

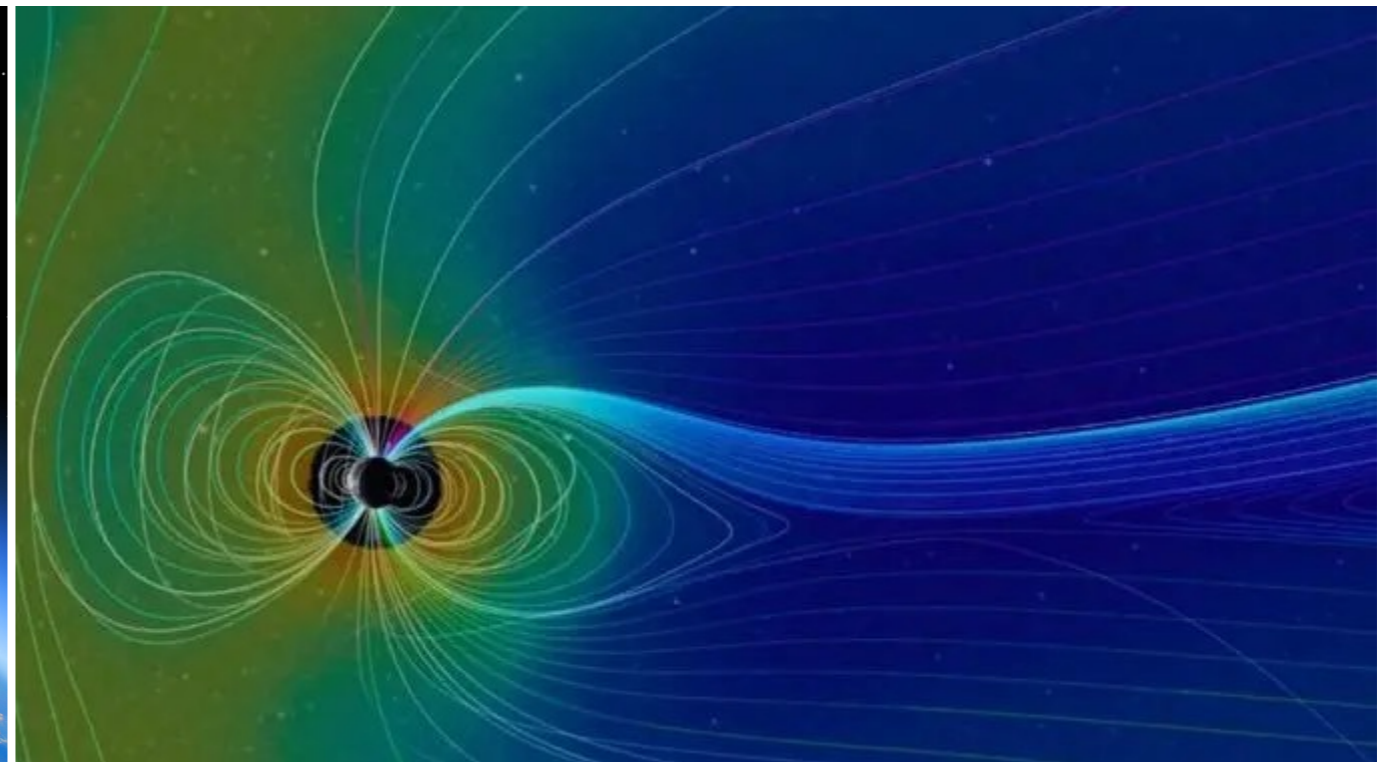
SPACE WEATHER

Introduction

Petra Vanlommel

Space Weather

The Sun's energy impacting earth's atmosphere and magnetic shield.



THE SUN AS A BALL OF ENERGY

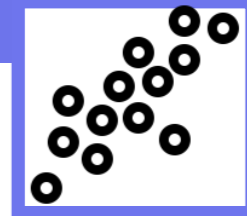
E.M. RADIATION



PLASMA

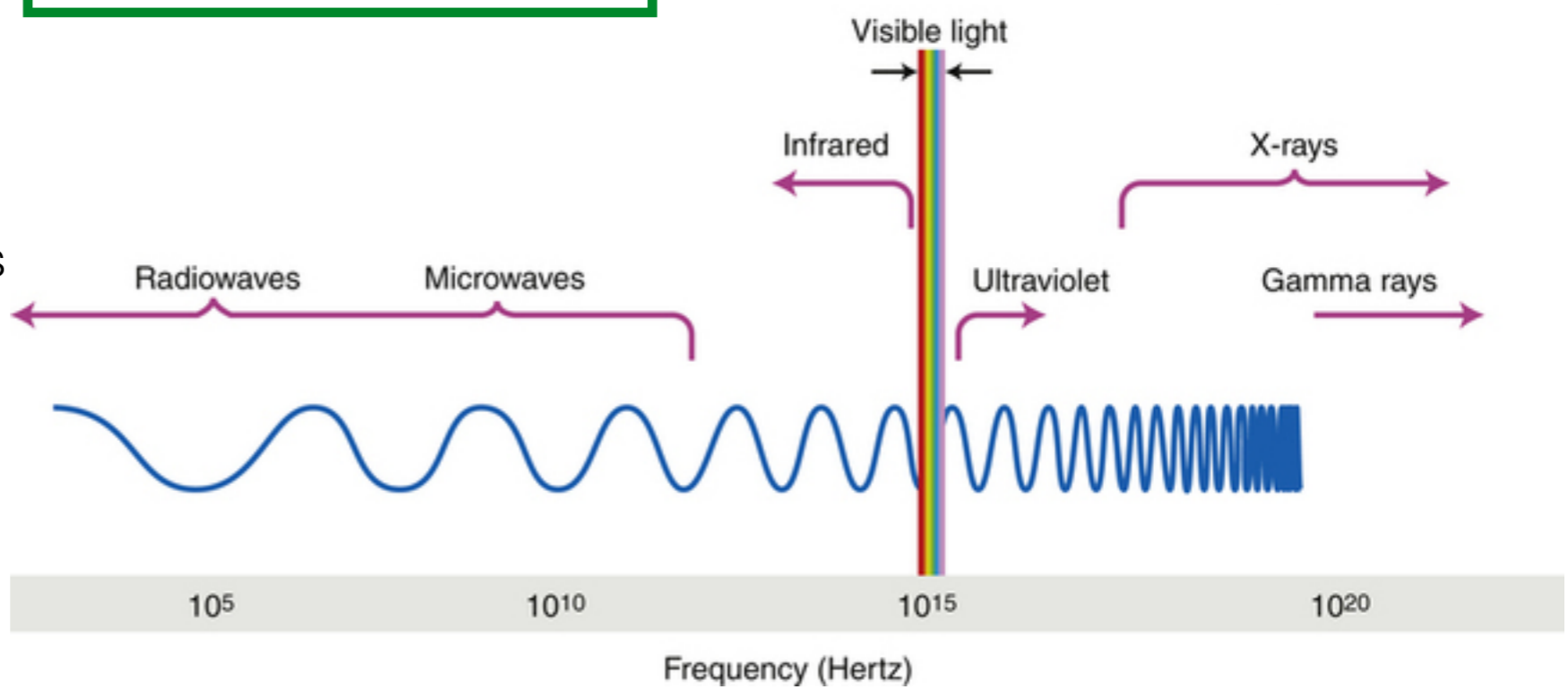


ENERGETIC
PARTICLES



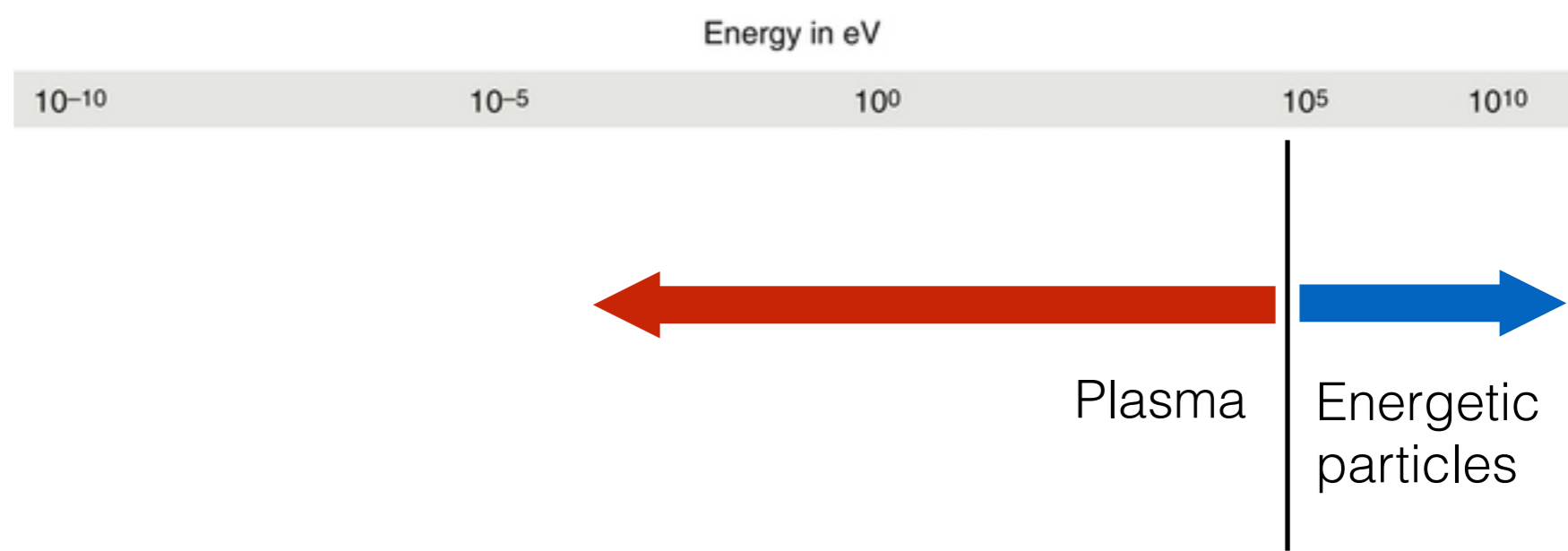
Electromagnetic radiation

- Photons / electromagnetic waves
- Speed of light



Particles

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



3 SPACE WEATHER PHENOMENA

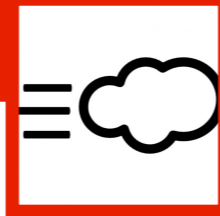
The sun's energy reaches the earth in 3 forms: light, moving gas and particle precipitation. This energy interacts with the magnetosphere and the atmosphere of the earth. This is space weather.

