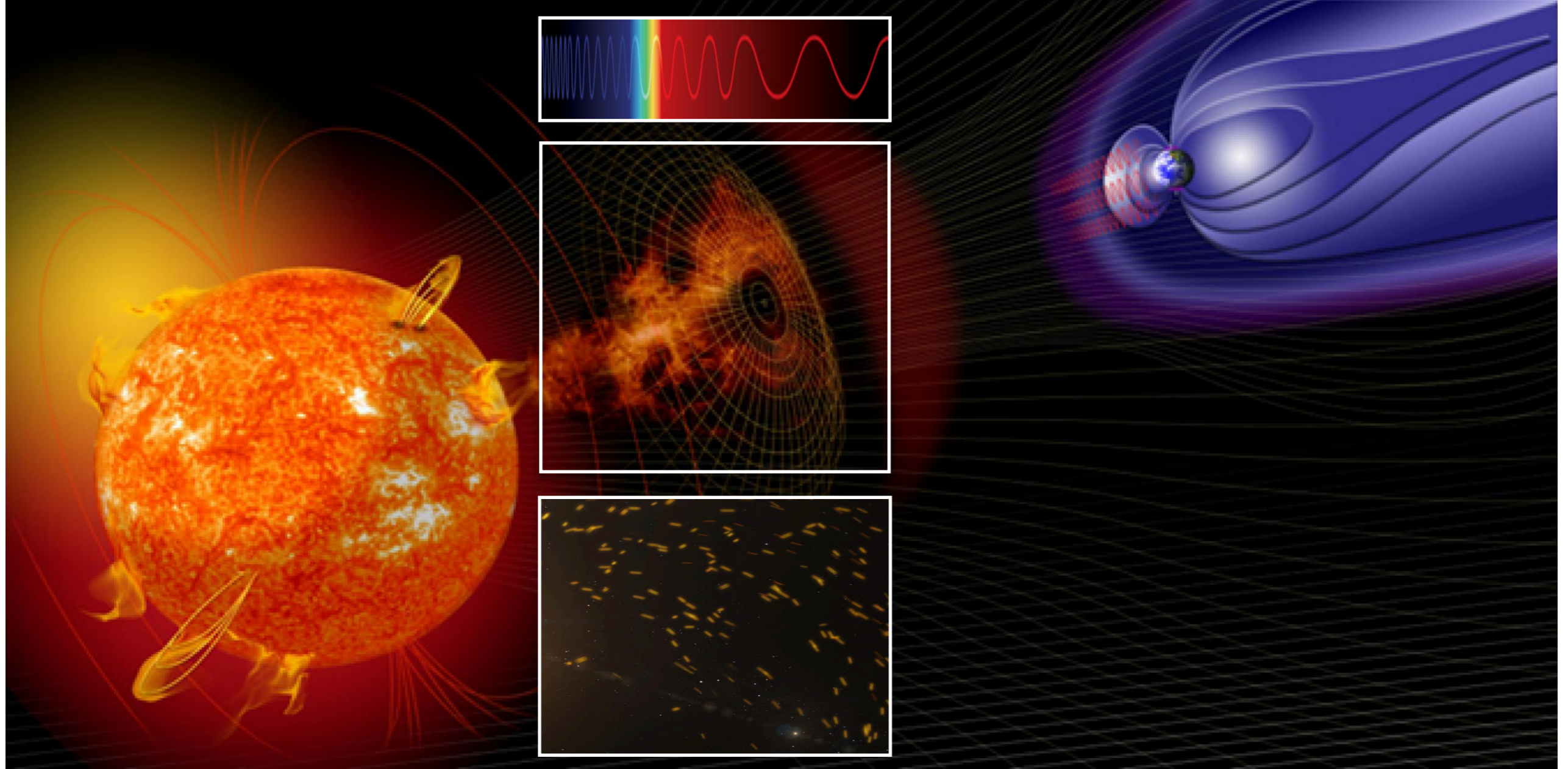


Role of the Ionosphere & SPWx in Military Communications

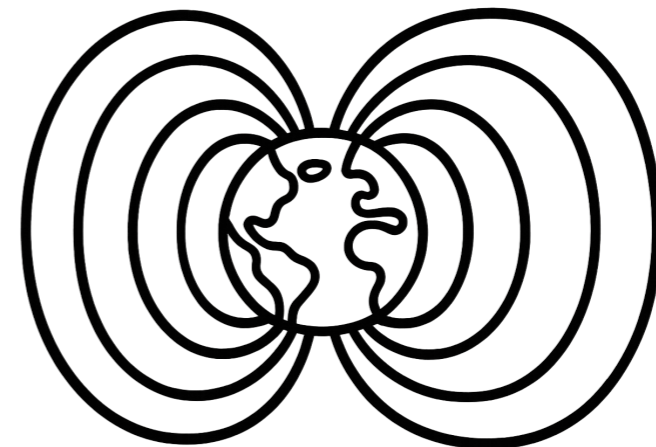
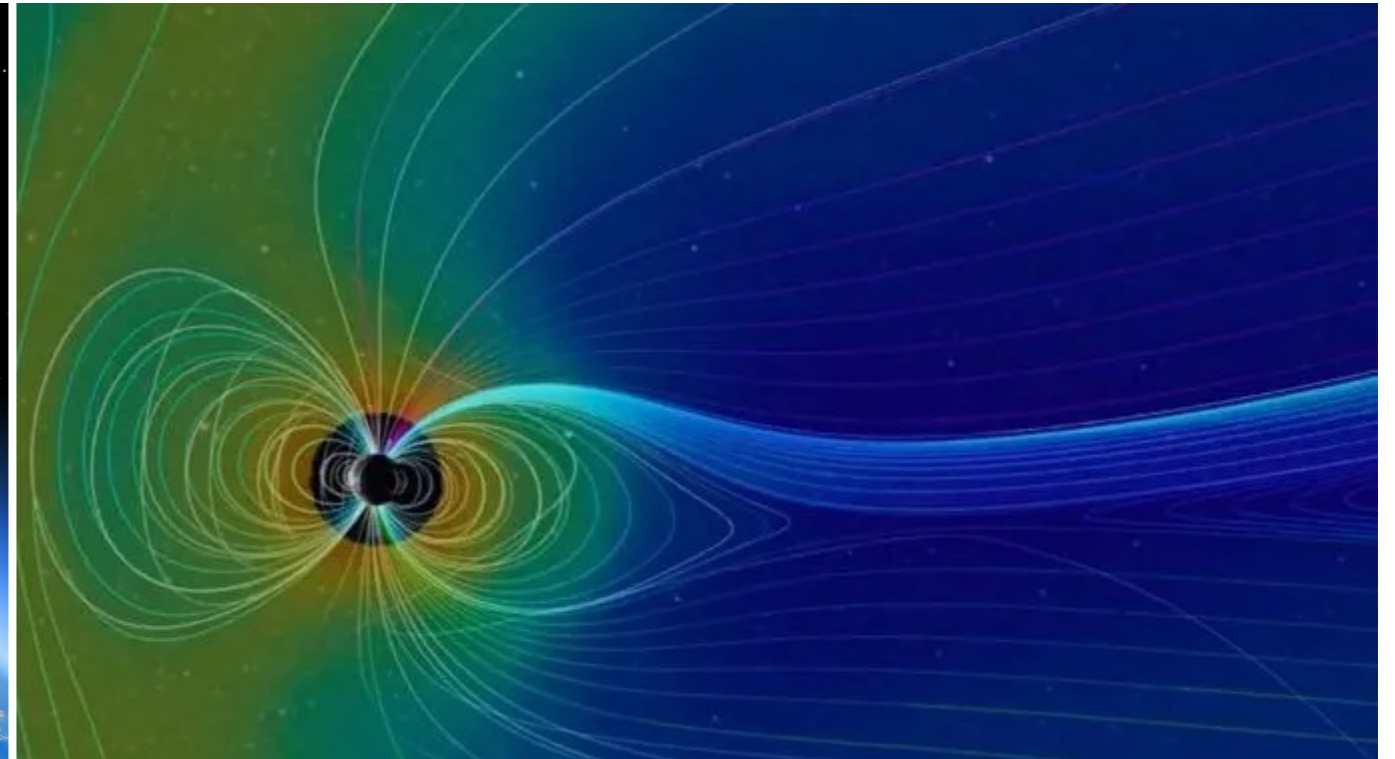


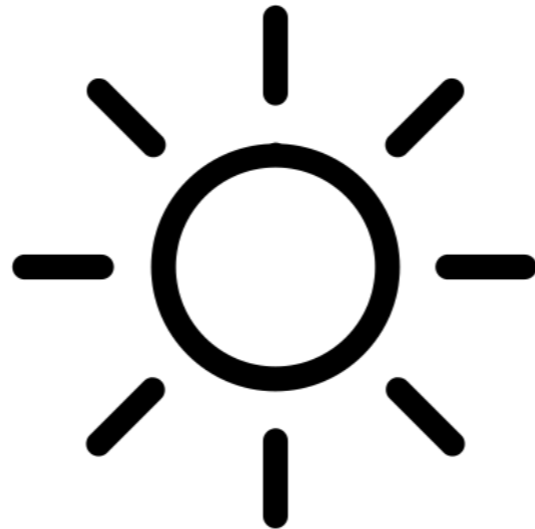


DRIVERS OF SPACE WEATHER

Space Weather

The Sun's energy impacting earth's atmosphere and magnetosphere





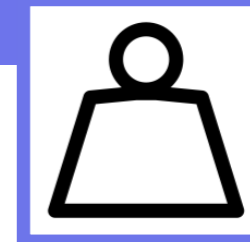
E.M. RADIATION



PLASMA



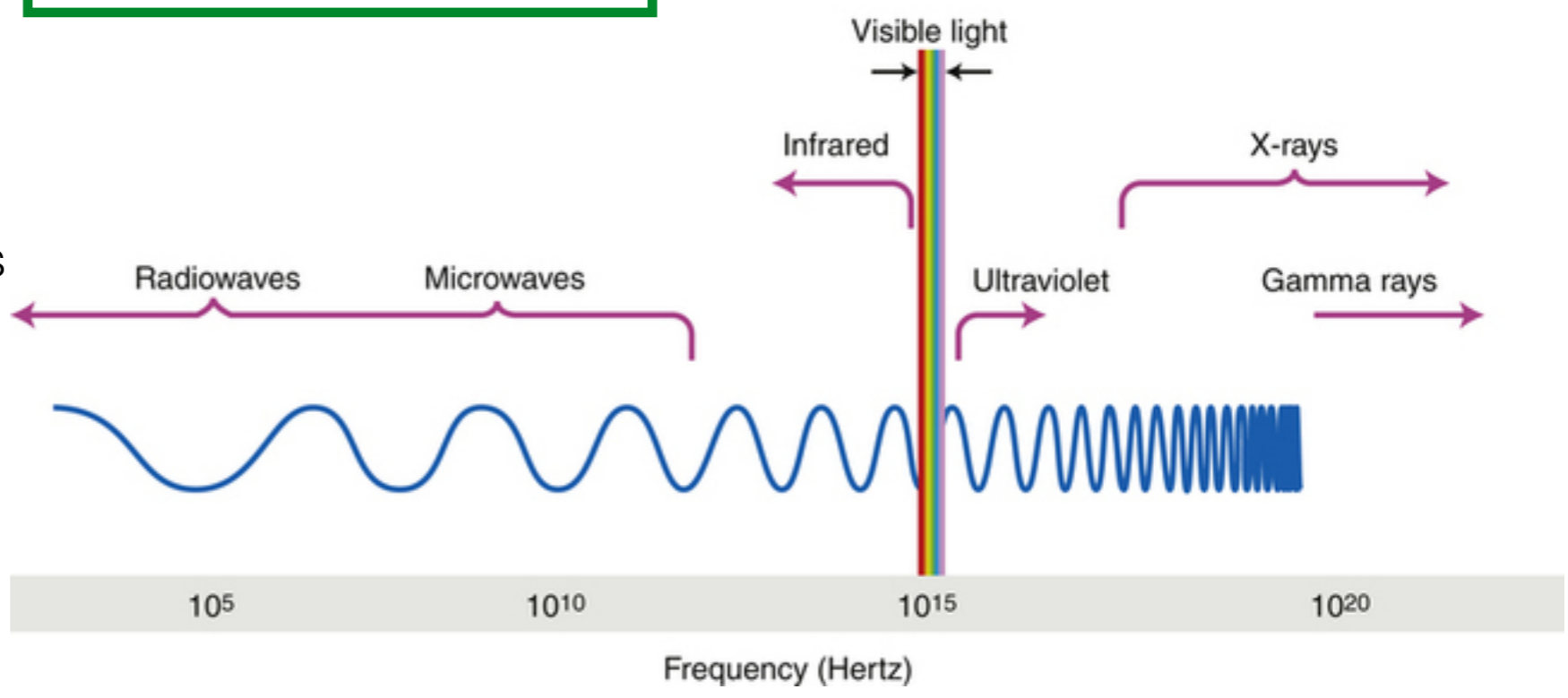
ENERGETIC
PARTICLES



Electromagnetic radiation

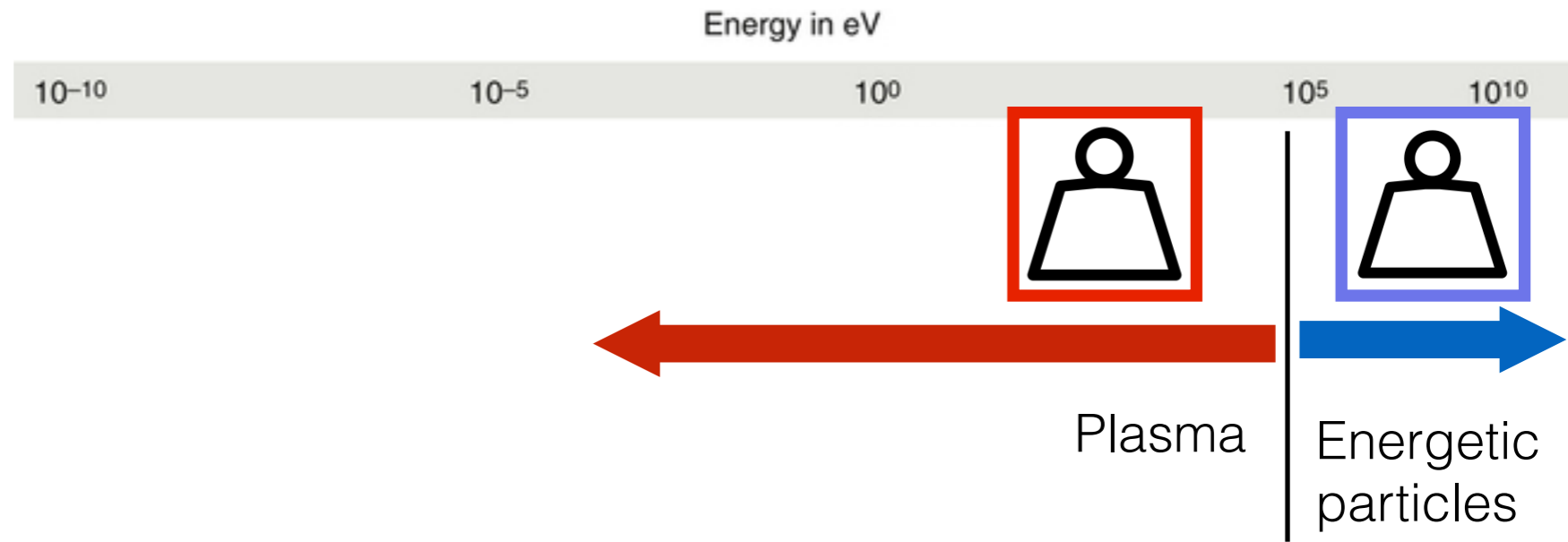


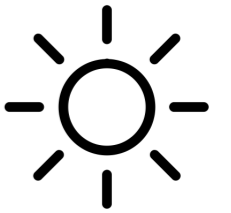
- Photons / electromagnetic waves
- Speed of light



Particles

- Atomic & sub-atomic particles
- m/s to fractions of speed of light





3 SPACE WEATHER PHENOMENA

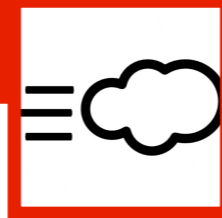
The sun's energy reaches the earth in 3 forms: light, moving gas and particle precipitation. This energy interacts with the magnetosphere and the atmosphere of the earth. This is space weather.

How and where the interaction occurs depends on the type of energy.

