The atmosphere of our favourite study object, the Sun

Petra Vanlommel
Solar-Terrestrial Centre of Excellence



SOLAR RESEARCH AND SPACE WEATHER

The Sun is our favourite research object. Because it is interesting and because it influences us in ways you don’t ‘see’ immediately.



THE CORONA - WHY DO WE CARE?

The region around the Sun becomes visible during a solar eclipse.



Image: Siberia 20080801
J.M.P., W. G. Wagner and H. Druckmüllerová



© 2017 Williams College
Composite by Christian Lockwood

696 000 km

$$P = P_0 e^{(-\frac{z}{H})}$$

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

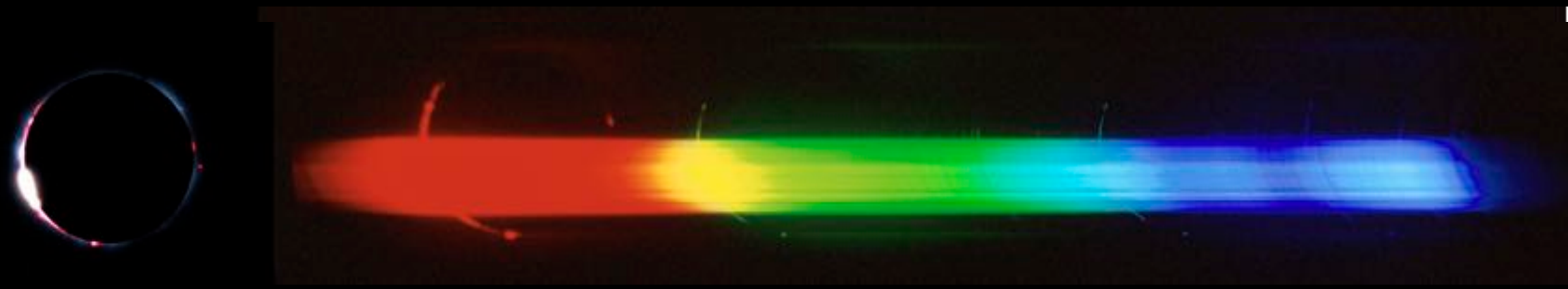
g= 270 m/s^2
M=1
~~**T= 5700**~~
>1 million C

H=270km

© 2017 Williams College
Composite by Christian Lockwood

Spectroscopic detective work

THE DIAMOND RING



Eclipse 1999, Hungary

Image Courtesy www.eurastro.de/webpages/MRSPECT.HTM

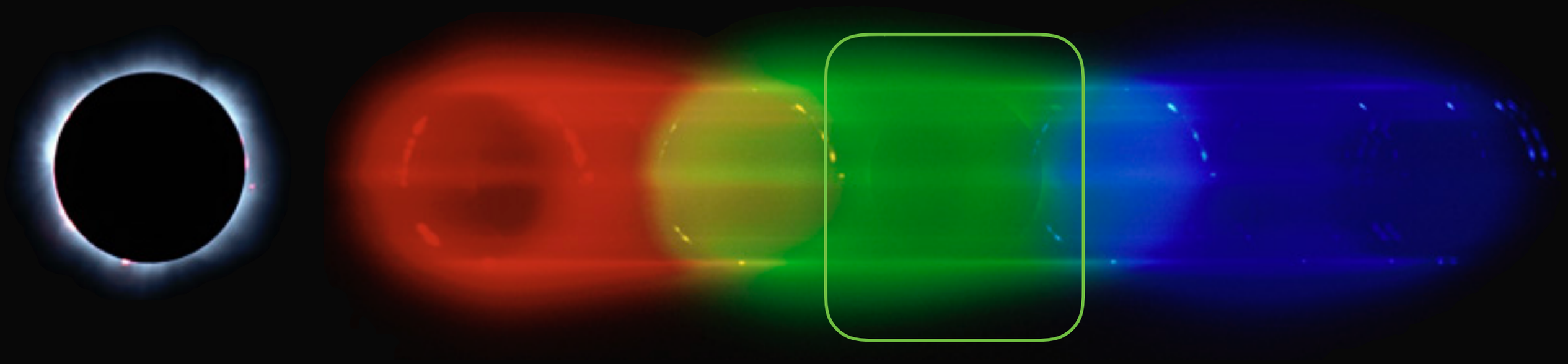
THE CHROMOSPHERE



Eclipse 1999, Hungary

Image Courtesy www.eurastro.de/webpages/MRSPECT.HTM

CORONAL SPECTRUM



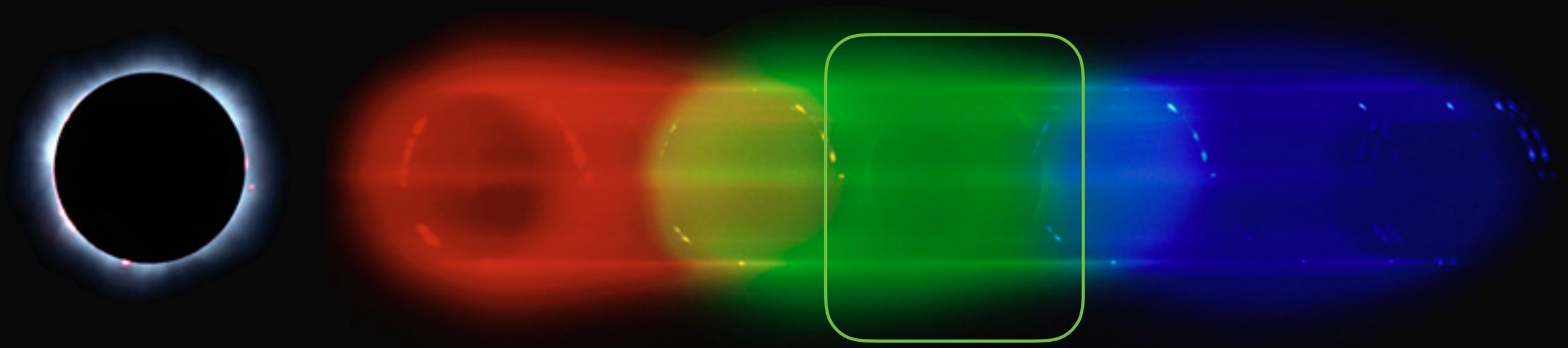
530.3nm

Coronium

Eclipse 1999, Hungary

Image Courtesy www.eurastro.de/webpages/MRSPECT.HTM

CORONAL SPECTRUM



530.3nm

~~Coronium~~

Bengt Edlen: Fe XIV

Eclipse 1999, Hungary

Image Courtesy www.eurastro.de/webpages/MRSPECT.HTM

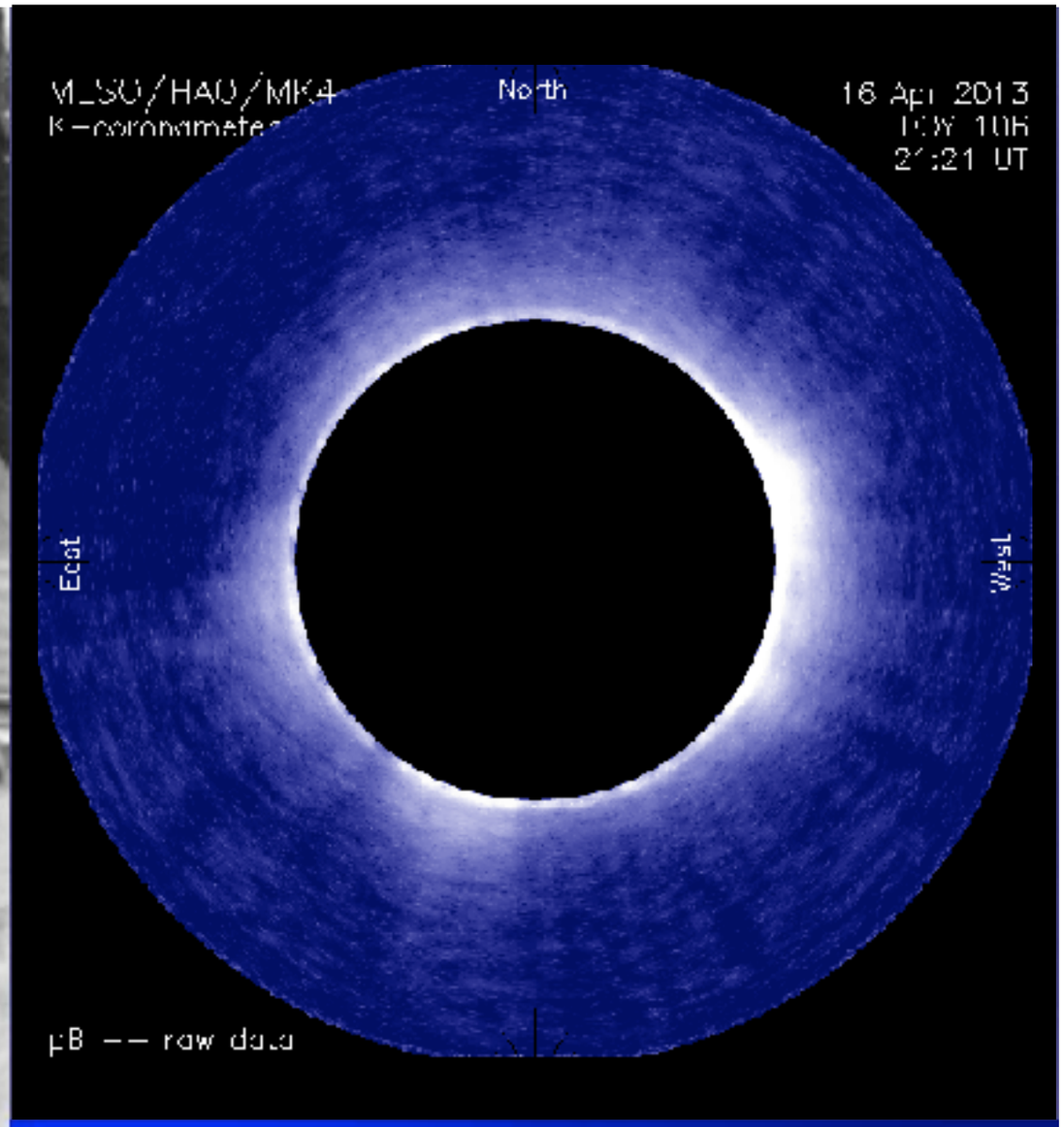
The corona is big & hot

Observe the corona

Corona in white light

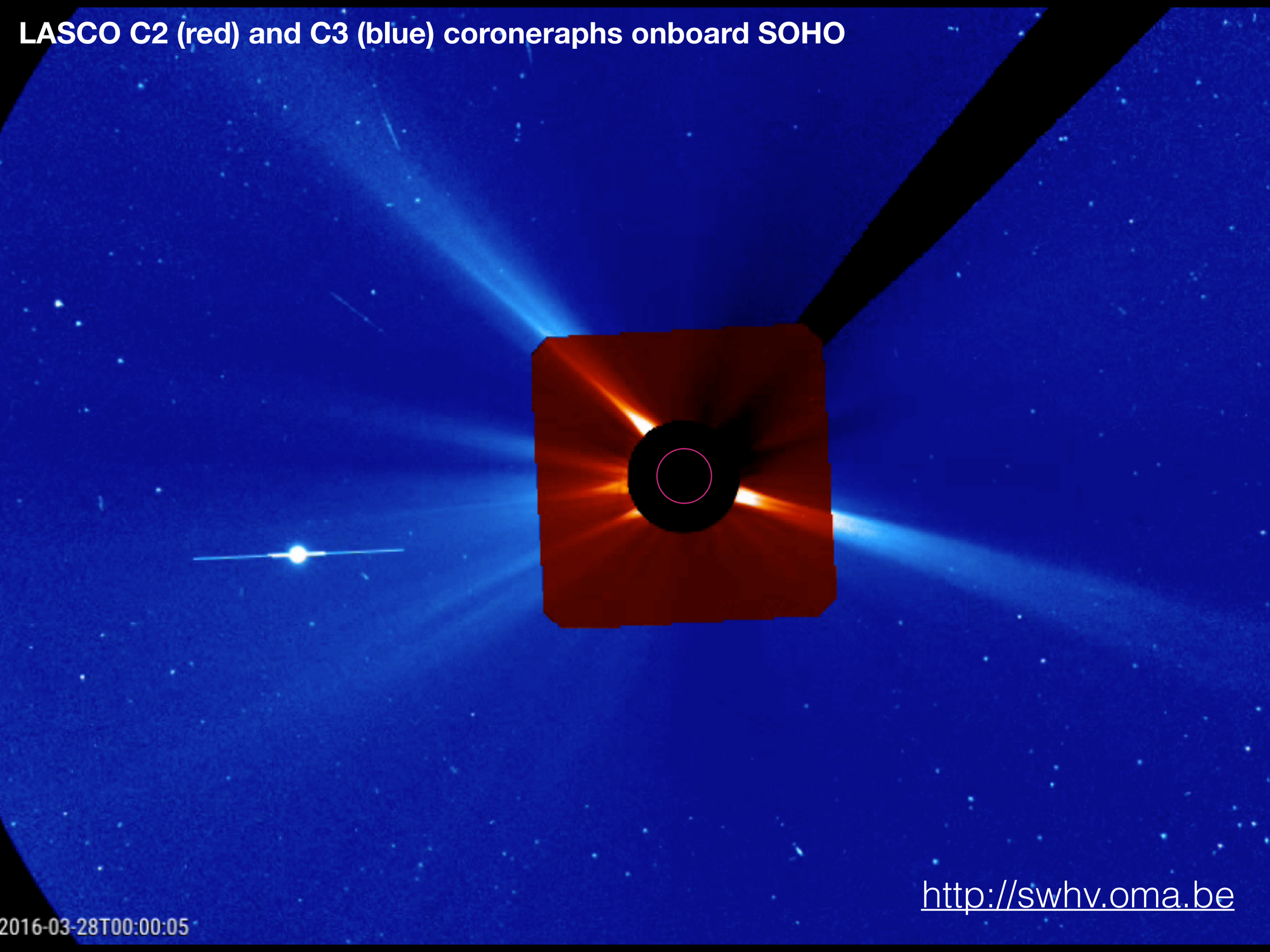
Coronagraphs create artificial eclipses





Bernard Lyot, 1939, at Pic du Midi
French Astronomer
Inventor of the Coronagraph

LASCO C2 (red) and C3 (blue) coroneraphs onboard SOHO



http://swhv.oma.be

Corona in EUV

What does the corona look like under the occulter?