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

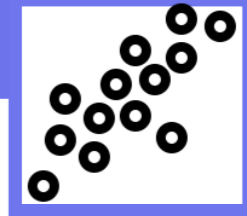
LIGHT



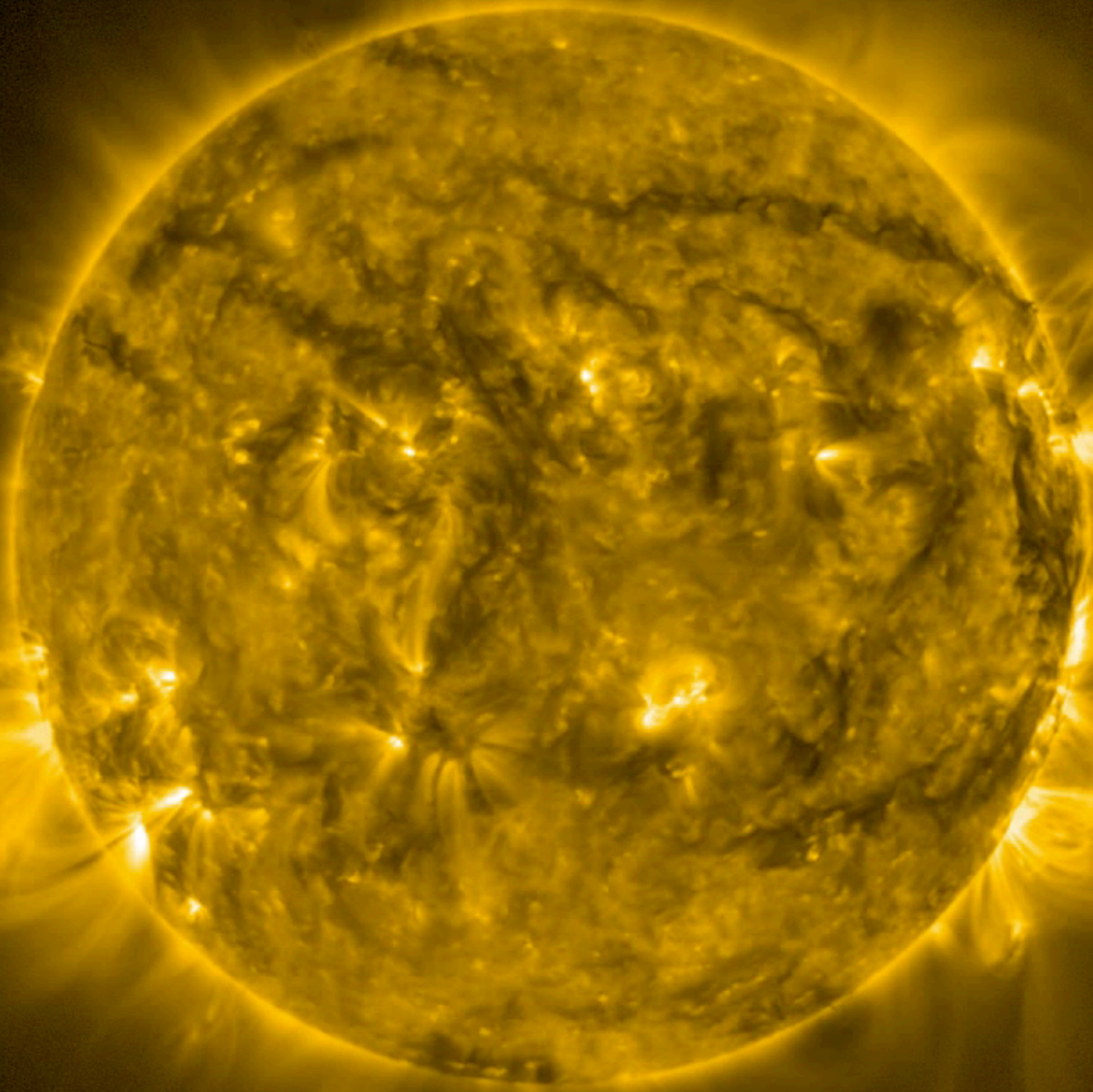
WIND



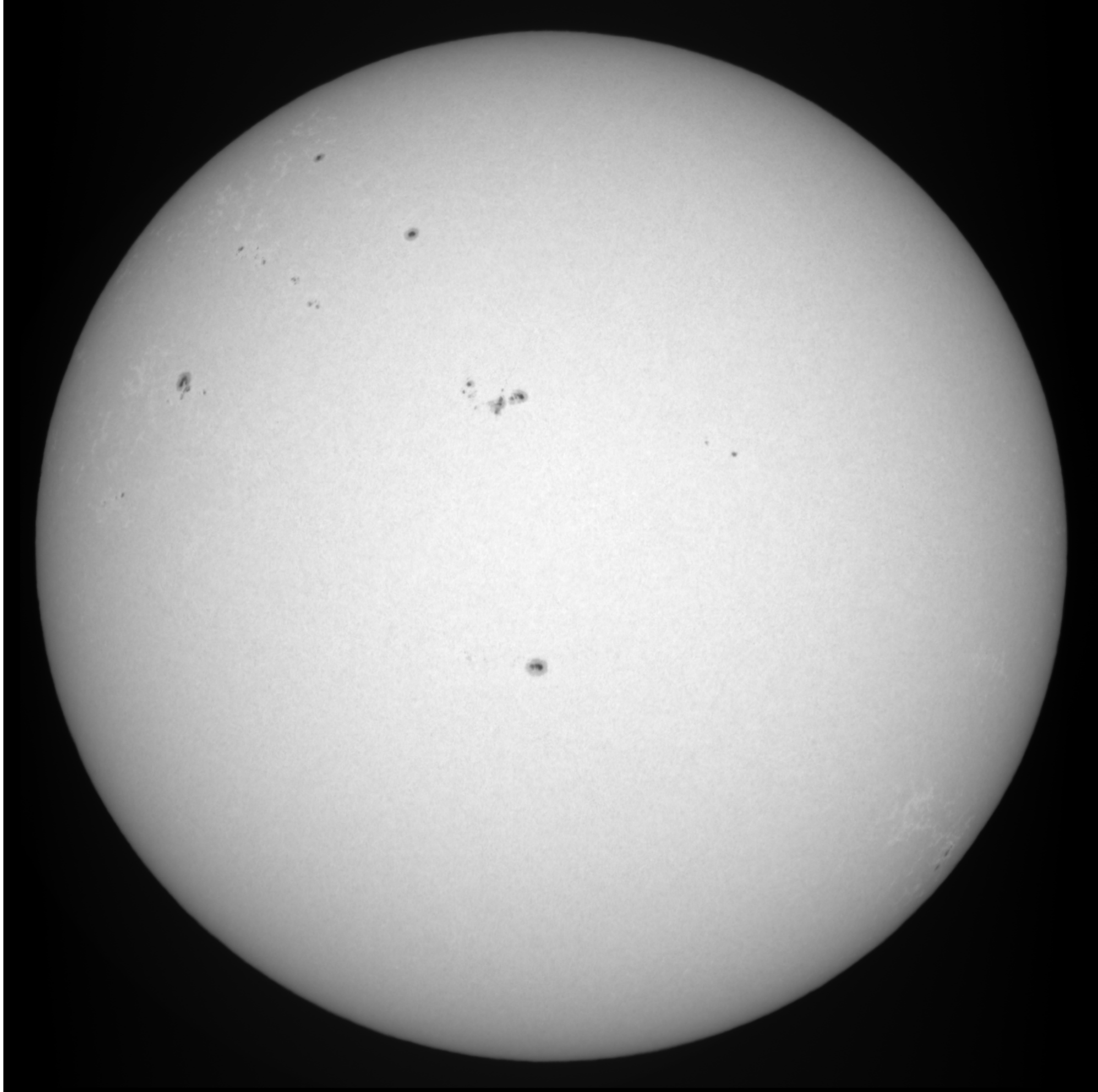
PARTICLE RAIN



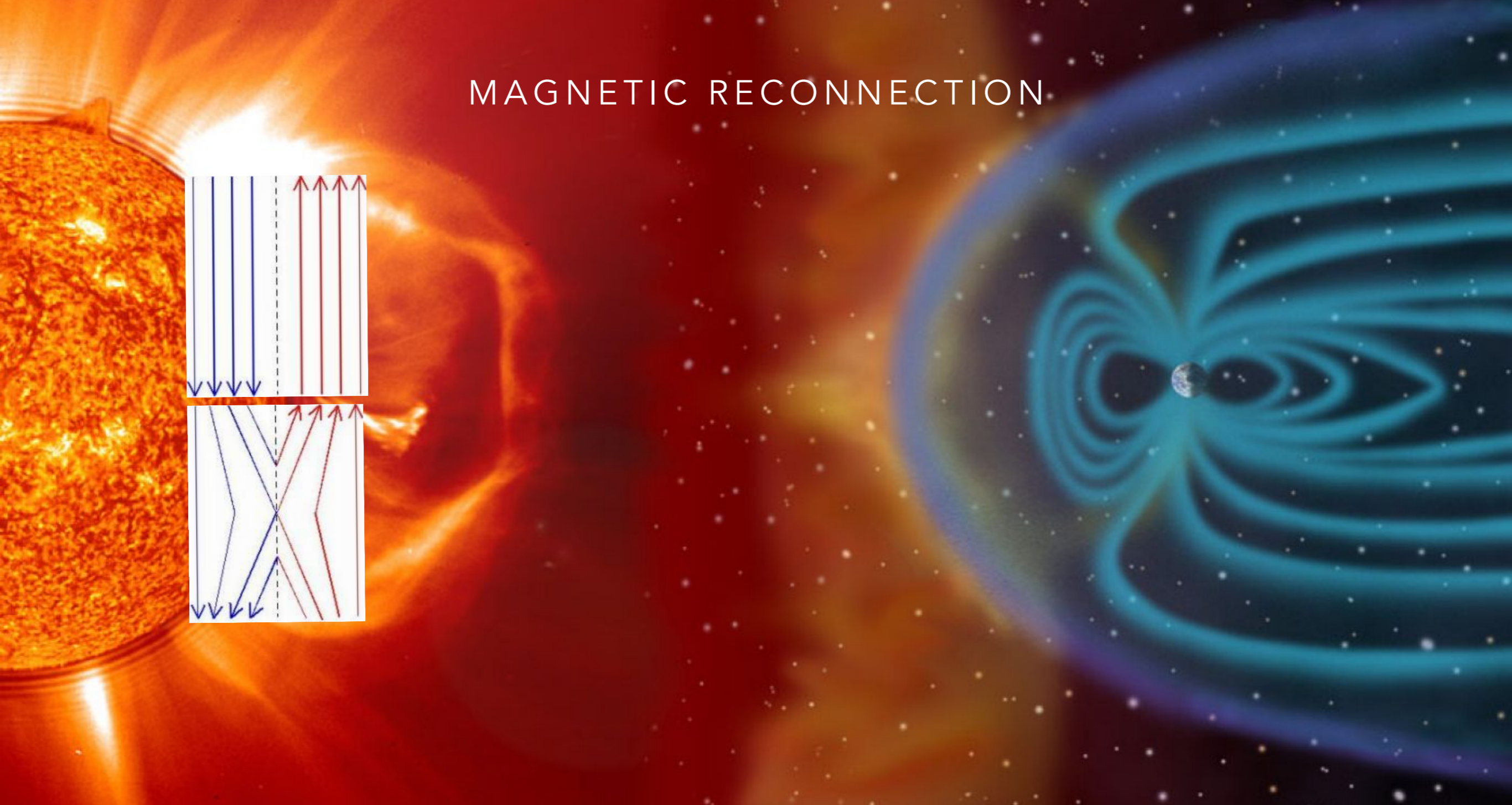
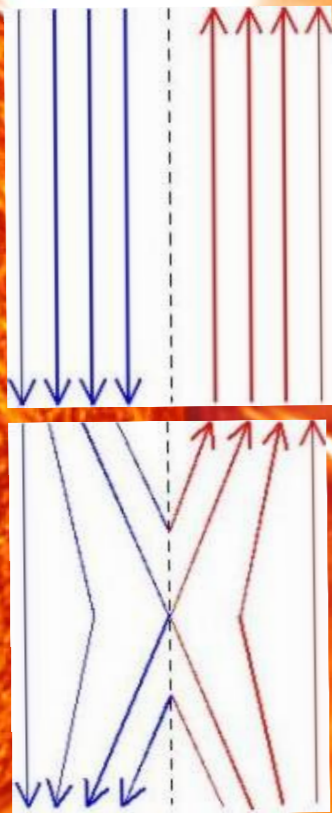
Magnetism drives the sun's dynamics



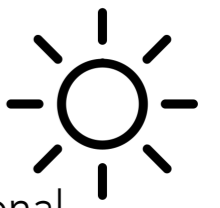
PROBA2/SWAP



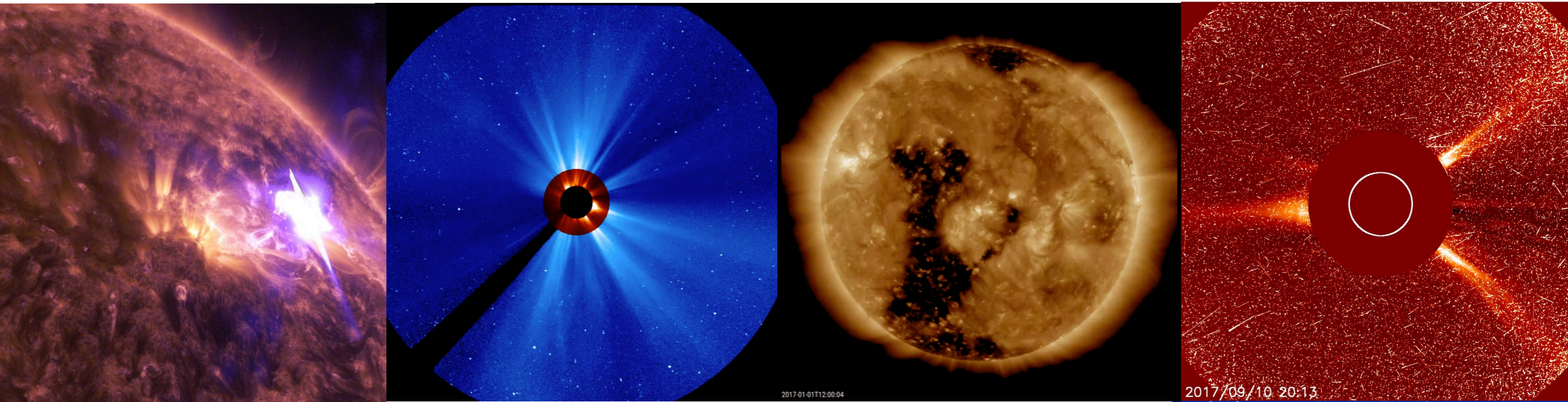
MAGNETIC RECONNECTION



SOLAR WEATHER & STORMS



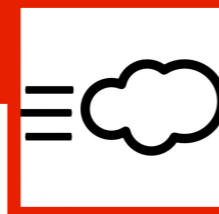
At a certain moment, energy can be released on a shorter time scale. A solar feature like a sunspot, an active region, coronal hole, filament etc. lies at the base of a solar storm in which energy is released. The release of energy might be in an abrupt, impulsive and brutal way (flare, Coronal Mass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



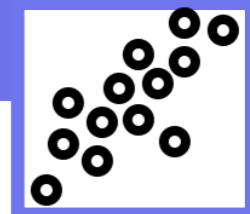
Flare



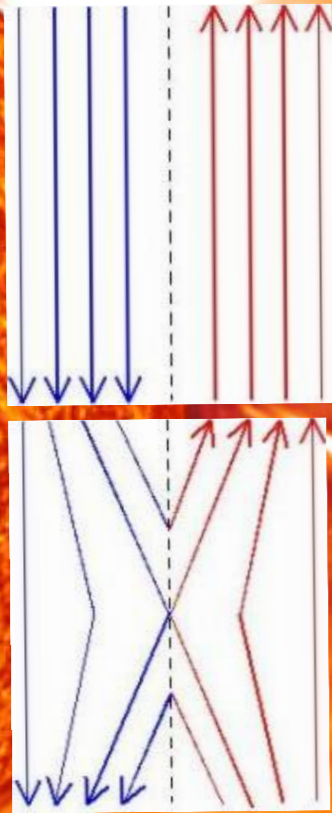
Coronal Mass Ejection
High Speed Stream



Energetic Particles



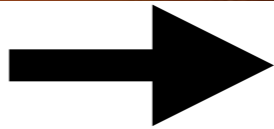
MAGNETIC RECONNECTION



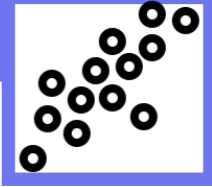
Flare



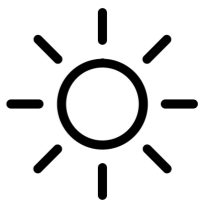
Coronal Mass Ejection



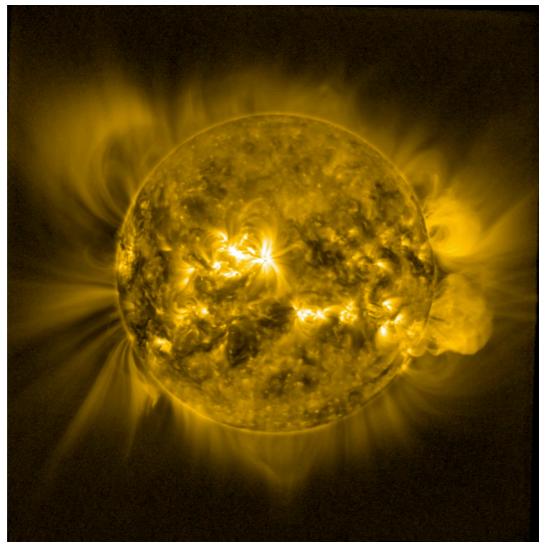
Energetic Particles



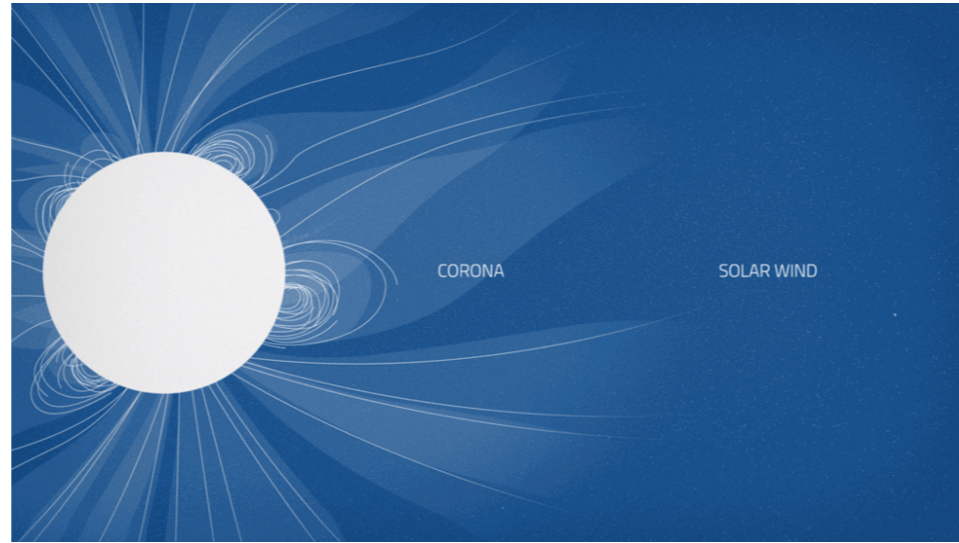
SOLAR SEASONS



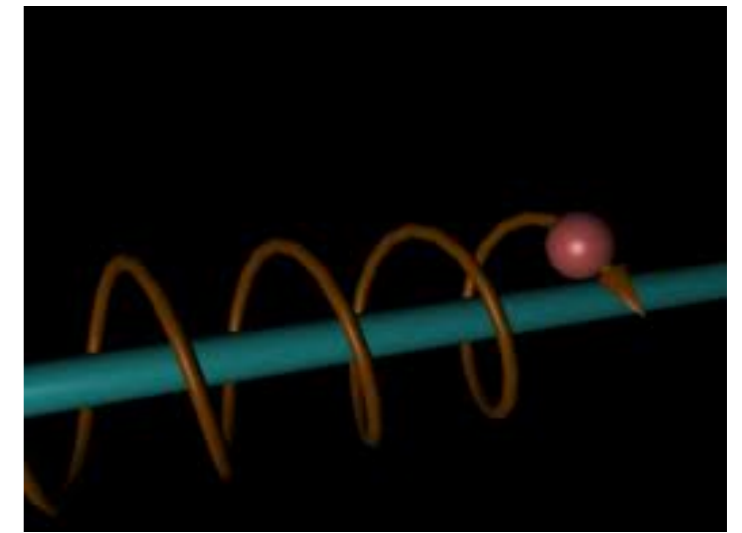
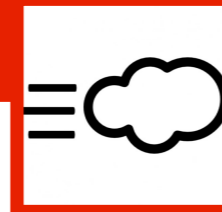
The sun has 2 seasons: an active and a low season with the typical variations in the three space weather phenomena. This seasonal variation is called the solar cycle and takes around 11 years.