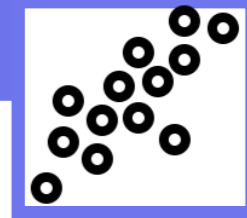
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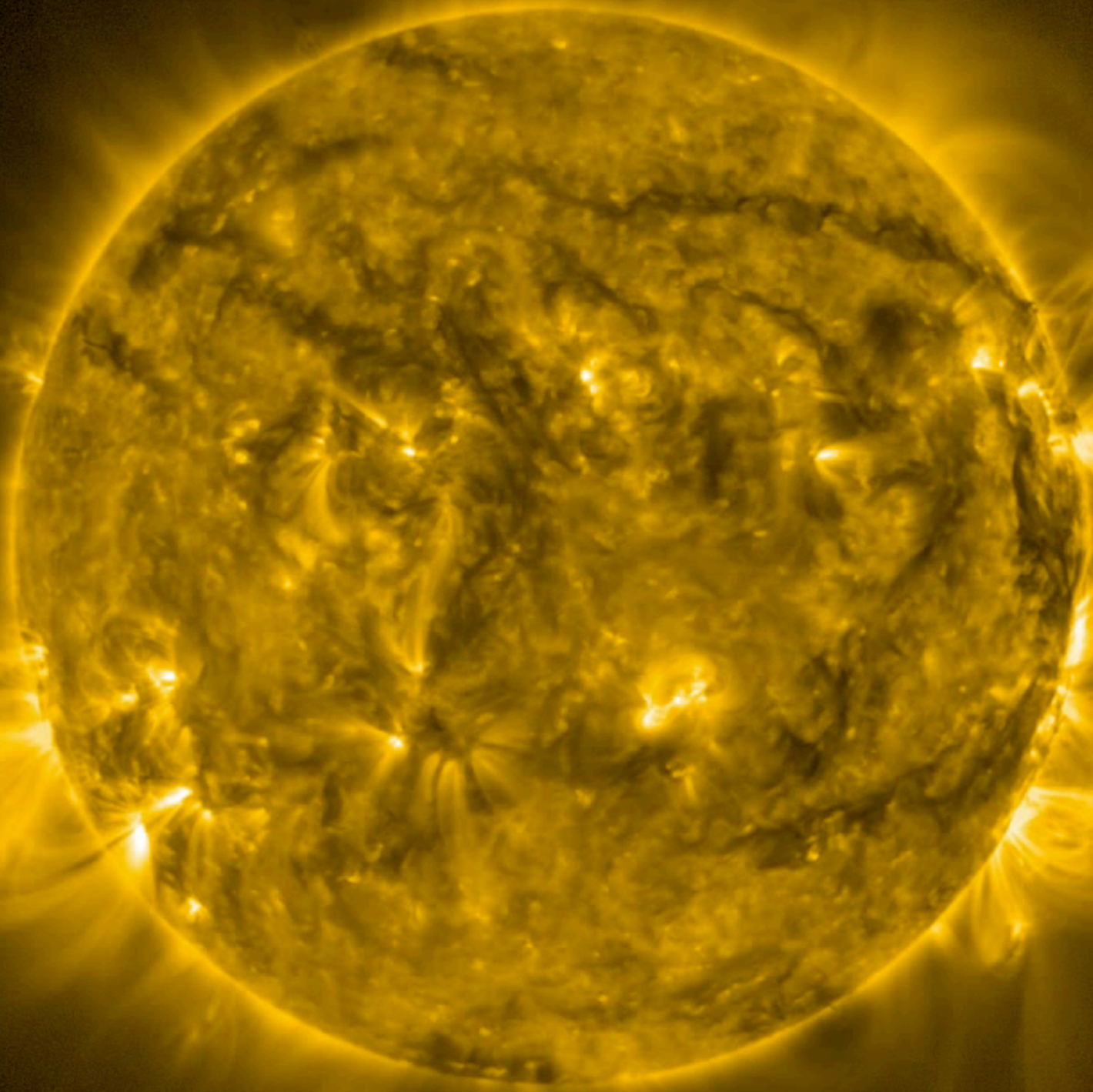
WIND



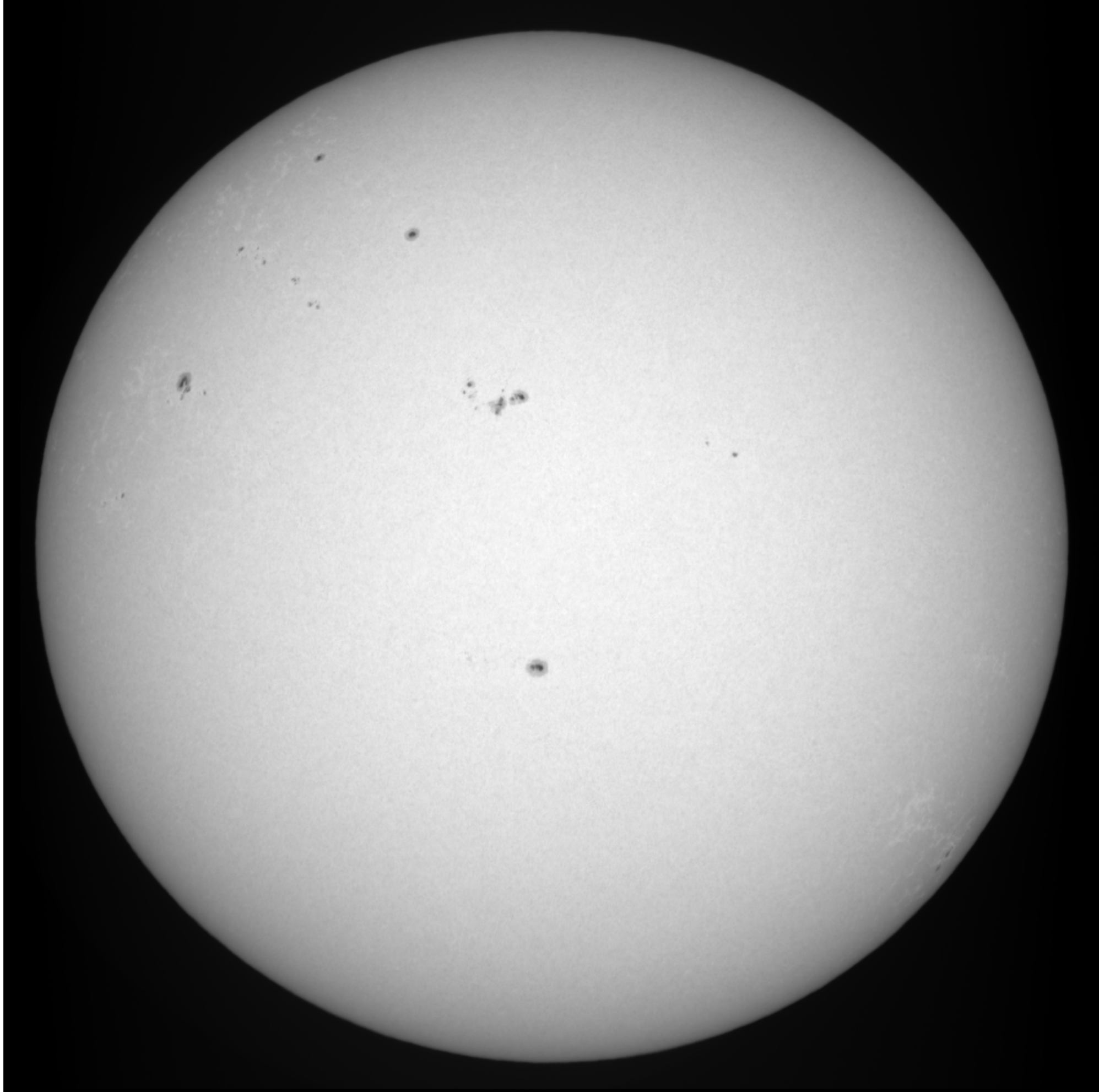
PARTICLE RAIN



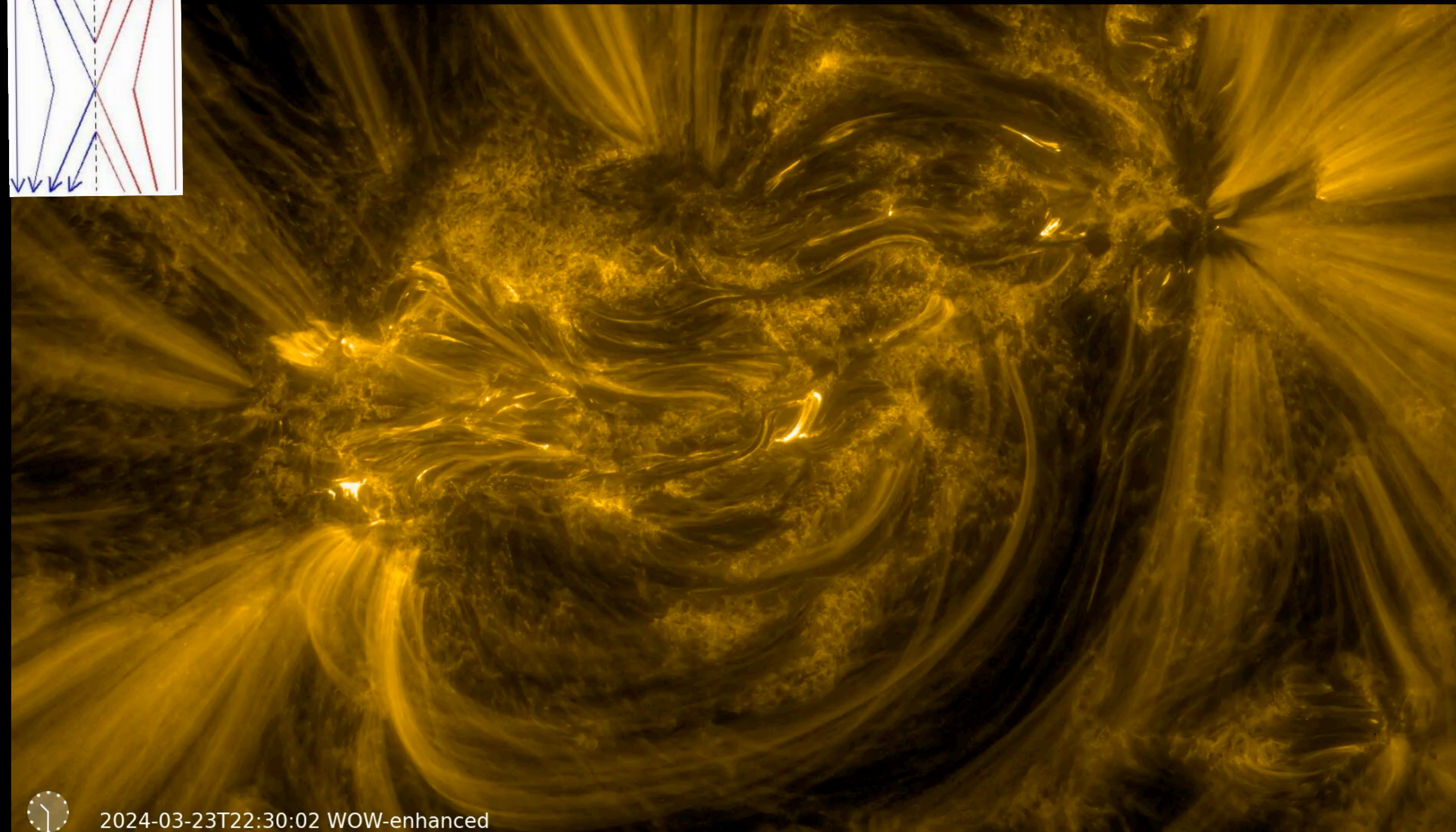
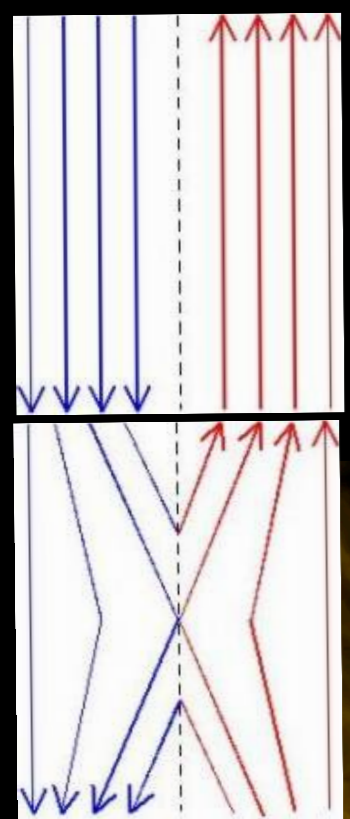
Magnetism drives the sun's dynamics



PROBA2/SWAP

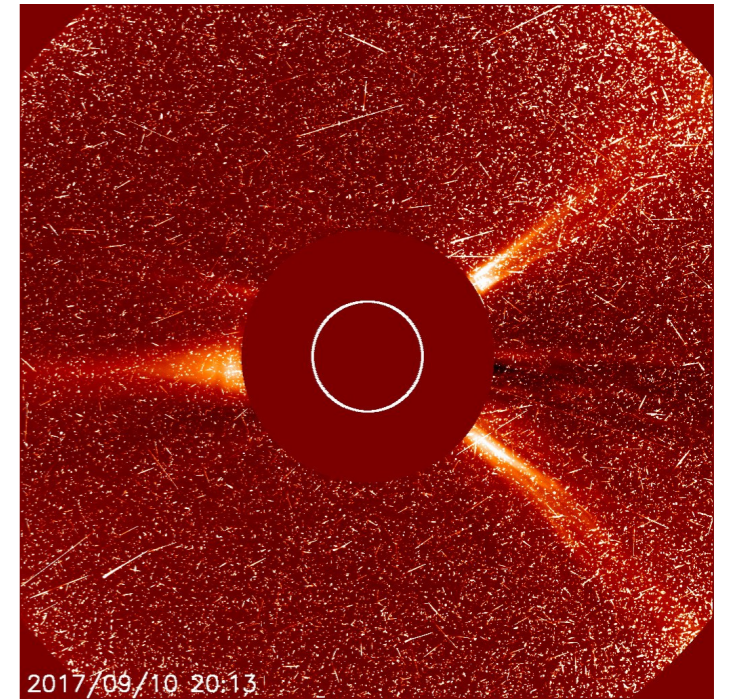
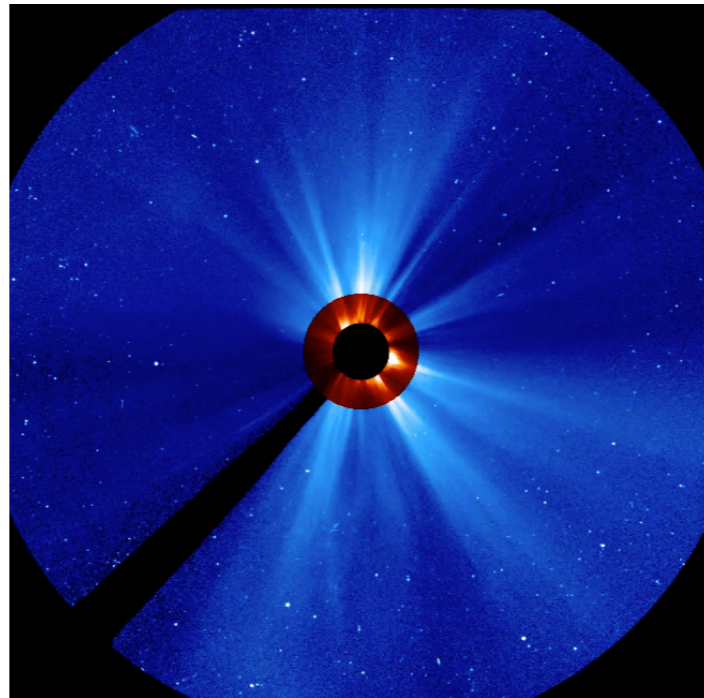
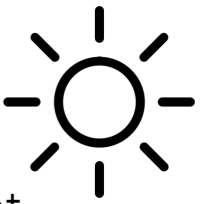


MAGNETIC RECONNECTION



SOLAR WEATHER & STORMS

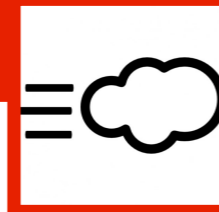
Energy can be released on a shorter time scale. A solar feature like a sunspot, an active region, coronal hole, filament etc. lies at the base of a solar storm in which energy is released. The release of energy might be in an abrupt, impulsive and brutal way (flare, Coronal Mass Ejection or CME, proton storm) or in a non-eruptive manner (Coronal Hole - CH).



