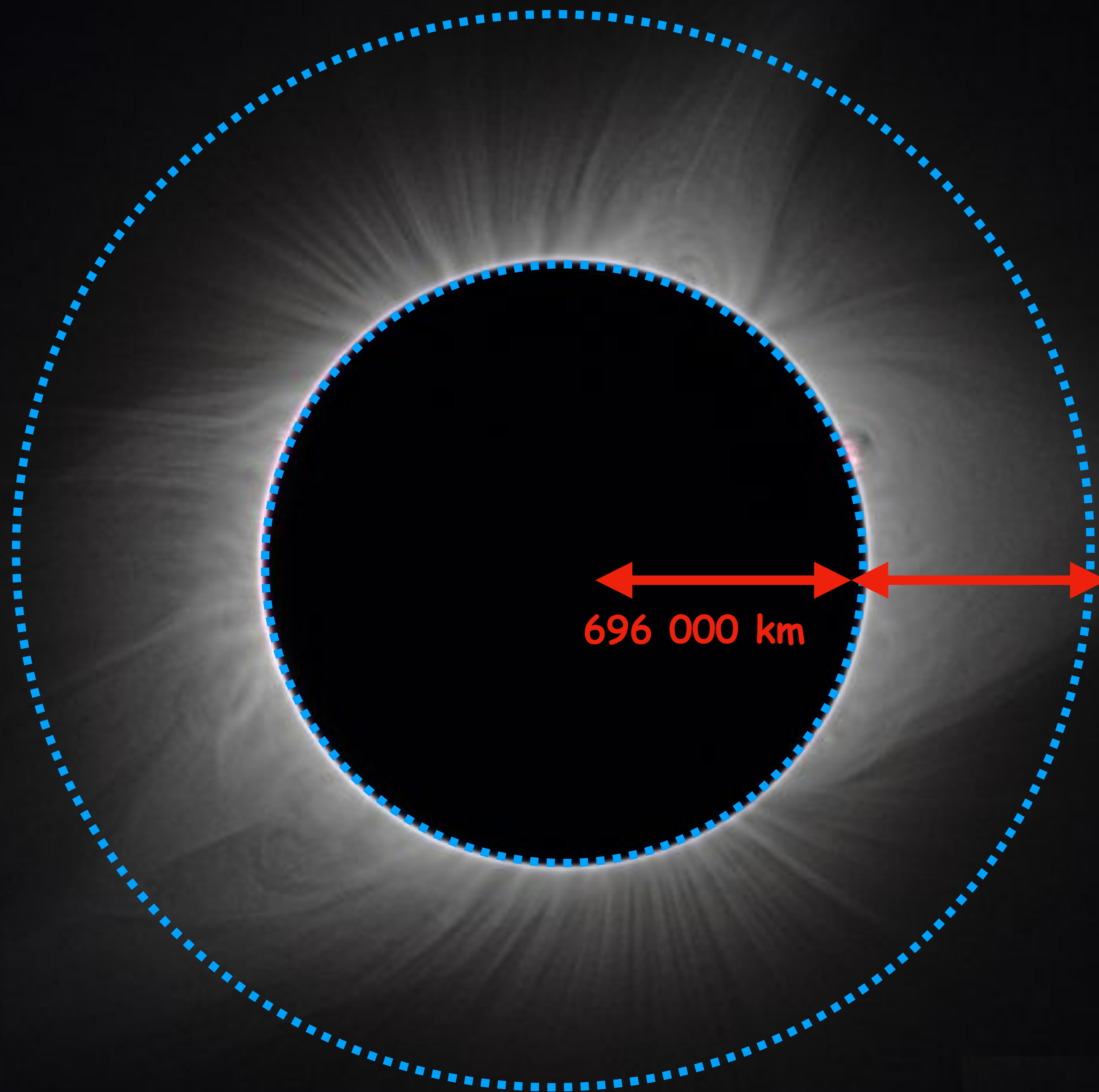
$$H = \frac{kT}{Mg}$$

$$g = 270 \text{ m/s}^2$$

$$M = 1$$

$$T = 5700$$

$$H = 270 \text{ km}$$



$$P = P_0 \exp\left(-\frac{z}{H}\right)$$

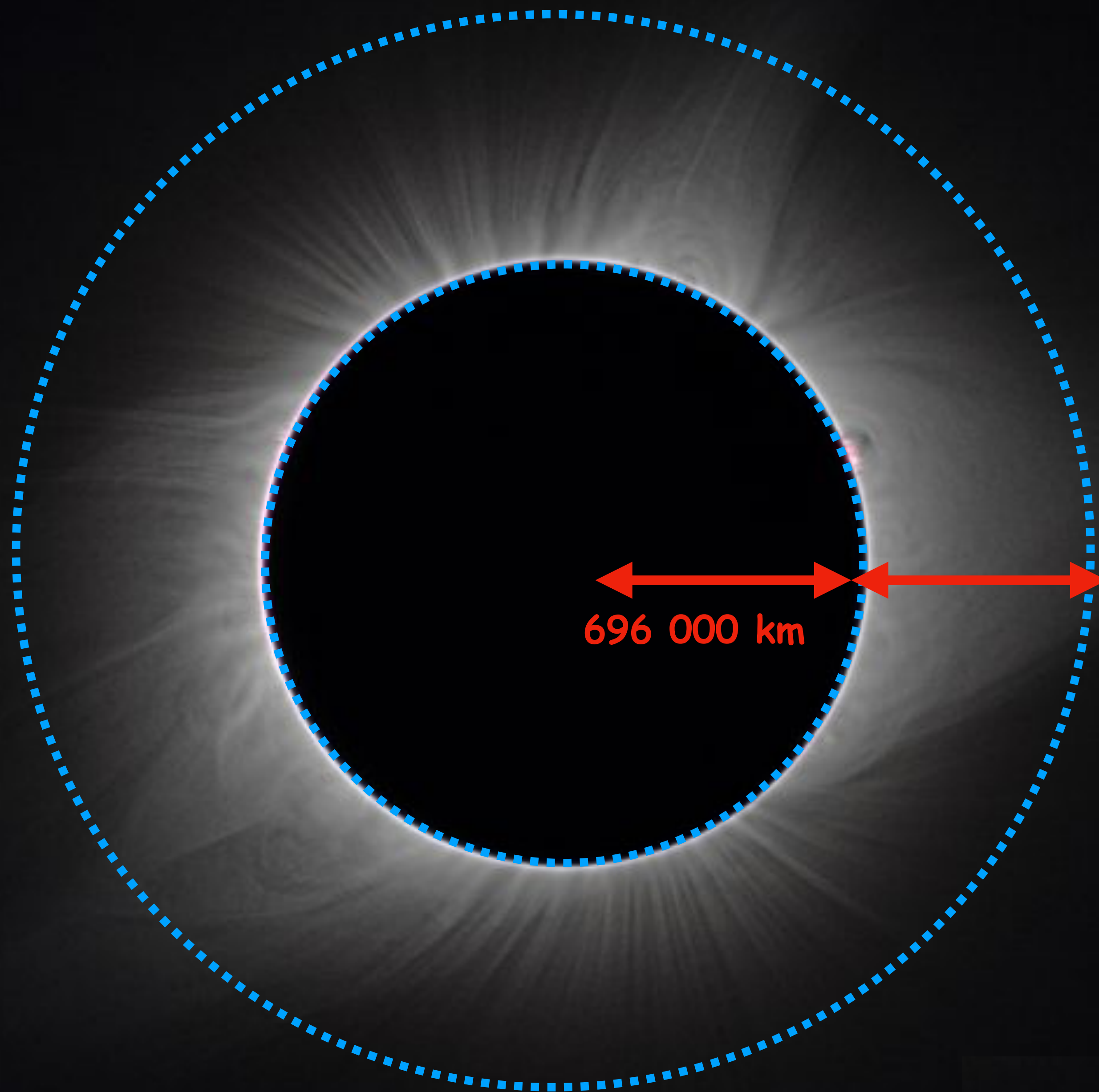
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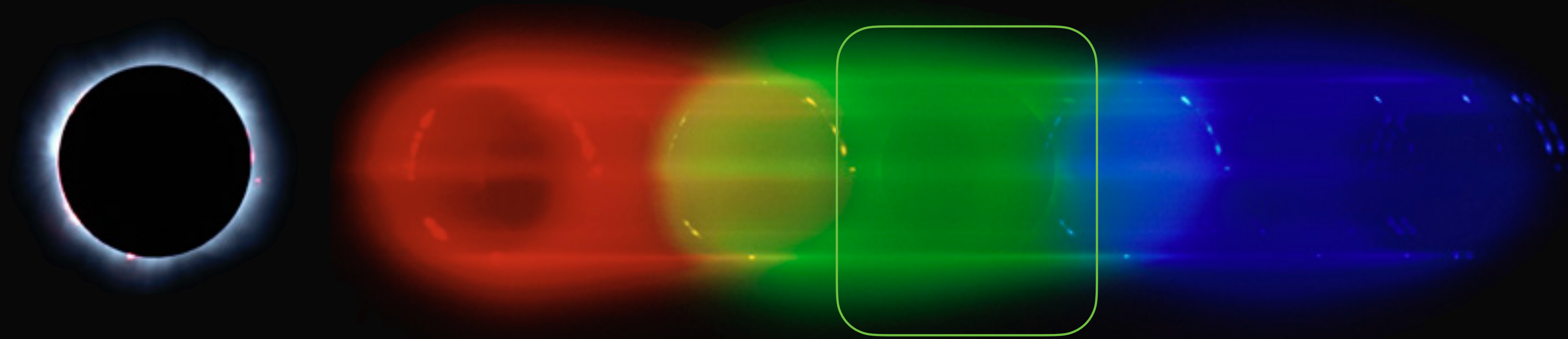
~~**T= 5700**~~

>1 million C

~~**H=270km**~~

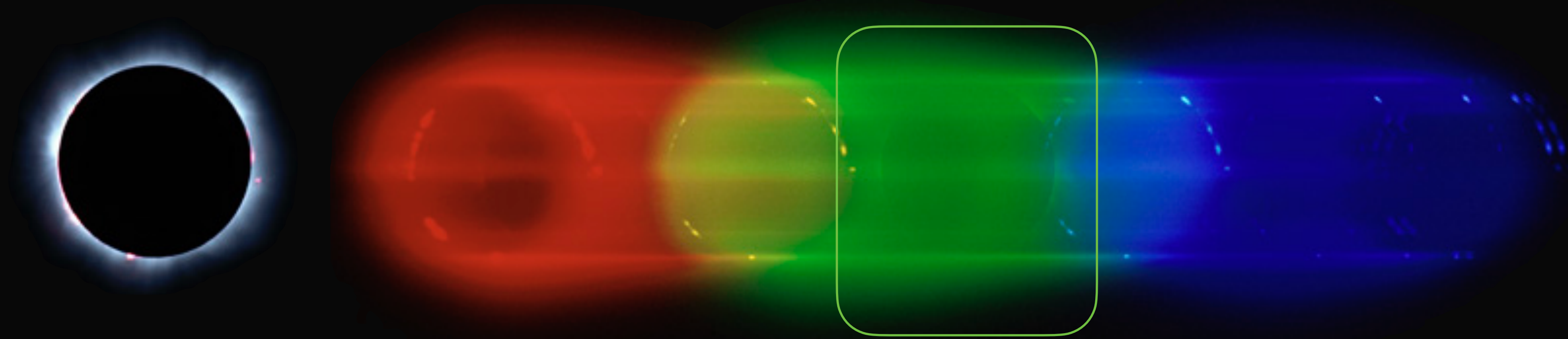
>696 000 km

Eclipse 1999, Hungary



530.3nm
Coronium

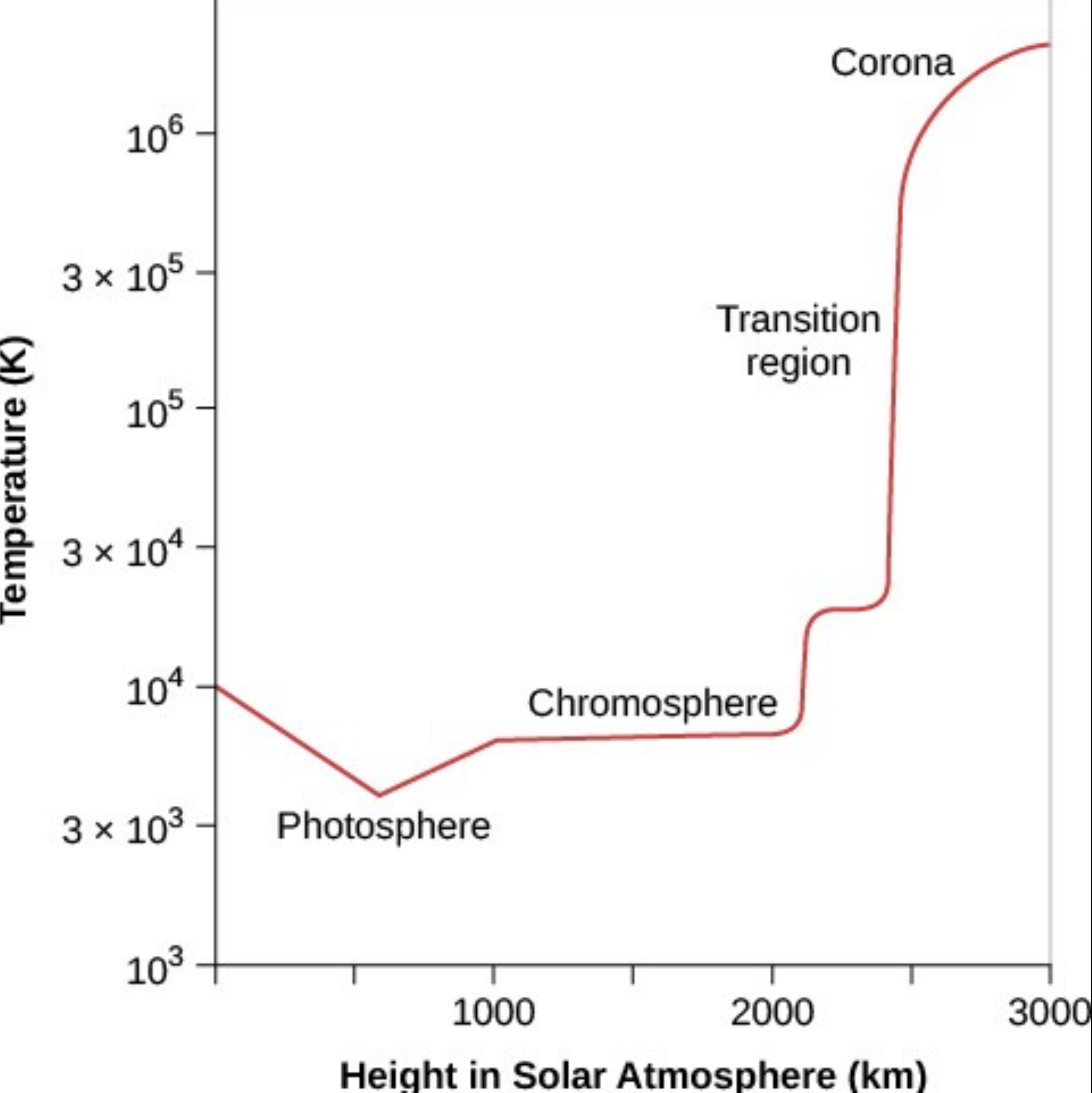
Eclipse 1999, Hungary

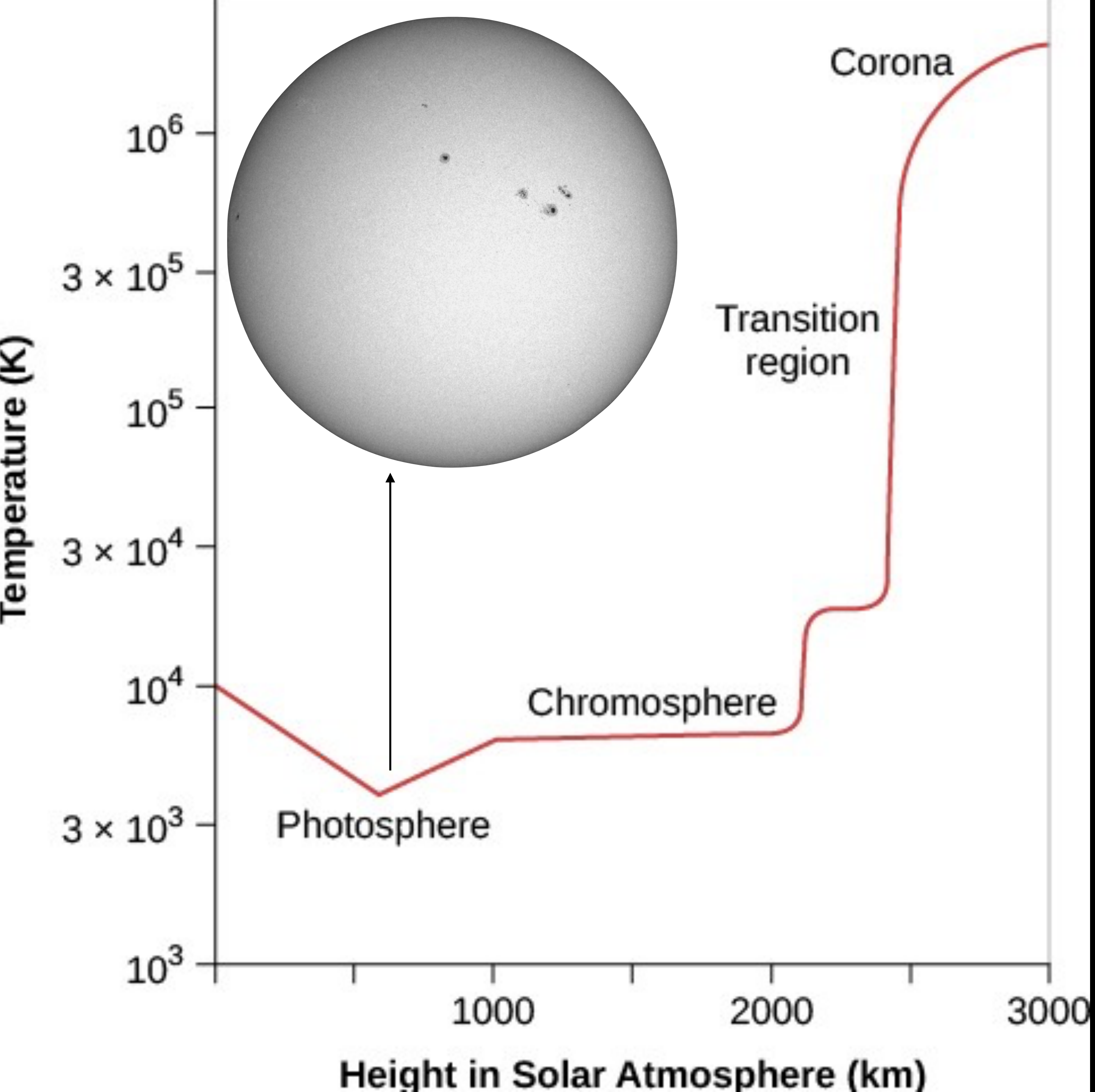


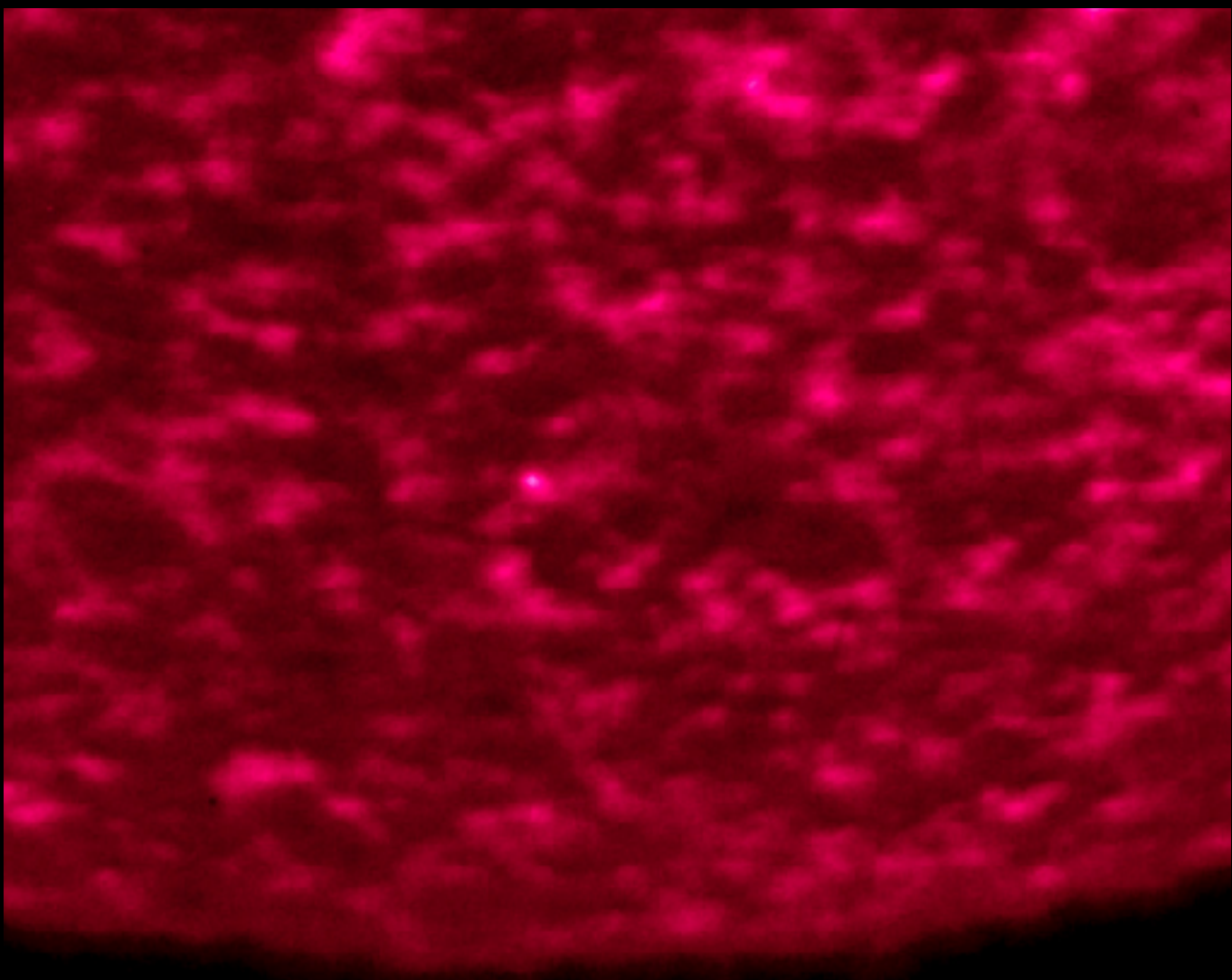
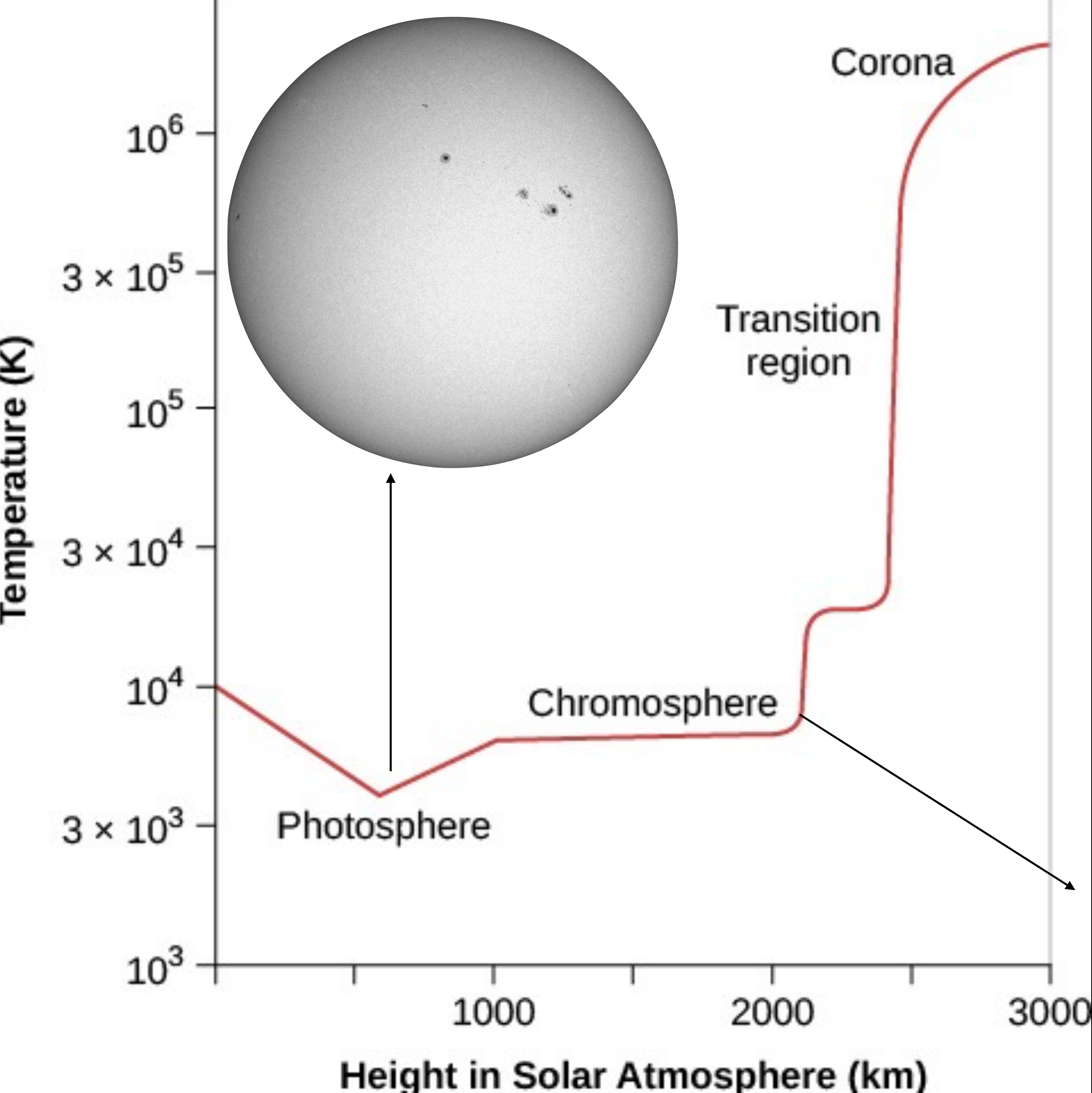
530.3nm

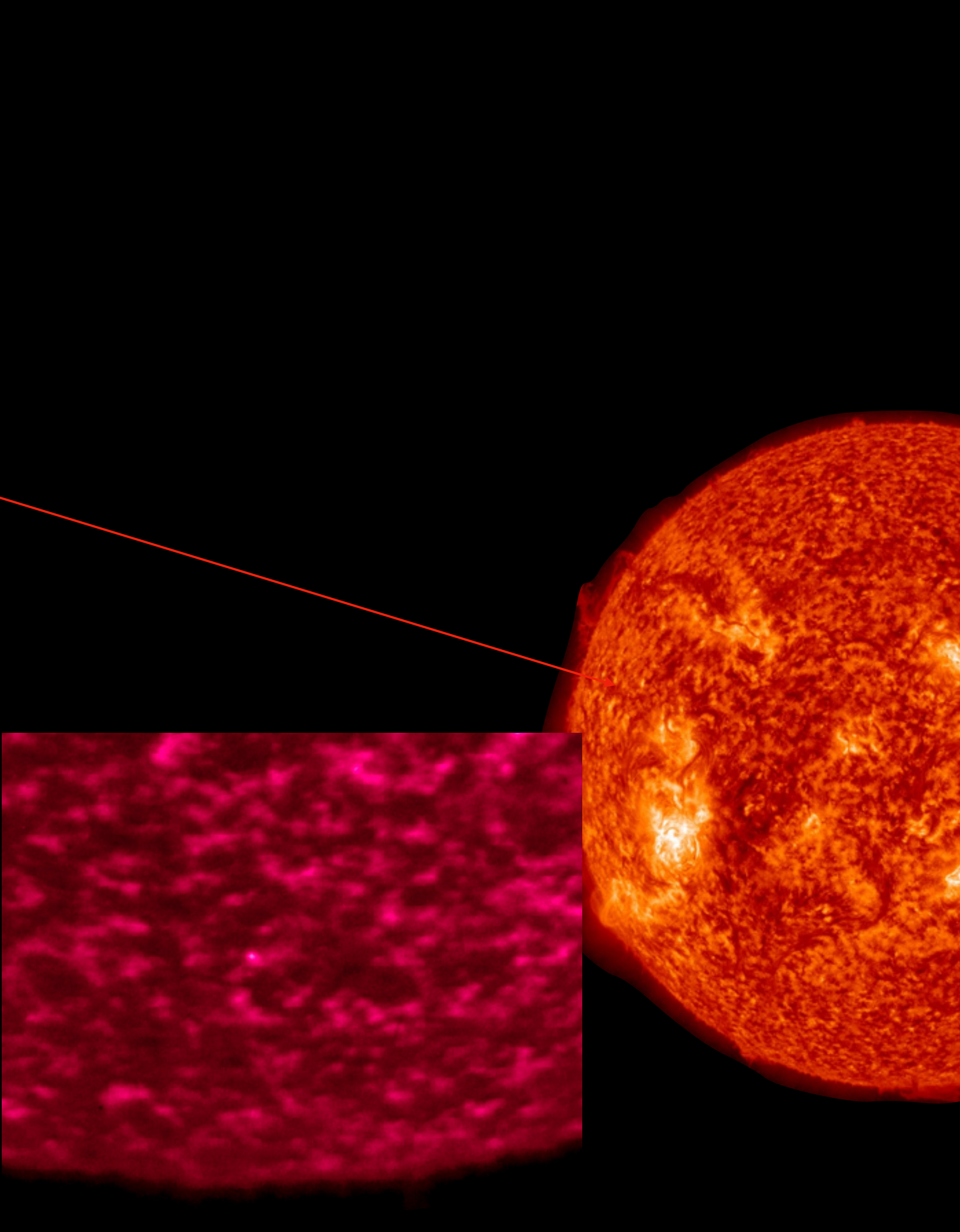
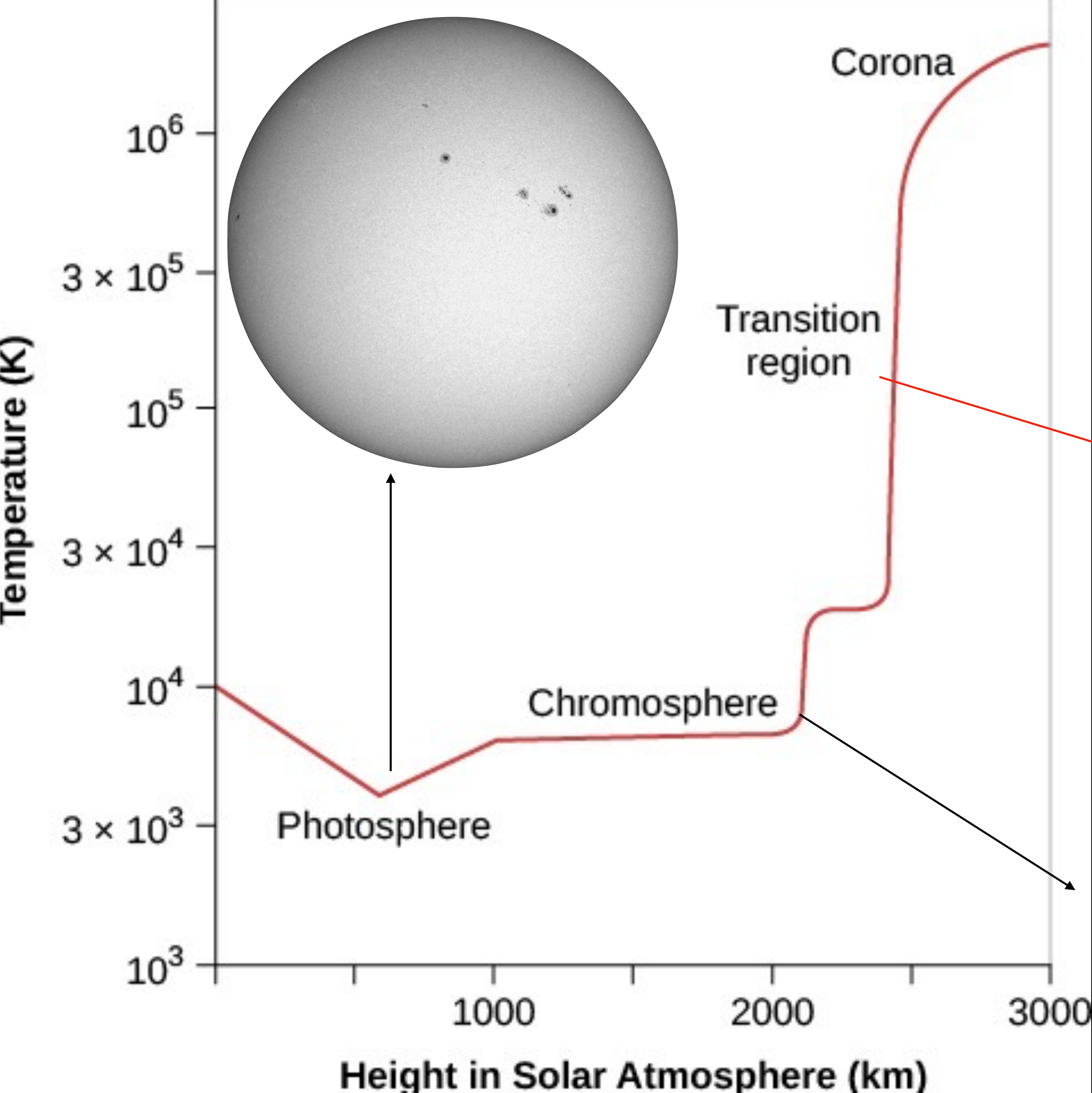
Coronium

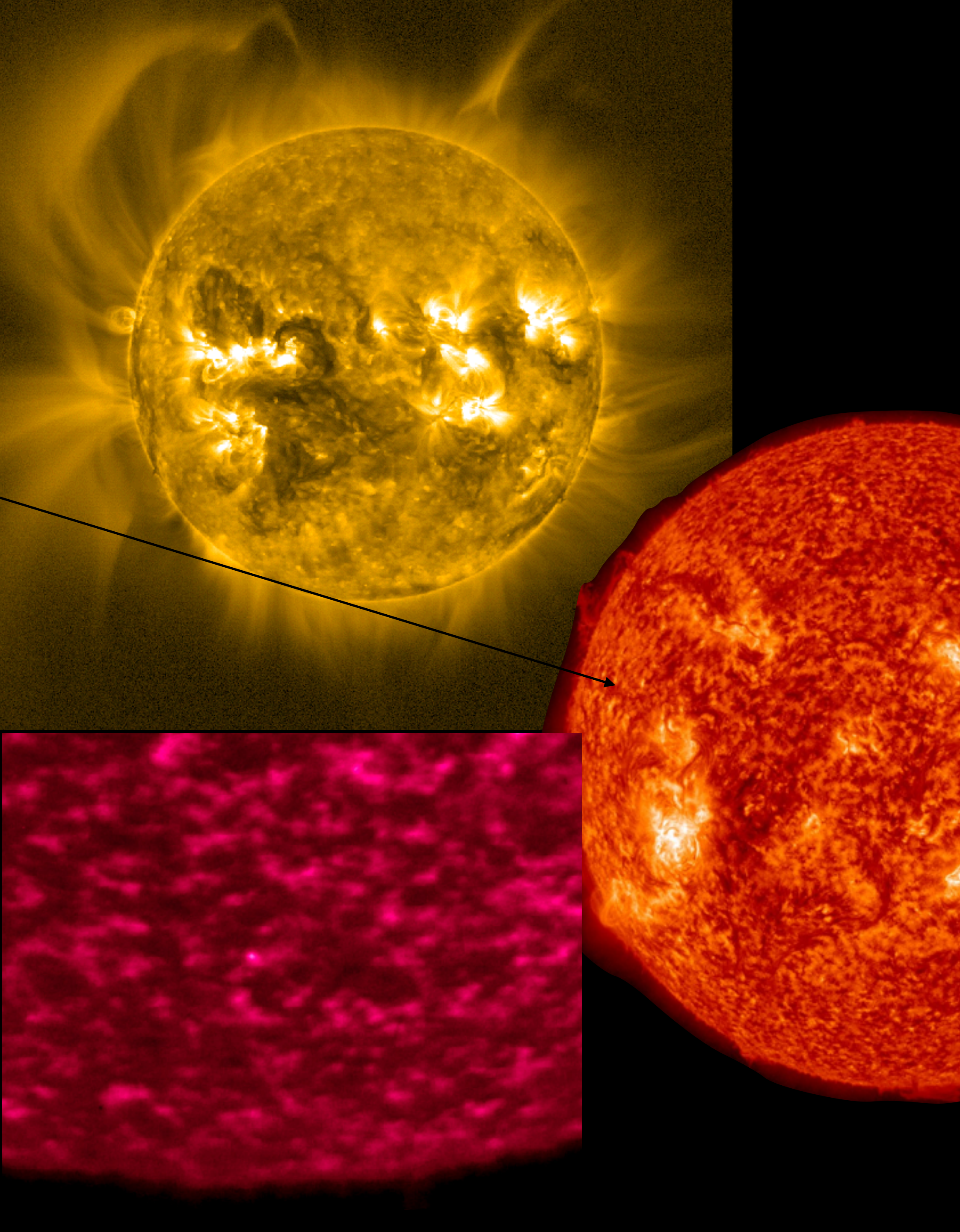
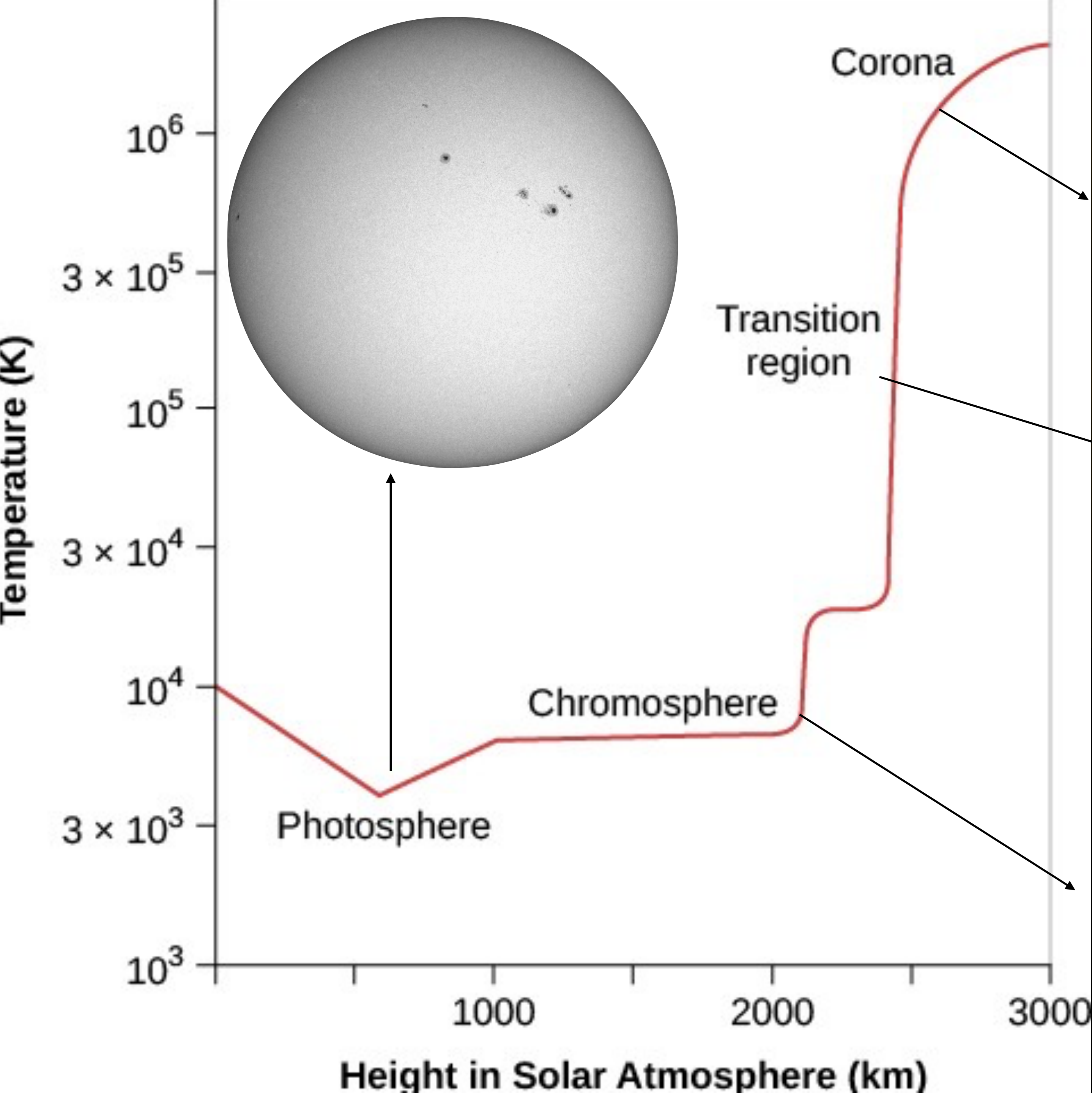
Bengt Edlen (~1930): Fe XIV











