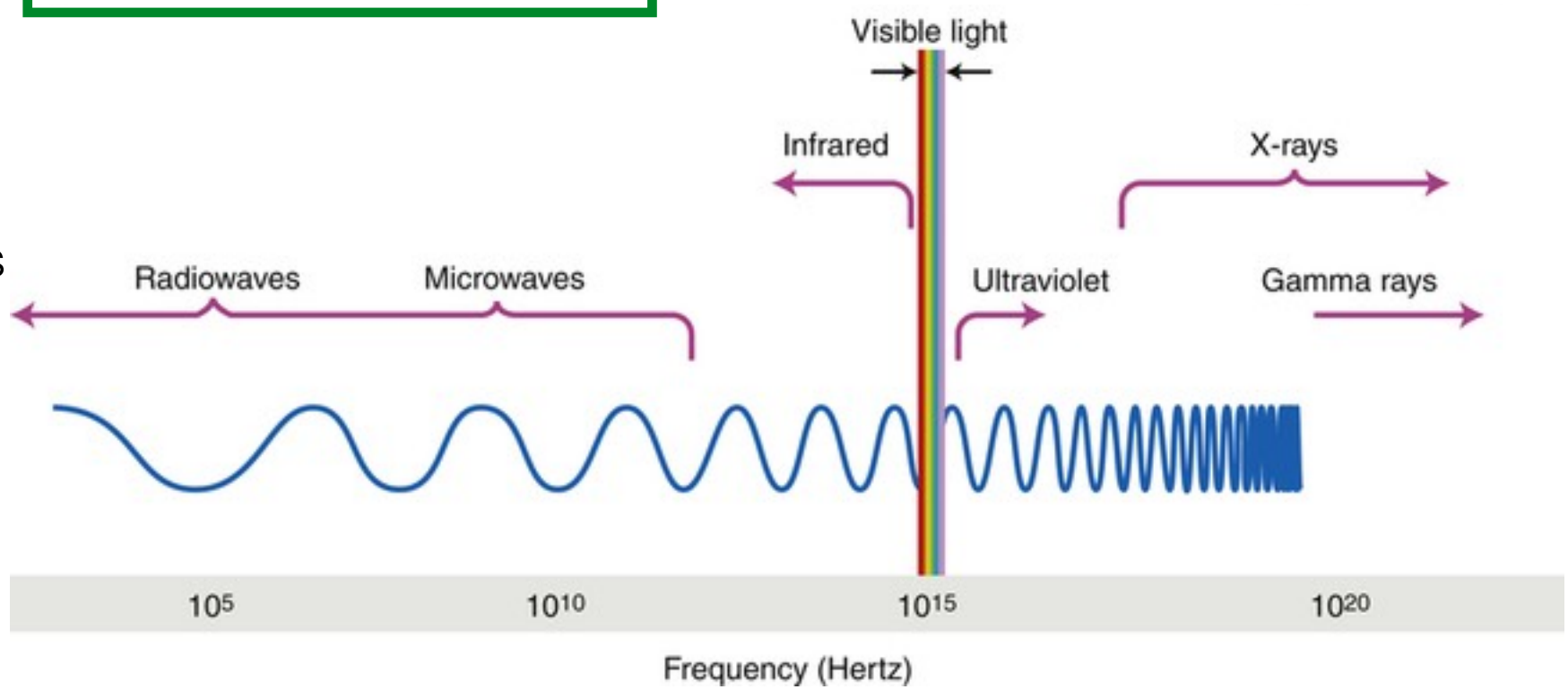


SOLAR WIND

What

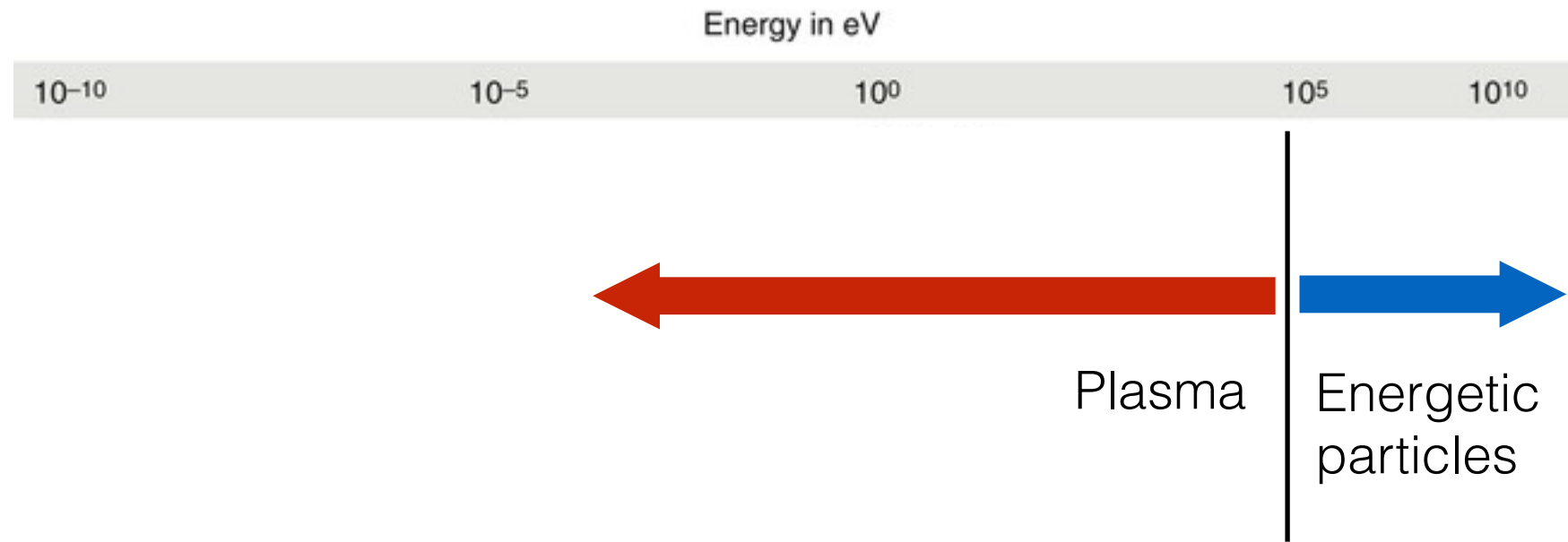
Electromagnetic radiation

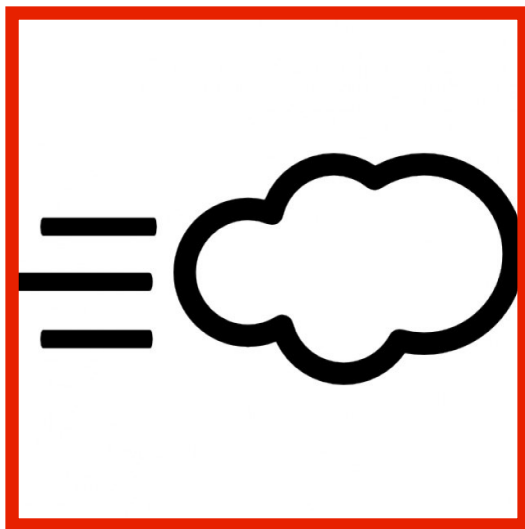
- Photons / electromagnetic waves
- Speed of light



Particles

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

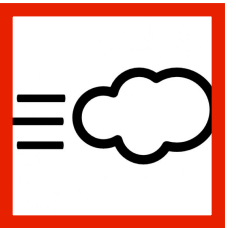
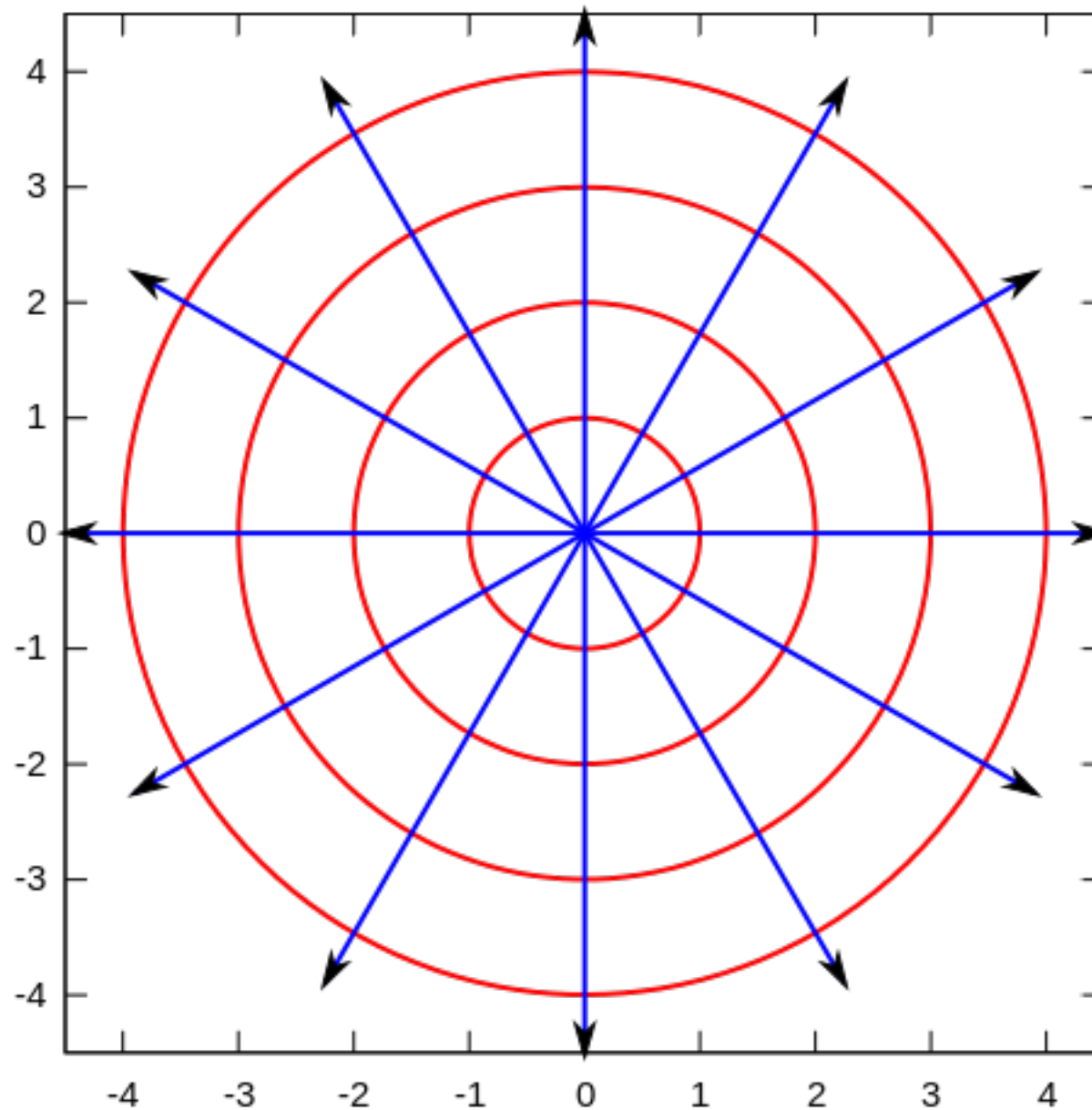


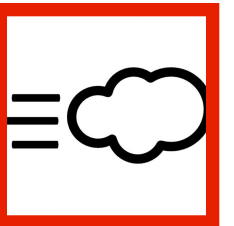


Outward moving plasma

RADIAL SOLAR WIND

The solar wind carries out solar material and solar magnetic field. The solar material and magnetic field becomes less dense the further away from the Sun.

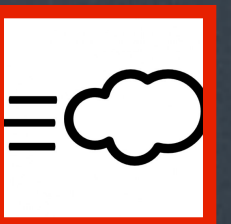




We need to understand the Interplanetary Magnetic field that is spread in the heliosphere.



Image: Siberia 20080801
J.M.P., W. G. Wagner and H. Druckmüllerová



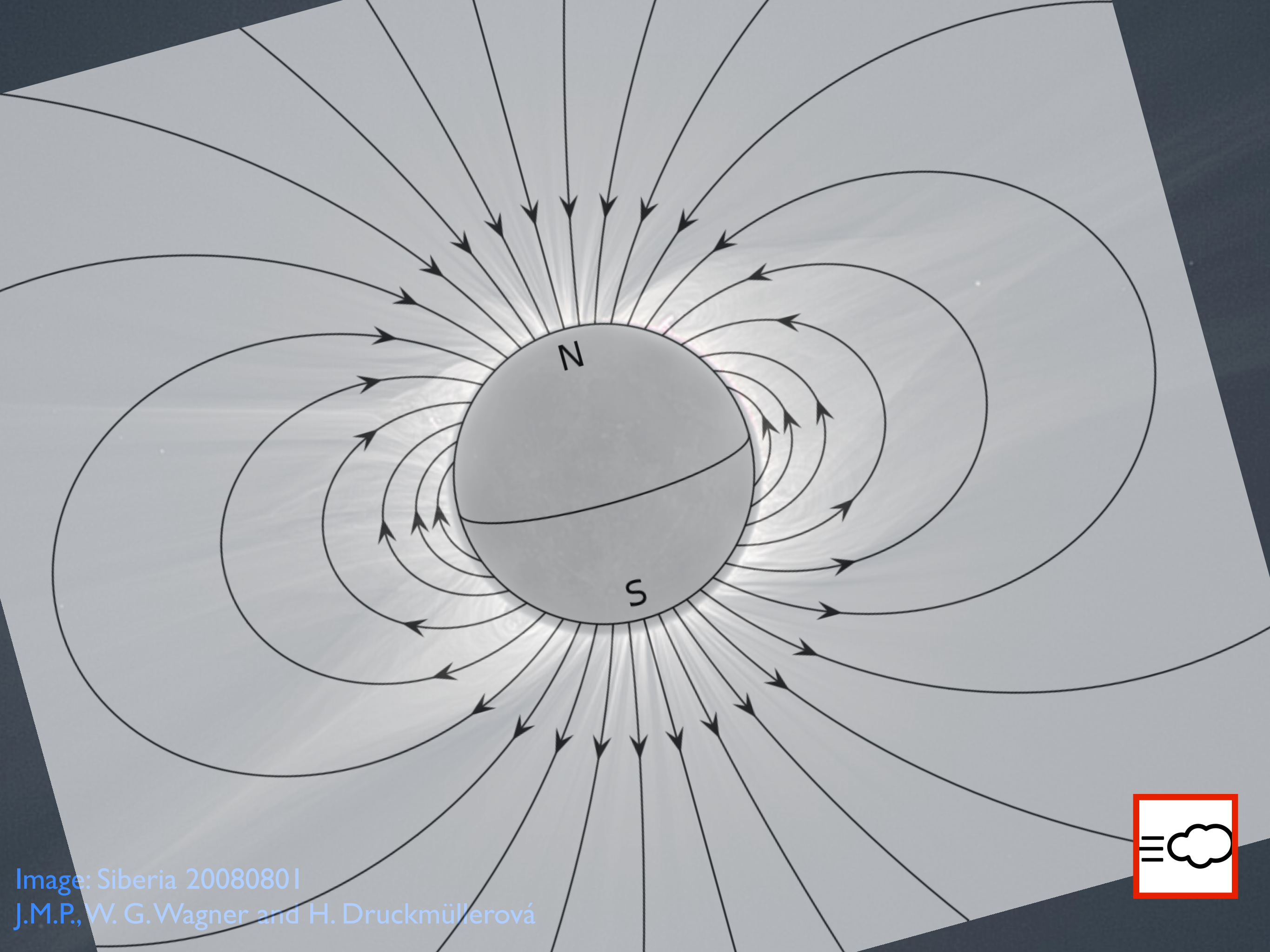
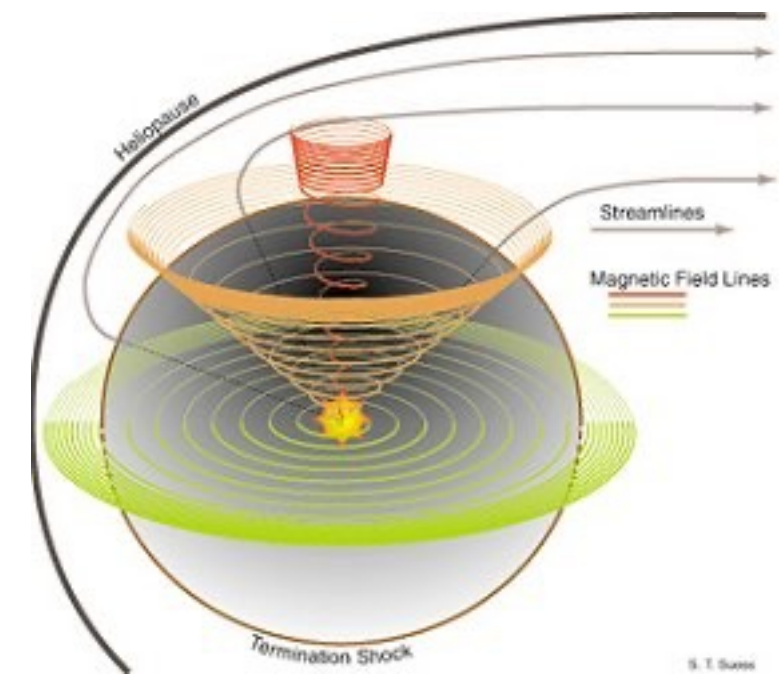
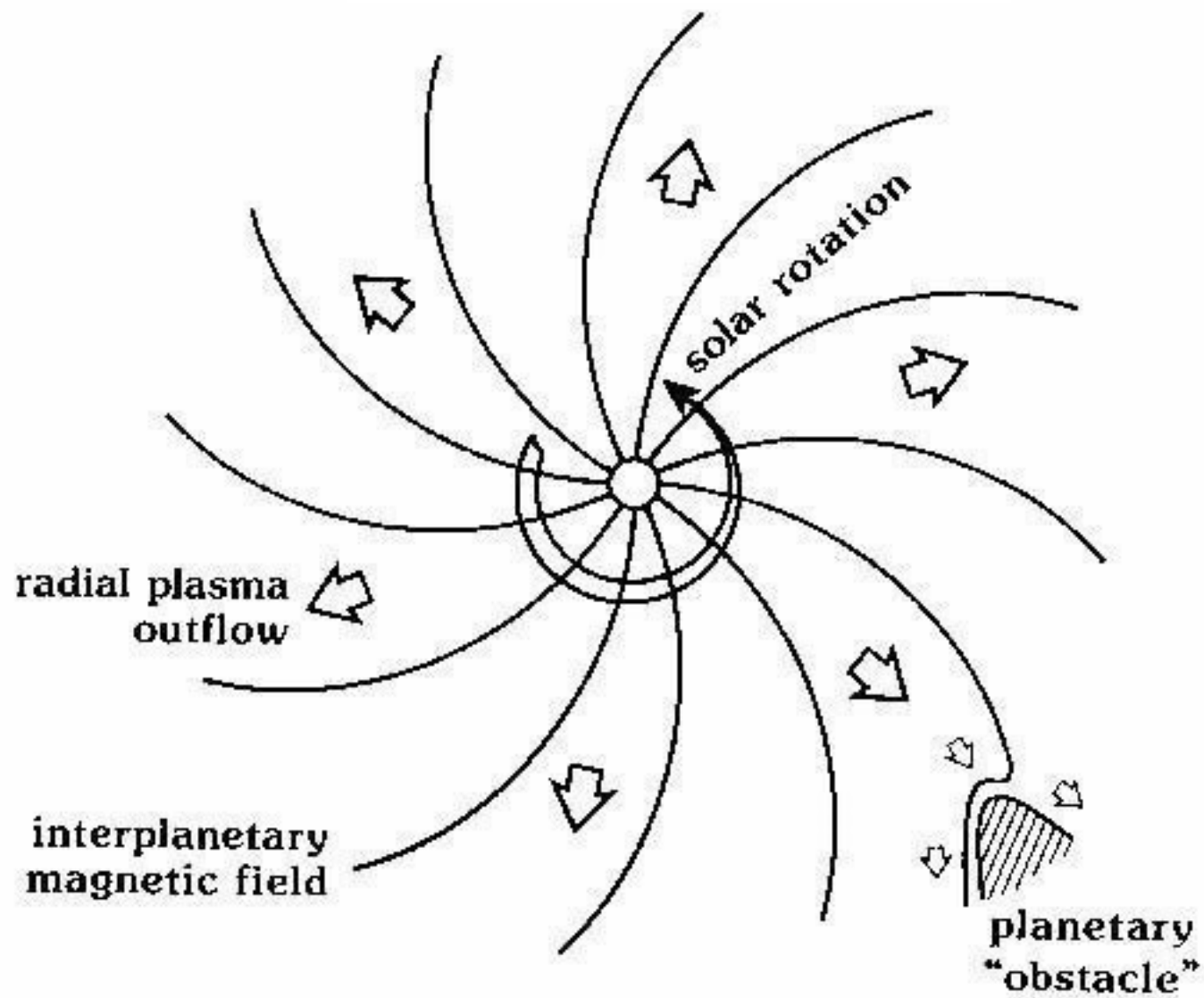
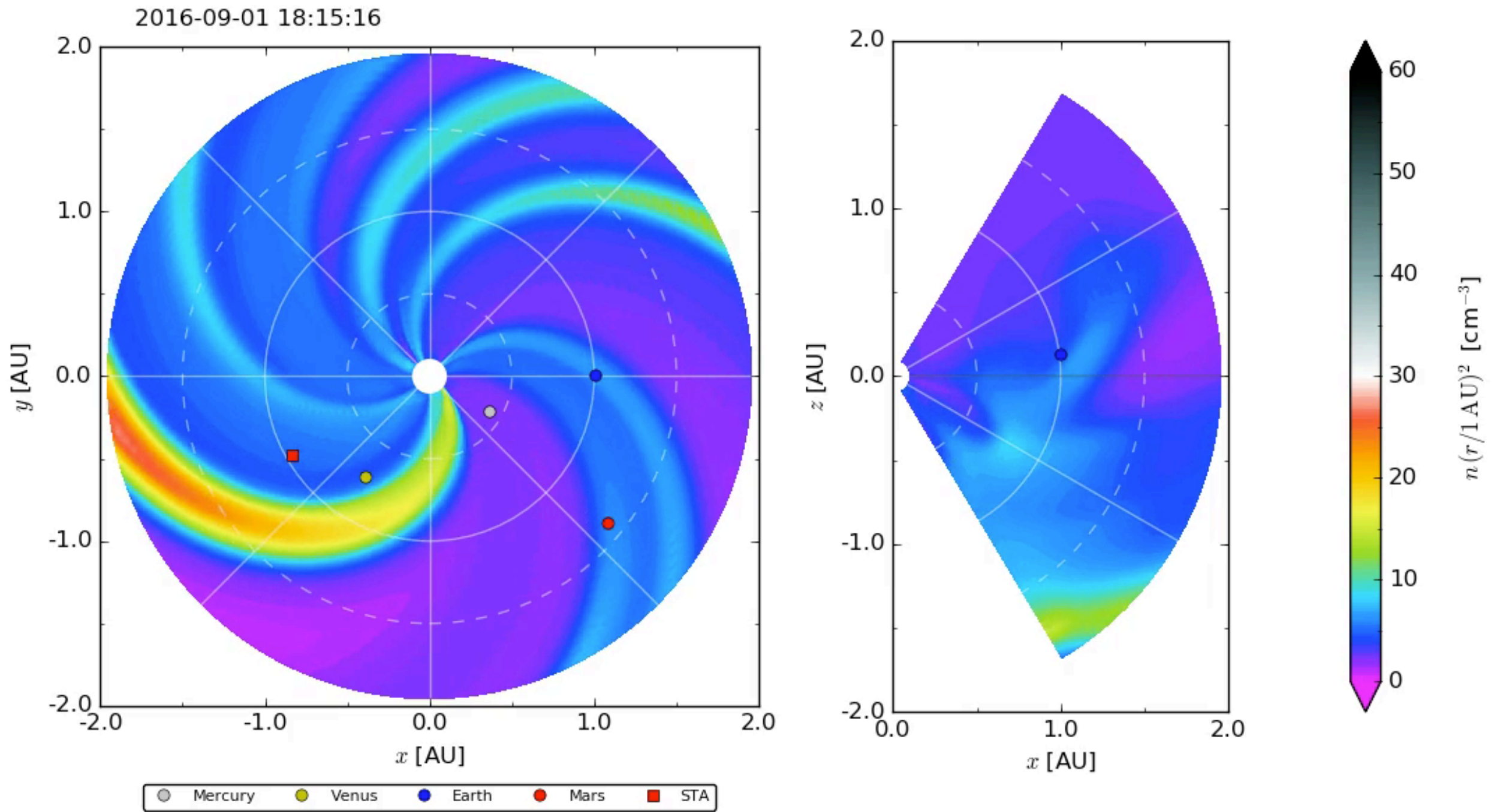


Image: Siberia 20080801
J.M.P., W. G. Wagner and H. Druckmüllerová

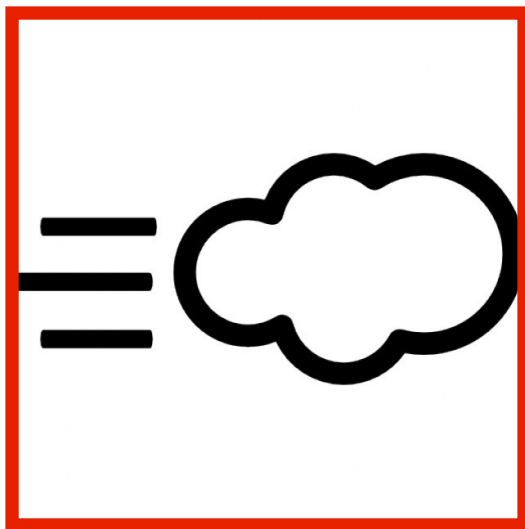
PARKER SPIRAL

The magnetic field stays connected to the Sun. As the Sun rotates, the magnetic field gets bended.



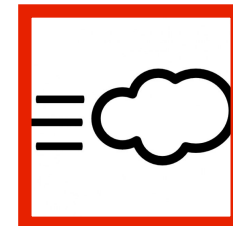


EUHFORIA, realtime simulations of the inner heliosphere



The moving plasma and the IMF together form the solar wind.

