Sun-Earth Connection; The Earth's Magnetosphere and the Importance of Space Weather

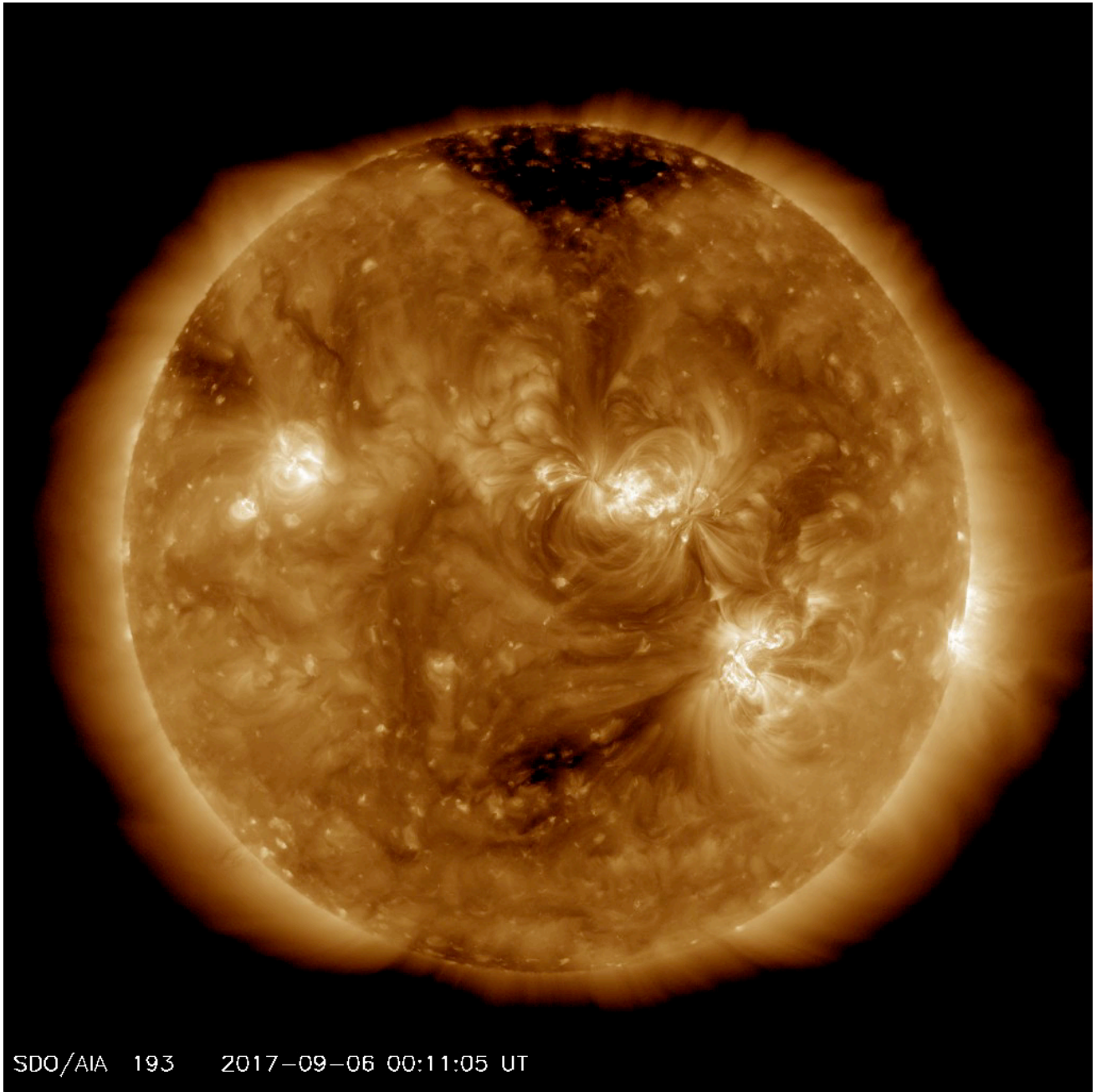
Presented by:

Dr. Alexa Halford/ Adapted from slides by Dr. Yari Collado-Vega

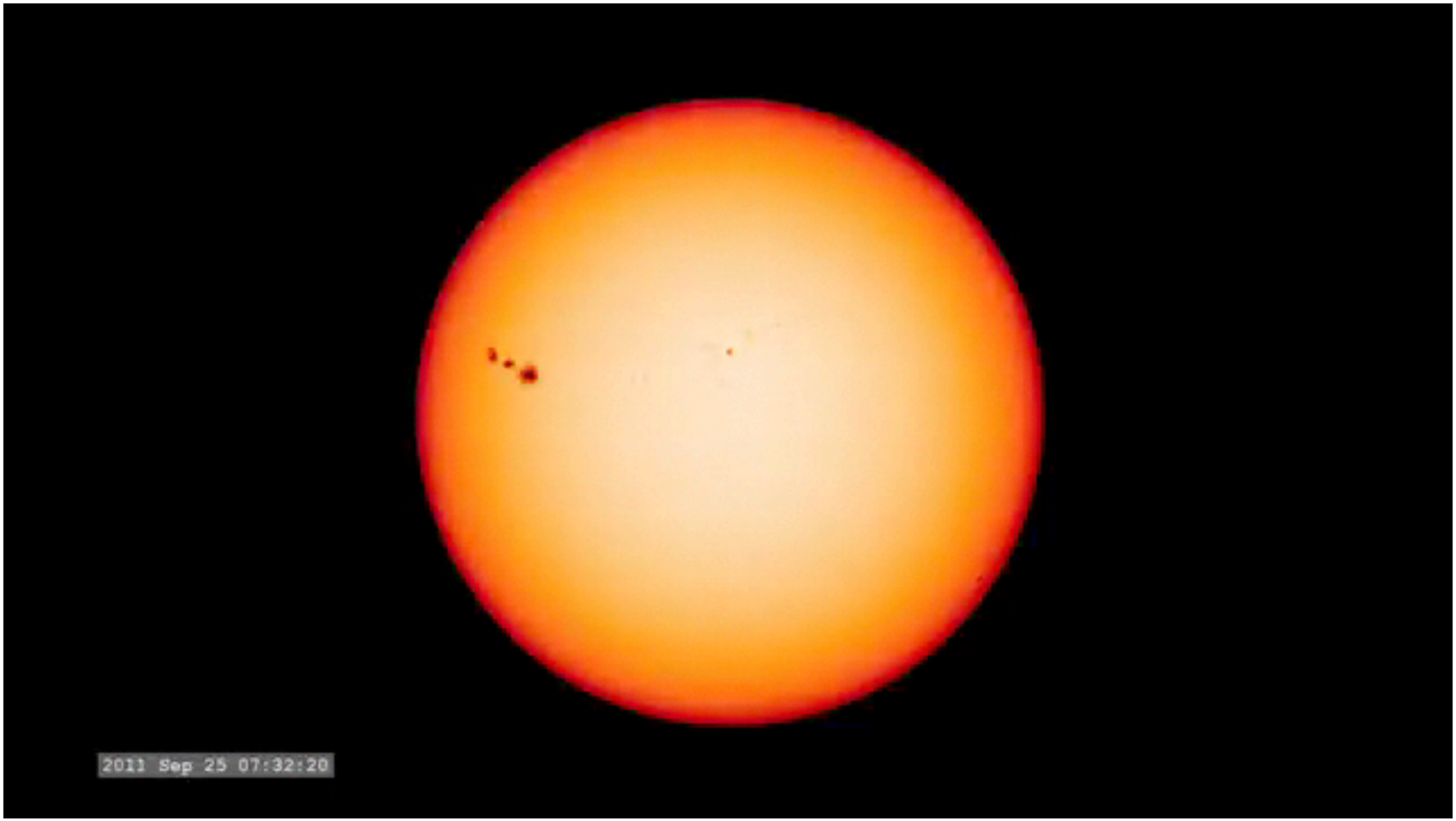
NASA Goddard Space Flight Center

Thanks to the CCMC team

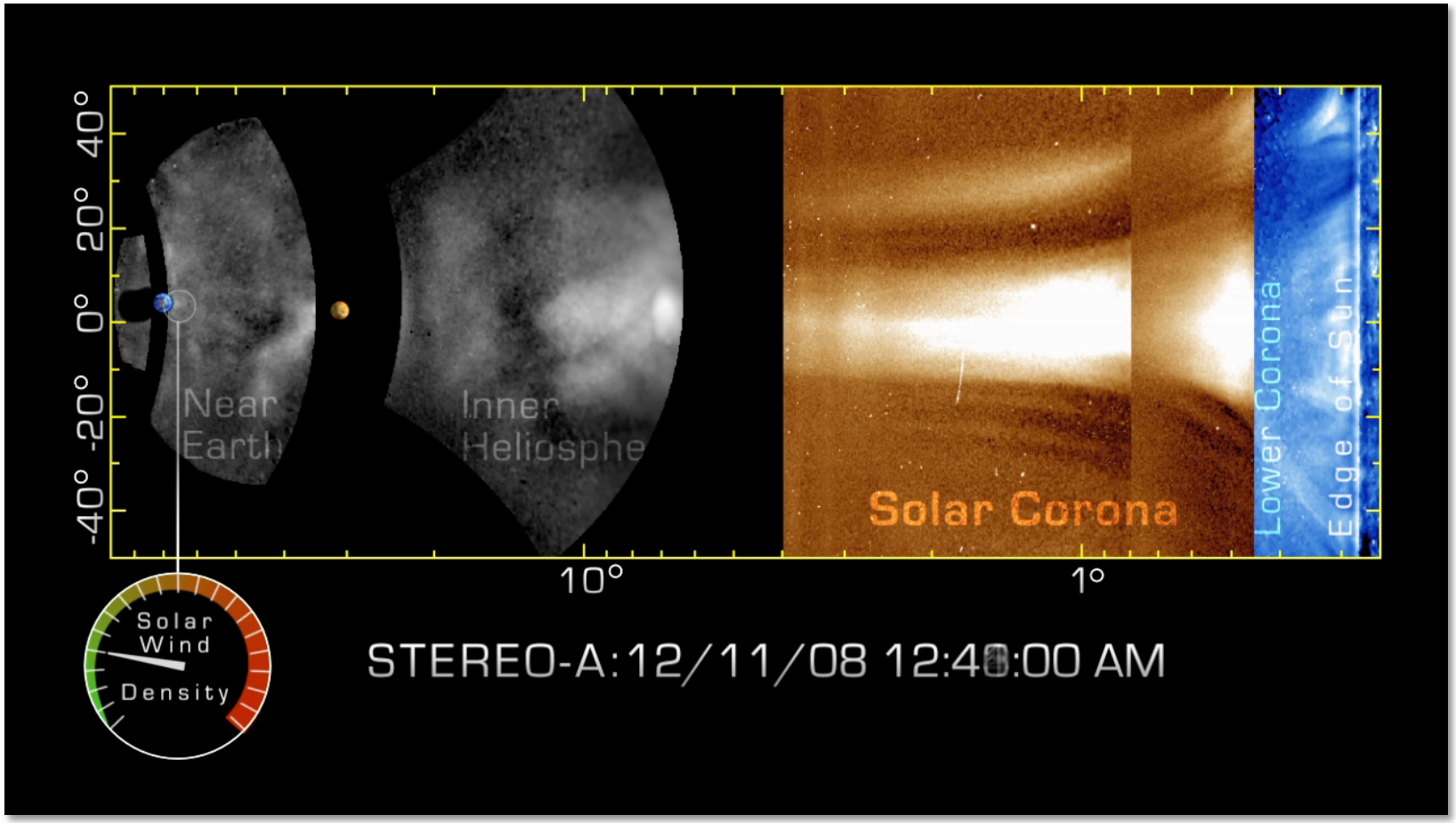
The Sun



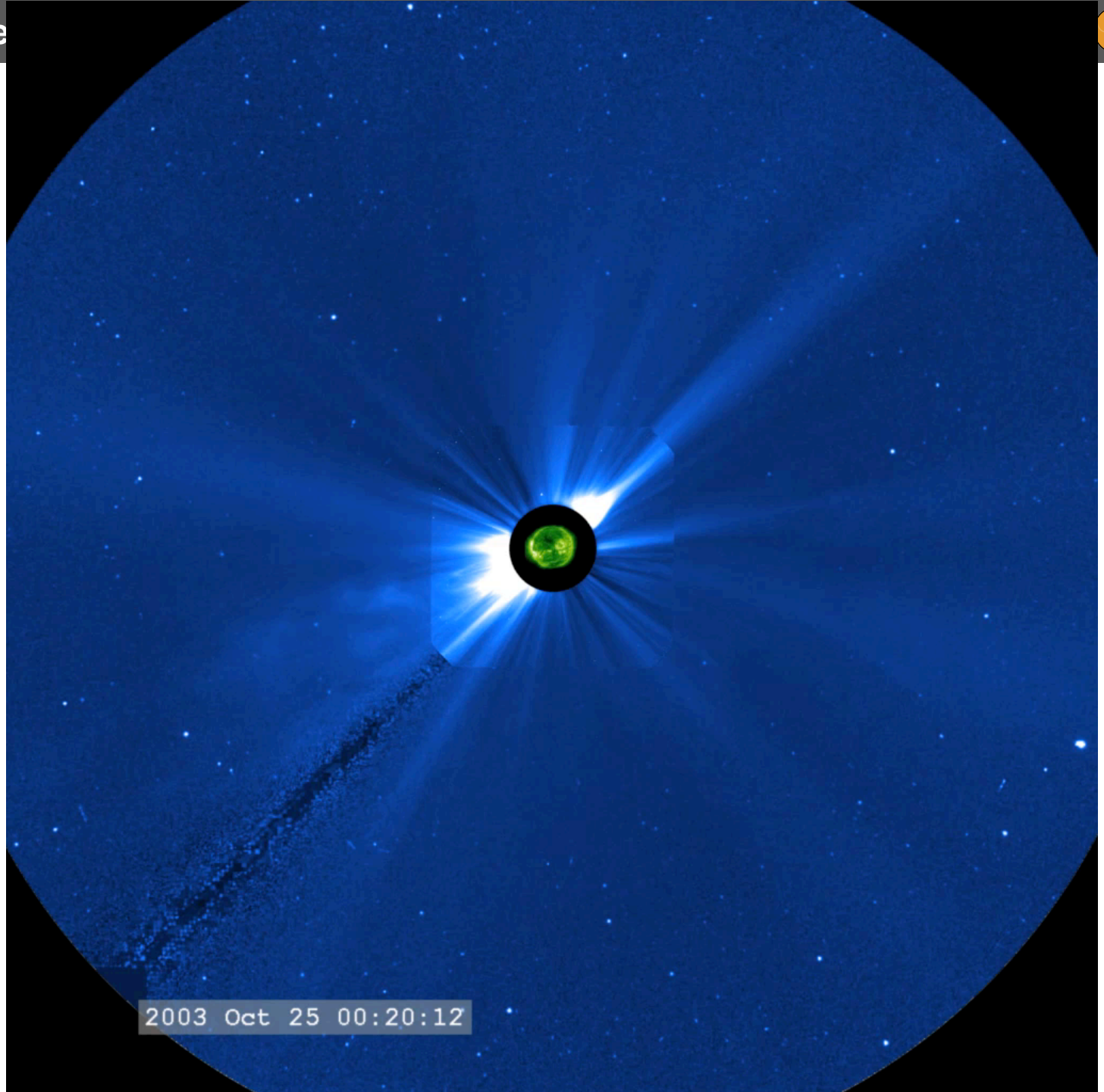
The Sun's Rainbow



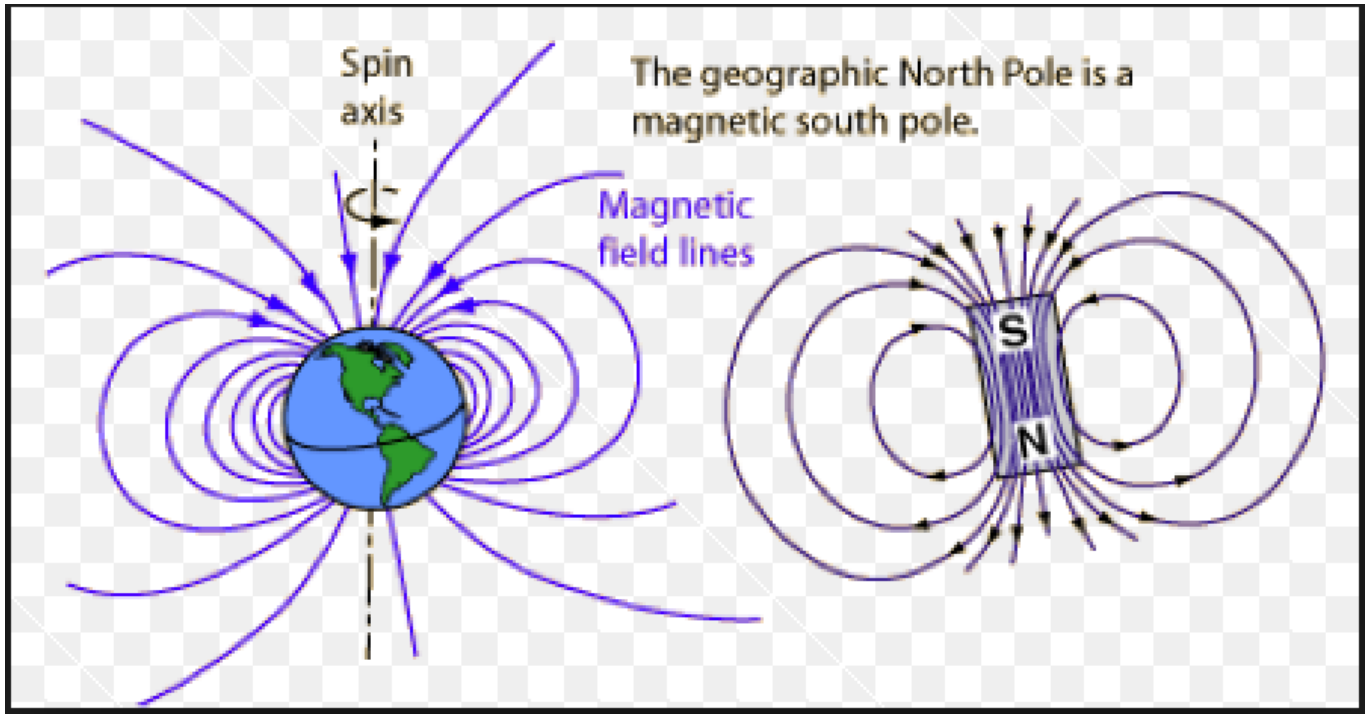
CME propagation



CME propagation to the Earth takes typically 2-4 days.

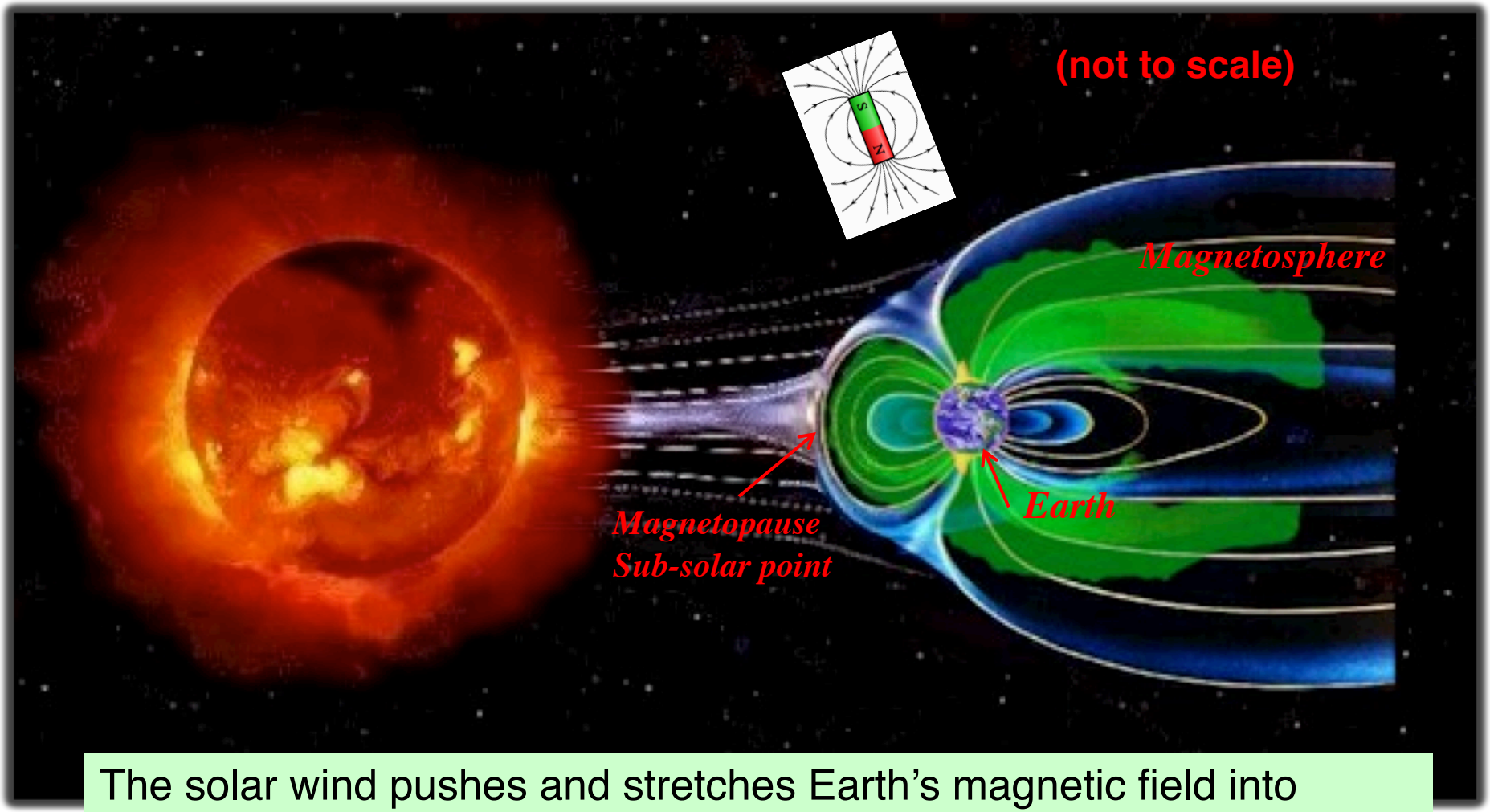

2003 Oct 25 00:20:12

Magnetic Field of the Earth



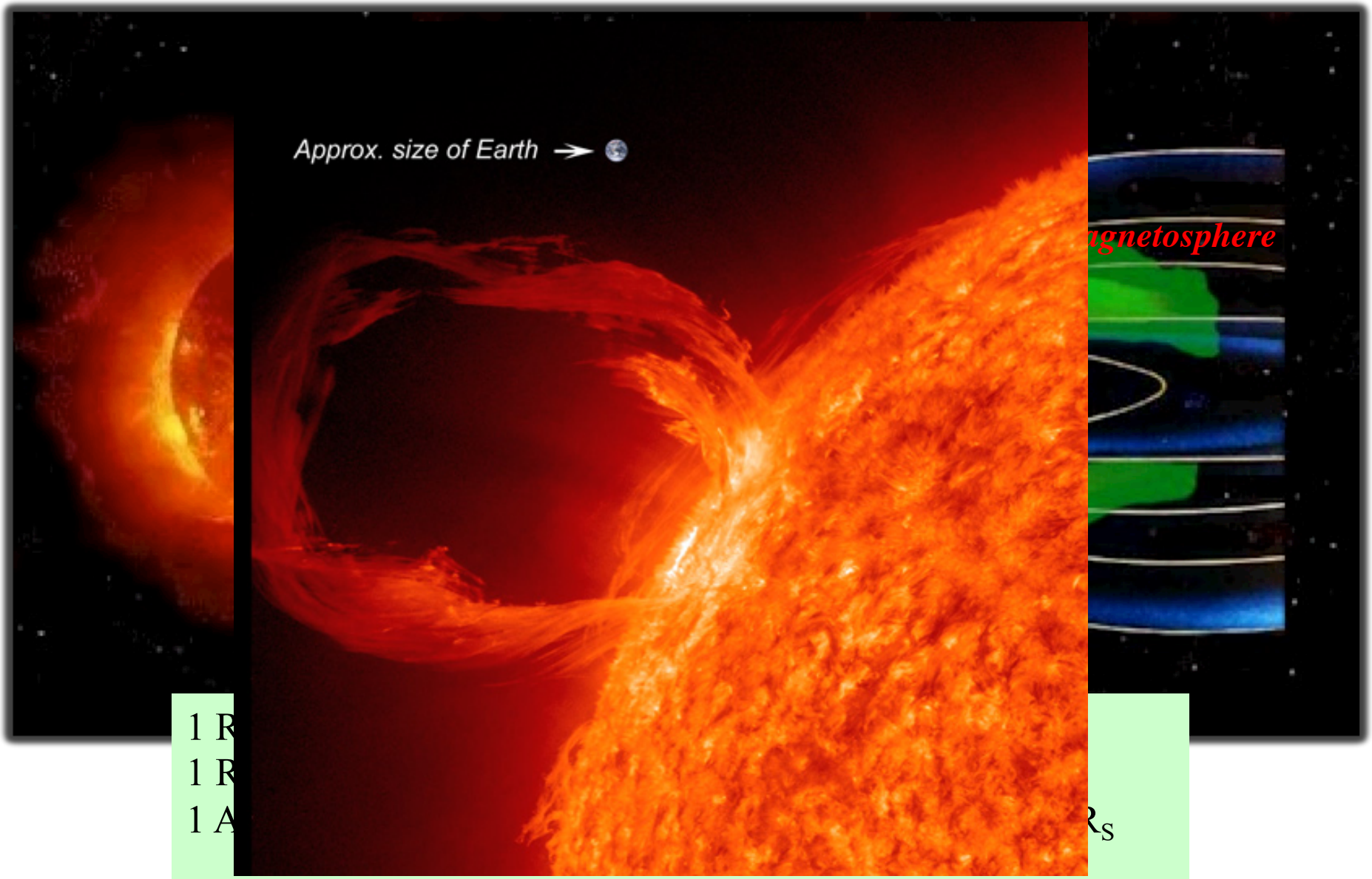
The Earth's magnetic field is similar to that of a bar magnet.

Earth's Magnetic Field



The solar wind pushes and stretches Earth's magnetic field into comet-shaped region called the magnetosphere. The magnetosphere and Earth's atmosphere protect us from the solar wind and other kinds of solar and cosmic radiation.