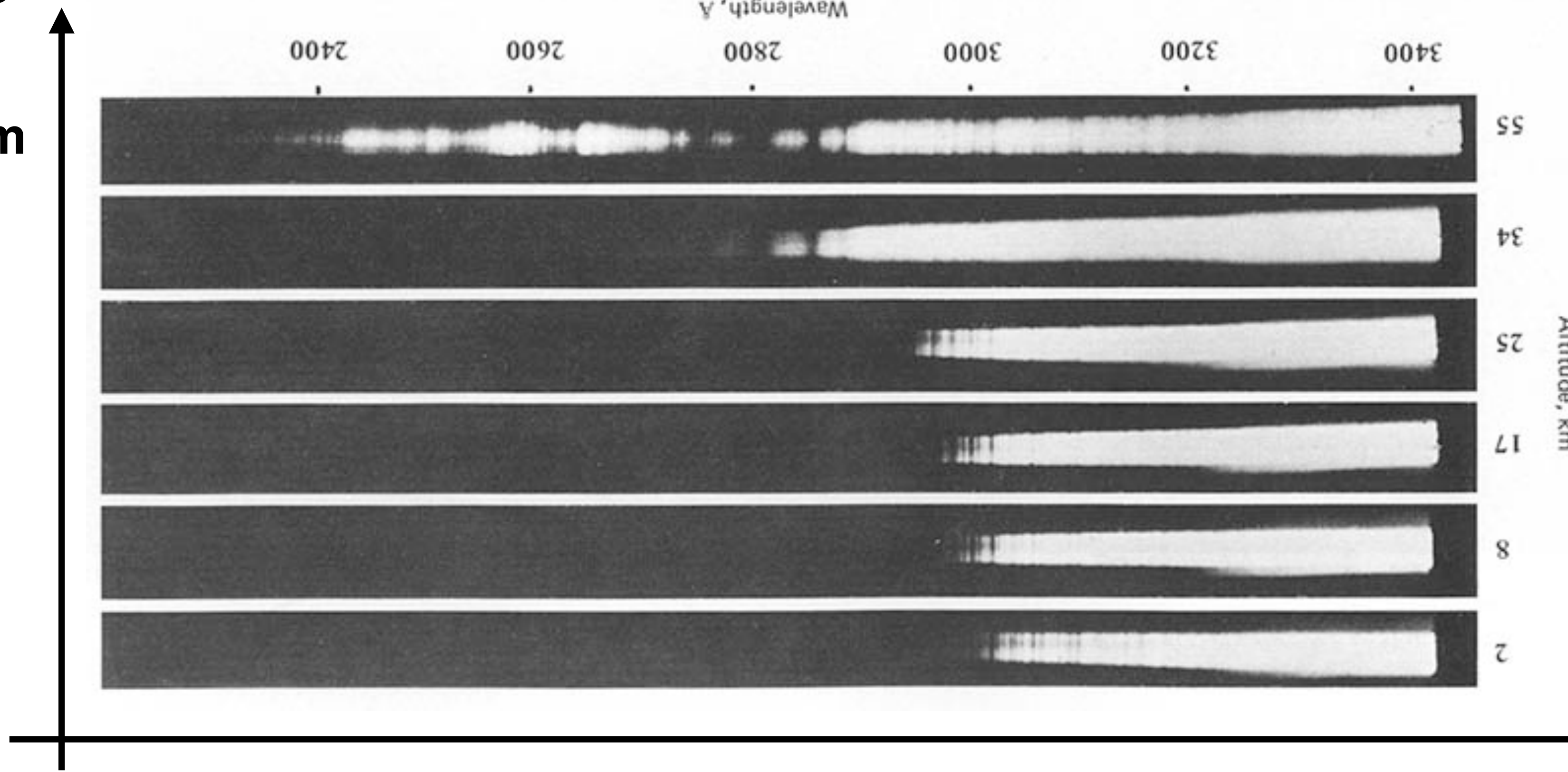
US NRL experiment: Spectrograph on V2-rocket in 1946



hoogte

55km

2km



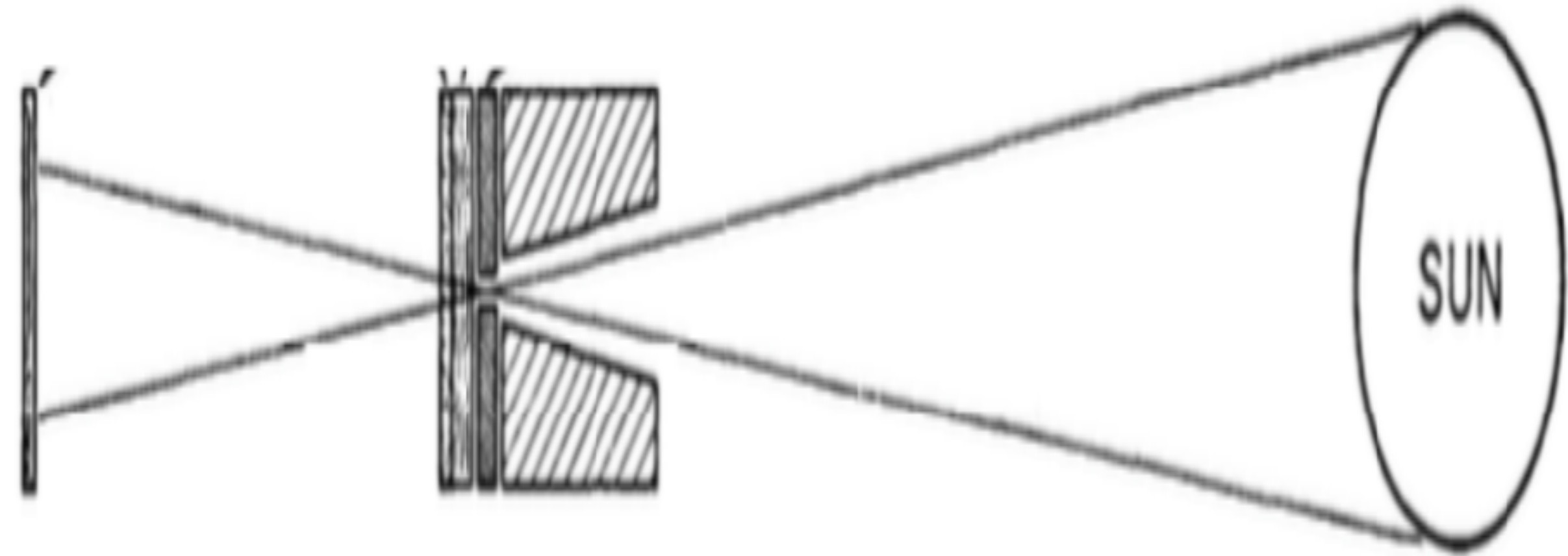
2400A

3400Ang

wavelength

[Tousey \(1967\) ApJ, 149, 239](#)

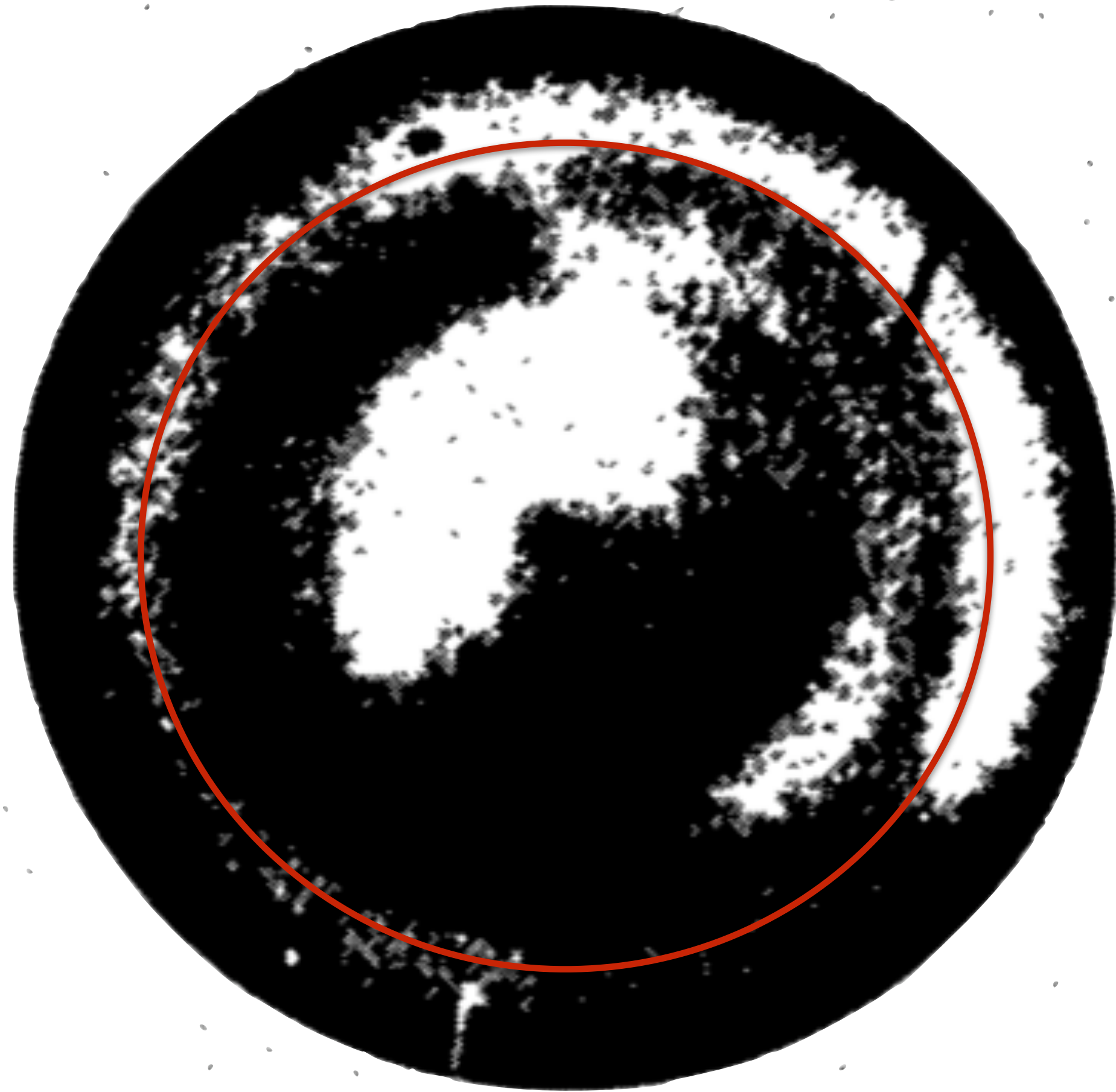
SOLAR X-RAY PHOTOGRAPH
NRL, APRIL 19, 1960



Pinhole camera
flown in 1960

[Friedman \(1963\) IAUS, 16, 45](#)

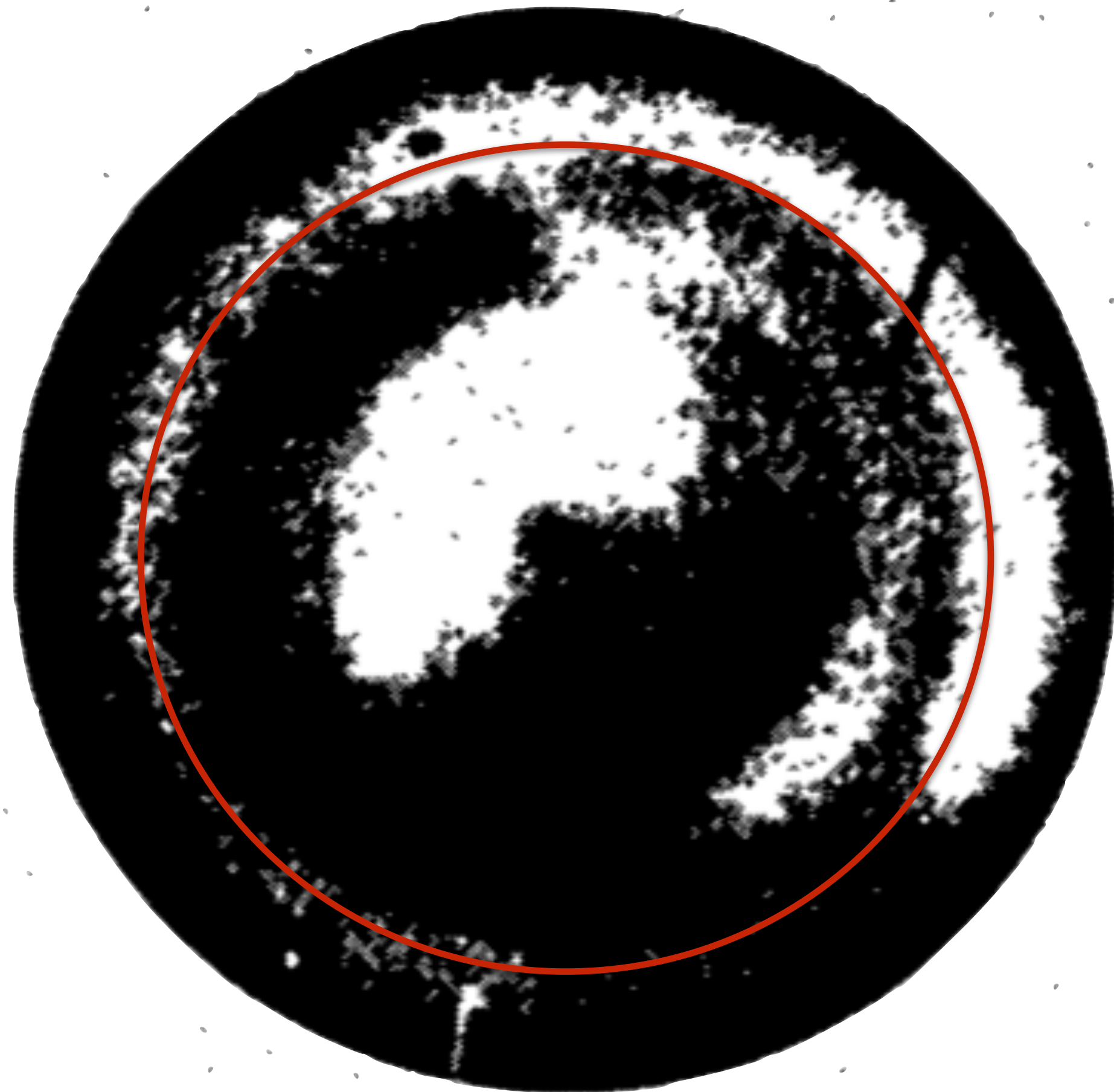
SOLAR X-RAY PHOTOGRAPH
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Pinhole camera
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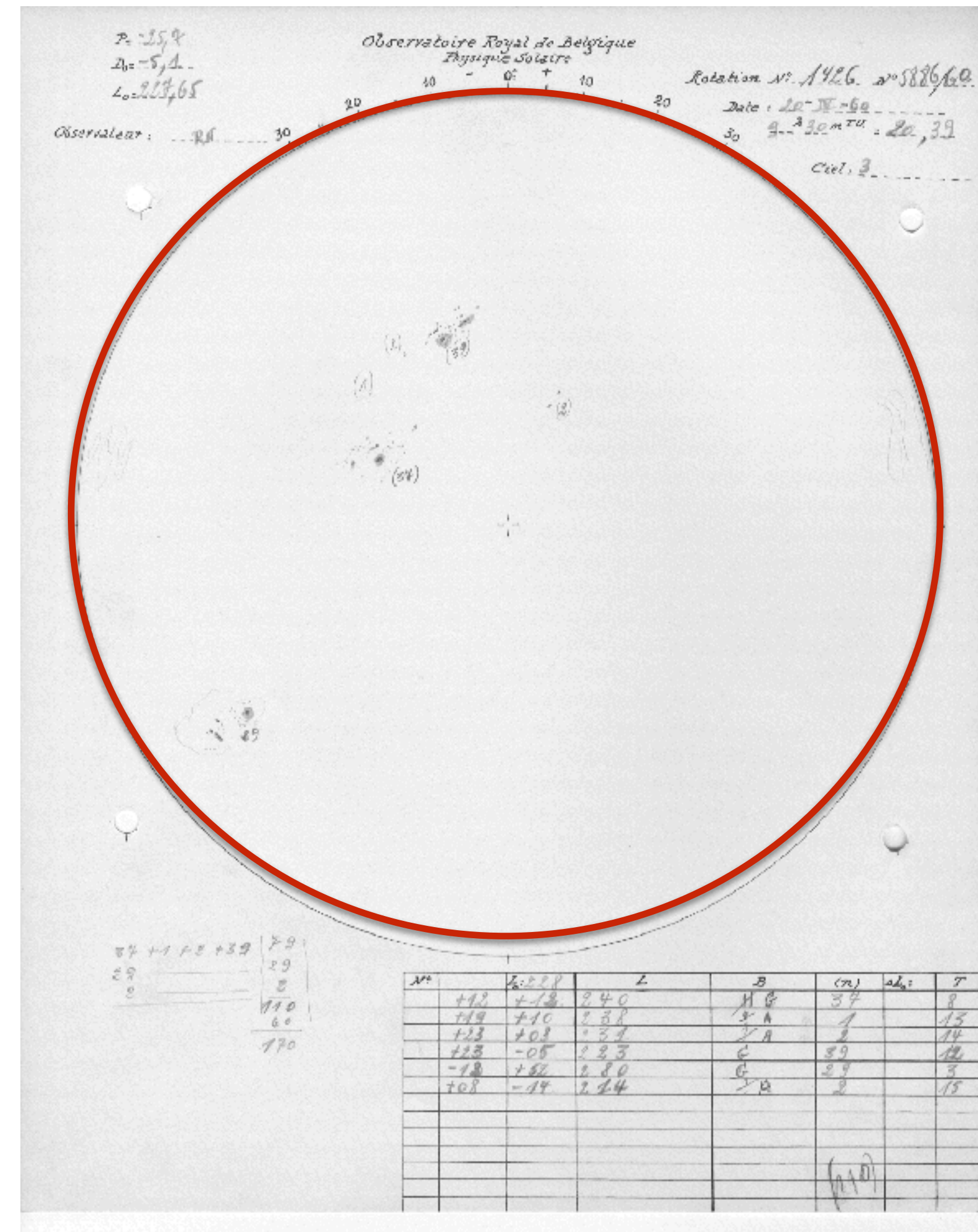
[Friedman \(1963\) IAUS, 16, 45](#)

SOLAR X-RAY PHOTOGRAPH
NRL, APRIL 19, 1960



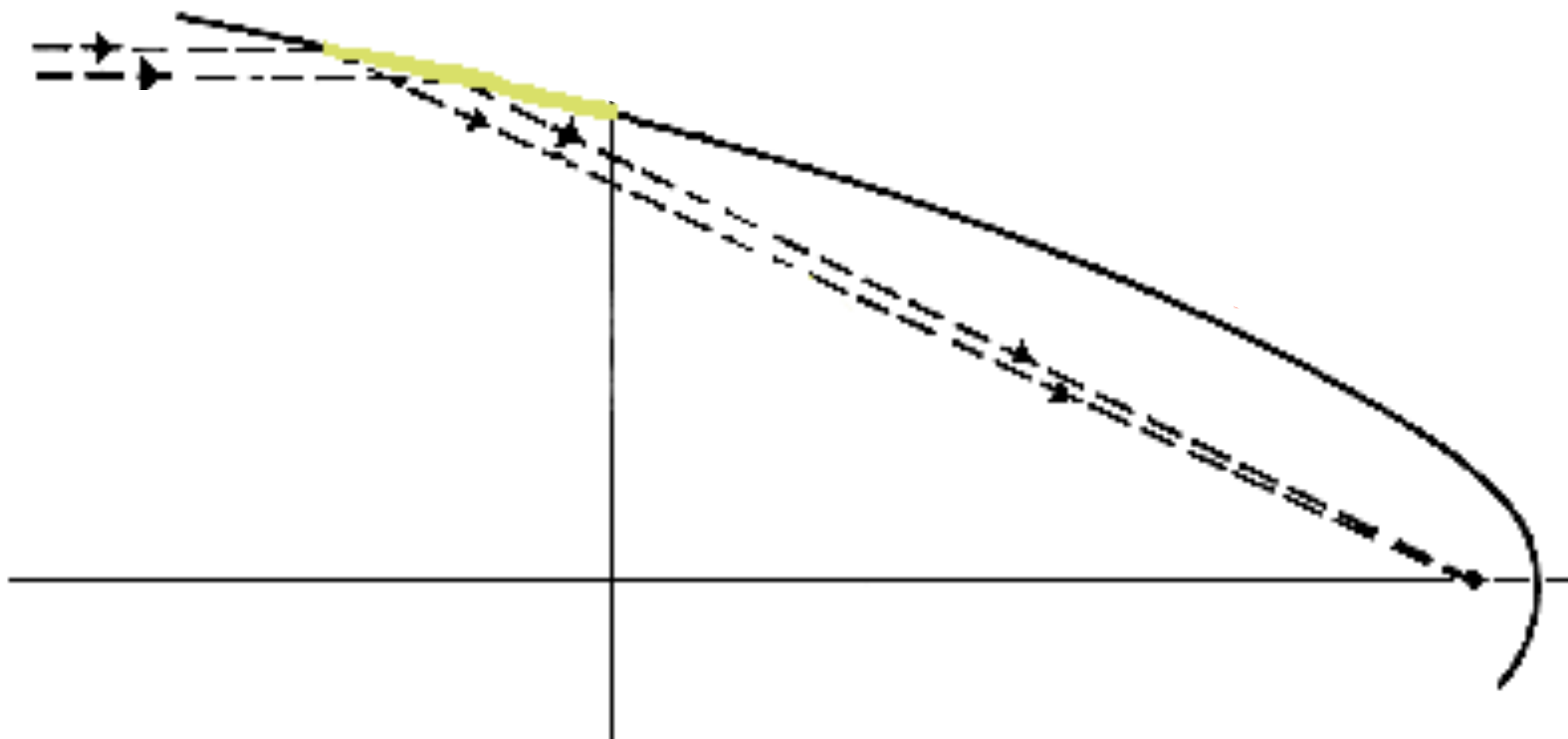
Pinhole camera
flown in 1960

[Friedman \(1963\) IAUS, 16, 45](#)

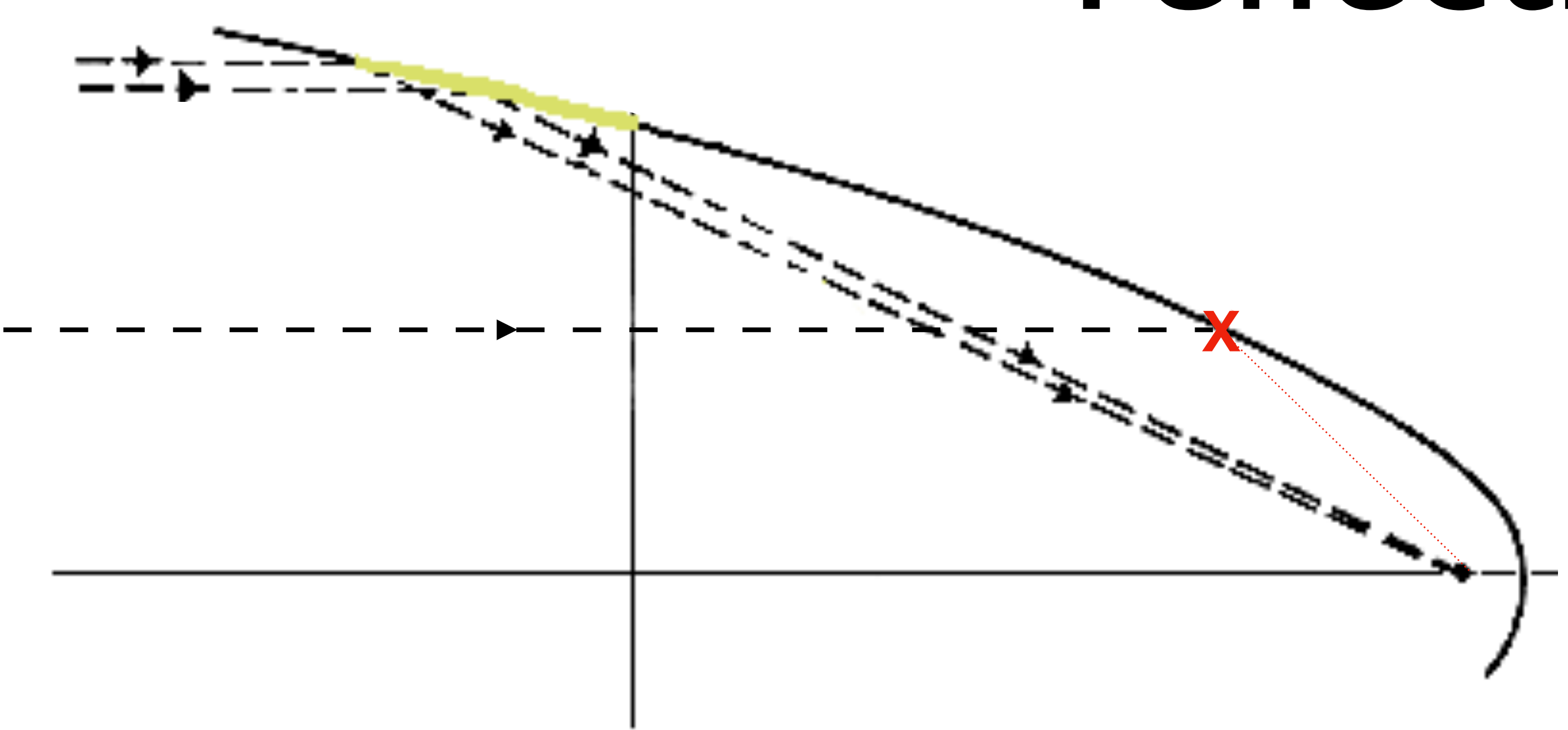


April 20 1960 Sunspot drawing
from Royal observatory of Belgium

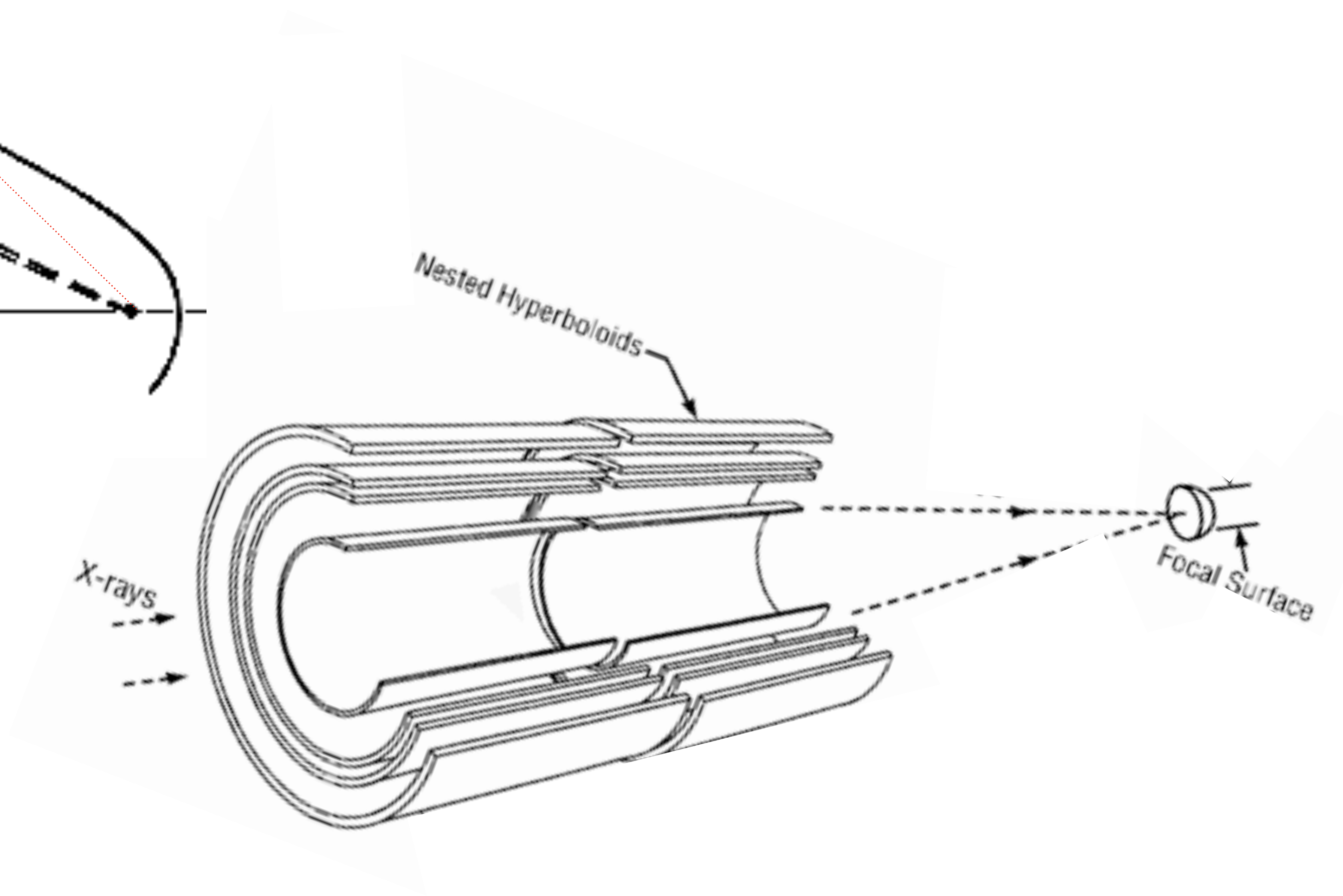
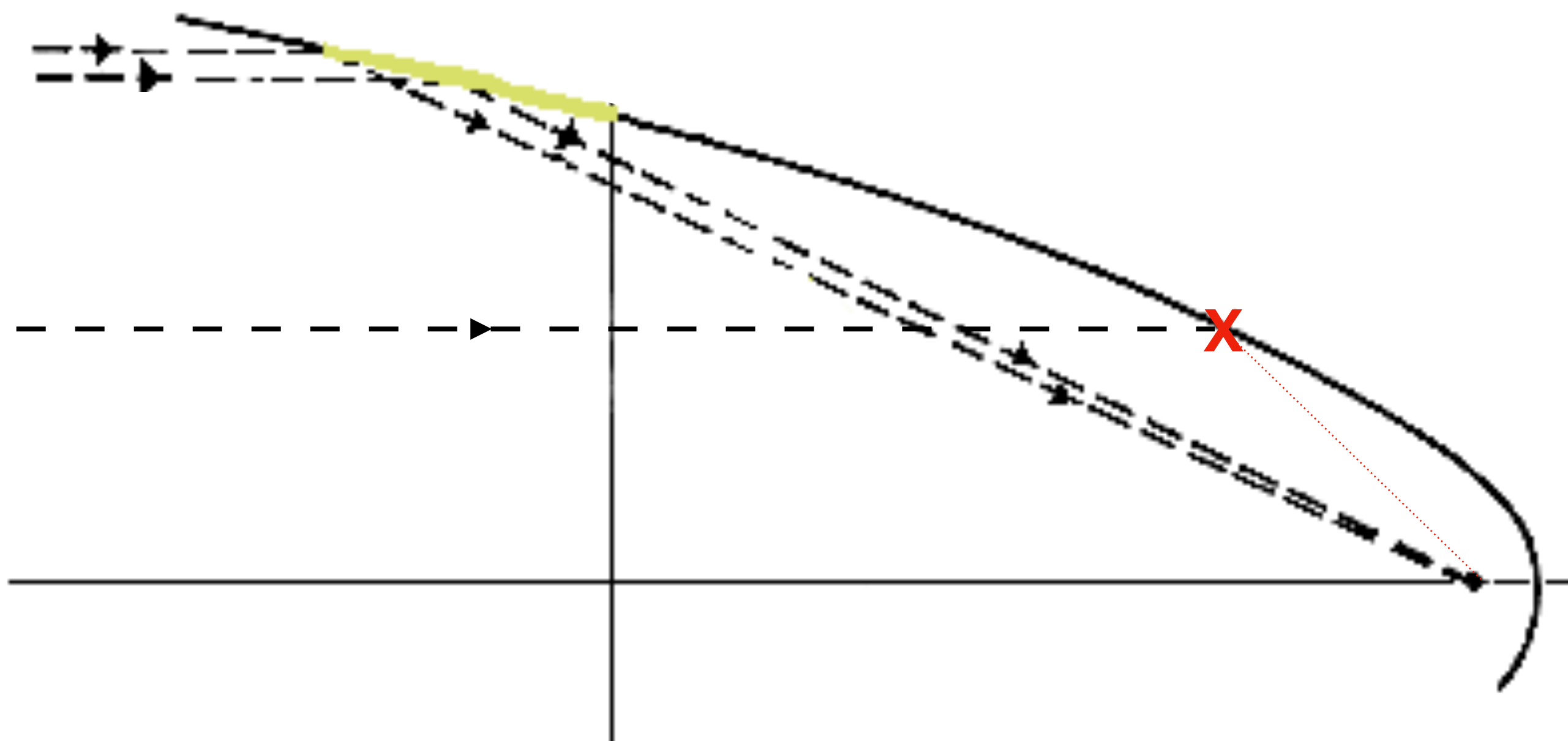
reflecting X-rays is hard



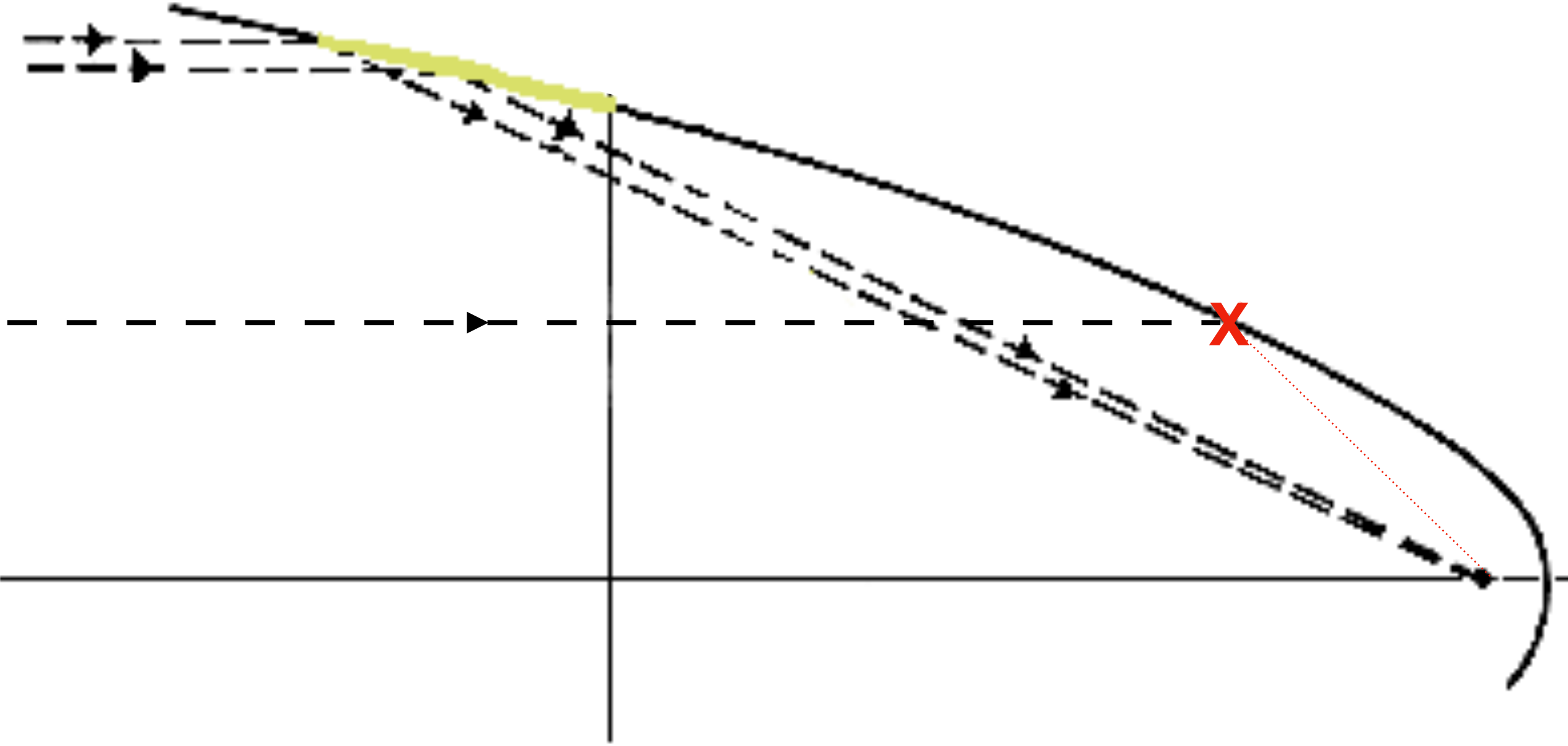
reflecting X-rays is hard



reflecting X-rays is hard



reflecting X-rays is hard



XMM mirrors during tests at Centre Spatial de Liege



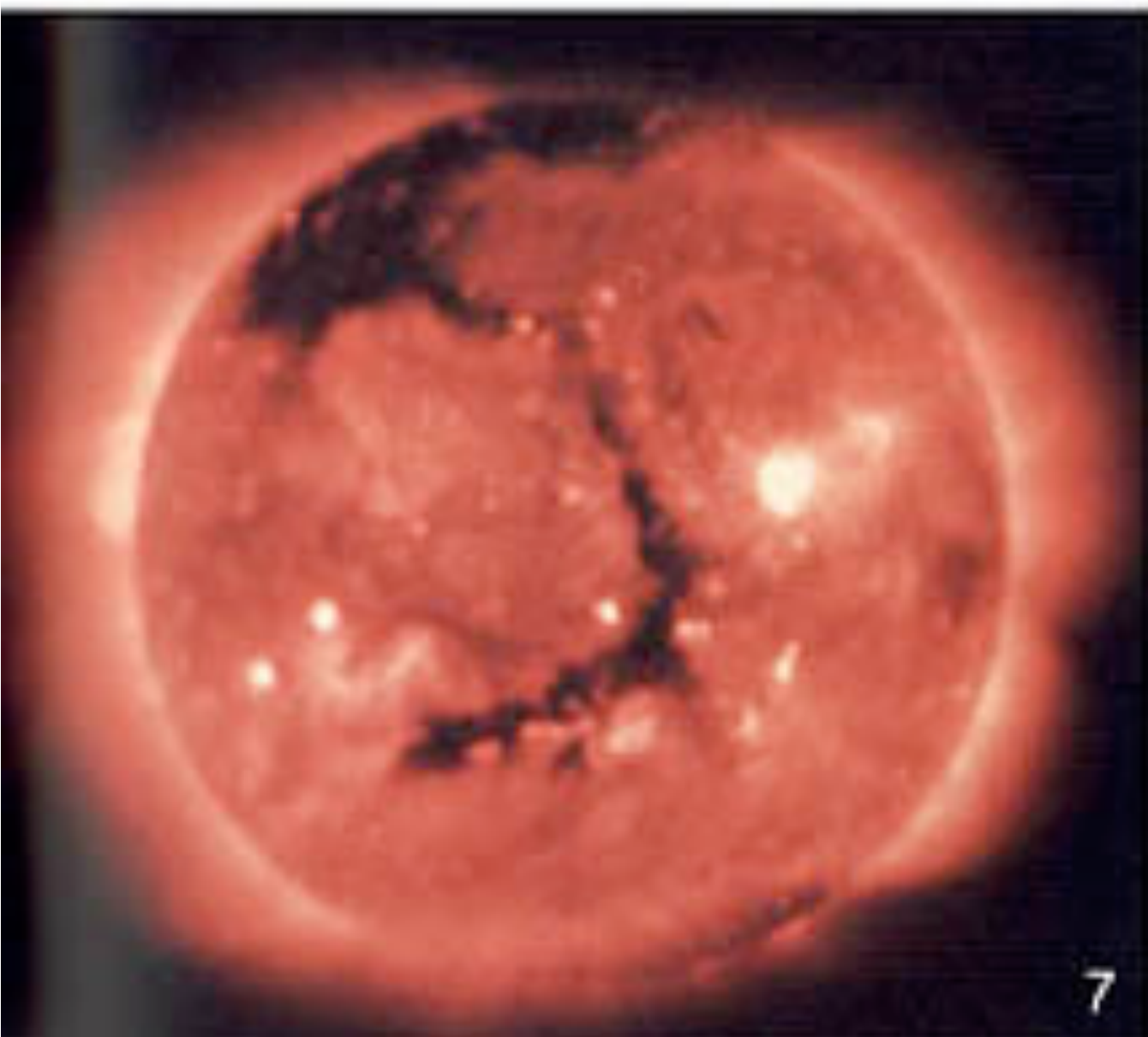
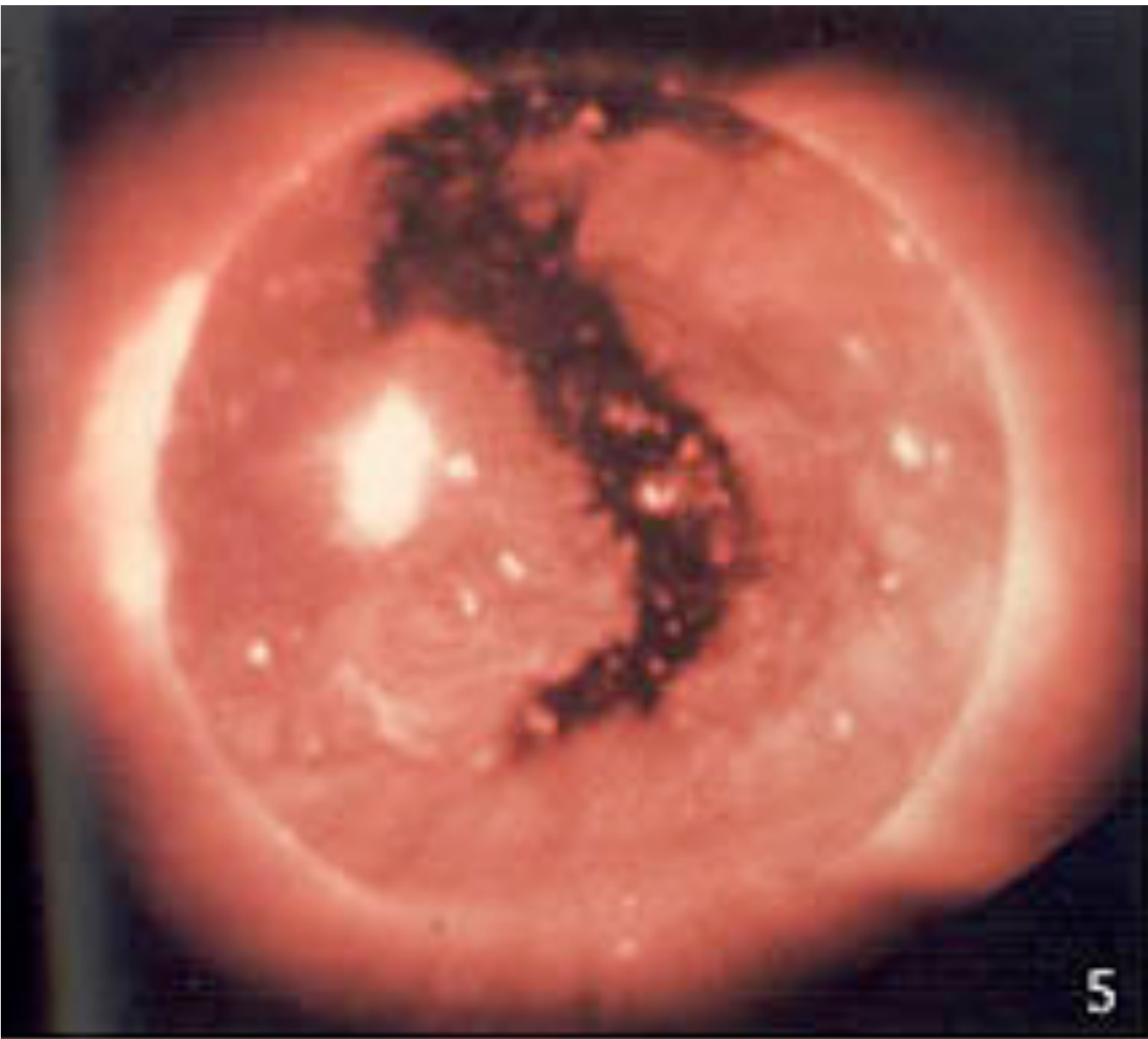
Skylab (1973-74)

