PECASUS

For civil aviation

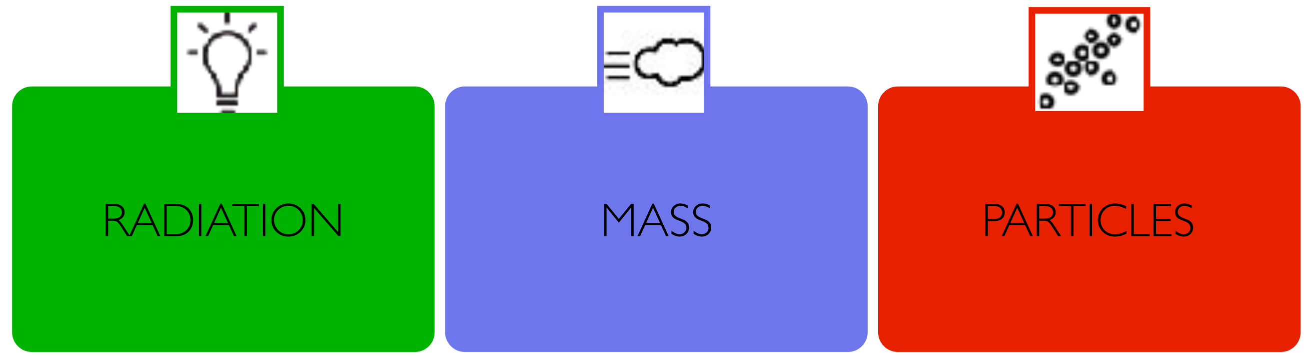
SPACE WEATHER INTRODUCTORY COURSE

For space weather operators

Rehearsal 

Solar wind = kinetic energy of a plasma in a magnetic environment 

THE SUN LOOSES ENERGY



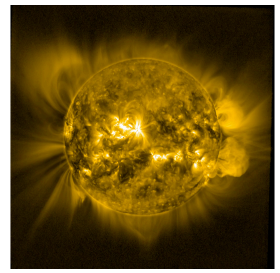
The sun is a gigantic ball of energy: magnetic energy, heat, moving plasma, …
Four states of matter are observable in everyday life: solid, liquid, gas, and plasma.
Plasma is the fourth state of matter. When you have solid material and you heat it, it becomes liquid. You keep on meeting it, it becomes a gas. When you still add heat, the atoms split into ions and electrons. The gas becomes electrically conductive creating electrical and magnetic field.

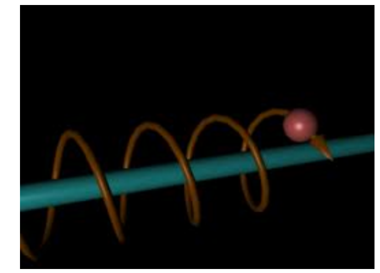
This energy is kept inside the Sun but also on its surface and in its atmosphere in magnetic structures like sunspots and magnetic loops, filaments or prominences ready to be released.

This energy is expelled, leaves the Sun to outer space in the form of electromagnetic radiation, kinetic, electric and magnetic energy.

Note: the solar plasma is hot. The plasma particles bump on each other. These collisions changes their kinetic energy. This change is emitted in the form of thermal radiation, light photons. Once these photons are at the solar surface, they can escape and move freely.
Thermal radiation is electromagnetic radiation generated by the thermal motion of charged particles in matter. You have thermal motion as soon as the temperature is above absolute zero.

ENERGY IN SOLAR JARGON





TOTAL SOLAR IRRADIANCE

SOLAR WIND

FAST PARTICLES

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

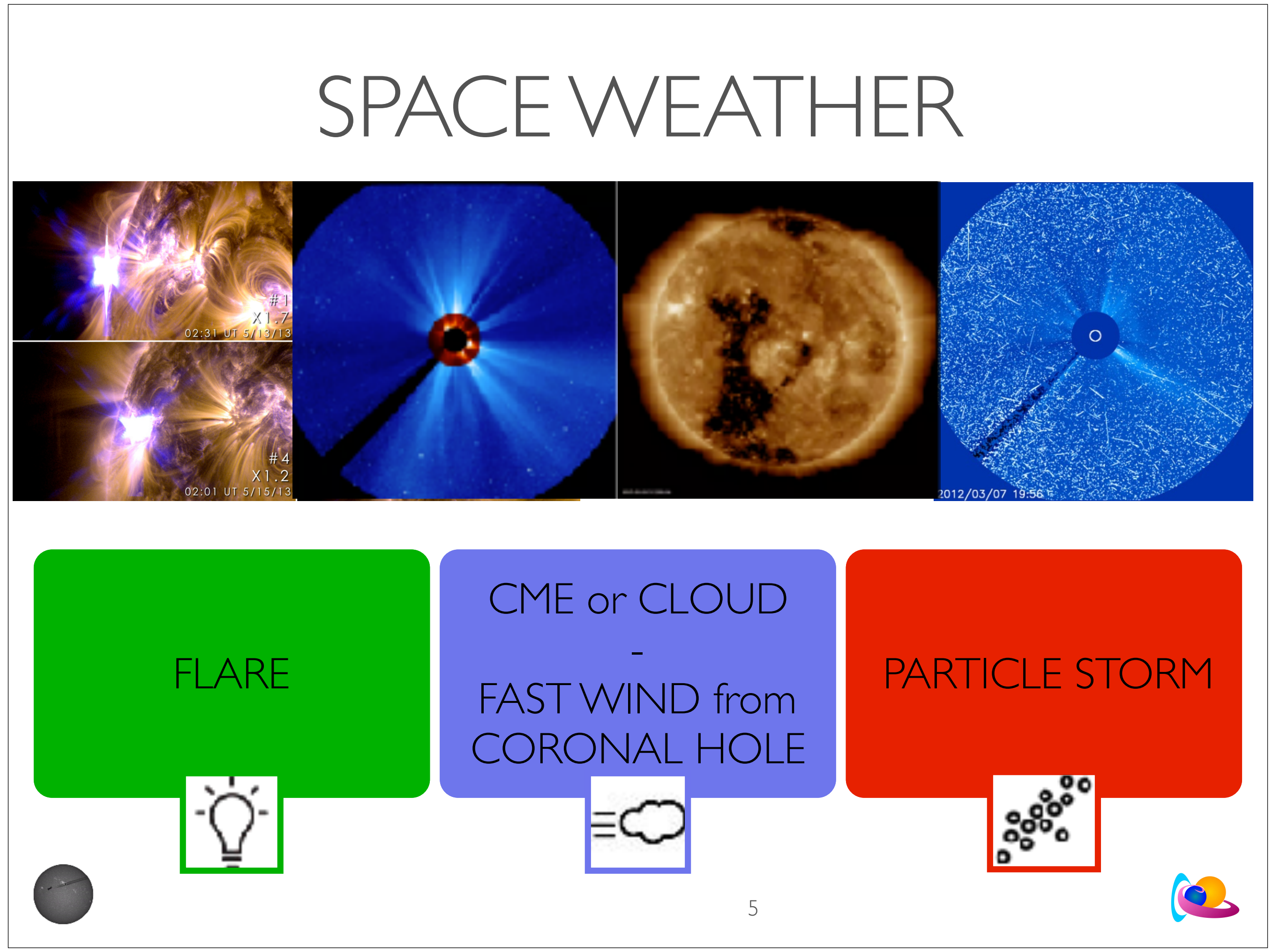
Near Earth, the IMF still controls the solar wind and its movement. Much much further away from the Sun, the IMF becomes very weak and doesn't control the solar wind anymore. But, this is not important for us. At 1AU, the IMF influences the plasma and the plasma the IMF.

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



Space weather is the changes that occur in the space environment.

A Flare is a sudden strong increase of the solar e.m. radiation. The light flash is localised on the solar surface.
SDO/AIA

A Coronal Mass Ejection is a plasma cloud that is ejected into space. You consider it as a cloud and not as a bunch of individual particles. It is superimposed on the background solar wind. You can see a CME as a complex magnetic bag with different magnetic layers with plasma in it that travels as a tsunami through space. It can go faster/as fast as/slower than the background solar wind. When it is faster, you will see a shock in front of the cloud. This is exactly the same as the shock you see in front of a speed boat.
A CME is visible as a white cloud in corona graphic images like the one on the slide. A coronagraph is a telescope that creates an artificial eclipse and makes pictures in the visible light of the region around the sun.
SOHO/LASCO C2 (red) and LASCO C3 (blue)

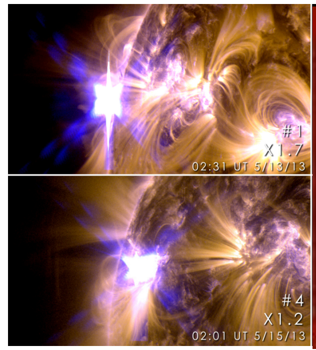
A coronal hole is a structure in the solar corona that you see as a black area in the EUV. It looks black because there is less plasma present that radiates in the EUV. The magnetic field lines are open, i.e. fan out into space. There are no magnetic loops above a coronal hole. The solar wind emanating from a CH is faster compared to the usual solar wind.
SDO/AIA

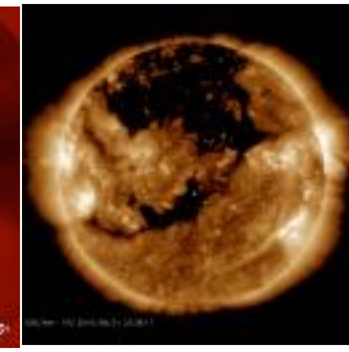
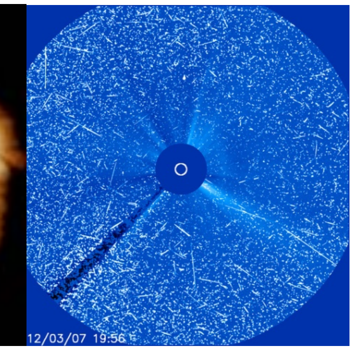
A particle storm is a bunch of electrically charged particles that circle around the IMF lines into space. They may impact telescopes. They are seen as white stripes and dots: this are particles that fall into the lens and blind the pixel(s). During that particular moment, the telescope can't see anymore through the impacted pixels. You can say that the dots and stripes represent a sort of in situ measurement.

In situ means that you measure a parameter local. Remote sensing means that you look at something from a distance.

Near Earth, the IMF still controls the solar wind and its movement. If we would go much much further, the CME magnetic bag with solar plasma would be almost empty (all the solar material is spread over an immense volume) and the magnetic bag would have evaporated. But, this doesn't matter for us. We are at 1AU and at 1AU the IMF and solar plasma make space weather in a normal way, in an extreme way.

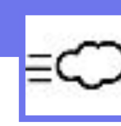
TIME SCALES OF SW



8 MIN

DAYS



HOUR

FORECAST

Flare probability

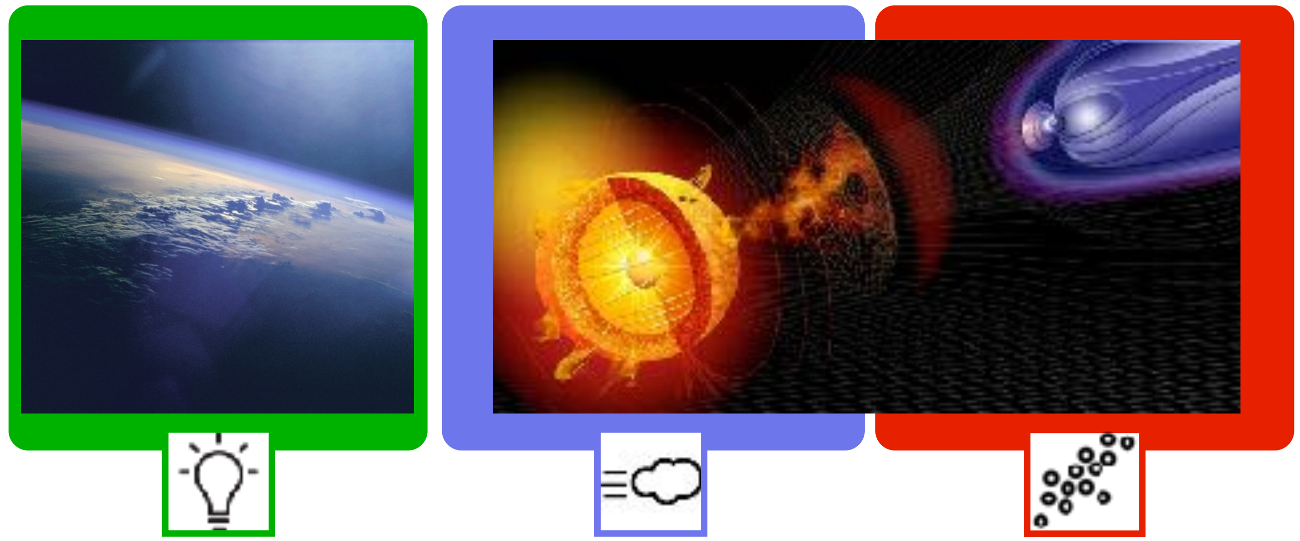
Perturbations of the Geomagnetic field

Probability

The Ap-index provides a daily average level for geomagnetic activity. Because of the non-linear relationship of the K-scale to magnetometer fluctuations, it is not meaningful to take the average of a set of K-indices. Instead, every 3-hour K-value will be converted back into a linear scale called the a-index. The average from 8 daily a-values gives us the Ap-index of a certain day. The Ap-index is thus a geomagnetic activity index where days with high levels of geomagnetic activity have a higher daily Ap-value.