Spatial Scales



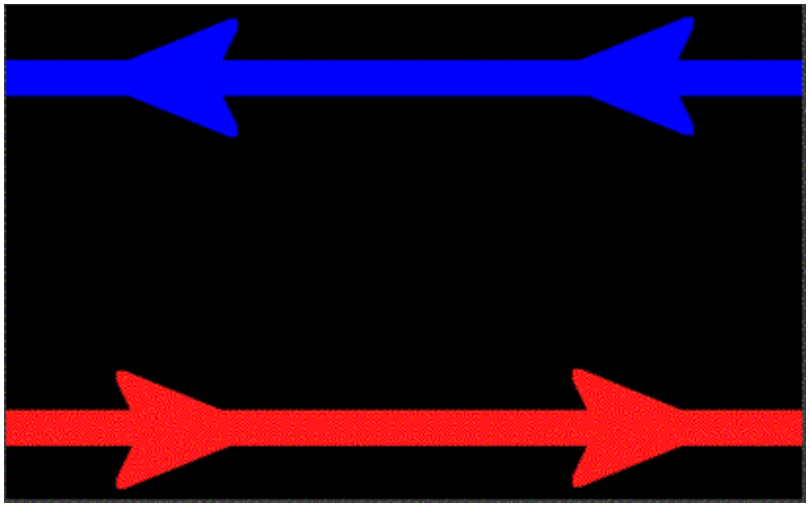
1 R

1 R

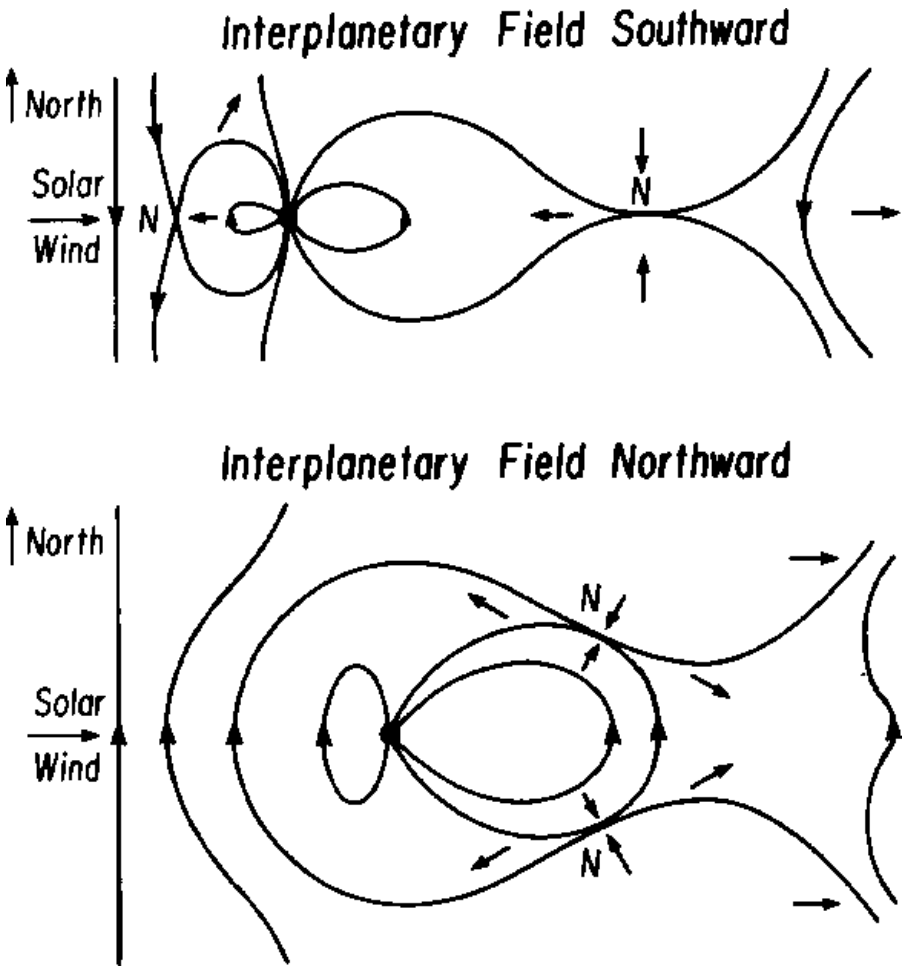
1 A

R_S

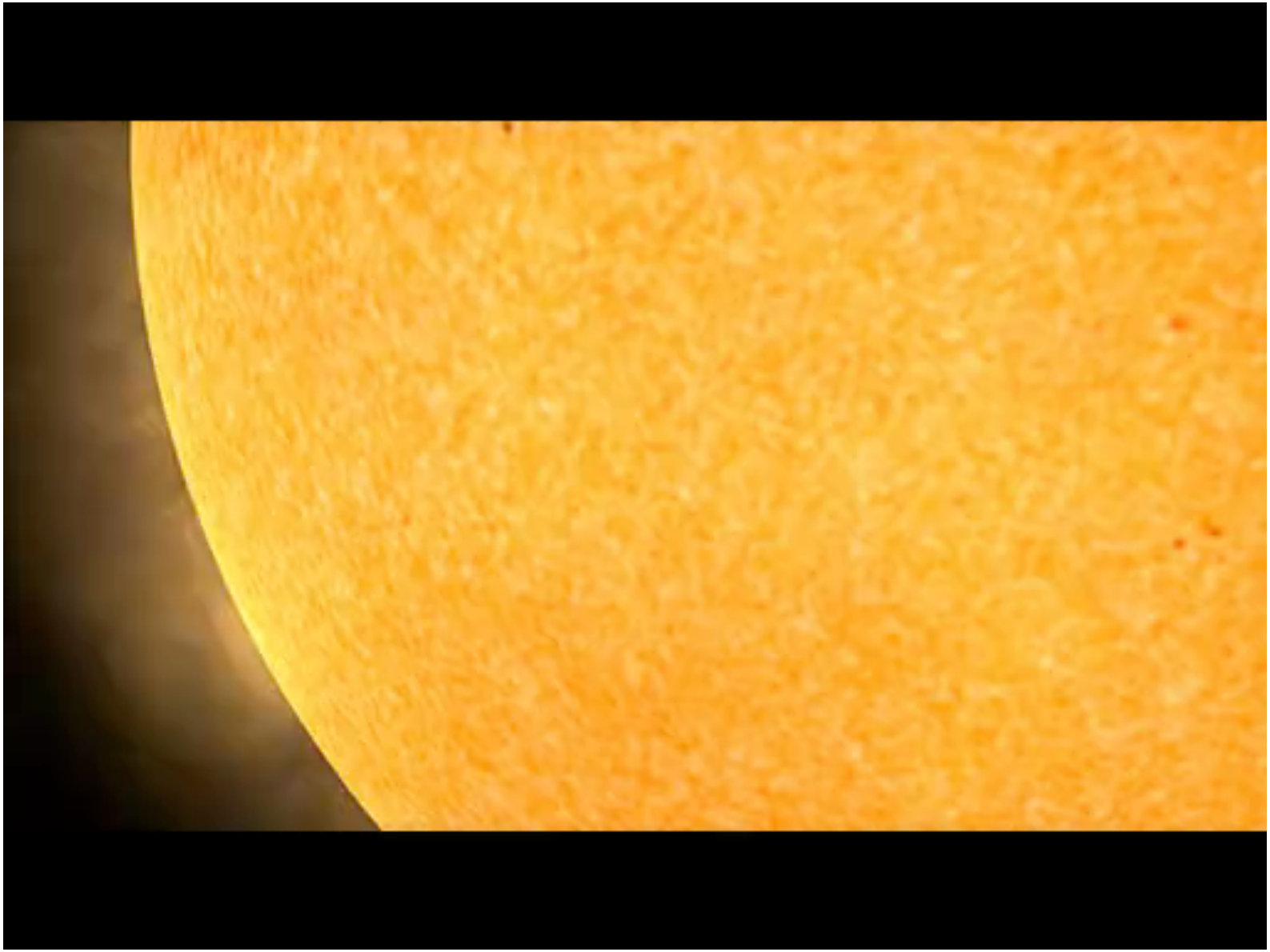
Magnetosphere for Southward and Northward IMF Orientation



Magnetic Reconnection

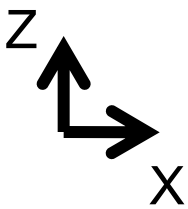


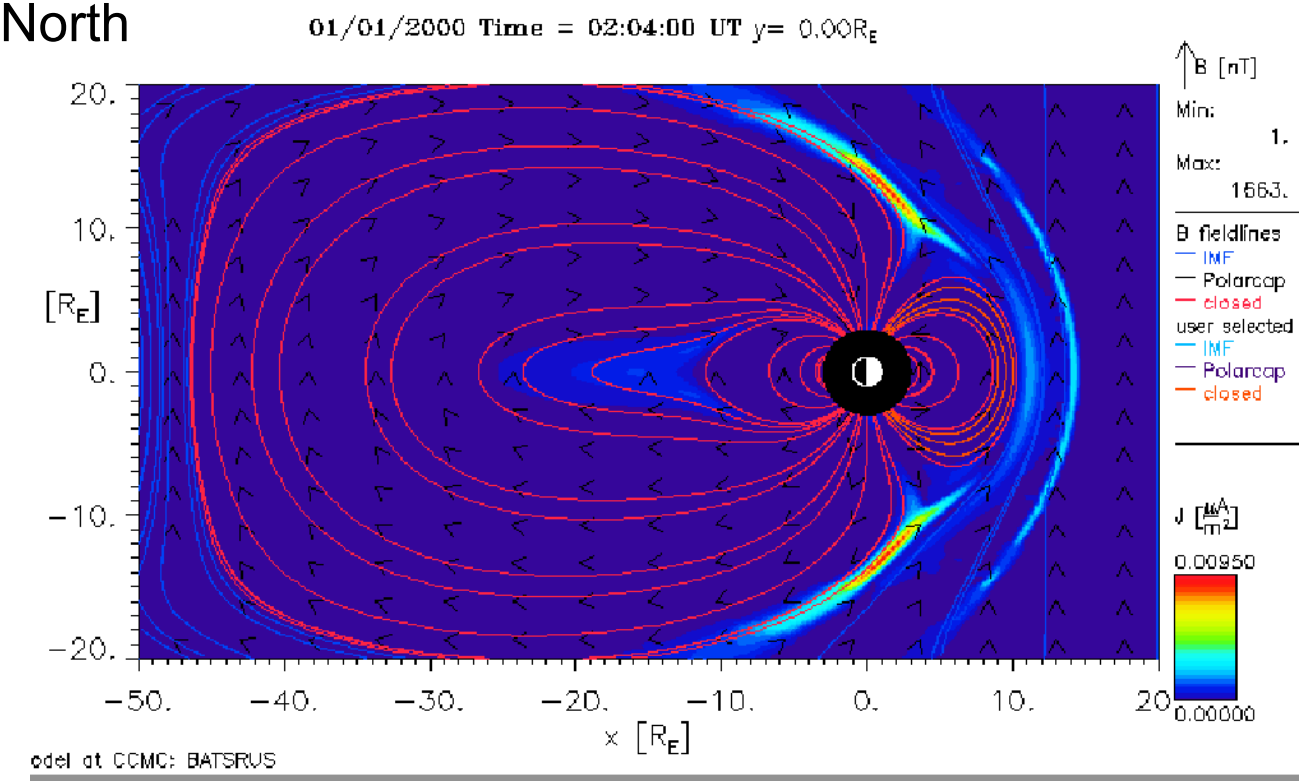
Dungey, 1961



Magnetosphere:
Northward IMF

X: Earth to Sun
Z: South to North





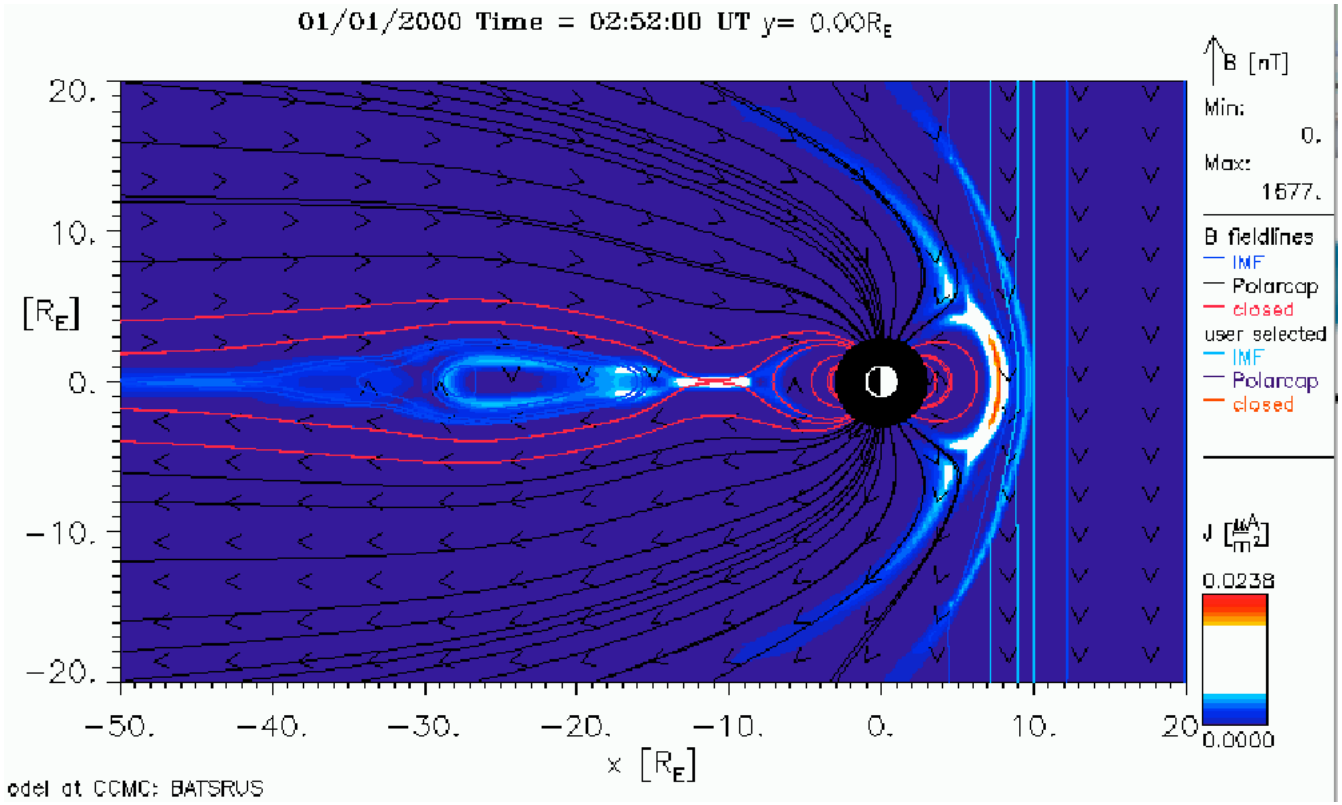
Sun

Red lines (closed): Magnetic field (MF) lines with both ends connected to the Earth

Black lines (open): MF lines with only one end a the Earth

Blue lines (interplanetary): MF lines with both ends in the interplanetary space

Magnetosphere:
Southward IMF



Red lines (closed): Magnetic field (MF) lines with both ends connected to the Earth

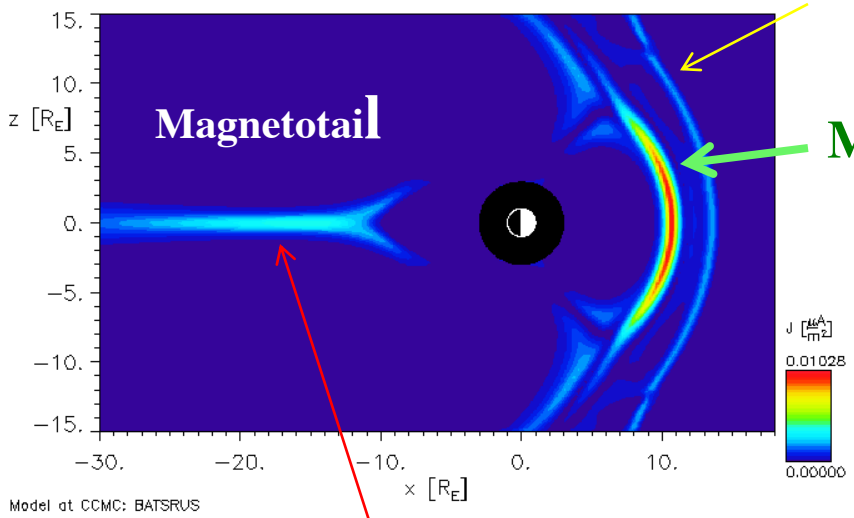
Black lines (open): MF lines with only one end a the Earth

