Onderzoek met Solar Orbiter/EUI en een vooruitblik op PROBA-3

David Berghmans
Koninklijke Sterrenwacht van België

Blankenberge 2016, Axel Lynen

Svalbard, Norway 2015 April 20

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

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

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

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

g= 270 m/s^2
M=1
T= 5700

H=270km

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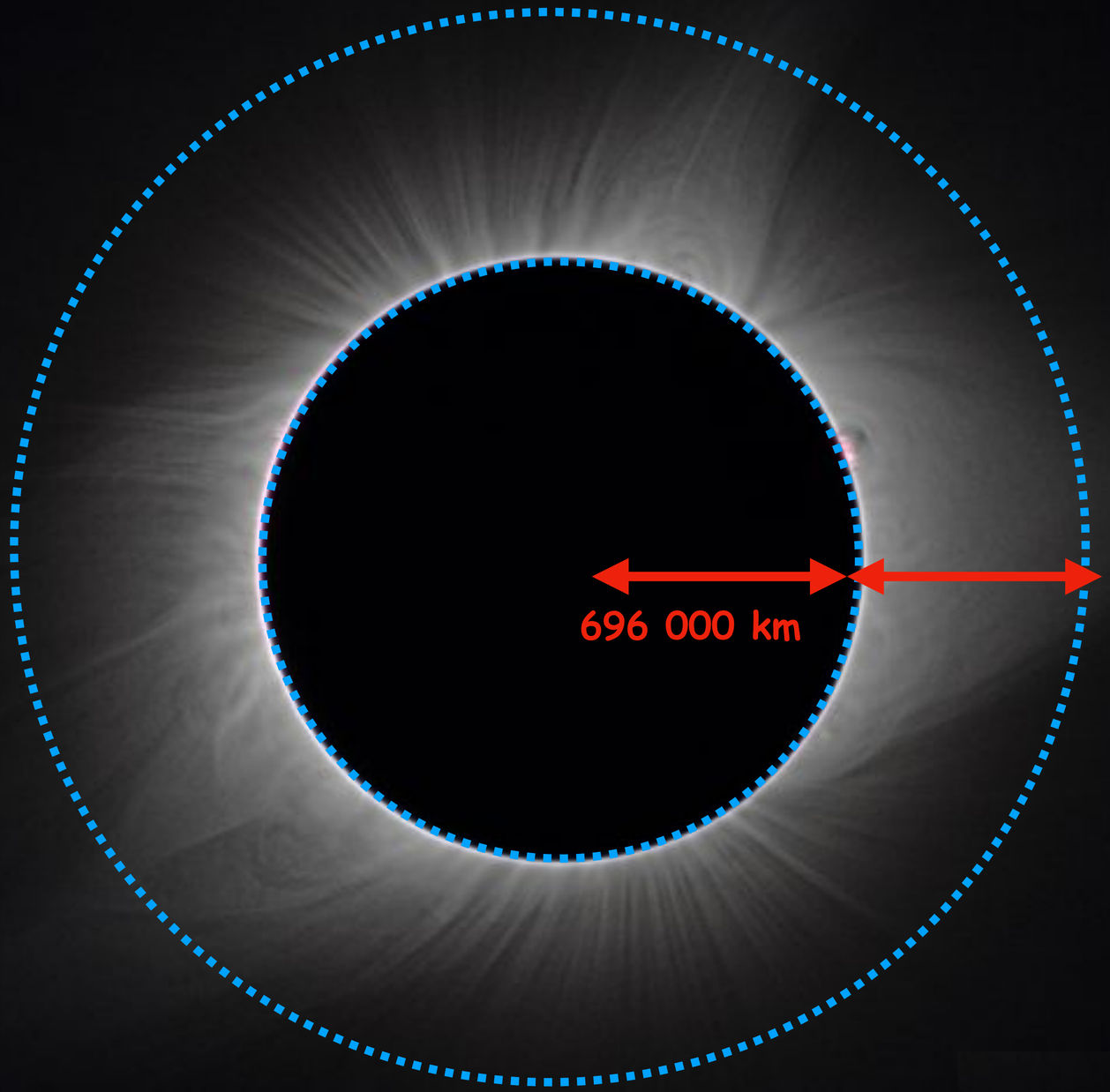

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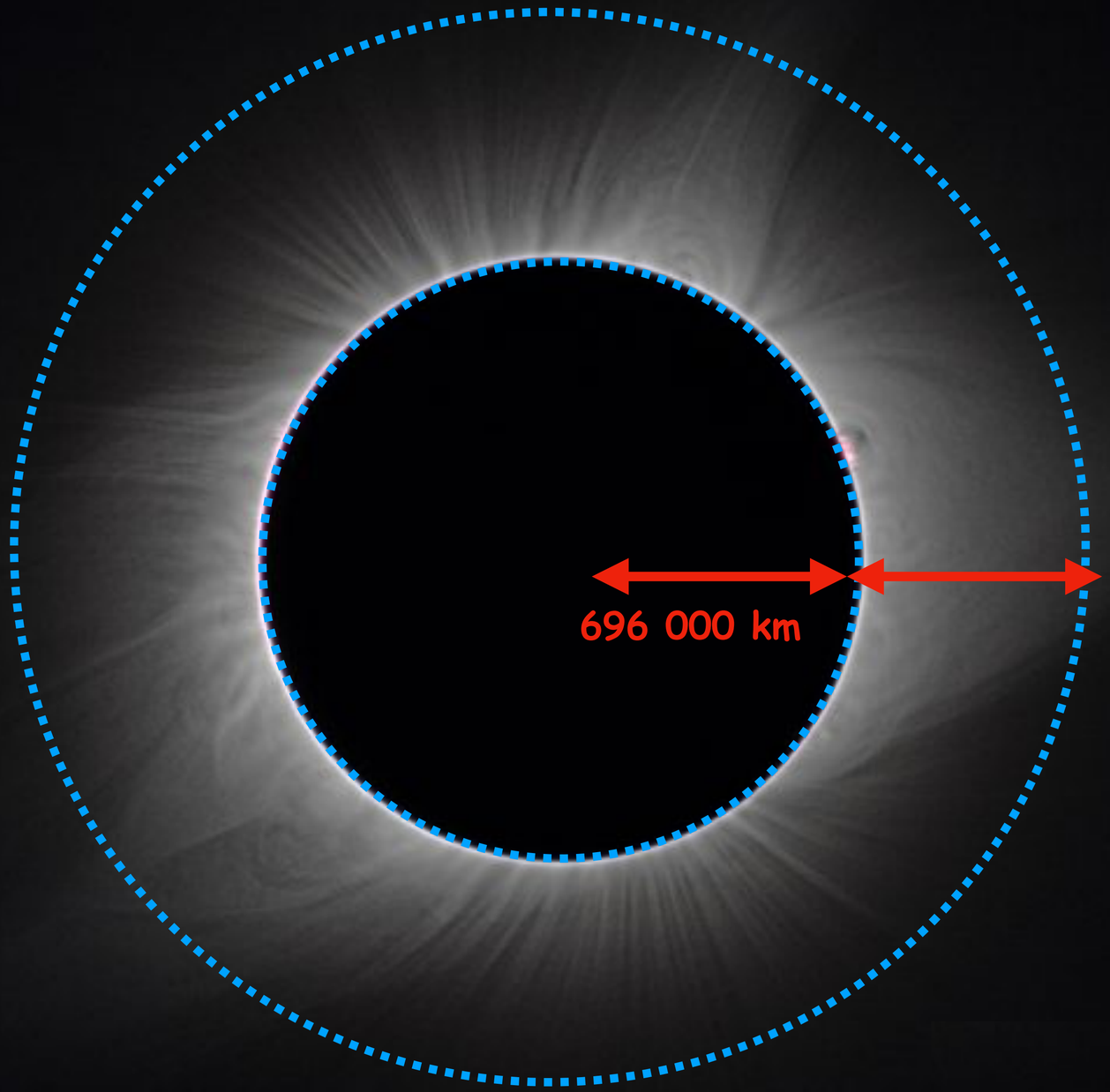

$$P = P_0 \exp\left(-\frac{z}{H}\right)$$

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

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

~~H=270km~~
>696 000 km

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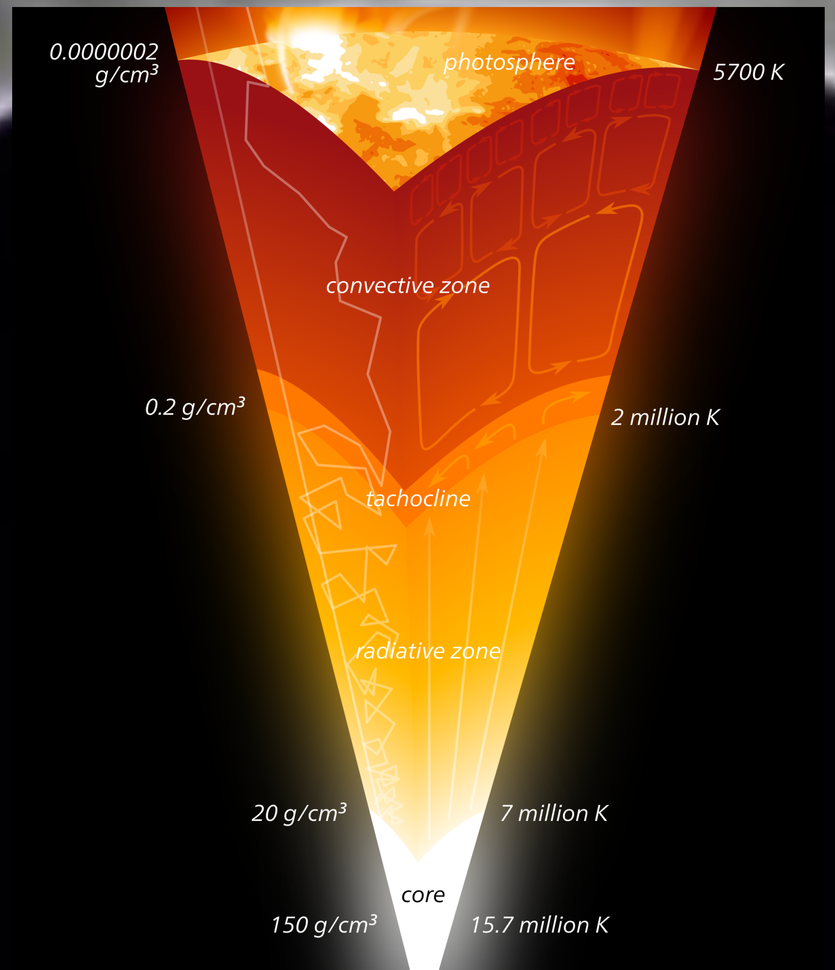
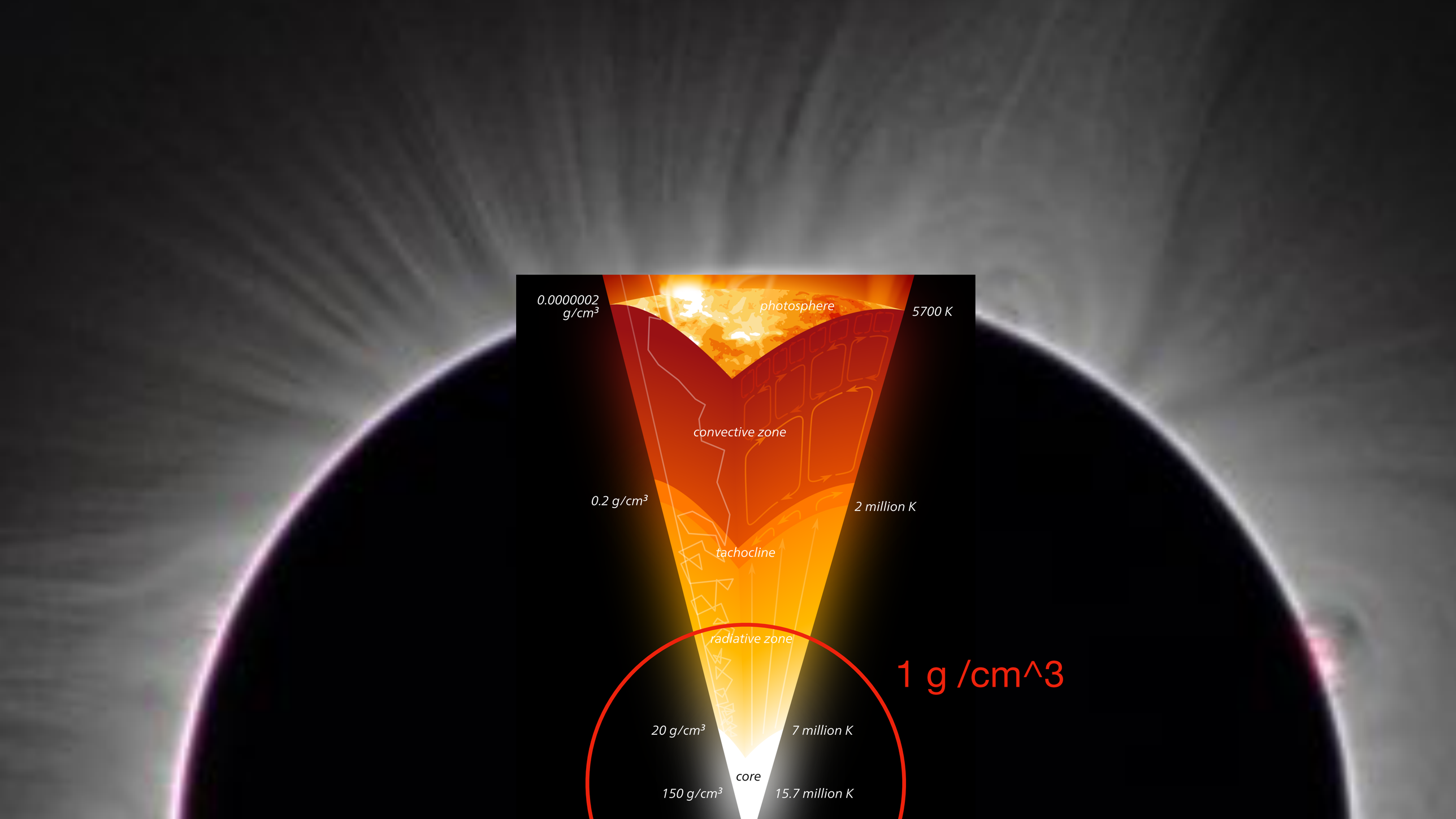
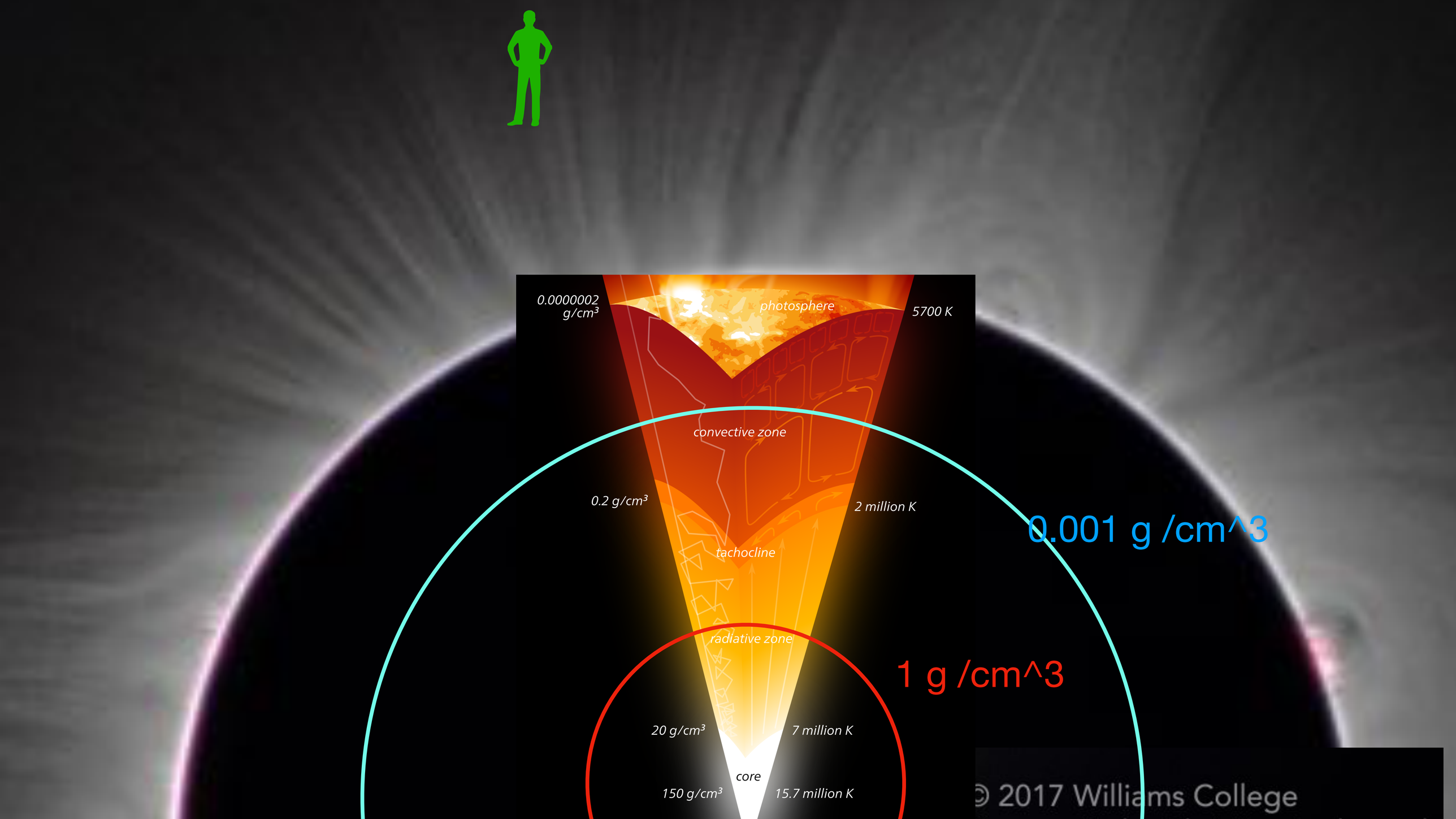
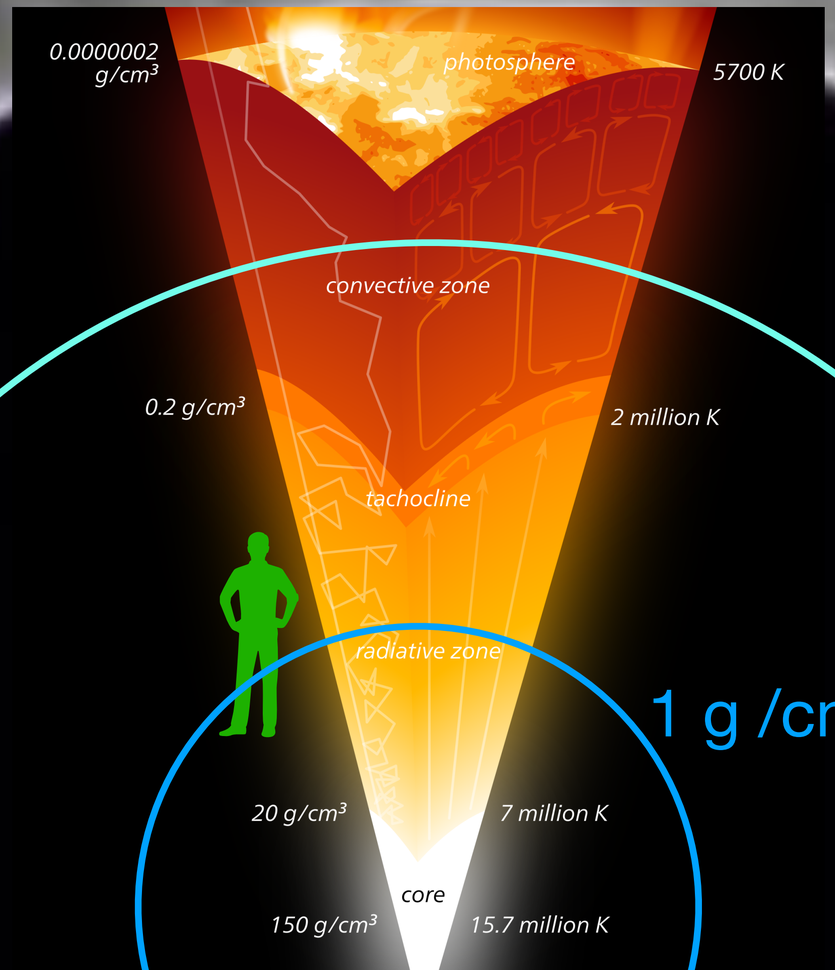

0.0000002 g/cm³
photosphere
5700 K
convective zone
0.2 g/cm³
2 million K
tachocline
radiative zone
20 g/cm³
7 million K
core
150 g/cm³
15.7 million K


0.0000002 g/cm³
photosphere
5700 K
convective zone
0.2 g/cm³
2 million K
tachocline
radiative zone
1 g /cm^3
20 g/cm³
7 million K
core
150 g/cm³
15.7 million K


0.0000002 g/cm³
photosphere
5700 K
convective zone
0.2 g/cm³
2 million K
0.001 g /cm^3
tachocline
radiative zone
1 g /cm^3
20 g/cm³
7 million K
core
150 g/cm³
15.7 million K
© 2017 Williams College

Dichtheid:
zonneoppervlak: 10^(-7) g /cm^3
corona: 10^(-16) g /cm^3



0.001 g /cm^3

1 g /cm^3

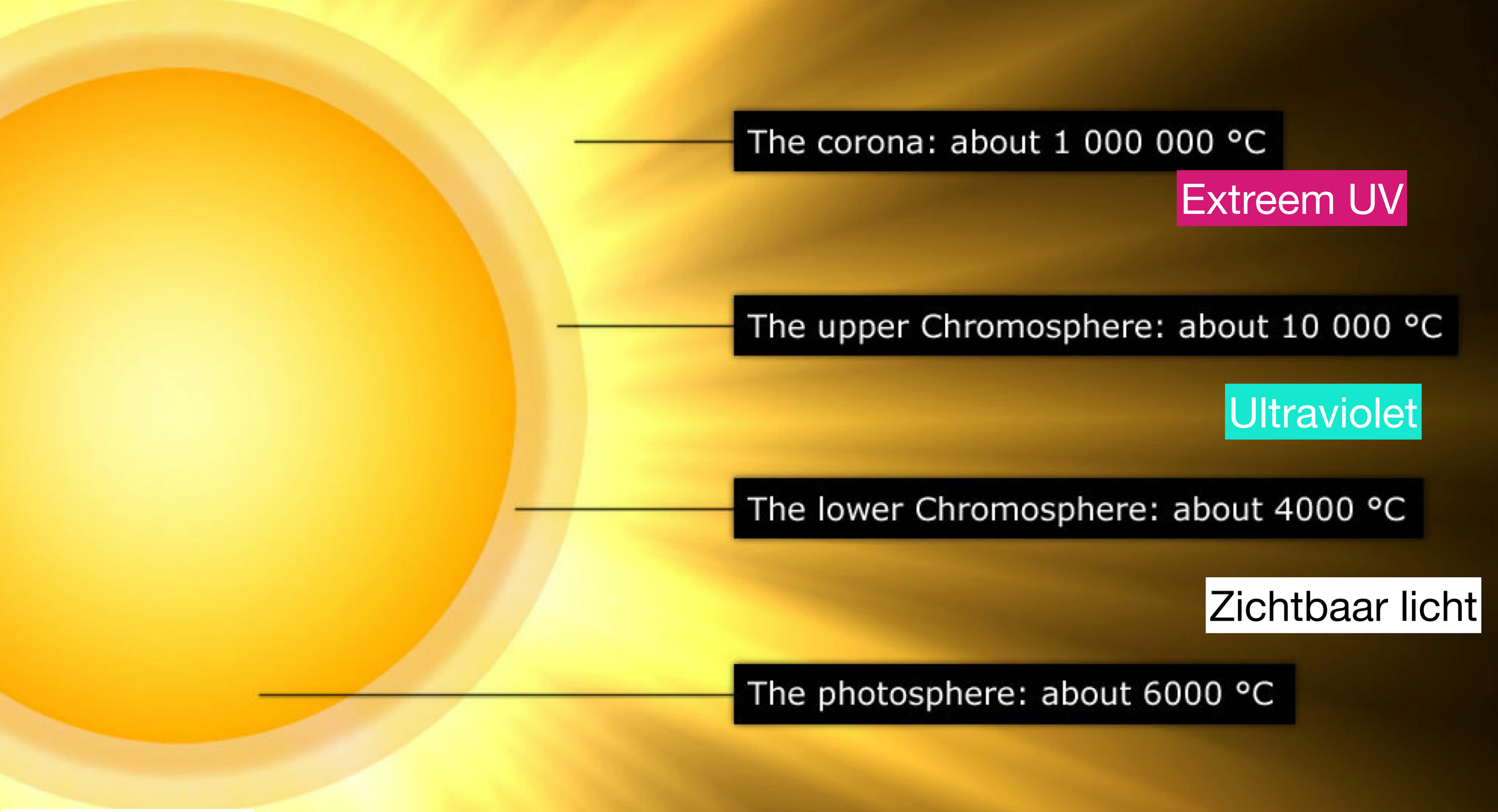
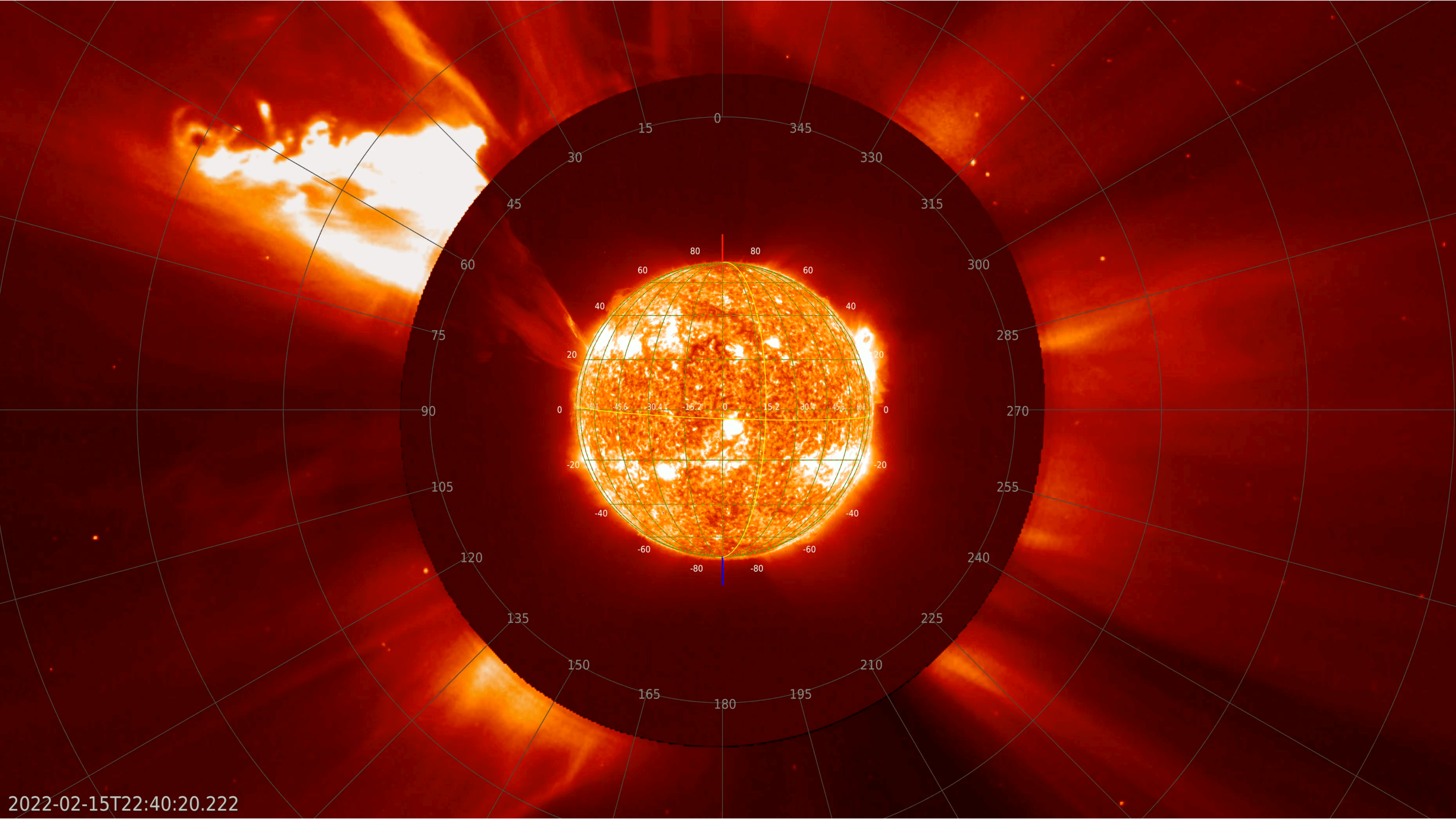