The solar wind is linked to open solar magnetic field lines.

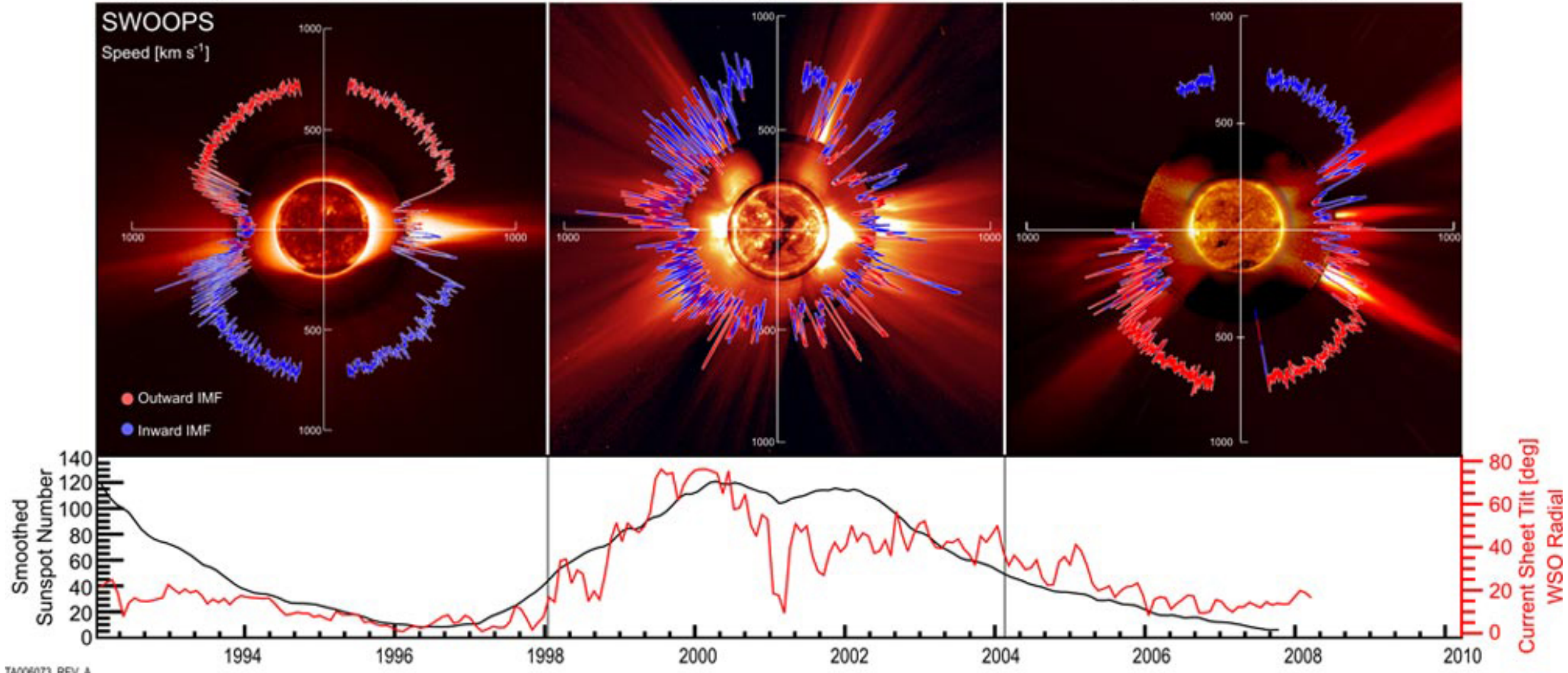


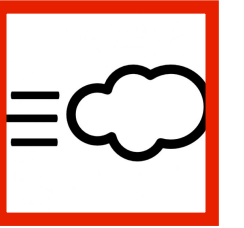
SLOW versus FAST

Ulysses First Orbit

Ulysses Second Orbit

Ulysses Third Orbit





SLOW versus FAST

250-400

km/s

400-800

High: ~ 10

Density, cm^{-3}

Low: ~ 3

Low: $\sim 10^4\text{K}$, $\sim 1\text{eV}$

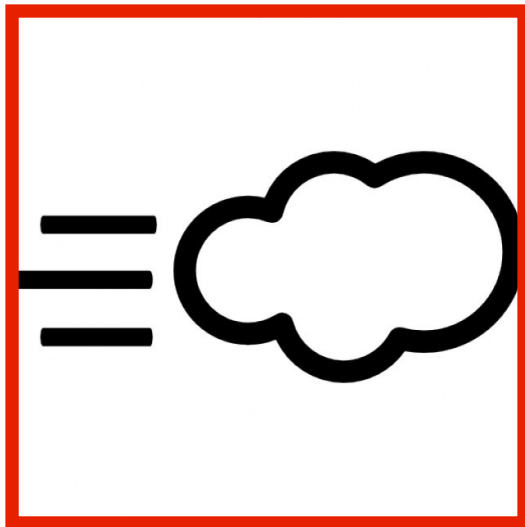
Temperature

High: $\sim 10^5\text{K}$, $\sim 10\text{eV}$

Variable

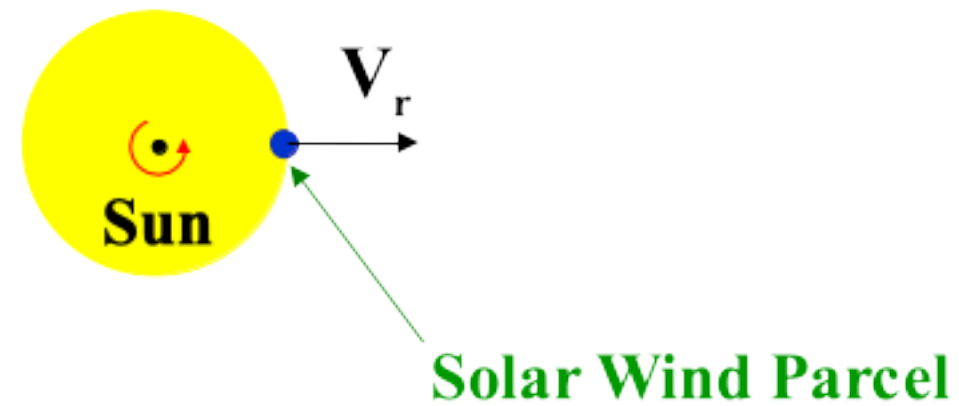
Behaviour

Stationary



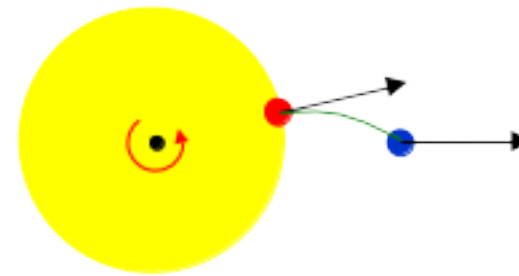
IMF is bended and the plasma flow is radial. Euh?

The Solar Wind and the Interplanetary Magnetic Field (Formation of the Parker Spiral)



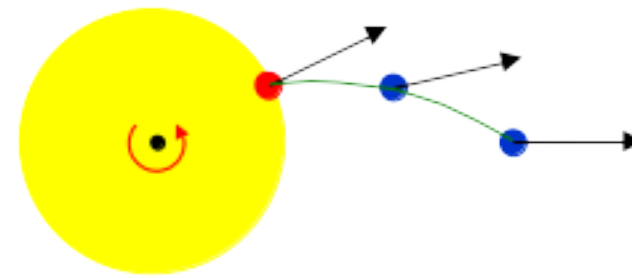
Arge, 2018

The Solar Wind and the Interplanetary Magnetic Field (Formation of the Parker Spiral)



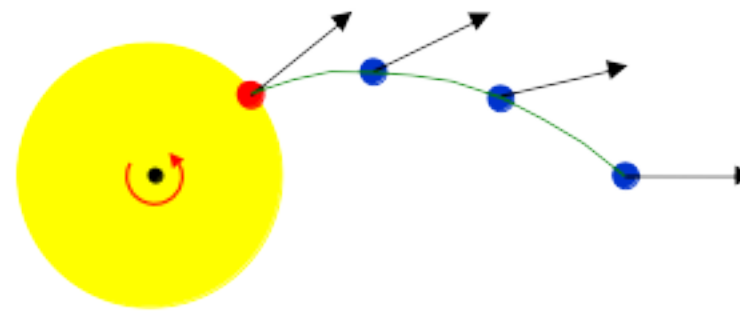
Arge, 2018

The Solar Wind and the Interplanetary Magnetic Field (Formation of the Parker Spiral)



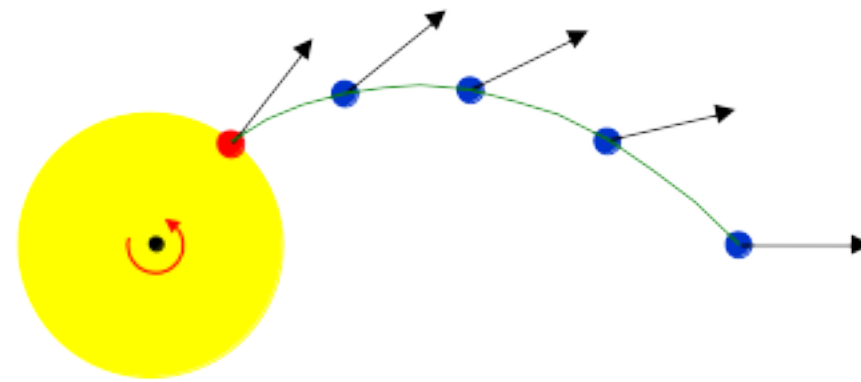
Arge, 2018

The Solar Wind and the Interplanetary Magnetic Field (Formation of the Parker Spiral)



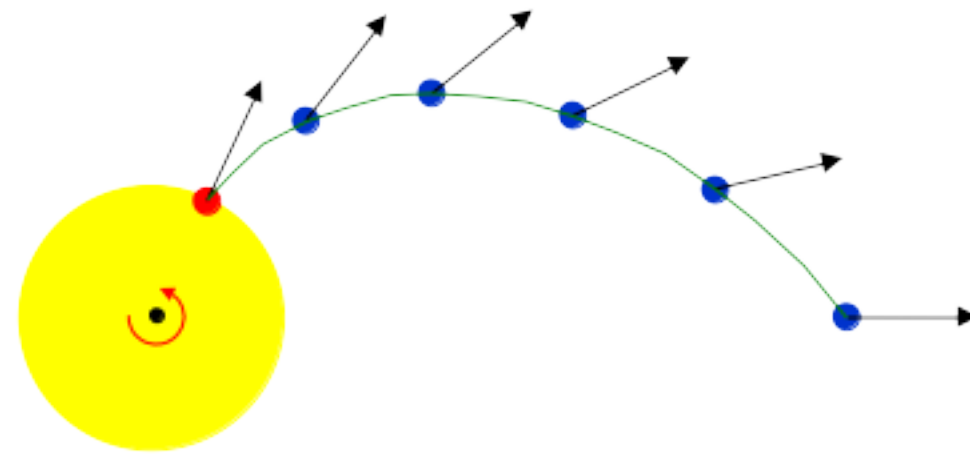
Arge, 2018

The Solar Wind and the Interplanetary Magnetic Field (Formation of the Parker Spiral)



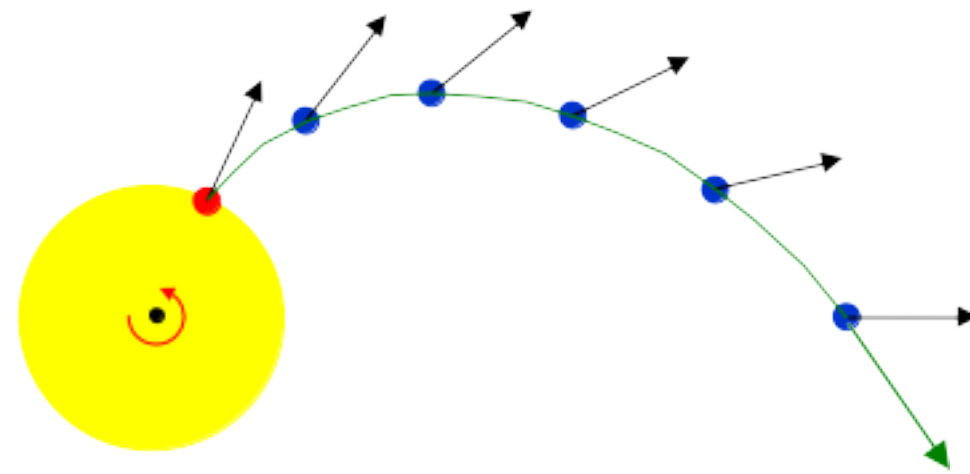
Arge, 2018

The Solar Wind and the Interplanetary Magnetic Field (Formation of the Parker Spiral)

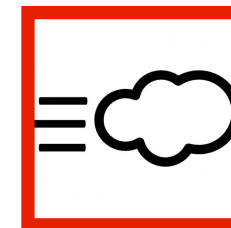
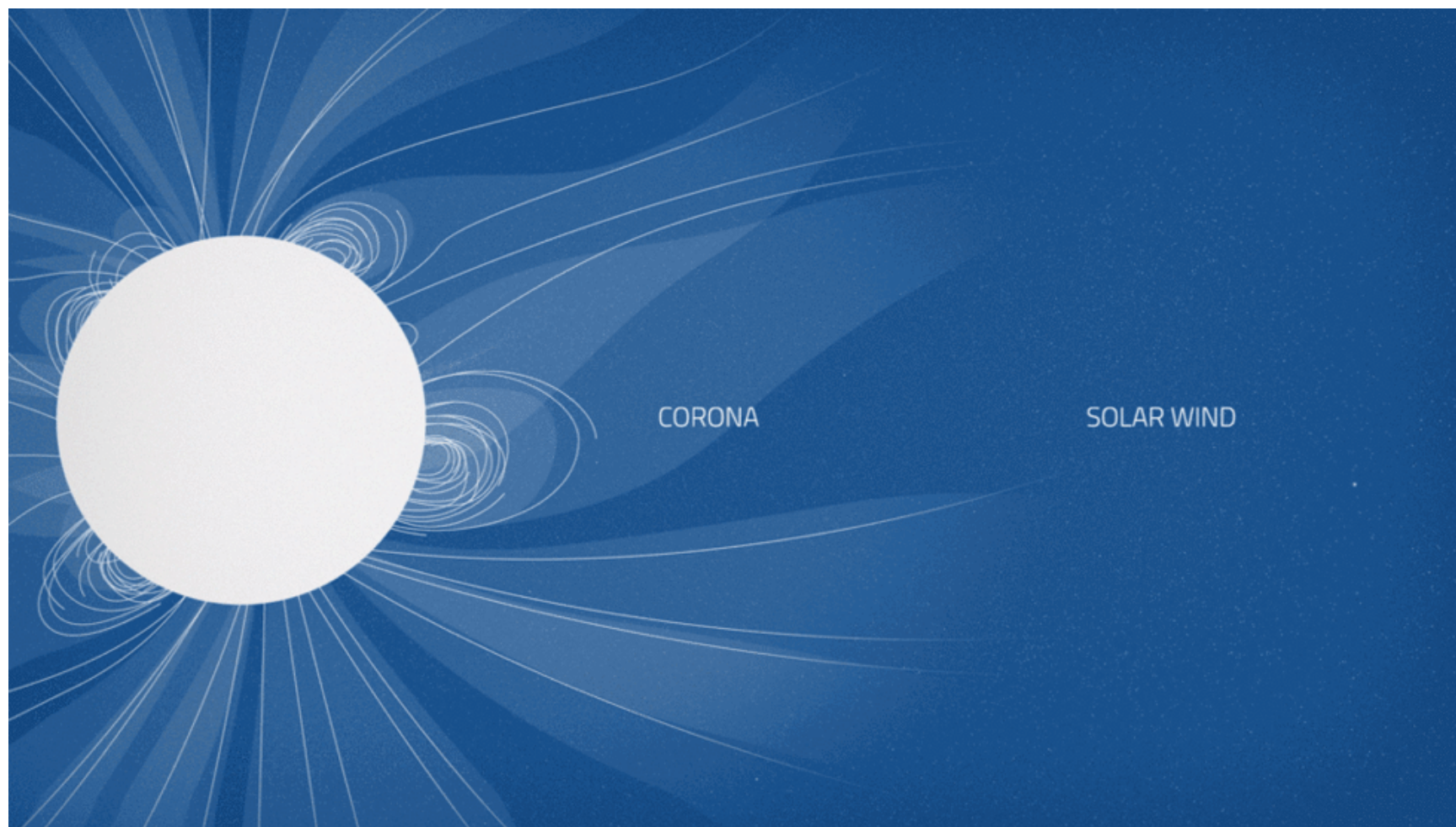


Arge, 2018

The Solar Wind and the Interplanetary Magnetic Field (Formation of the Parker Spiral)



Arge, 2018

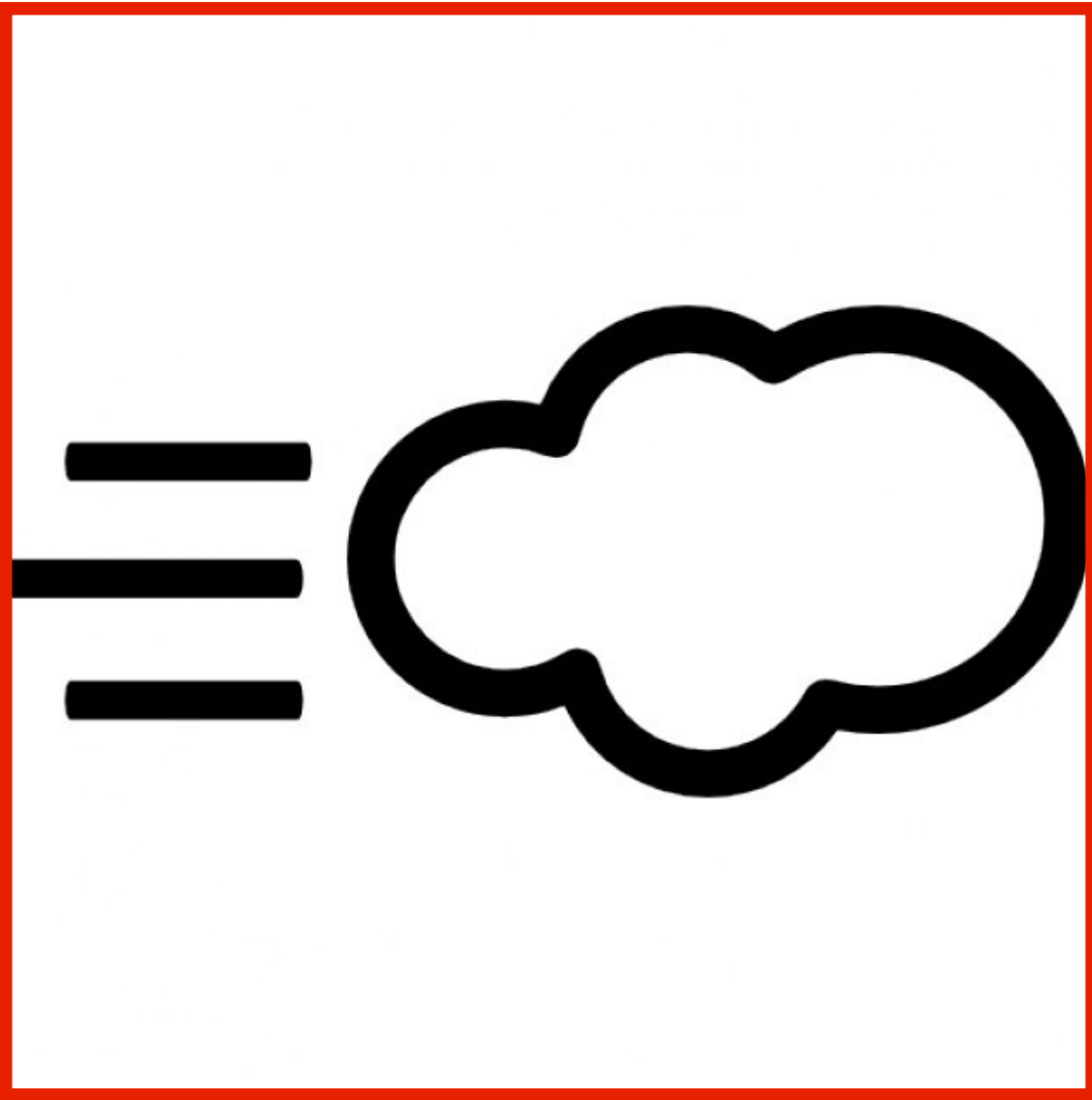


Continuous radial outflow of gas - Consists of charged particles

Shapes the IMF - Can carry magnetic structures.

Is the IMF **Straight/Bended**?

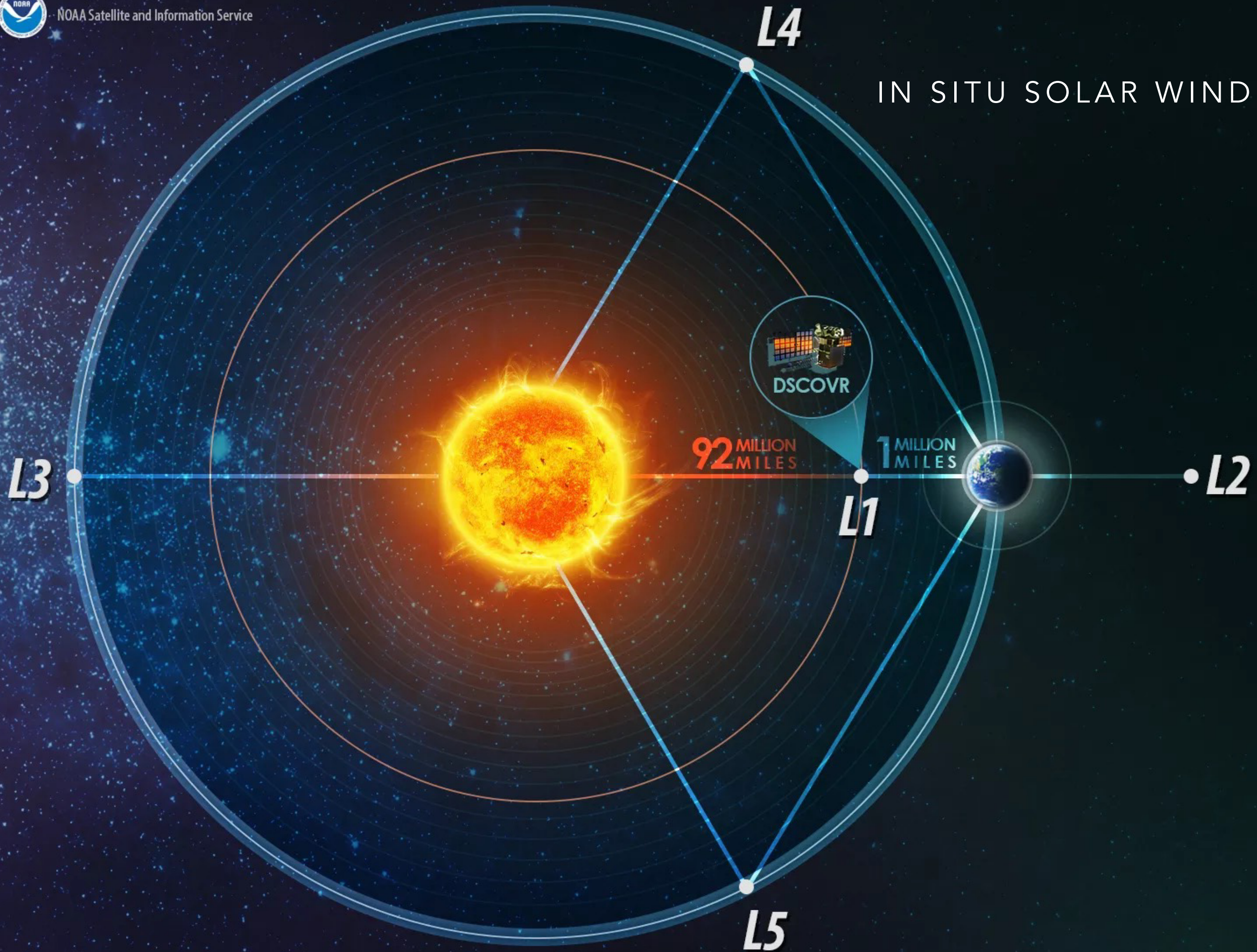
IMF are **open/closed** magnetic field lines?

