

SPACE WEATHER

Introduction

Petra Vanlommel

The source of weather

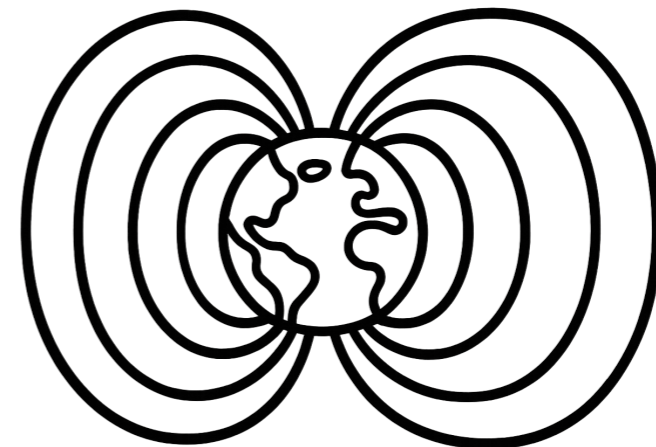
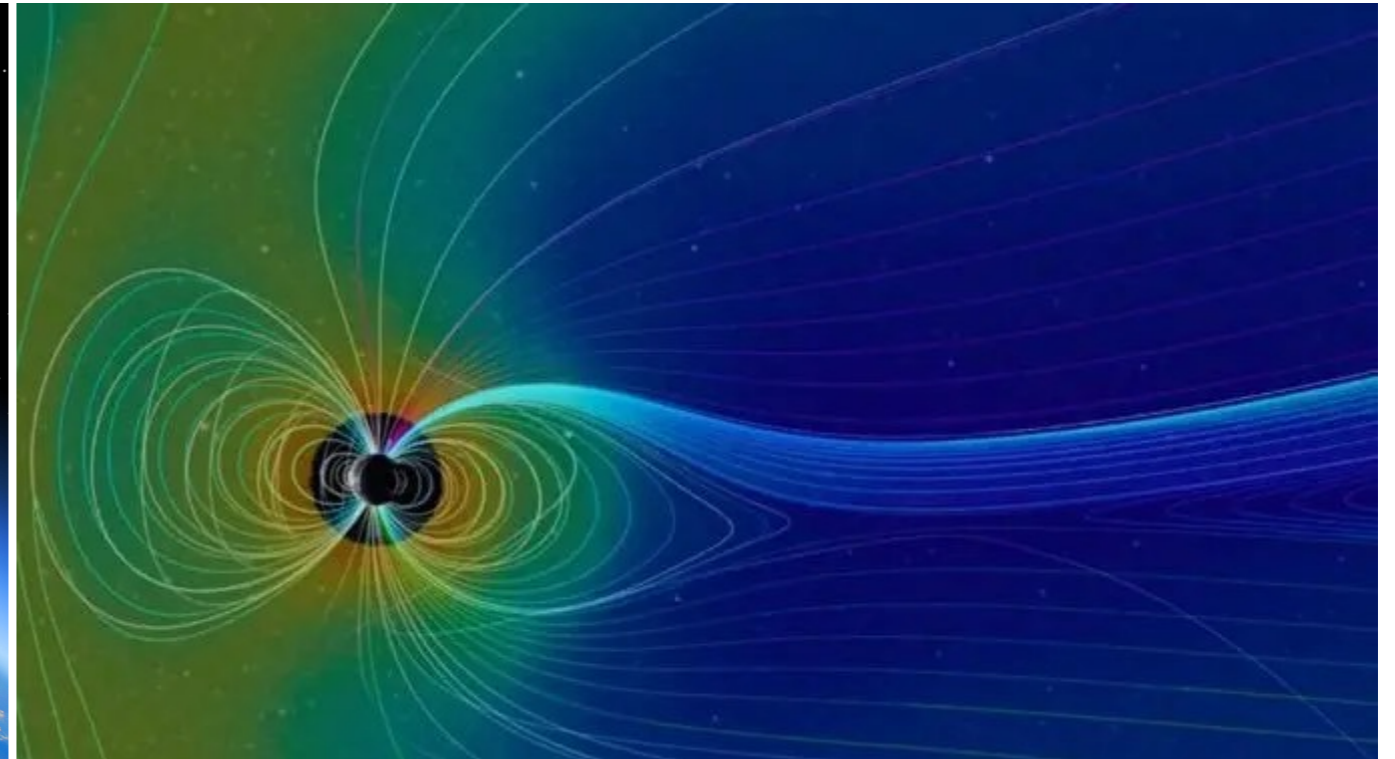


The main source of space weather



Space Weather

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



THE SUN AS A BALL OF ENERGY

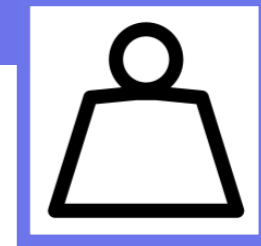
E.M. RADIATION



PLASMA



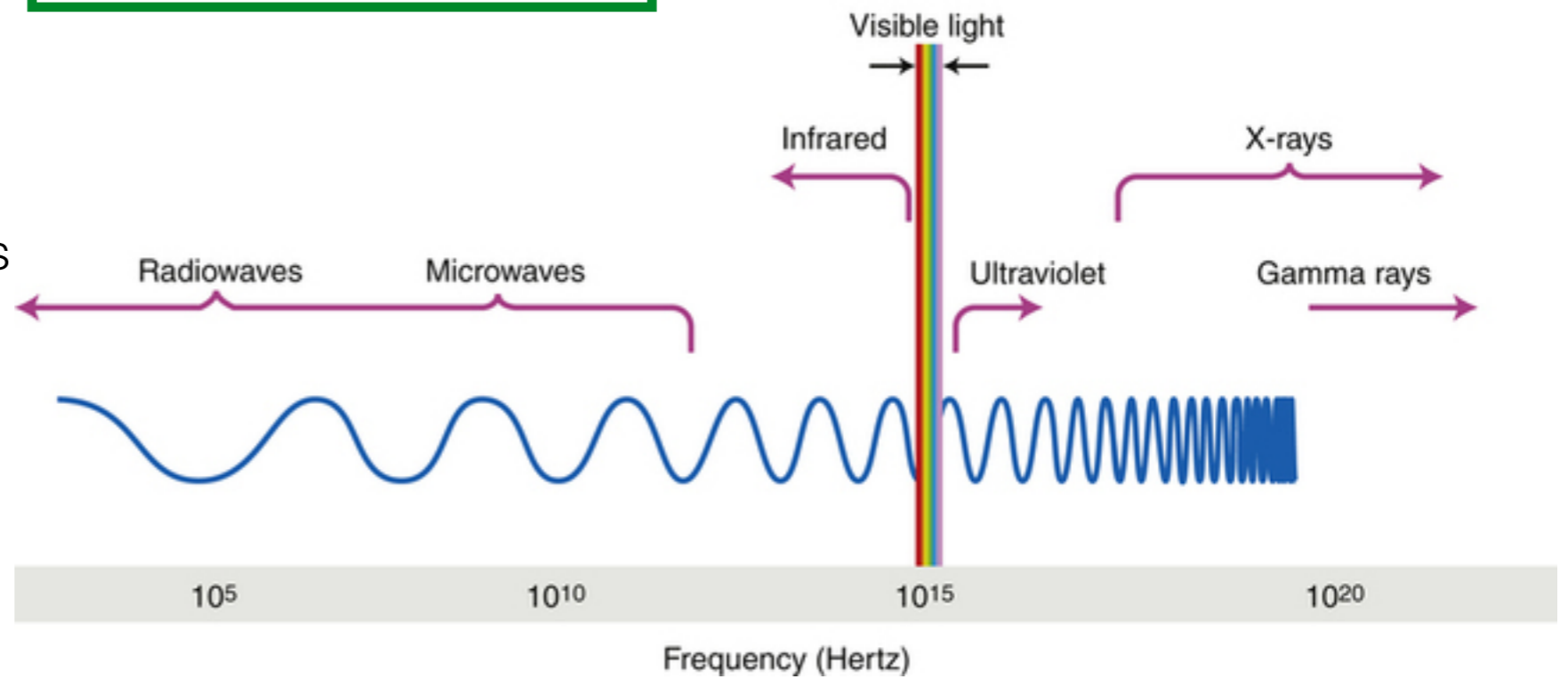
ENERGETIC
PARTICLES



Electromagnetic radiation

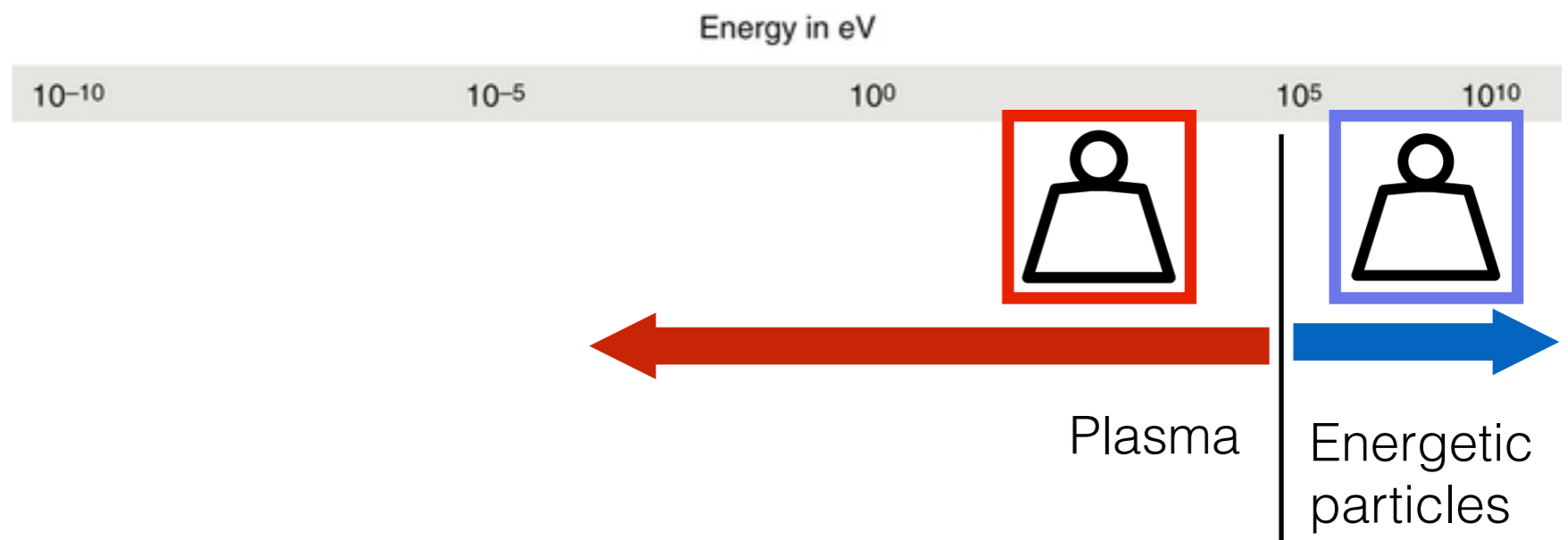


- Photons / electromagnetic waves
- Speed of light



Particles

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



THE SUN AS A BALL OF ENERGY

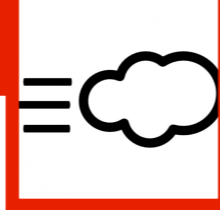
The sun's energy reaches the earth in 3 forms: light, moving gas and particle precipitation. This energy interacts with the magnetosphere and the atmosphere of the earth. This is space weather.