Blue lines (interplanetary): MF lines with both ends in the interplanetary space

Magnetosphere in Different Cut Planes

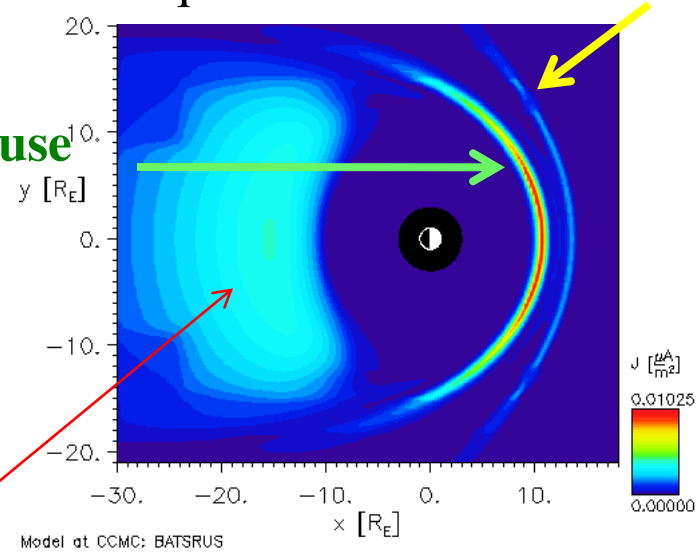
meridional cut Y=0

Bow shock

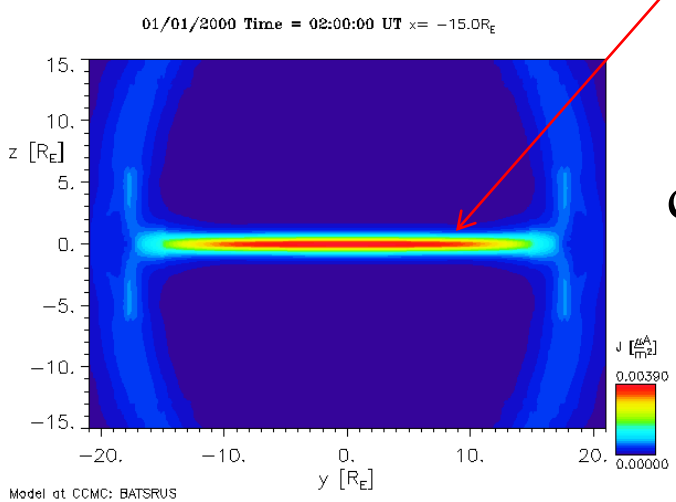


equatorial cut Z=0

Bow shock

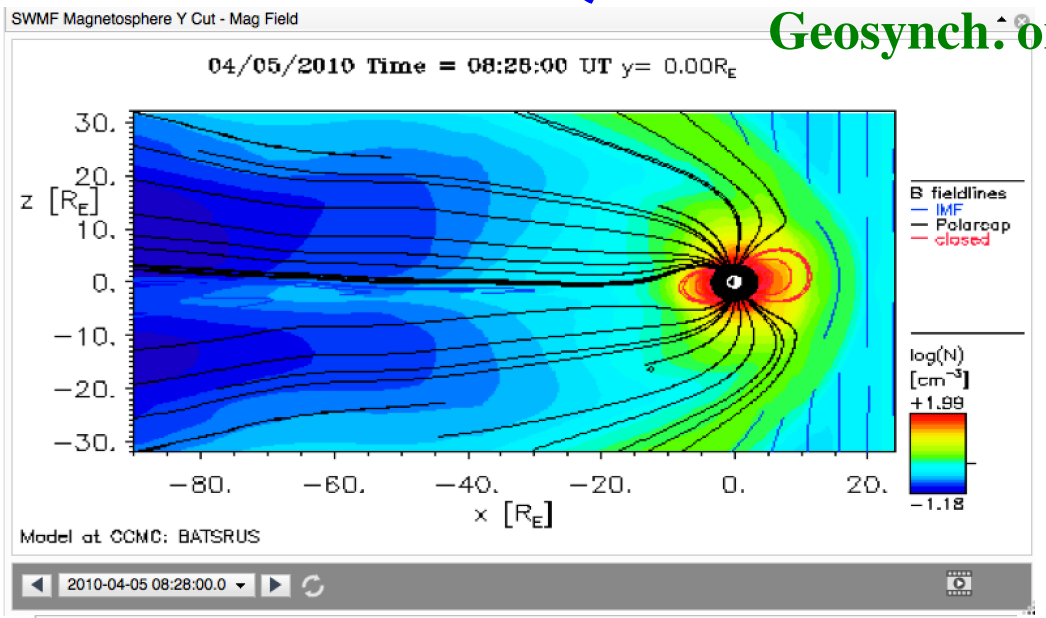


Magnetotail current sheet

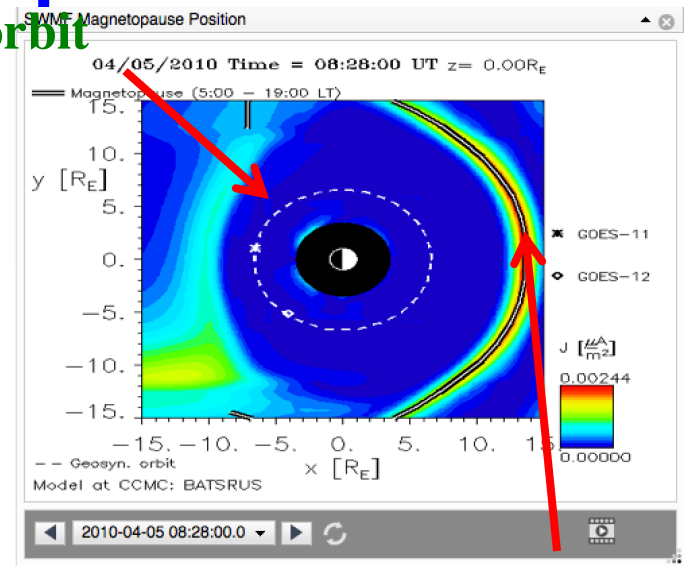


cross-tail cut X= -15 R_E

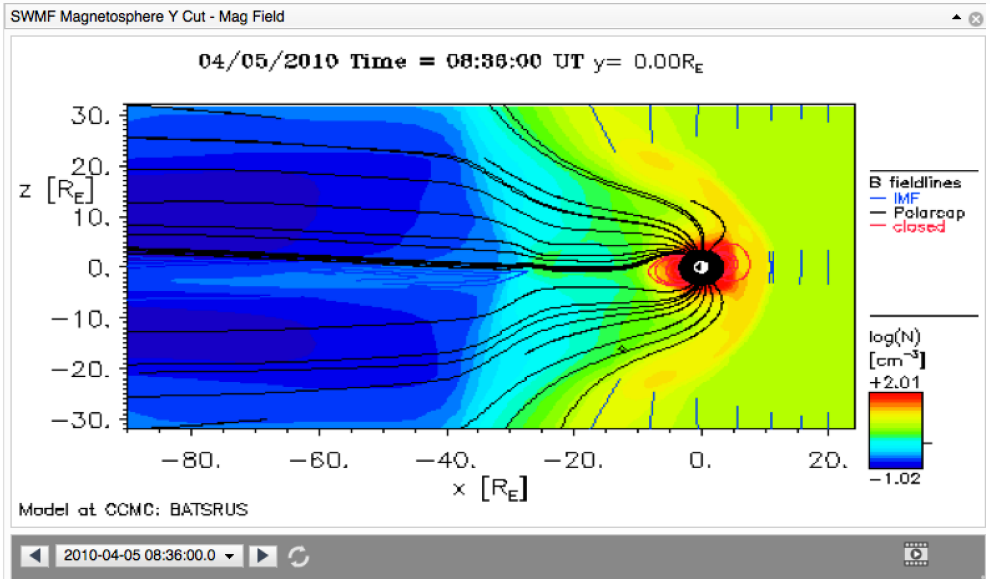
Magnetosphere:
Quiet vs. Compressed

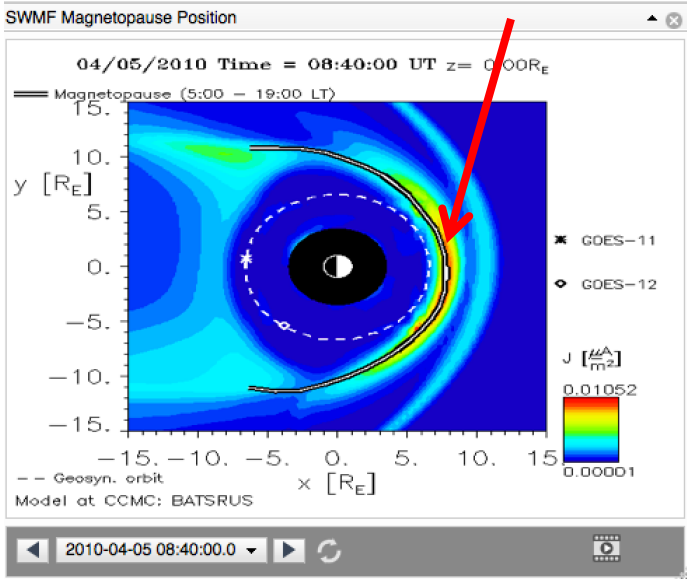


Geosynch. orbit

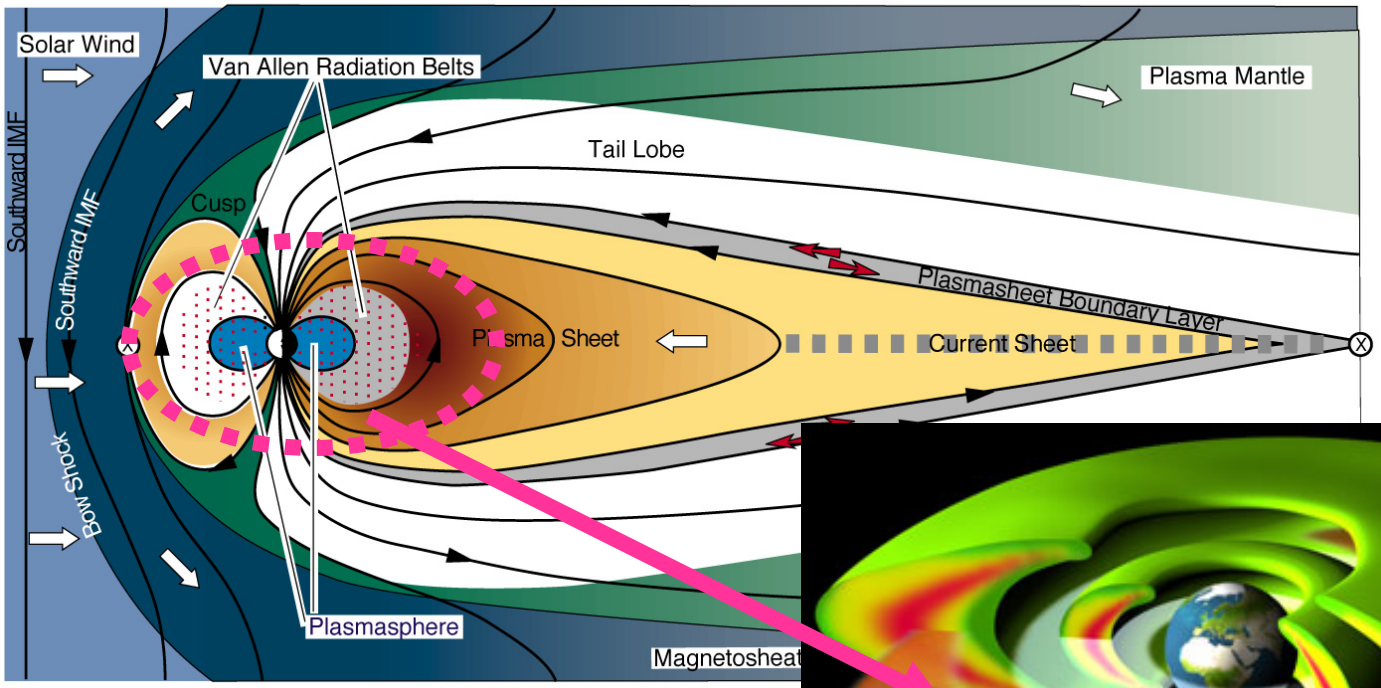


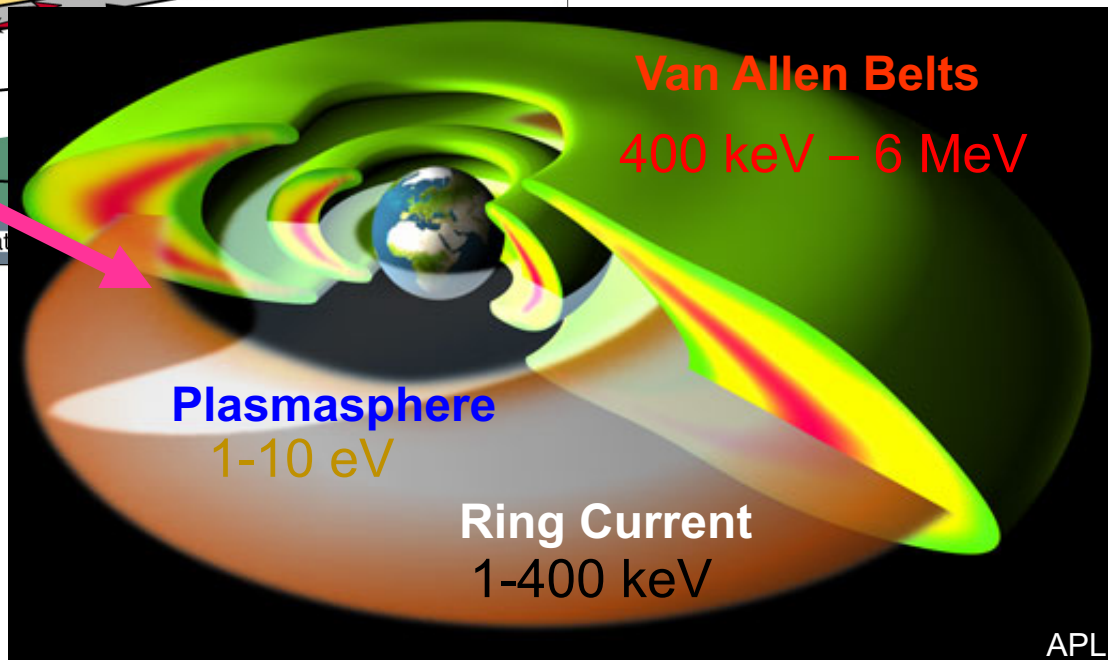
Magnetopause





Inner Magnetosphere (up to ~ 10 RE)