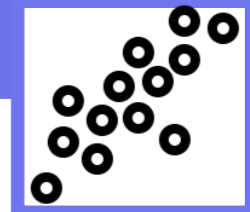
Flare



Coronal Mass Ejection

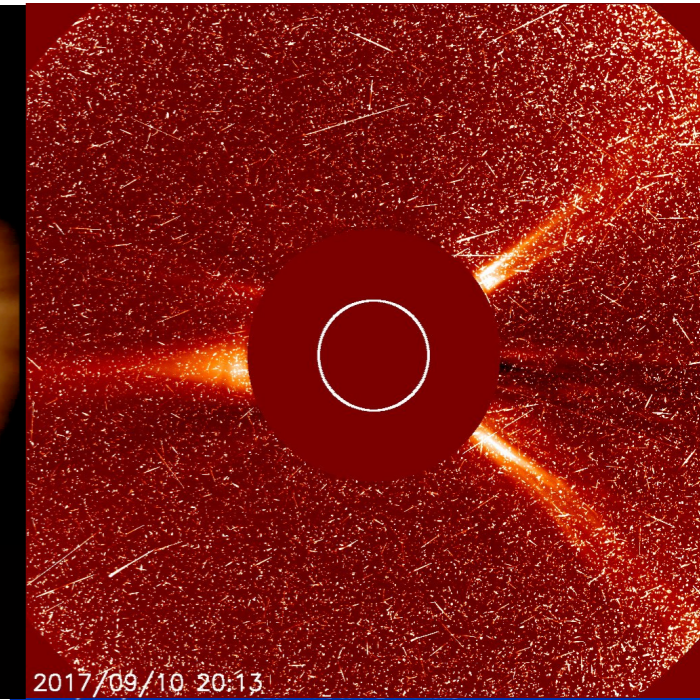
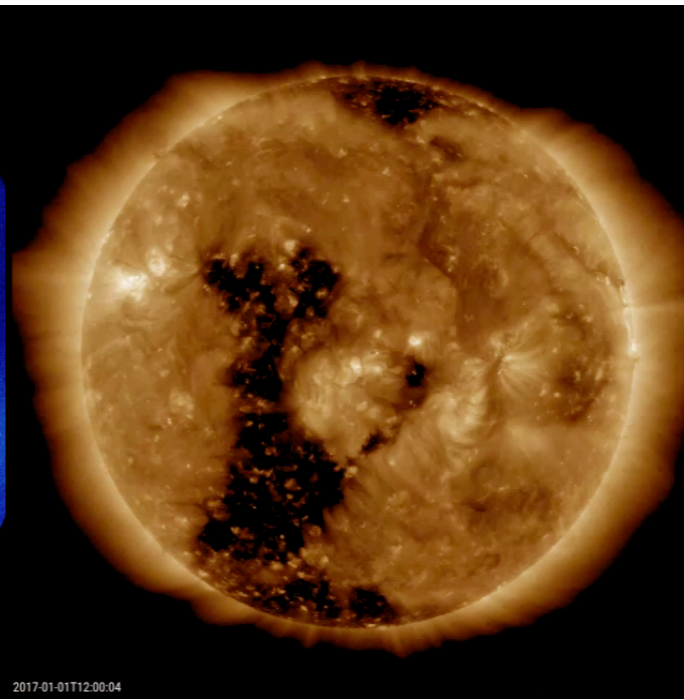
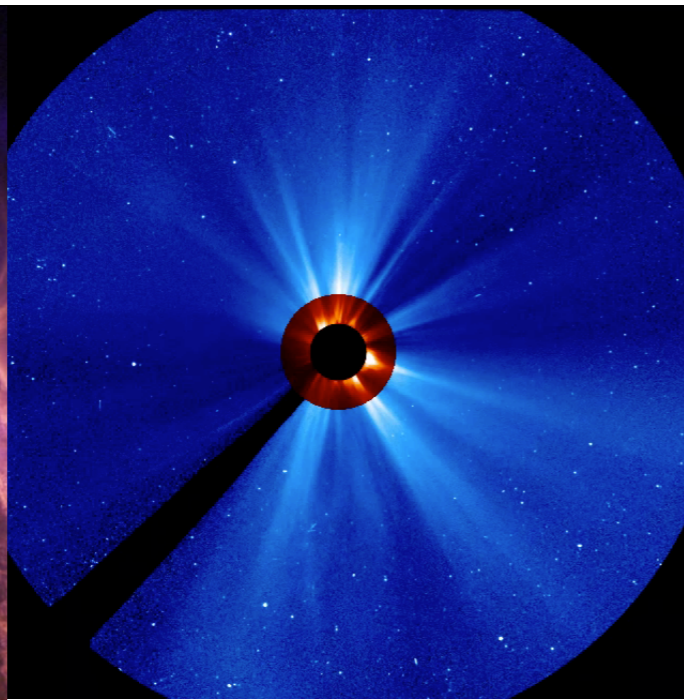
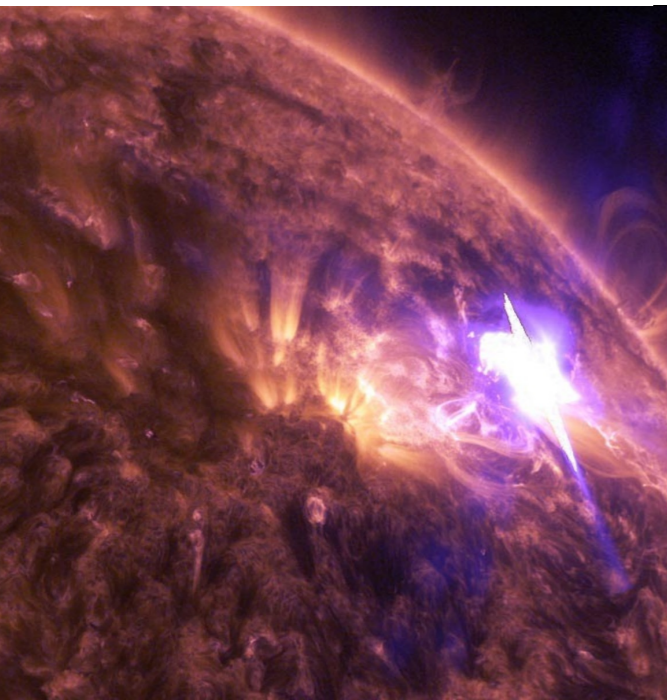
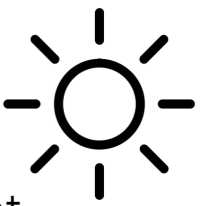


Particle Storm



SOLAR WEATHER & STORMS

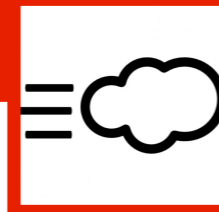
Energy can be released on a shorter time scale. A solar feature like a sunspot, an active region, coronal hole, filament etc. lies at the base of a solar storm in which energy is released. The release of energy might be in an abrupt, impulsive and brutal way (flare, Coronal Mass Ejection or CME, proton storm) or in a non-eruptive manner (Coronal Hole - CH).



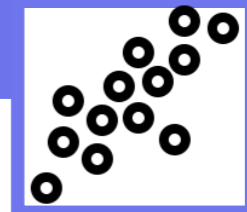
Flare



Coronal Mass Ejection
High Speed Stream

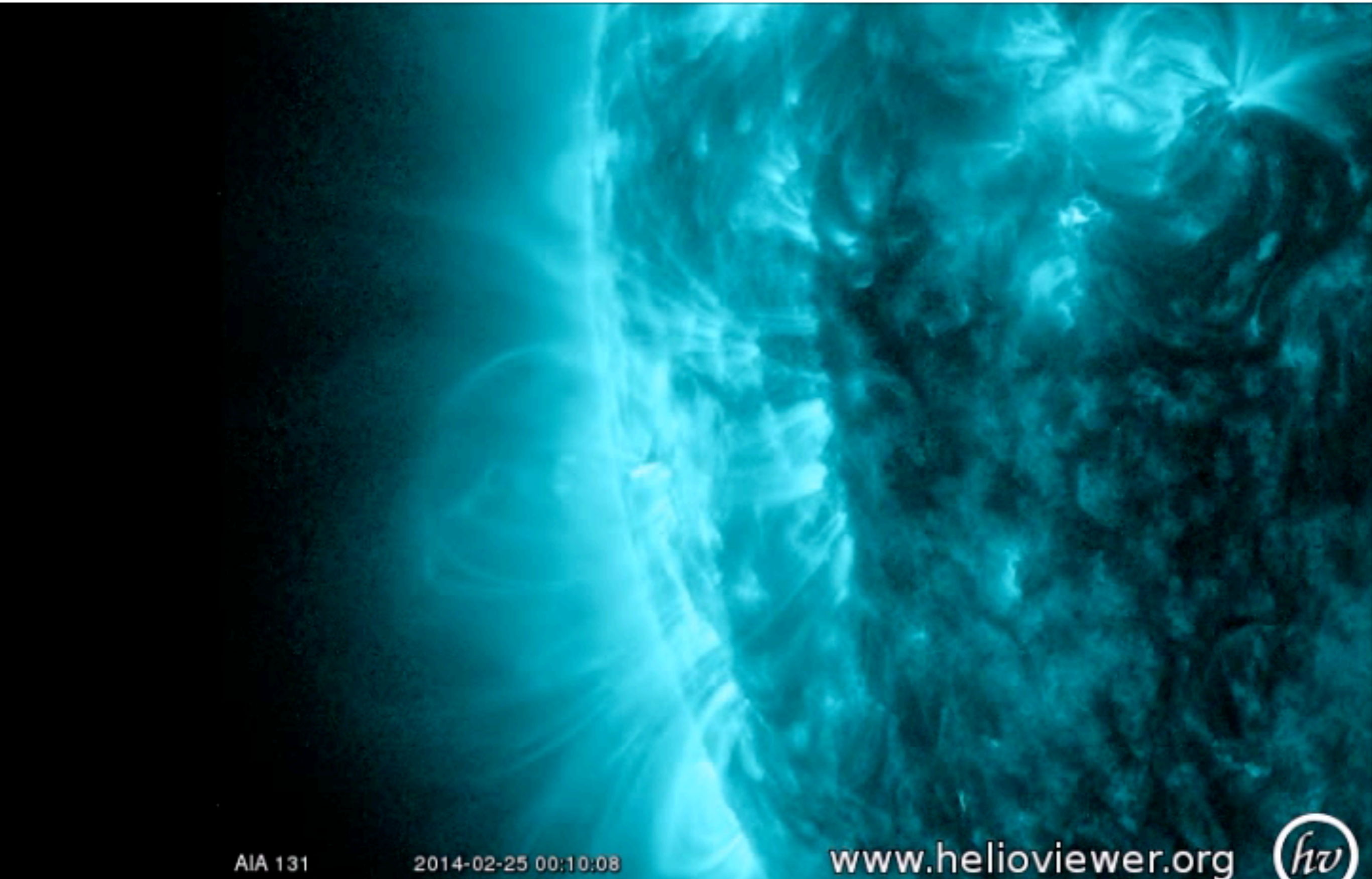


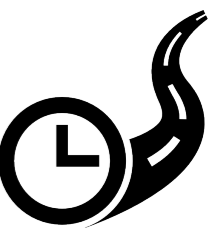
Particle Storm





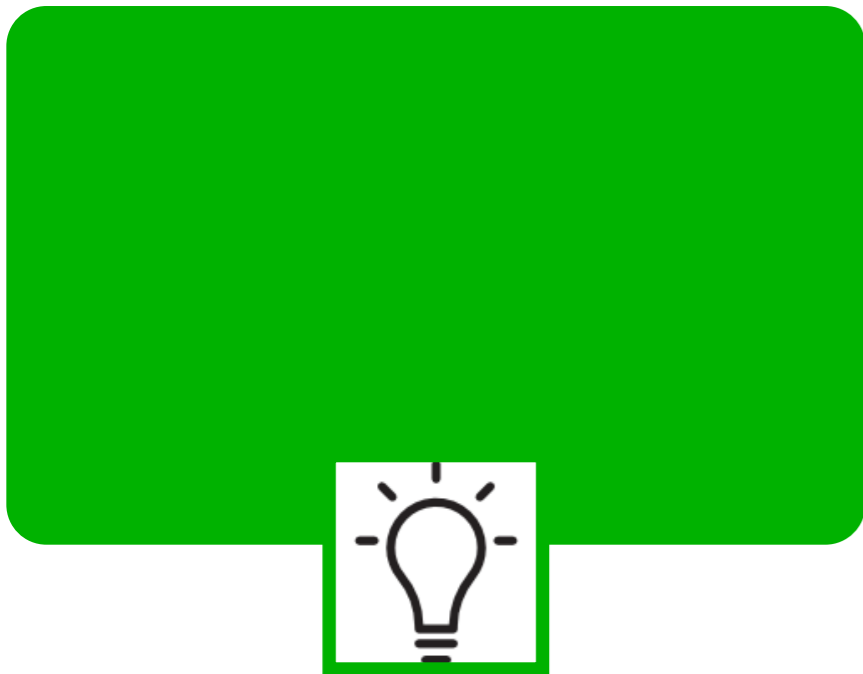
A flare is a light flash near an active region. A volume of plasma is suddenly heated and therefore lights up.





AU TRANSIT TIME

The energy released during a solar storm moves through space, each with its own typical speed: speed of light,





AU TRANSIT TIME

The energy released during a solar storm moves through space, each with its own typical speed: speed of light, ...

8 MIN



STORM SCALE



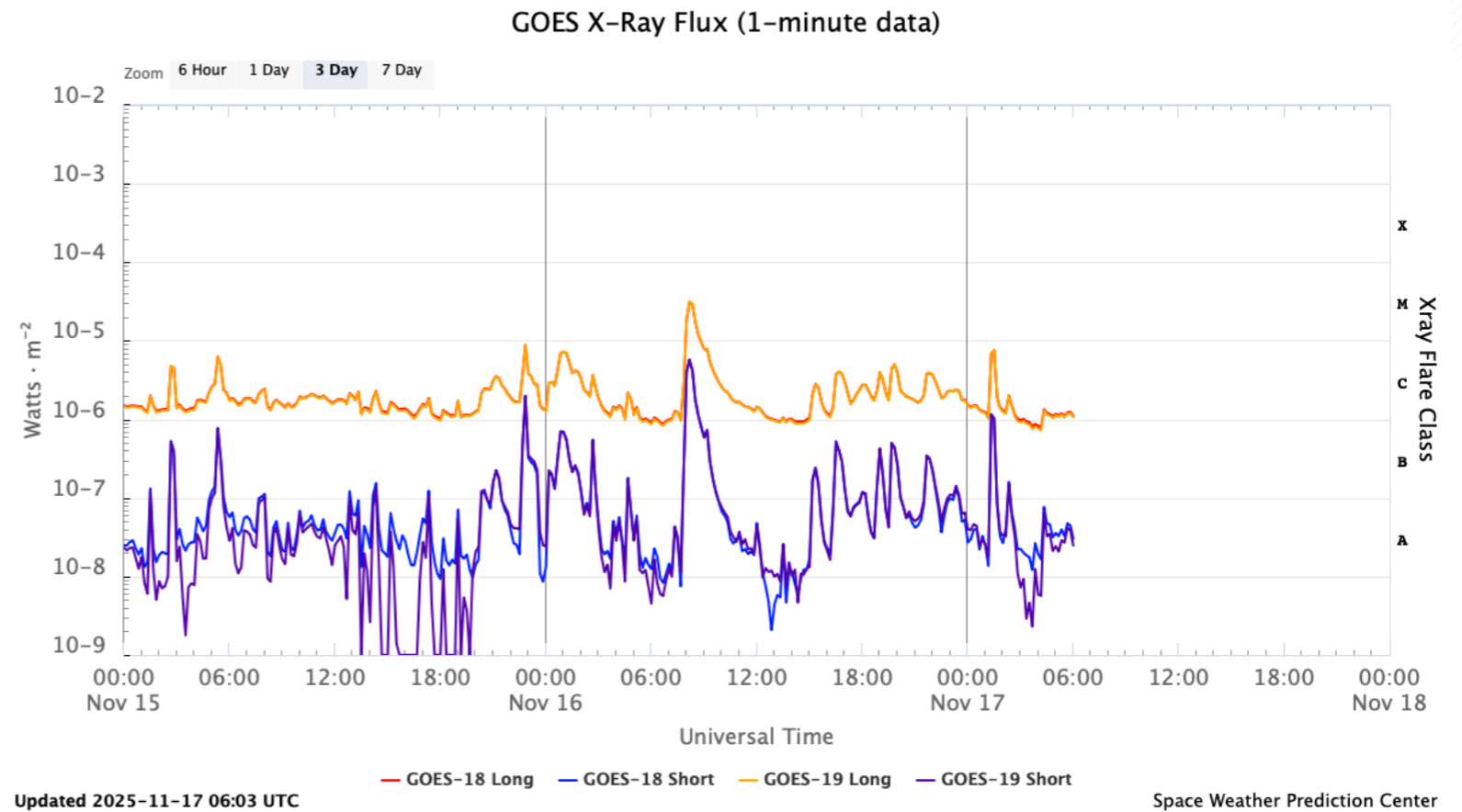
<https://www.swpc.noaa.gov/products/goes-x-ray-flux>