Illustration: Per Byhring

De corona is zeer groot,
zeer heet en zeer ijl …

De corona is zeer groot,
zeer heet en zeer ijl …

en toch boordevol energie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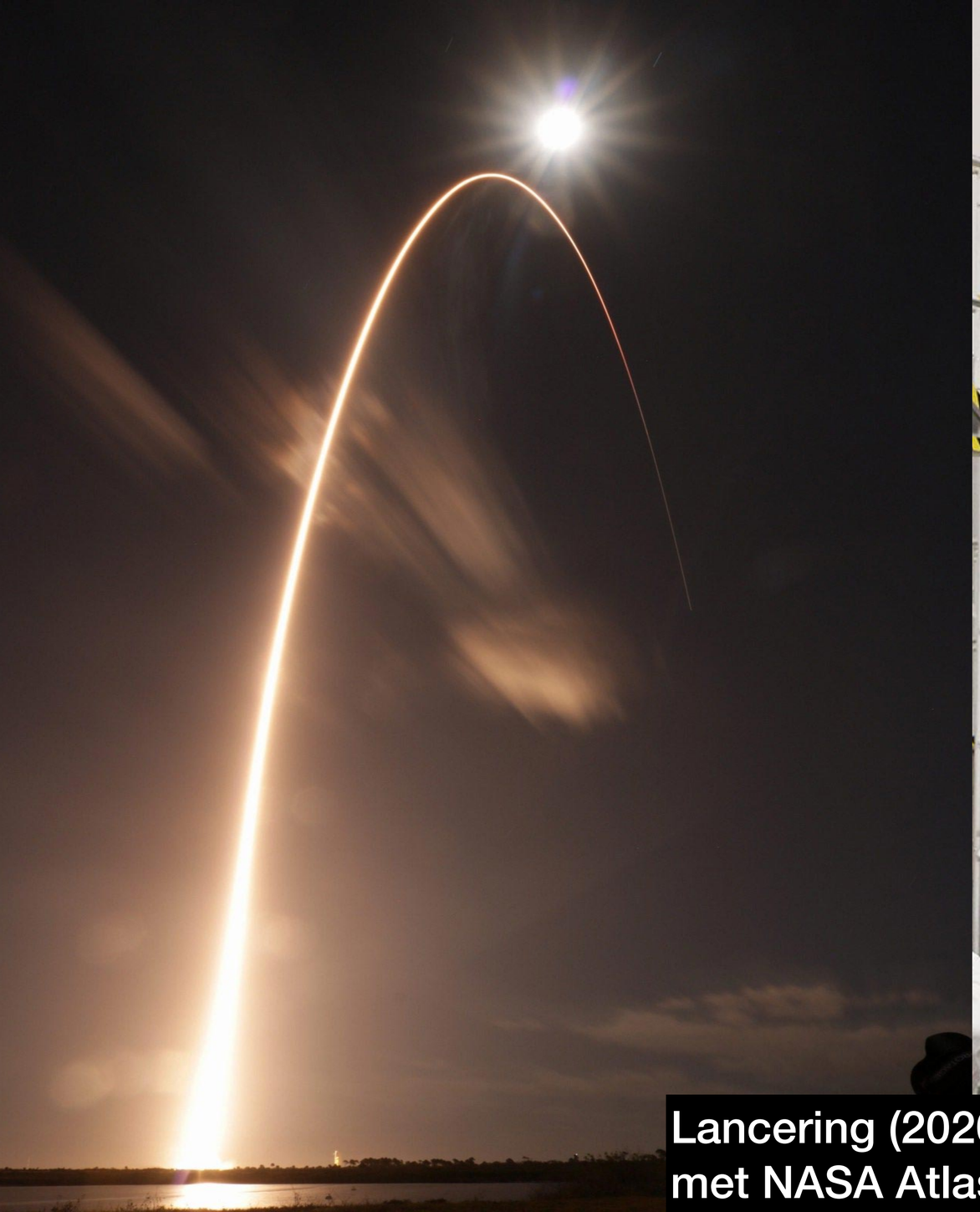
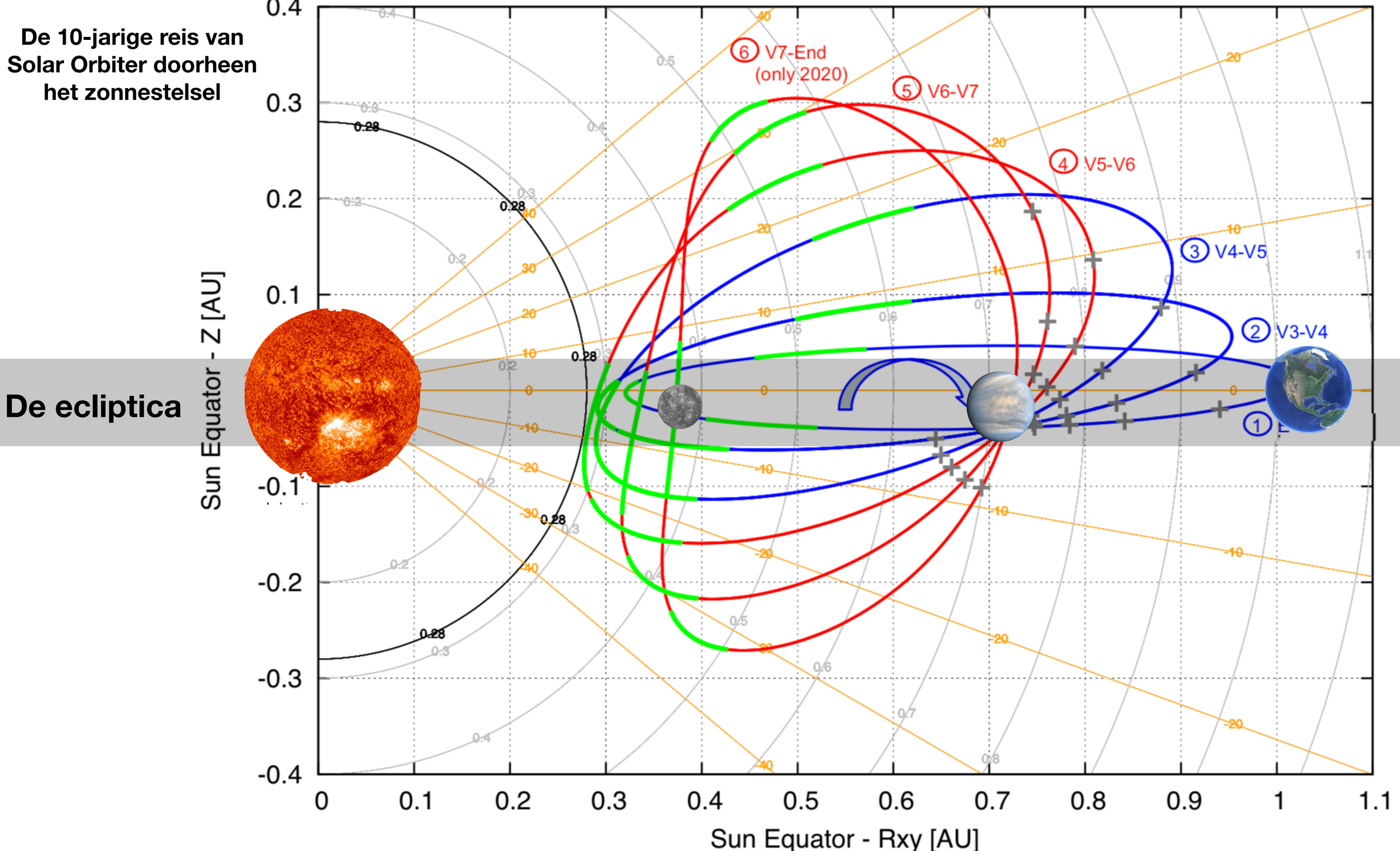
Solar Orbiter



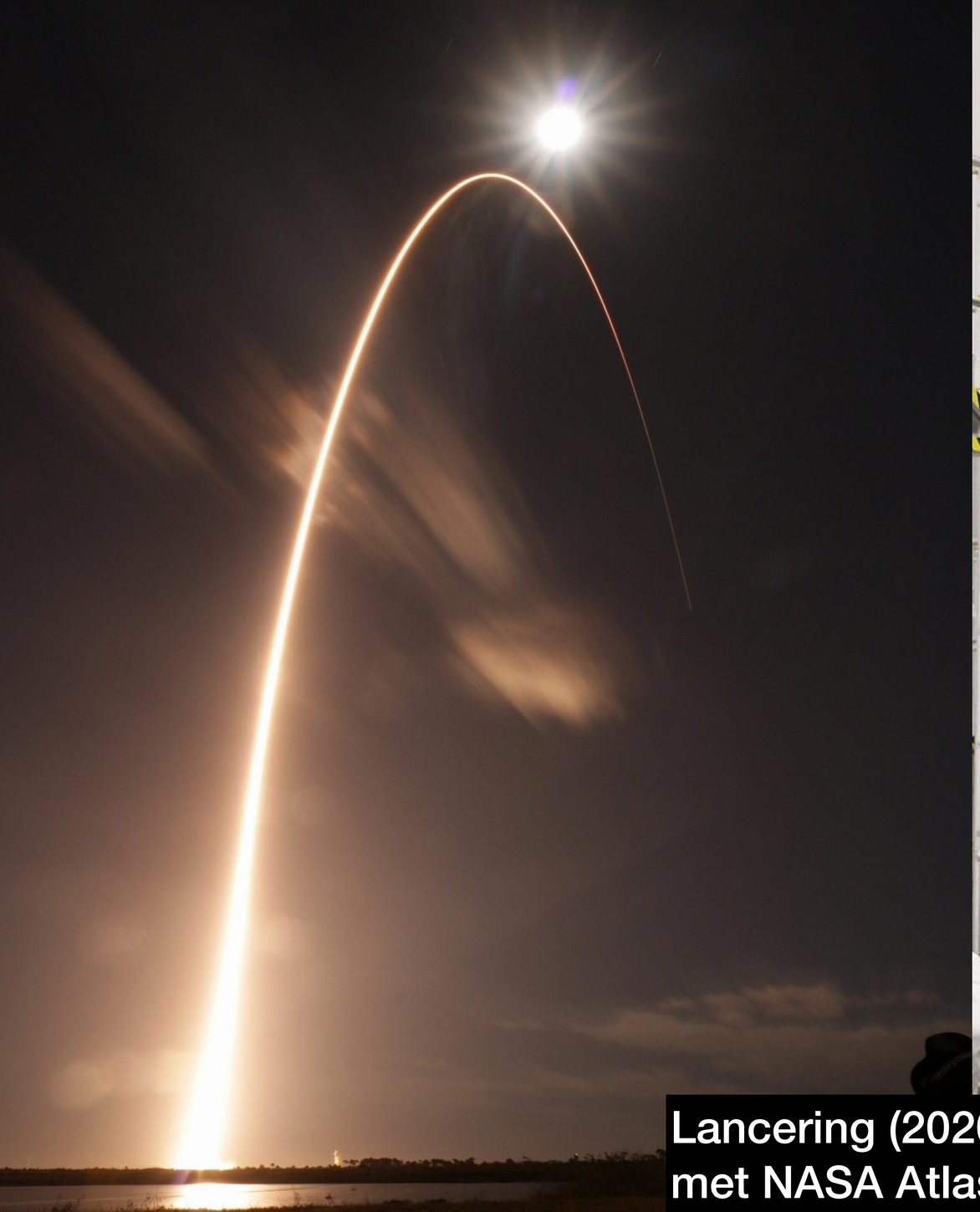
Lancering (2020 Feb 10)
met NASA Atlas V raket

De 10-jarige reis van Solar Orbiter doorheen het zonnestelsel



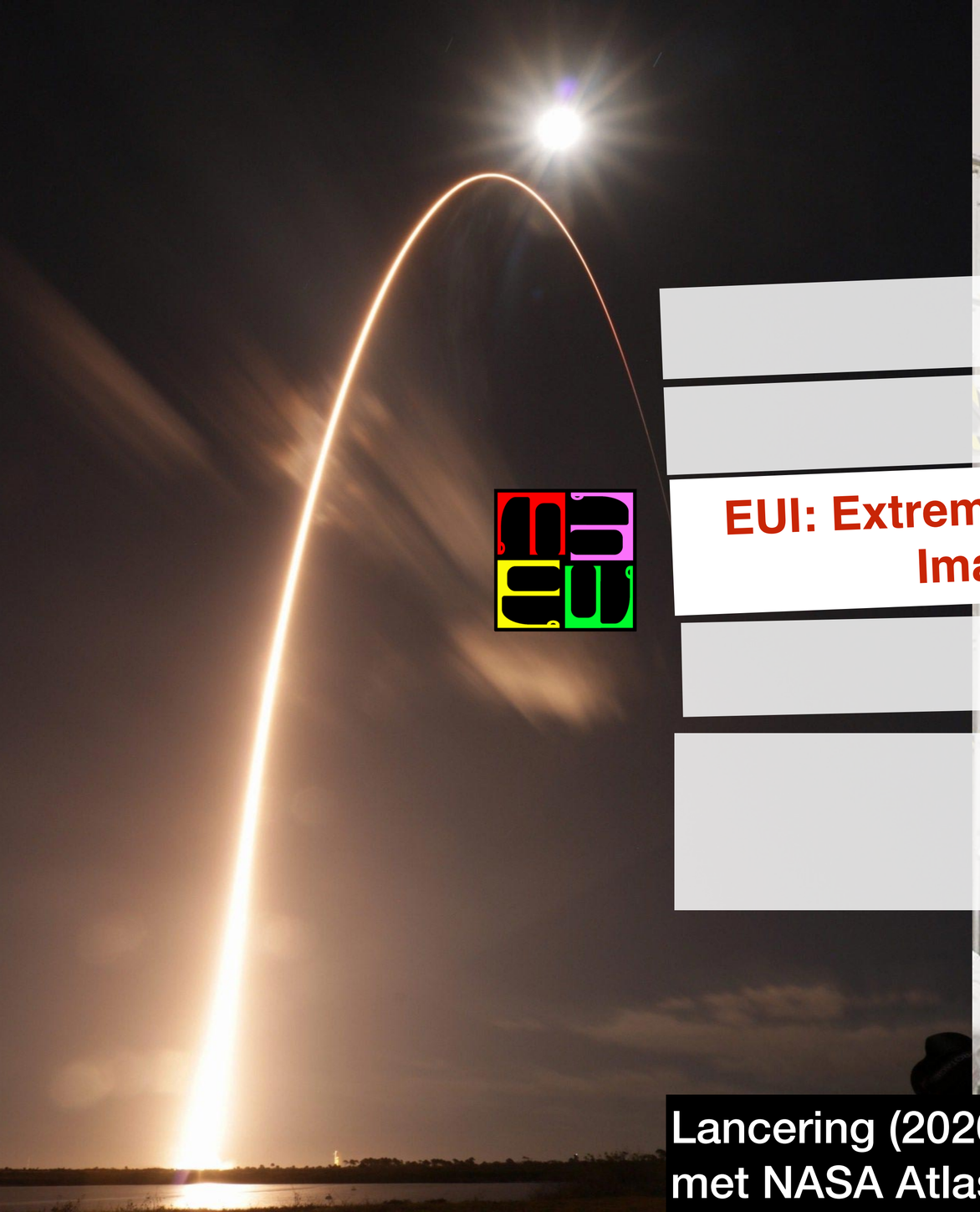
De ecliptica

Image Courtesy ESA, 'CREMA report'.



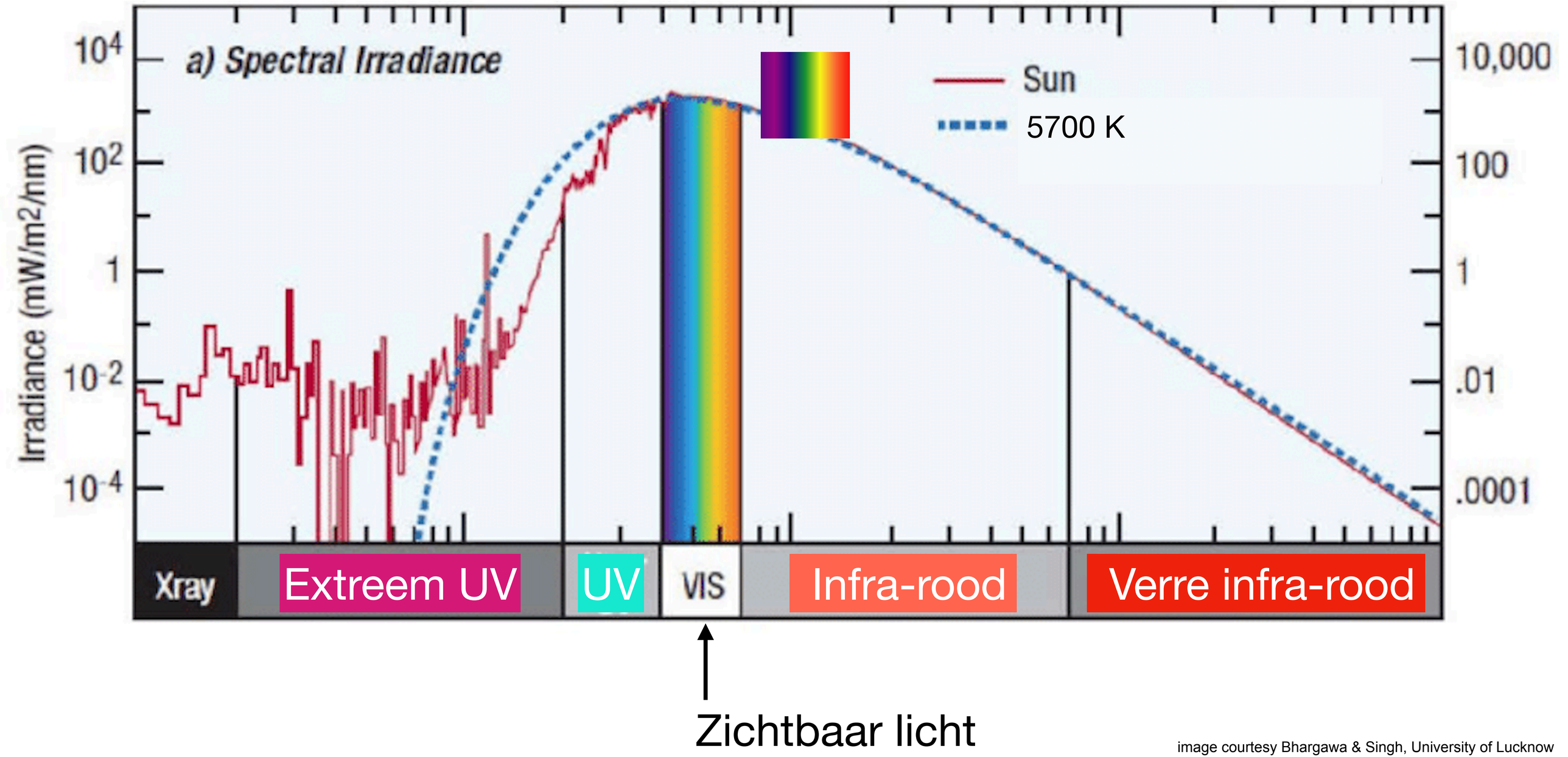
Lancering (2020 Feb 10)
met NASA Atlas V raket

EUI: Extreme Ultraviolet Imager



Lancering (2020 Feb 10)
met NASA Atlas V raket

EUI OBS ST
30mm
47.4mm
2.75mm edge



Zichtbaar licht

image courtesy Bhargawa & Singh, University of Lucknow

Vanwege de kleine gaten in het hitteschild is het nodig om heldere delen van het spectrum te gebruiken

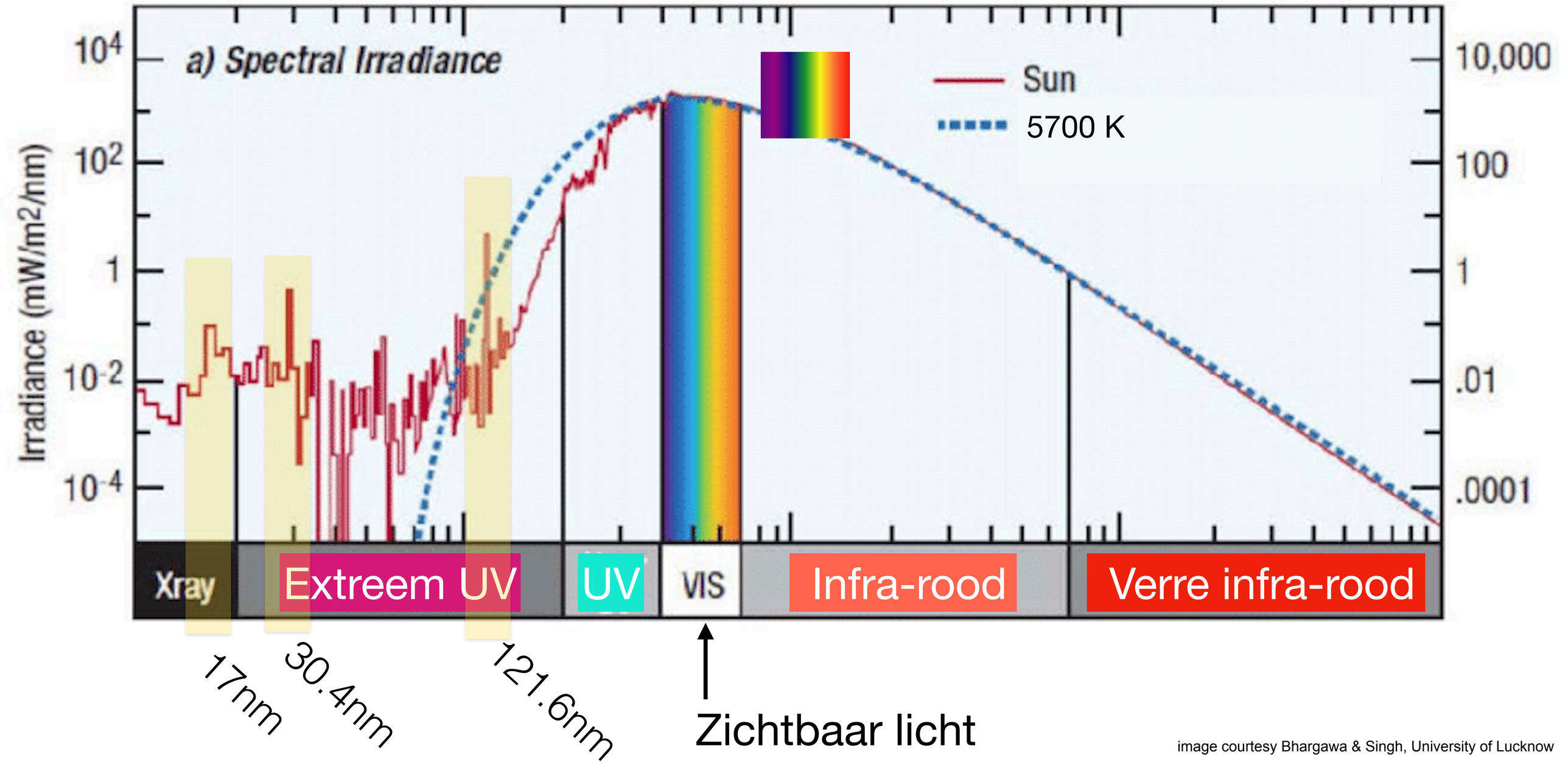
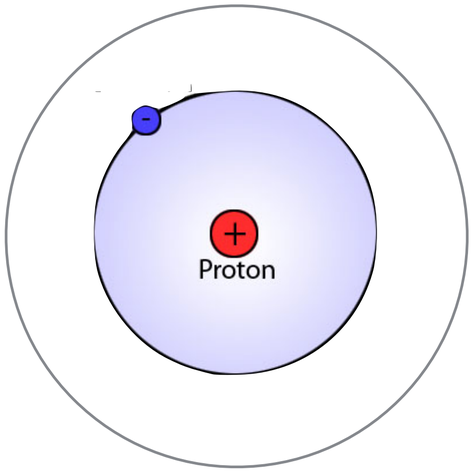
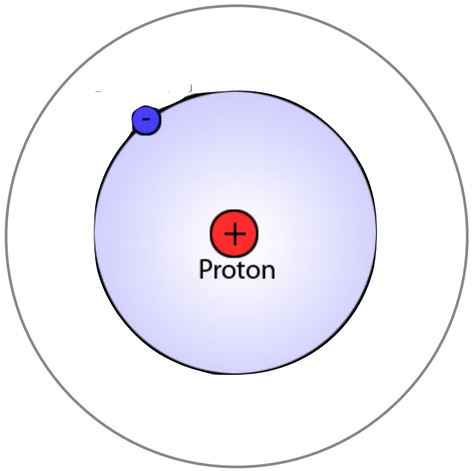


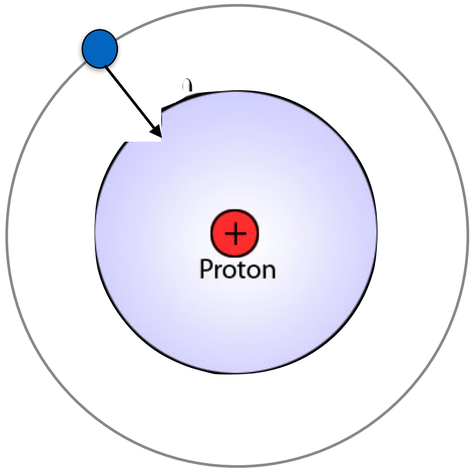
image courtesy Bhargawa & Singh, University of Lucknow

>70% waterstof



>70% waterstof

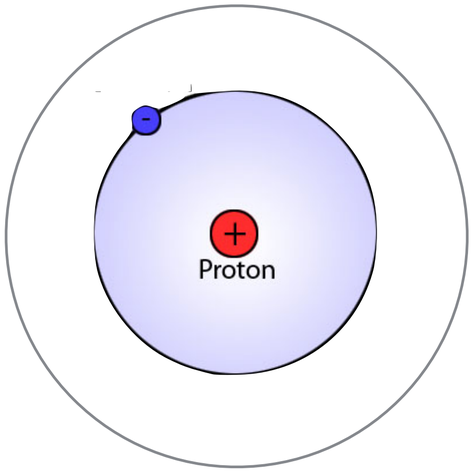


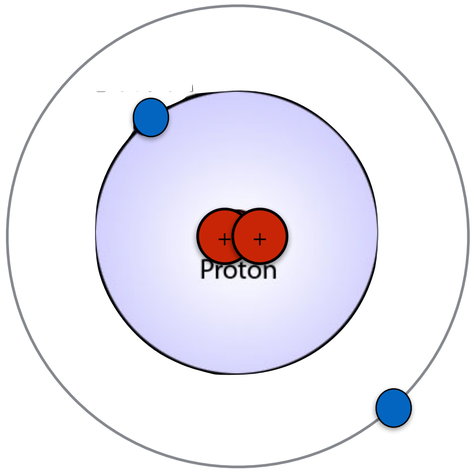


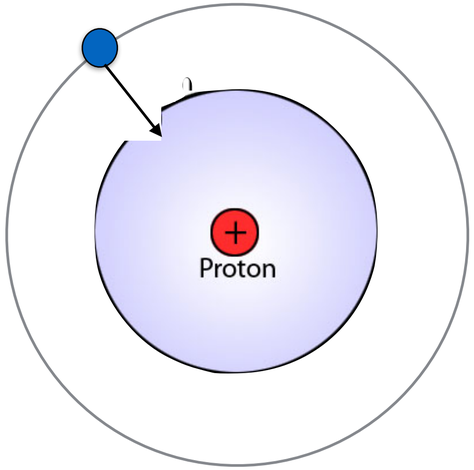
H I Lyman alfa 121.6nm
chromosfeer

>70% waterstof

<30% helium







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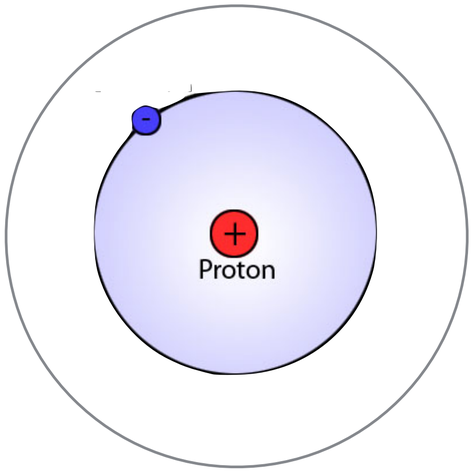