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

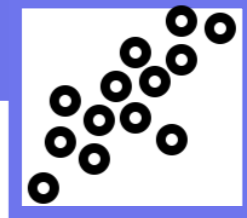
LIGHT



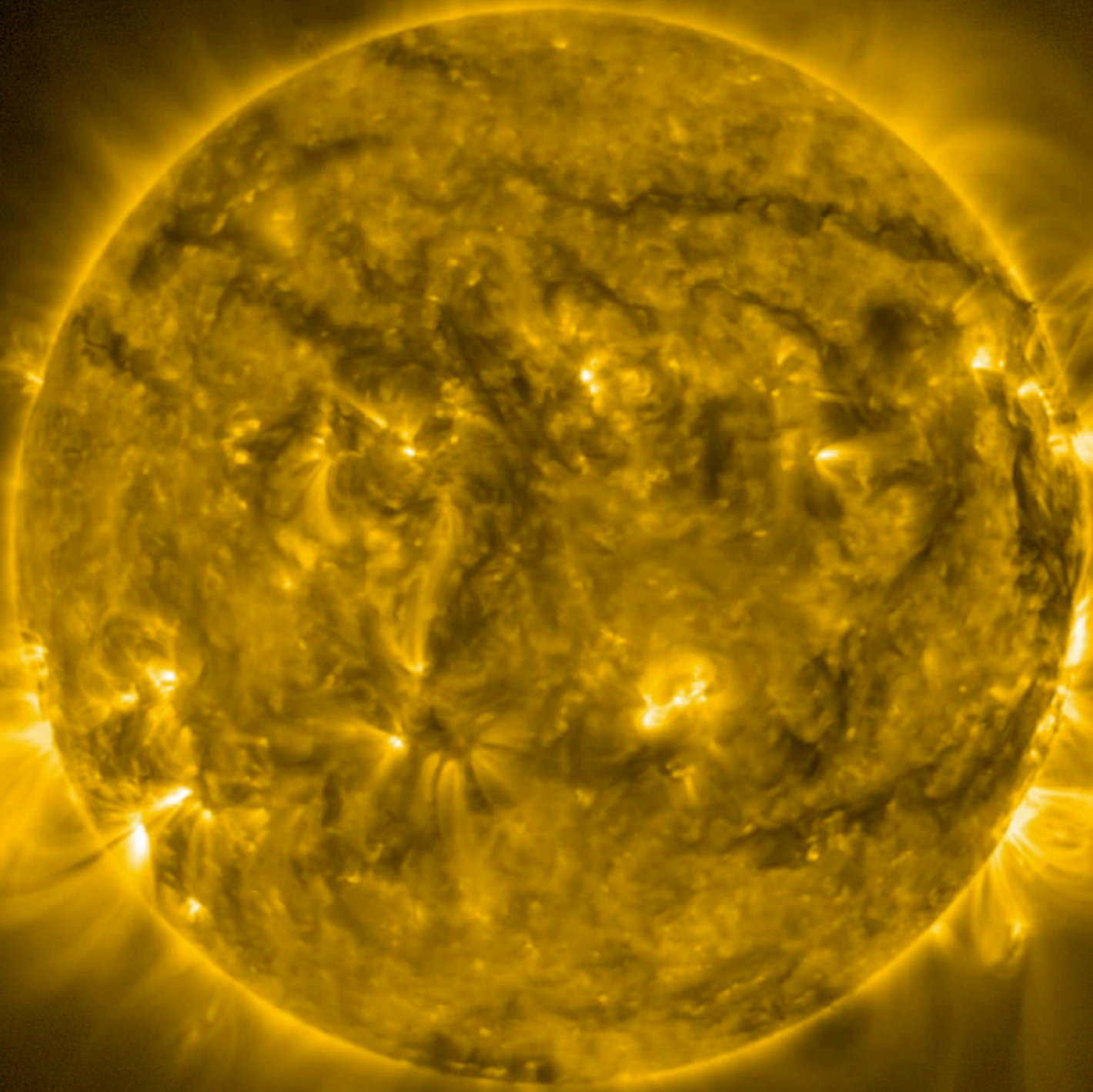
WIND



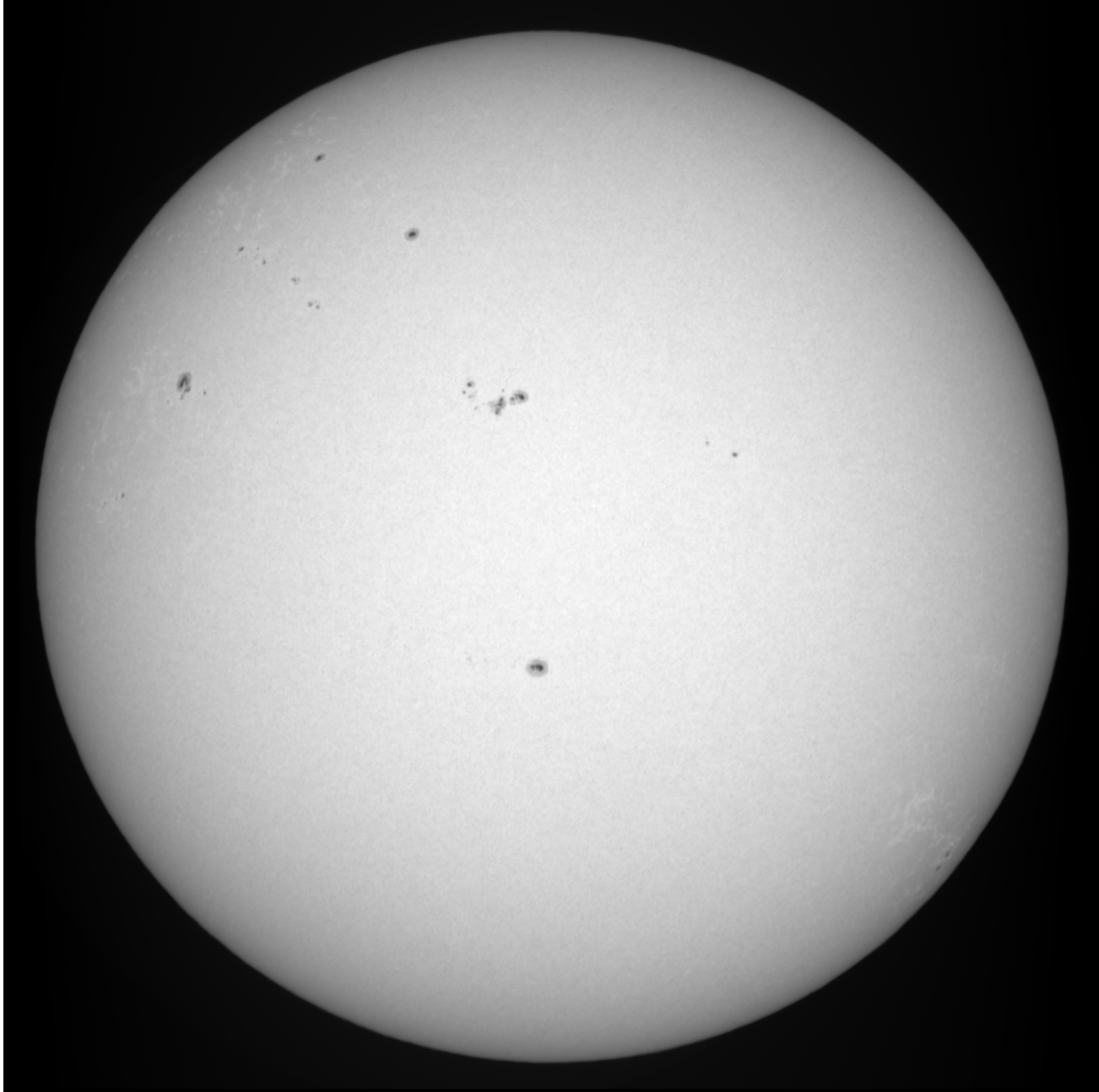
FAST PARTICLES



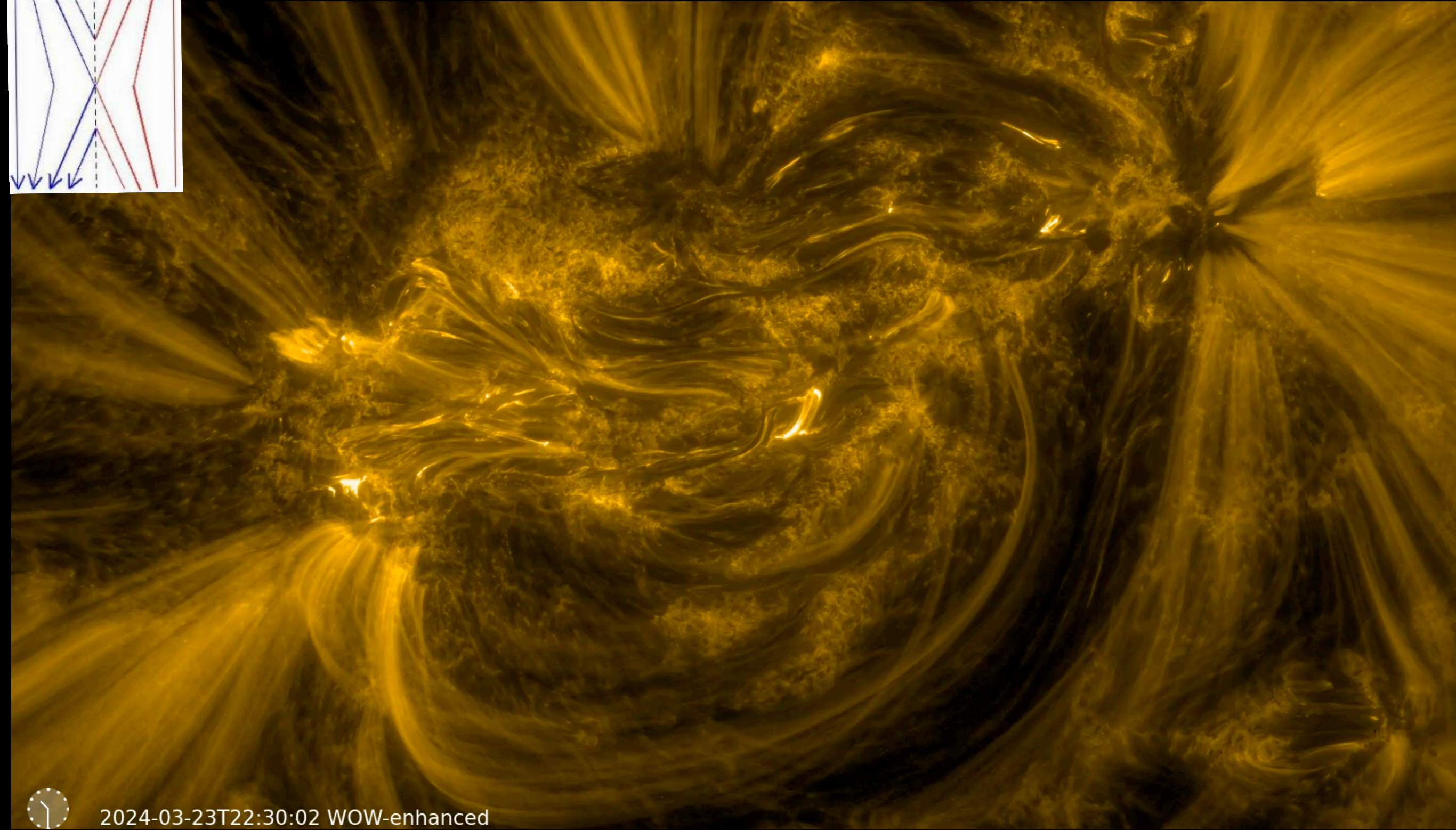
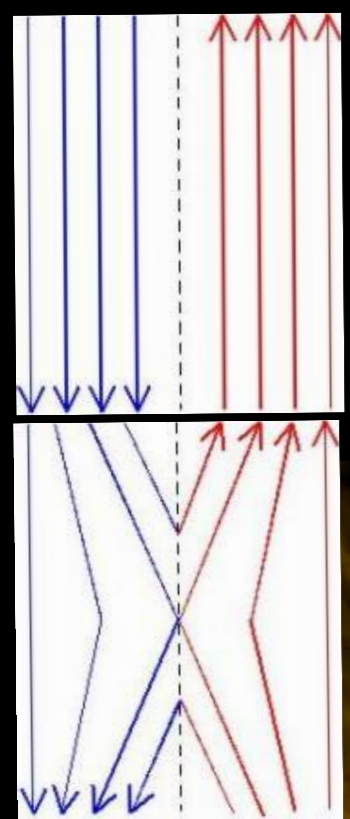
Magnetism drives the sun's dynamics



PROBA2/SWAP

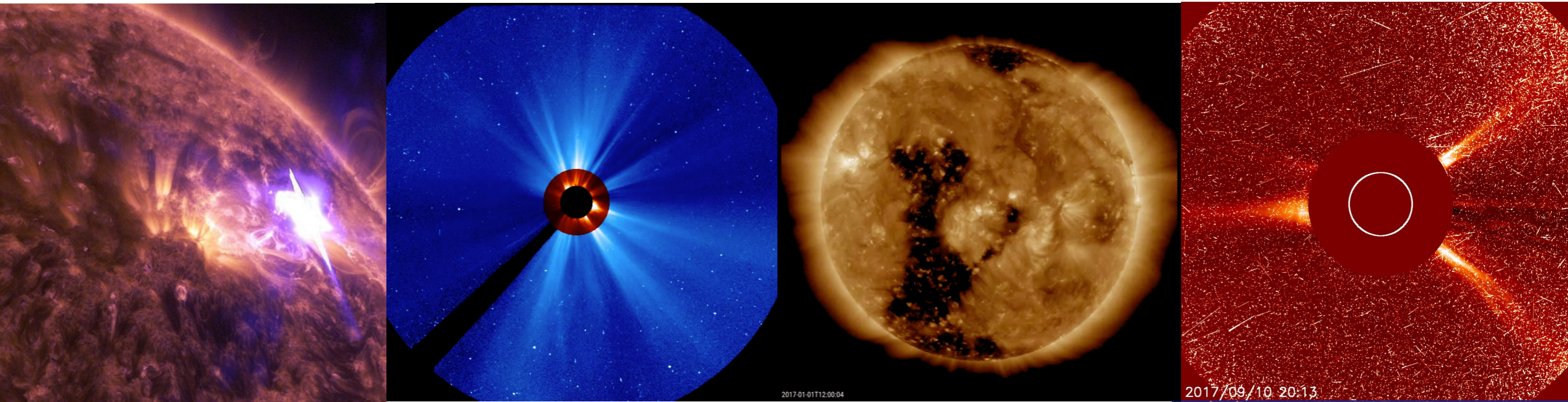
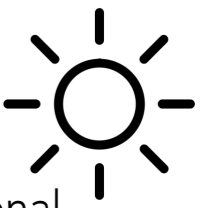


MAGNETIC RECONNECTION



SOLAR WEATHER & STORMS

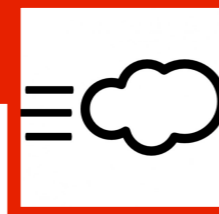
At a certain moment, energy can be released on a shorter time scale. A solar feature like a sunspot, an active region, coronal hole, filament etc. lies at the base of a solar storm in which energy is released. The release of energy might be in an abrupt, impulsive and brutal way (flare, Coronal Mass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