<http://history.nasa.gov/SP-402/ch1.htm>

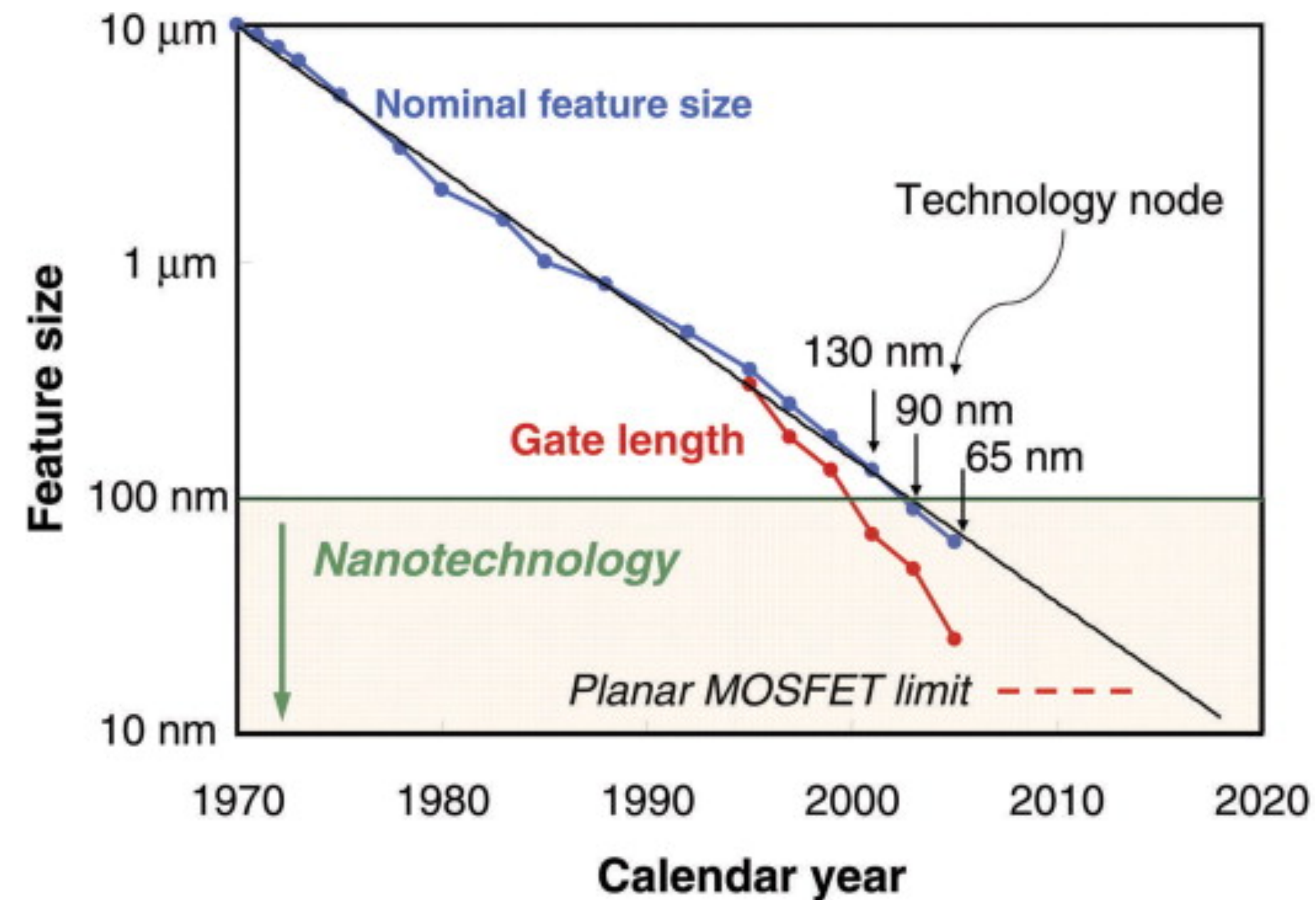


Skylab (1973-74)

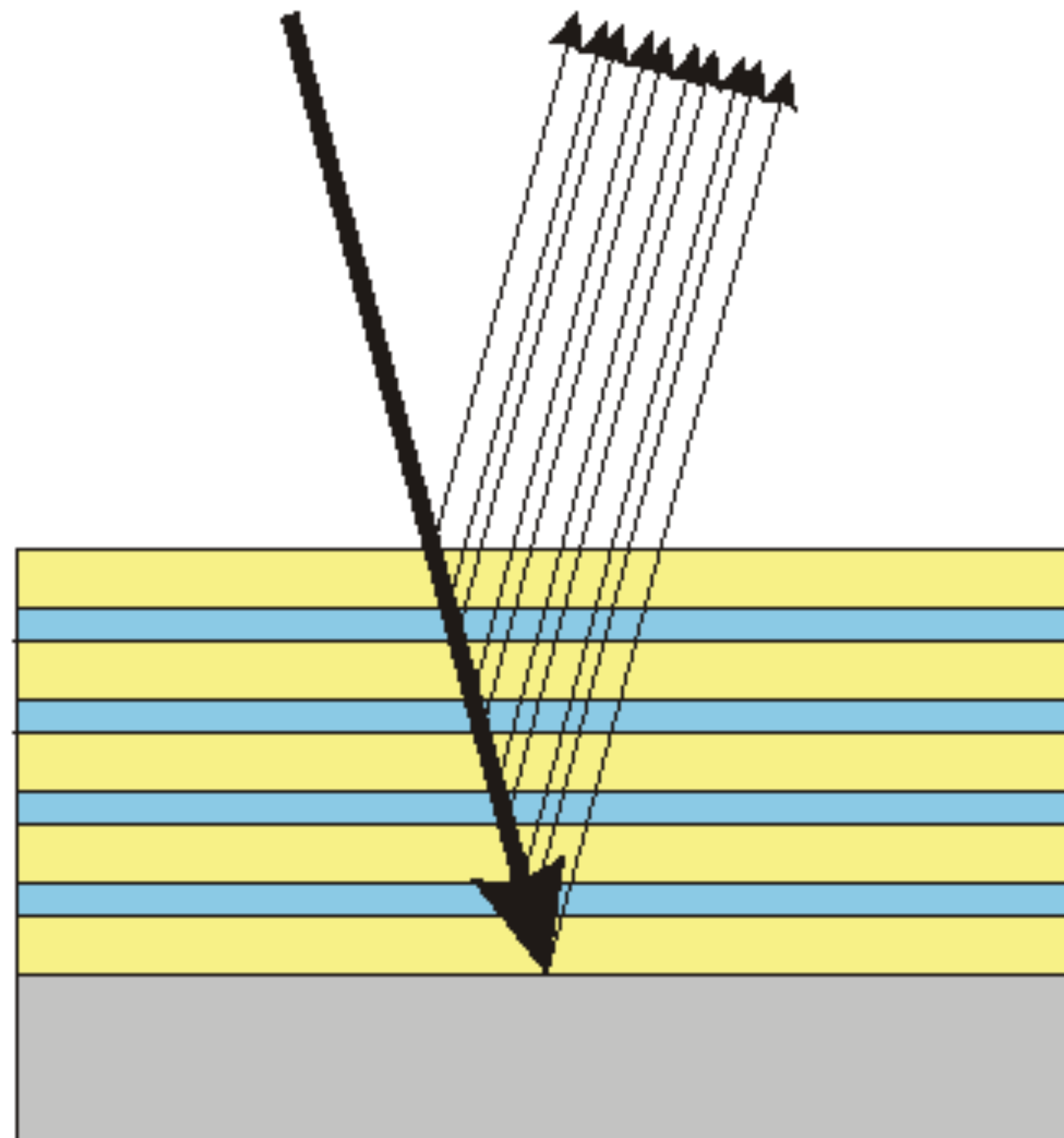
<http://history.nasa.gov/SP-402/ch1.htm>



1990s: EUV lithography develops normal incidence EUV optics



"EUV light at 13.5 nanometers can etch features as small as 100 nanometers across,"

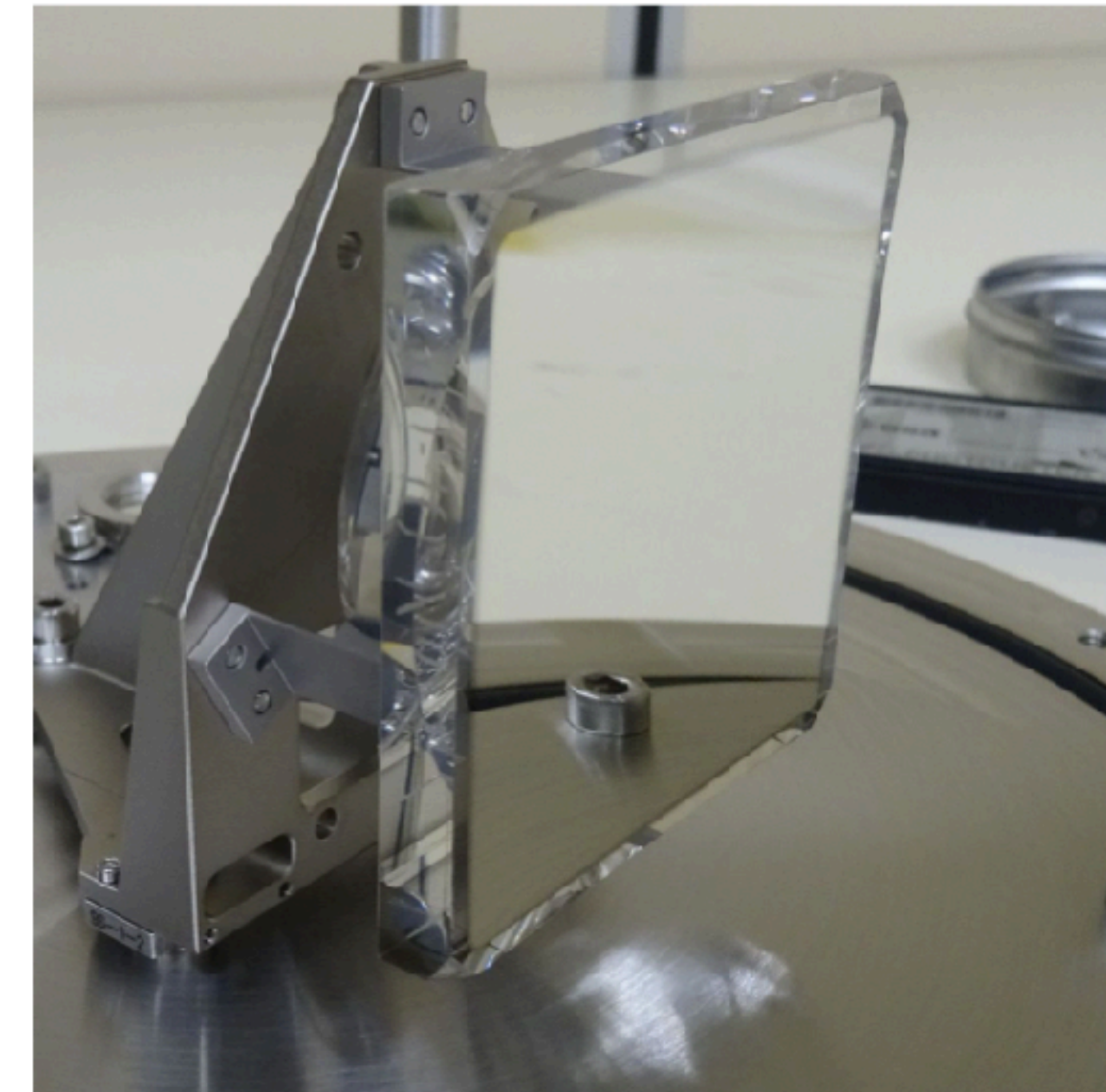


Molybdenum:

heavy scatter element that absorbs EUV strongly

Silicon:

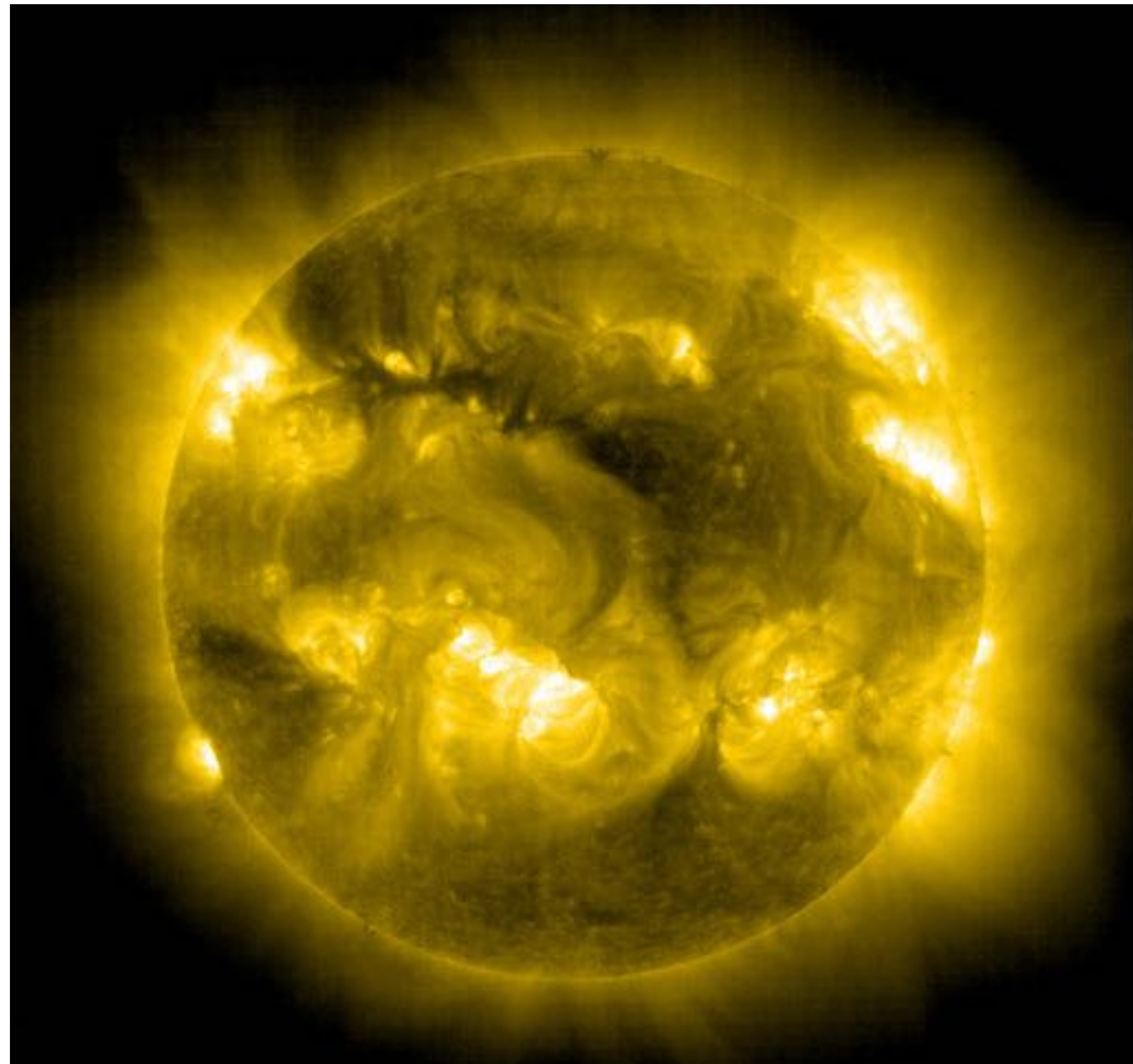
light element that absorbs EUV only weakly





EIT

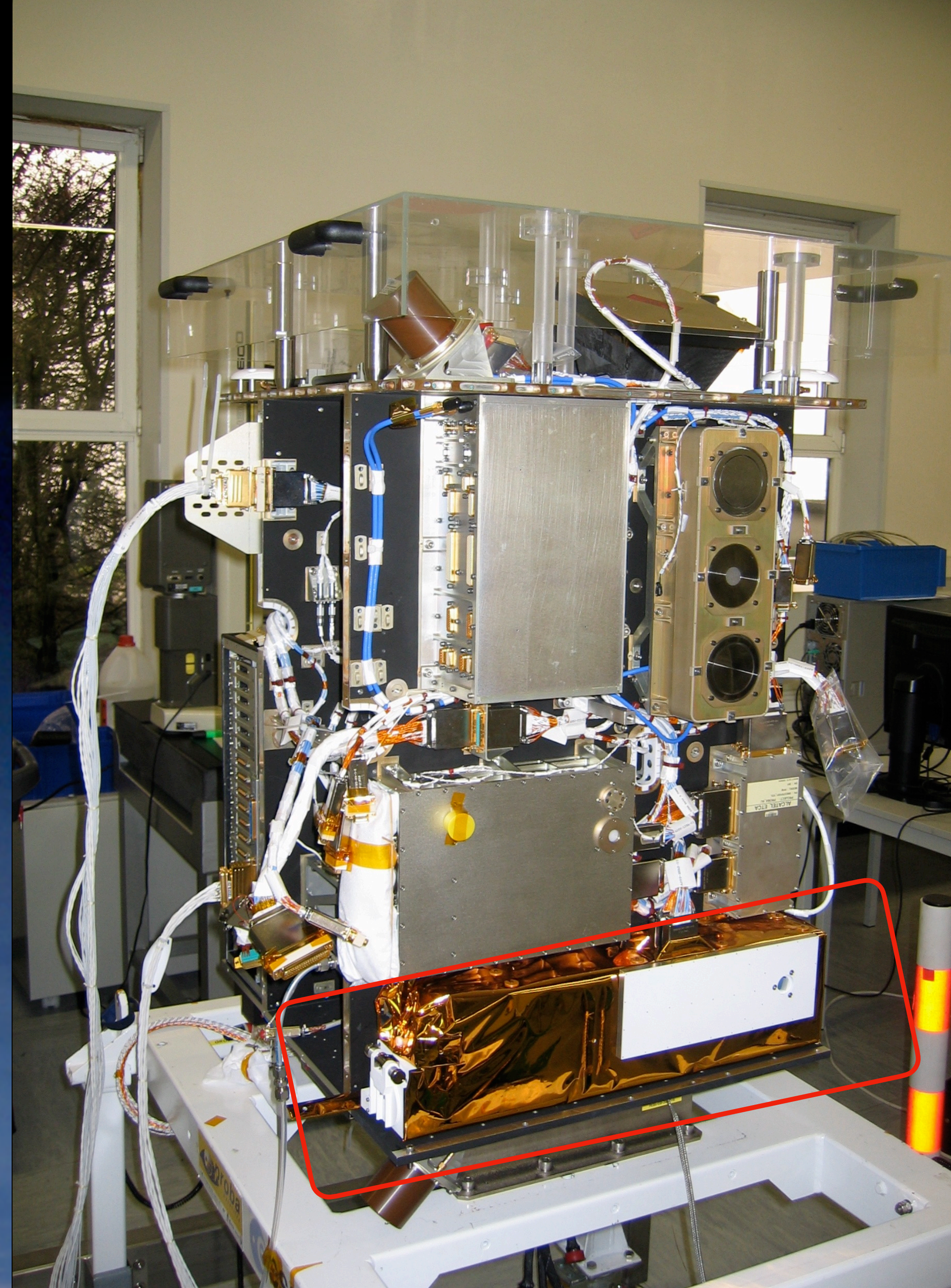
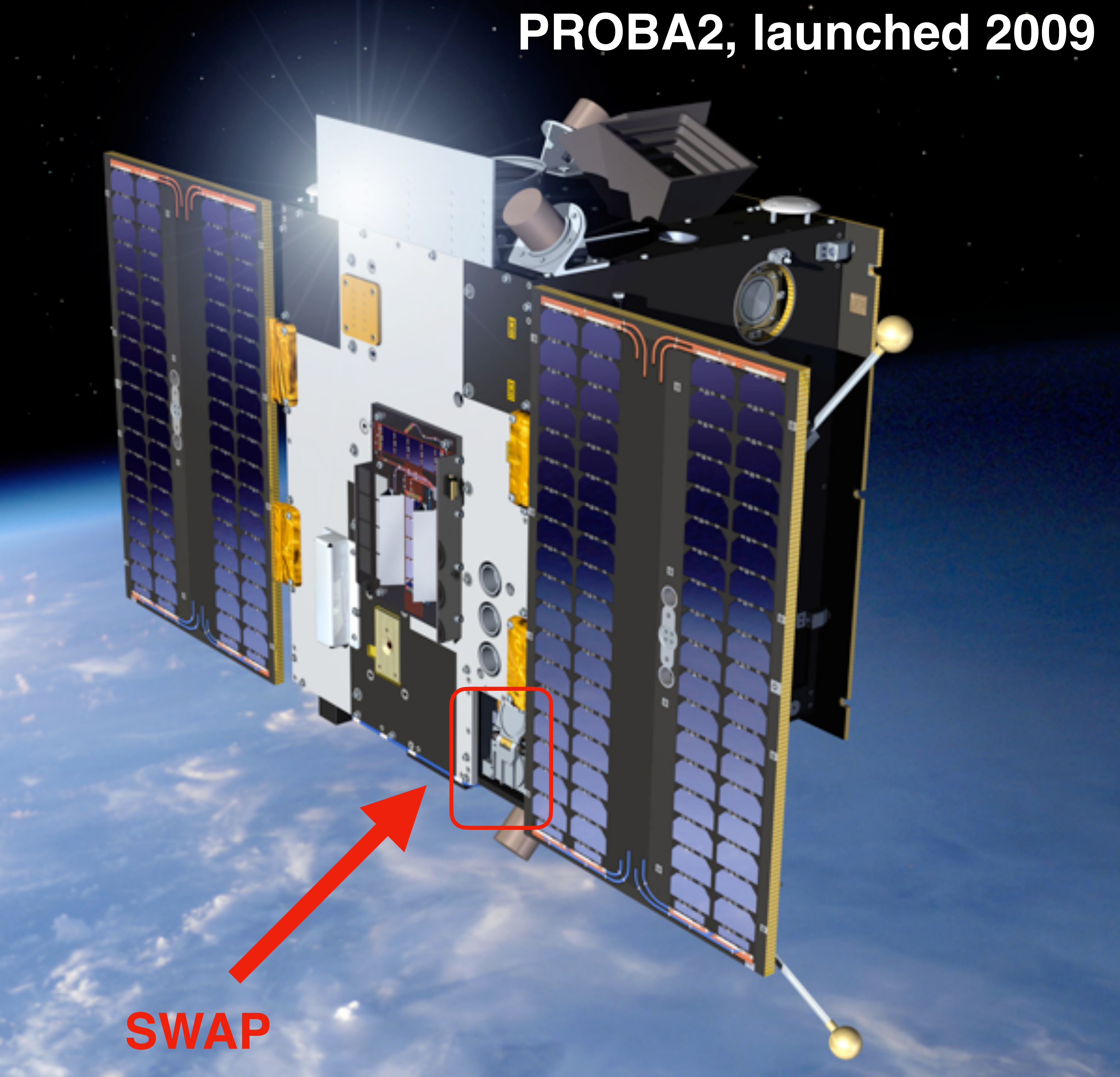
Extreme
Imaging Telescope



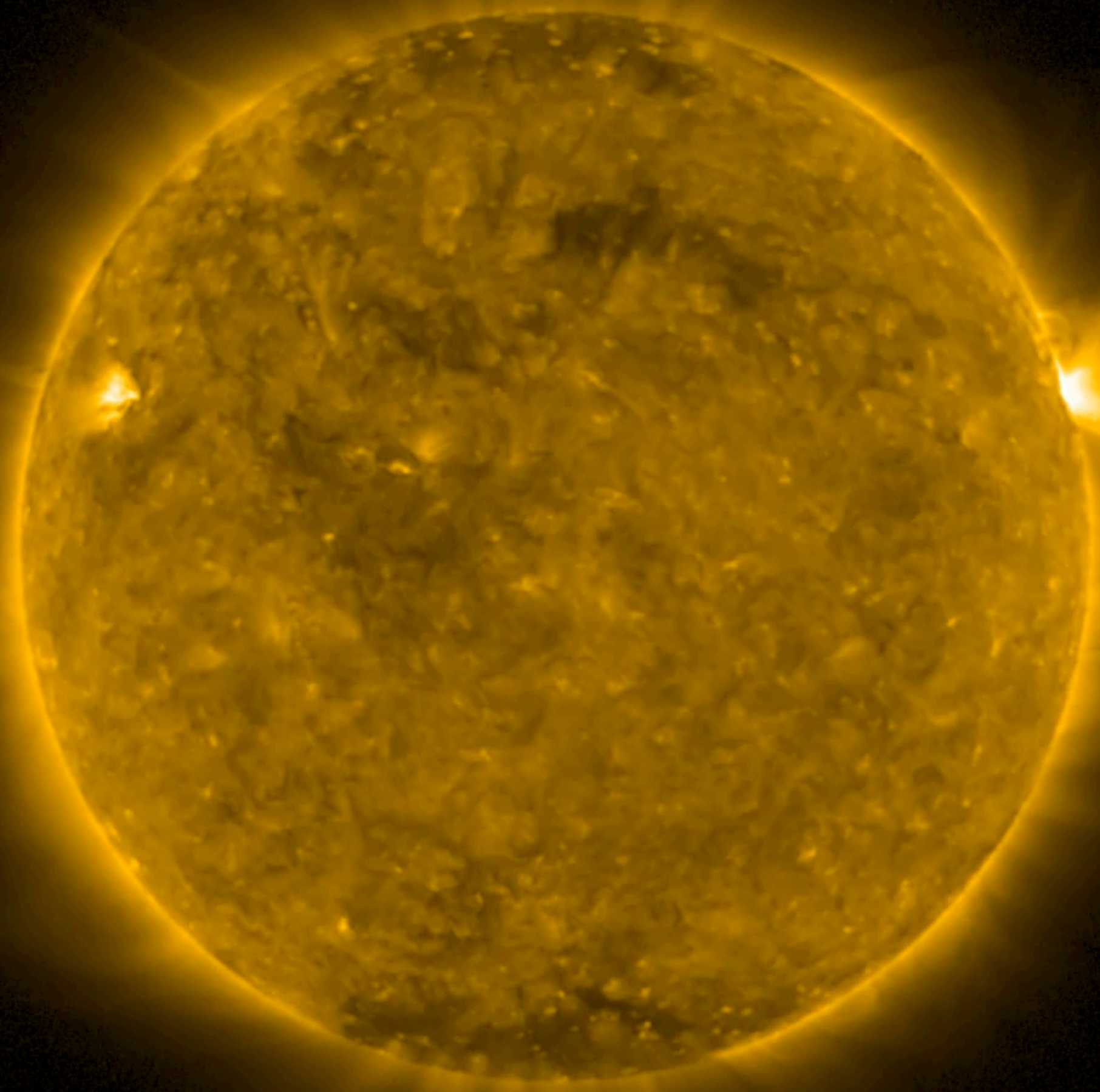
2023/03/12 13:06

>27 years after launch

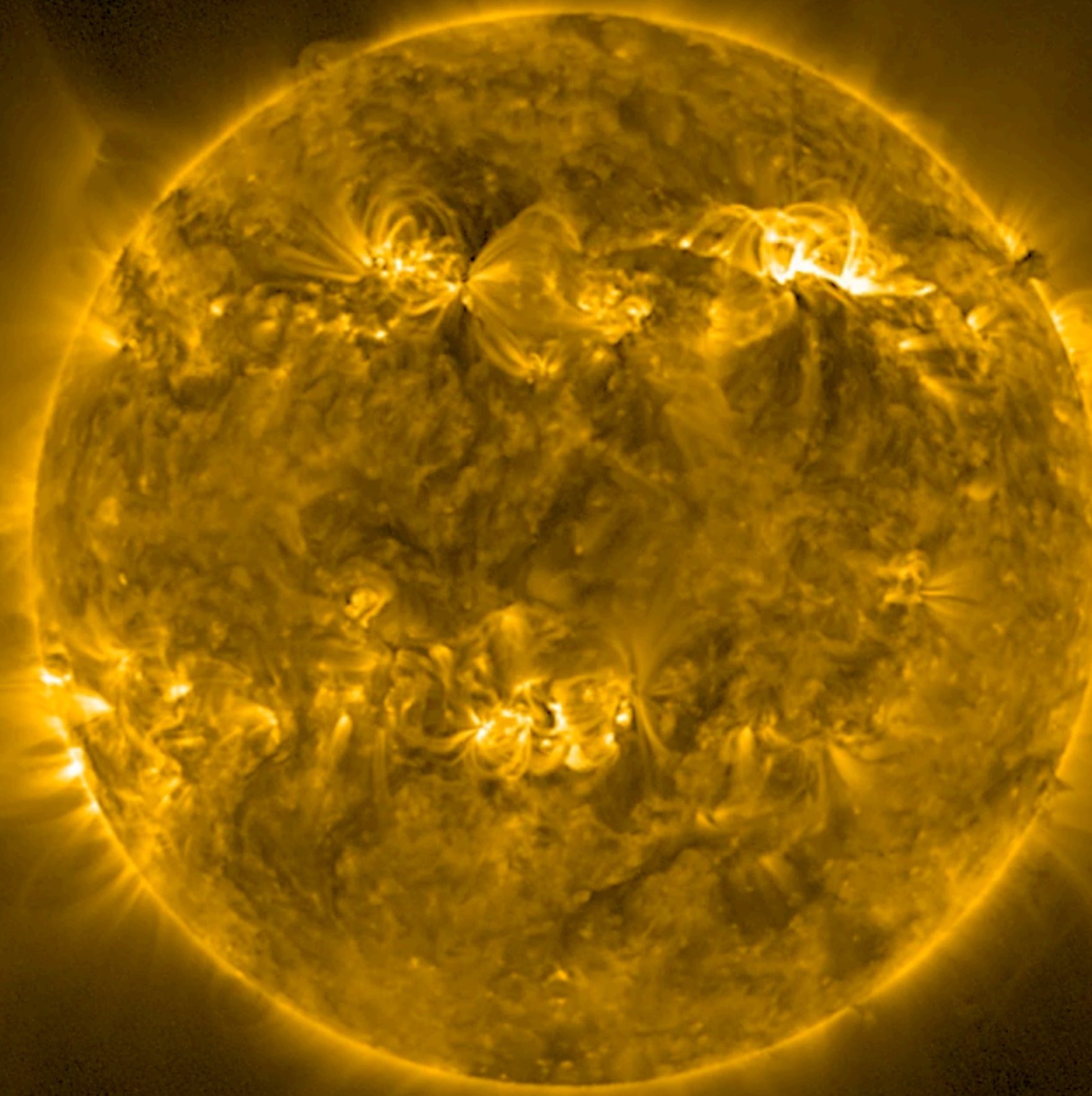
PROBA2, launched 2009



SWAP



PROBA2/SWAP 174 2017-12-30T22:49:01



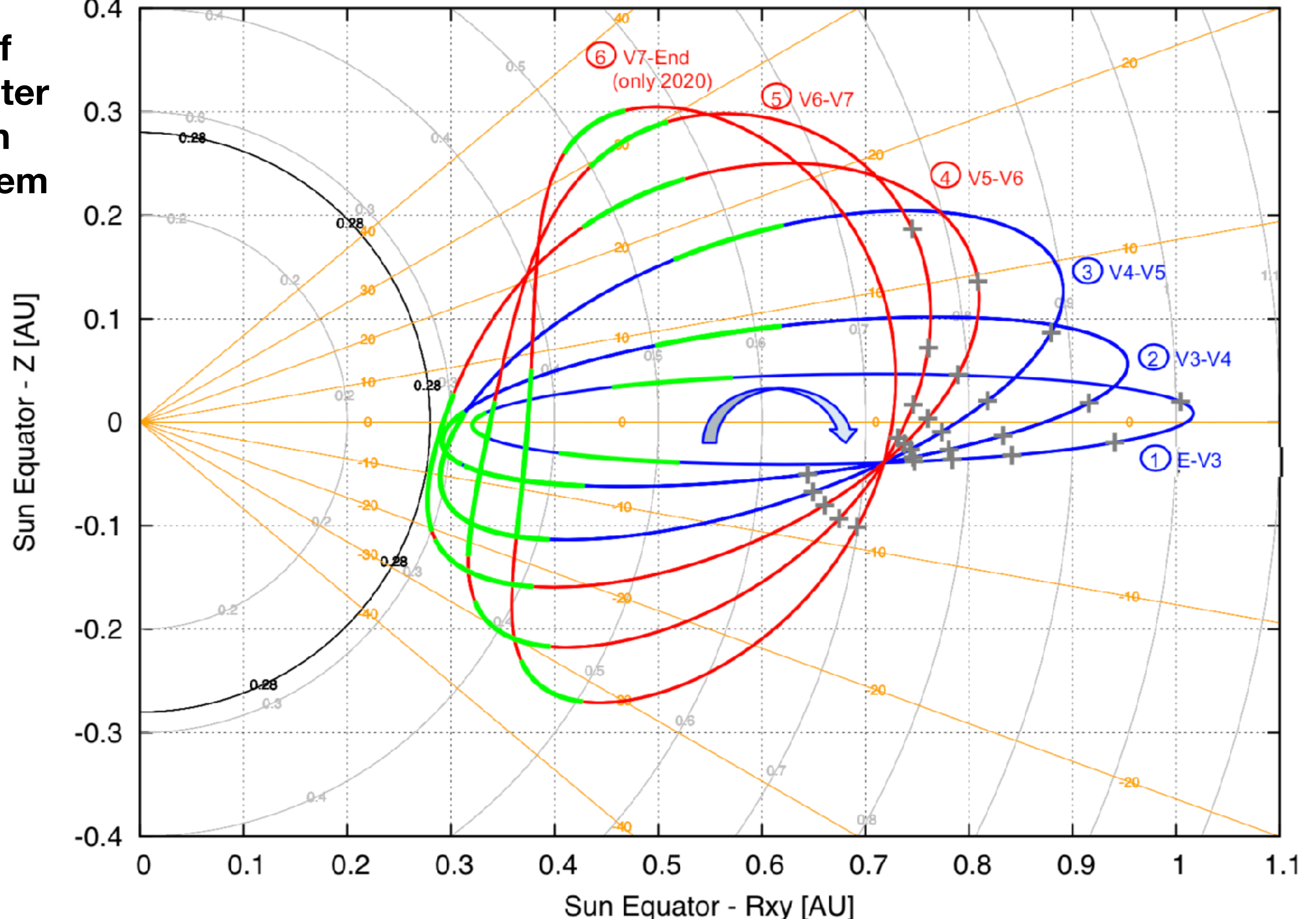
PROBA2/SWAP 174 2023-02-25T01:35:16



The Extreme Ultraviolet Imager on Solar Orbiter

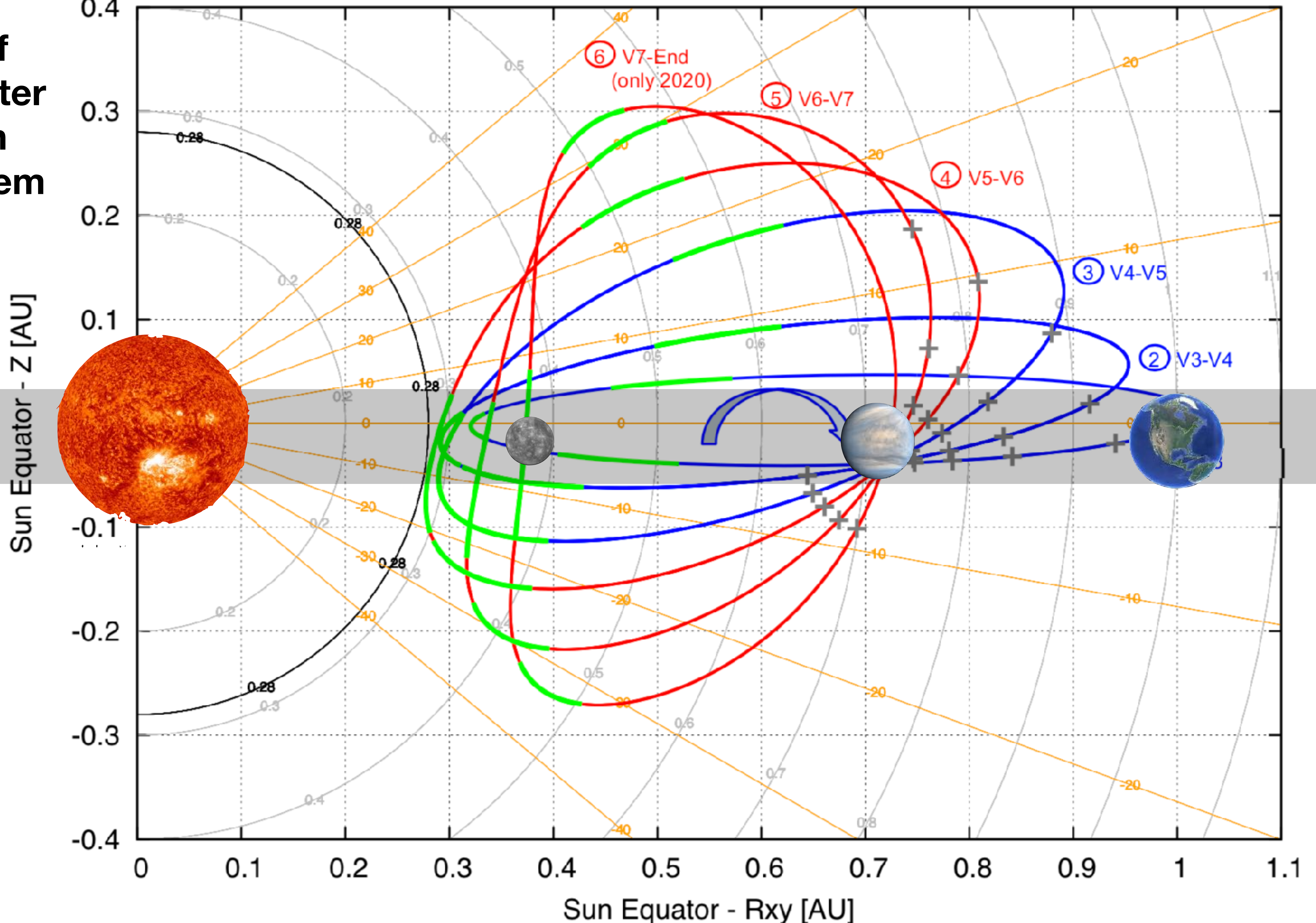
- 1. The sharpest images ever of the solar corona**
- 2. The first images of the poles of the Sun**
- 3. Linking remote images with in-situ plasma measurements**