LOOKING AT AN OBJECT

A picture of a hand in visible light.



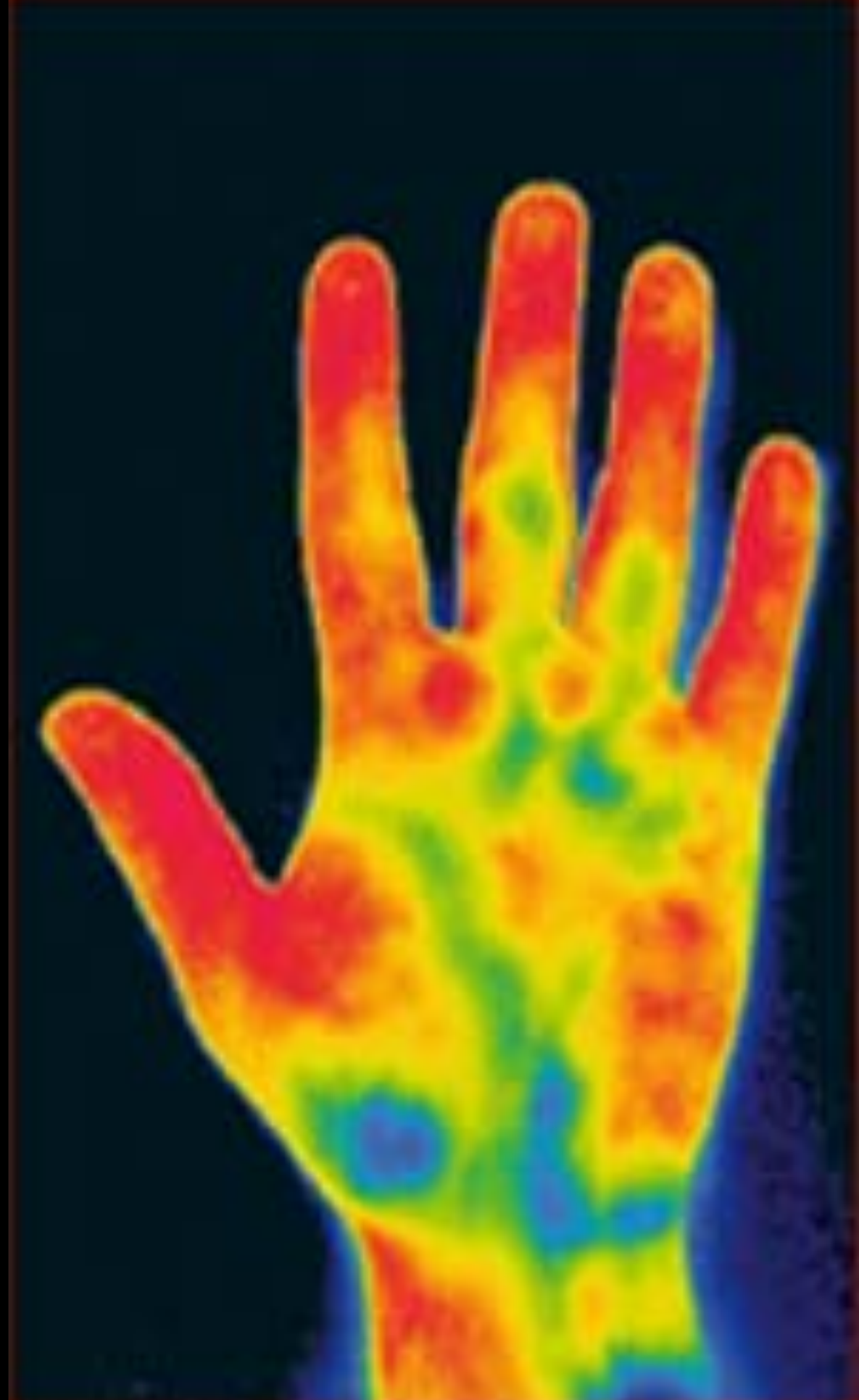
LOOKING AT AN OBJECT

...in x-rays.

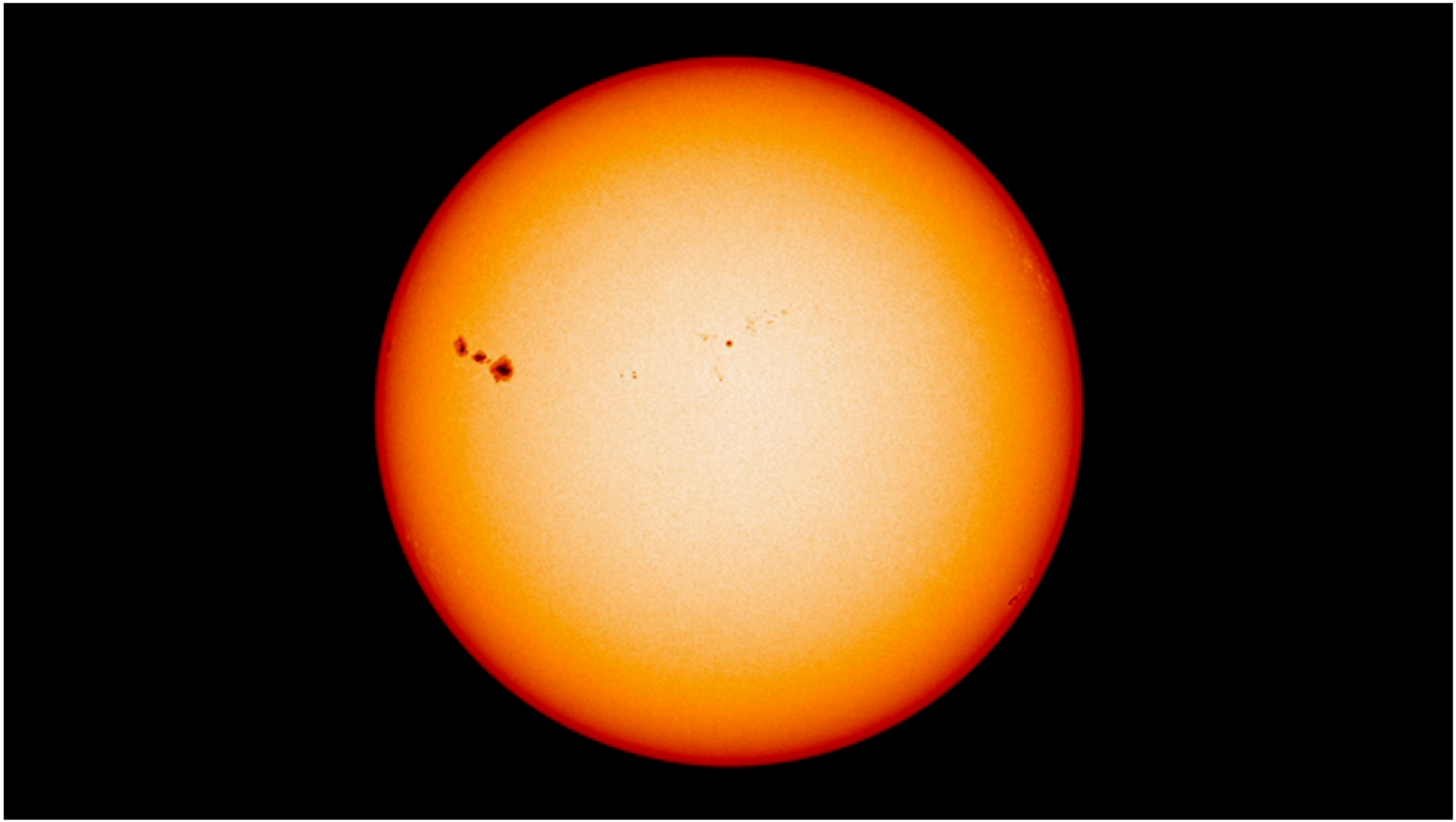


LOOKING AT AN OBJECT

...in infra-red.



LOOKING AT AN OBJECT IN ALL SORTS OF LIGHT



SUNLIGHT

A particular wave length, gives view to a particular layer.

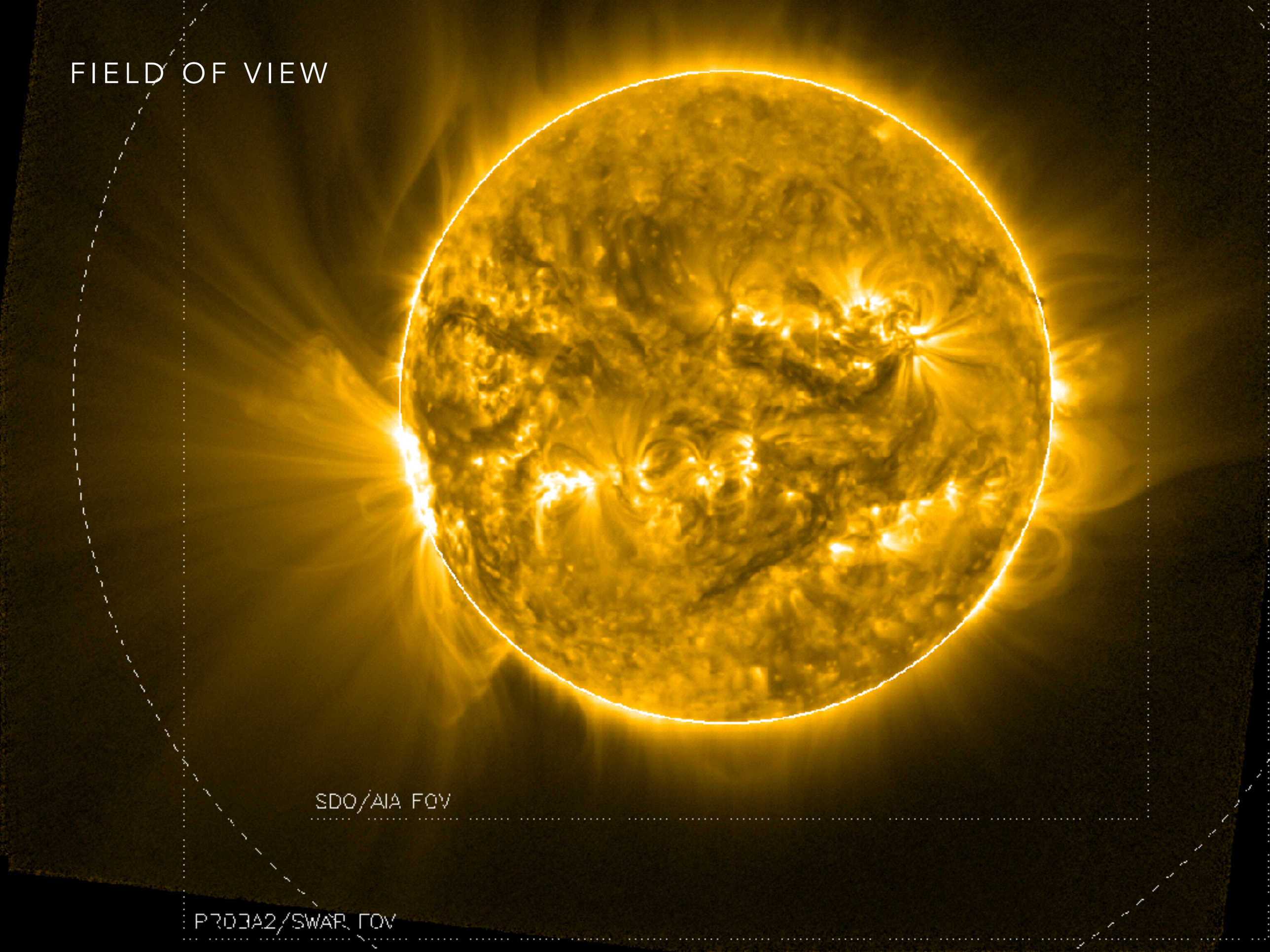
SWAP ONBOARD PROBA2

May I present you the '**S**un **W**atcher using **A**ctive Pixel System detector and Image **P**rocessing' telescope. It is 'ours'.