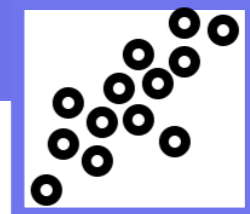
Flare



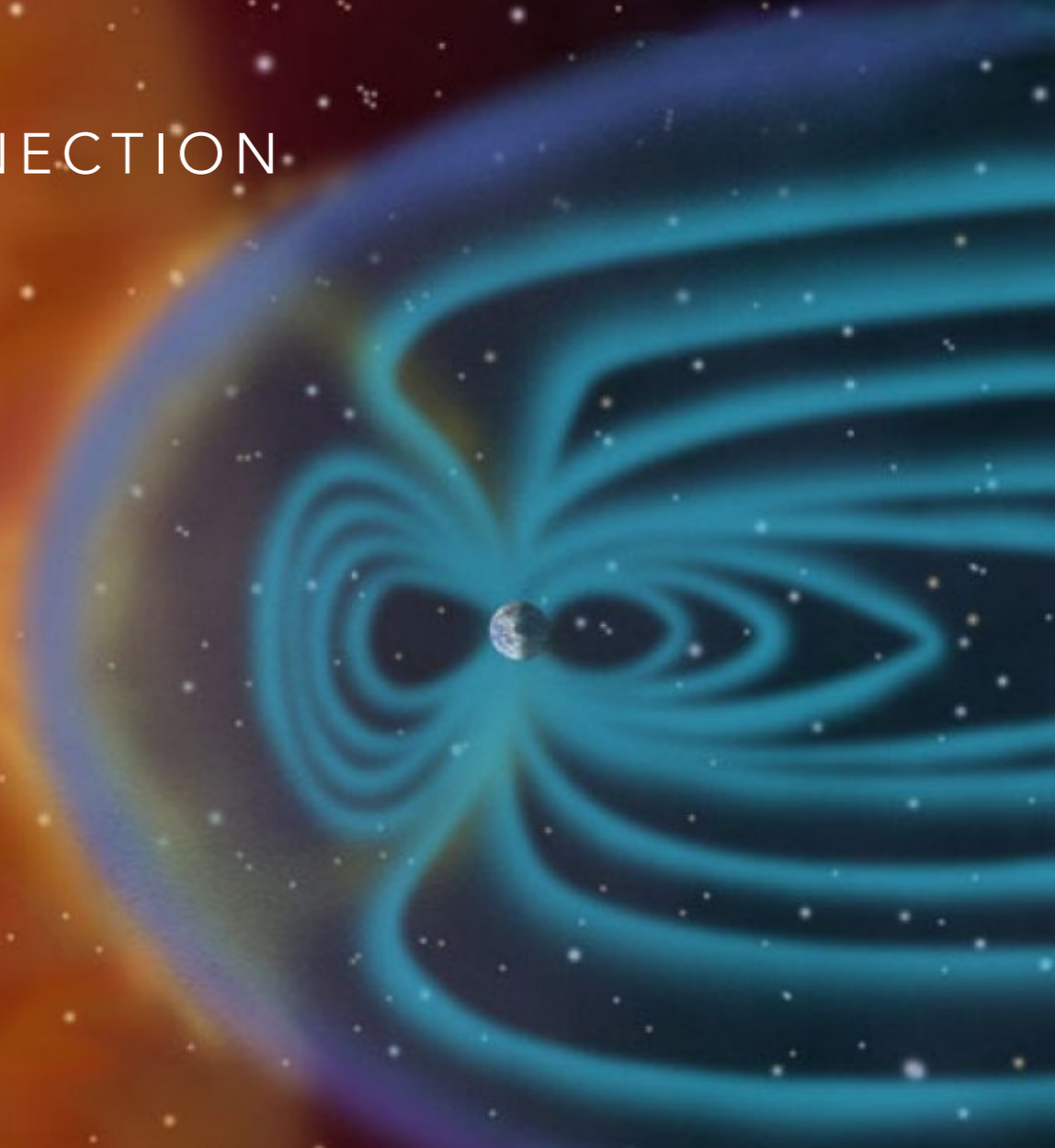
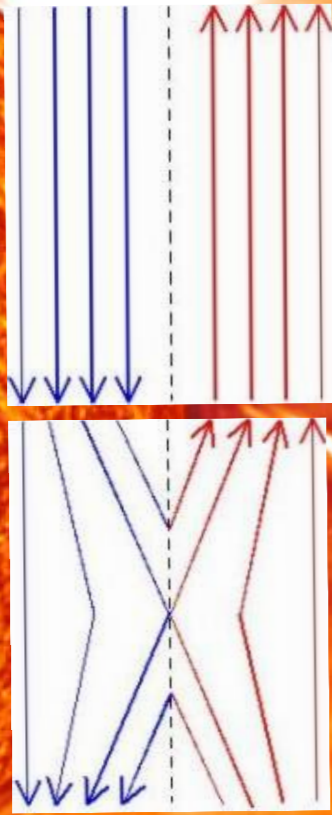
Coronal Mass Ejection
High Speed Stream



Energetic Particles



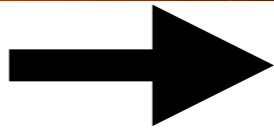
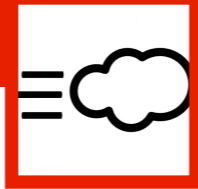
MAGNETIC RECONNECTION



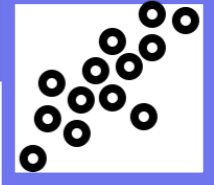
Flare

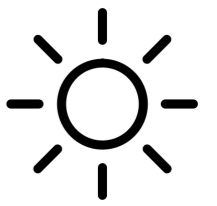


Coronal Mass Ejection



Energetic Particles

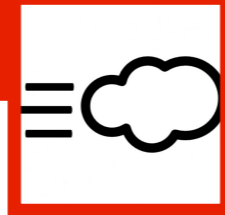




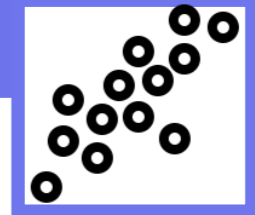
e.m. radiation
FLARE

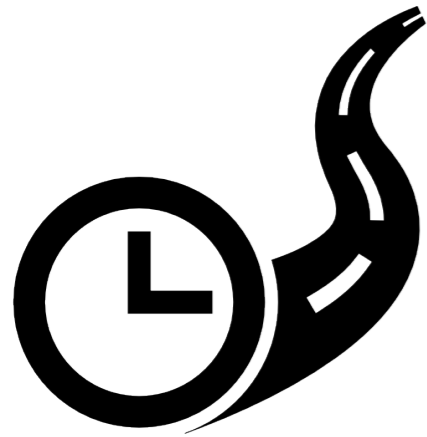


Solar wind
CME - HSS



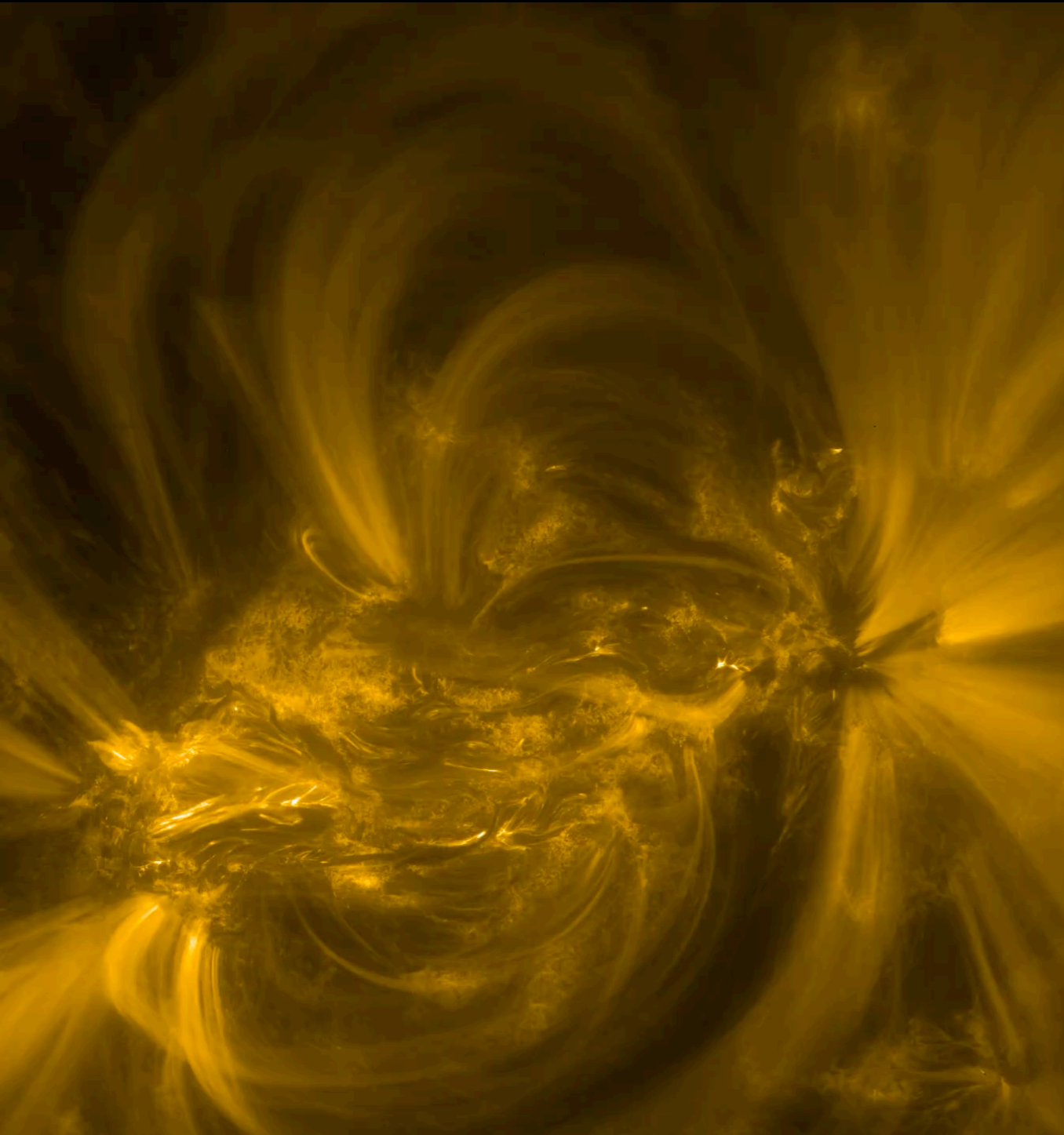
Energetic Particles



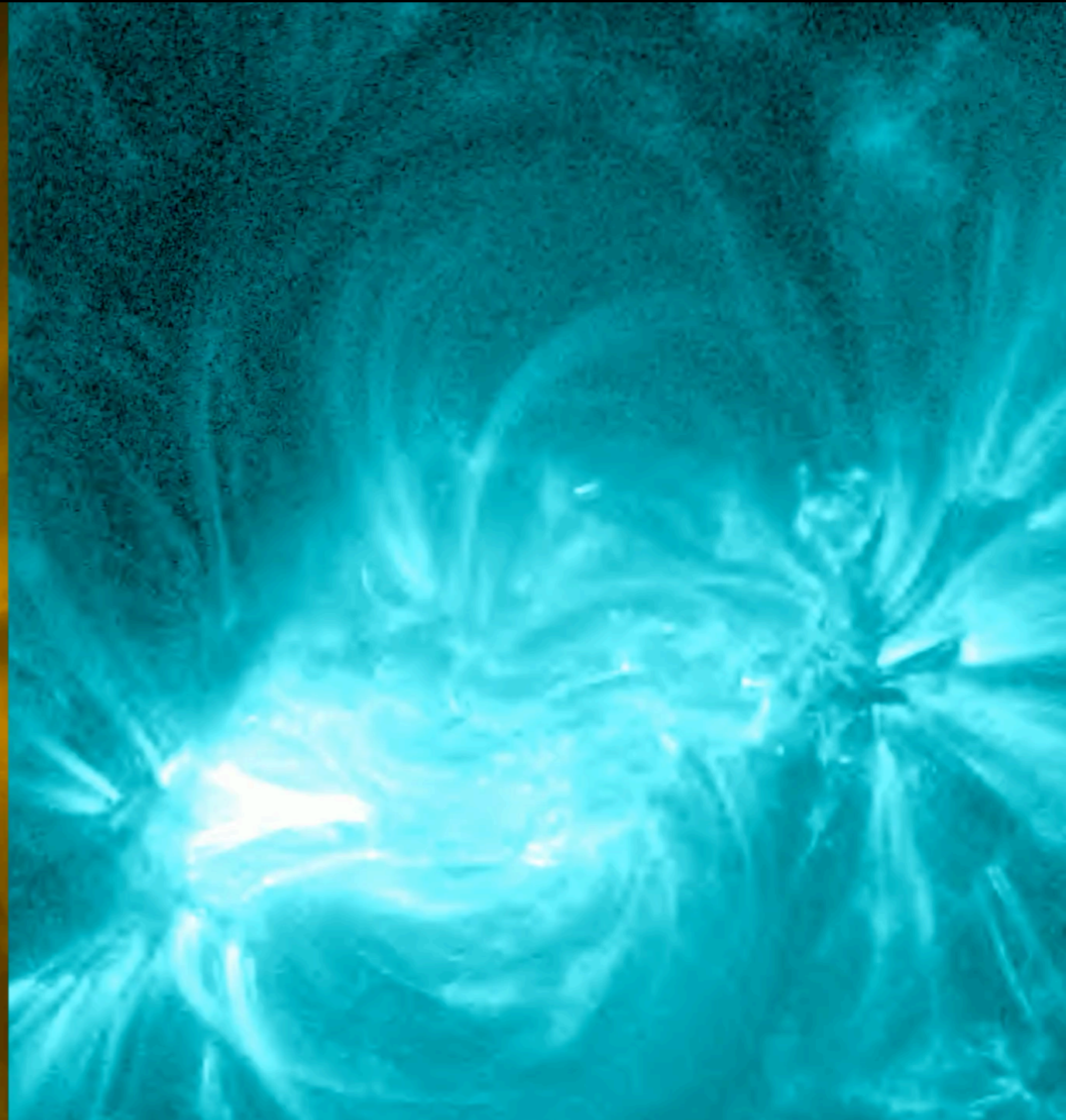




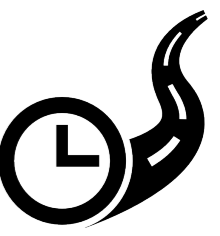
A flare is a light flash near an active region. A volume of plasma is suddenly heated and therefore lights up.