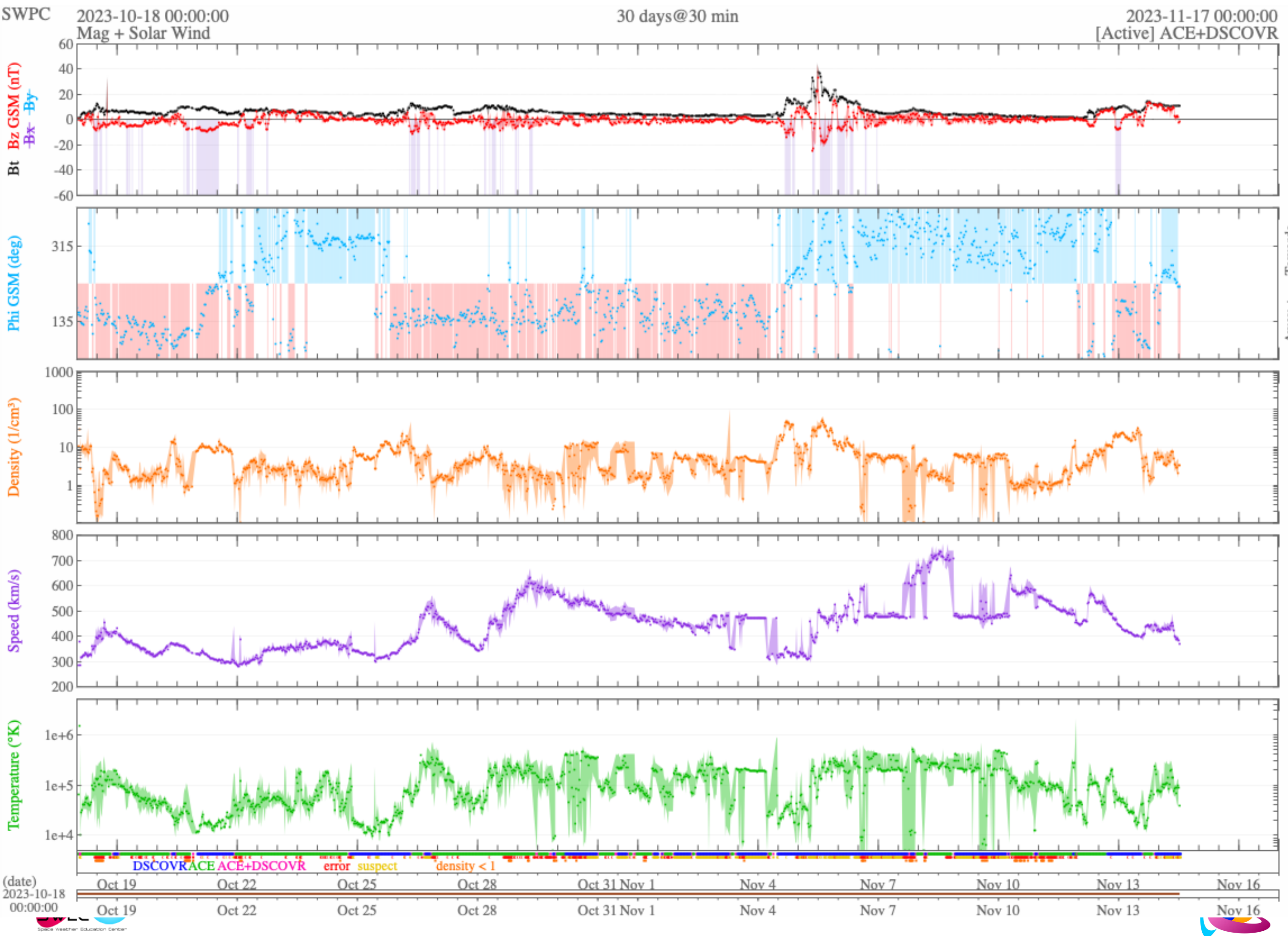


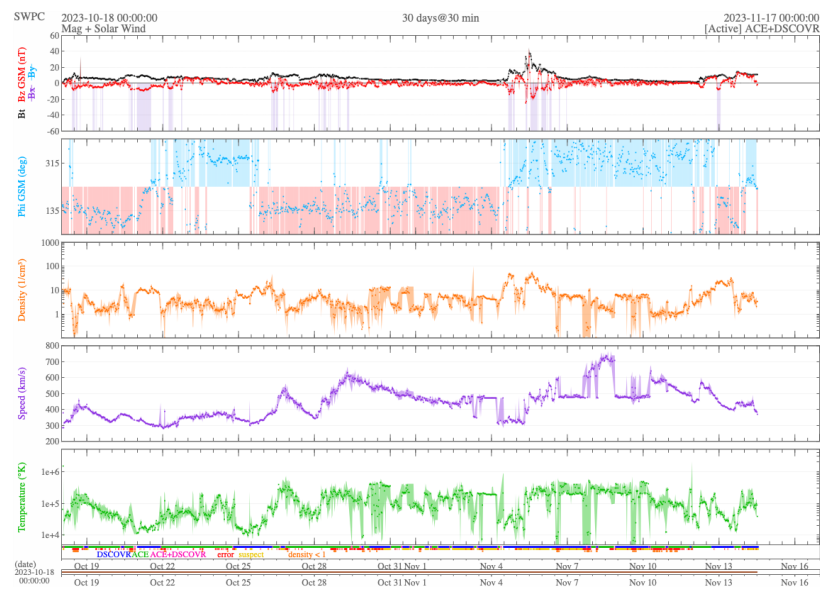
SOLAR WIND

Near Earth

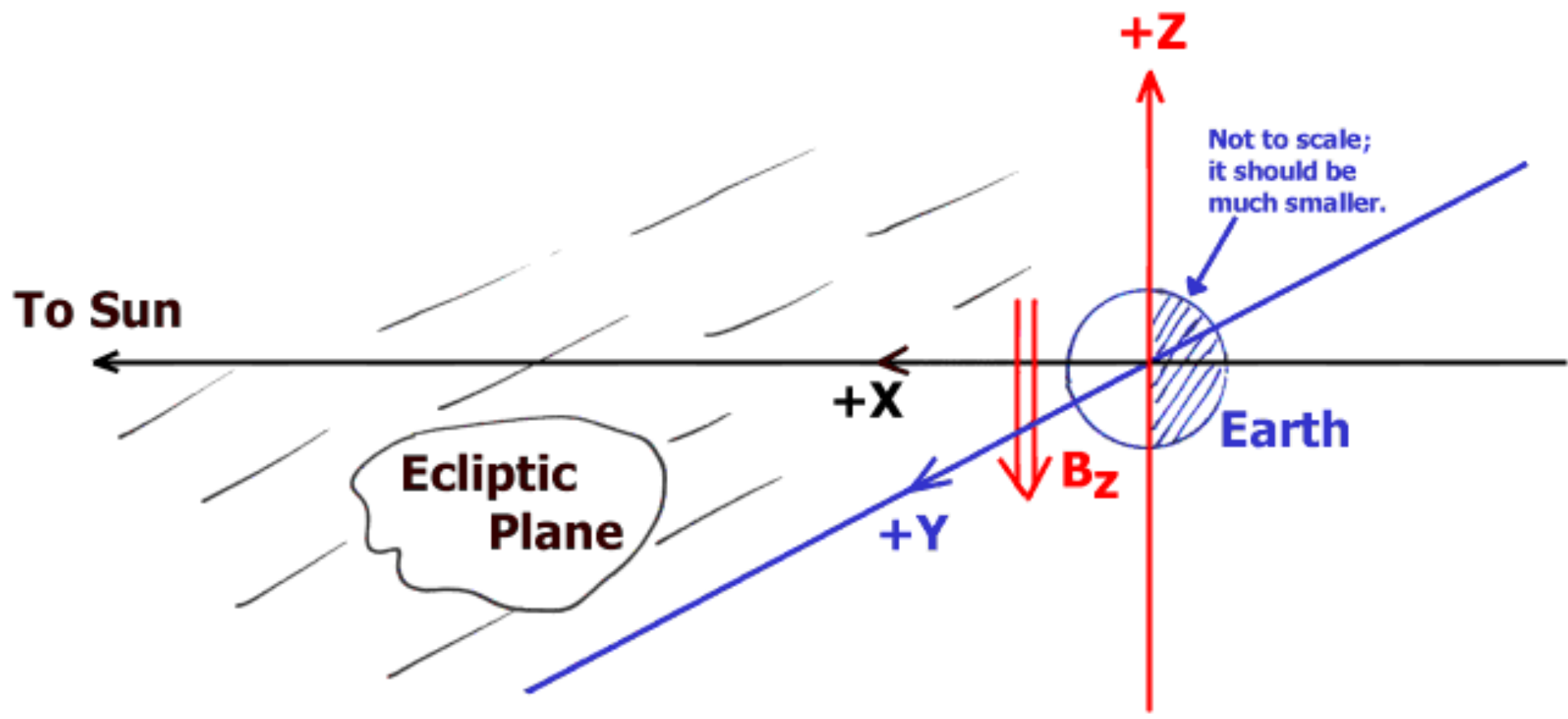
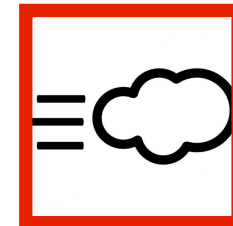
IN SITU SOLAR WIND



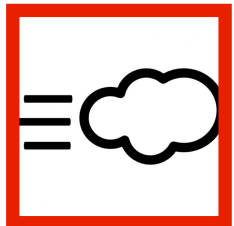
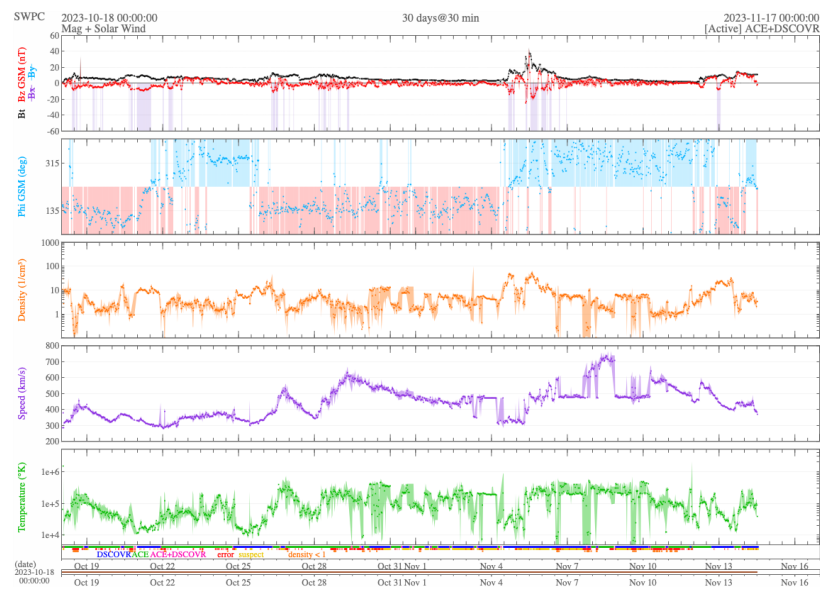




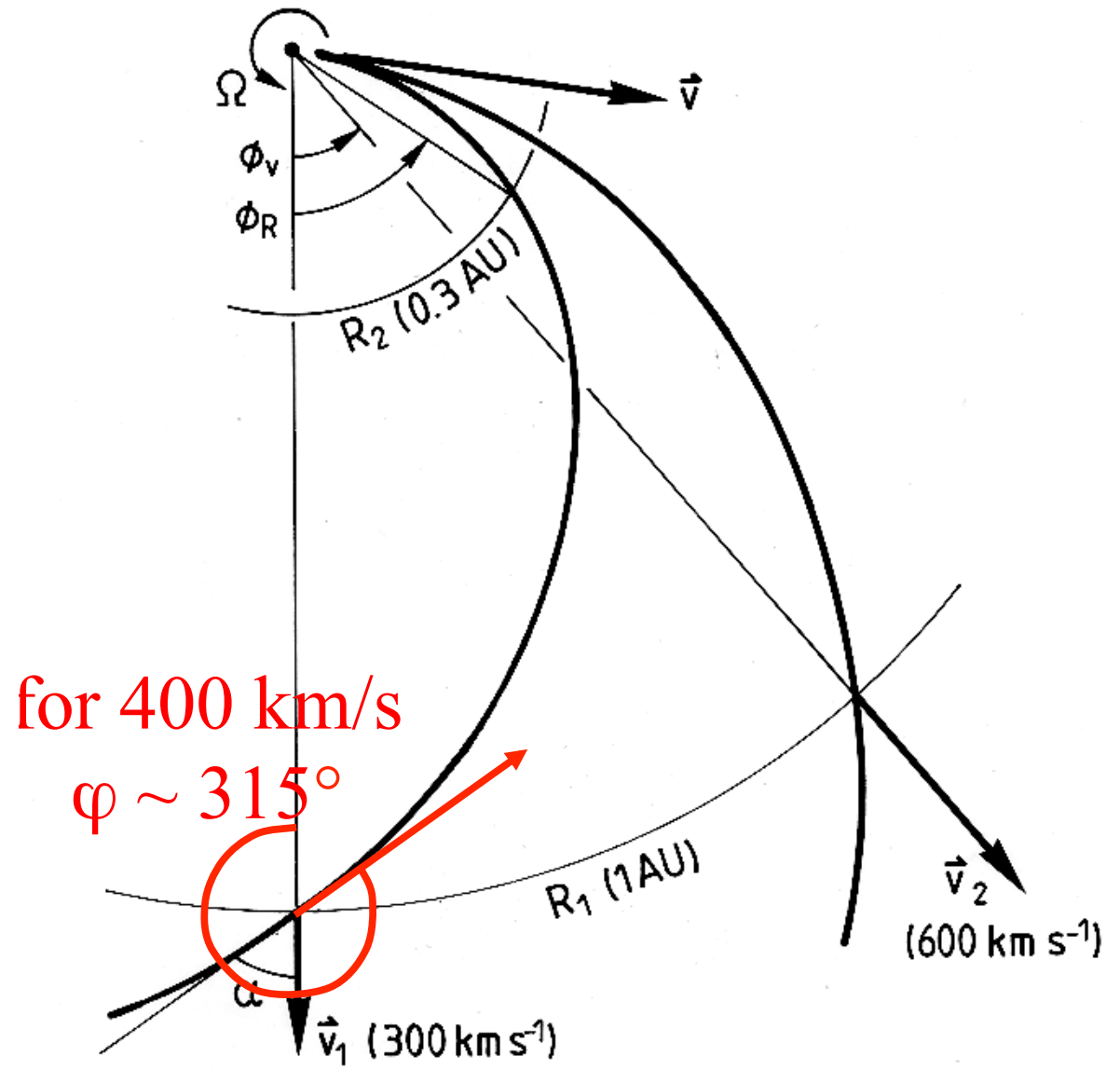
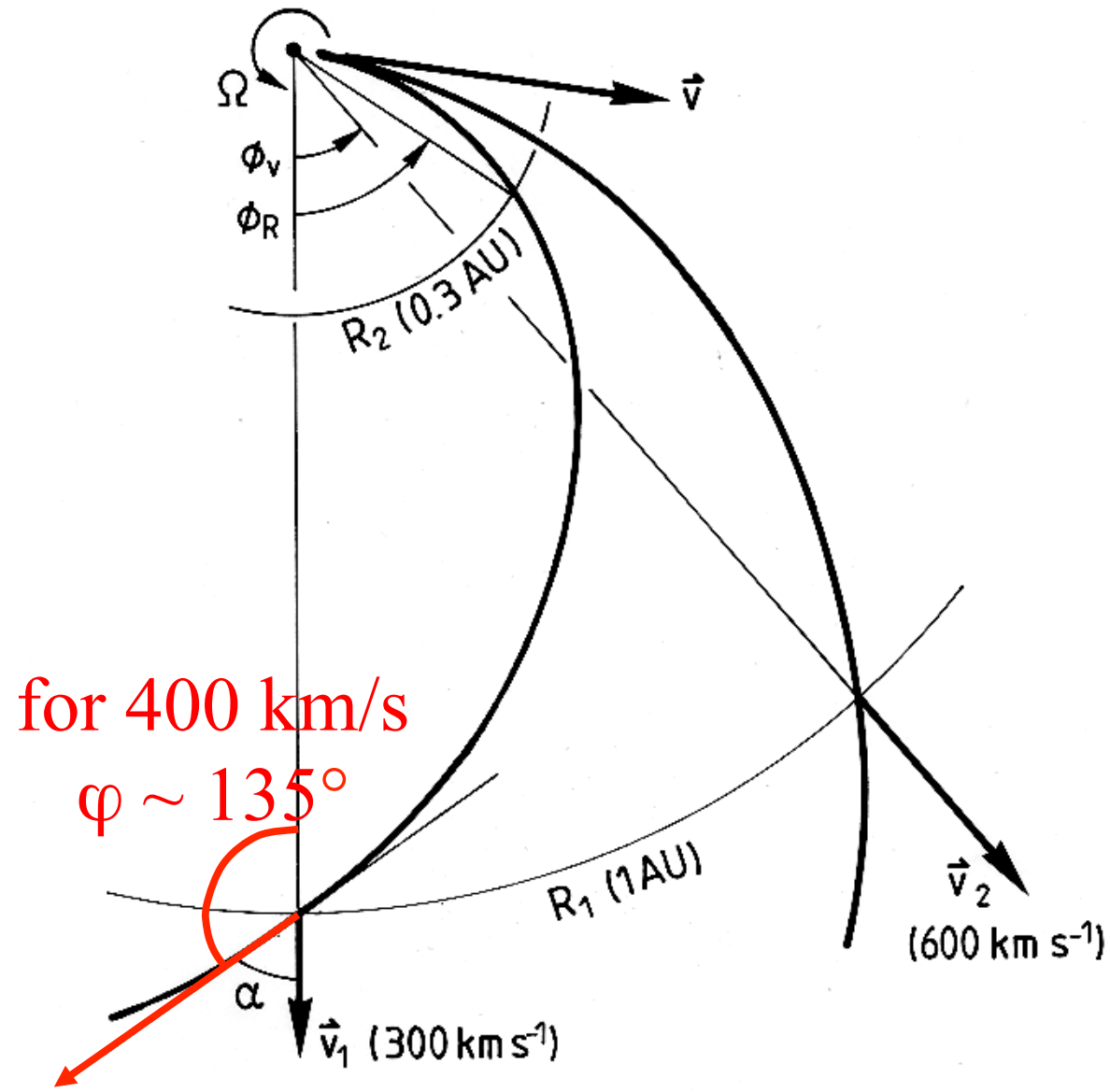
COORDINATE SYSTEM



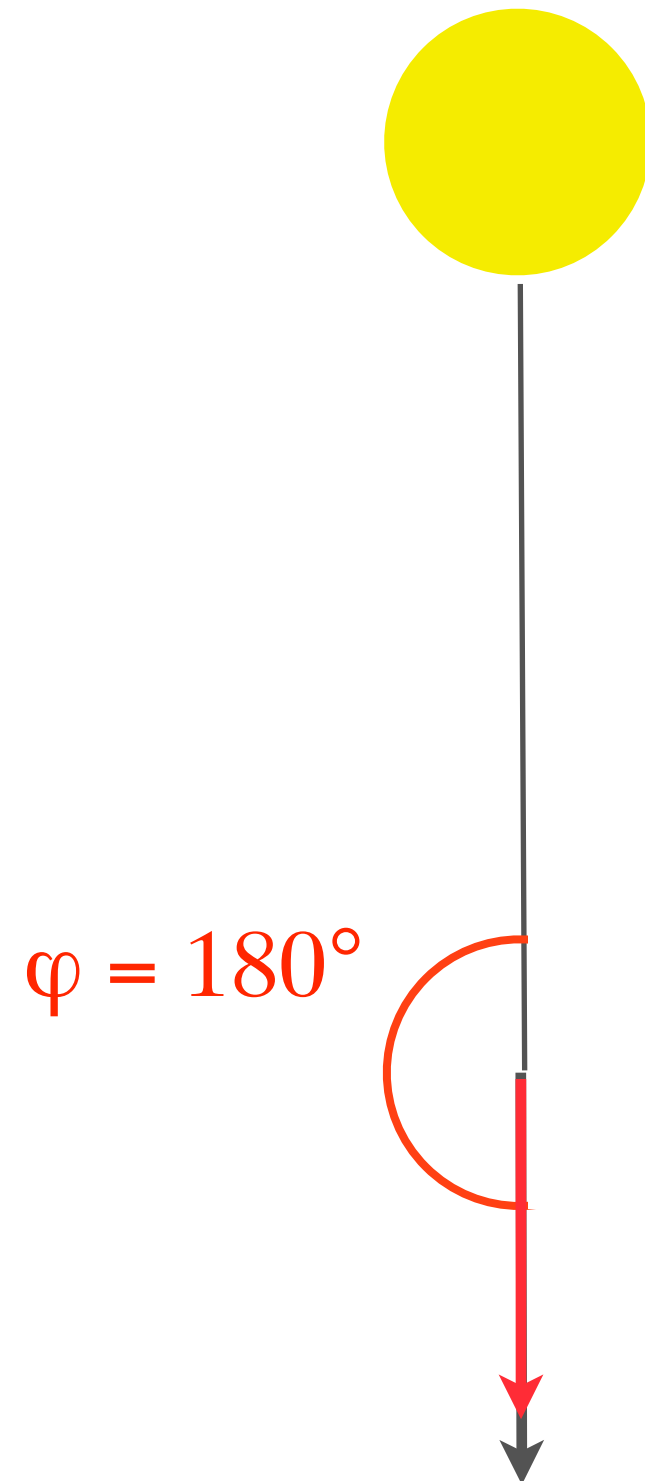
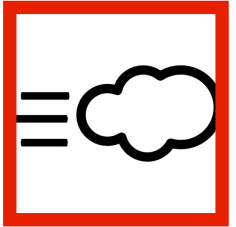
+Z is perpendicular to the Ecliptic Plane.



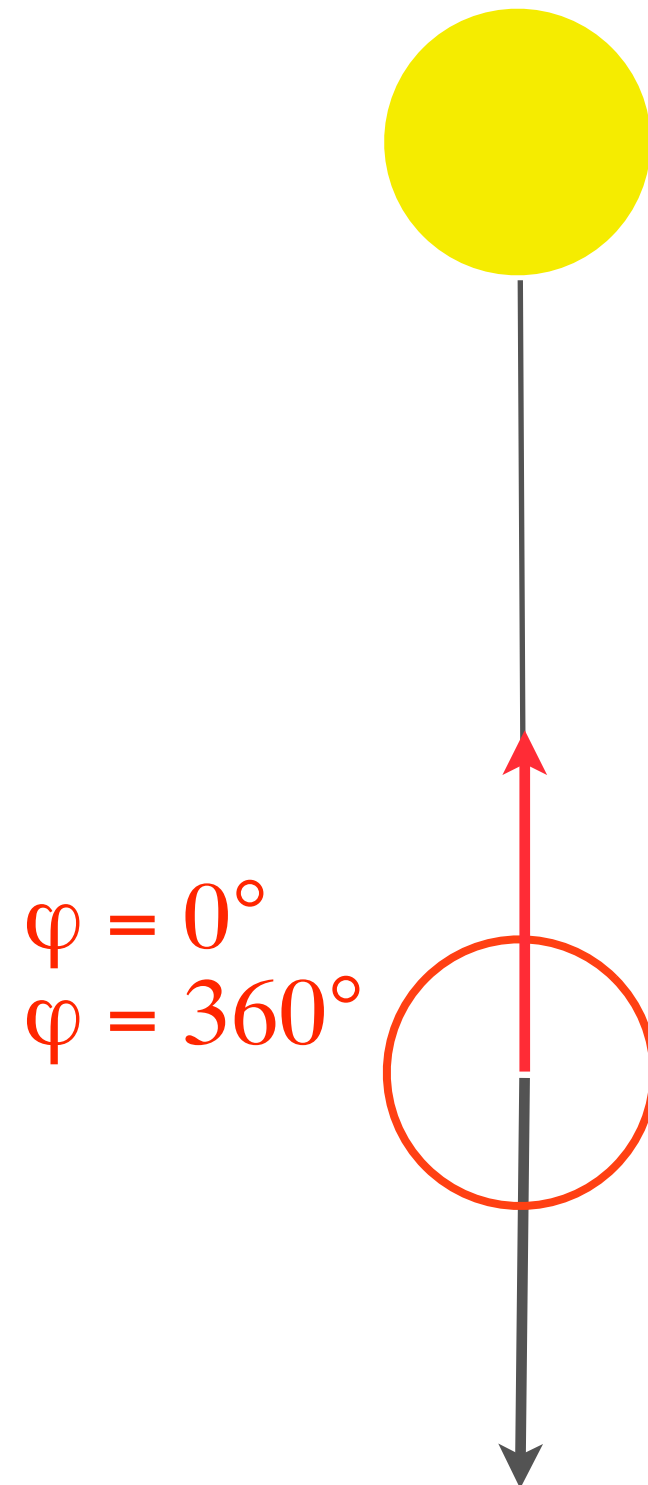
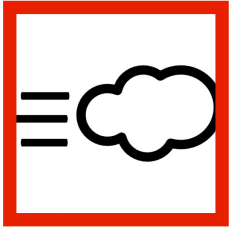
IMF POLARITY



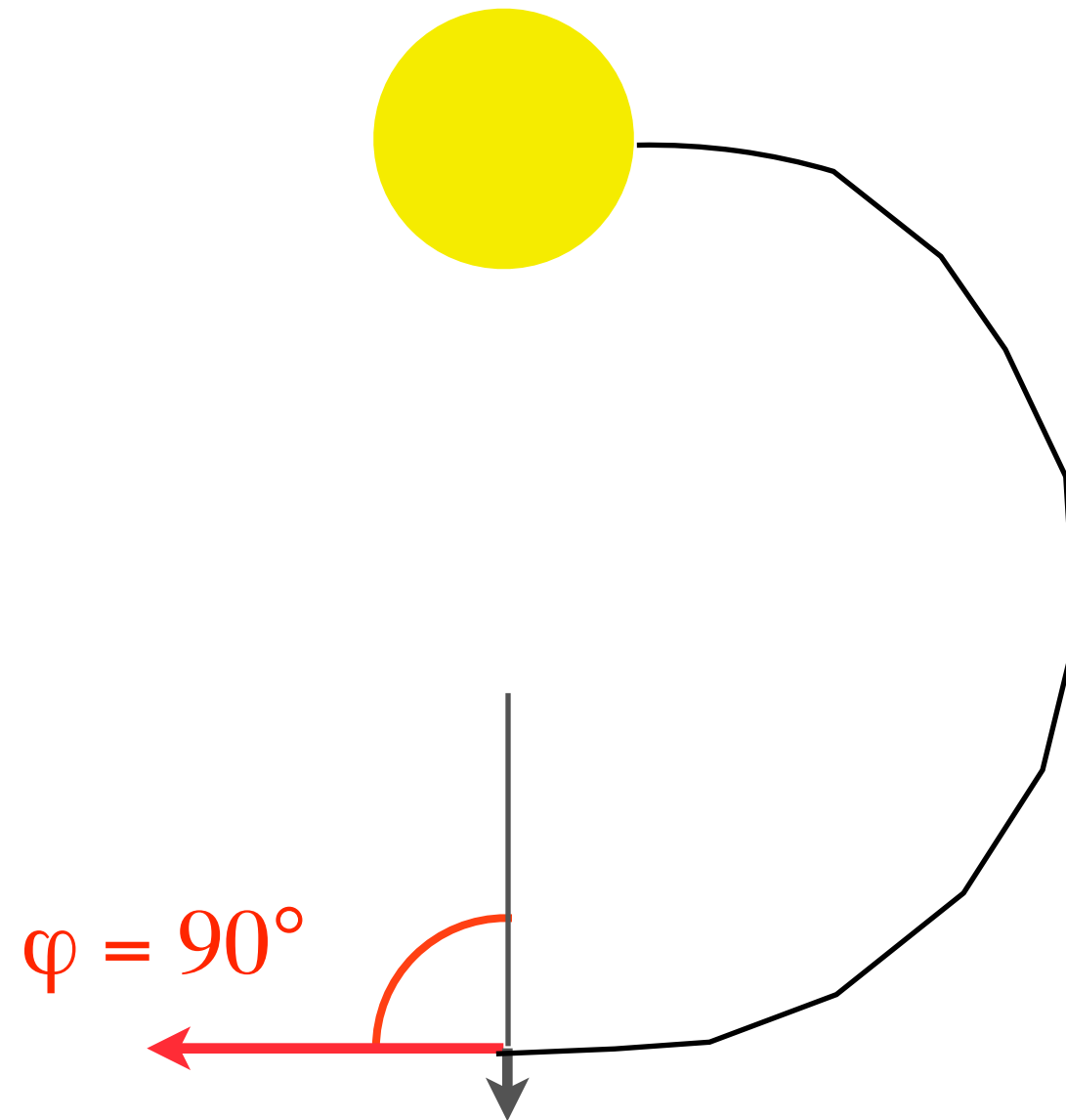
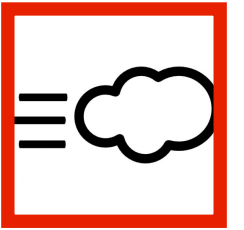
EXTREME FAST