OUR NATURAL PROTECTION

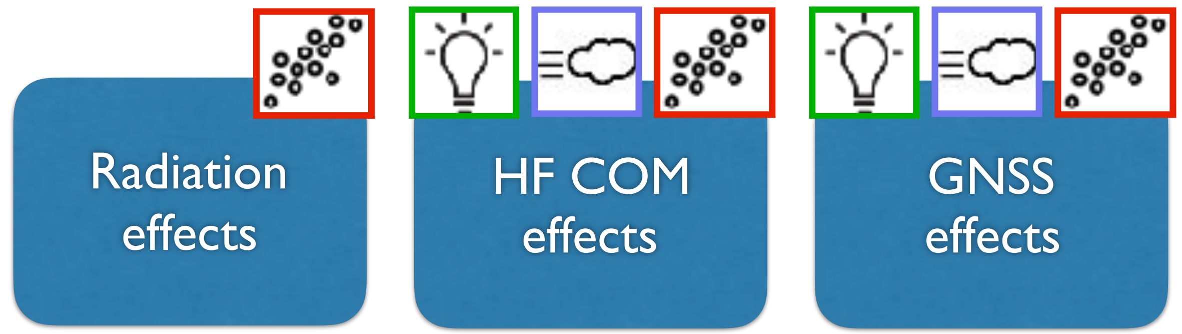
The earth atmosphere and magnetosphere protects biological live against space climate and space weather impacts.



The earth magnetic field protects human and biological live against the solar wind.
The earth magnetic field guides the solar protons that reach the Earth’s magnetosphere and ionosphere towards the poles.

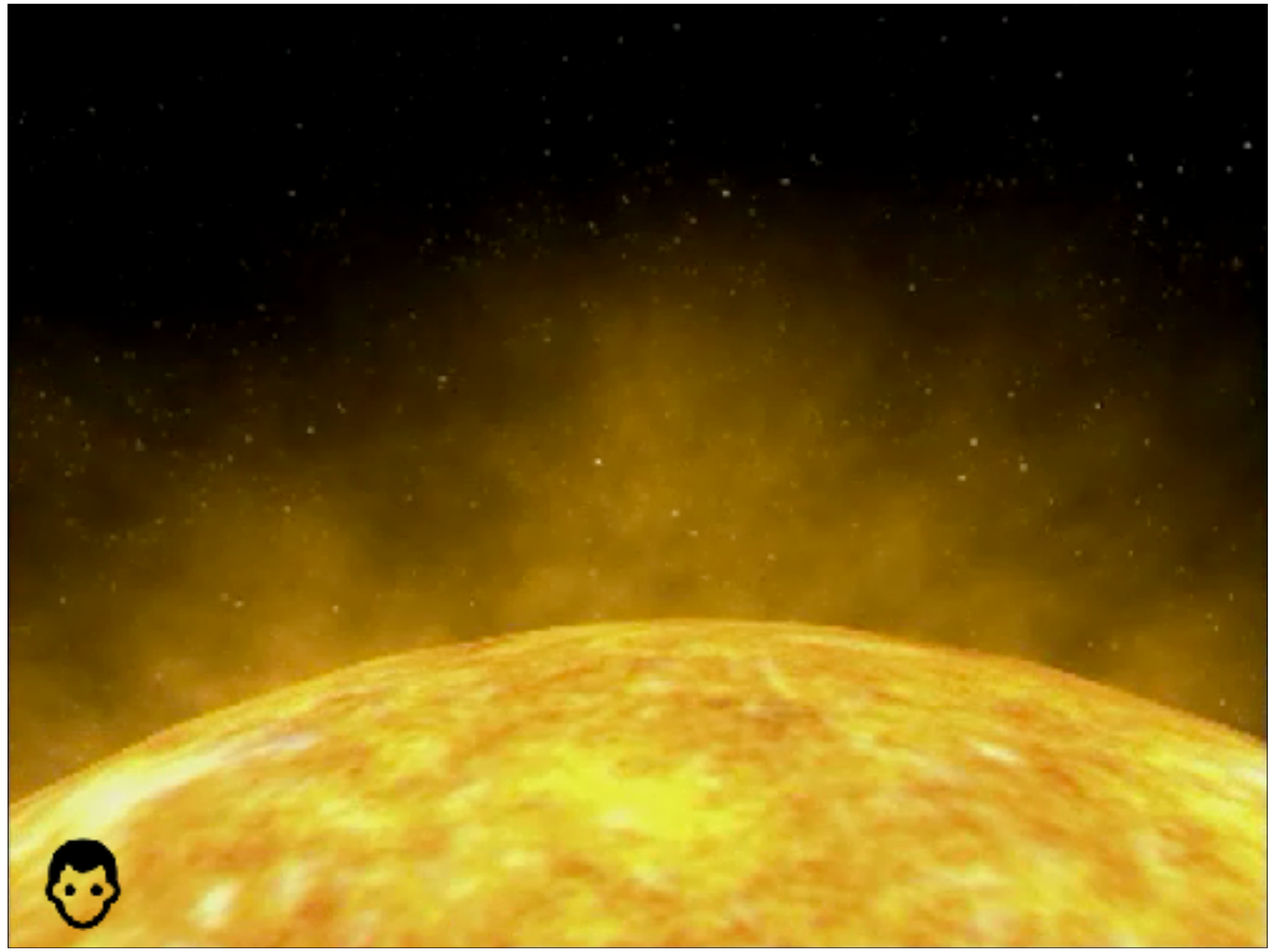
The earth atmosphere protects human and biological live against solar e.m. radiation.
The earth atmosphere is not blown away by the solar wind thanks to the magnetosphere.

Nevertheless, our technology is impacted. PECASUS concerns impacts on aviation operations.



Monitoring & forecasting space weather should result in 3 advisory messages.

NOTAM = NOtice To AirMen



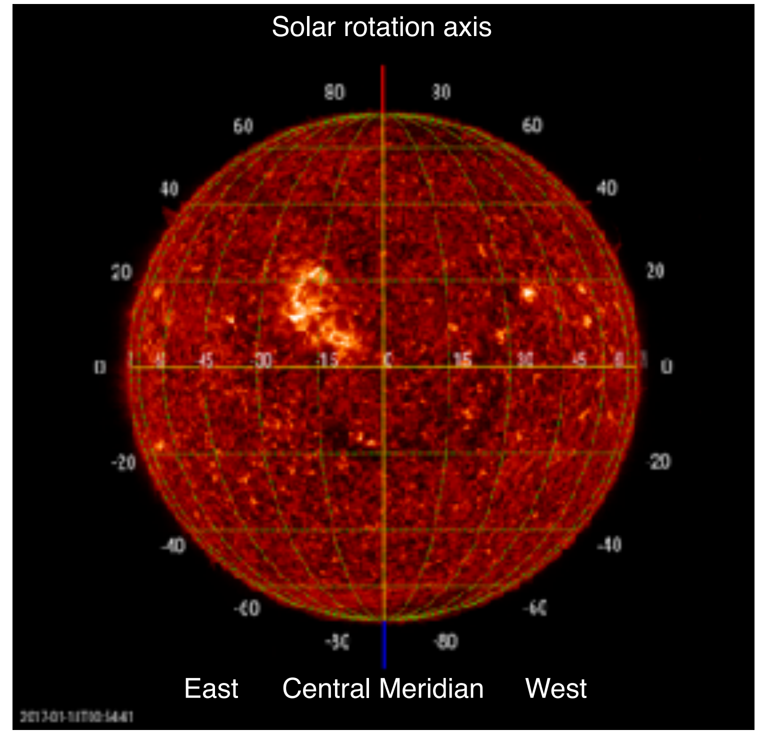
POSITIONING

Solar North Pole

Magnetic South Pole
positive/outward
yellow/white

Solar South Pole

Magnetic North Pole
negative/inward
blue/black



Northern hemisphere

Solar Equator

Southern hemisphere

Before going into more detail of flares (e.m. waves), CME's and CH's (solar plasma that moves through space) and SEPs (Solar Energetic Particles)/plasma storms (electrically charged particles that move along magnetic field lines through space), we have to be able to 'navigate' on the sun.

Two important circles/lines are: the central meridian and the solar equator.
You determine positions on the solar surface

Solar equatorial plane is not the ecliptic (plane in which the Earth orbits). The earth has a certain heliographic latitude. In summer and winter, the earth looks more on the poles. While in spring and autumn, earth is located in the solar equatorial plane.

magnetic reversal - at solar maximum: magnetic north pole becomes the magnetic south pole and reversed.
A magnetic cycle of 22 years.

SOLAR WIND

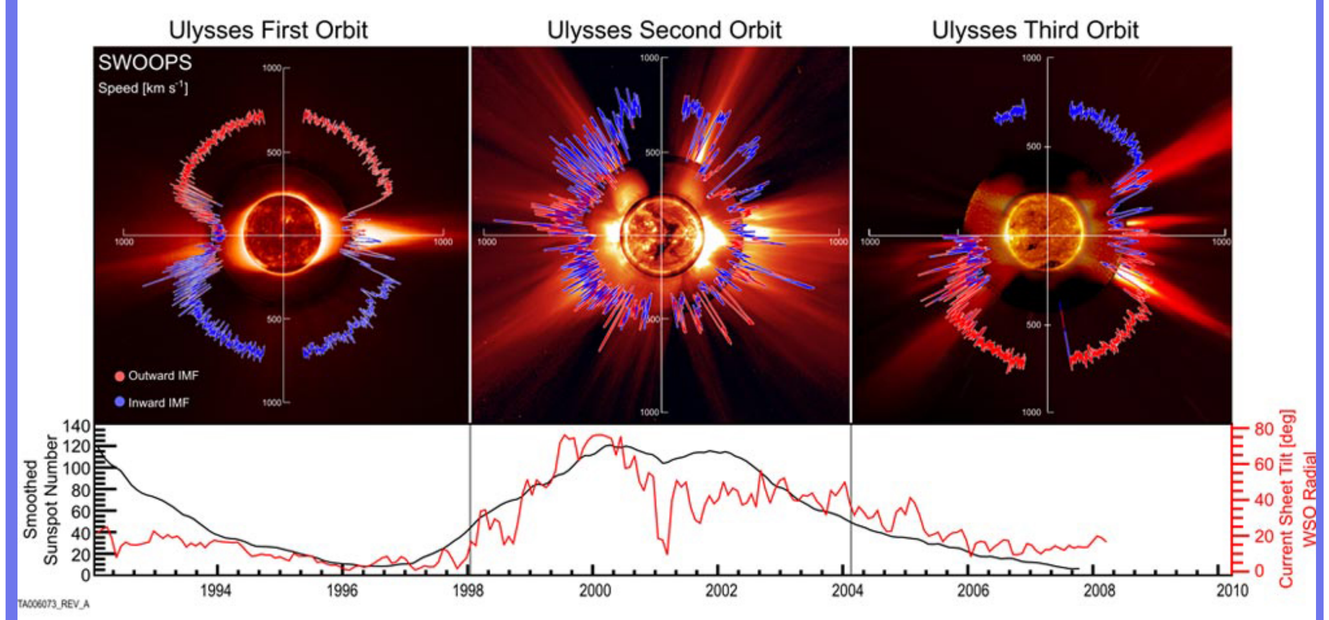
Plasma and magnetic field constitute the solar wind. Both are tied together and define together the solar wind and how it interacts with the Earth magnetic field.

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 WIND

How fast is it?

Ulysses passing all latitudes measuring the solar wind speed. Ulysses made 3 orbits around the Sun.

It seems that the solar wind is not the same on all places of the solar disk, it depends on the latitude.

During solar minimum: more structured. Only near the equator, it looks like a mess.

During solar maximum: global and local magnetic field mingle strongly. The solar wind looks more like a mess.

Larger areas with fast solar wind streams. Fast solar wind streams are associated with coronal holes. These are regions with open magnetic field regions of the corona. While slow streams are associated with closed field regions primarily concentrated near the equatorial (or streamer) belt.

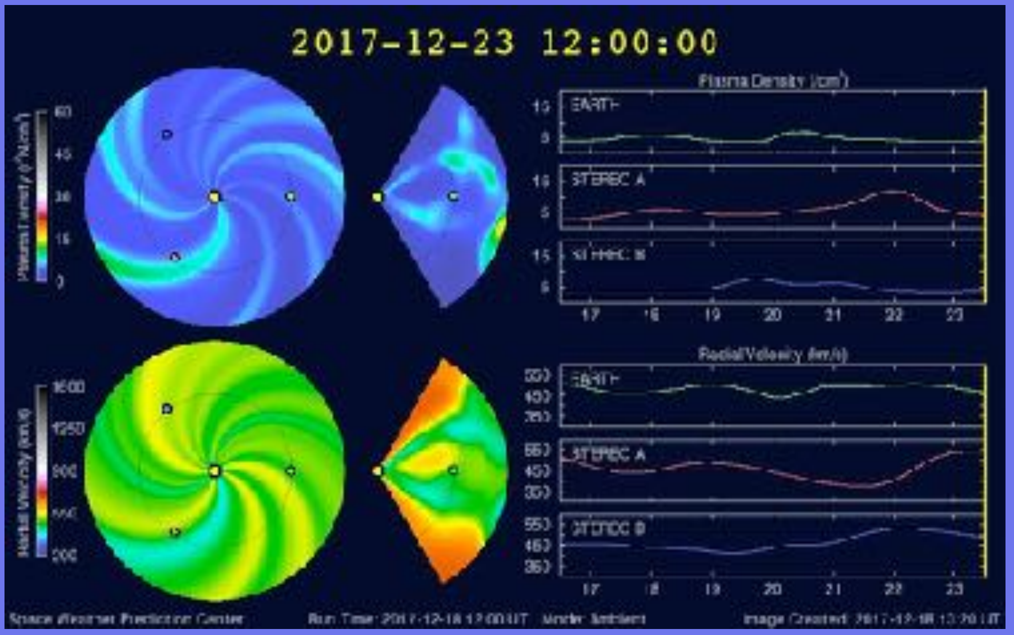
Solar minimum is the season of polar coronal holes extending to low latitudes.

