

Getting to know our star: Solar Orbiter and space missions studying the Sun

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The Sun: our star



The Sun is 'our' star, the source of light and energy, and thus life on Earth



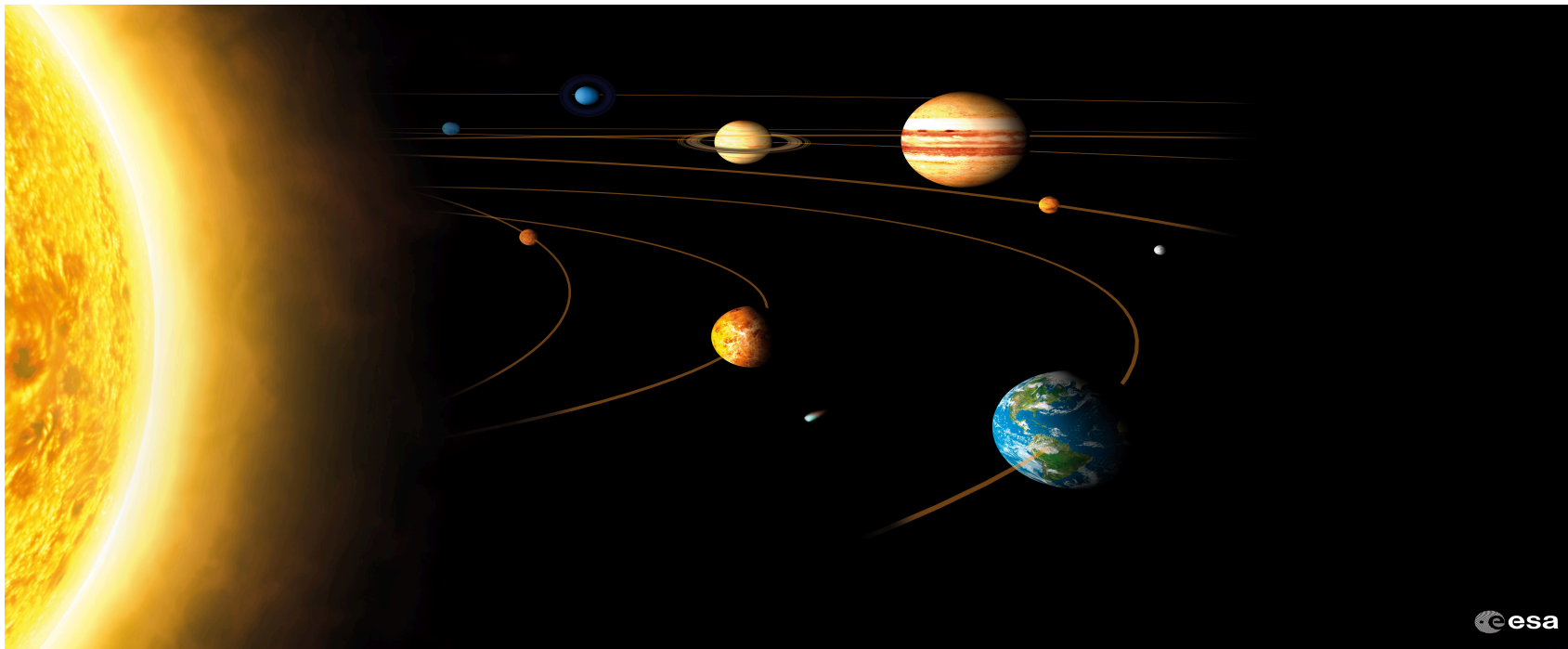
- 4.5 billion years old
- 150 million km away from the Earth
- Diameter 1.4 million km
= 109 * Earth diameter
- Sun weighs 330 000 times more than Earth

It is a very ordinary star: not particularly big or small, old or young, but much closer to us than any other

The Sun: our star



The Sun is 'our' star, the source of light and energy, and thus life on Earth.



Humans have always been fascinated about the Sun. We want to get to know our star and how it affects us.

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But the Sun is a quiet star, no?

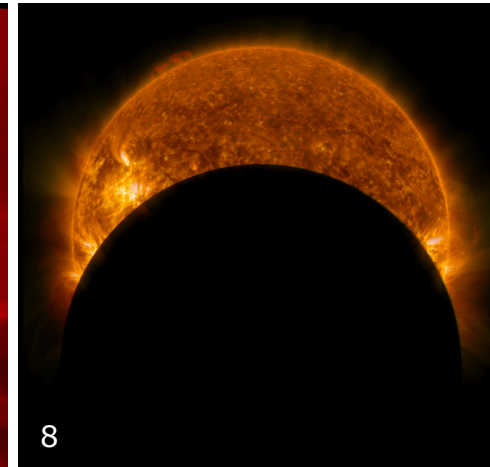
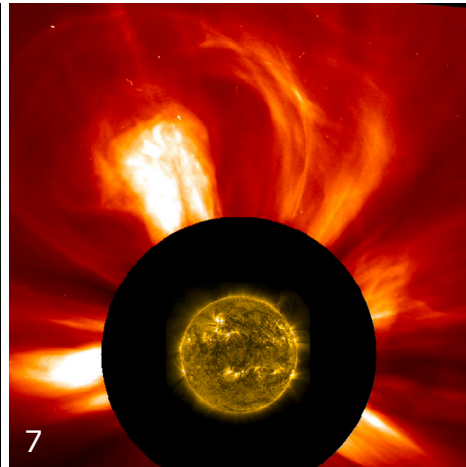
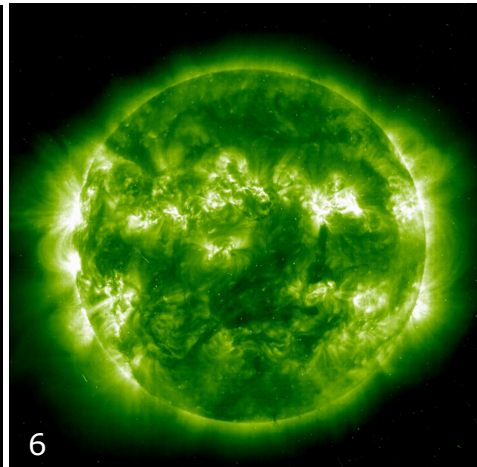
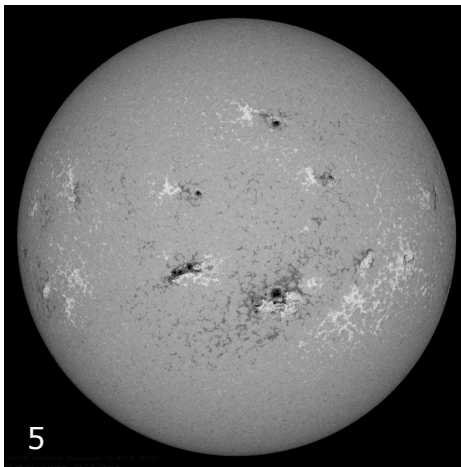
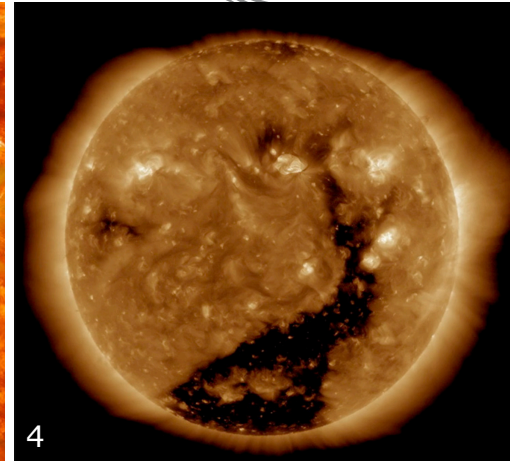
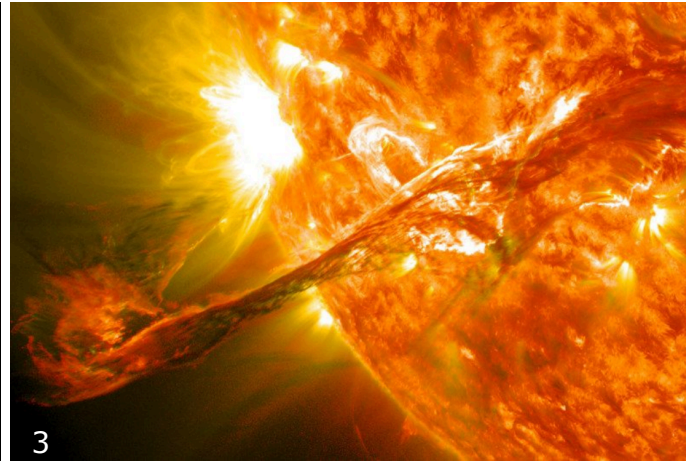
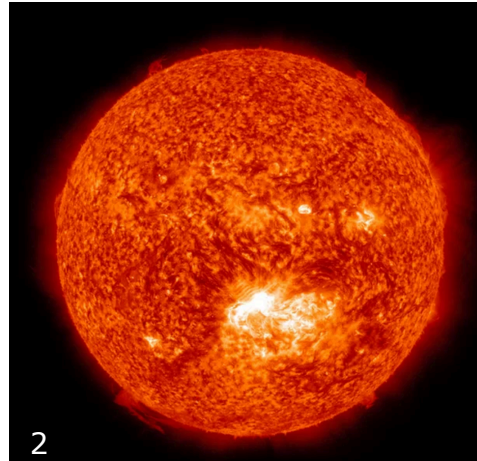


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Quiz: Which of these pictures show the Sun?



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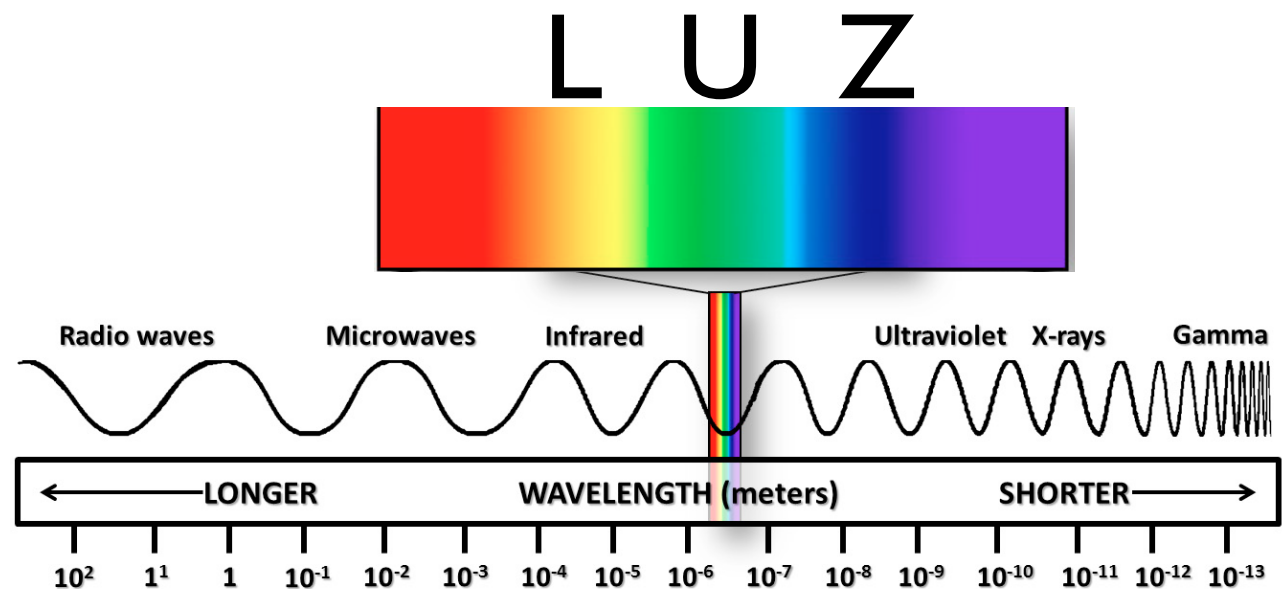


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Light has different wavelengths/colours



The sun radiates light in a whole range of colours and wavelengths.
Some we can see with our eyes (visible light), for other wavelengths we use special filters or cameras/detectors.



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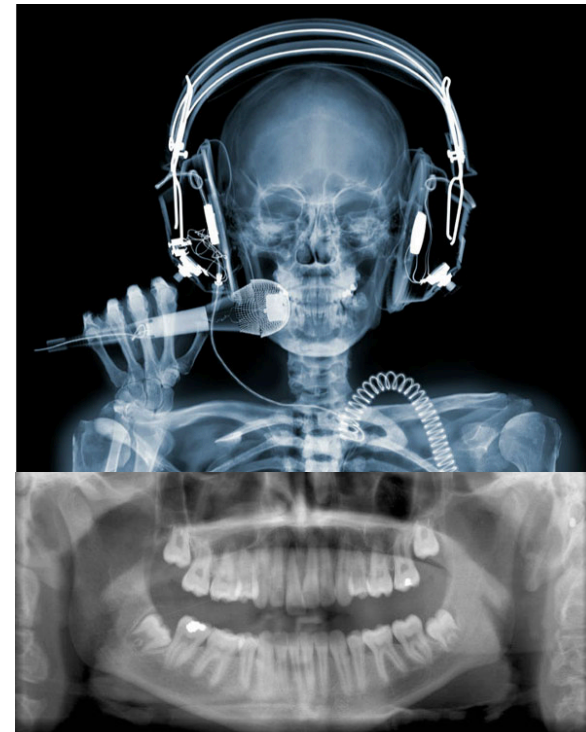


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Light has different wavelengths/colours



Depending on the filter or camera you use, an object can be transparent or opaque for a certain type of colour of the light.