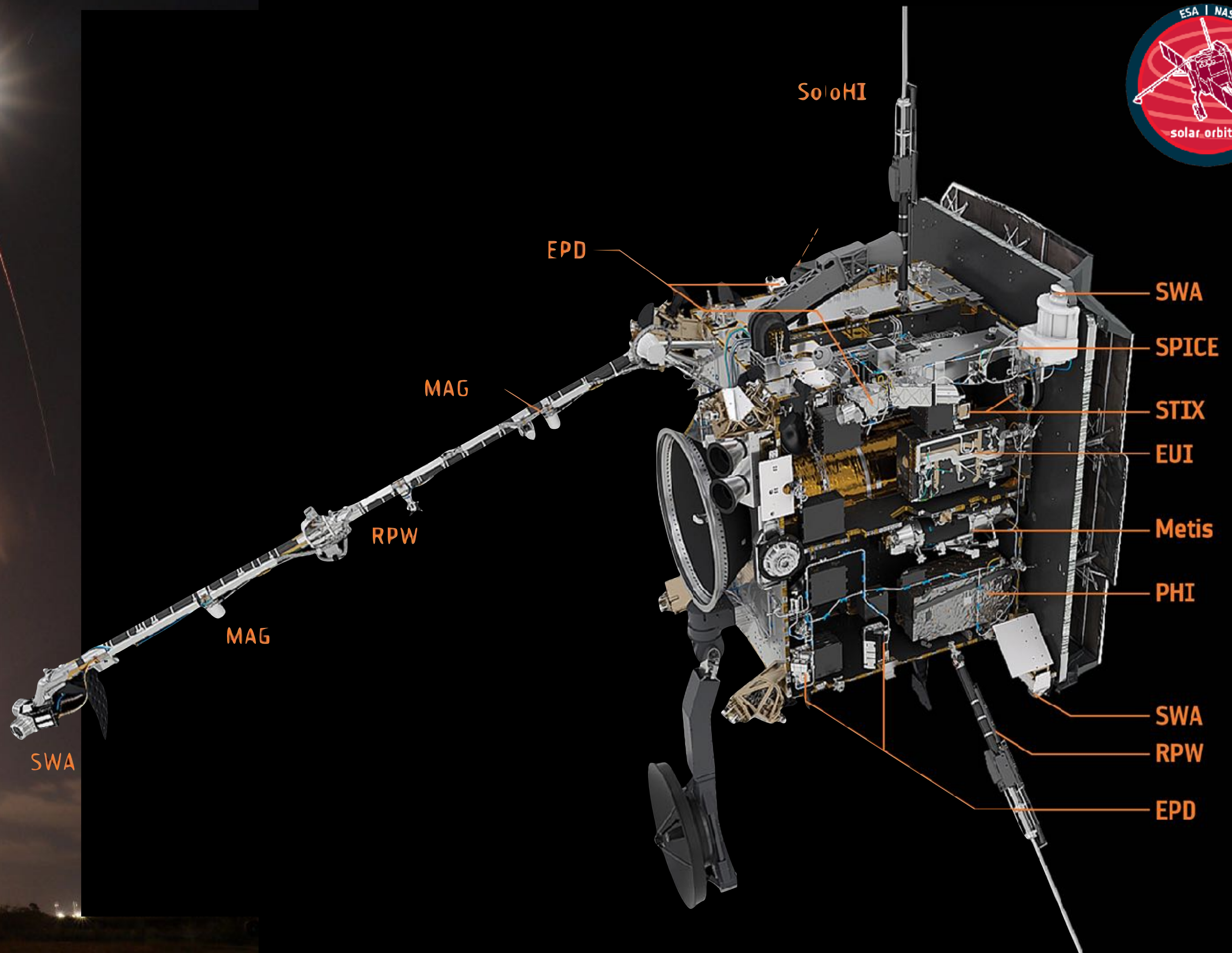
Travel of Solar Orbiter through solar system



Travel of Solar Orbiter through solar system

Ecliptica







Launch 2020 Feb 10





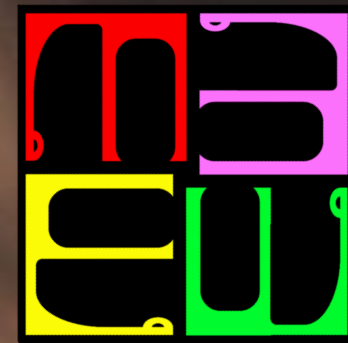
SPICE Spectrometer

STIX: X-ray Telescope

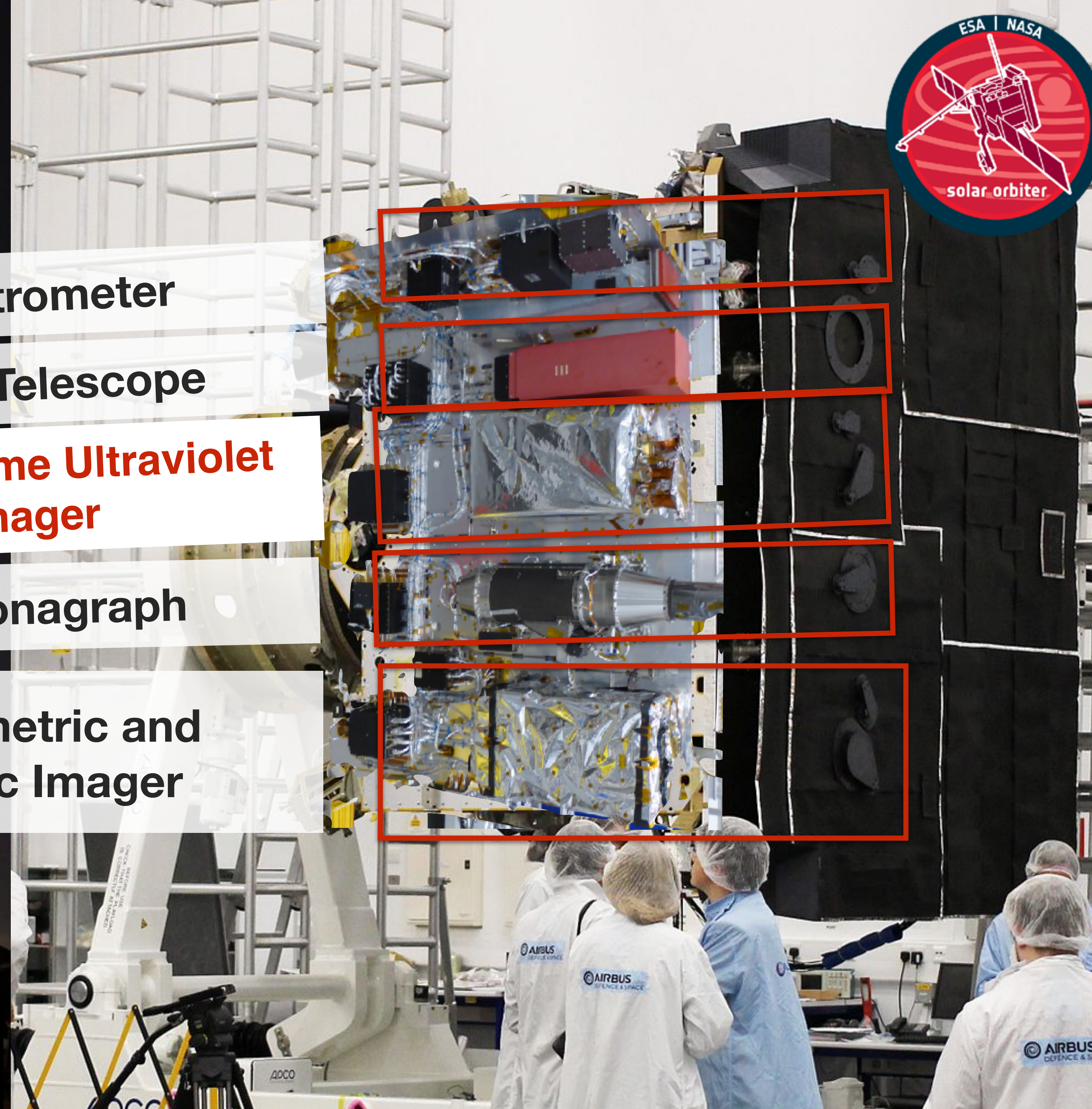
EUI: Extreme Ultraviolet Imager

METIS Coronagraph

PHI: Polarimetric and Helioseismic Imager



Launch 2020 Feb 10



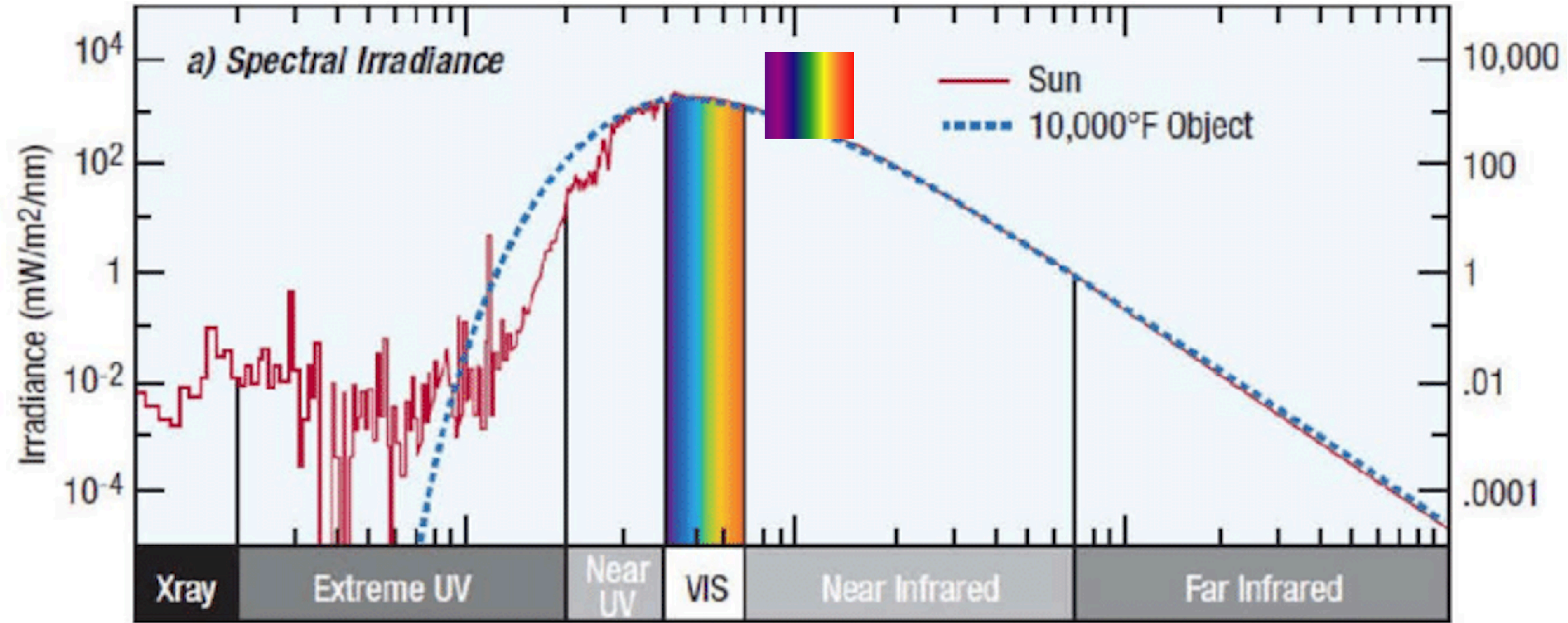


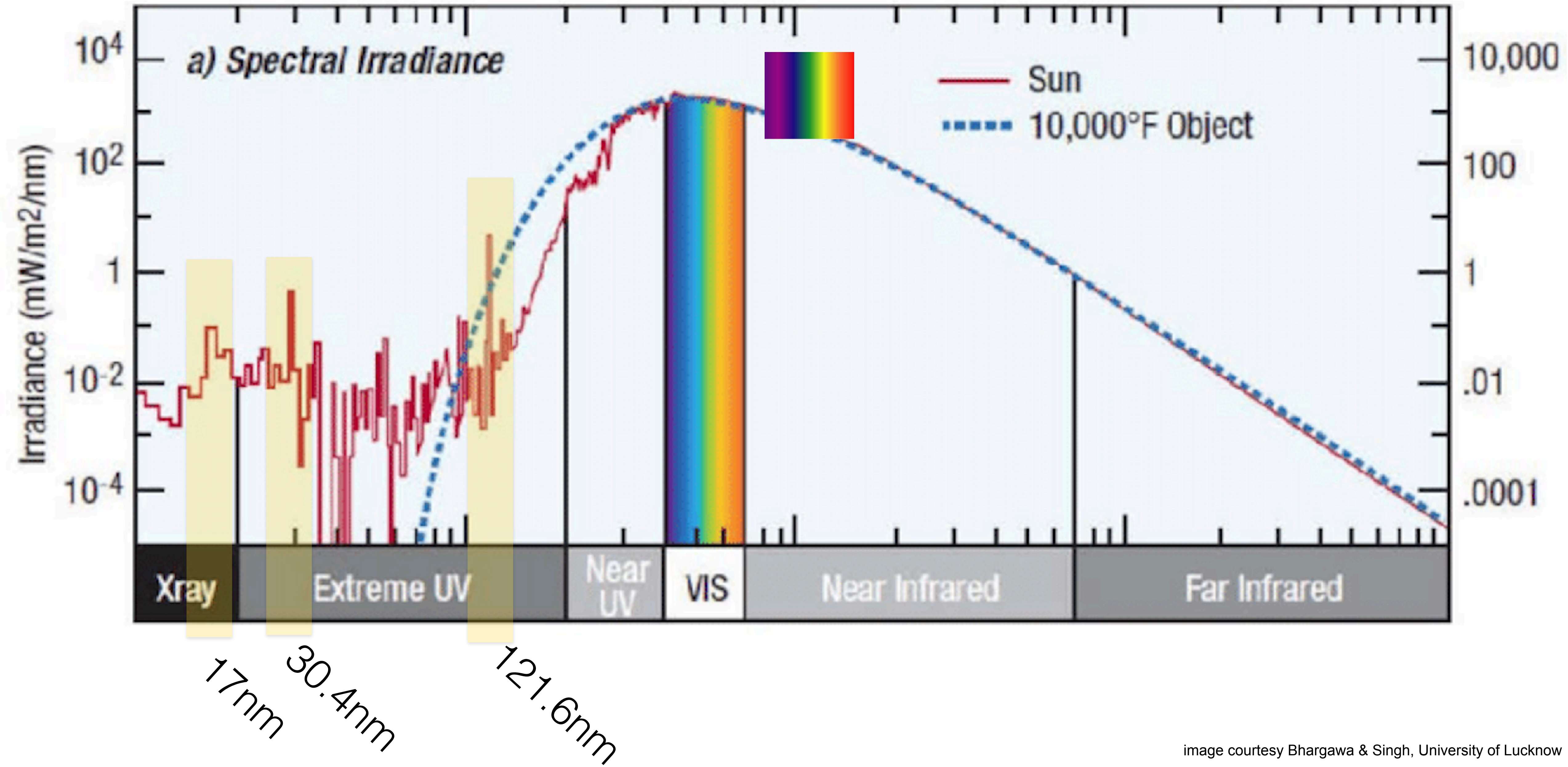
EUI OBS ST

30mm

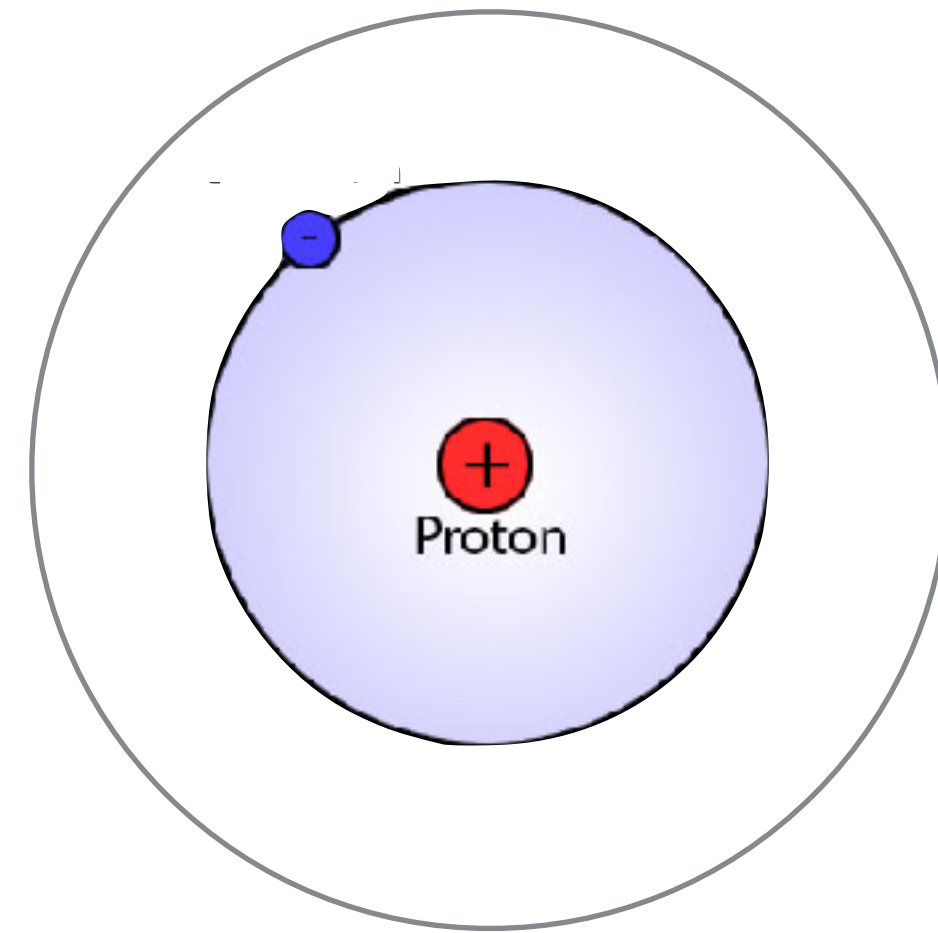
47.4mm

2.75mm edge

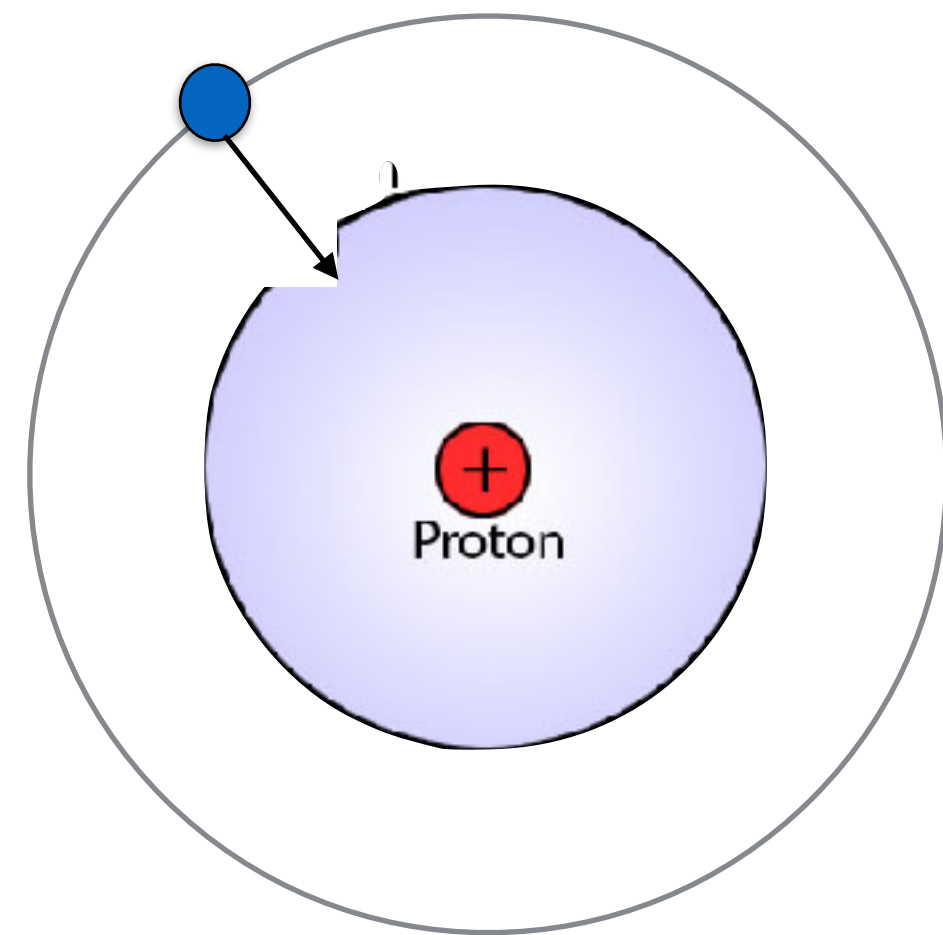
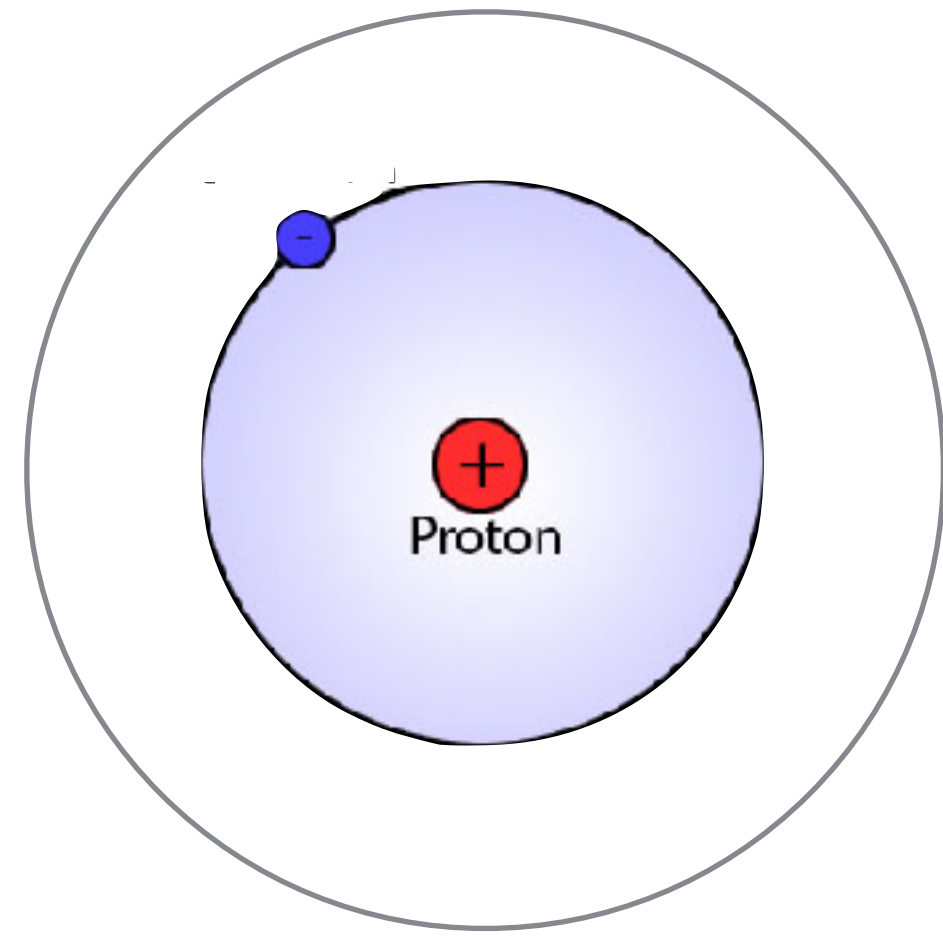




>70% hydrogen



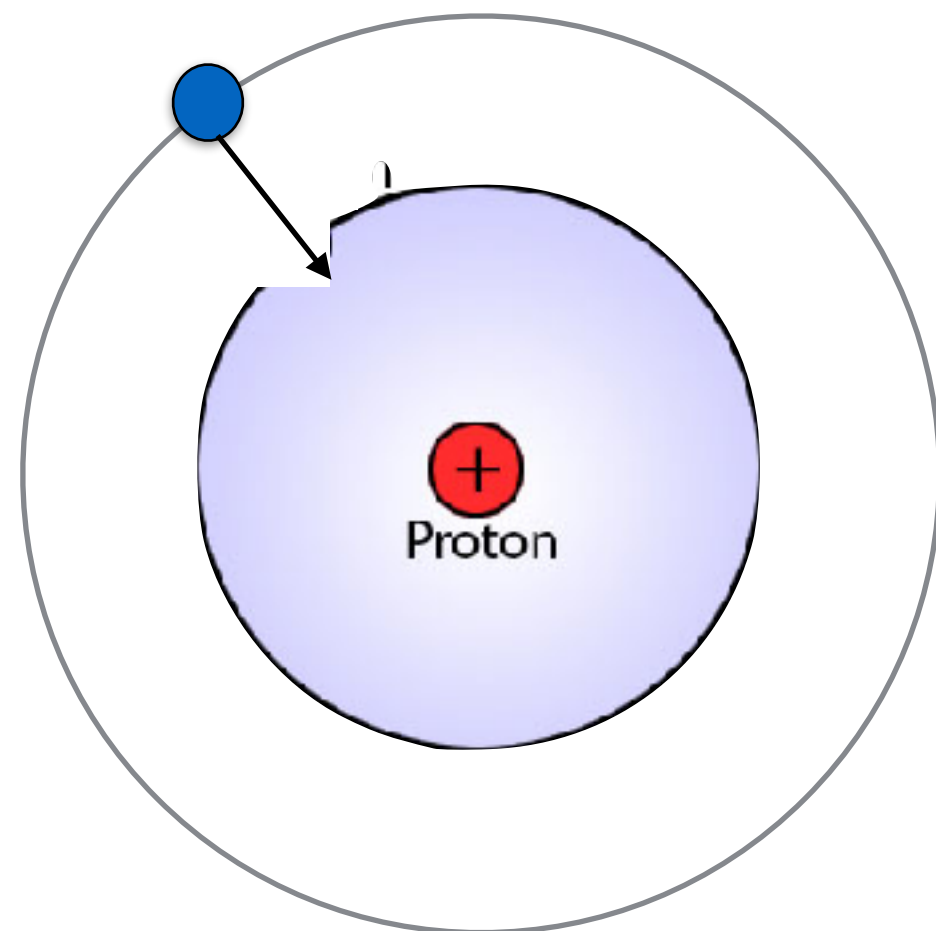
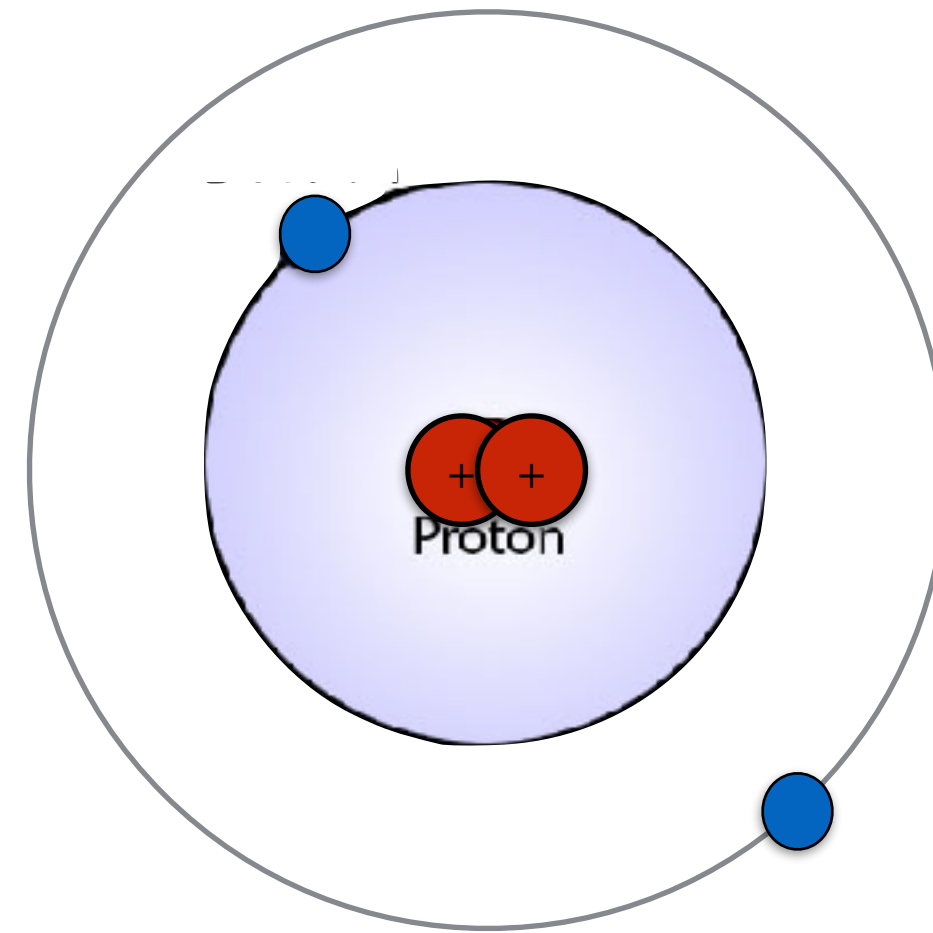
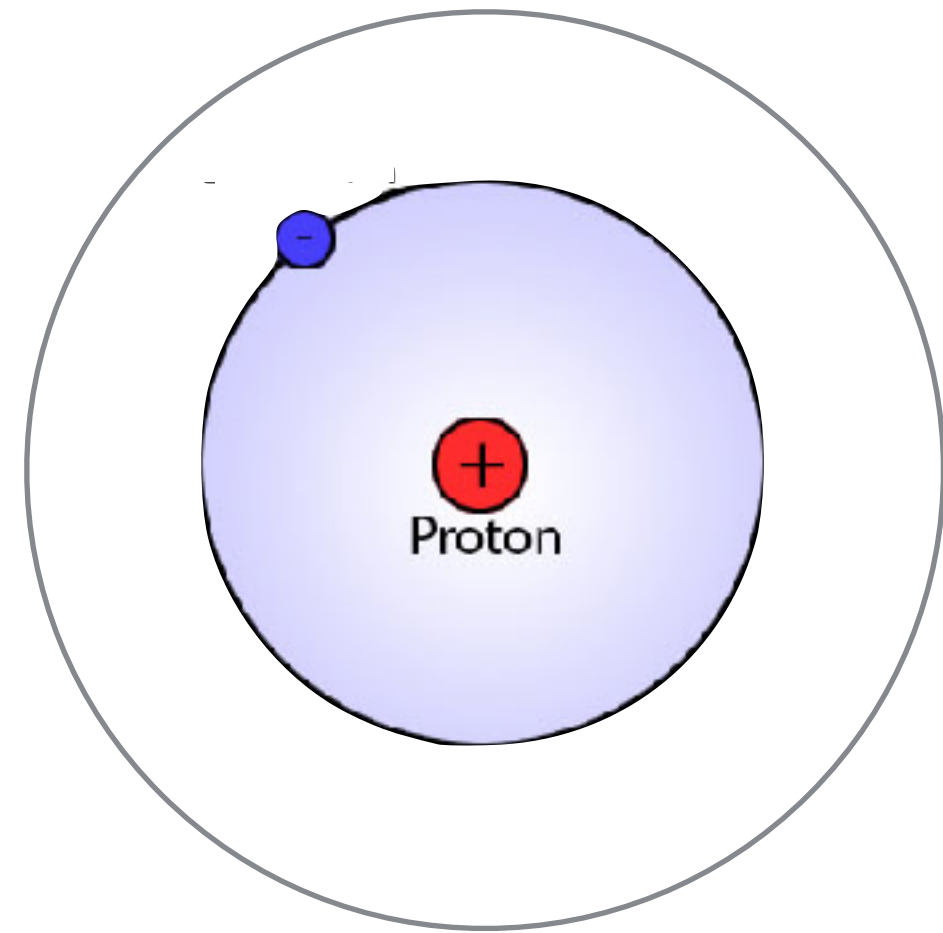
>70% hydrogen



H I Lyman alfa 121.6nm
chromosphere

>70% hydrogen

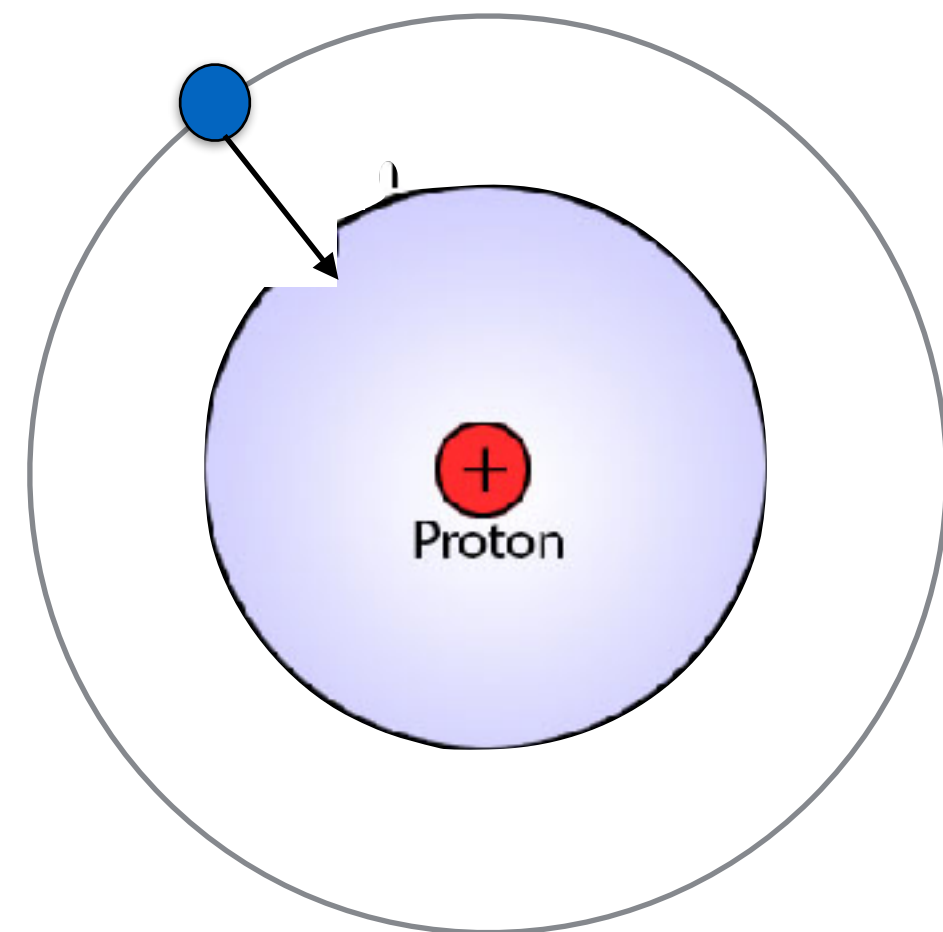
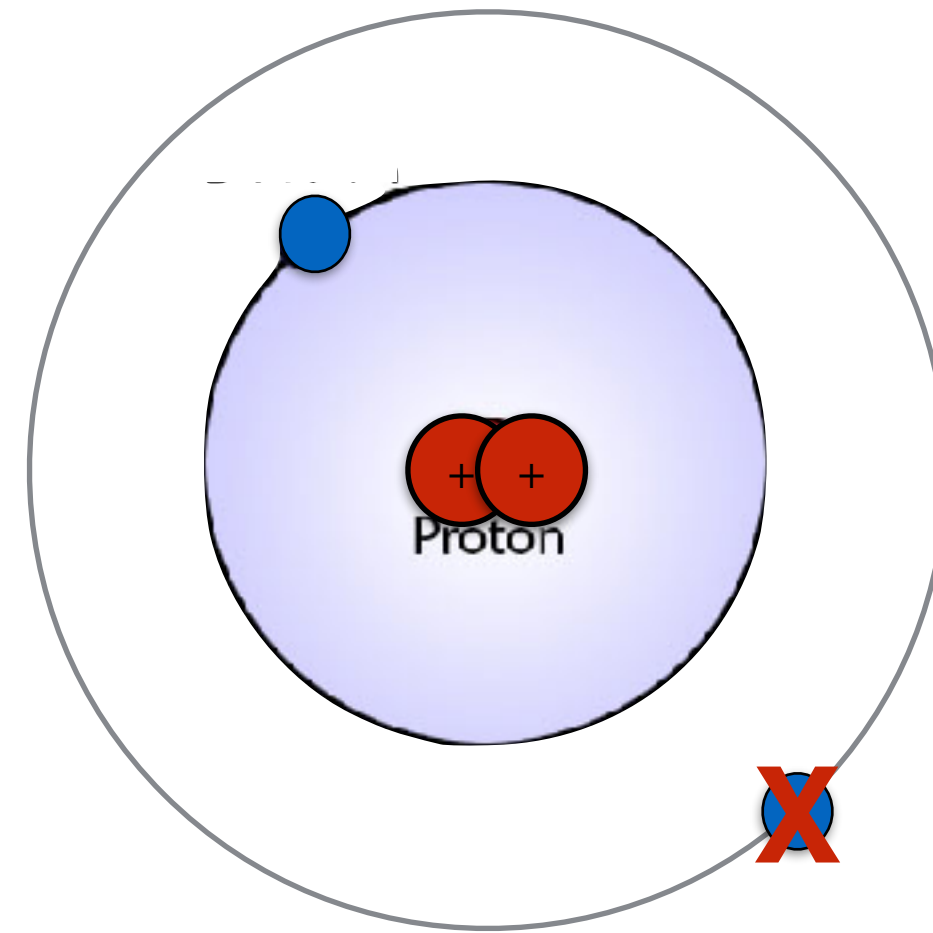
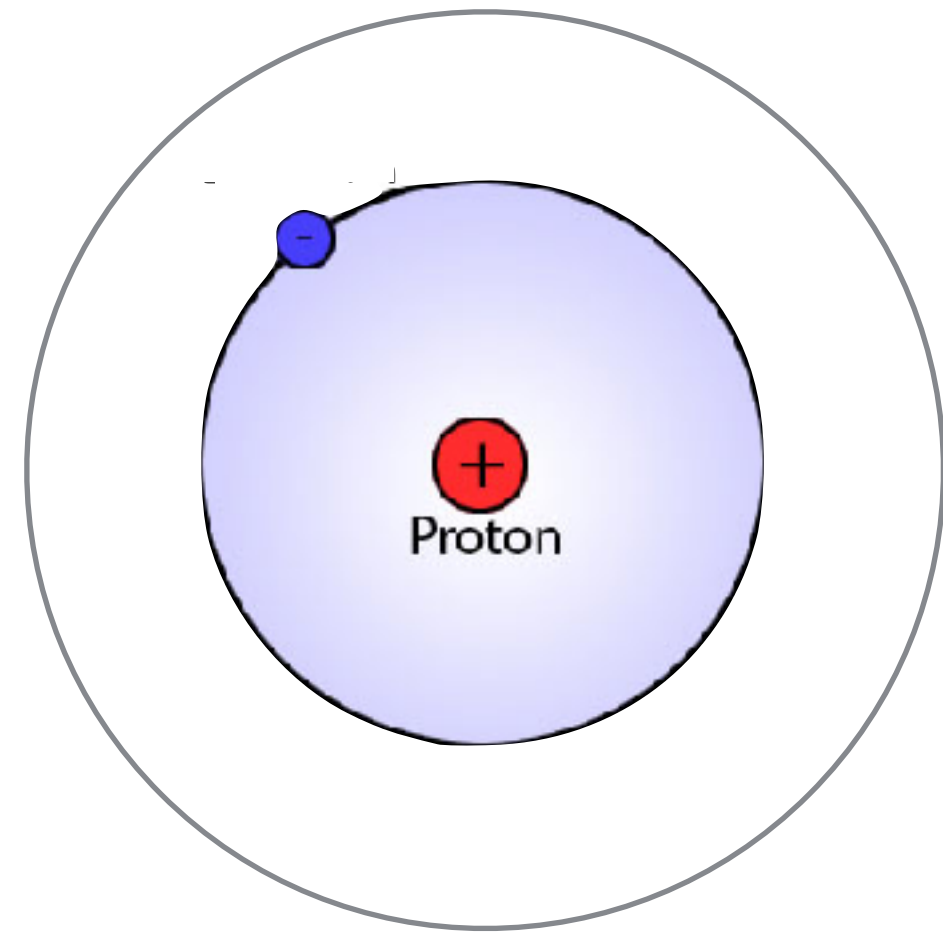
<30% helium