STORM SCALE



A,B,C,M,X



<https://www.swpc.noaa.gov/products/goes-x-ray-flux>



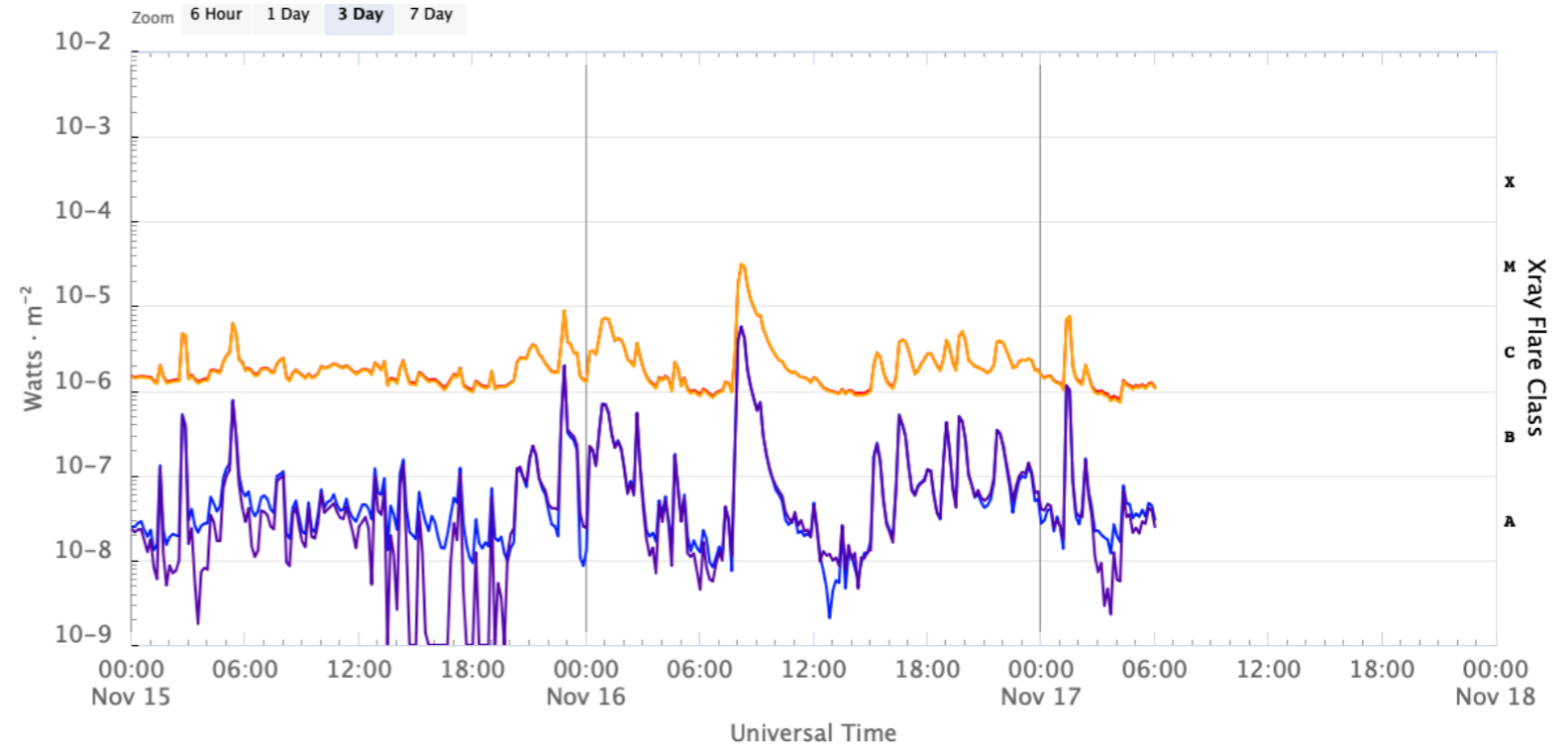
DURATION



MINs to HOUR



GOES X-Ray Flux (1-minute data)

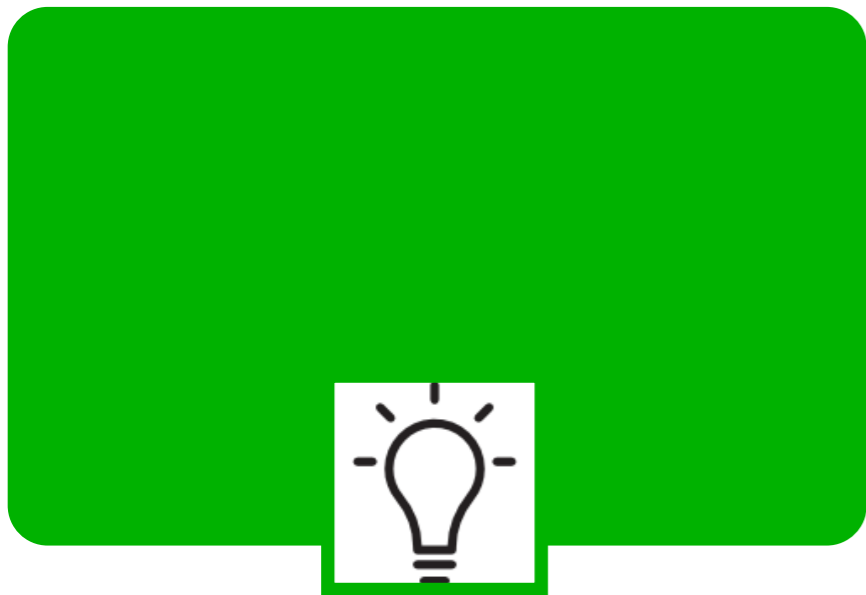


Updated 2025-11-17 06:03 UTC

Space Weather Prediction Center



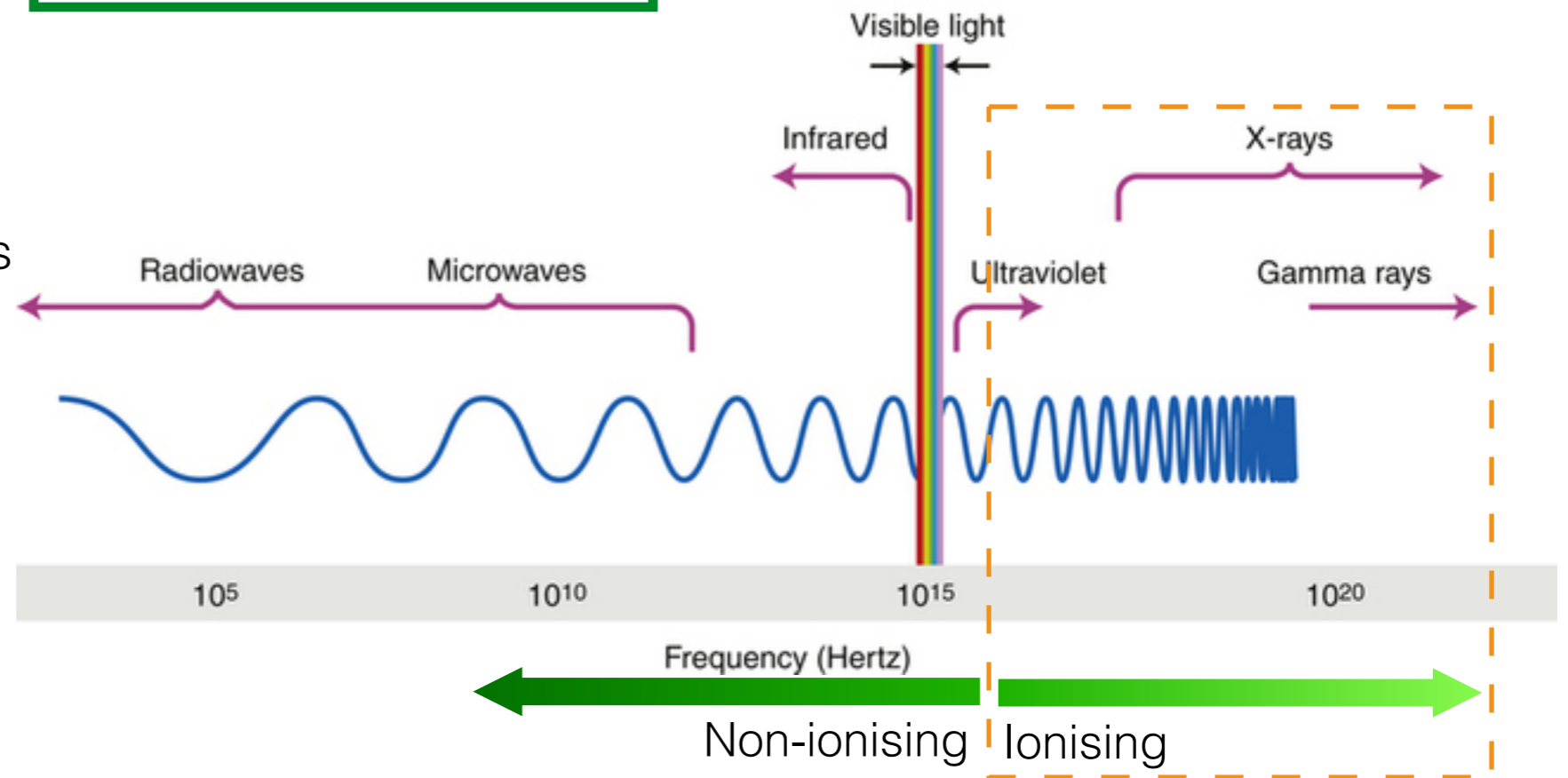
IMPACT



Electromagnetic radiation



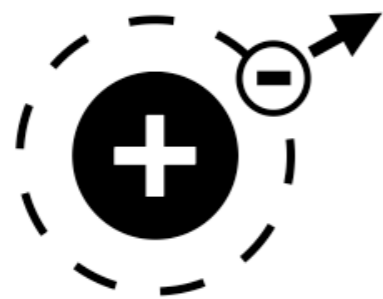
- Photons / electromagnetic waves
- Speed of light



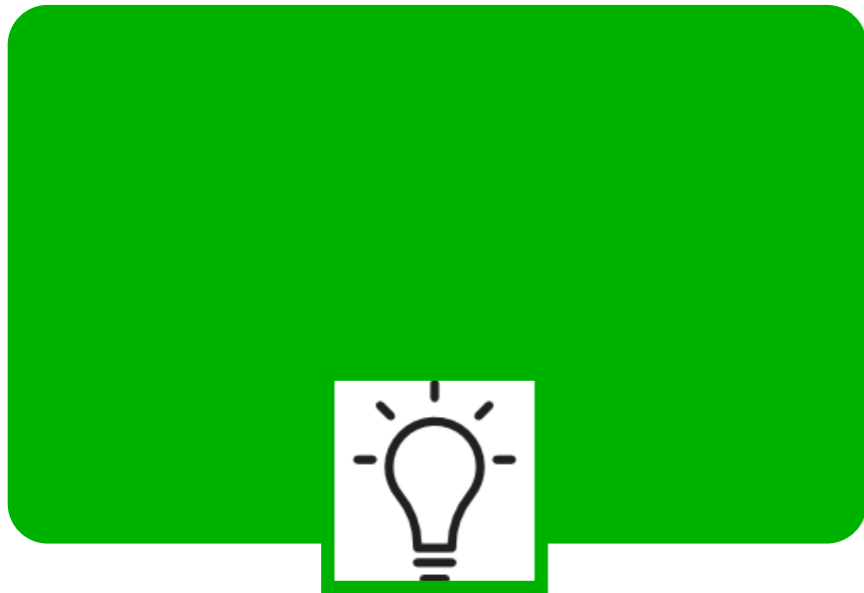
IMPACT



Ionisation

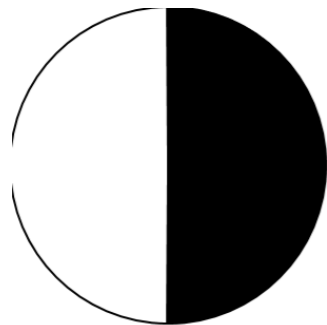


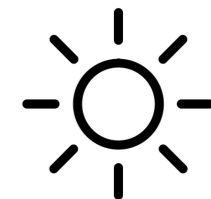
AREA OF IMPACT



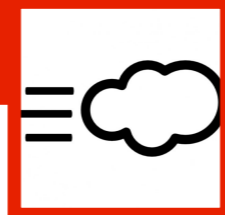
AREA OF IMPACT

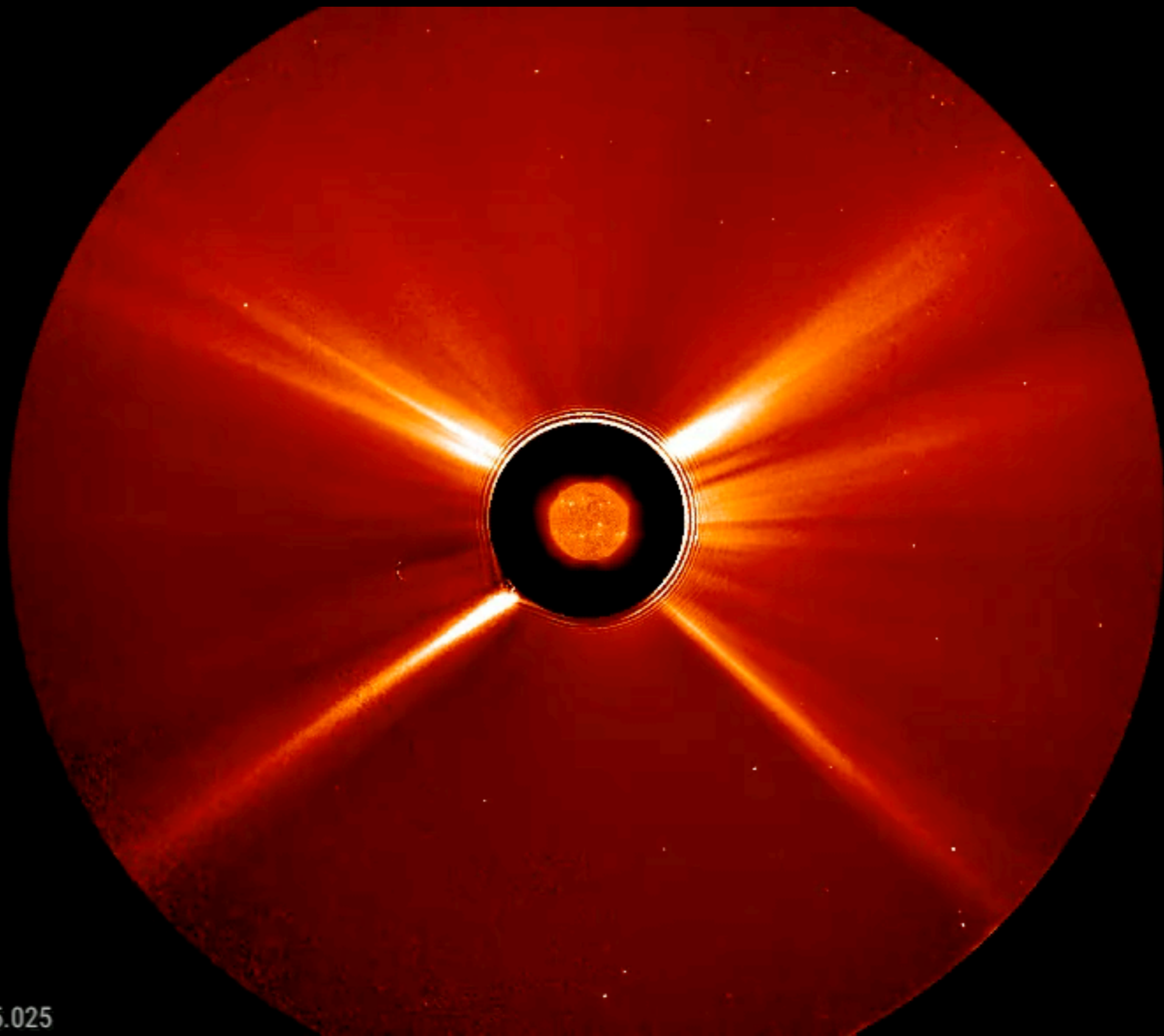
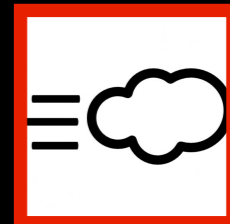
Illuminated area



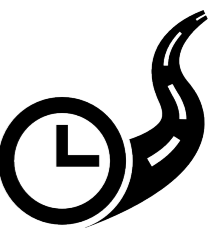


Solar wind
CME - HSS





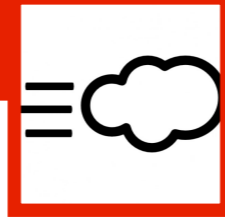
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AU TRANSIT TIME

The energy released during a solar storm moves through space, each with its own typical speed: speed of light, order of a few 100 km/s,....

8 MIN





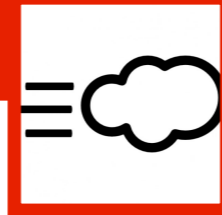
AU TRANSIT TIME

The energy released during a solar storm moves through space, each with its own typical speed: speed of light, order of a few 100 km/s, relativistic speeds.