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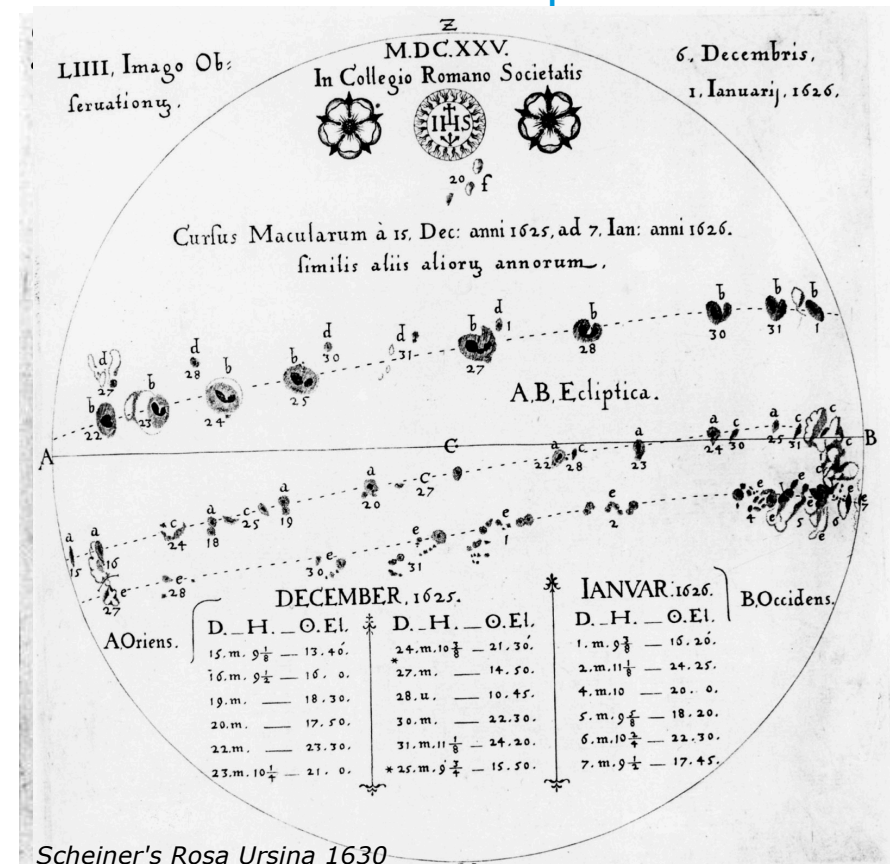
Early solar observations – from Earth



In ancient times: solar observations by naked eye -> **existence of sunspots**

No systematic studies until invention telescope by Galileo Galilei early 17th century.

Mid 19th century: Daily drawings
-> number of sunspots vary with a regular period: **11 years sunspot cycle**

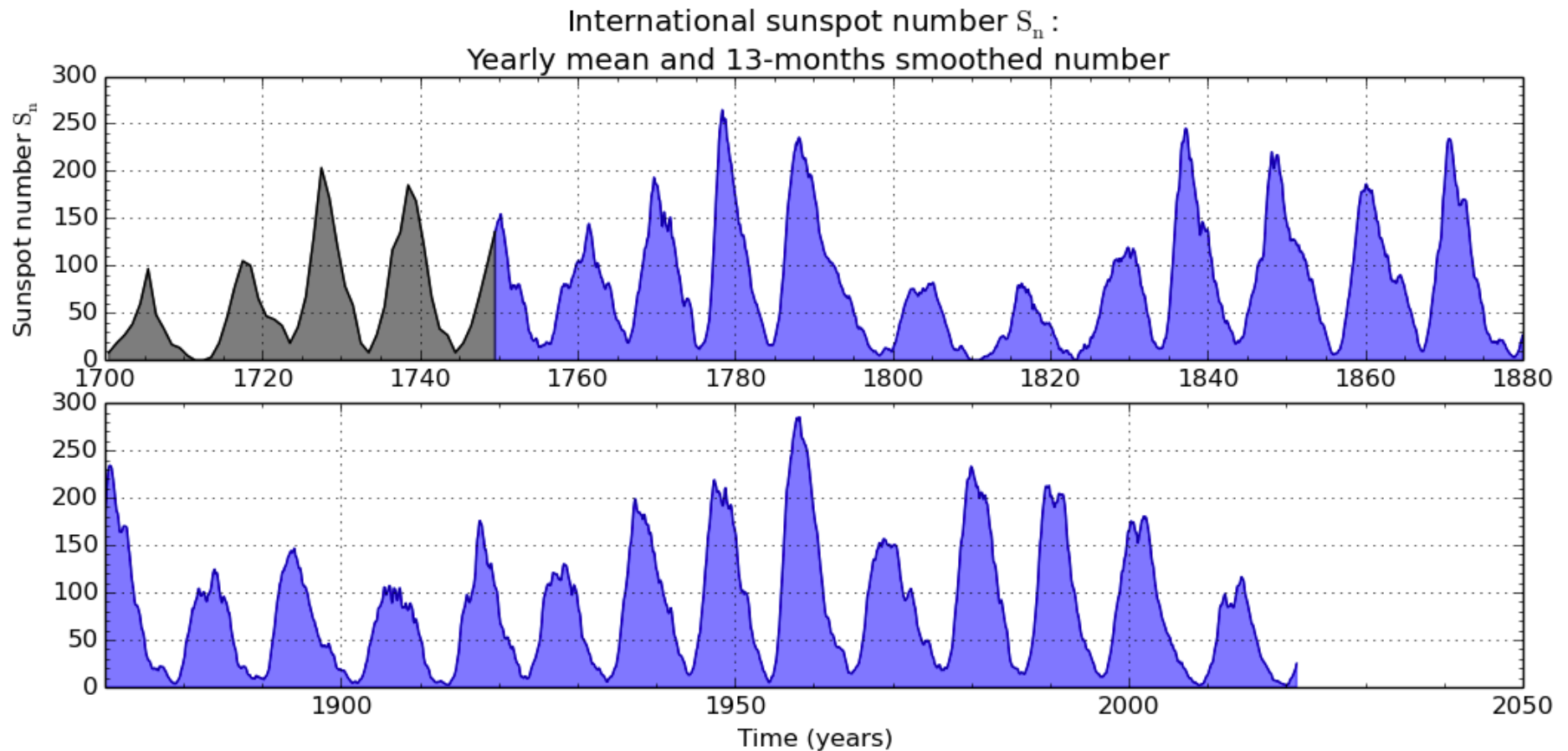


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Early solar observations – from Earth



SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2021 November 1

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Recent solar observations – from Earth

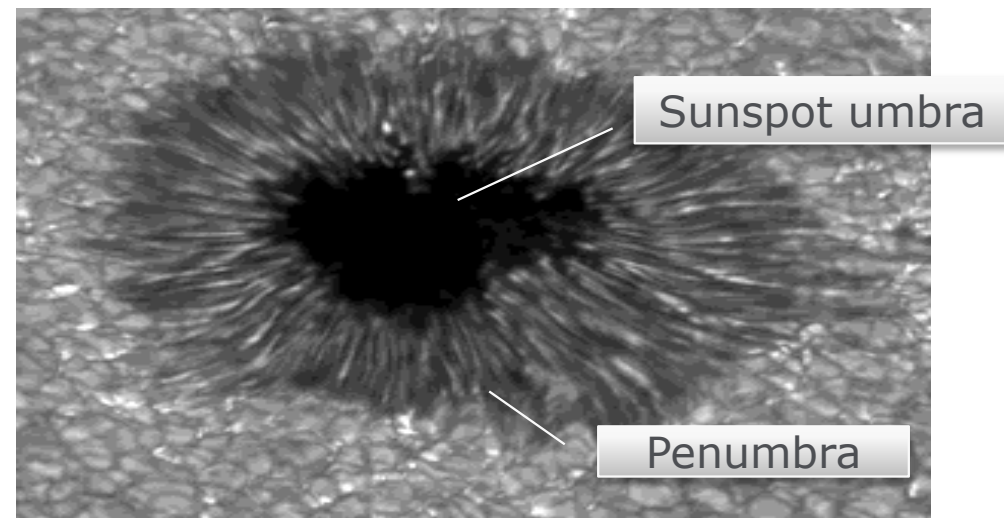


We still observe the Sun, from Earth, in what-we-call 'visible light'



Dark sunspots: 1500° cooler
than surroundings

Photosphere (*photo* = *light*)
~ solar 'surface'

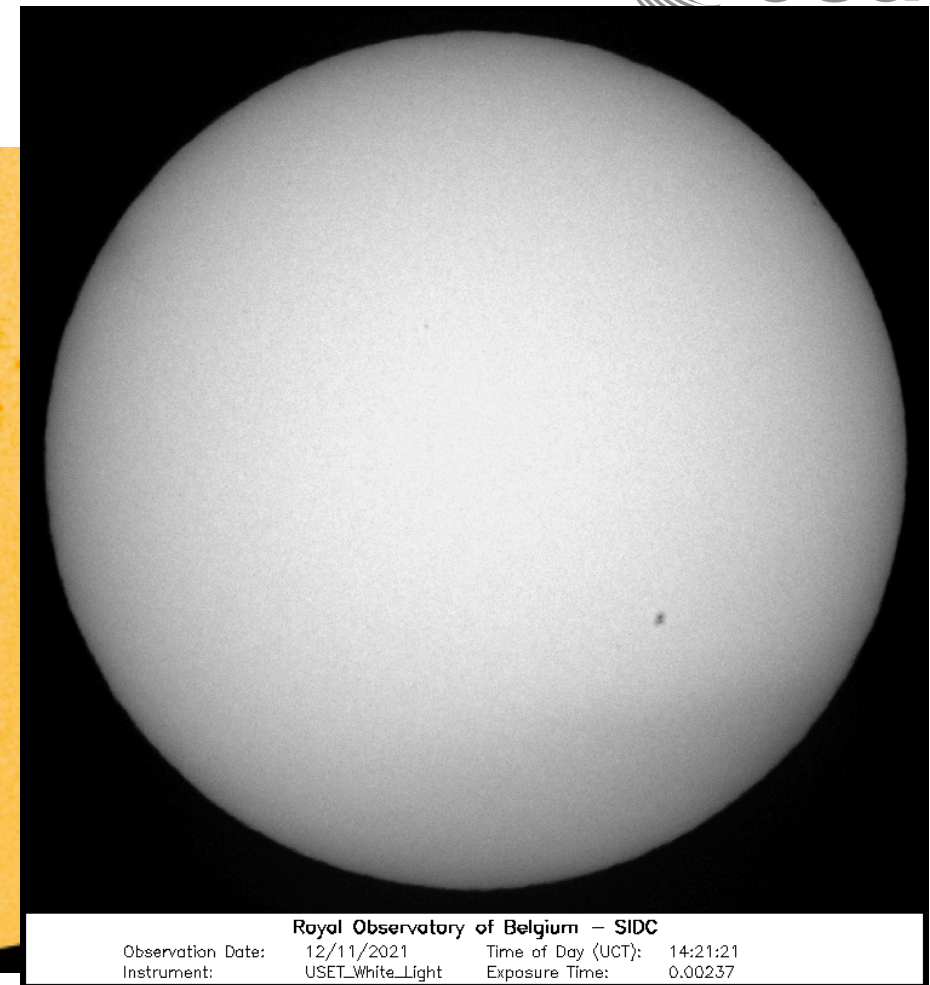
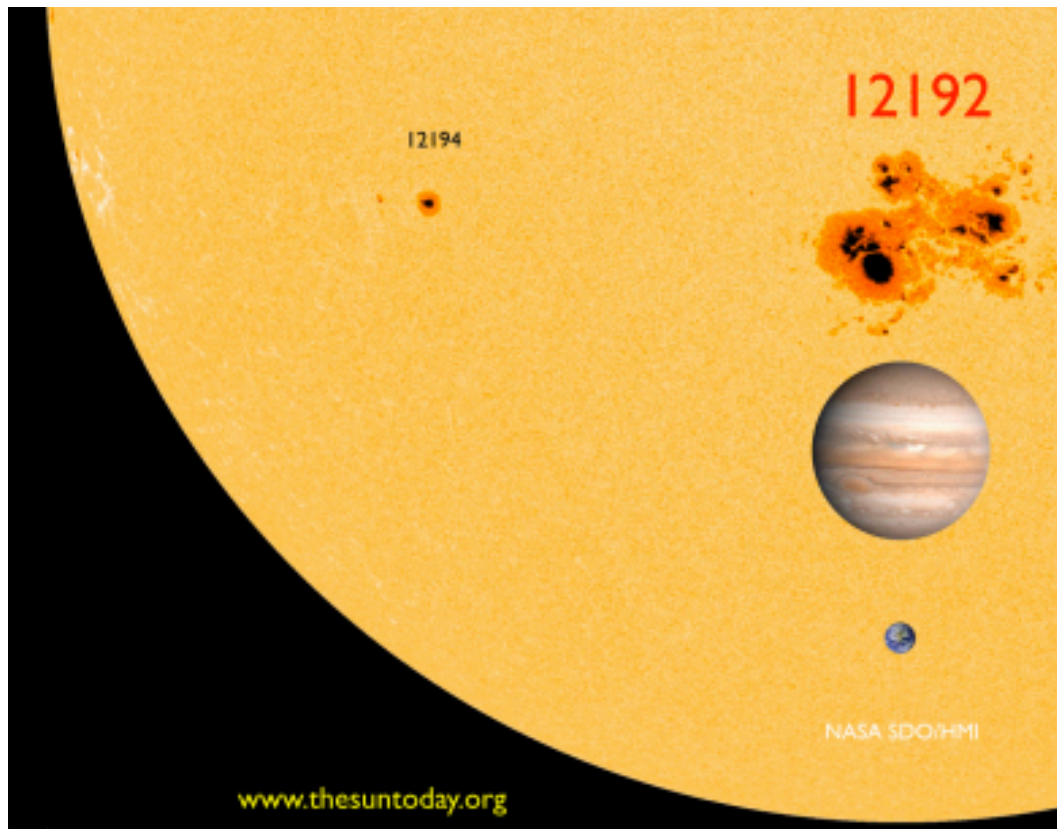


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Sunspots



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Filtering the Sun's light – H alpha observations

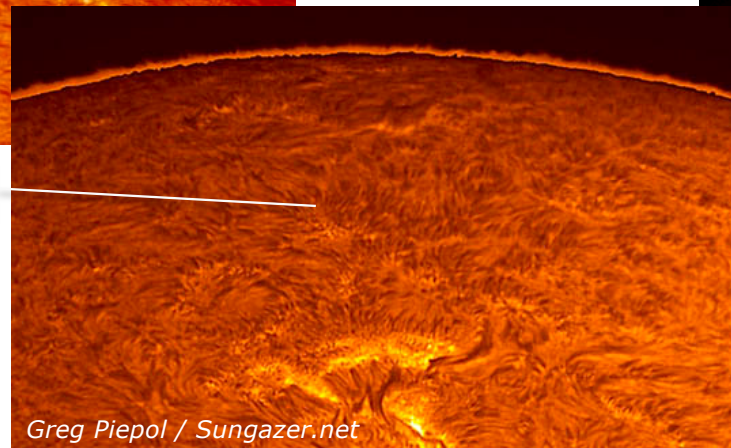
Chromosphere (*chromo* = colour)