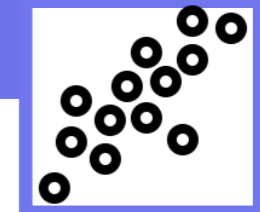
 PROBA2/SWAP



Solar Wind
CME - HSS



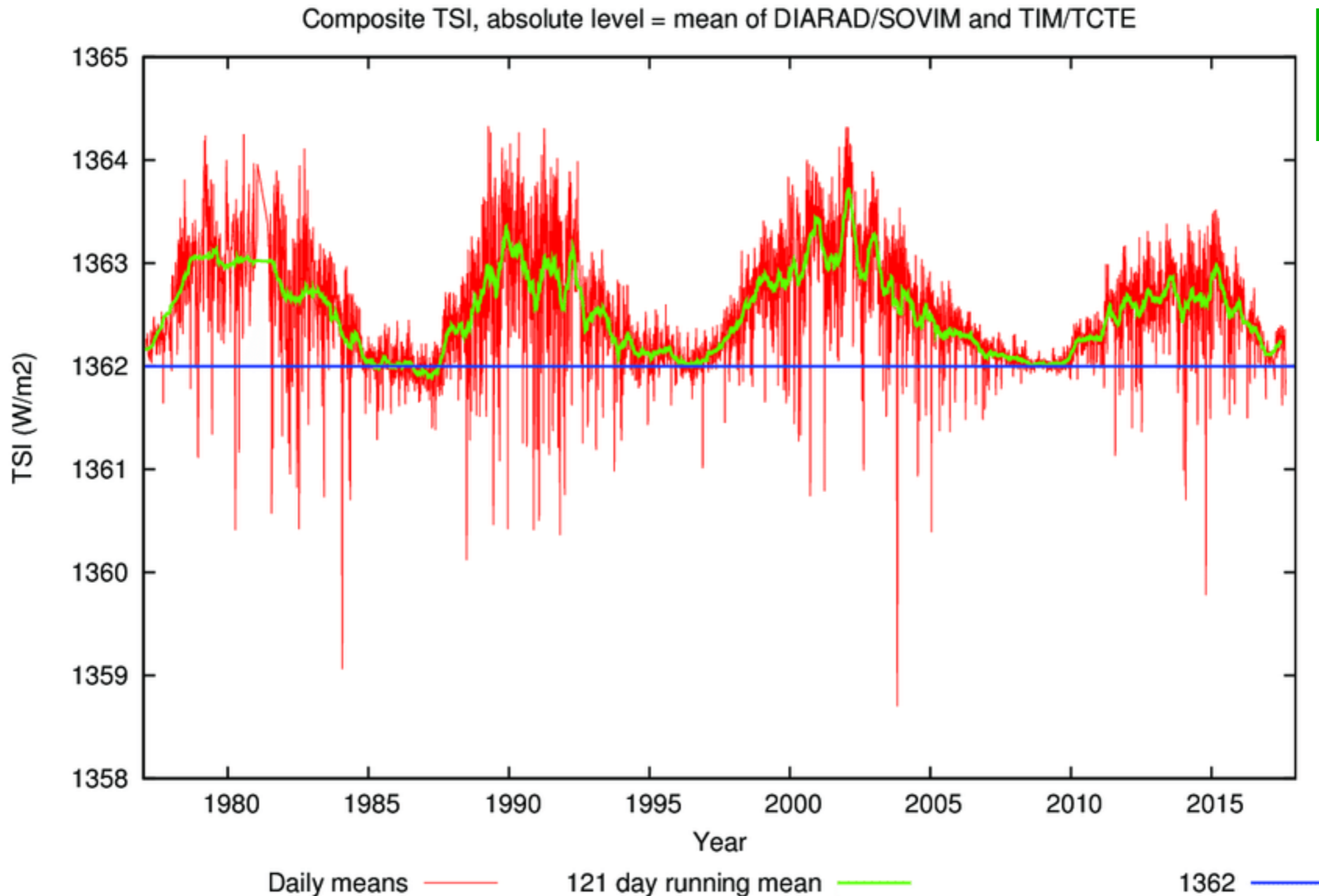
Energetic Particles



SEASONAL BEHAVIOUR OF LIGHT

The solar irradiance, i.e. all the solar light, varies over the solar seasons.

The sun radiates stronger in the high season compared to the low season.



SEASONAL BEHAVIOUR OF THE SOLAR WIND

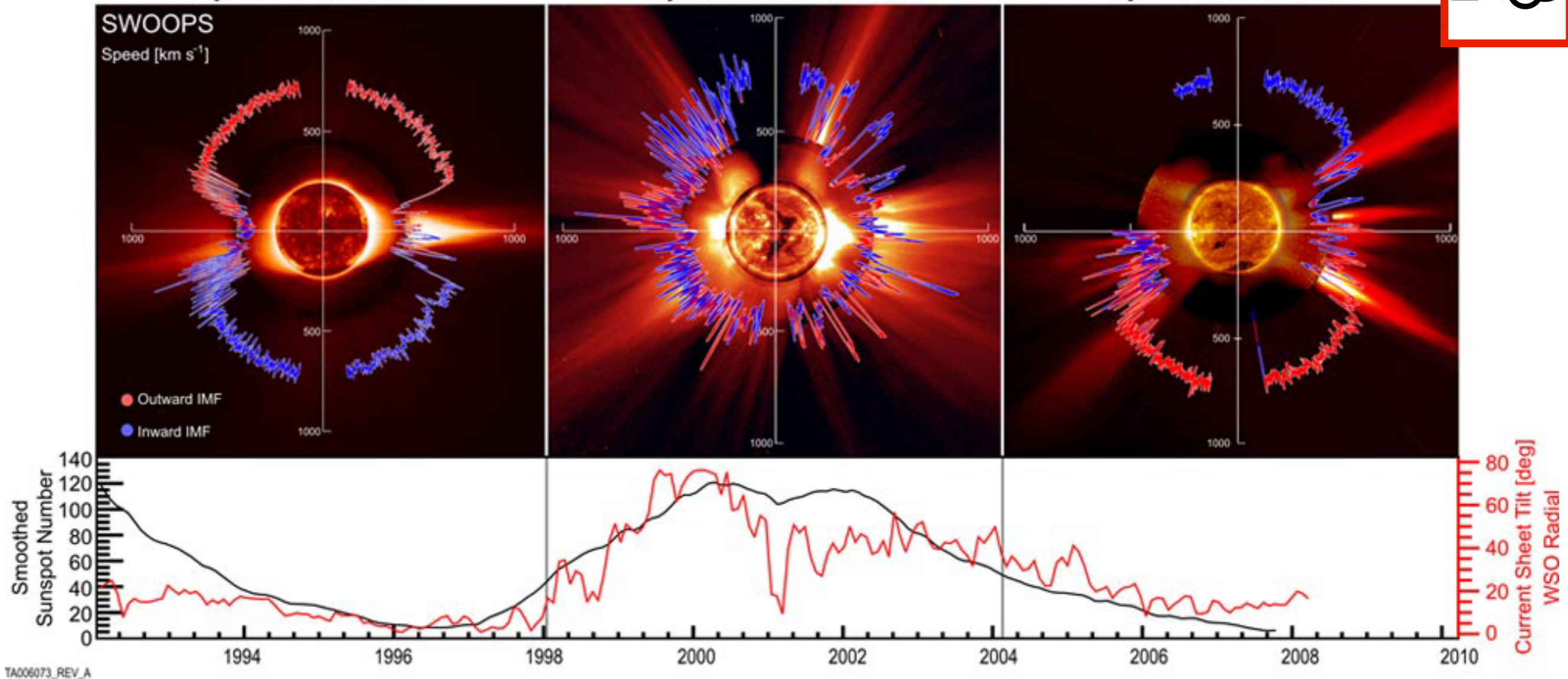
The solar wind varies over the solar seasons. The variation depends on the solar latitude. In the low season, the solar wind is slower near the equator compared to the higher latitudes and is more nicely structured. In the high season, the solar wind varies over all latitudes.



Ulysses First Orbit

Ulysses Second Orbit

Ulysses Third Orbit

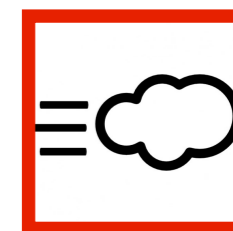
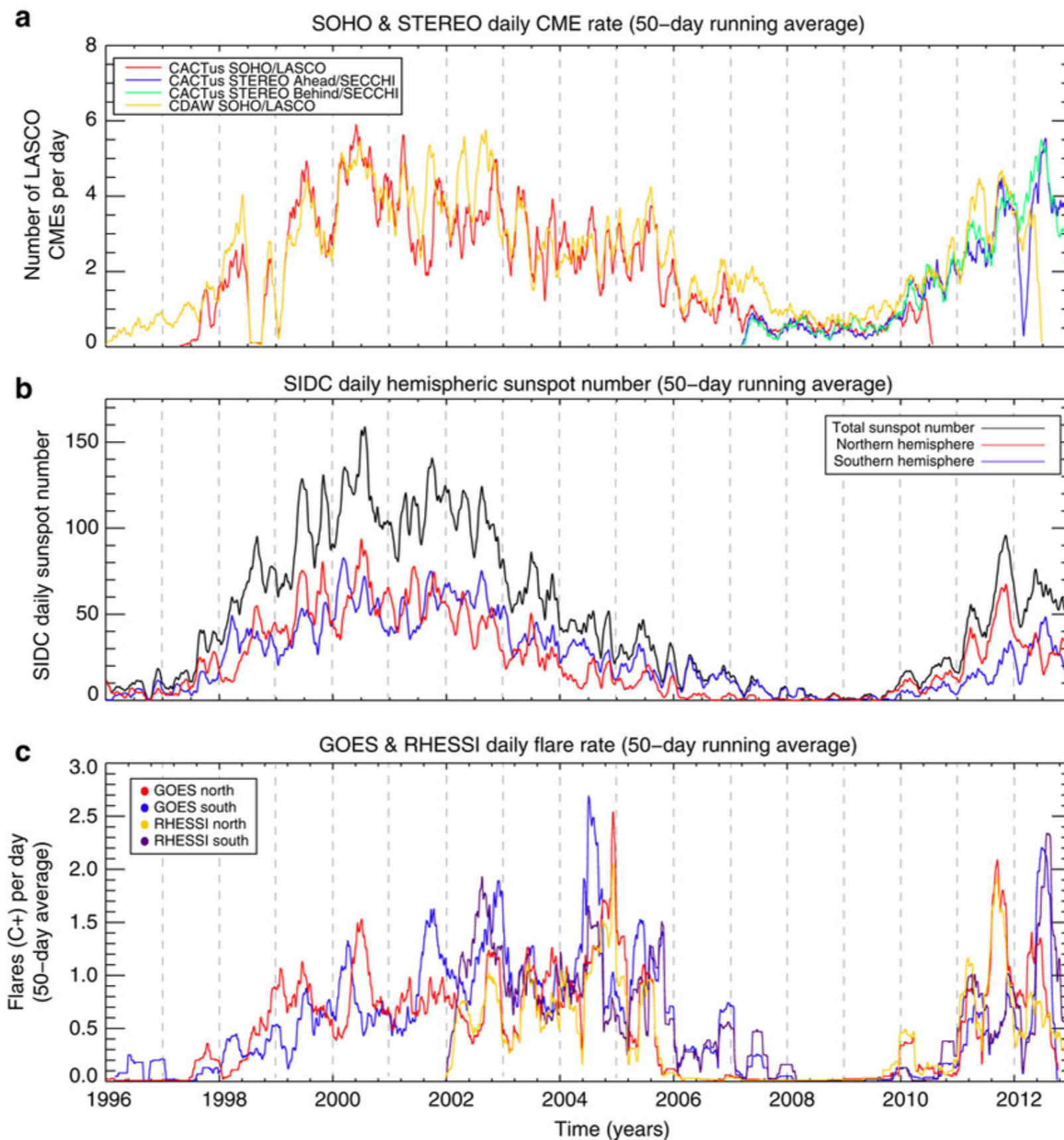


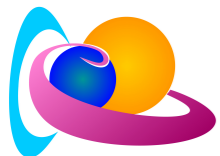
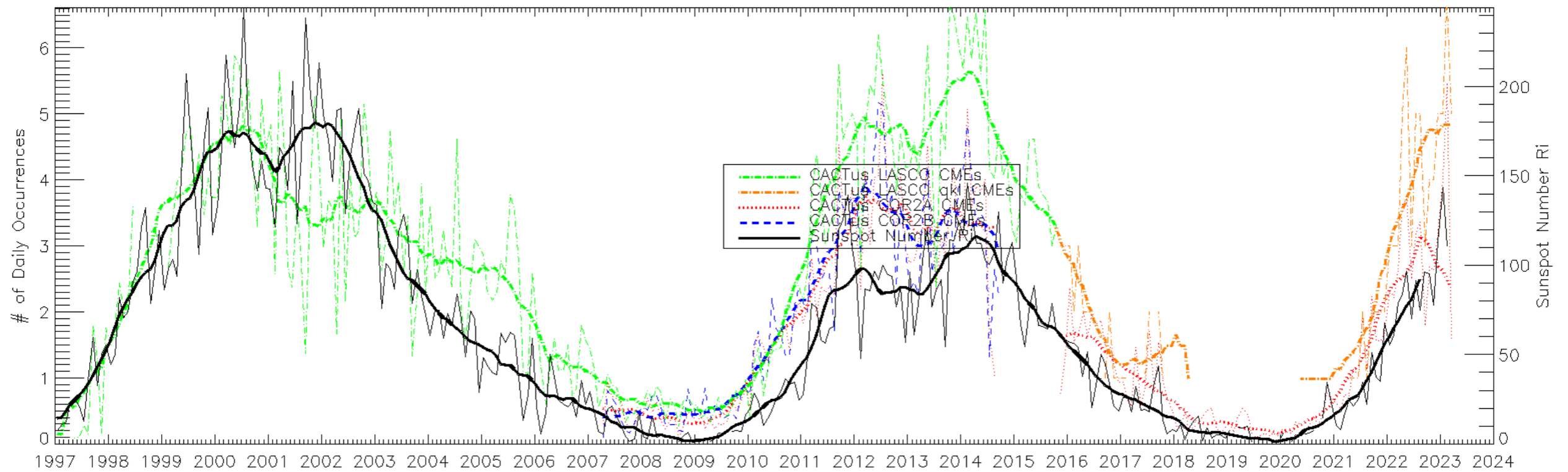
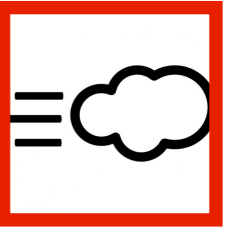
TA006073_REV_A



SEASONAL BEHAVIOUR OF SOLAR LIGHT & WIND STORMS

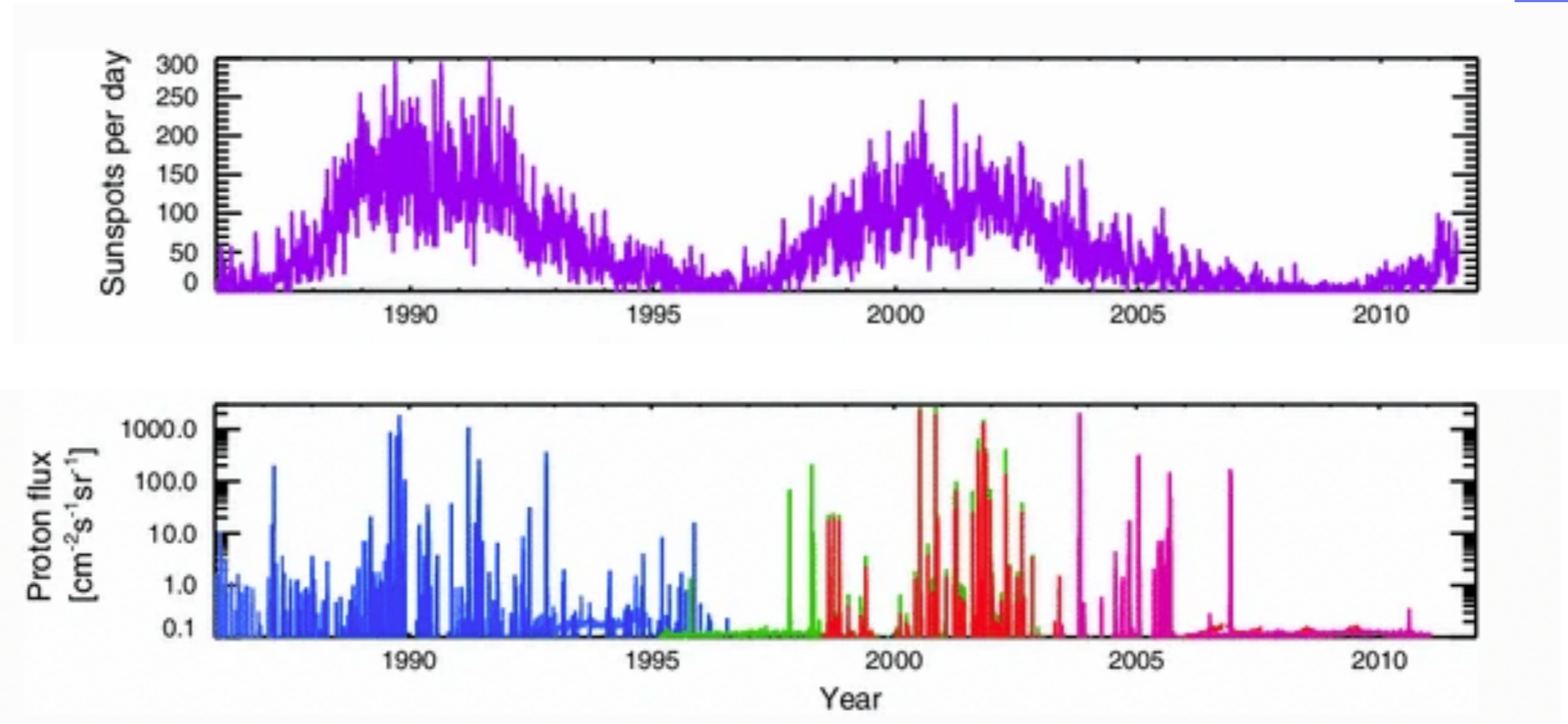
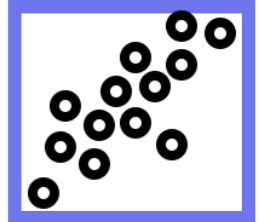
The seasonal behaviour is also visible in the variability of the Sun's eruptive output. You see here a comparison of the variation in the CME and flare rates over solar cycle 23 with the sunspot number.