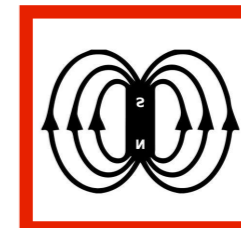
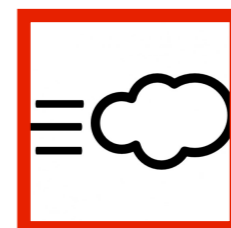
8 MIN

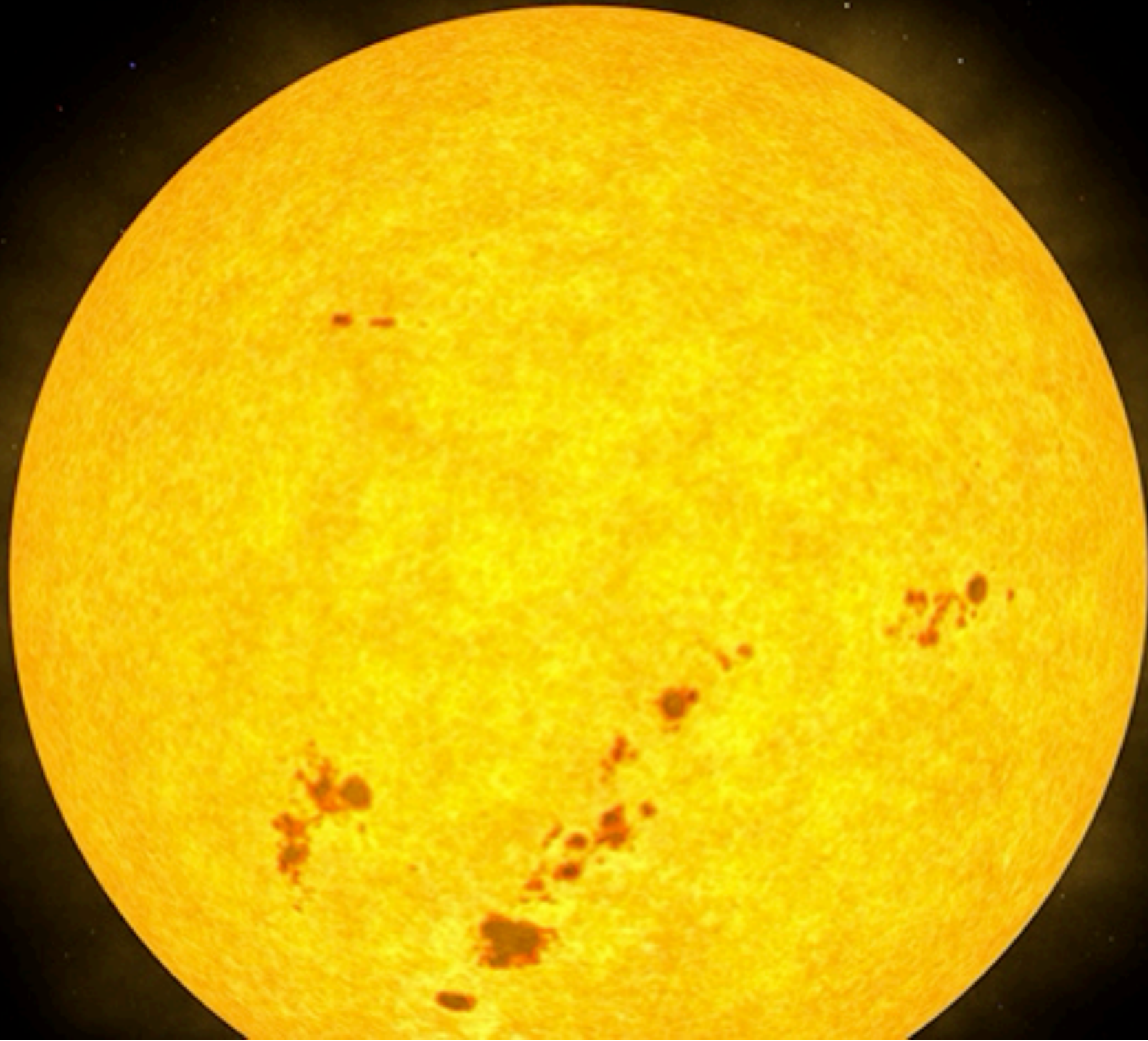
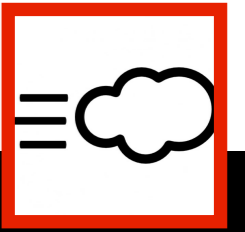


DAYS



STORM SCALE - GEOMAGNETIC STORM



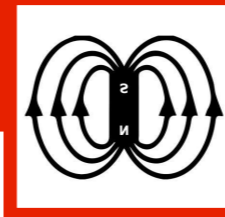


STORM SCALE



<https://kp.gfz.de/en/>

A,B,C,M,X

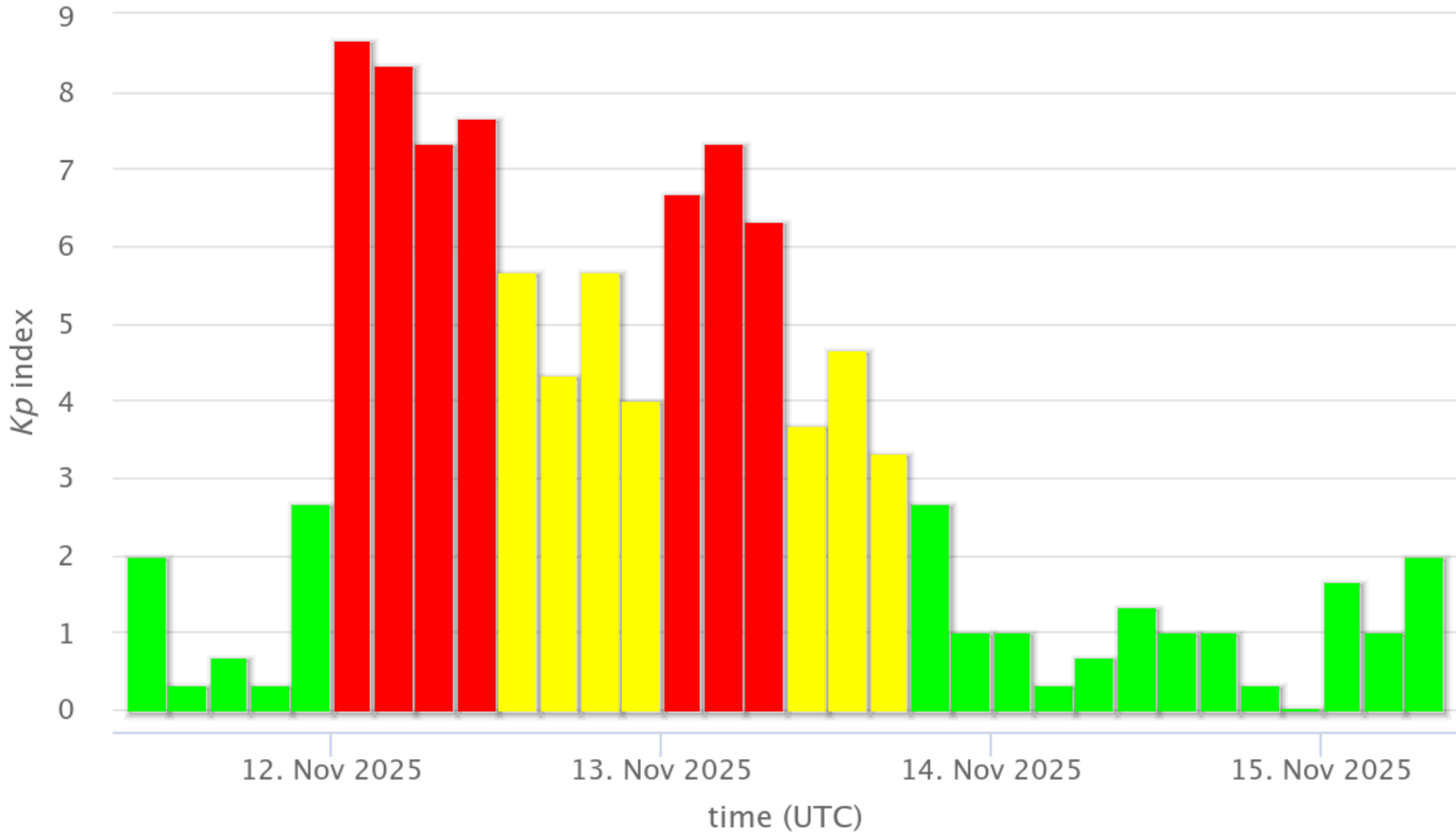


STORM SCALE



Most recent geomagnetic storm with Kp index > 6

GFZ Helmholtz Centre for Geosciences (CC BY 4.0)

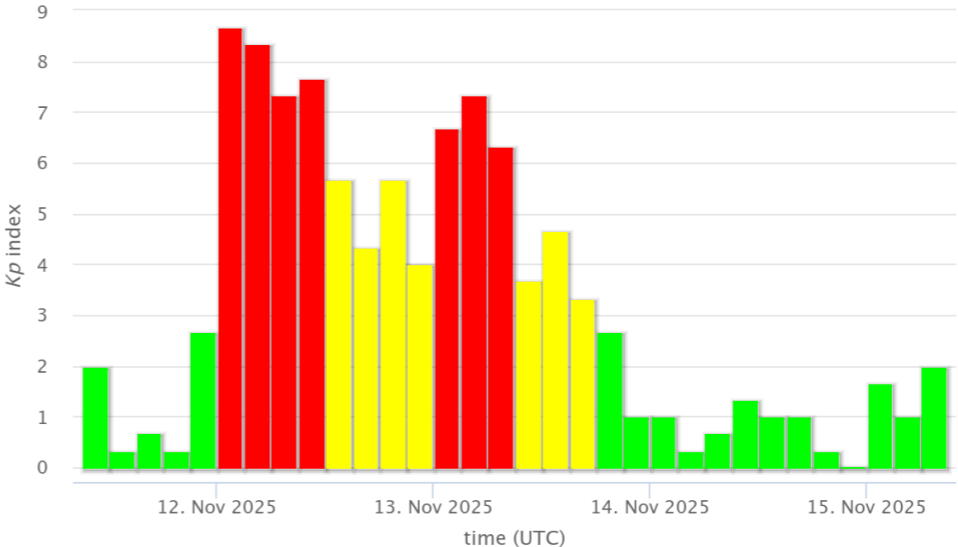


STORM SCALE



Most recent geomagnetic storm with Kp index > 6

GFZ Helmholtz Centre for Geosciences (CC BY 4.0)



A,B,C,M,X

Kp
0 - 9

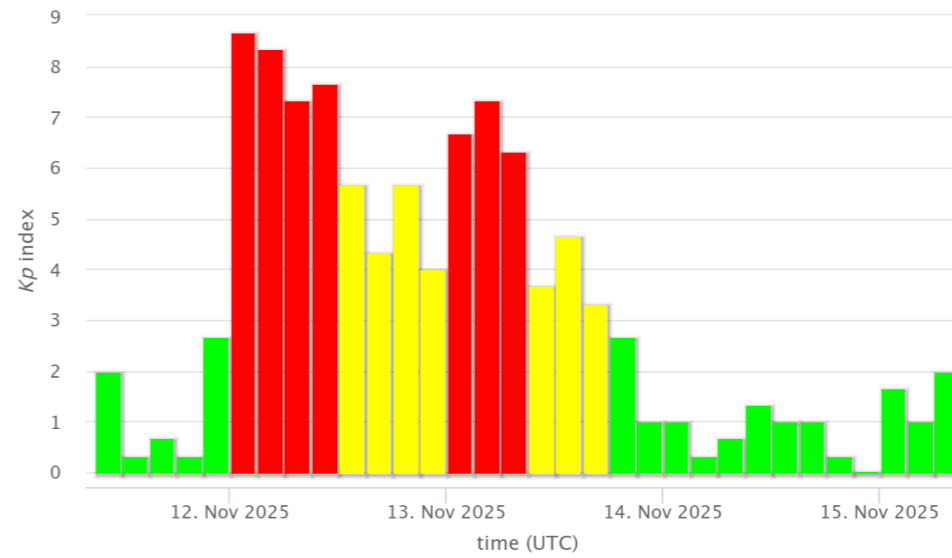


DURATION



Most recent geomagnetic storm with Kp index > 6

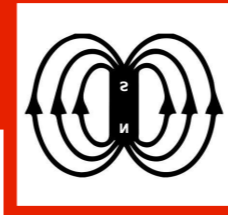
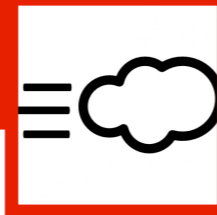
GFZ Helmholtz Centre for Geosciences (CC BY 4.0)



MINs to HOUR



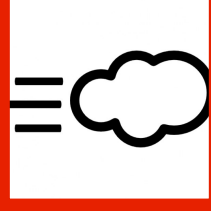
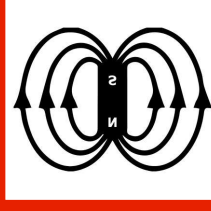
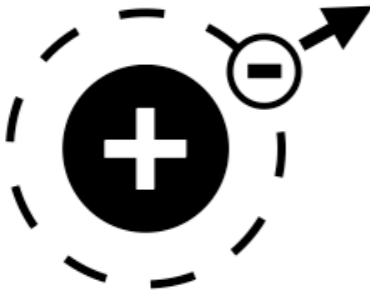
DAY+

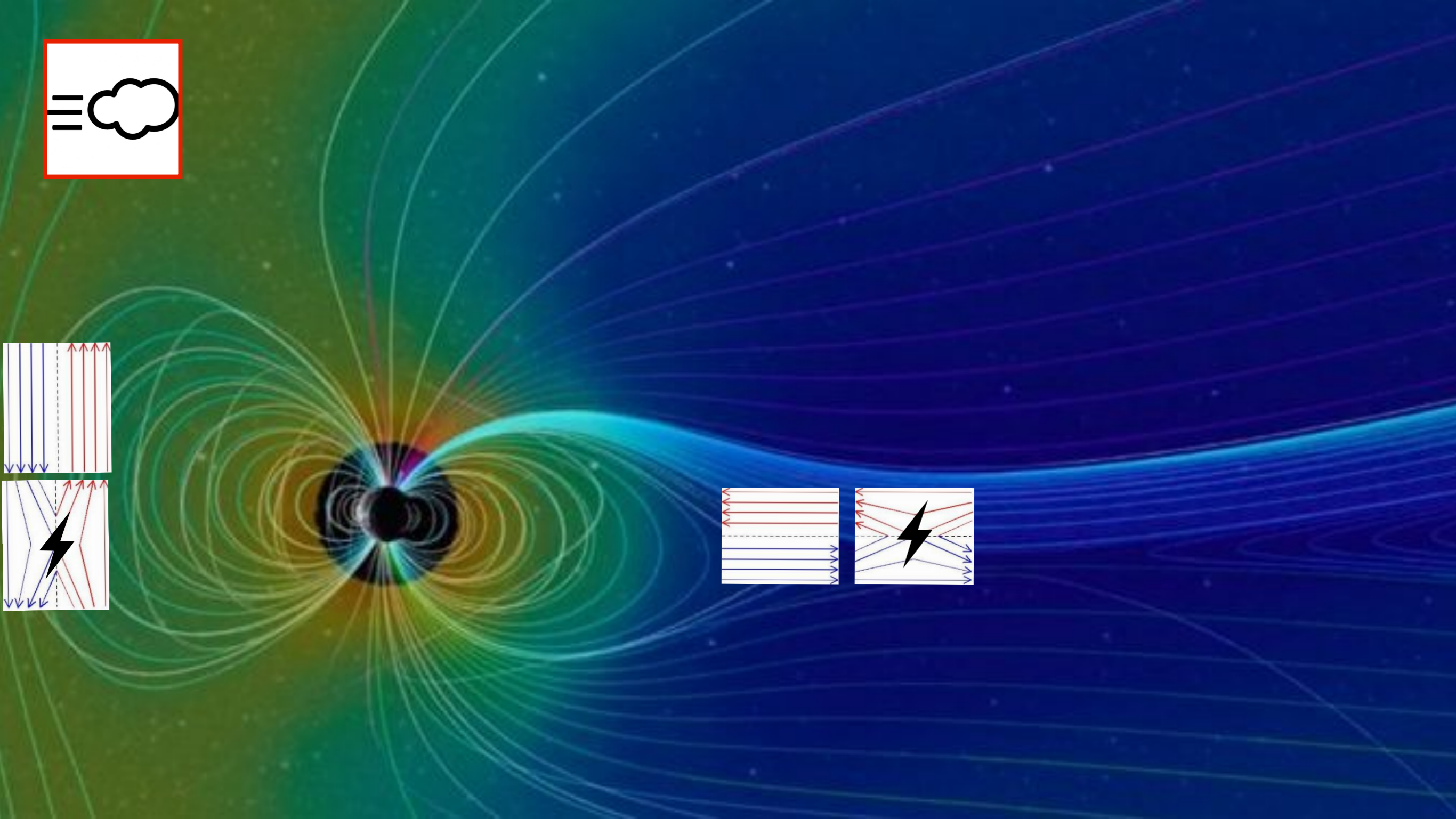
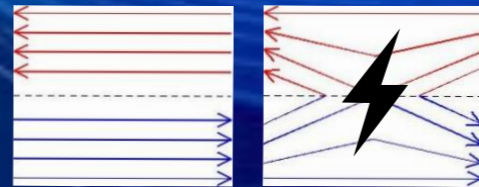
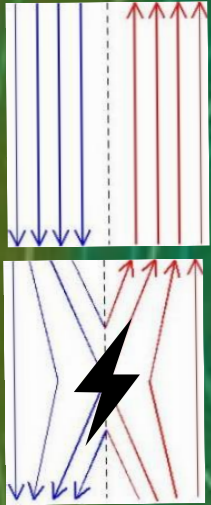