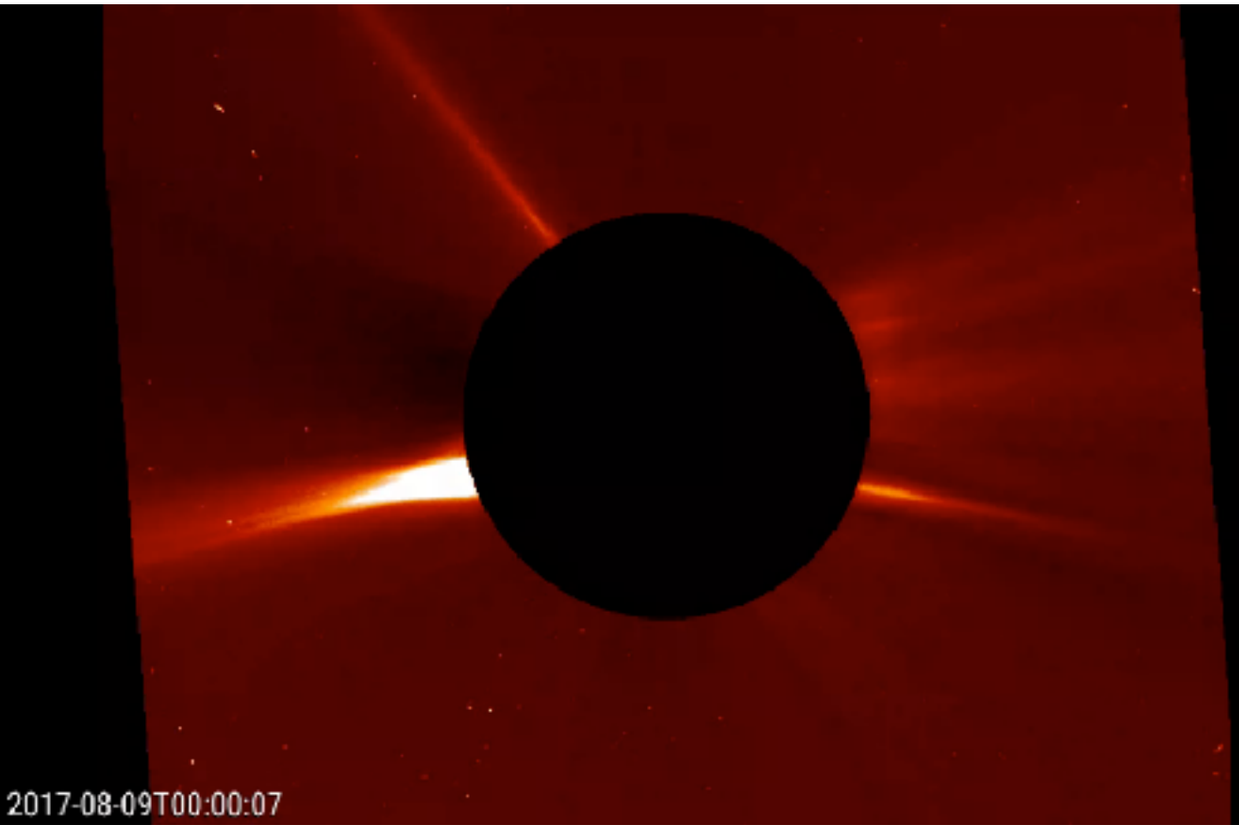
SWAP 174 Å 2012-06-21 06:10:32 CR 2125

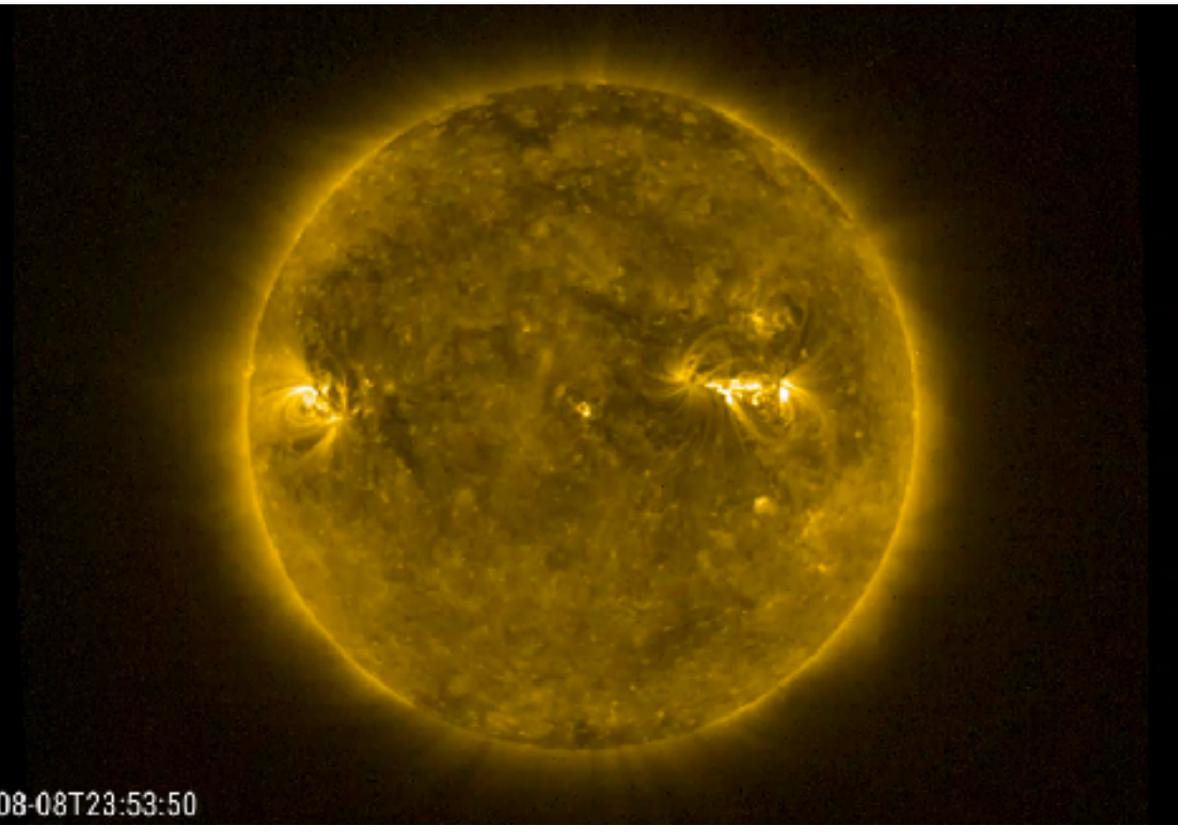
FIELD OF VIEW



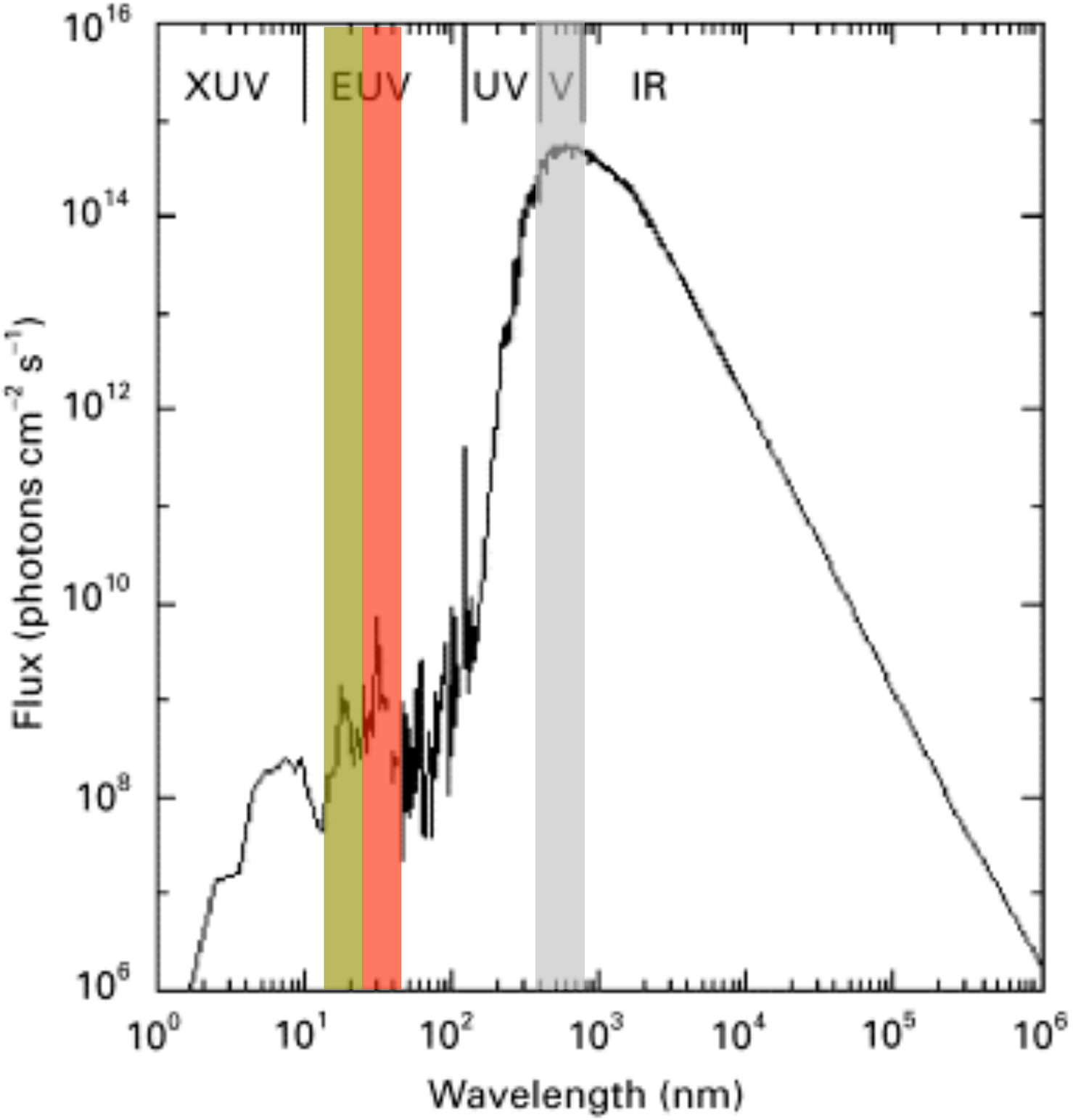
OBSERVING THE CORONA

EUV imagers and coronagraphs observe both the corona, but in a different way.

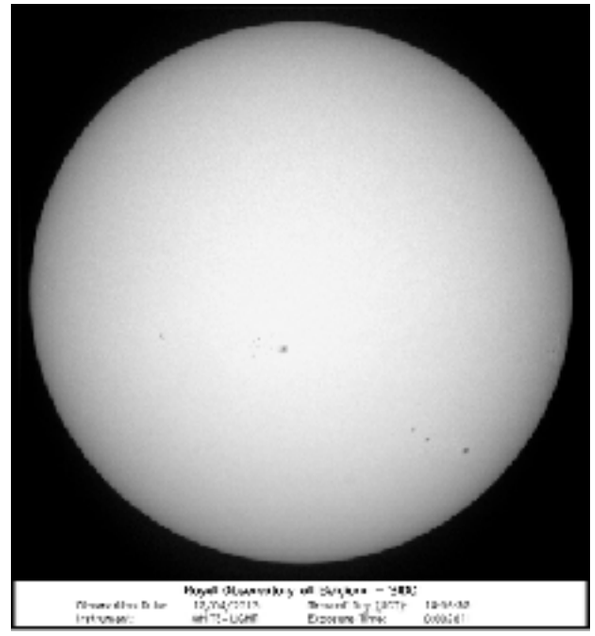




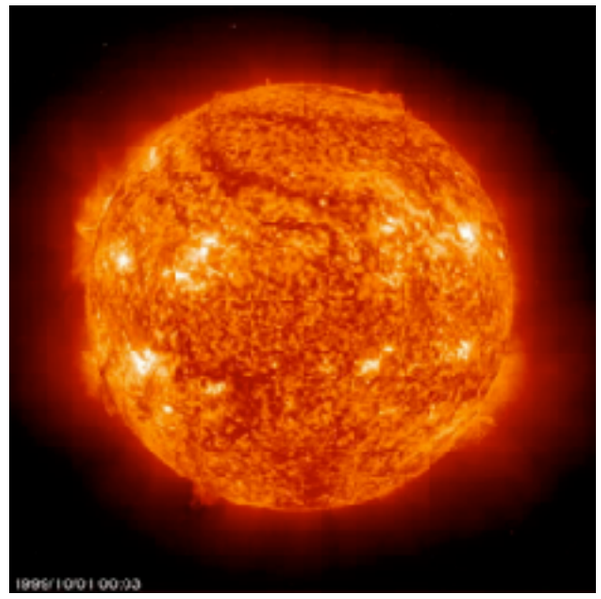
EUV imagers



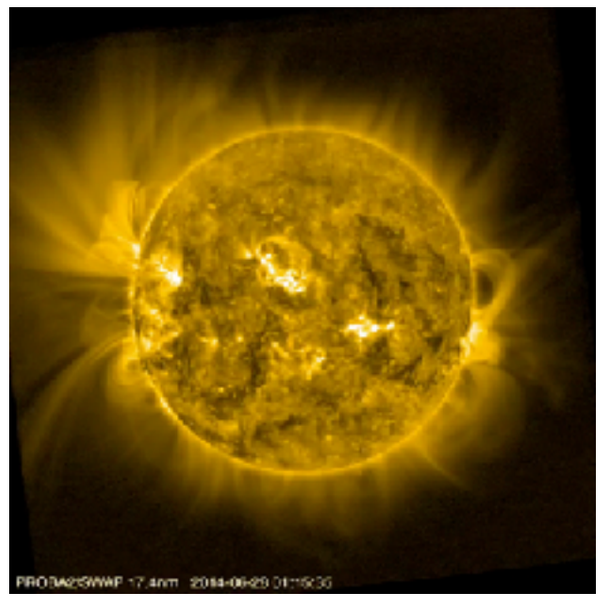
[SOLAR2000, Tobiska 2000]