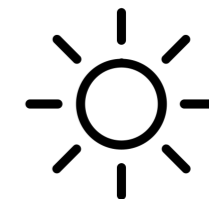




SEASONAL BEHAVIOUR OF SOLAR PARTICLE STORMS

The seasonal behaviour is also visible in the variability of the Sun's eruptive output. You see here a comparison of the variation of the proton flux over solar cycle 23 with the sunspot number.

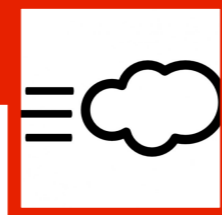




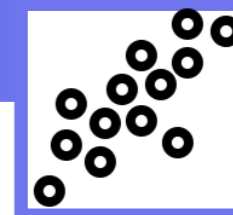
e.m. radiation
FLARE

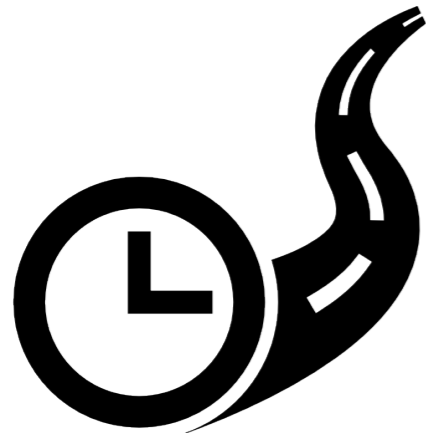


Solar wind
CME - HSS

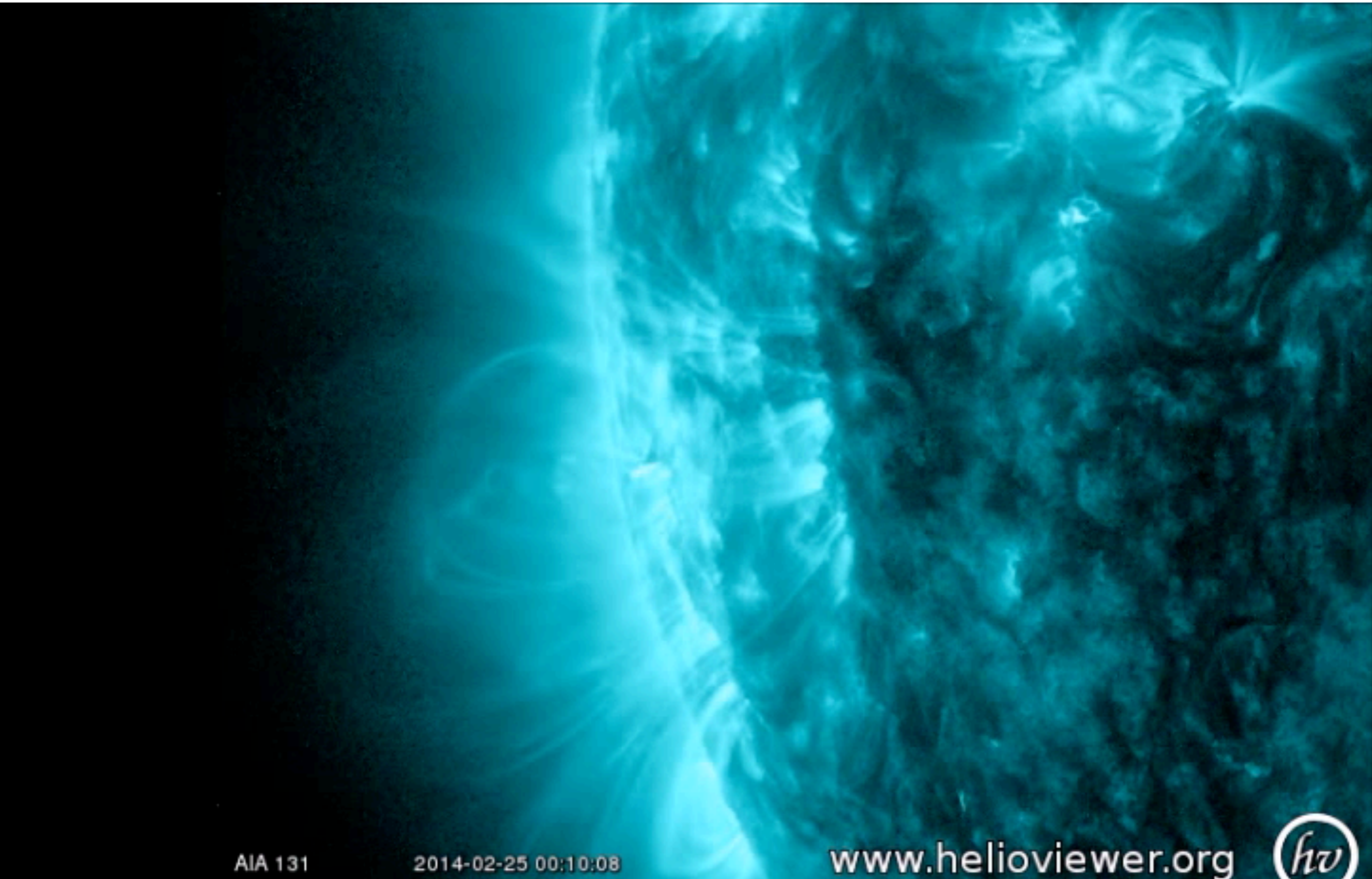


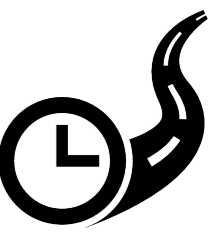
Energetic Particles





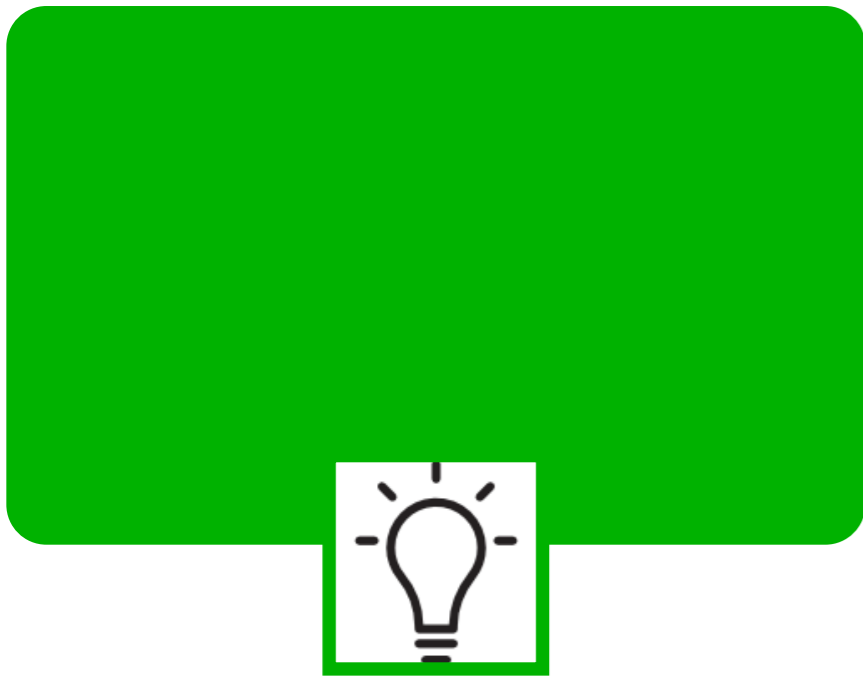
A flare is a light flash near an active region. A volume of plasma is suddenly heated and therefore lights up.





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



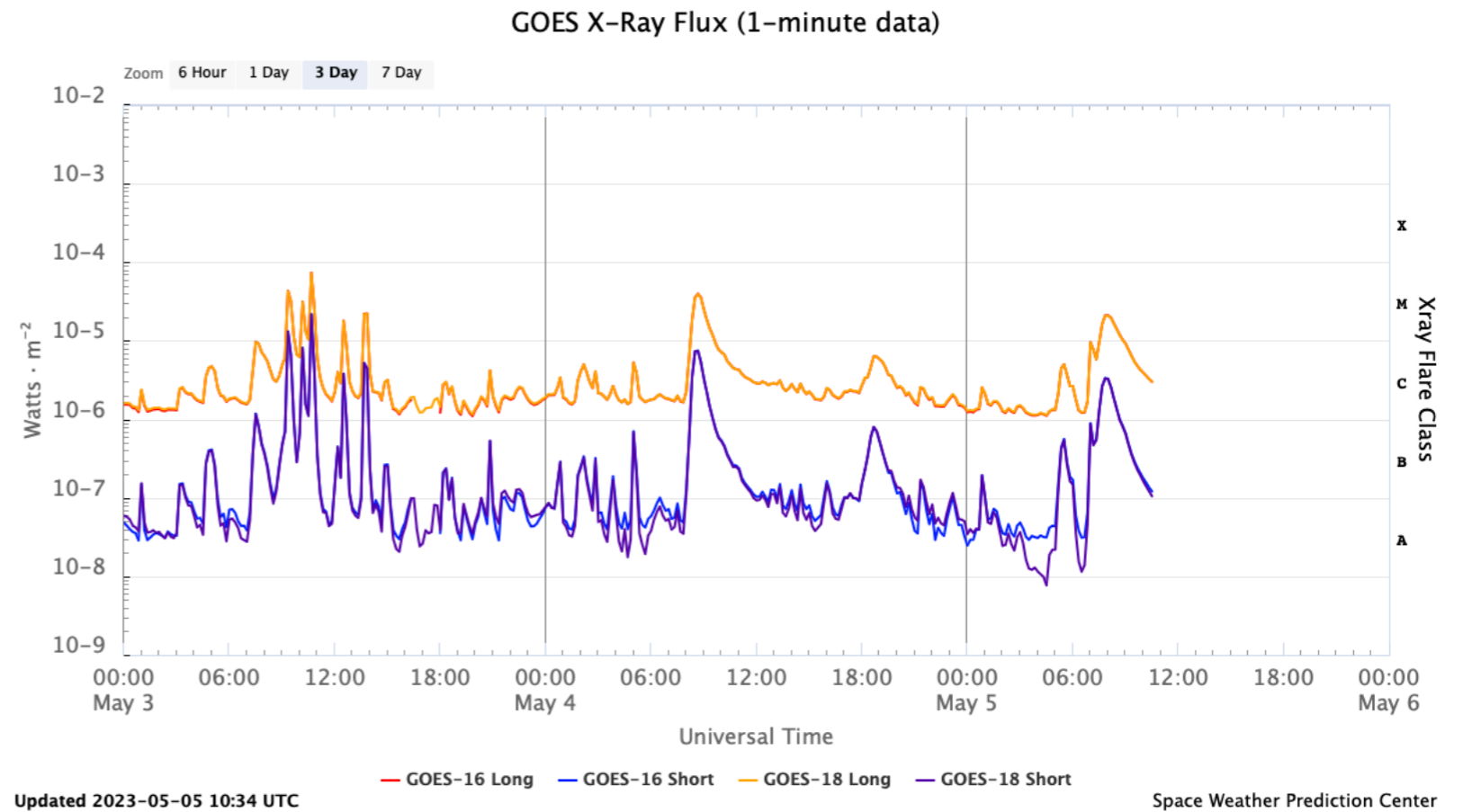
<https://www.swpc.noaa.gov/products/goes-x-ray-flux>



STORM SCALE



A,B,C,M,X



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



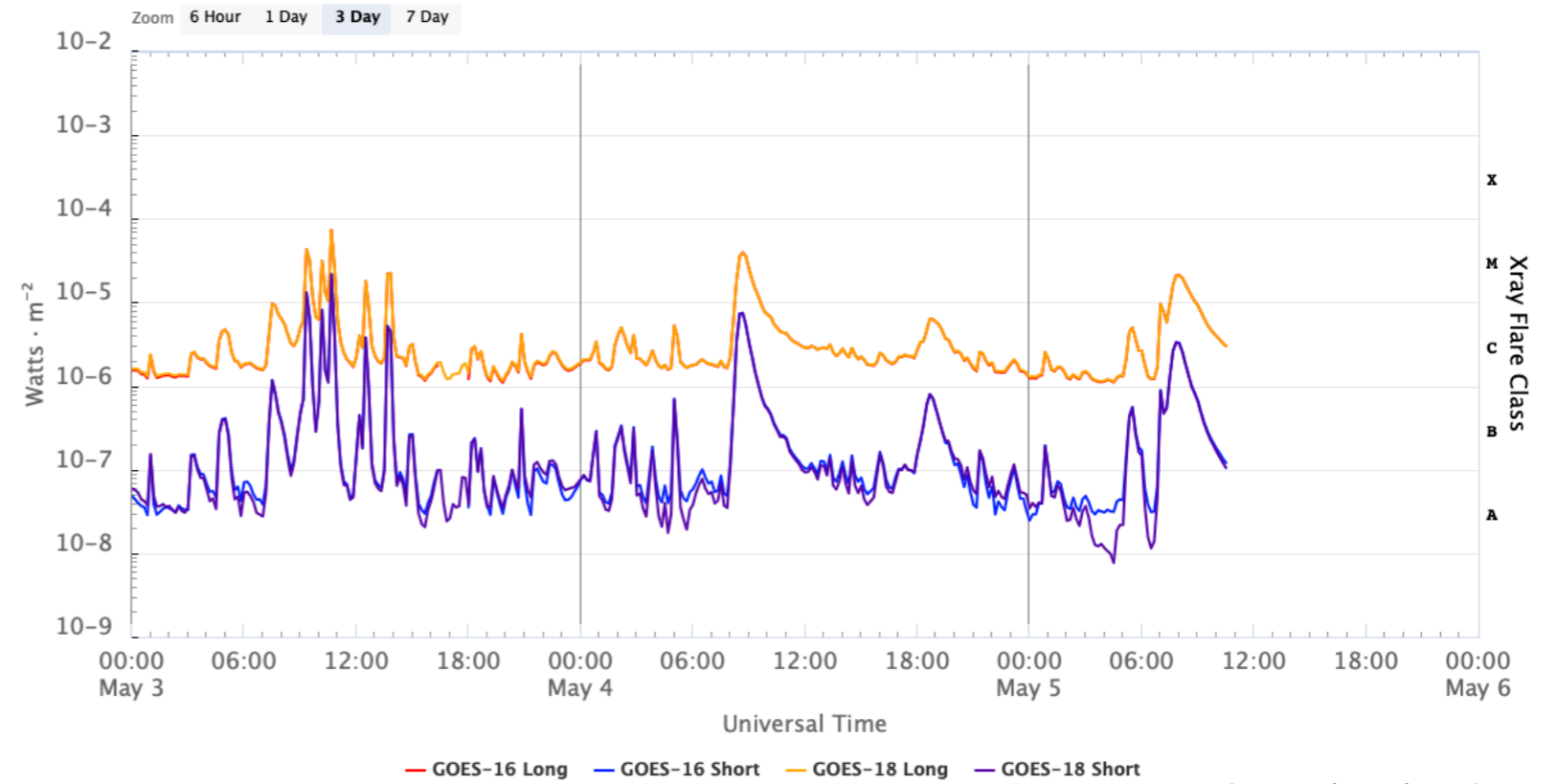
DURATION



MINs to HOUR



GOES X-Ray Flux (1-minute data)