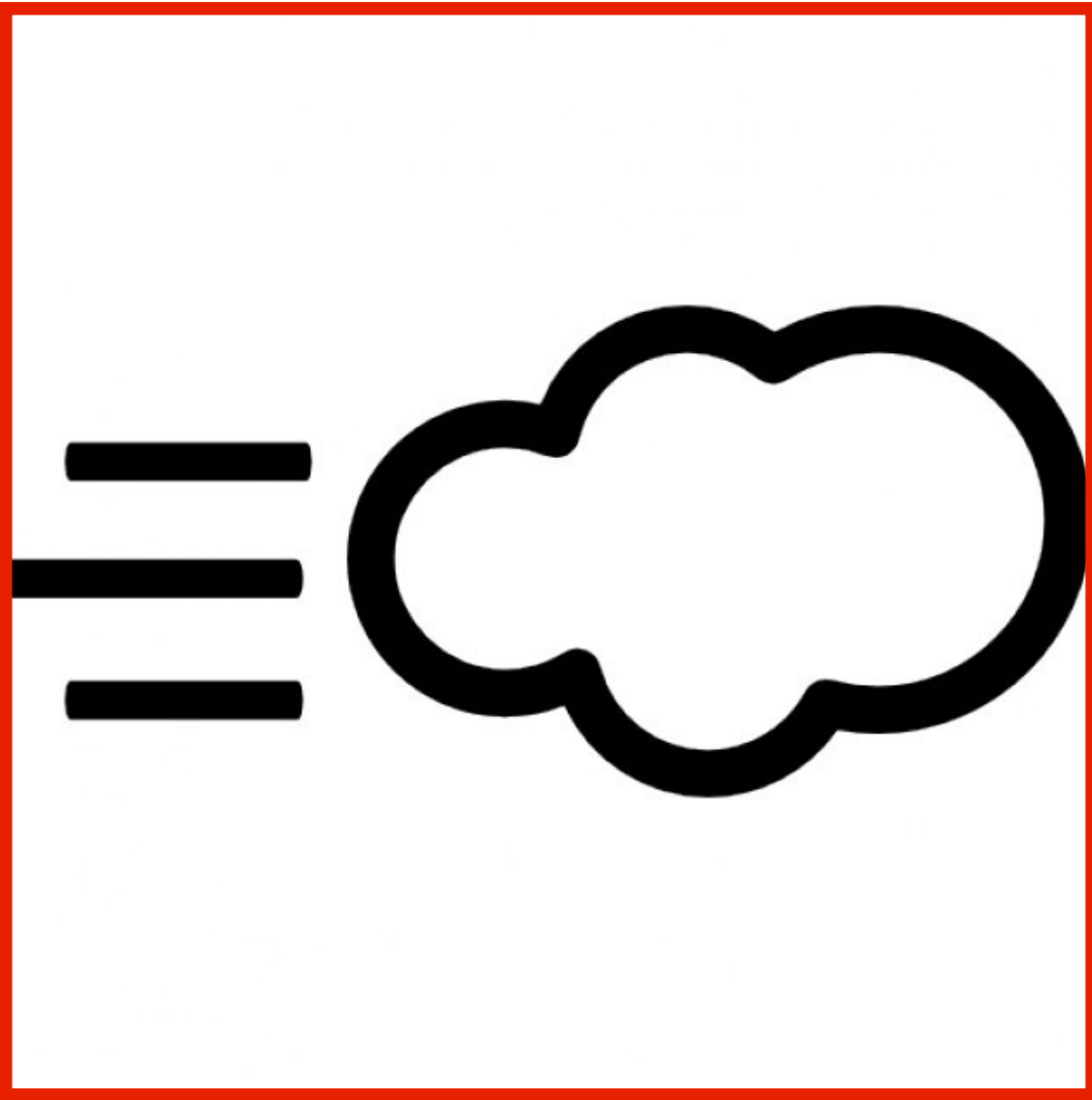


EXTREME FAST



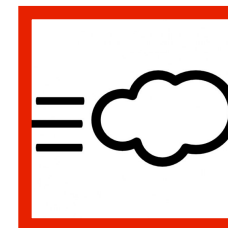
EXTREME SLOW





SOLAR WIND

Transients



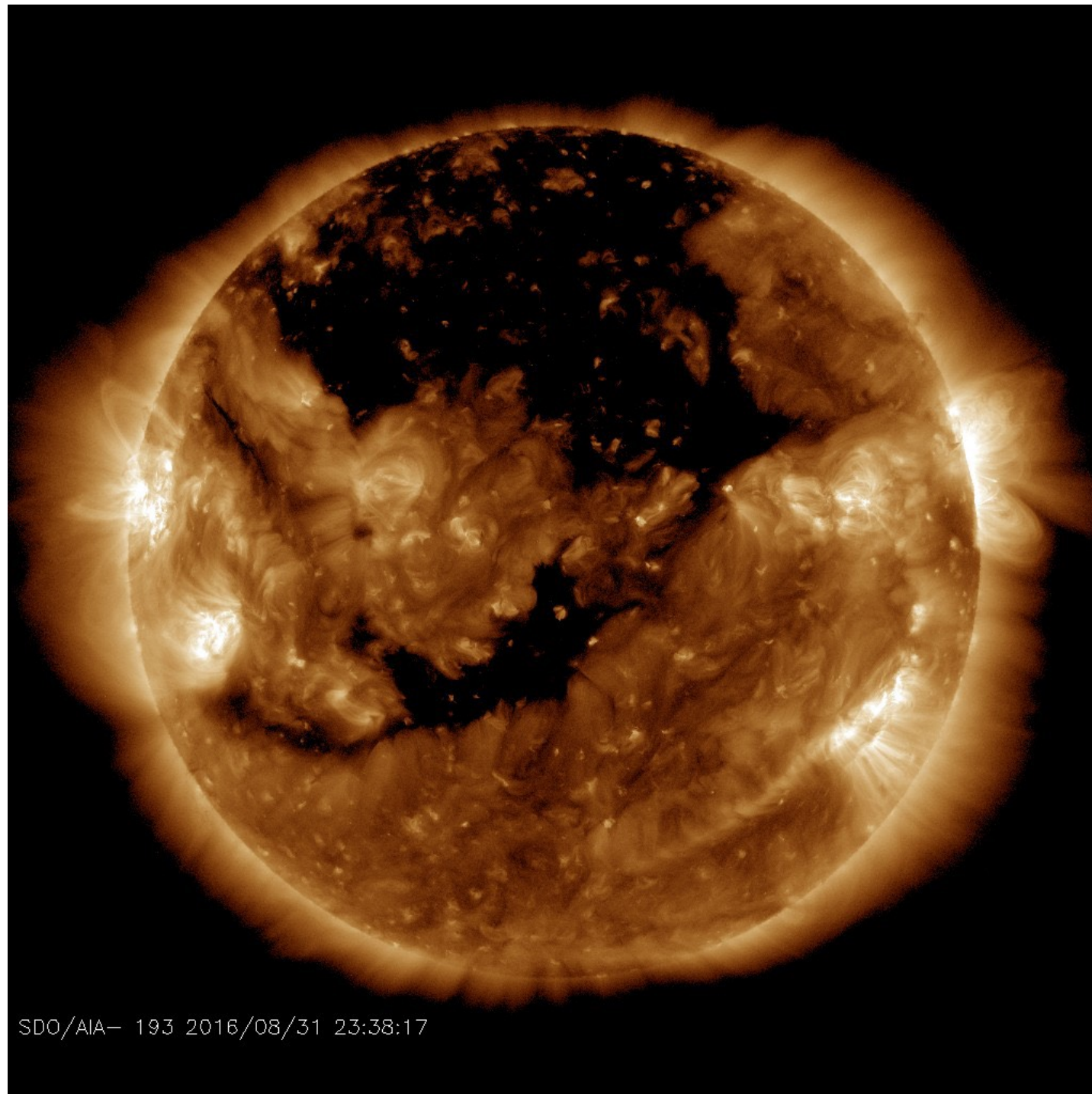
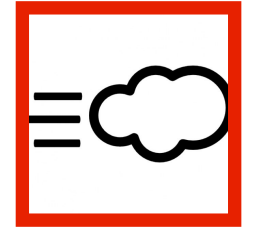
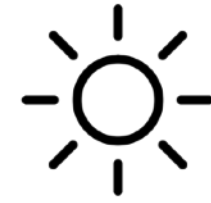
Transients

High Speed Streams (HSSs)

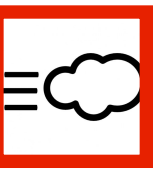
And

Co-rotating Interaction Regions (CIRs)

Coronal Hole

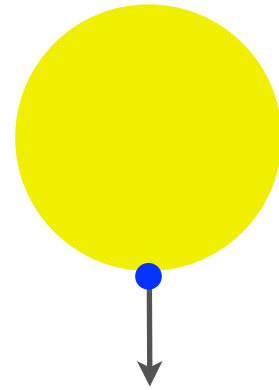


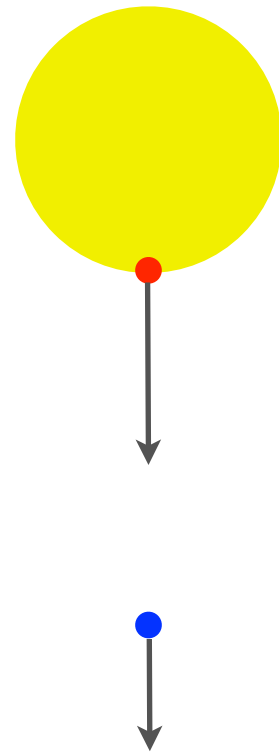
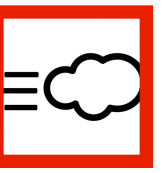
SDO/AIA- 193 2016/08/31 23:38:17

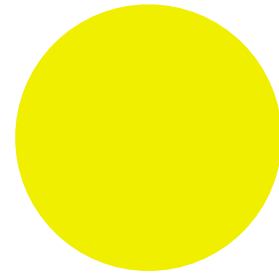
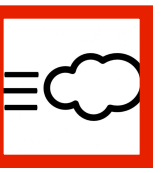


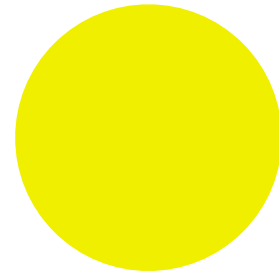
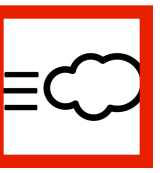
WHAT HAPPENS WHEN FAST CATCHES SLOW?

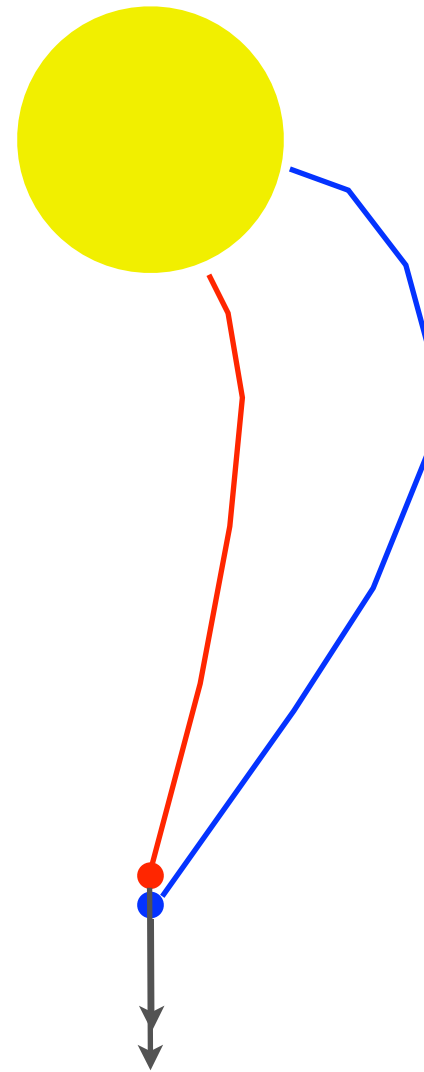
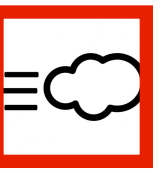
Top View









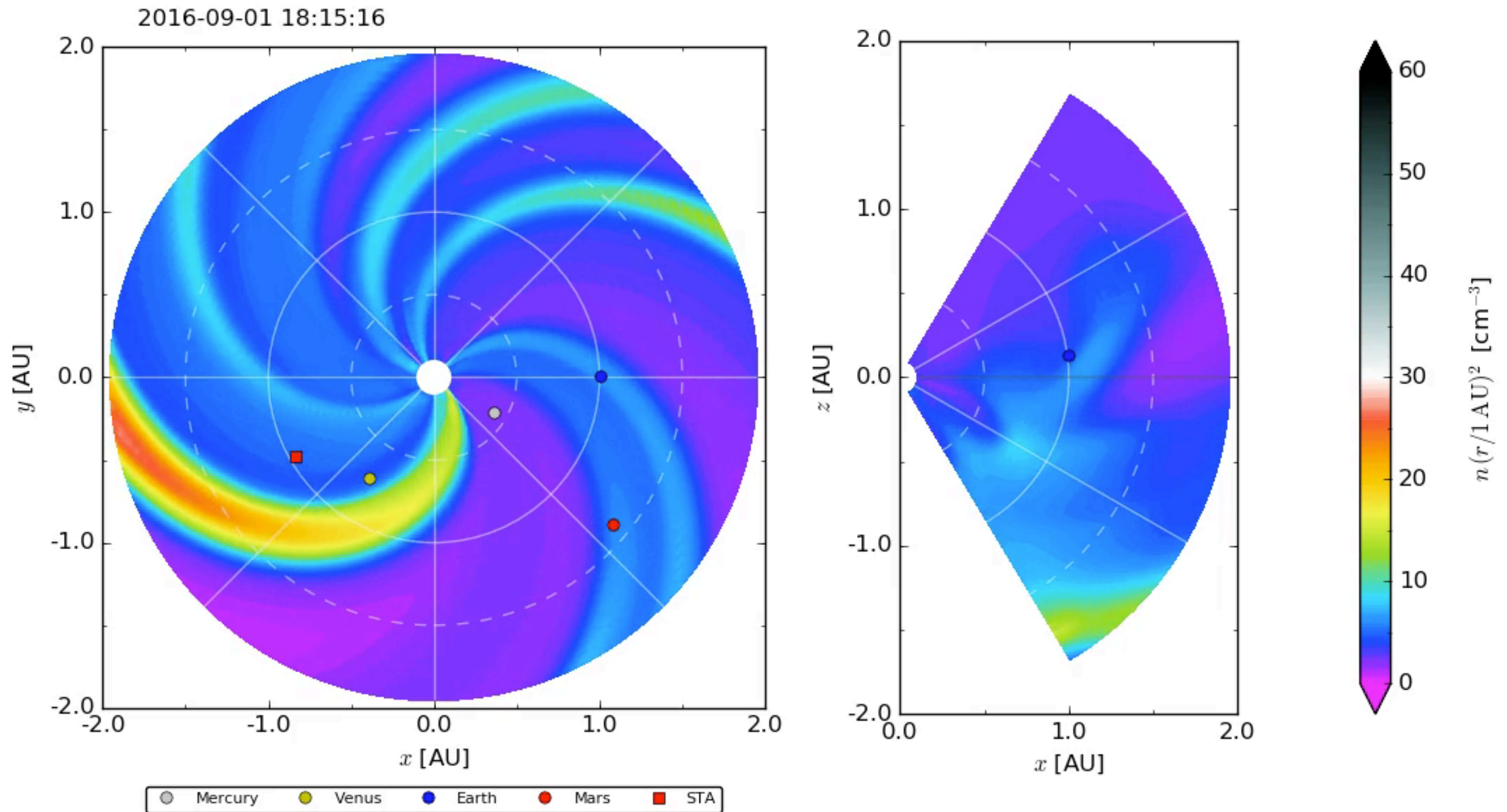


Interaction Region
Rotates together with the Sun

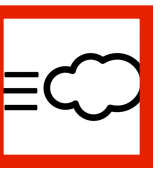


Co-rotating Interaction Region

Co-rotating Interaction Region

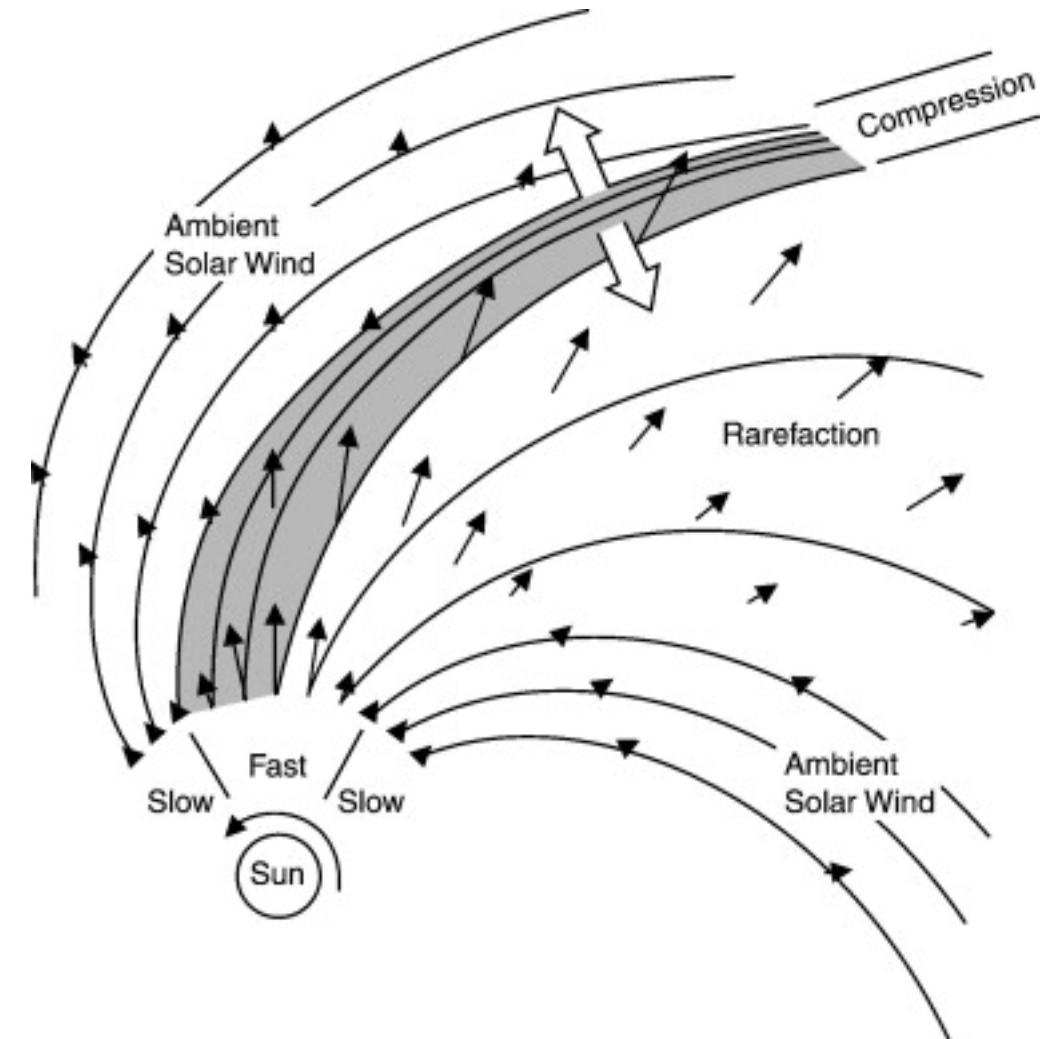


EUHFORIA, realtime simulations of the inner heliosphere



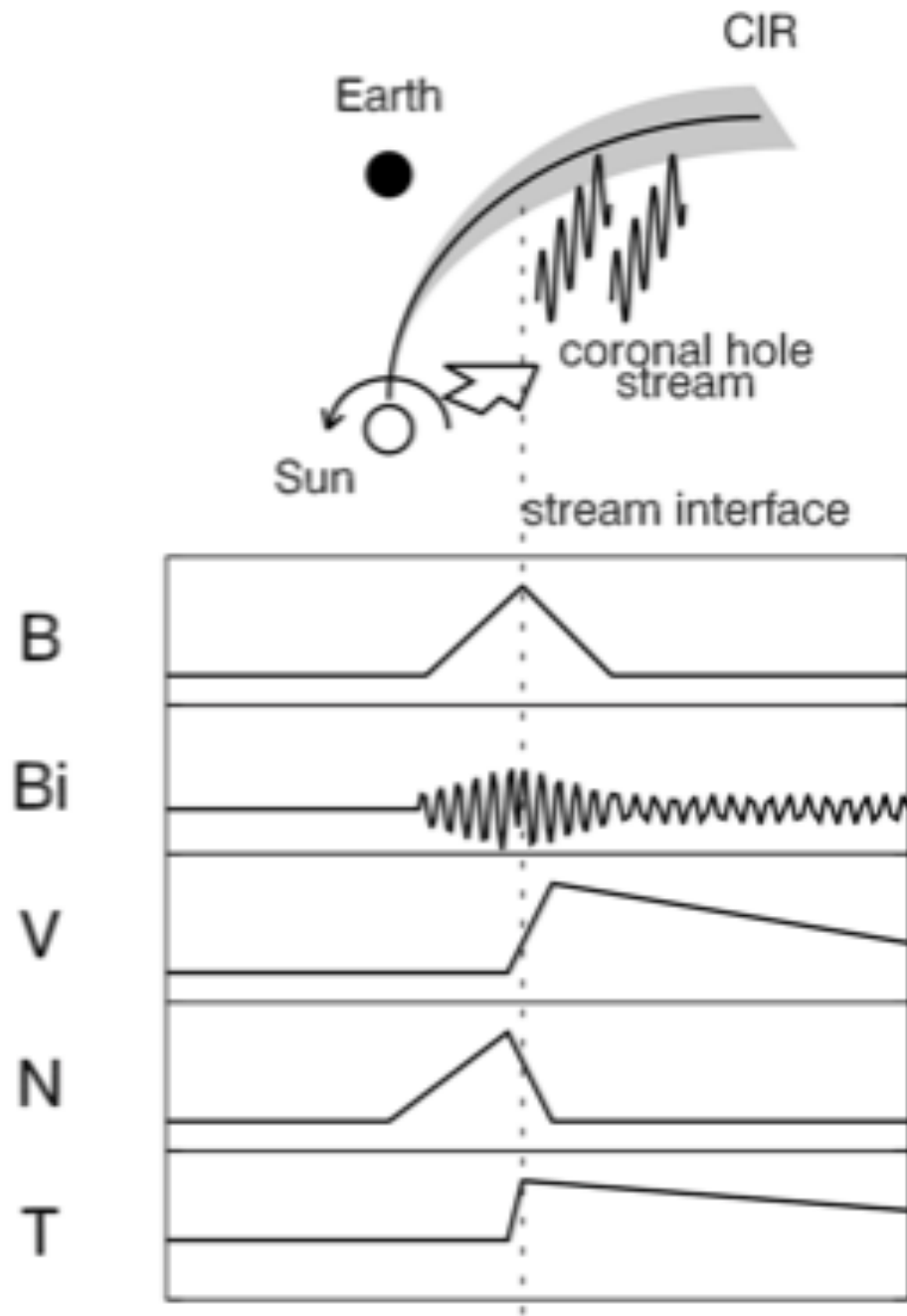
Co-rotating Interaction Region

- A HSS co-rotates with the Sun, generating a CIR
- CH can appear everywhere on the Sun
- If close to the equator, the associated HSS will arrive ± 3 days at Earth ($v \sim 600$ km/s)
- Radial!