5700K



80000K



few MK

collected light is emitted by ions ~ (density)^2

Sun

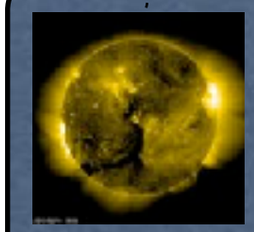
i+

i+

All emission along the line of sight is summed up equally

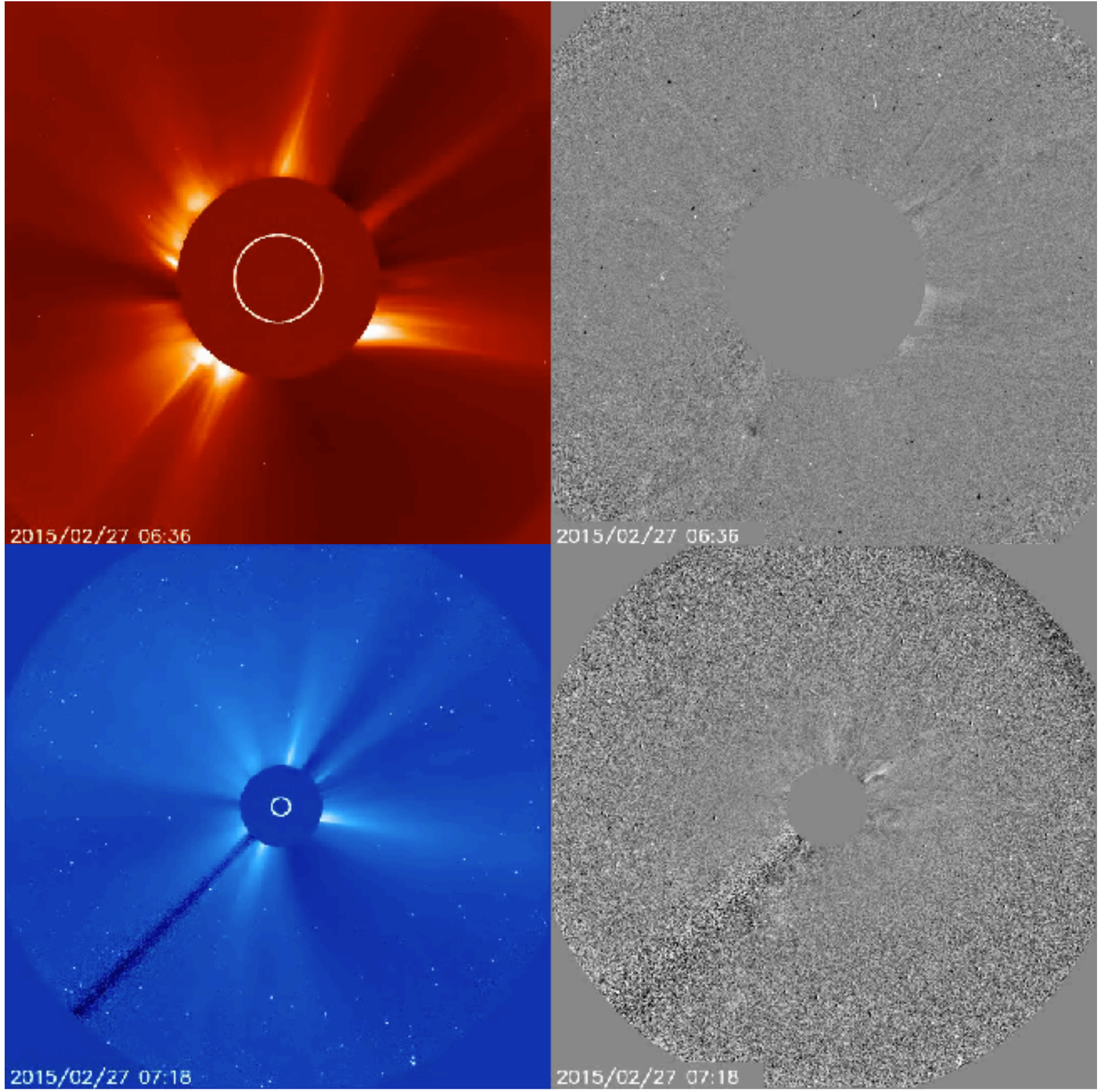
i+

filter for EUV only specific T visible



EUV telescope

Coronagraphs



SOHO / LASCO c2&c3 running difference

collected light is emitted by ions ~ (density)^2

Sun

i+

i+

All emission along the line of sight is summed up equally

i+

filter for EUV only specific T visible

EUV telescope

e-

e-

Sun

collected light is refracted on electrons ~(density)

e-

e-

All emission along the line of sight is summed up but not equally

occulter

visible light

Corona-graph

Combine EUV imagers & coronagraphs

Combine EUV & coronagraph images

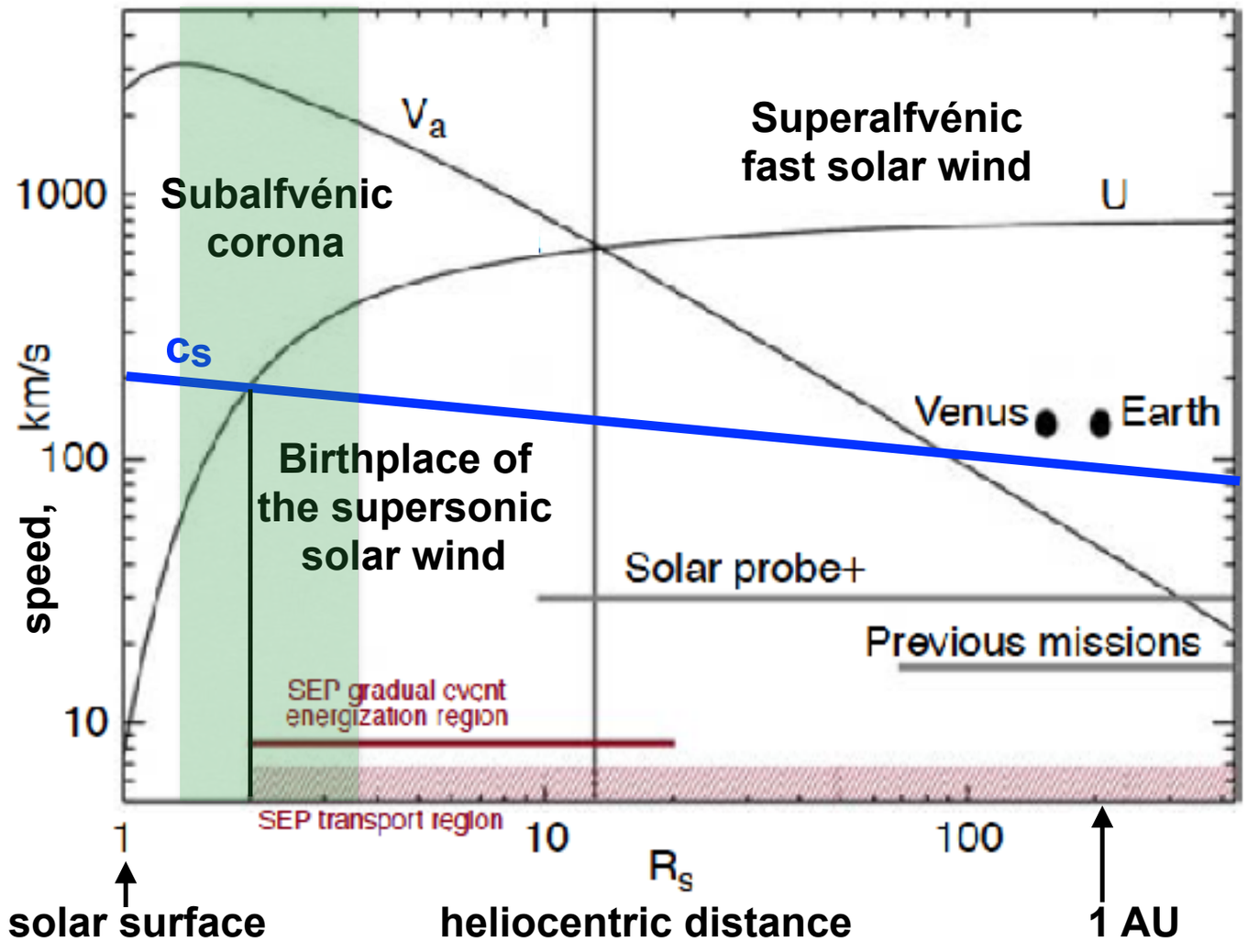
OBSERVATIONAL GAP - WE ARE MISSING A PART

SWAP 174 2012-07-08 23:02:04
LASCO C2 2012-07-08 23:12:06
AIA 304 2012-07-08 23:01:32

www.helioviewer.org

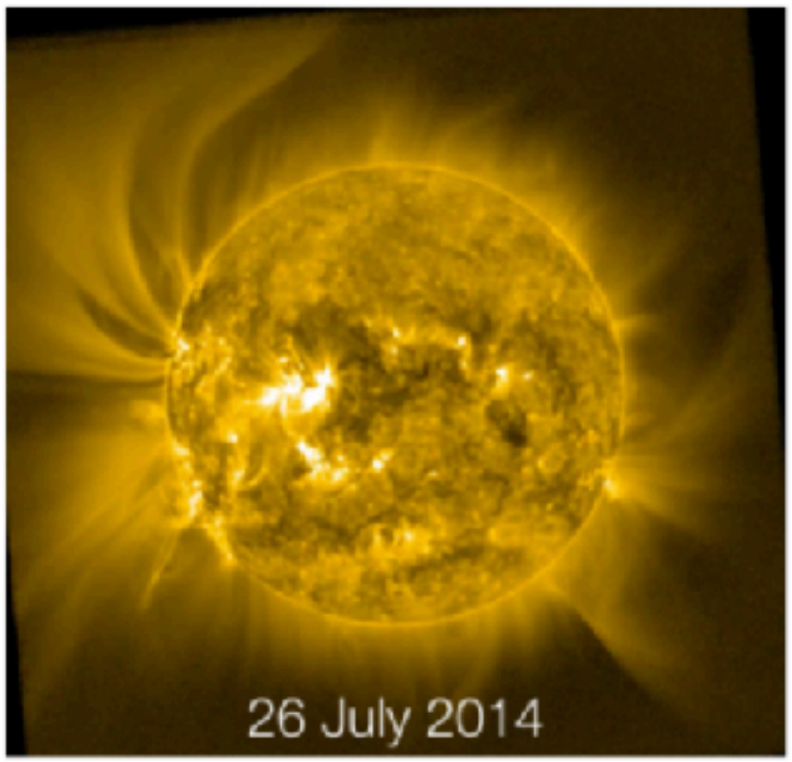
THE GAP IN THE INNER SOLAR CORONA

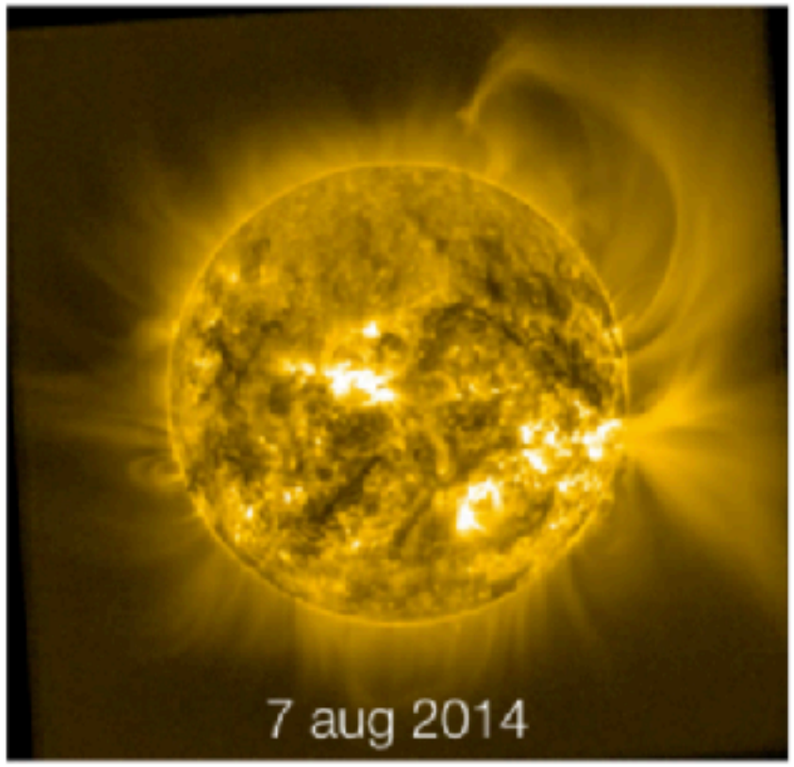
That's the place where all fun happens: the solar wind is generated, CME's are accelerated, …

