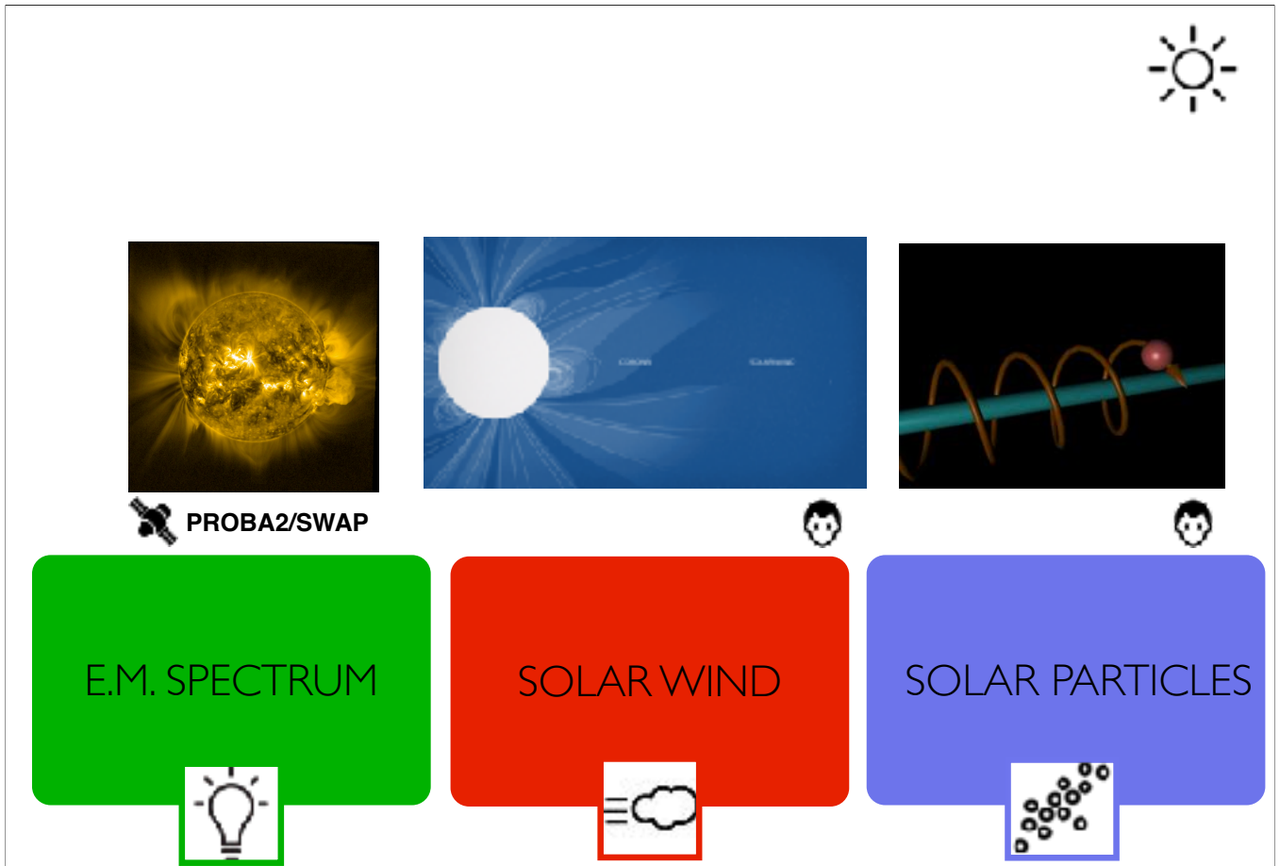


The outward flow of solar particles and magnetic fields from the Sun. Typically at 1 AU, solar wind velocities are near 375 km/s and proton and electron densities are near 5 cm-3. The total intensity of the interplanetary magnetic field is nominally 5 nT.

TSI, e.m. radiation is not linked to the IMF. It doesn't follow the magnetic field lines.
PROBA2/SWAP, the sun in the EUV.