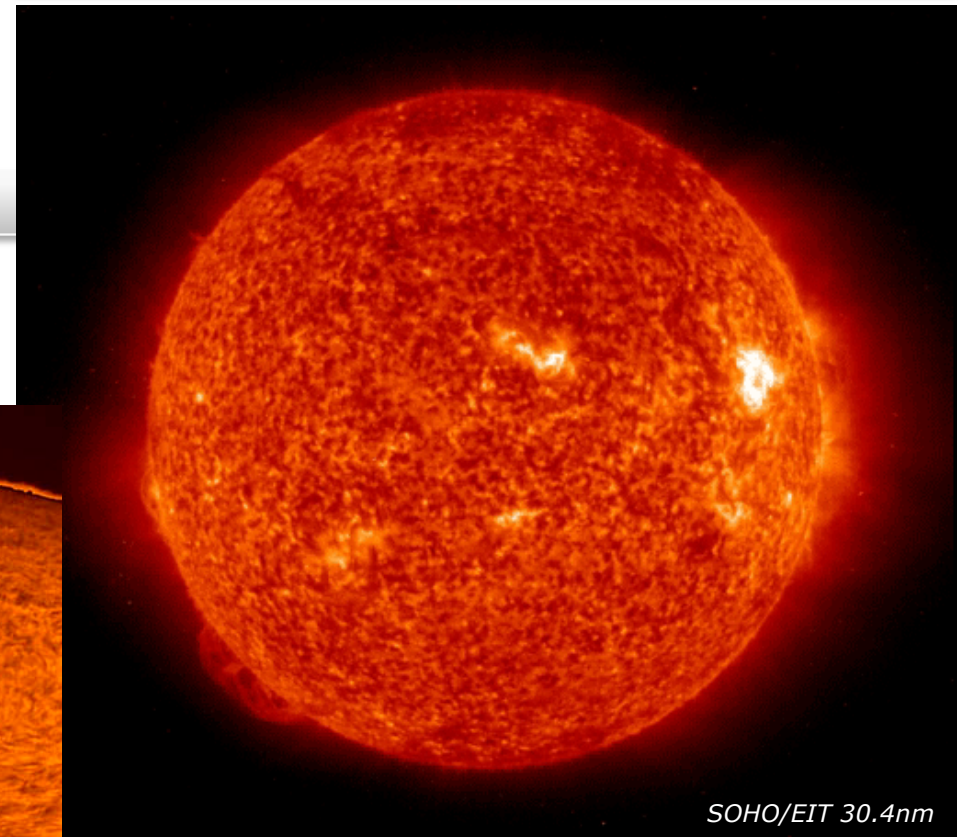
Solar filaments = prominences

Bob Antol / stargate4173.com

Spicules



Greg Piepol / Sungazer.net



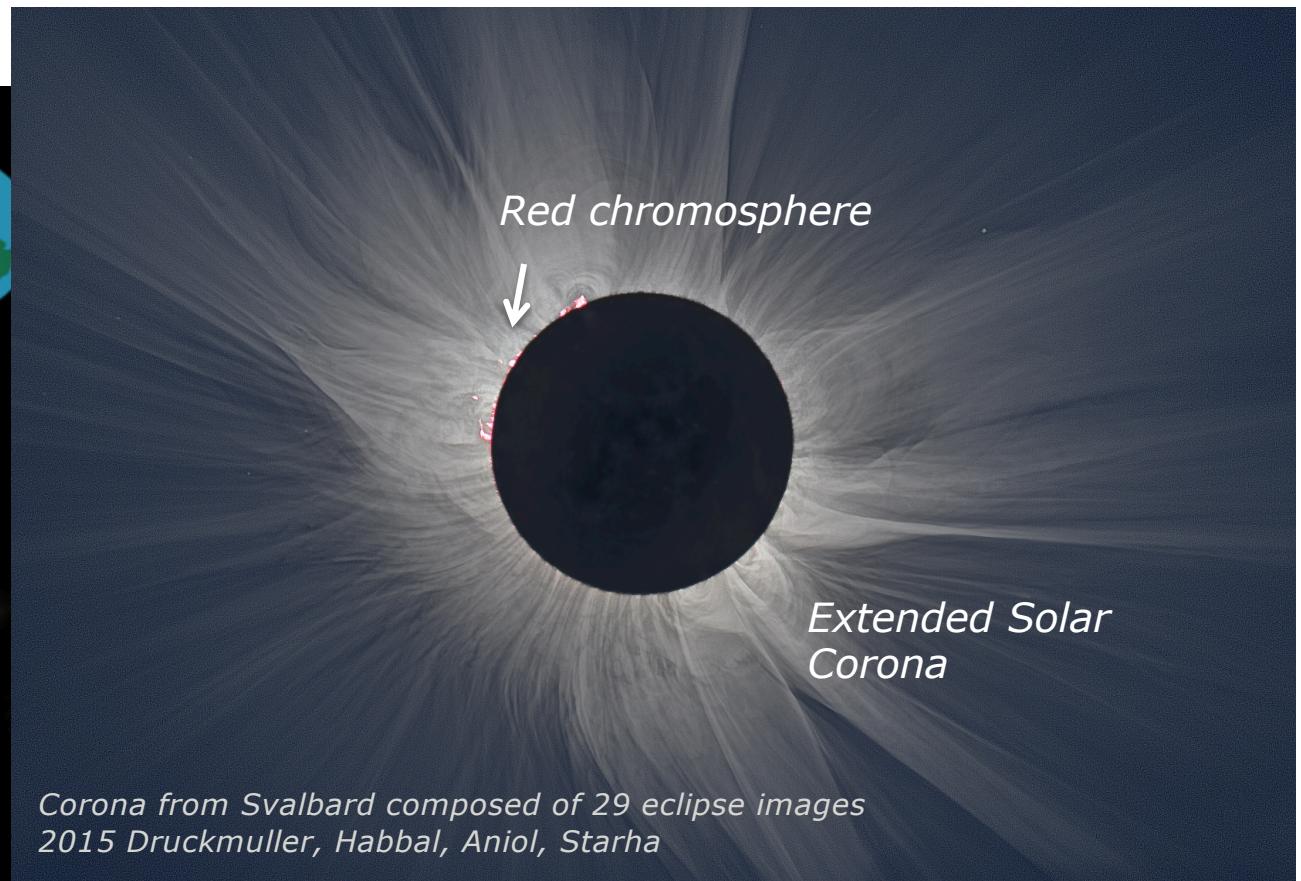
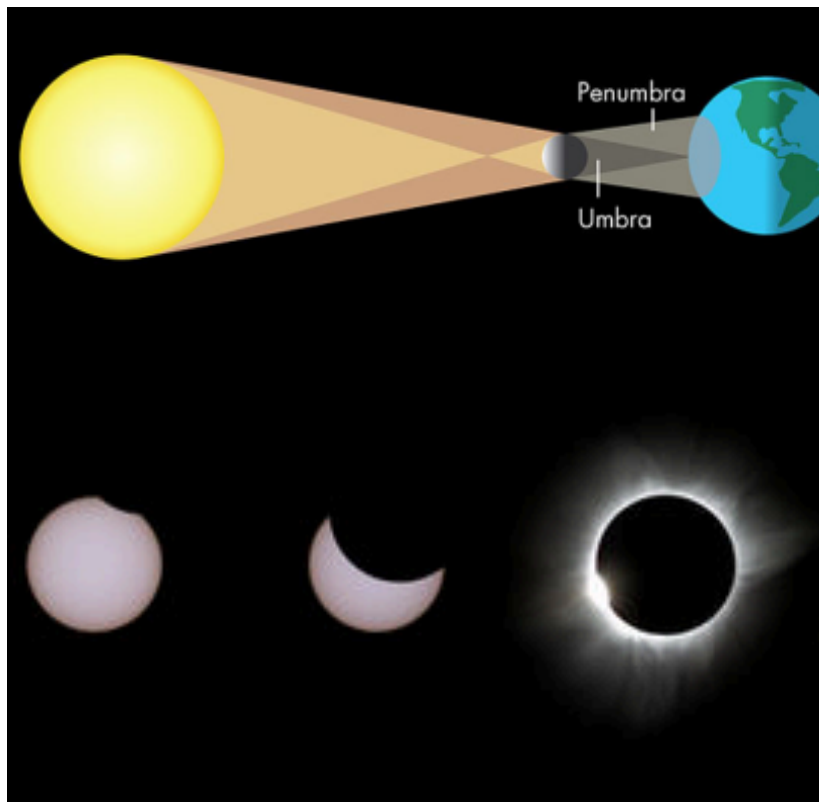
SOHO/EIT 30.4nm

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But there must be more ...

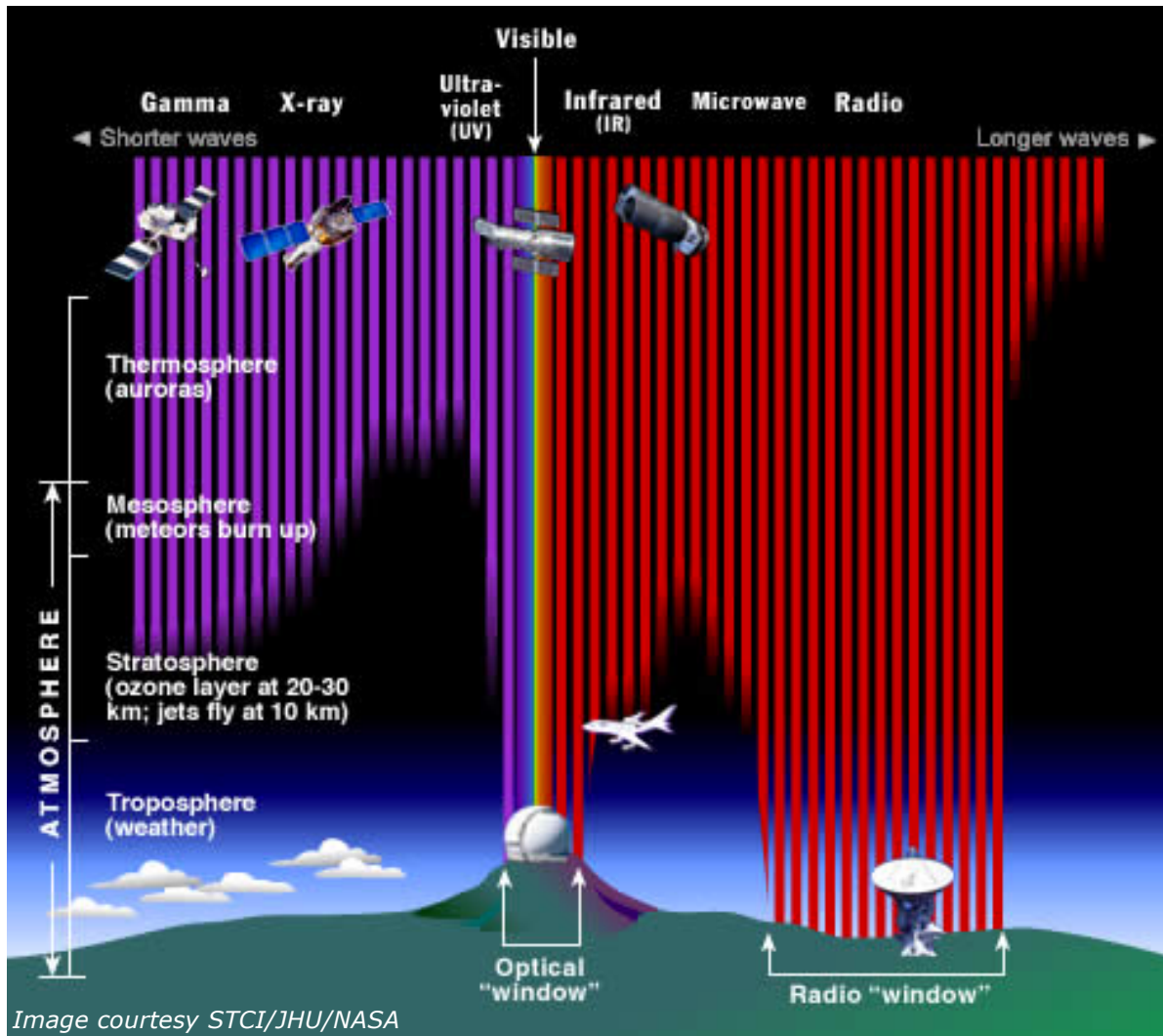


Solar eclipse, the moon shields the bright light from the photosphere, and something magical happens ...