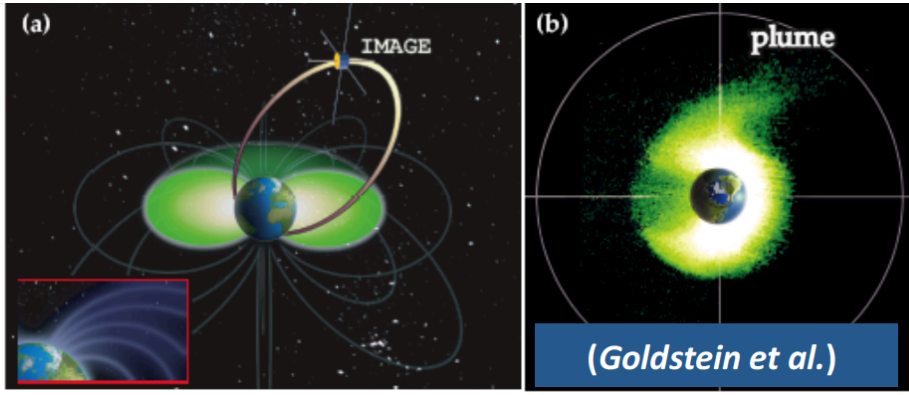


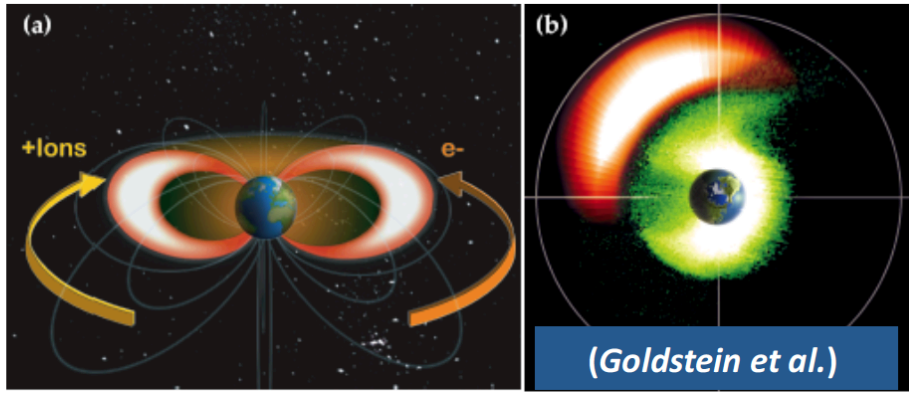


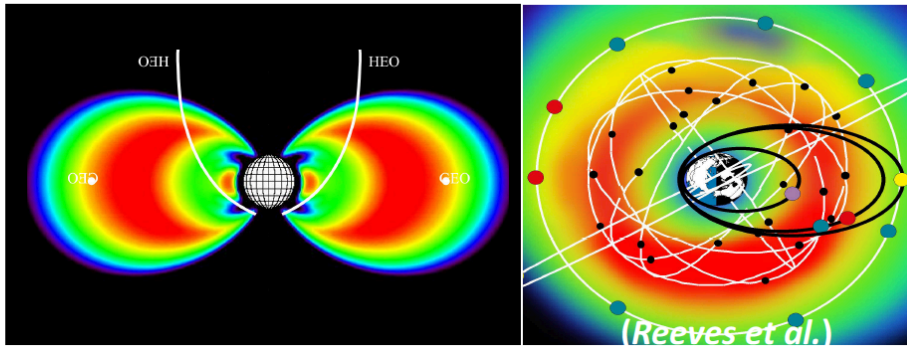
Inner Magnetosphere Plasmas

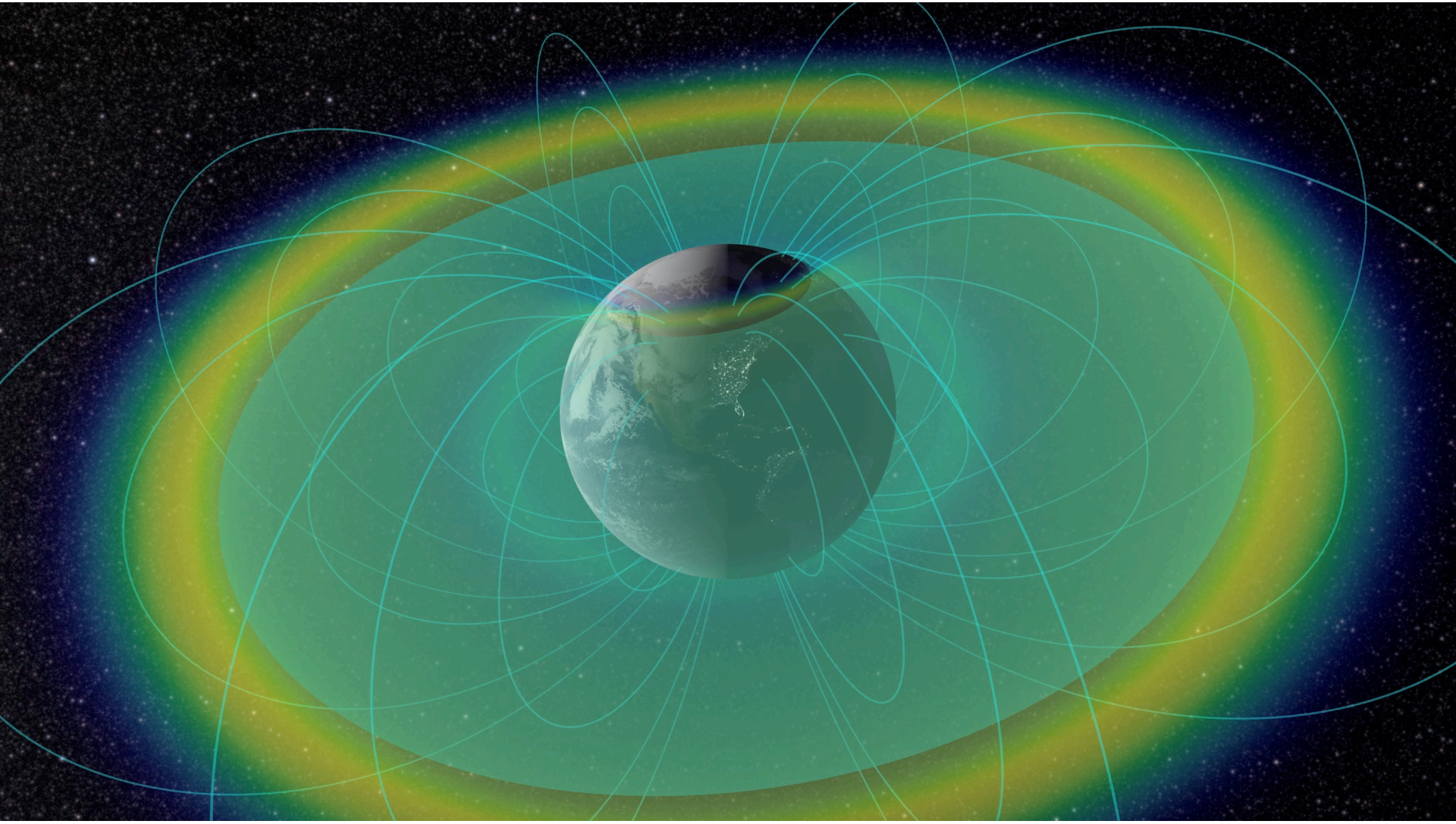
- Plasmasphere
  - 1-10 eV ions
  - ionospheric origin
- Ring current
  - 1-400 keV ions
  - both ionospheric and solar wind origin
- Outer radiation belt
  - 0.4-10 MeV electrons
  - magnetospheric origin

Inner magnetosphere: Gigantic Particle accelerator

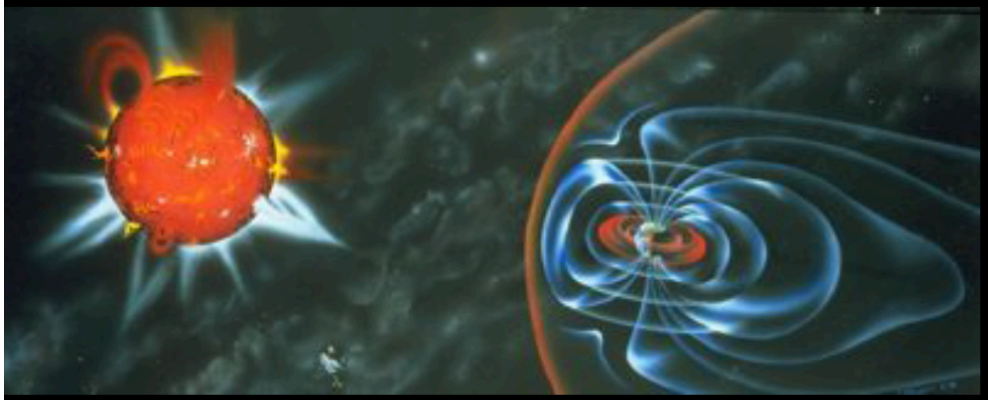






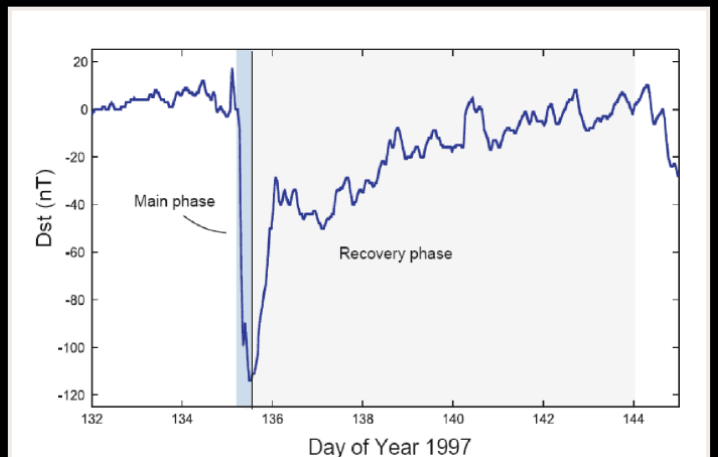


Magnetic Storms



- Most intense solar wind-magnetosphere coupling
- Associated with solar coronal mass ejections (CME), coronal holes HSS
- IMF Bz southward, strong electric field in the tail
- Formation of ring current and other global effects

- Dst measures ring current development
  - Storm sudden commencement (SSC), main phase, and recovery phase
  - Duration: days

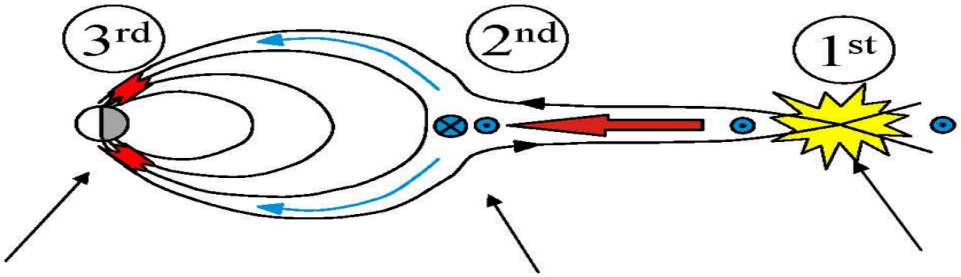


Substorms

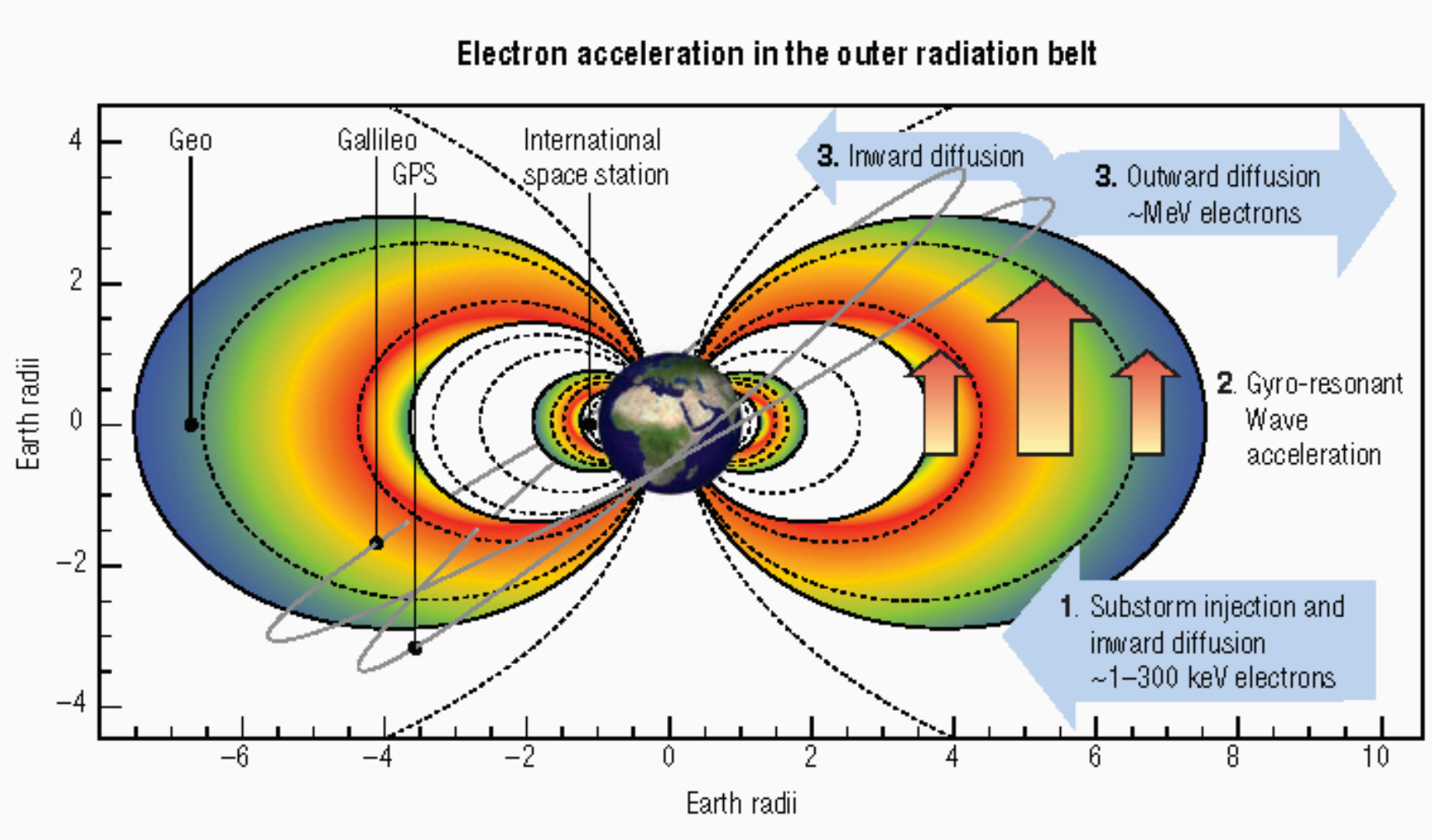
- Instabilities that abruptly and explosively release solar wind energy stored within the Earth's magnetotail.
- manifested most visually by a characteristic global development of auroras
- Last ~ hours