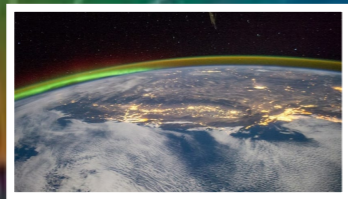
IMPACT



Ionisation

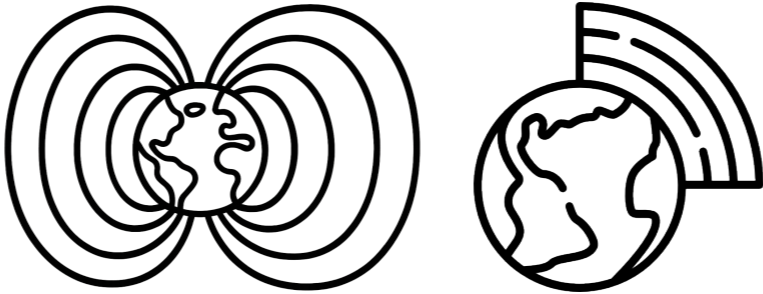









MAGNETOSPHERE - IONOSPHERE COUPLING

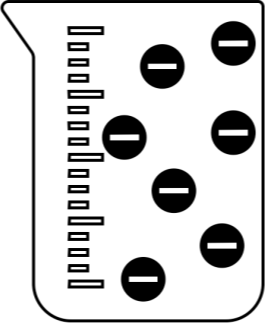
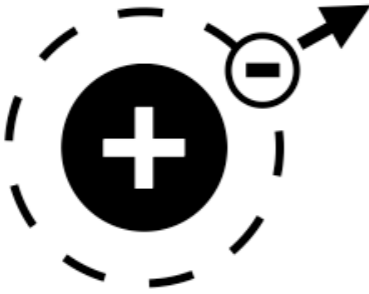
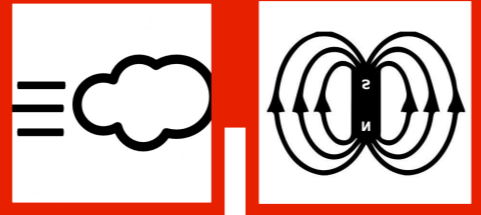
IMPACT



Ionisation



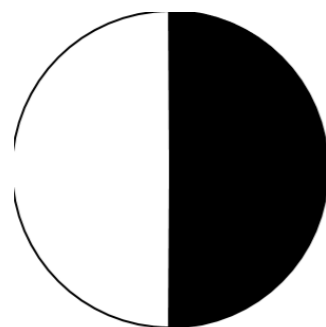
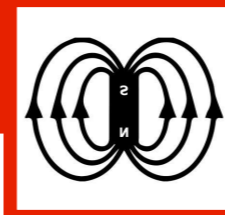
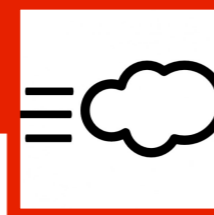
Particle content



AREA OF IMPACT



Illuminated area



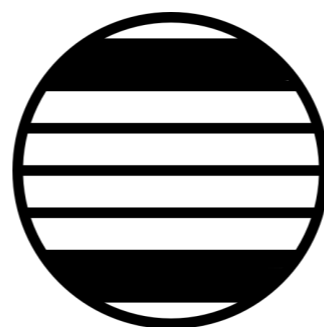
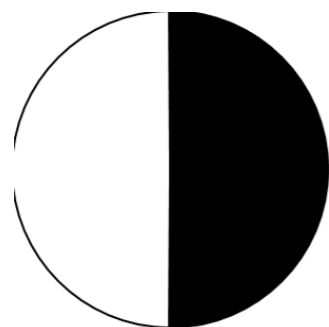
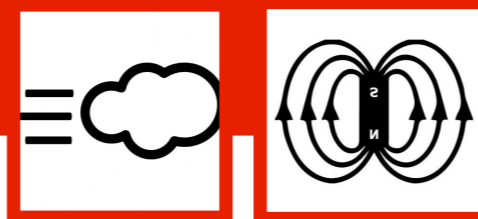
AREA OF IMPACT

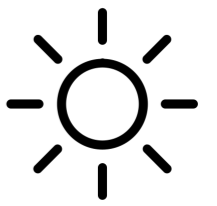


Illuminated area

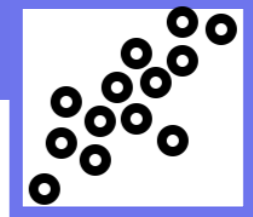


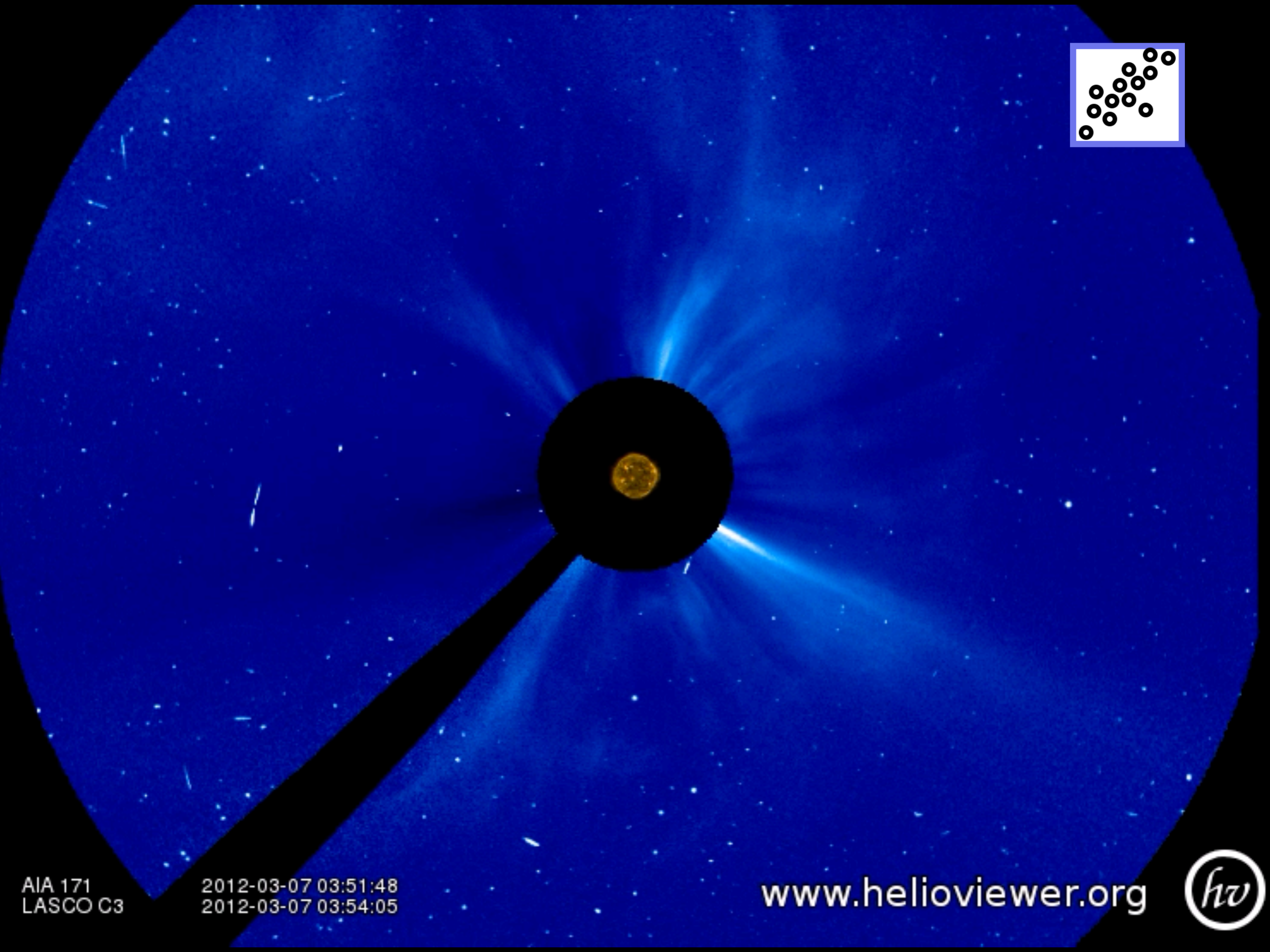
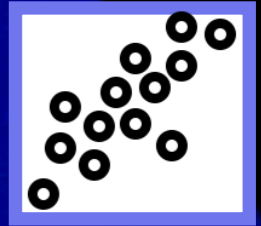
Auroral Oval & more Latitude





Energetic Particles





AIA 171
LASCO C3

2012-03-07 03:51:48
2012-03-07 03:54:05

www.helioviewer.org





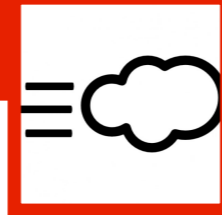
AU TRANSIT TIME

The energy released during a solar storm moves through space, each with its own typical speed: speed of light, order of a few 100 km/s, relativistic speeds.

8 MIN



DAYS





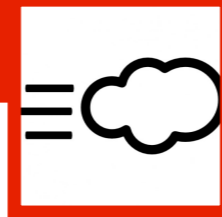
AU TRANSIT TIME

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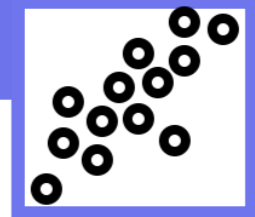
8 MIN



DAYS



HOUR



STORM SCALE

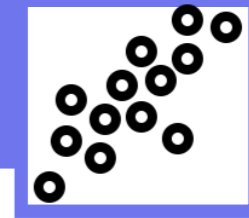
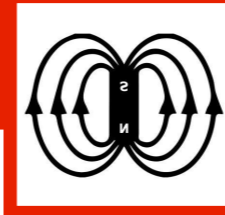
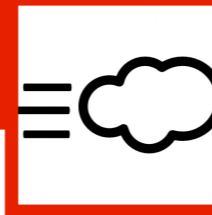


<https://www.swpc.noaa.gov/products/goes-proton-flux>

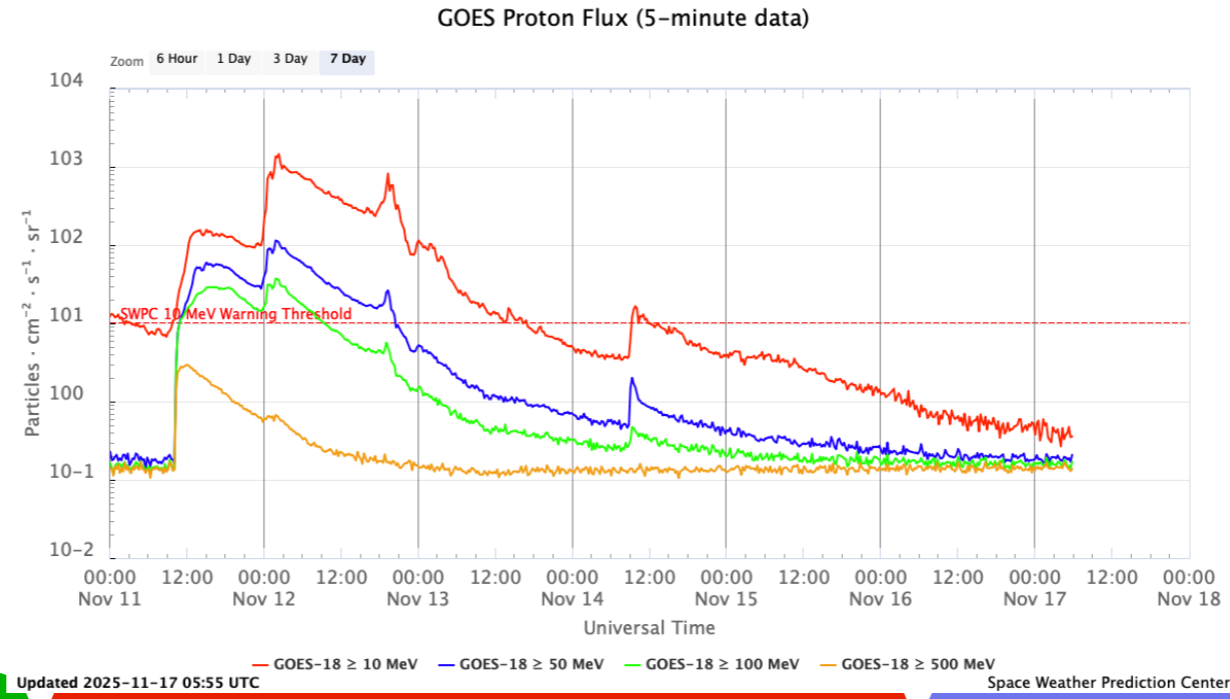
A,B,C,M,X



Kp
0 - 9



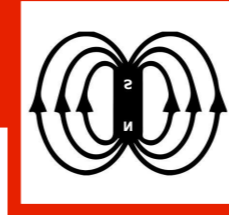
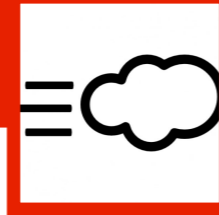
STORM SCALE



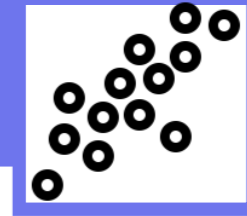
A,B,C,M,X



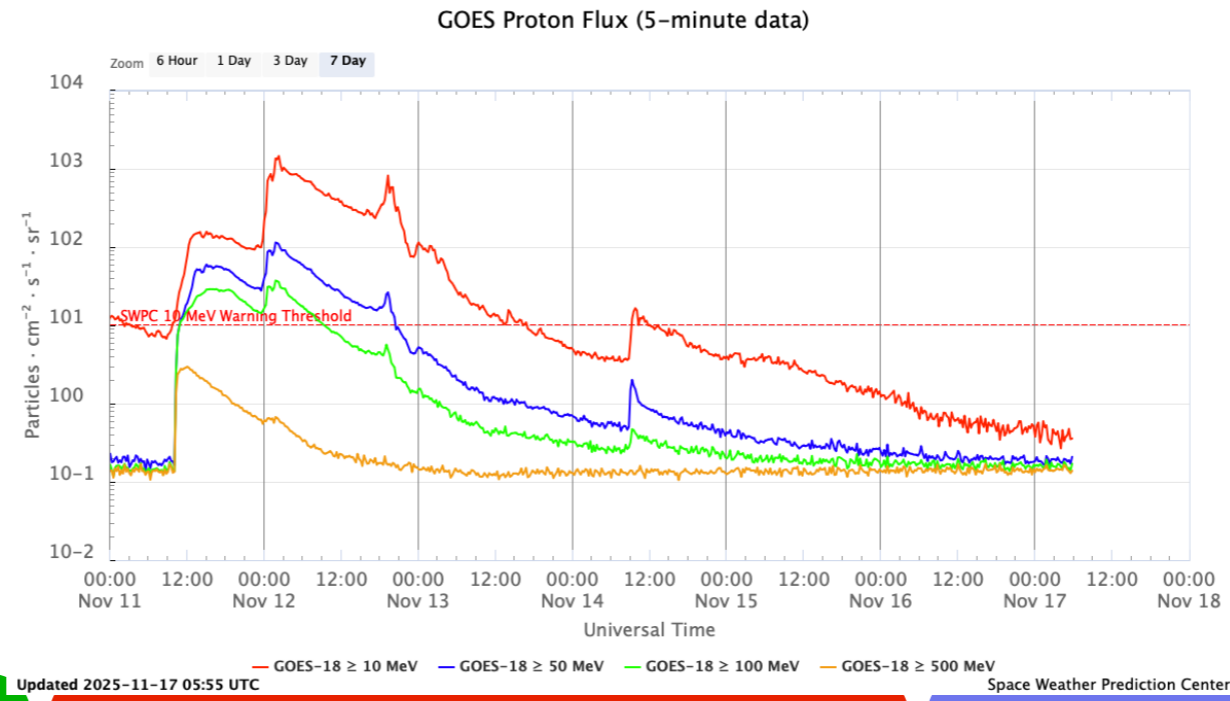
Kp
0 - 9



Storm - major storm



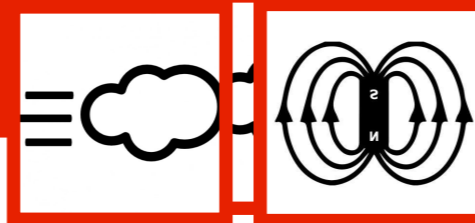
DURATION



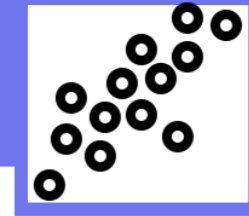
MINs to HOUR



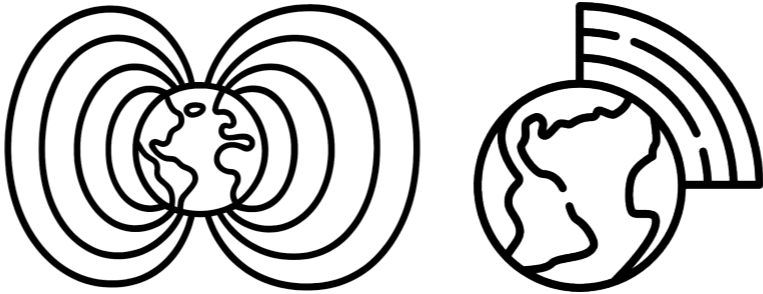
DAY+




HOURS to DAYS



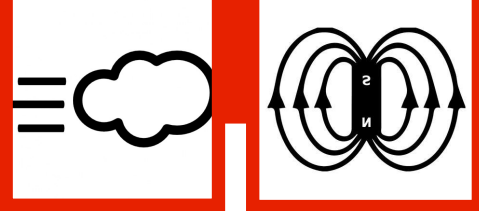
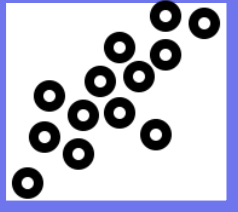
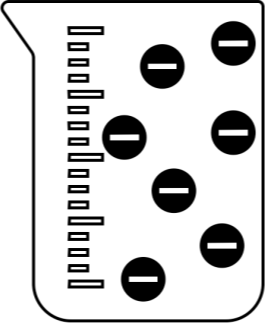
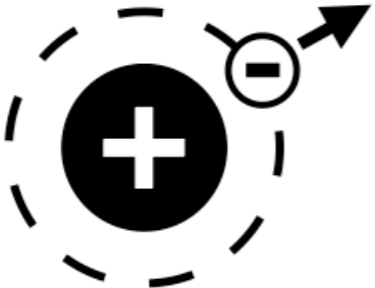
IMPACT