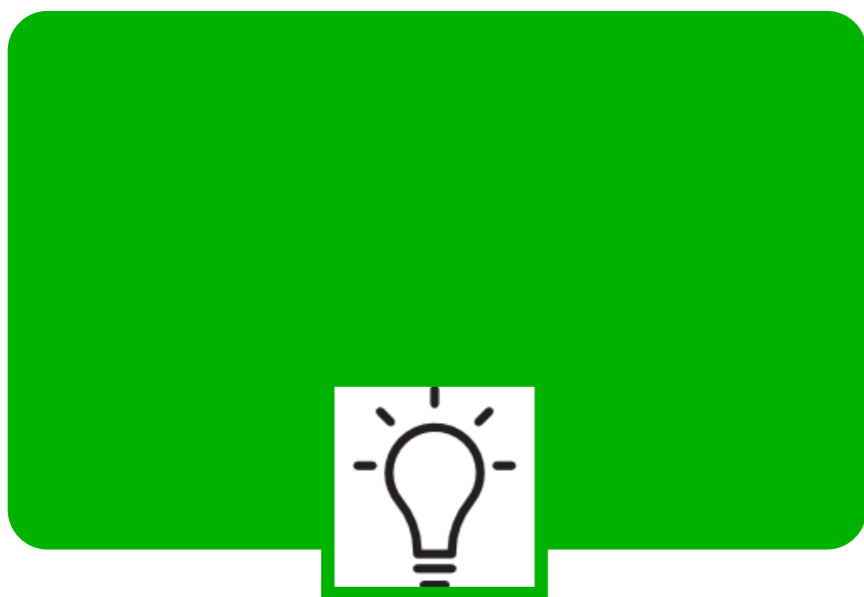


Updated 2023-05-05 10:34 UTC

Space Weather Prediction Center

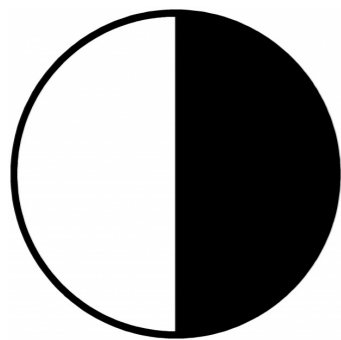


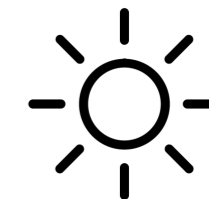
AREA OF IMPACT



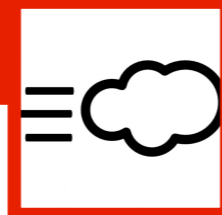
AREA OF IMPACT

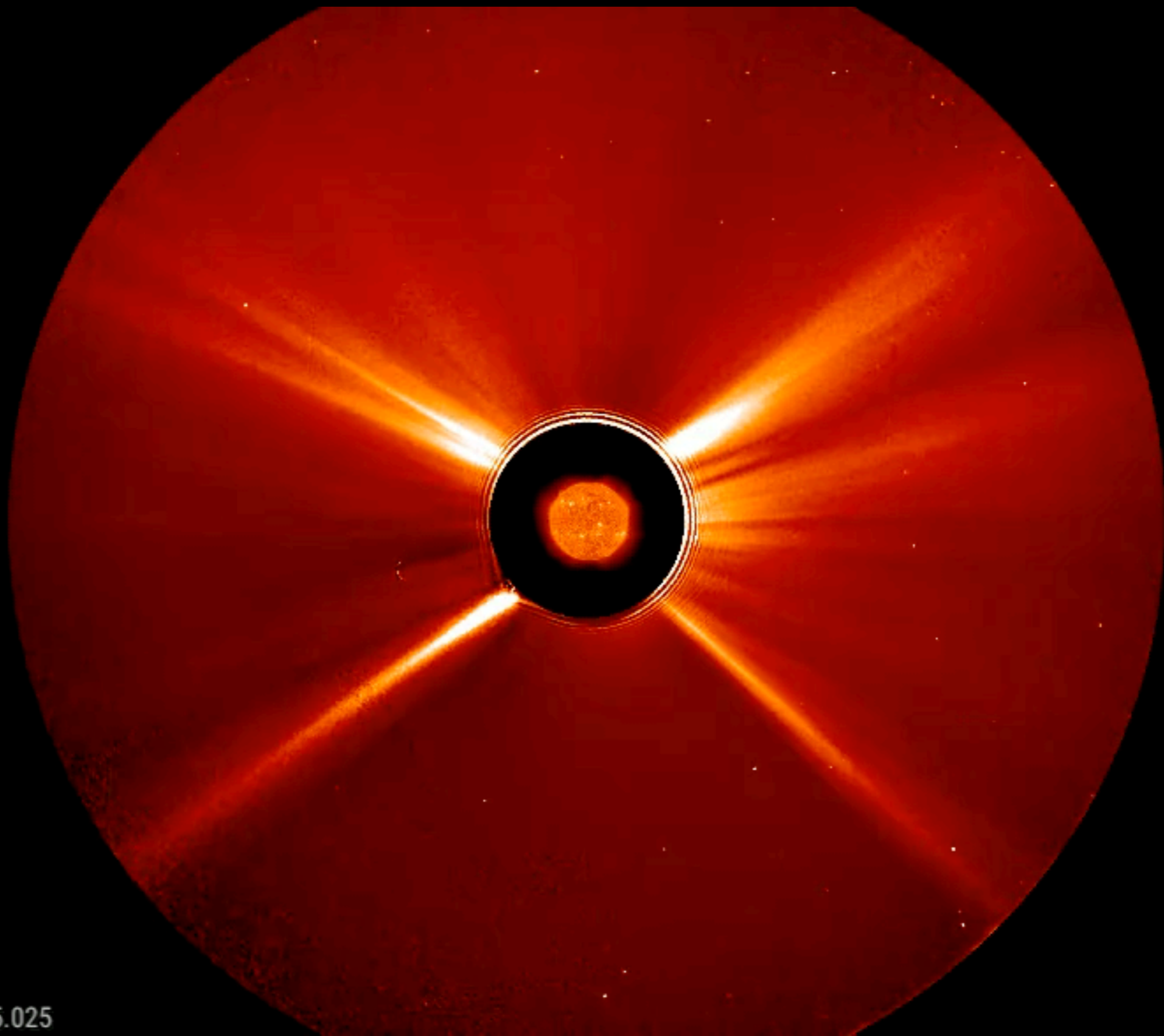
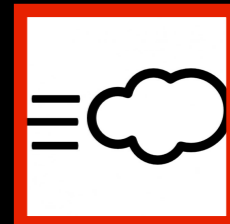
Illuminated area



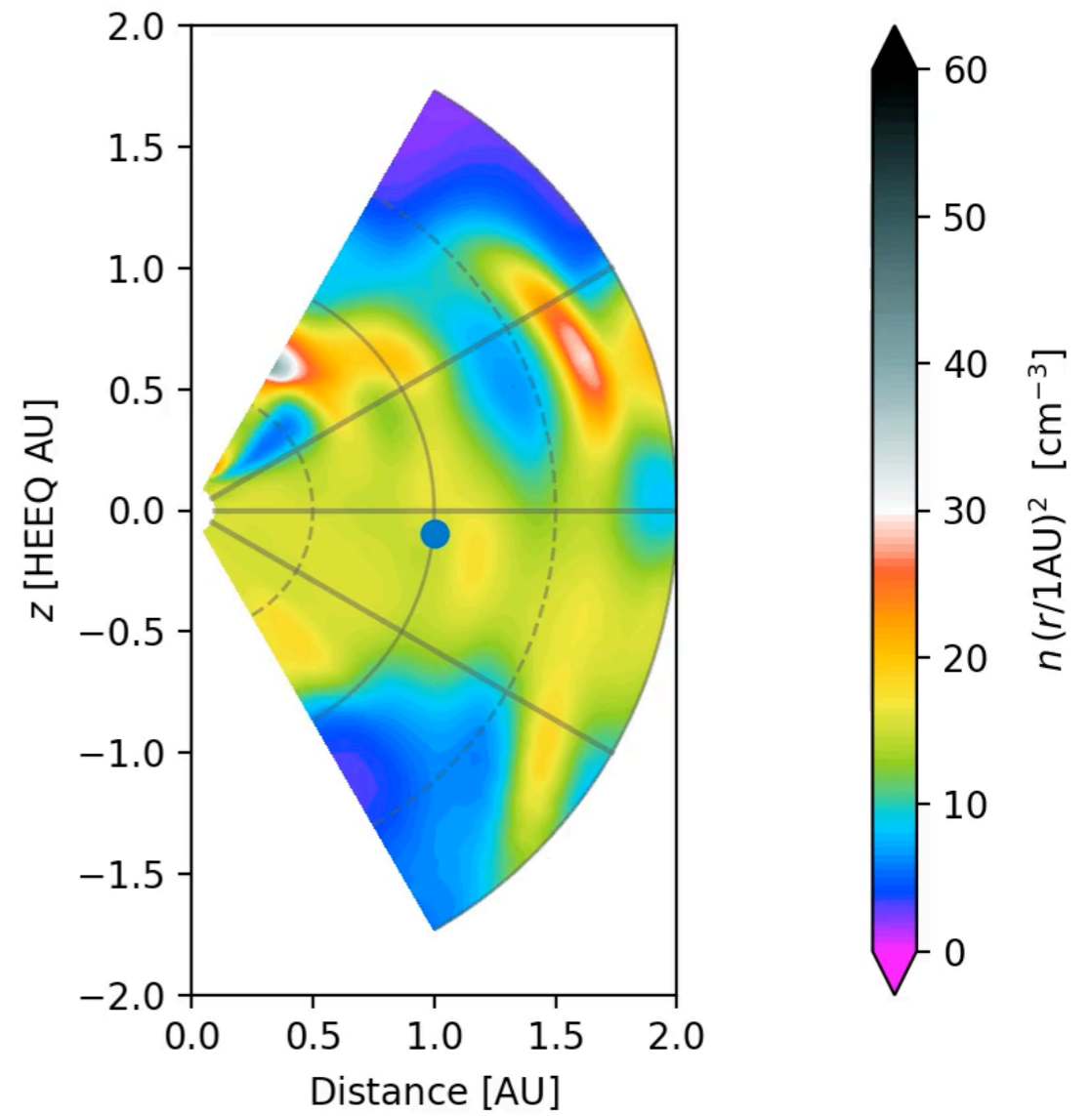
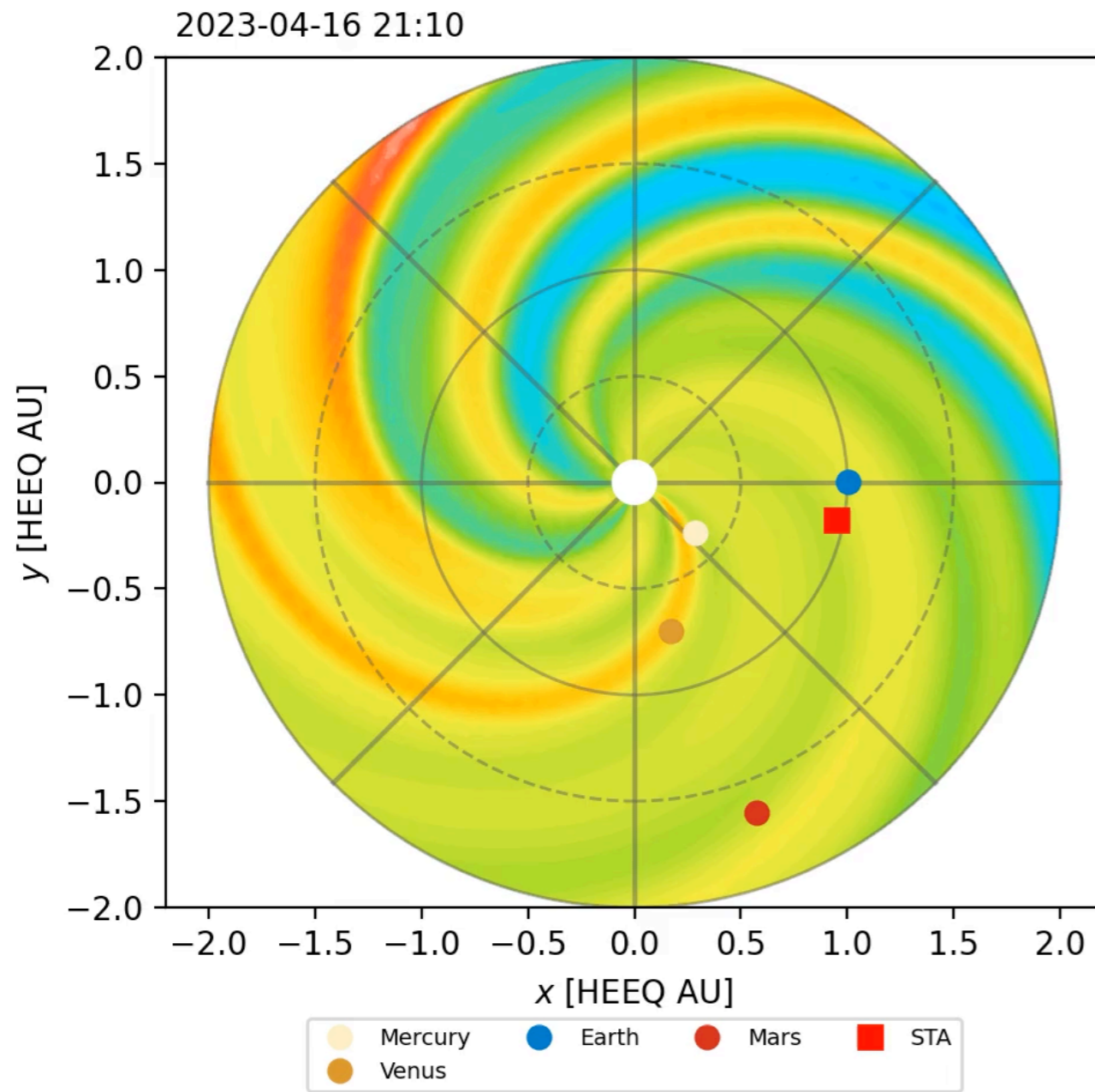
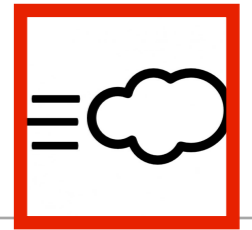