SLOW VERSUS FAST

250-400	km/s	400-800
High: ~10	Density, cm^{-3}	Low: ~3
Low: ~10^4K, ~1eV	Temperature	High: ~10^5K, ~10eV
Variable	Behaviour	Stationary

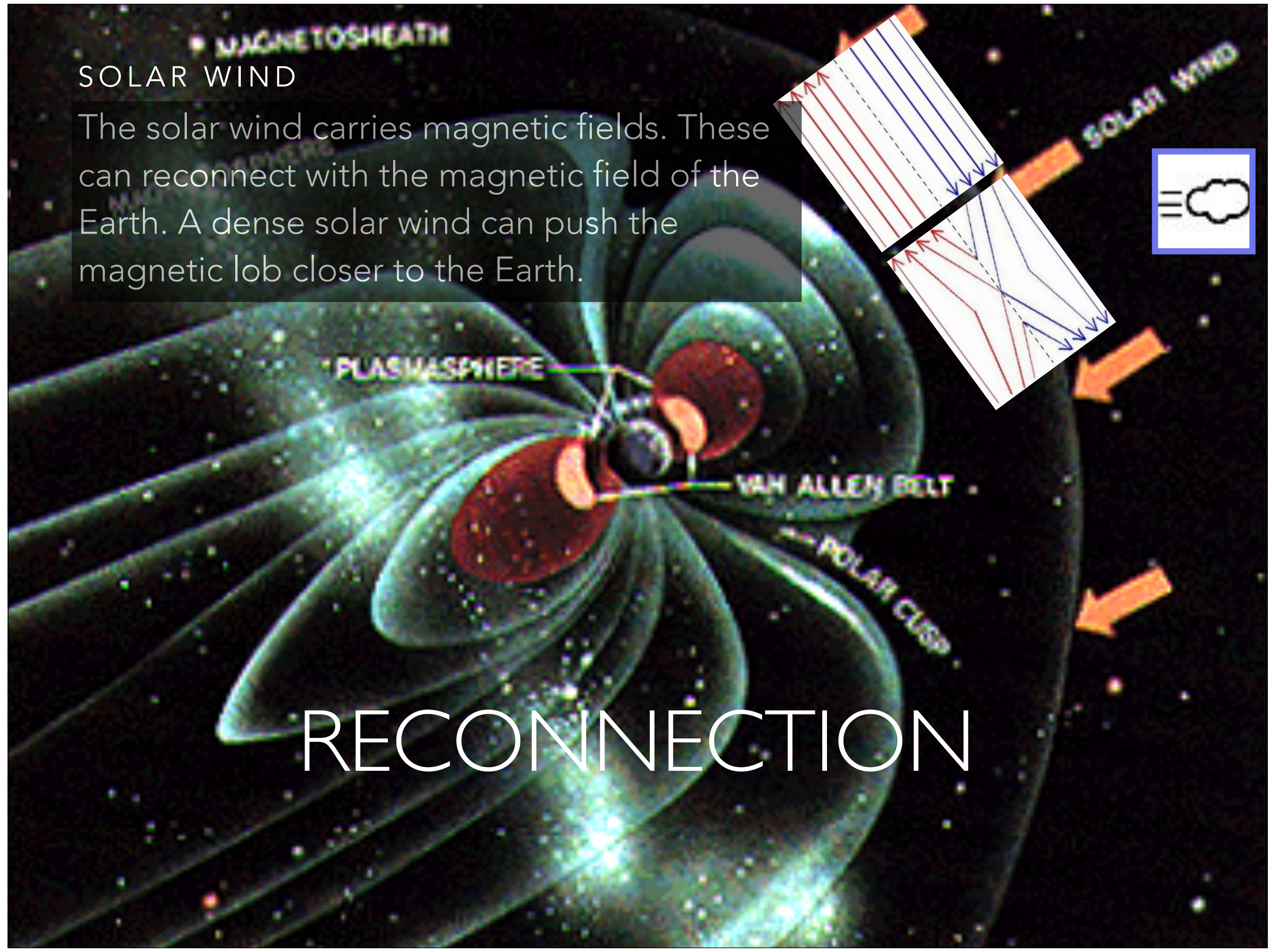
SOLAR WIND

The solar wind blows over the Earth and can deposit energy causing space weather impacts.



http://www.swpc.noaa.gov/products/wsa-enlil-solar-wind-prediction

WSA-Enlil is a large-scale, physics-based prediction model of the heliosphere, used by the Space Weather Forecast Office to provide 1-4 day advance warning of solar wind structures and Earth-directed coronal mass ejections (CMEs) that cause geomagnetic storms. Solar disturbances have long been known to disrupt communications, wreak havoc with geomagnetic systems, and to pose dangers for satellite operations.



This is the earths magnetosphere. The sun is somewhere far away in the right top corner.
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.

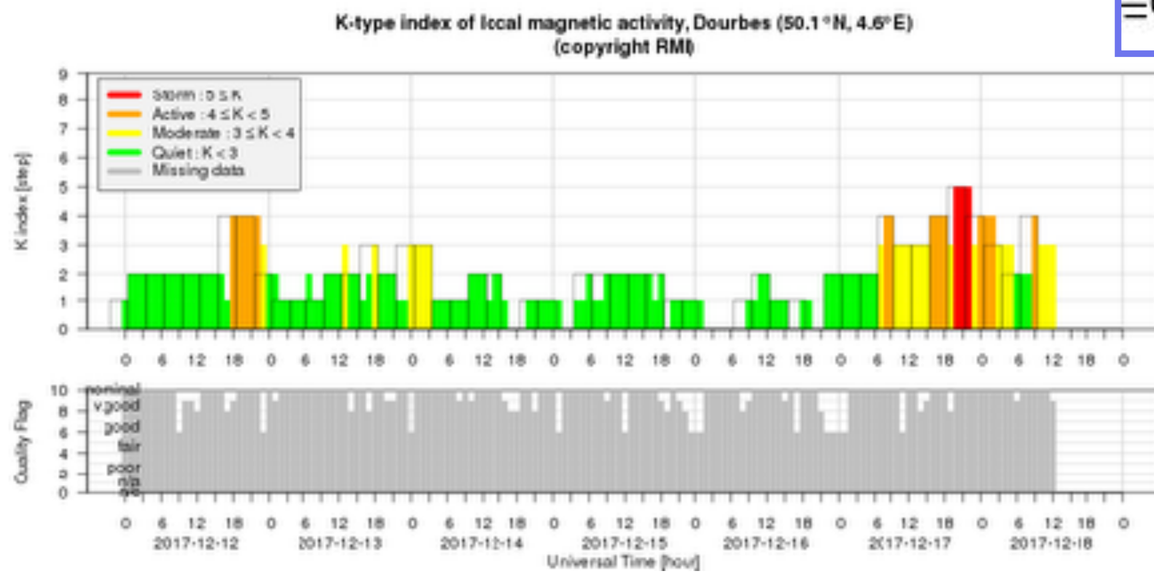
A magnetic field is imbedded in the solar wind. This magnetic field can interact with the magnetic field of the earth at the boundaries of the earth magnetosphere. This interaction is called reconnection. It happens when 2 magnetic regions are confronted with each other.

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 IMF is.

0.3 T - solar sunspot
5mT - strength of a typical refrigerator magnet
31.869 μT (3.1 × 10 T) - strength of Earth's magnetic field at 0° latitude, 0° longitude

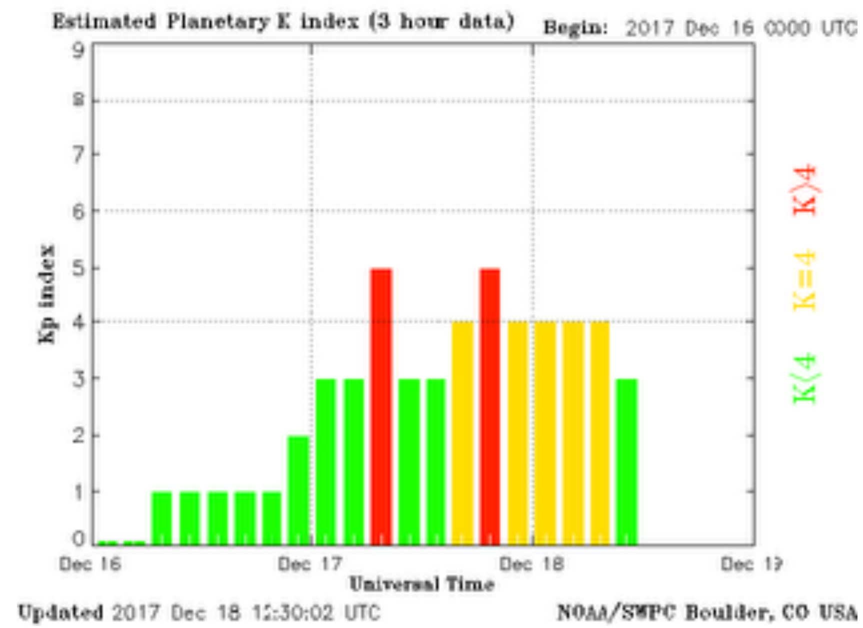
GEOMAGNETIC STORM

Magnetic reconnection between the solar wind magnetic field and the magnetic field of the Earth introduces magnetic disturbances. The strength of a geomagnetic storm is given by a local K of the planetary Kp index.



GEOMAGNETIC STORM

Magnetic reconnection between the solar wind magnetic field and the magnetic field of the Earth introduces magnetic disturbances. The strength of a geomagnetic storm is given by a local K of the planetary Kp index.



NOAA SPACE WEATHER SCALES

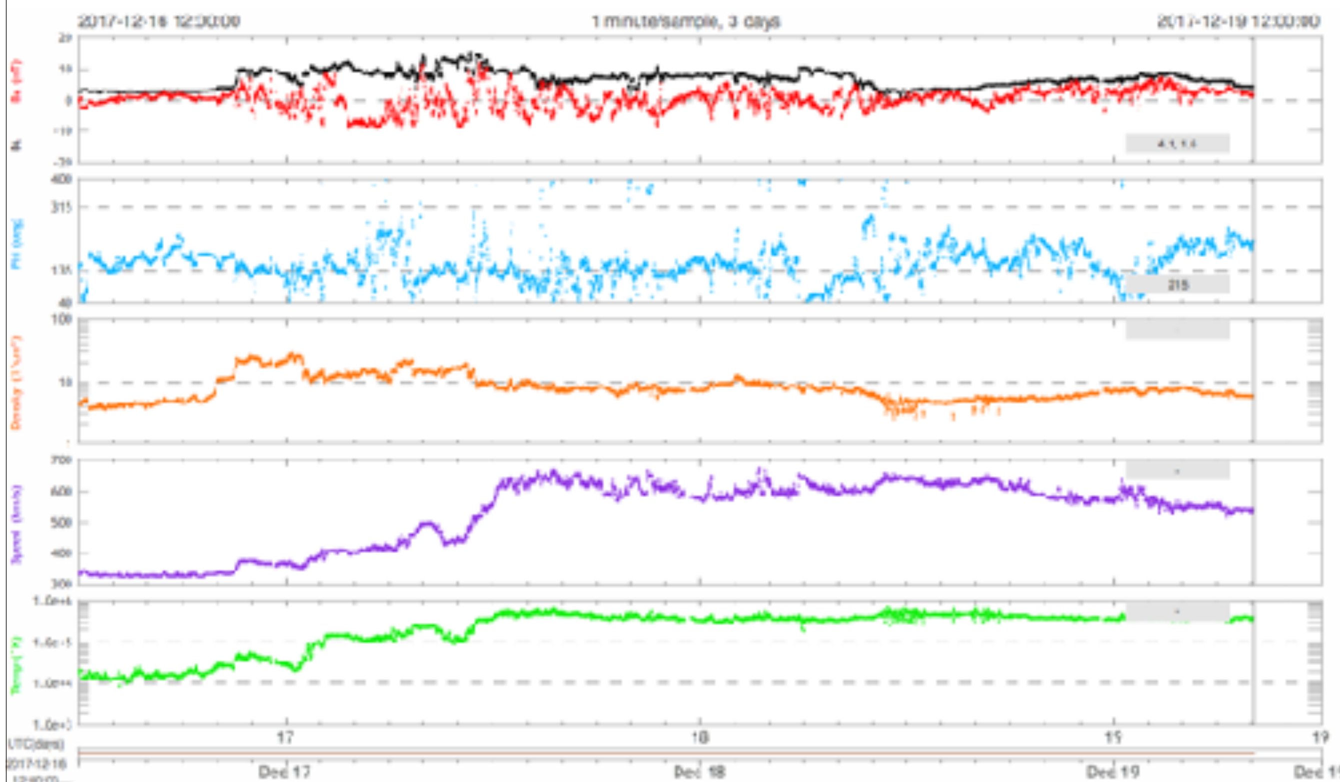
The effect of a geomagnetic storm depends on how strong the geomagnetic field is disturbed. This is described by an index K.

Category Scale	Category Descriptor	Effect (Duration of event will influence severity of effects)	Physical measure	Average Frequency (1 cycle = 11 years)
Geomagnetic Storms			Kp values* determined every 3 hours	Number of storm events when Kp level was met; (number of storm days)
G 5	Extreme	Power systems: widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. Spacecraft operations: may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. Other systems: pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.).**	Kp=9	4 per cycle (4 days per cycle)
G 4	Severe	Power systems: possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. Spacecraft operations: may experience surface charging and tracking problems, corrections may be needed for orientation problems. Other systems: induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.).**	Kp=8	100 per cycle (60 days per cycle)
G 3	Strong	Power systems: voltage corrections may be required, false alarms triggered on some protection devices. Spacecraft operations: surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. Other systems: intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.).**	Kp=7	200 per cycle (130 days per cycle)
G 2	Moderate	Power systems: high-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. Spacecraft operations: corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. Other systems: HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.).**	Kp=6	600 per cycle (360 days per cycle)
G 1	Minor	Power systems: weak power grid fluctuations can occur. Spacecraft operations: minor impact on satellite operations possible. Other systems: migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine).**	Kp=5	1700 per cycle (900 days per cycle)

* Based on this measure, but other physical measures are also considered.