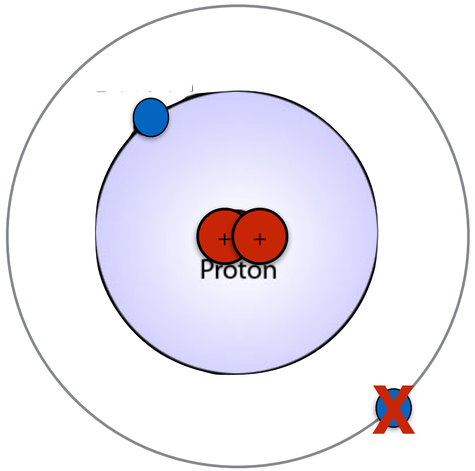

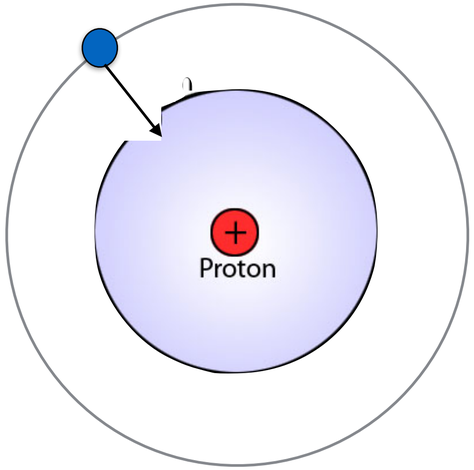

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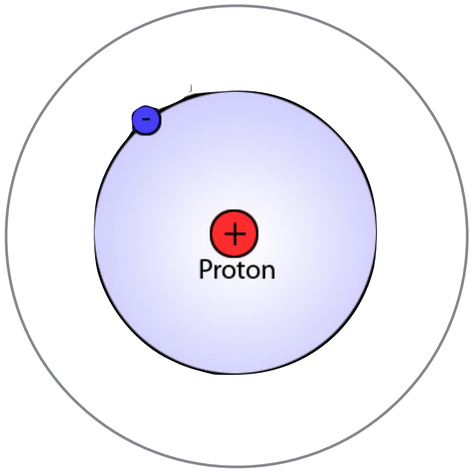
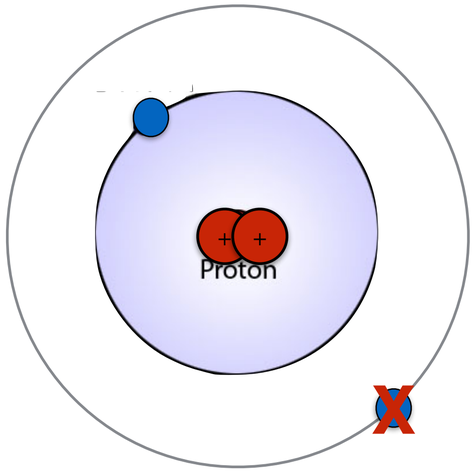
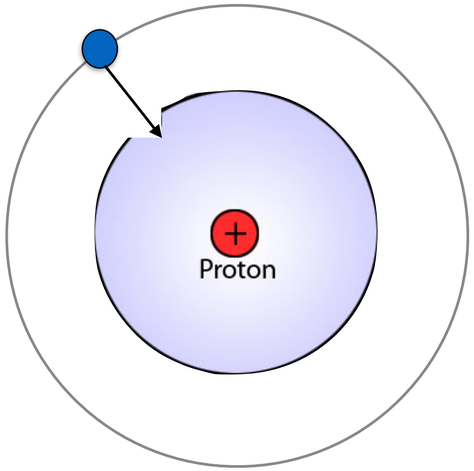
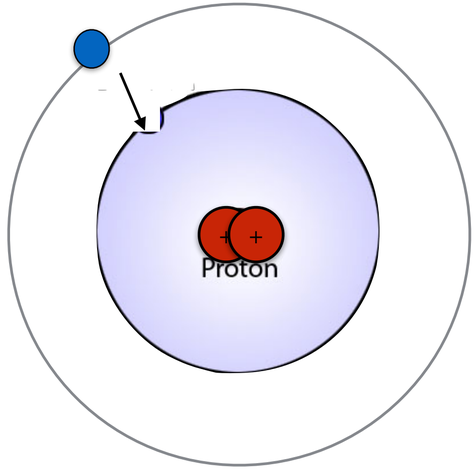








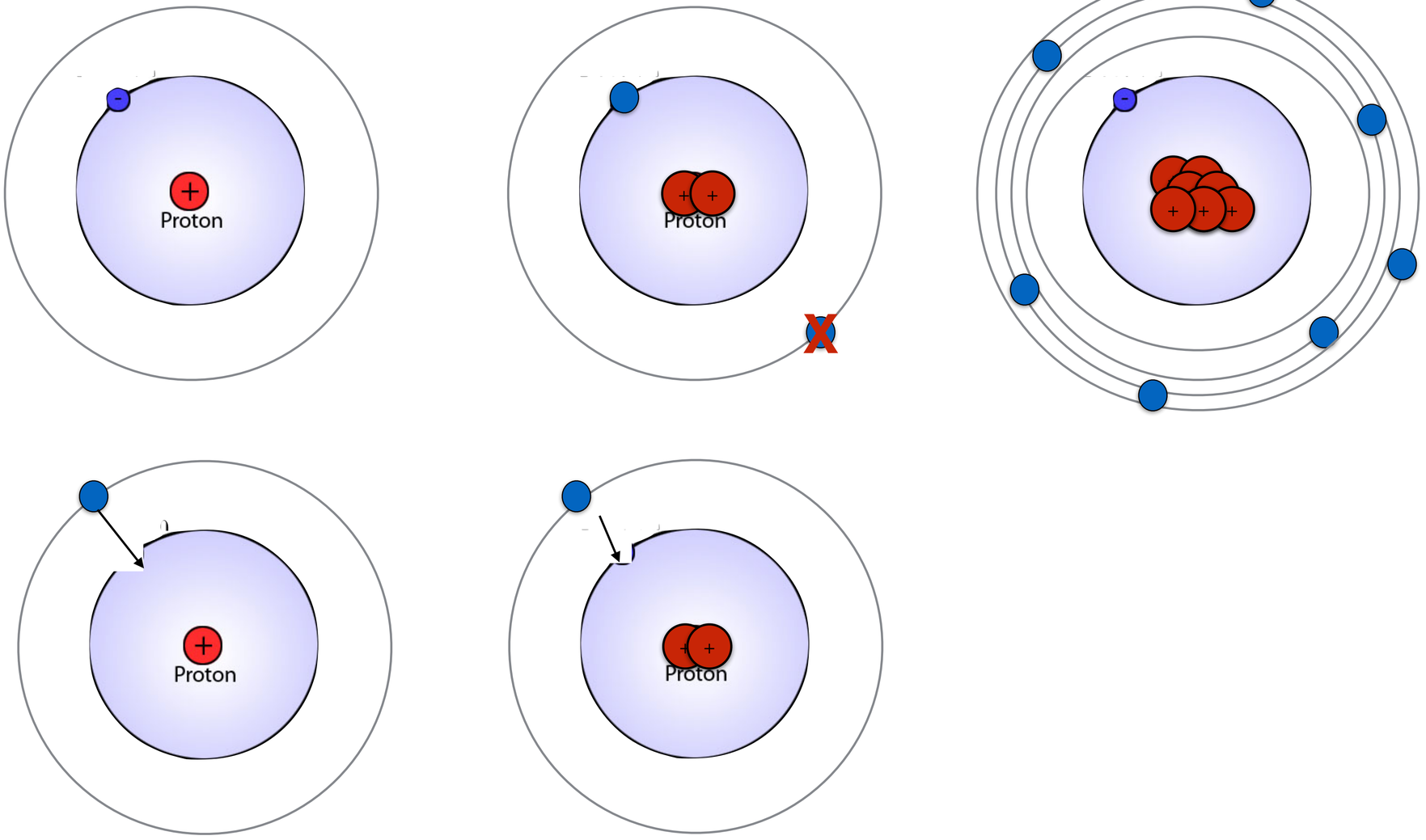
H I Lyman alfa 121.6nm
chromosfeer

He II 30.4nm
transitie laag

>70% waterstof

<30% helium

1% zwaardere elementen



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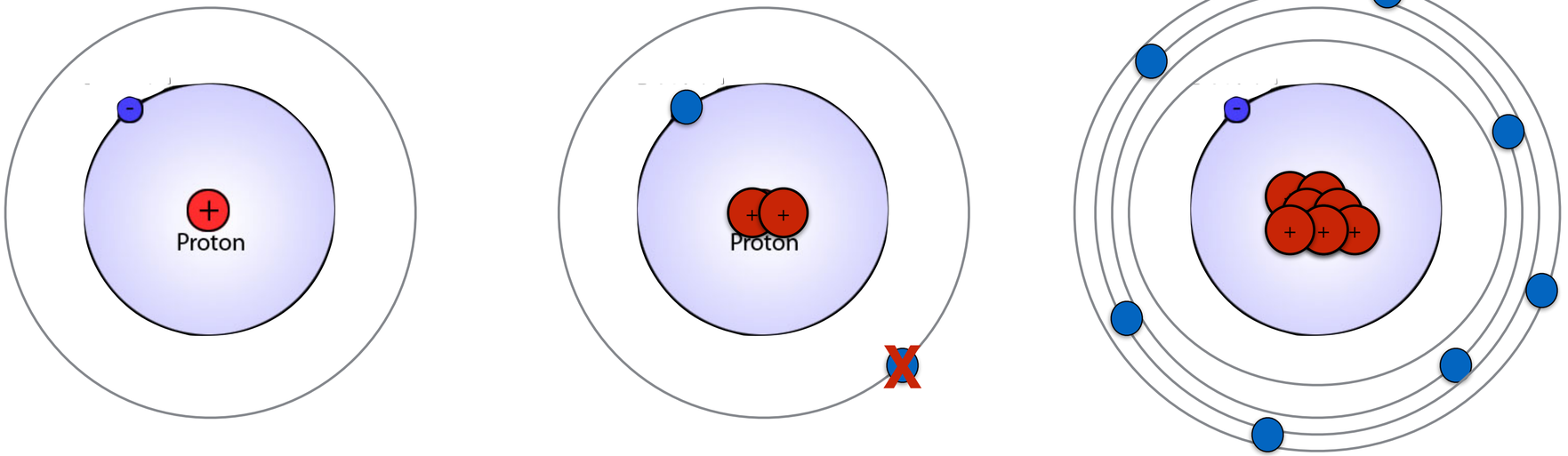

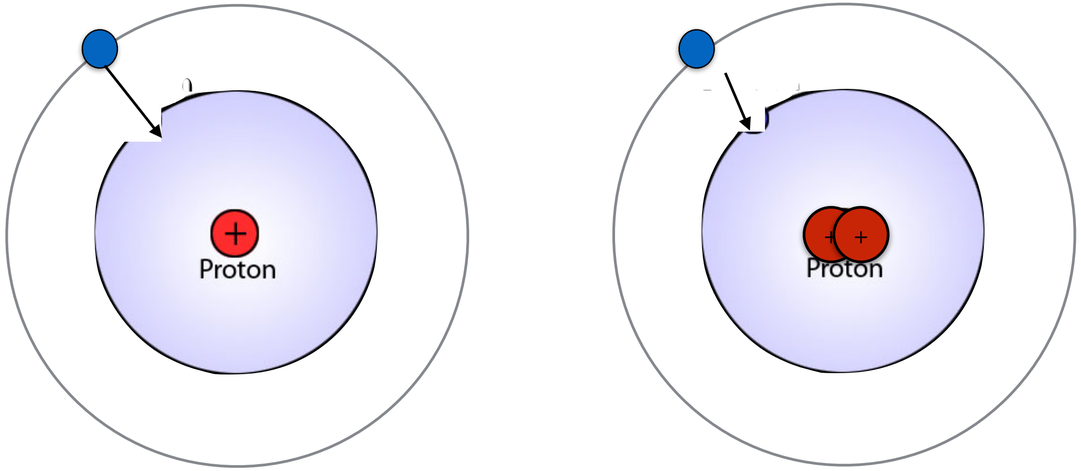

...te ingewikkeld...

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chromosfeer

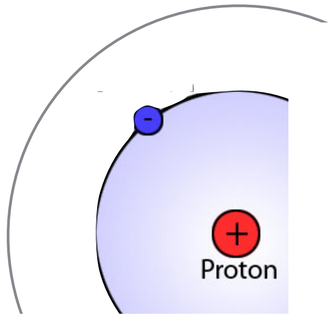
He II 30.4nm
transitie laag

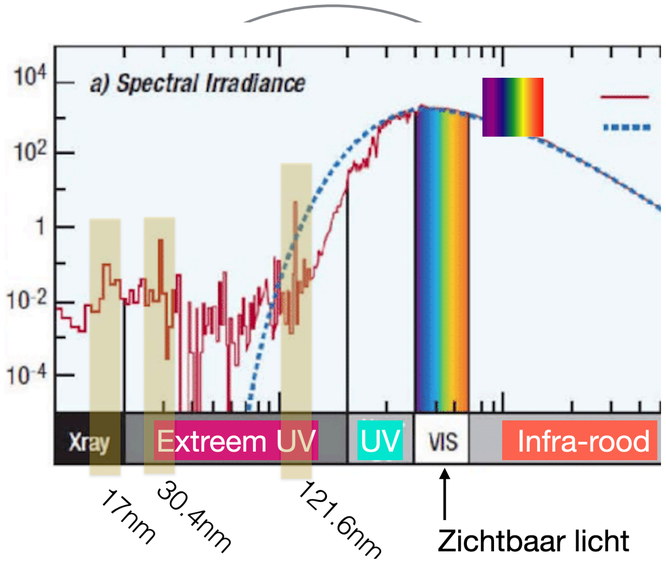
Fe IX, X, XI ~ 17nm
lage corona

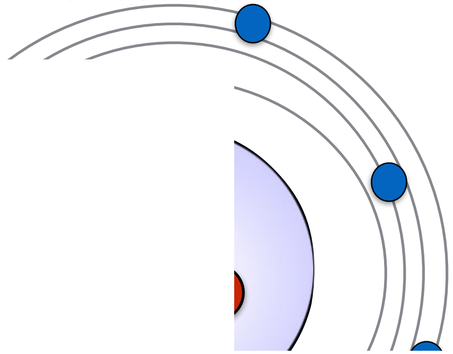
>70% waterstof

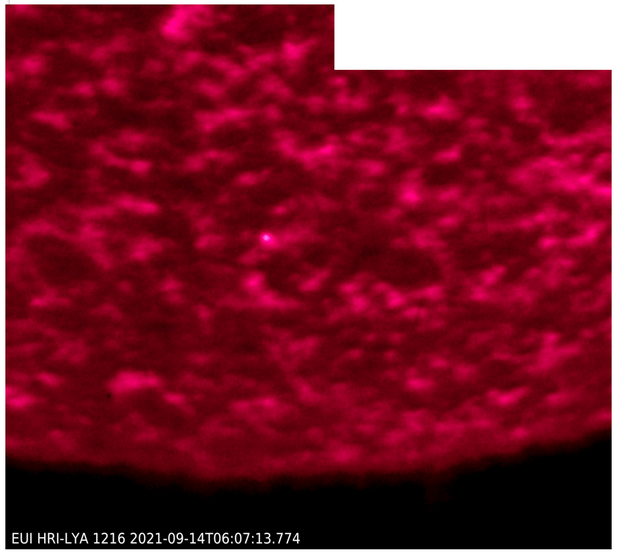
<30% helium

1% zwaardere elementen

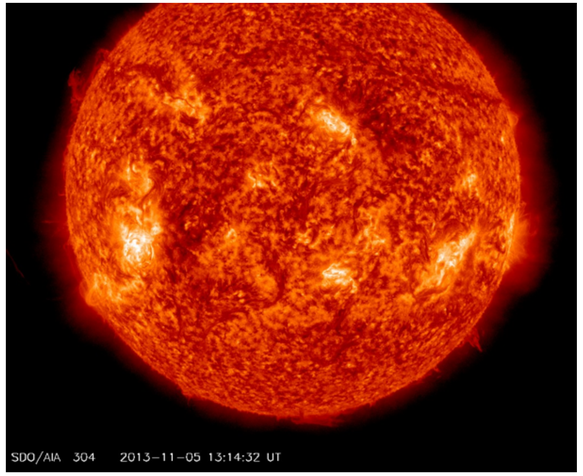




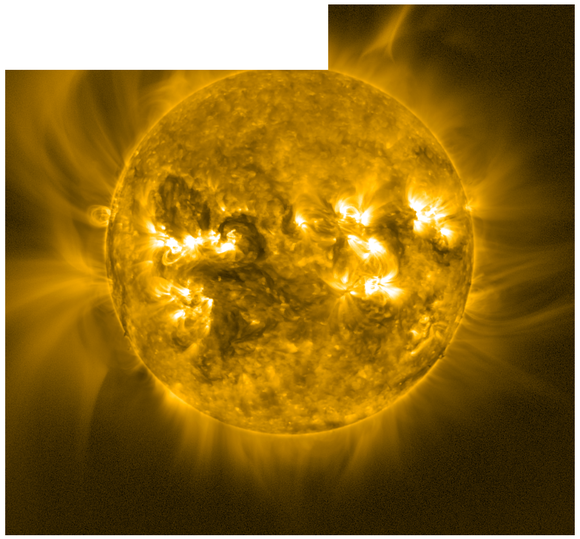




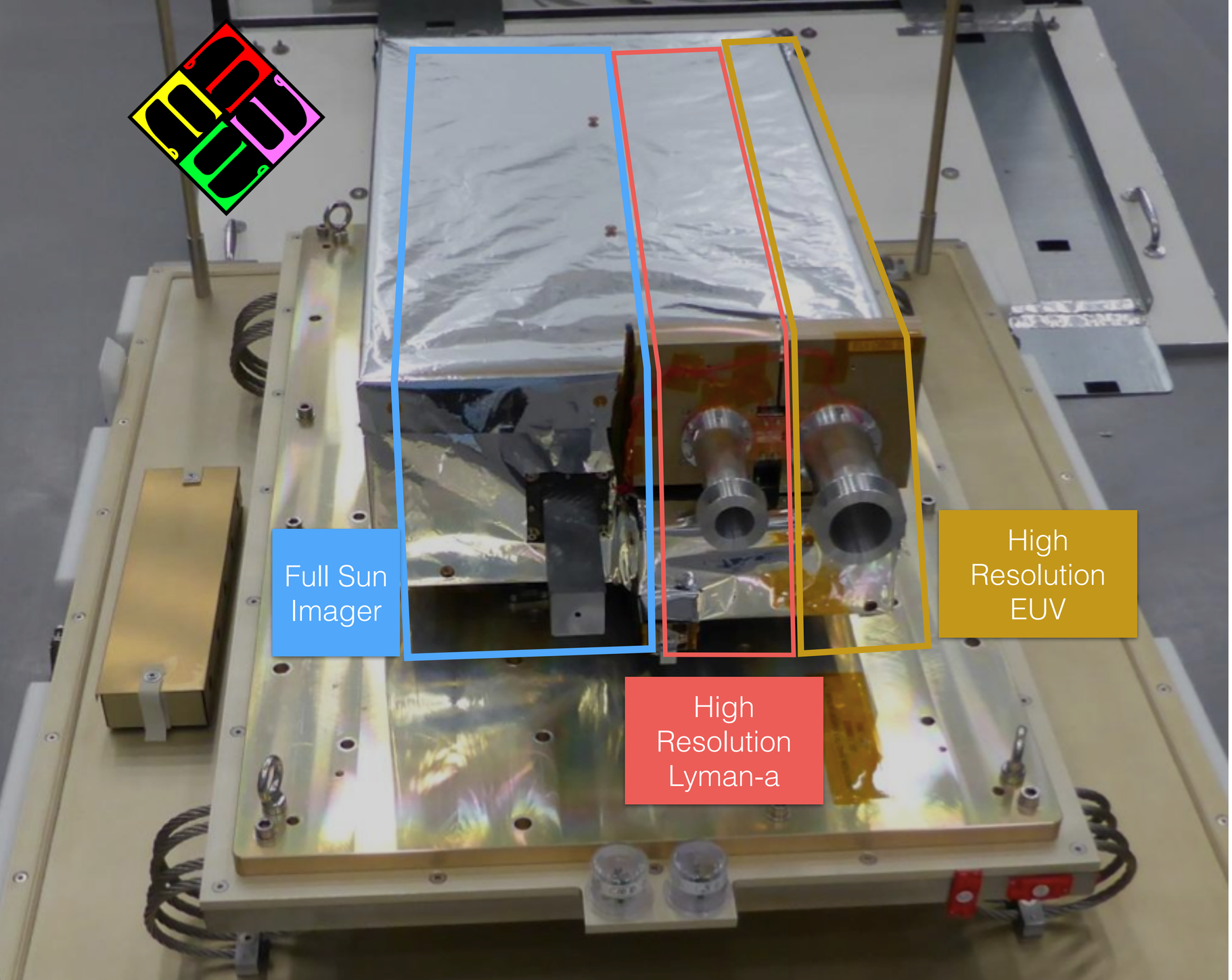
H I Lyman alfa 121.6nm
chromosfeer



He II 30.4nm
transitie laag



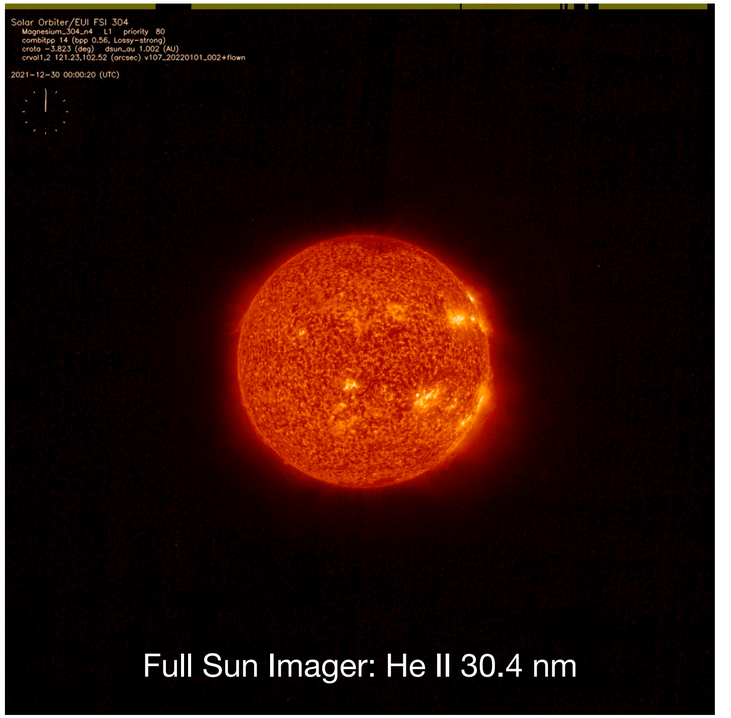
Fe IX, X, XI ~ 17nm
lage corona



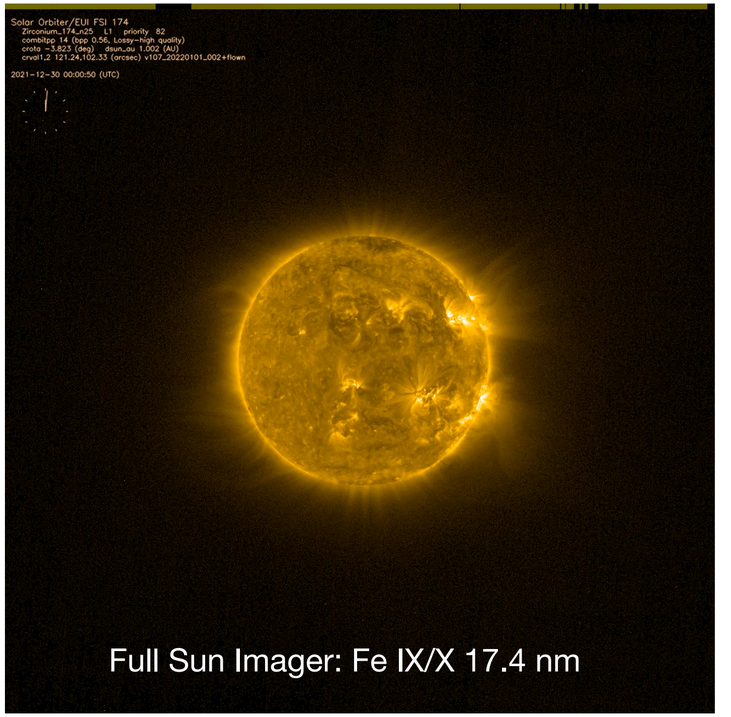
De “Extreme Ultraviolet Imager” (EUI) is gebouwd door:

- 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 Belgie

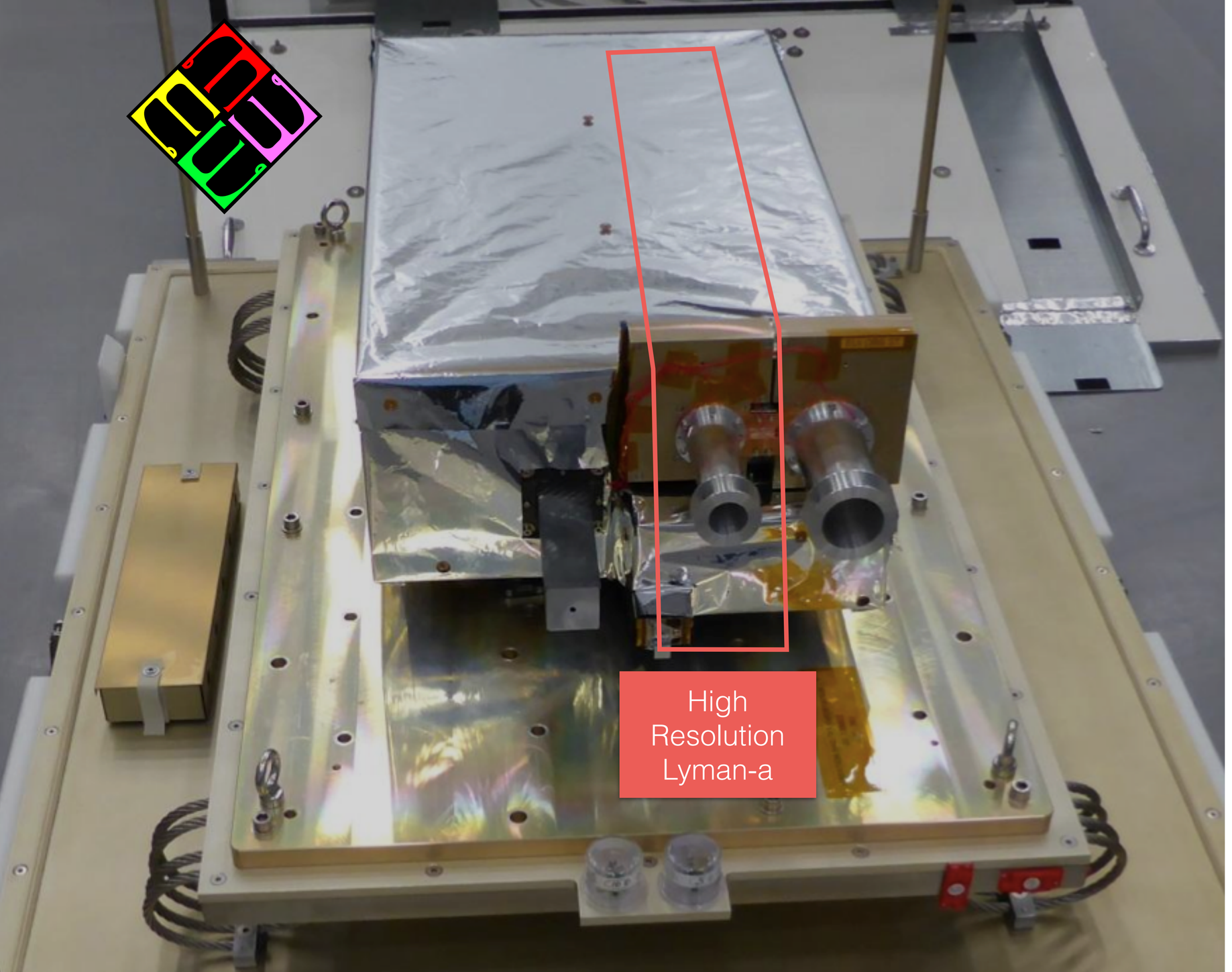
Full Sun Imager



Full Sun Imager: He II 30.4 nm



Full Sun Imager: Fe IX/X 17.4 nm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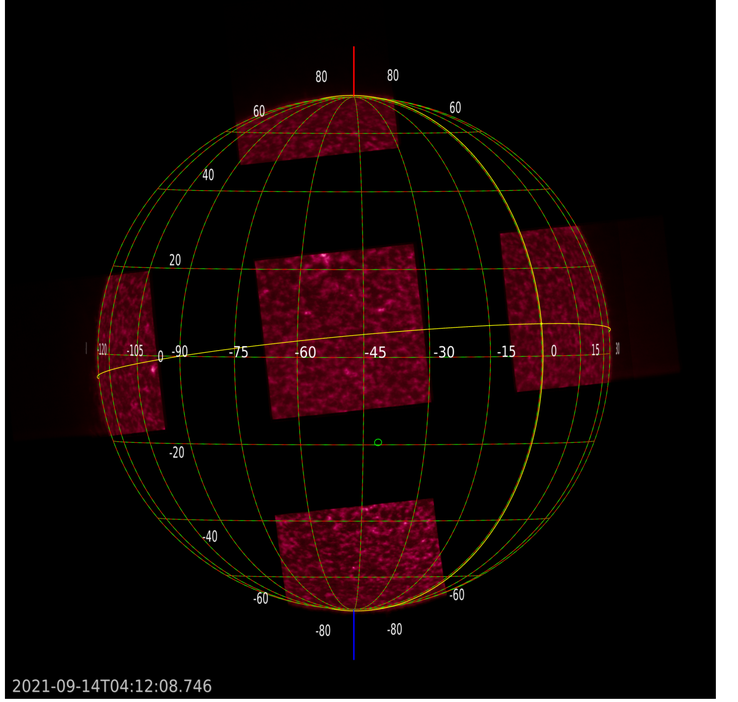
Resolution
Lyman-a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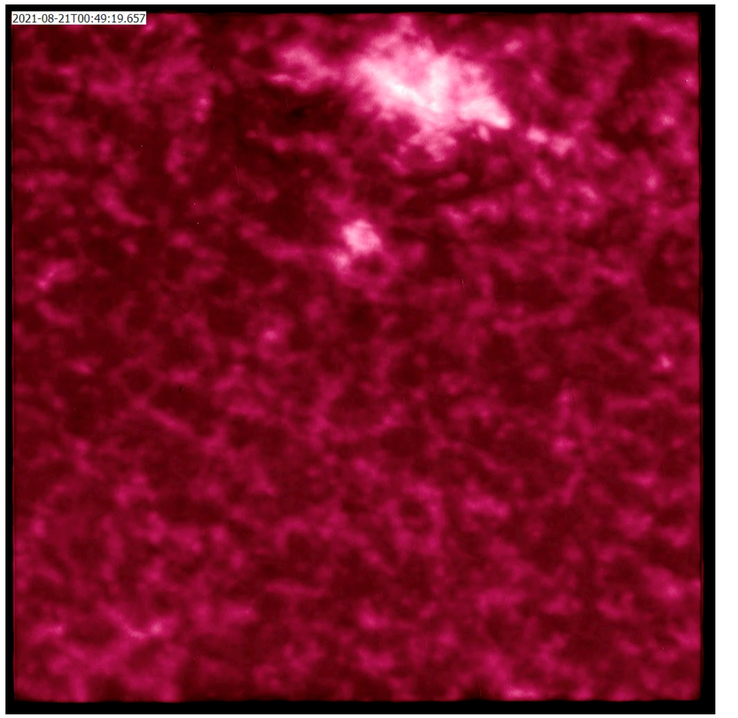
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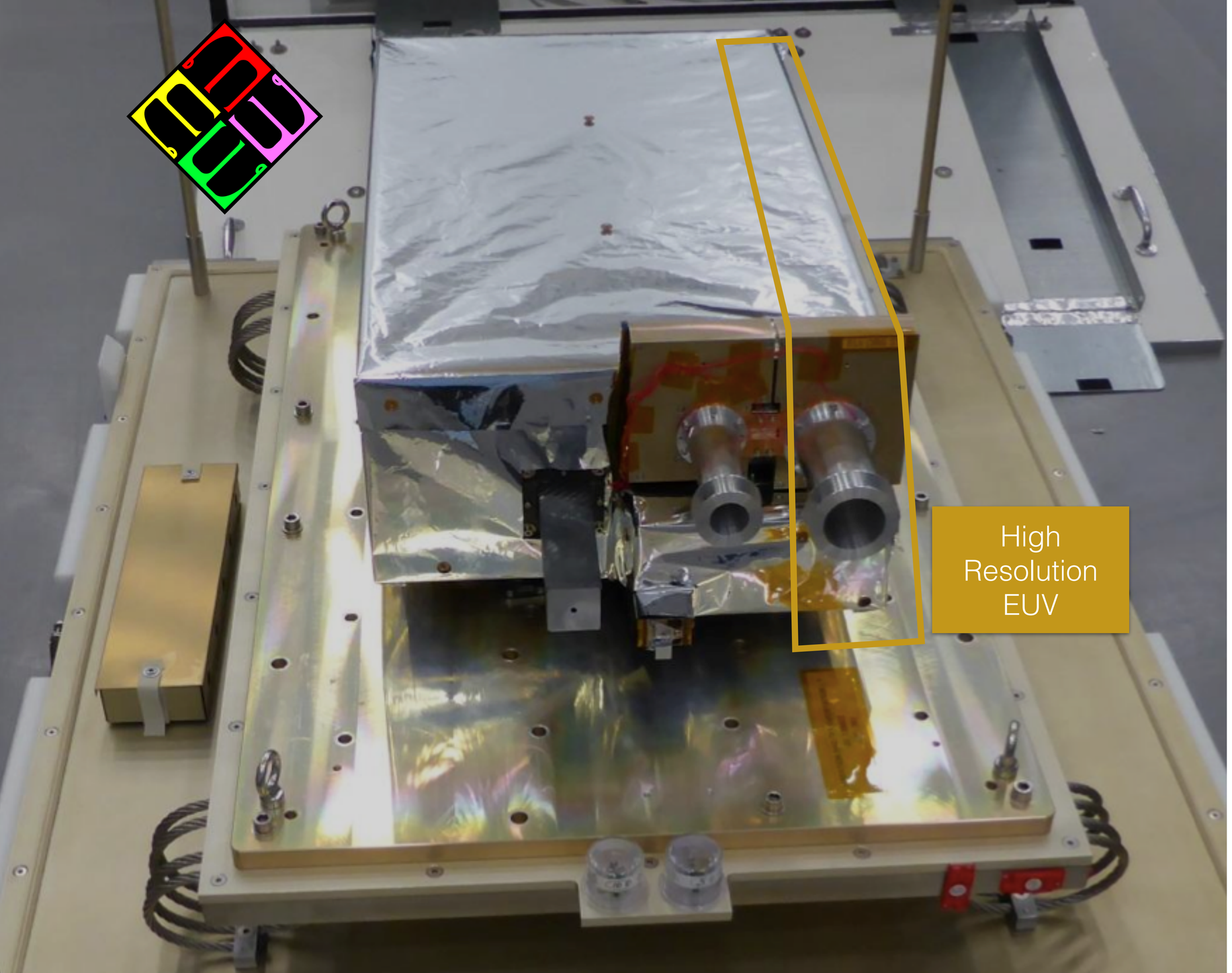
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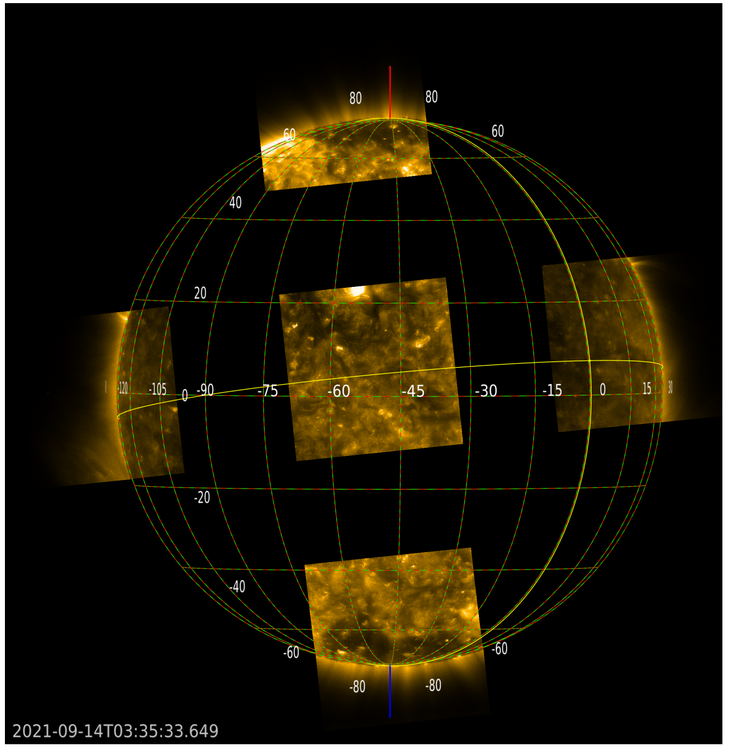
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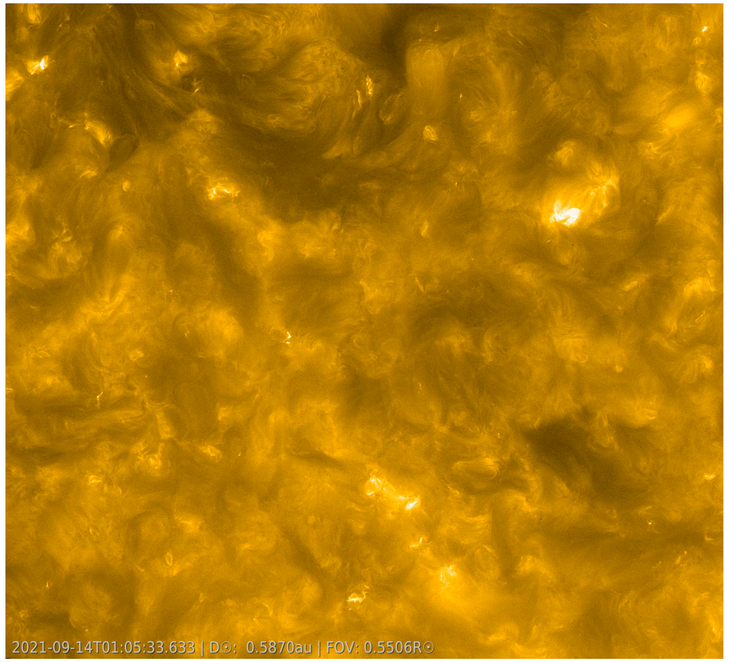
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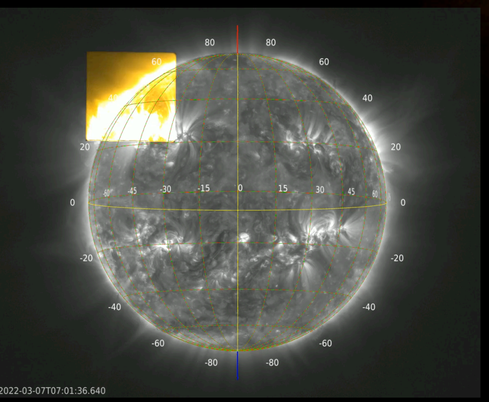
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Forbes

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

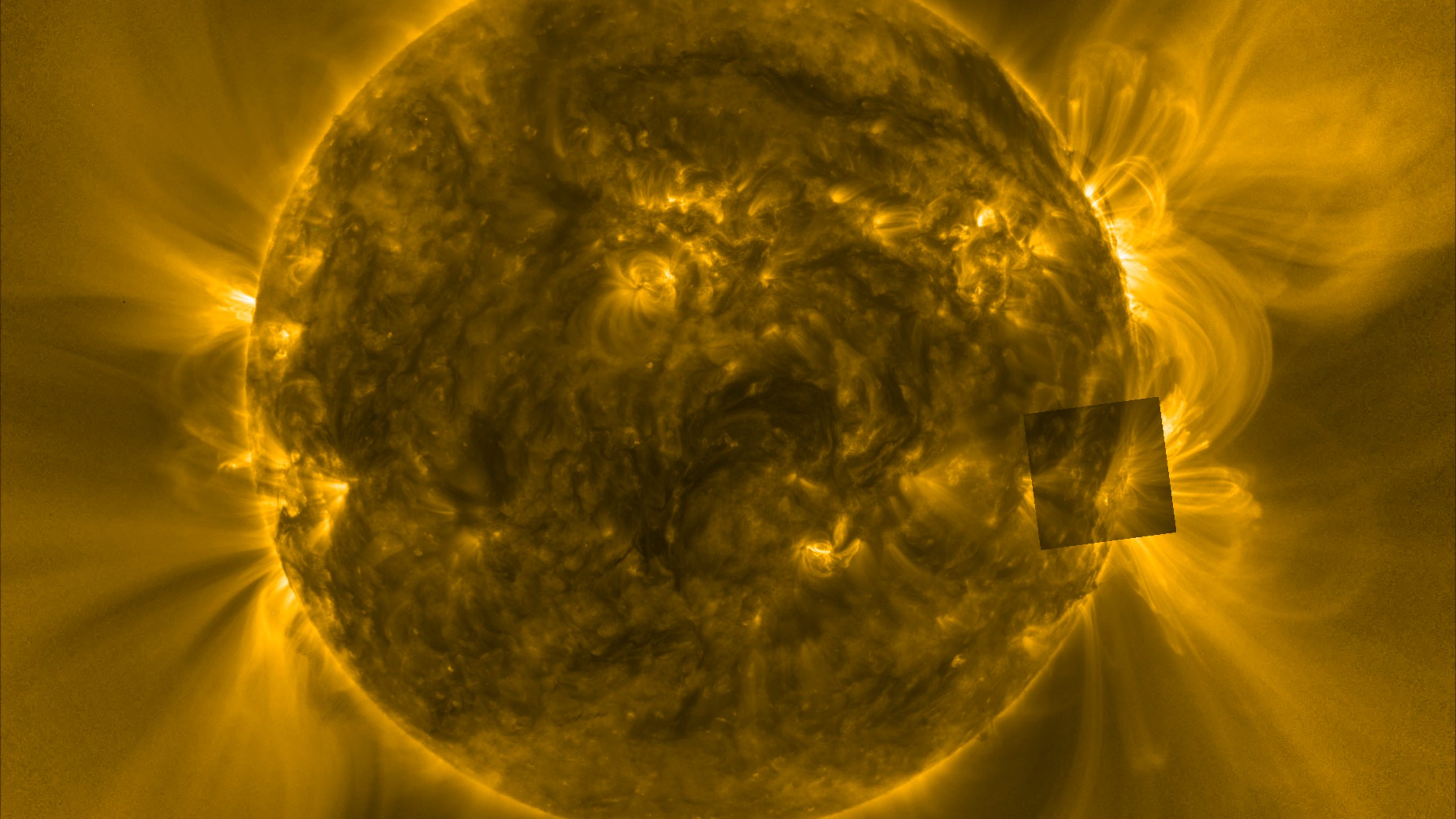
Listen to article 3 minutes

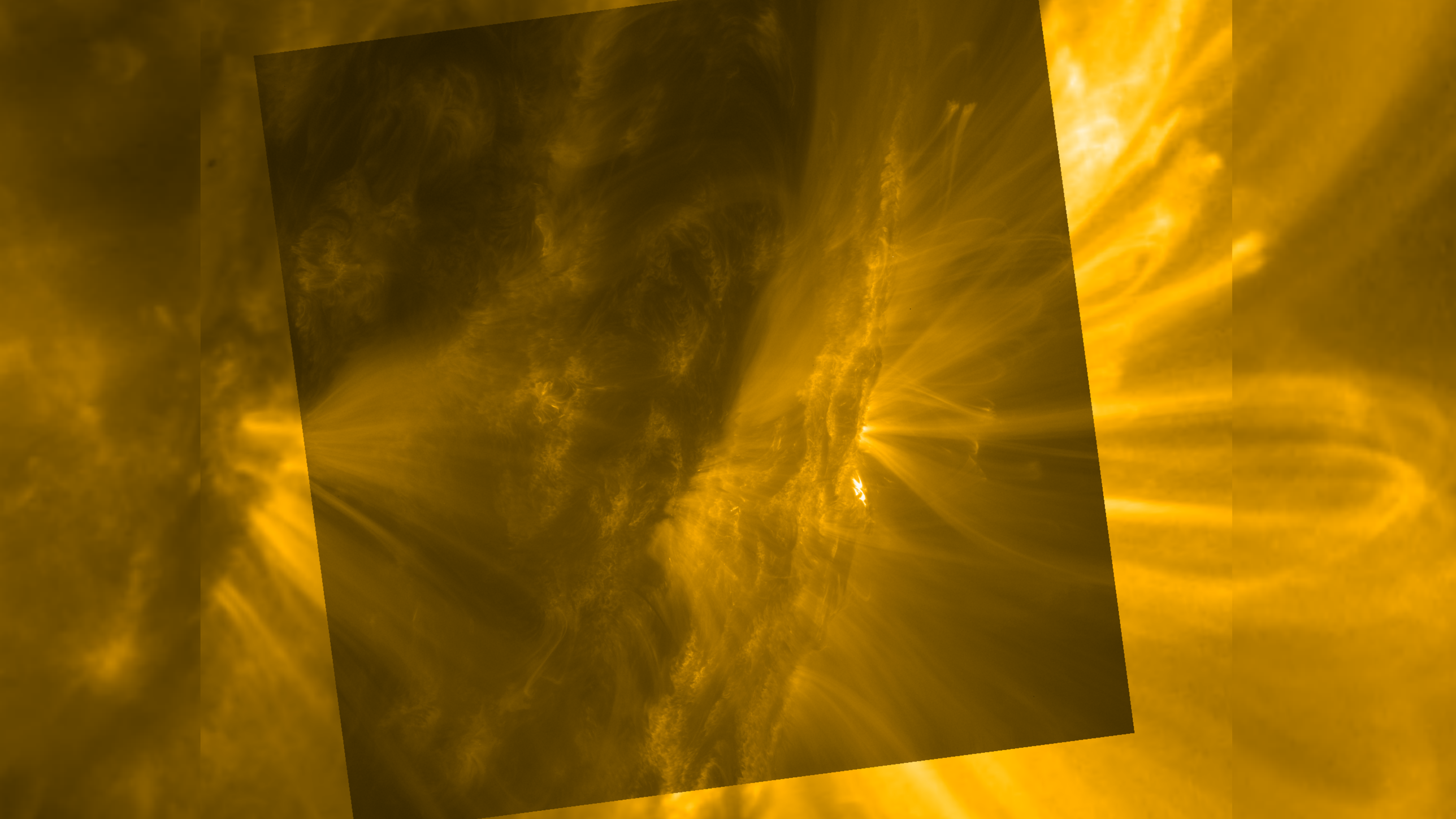
The European Space Agency's Solar Orbiter has returned an incredible 83 megapixel image of the Sun.
ESA/ATG MEDIALAB

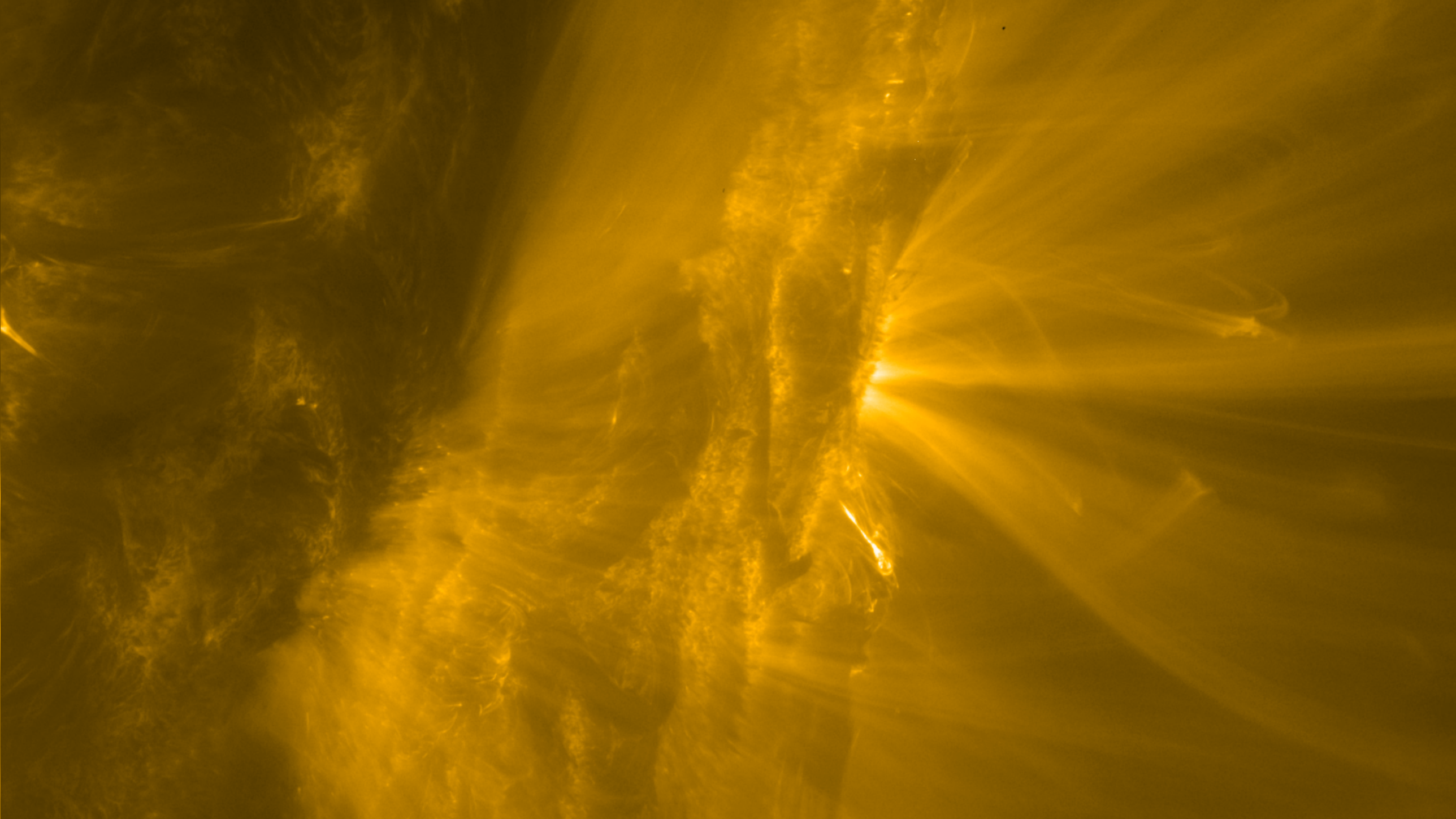
If you only look at one “space photo” this year then this one *has* to be it.