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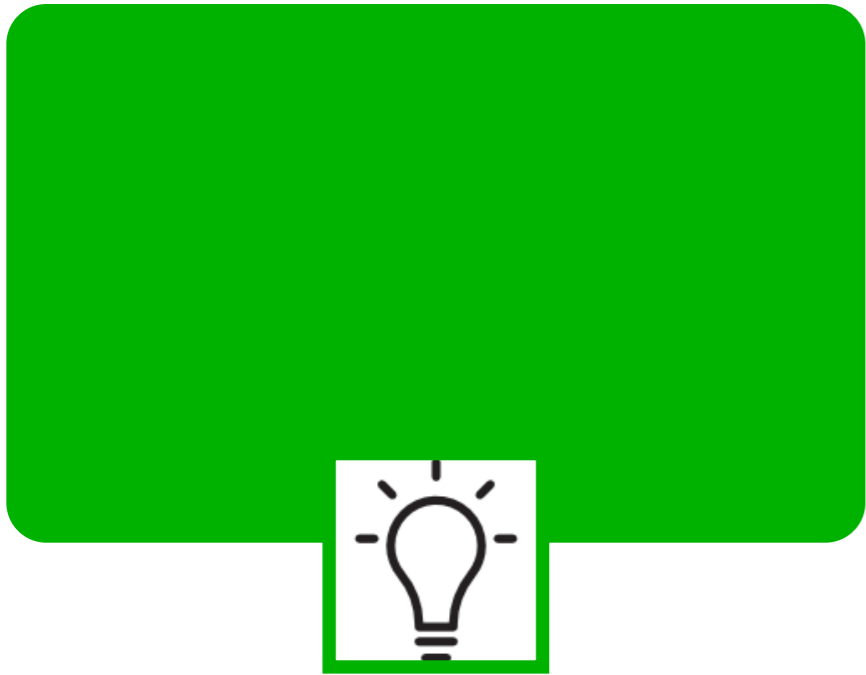


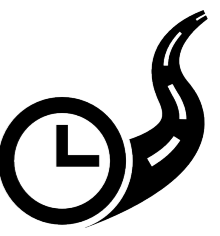
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AU TRANSIT TIME

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





AU TRANSIT TIME

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

8 MIN



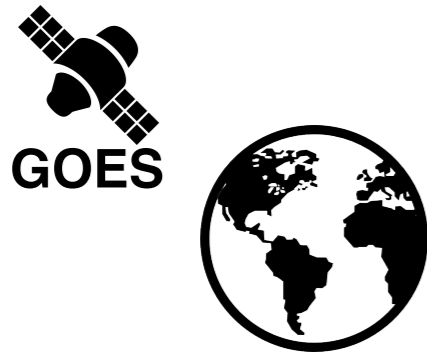
STORM SCALE



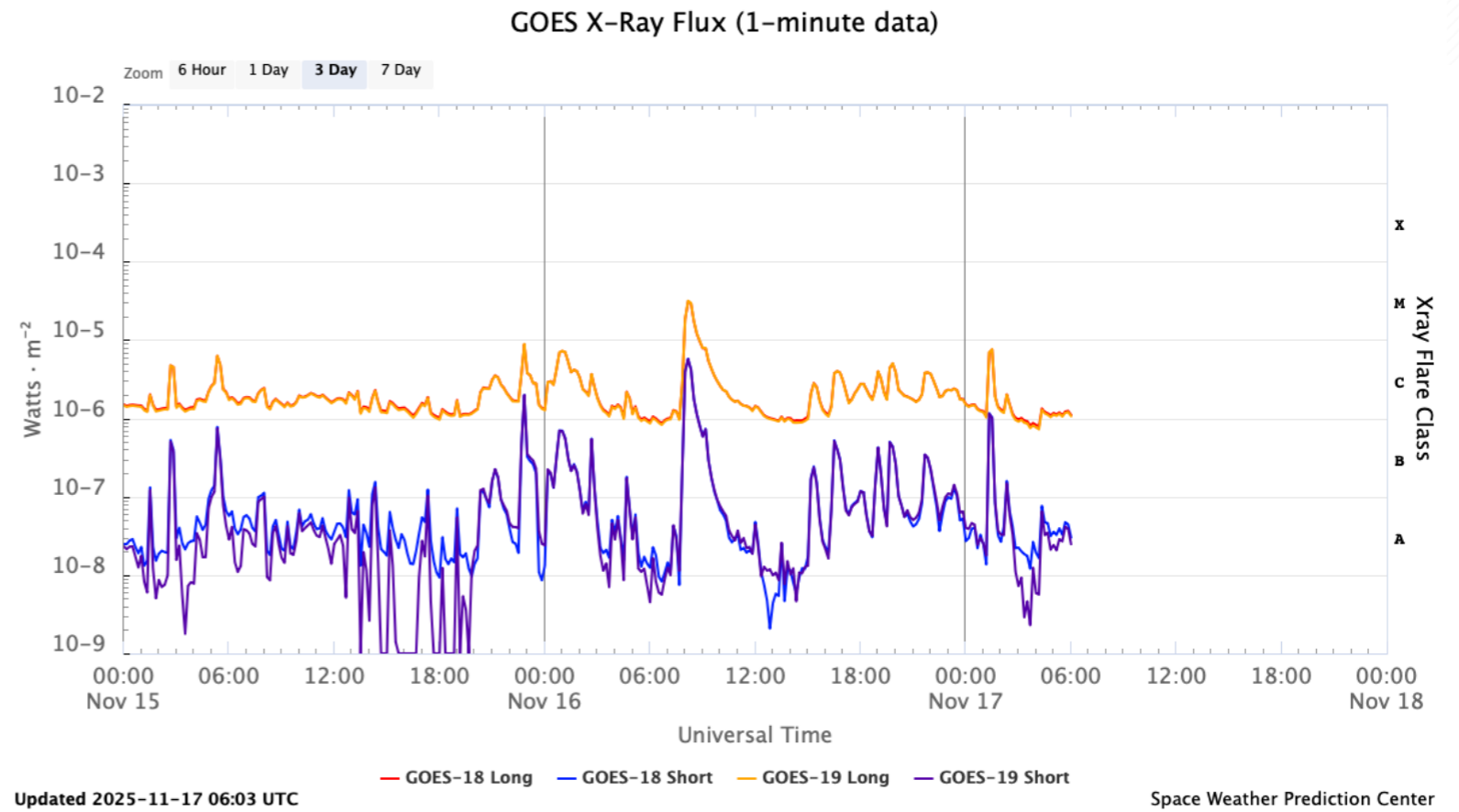
<https://www.swpc.noaa.gov/products/goes-x-ray-flux>



STORM SCALE



A,B,C,M,X



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



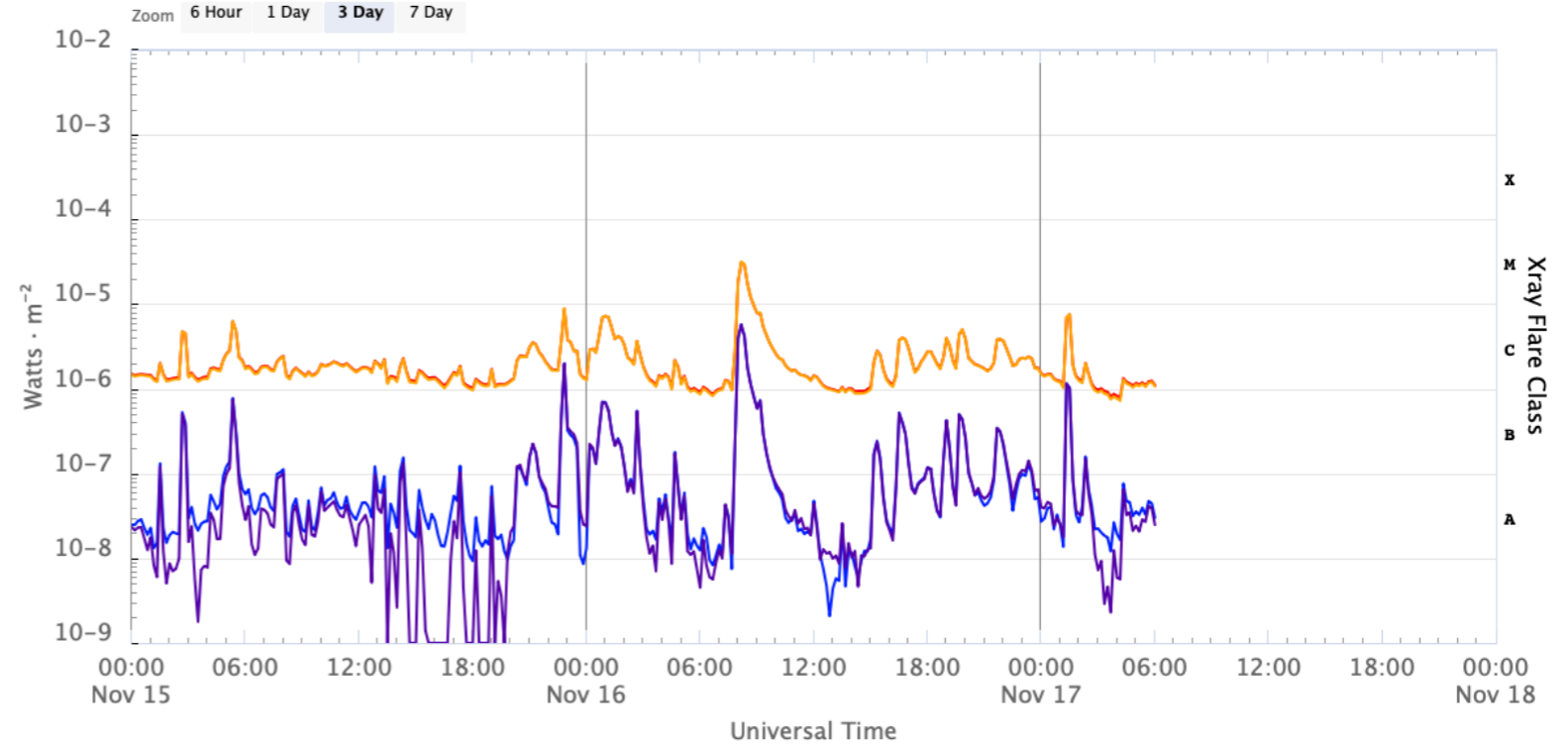
DURATION



MINs to HOUR



GOES X-Ray Flux (1-minute data)



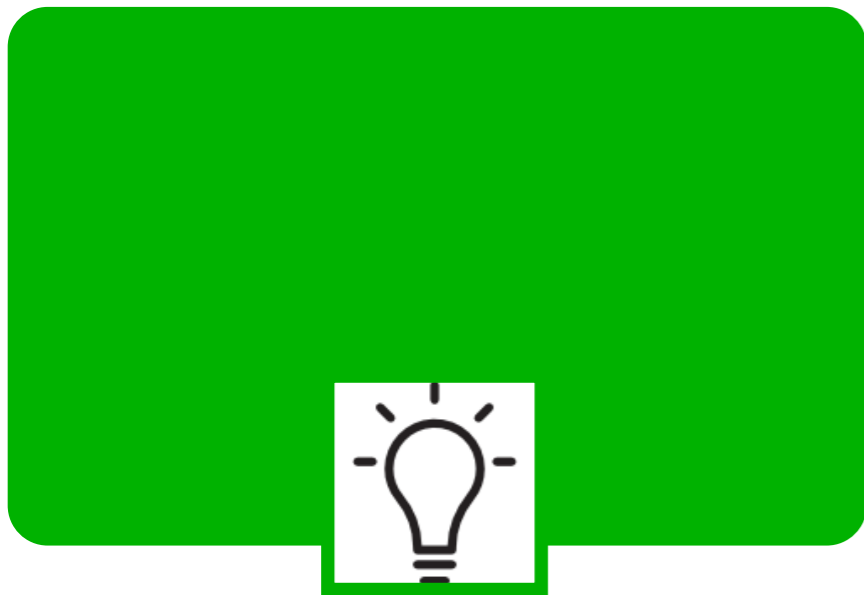
Updated 2025-11-17 06:03 UTC

— GOES-18 Long — GOES-18 Short — GOES-19 Long — GOES-19 Short

Space Weather Prediction Center



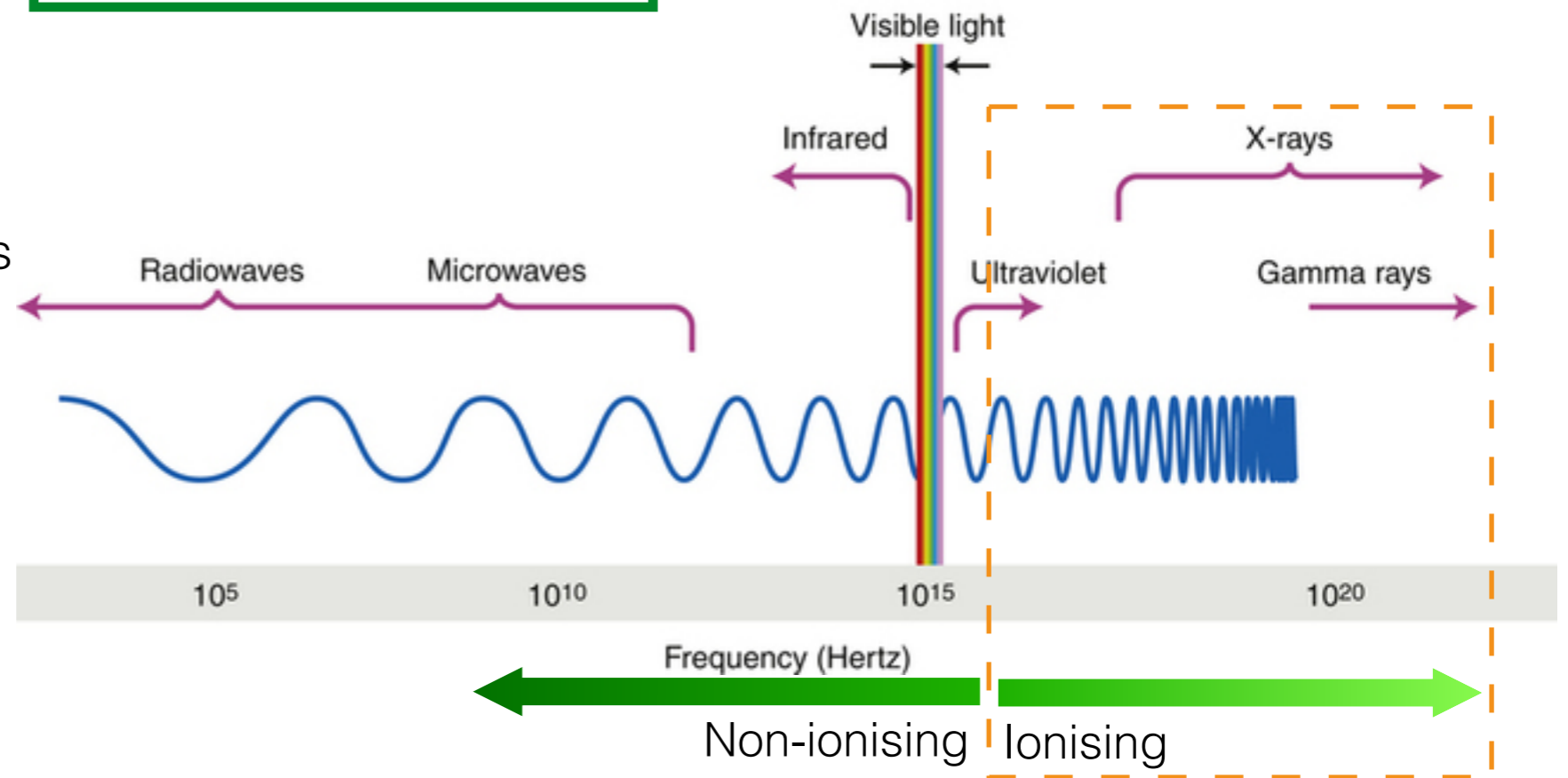
IMPACT



Electromagnetic radiation



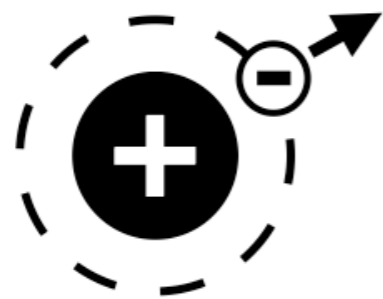
- Photons / electromagnetic waves
- Speed of light