** For specific locations around the globe, use geomagnetic latitude to determine likely sightings (see www.sec.noaa.gov/Aurora)

SOLAR WIND MEASUREMENTS AT L1

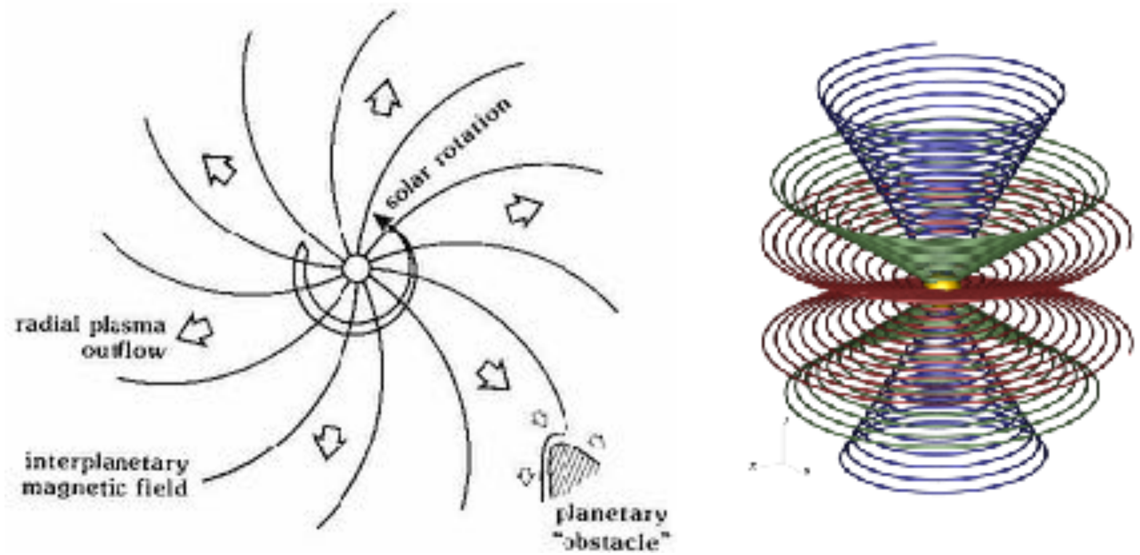


This are in situ solar wind measurements done by the
NOAA DSCOVR satellite
http://www.swpc.noaa.gov/products/real-time-solar-wind

This satellite is located at the Lagrangian point L1: in between the earth and the sun. When the earth moves around the sun, L1 follows. We call L1 one hour upstream of earth. This refers to the solar wind. It takes the solar wind from that point roughly 1 hour to reach the magnetosphere of the earth.

INTERPLANETARY MAGNETIC FIELD

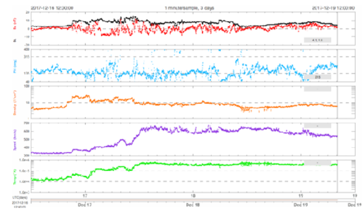
The interplanetary space is filled with the magnetic field of the dipolar Sun.



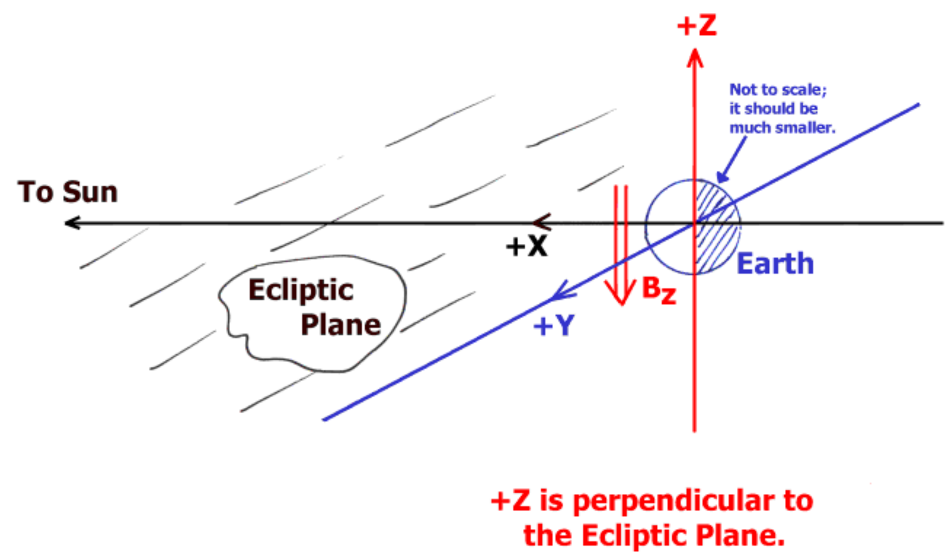
Left: This is a view of the global IMF in the solar equatorial plane.
Right: The IMF and our space is 3D. You have at a particular latitude also IMF lines coming out. Also these lines bend because of the solar rotation. All IMF lines at a particular latitude form a magnetic coin. The solar equatorial plane is a flat cone :)

This is the ideal IMF.
left: It has no component perpendicular on the solar equatorial plane.
right: it has no component perpendicular to the surface of the magnetic cone.

The frozen-flux theorem: IMF and plasma are glued.
The food points of the magnetic field lines are attached to the sun. At the same time, the plasma of the solar wind on the further distance is glued to that same magnetic field line. When the sun rotates, the IMF is forced to bend.



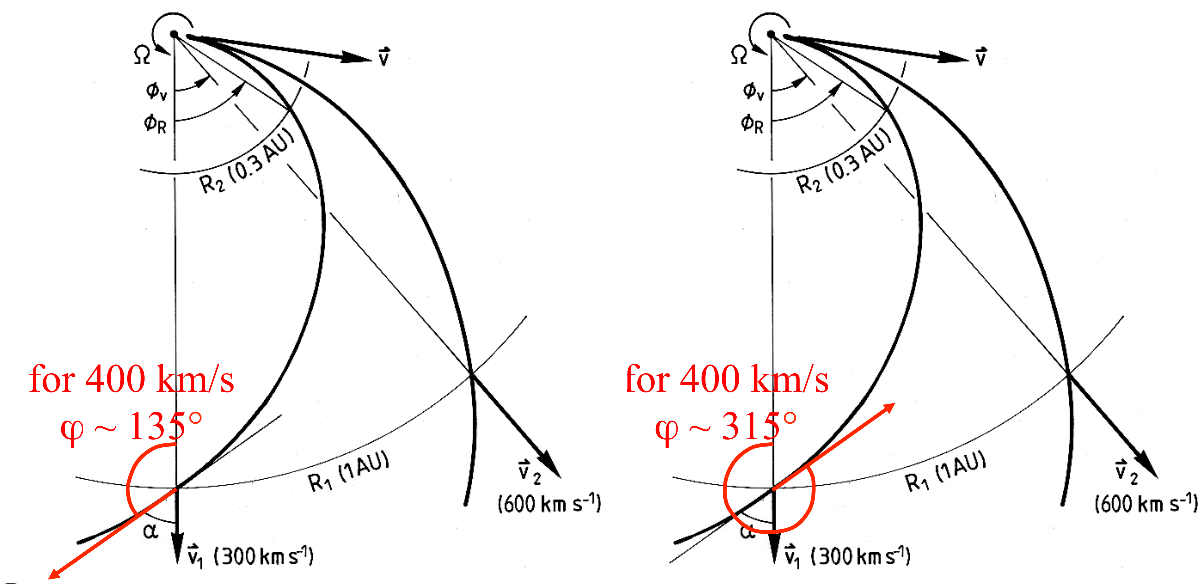
COORDINATE SYSTEM



GSE: Geocentric Solar Ecliptic system. This has its X-axis pointing from the Earth toward the Sun and its Y-axis is chosen to be in the ecliptic plane pointing towards dusk (thus opposing planetary motion). Its Z-axis is parallel to the solar ecliptic pole. Relative to an inertial system this system has a yearly rotation.

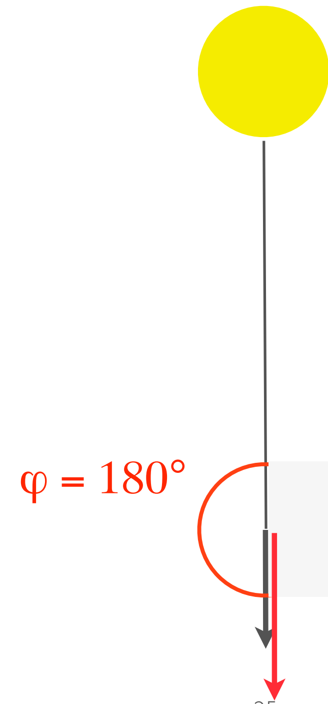
Ecliptic plane: plane in which the Earth orbits around the Sun.

IMF POLARITY

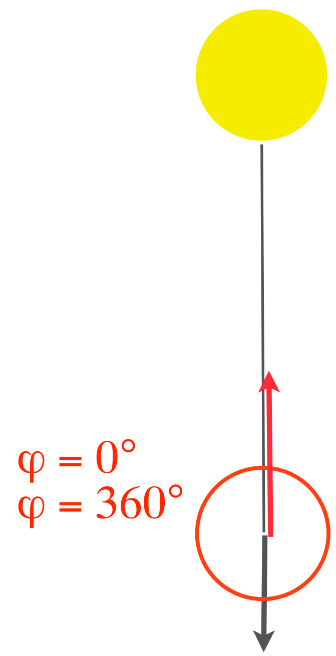


This is the IMF in the solar equatorial plane.

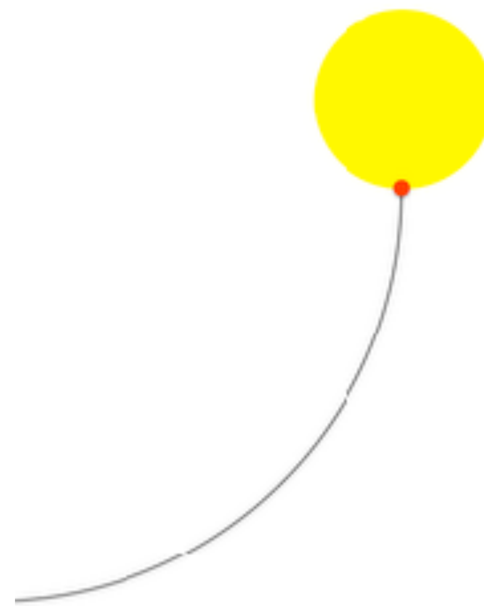
EXTREME FAST

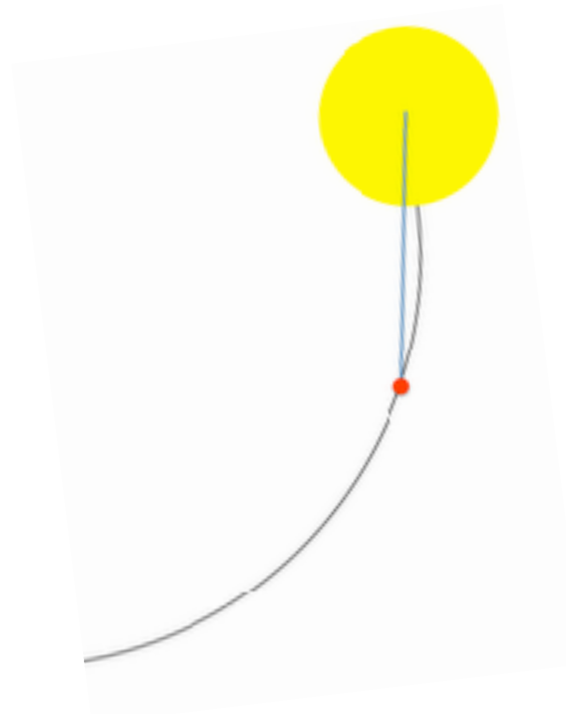


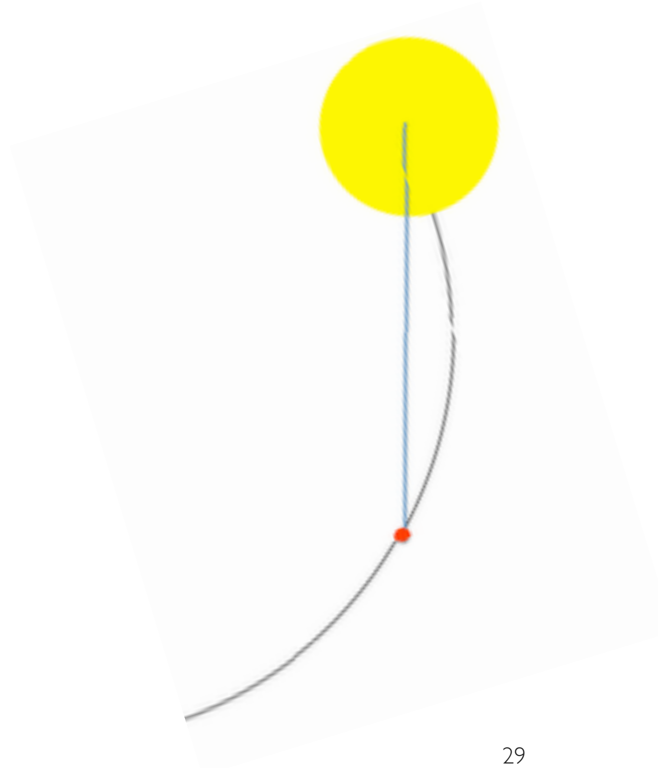
EXTREME FAST

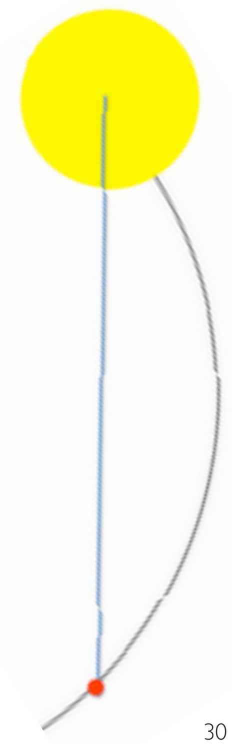


SOLAR WIND IS RADIAL & IMF BENDS.