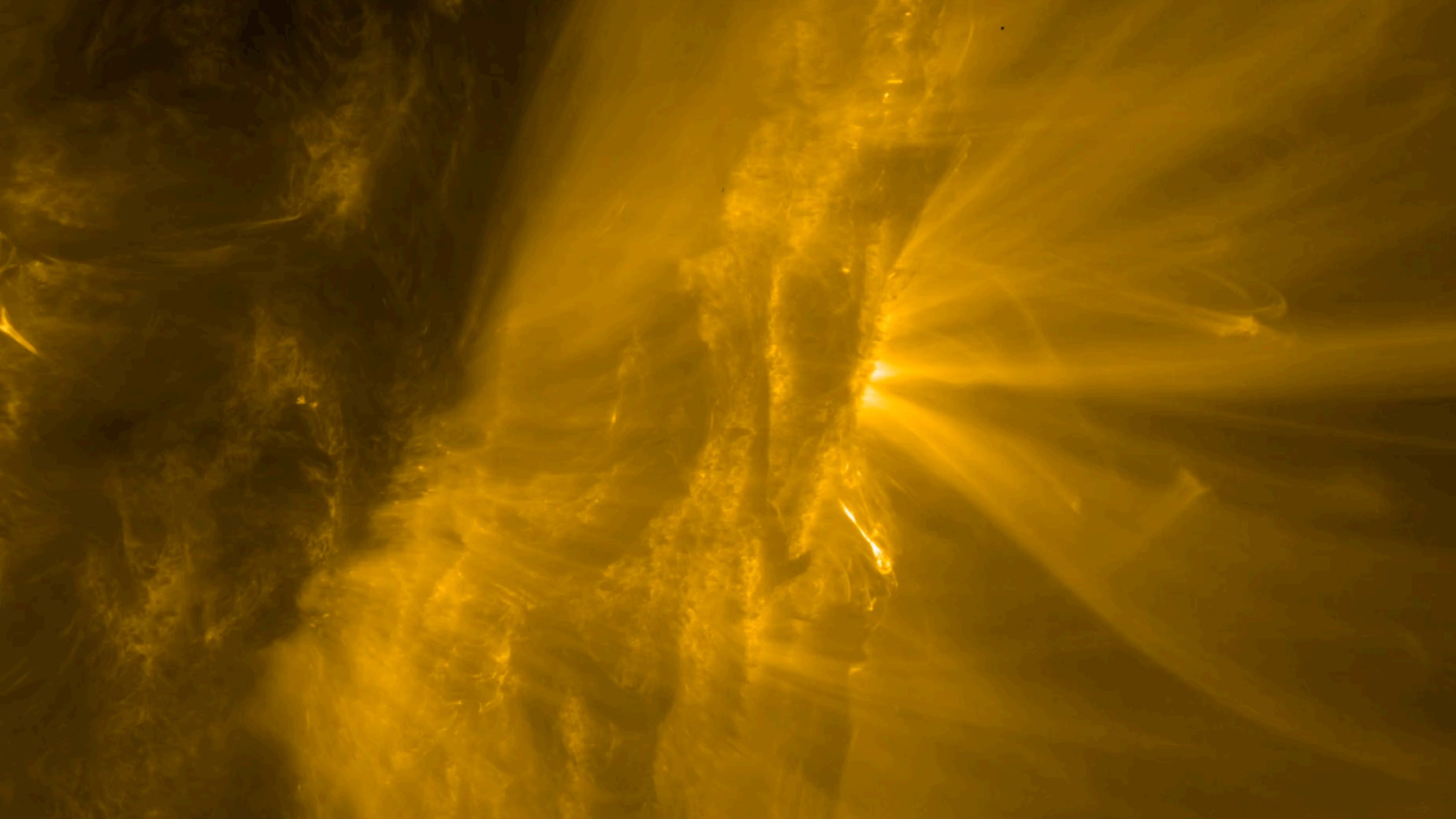
Cookies on Forbes

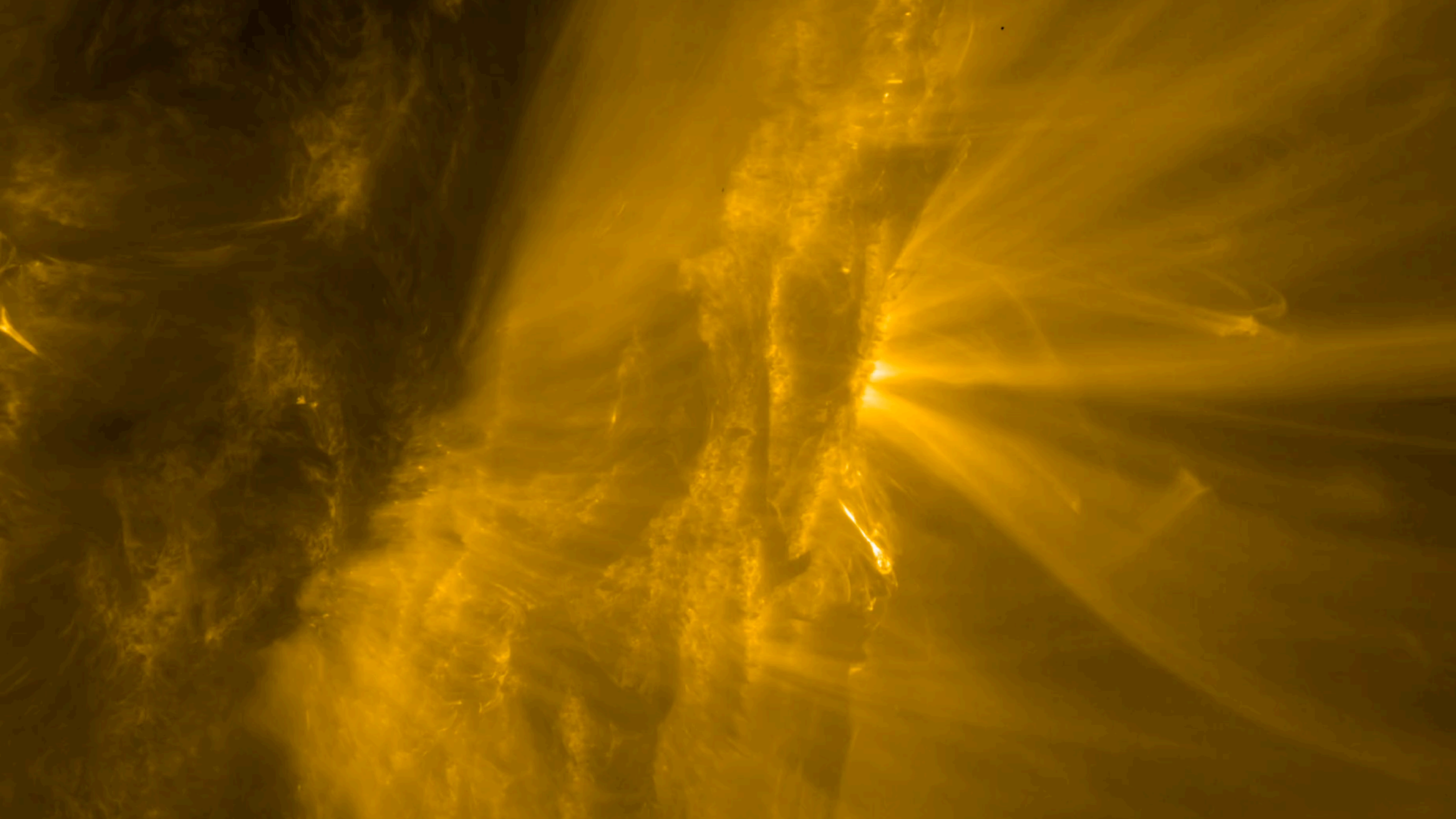
zonnevlammen



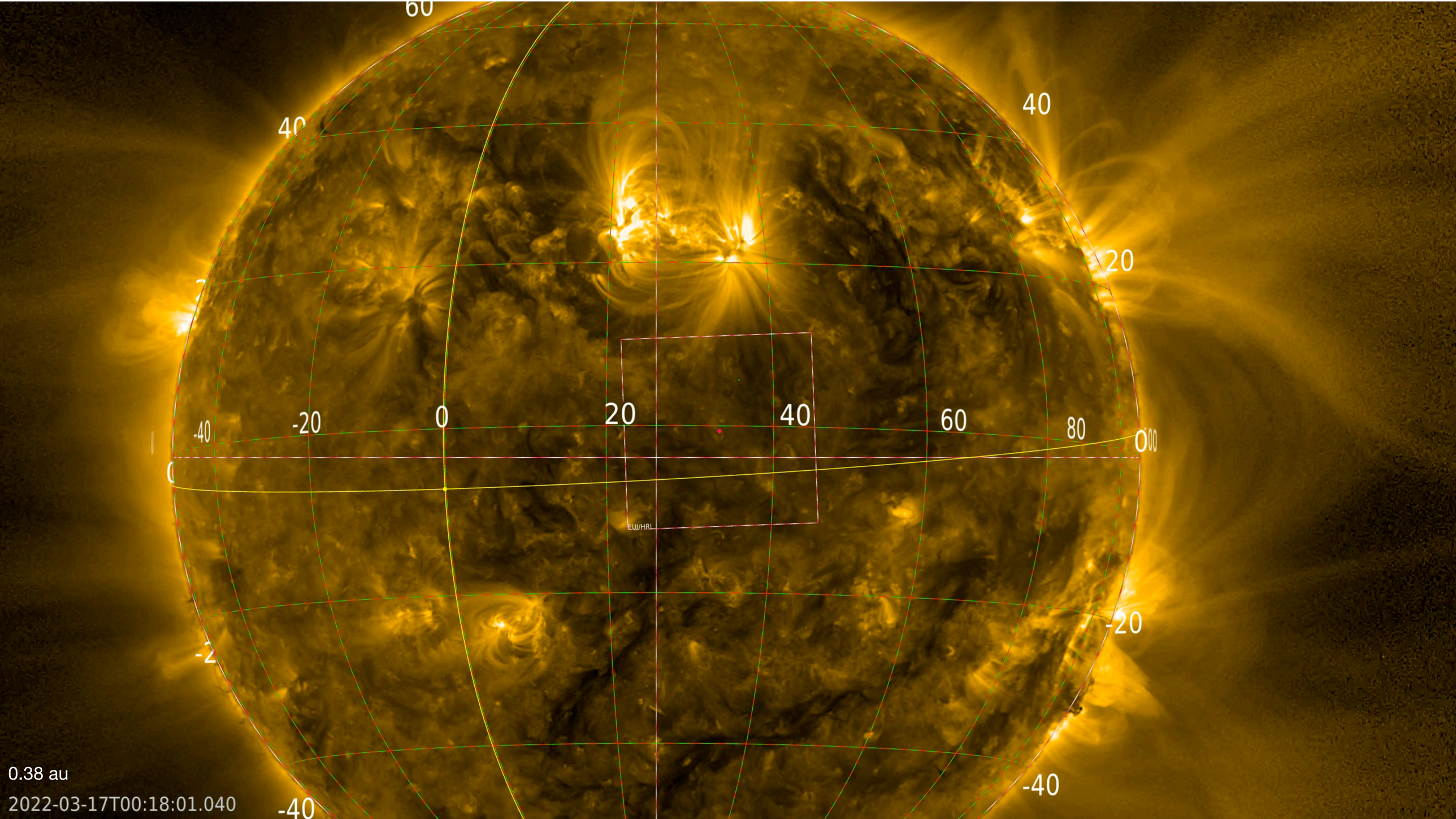








kleine zonnevlammen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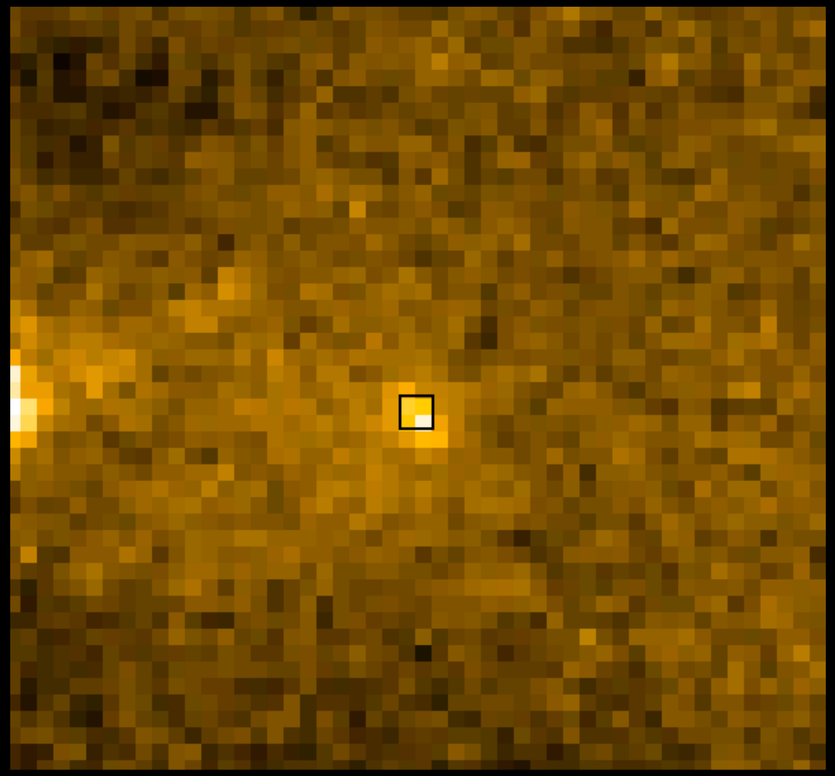
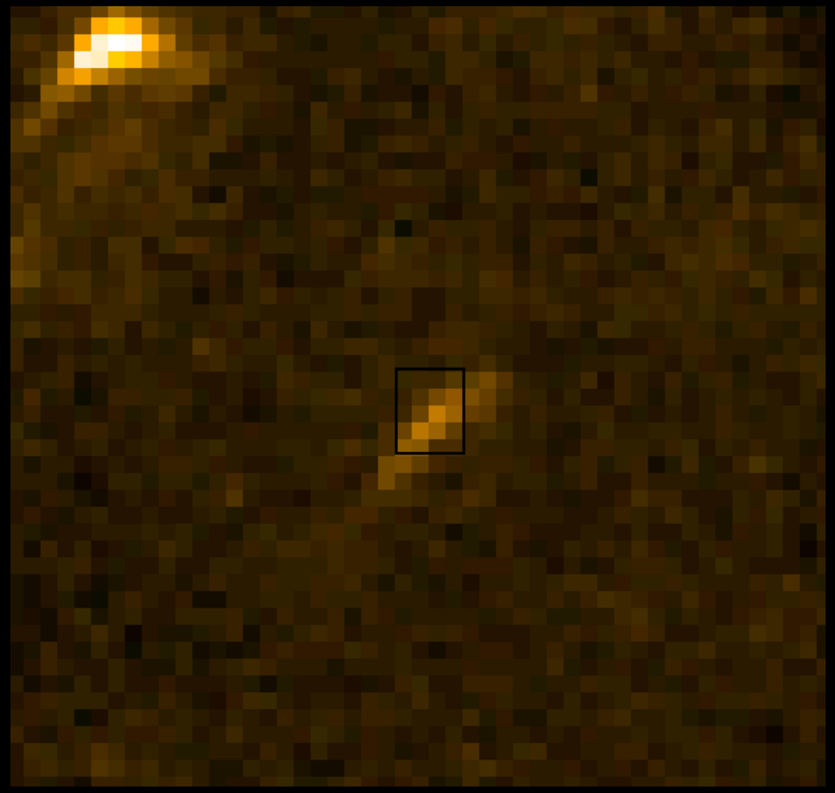
“kampvuren” (EUV quiet Sun brightenings)



HRIEUV 10x10 Mm2



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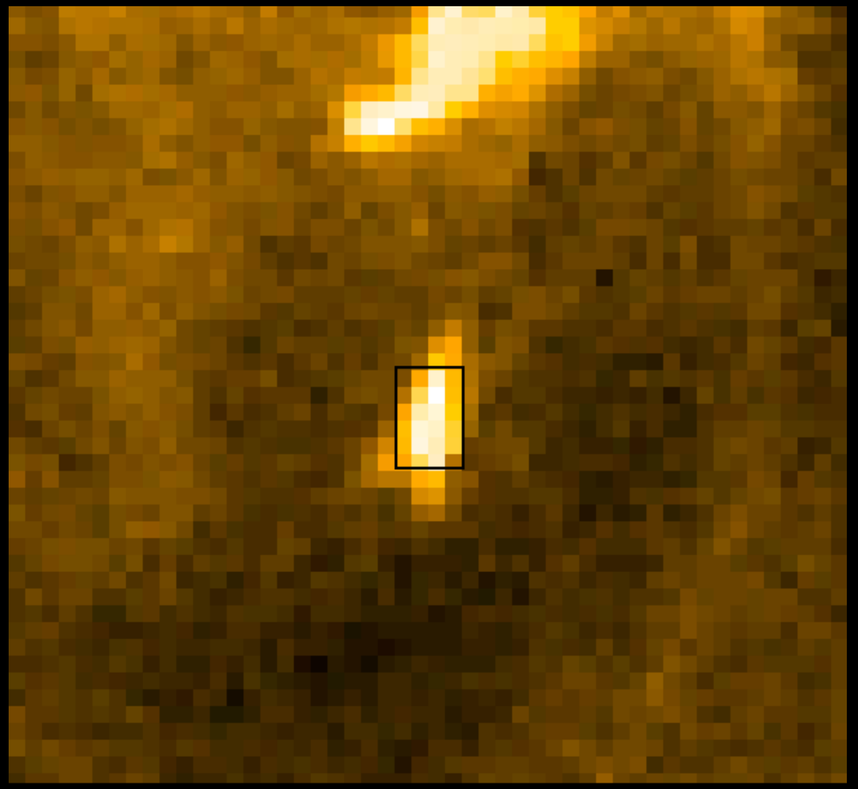


HRIEUV 10x10 Mm2

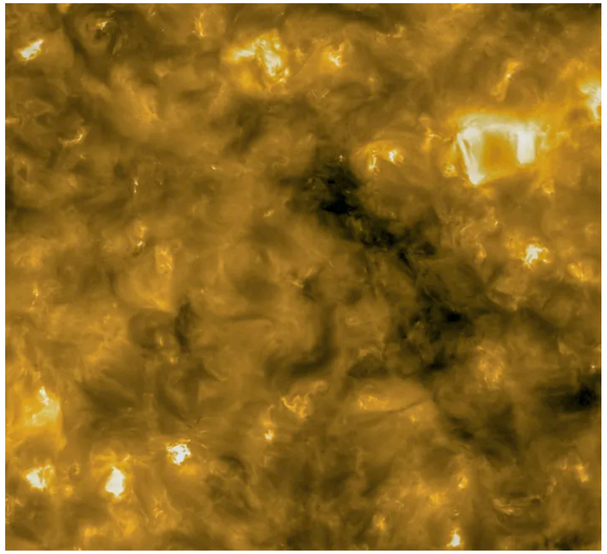
NATIONAL GEOGRAPHIC

SCIENCE TRAVEL ANIMALS CULTURE & HISTORY EN

Gather ‘round the campfire

Launched in February 2020, ESA’s Solar Orbiter is currently looping around the sun, using gravitational encounters with Venus to help boost it into an orbit where it can see the sun’s poles. For now, the spacecraft is busy studying our home star with a variety of onboard instruments that will help illuminate our understanding of its influence on Earth.

Last May, those cameras caught sight of some 1,500 miniature flares in the low solar atmosphere—or rather, flares that are miniature by solar standards, since some of them would span entire continents. The small eruptions last for tens of seconds, and the team named them “campfires.”



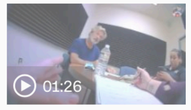
CNN World Africa Americas Asia Australia More

Solar Orbiter mission shares closest sun, reveals 'campfires' near its surf

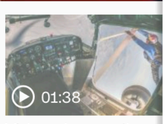
By Ashley Strickland, CNN

Updated 0103 GMT (0903 HKT) July 17, 2020

See the Solar Orbiter launch into space



Bodycam video shows chaotic moments after 'Rust' shooting



Video shows pilots switching planes mi air, one crash lands

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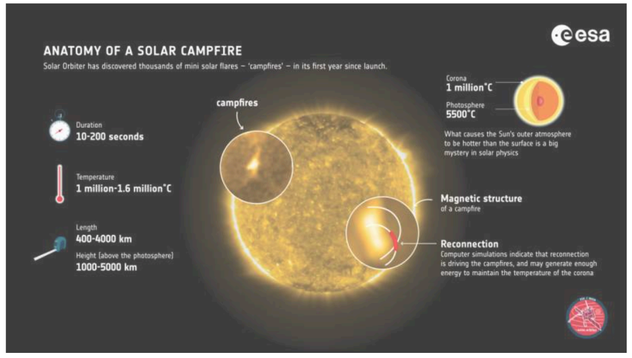
APRIL 27, 2021

'Campfires' offer clue to solar heating mystery

by European Space Agency



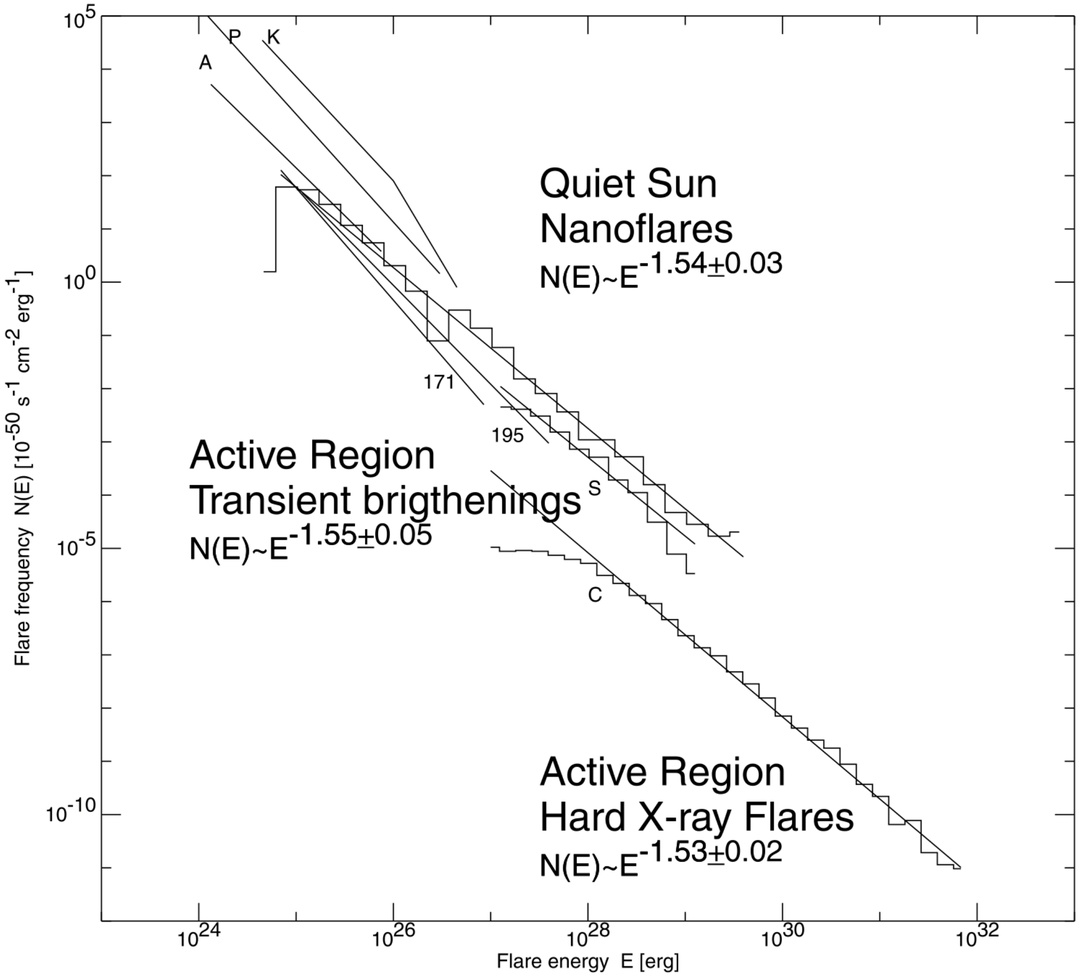
This graphic provides a summary of what ESA's Solar Orbiter mission, as well as computer modelling, has reve…

Computer simulations show that the miniature solar flares nicknamed 'campfires," discovered last year by ESA's Solar Orbiter, are likely driven by a process that may contribute significantly to the heating of the sun's outer atmosphere, or corona. If confirmed by further observations this adds a key piece to the puzzle of what heats the solar corona—one of the biggest mysteries in solar physics.

Campfires are one of many subjects being

Waarom zijn “kampvuren” belangrijk?

Verdeling van de energie-inhoud van kleine zonnevlammen

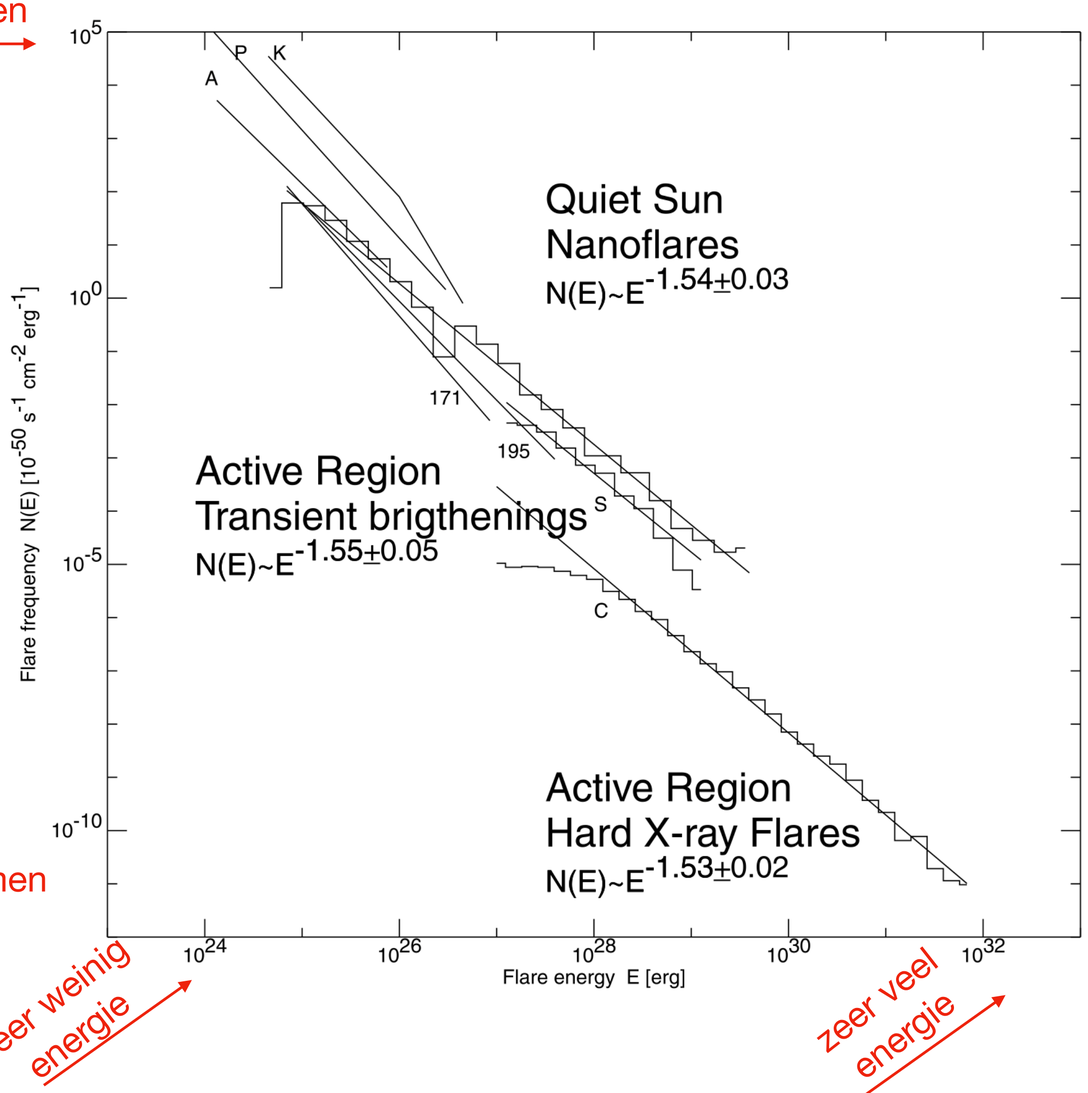


Aschwanden, Parnell 2002

Waarom zijn “kampvuren” belangrijk?

Verdeling van de energie-inhoud van kleine zonnevlammen

veel zonnevlammen



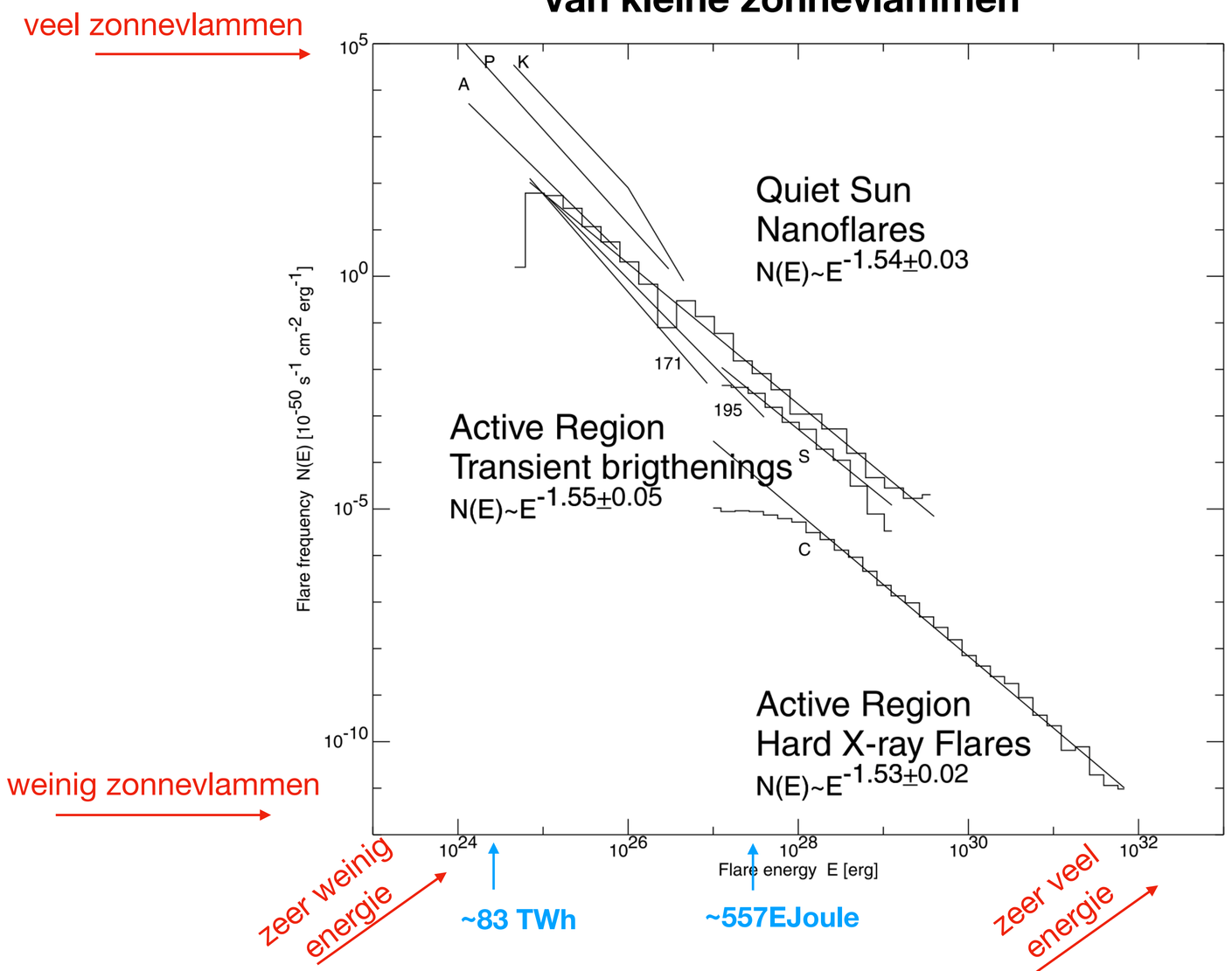
weinig zonnevlammen

zeer weinig energie

zeer veel energie

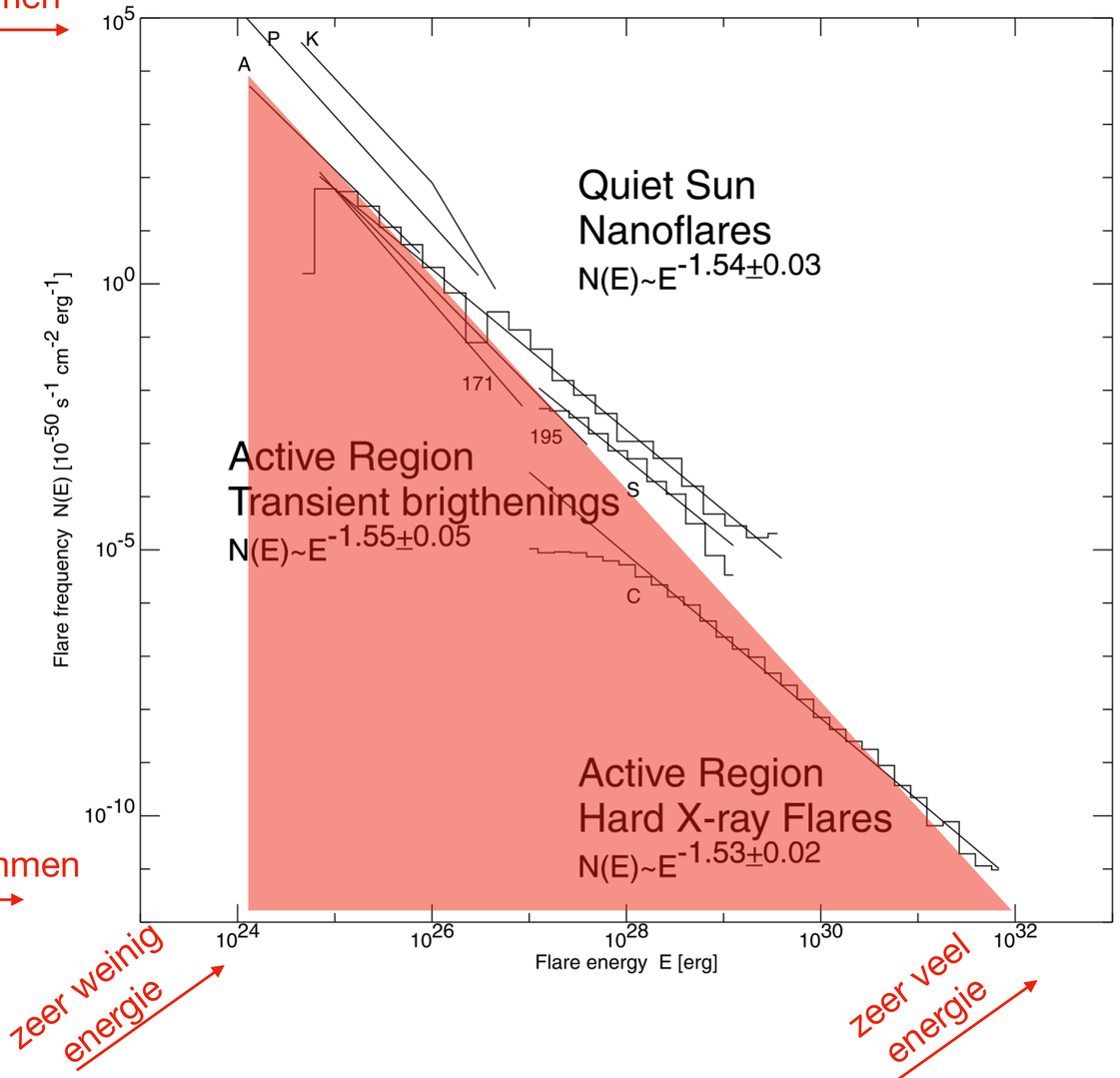
Waarom zijn “kampvuren” belangrijk?