H I Lyman alfa 121.6nm
chromosphere

>70% hydrogen

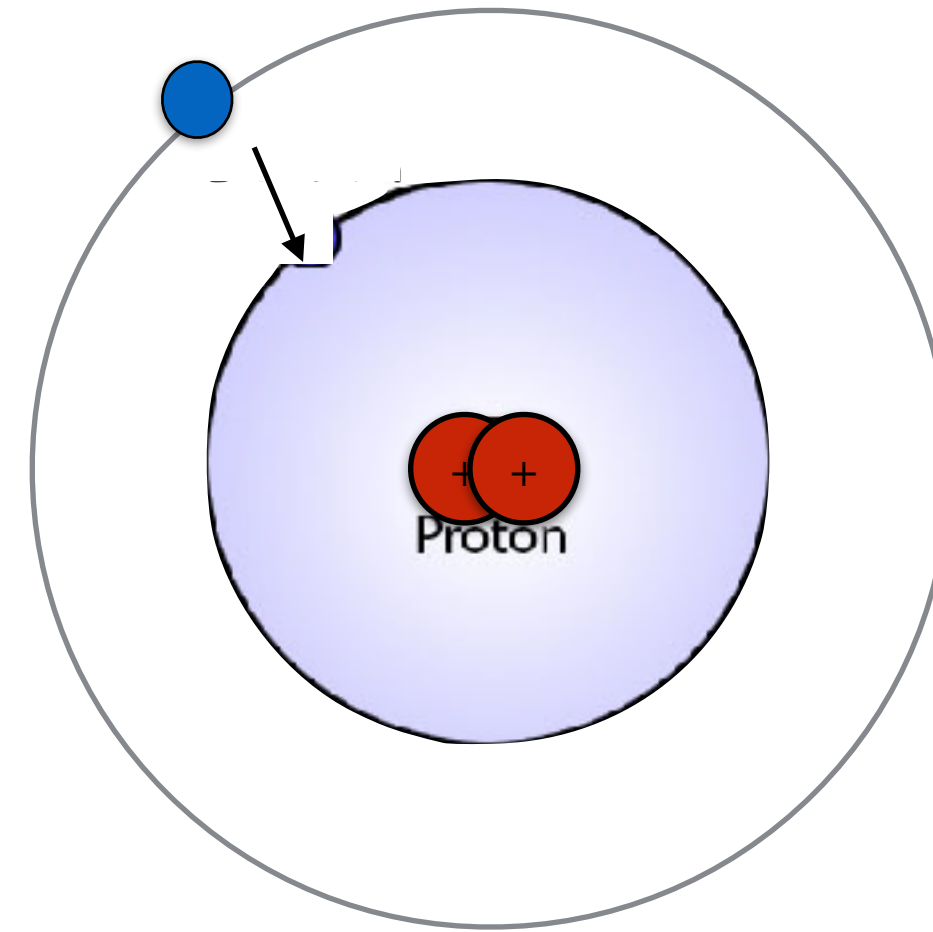
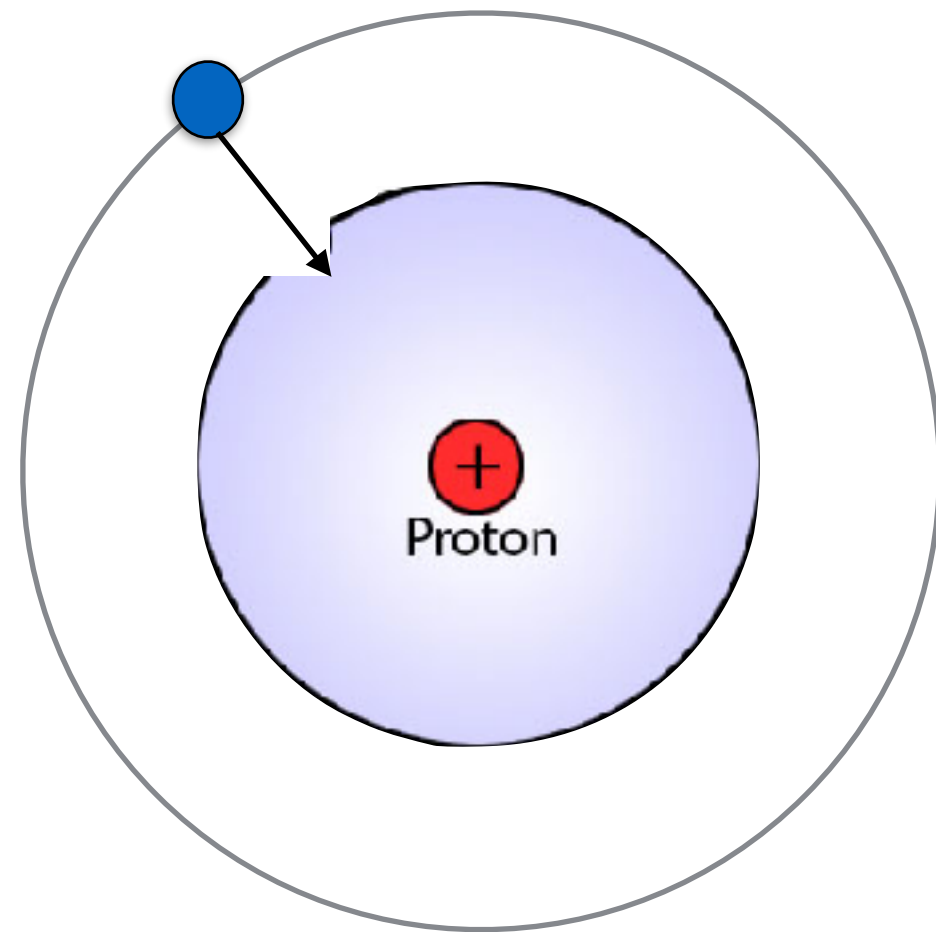
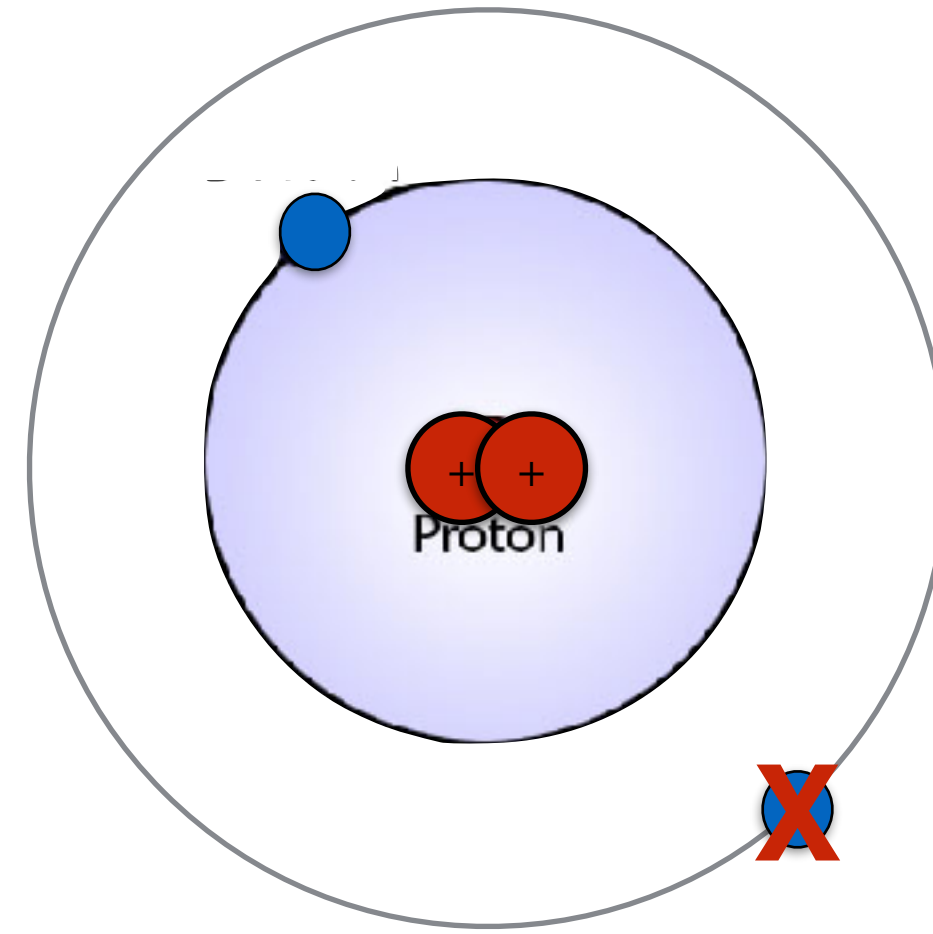
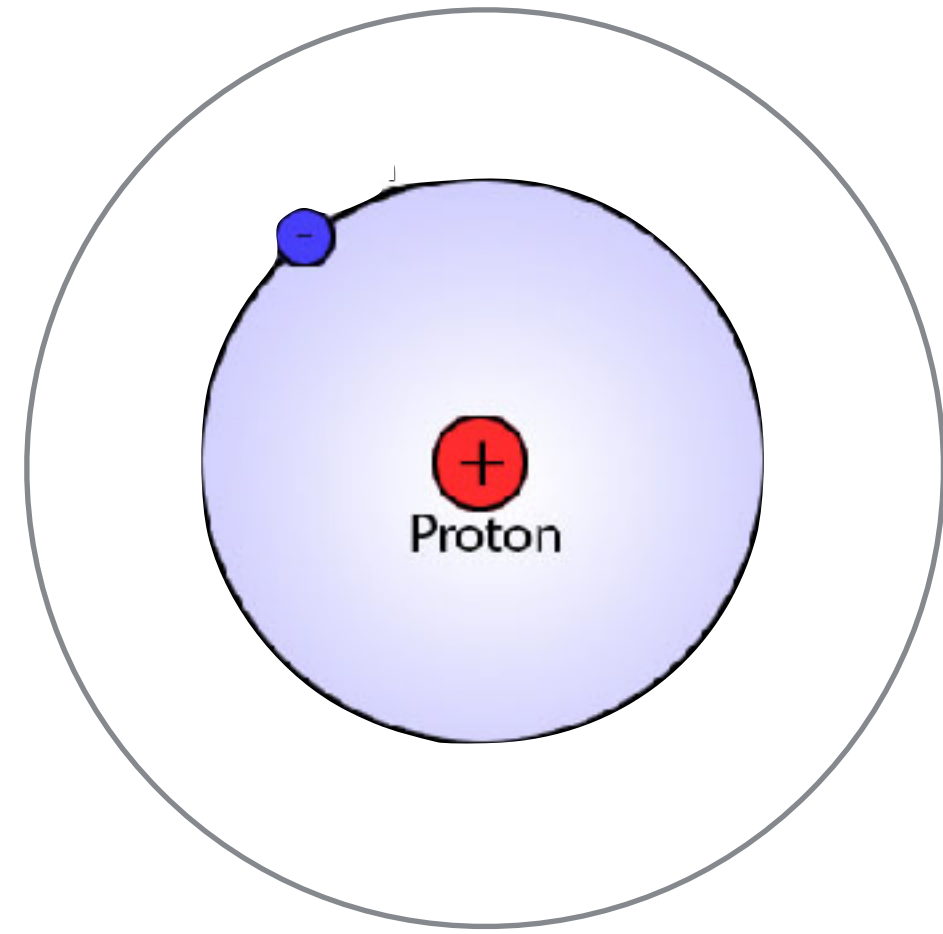
<30% helium



H I Lyman alfa 121.6nm
chromosphere

>70% hydrogen

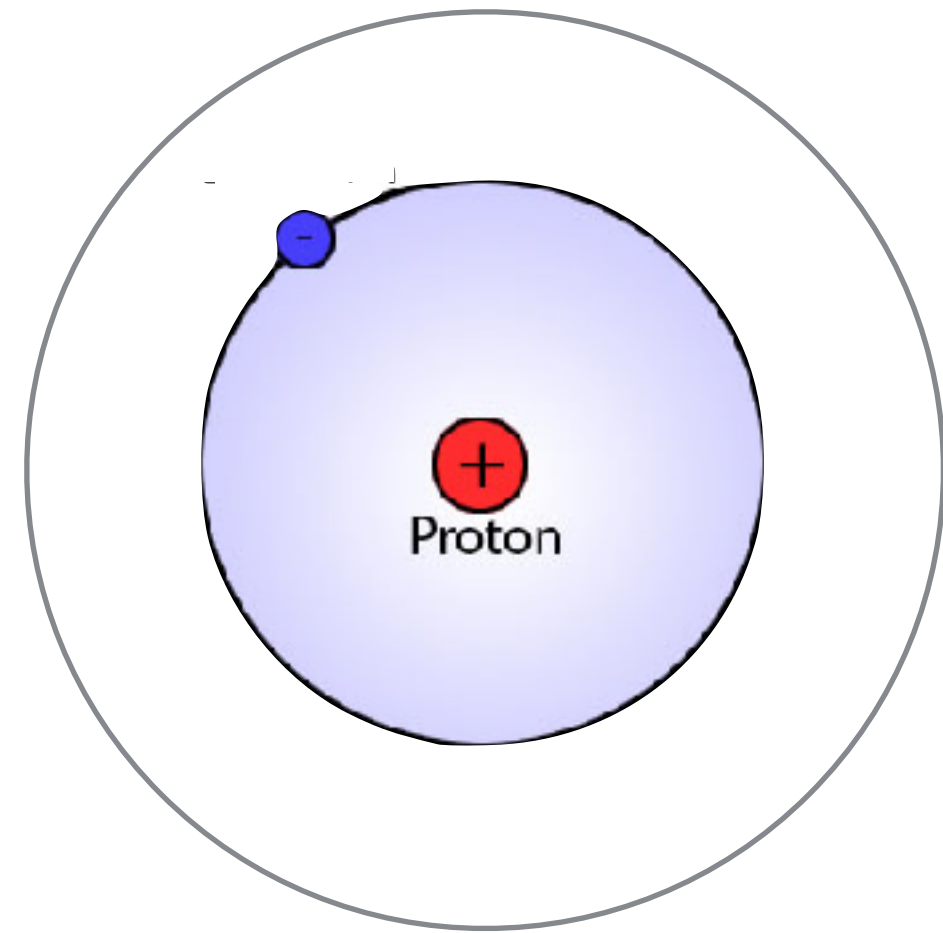
<30% helium



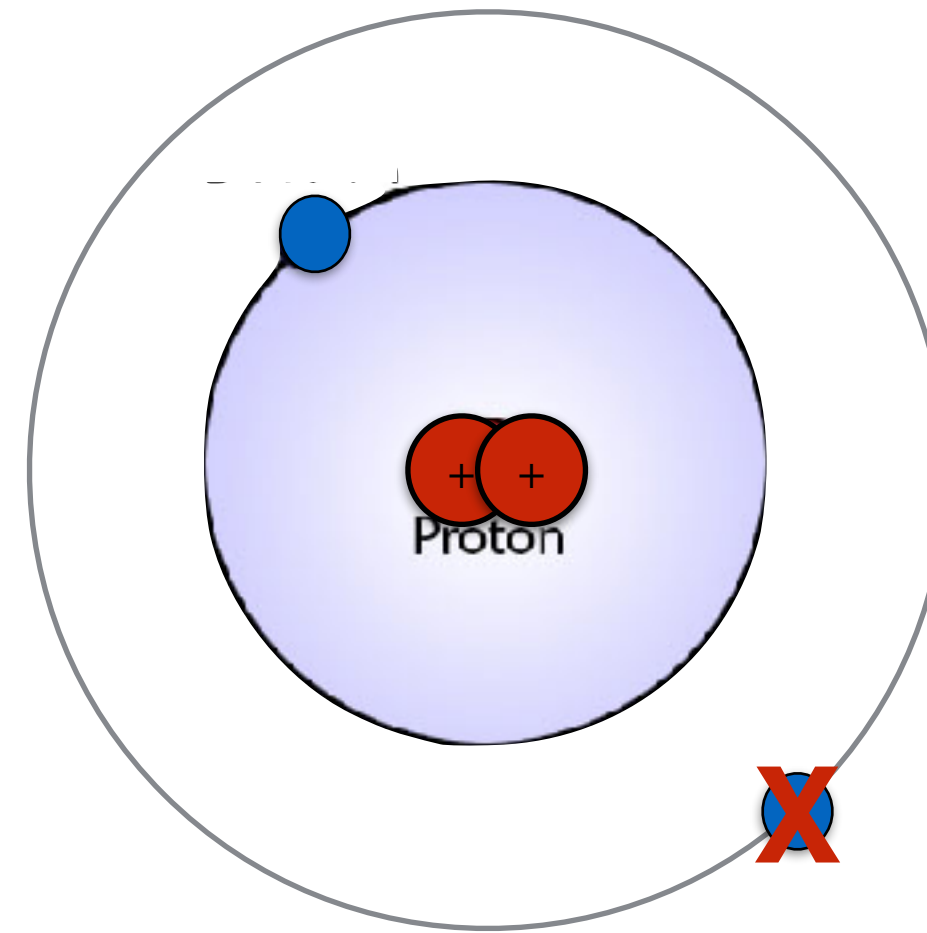
H I Lyman alfa 121.6nm
chromosphere

He II 30.4nm
transition layer

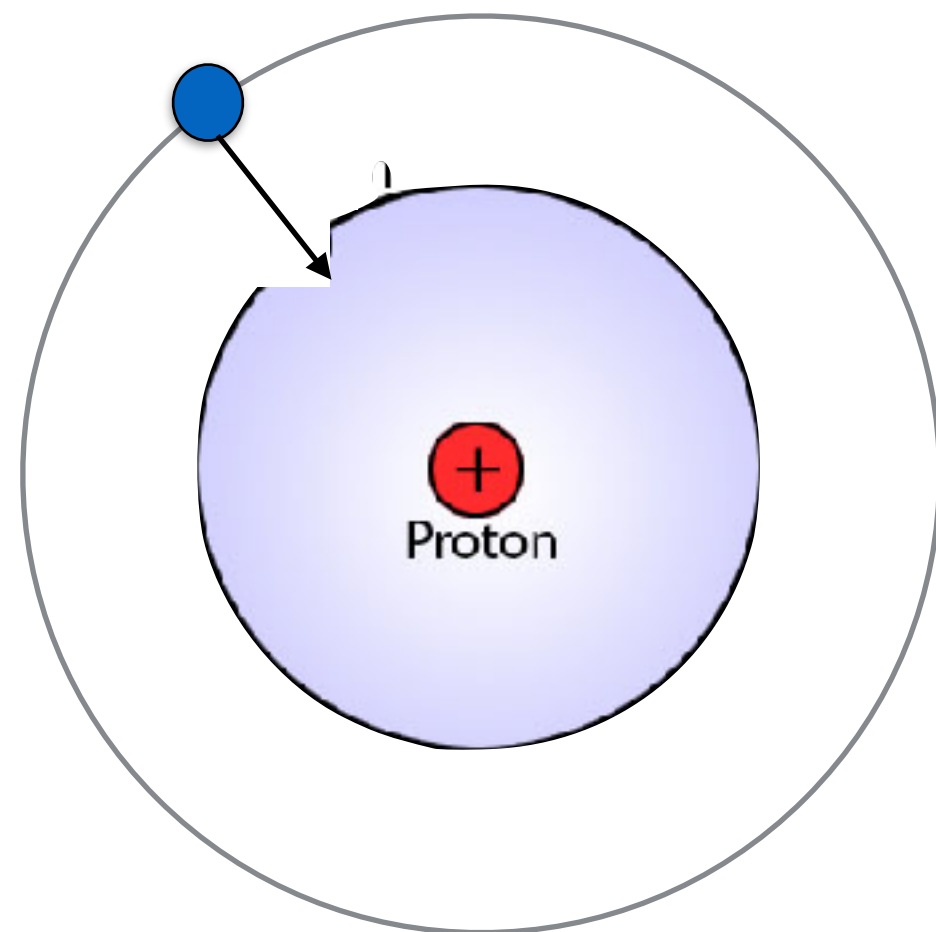
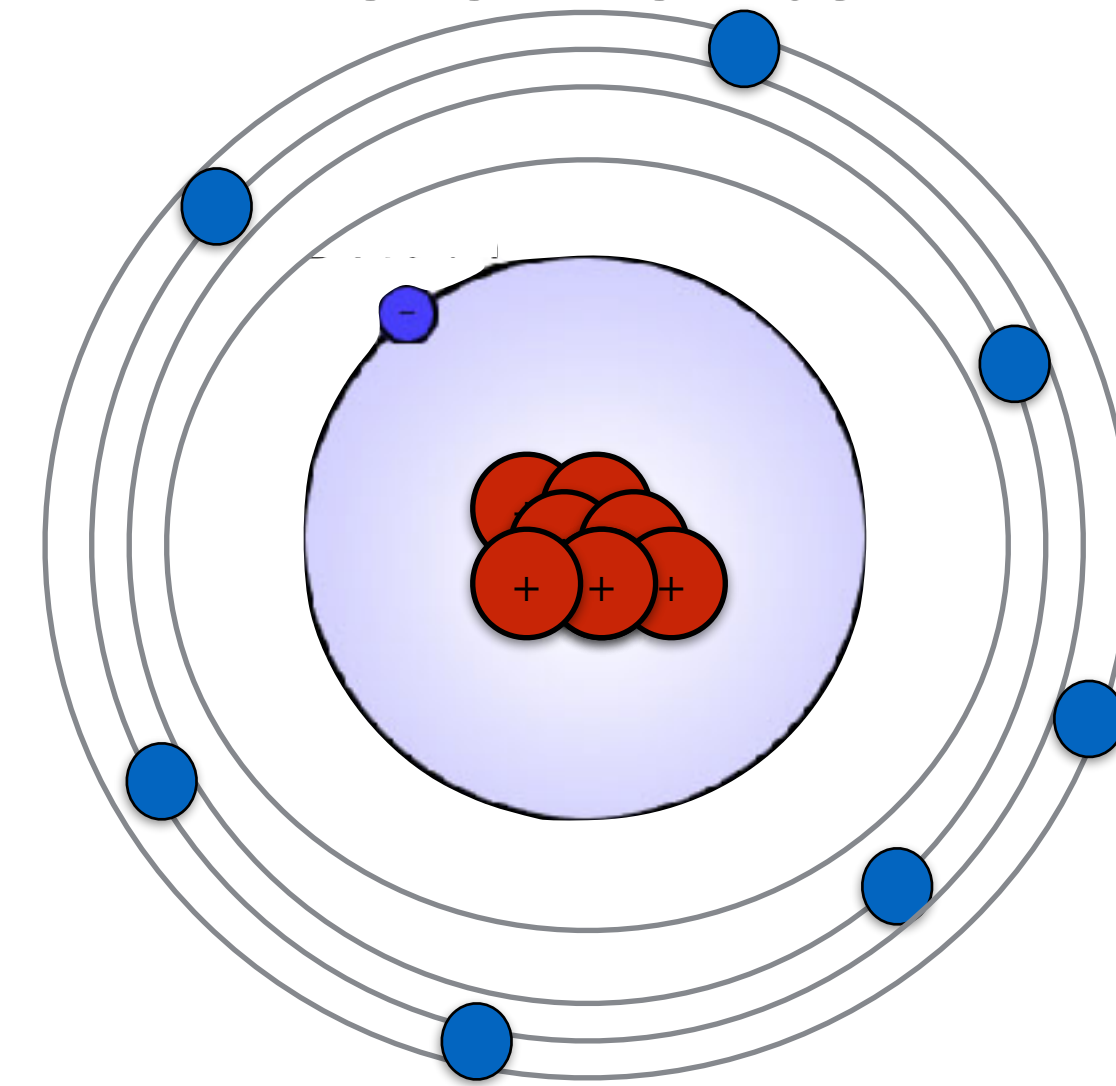
>70% hydrogen



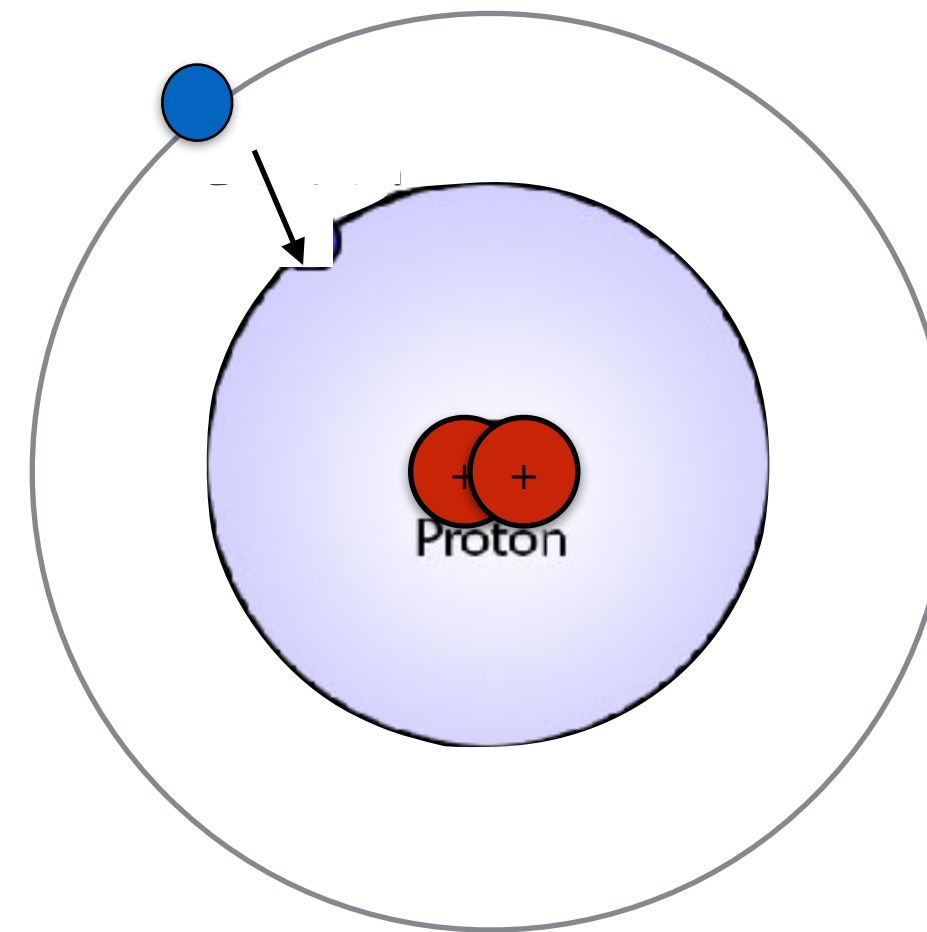
<30% helium



1% heavier elements



H I Lyman alfa 121.6nm
chromosphere

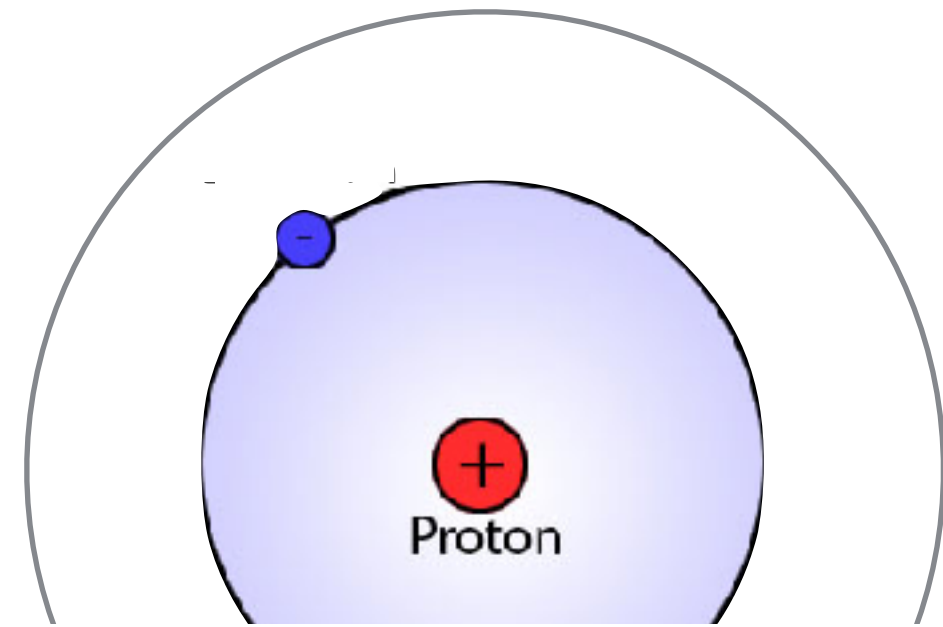


He II 30.4nm
transition layer

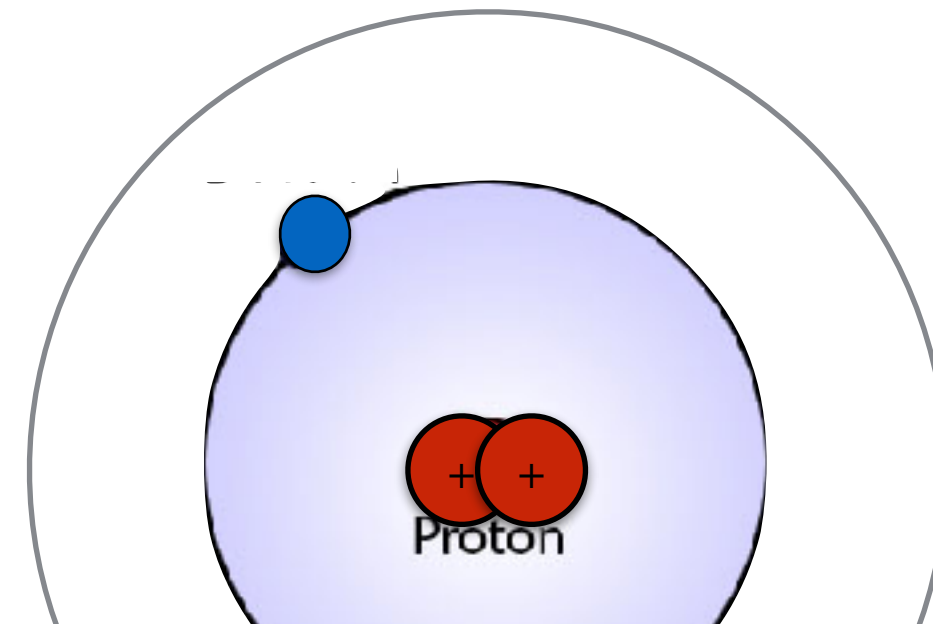
...too complicated...

Fe IX, X, XI ~ 17nm
low corona

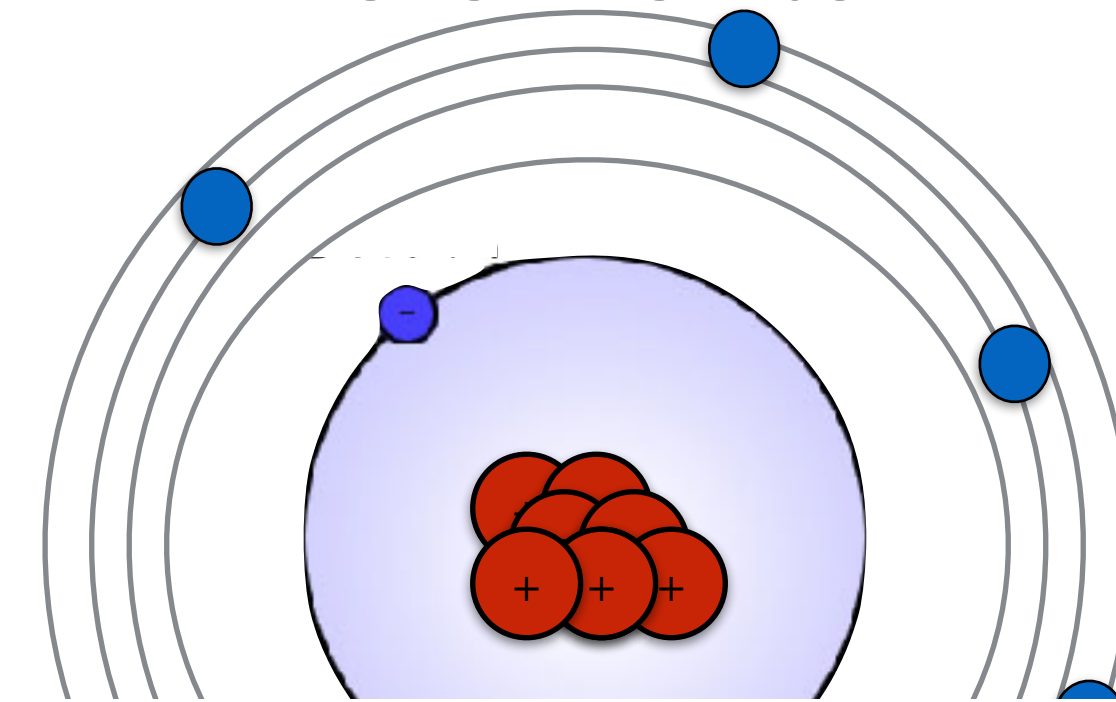
>70% hydrogen



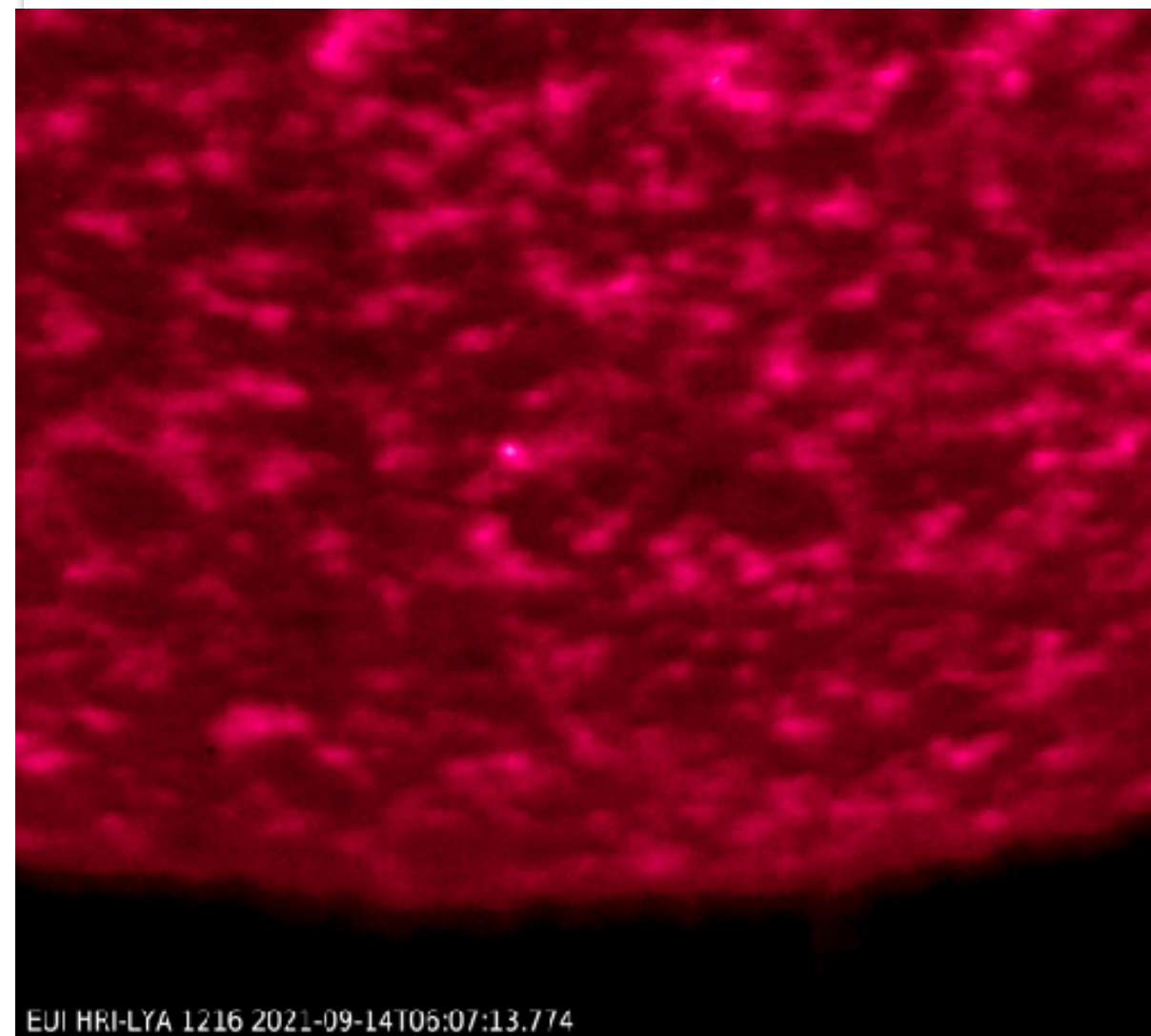
<30% helium



1% heavier elements

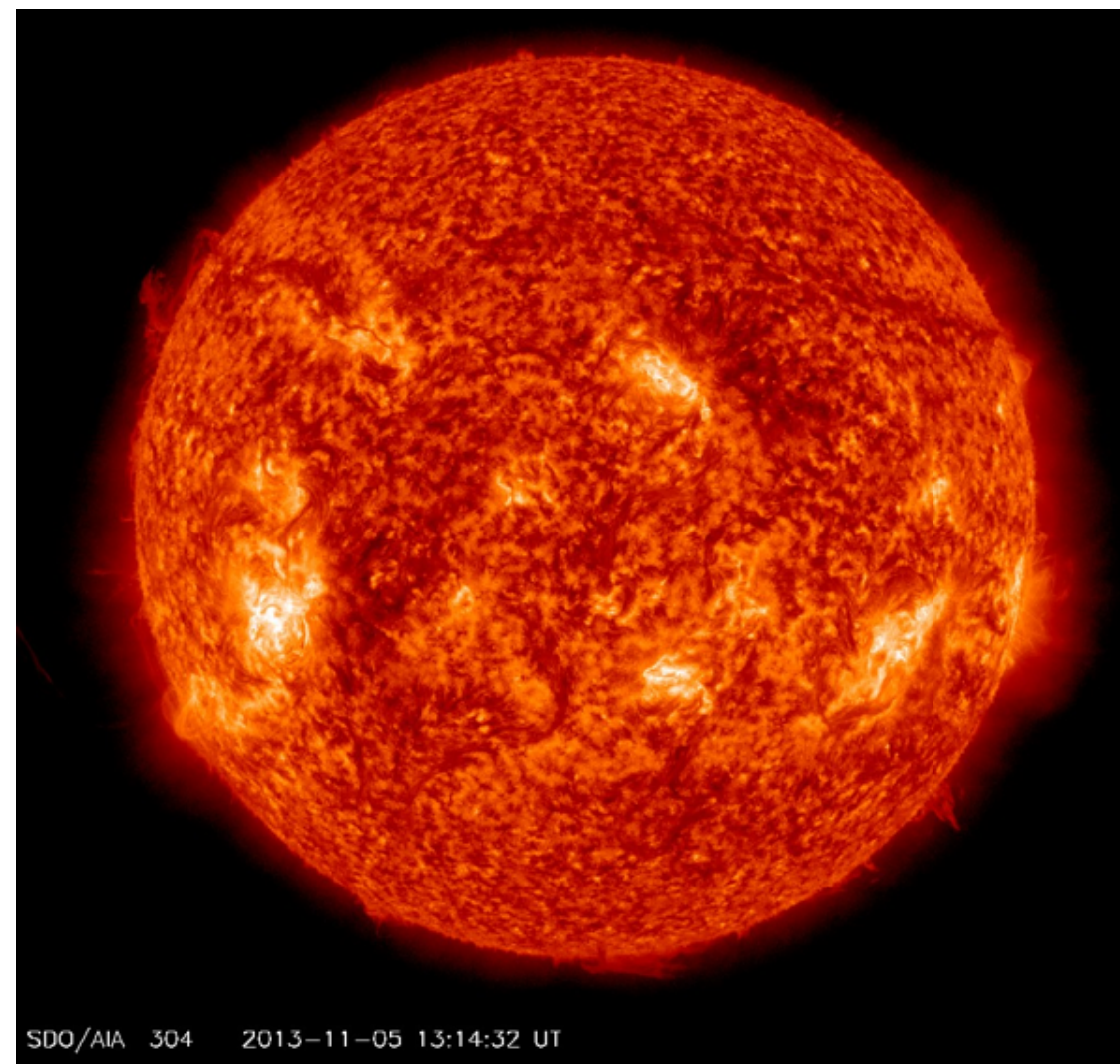


EUI/HRIEUV



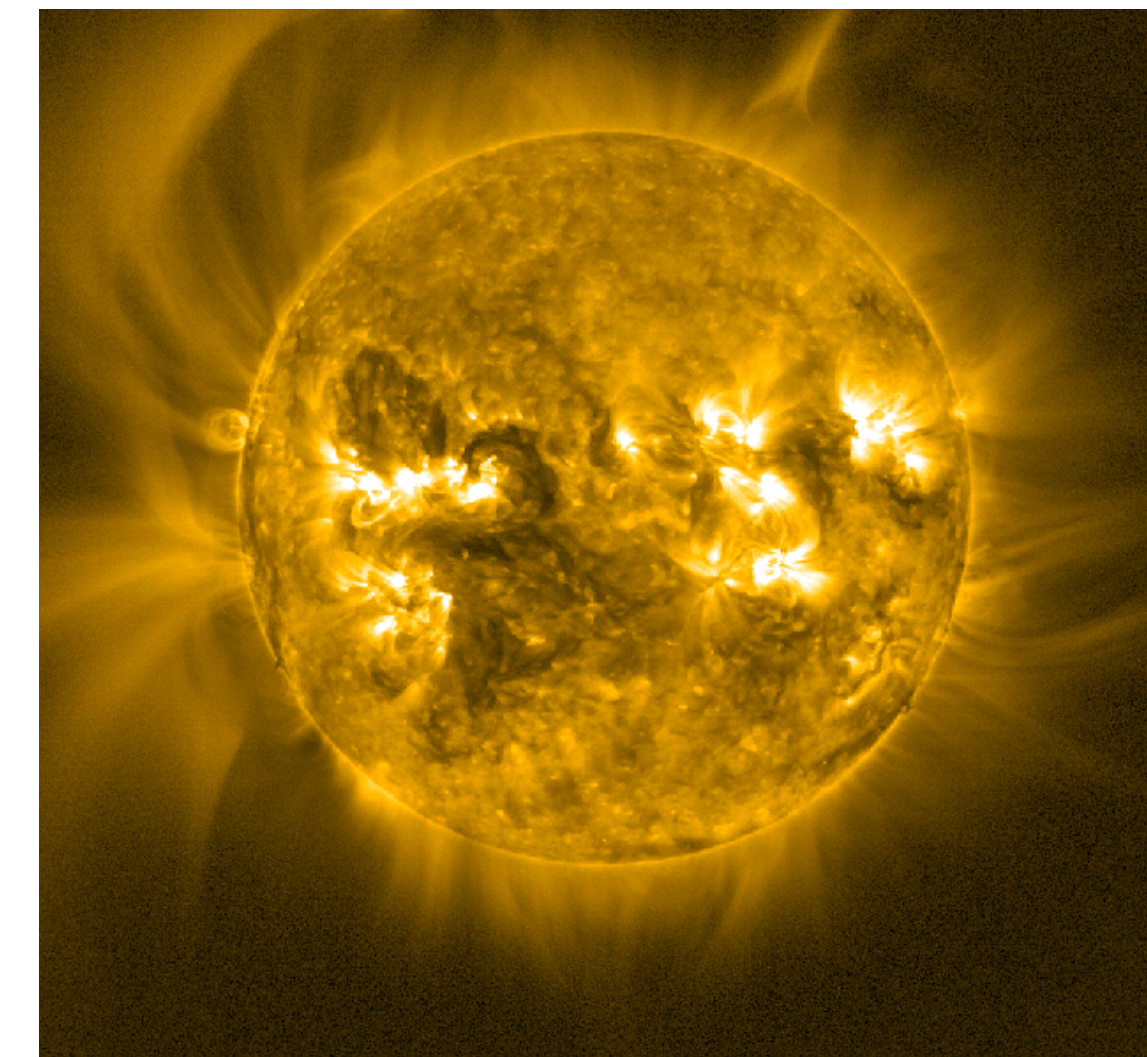
H I Lyman alfa 121.6nm
chromosfeer
enkele tienduizenden C