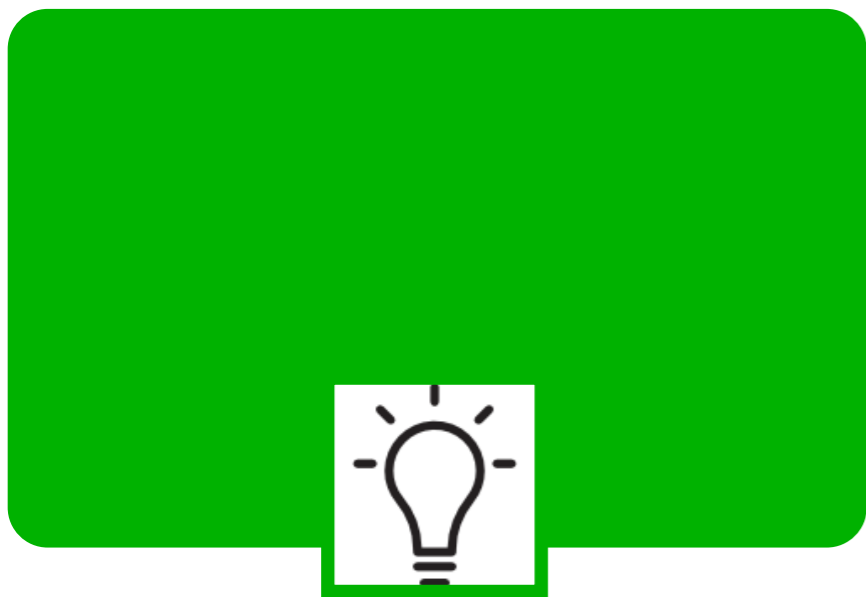
IMPACT



Ionisation



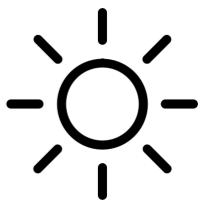
AREA OF IMPACT



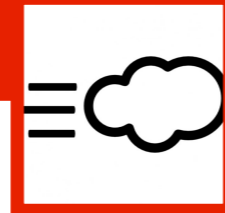
AREA OF IMPACT

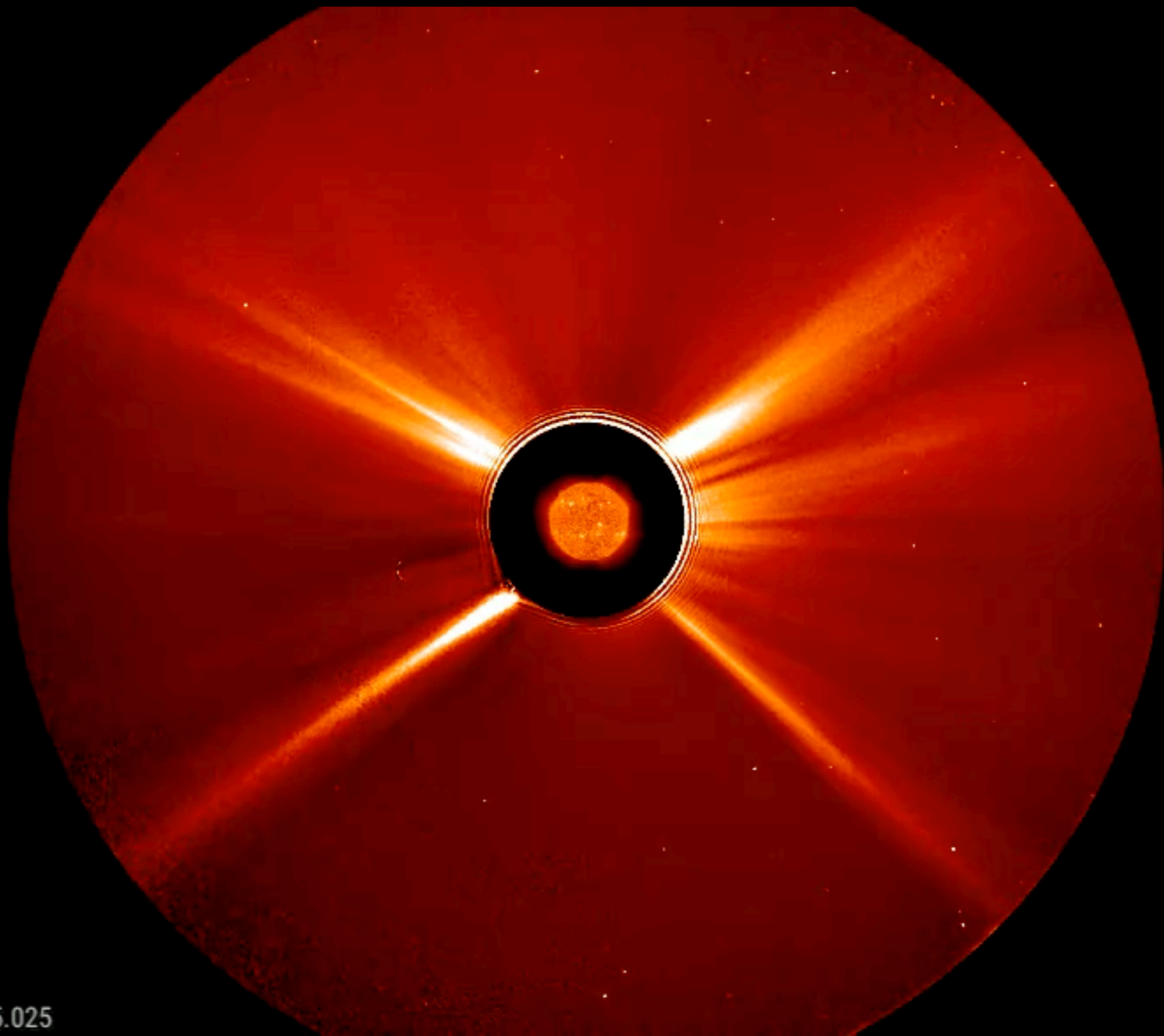
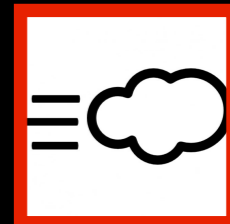
Illuminated area





Solar wind
CME - HSS





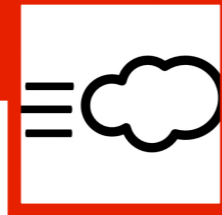
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AU TRANSIT TIME

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





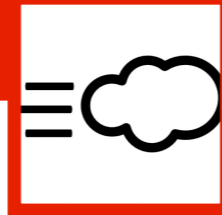
AU TRANSIT TIME

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.

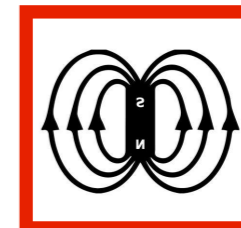
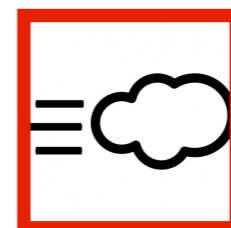
8 MIN



DAYS



STORM SCALE - GEOMAGNETIC STORM

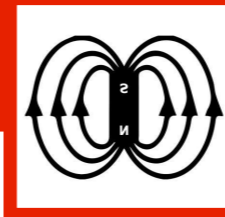
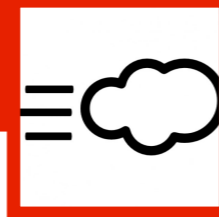


STORM SCALE



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

A,B,C,M,X

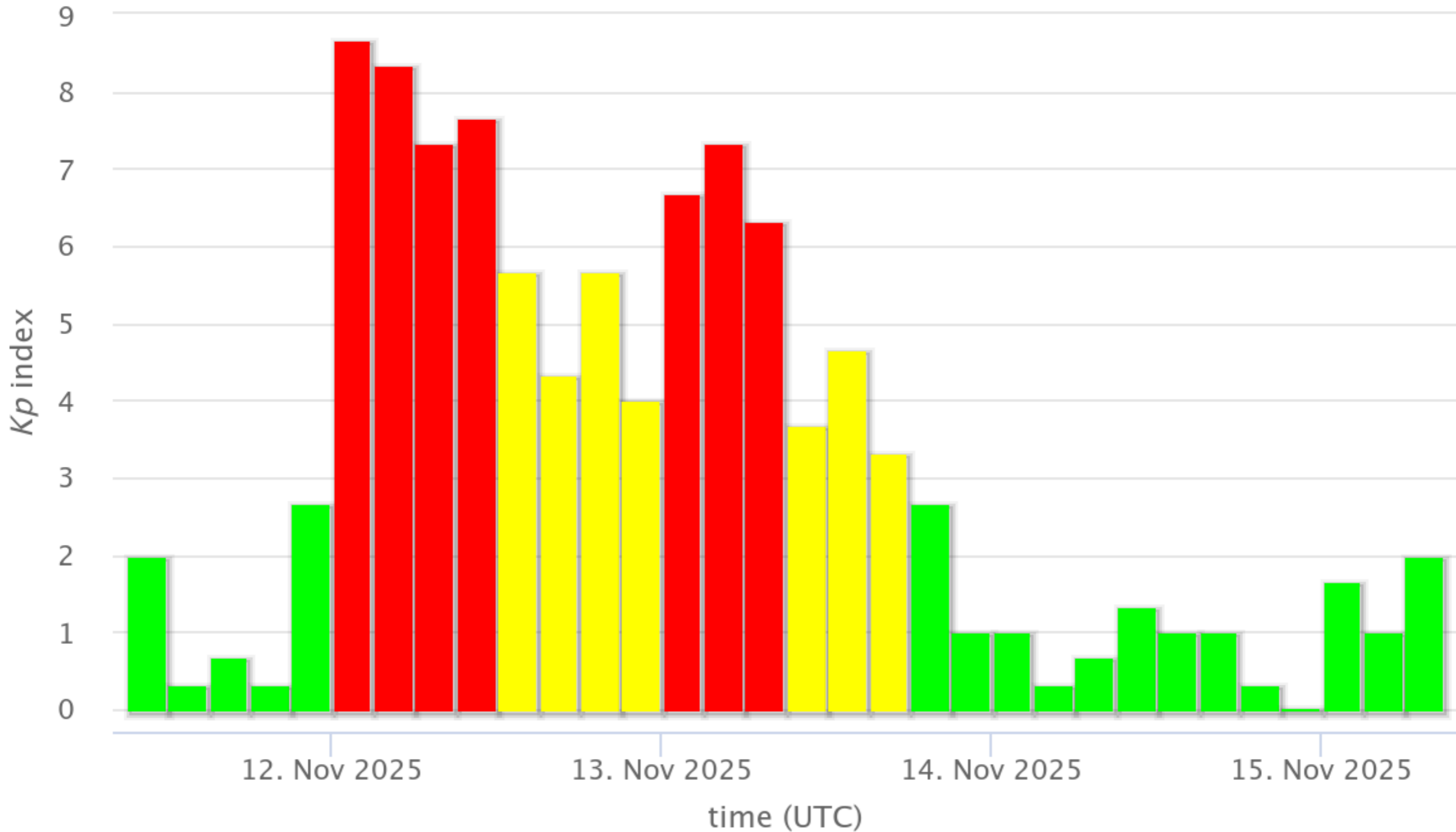


STORM SCALE



Most recent geomagnetic storm with Kp index > 6

GFZ Helmholtz Centre for Geosciences (CC BY 4.0)