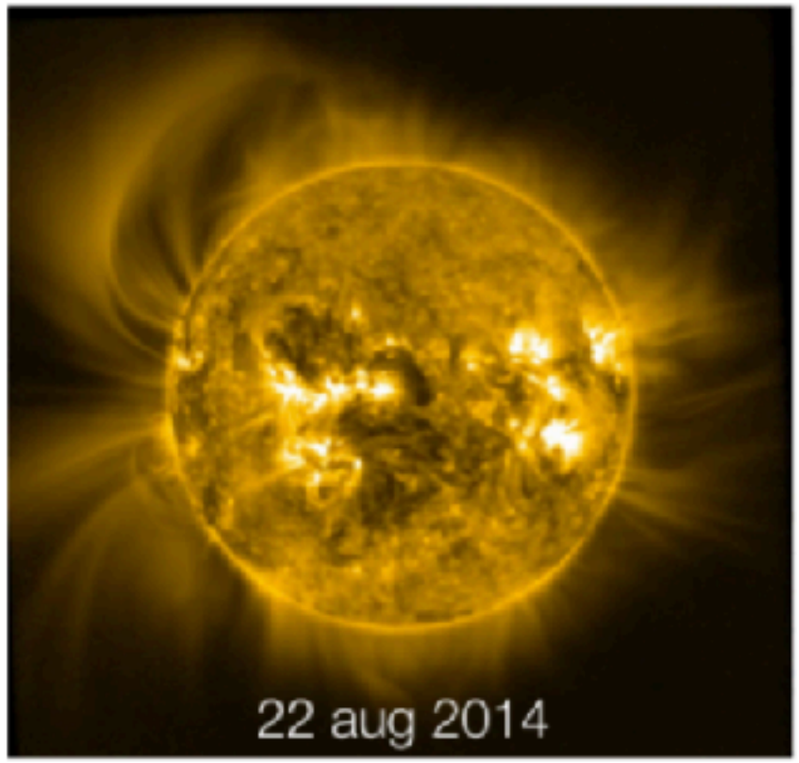


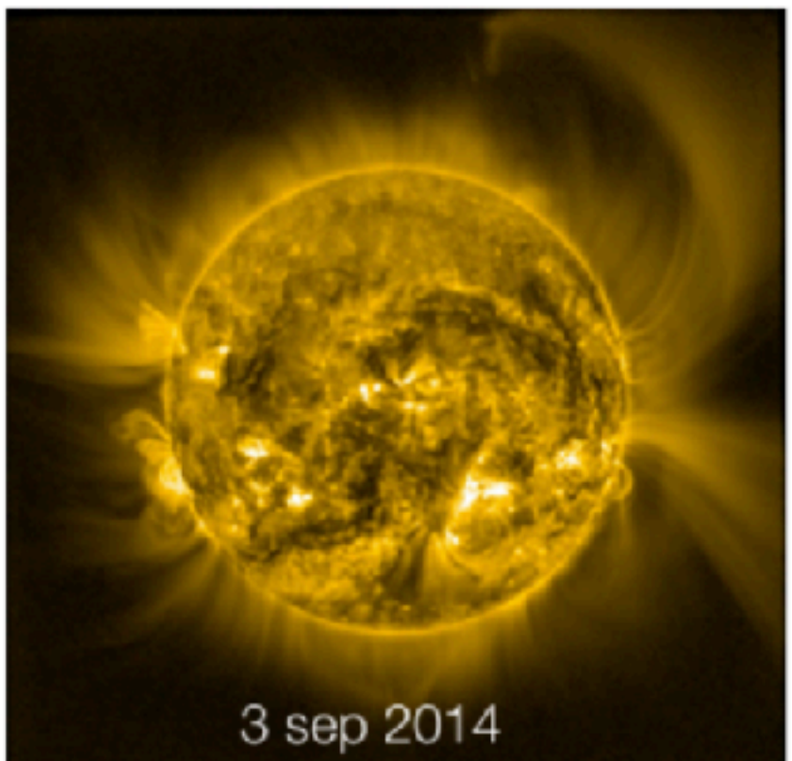
THE GAP IN THE INNER SOLAR CORONA

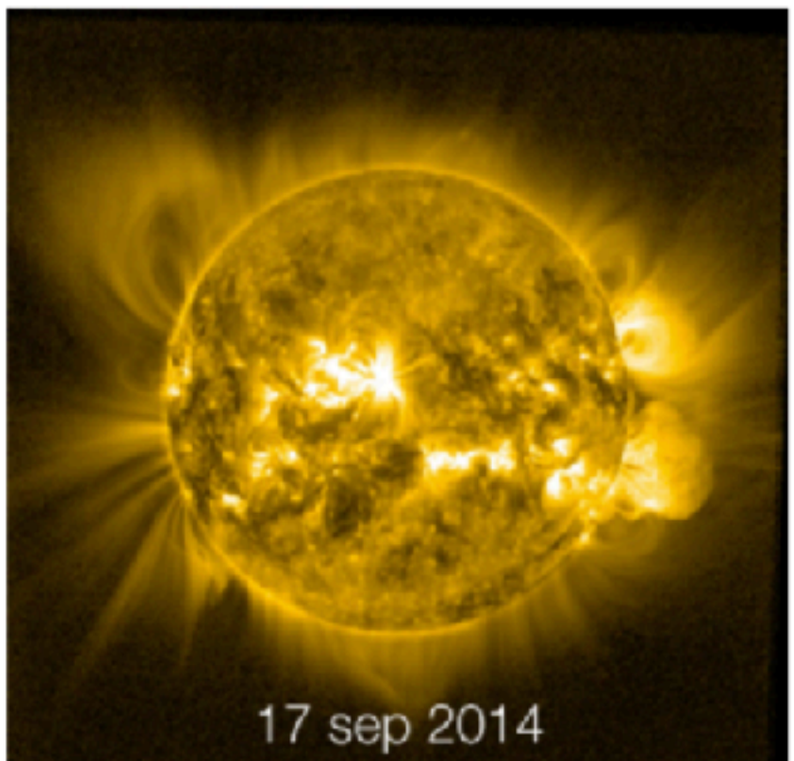
There are surprisingly long lived structures in the gap. We want to see how they connect to the outer part of the solar corona.

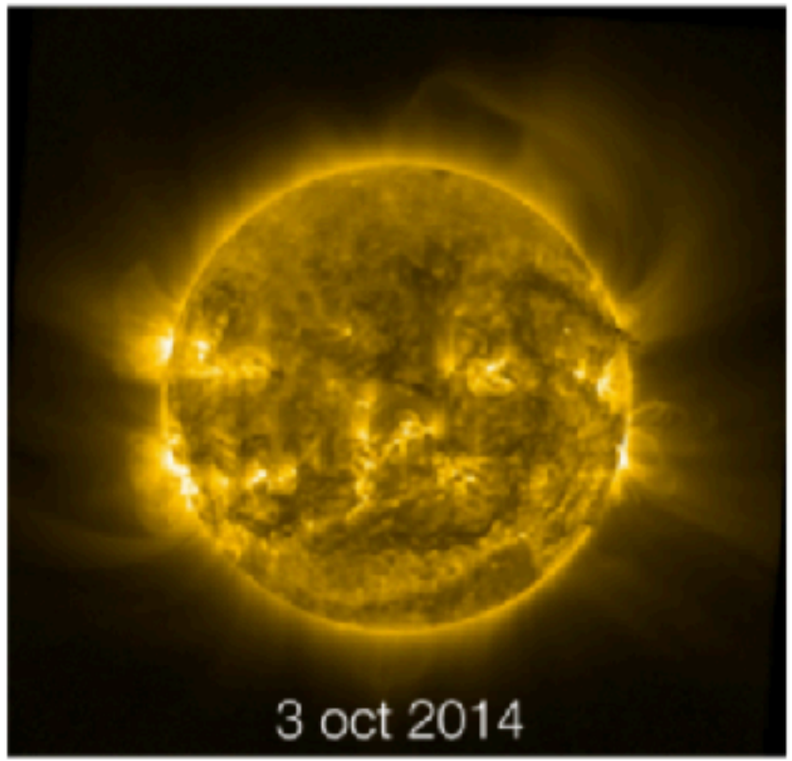






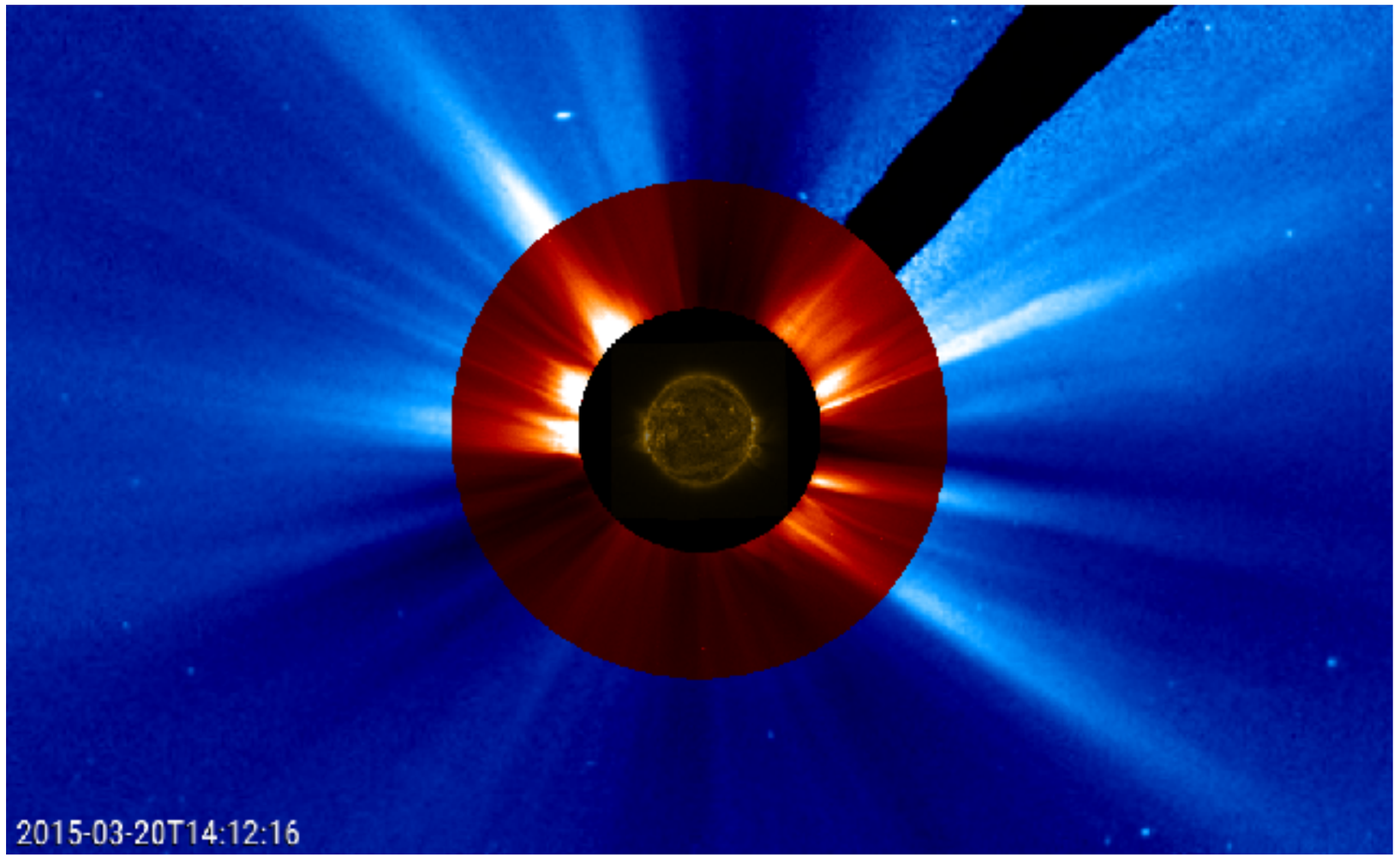






OBSERVATIONAL GAP

How we are going to fill it up?



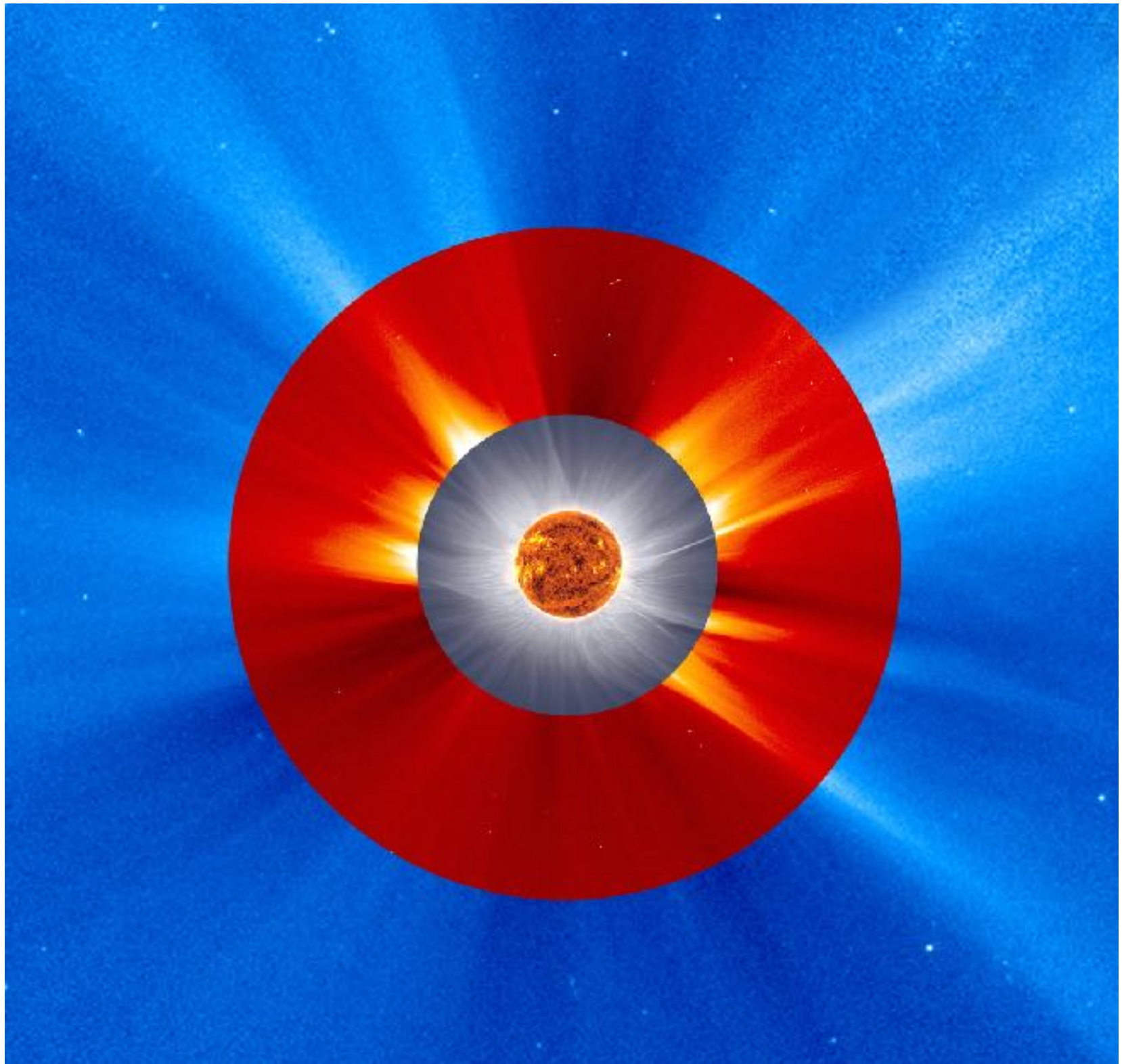
OBSERVATIONAL GAP

We watch natural solar eclipses.