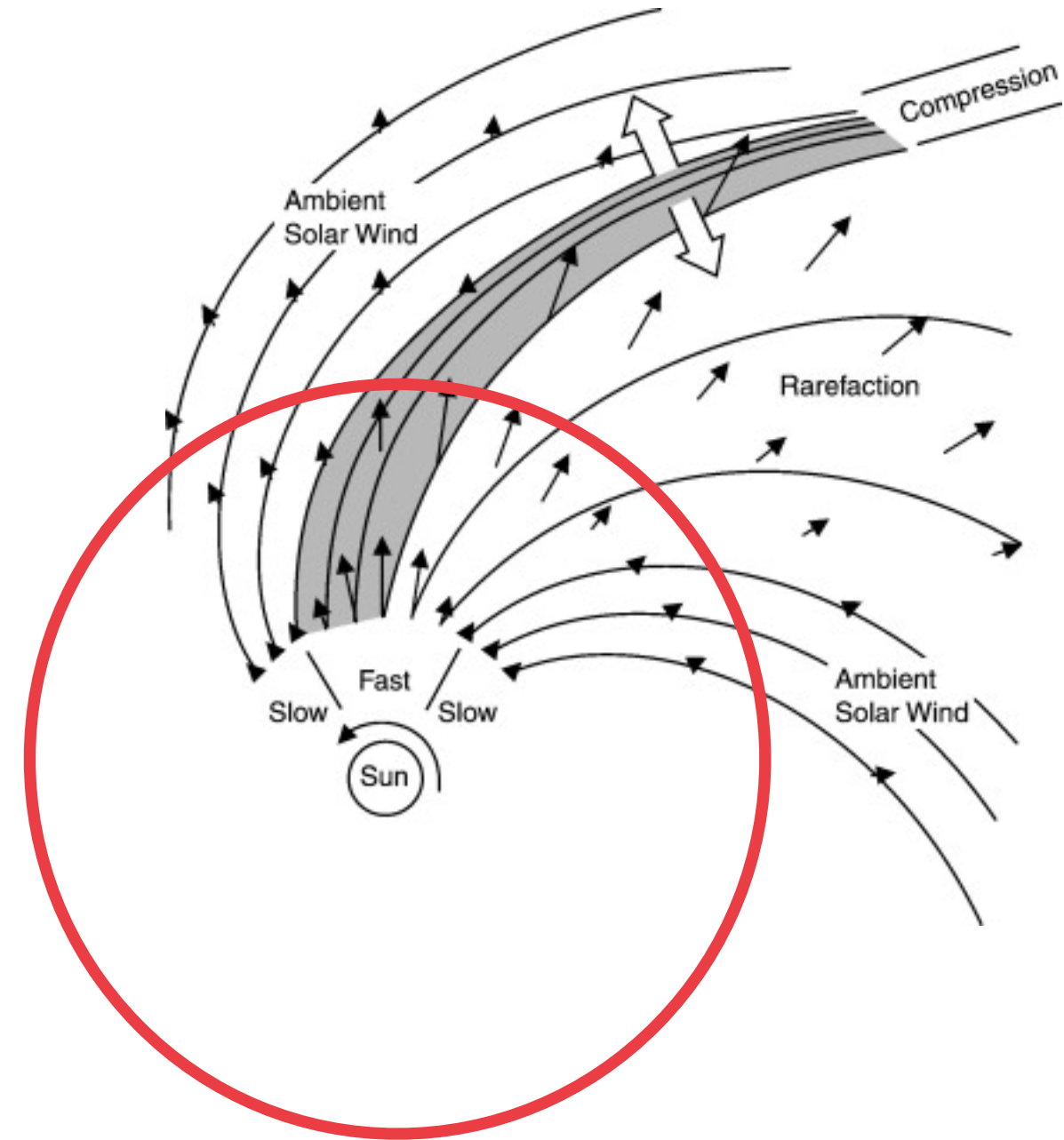


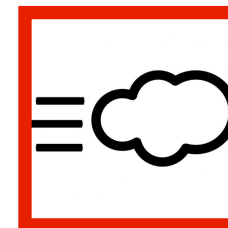


Co-rotating Interaction Region



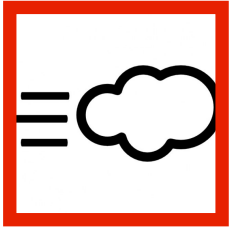
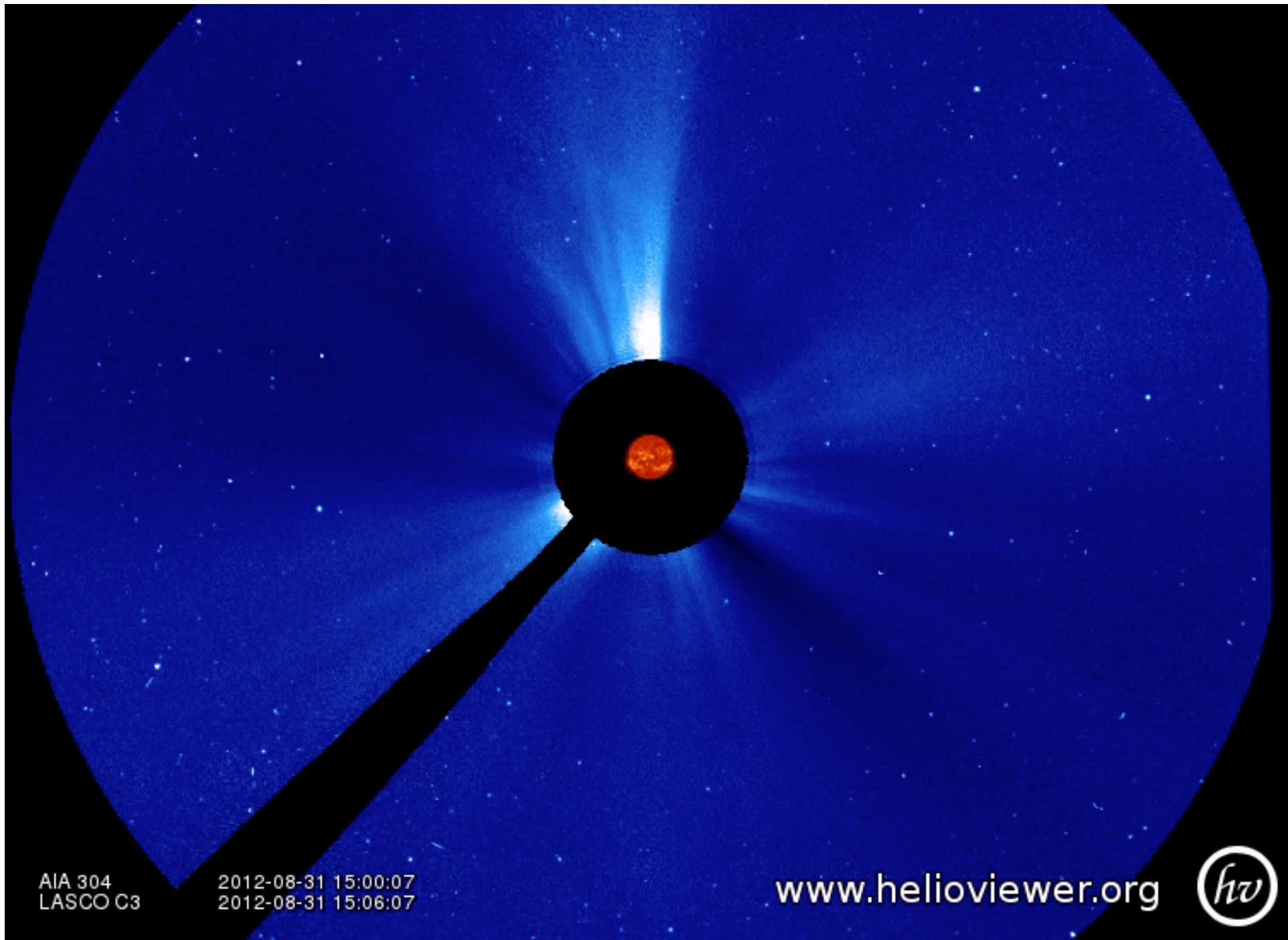
Earth





Transients

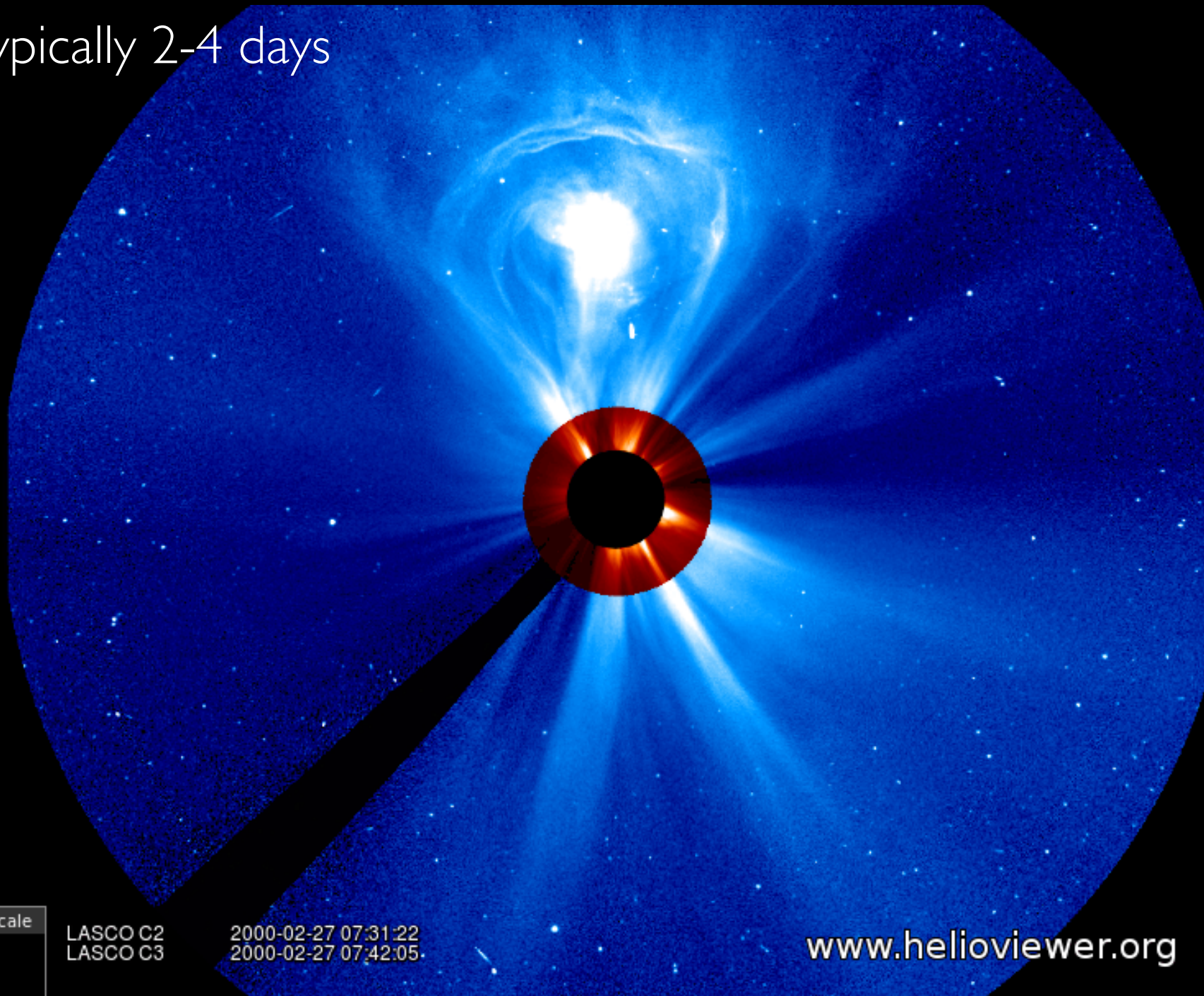
Coronal Mass Ejections

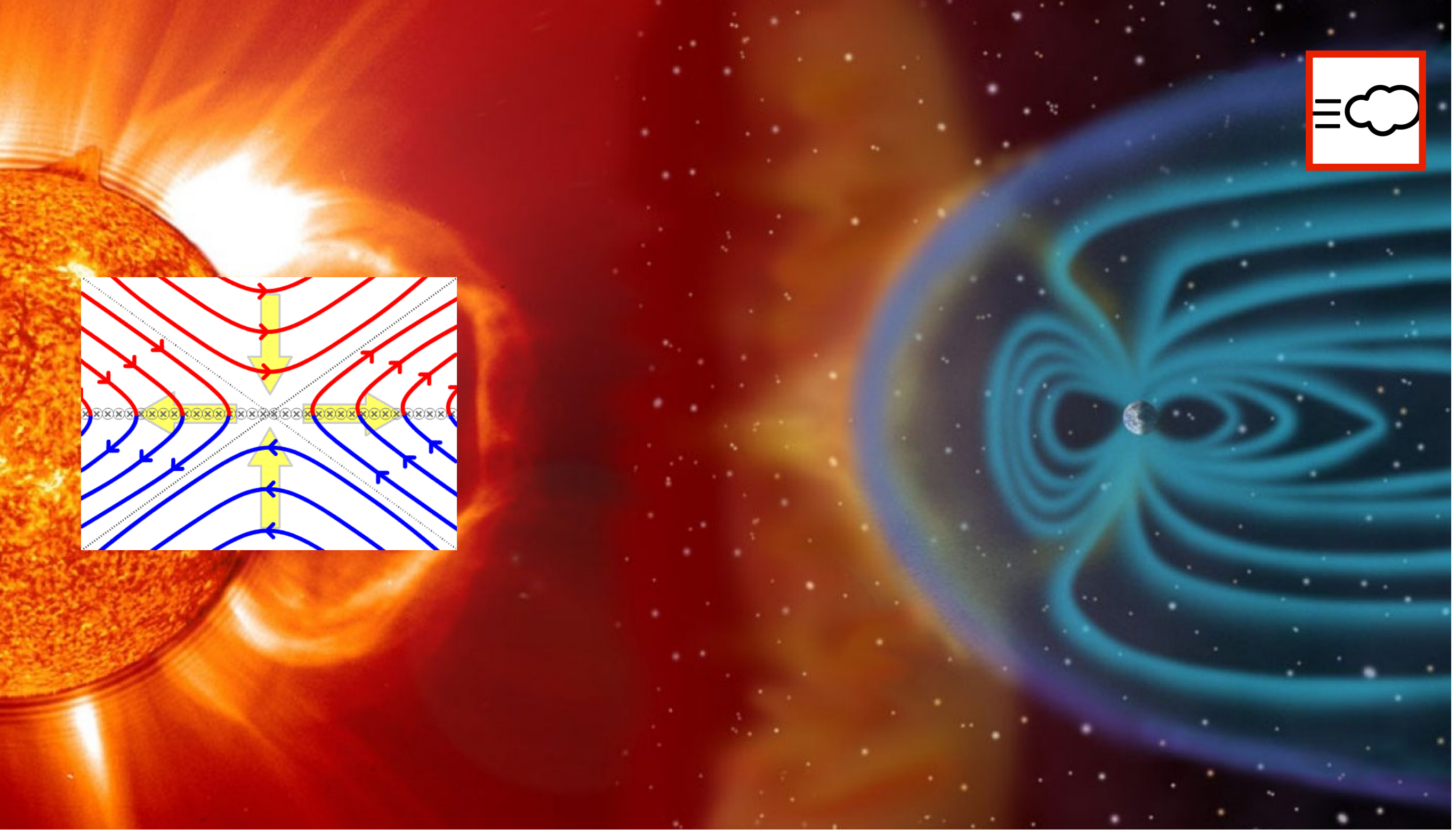


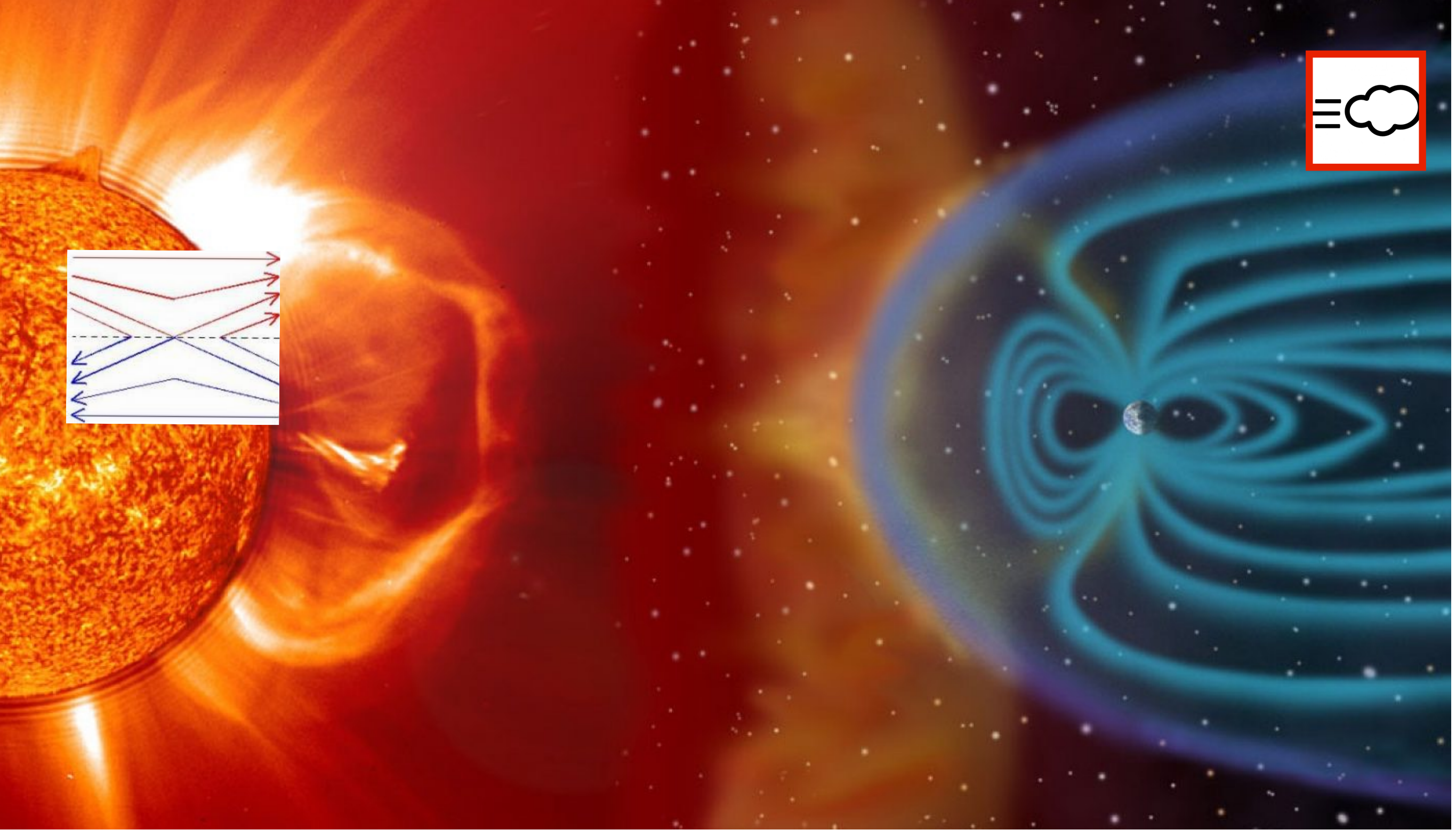
A new, discrete, bright white light feature in the coronagraph field-of-view with a predominantly, radial outward velocity.



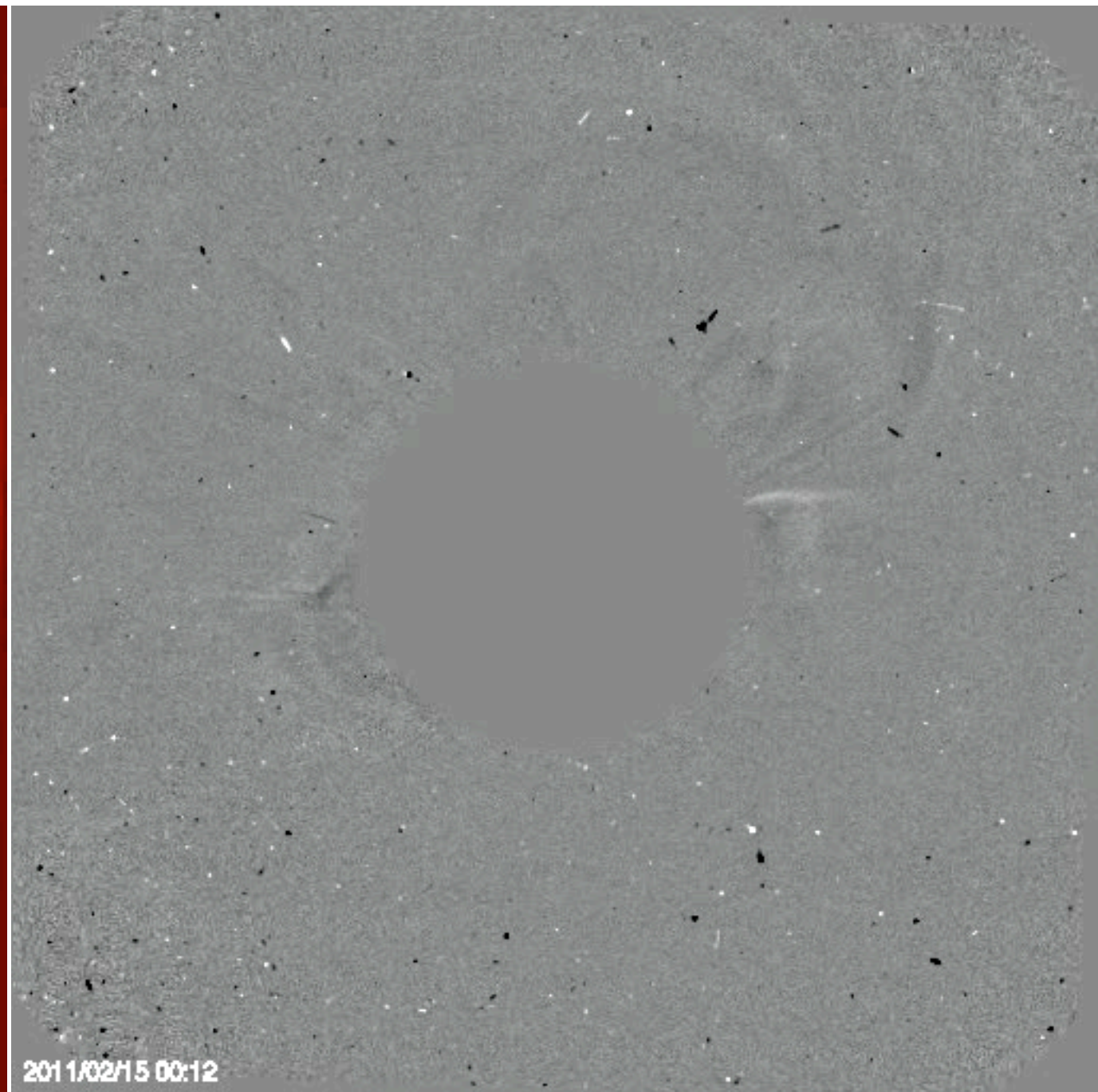
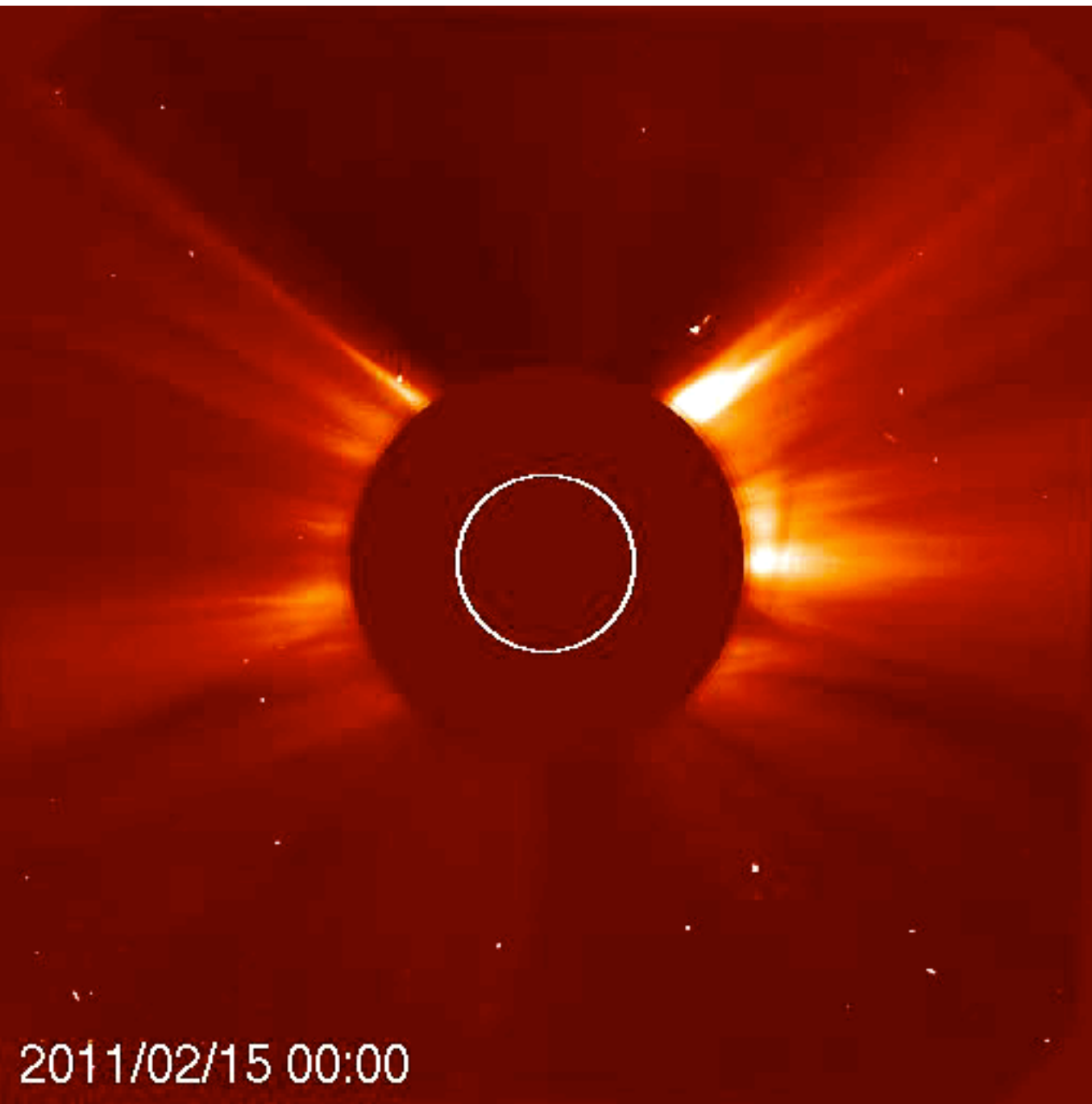
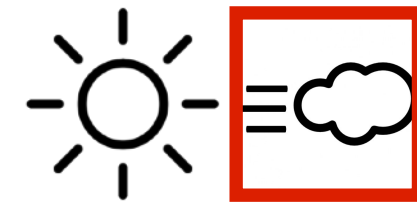
- Trigger the strongest geomagnetic storms
- < 1 /day during solar min, ~ 3 during solar max
- V between 400 and 2000 km/s
- Travel time typically 2-4 days