However, plasma containing ions and electrons has to follow the magnetic field lines. Or you can also say that the magnetic field lines guide the plasma.
The solar wind plasma is glued to the IMF - or the IMF is glued to the plasma.
The plasma in the solar wind is considered as a gas, a group of particles behaving and moving in group. You don't speak about that particular particle in the solar wind, you speak about the solar wind, a whole bunch together.
Cartoon

Electrically charged particles have to follow the IMF. These electrically charged particles are considered as individuals and behave as individuals.
Cartoon

Near Earth, the IMF still controls the solar wind and its movement. Much much further away from the Sun, the IMF becomes very weak and doesn't control the solar wind anymore. But, this is not important for us. At 1AU, the IMF influences the plasma and the plasma the IMF.

About the animated gif:
Conceptual animation (not to scale) showing the sun's corona and solar wind.
Credits: NASA's Goddard Space Flight Center/Lisa Poje

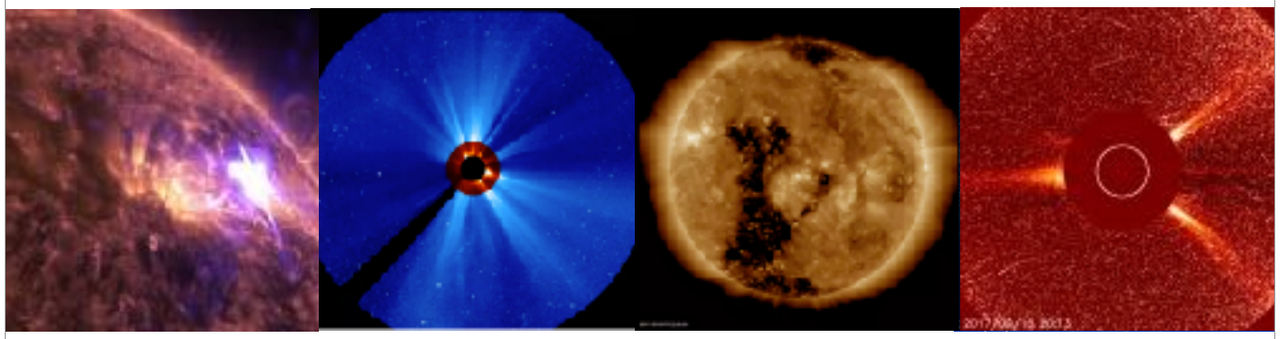
The solar wind is a continuous radial stream of solar plasma that leaves the sun and moves away from it. It fils the space between the planets with solar mass. The solar wind reaches the boundaries of the heliosphere, a magnetic shield around the Sun. In the heliosphere, the Sun sets the rules and you have solar weather. Outside the heliosphere, you have the rest of the galaxy. Earth is in the heliosphere.

A nice movie is found on

https://www.nasa.gov/feature/goddard/2016/images-from-sun-s-edge-reveal-origins-of-solar-wind

https://youtu.be/QYM2_ytkjQo

SOLAR STORMS



FLARE

CME
CORONAL HOLE

PARTICLE STORM

Flare: side of the sun facing earth
Solar wind disturbance: central meridian or extend of cloud
Particle storm: magnetically connected with Earth

SOLAR STORMS

SDO/AIA

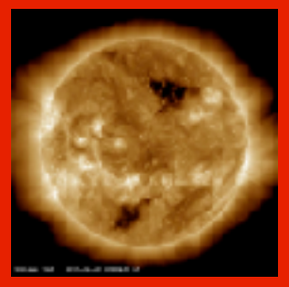
SUNSPOTS
ACTIVE REGIONS

Flare: side of the sun facing earth
Solar wind disturbance: central meridian or extend of cloud
Particle storm: magnetically connected with Earth

SOLAR WIND VARIATIONS

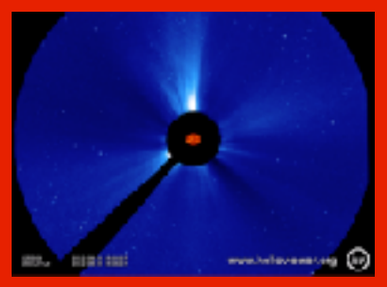
Non-eruptive

Coronal Hole



Eruptive

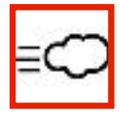
Coronal Mass Ejection



The variations in the solar wind introduce space weather events.

CME - suddenly, a mass is ejected into space. A CME is an eruptive event. You can have filament eruptions or plasma ejections associated with flares. We come back to this.