OBSERVATIONAL GAP

We bring together both observations and close the gap.



OBSERVATIONAL GAP

Very nice but …



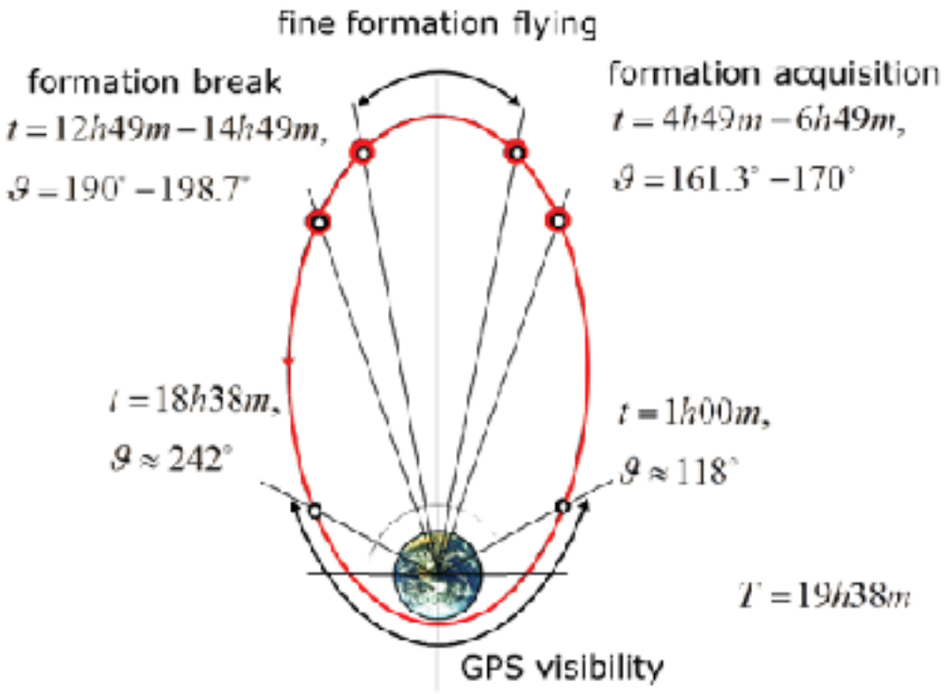
Filling the gap: ASPIICS on PROBA-3

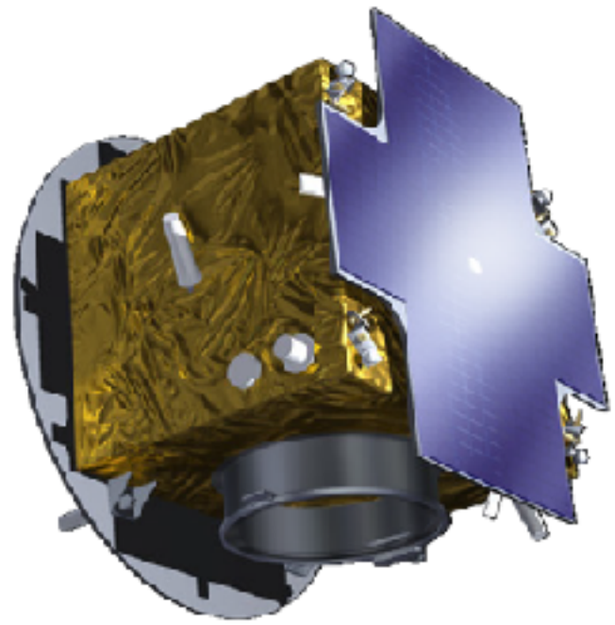
OBSERVATIONAL GAP

To close the ‘gap’, we make our own perfect eclipse with a special coronagraph ASPIICS onboard of PROBA3.

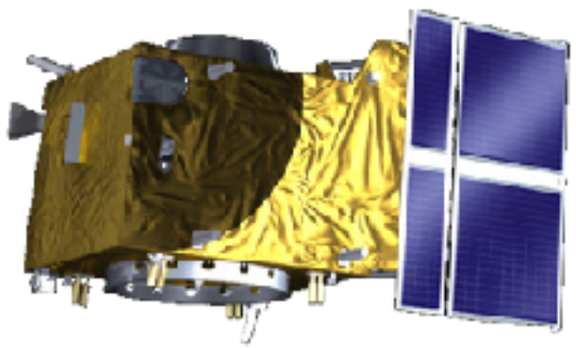


THE ULTIMATE CORONAGRAPH





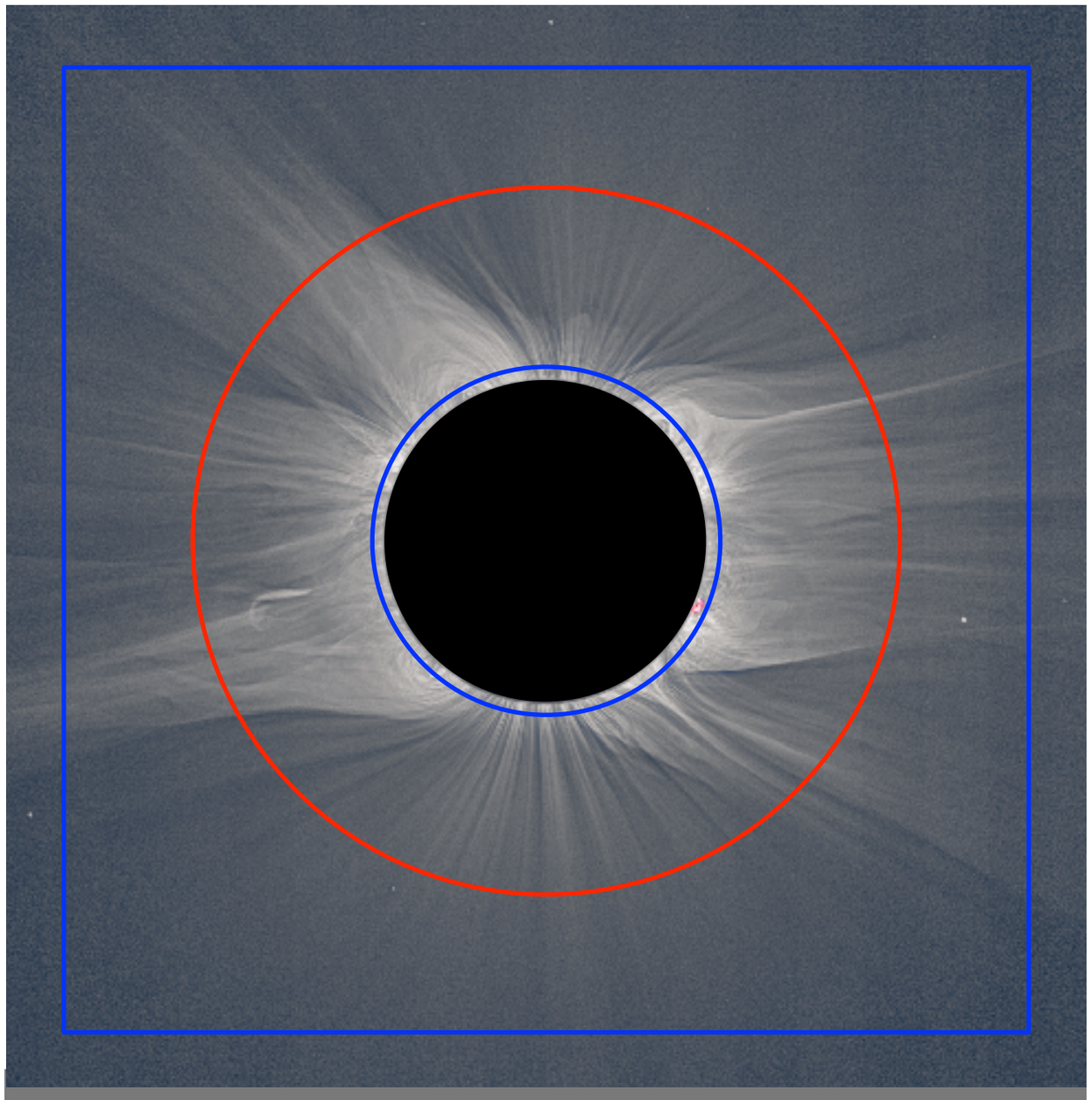
towards the Sun



- The formation flying is maintained over 6 hours in every 20-hour orbit: *around a factor 100 improvement* in the duration of uninterrupted observations in comparison with a total eclipse.

- A technological challenge: the distance between the spacecraft is 150 m, and the accuracy of their positioning should be around a few millimeters!

PROBA-3/ASPIICS in comparison with other coronagraphs

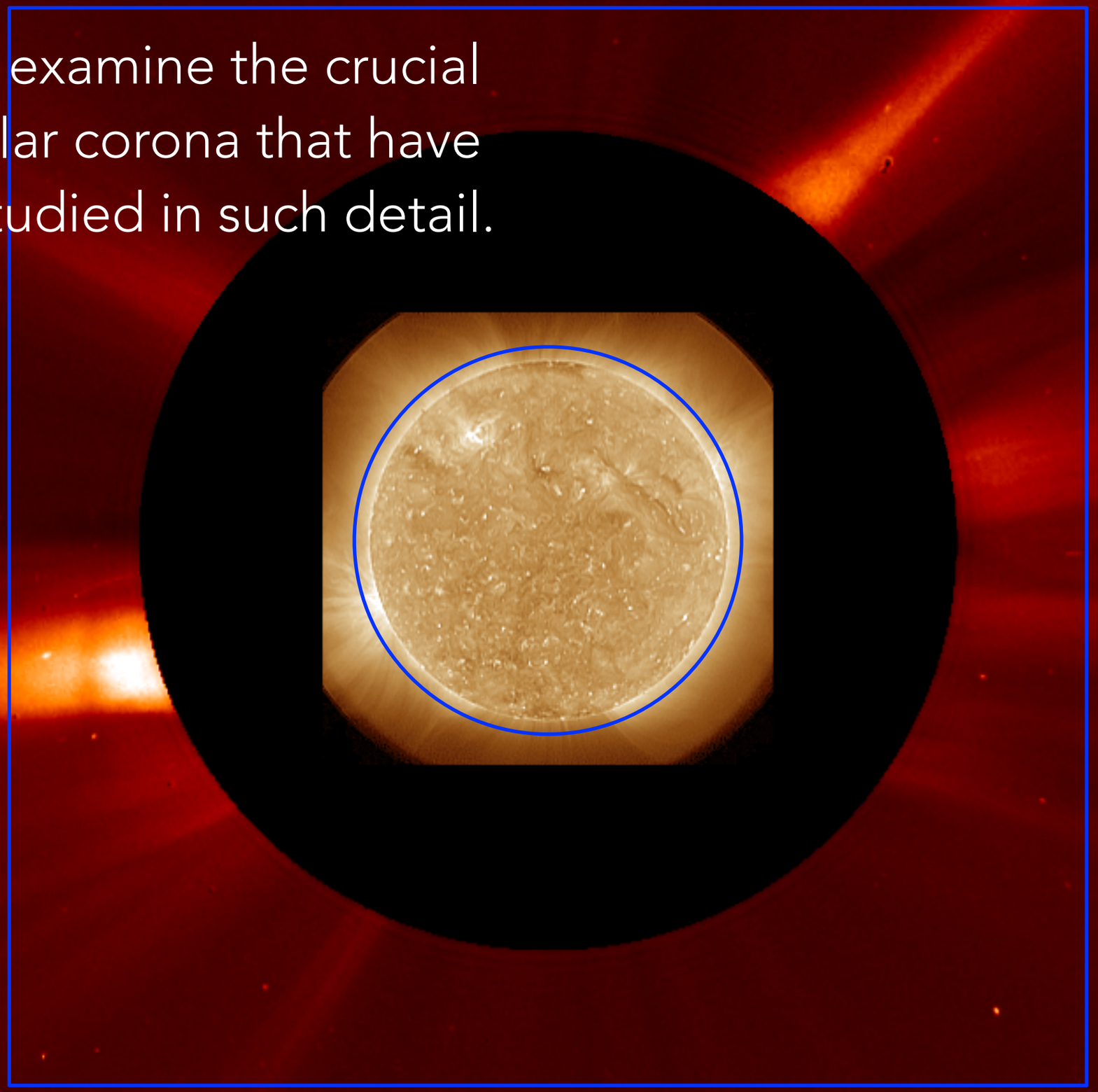


ASPIICS - 1.08 $R_\odot$

SOHO/LASCO C2 - 2.2 $R_\odot$

- The inner edge of the ASPIICS field of view (1.08 $R_\odot$) will be lower than that of any other existing or planned space coronagraph.
- ASPIICS will therefore fill The Gap between the typical fields of view of EUV imagers and externally occulted coronagraphs!
- The spatial resolution of ASPIICS will be at least 3.5 times better than the resolution of other coronagraphs.

PROBA-3 will examine the crucial part of the solar corona that have never been studied in such detail.