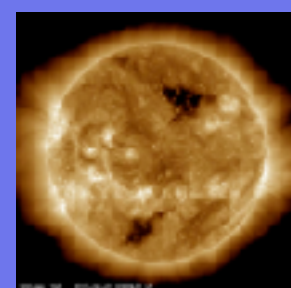


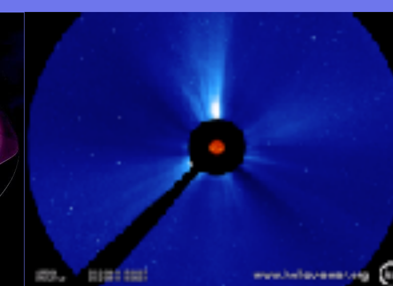




SOLAR WIND VARIATIONS

Non-eruptive	Eruptive
Coronal Hole Sector Boundary Crossing	Coronal Mass Ejection

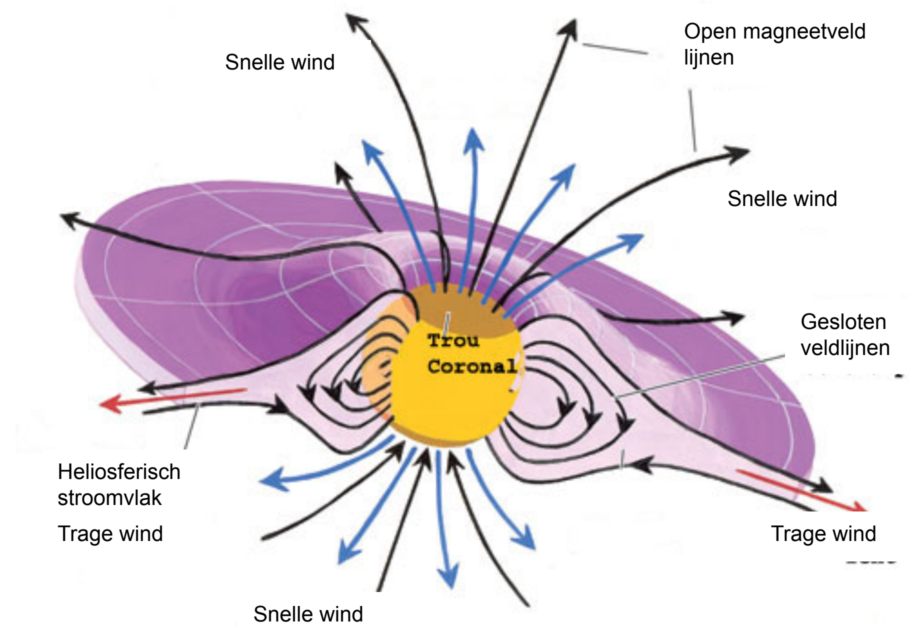




The variations in the solar wind introduce space weather events.

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 emanates from a CH.
A sector boundary crossing is also not eruptive.

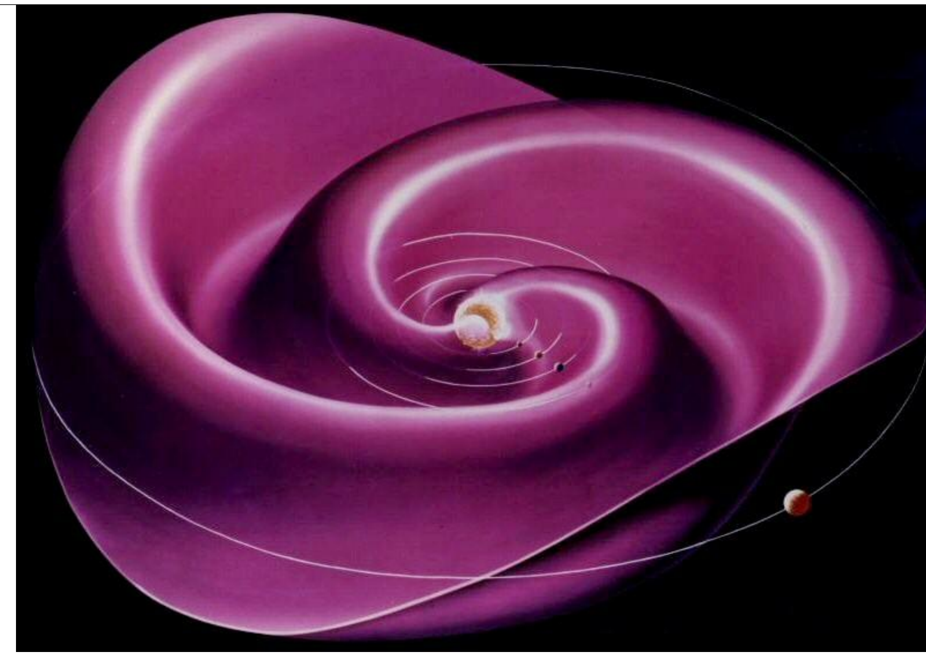


SECTOR BOUNDARY CROSSING

Heliospheric current sheet

The heliospheric current sheet is a layer between regions with opposite magnetic field lines.
The heliospheric current sheet is in a perfect world a flat sheet, perpendicular on the dipole axis of the Sun.
The dipole axis is not the same as the solar rotation axis. The heliospheric current sheet is therefore not the same plane at the solar equatorial plane.

And there is also the third plane: the ecliptic plane. This is plane in which the earth orbits the sun.

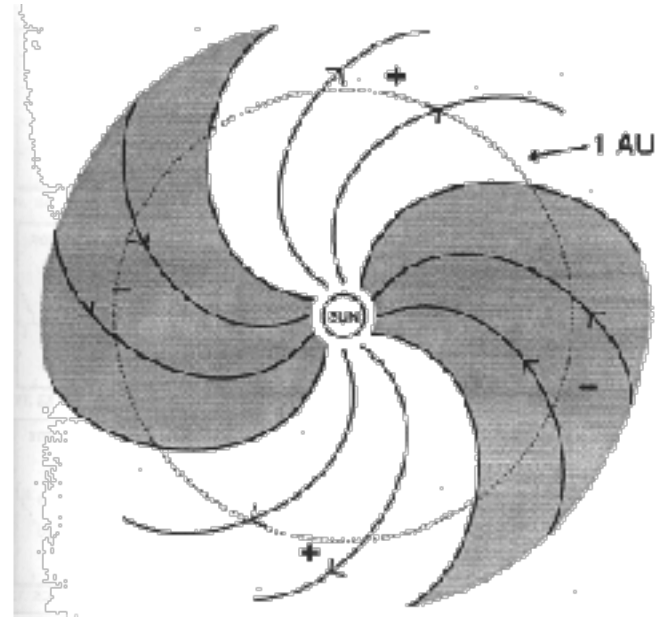


SECTOR BOUNDARY CROSSING

Ballerina Skirt

Neither the solar rotation axis nor the effective dipole axis are perpendicular to the ecliptic plane. Accordingly, the Sun's rotation causes the heliospheric current sheet to move up and down at a fixed observer's position, with associated changes in the plasma density and the direction (towards/away) of the magnetic field. This wavy pattern of the current sheet is sometimes referred to as the “ballerina skirt" .

In this picture, you see 2 waves. There can be more.



SECTOR BOUNDARY CROSSING

Magnetic sectors

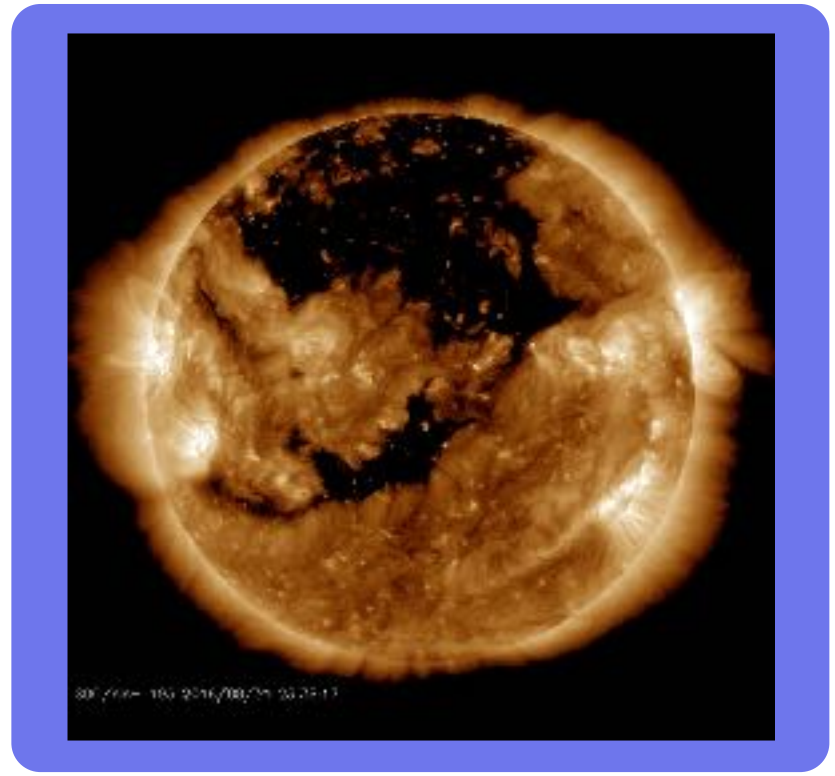
Cravens, 1997

distinct, long-lasting intervals of uniform solar wind field direction exist, called ``sectors''

Going from one sector to another, changes in the **plasma density** and the **direction (towards/away) of the magnetic field** occur.

When you pass from one sector to another sector, the density and Bz of the solar wind measured at the L1 point by ACE or DSCVR can change and have a geomagnetic impact. But in general, sector boundary crossings do not do much.

CORONAL HOLE



open field structure, source of fast solar wind
non eruptive
radial - plasma leaving when it is at the central meridian, reaches Earth

What is important determining when and how strong the impact of a CH will be:

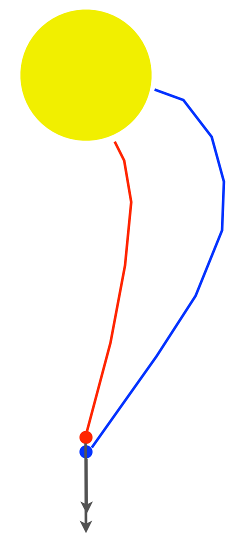
- The heliographic latitude of earth
- The latitude of the CH on the solar disk: the part of a CH with a low latitude is important. Polar coronal holes have only an impact when they extent to lower latitudes.
- It is the material that leave at the central meridian that will reach earth. You have to guess how fast the solar wind is. Calculate the time the material needs to cross the distance 1AU and you have an estimate of the arrival time of the CH wind near Earth.

at the central meridian

WHAT HAPPENS WHEN FAST CATCHES SLOW?

Top View

What happens when fast catches slow solar wind material?



Continuous process - the source of the fast particles, i.e. stays present.

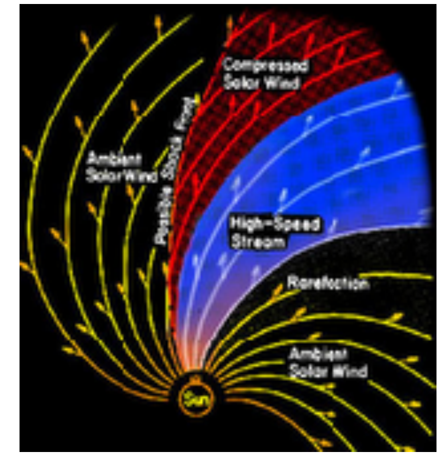
When fast solar-wind streams, emanating from coronal holes, interact with slow streams, they can produce Co-rotating Interaction Regions in interplanetary space. The magnetic fields of the slow streams in the solar wind are more curved due to the lower speeds, and the fields of the fast streams are more radial because of their higher speeds. Intense magnetic fields can be produced at the interface (IF) between the fast and slow streams in the solar wind. The Co-rotating Interaction Regions are bounded by a forward shock (FS) and a reverse shock (RS).

One reason why two shocks are eventually formed at a CIR is due to symmetry about the pressure enhancement caused by compression and entraining of the slow wind ahead of the fast stream (Figure 10.9 [Gosling, 1996]): shocks are driven away from the pressure increase in both directions, resulting in a so-called \Forward-Reverse shock pair" in which the forward shock propagates away from the Sun while the reverse shock propagates towards the Sun but is carried out with the solar wind flow.

http://www.boulder.swri.edu/~deforest/Movies.html

Coronal Hole

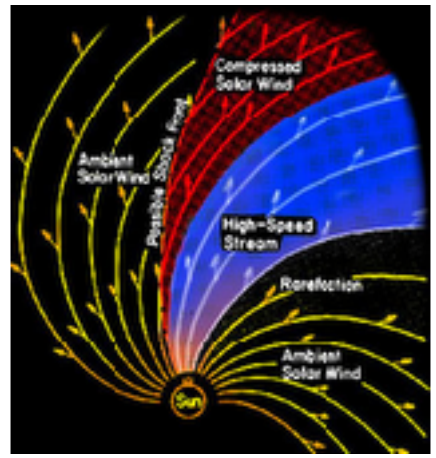
- Co-rotating structure
- Radial!
- No extra mass-flux

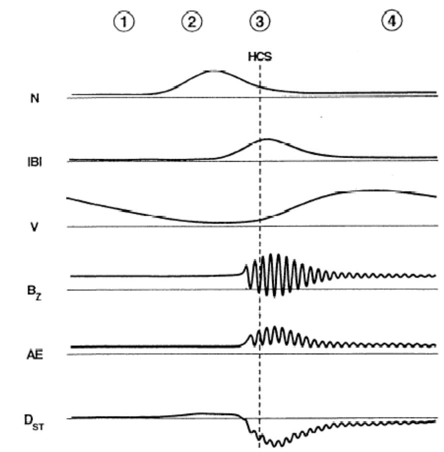


The Dst is a **geomagnetic index** which monitors the world wide magnetic storm level. It is constructed by averaging the horizontal component of the geomagnetic field from mid-latitude and equatorial magnetograms from all over the world. Negative Dst values indicate a magnetic storm is in progress, the more negative Dst is the more intense the magnetic storm. The negative deflections in the Dst index are caused by the storm time **ring current which flows around the Earth from east to west in the equatorial plane**. The ring current results from the differential gradient and curvature drifts of electrons and protons in the near Earth region and its strength is coupled to the solar wind conditions. Only when there is an eastward electric field in the solar wind **which corresponds to a southward interplanetary magnetic field (IMF)** is there any significant ring current injection resulting in a negative change to the Dst index. Thus, by knowing the solar wind conditions and the form of the coupling function between solar wind and ring current, an estimate of the Dst index can be made.

The **Auroral Electrojet Index, AE,** is designed to provide a global, quantitative measure of **auroral zone magnetic activity produced by enhanced Ionospheric currents** flowing below and within the auroral oval.