A CH is not eruptive. A CH is present, it doesn't pop up suddenly. A CH can of course slowly appear or disappear, become bigger, become smaller but not on time scale of a few minutes. It is also not the case that a CH ejects material and a little bit later, not any more. The solar wind continuously emanated from a CH.

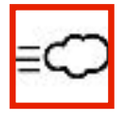


Solar wind =

Interplanetary Magnetic Field

+

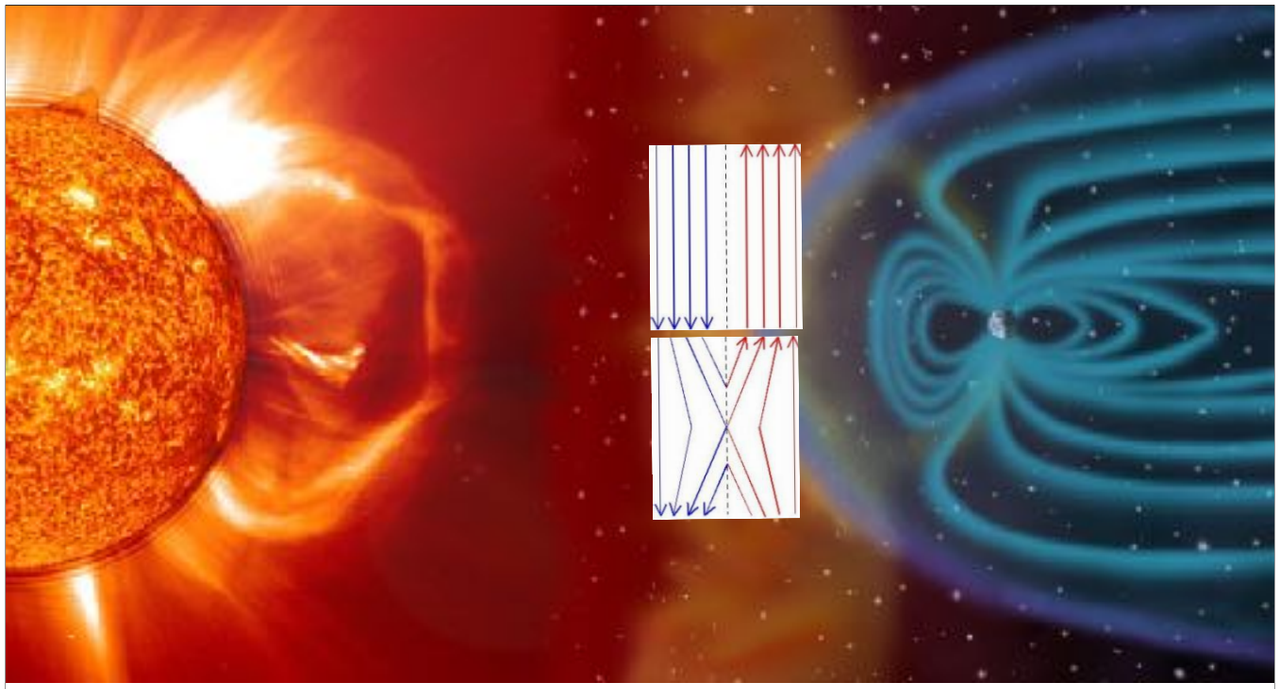
Plasma



Solar wind is

Radial and associated with open magnetic field lines.

CH —> strong wind



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.

This is the earths magnetosphere. The sun is on the left.
The earth is a giant dipole - similar as the sun. Except, the solar magnetic dipole field reverses every 11 year. The Earths magnetic poles don't. They are already for ages like this.
The part of the earths dipole facing the sun/solar wind is pushed more together, while the part behind the earth is stretched and forms a tail. In front of the magnetic structure, you have a shock.

This is a structure similar like a shock in front of a speed boat that moves very fast over water: the water waves that the moving boat initiate are slower compared to the speed of the boat. The boat is super-water wave.
When a plane is super-sonic, there is also a shock in front of it. The pressure waves that the moving plane creates move much slower than the plane.