SDO: below 1.27 $R_\odot$
ASPIICS: 1.08–3.0 $R_\odot$
SOHO/LASCO C2: above 2.2 $R_\odot$

OBSERVATIONAL GAP

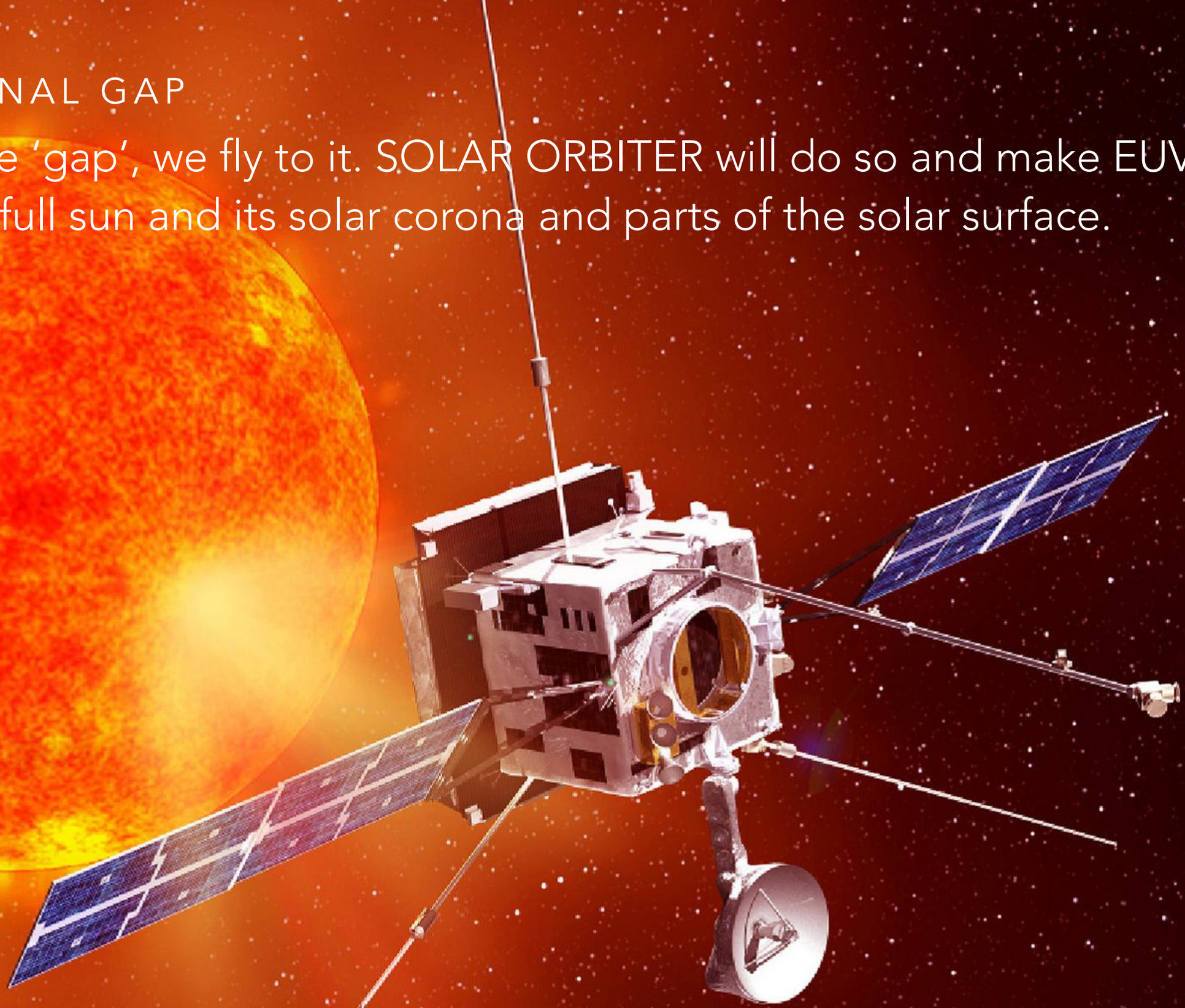
The PROBA3 spacecraft will be launched by the end of 2020.



OBSERVATIONAL GAP

Or, to close the ‘gap’, we fly to it. SOLAR ORBITER will do so and make EUV images of the full sun and its solar corona and parts of the solar surface.





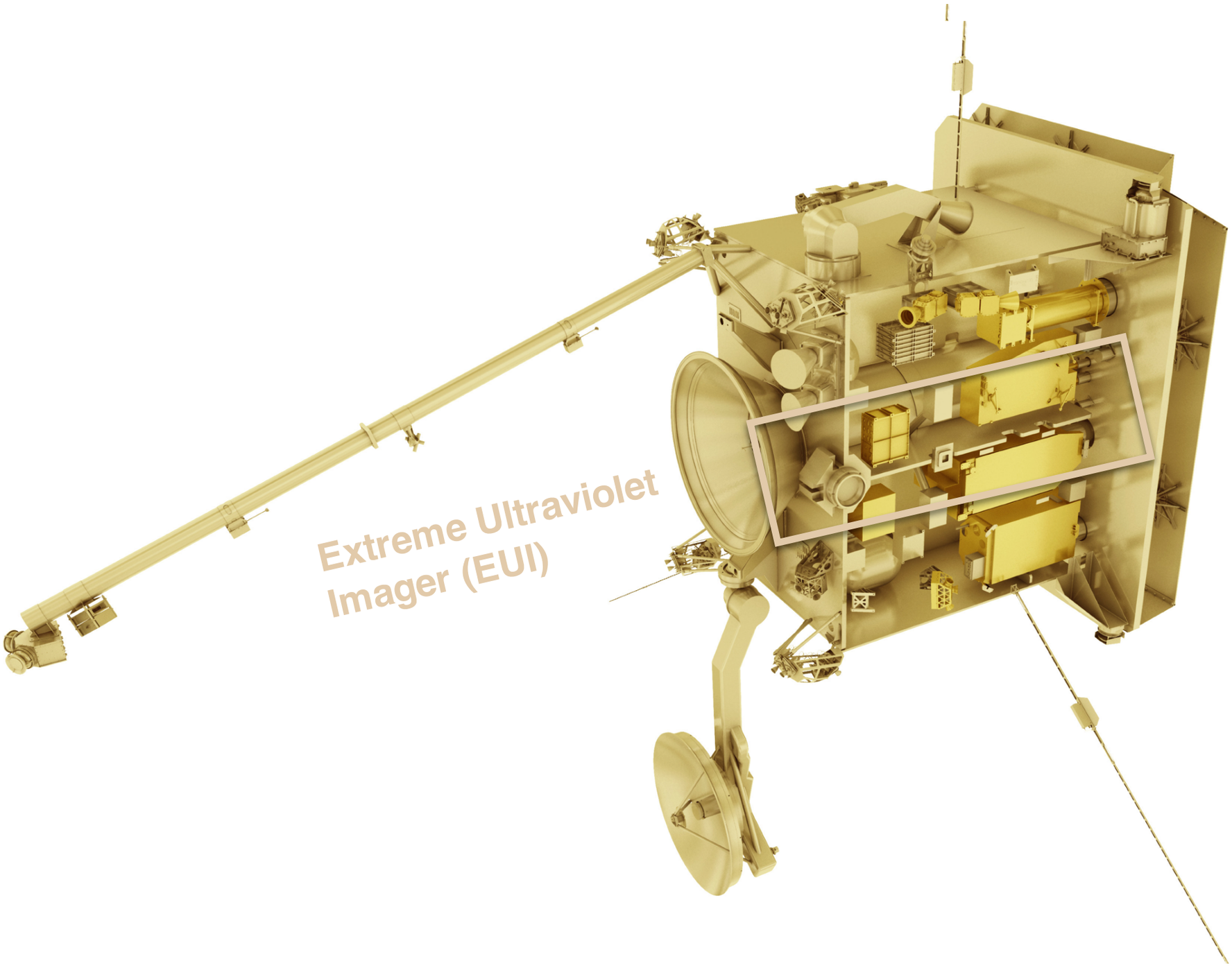
esa

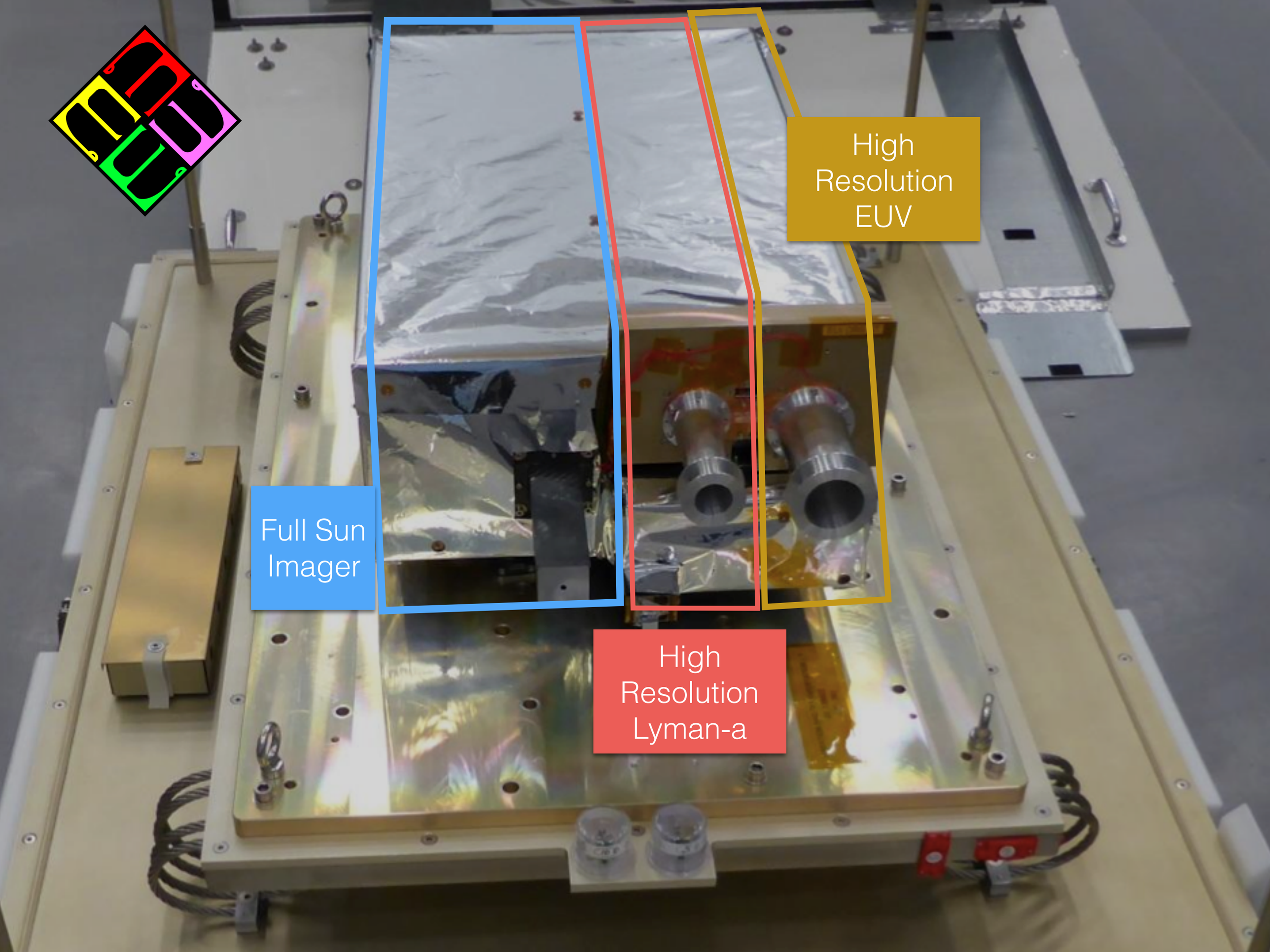
Approaches the Sun < 0.28 AU or <60 SR
View >30° latitude