IN CORONAGRAPHS



SOHO / LASCO c2



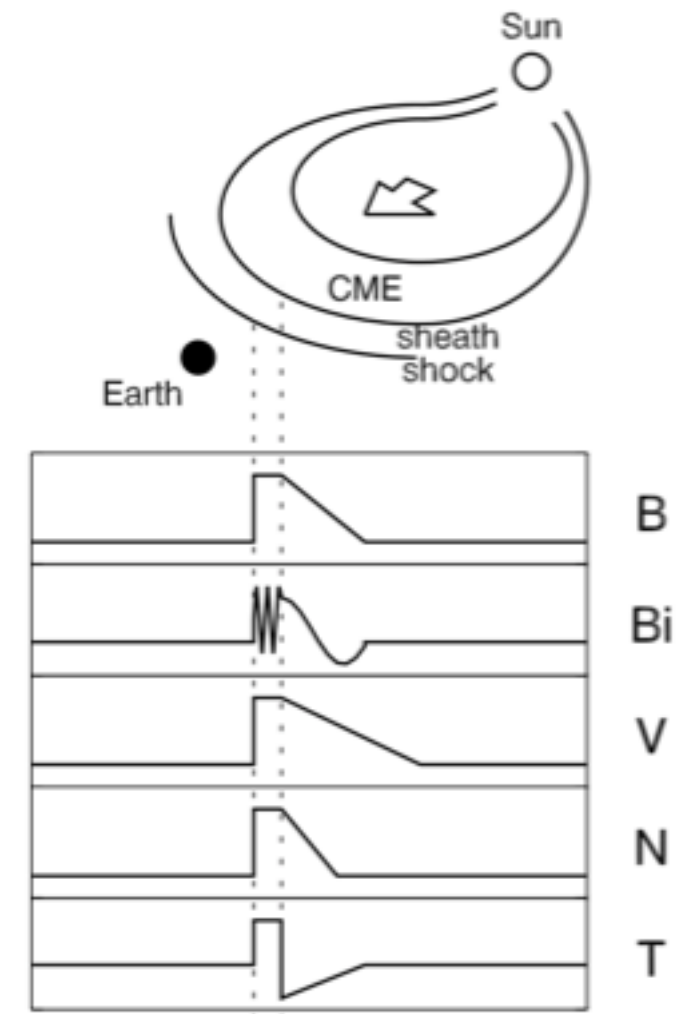
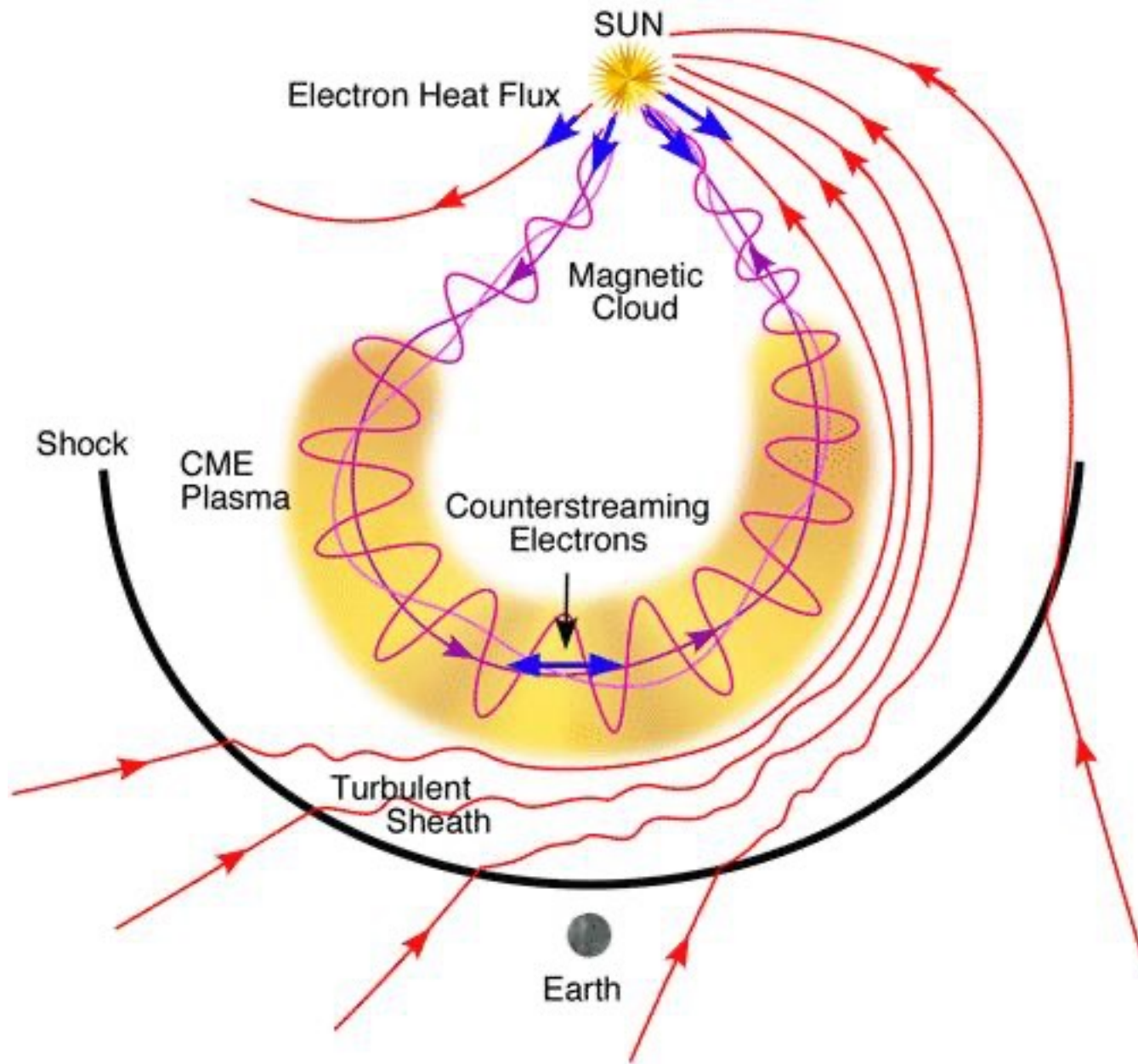
running difference



HALO CME ALERT + PRESTO



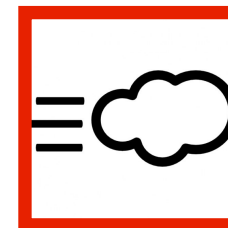
INTERPLANETARY CORONAL MASS EJECTION - ICME



DIFFERENCES



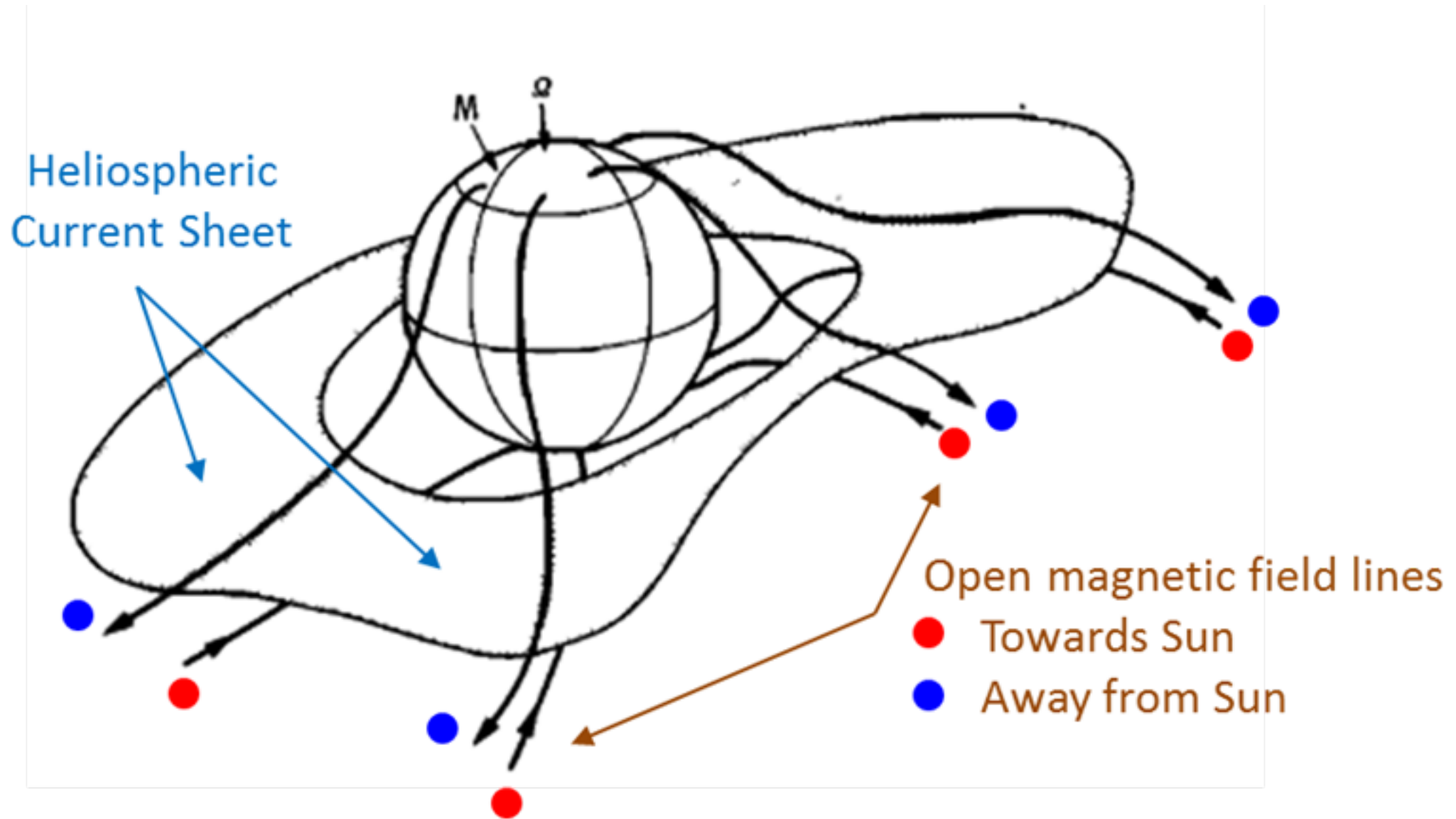
ICME	CIR
Expanding	Compressing
Declining speed profile	Increasing speed profile
Low T (wrt V)	High T
High B (any value above 10 nT)	High B (until ~20nT)
CME	CH (also previous rotation)
Rotation in B	High variation in B
ICMEs and CIRs can interact	



Transients

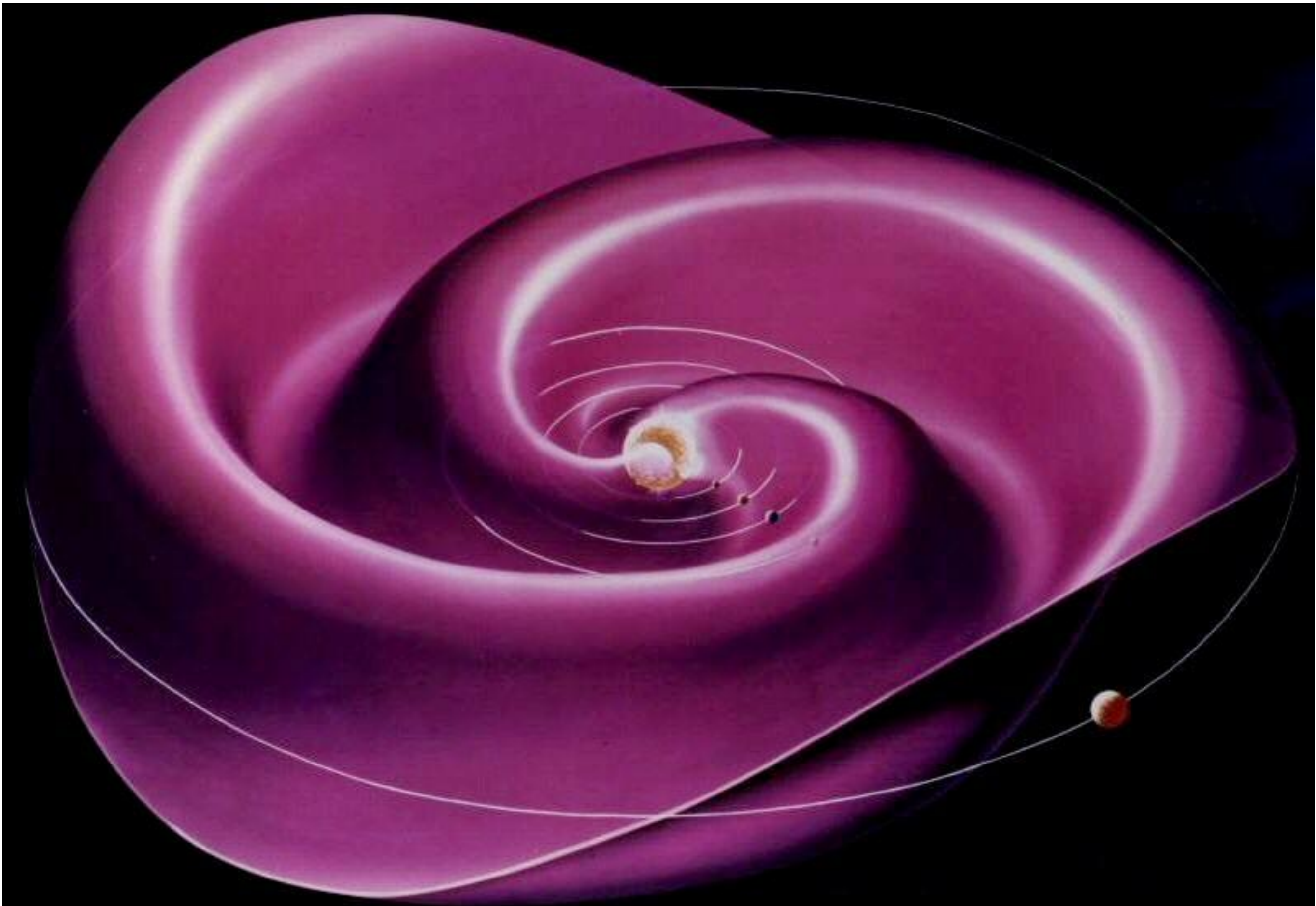
Sector Boundary Crossing

HELIOSPHERIC CURRENT SHEET

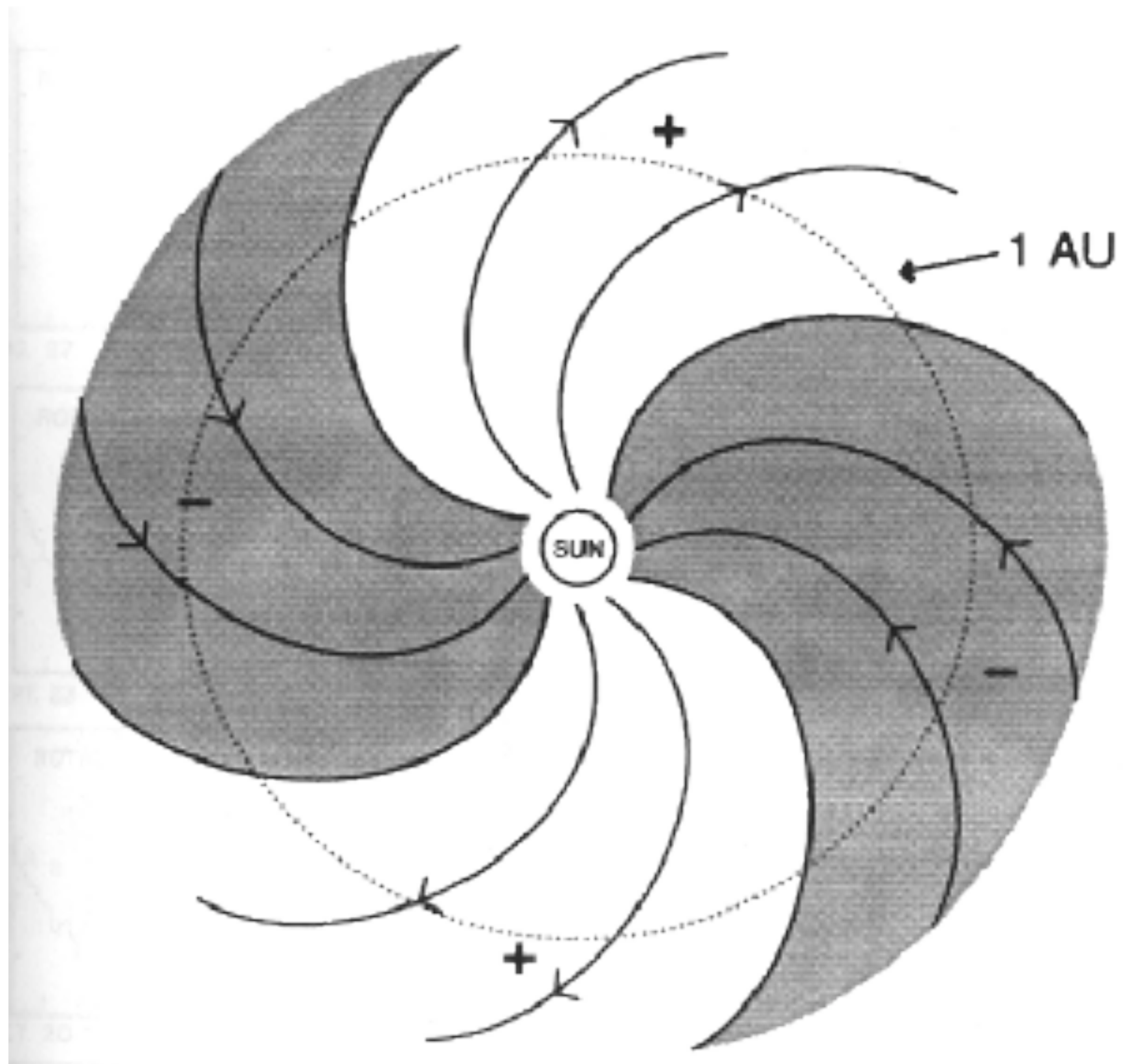
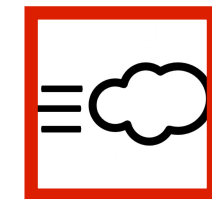


Adapted from Smith et al., 1978

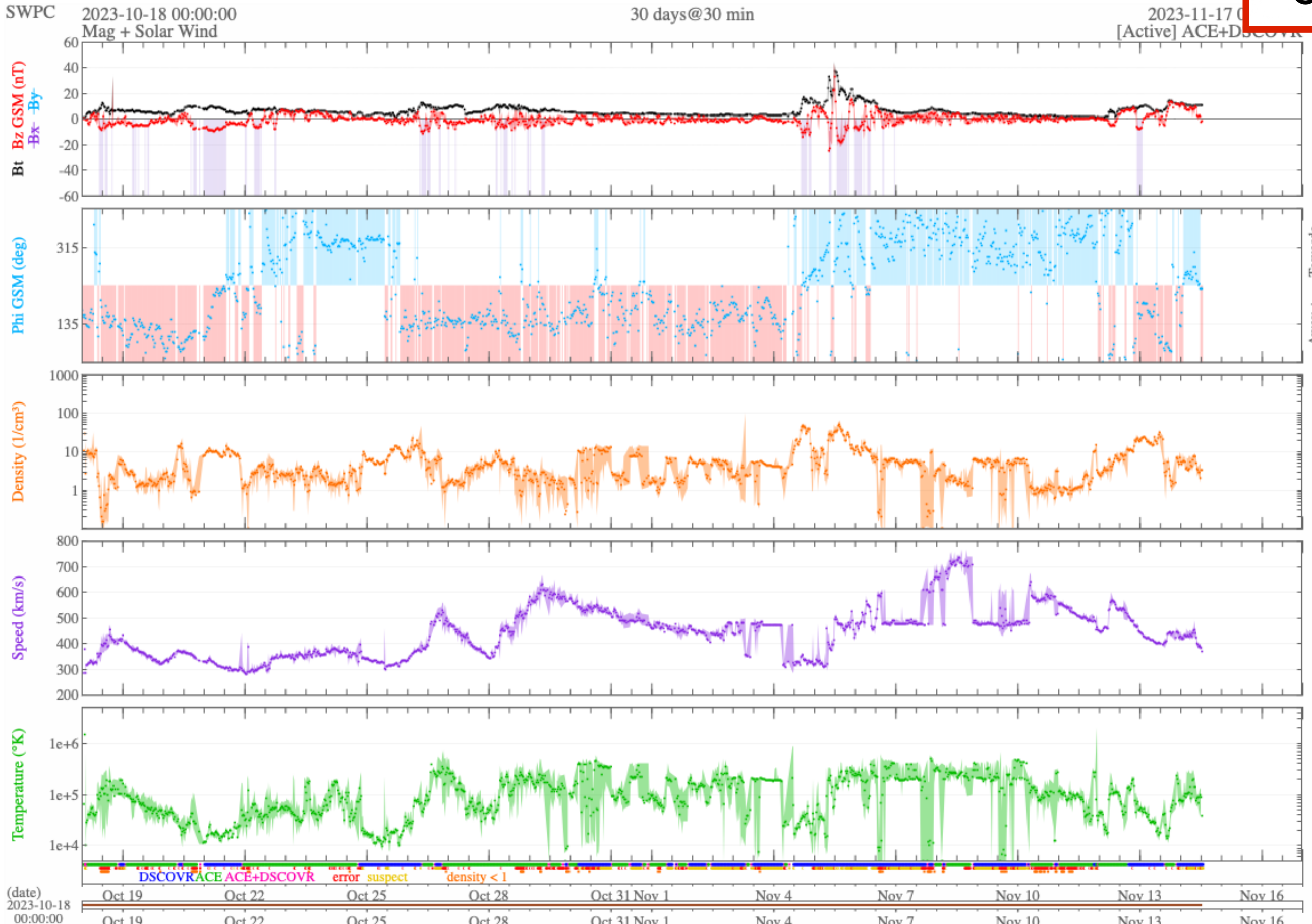
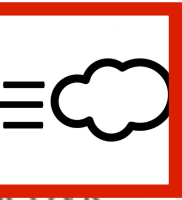
BALLERINA SKIRT