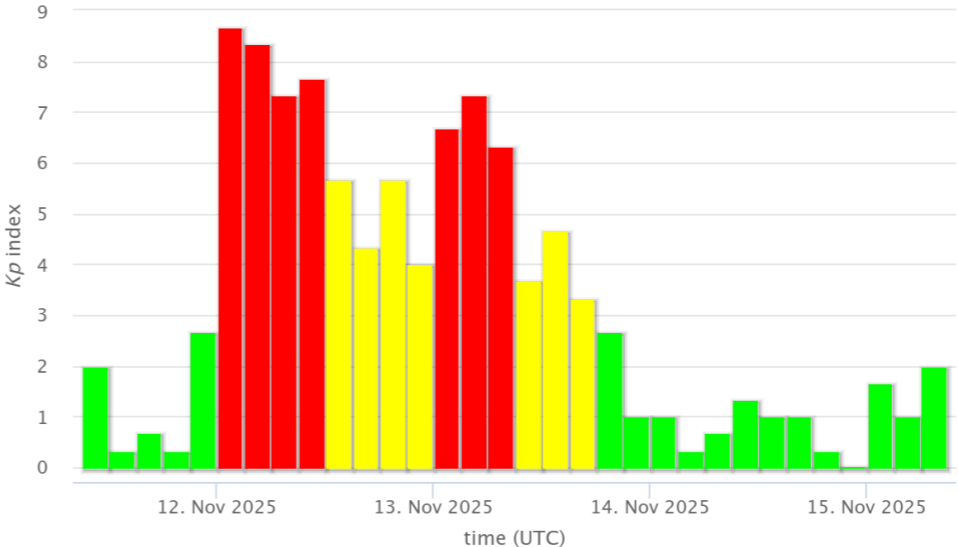


STORM SCALE



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

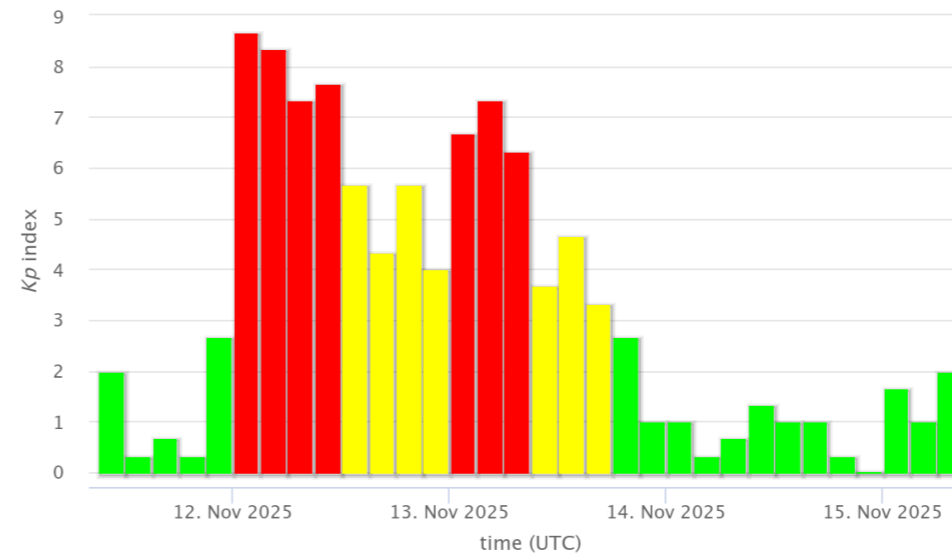


DURATION



Most recent geomagnetic storm with Kp index > 6

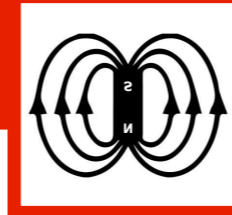
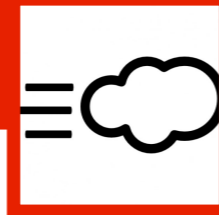
GFZ Helmholtz Centre for Geosciences (CC BY 4.0)



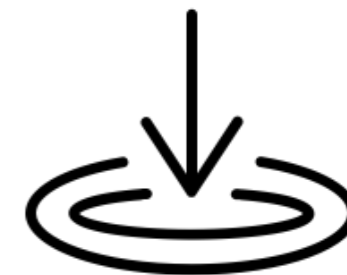
MINs to HOUR



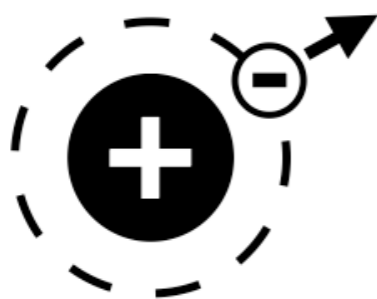
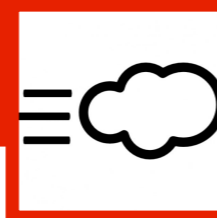
DAY+

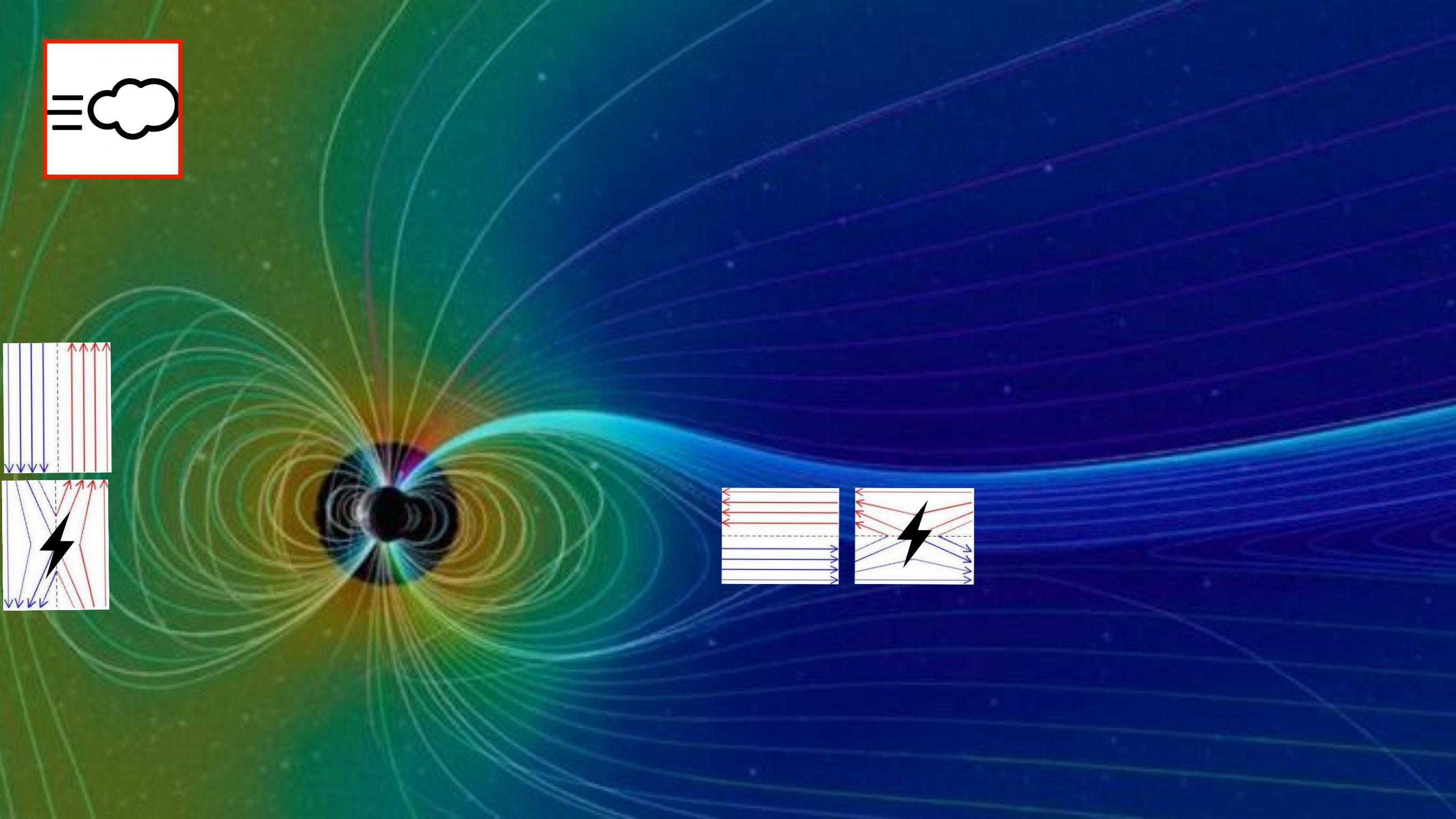
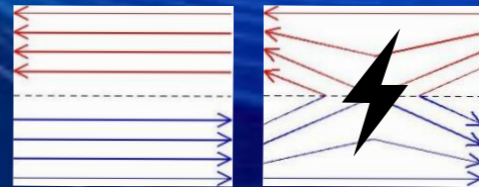
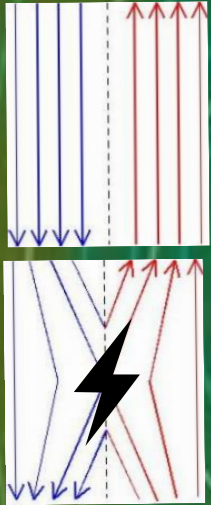


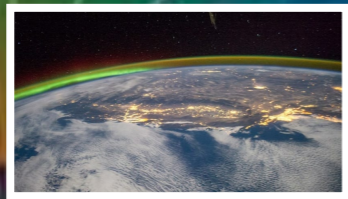
IMPACT



Ionisation

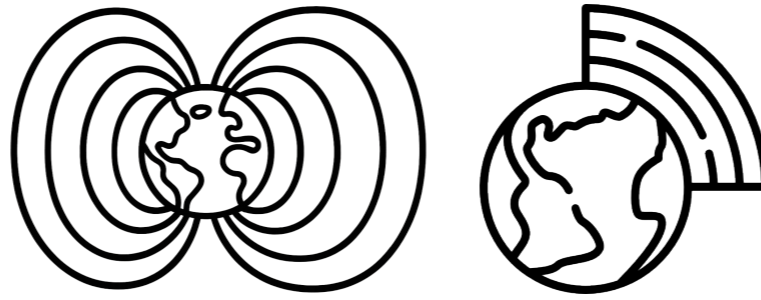




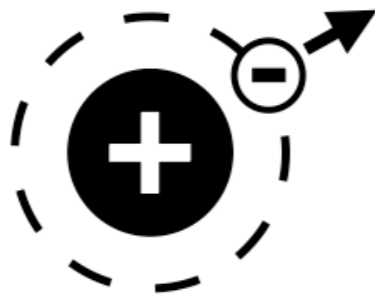


MAGNETOSPHERE - IONOSPHERE COUPLING

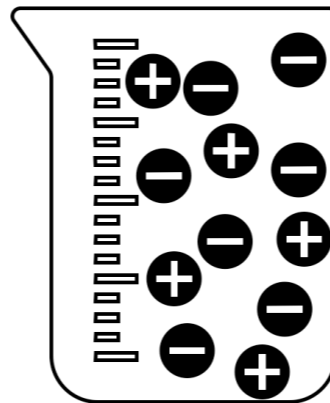
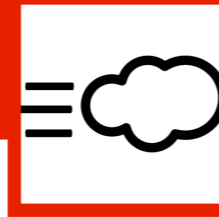
IMPACT



Ionisation



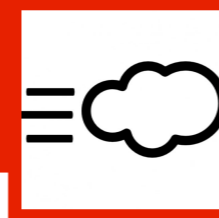
Particle content changes



AREA OF IMPACT



Illuminated area



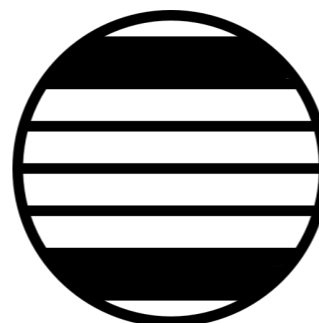
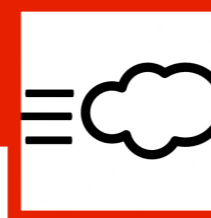
AREA OF IMPACT

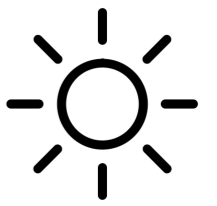


Illuminated area

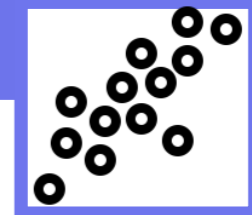


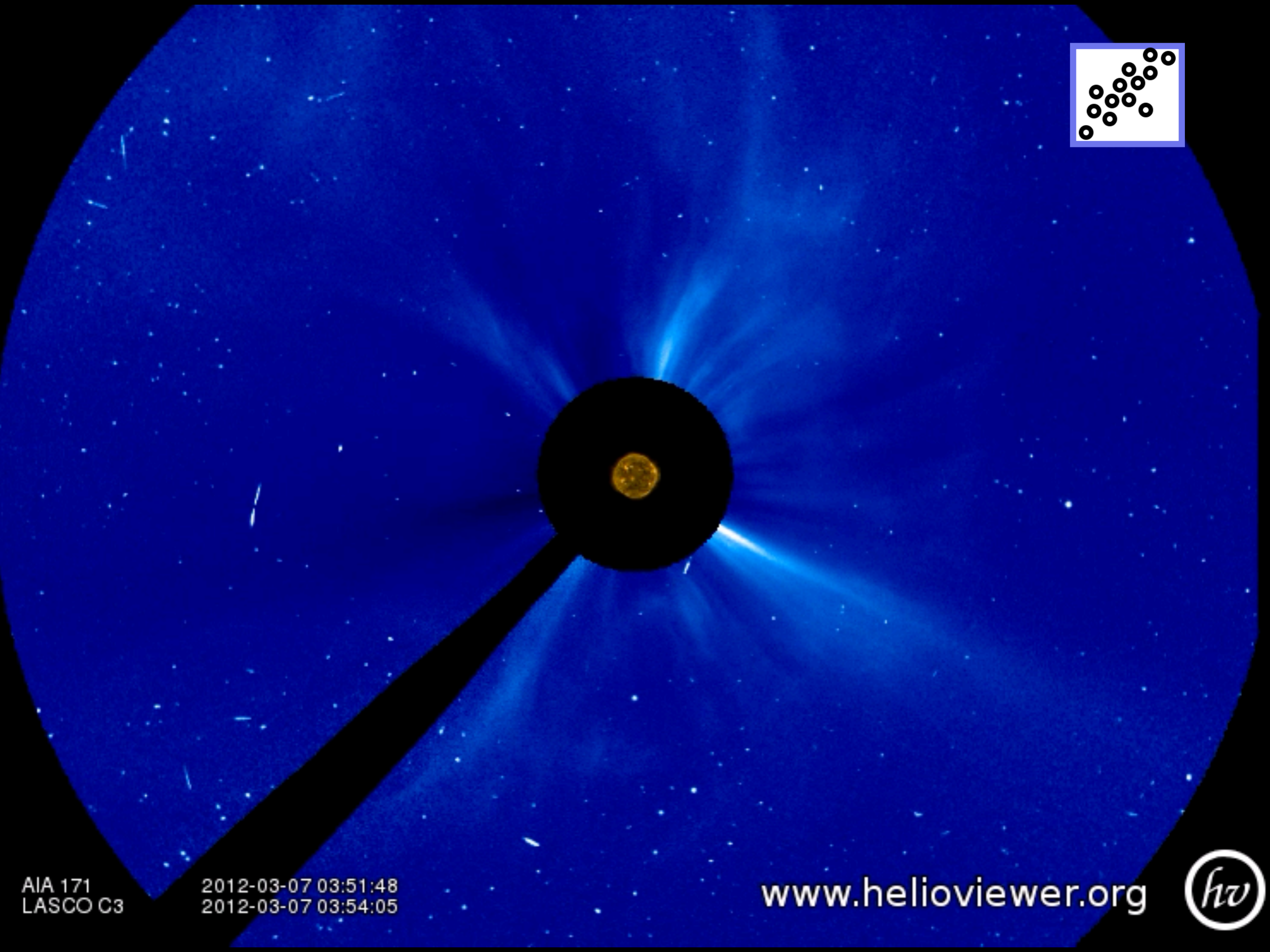
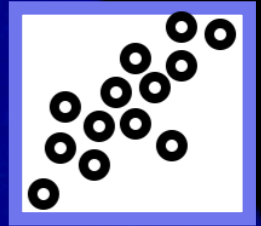
Auroral Oval & more Latitude