Coronal hole at L1

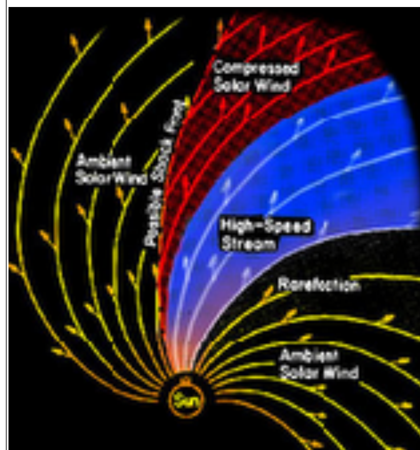


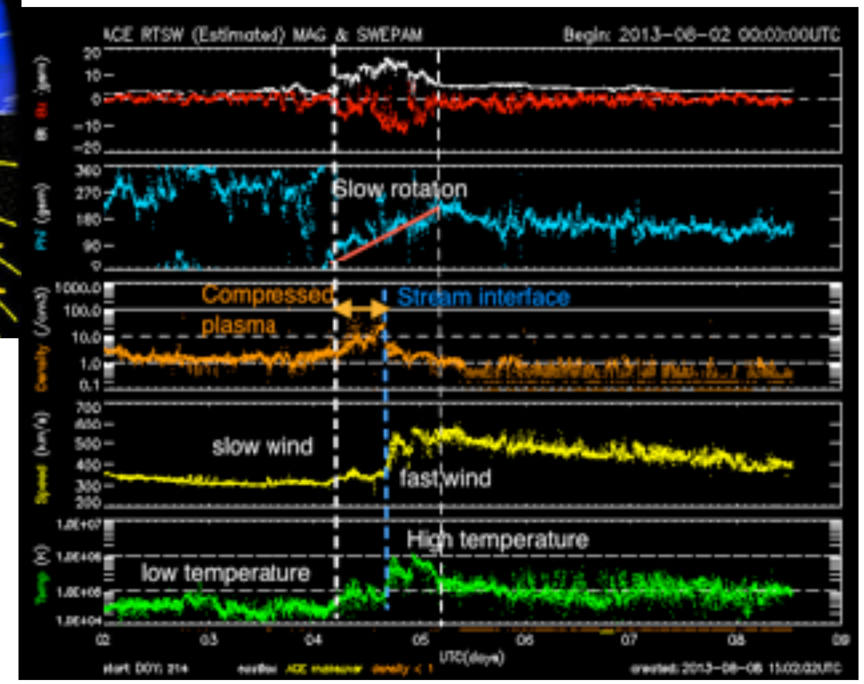


The Dst is a **geomagnetic index** which monitors the world wide magnetic storm level. It is constructed by averaging the horizontal component of the geomagnetic field from mid-latitude and equatorial magnetograms from all over the world. Negative Dst values indicate a magnetic storm is in progress, the more negative Dst is the more intense the magnetic storm. The negative deflections in the Dst index are caused by the storm time **ring current which flows around the Earth from east to west in the equatorial plane**. The ring current results from the differential gradient and curvature drifts of electrons and protons in the near Earth region and its strength is coupled to the solar wind conditions. Only when there is an eastward electric field in the solar wind **which corresponds to a southward interplanetary magnetic field (IMF)** is there any significant ring current injection resulting in a negative change to the Dst index. Thus, by knowing the solar wind conditions and the form of the coupling function between solar wind and ring current, an estimate of the Dst index can be made.

The **Auroral Electrojet Index, AE,** is designed to provide a global, quantitative measure of **auroral zone magnetic activity produced by enhanced Ionospheric currents** flowing below and within the auroral oval.

Coronal hole at L1

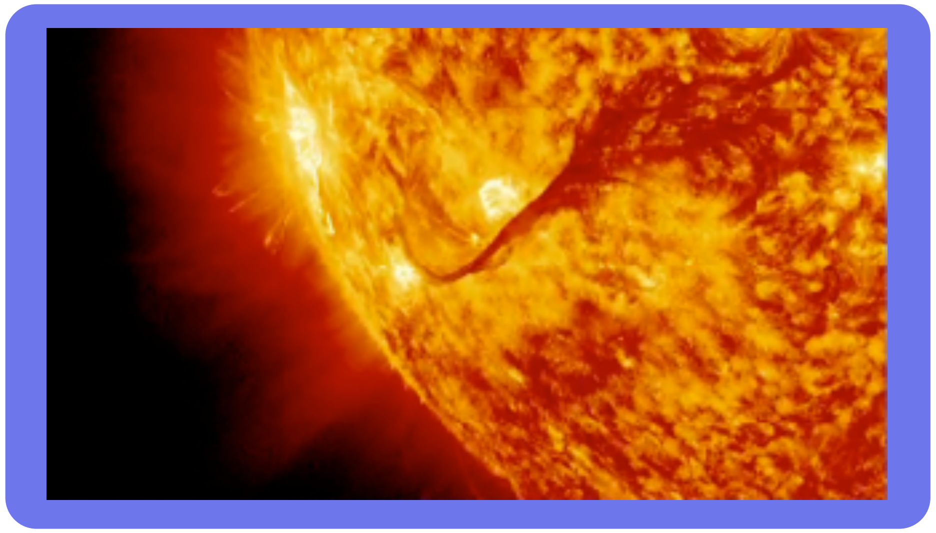




This is the solar wind measured by the satellite ACE at L1.

On Aug 4, an interaction region of a slow and fast solar wind arrived near Earth. This interaction region is indicated in the ACE graphs with white dotted lines in the figure below, denoting the beginning and the end of this particular solar wind event. The magnetic field became much stronger as there is a clear bump in the white curve in the top panel. The plasma is also more compressed in such a region where the slow and fast wind interact. The blue dotted line is the so-called stream interface. It is a rather abrupt transition where the solar wind speed increases suddenly and the plasma becomes hotter and less dense. The magnetic field rotated from the sector where the magnetic field points towards the Sun (Phi = 0° or 360°) to a sector with the magnetic field pointing outwards (Phi = 180°). A rotation is however atypical for this sort of solar wind structures. In normal circumstances - if you could ever speak about normal circumstances in space weather physics - the Phi-parameter fluctuates. In the interaction region, it seems that the magnetic field has difficulties with choosing a clear pointing direction.

Characteristics
- High speed
- Increasing V profile
- High temperature
- High B (normally below 20nT) - high variability
- Stream interface: compression, highest values of everything (except speed)
- Shocks (not very often at 1AU)
- CH at ~40W on the Sun
- The high speed part can also be geoeffective if V is > 600 and Bz <-5nT

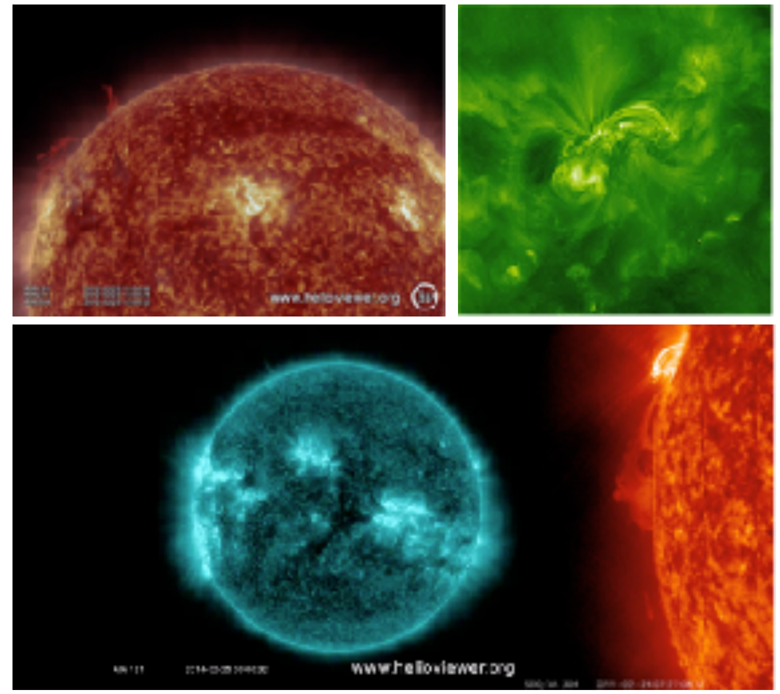


CME

A new, discrete, bright white light feature in the coronograph

Eruptive – transient

Where do they come from? How to recognise them?



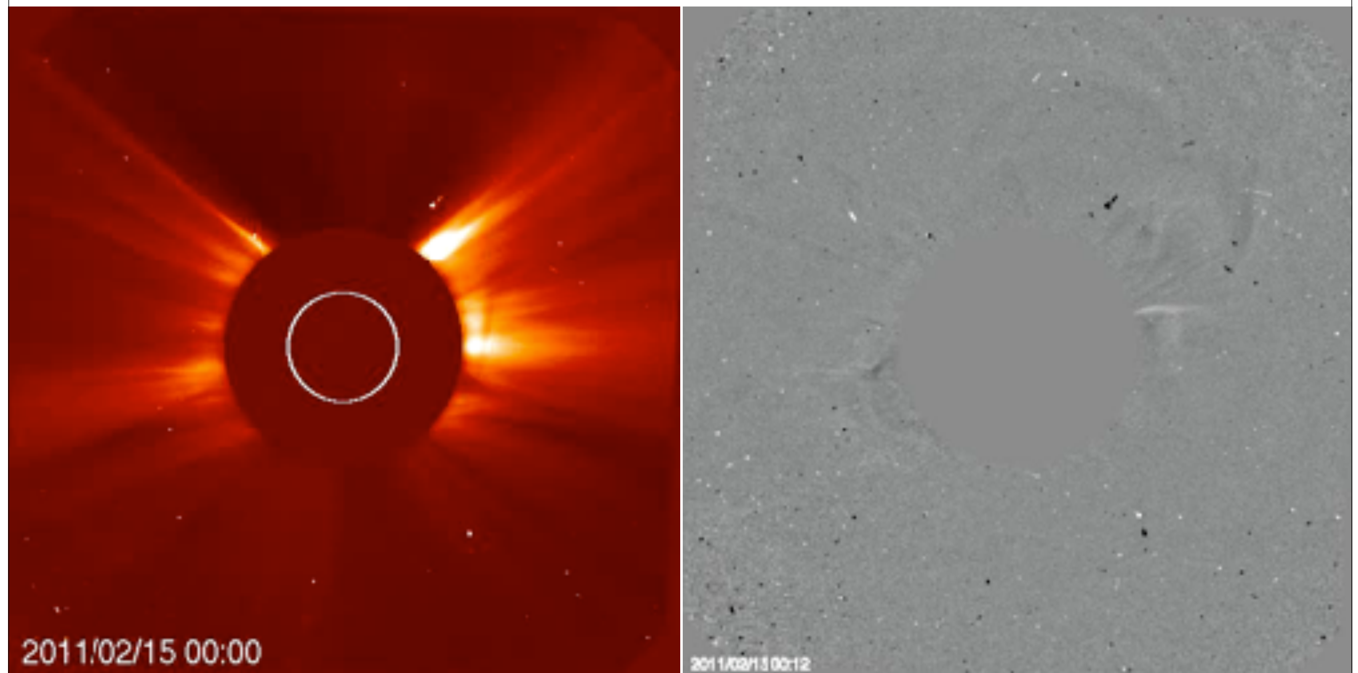
coronal magnetic loops that ‘break’ and catapult plasma into space – often associated with solar flares but not necessarily.

On disk signatures:
• Post-eruption loops
• Dimming
• Filament eruption
• EIT wave

Stealth CME’s: no on disk signatures – leave from the high corona

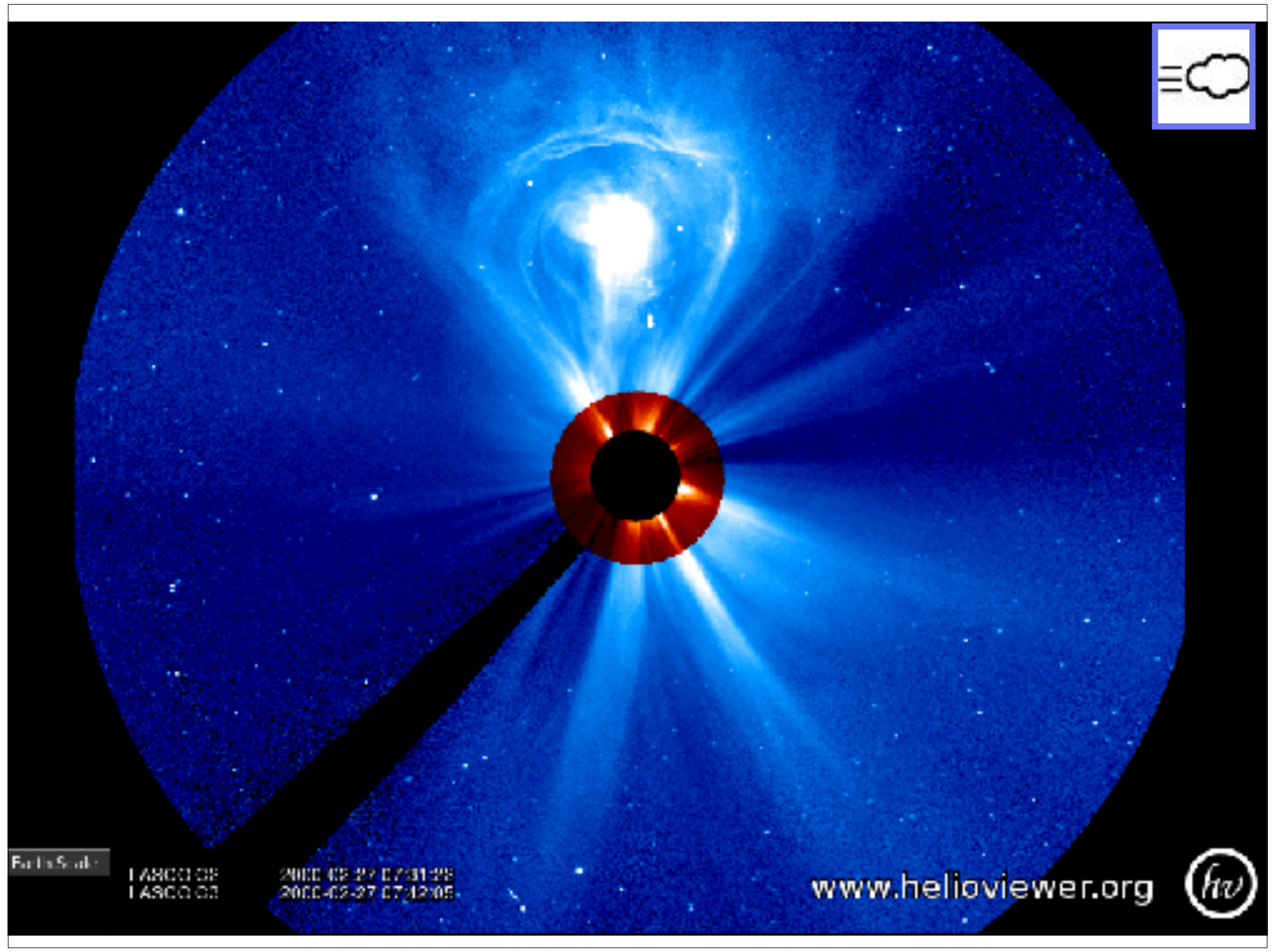
top left
An at least 400.000 km long filament in the northeast solar quadrant erupted in the night of 23-24 February, without leaving an x-ray signature. Usually, a shock wave spreads out from the blast side in a more or less round shape. However in this case, because of the length of the filament, the solar tsunami spread parallel from where the filament originally was located. This "canyon-of-fire" as it was soon dubbed on the internet, raced away with speeds up to 20.000 km/h and swiftly covered a transient coronal hole (dark patch to the lower right of the erupted filament) that was generated earlier by the eruption.