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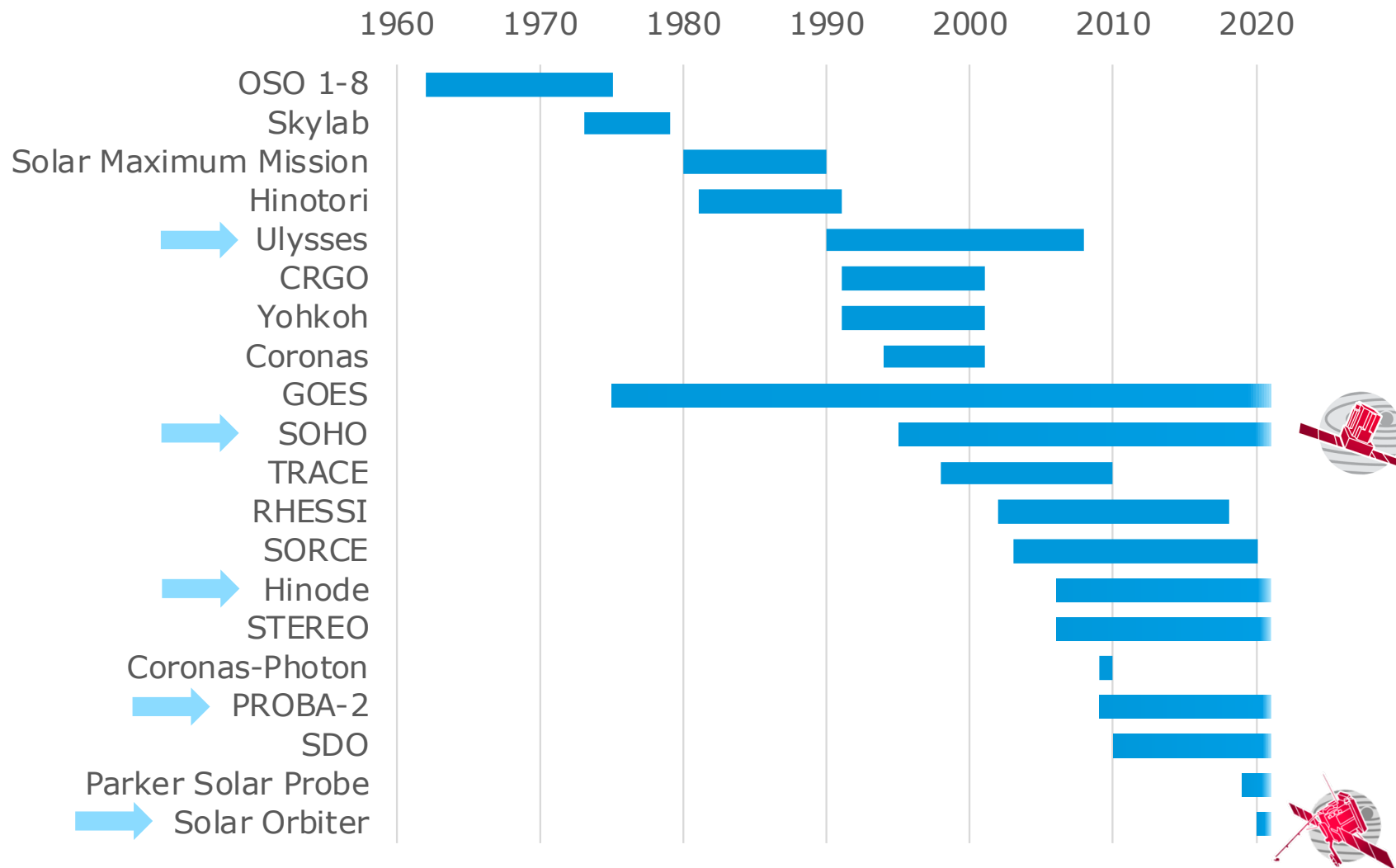
In order to know more: go to space!



The Earth's atmosphere limits the 'colours' we can see.

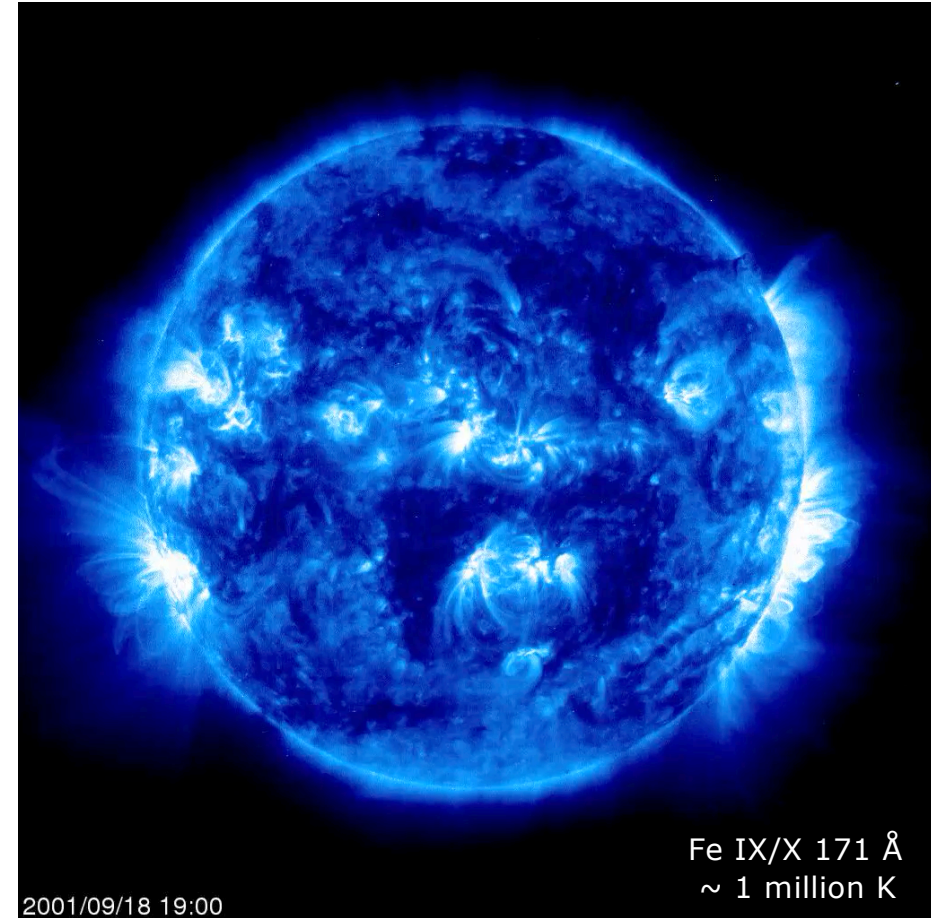
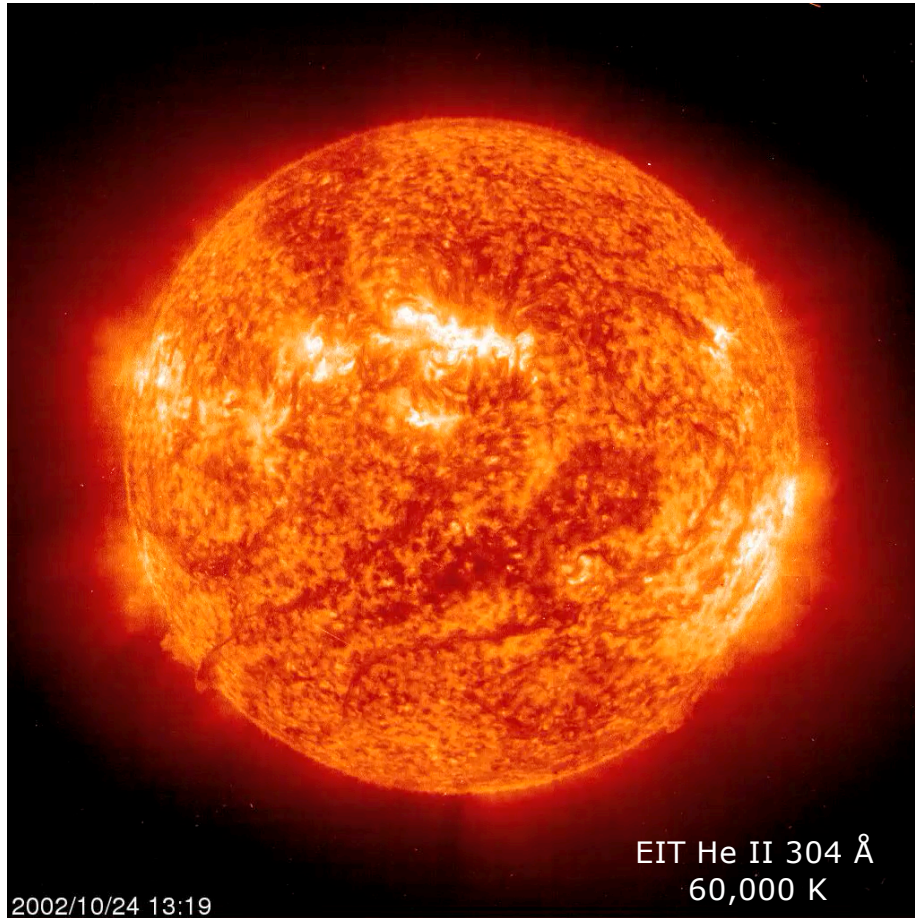
From analysing the Sun's spectrum, we knew that the corona must be very hot.

The Sun should be emitting light that we cannot see on Earth...



ESA Missions
or partnerships

Sun from Space: The beauty of the solar corona

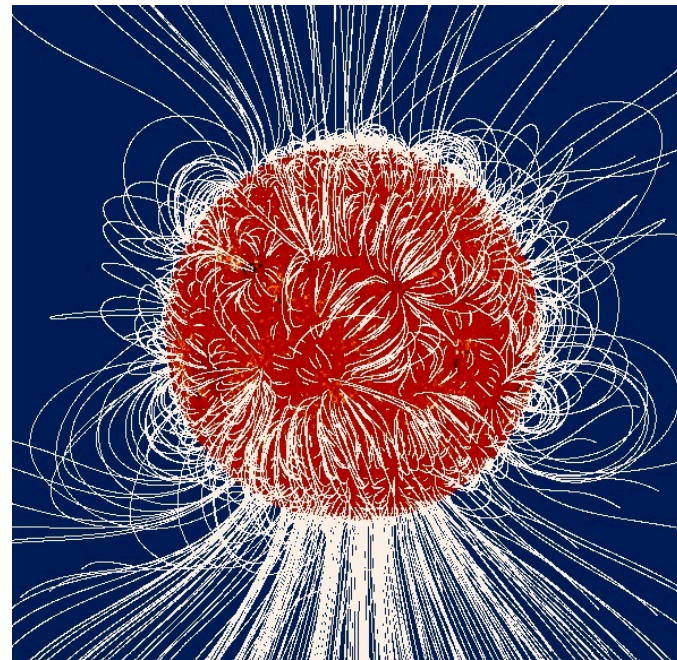
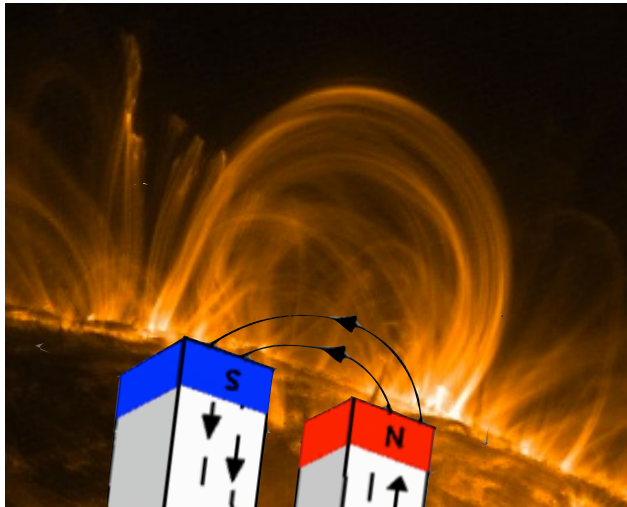


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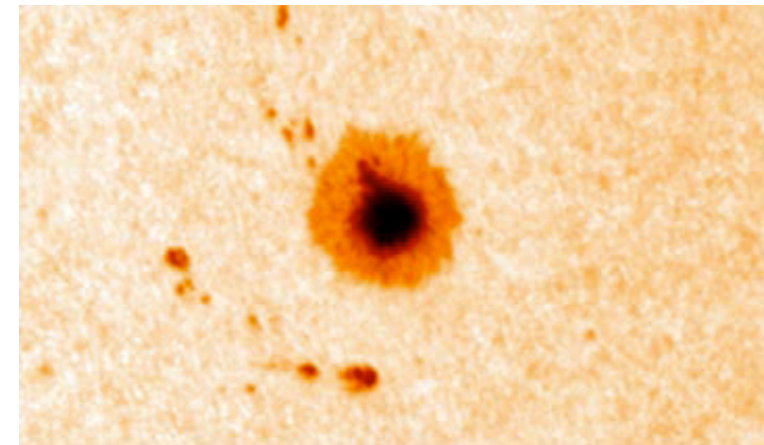


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Sun from space: Magnetic field causes dynamics