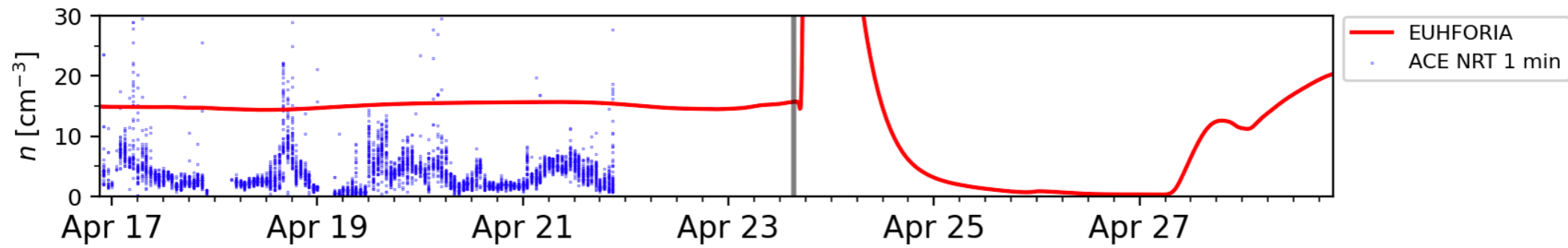
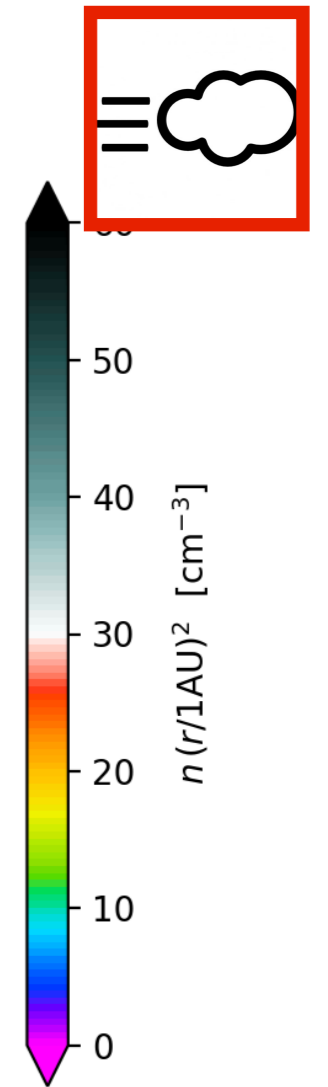
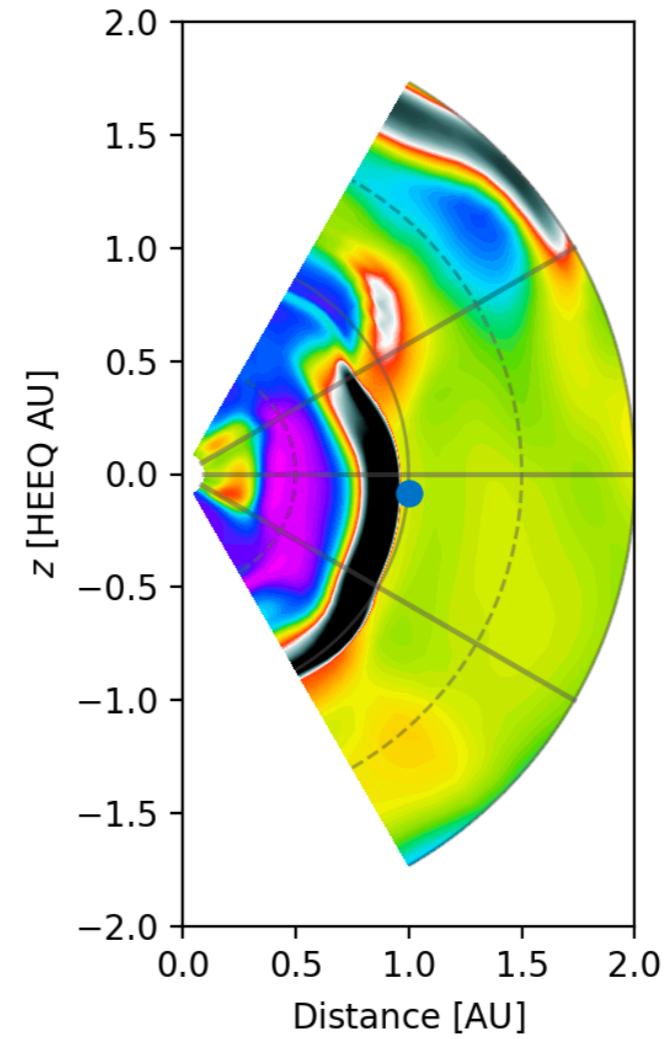
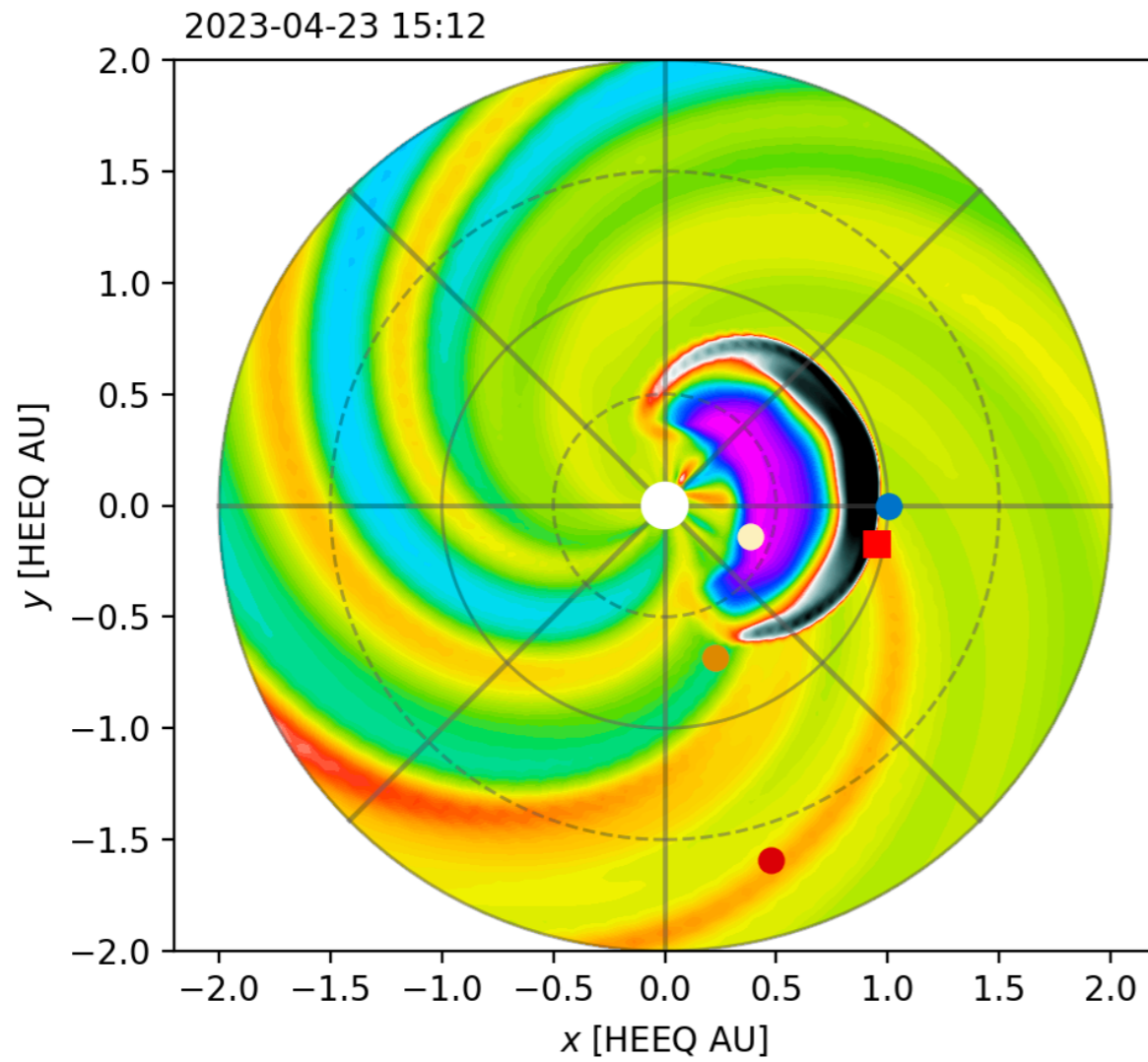
Solar wind
CME - HSS





2022-02-15T16:25:45.025



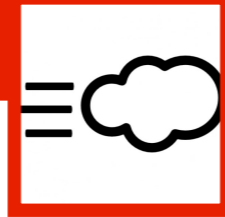




AU TRANSIT TIME

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





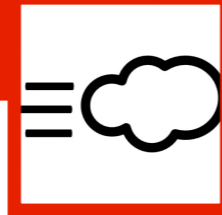
AU TRANSIT TIME

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.

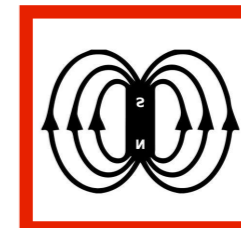
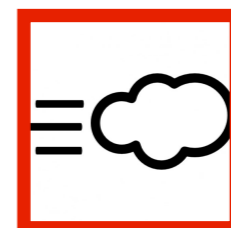
8 MIN

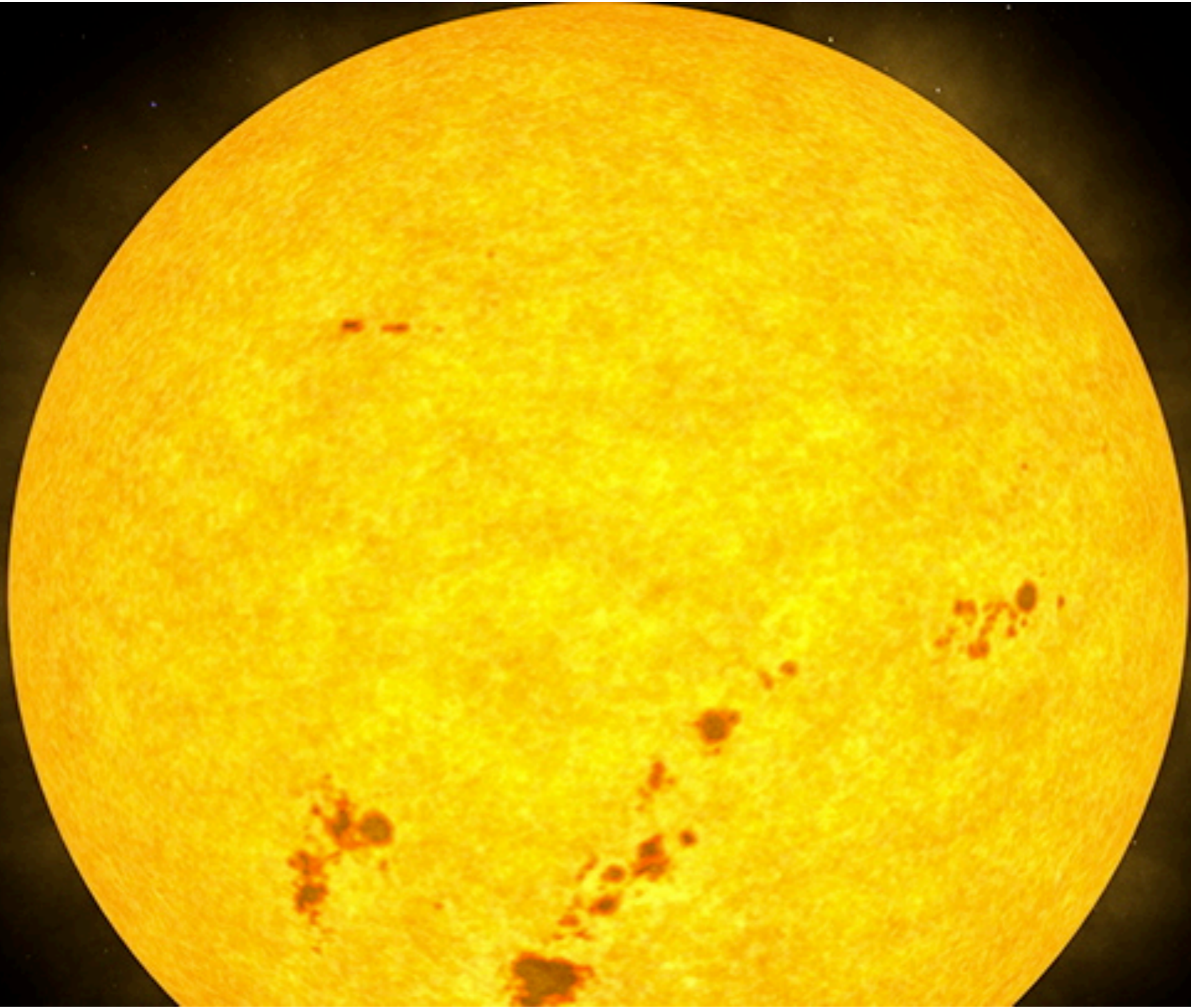
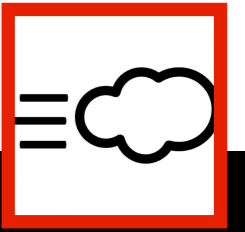