NASA


S TSC
-TC-10000
ET WEIGHT: 1500 KG
GROSS WEIGHT: 1860 KG
SWL: 360 KG
FRONT SIDE

Mission 2019-2028 ; 10 instruments ; in-situ & remote sensing

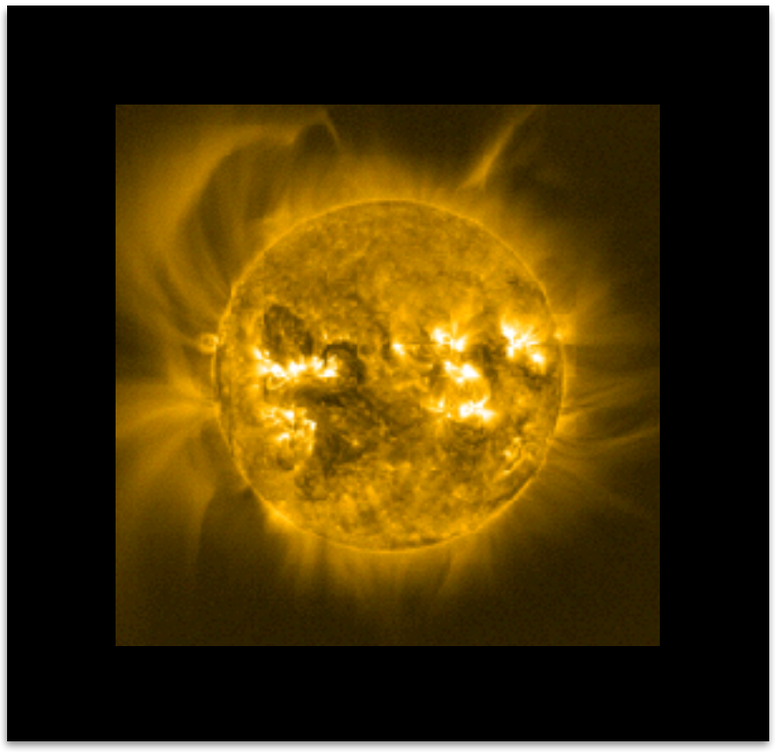


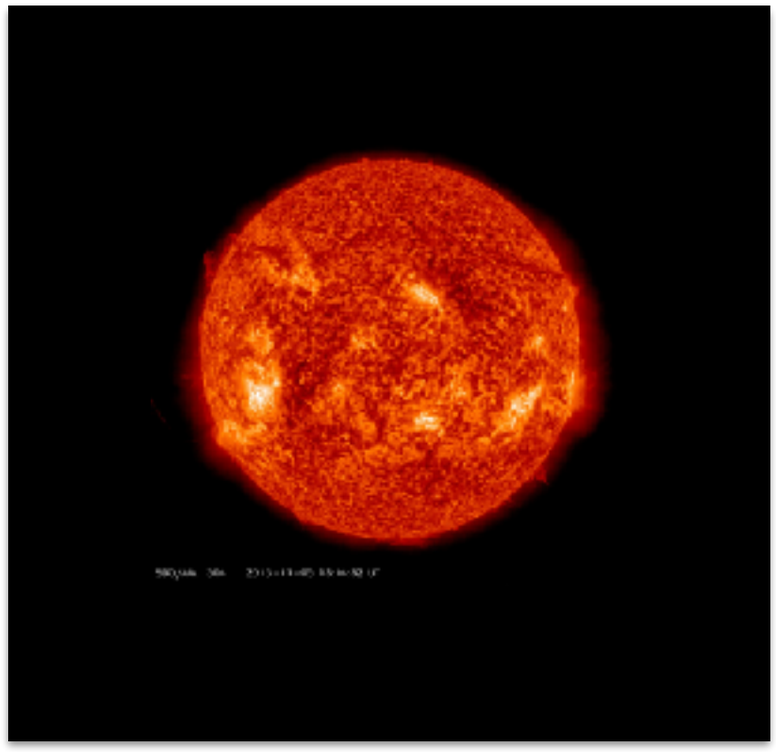

Full Sun Imager
High Resolution Lyman-a
High Resolution EUV

FSI: Full Sun Imager

FOV: 3.8°x3.8°, @ 0.28 AU: 4 Rsun x 4 Rsun

17nm



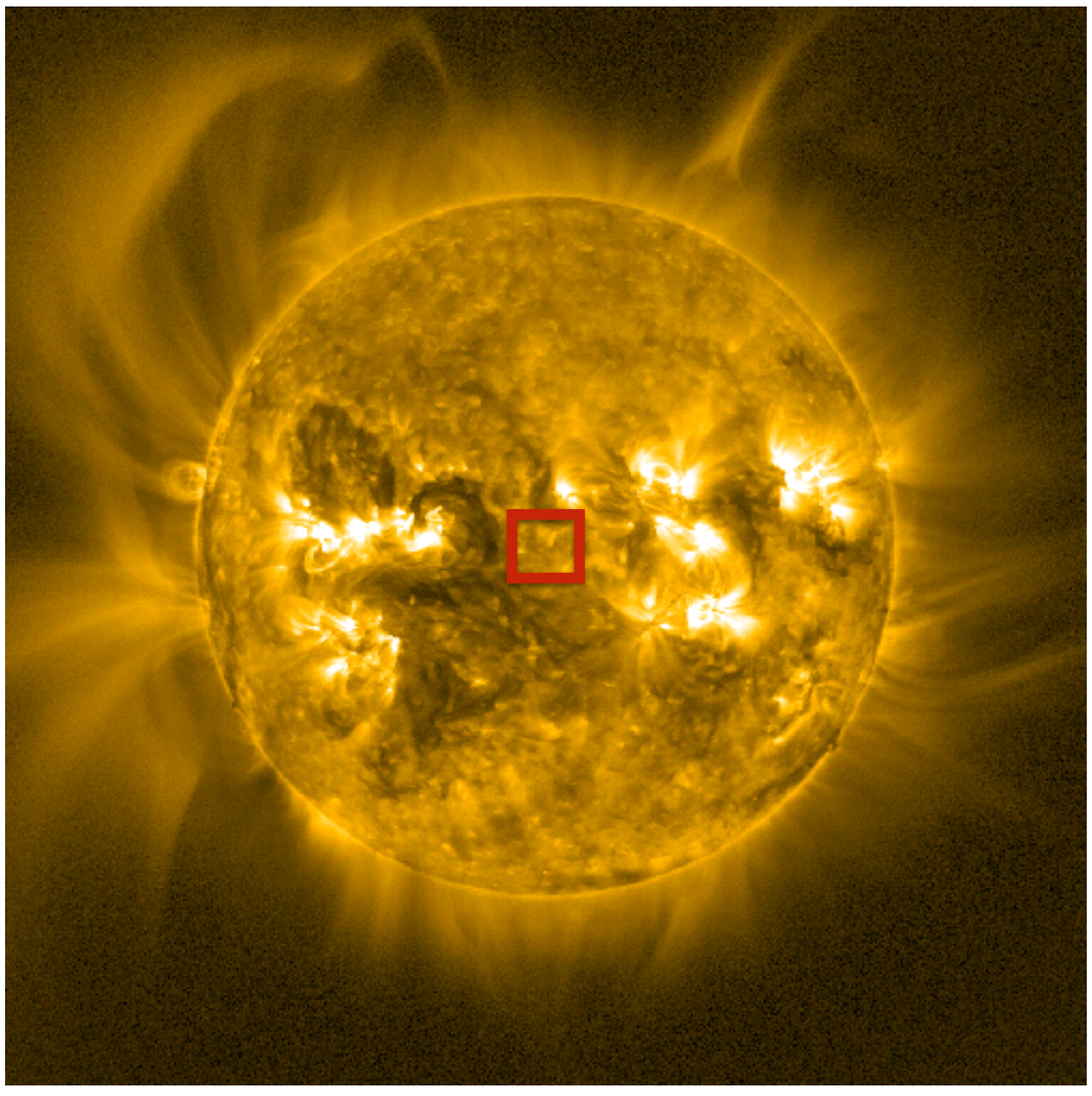


30.4nm

resolution: 9 arcsec on 2 pixels

@ 0.28 AU =1830 km on 2 pixels

HRI:High Resolution Imagers



field of view:

17’x17’

@ 0.28 AU =

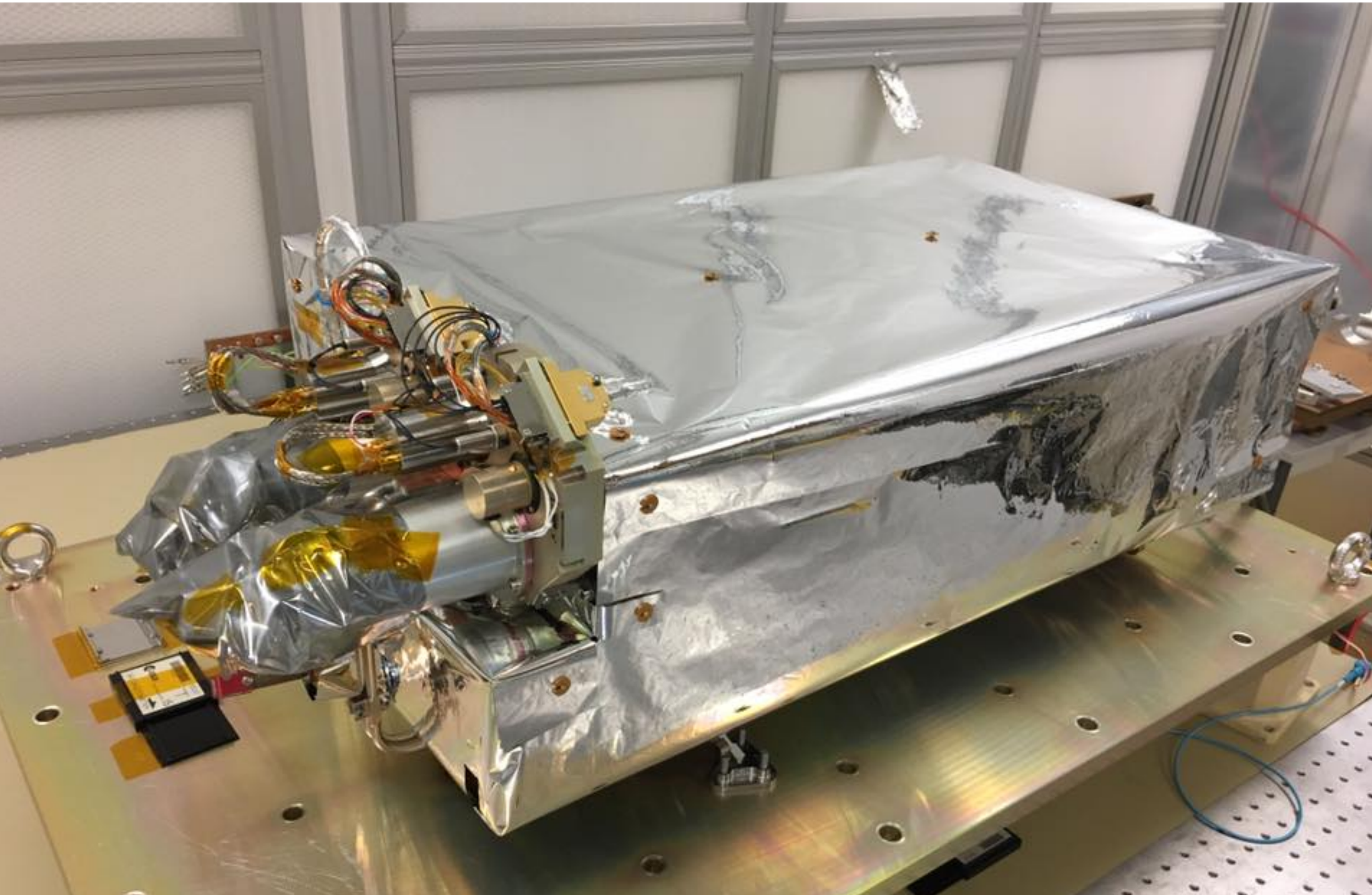
0.16 RSun x 0.16 RSun

resolution:

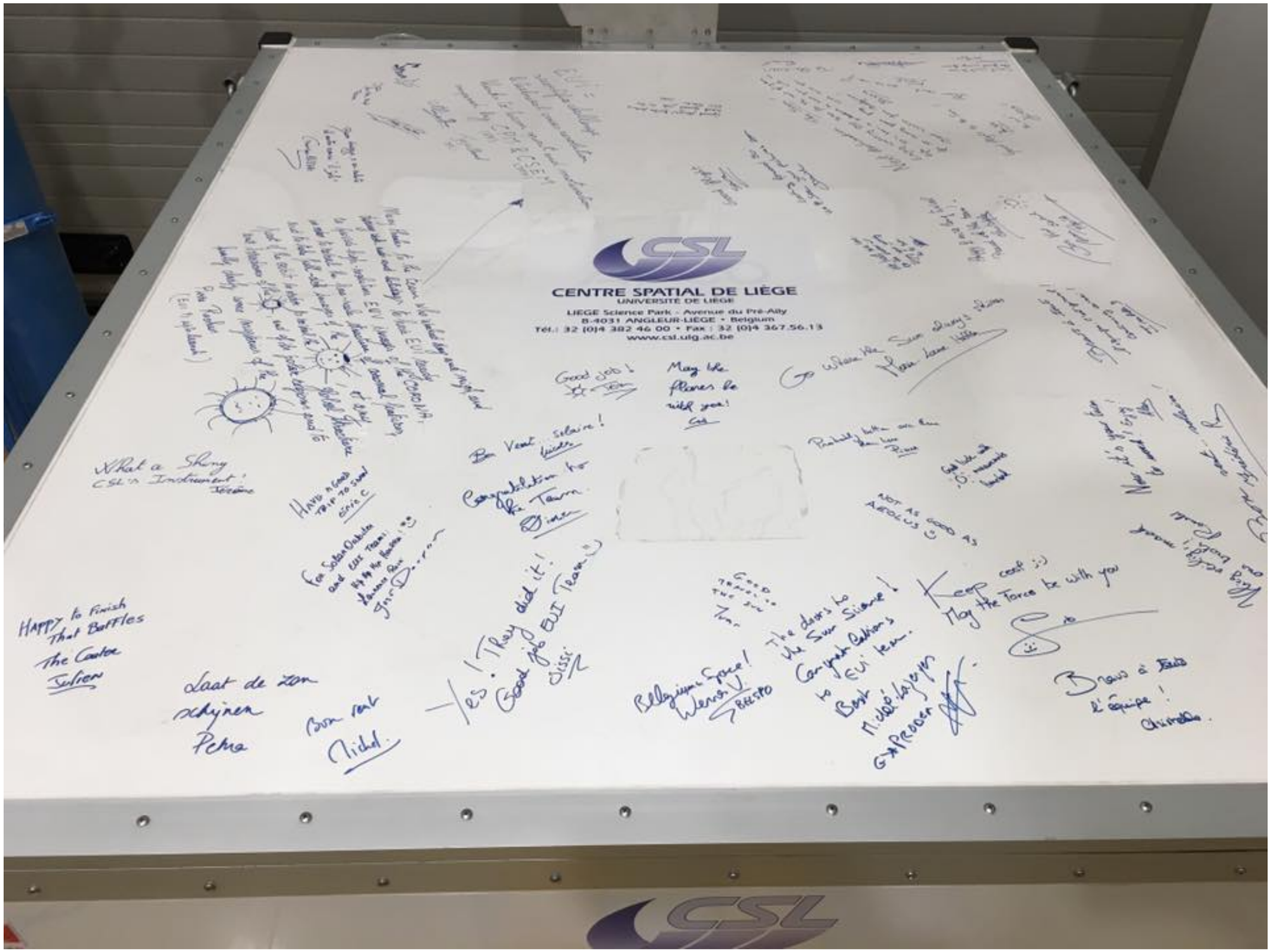
1 arcsec on 2 pixels

@ 0.28 AU = 200km

Wrapped



Put it in a box …



And have a party!



Conclusions



- the corona is big, hot & interesting
- to see the corona, you must get rid of solar visible light
- coronagraphs see the outer corona, EUV imagers see the inner corona
- the gap in between is where space weather originates
- the ASPIICS coronagraph on PROBA-3 and the EUI telescopes on Solar Orbiter will close the gap



Thanks: BELSPO/PRODEX for financing our instruments, CSL & partners for building them, colleagues at ROB for getting all the work done, A. Zhukov and D. Berghmans for providing several slides.