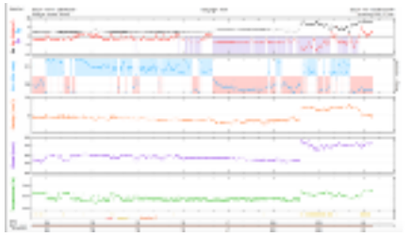
In the case of a speed boat, the boat moves through the water.
In our case, it is the solar wind that blows over the earth. It is just a matter of reference, but the result is the same: a shock.

A magnetic field is imbedded in the solar wind. This magnetic field can interact with the magnetic field of the earth at the boundaries of the earth magnetosphere. This interaction is called reconnection. It happens when 2 magnetic regions are confronted with each other.

The blue magnetic field lines are imbedded in the solar wind.
The red magnetic field lines represent the earth magnetosphere.
The blue and the red magnetic region have to face each other. Opposite magnetic field lines can reconnect easily and 'open'. This causes geomagnetic storms. Magnetic field lines in the same direction interact less.
Therefore, it is very important to know how strong the

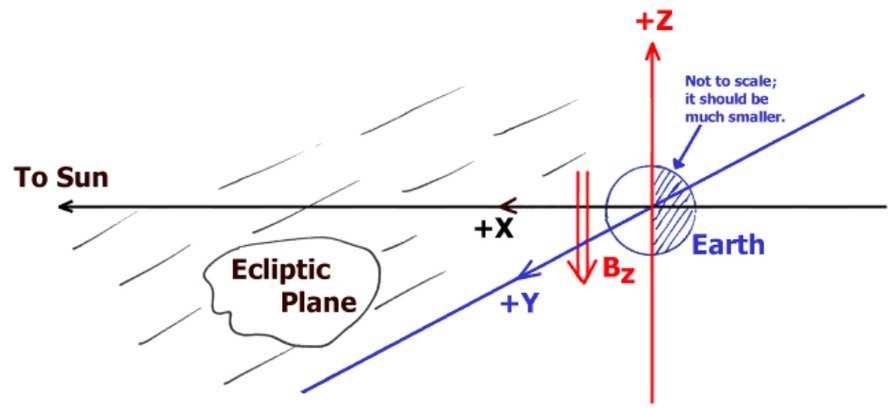
0.3 T - solar sunspot
5mT - strength of a typical refrigerator magnet
31.869 μT (3.1×10^{-5} T) - strength of Earth's magnetic field at 0° latitude (North/South), 0° longitude (west/east)
1 to 5 nT - IMF at L1

https://www.swpc.noaa.gov/products/real-time-solar-wind



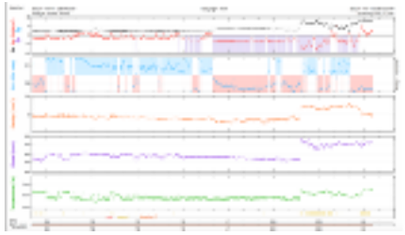
DSCOVR

COORDINATE SYSTEM



+Z is perpendicular to the Ecliptic Plane.

GSM: Geocentric Solar Magnetospheric coordinate system.
The x-axis of the GSM coordinate system is defined along the line connecting the center of the Sun to the center of the Earth. The origin is defined at the center of the Earth, and is positive towards the Sun. The y-axis is defined as the cross product of the GSM x-axis and the magnetic dipole axis; directed positive towards dusk. The z-axis is defined as the cross product of the x- and y-axes. The magnetic dipole axis lies within the xz plane.