MPS, Germany

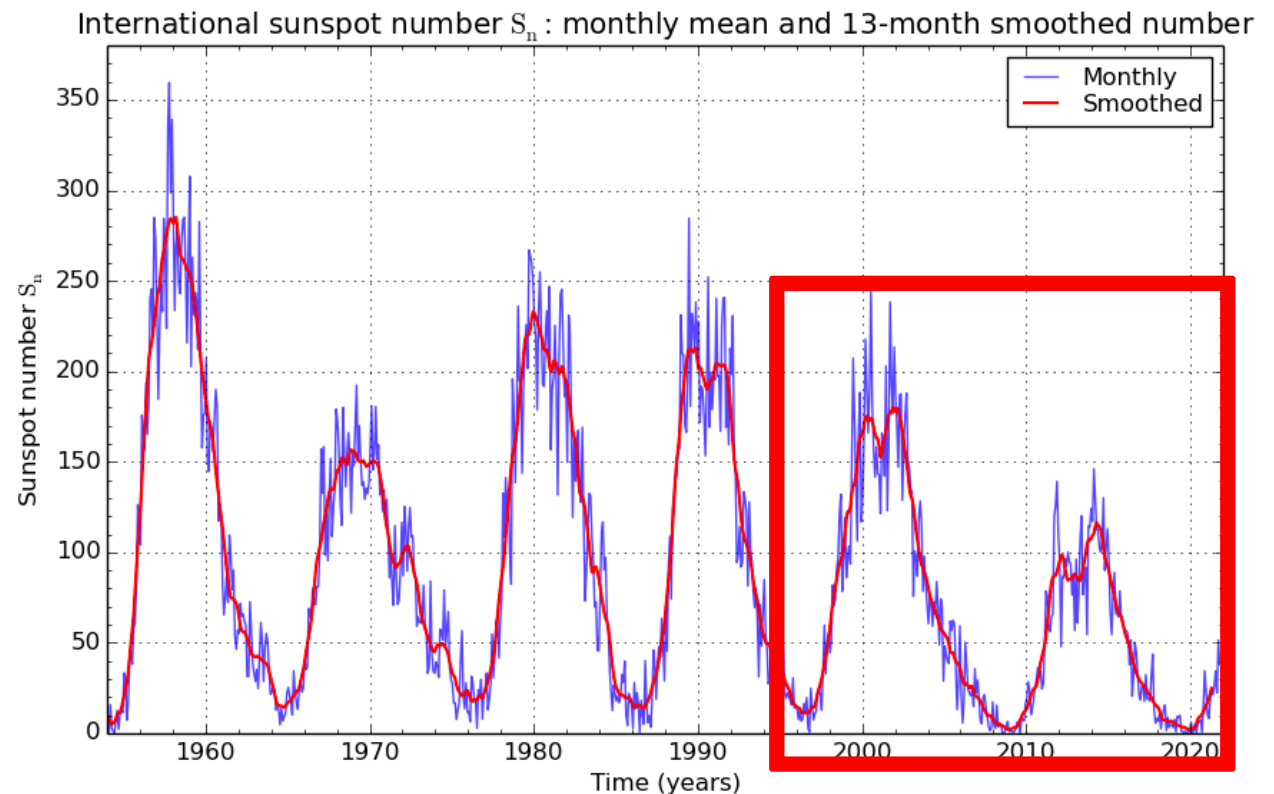
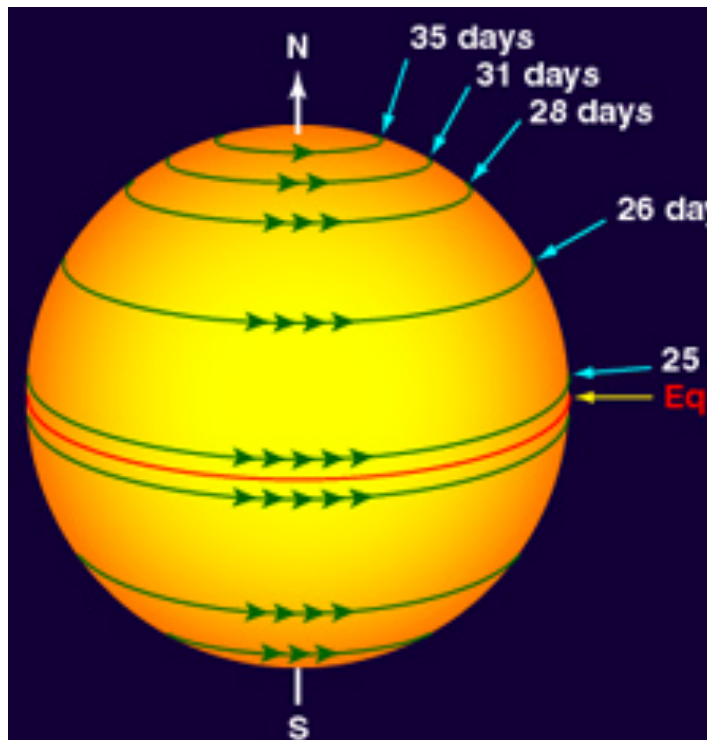


SOHO/MDI, ESA&NASA hotshot 2001

Changing solar activity over the solar cycle



Plasma confined by magnetic field + differential rotation => solar cycle

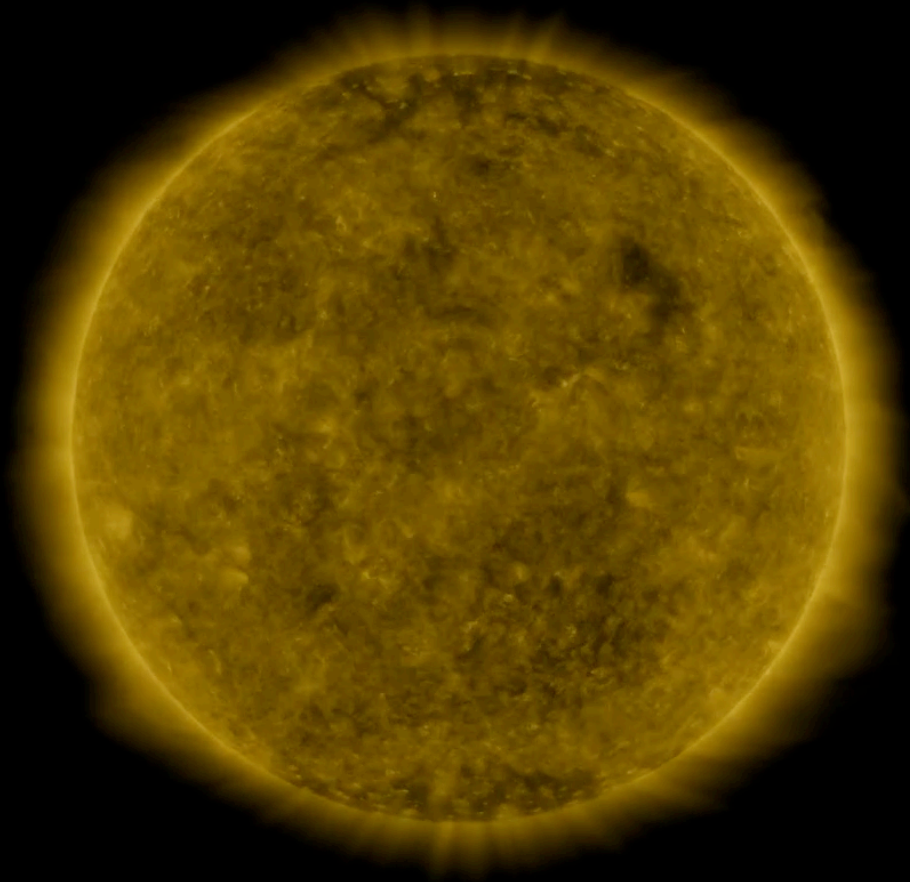


SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2021 November 1
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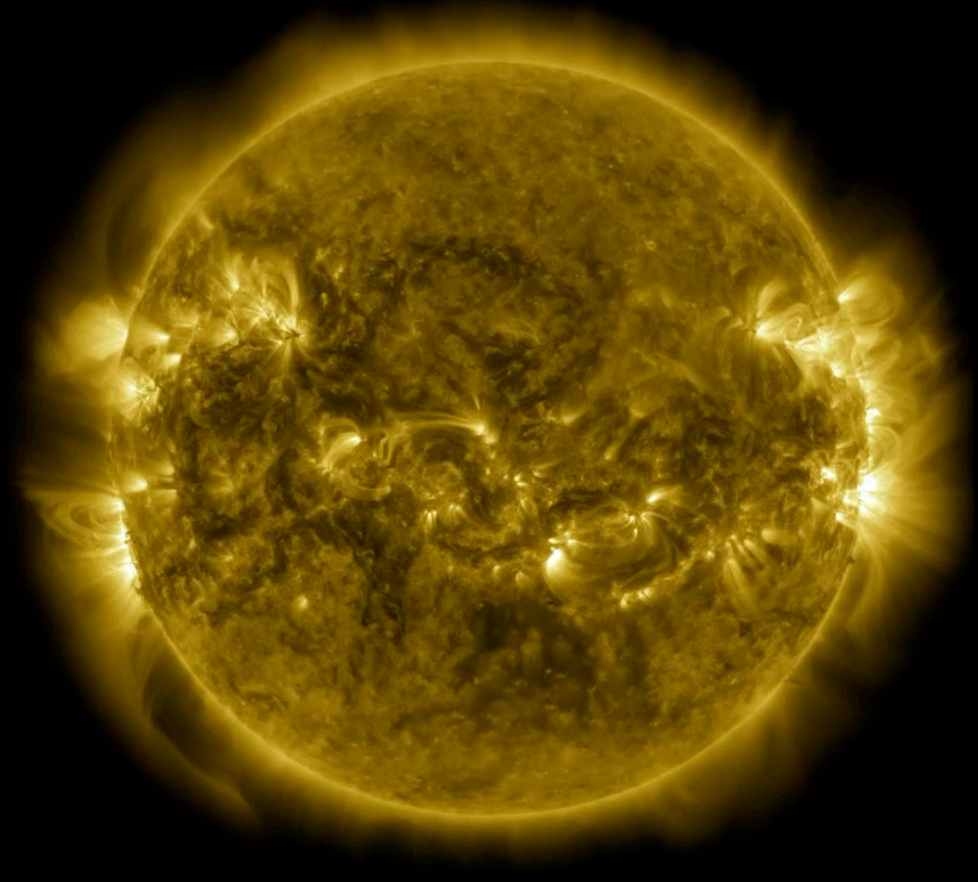


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SOLAR MINIMUM



SOLAR MAXIMUM



Credit: NASA/SDO

Space Weather



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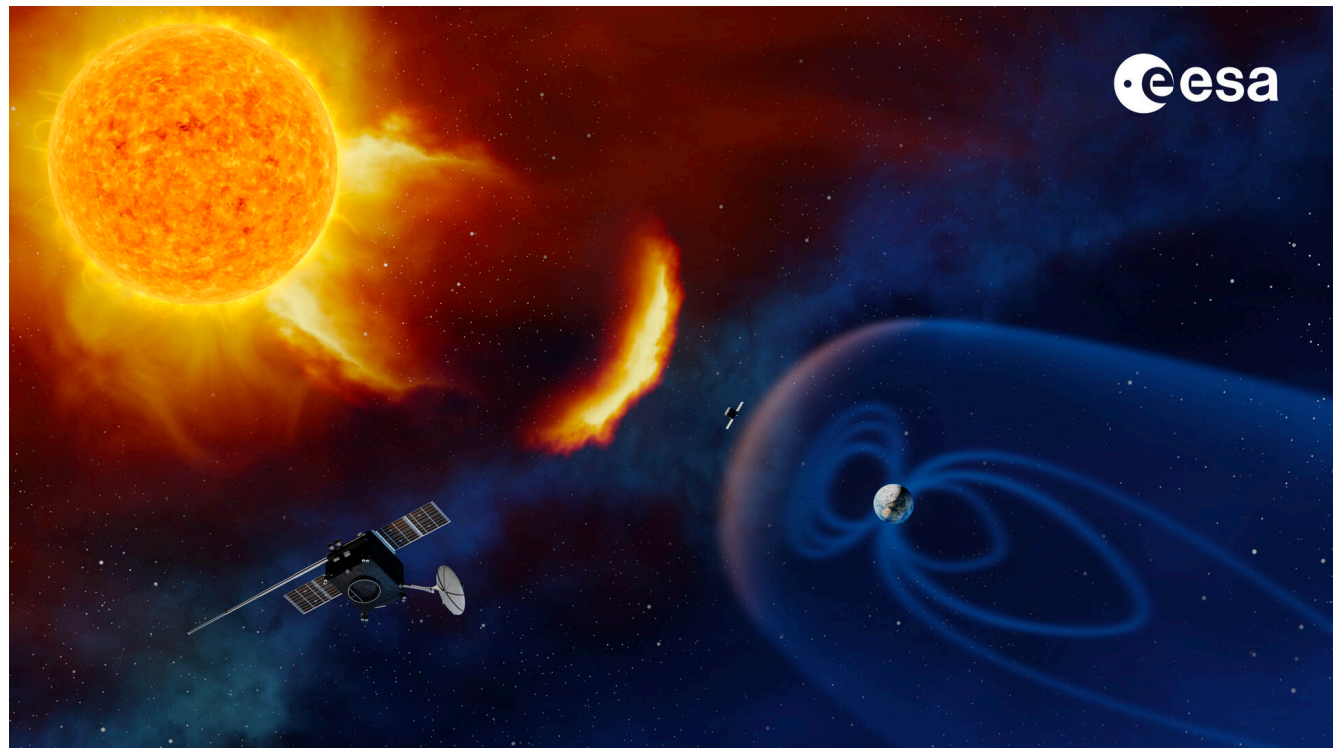
Solar influence on Earth



Solar wind = continuous stream of plasma escaping from the Sun.

Coronal mass ejection: a large cloud of electrically charged particles suddenly escapes into space.

If it hits Earth, it can affect its magnetic field, atmosphere, technology and create auroras.



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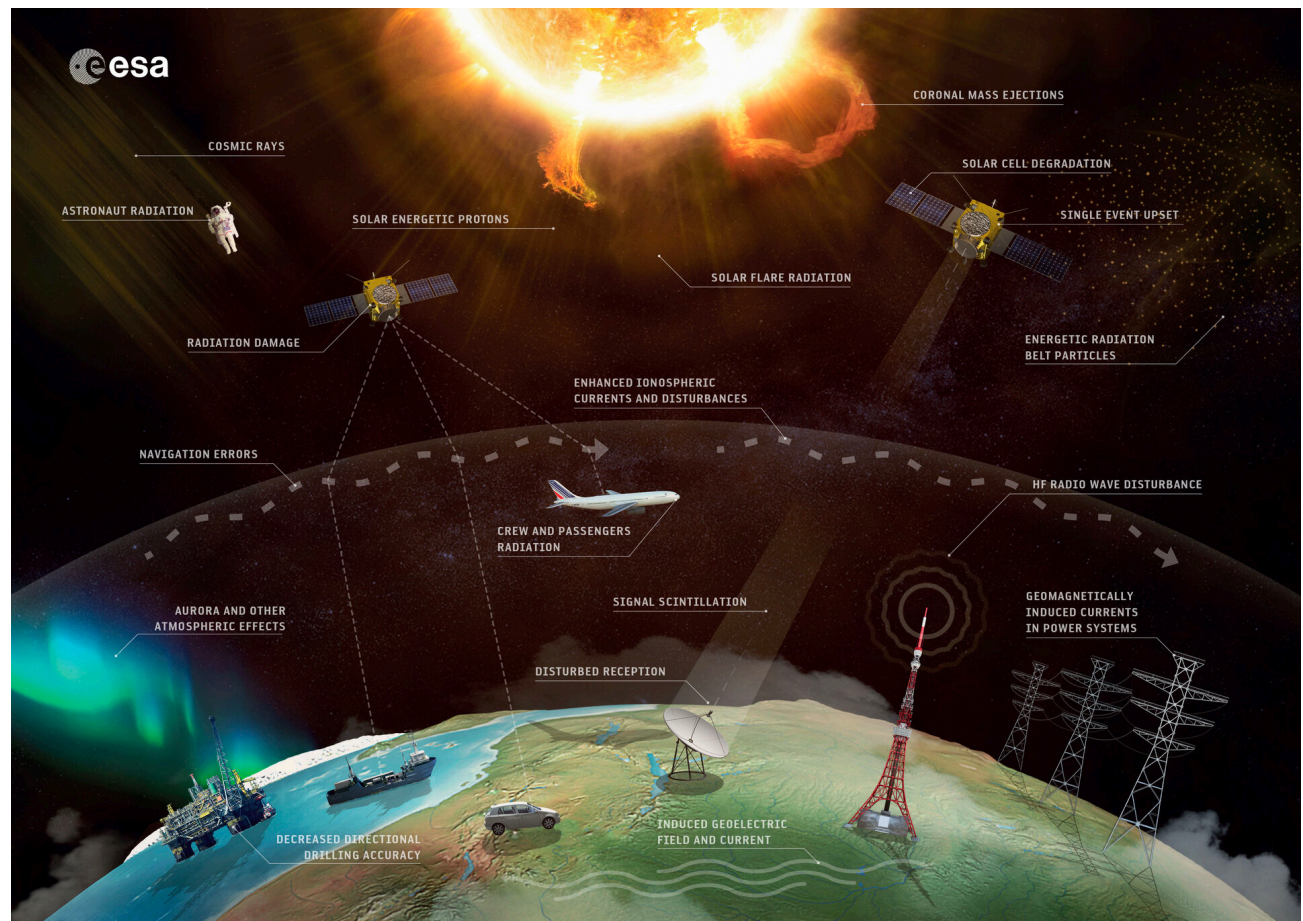