From 2008 THEMIS Science Nuggets
By Angelopoulos

Reconnection Model
(Explosion)

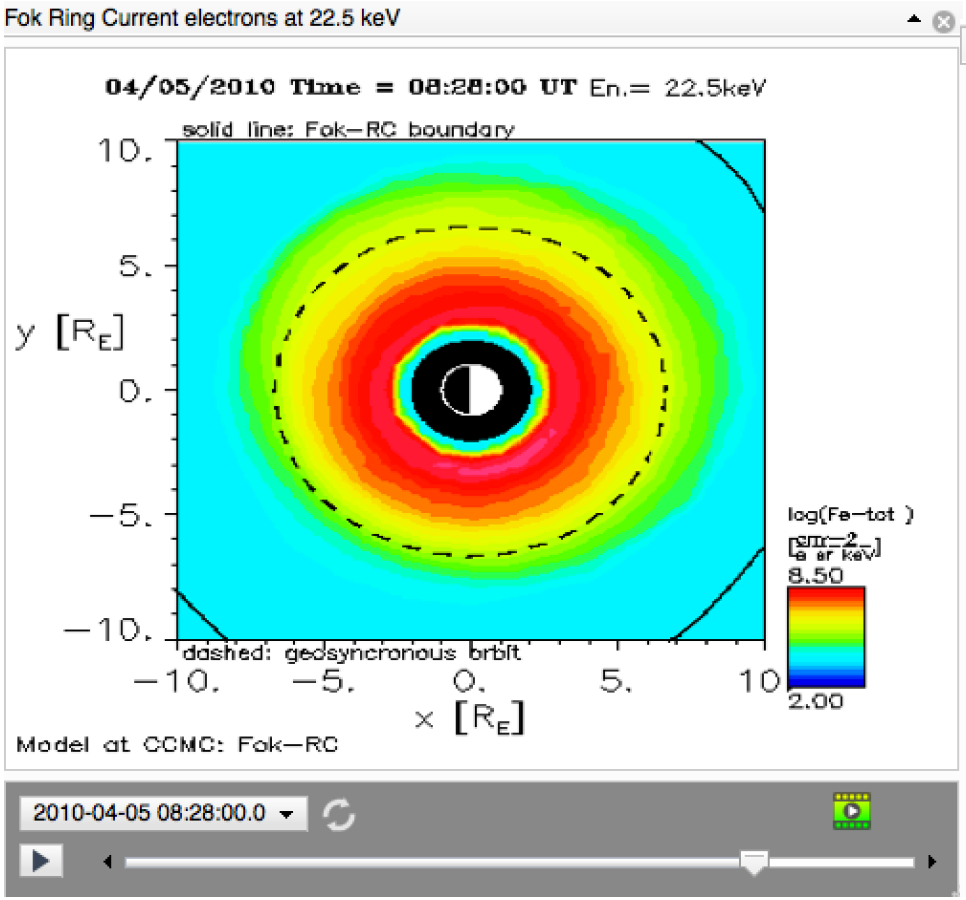


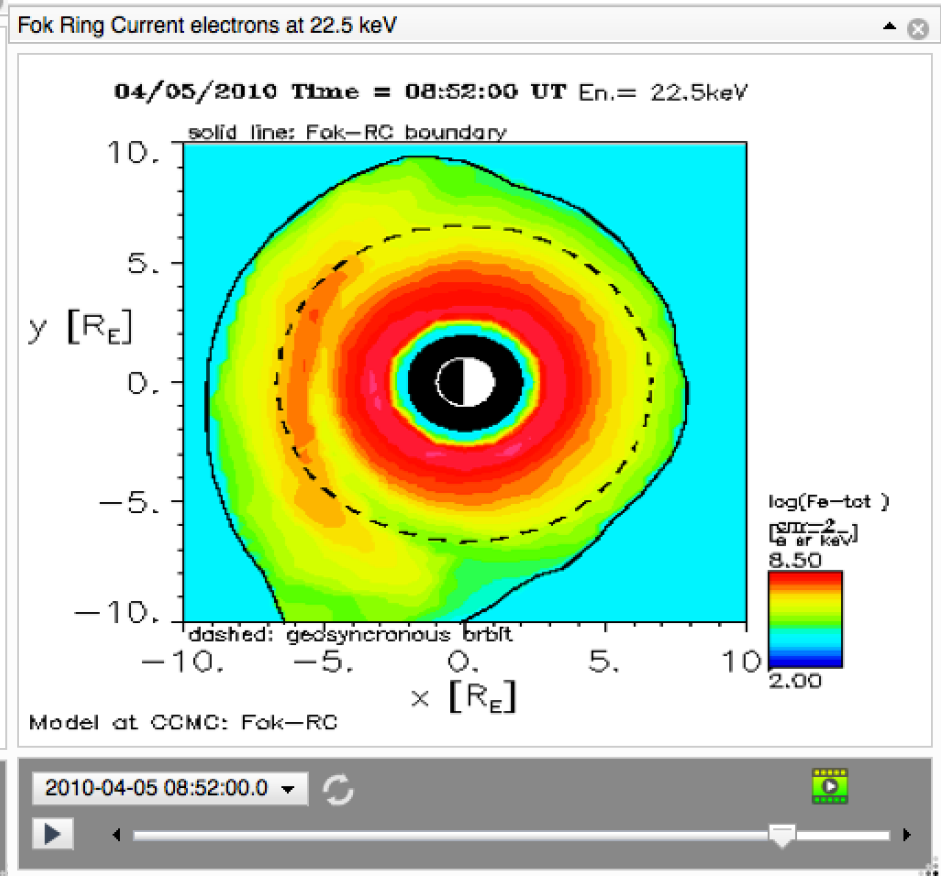
Key regions: Aurora Current Disruption Reconnection



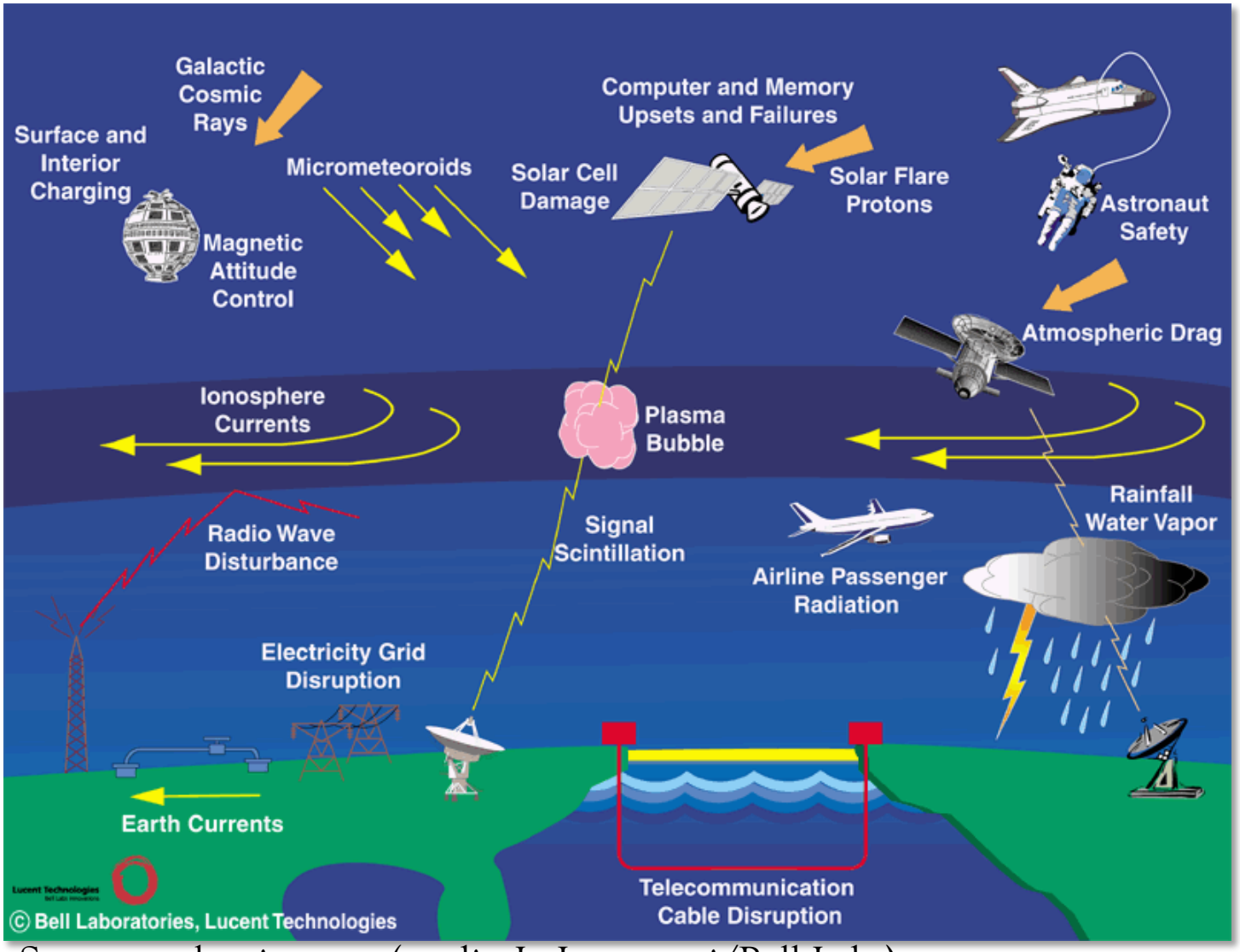
Horne et al., 2007, Nature Physics

Ring Current:
Quiet vs. Active



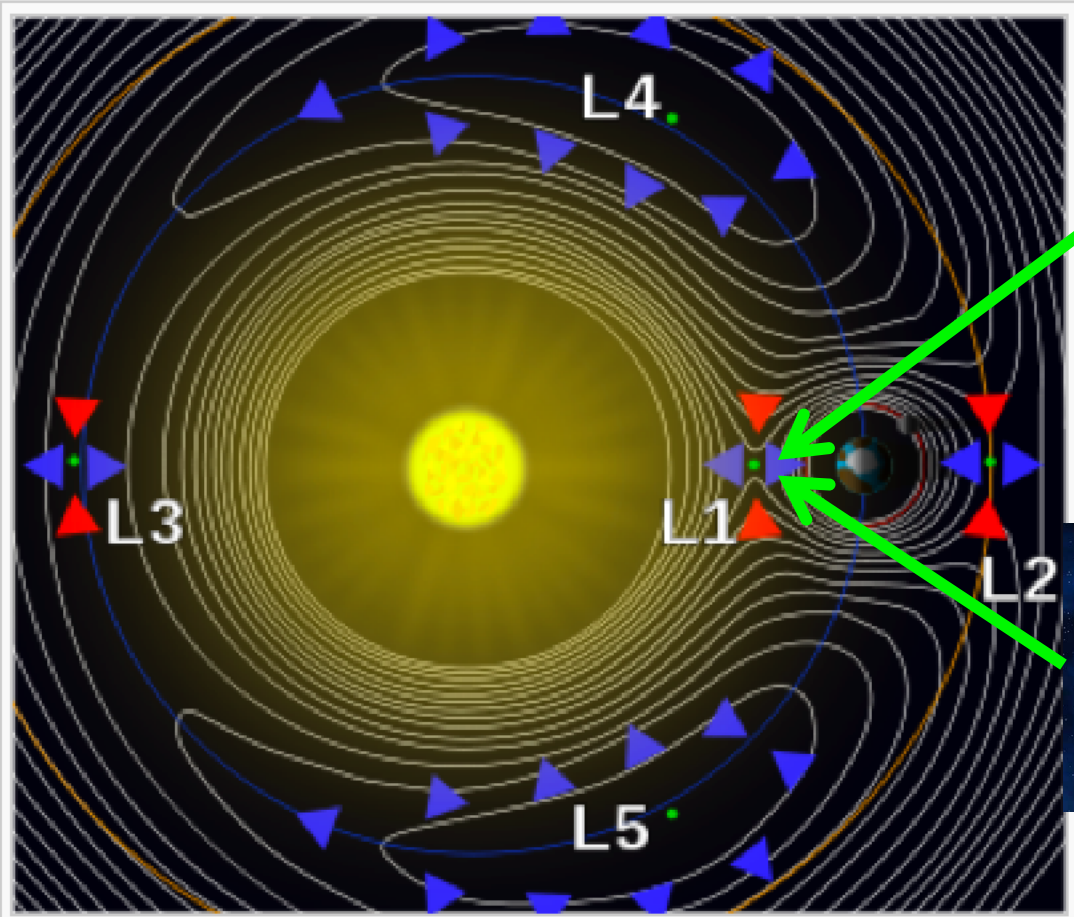


Space Weather Impacts



Space weather impacts (credit: L. Lanzerotti/Bell Labs)