Verdeling van de energie-inhoud van kleine zonnevlammen



Waarom zijn “kampvuren” belangrijk?

veel zonnevlammen



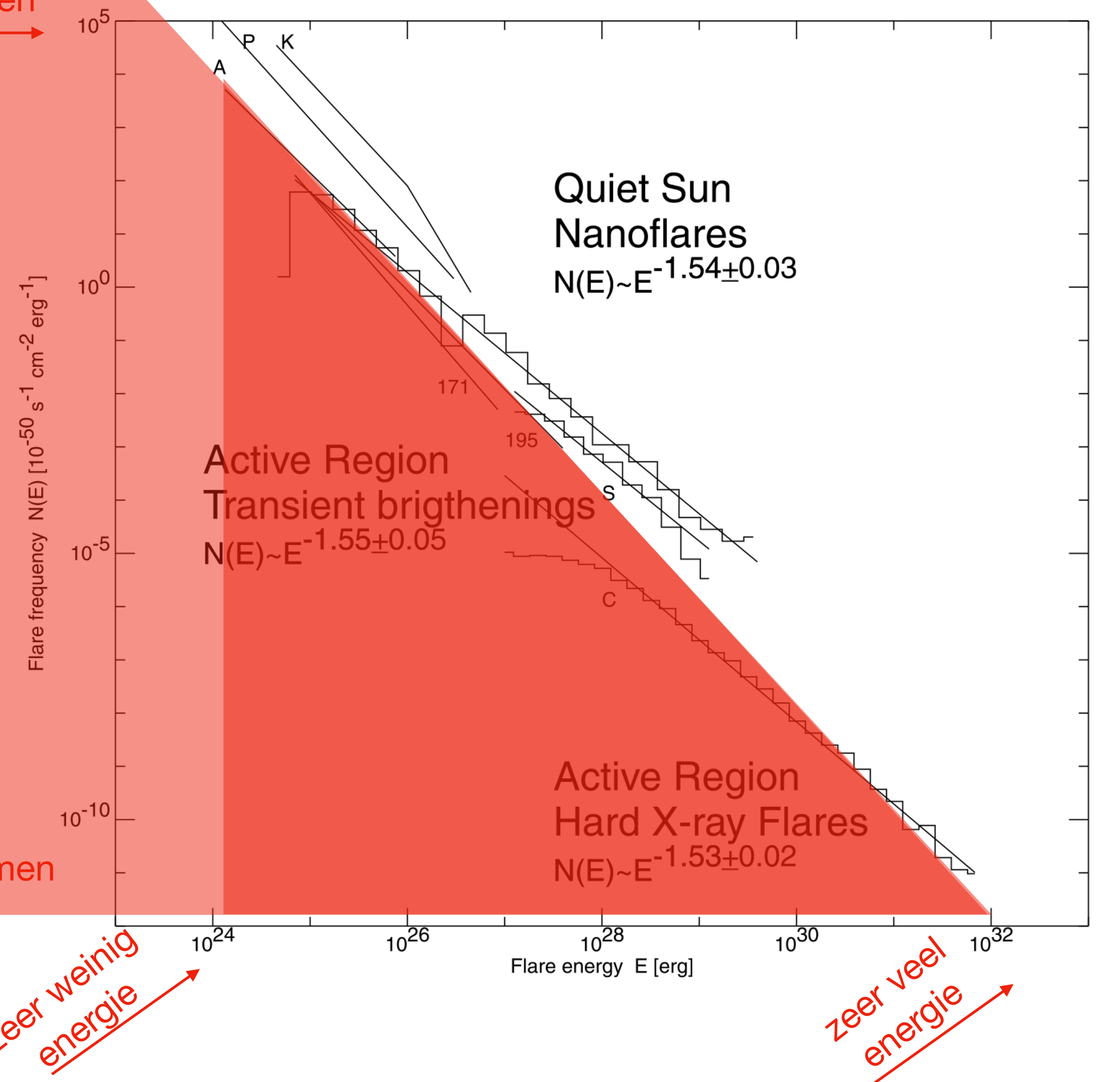
weinig zonnevlammen

zeer weinig energie

zeer veel energie

Waarom zijn “kampvuren” belangrijk?

veel zonnevlammen



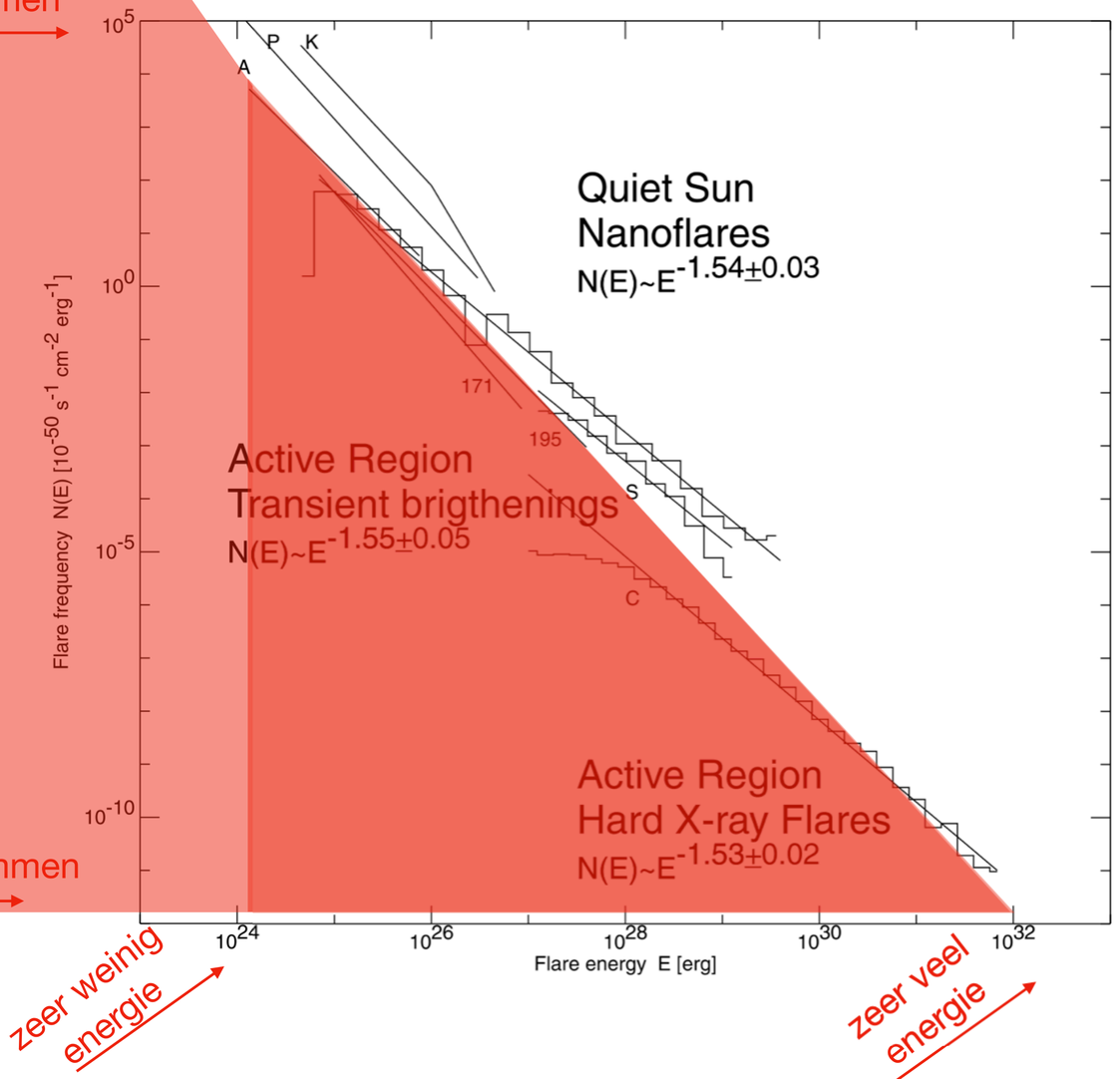
weinig zonnevlammen

zeer weinig energie

zeer veel energie

Waarom zijn “kampvuren” belangrijk?

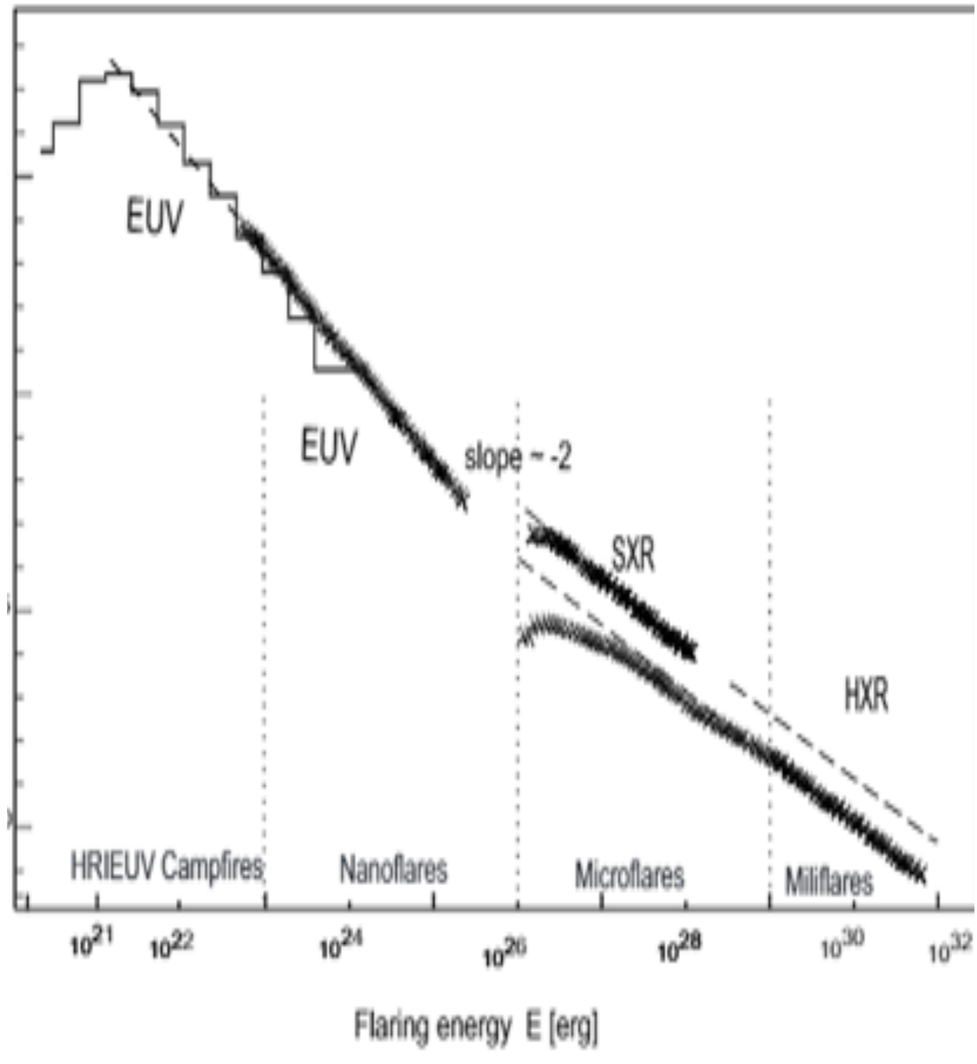
veel zonnevlammen

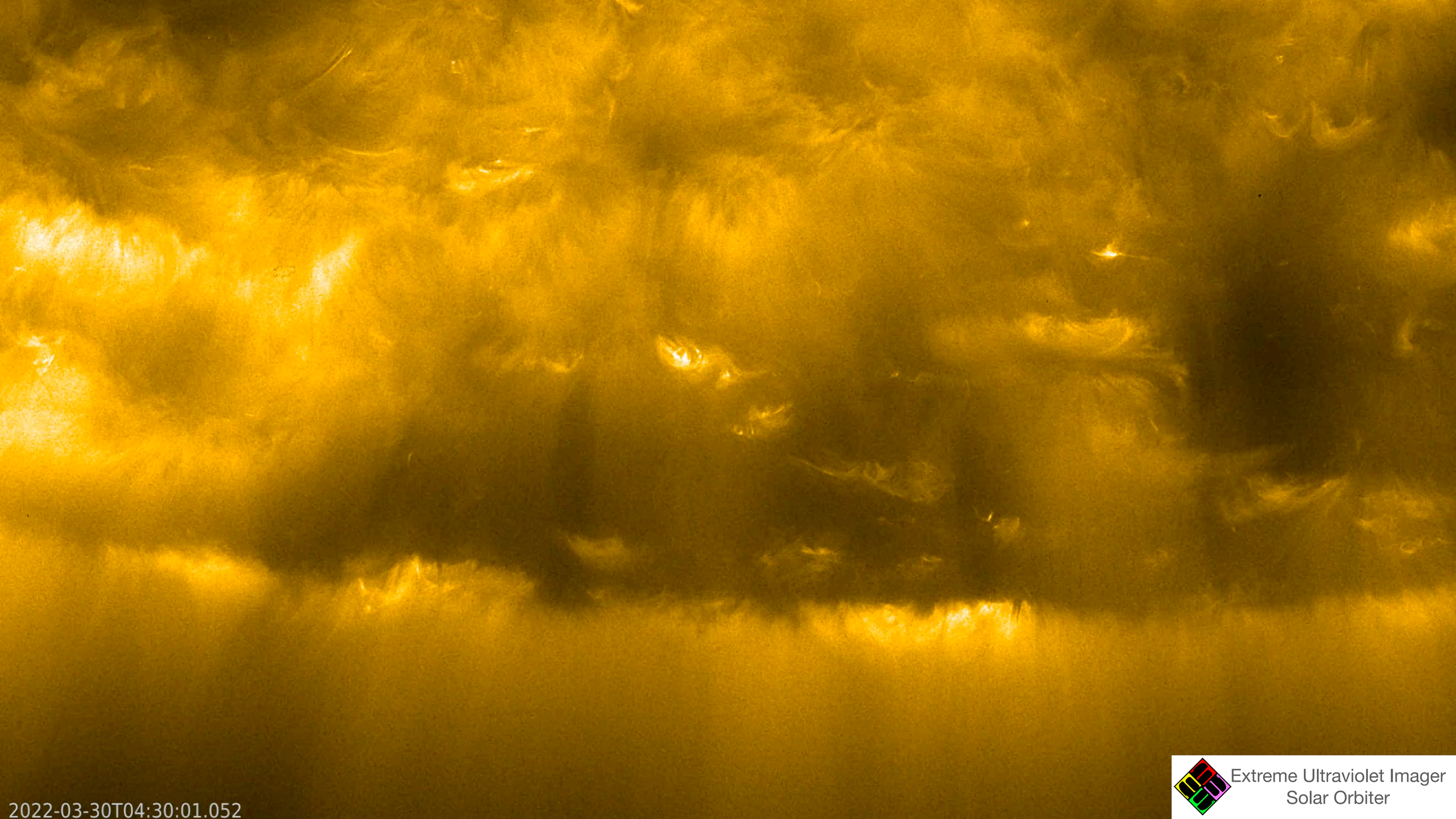


weinig zonnevlammen

zeer weinig energie

zeer veel energie

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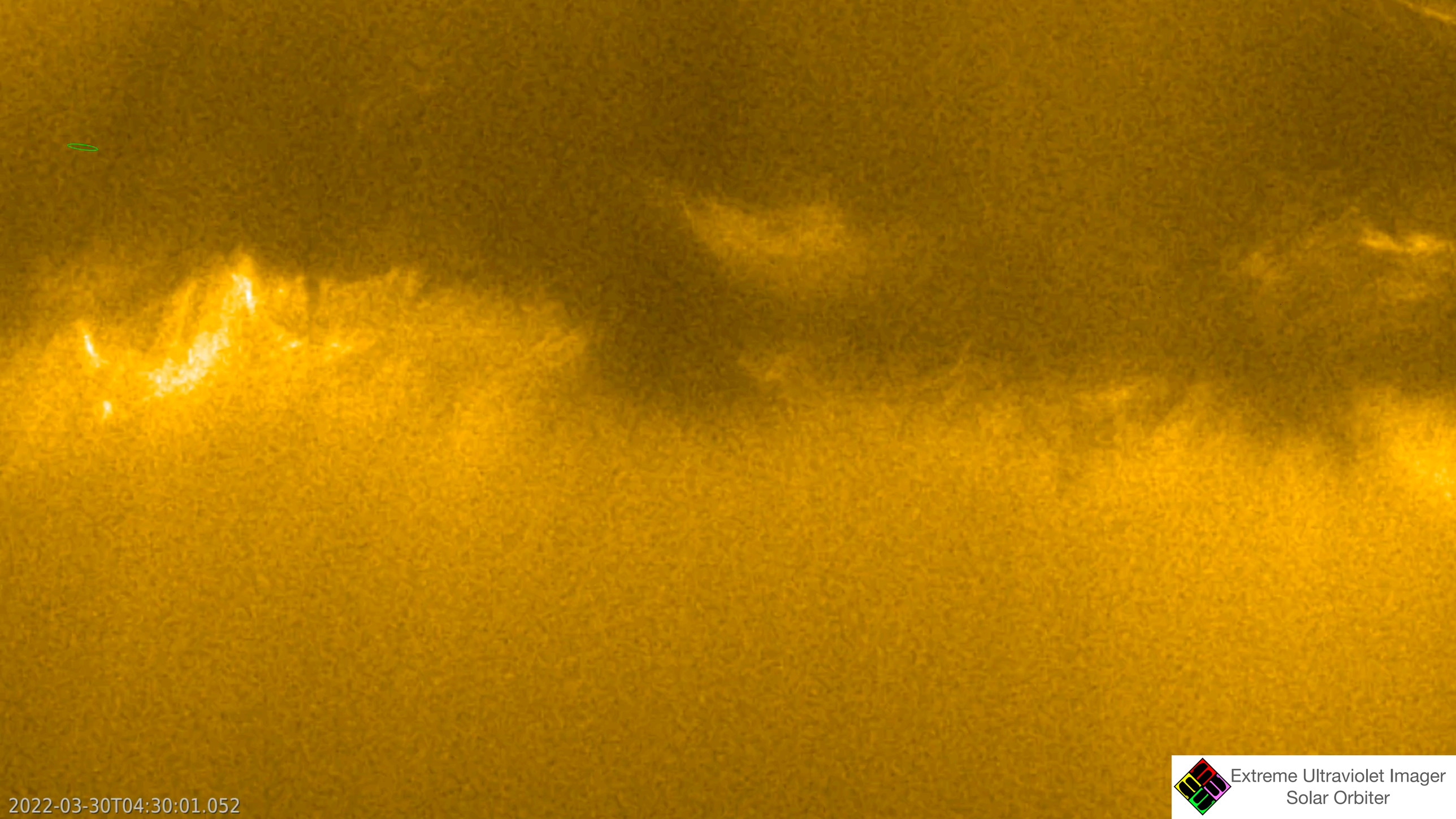
Solar Orbiter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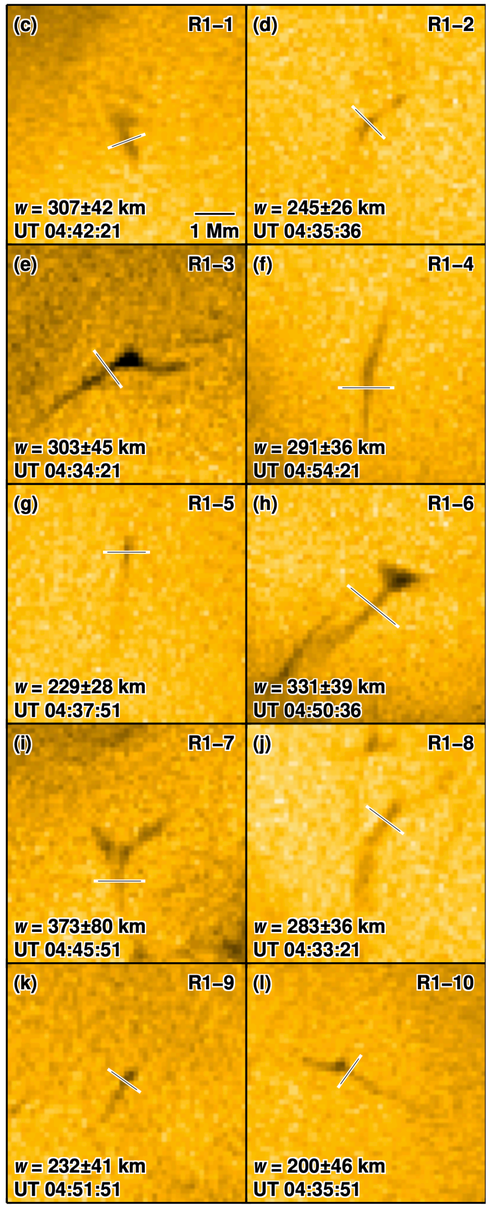
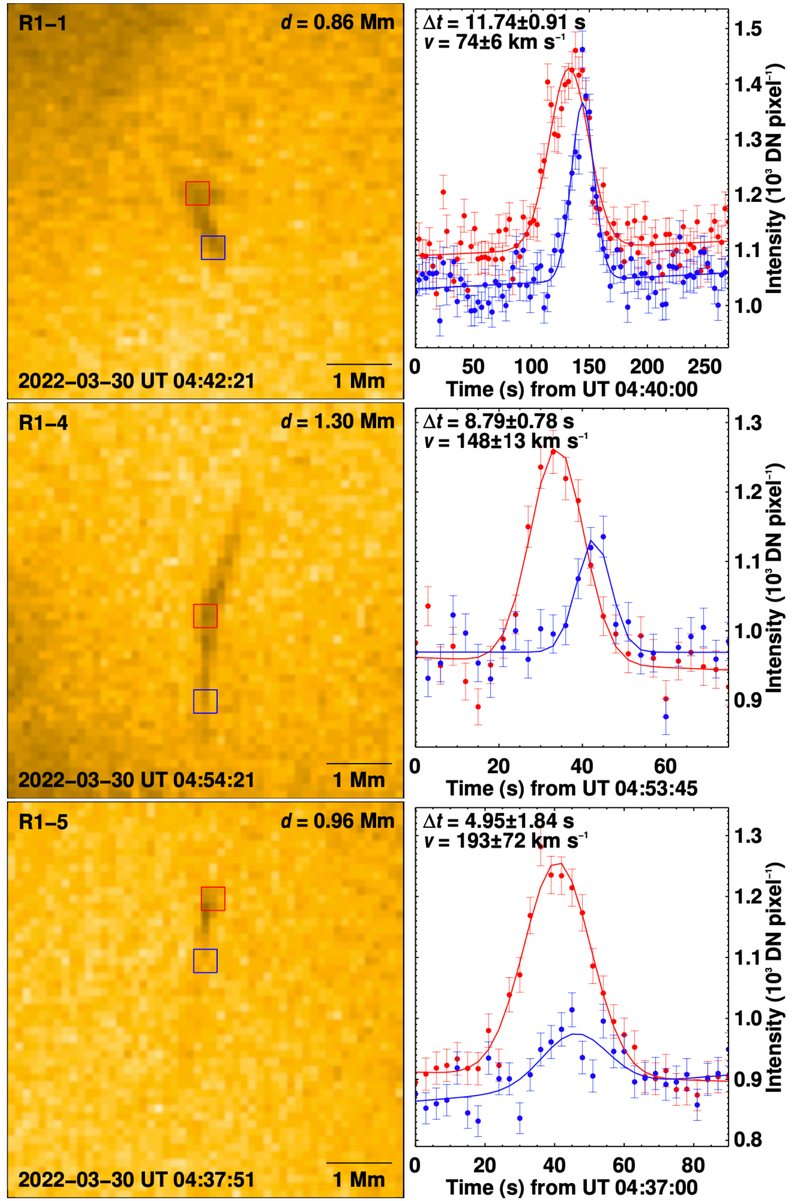
Extreme Ultraviolet Imager
Solar Orbiter

PICOJETS


(c) R1–1
w = 307±42 km
UT 04:42:21
1 Mm
(d) R1–2
w = 245±26 km
UT 04:35:36
(e) R1–3
w = 303±45 km
UT 04:34:21
(f) R1–4
w = 291±36 km
UT 04:54:21
(g) R1–5
w = 229±28 km
UT 04:37:51
(h) R1–6
w = 331±39 km
UT 04:50:36
(i) R1–7
w = 373±80 km
UT 04:45:51
(j) R1–8
w = 283±36 km
UT 04:33:21
(k) R1–9
w = 232±41 km
UT 04:51:51
(l) R1–10
w = 200±46 km
UT 04:35:51