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Space weather effects on Earth



- Radiation (astronauts, spacecraft, planes, ...)
- Changes in upper atmosphere (satellite drag, navigation errors, radio communication, ...)
- Magnetically induced effects (overload on power networks, pipeline corrosion, ...)
- Aurora

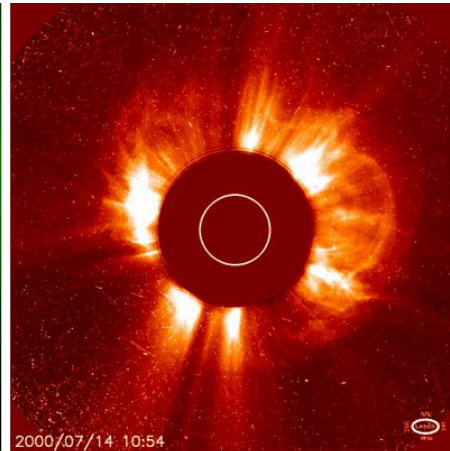
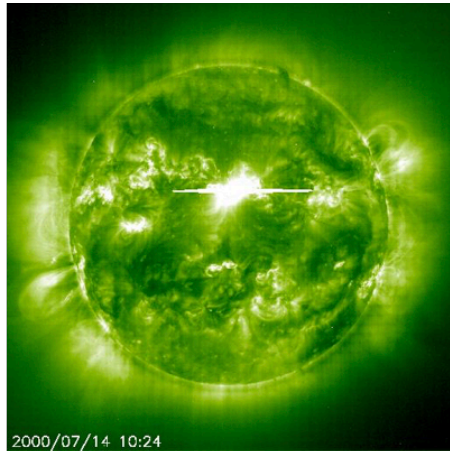


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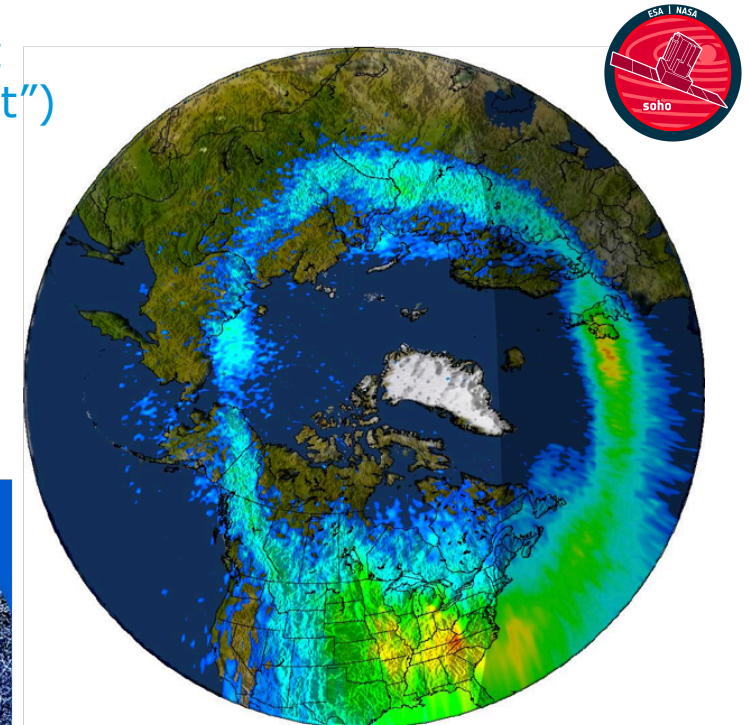
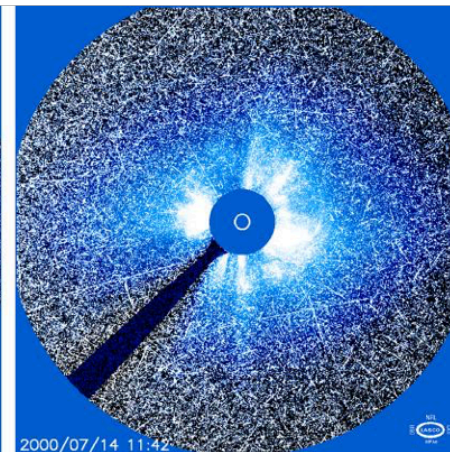
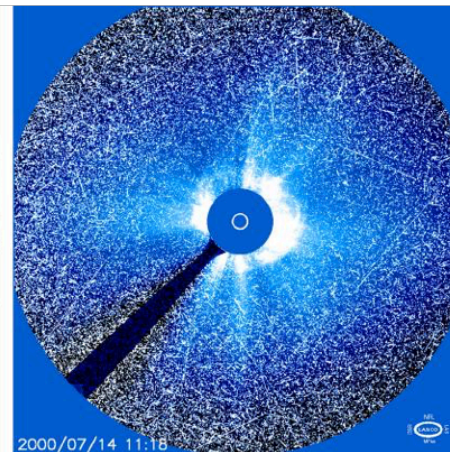
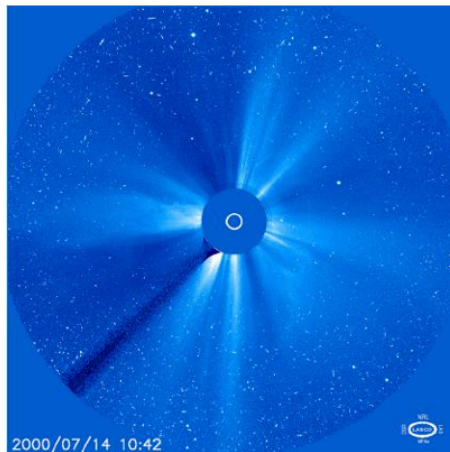


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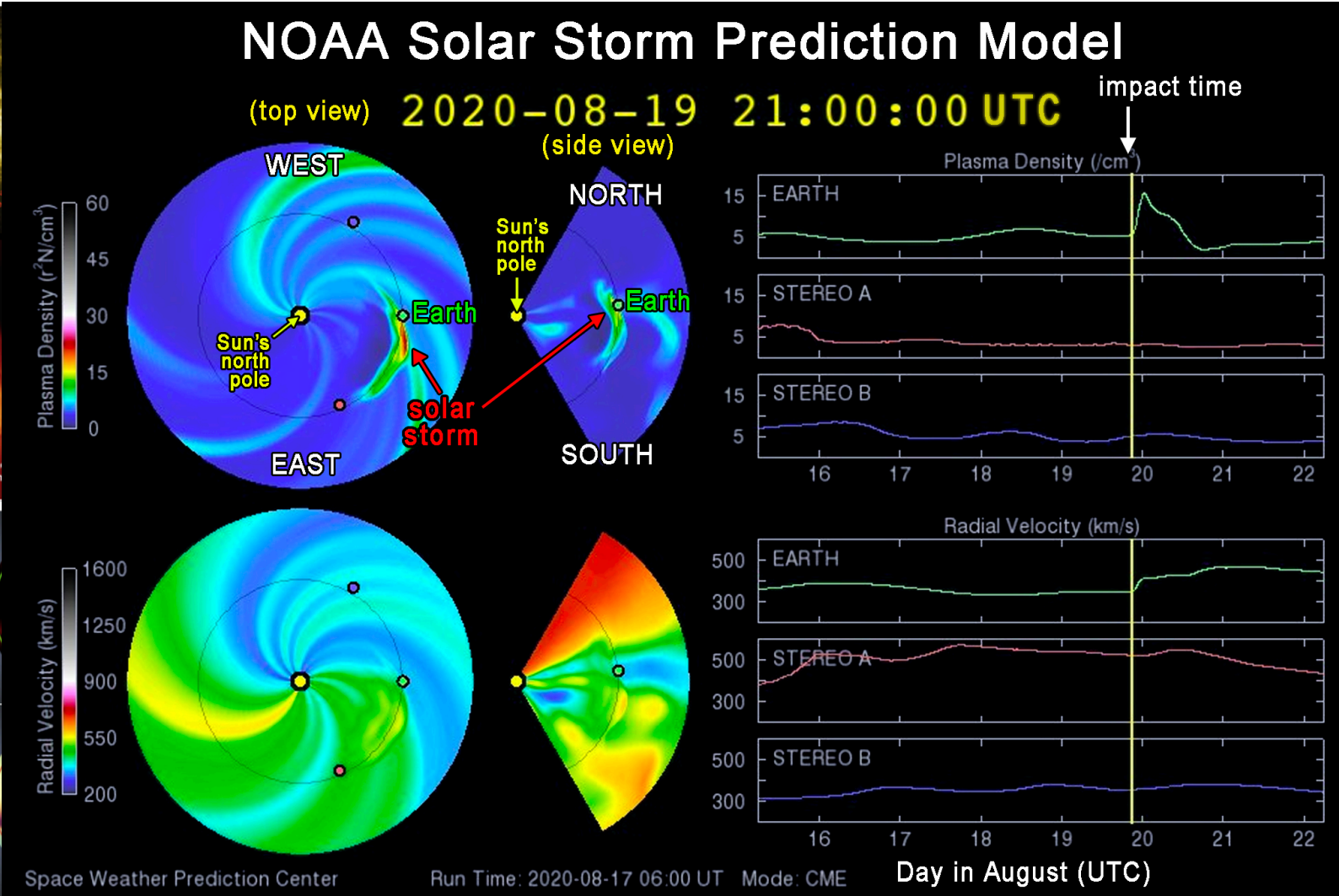
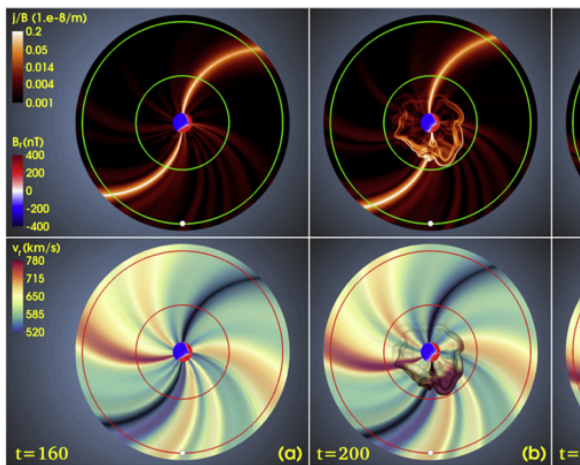
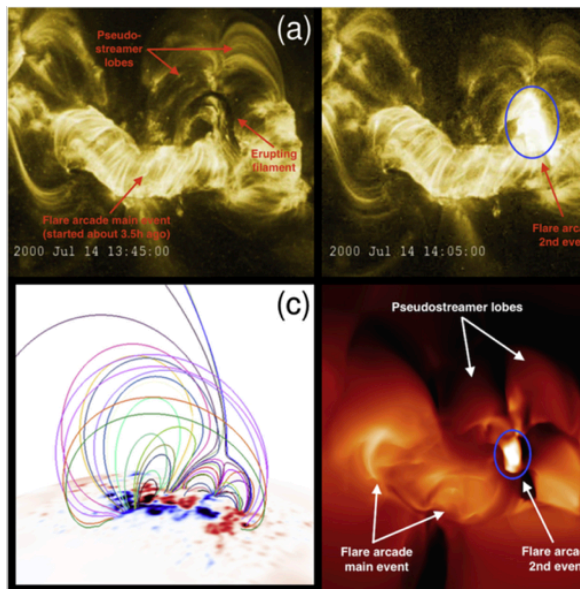
SOHO: Birth of Space Weather observations



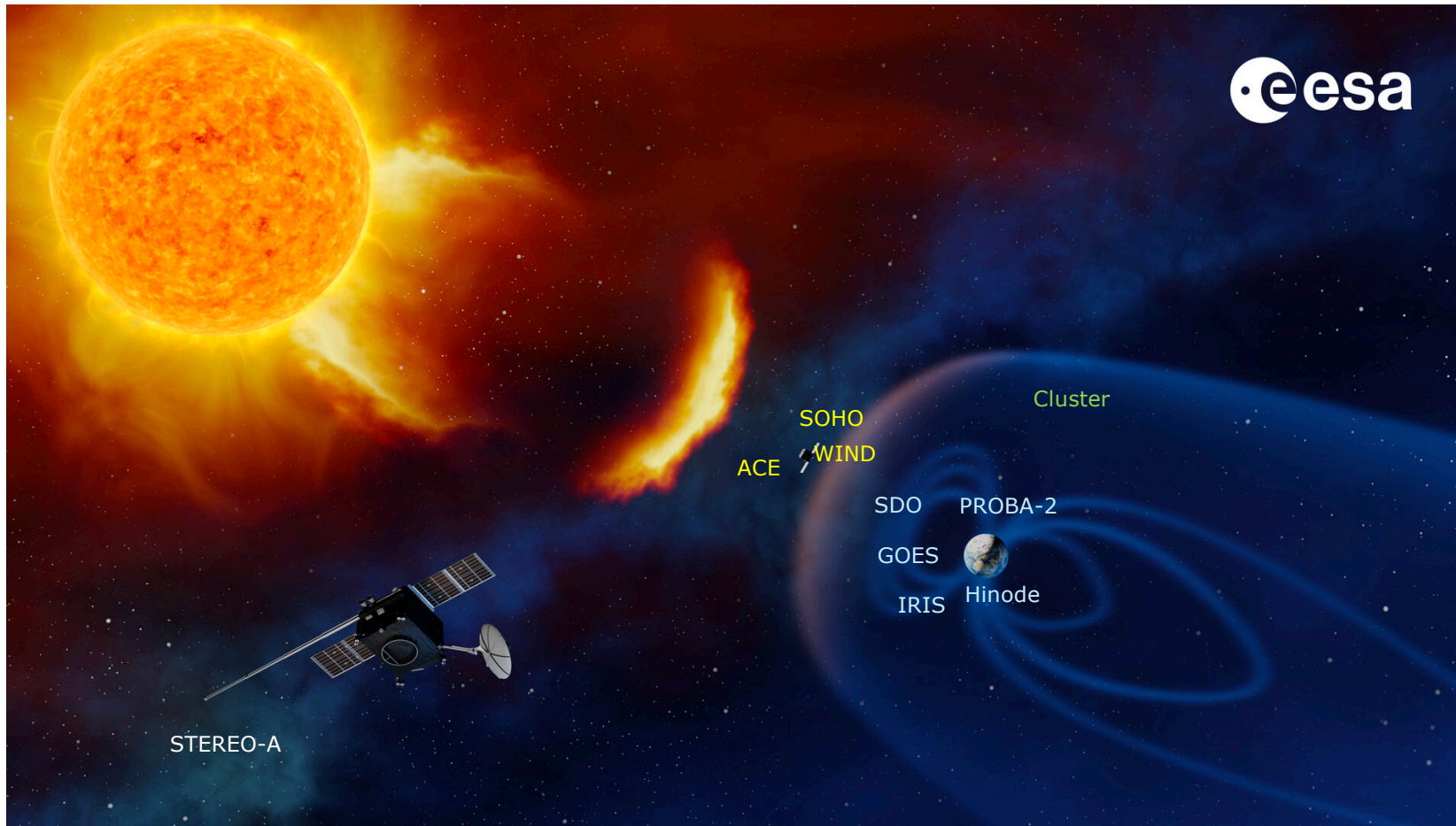
14 July 2000 Event
("Bastille Day Event")



... and Space Weather simulations & forecast!