Lagrange Point – L1



Advanced
Composition
Explorer

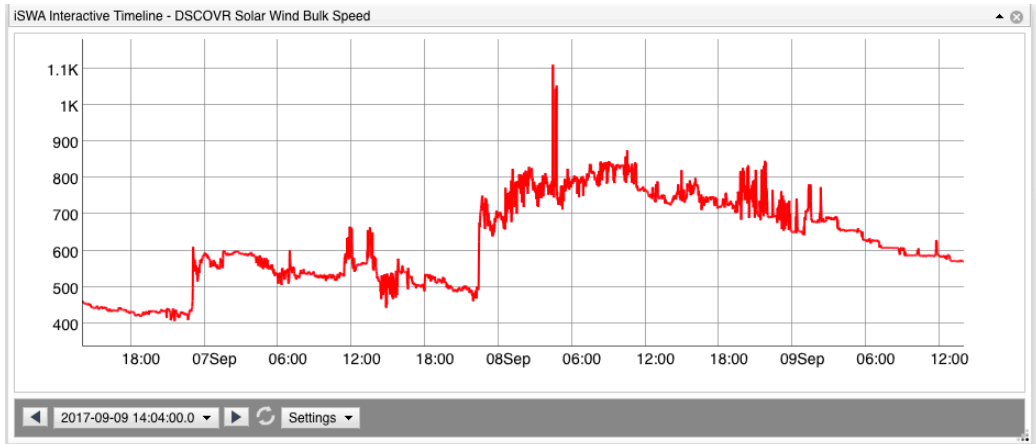
DSCOVR

L1 (Solar Wind Monitor ACE/DSCOVR location): ~ 200 R_E sunward
You can fit 1 Sun between the Earth and L1.
2 R_S (Solar diameter) ~ 220 R_E