SDO/AIA



He II 30.4nm
transitie laag
~80000 C

PROBA2/SWAP



Fe IX, X, XI ~ 17nm
lage corona
1 miljoen C

De "Extreme Ultraviolet Imager" (EUI) is gebouwd door:



Centre Spatial de Liège



Institut d'Astrophysique Spatiale



Laboratoire Charles Fabry,
Institut d'Optique



Max Planck Institute for
Solar System Research



Physikalisch-Meteorologisches
Observatorium Davos



UCL-Mullard Space Science Laboratory



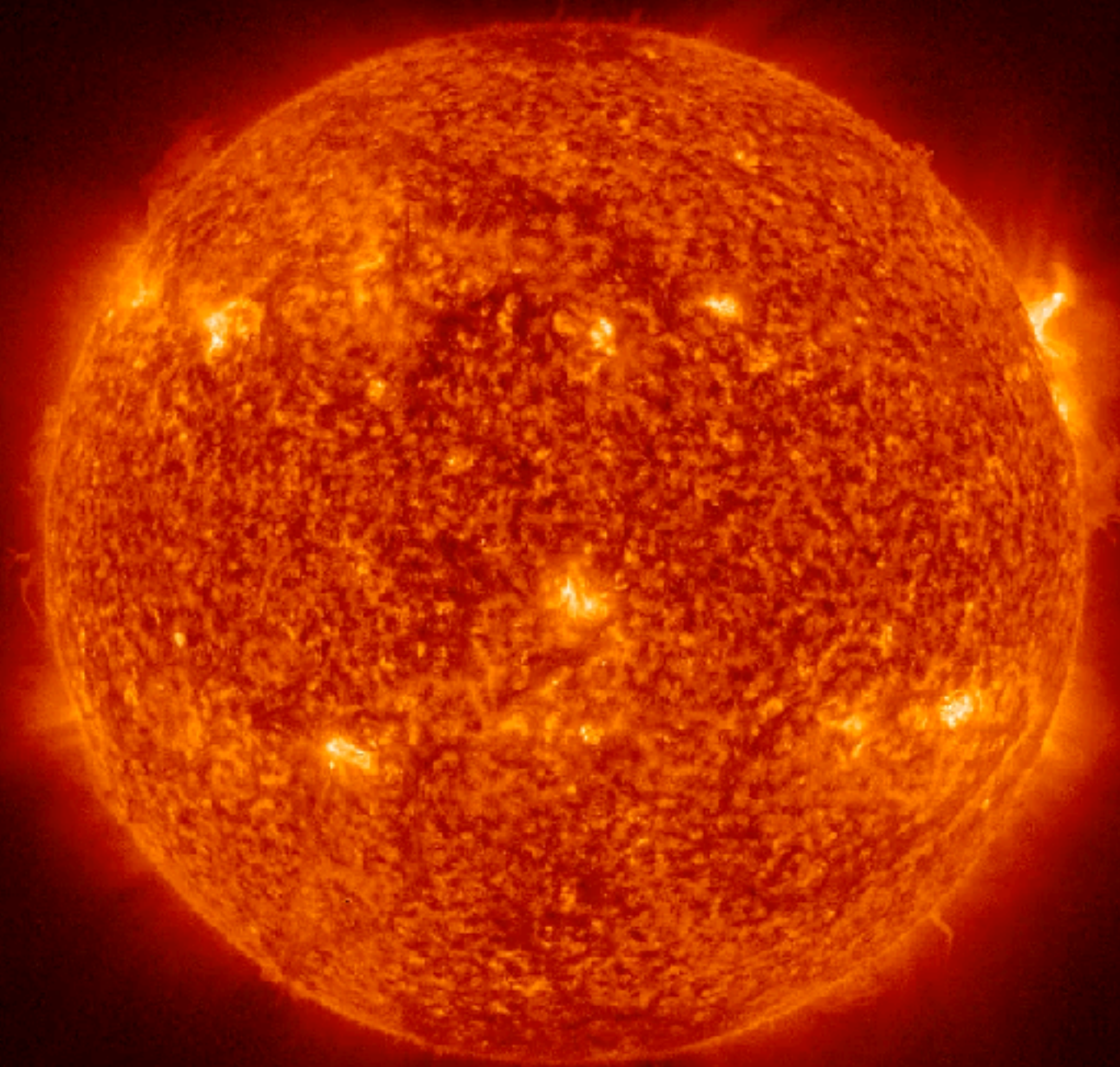
Koninklijke Sterrenwacht van België



Full Sun
Imager

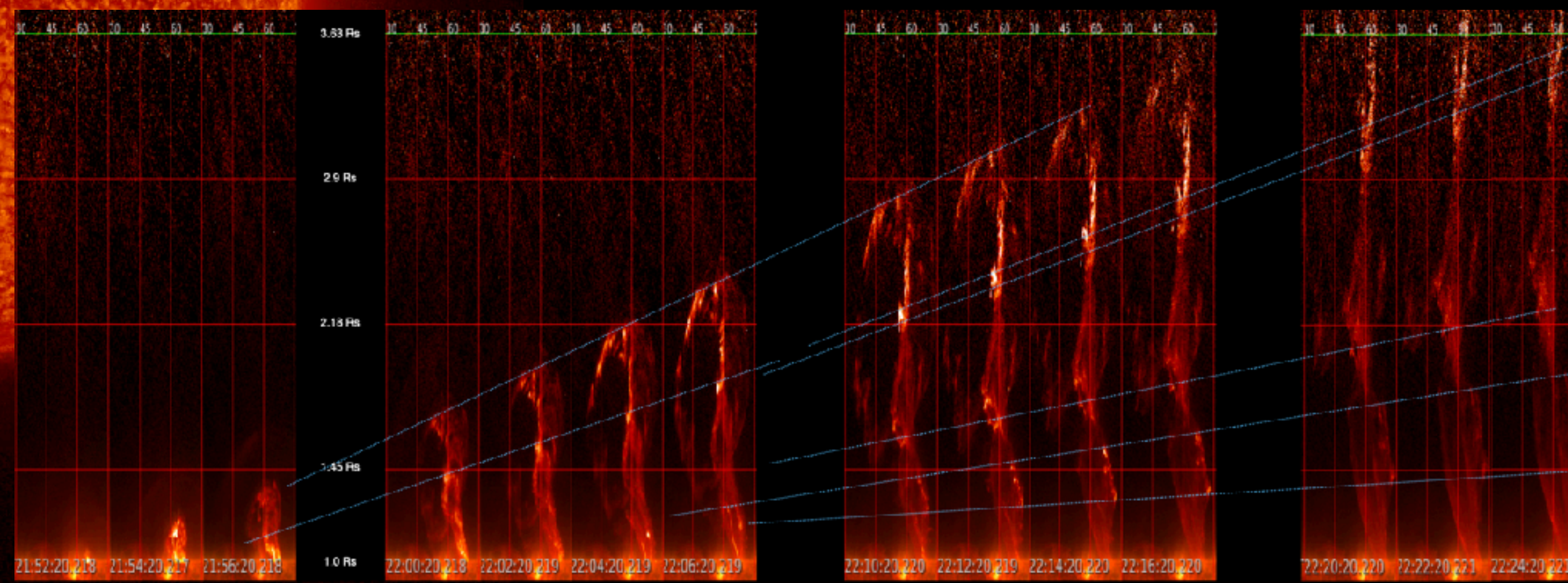
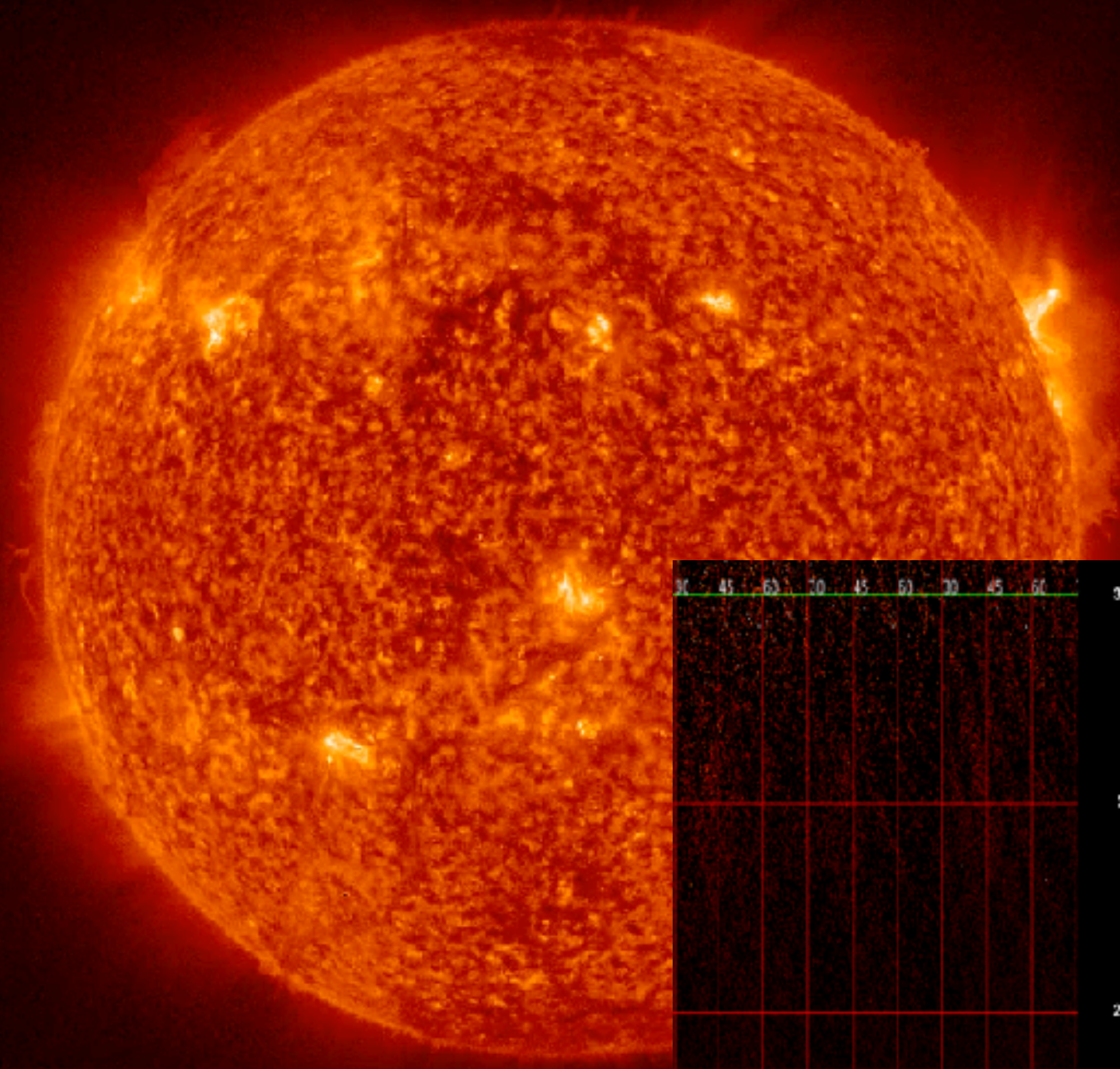
High
Resolution
EUV

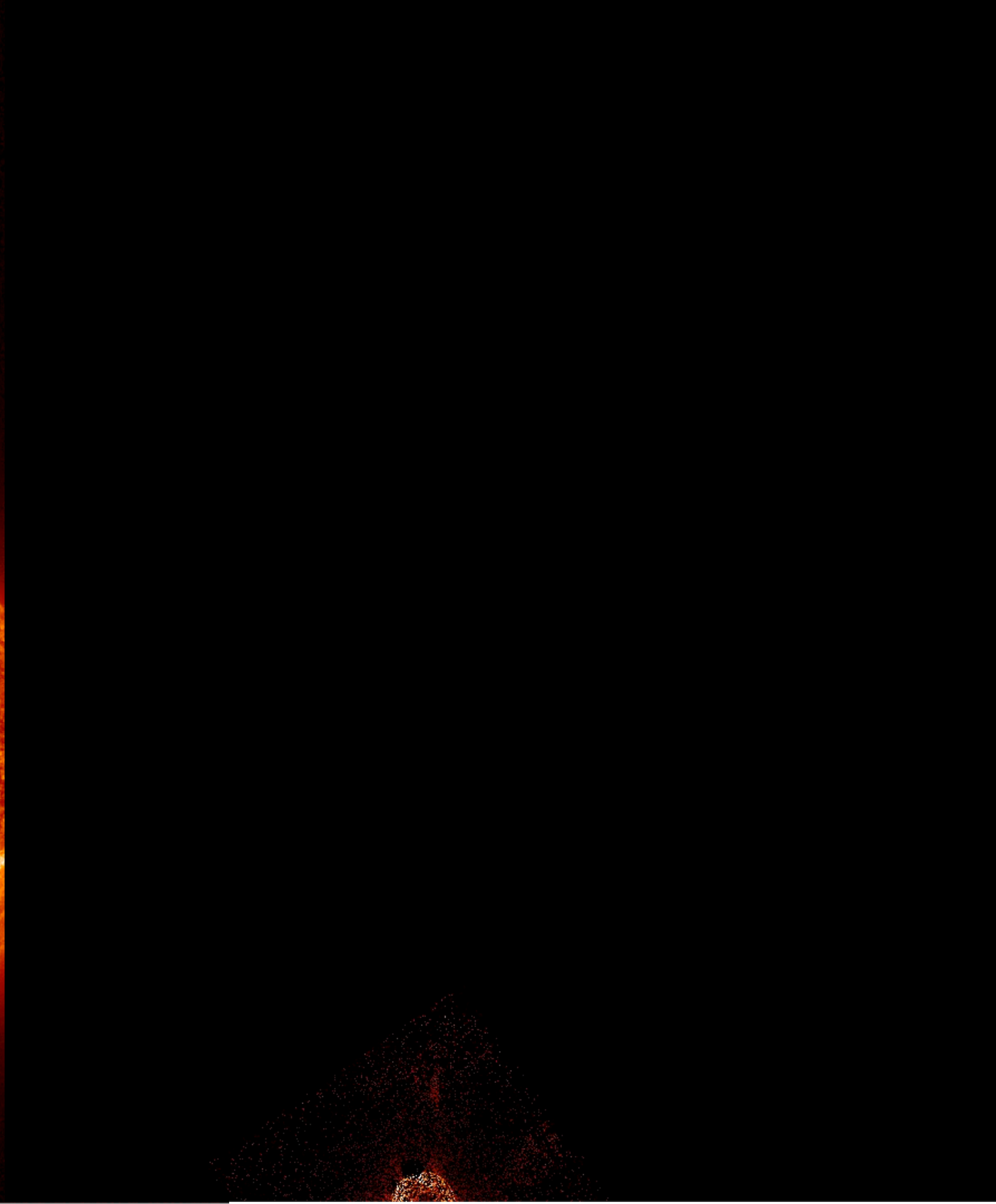
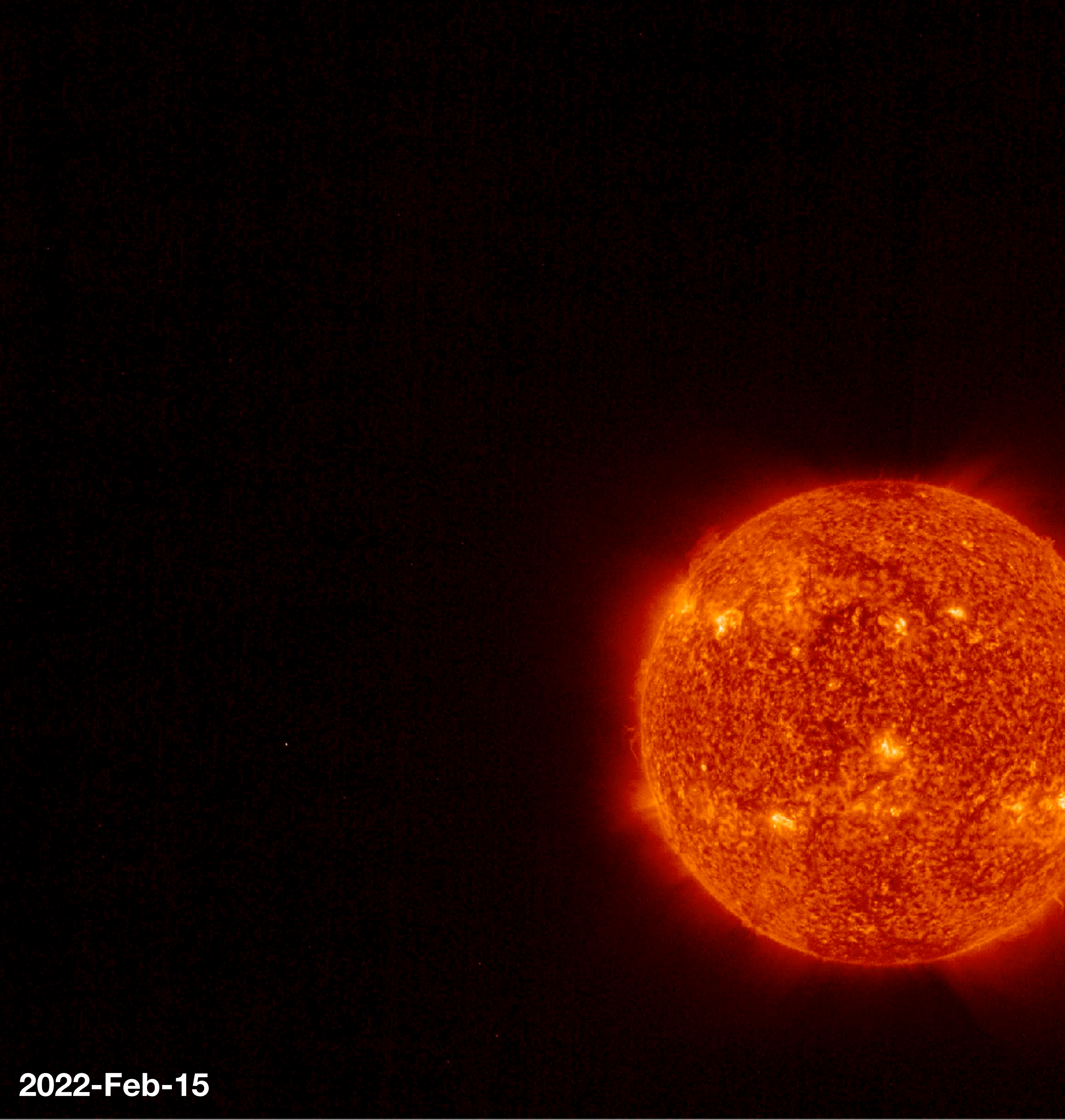
High
Resolution
Lyman-a



2022-Feb-15

2022-Feb-15





2022-Feb-15

5x5 Mosaic image made by HRIEUV telescope of EUI on 2022 March 7 Solar Orbiter was halfway the Earth-Sun line

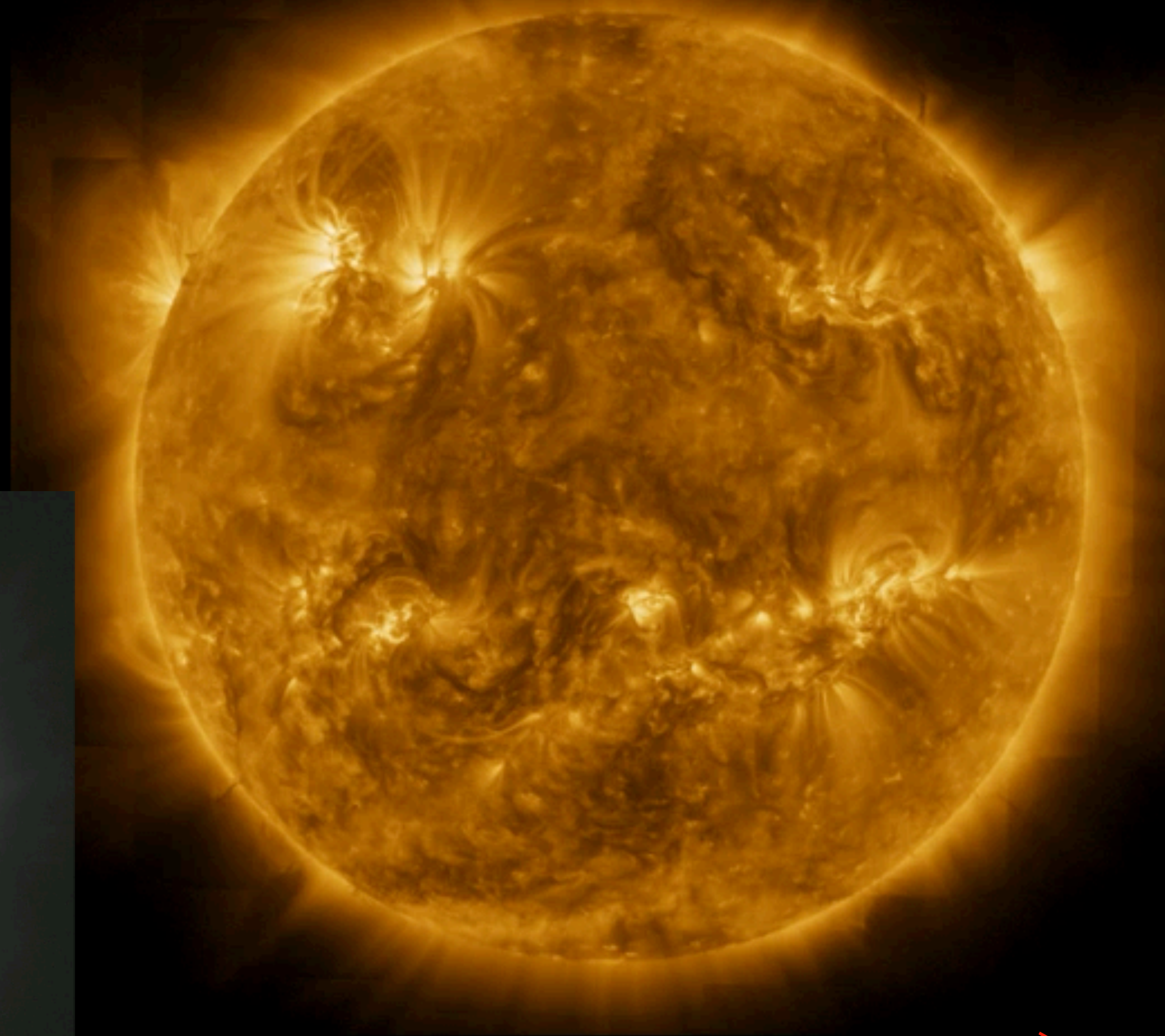
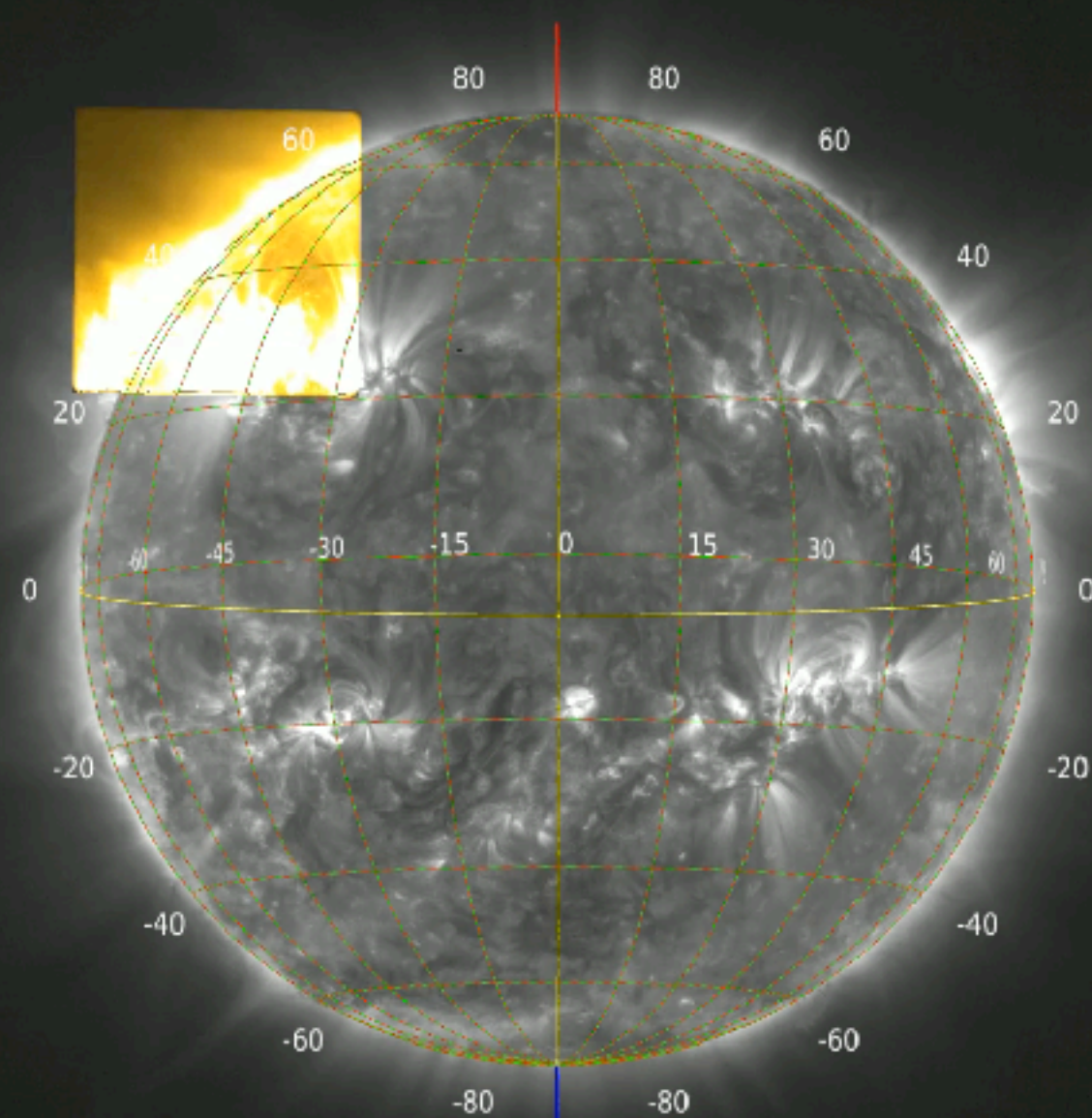


Image processing by Emil Kraaikamp (ROB)
ESA&NASA/Solar Orbiter/EUI team



2022-03-07T07:01:36.640

Forbes

SCIENCE


See The Jaw-Dropping New 83 Megapixel Photo Of The Sun Sent Back From A Spacecraft Halfway There

Jamie Carter Senior Contributor @
I inspire people to go stargazing, watch the Moon, enjoy the night sky [Follow](#)

Apr 2, 2022, 04:51am EDT

[Listen to article 3 minutes](#)

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[t](#)
[in](#)



The European Space Agency's Solar Orbiter has returned an incredible 83 megapixel image of the Sun.

CC BY/ATC MEDIALAB

[Cookies on Forbes](#)

If you only look at one "space photo" this year then this one *has* to be it.

5x5 Mosaic image made by HRIEUV telescope of EUI on 2022 March 7
Solar Orbiter was halfway the Earth-Sun line

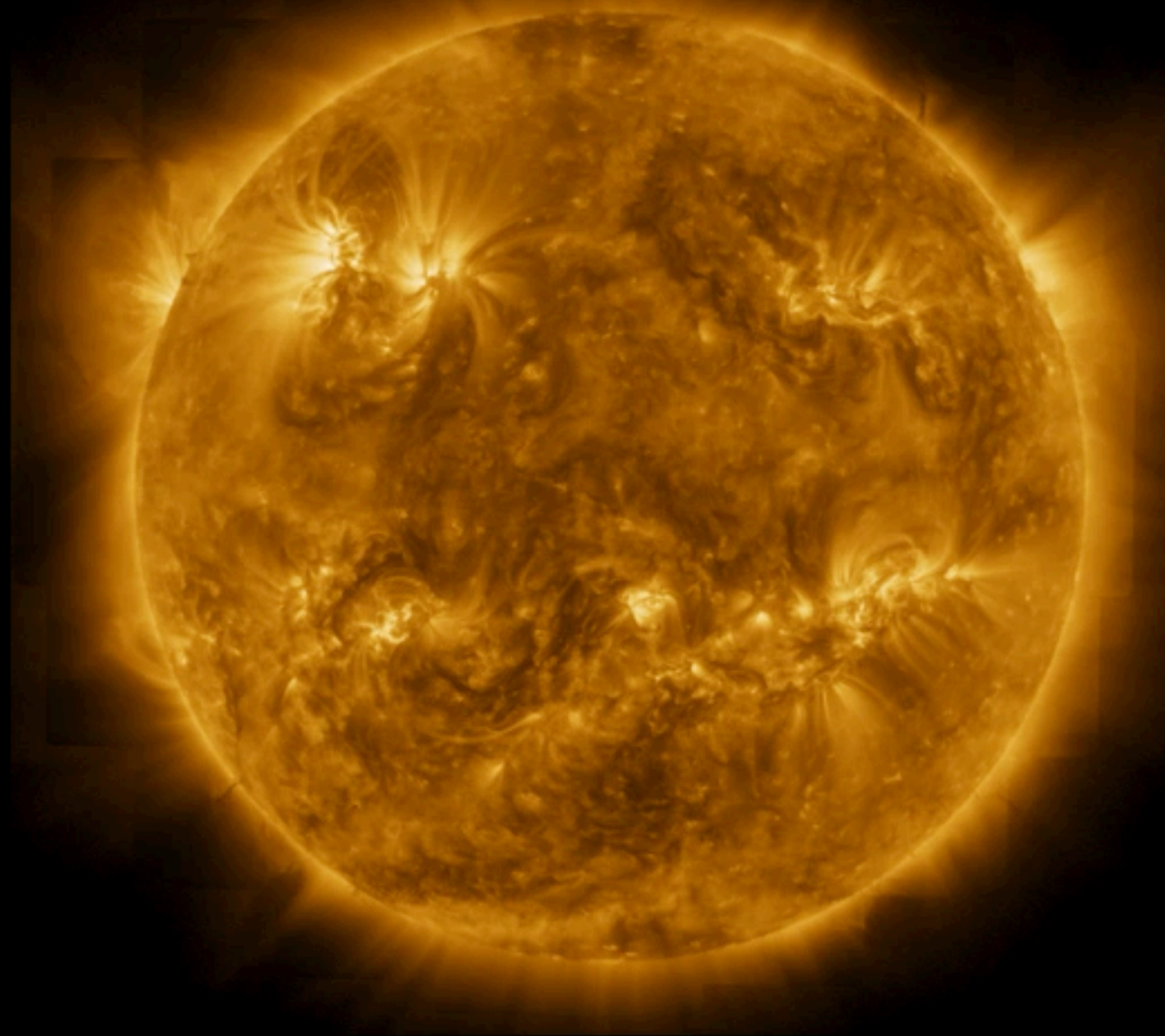
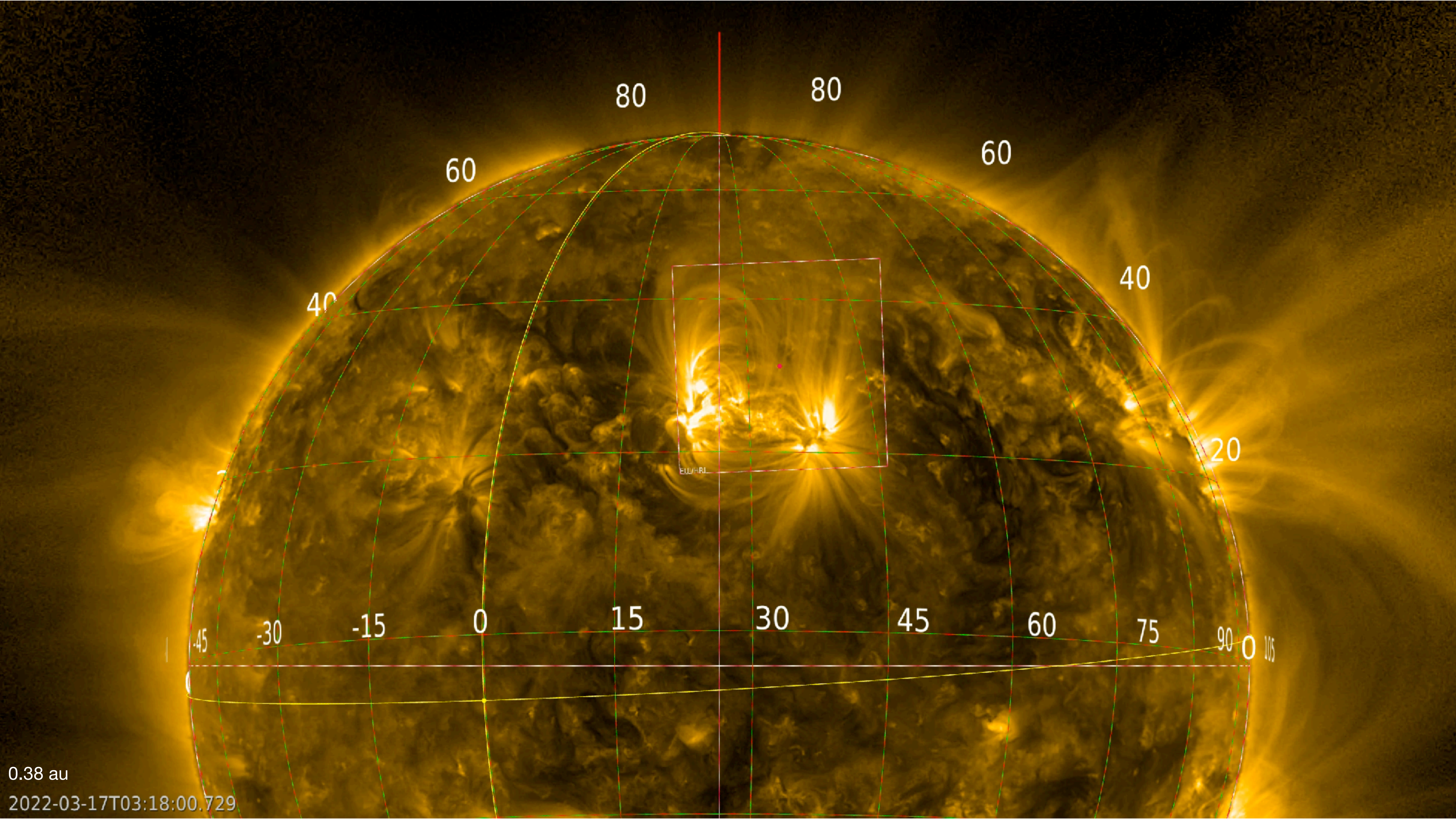
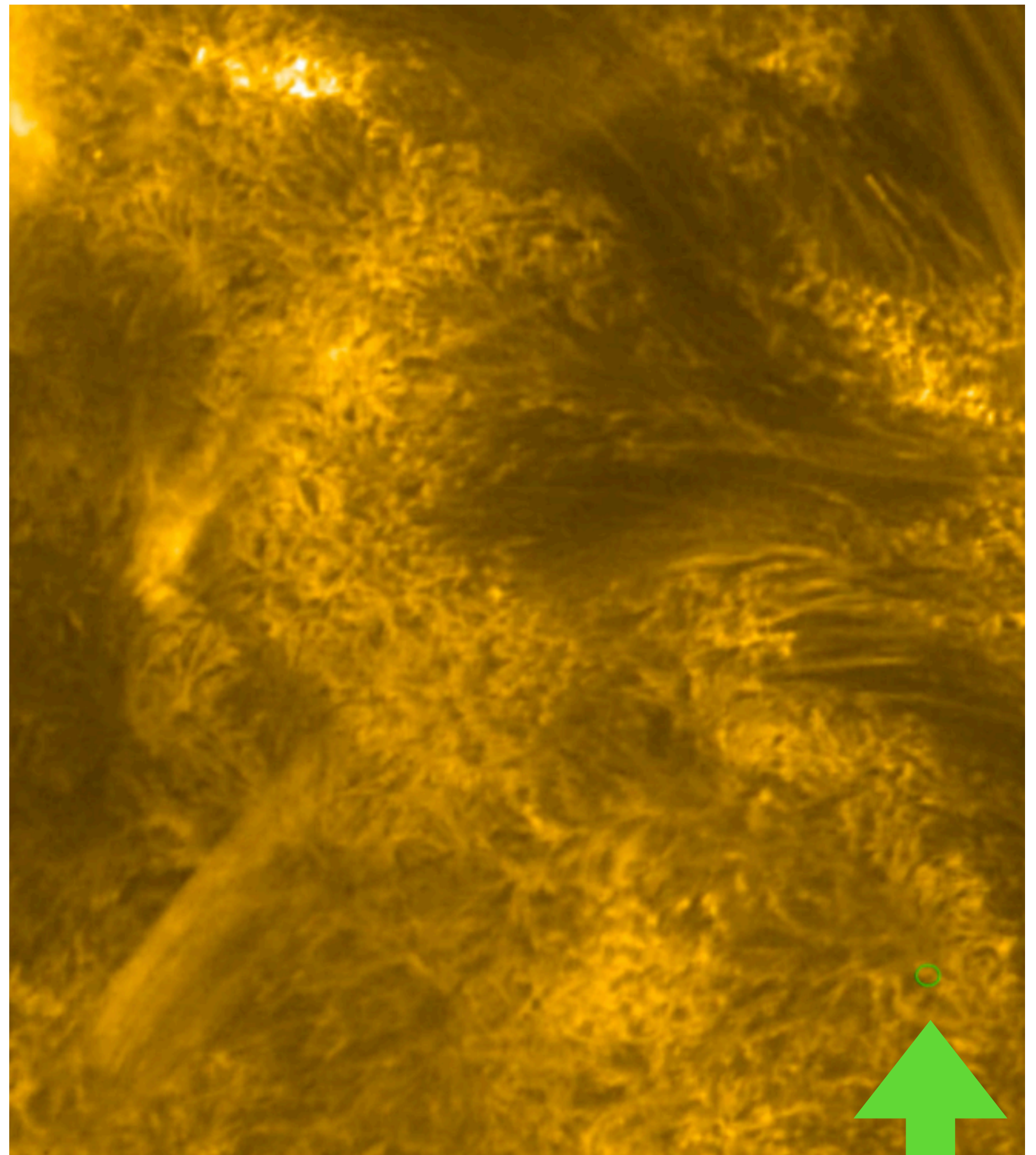


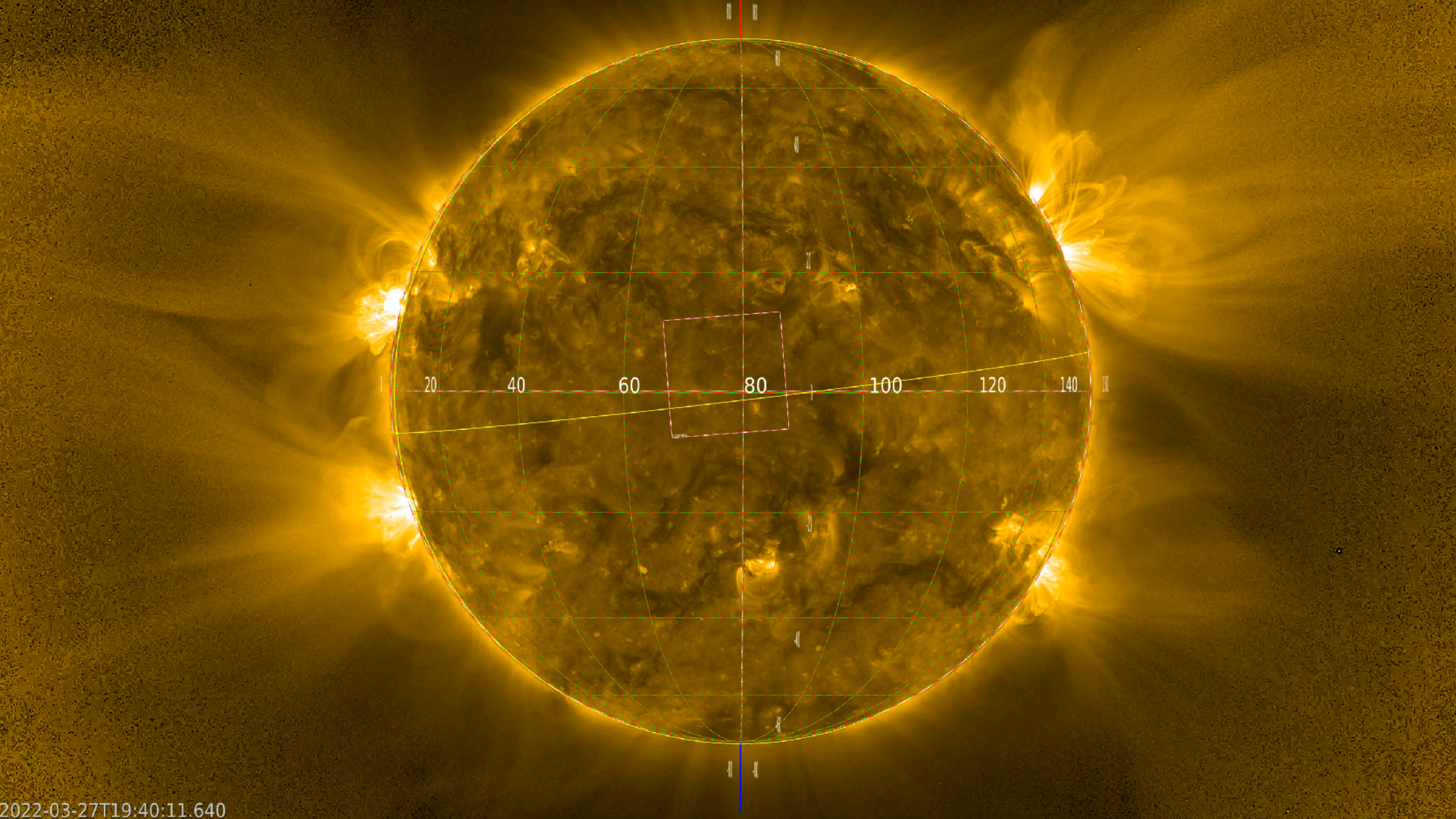
Image processing by Emil Kraaikamp (ROB)
ESA&NASA/Solar Orbiter/EUI team