Satellite fleet observing the Sun and its effects



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So are we done then? Do we know it all?

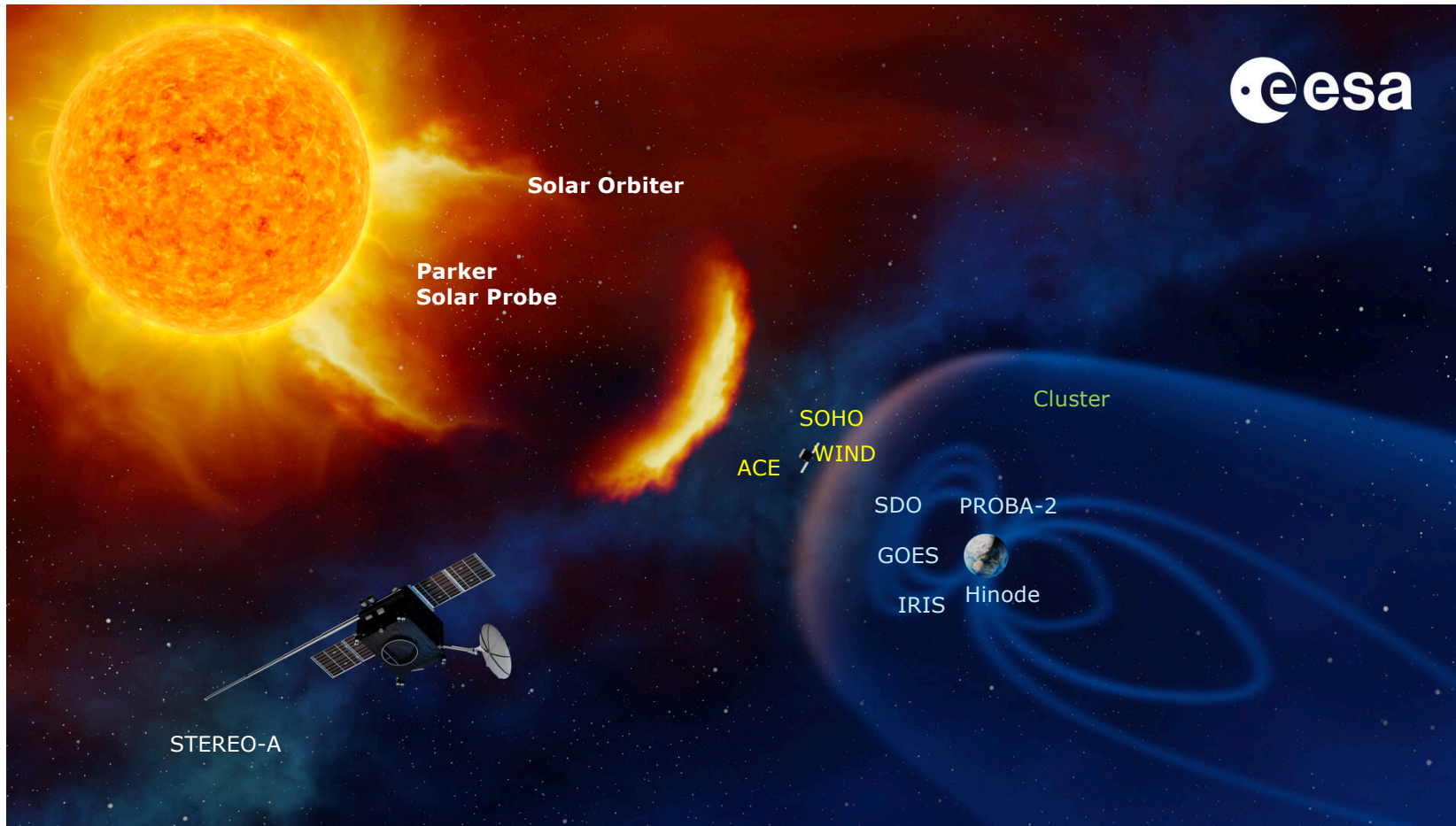


Not really ... many questions remain!

- How does the solar wind evolve between the time it leaves the Sun and the time it arrives at Earth?
- What changes have coronal mass ejections and energetic particles made in that time? **We want to explore the solar wind from close-by to far-out.**
- How to link effects on Earth to their source regions on the Sun? How to better predict them?
We want to go close to the Sun, to link cause and effect. We want to fly through a CME, measure solar activity when it has only just left the Sun.
- How is the magnetic field created? Can we predict the next solar cycle?
We never saw the solar poles! How would they look like?

This knowledge will help us understand and predict better the sun's influence on us!

Satellite fleet observing the Sun and its effects



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Solar Orbiter – Launched 10 Feb 2020



Exploring the Sun-Heliosphere connection

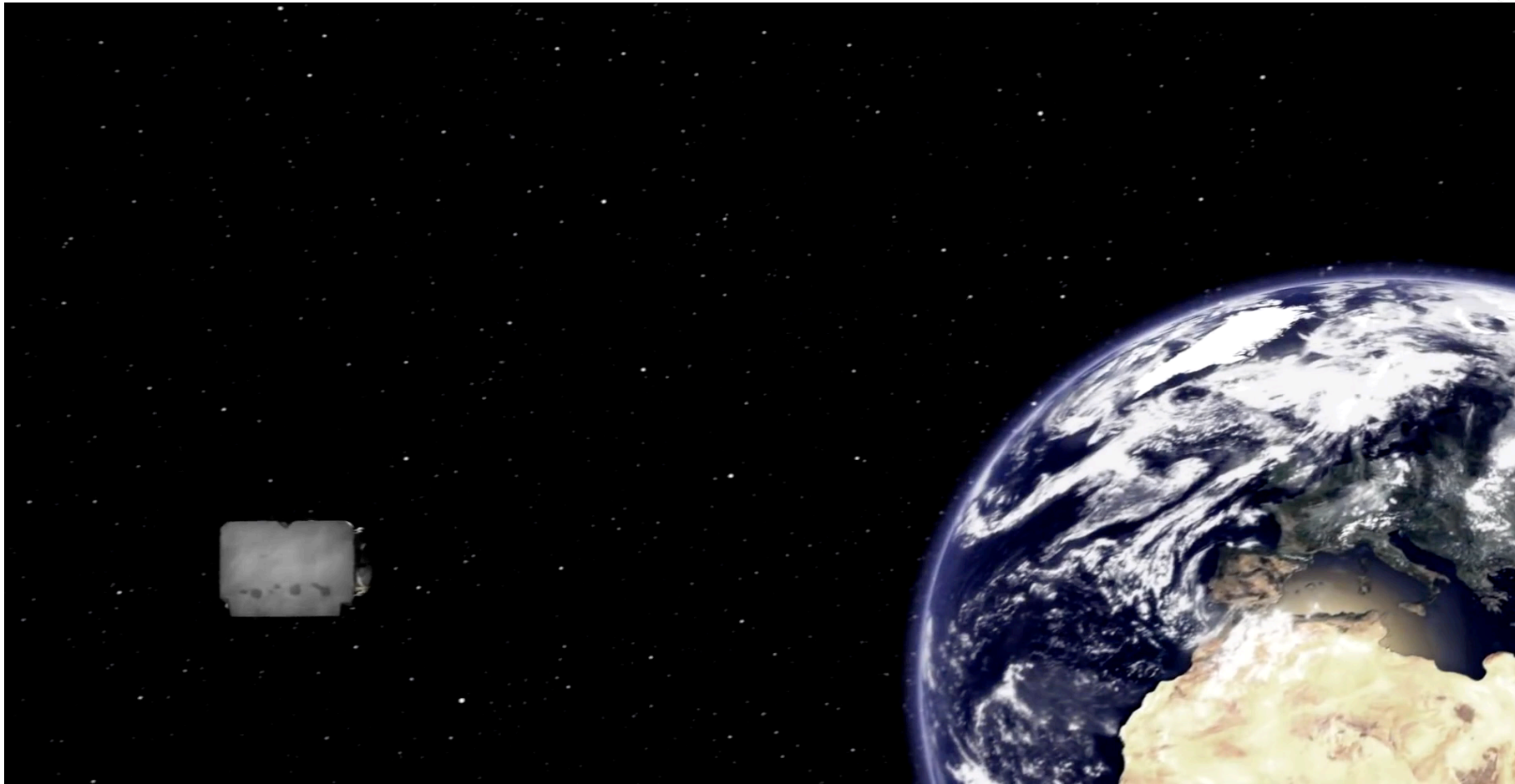
- **Explore** the solar wind, both close to the Sun as far out
- **Link** the solar activity as seen close to the surface with what we measure at the satellite
- Observe the solar **poles** for the very first time

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Solar Orbiter

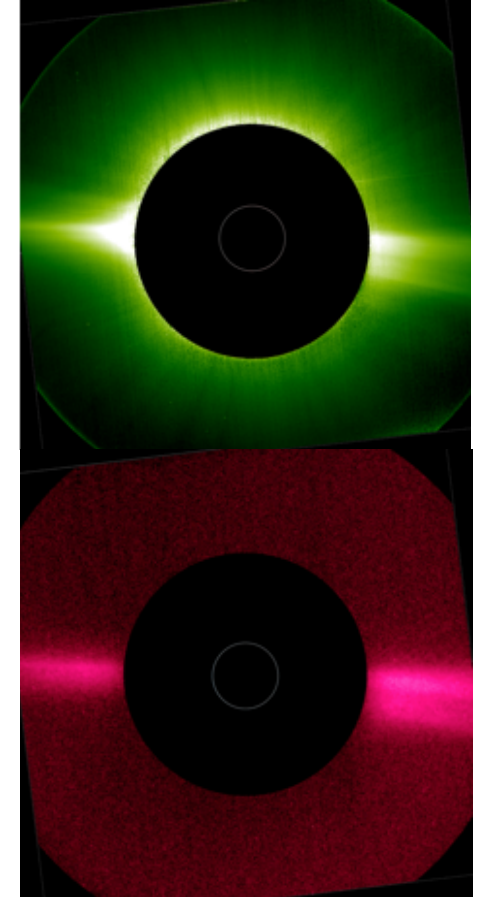
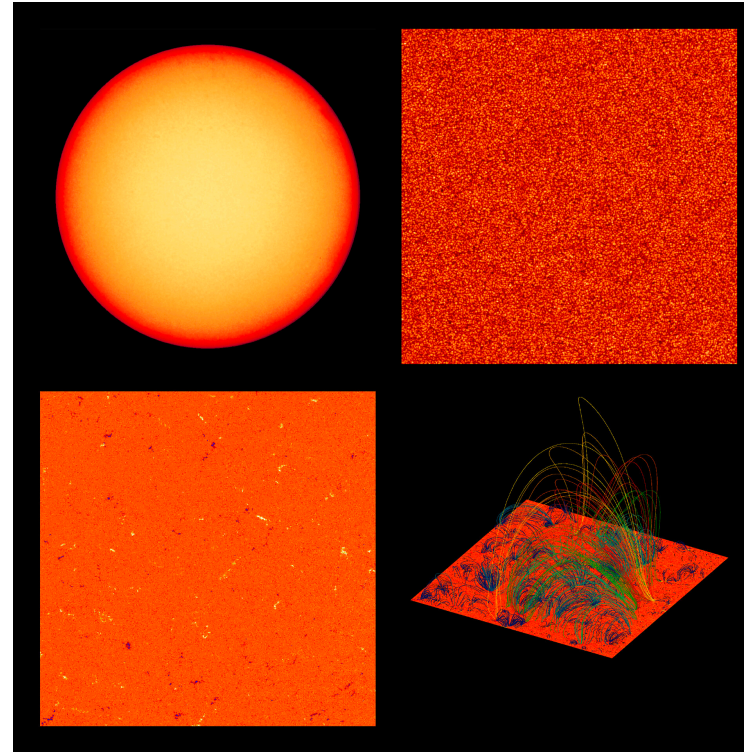
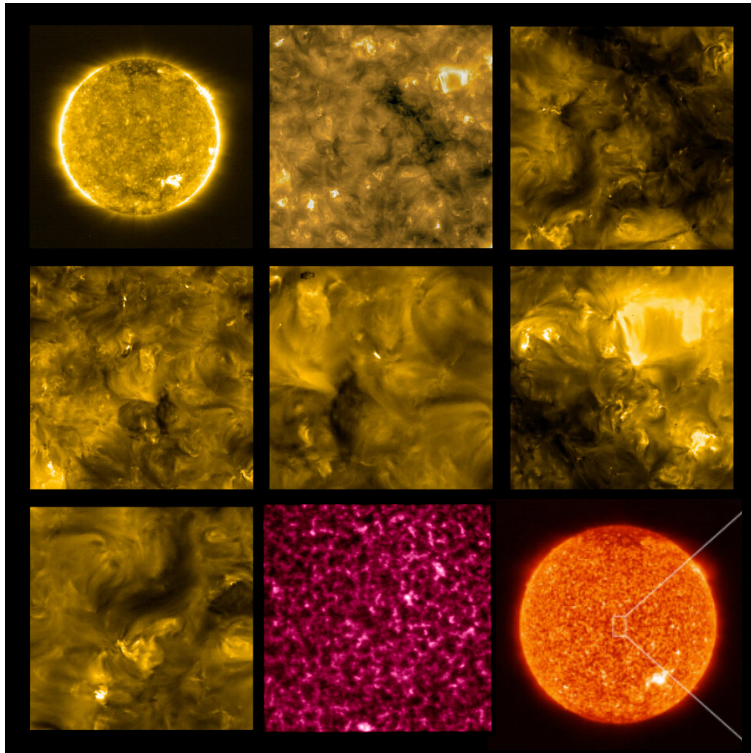


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Solar Orbiter first light at 0.5AU (Jun 2020)



Solar Orbiter is still on its way to its science orbit, but already delivering beautiful images and new mysteries!