CORONAL MASS EJECTION



SOHO / LASCO c2 running difference

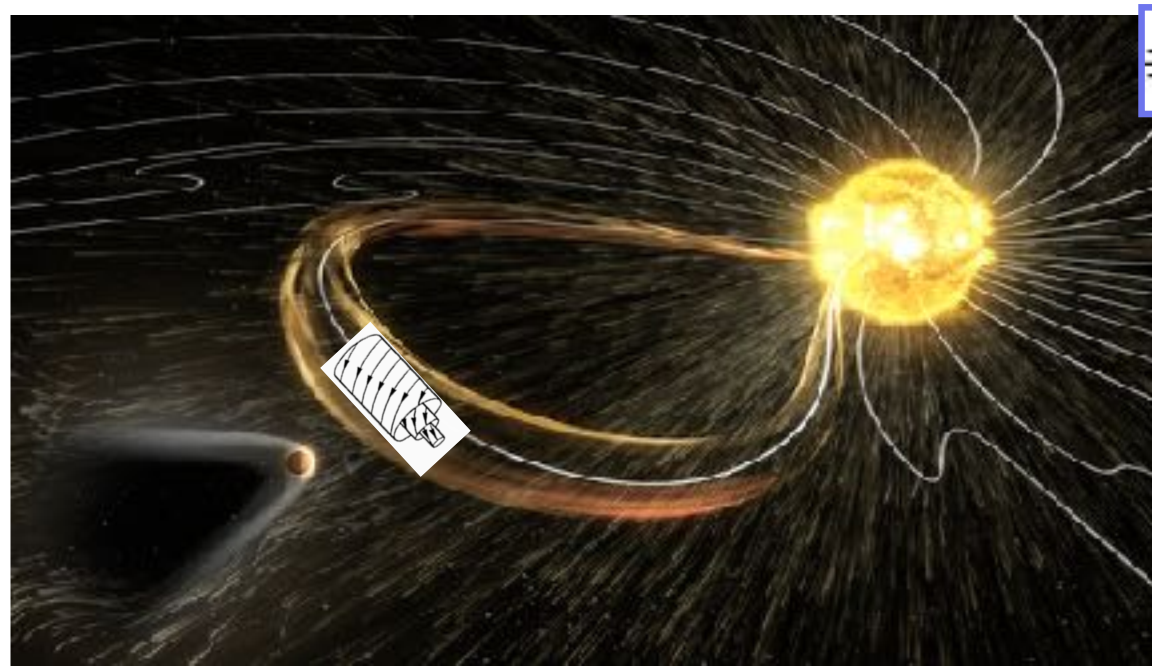
CMEs cause the most extreme geomagnetic storms. Therefore, there is great interest in understanding the properties of CMEs, especially when they have a halo signature around the solar disk that indicates the CME is aimed at Earth.
Furthermore, if the CME results in a magnetic cloud with a strong and out of ecliptic magnetic field, forecasts are likely for strong to extreme storms.



Transient: only lasting for a short time

Low density, but enormous and therefore massive.

CME is large: compare its size with the size of the sun.

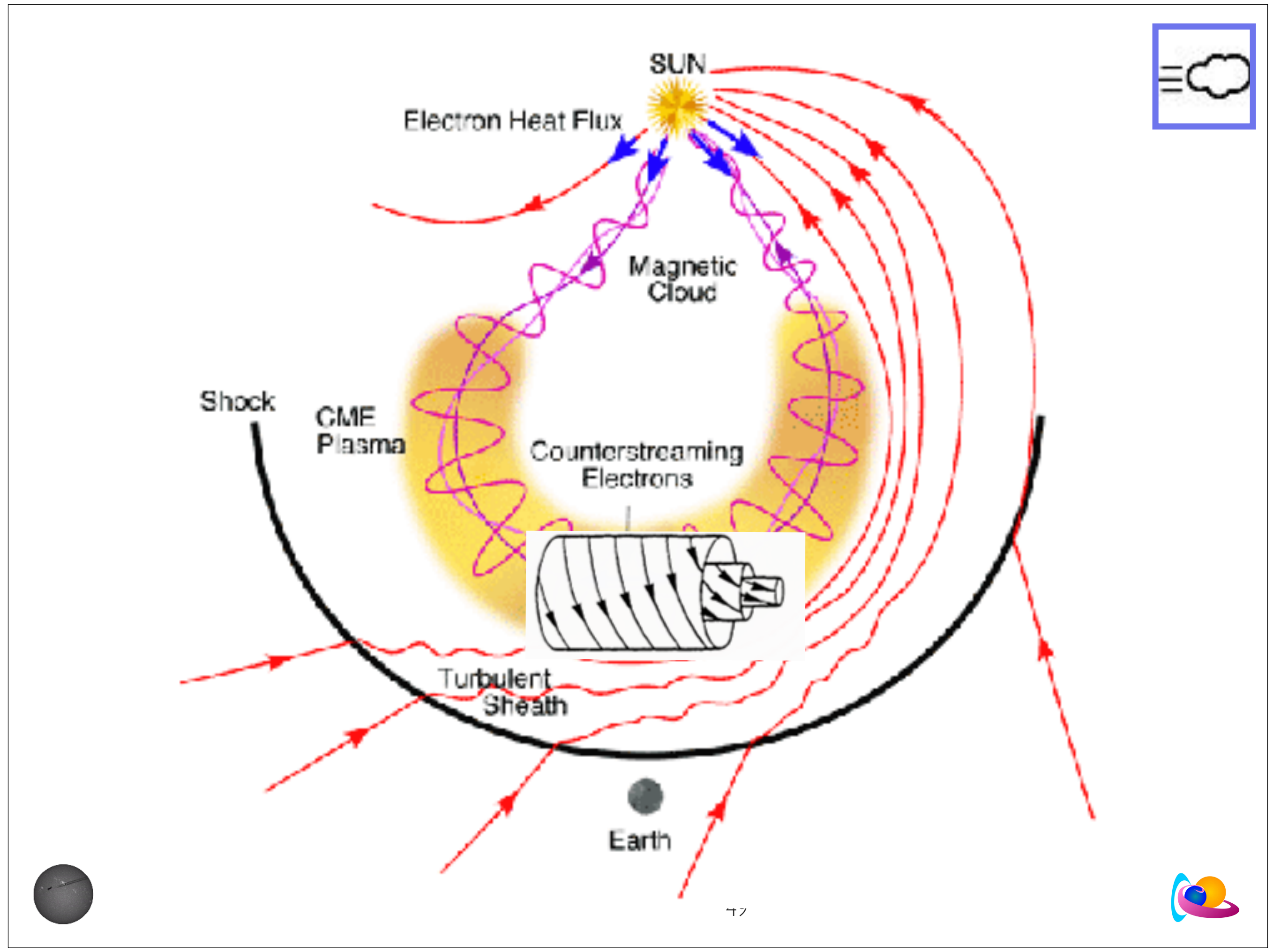


A CARTOON OF A CME

Magnetic twisted structure that stays linked with the Sun.

It pushes and deforms the IMF.

A CME approaches Mars (artist's concept). The Red Planet is thought to have lost much of its atmosphere to such extreme space weather. Unlike Earth, Mars lacks a global magnetic field to deflect the incoming solar wind.
Credit: NASA/GSFC



Shock (if the ICME is fast enough)
…followed by shocked sheath plasma (compressed and heated, with oscillating magnetic field)
…followed often by the driver gas (ICME itself):

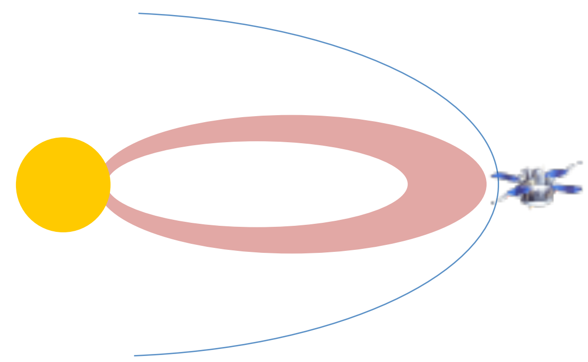
  Strong magnetic field
  Temperature depression: typically < ~ 105 K ~ 10 eV
  Low variance of the magnetic field
  Large-scale smooth field rotation (magnetic cloud): in about 30% of cases

Even CMEs originating at the limb can arrive to the Earth (provided they are wide enough). In Most of such cases however, only the inerplanetary shock is observed as the angular extend of the shock is larger than that of a corresponding CME. The CME thus misses the Earth and only the shock arrives. (magnetically connected)

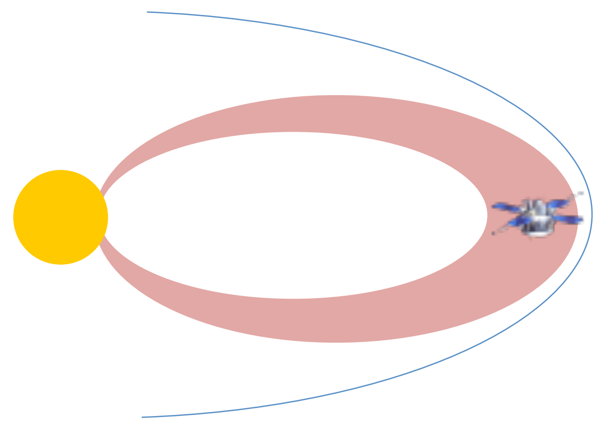
A CME-driven shock has larger angular extent than the CME itself!
To be geoeffective, the CME-associated disturbance should:
1) arrive to the Earth;
2) have a suitable magnetic field configuration: IMF Bz component should be negative (southward), strong enough and long-lasting.

tijdelijke oorzaak
afmetingen: film van bart van der holst, michigan
http://csem.engin.umich.edu

Depending on where the satellite sweeps through the magnetic structure, you see different structures.

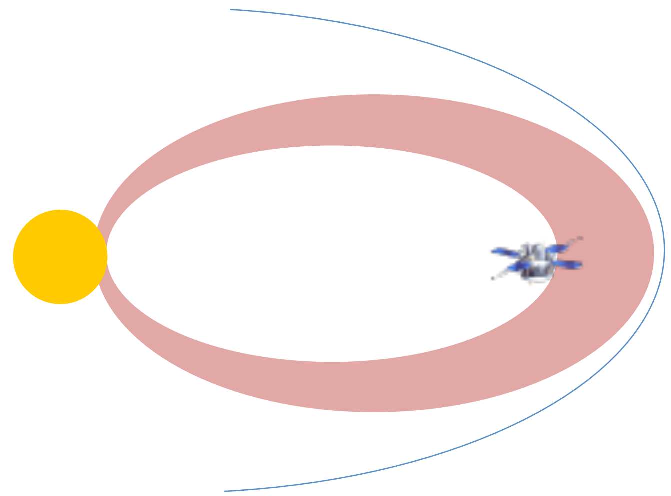


Depending on where the satellite sweeps through the magnetic structure, you see different structures.

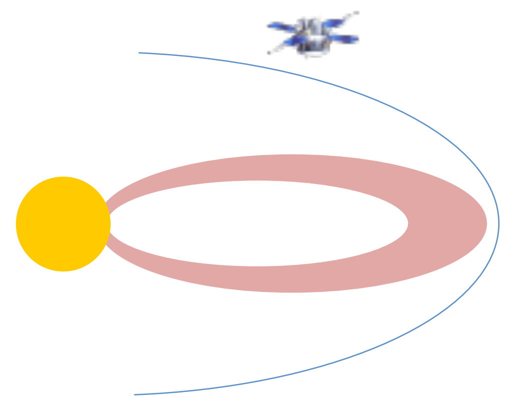


IN SITU

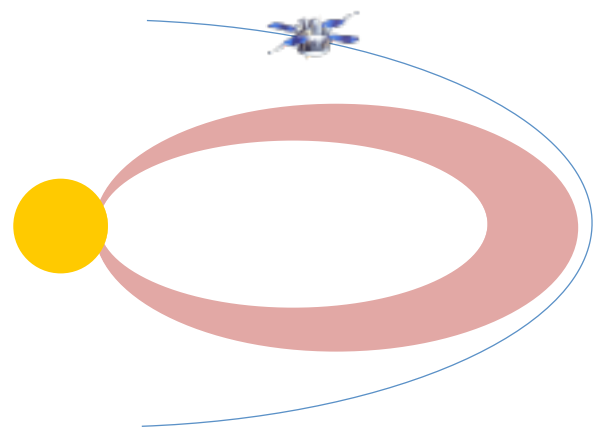
Depending on where the satellite sweeps through the magnetic structure, you see different structures.