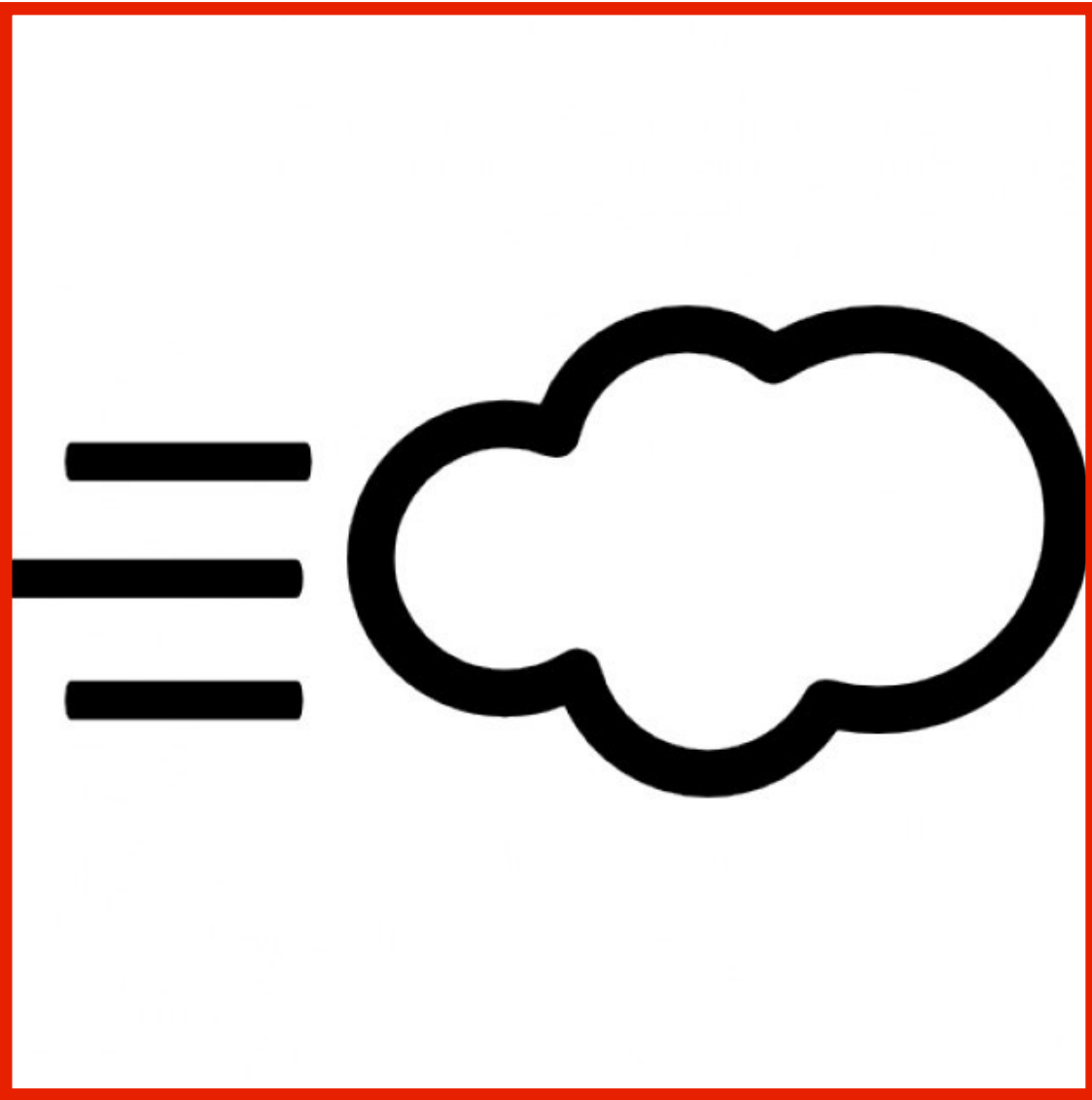


AWAY/TOWARDS SECTORS



IN SITU

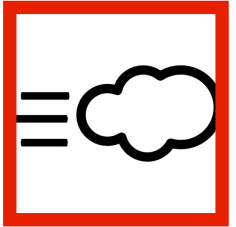




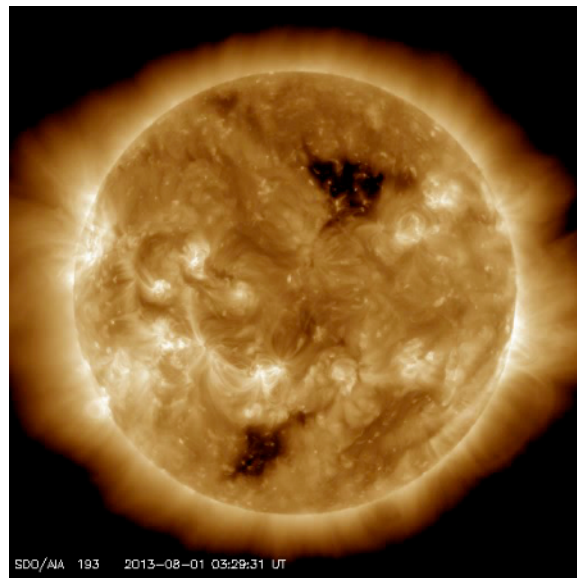
SOLAR WIND

Question

SOLAR WIND VARIATIONS

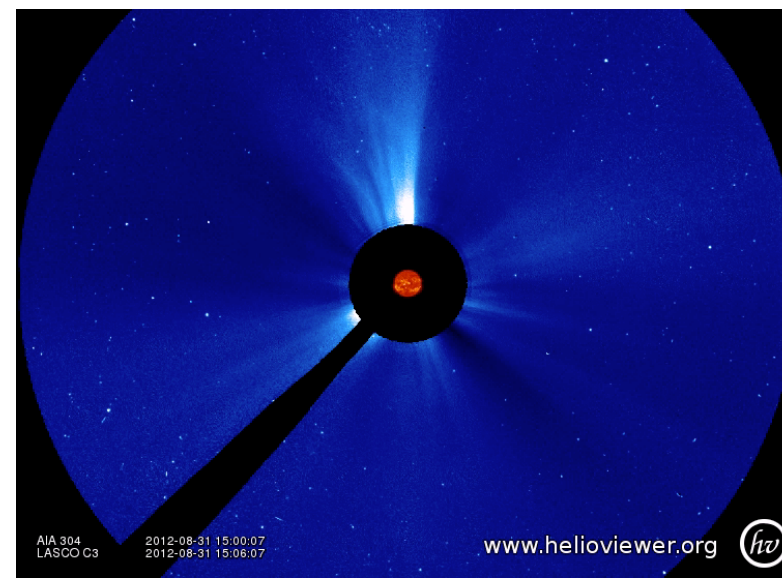


Coronal Hole



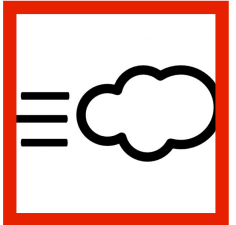
Non-eruptive
Eruptive

Coronal Mass Ejection

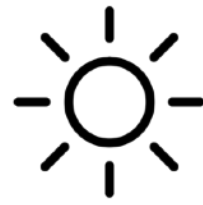


Magnetic reconnection
No magnetic reconnection

SOLAR WIND VARIATIONS

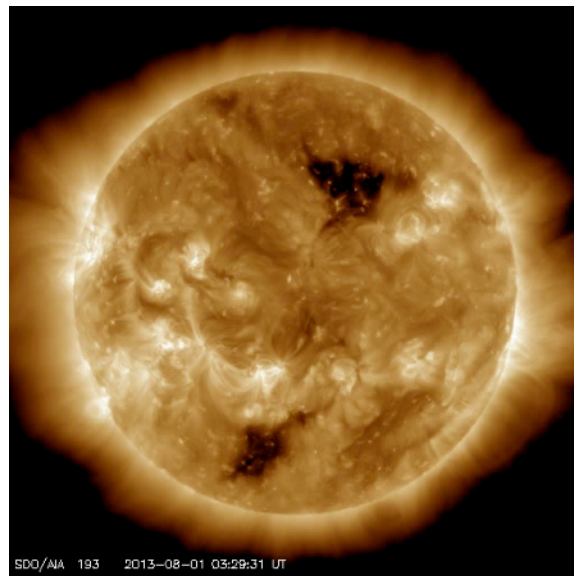


Non-eruptive
No B reconnection

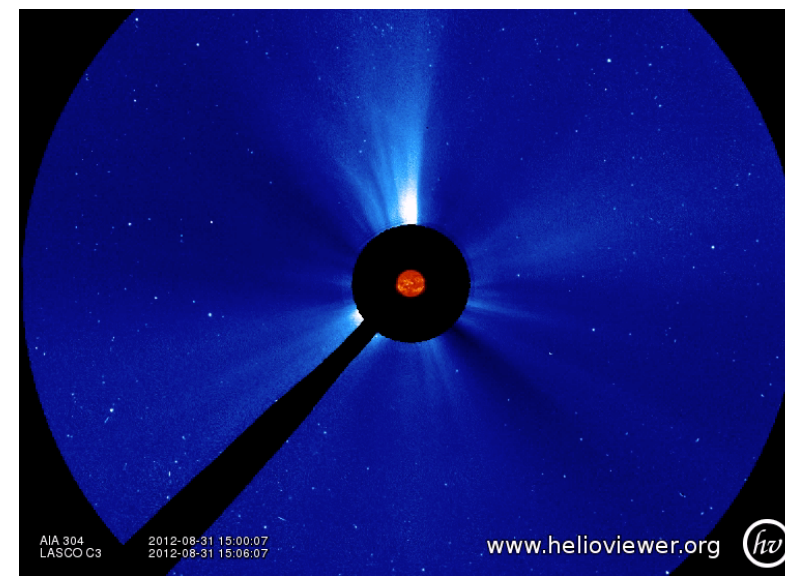


Eruptive
B reconnection

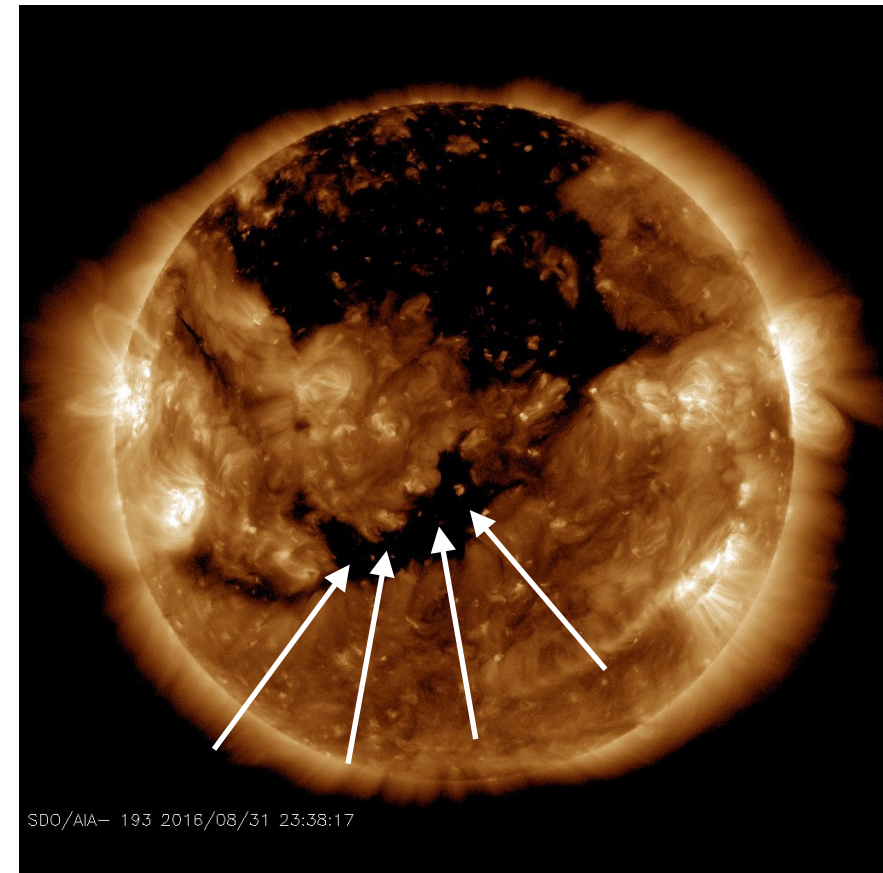
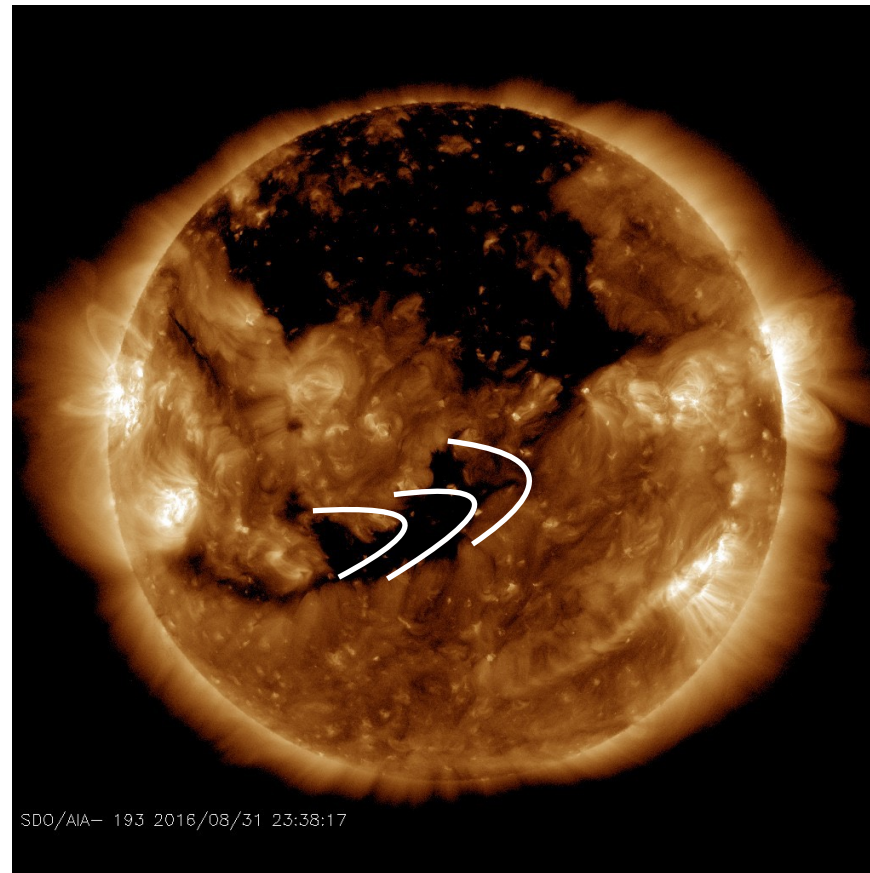
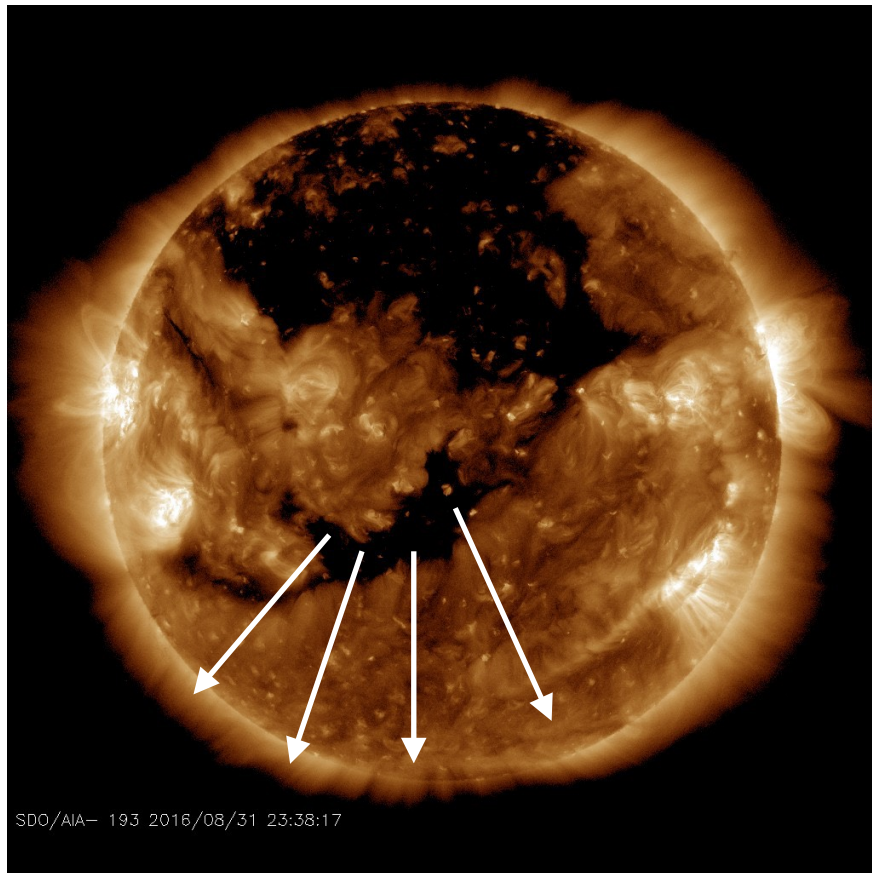
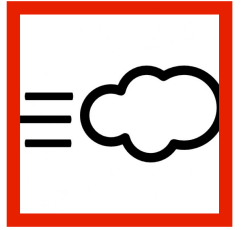
Coronal Hole

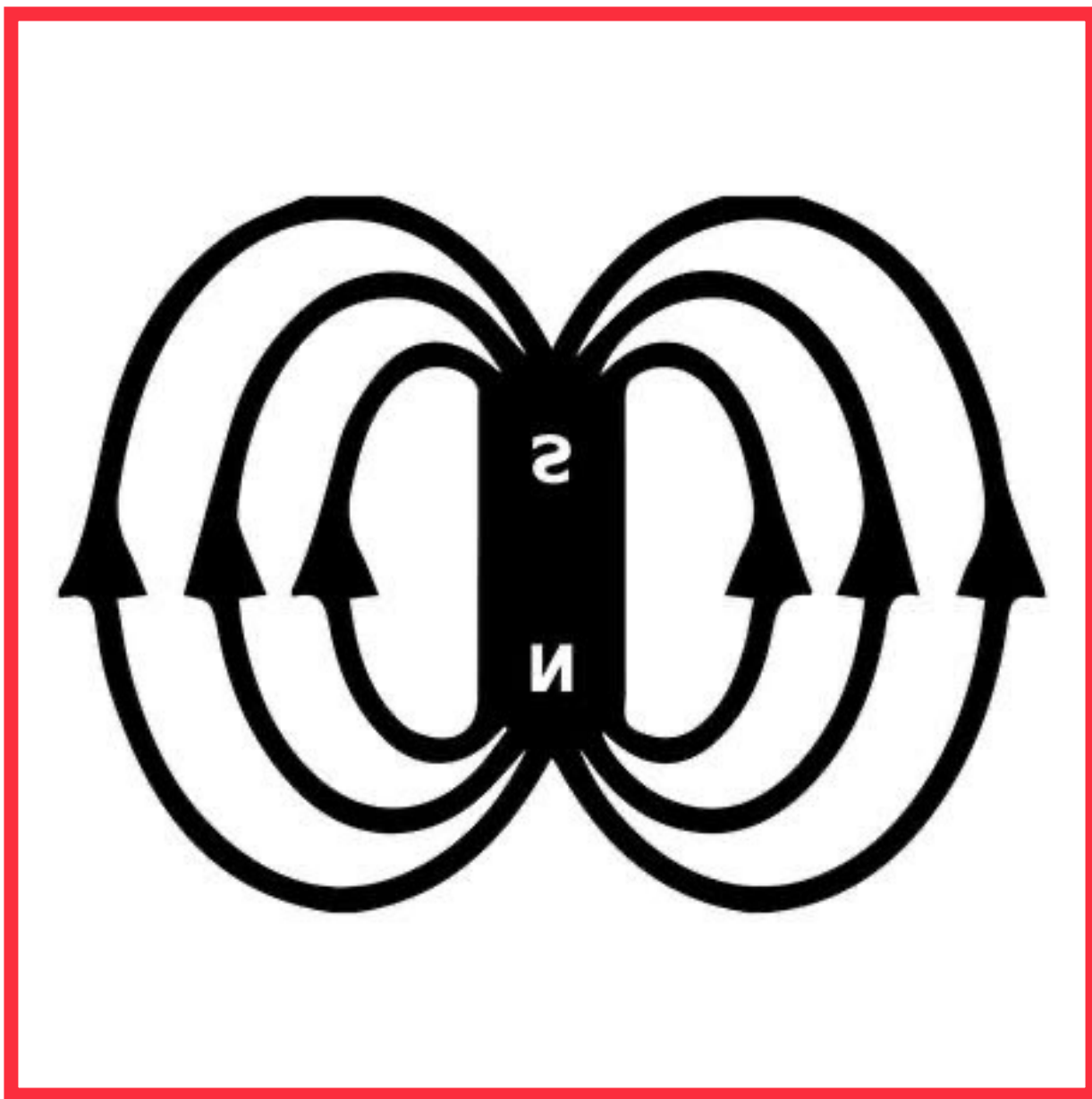


Coronal Mass Ejection



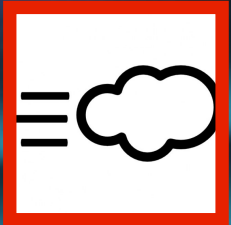
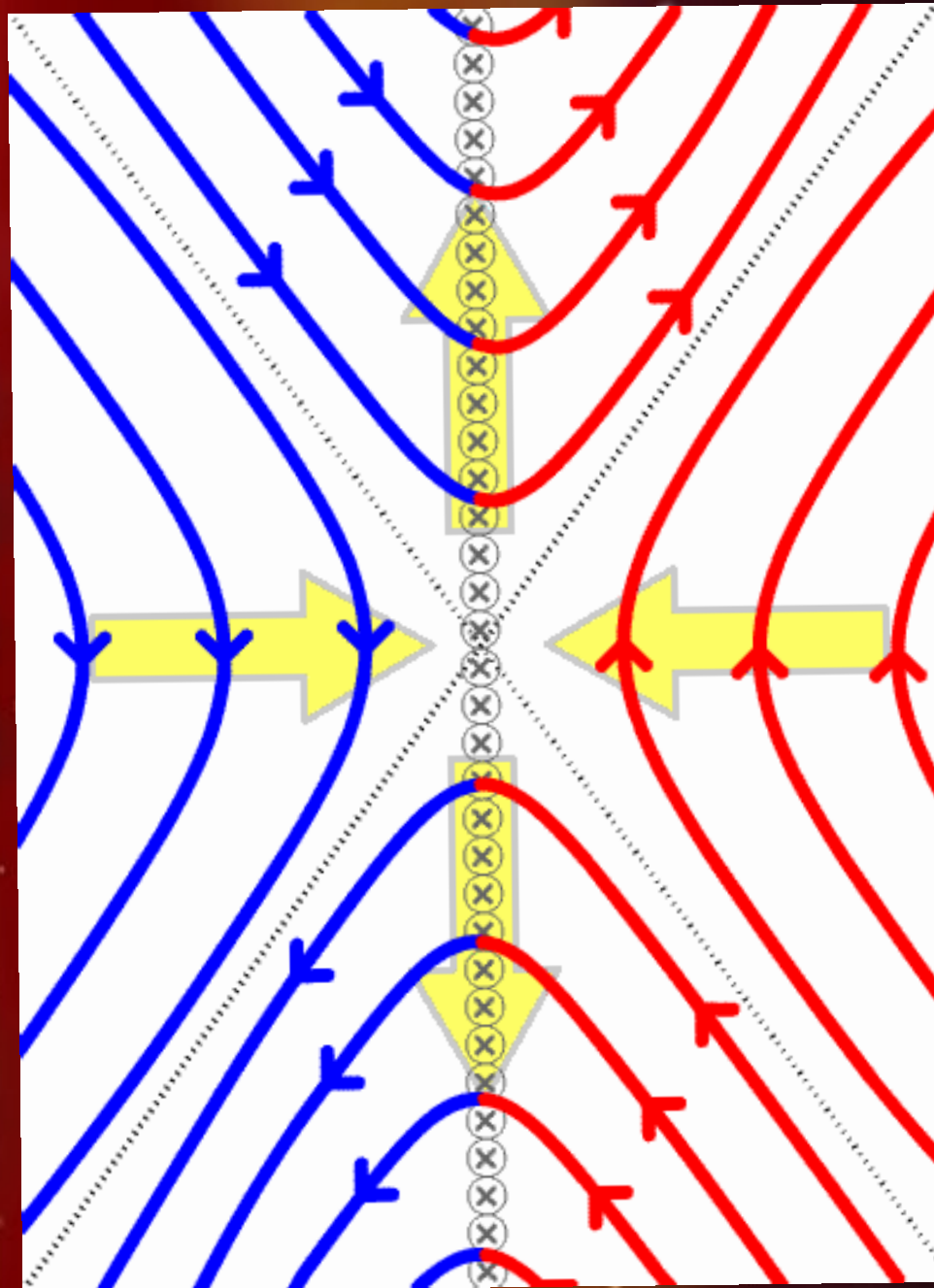
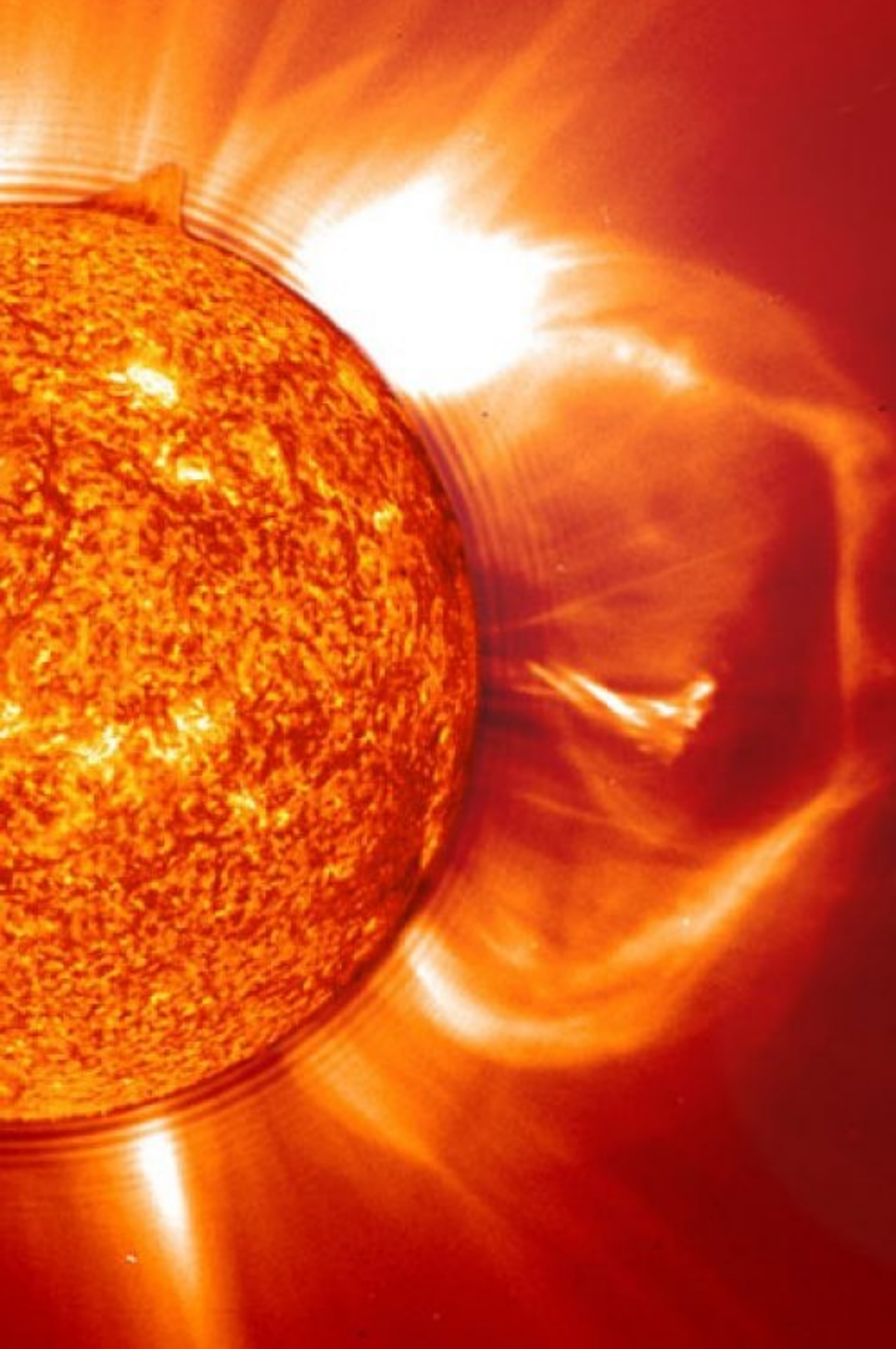
B OF CORONAL HOLE





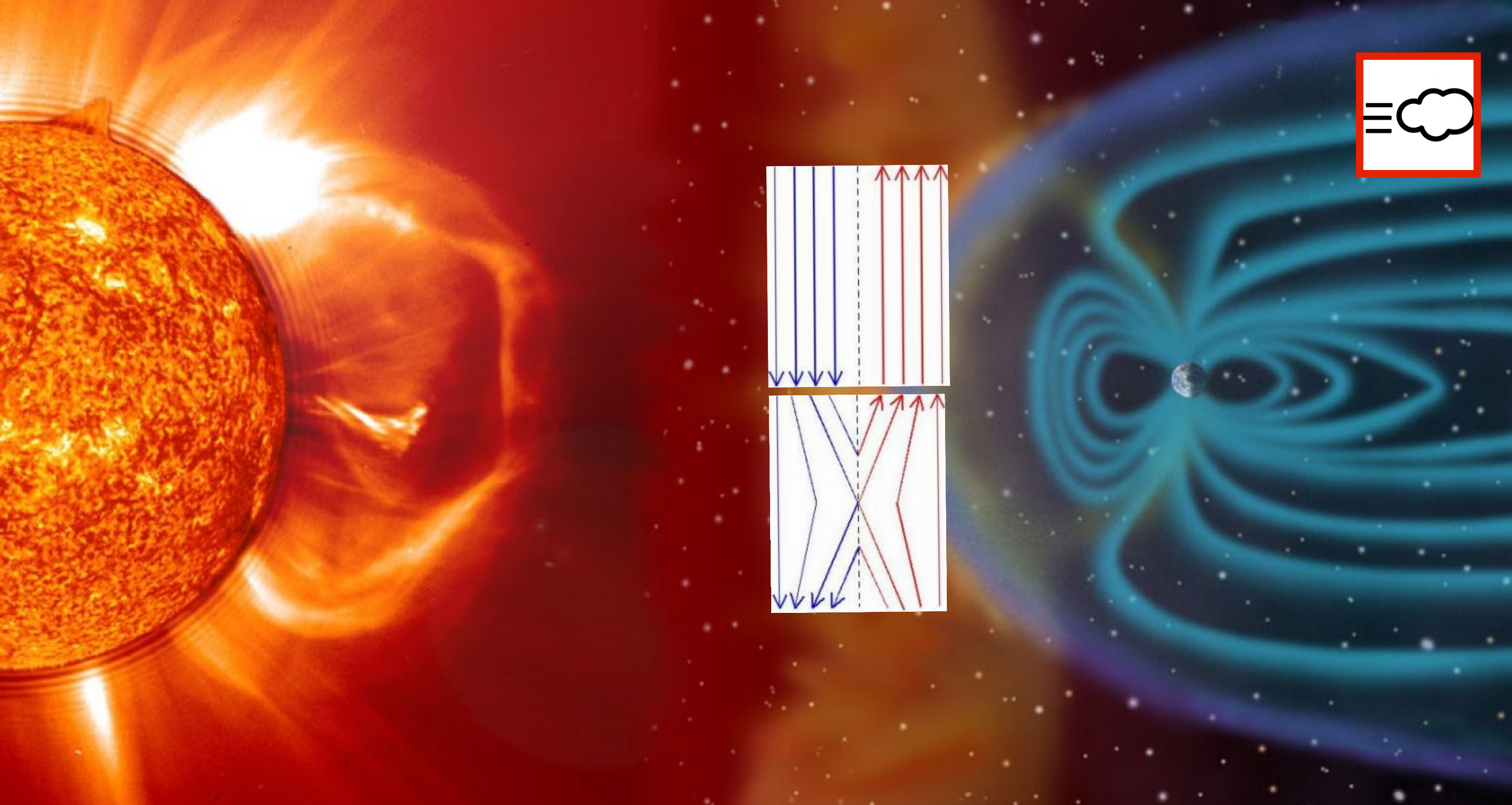
SOLAR WIND

Meets the Earth's magnetic field - geoeffectivity



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.