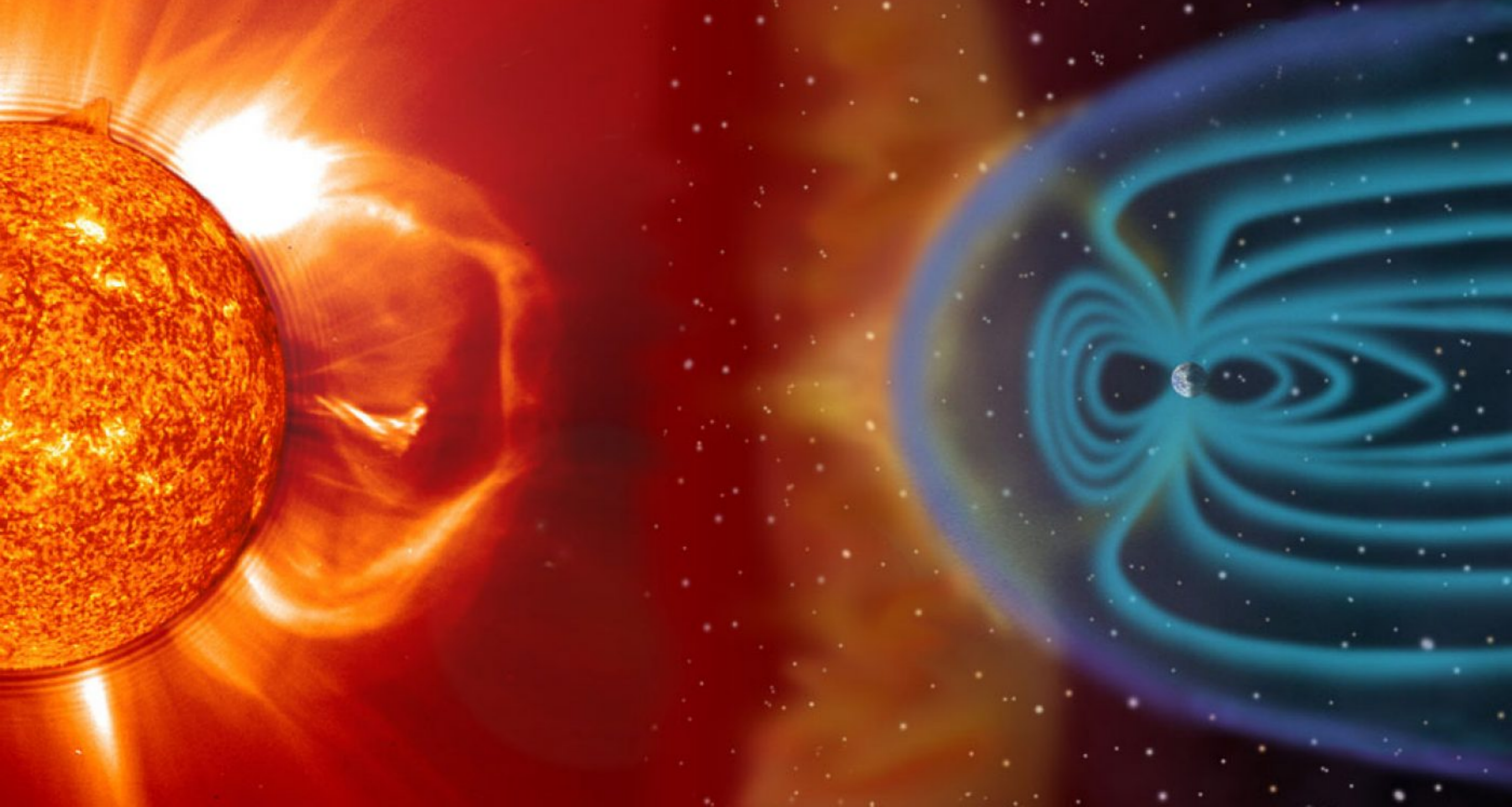
DAYS



STORM SCALE - GEOMAGNETIC STORM

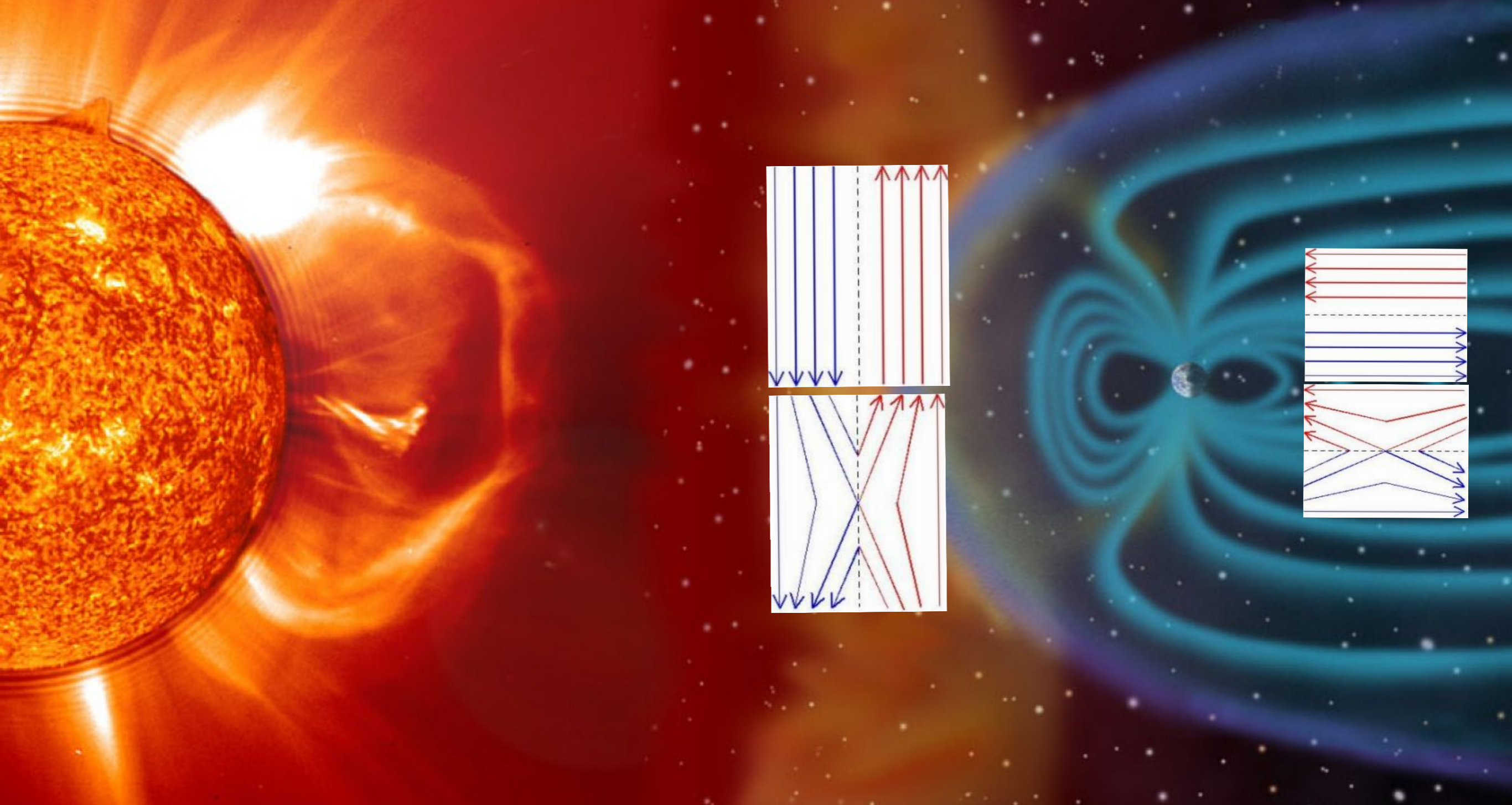






RECONNECTION

The magnetic field carried by the solar wind can couple with the magnetic field of Earth. This coupling is stronger when the solar wind magnetic field is opposite to the magnetic field of Earth.



RECONNECTION

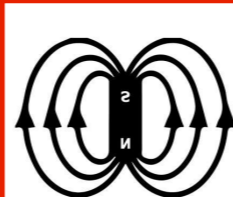
The magnetic field carried by the solar wind can couple with the magnetic field of Earth. This coupling is stronger when the solar wind magnetic field is opposite to the magnetic field of Earth.

STORM SCALE



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

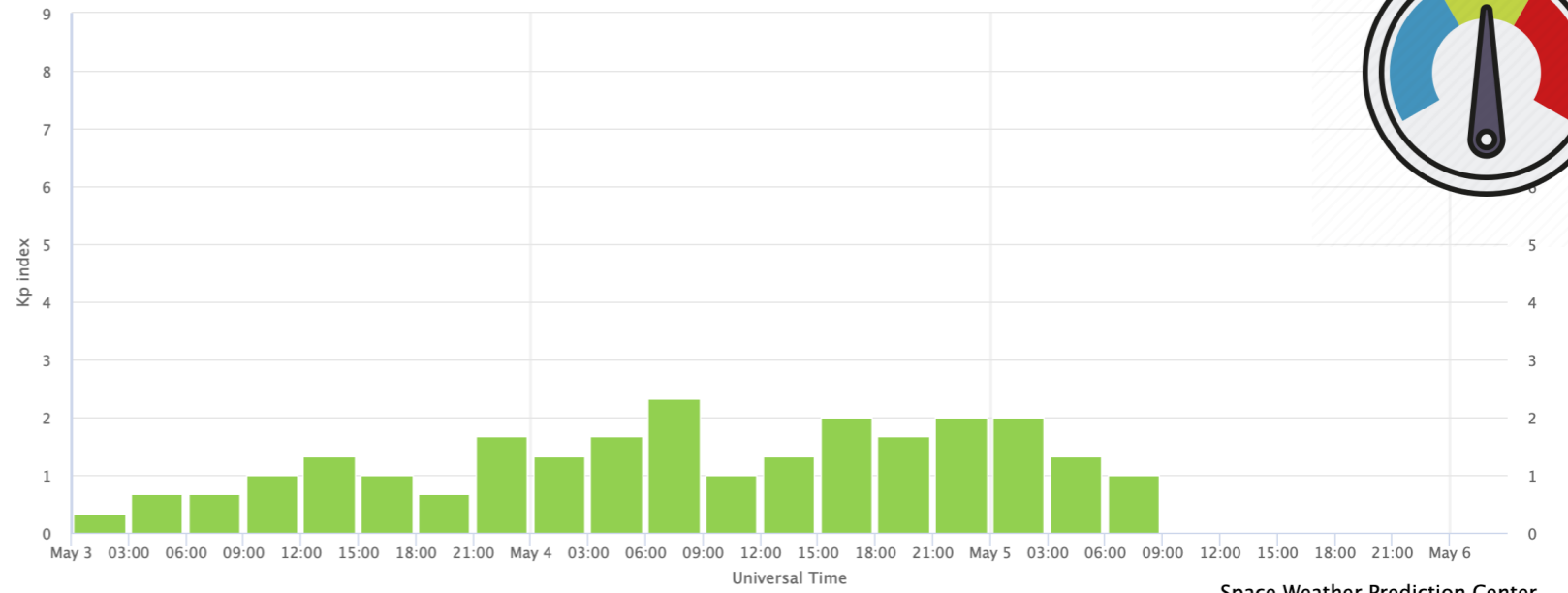
A,B,C,M,X



STORM SCALE

Estimated Planetary K index (3 hour data)

Begin: Wed, 03 May 2023 00:00:00 GMT

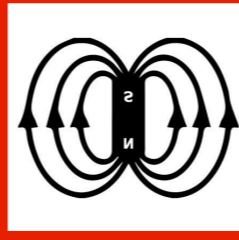


Space Weather Prediction Center

A,B,C,M,X



Kp
0 - 9



DURATION



MINs to HOUR

A white square icon containing a black outline of a lit lightbulb, representing a short duration or immediate action.

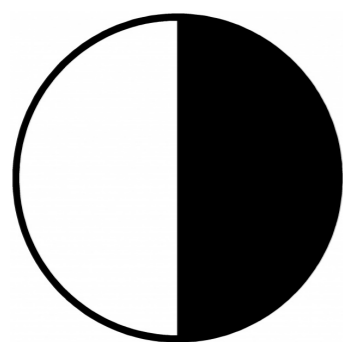
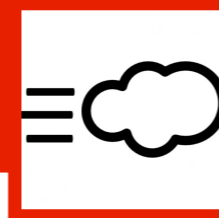
DAY+

A white square icon containing a black diagram of magnetic field lines with arrows, representing a long duration or extended period.

AREA OF IMPACT

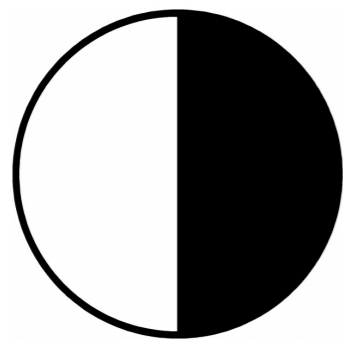


Illuminated area

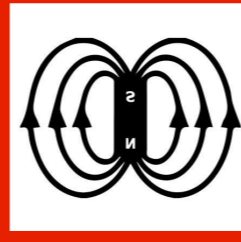


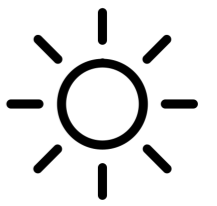
AREA OF IMPACT

Illuminated area

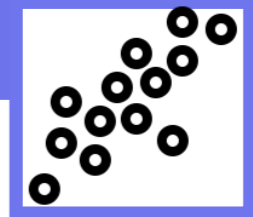


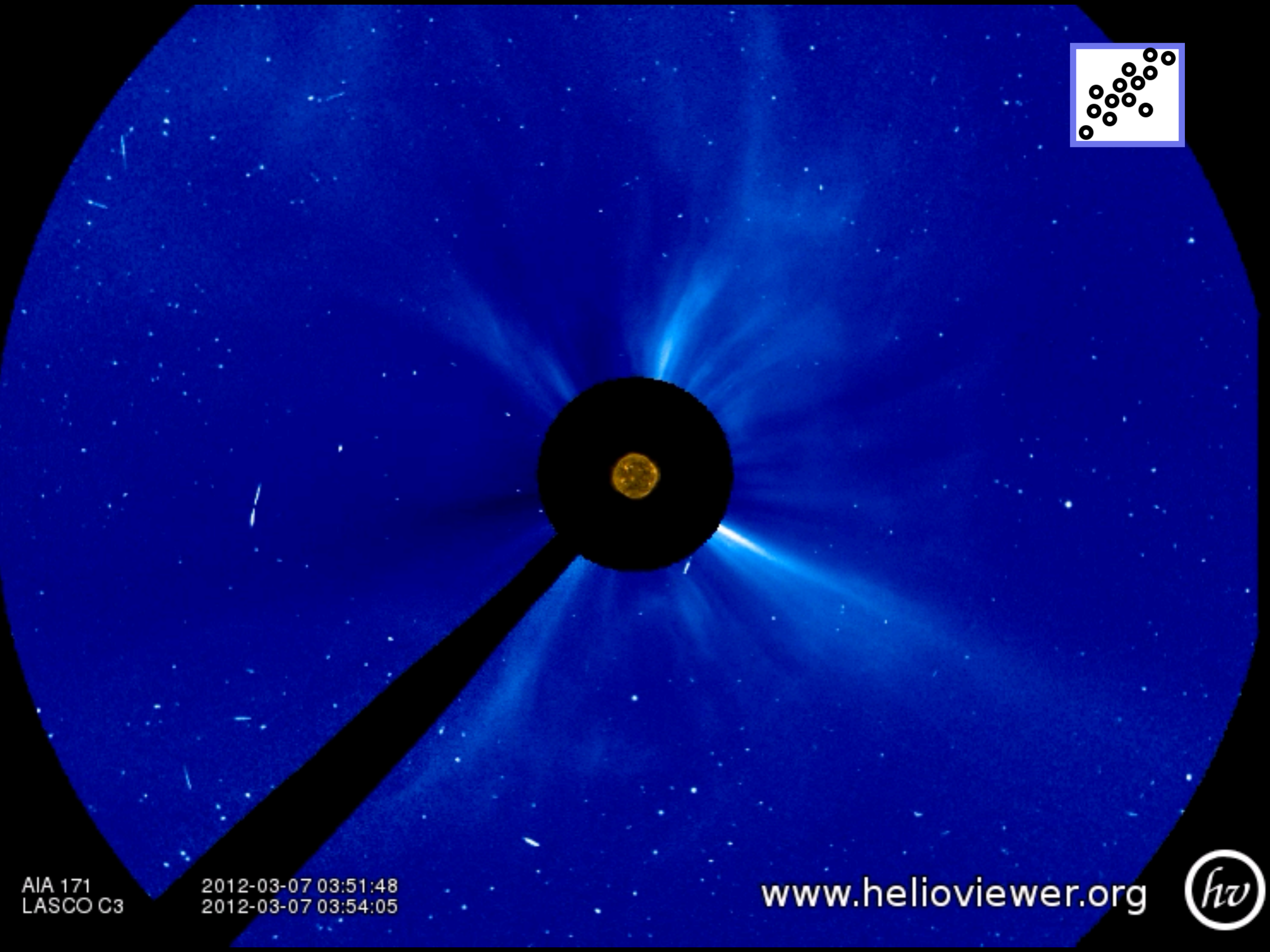
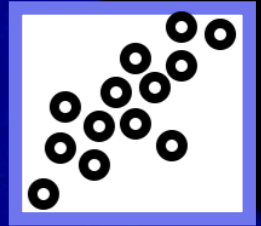
Polar Cap





Energetic Particles





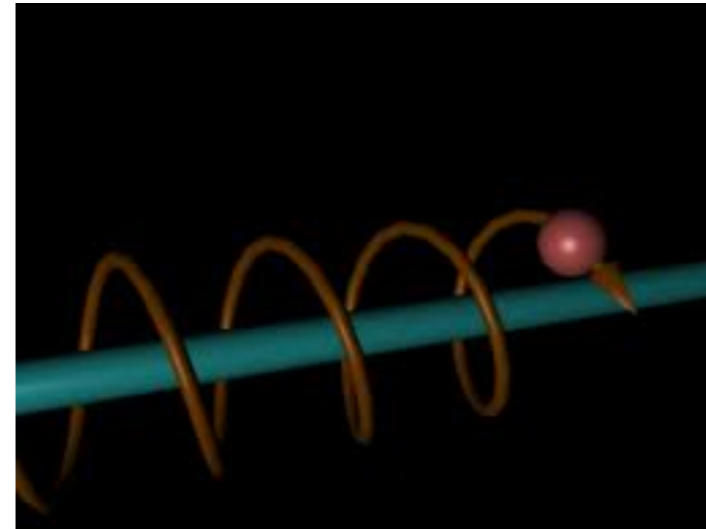
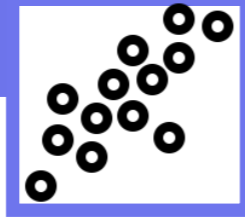
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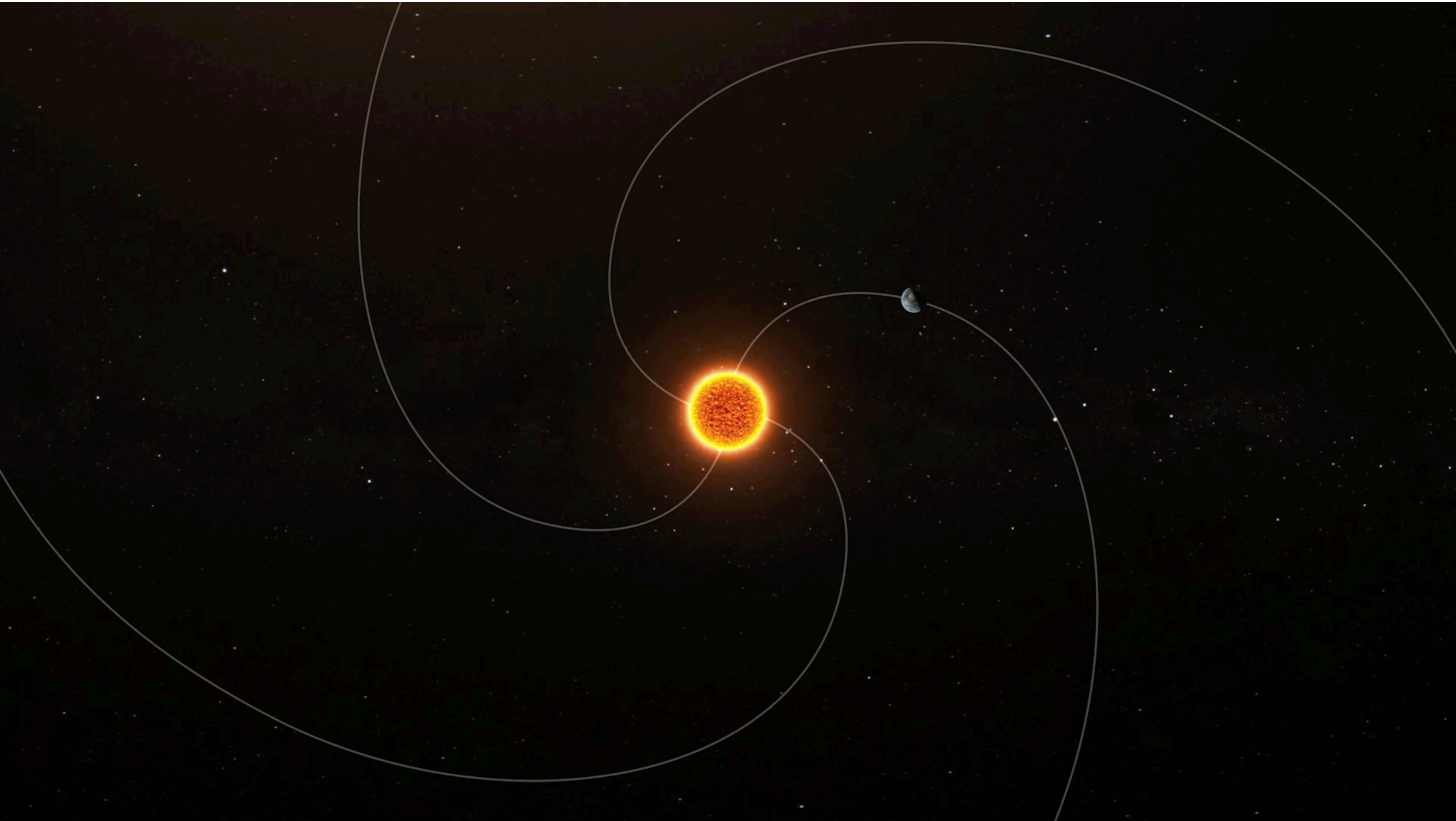
www.helioviewer.org

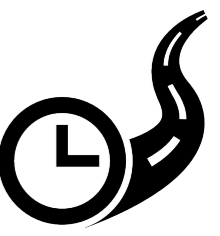


SOLAR PARTICLES



Solar energetic particles follow magnetic field lines.