1000 km = 1 Mm





20

40

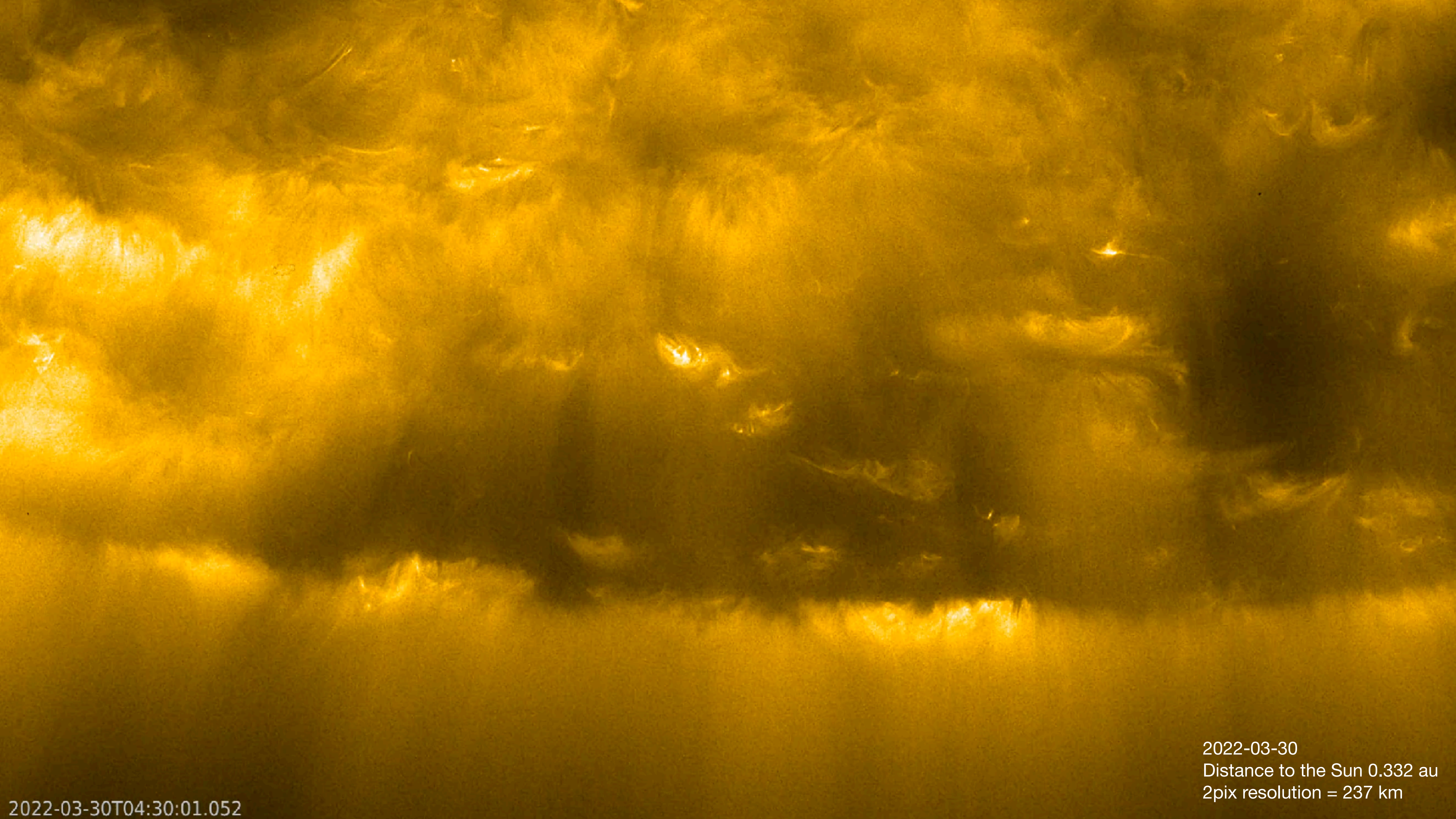
60

80

100

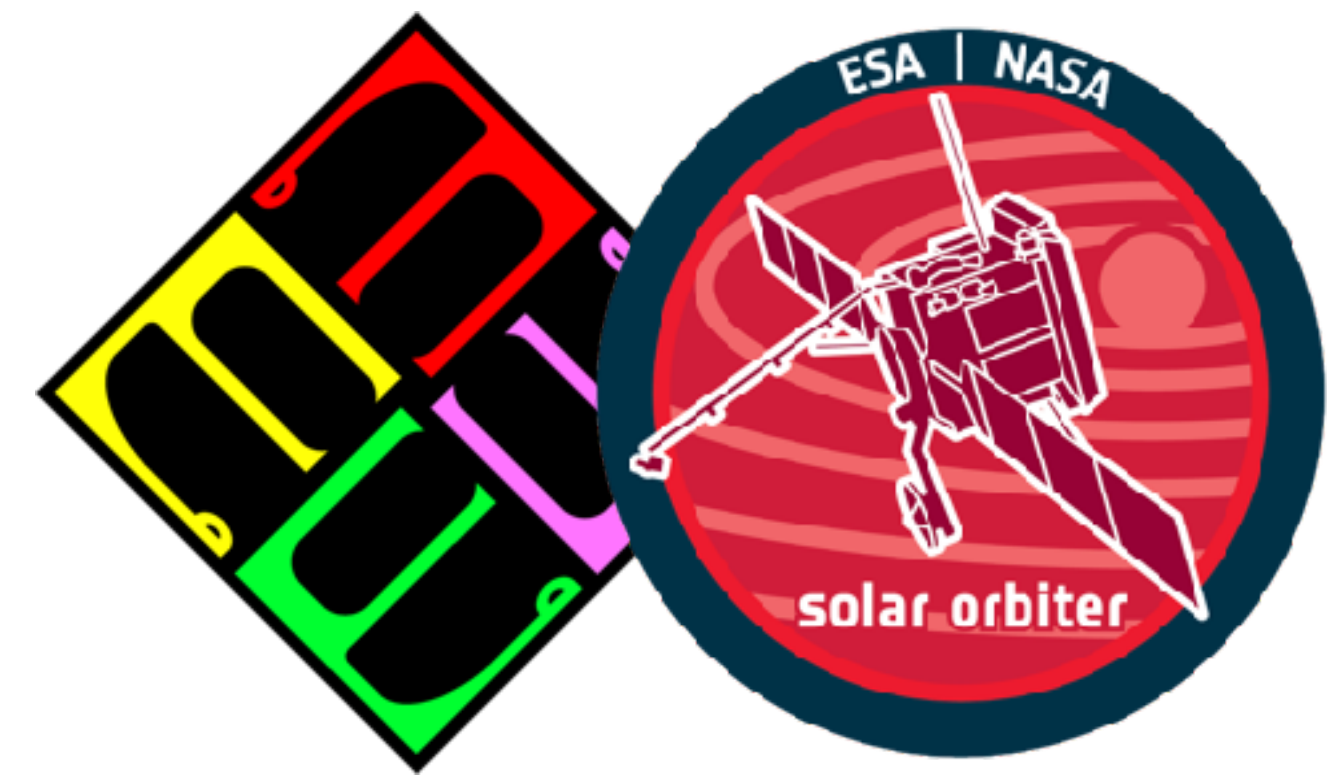
120

140



2022-03-30T04:30:01.052

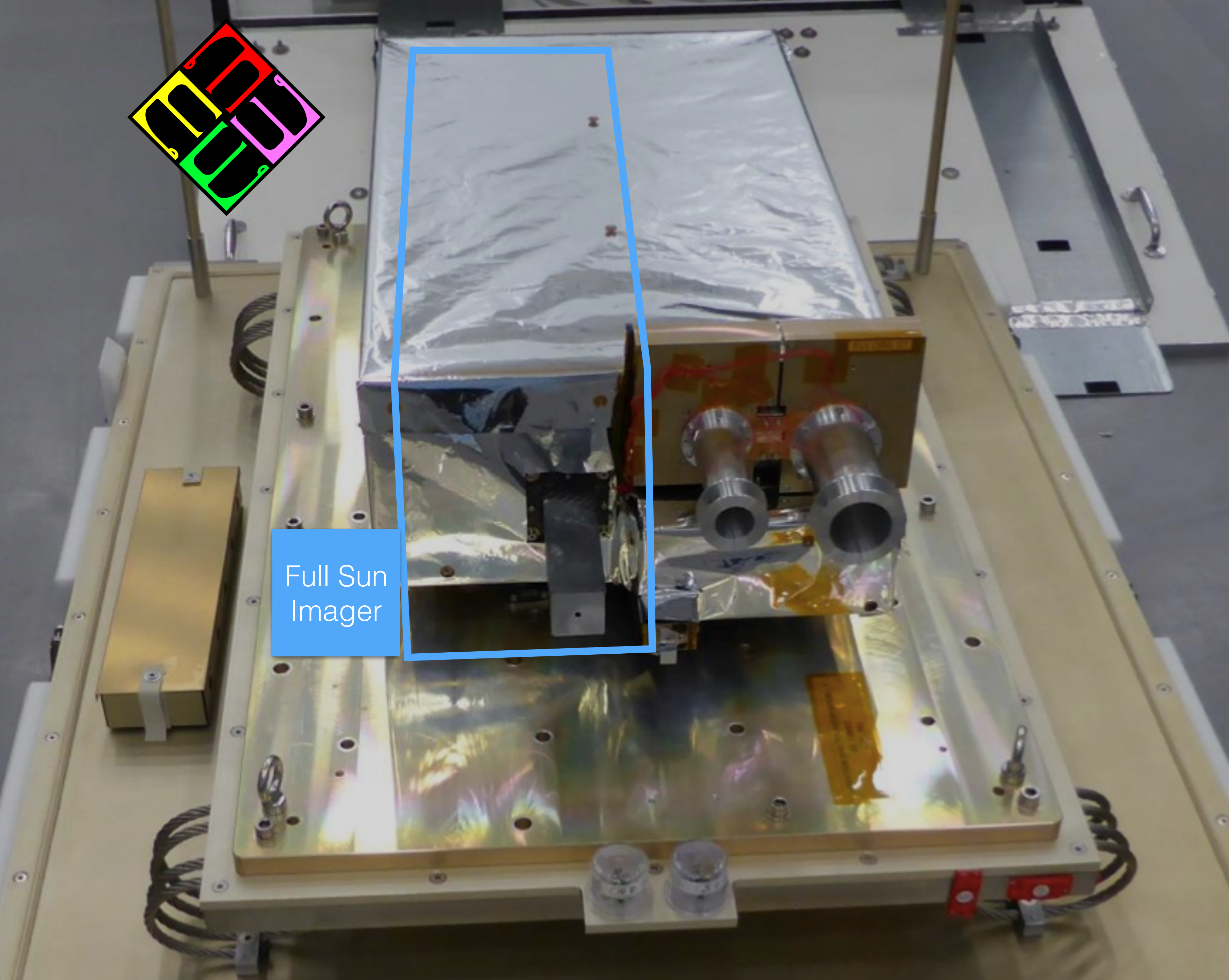
2022-03-30
Distance to the Sun 0.332 au
2pix resolution = 237 km



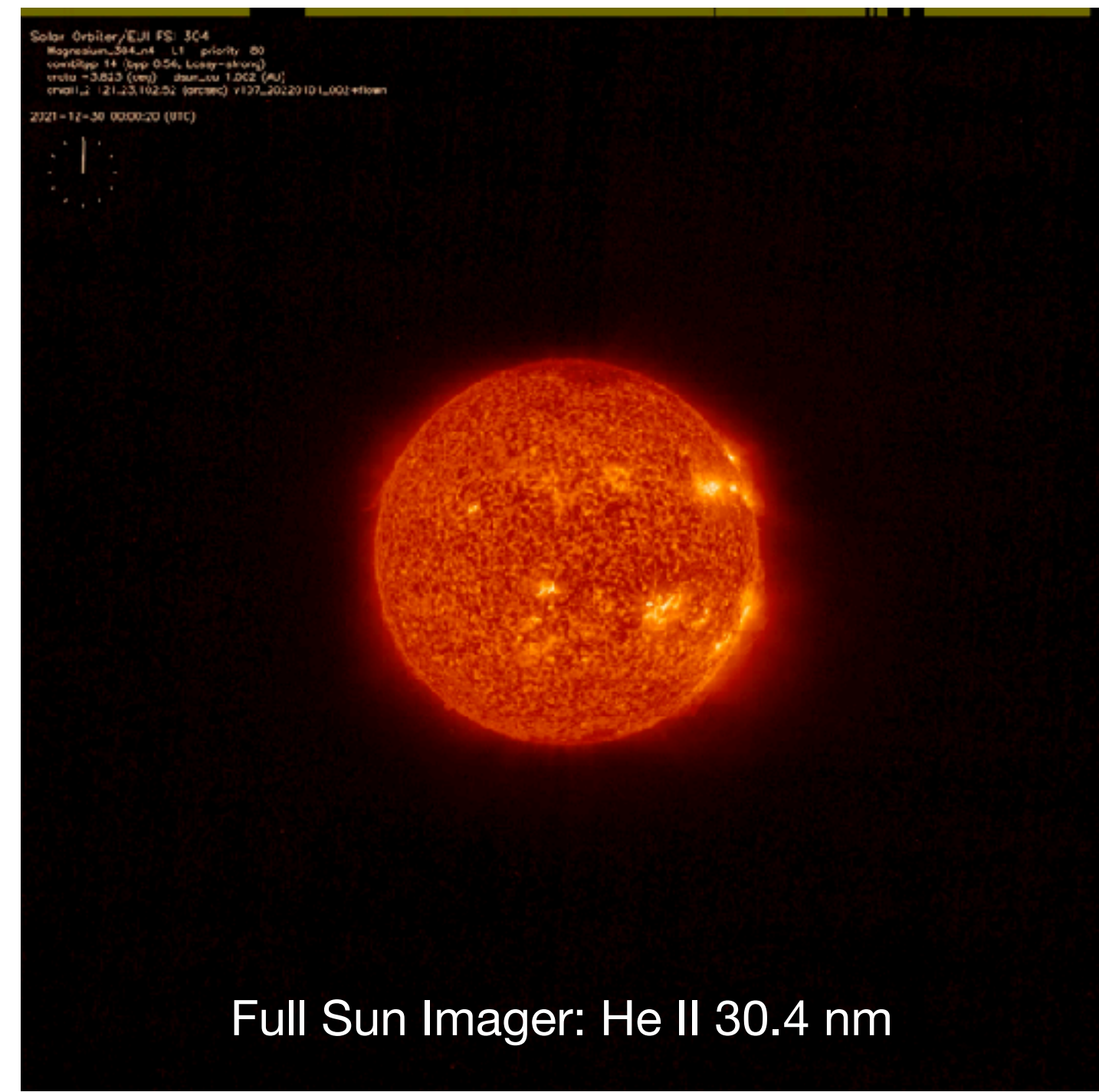
Thanks



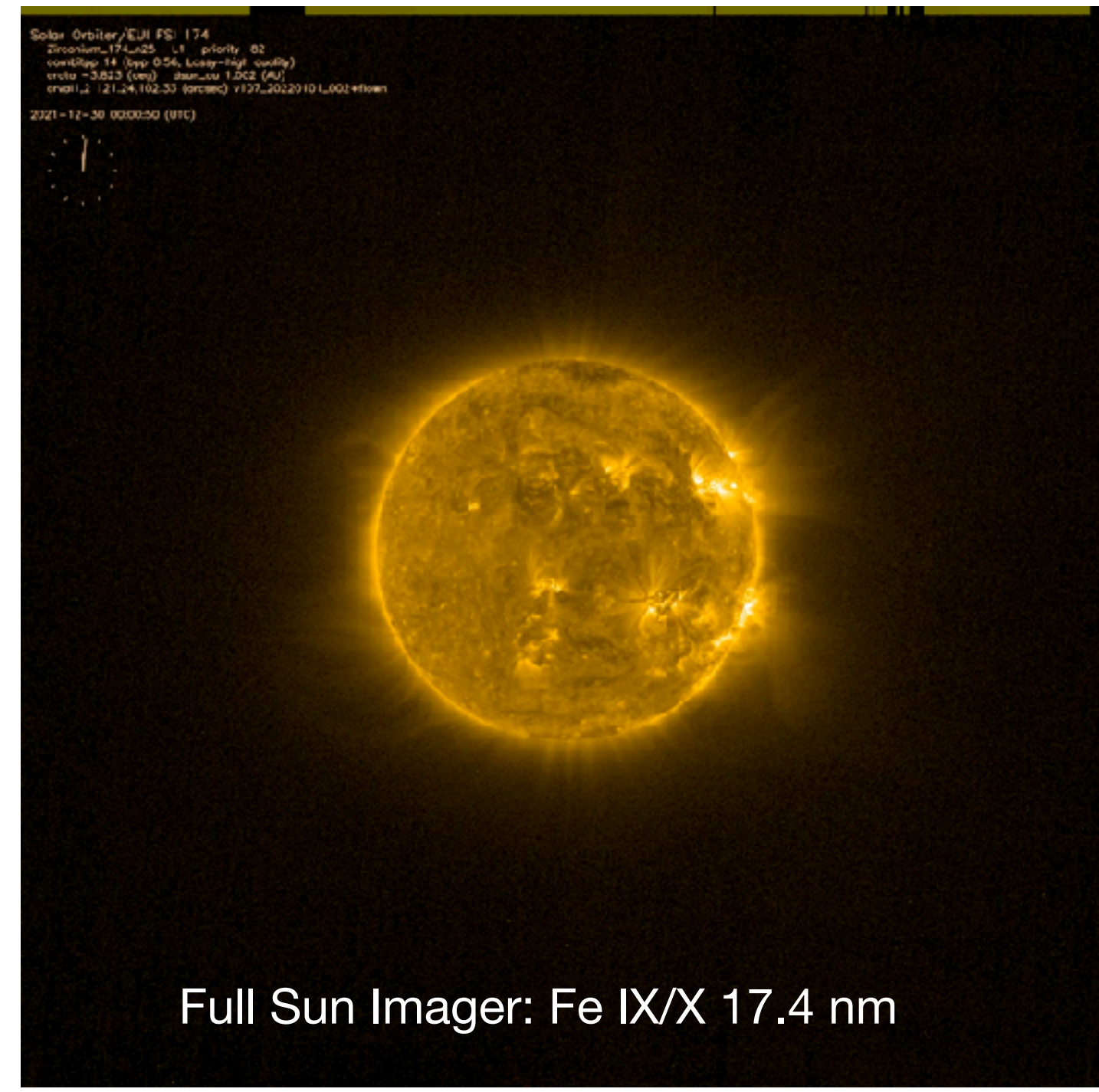




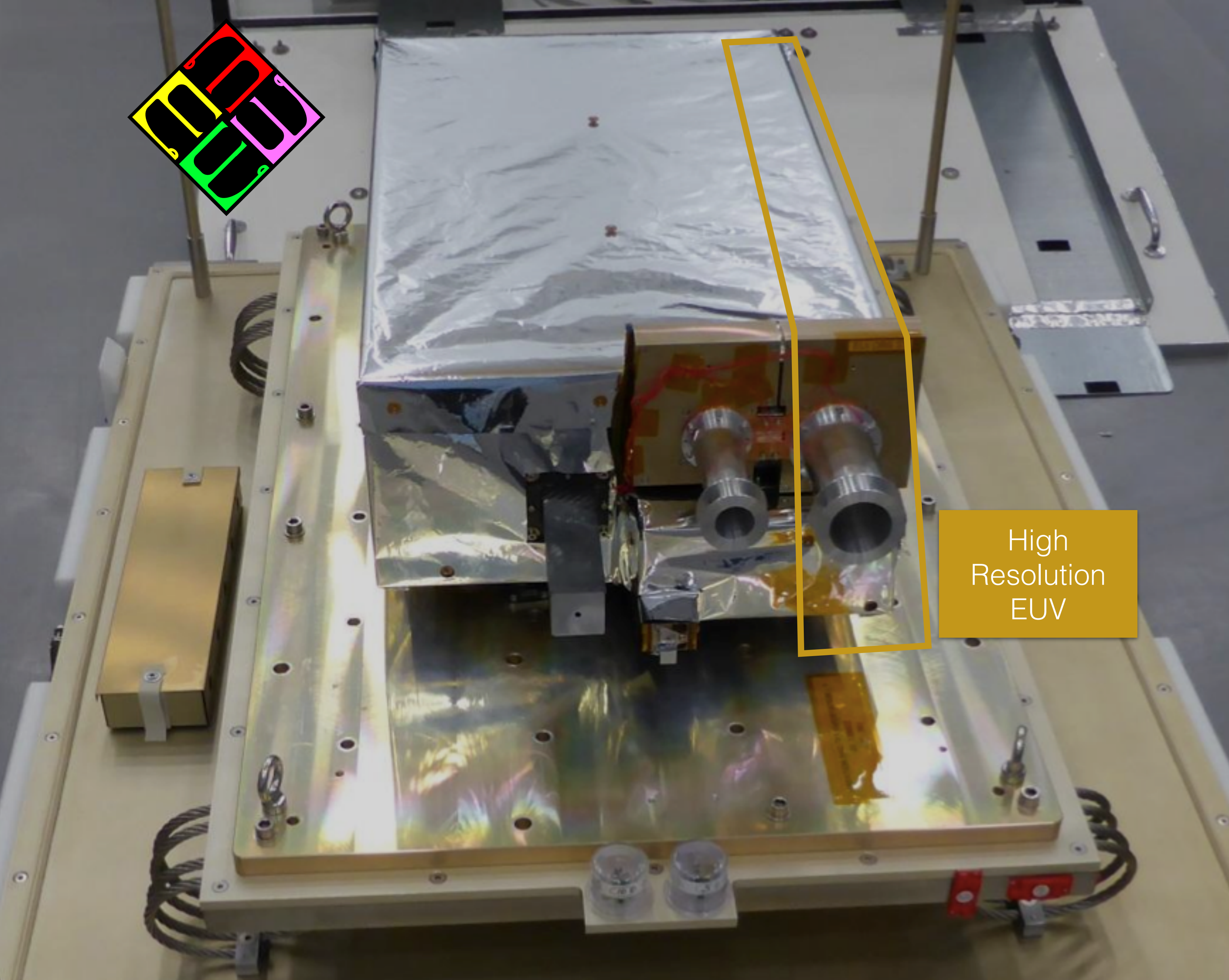
Full Sun Imager



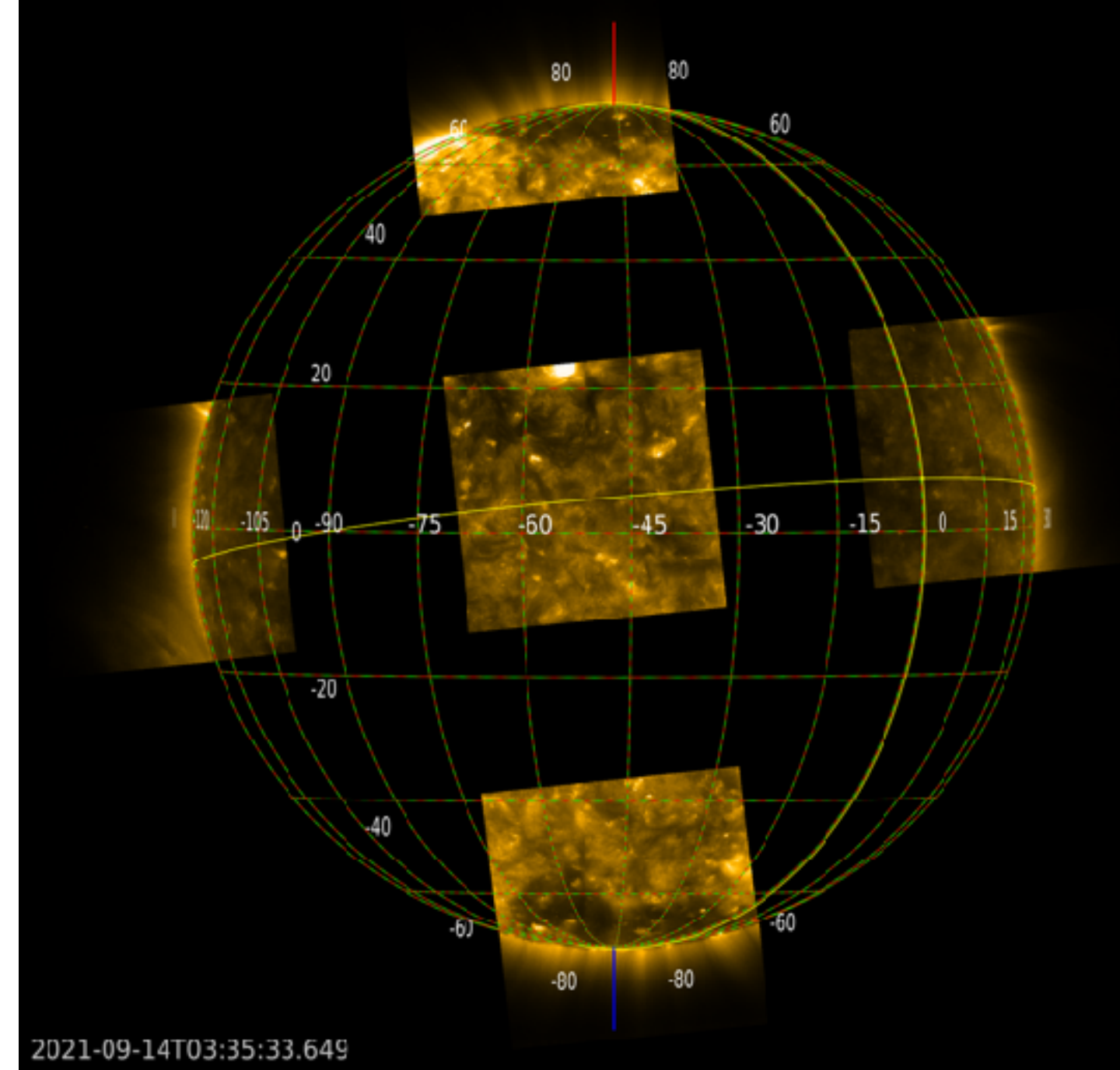
Full Sun Imager: He II 30.4 nm



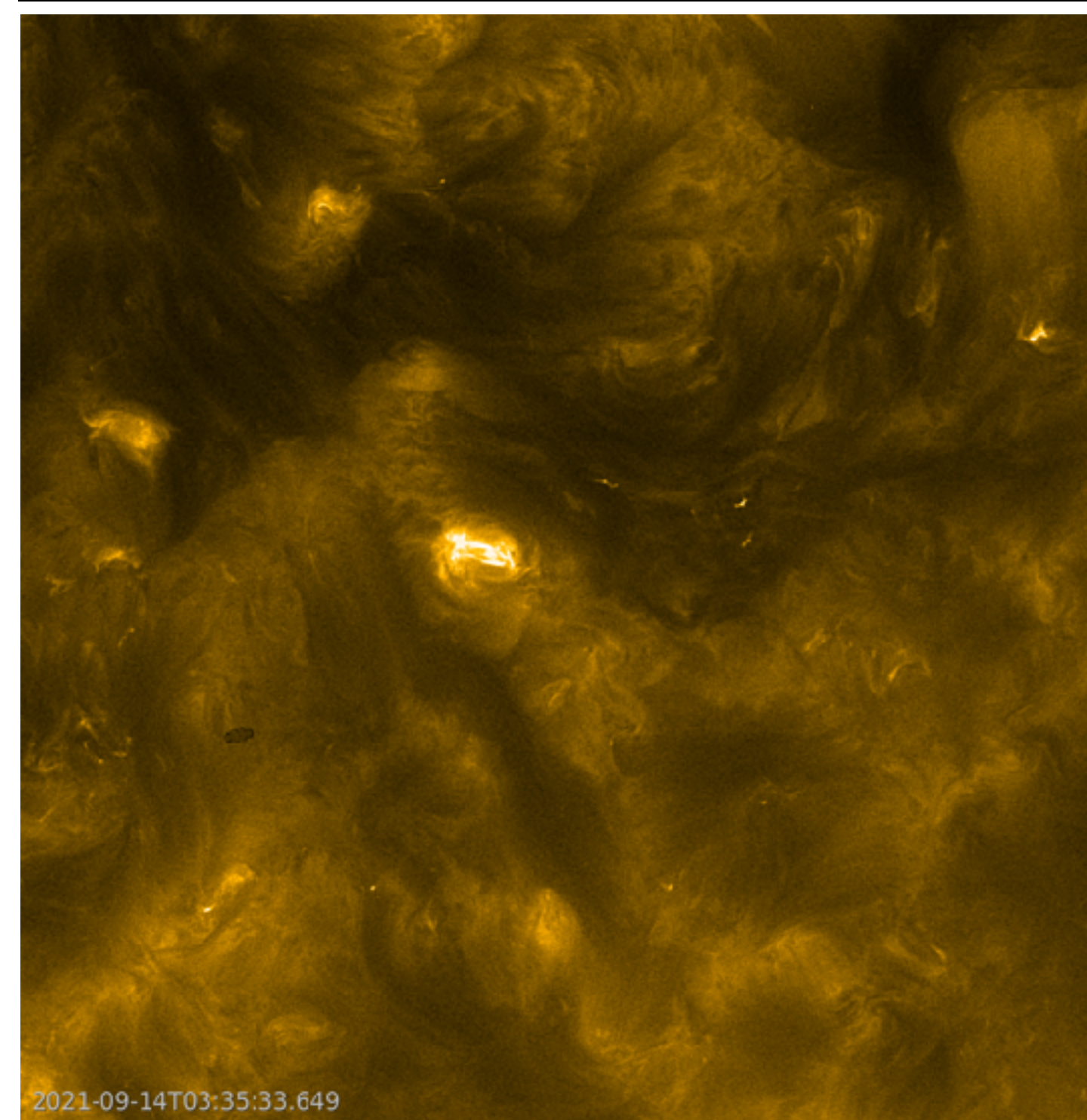
Full Sun Imager: Fe IX/X 17.4 nm



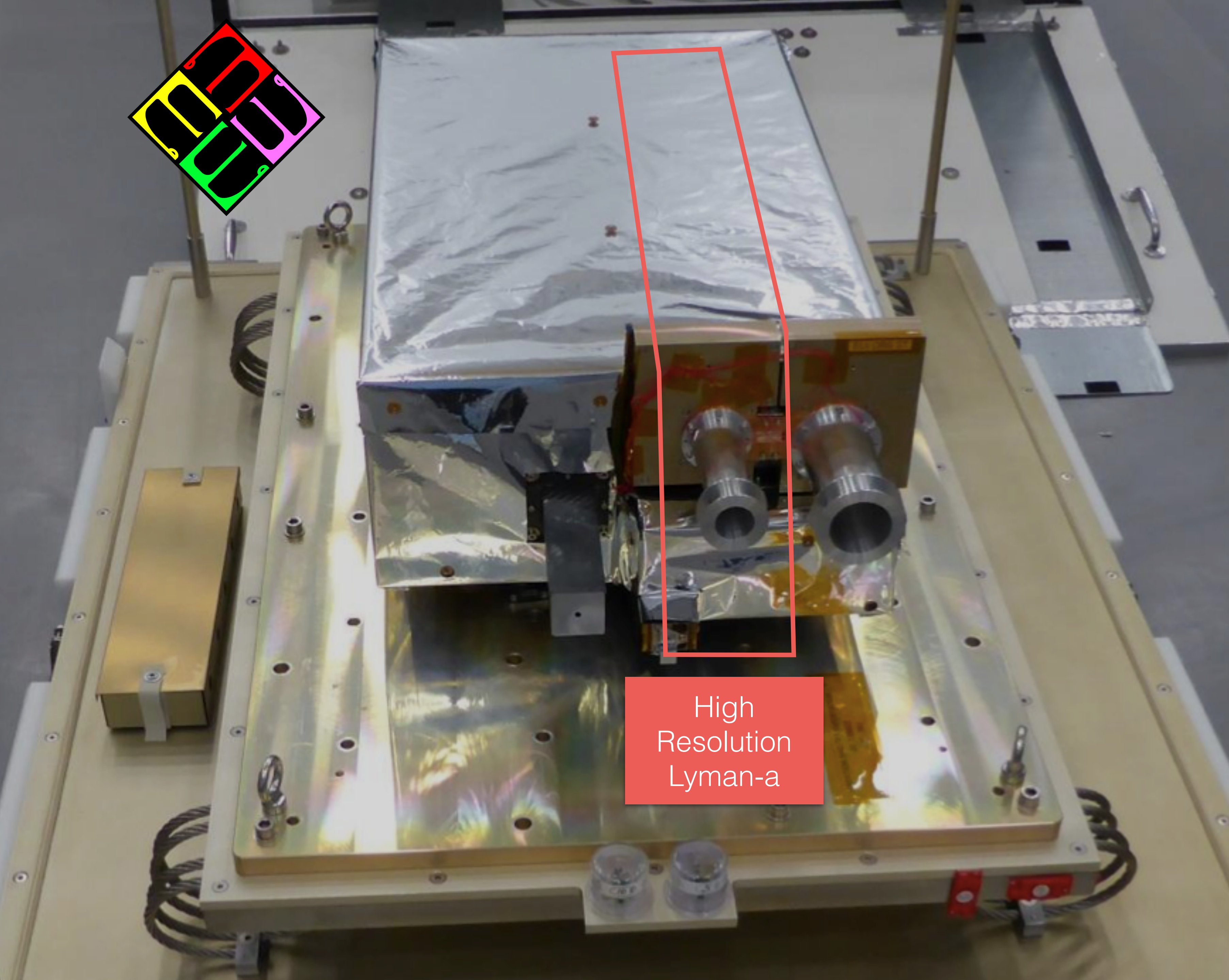
High Resolution EUV



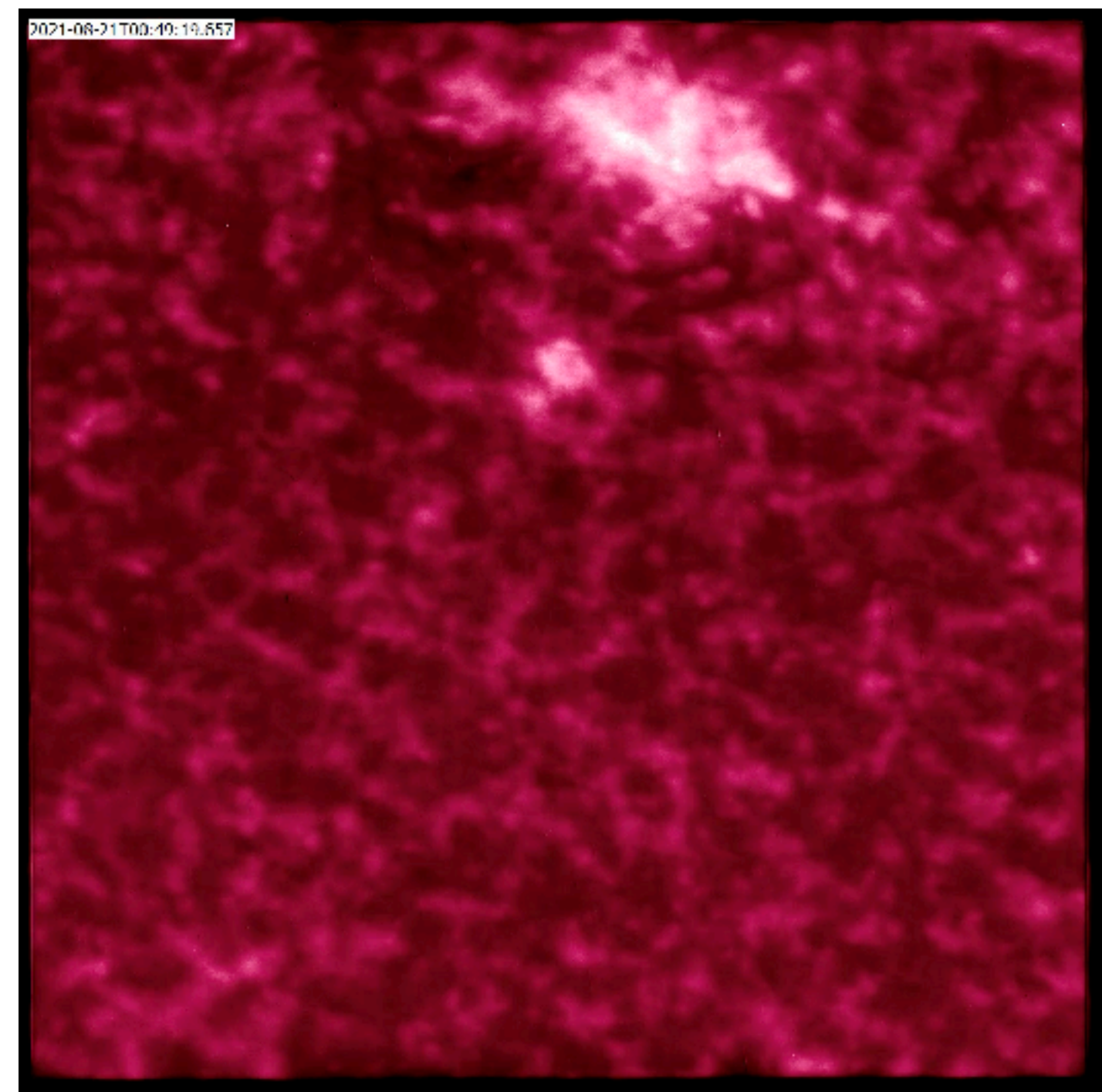
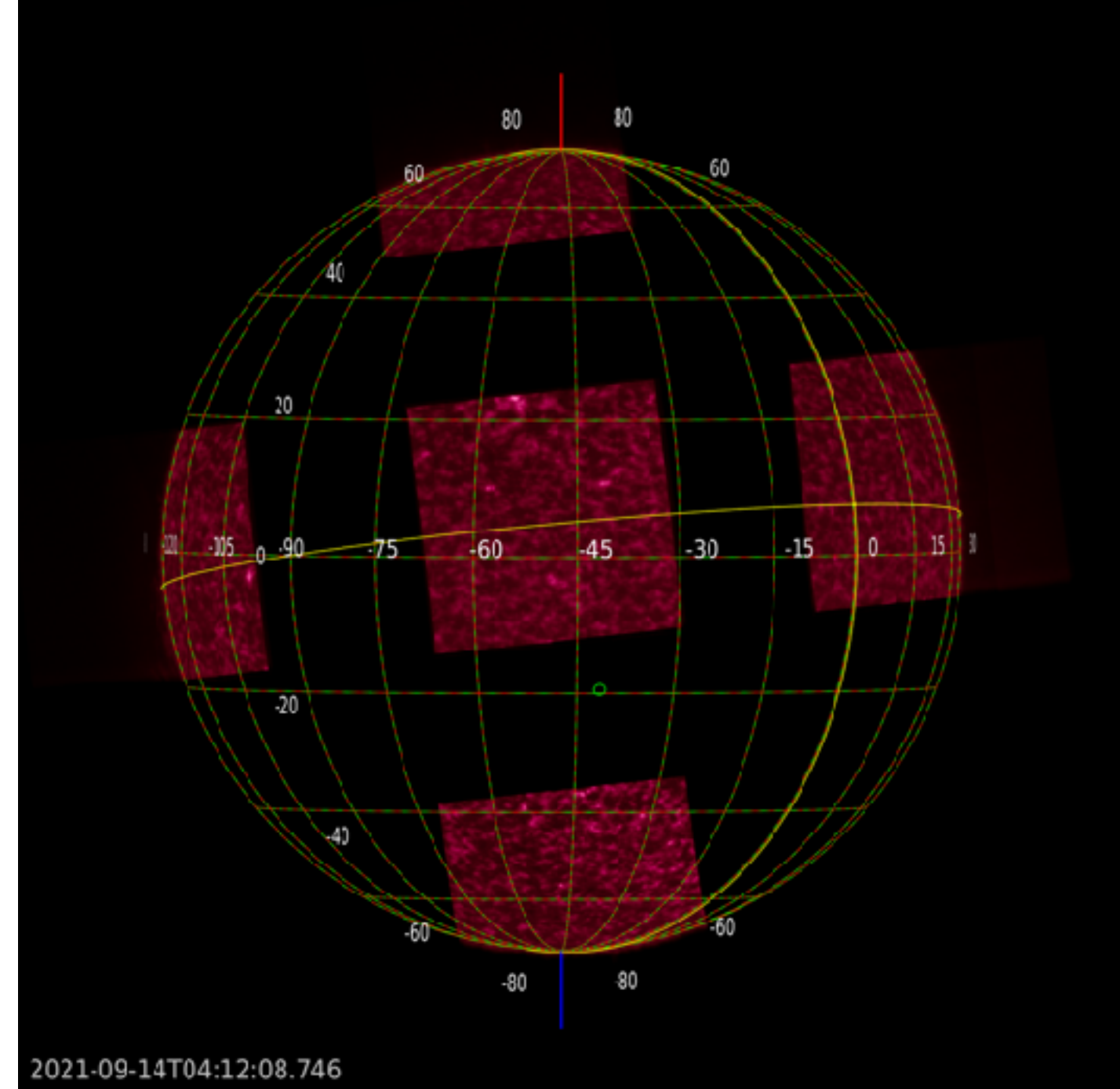
2021-09-14T03:35:33.649