R1–1
d = 0.86 Mm
2022–03–30 UT 04:42:21
1 Mm
Δt = 11.74±0.91 s
v = 74±6 km s⁻¹
Intensity (10³ DN pixel⁻¹)
Time (s) from UT 04:40:00
R1–4
d = 1.30 Mm
2022–03–30 UT 04:54:21
1 Mm
Δt = 8.79±0.78 s
v = 148±13 km s⁻¹
Intensity (10³ DN pixel⁻¹)
Time (s) from UT 04:53:45
R1–5
d = 0.96 Mm
2022–03–30 UT 04:37:51
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Δt = 4.95±1.84 s
v = 193±72 km s⁻¹
Intensity (10³ DN pixel⁻¹)
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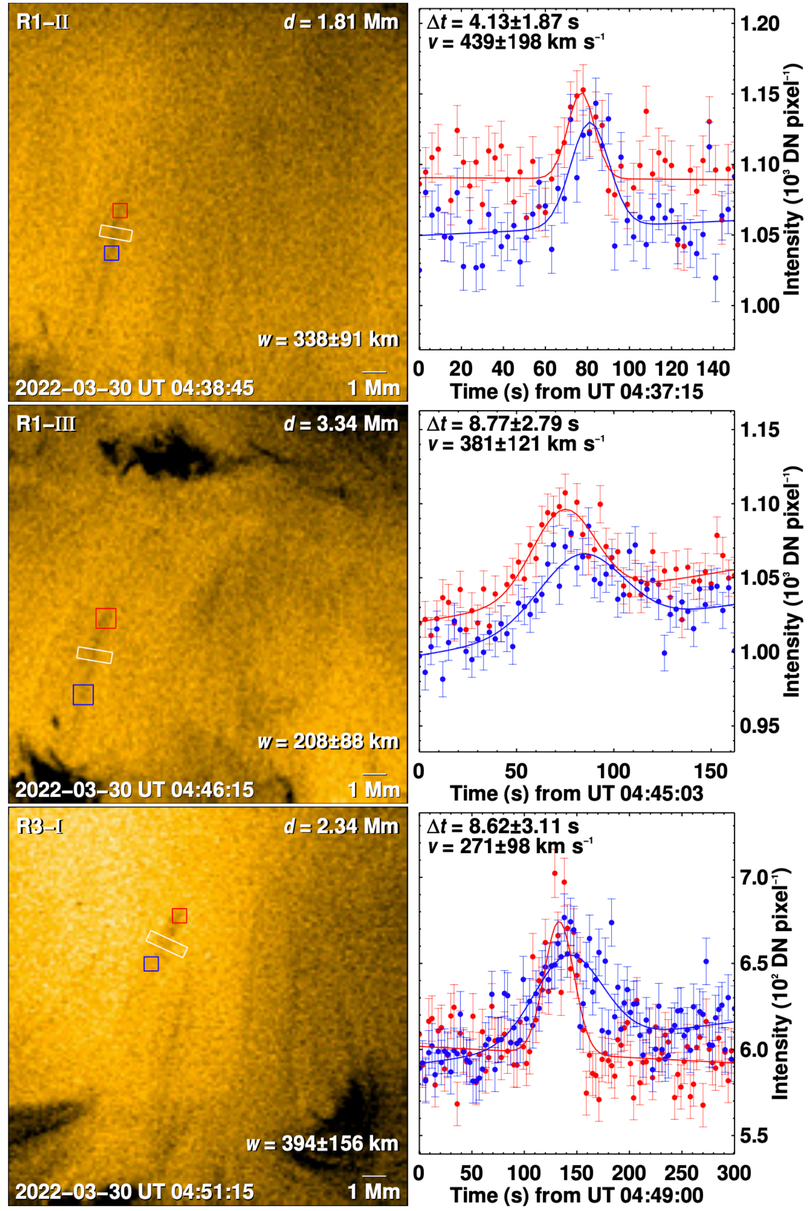
R1–II
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w = 338±91 km
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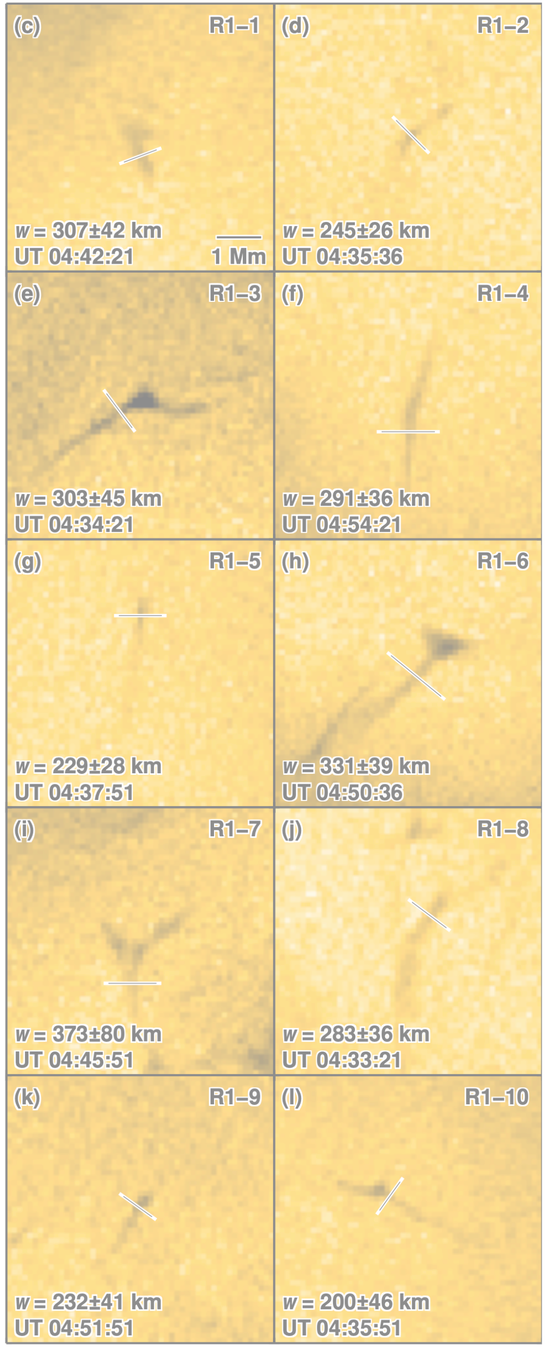
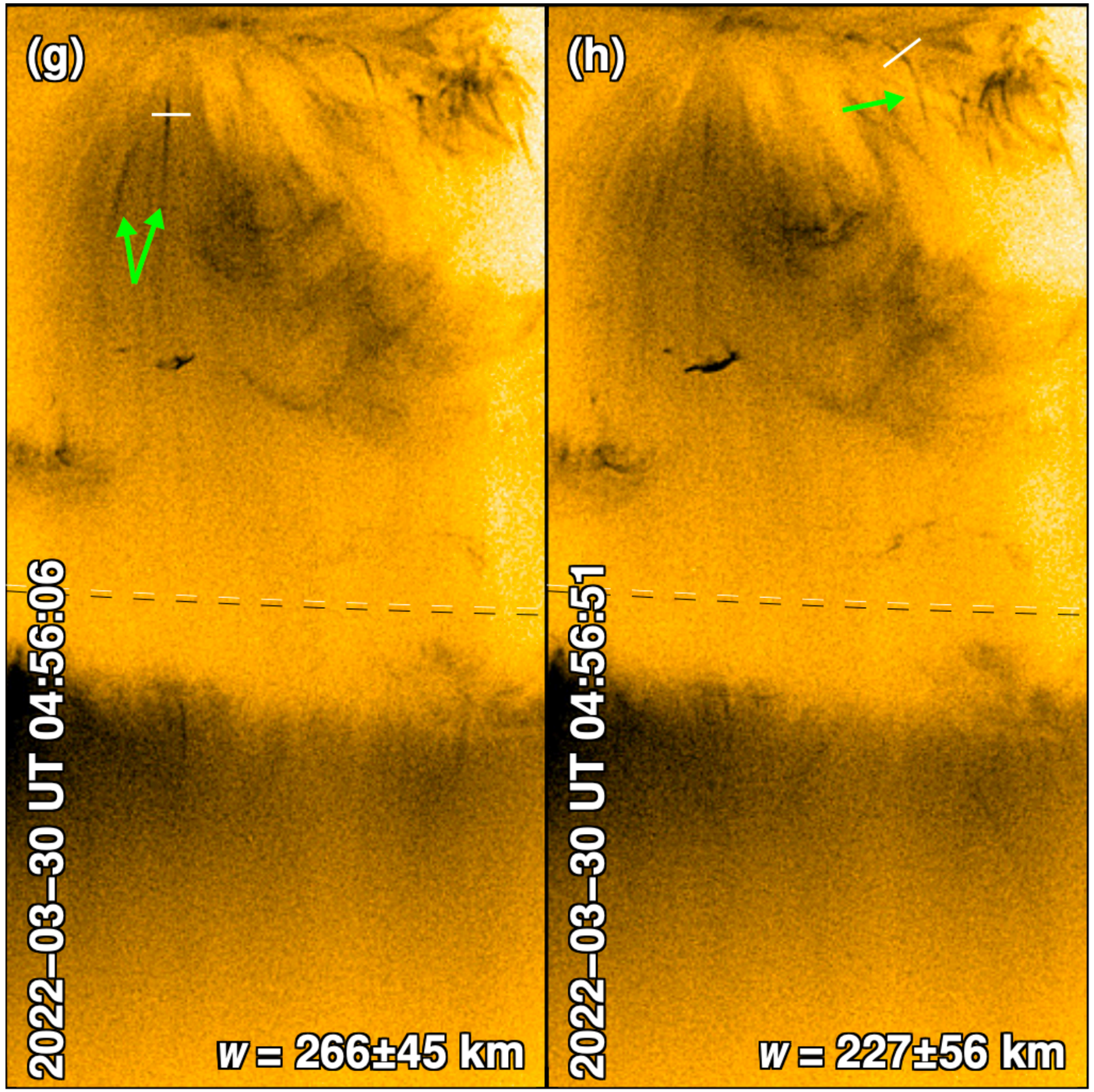
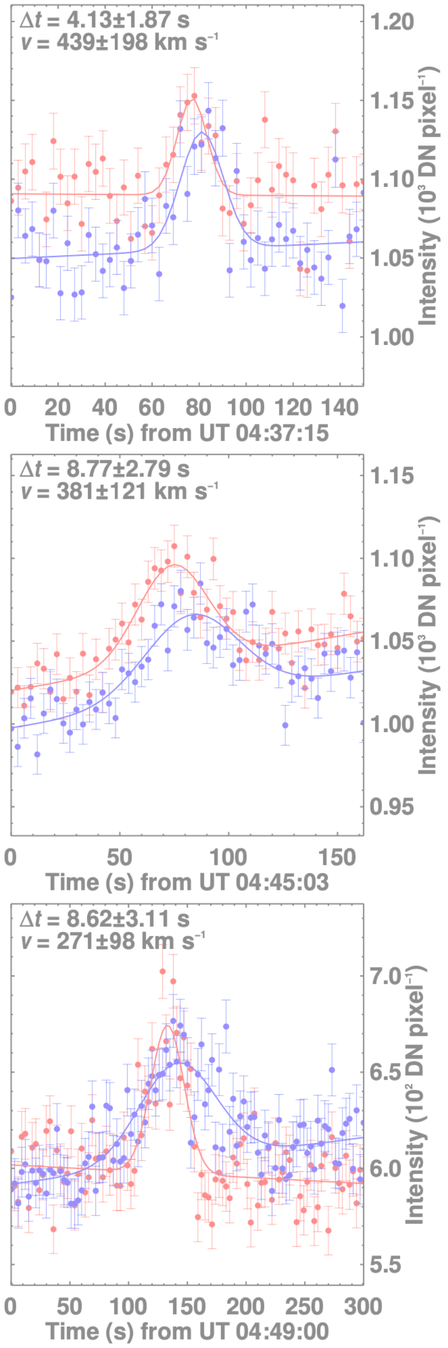
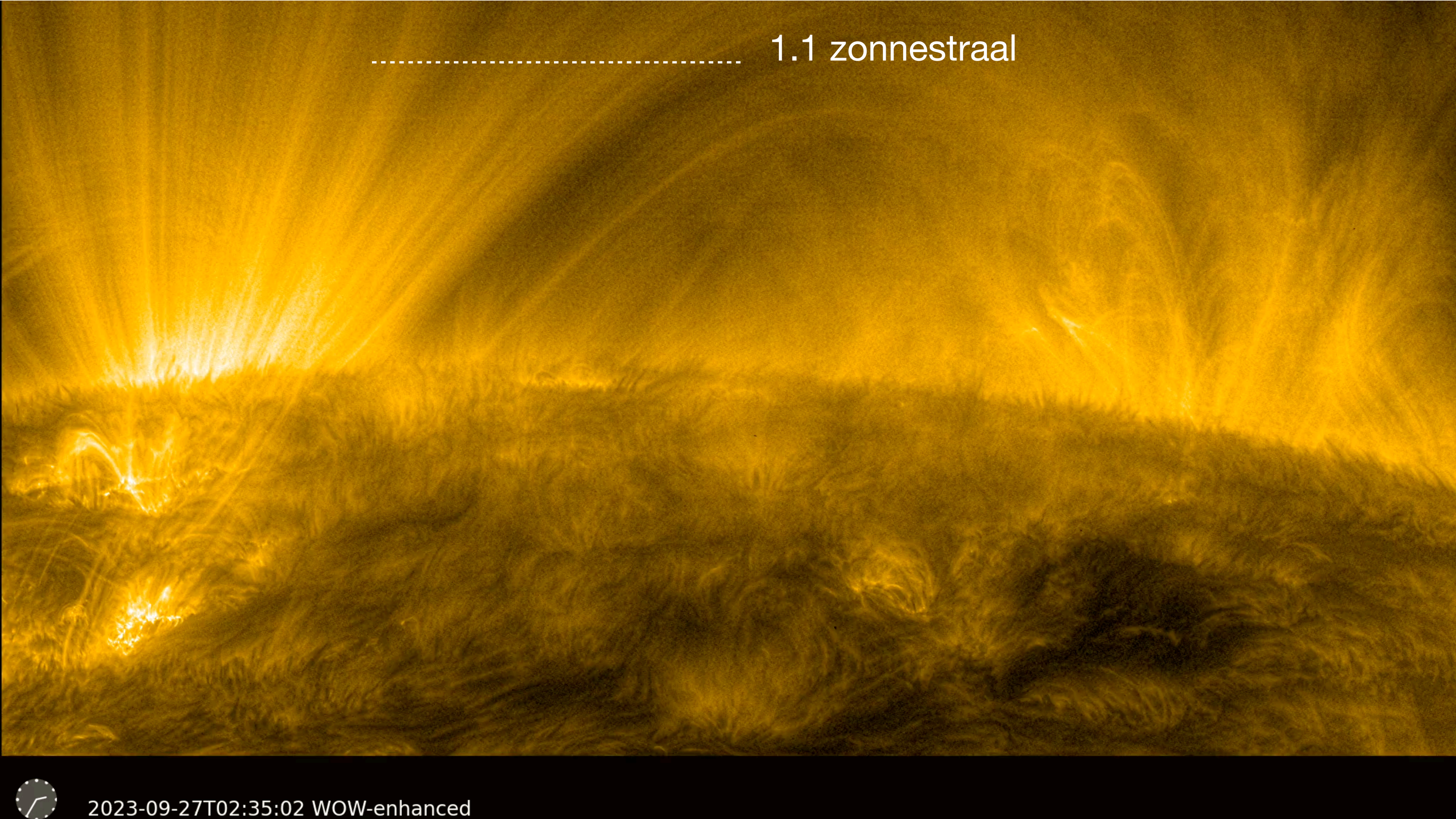
1 Mm
Δt = 4.13±1.87 s
v = 439±198 km s⁻¹
Intensity (10³ DN pixel⁻¹)
Time (s) from UT 04:37:15
R1–III
d = 3.34 Mm
w = 208±88 km
2022–03–30 UT 04:46:15
1 Mm
Δt = 8.77±2.79 s
v = 381±121 km s⁻¹
Intensity (10³ DN pixel⁻¹)
Time (s) from UT 04:45:03
R3–I
d = 2.34 Mm
w = 394±156 km
2022–03–30 UT 04:51:15
1 Mm
Δt = 8.62±3.11 s
v = 271±98 km s⁻¹
Intensity (10² DN pixel⁻¹)
Time (s) from UT 04:49:00

Lakshmi Pradeep Chitta et al , 2023, Science





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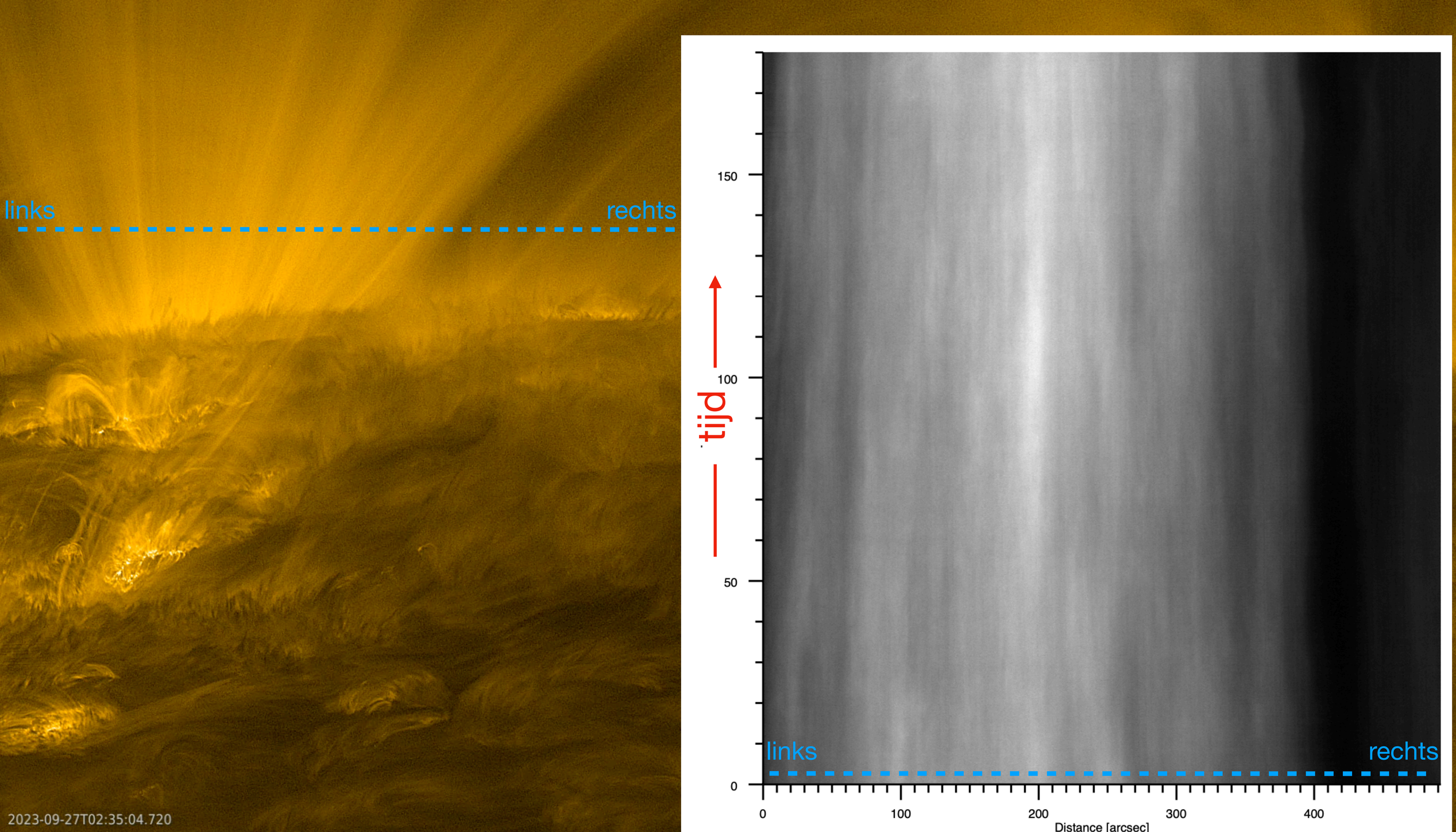
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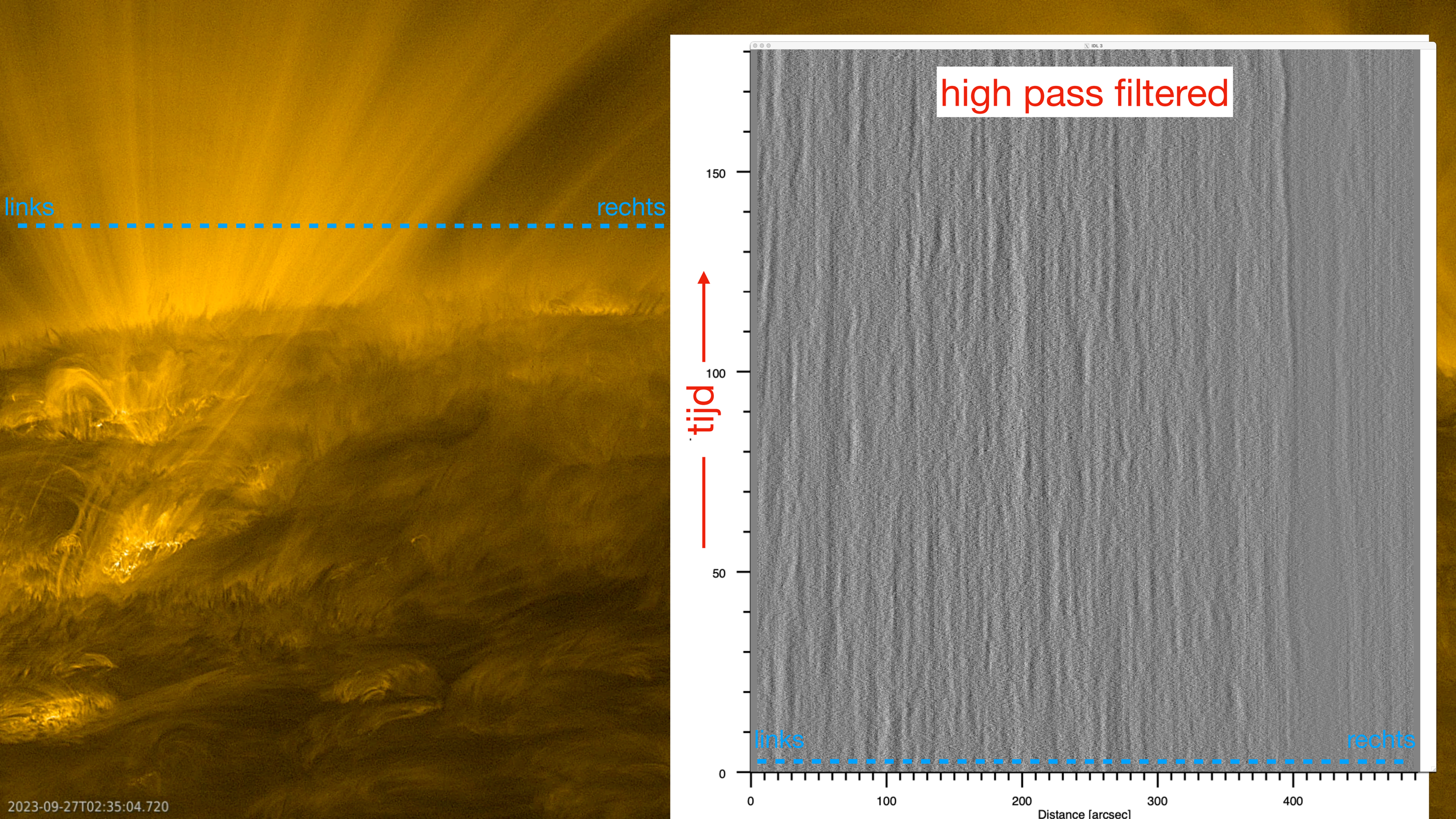
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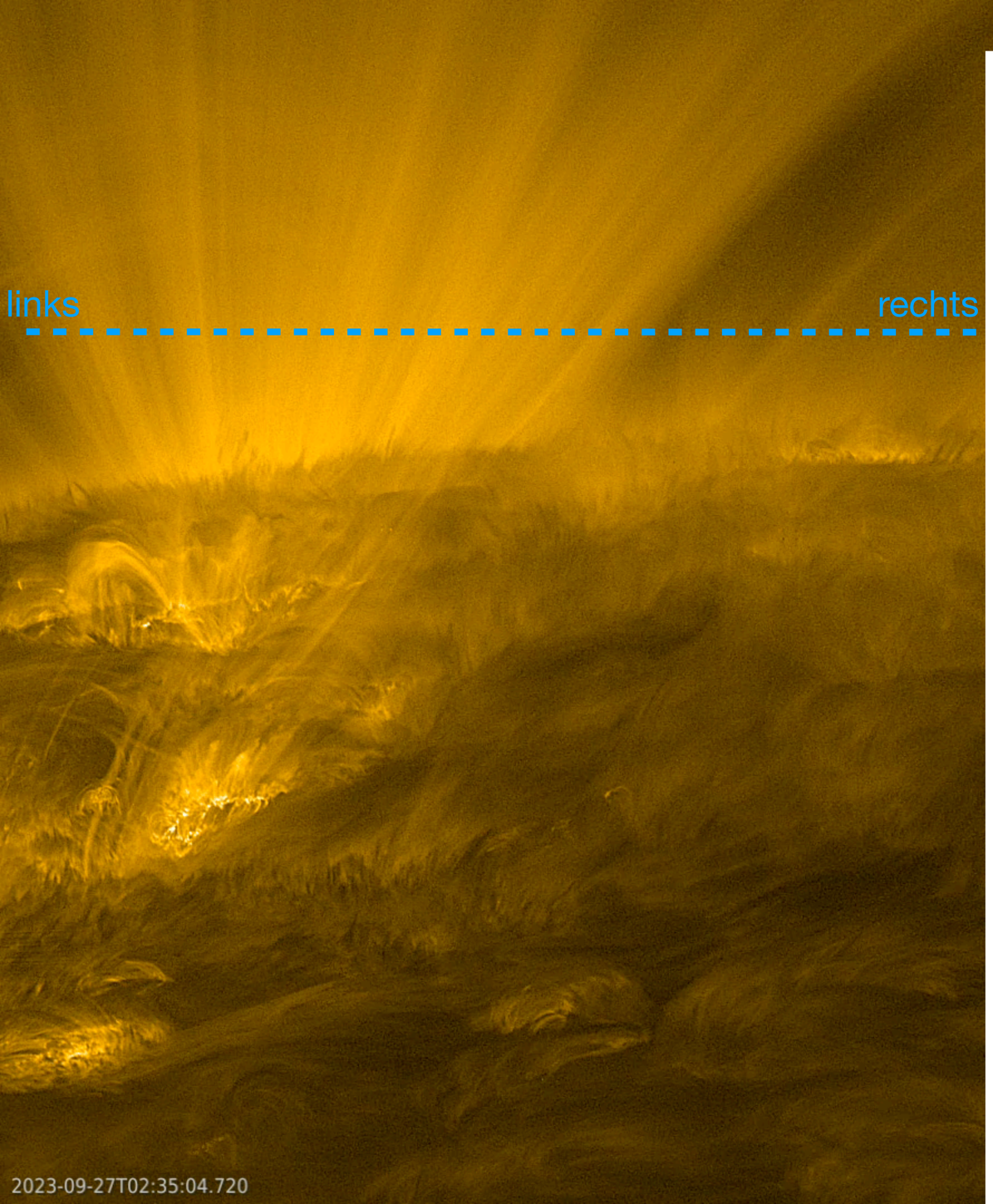
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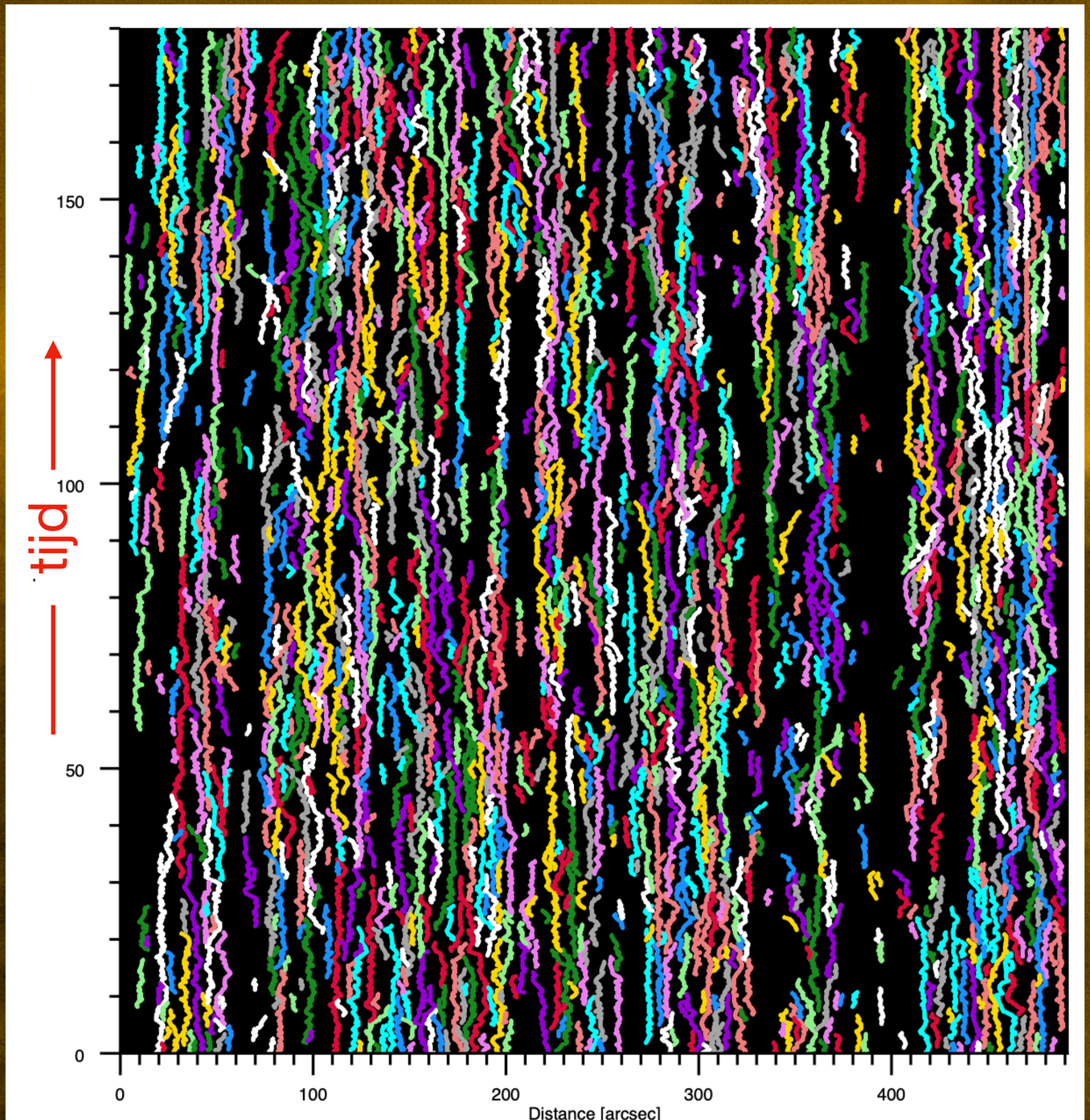
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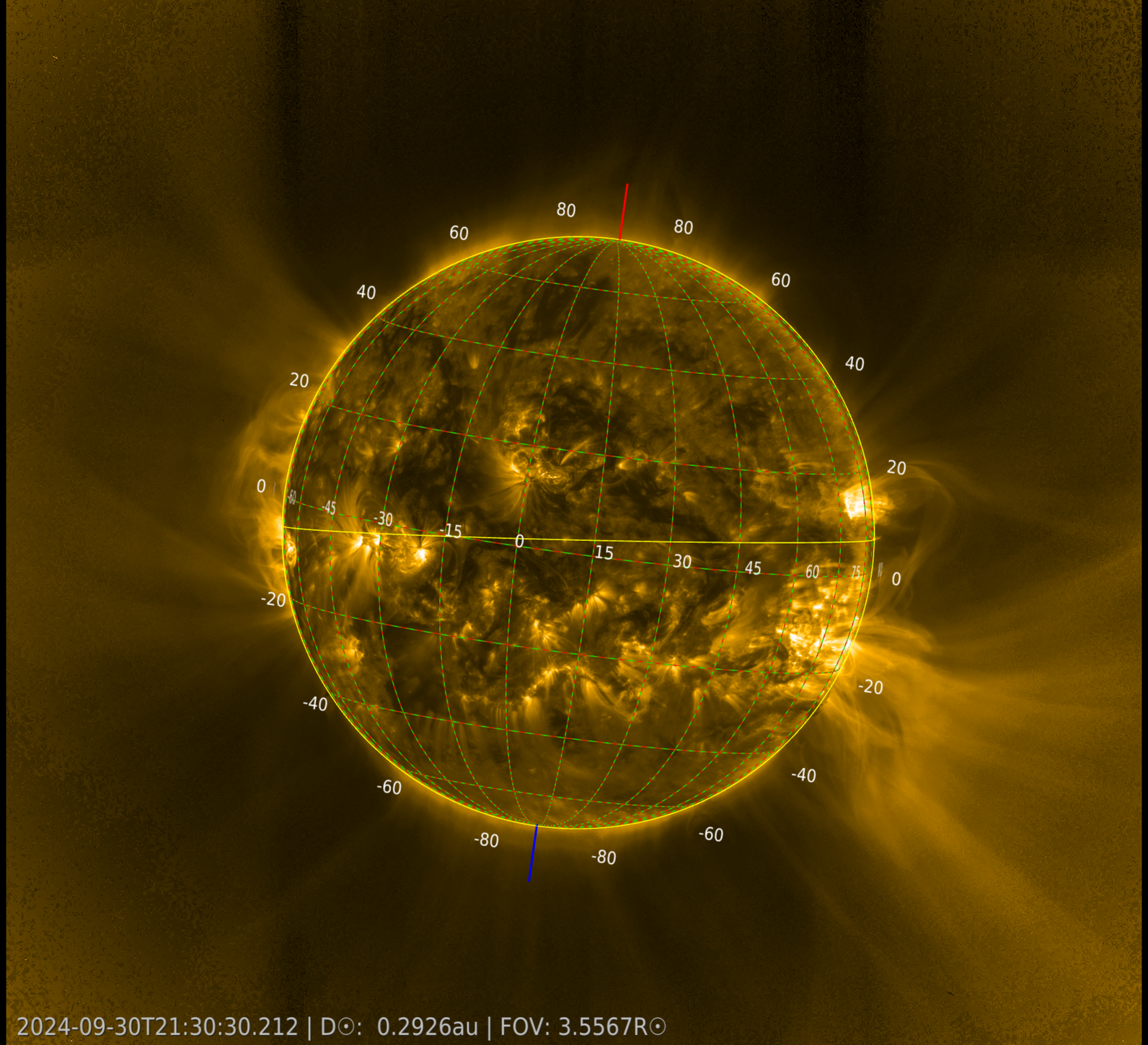