Energetic Particles



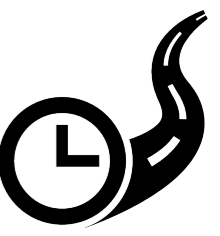


AIA 171
LASCO C3

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www.helioviewer.org





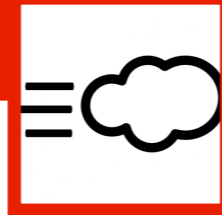
AU TRANSIT TIME

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





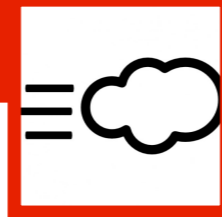
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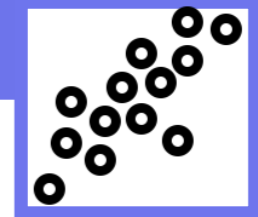
8 MIN



DAYS



HOUR



STORM SCALE

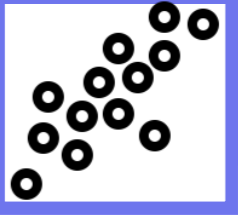



<https://www.swpc.noaa.gov/products/goes-proton-flux>

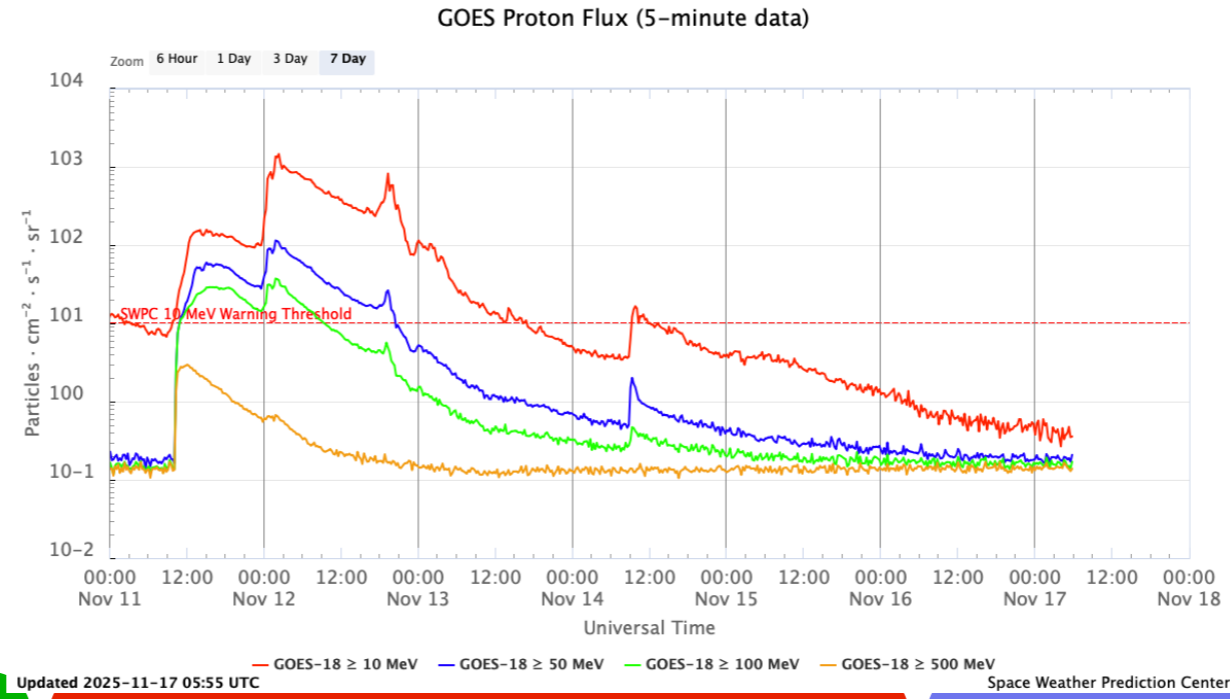
A,B,C,M,X



Kp
0 - 9



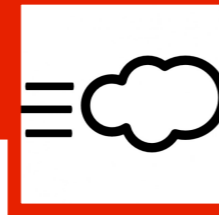
STORM SCALE



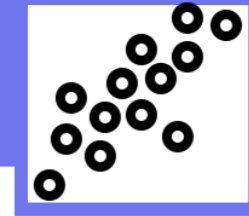
A,B,C,M,X



Kp
0 - 9



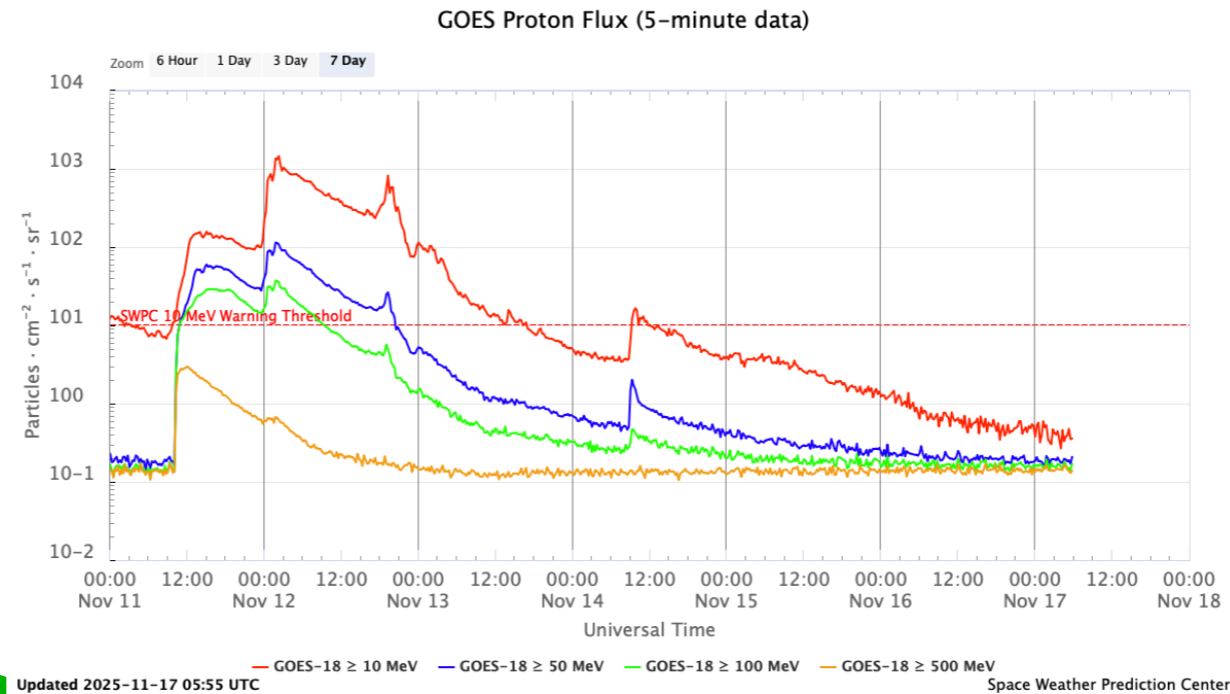
Storm - major storm



GOES



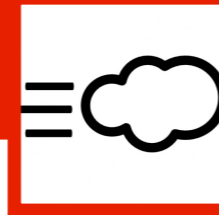
DURATION



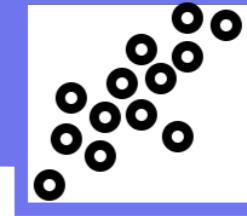
MINs to HOUR



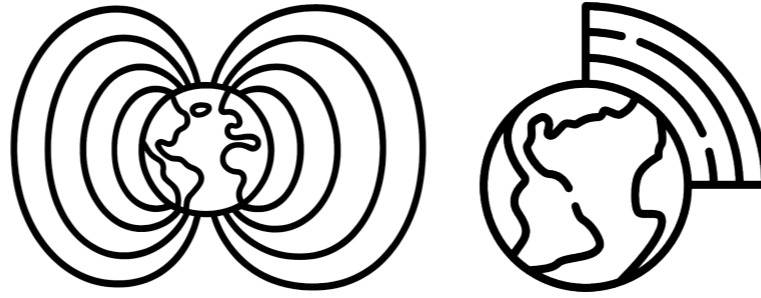
DAY+



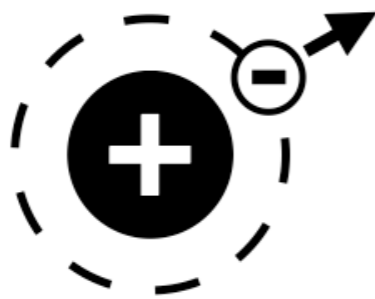
HOURS to DAYS



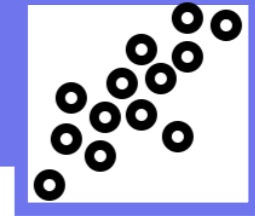
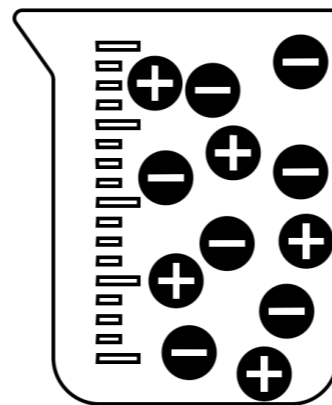
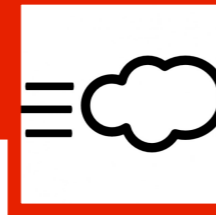
IMPACT