Depending on where the satellite sweeps through the magnetic structure, you see different structures.

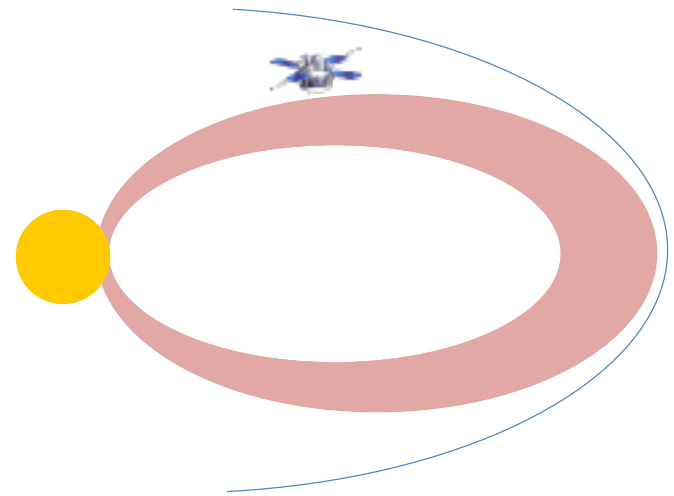


Depending on where the satellite sweeps through the magnetic structure, you see different structures.



IN SITU

Depending on where the satellite sweeps through the magnetic structure, you see different structures.



MAGNETIC MASS STRUCTURE

When you smash big heavy sac on an object, the impact is much higher compared to the situation when you small with a light plastic sac.

A Coronal Mass Ejection is a plasma cloud that is ejected into space. You consider it as a cloud and not as a bunch of individual particles. It is superimposed on the background solar wind. You can see a CME as a complex magnetic bag with different magnetic layers with plasma in it that travels as a tsunami through space. It can go faster/as fast as/slower than the background solar wind. When it is faster, you will see a shock in front of the cloud. This is exactly the same as the shock you see in front of a speed boat.

CME’s zijn plasma-blobs die uit de zonneatmosfeer ontsnappen. Het is een magnetische plasmastructuur in de zonnewind die zich een weg baant door het interplanetair magnetisch veld en die wordt beïnvloed door de zonnewind. Bekijk het als een magnetische/plastieken tas gevuld met plasma.
De tas wordt beïnvloed door de omringende zonnewind en kan deze versnellen of vertragen. Als de tas trager gaat dan de zonnewind, wordt deze versneld door de zonnewind. Als de tas sneller gaat dan de zonnewind, heeft de zonnewind een vertragend effect. Als je ver genoeg van de zon zou gaan staan, zal je geen plotse sprong in in situ plasma-snelheid meer waarnemen.
De tas is ook niet ‘dicht’: plasma kan erin en kan eruit zodat uiteindelijk ook het dichtheidsprofiel vlak wordt. Het wordt dan een magnetische tas zonder speciale inhoud. De natuur heeft de neiging om alles te egaliseren. Op 1AU is dit dikwijls nog niet het geval.

CME’s en de zonnewind versnellen tussen 1 en 5-10 zonneradii. De zonnewind versnelt in de lage corona van 20 km/s tot 200 - 800 km/s. Er zijn idd al CME’s waargenomen met snelheden minder dan 100 km/s. Dikwijls zijn dit kleine plasma structuren die je ziet vertrekken, maar uiteindelijk worden deze toch versneld tot de snelheid van de zonnewind.

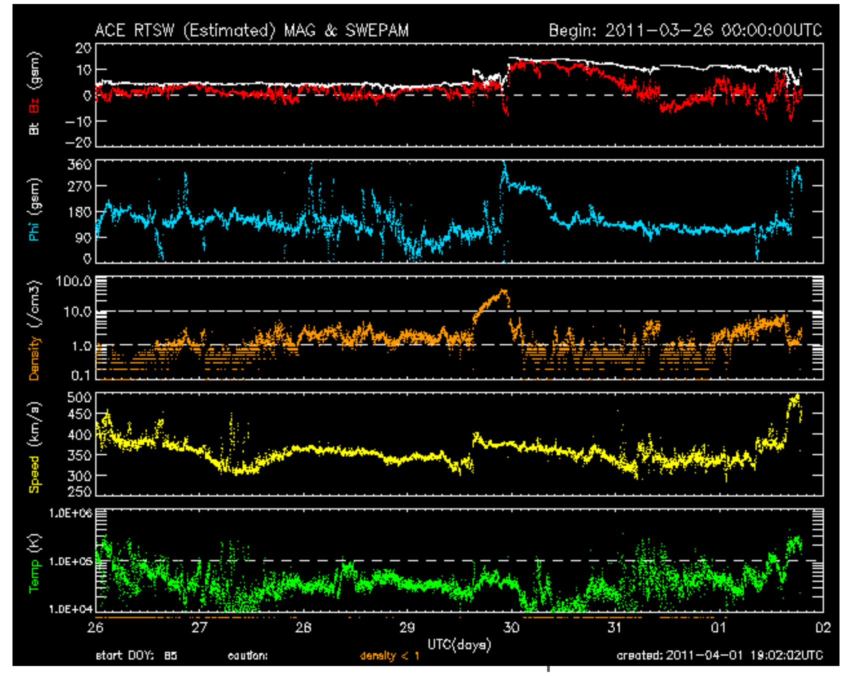
Een trage CME kan een effect hebben op de magnetosfeer, niet zozeer omwille van de plasma- en kinetische druk maar eerder doordat de magnetische zak koppelt met het aardmagnetisch veld. Maar meestal heeft een trage en lichte CME geen sterke magnetische tas.

Denk aan de analogie met een plastiek winkeltasje: voor weinig heb je geen sterke, grote tas nodig, voor heel veel en zware dingen heb je een grote, sterke tas nodig. Smak je een grote, zware tas ergens tegen, is het effect groter dan dat je een klein onnozel plastiek tasje met zo goed als niks in ergens tegenaan gooit (ver zal je in het laatste geval zelfs niet kunnen gooien).

IN SITU

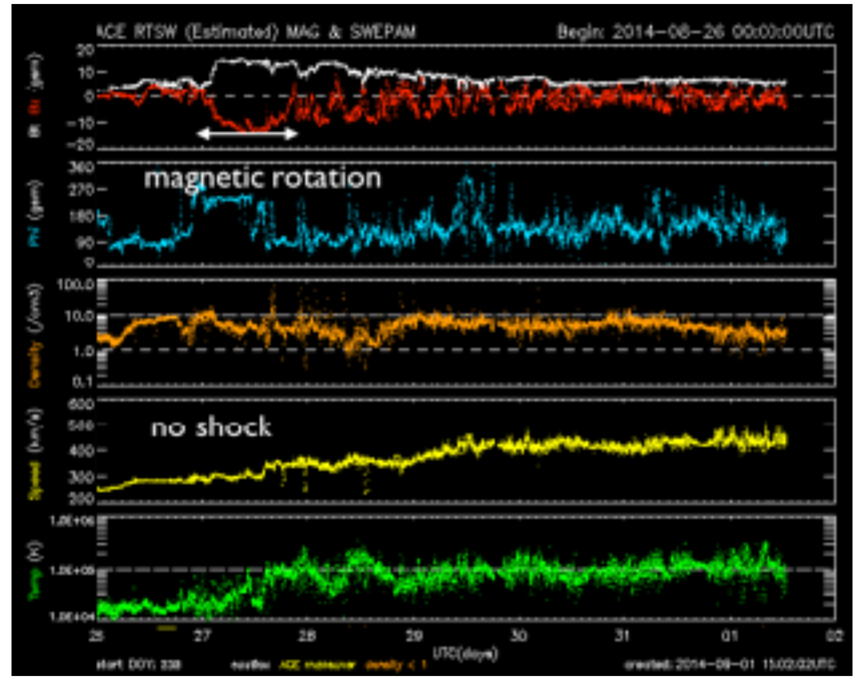
ACE and DSCVR measure the solar wind parameters at L1. This is 1 hour upstream.

- Shock
- Sheath
- High B
- Smooth rotation in Phi
- Decreasing speed
- Low T



IN SITU

A magnetic structure passed at the L1 point, but no shock was seen.



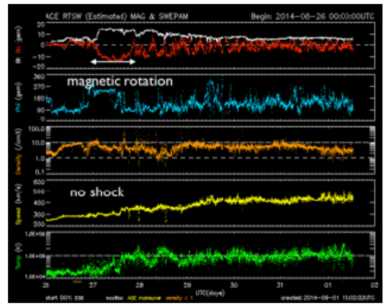
Solar wind observations of ACE indicated the passage of a magnetic cloud on August 27 which can be probably traced back to two consecutive C6 flares on August 22, one peaking at 12:27UT and one peaking at 15:52 UT both associated with partial halo CME's with very similar coronagraphic appearance.
How to interpret the ACE data?
The first signs of a magnetic structure were detected around 0:00 UT on August 27. There was no shock preceding the magnetic structure: the density (orange) nor the solar wind speed (yellow) did not jump suddenly to a higher or lower value. No problem, we can live without shocks.
Although, the data show clearly a magnetic rotation: Bz (red) evolves from zero to a strong negative value back to zero. It means that the magnetic flux rope is oriented vertical such that the magnetic field at the border of the tube that passes first ACE is oriented along the plane perpendicular to the z-axis. When the tube moves further, the Bz-component grows negative and is maximum near the center of the tube. Then Bz becomes again zero telling us that the magnetic field is oriented along the plane perpendicular to the z-axis but now in the opposite direction compared with the front side of the tube. If these sentences are too much to understand at once, reread them with the cartoon below in mind. The flux rope cartoon is taken from an article 'Magnetic stress in solar system plasmas' , Aust. J. Phys, 52, 1999 by C.T. Russel. The ecliptic plane is reduced to a line since the cartoon presents a side view of the system. The flux rope moves to the right and passes at some point ACE.

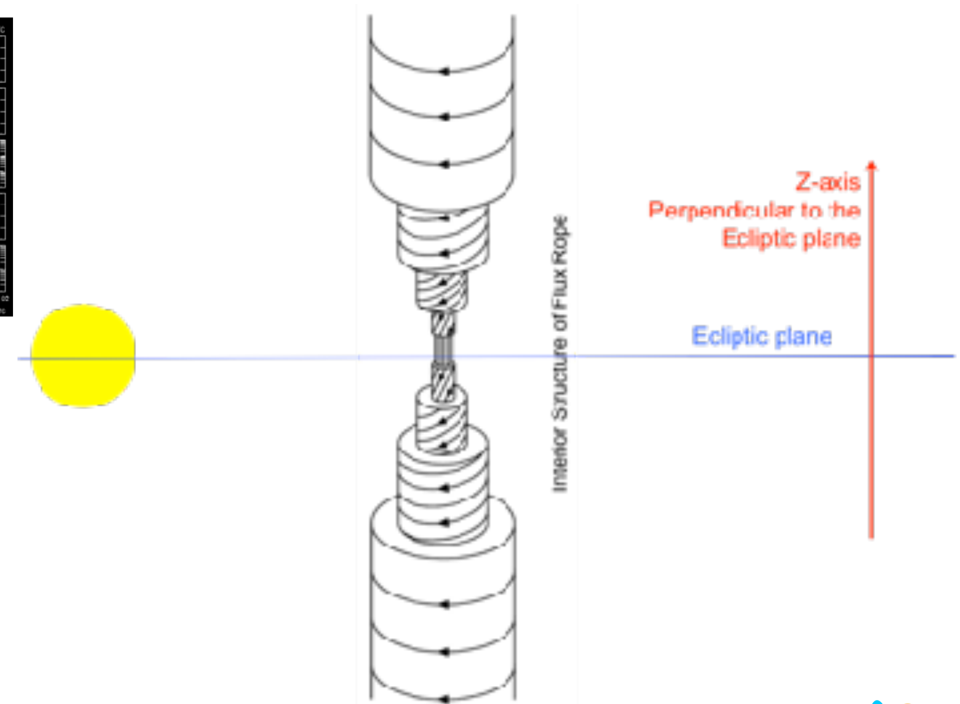
STCE Newsletter 25 Aug 2014 - 31 Aug 2014 Page 11 of 18

There is however 1 particularity: you expect the temperature to drop while passing a magnetic cloud. This is not really the case. But again, no problem. The magnetic rotation is clear enough to determine the 'thing' as a magnetic cloud.

IN SITU

A magnetic structure passed at the L1 point, but no shock was seen.





Solar wind observations of ACE indicated the passage of a magnetic cloud on August 27 which can be probably traced back to two consecutive C6 flares on August 22, one peaking at 12:27UT and one peaking at 15:52 UT both associated with partial halo CME's with very similar coronagraphic appearance.
How to interpret the ACE data?
The first signs of a magnetic structure were detected around 0:00 UT on August 27. There was no shock preceding the magnetic structure: the density (orange) nor the solar wind speed (yellow) did not jump suddenly to a higher or lower value. No problem, we can live without shocks.
Although, the data show clearly a magnetic rotation: Bz (red) evolves from zero to a strong negative value back to zero. It means that the magnetic flux rope is oriented vertical such that the magnetic field at the border of the tube that passes first ACE is oriented along the plane perpendicular to the z-axis. When the tube moves further, the Bz-component grows negative and is maximum near the center of the tube. Then Bz becomes again zero telling us that the magnetic field is oriented along the plane perpendicular to the z-axis but now in the opposite direction compared with the front side of the tube. If these sentences are too much to understand at once, reread them with the cartoon below in mind. The flux rope cartoon is taken from an article 'Magnetic stress in solar system plasmas' , Aust. J. Phys, 52, 1999 by C.T. Russel. The ecliptic plane is reduced to a line since the cartoon presents a side view of the system. The flux rope moves to the right and passes at some point ACE.

There is however 1 particularity: you expect the temperature to drop while passing a magnetic cloud. This is not really the case. But again, no problem. The magnetic rotation is clear enough to determine the 'thing' as a magnetic cloud.