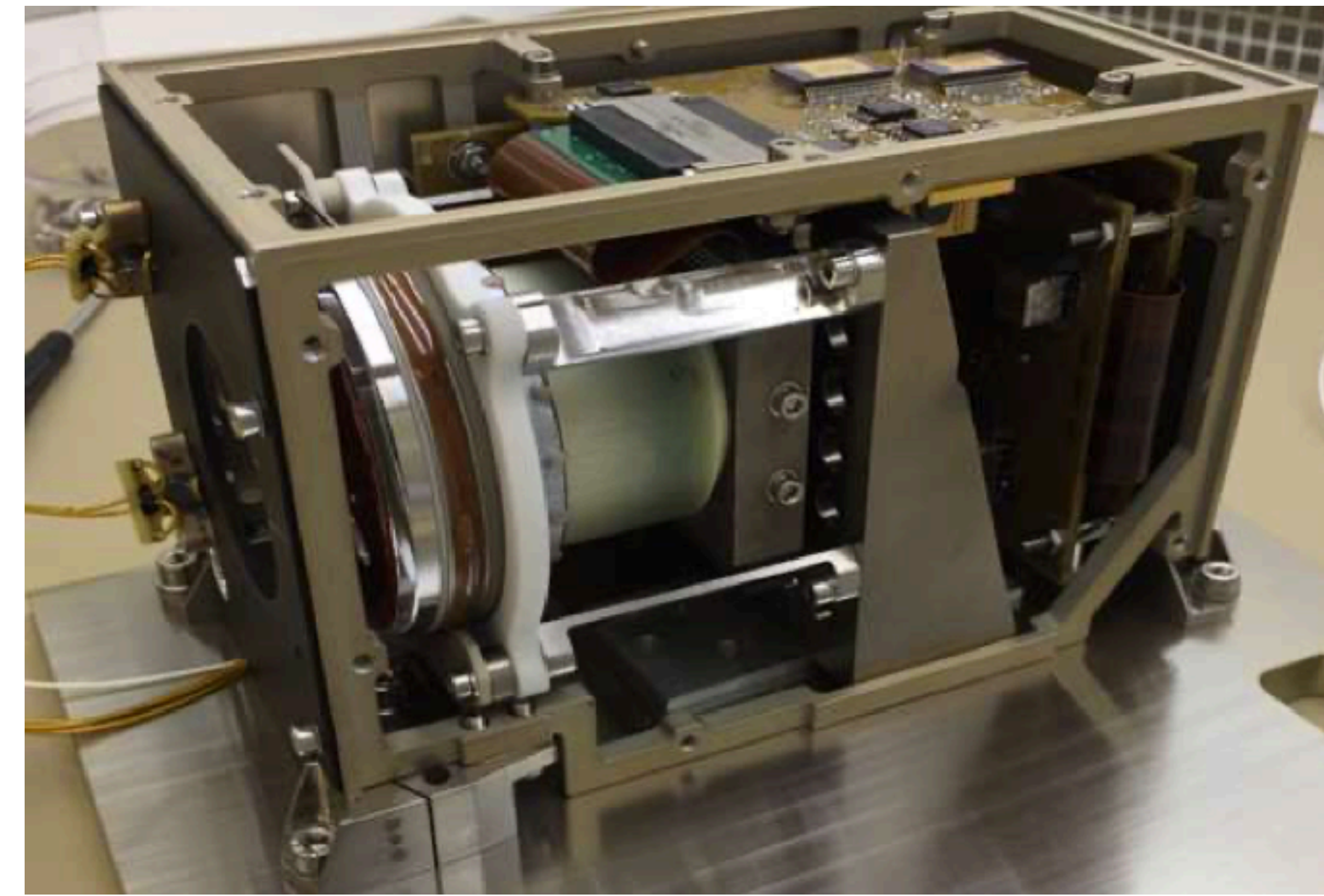
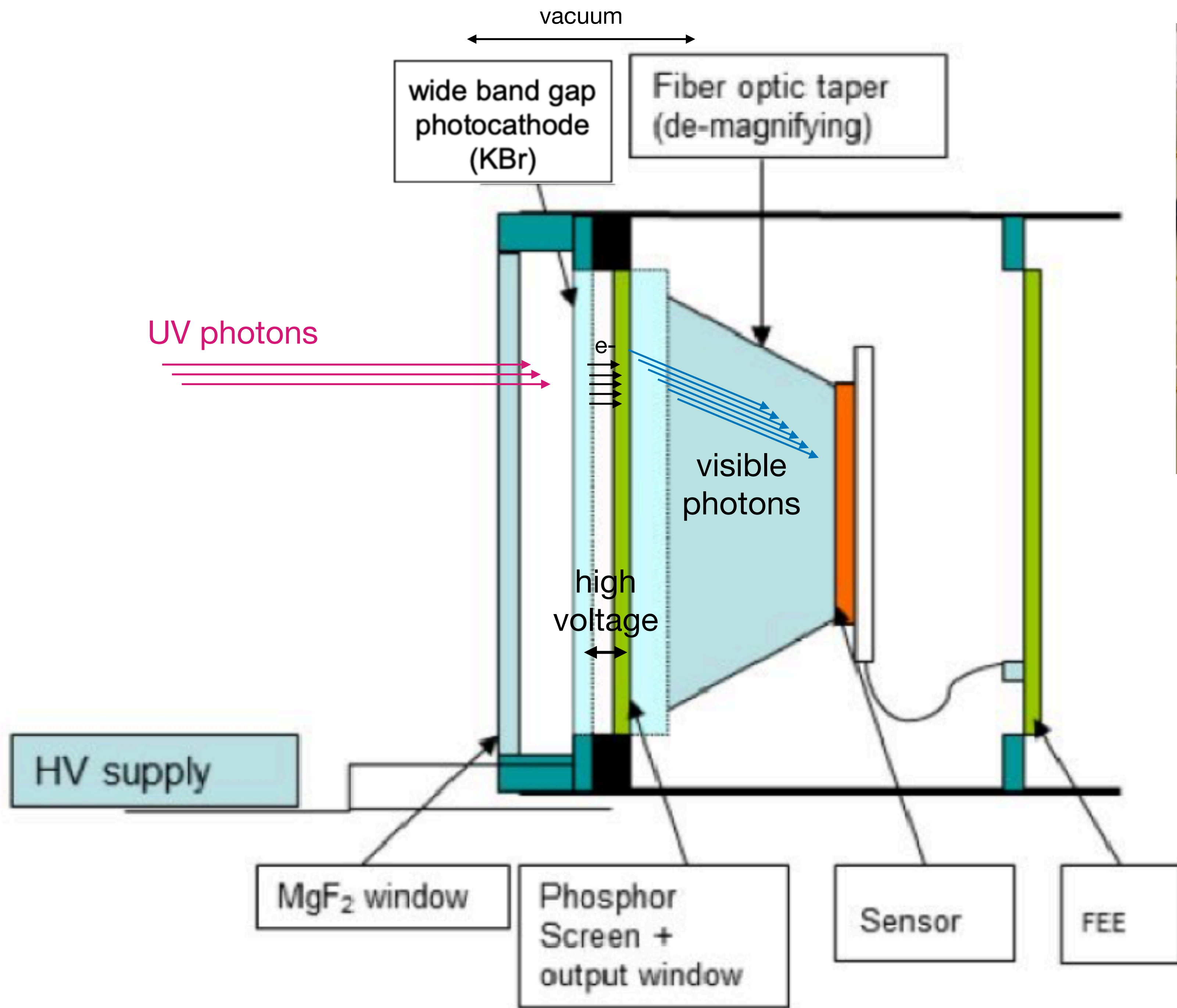


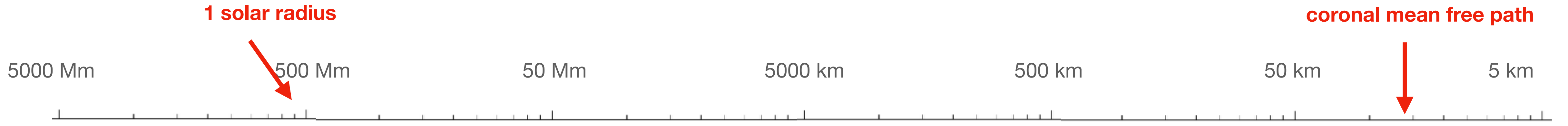
2021-09-14T03:35:33.649



High Resolution Lyman-a



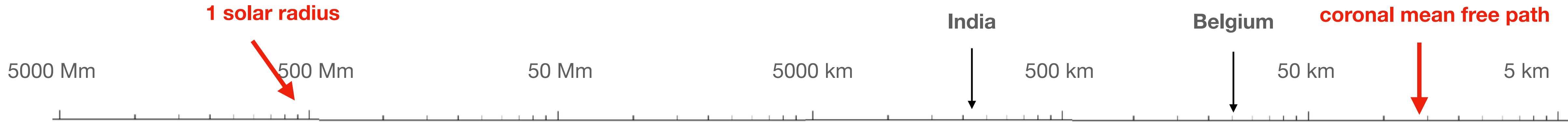




**Solar-Terrestrial
Physics**

Space Weather

**Kinetic
Plasma
physics**



**Solar-Terrestrial
Physics**

Space Weather

**Kinetic
Plasma
physics**



1 solar radius

coronal mean free path

5000 Mm

500 Mm

50 Mm

5000 km

500 km

50 km

5 km

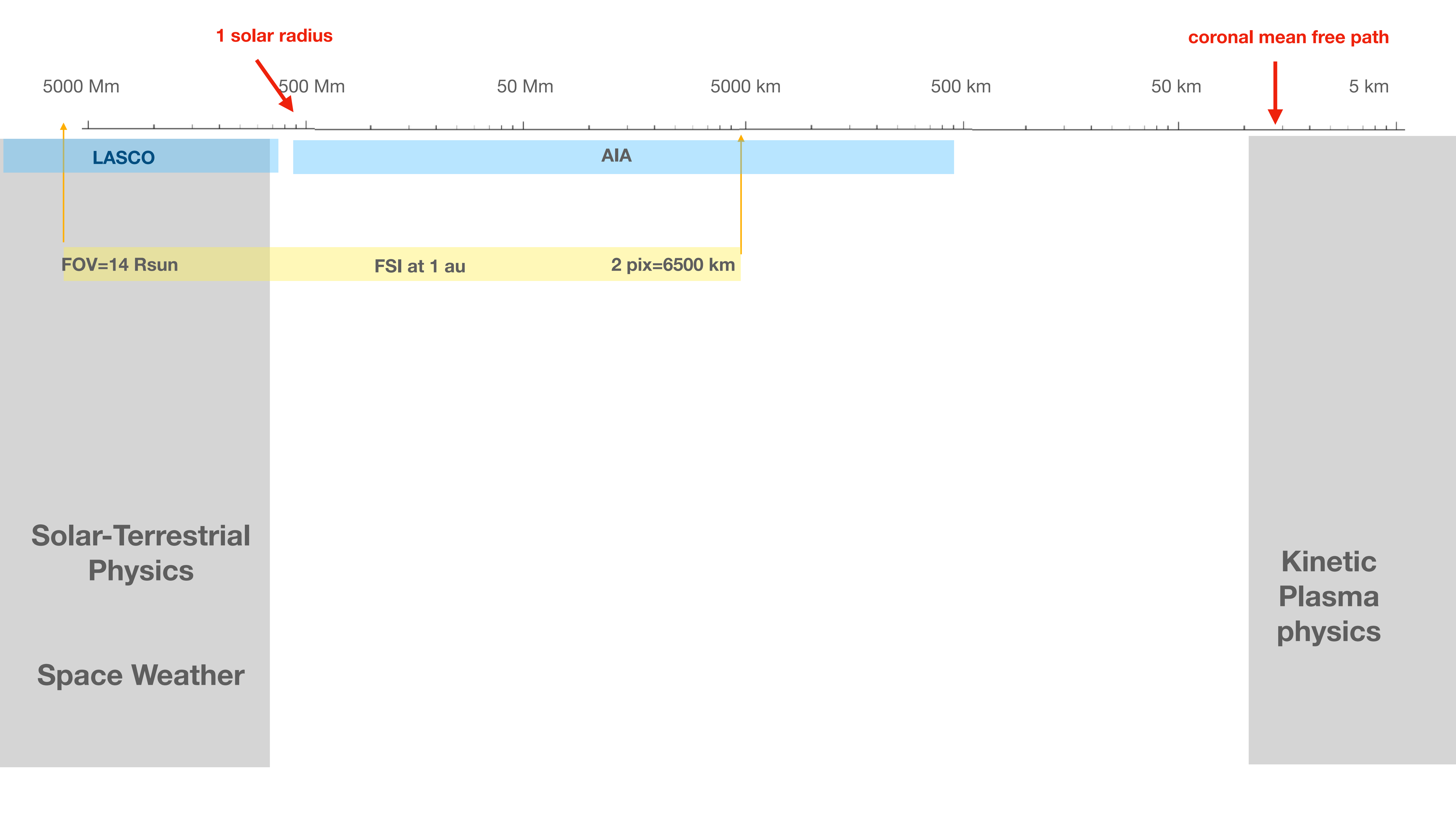
LASCO

AIA

Solar-Terrestrial
Physics

Space Weather

Kinetic
Plasma
physics



1 solar radius

coronal mean free path

5000 Mm

500 Mm

50 Mm

5000 km

500 km

50 km

5 km

LASCO

AIA

FOV=14 Rsun

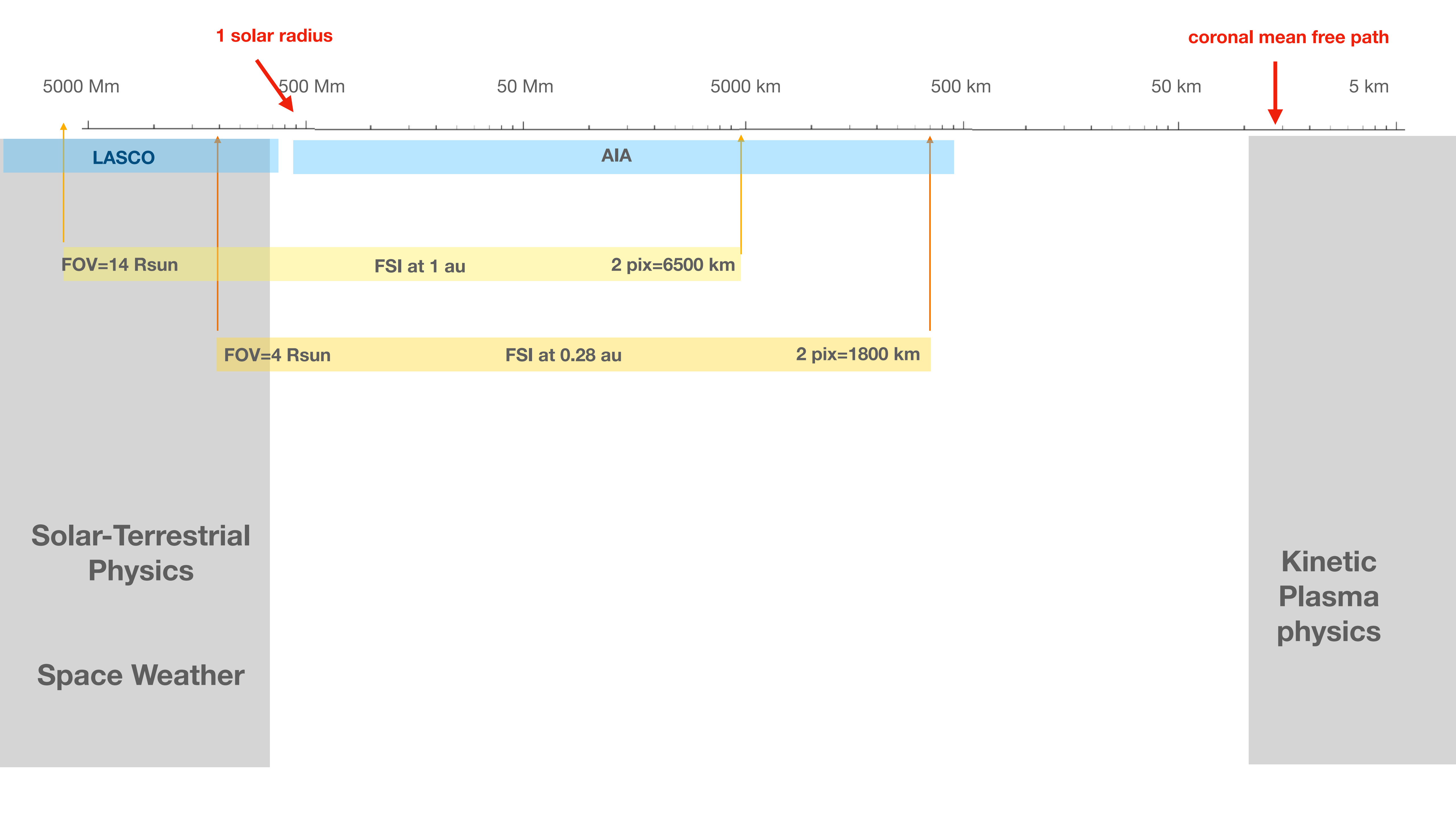
FSI at 1 au

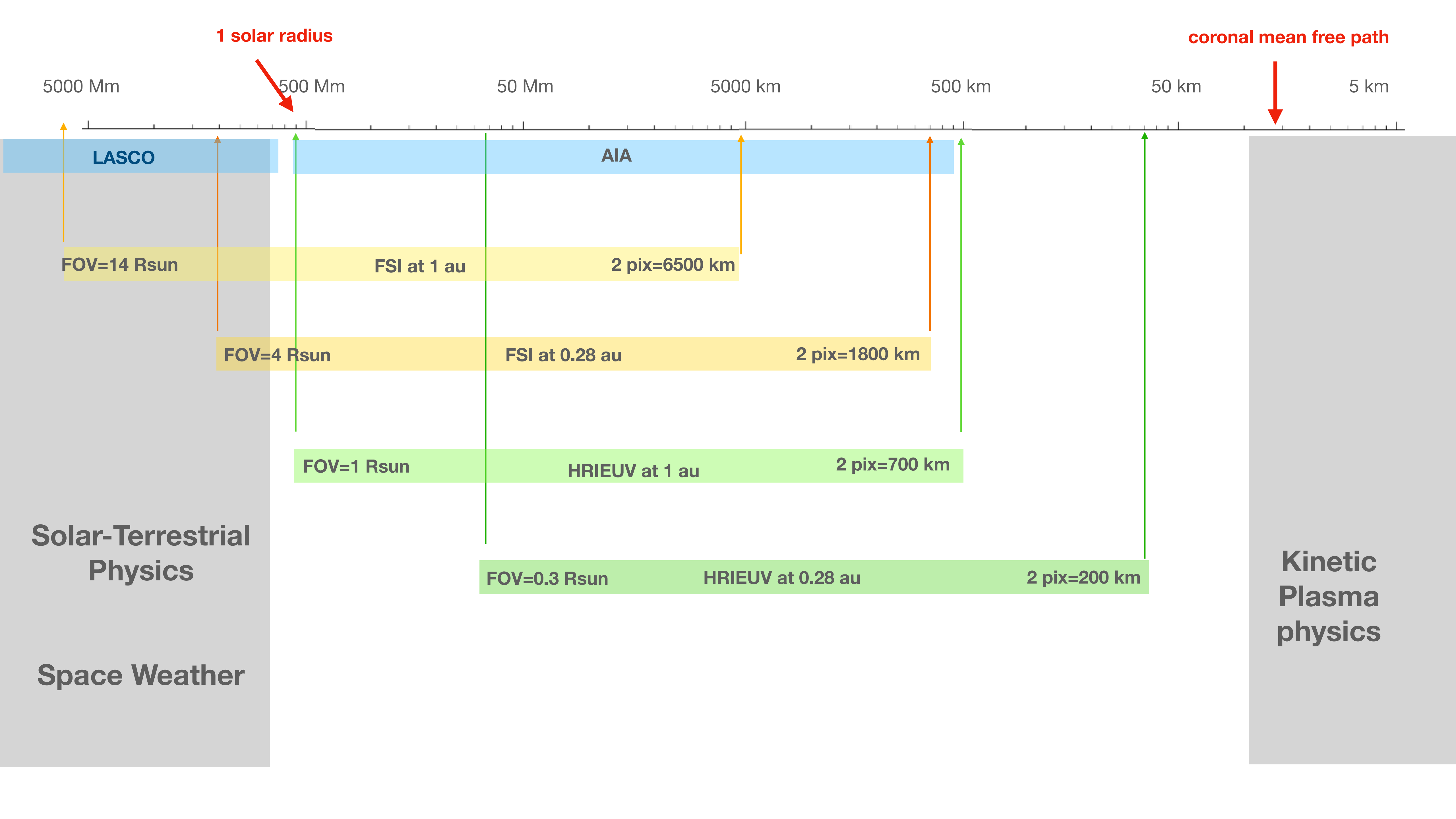
2 pix=6500 km

Solar-Terrestrial
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Space Weather

Kinetic
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physics





coronal mean free path

50 Mm

5000 km

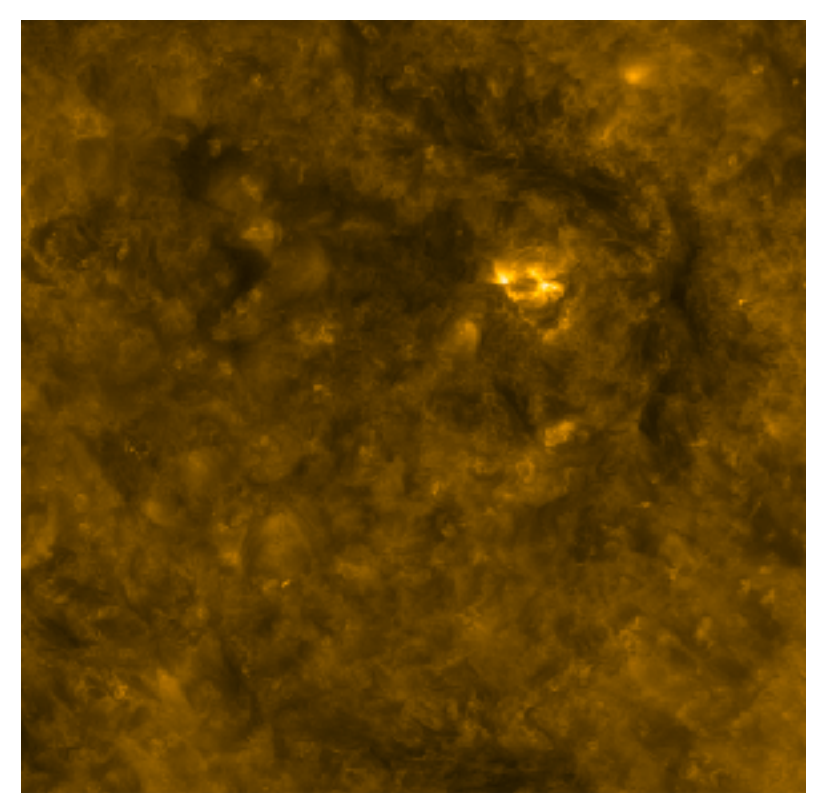
500 km

50 km

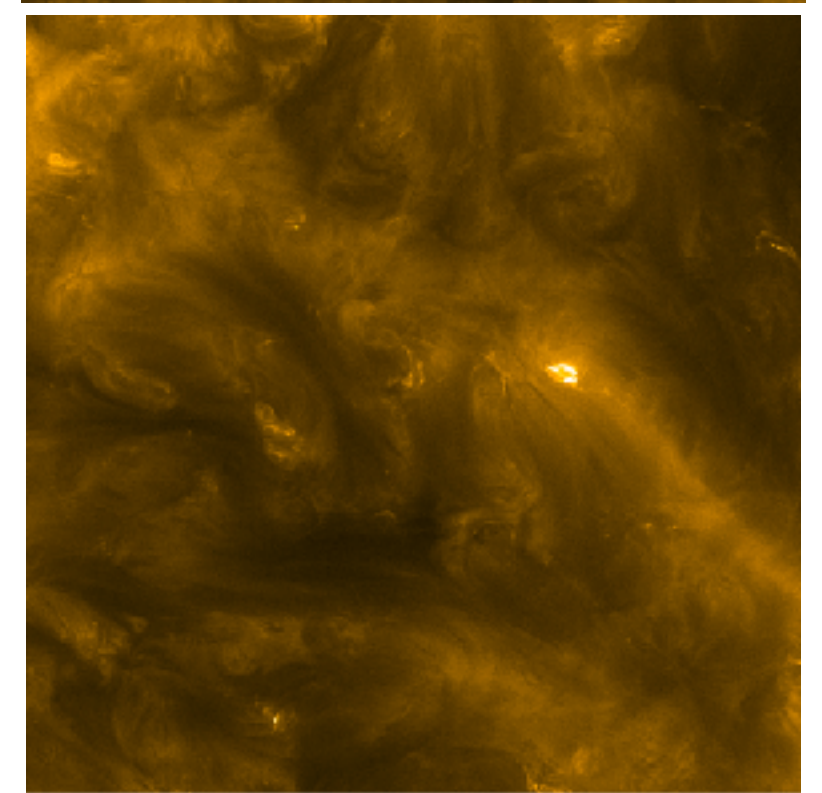
5 km



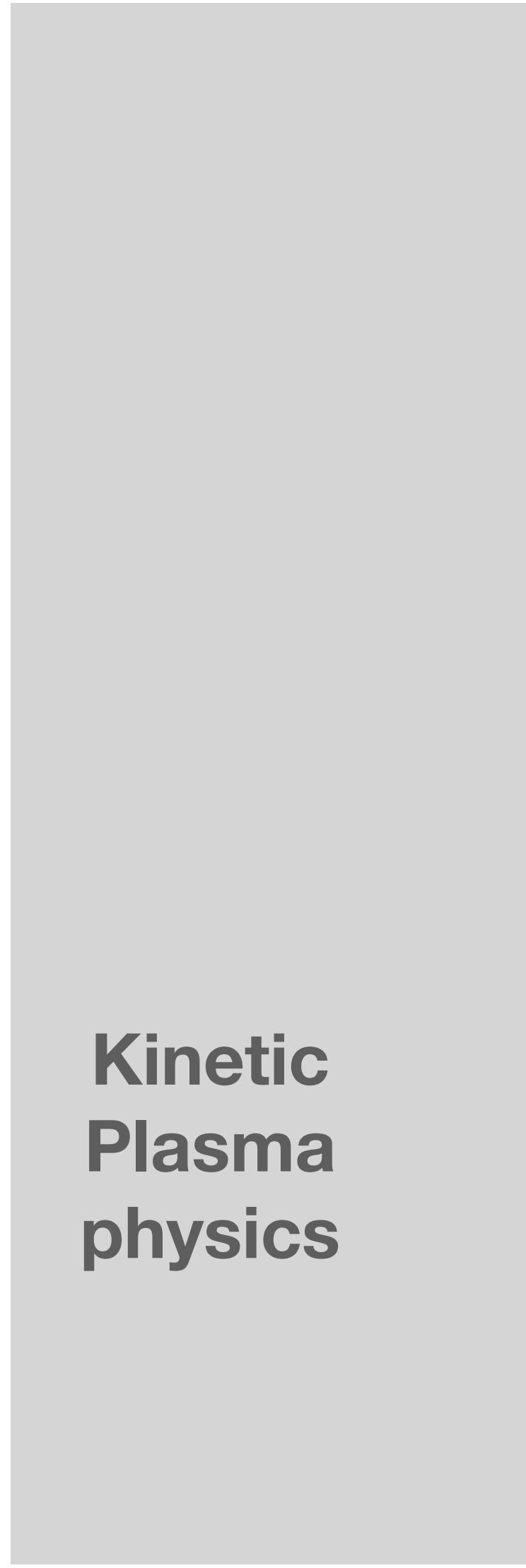
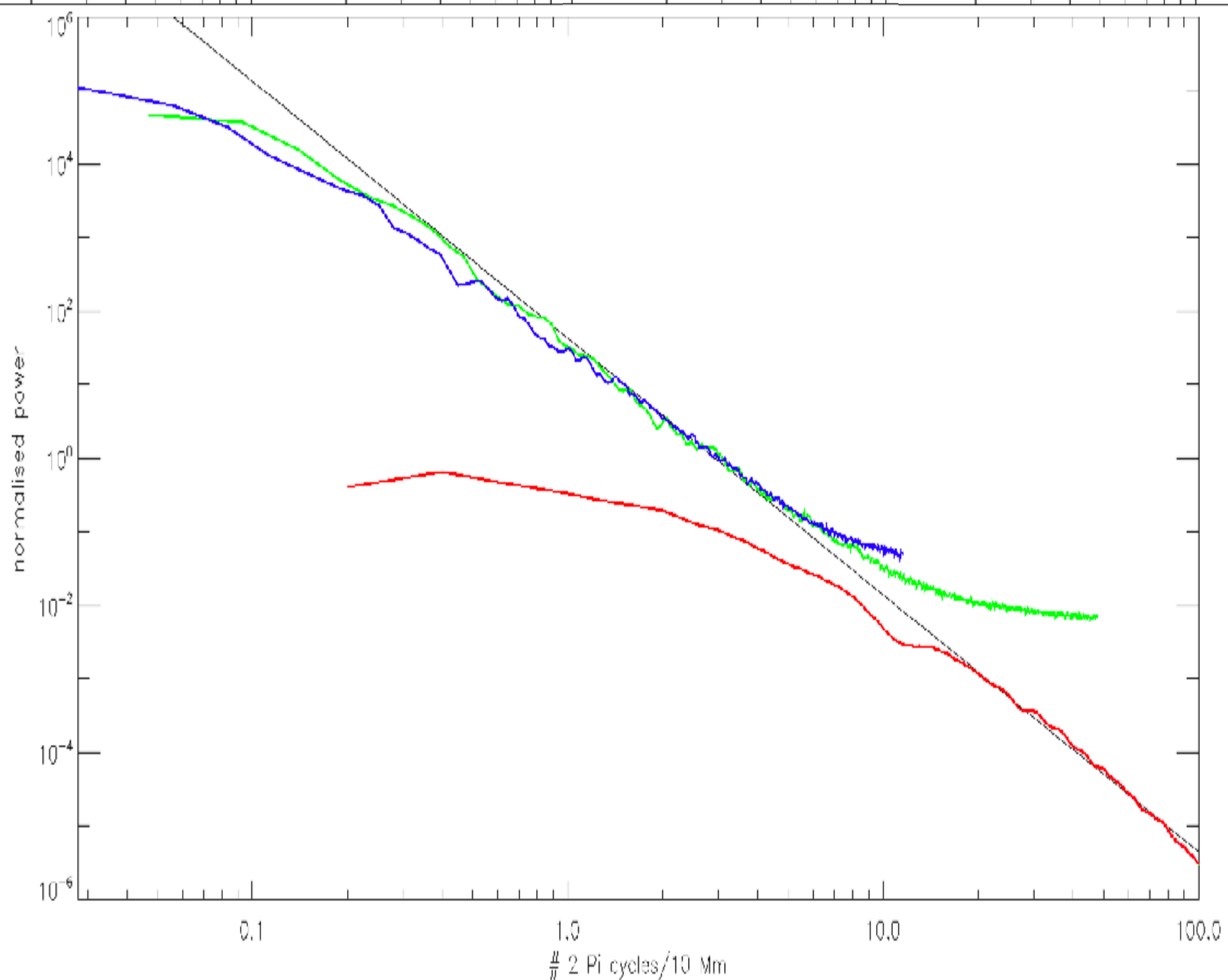
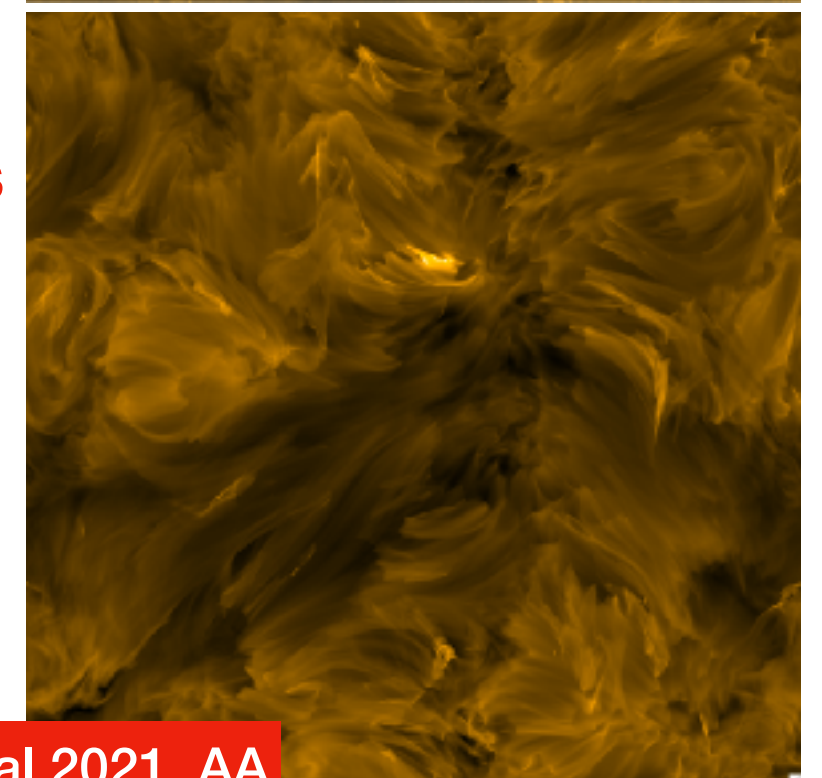
AIA 171



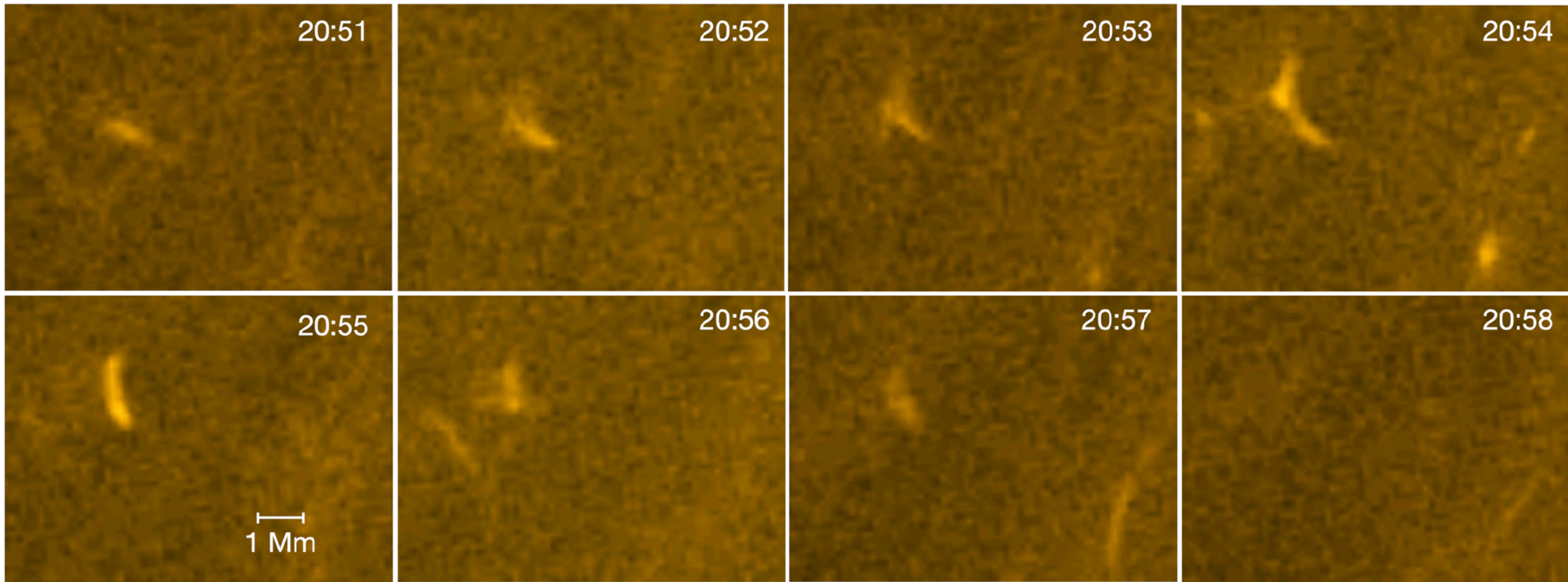
EUI HRIEUV



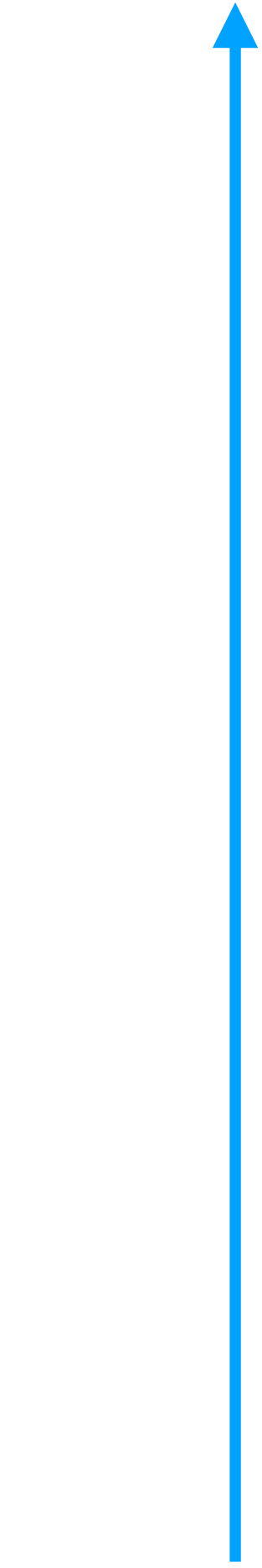
MuRAM simulations



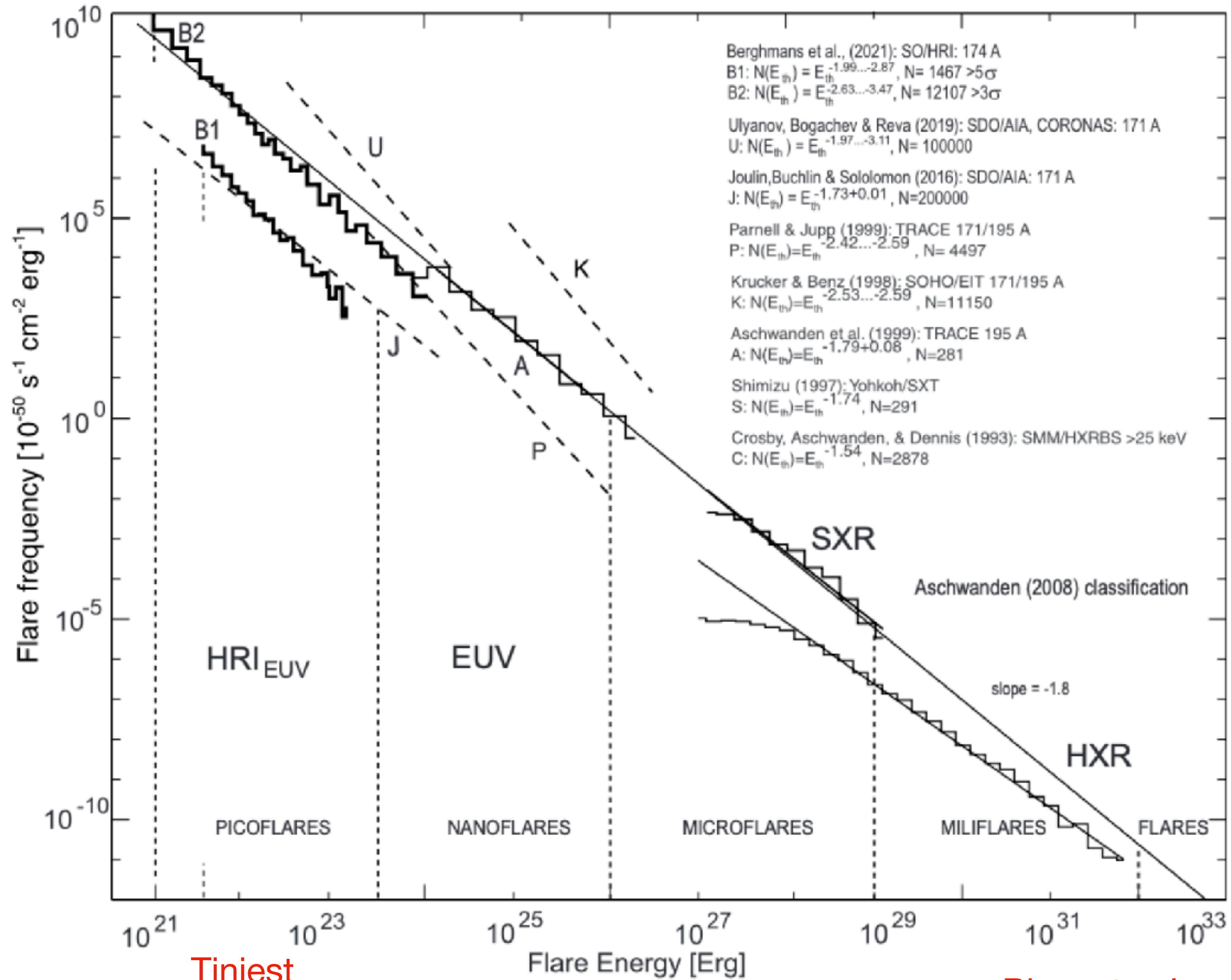
2022 March 22 Small EUV brightenings a.k.a. “campfires”



Very frequent



Very seldom



Tiniest
EUV brightenings
“campfires”



Biggest solar
flares