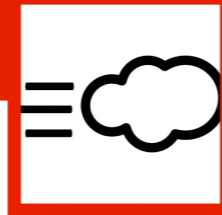
AU TRANSIT TIME

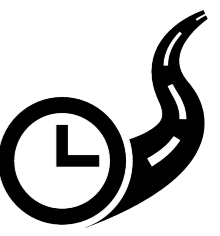
The energy released during a solar storm moves through space, each with its own typical speed: speed of light, order of a few 100 km/s, relativistic speeds.

8 MIN



DAYS





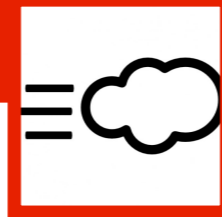
AU TRANSIT TIME

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.

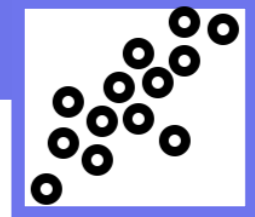
8 MIN



DAYS



HOUR



STORM SCALE

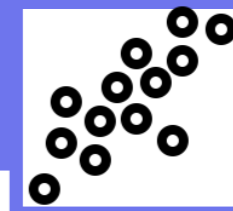
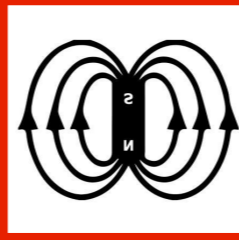


<https://www.swpc.noaa.gov/products/goes-proton-flux>

A,B,C,M,X

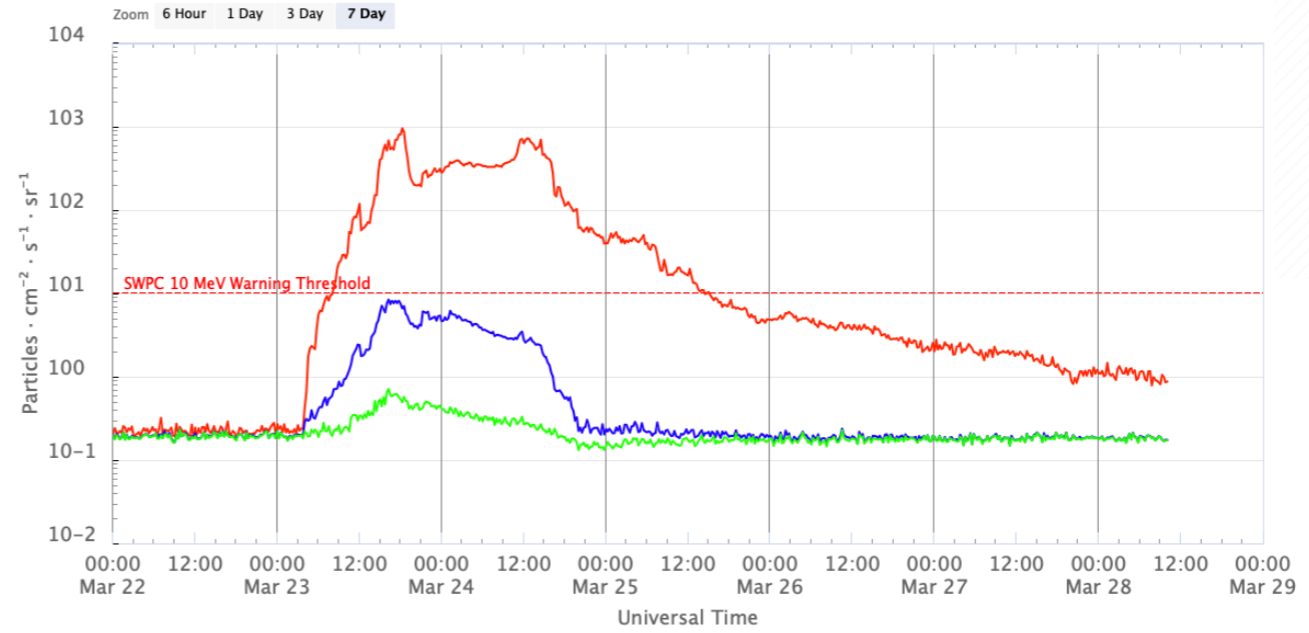


Kp
0 - 9



STORM SCALE

GOES Proton Flux (5-minute data)

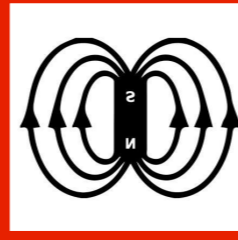


A,B,C,M,X



Updated 2024-03-28 10:10 UTC

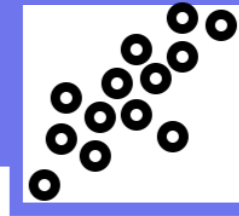
Kp
0 - 9



— GOES-18 ≥ 10 MeV — GOES-18 ≥ 50 MeV — GOES-18 ≥ 100 MeV

Space Weather Prediction Center

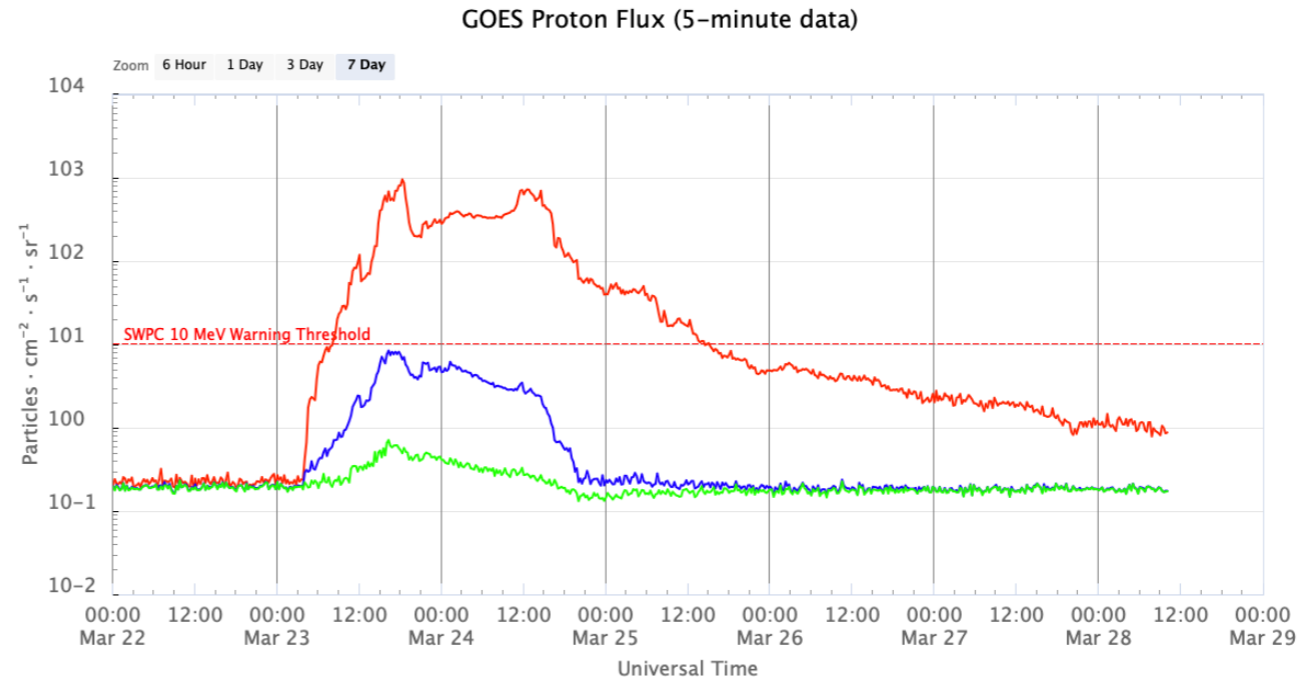
Storm - major storm



GOES



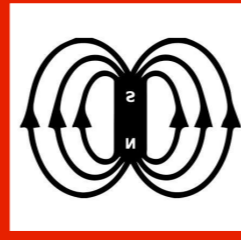
DURATION



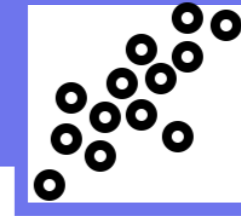
MINs to HOUR



DAY+



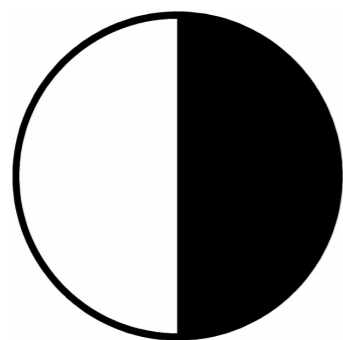
HOURS to DAYS



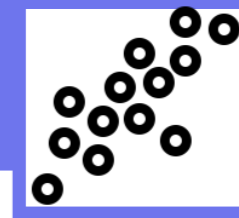
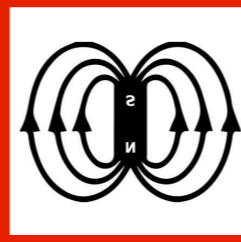
AREA OF IMPACT

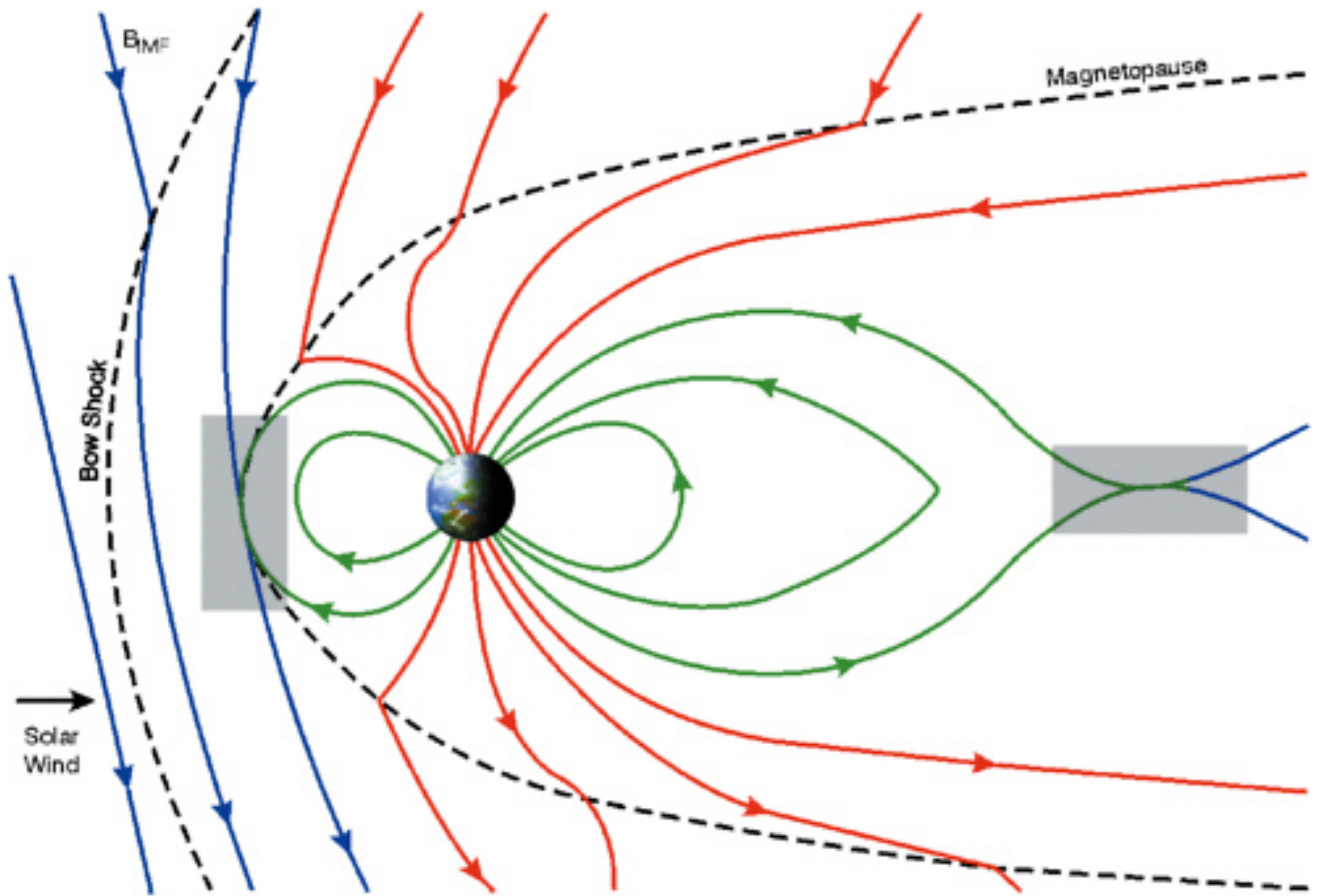


Illuminated area



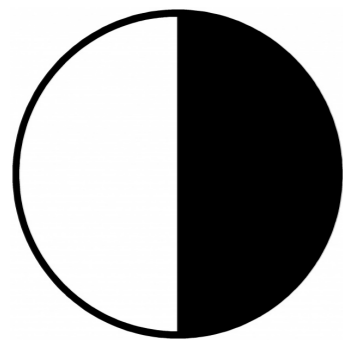
Polar Cap



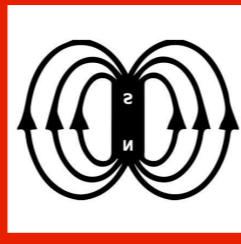


AREA OF IMPACT

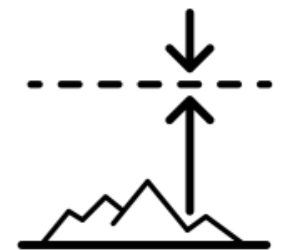
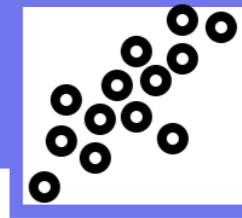
Illuminated area



Polar Cap



Polar Cap
High Altitude



OVERVIEW



8 min

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

Min to Hour

Illuminated area

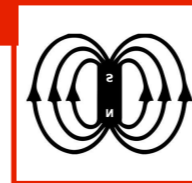


Days

Kp: 0 - 9

Day+

Polar Caps



Hour

Protons:
Storm - Major Storm

Hours to Days

Polar Caps
High Altitude