On 27 Nov Solar Orbiter will swing by Earth to reach scientific orbit (<https://solarorbiter.esac.esa.int/where/>)

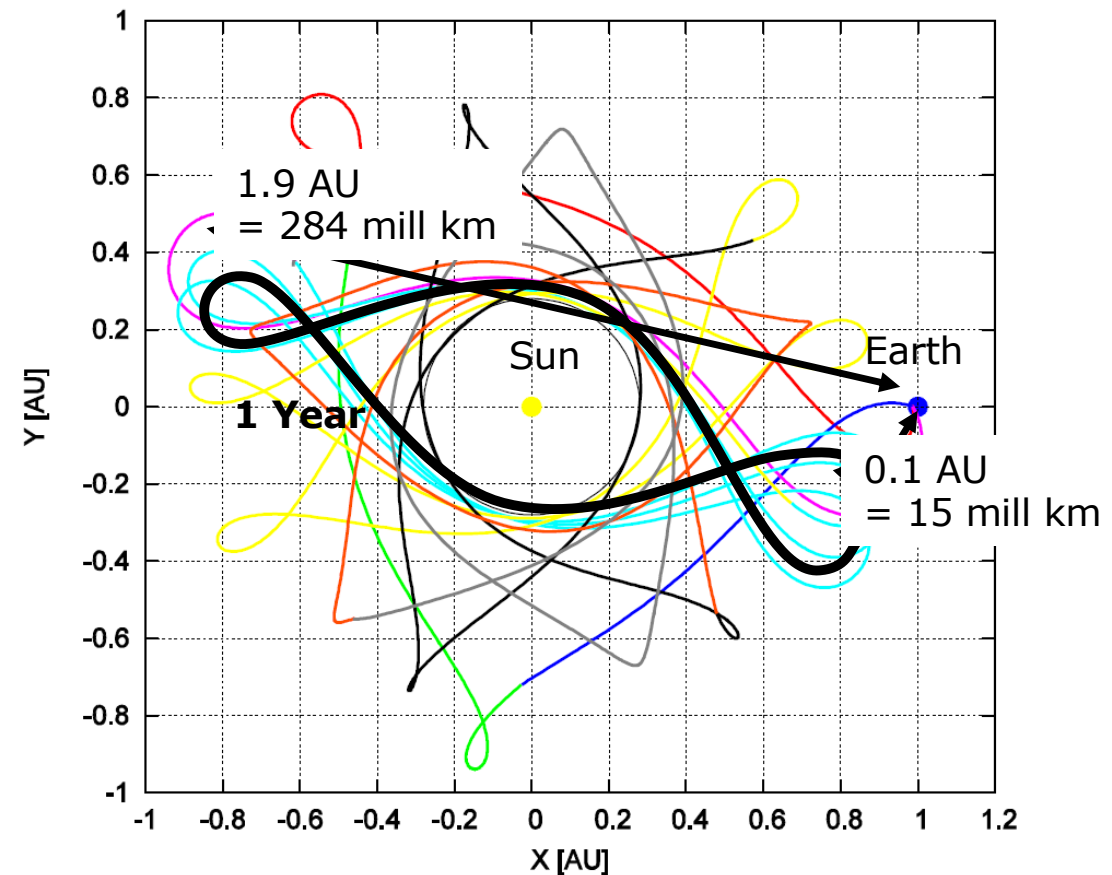


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Solar Orbiter explores whole solar environment



- Often very far from Earth
- Changing distances from the Sun
- Different observations at each opportunity
- Difficulties to bring the data back: onboard memory to store it



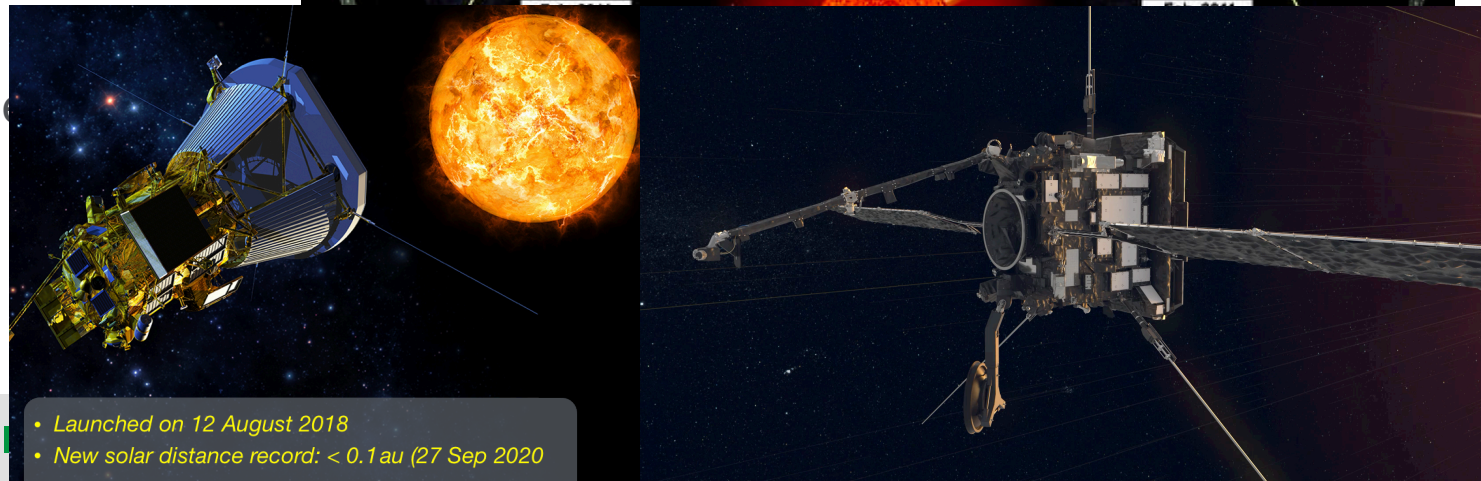
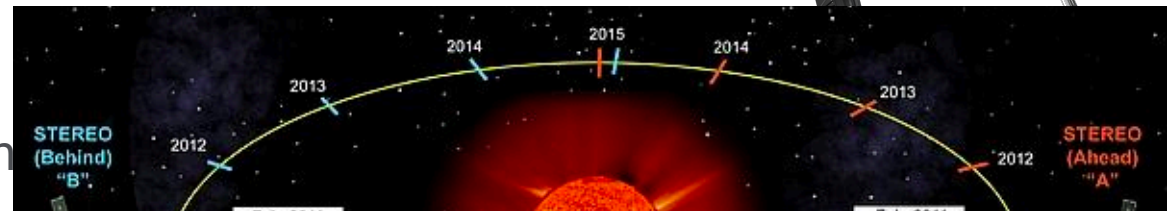
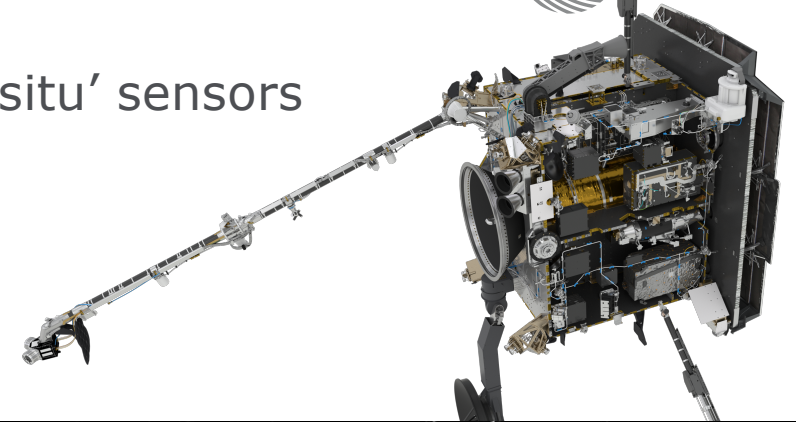
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Solar Orbiter: all about coordination!

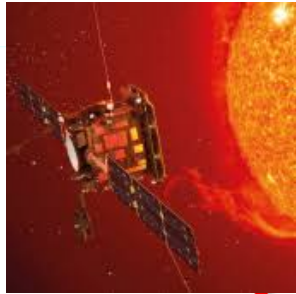
- Between 6 'remote sensing' telescopes and 4 'in-situ' sensors
- Between solar observatories viewing the Sun from different angles
- Between solar observatories sensing
- Between different space



- Launched on 12 August 2018
- New solar distance record: < 0.1 au (27 Sep 2020)



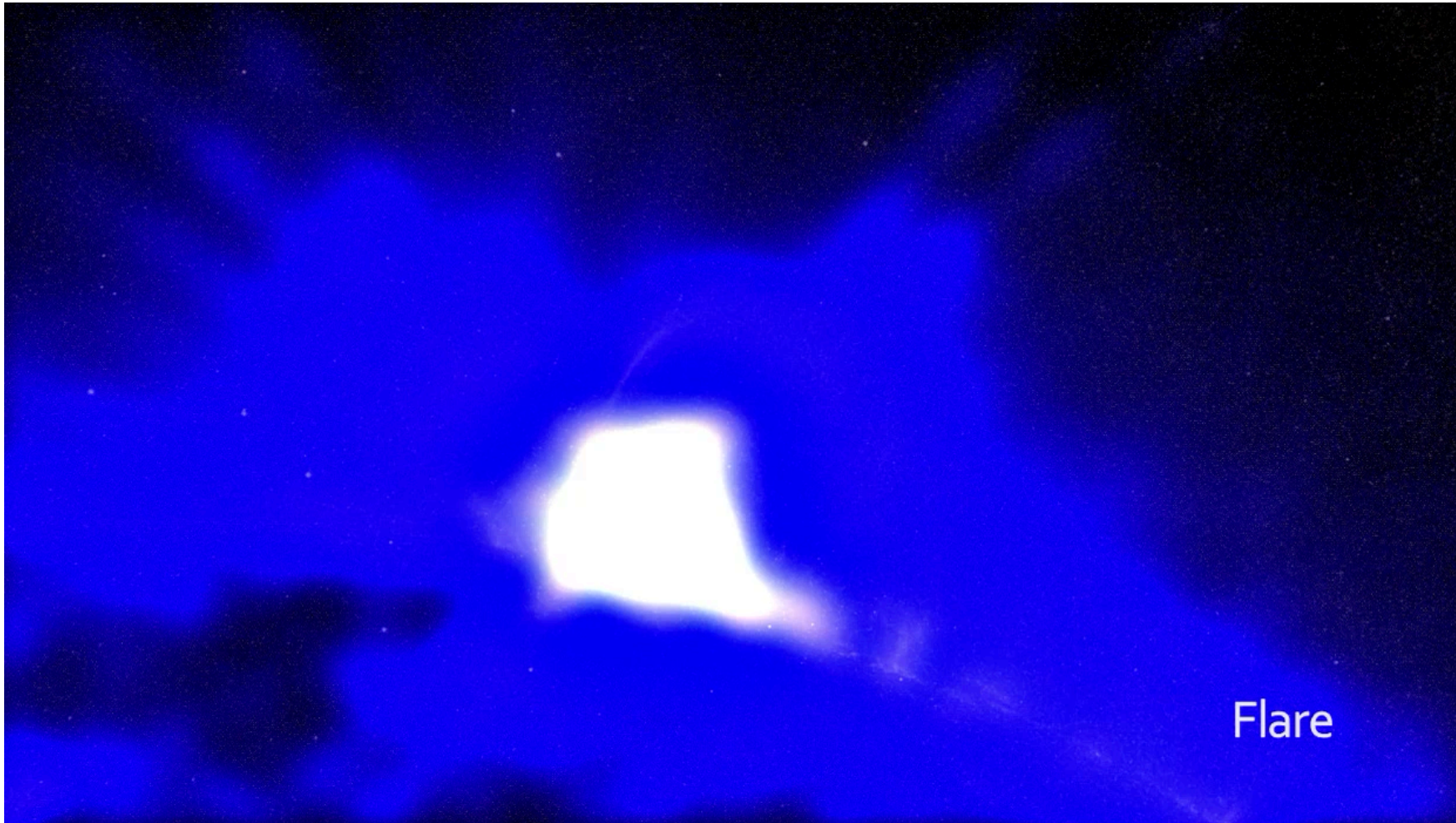
Solar Orbiter operations: European coordination



- The satellite was built in UK, under coordination by ESTEC (NL)
- The instruments were built by scientific institutes over Europe (one in US)
- ESAC (E) coordinates instrument operations with the teams
- ESAC sends the commands to ESOC (D)
- ESOC adds spacecraft commanding
- ESOC sends all commands to the SC via antennas in Spain, Australia, Argentina



Stay tuned for more exciting results to come!



Flare

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Movie credit: NASA Science Visualization Studio, SOHO and SDO, <https://svs.gsfc.nasa.gov/11667>



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