Ionisation



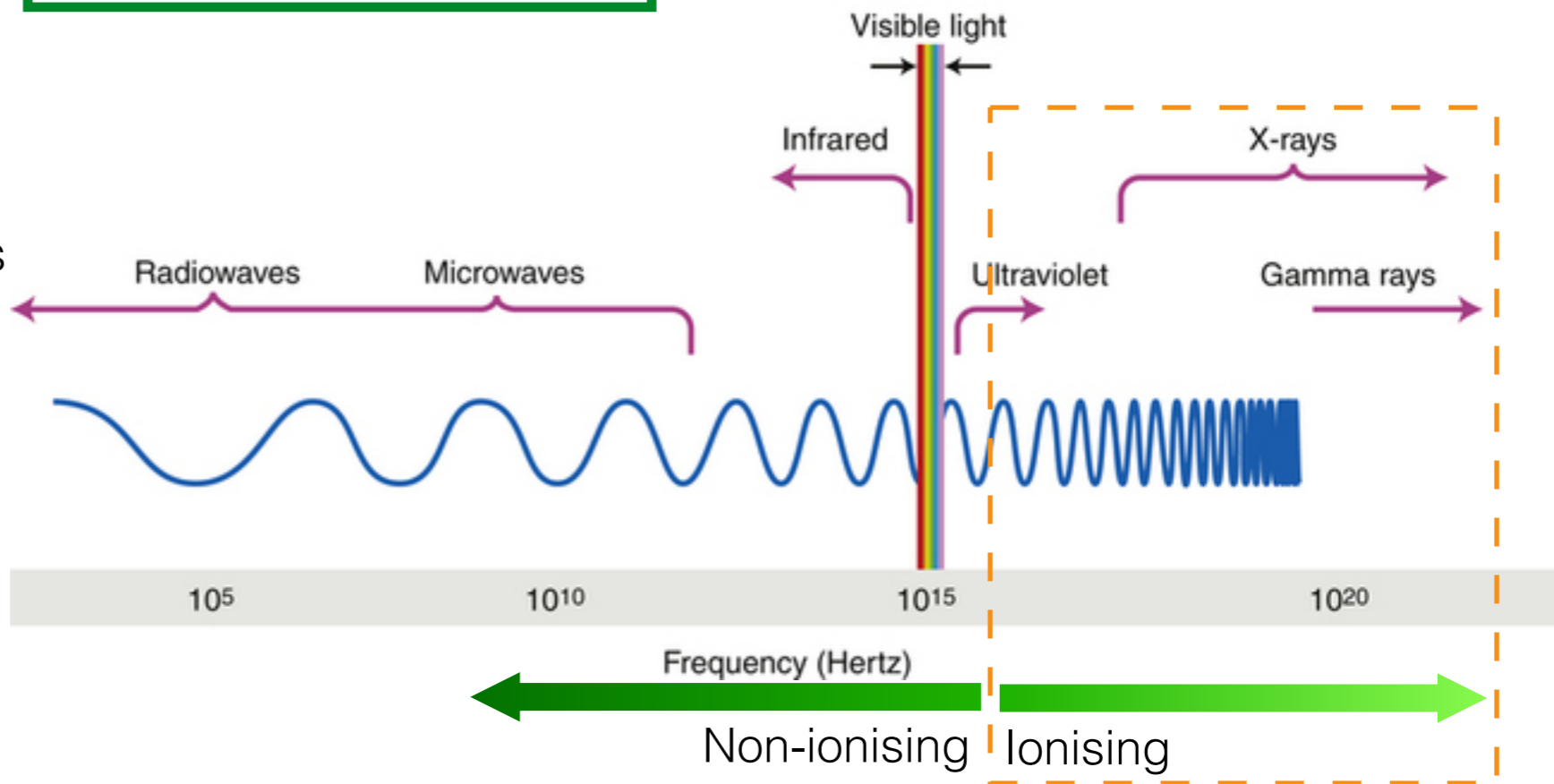
Particle content

Electromagnetic radiation

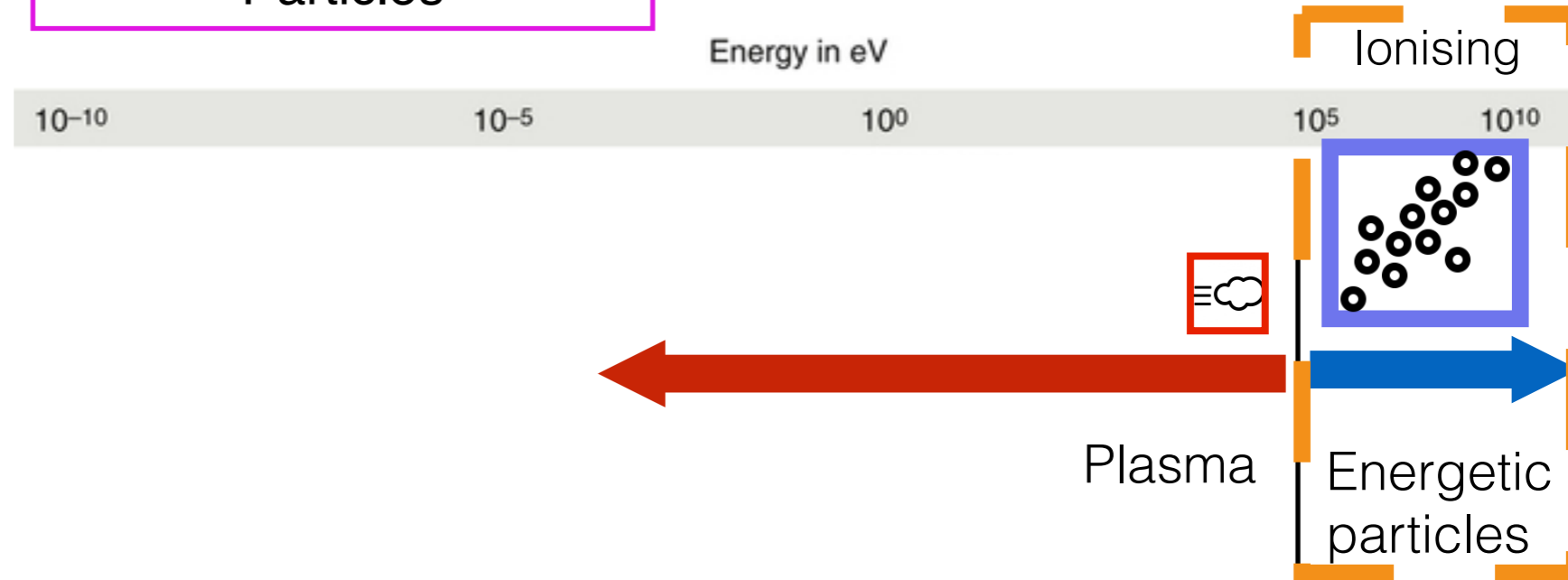


- Photons / electromagnetic waves
- Speed of light

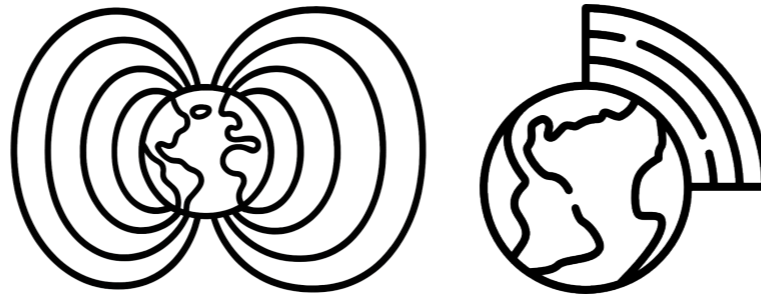


Particles

- Atomic & sub-atomic particles
- m/s to fractions of speed of light



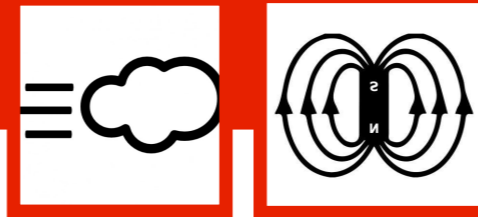
IMPACT



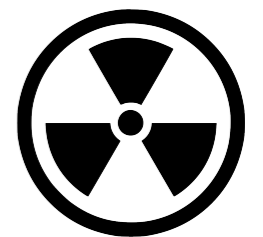
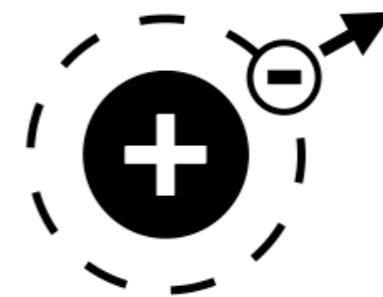
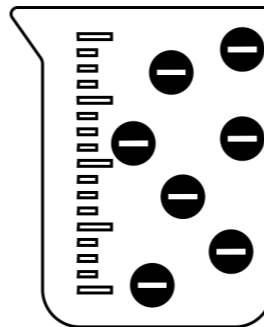
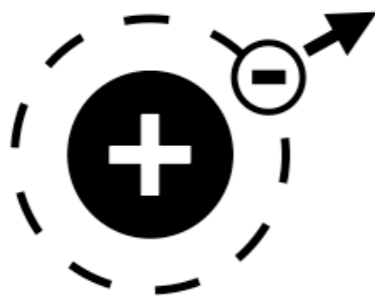
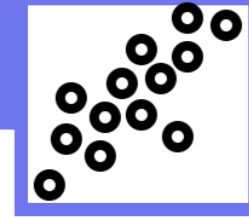
Ionisation



Particle content



Ionisation
Particle Radiation



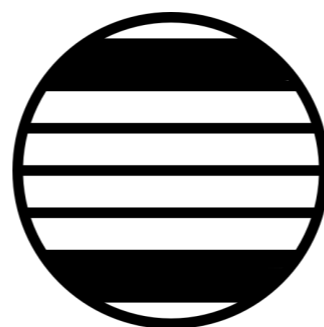
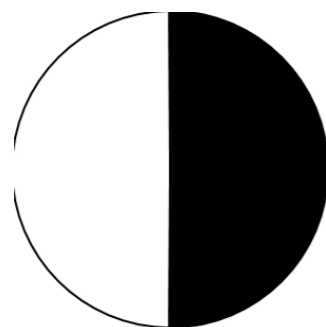
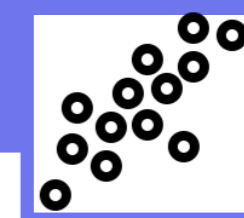
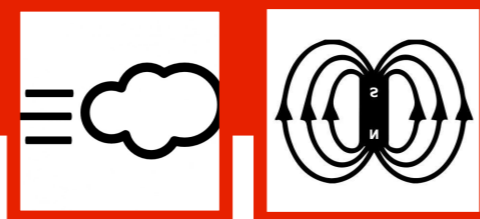
AREA OF IMPACT



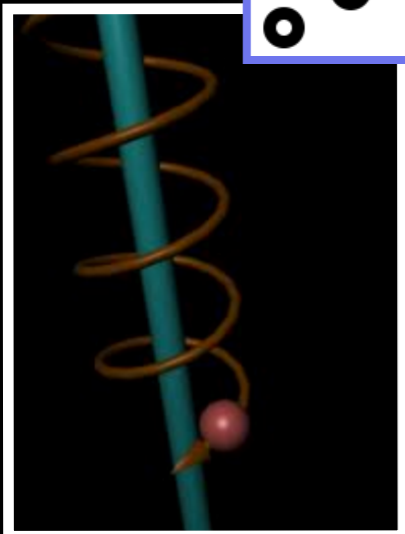
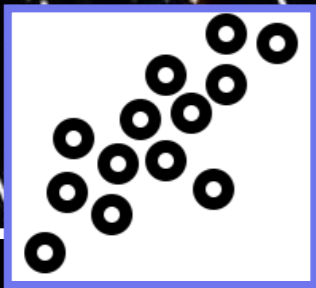
Illuminated area



Auroral Oval & more Latitude

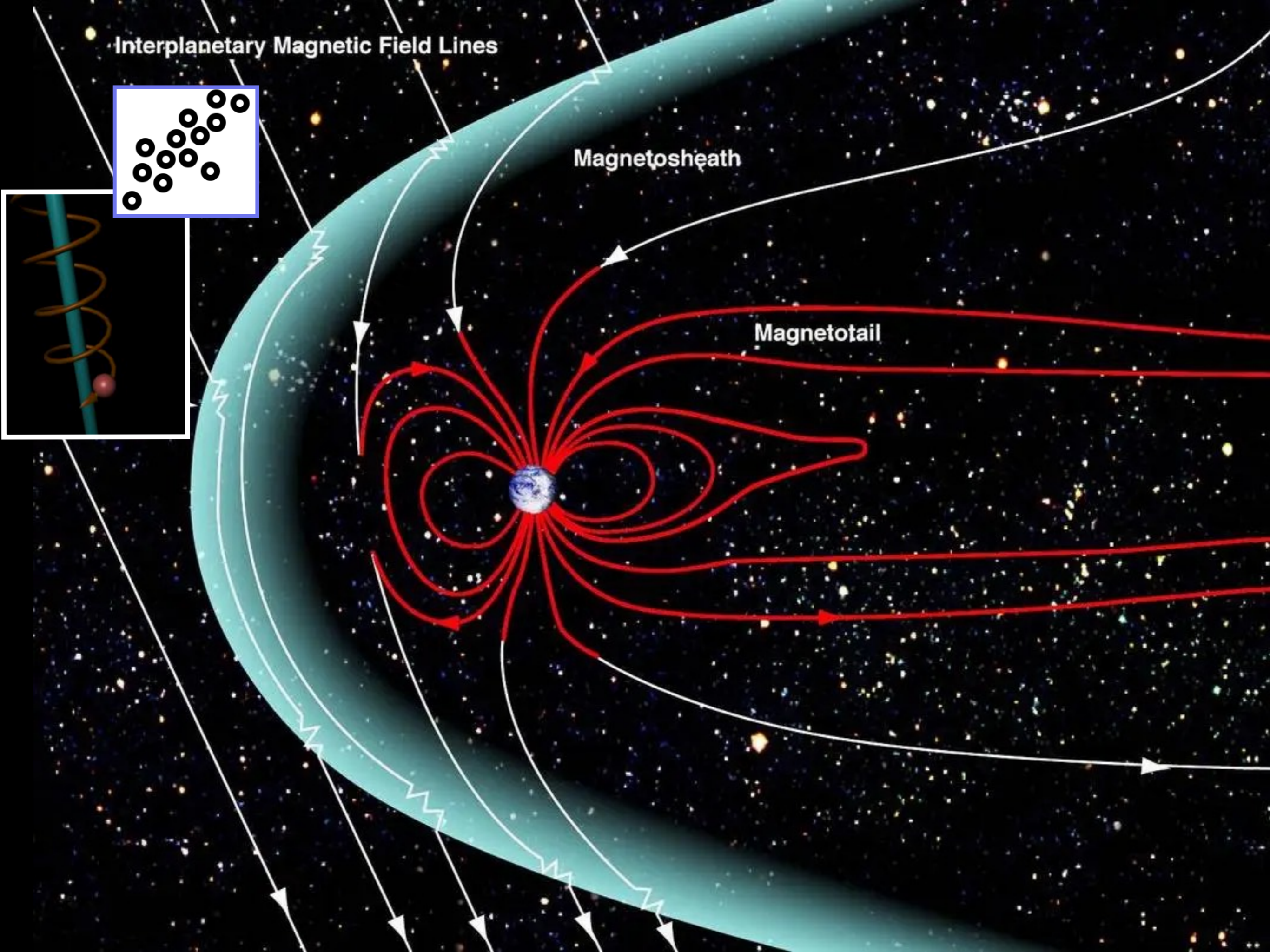


Interplanetary Magnetic Field Lines



Magnetosheath

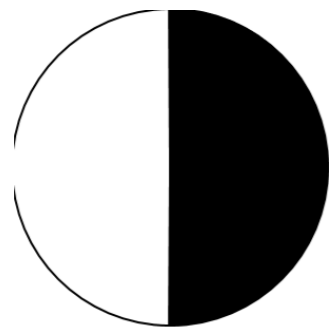
Magnetotail



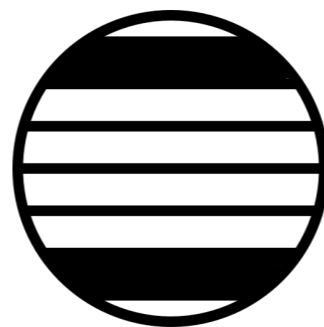
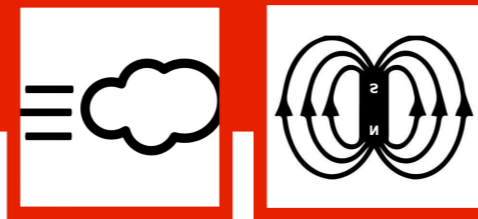
AREA OF IMPACT