Ionisation



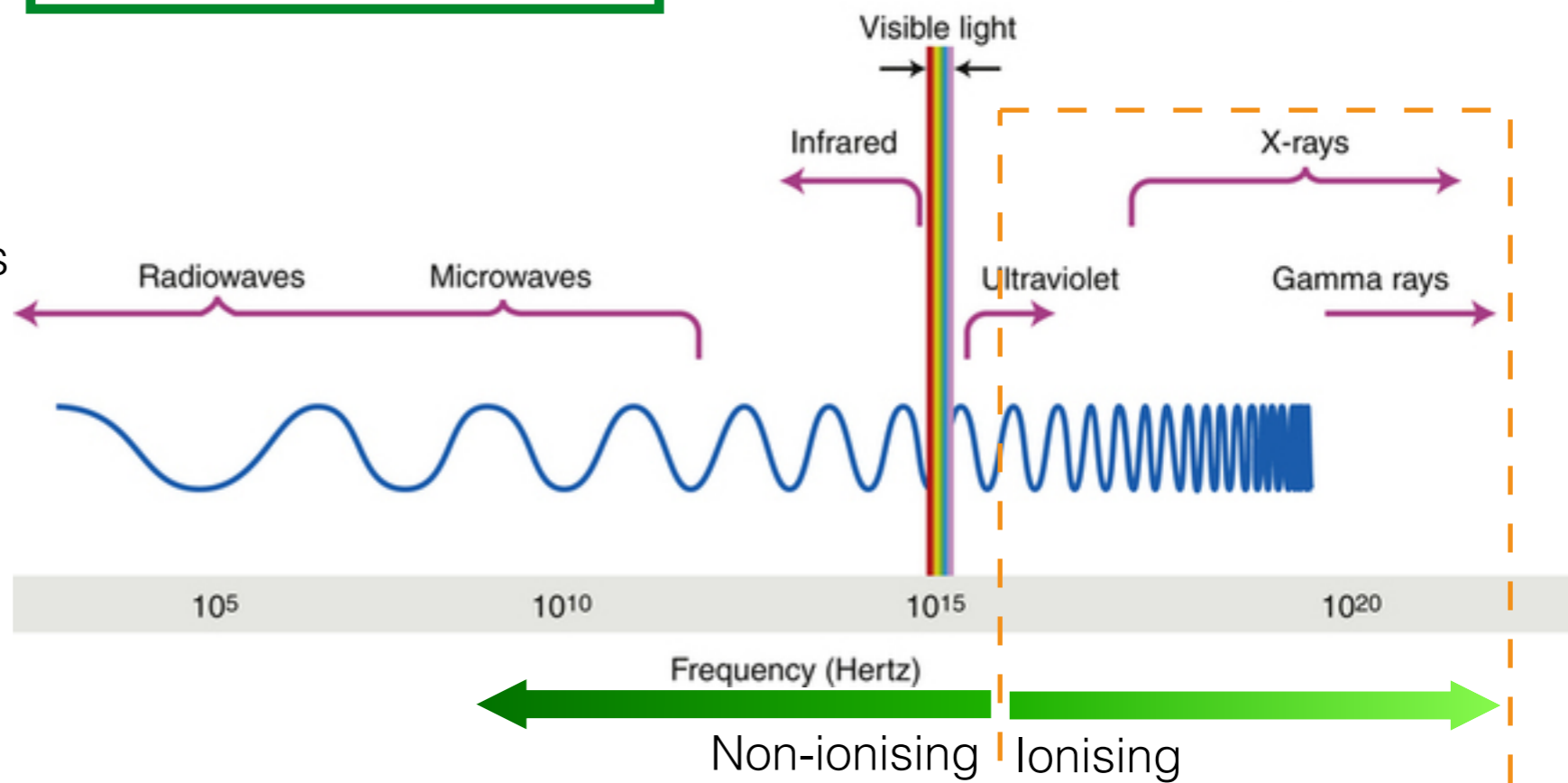
Inflow/depletion
Running electrons



Electromagnetic radiation

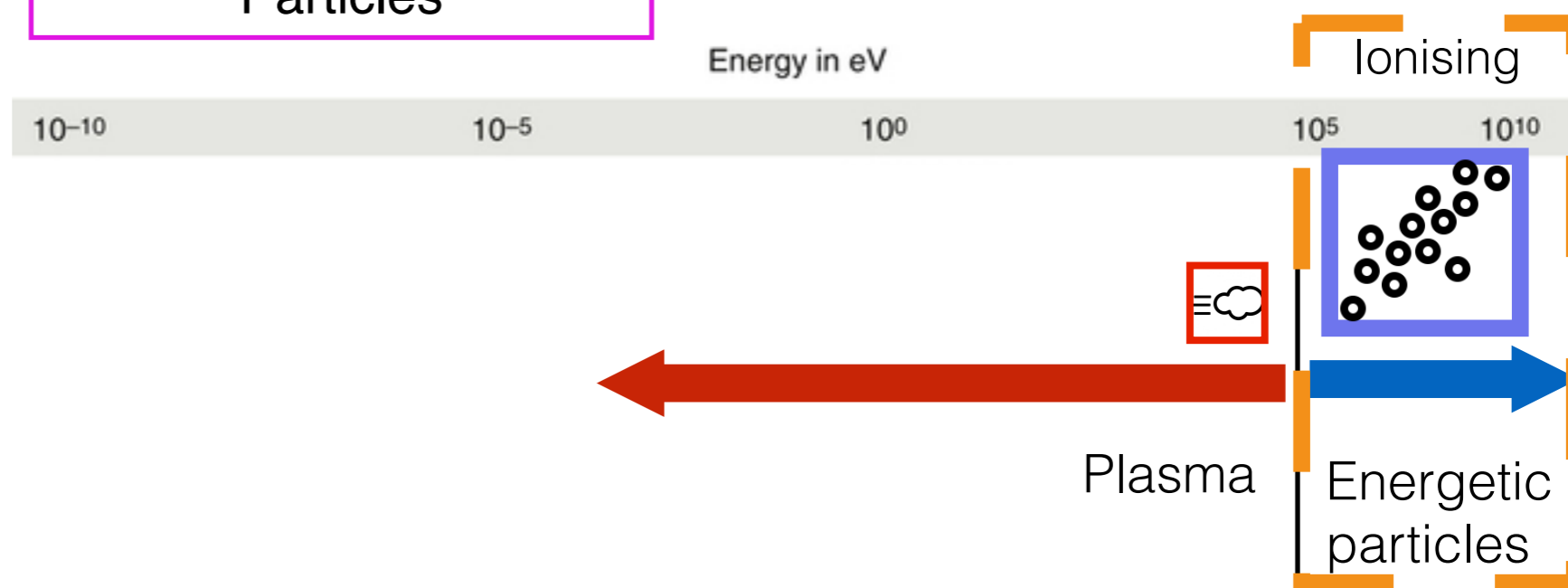


- Photons / electromagnetic waves
- Speed of light

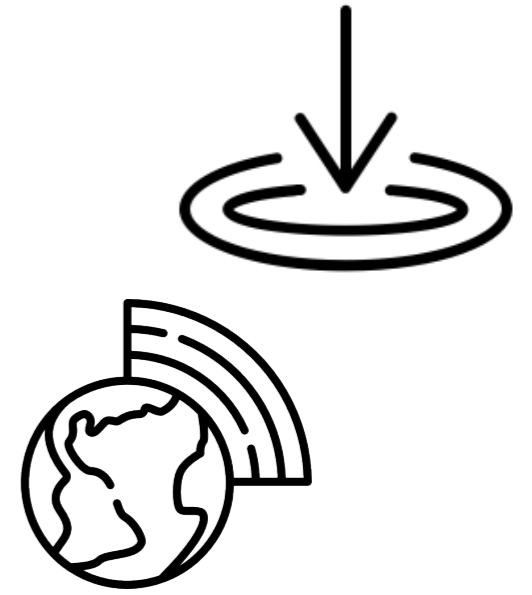
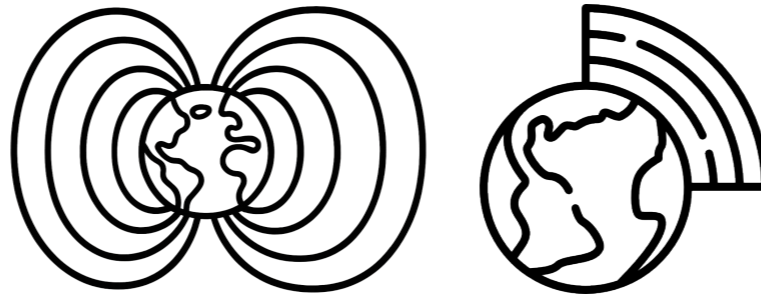


Particles

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



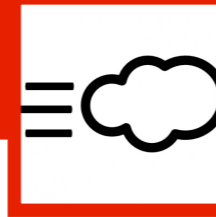
IMPACT



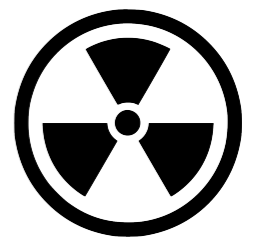
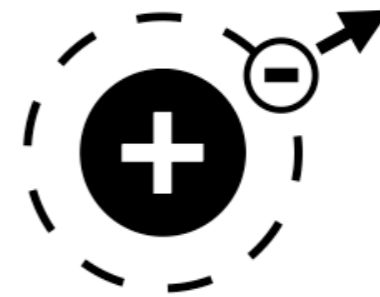
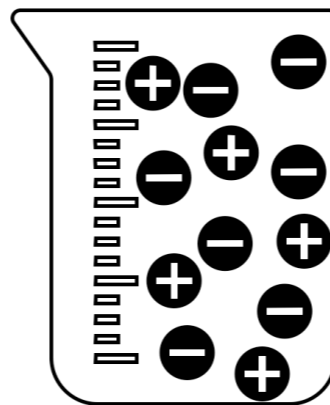
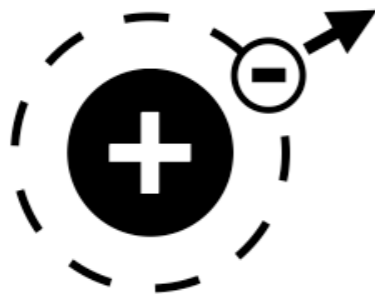
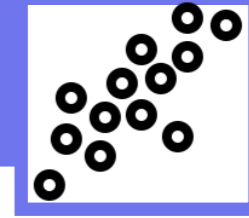
Ionisation



Particle content changes



Ionisation
Particle Radiation



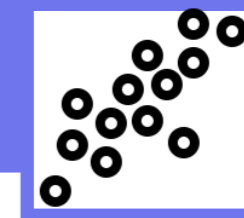
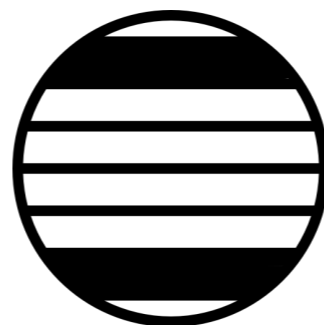
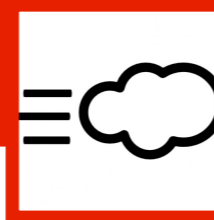
AREA OF IMPACT



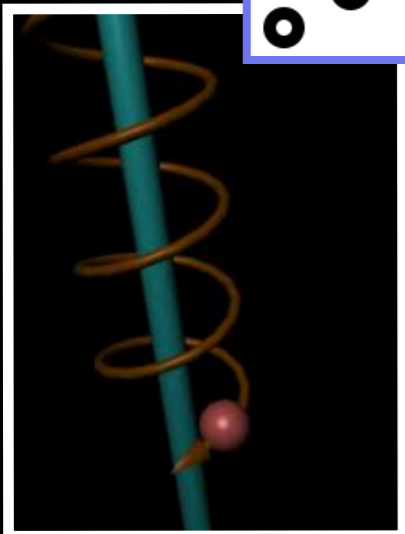
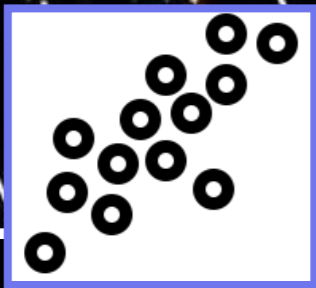
Illuminated area



Auroral Oval & more Latitude

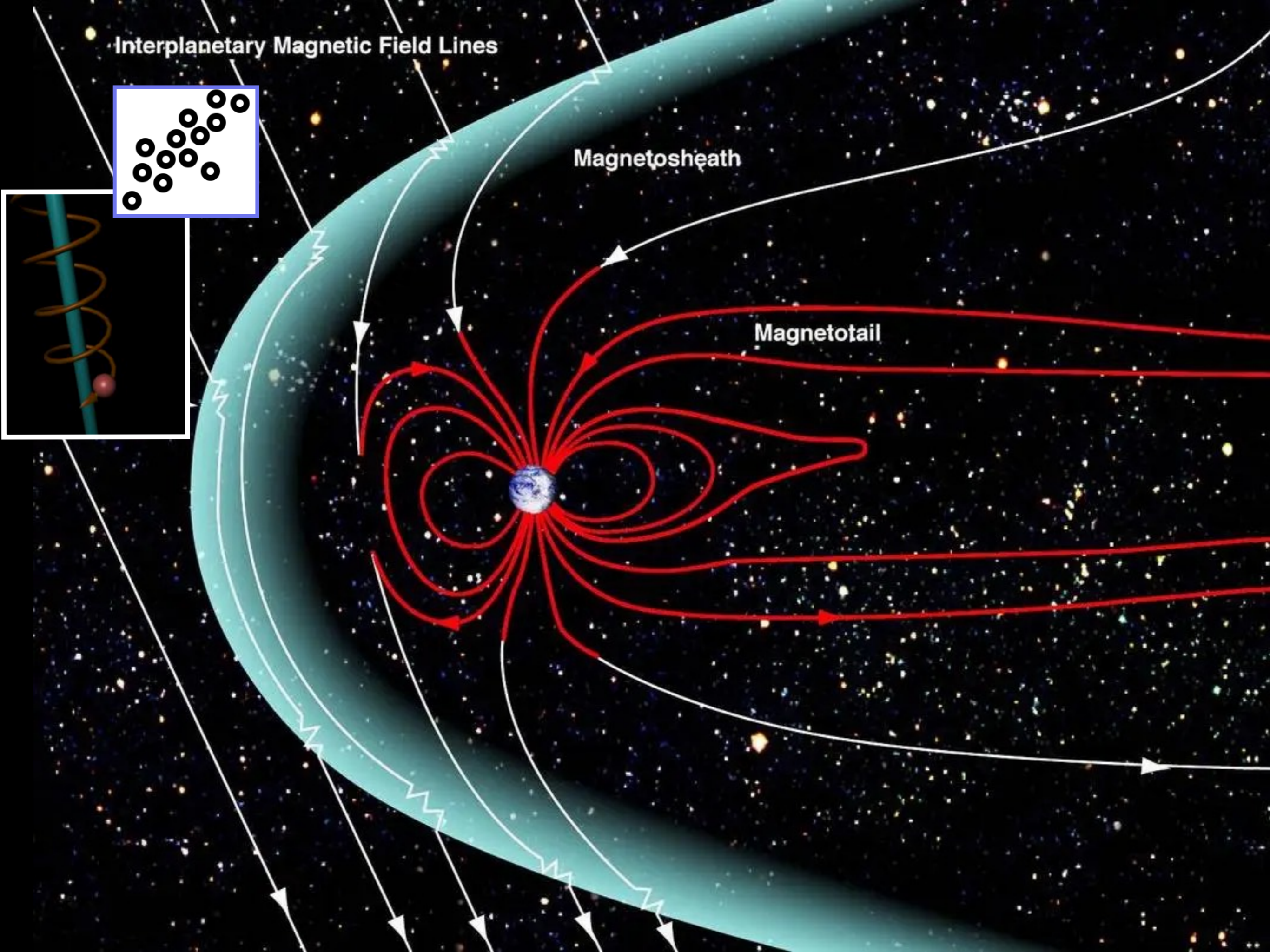


Interplanetary Magnetic Field Lines



Magnetosheath

Magnetotail



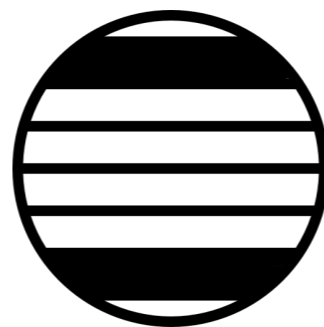
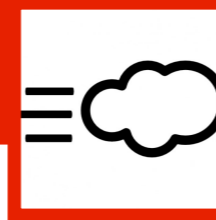
AREA OF IMPACT



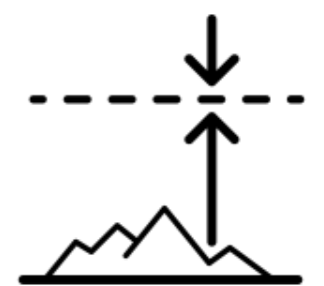
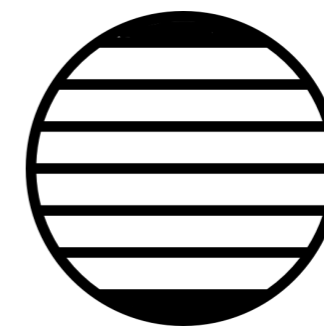
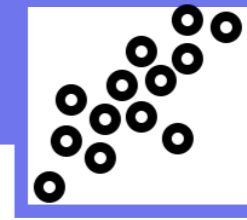
Illuminated area



Auroral Oval & more Latitude



Polar Cap
High Altitude





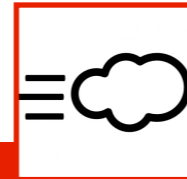
8 min

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

Min to Hour

Ionisation

Illuminated area



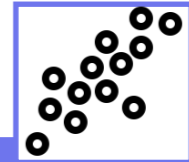
Days

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