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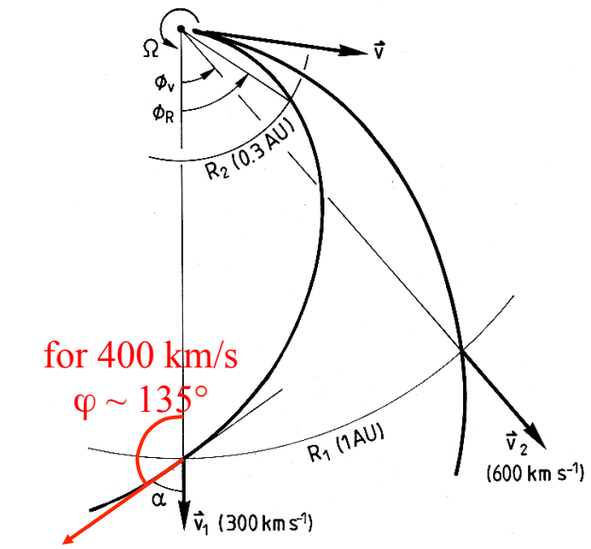
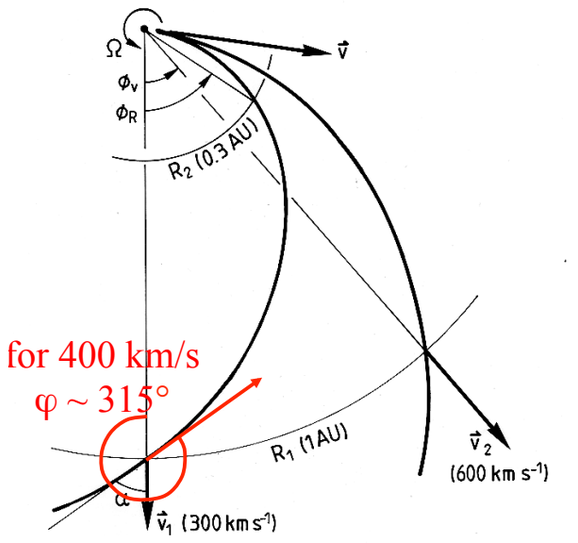
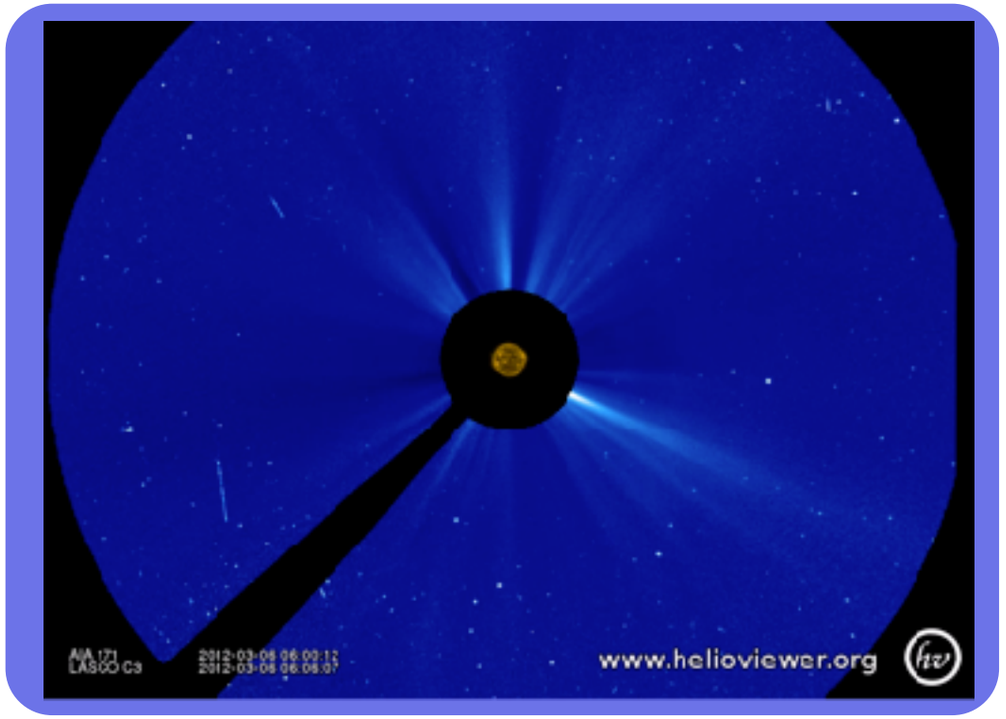
IMF POLARITY





This is the IMF in the solar equatorial plane.