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5000"
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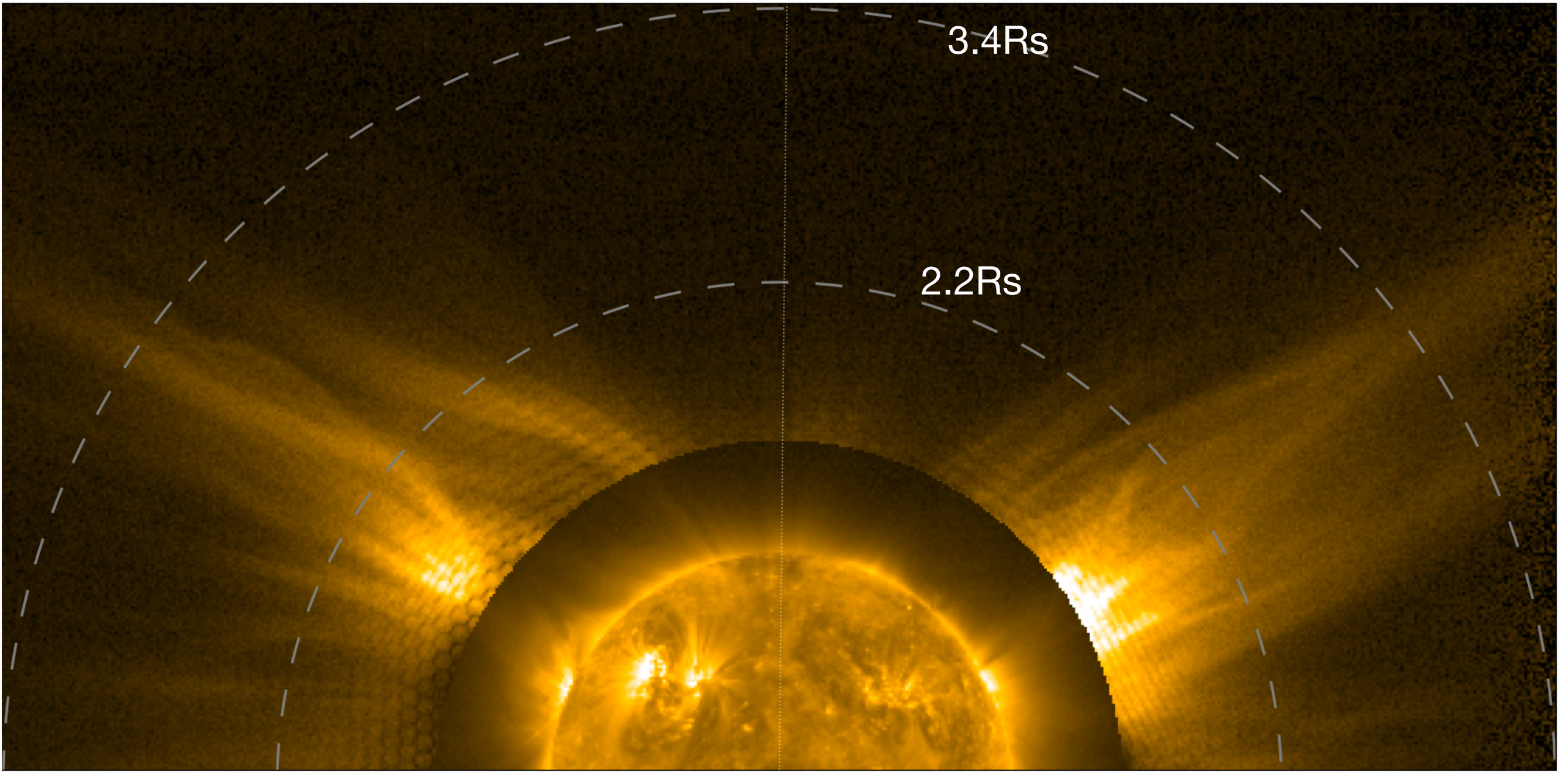
-5000"
Helioprojective Latitude (Solar-Y)
-5000"
0"
5000"
Helioprojective Longitude (Solar-X)

5000"
0"
-5000"
Helioprojective Latitude (Solar-Y)
-5000"
0"
5000"
Helioprojective Longitude (Solar-X)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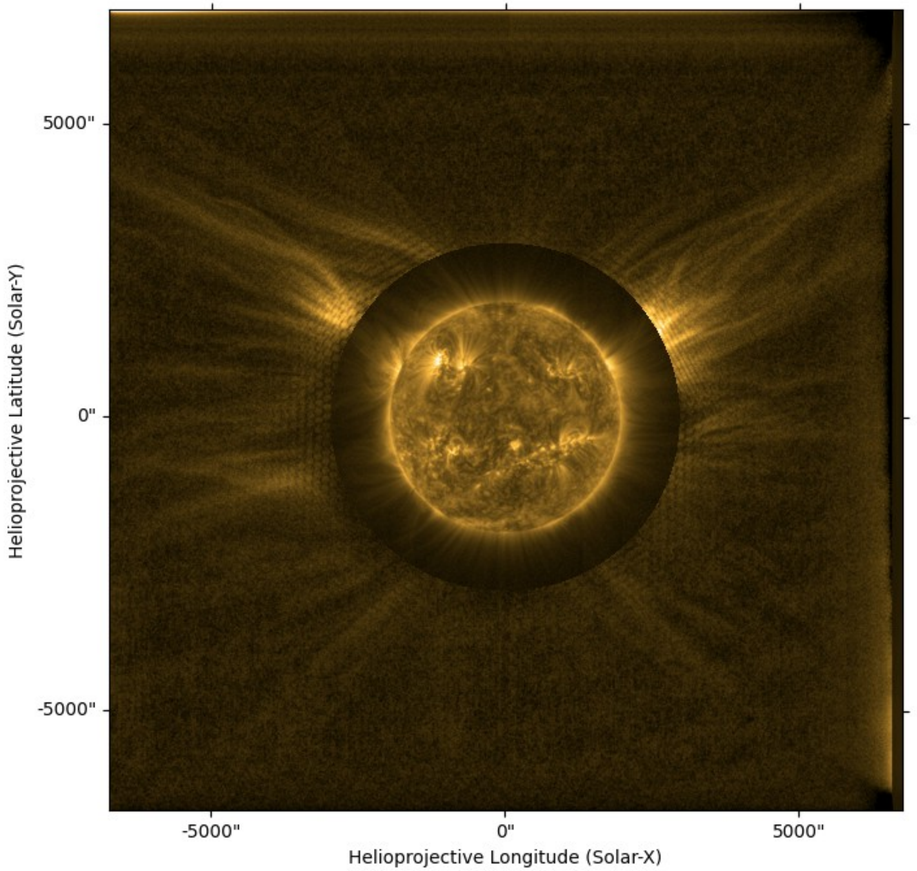
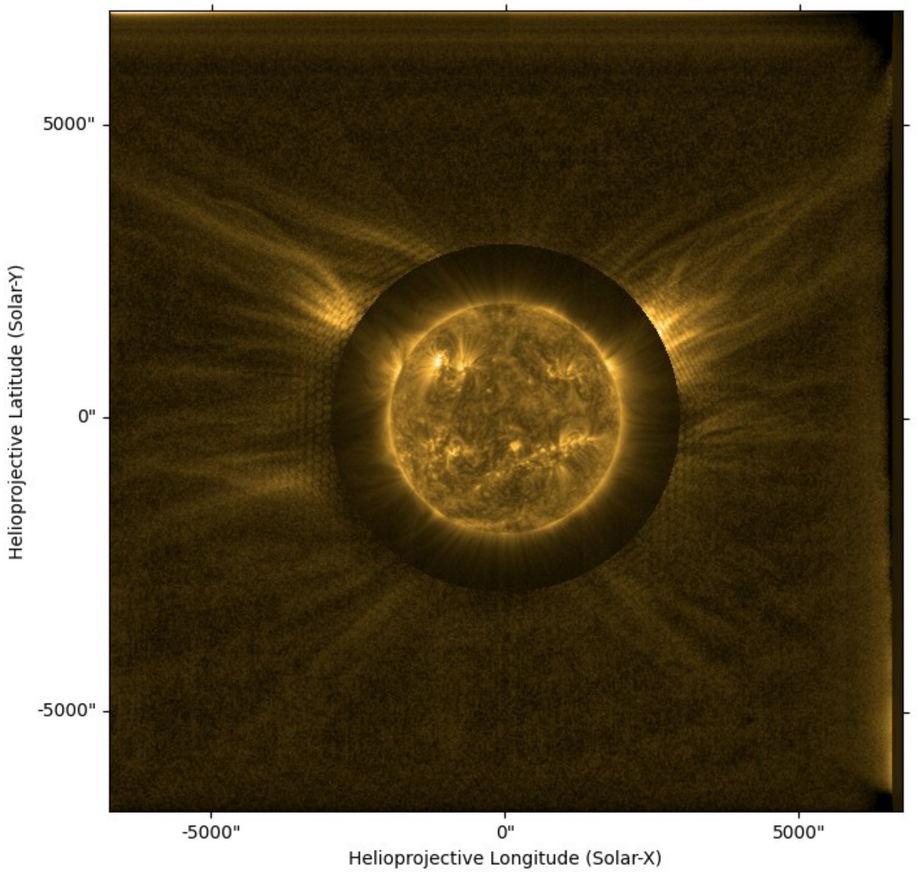
2.2Rs



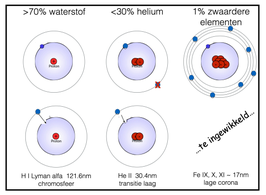
2024 Andreas Möller, Miloslav Druckmüller



E-corona
(emissionlijnen)

2024 Andreas Möller, Miloslav Druckmüller

K-corona
(vrije electronen)



Sun

i+

i+

i+

EUV-licht wordt uitgestraald door ion-electron botsingen (massadichtheid)^2

alle EUV-licht langs de kijkrichting wordt opgeteld

filter om EUV golflengtes te selecteren

EUV telescope

Helioprojective Latitude (Solar-Y)

0"

-5000"

-5000"

5000"

e-

e-

e-

Sun

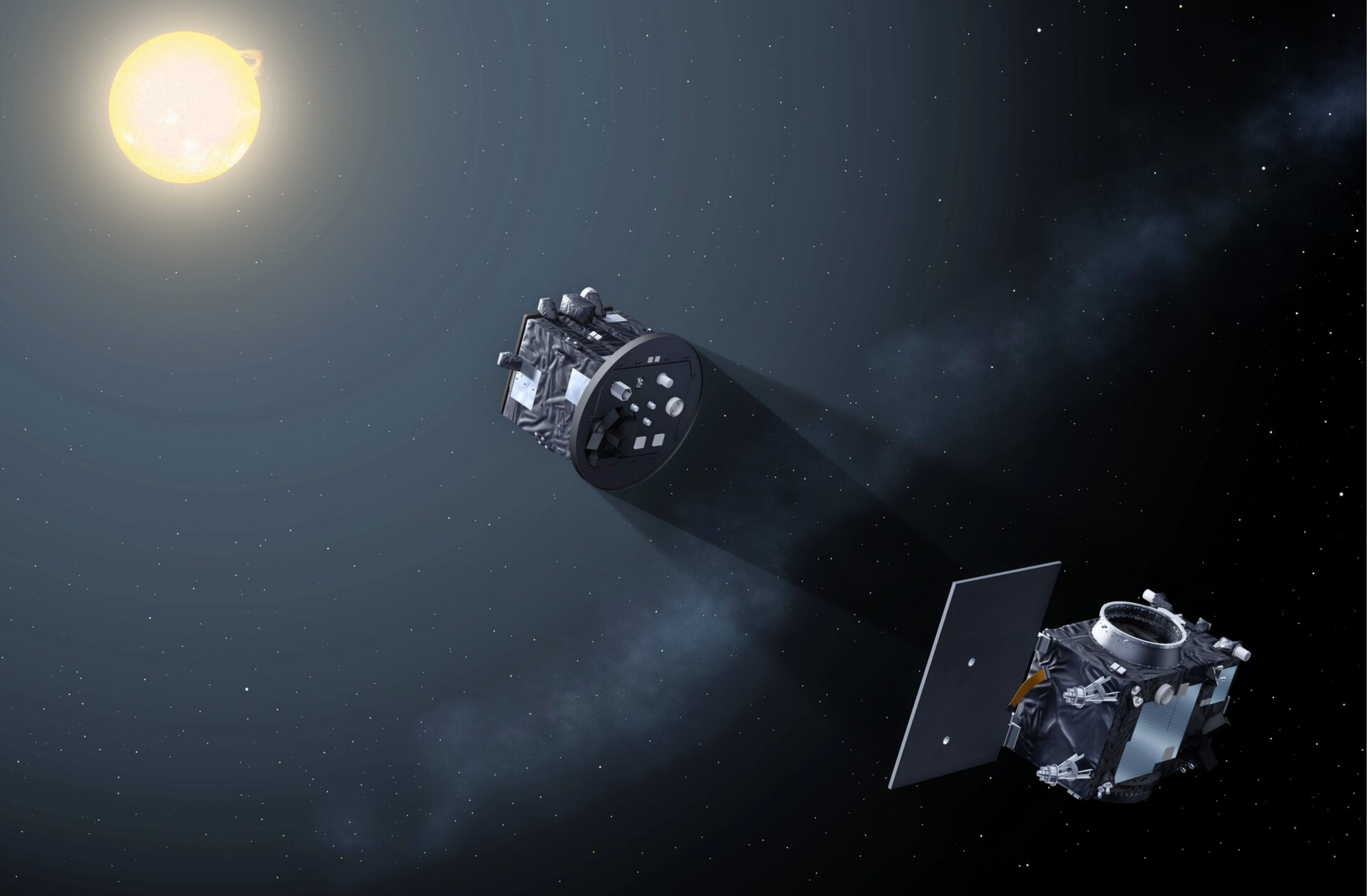
zichtbaar zonnelicht wordt weerkaatst op vrije electronen ~(massadichtheid)

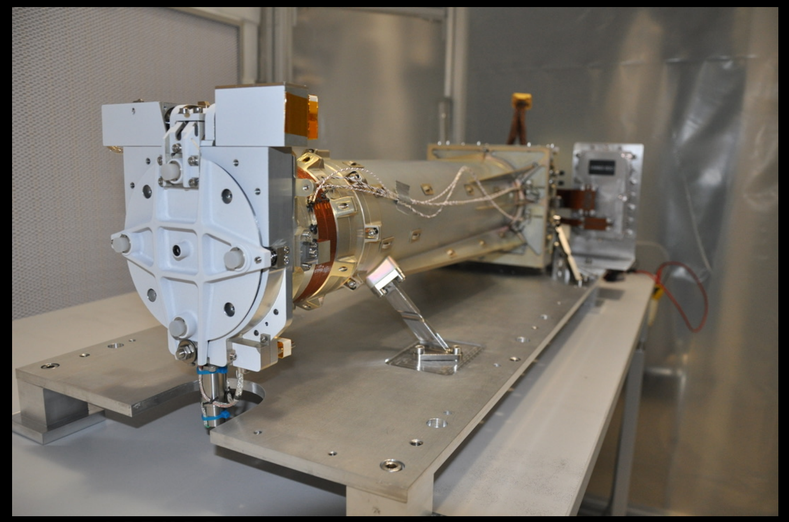
e-

occultor

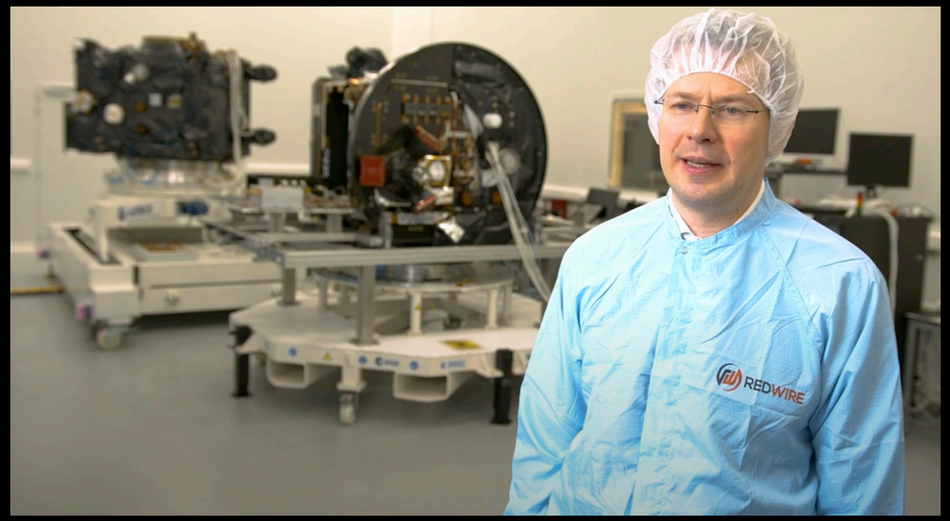
alle weerkaatst zonnelicht langs de kijkrichting wordt opgeteld, maar de weerkaatsing werkt best in rechte hoeken

Corona-graph

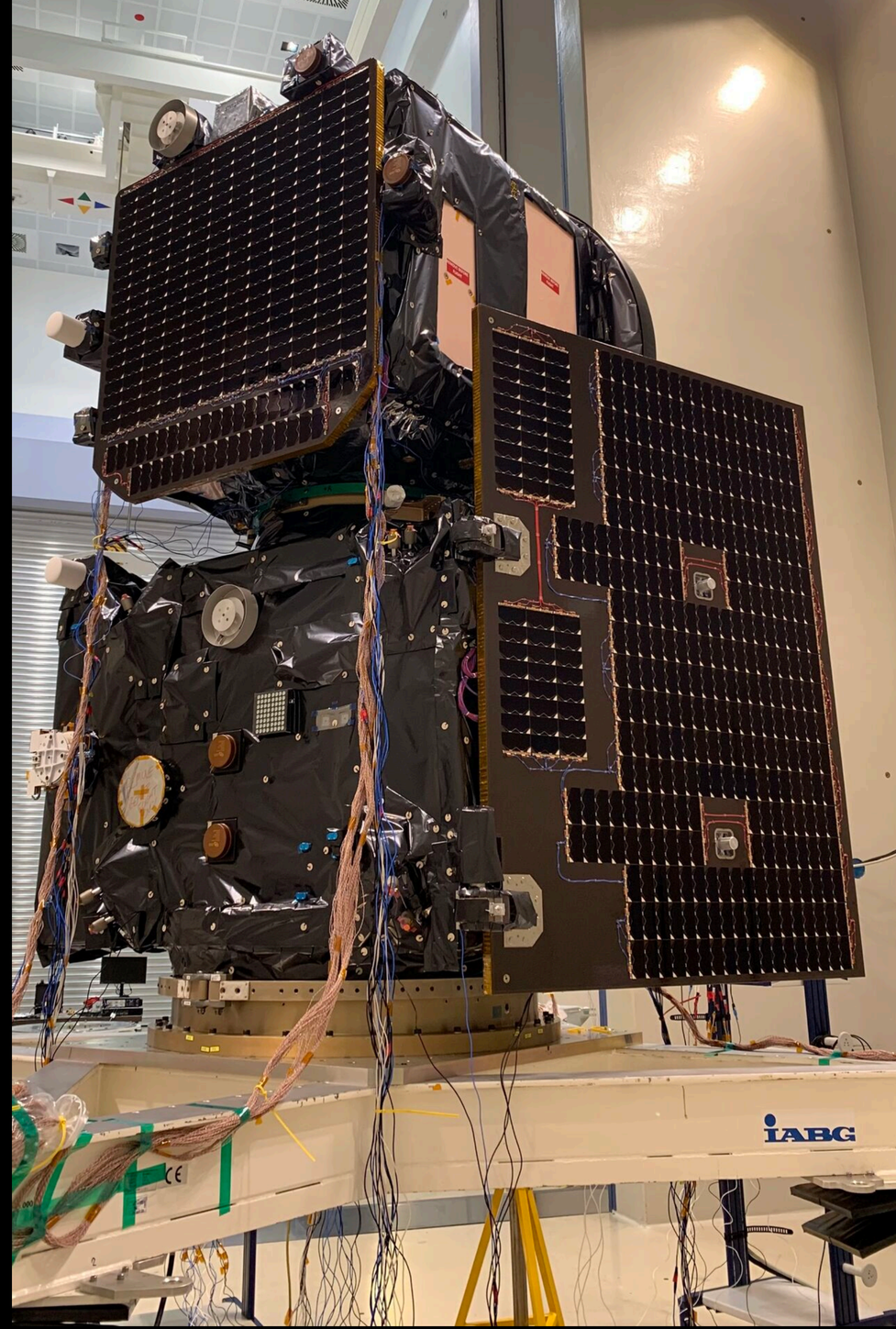




ASPIICS coronograaf @
Centre Spatial de Liège



Dr Andrei Zhukov @ Redwire Kruibeke



Vlucht naar India 2024-10-15
Lancering 2024-11-29

Bedankt

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Koninklijke Sterrenwacht van België

Bedankt

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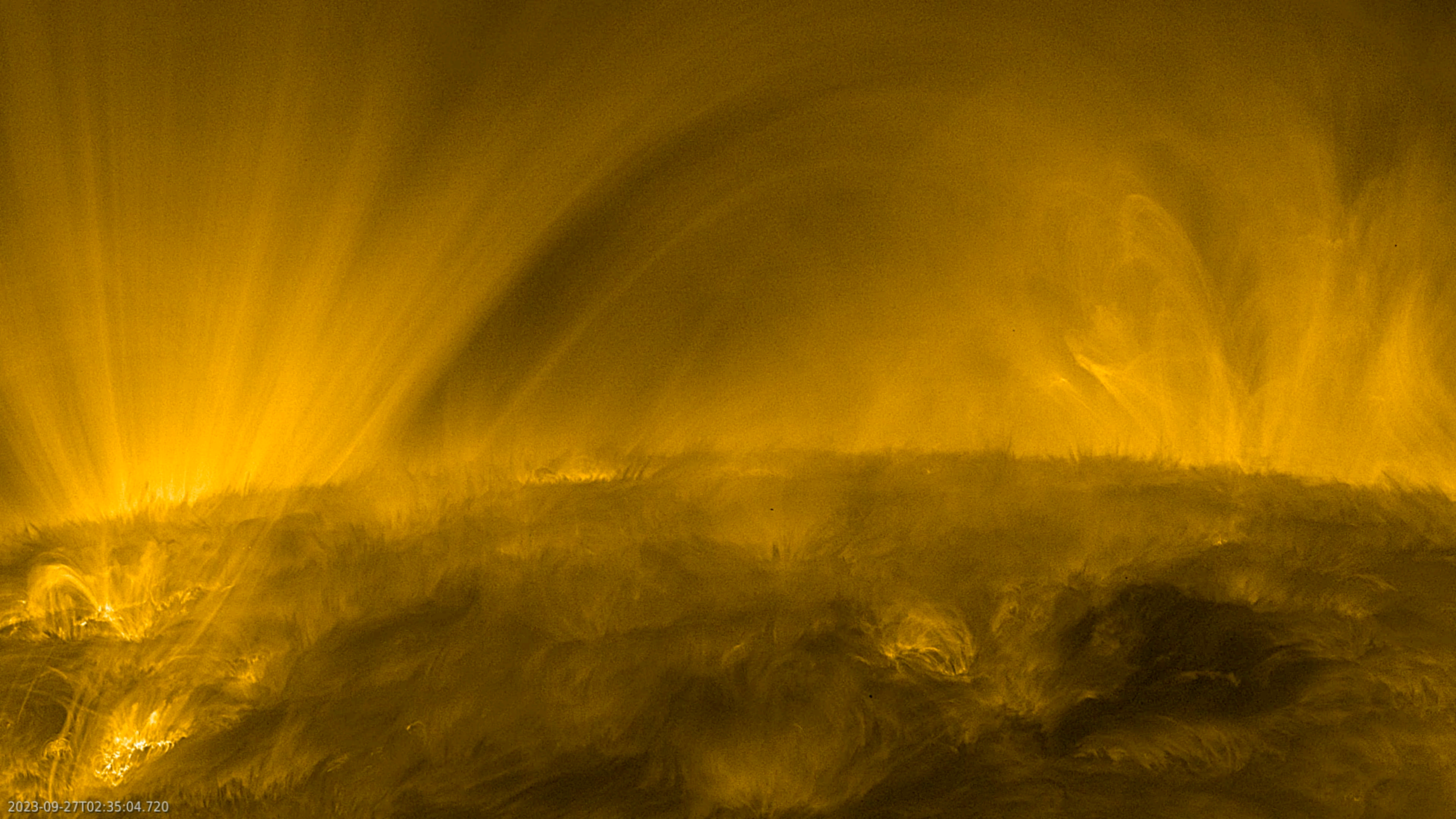
Koninklijke Sterrenwacht van België

Federaal
Wetenschapsbeleid

Solar Energy
Solar Storm
Space Weather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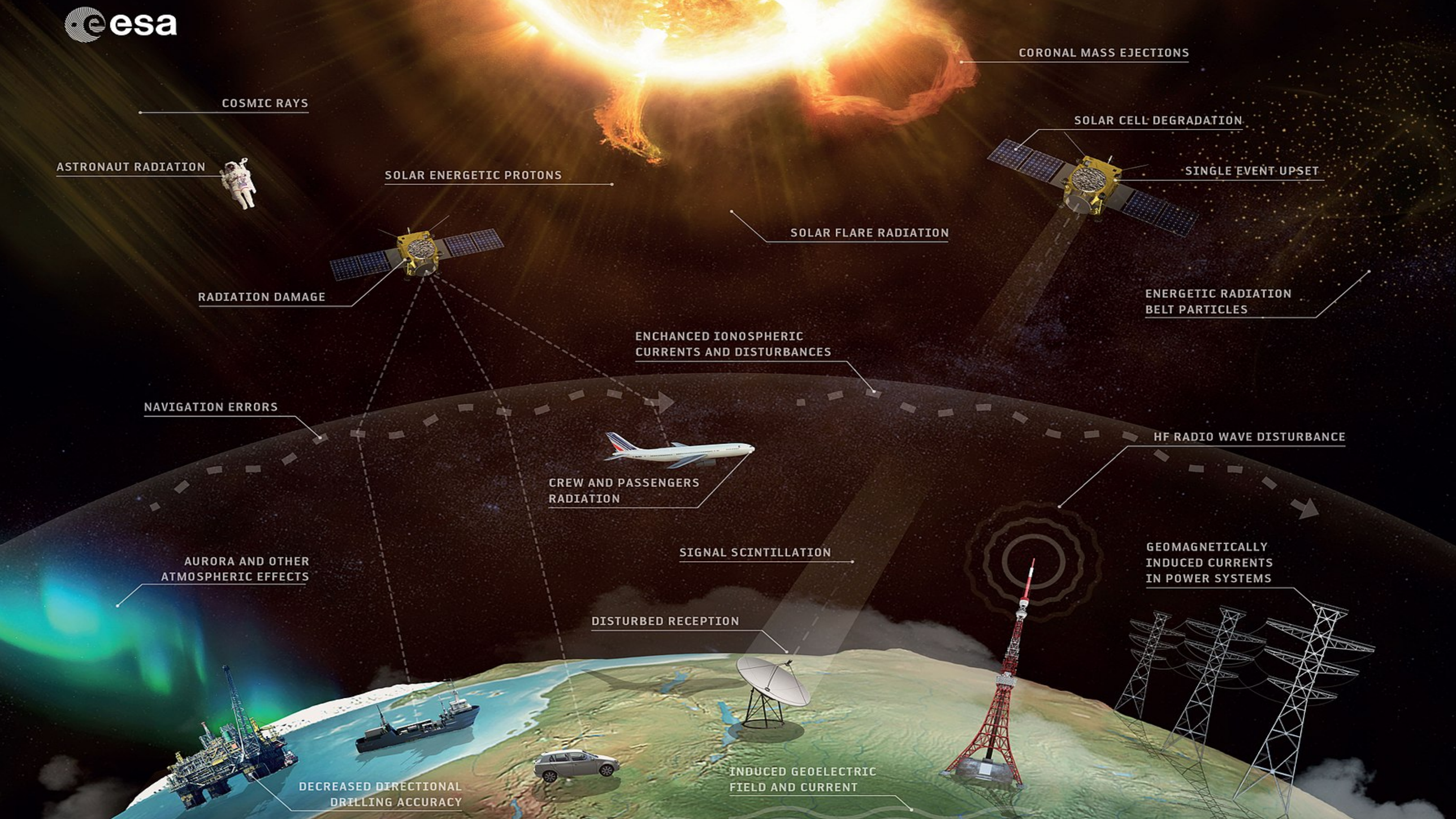
esa
CORONAL MASS EJECTIONS
COSMIC RAYS
SOLAR CELL DEGRADATION
ASTRONAUT RADIATION
SOLAR ENERGETIC PROTONS
SINGLE EVENT UPSET
SOLAR FLARE RADIATION
RADIATION DAMAGE
ENERGETIC RADIATION BELT PARTICLES
ENCHANCED IONOSPHERIC CURRENTS AND DISTURBANCES
NAVIGATION ERRORS
HF RADIO WAVE DISTURBANCE
CREW AND PASSENGERS RADIATION
SIGNAL SCINTILLATION
AURORA AND OTHER ATMOSPHERIC EFFECTS
GEOMAGNETICALLY INDUCED CURRENTS IN POWER SYSTEMS
DISTURBED RECEPTION
DECREASED DIRECTIONAL DRILLING ACCURACY
INDUCED GEOELECTRIC FIELD AND CURRENT