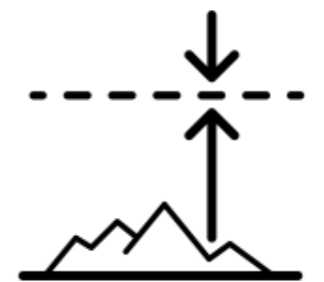
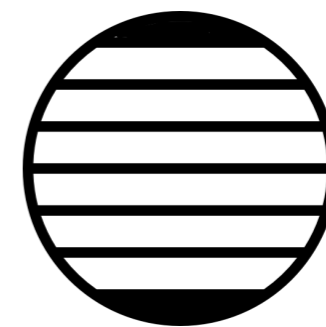
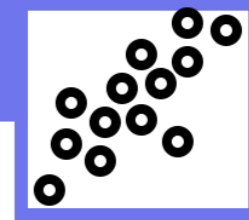
Illuminated area



Auroral Oval & more Latitude



Polar Cap
High Altitude





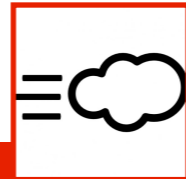
8 min

X-ray: A,B,C,M,X

Min to Hour

Ionisation

Illuminated area



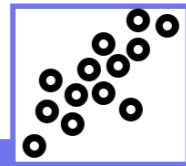
Days

Kp: 0 - 9

Day+

Particle content

Auroral Oval & more
Latitude



Hour

Proton flux:
(Major) Storm

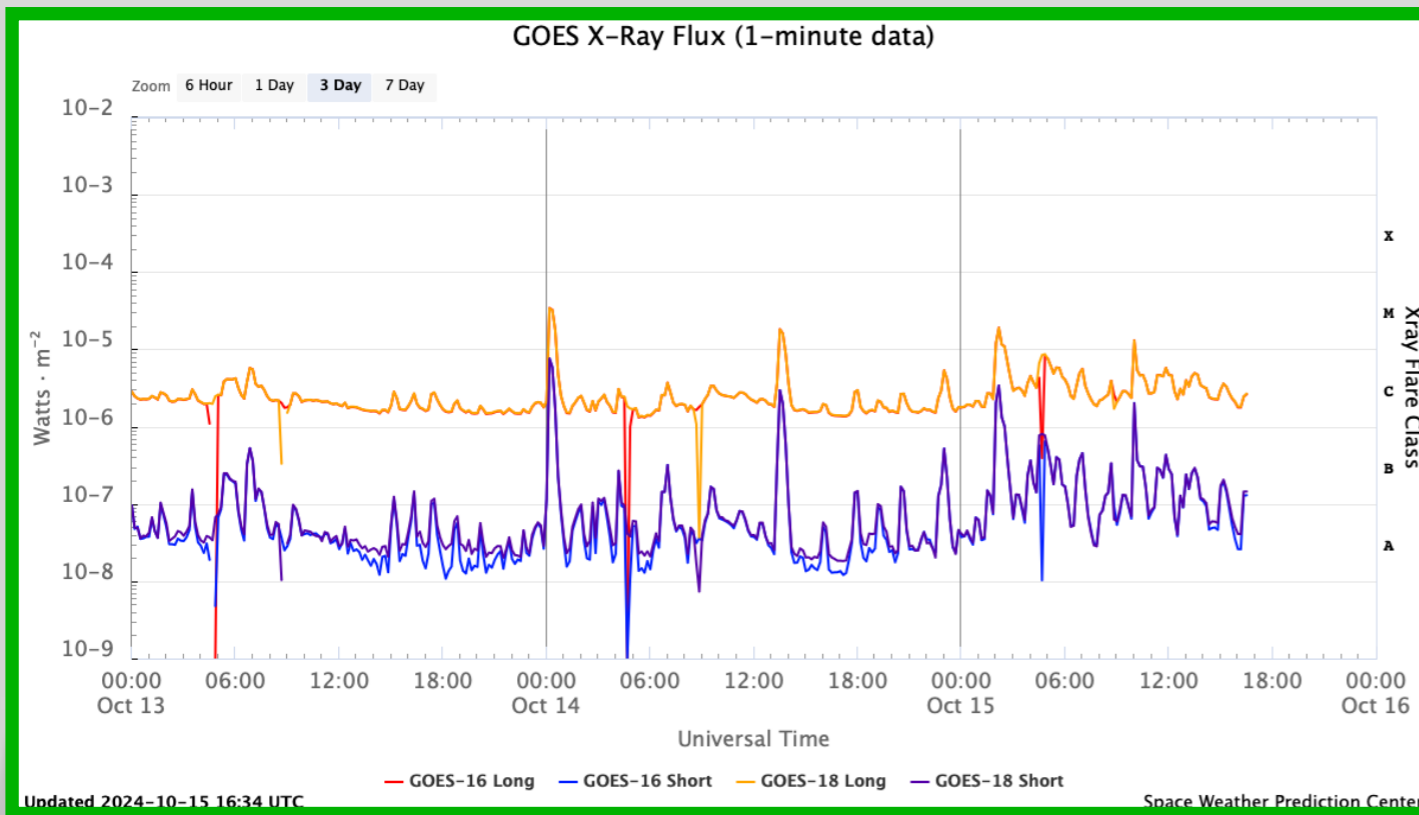
Hours to Days

Ionisation
Particle radiation

Polar Caps
High Altitude



X-ray Flux Passport



Type

X-ray output (0.1-0.8 nm and 0.05-0.4 nm) of the solar spectrum versus time.

Use

To quantify solar flares happening on the side of the Sun facing Earth.

Units

$W \cdot m^{-2}$
Integrated over 1 min

Data location

<https://www.swpc.noaa.gov/products/goes-x-ray-flux>

Sensor

GOES-16 satellite
GOES-18 satellite

Sensor location

Geostationary orbit

Cadence

Integrated over 1 min

Plot

X-axis: time in UTC

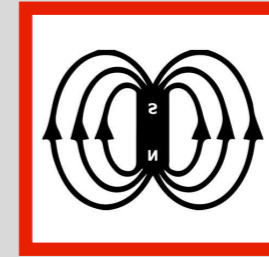
Y-axis: X-ray flux in W/m^2 , i.e. how much energy (Joule) passes in 1 sec ($W=Watt=J/s$) through 1 square meter at geostationary height.

Classes

The long wavelength (0.1-0.8 nm, red and orange) is the reference for identification of the class. The red is measured by GOES 18, orange by GOES 16.

The flare classes are indicated on the right of the graphs. When the peak of the red/orange curve is in blue/green/yellow/orange/red, it is a A/B/C/M/X-class flare.

Kp-index Passport



What

Kp-index (NOAA) represents the planetary geomagnetic condition or the state of the magnetic field of Earth. It is a planetary index and is valid for the globe.

Use

To quantify the disturbance of the magnetic field of Earth. The scale ranges from 0 to 9, with 0 indicating no disturbance and 9 the highest disturbance of the Earth magnetic field .

Plot

X-axis: data and time in UTC, time stamp every 3 hours. Ranges from 3 days in the left (left) to now (right).

Y-axis:

coloured bars of 3 hours wide, height= Kp-index (NOAA)
Height of a bar represents a number: 0, 0+, 1-, 1, 1+, 2-, 2, 2+, ... 8-, 8, 8+, 9-, 9.

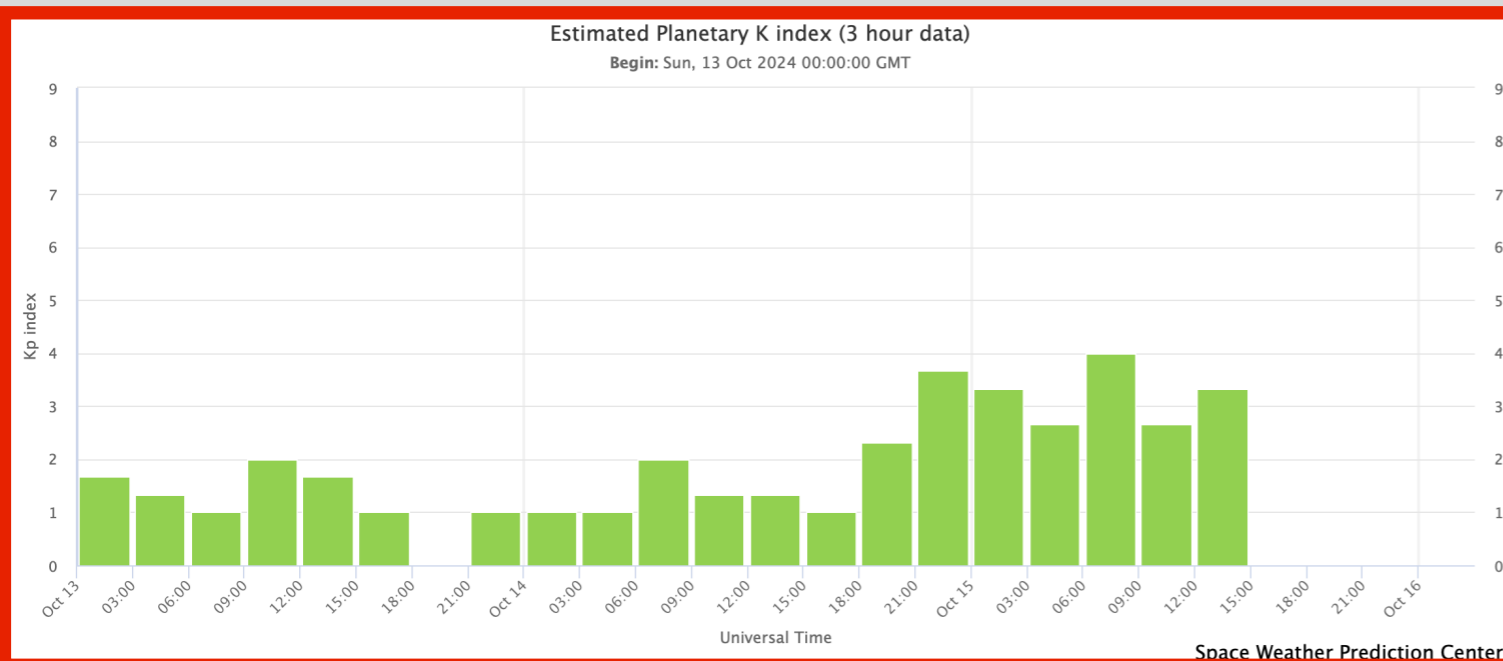
With e.g. 2- = 1,70 and 2+ = 2,30 etc.

Estimated

by NOAA, US

Data location

<https://www.swpc.noaa.gov/products/planetary-k-index>



Definitive

The values become definitive after calculation and confirmation by the German Research Centre for Geosciences, Potsdam.

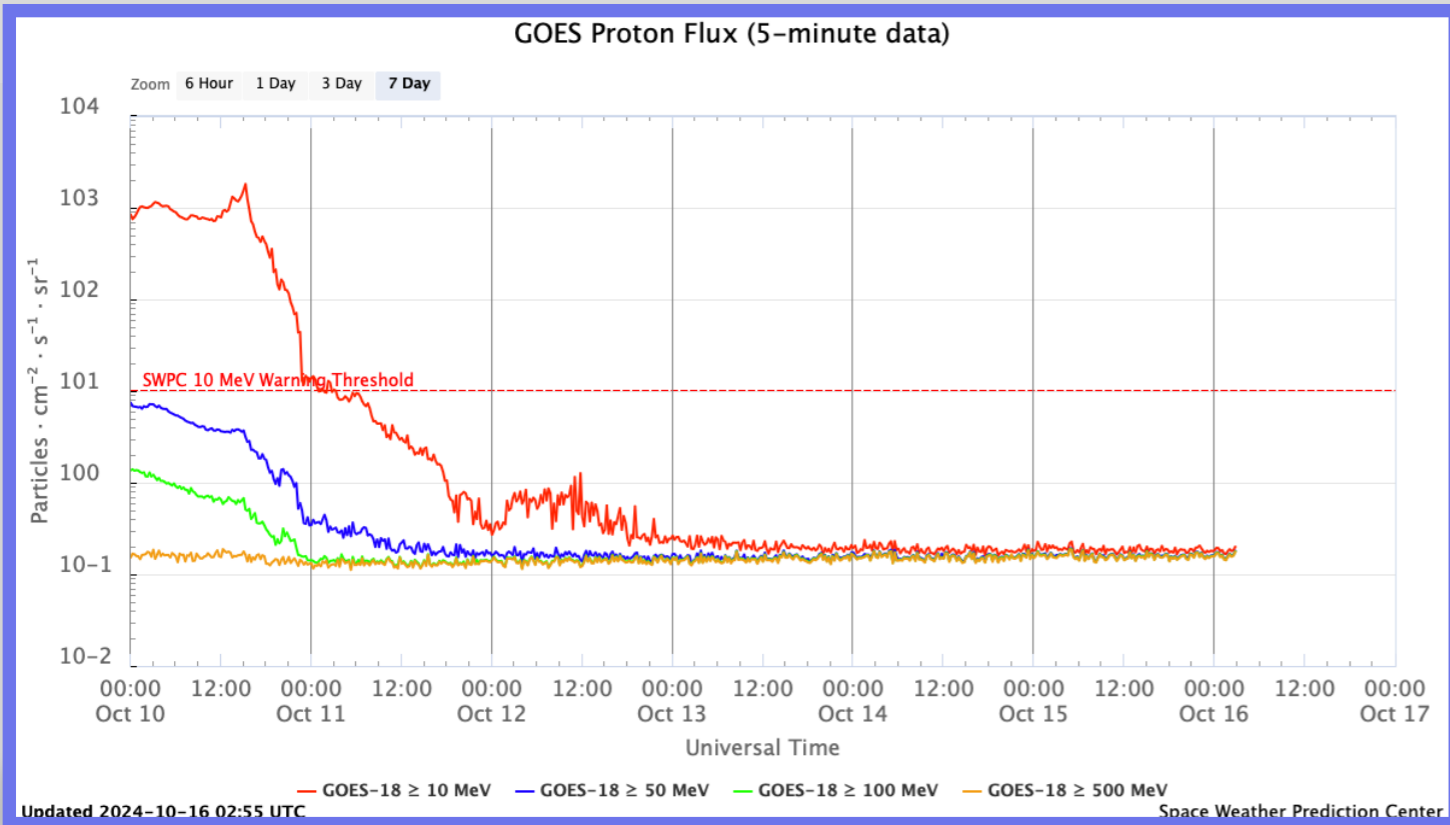
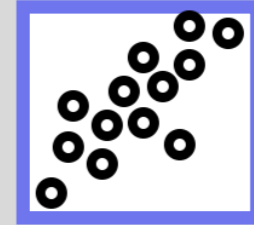
Observatories

Thirteen (13) Geomagnetic Observatories between 44 degrees and 60 degrees northern or southern geomagnetic latitude.

Magnetometers

The calculation is based upon the measurements done by magnetometers.

Proton Flux Passport



Type

Graph, flux of solar protons versus time.

Use

To quantify proton events impacting Earth.

Units

Particles/(cm²*s*sr) with s=second and sr=steradian

Sensor

GOES-18 satellite

Sensor location

Geostationary orbit

Cadence

Integrated over 5 min

Data location

<https://www.swpc.noaa.gov/products/goes-proton-flux>

Plot

X-axis: time in UTC

Y-axis: Particles/(cm²*s*sr), i.e. how many solar protons with a particular energy (eV) pass in 1 sec through 1 square centimeter from a cone with the Sun at the apex. The count is done at geostationary height.

The 4 colours represent 4 energies.