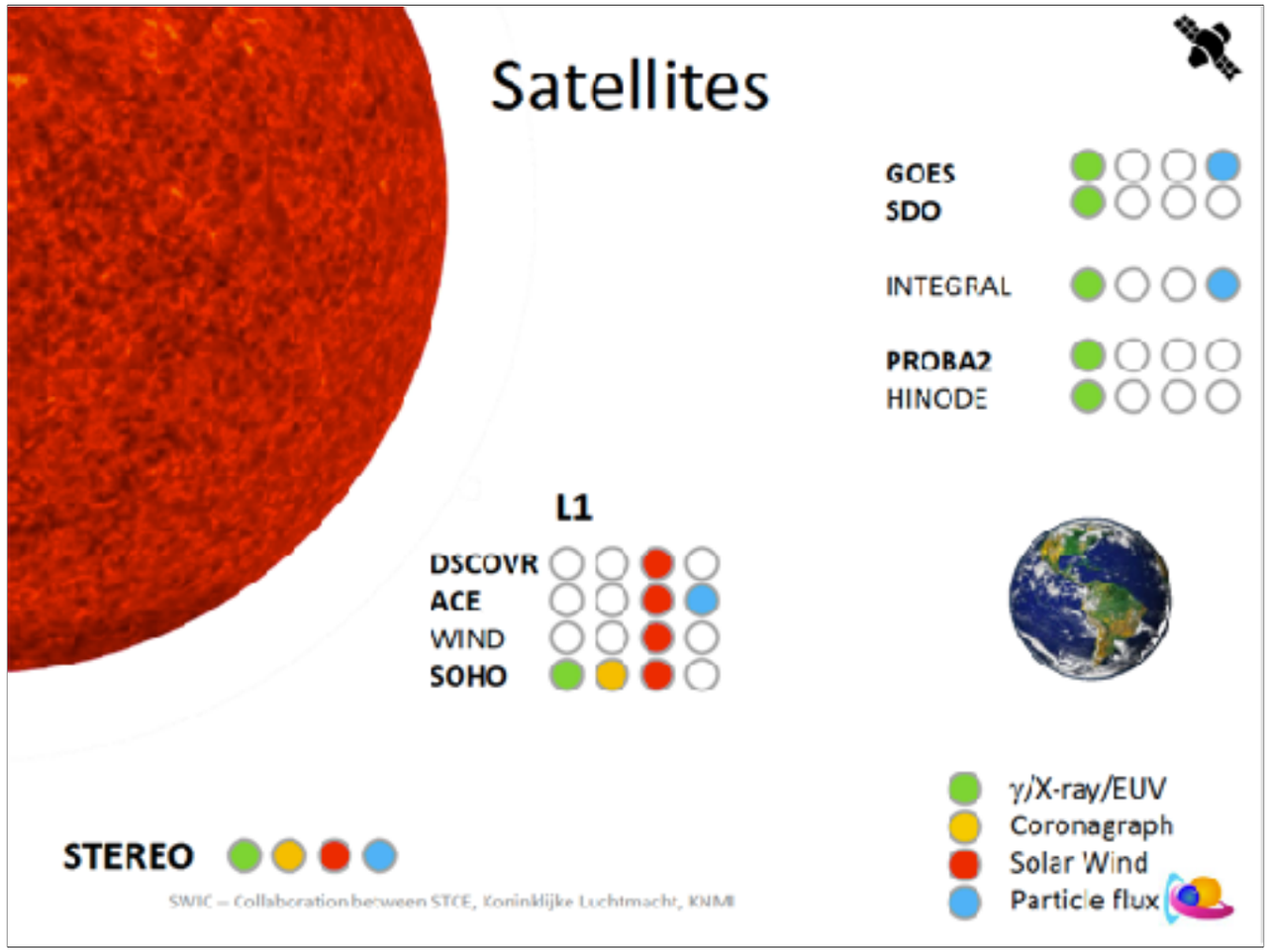
SOLAR ENERGETIC PARTICLES

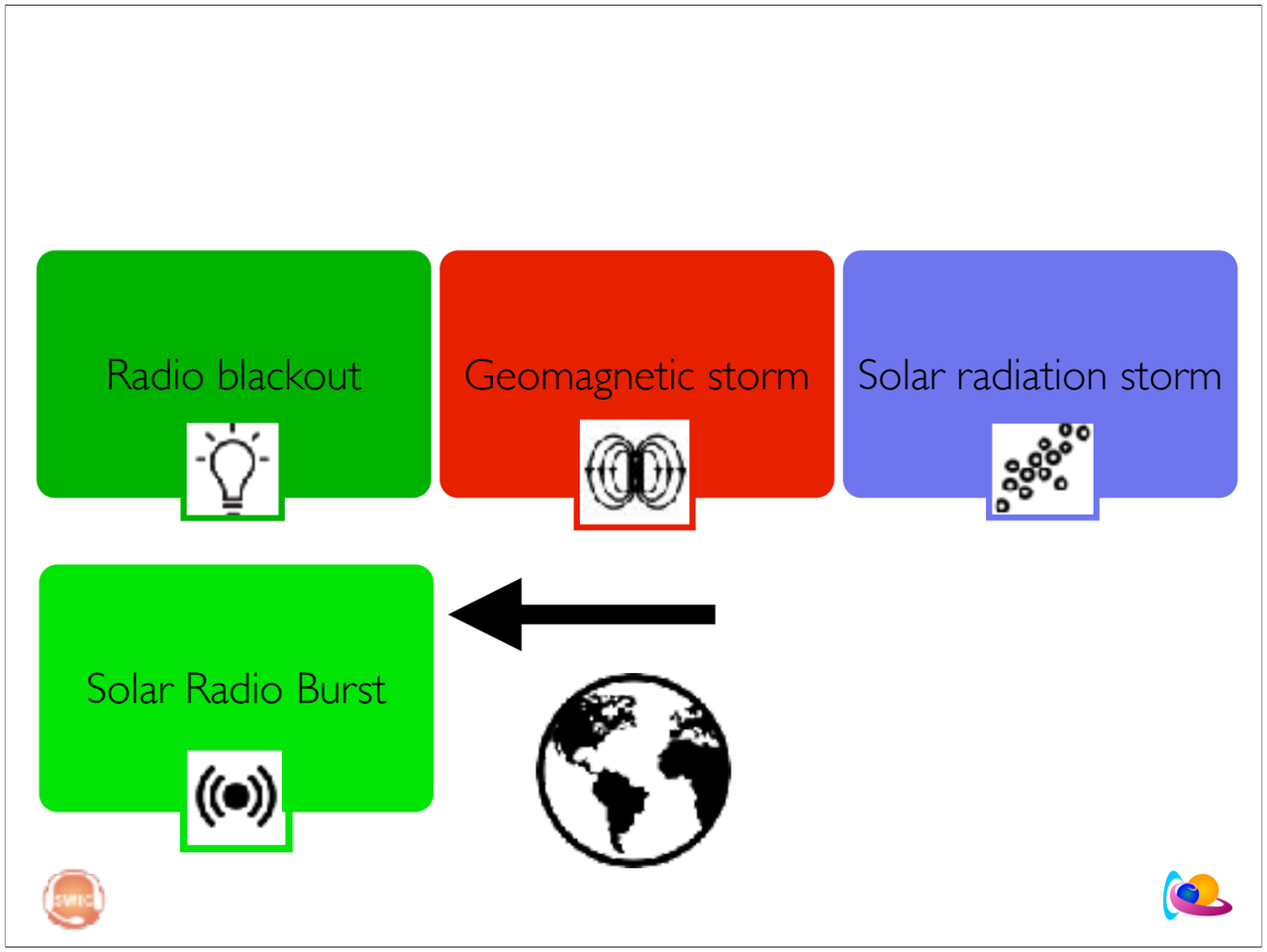


Electrically charged particles that are ejected by the Sun. They spiral around magnetic field lines.
They are ejected during a flare or CME event. The solar event accelerates the particles.

Solar radiation storms occur when a large-scale magnetic eruption, often causing a coronal mass ejection and associated solar flare, accelerates charged particles in the solar atmosphere to very high velocities. The most important particles are protons which can get accelerated to 1/3 the speed of light or 100,000 km/sec. At these speeds, the protons can traverse the 150 million km from sun to Earth in just 30 minutes. When they reach Earth, the fast moving protons penetrate the magnetosphere that shields Earth from lower energy charged particles. Once inside the magnetosphere, the particles are guided down the magnetic field lines such that they penetrate the atmosphere near the north and south poles.

100 = 10^0
101 = 10^1
102 = 10^2


Satellites
GOES
SDO
INTEGRAL
PROBA2
HINODE
L1
DSCOVR
ACE
WIND
SOHO
STEREO
γ/X-ray/EUV
Coronagraph
Solar Wind
Particle flux
SWIC – Collaboration between STCE, Koninklijke Luchtmacht, KNMI


Radio blackout
Geomagnetic storm
Solar radiation storm
Solar Radio Burst

URSIGRAM