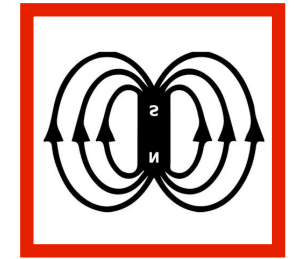


RECONNECTION

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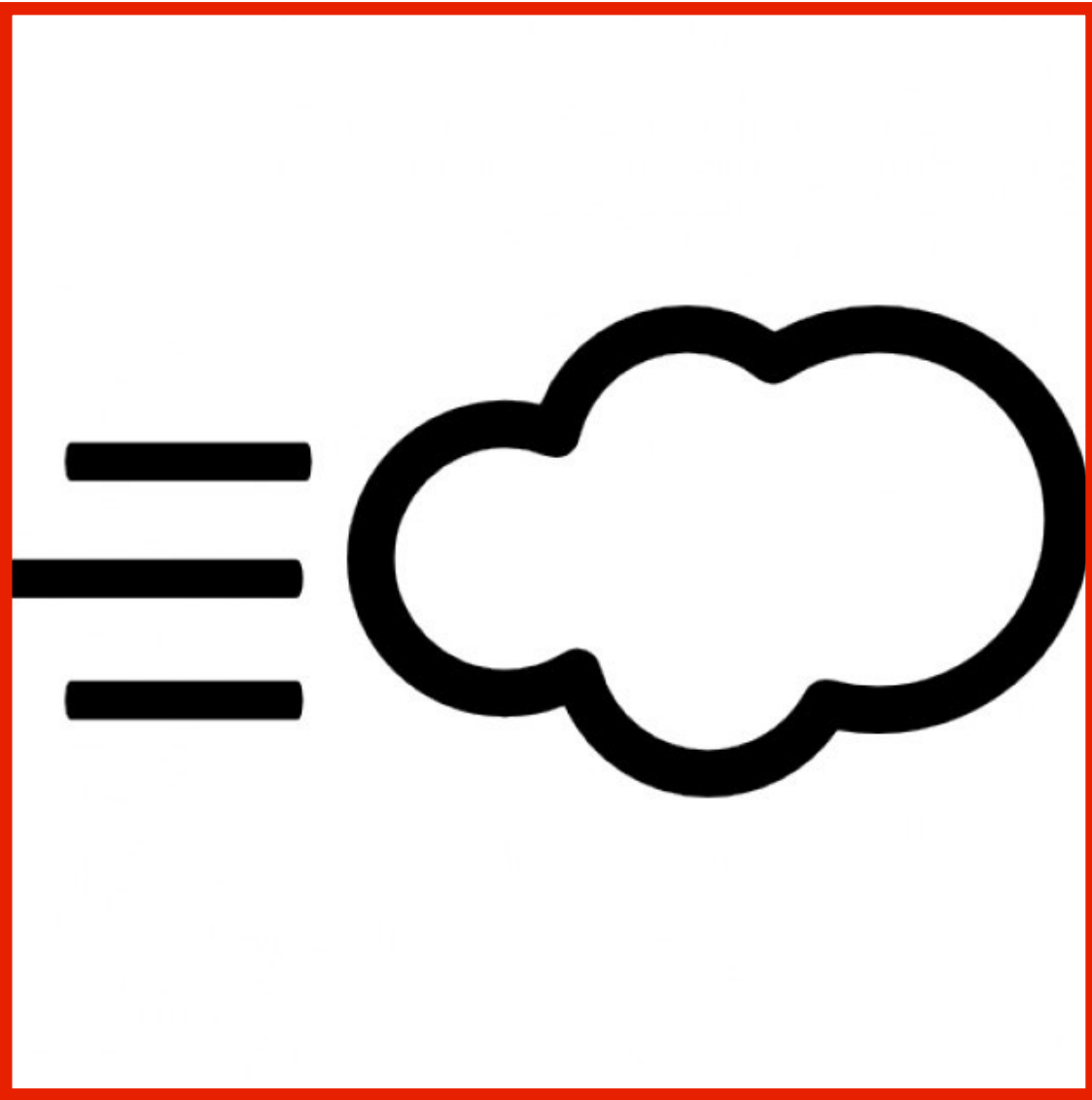


GEOMAGNETIC CONDITIONS



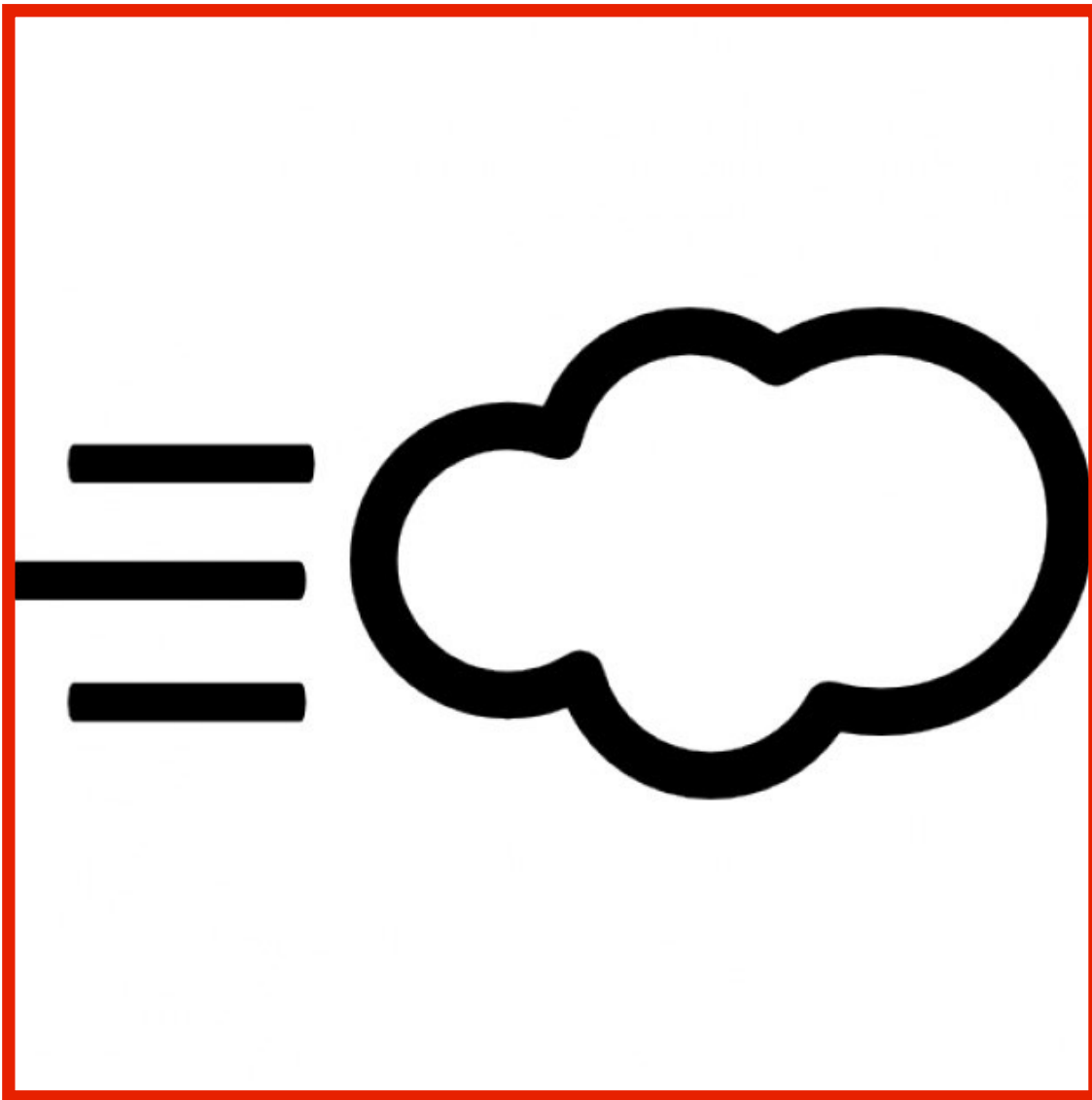
<https://www.swpc.noaa.gov/products/planetary-k-index>

http://ionosphere.meteo.be/geomagnetism/K_BEL/



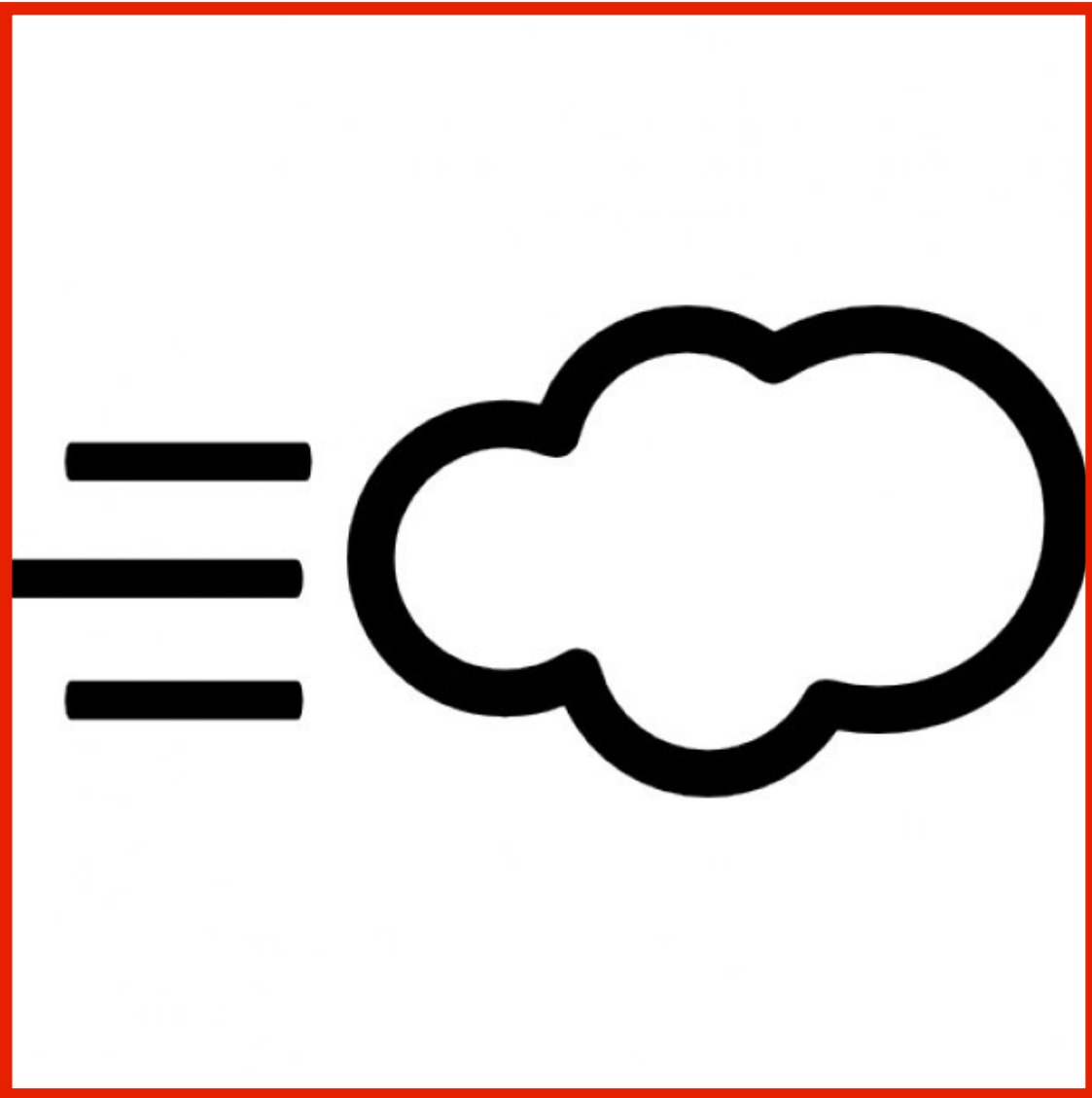
SOLAR WIND

Questions



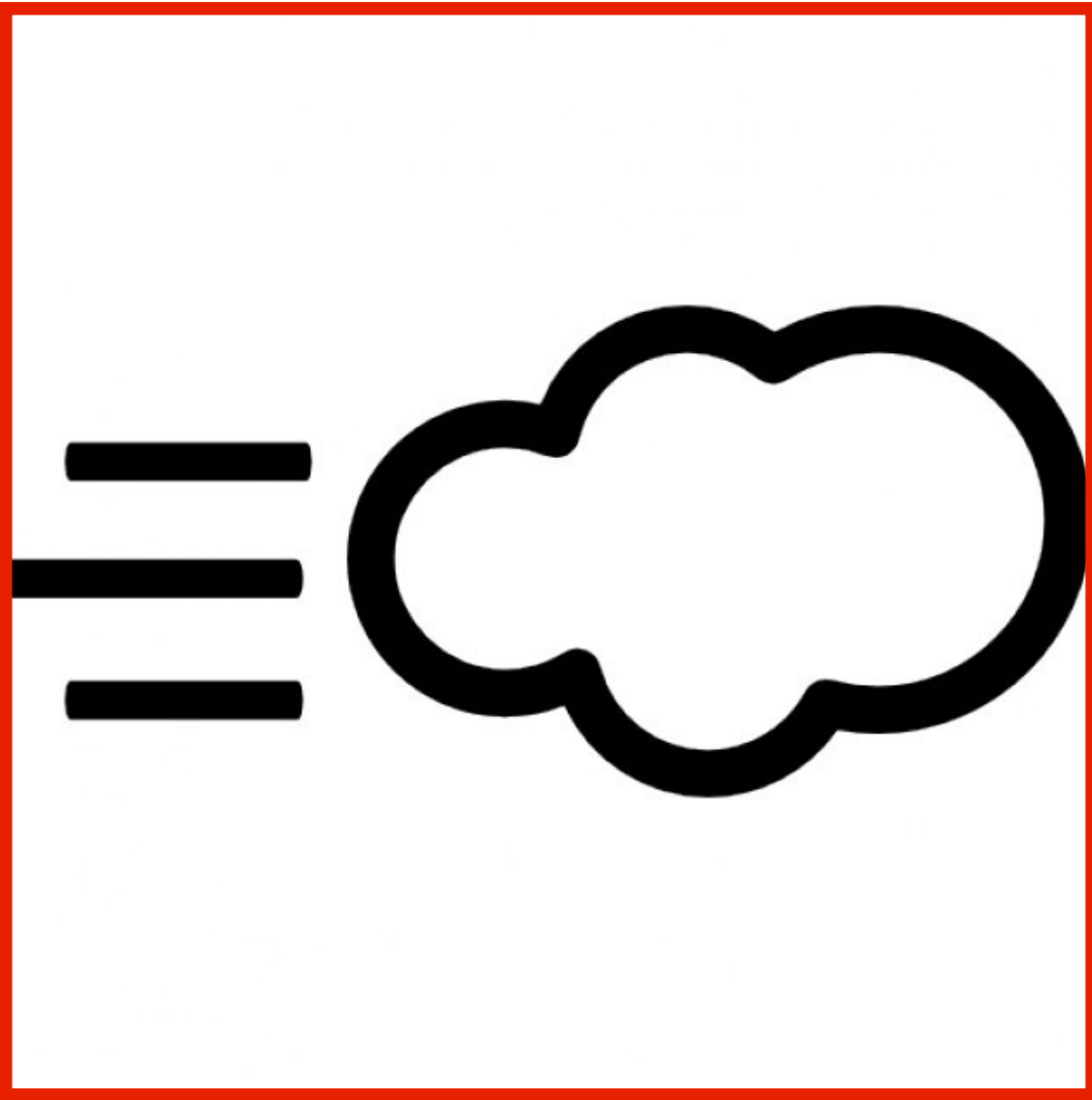
SOLAR WIND

Name 3 transients



SOLAR WIND

Name a satellite that
measures the solar
wind at L1



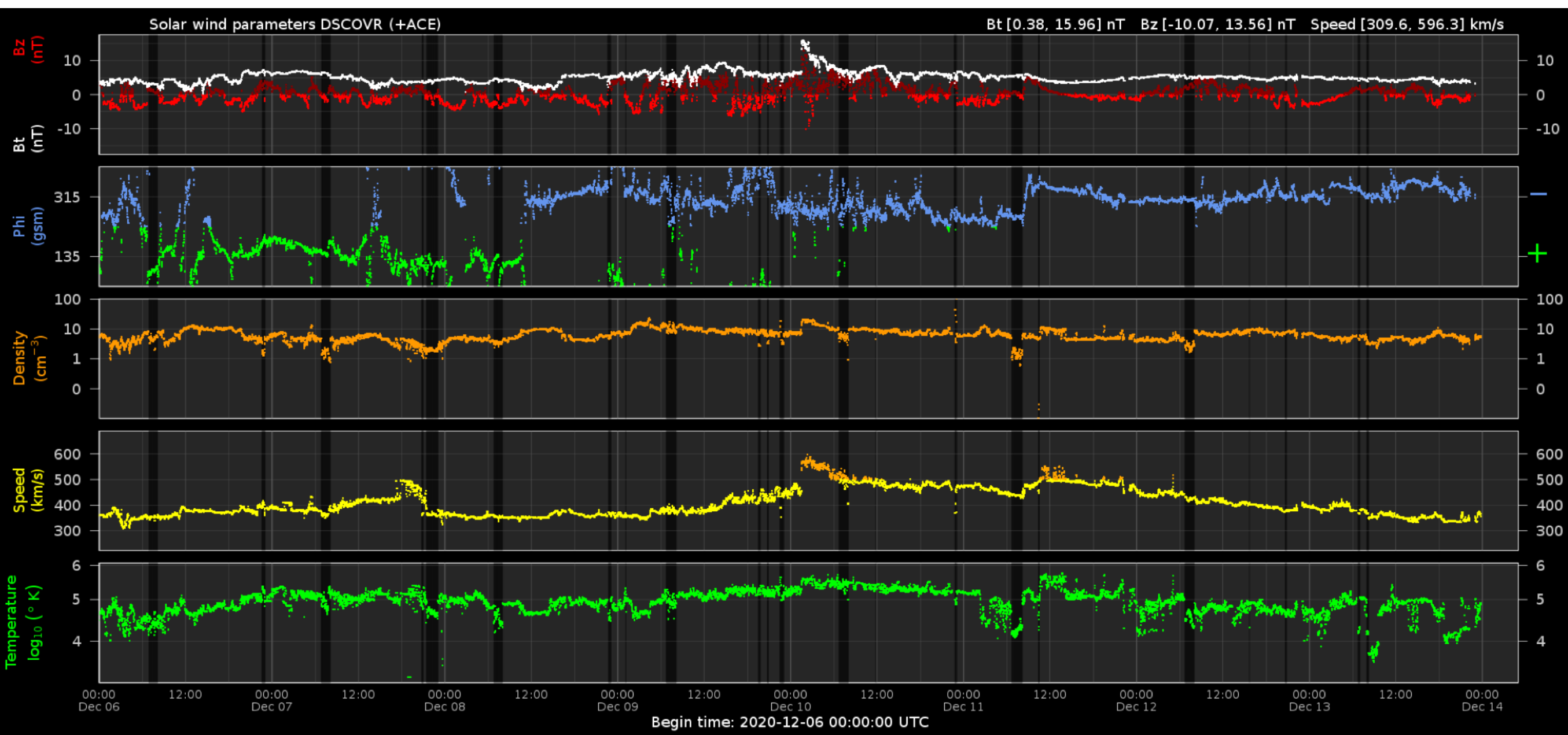
SOLAR WIND

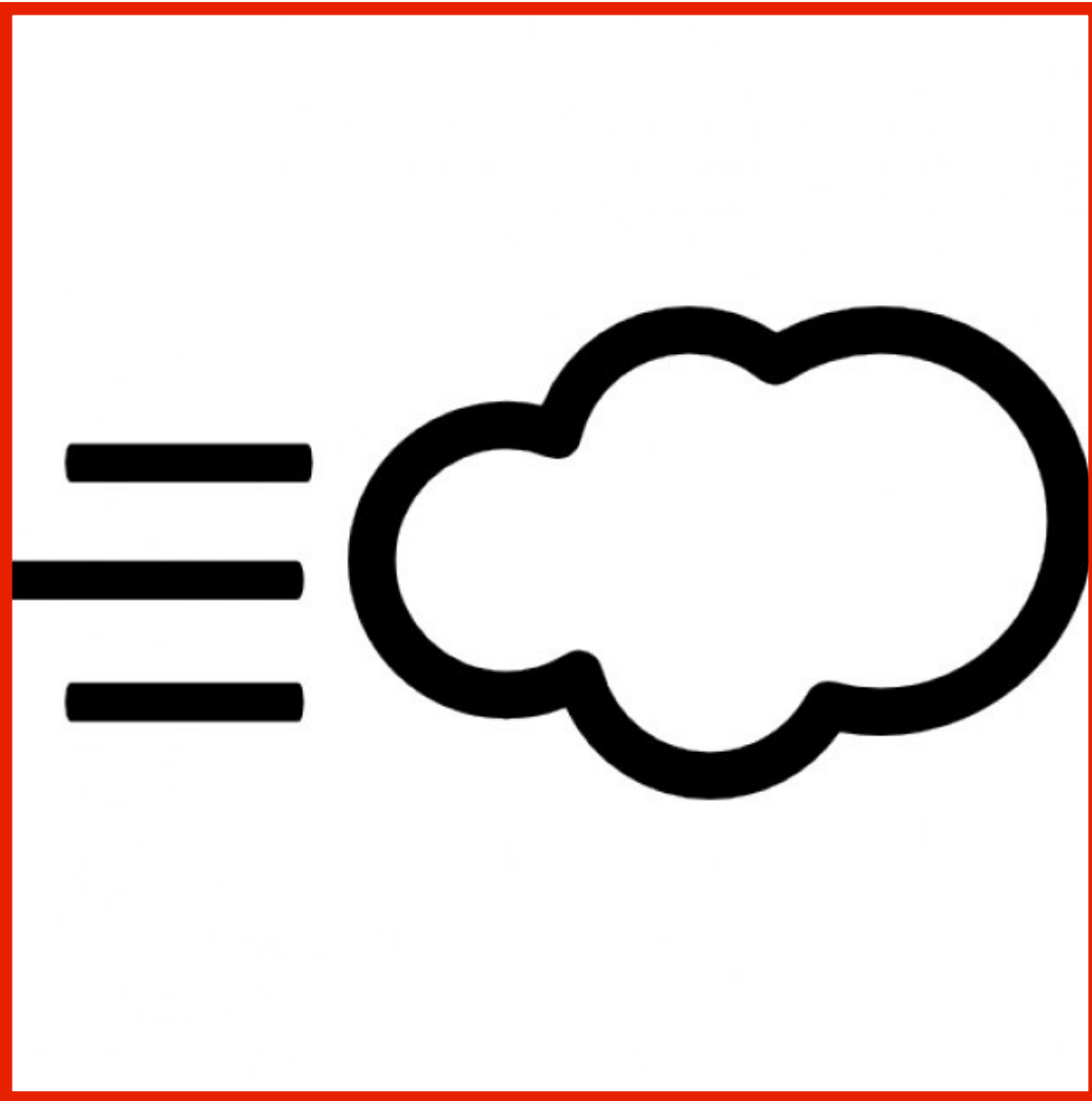
Name the 5 panels in ACE or DSCVR graphs.

Solar wind parameters DSCOVR (+ACE), Kp-index (NOAA), K-index (Dourbes)

Bt [0.56, 15.18] nT Bz [-11.34, 11] nT Speed [322.2, 596.8] km/s







SOLAR WIND

Name 3 clearly distinct places where magnetic reconnection takes place.