Solar Wind Parameters at DSCOVR

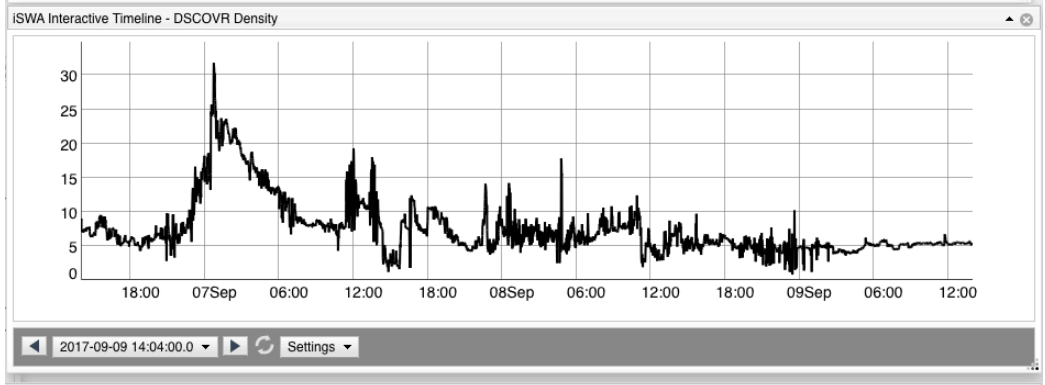
on 09/2017

km/s



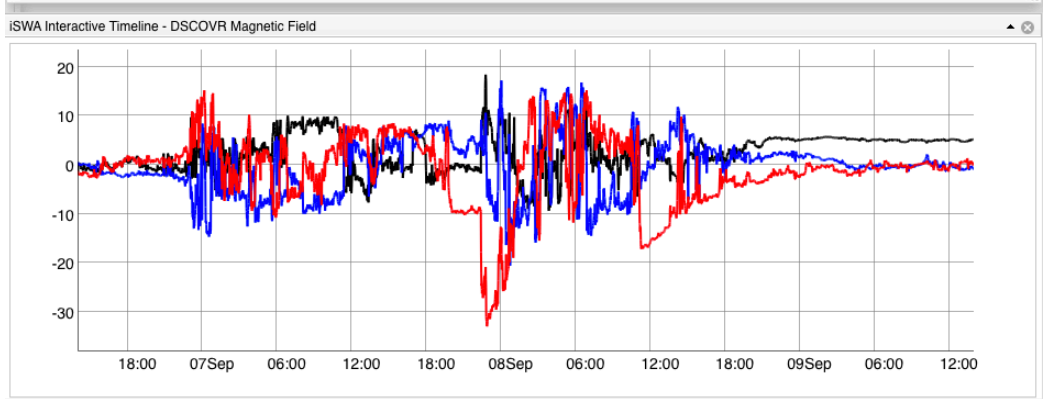
Velocity

part/cm^3



Density

nT



Magnetic field

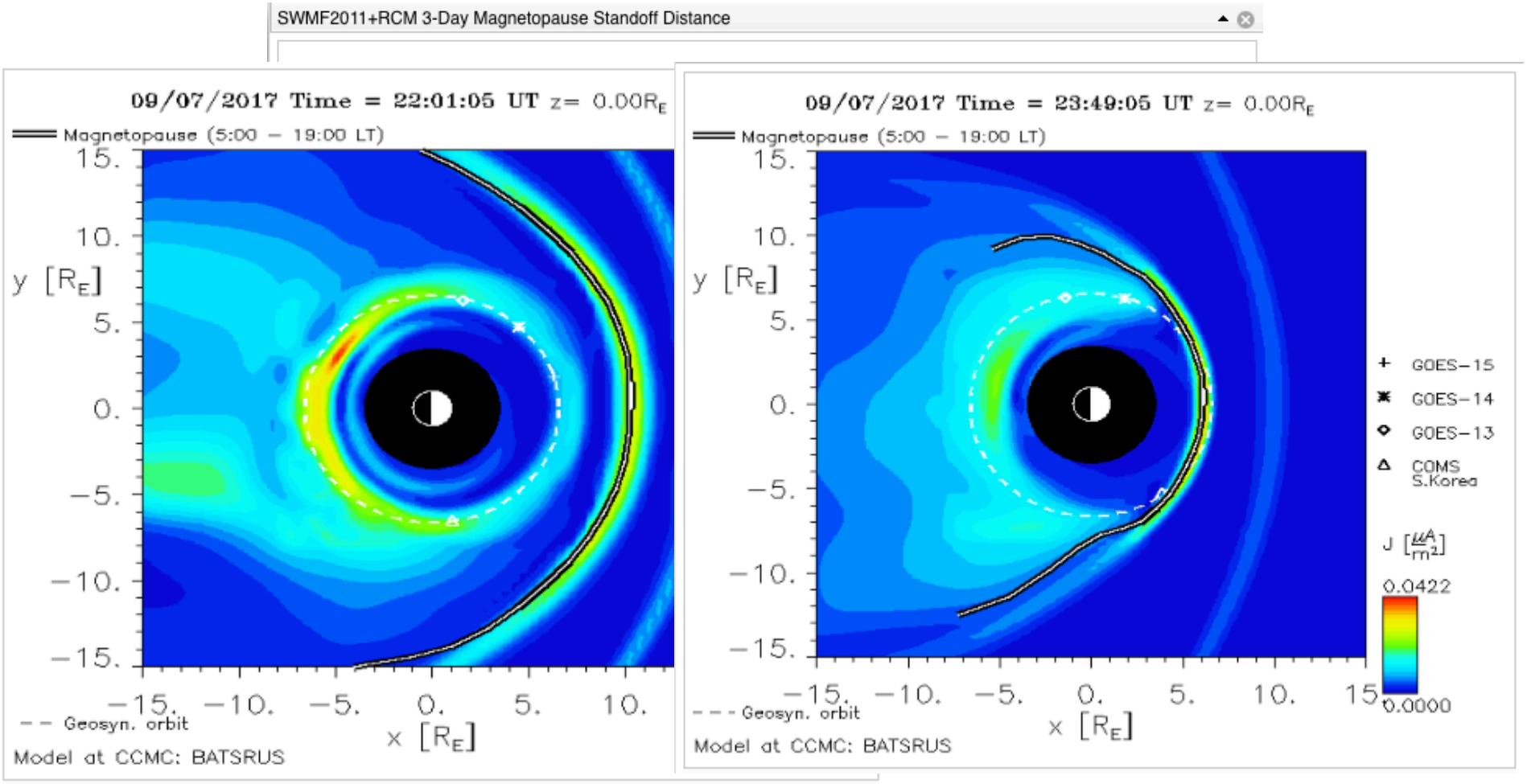
B_x, B_y, B_z

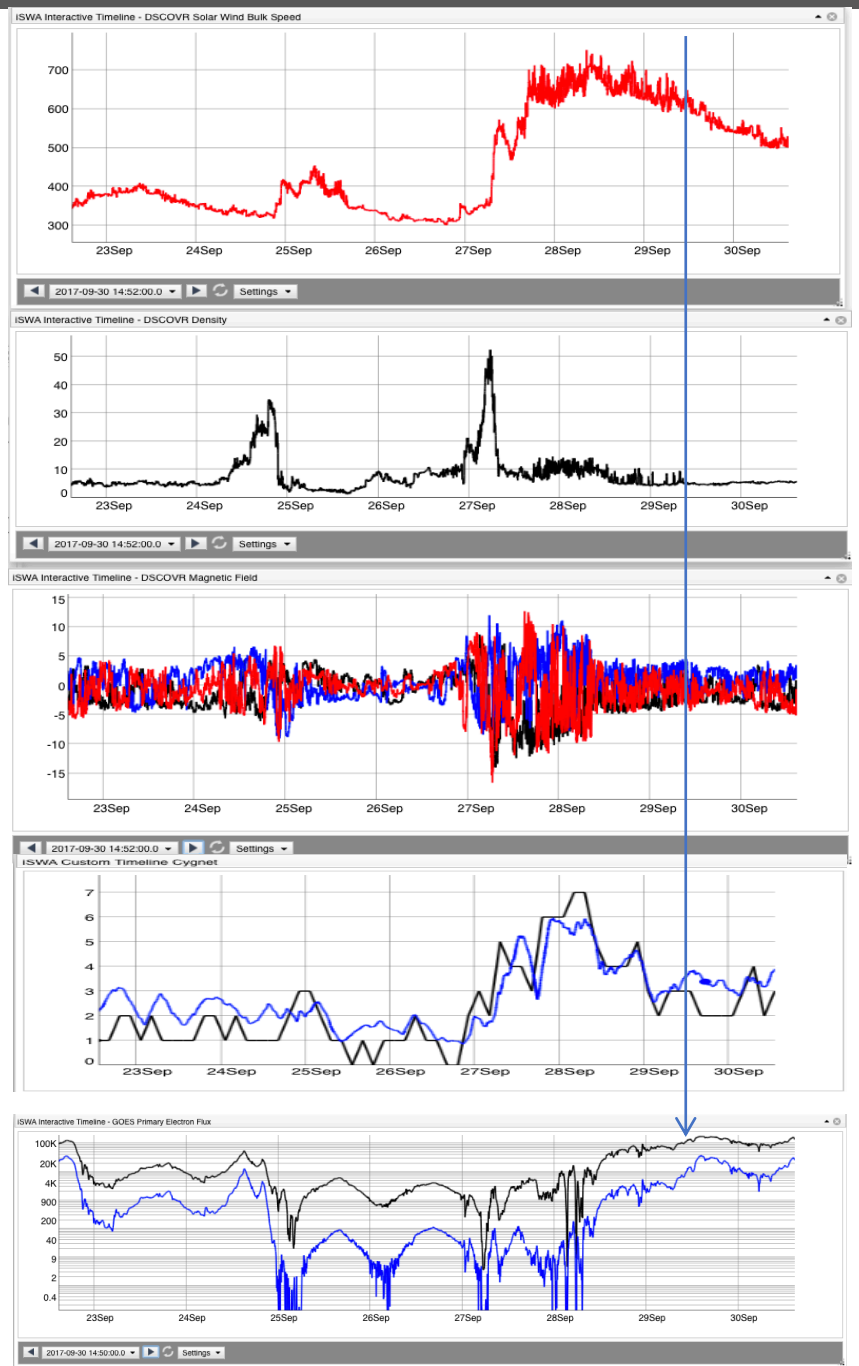
X: Earth to Sun

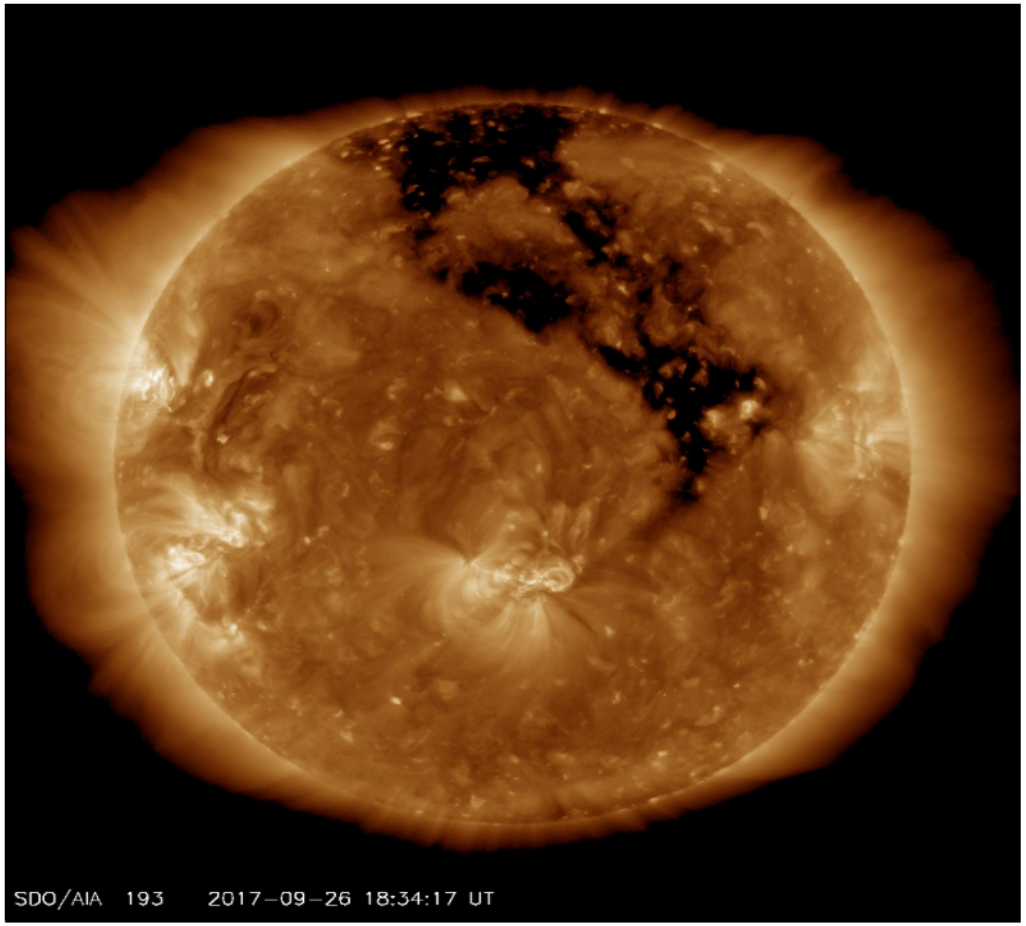
Z: North to South

Magnetopause Stand-off Distance

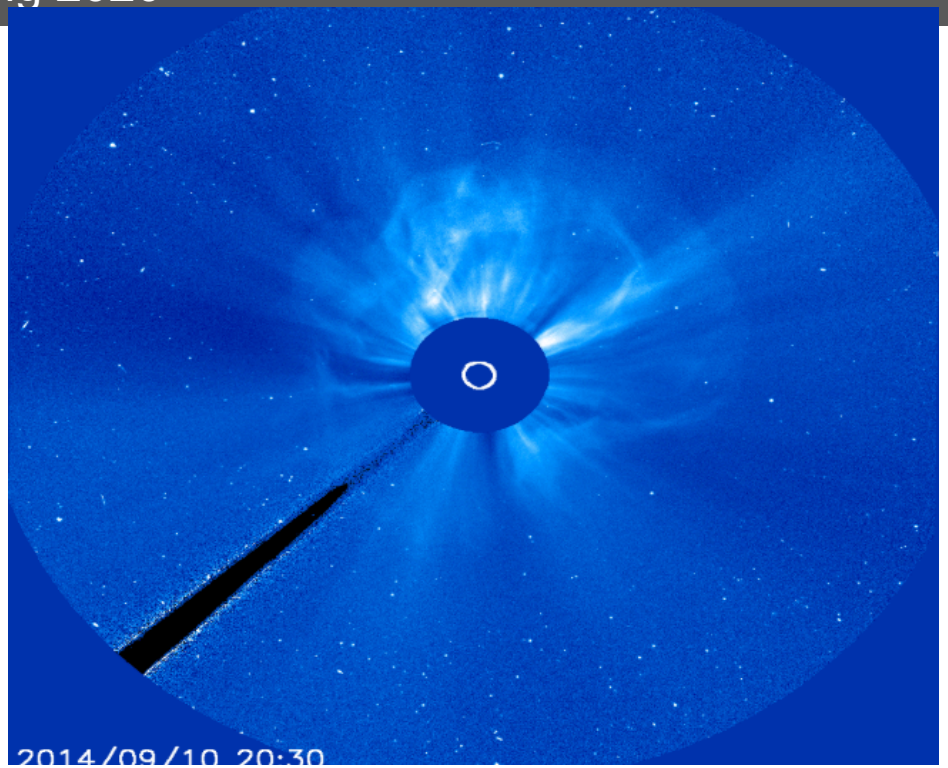
Degree of compression of MP due to dynamic pressure of solar wind







HSS and radiation belt electron flux enhancement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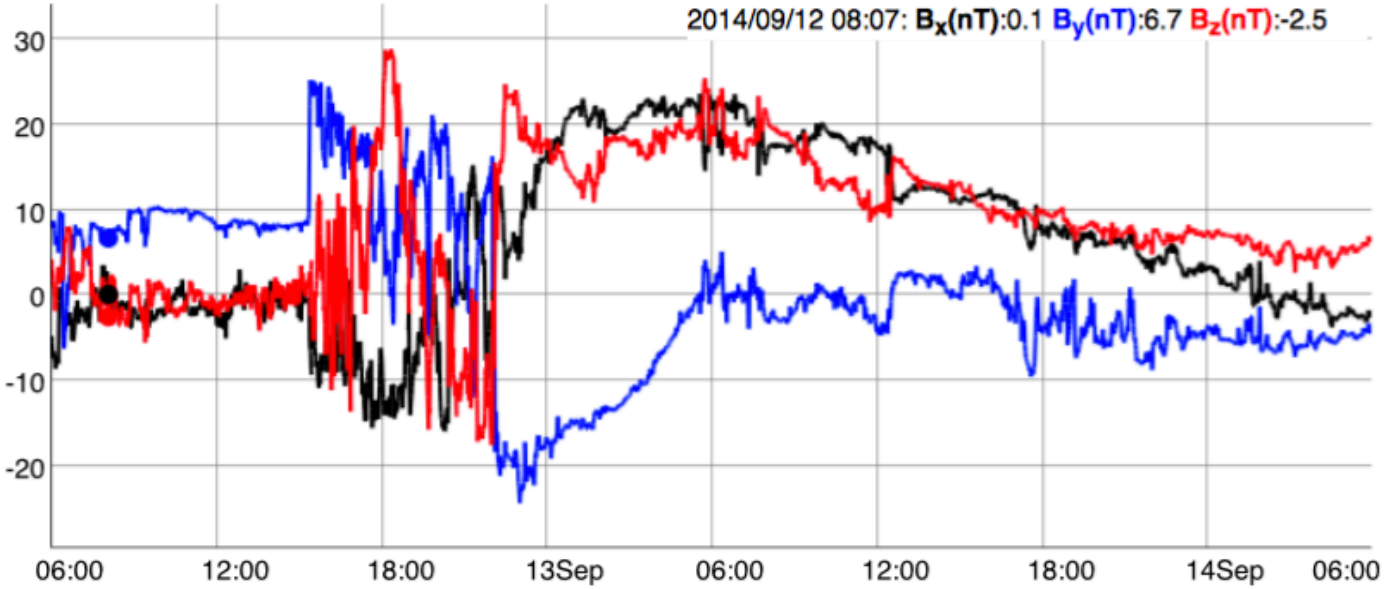
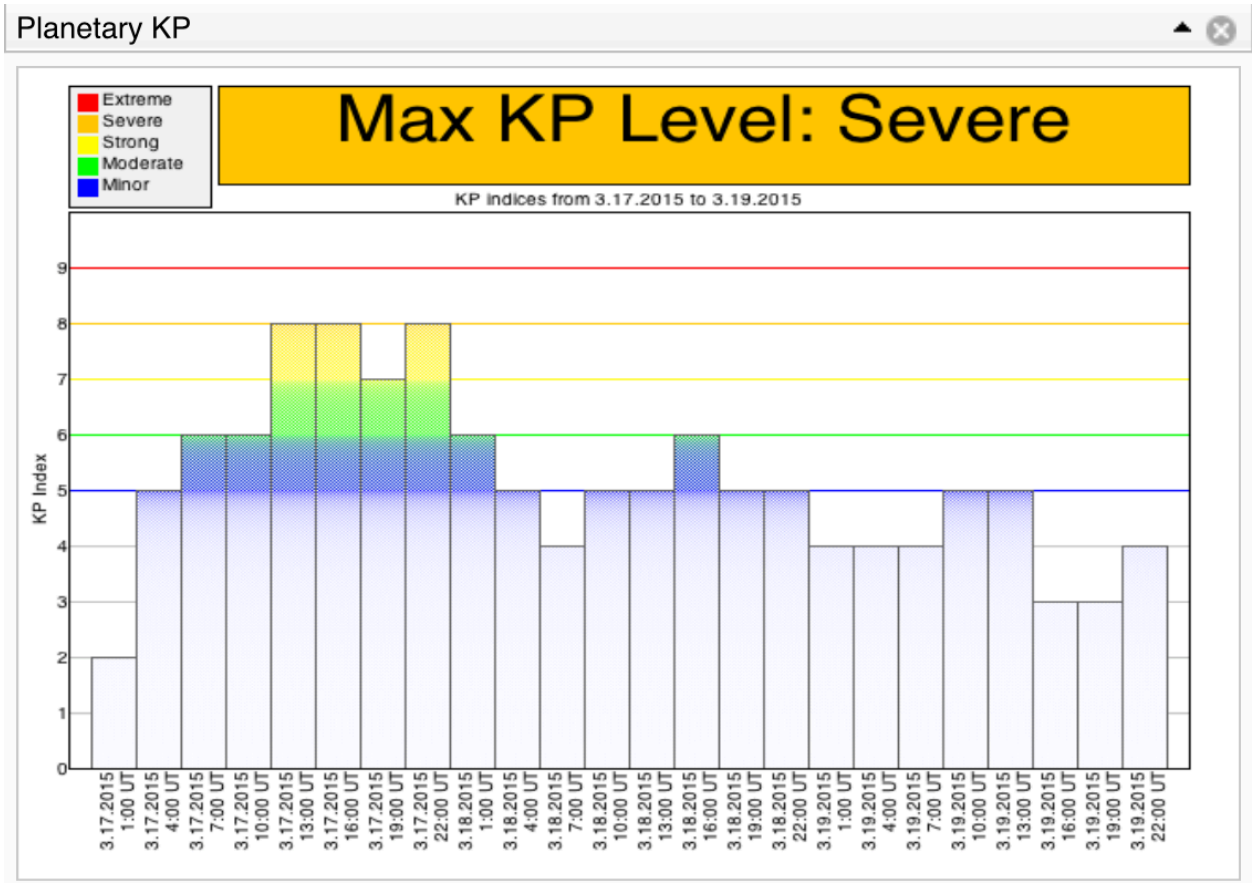

2014/09/12 08:07: B_x(nT):0.1 B_y(nT):6.7 B_z(nT):-2.5
30
20
10
0
-10
-20
06:00
12:00
18:00
13Sep
06:00
12:00
18:00
14Sep
06:00

Kp index

"*p*lanetarische *K*ennziffer" (= planetary index).

- Geomagnetic activity index - range from 0-9 disturbance levels of magnetic field on the ground – currents



Threshold Kp>=6

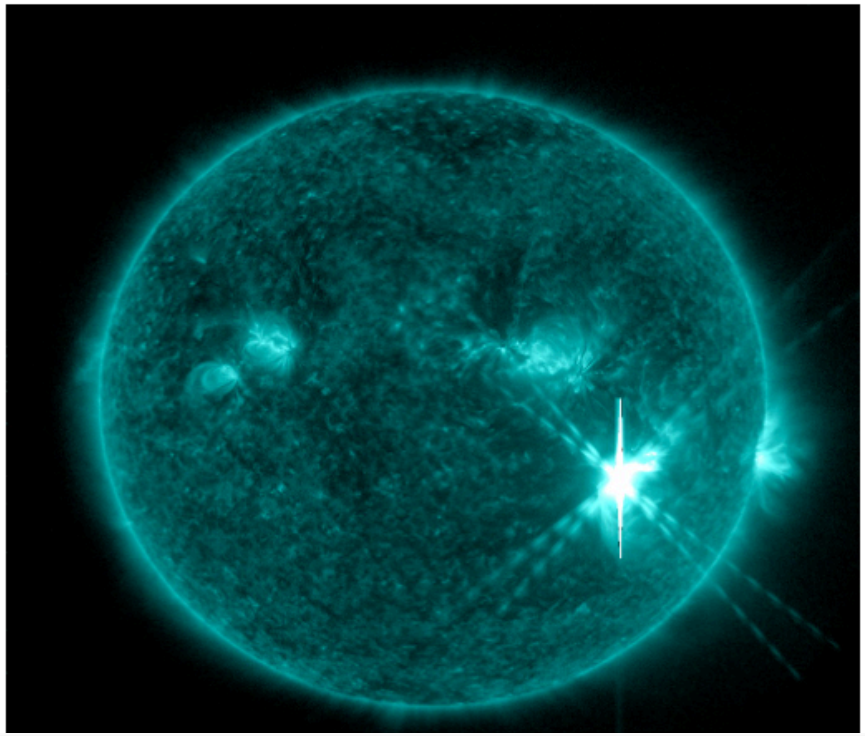
Energetic Proton Flux

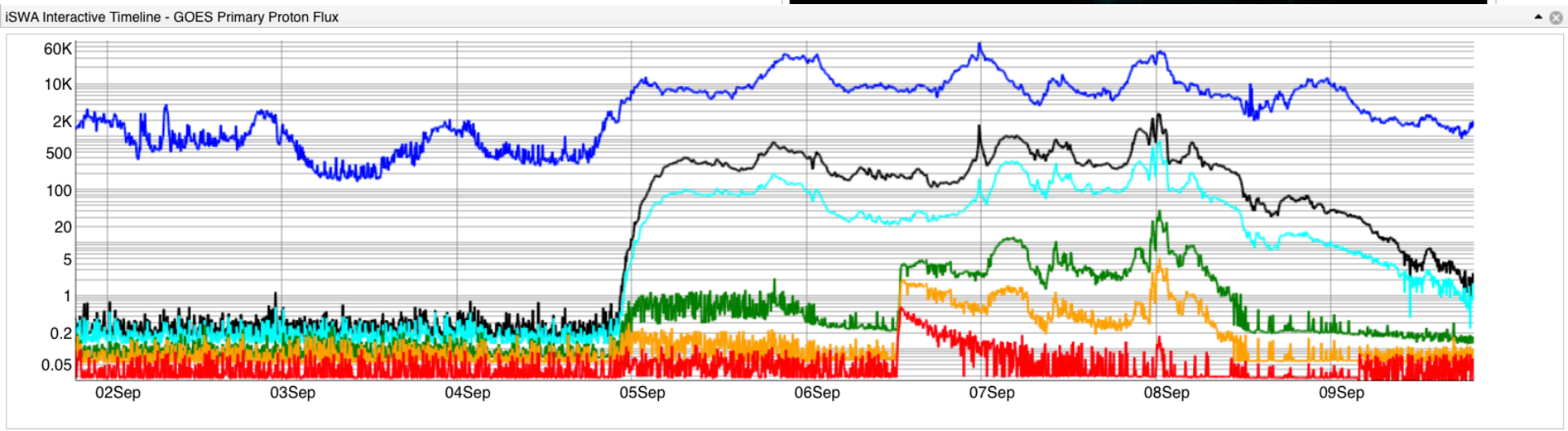
- >10 MeV flux by GOES spacecraft

Threshold: 10 pfu

- >100 MeV flux by GOES spacecraft

Threshold: 1 pfu





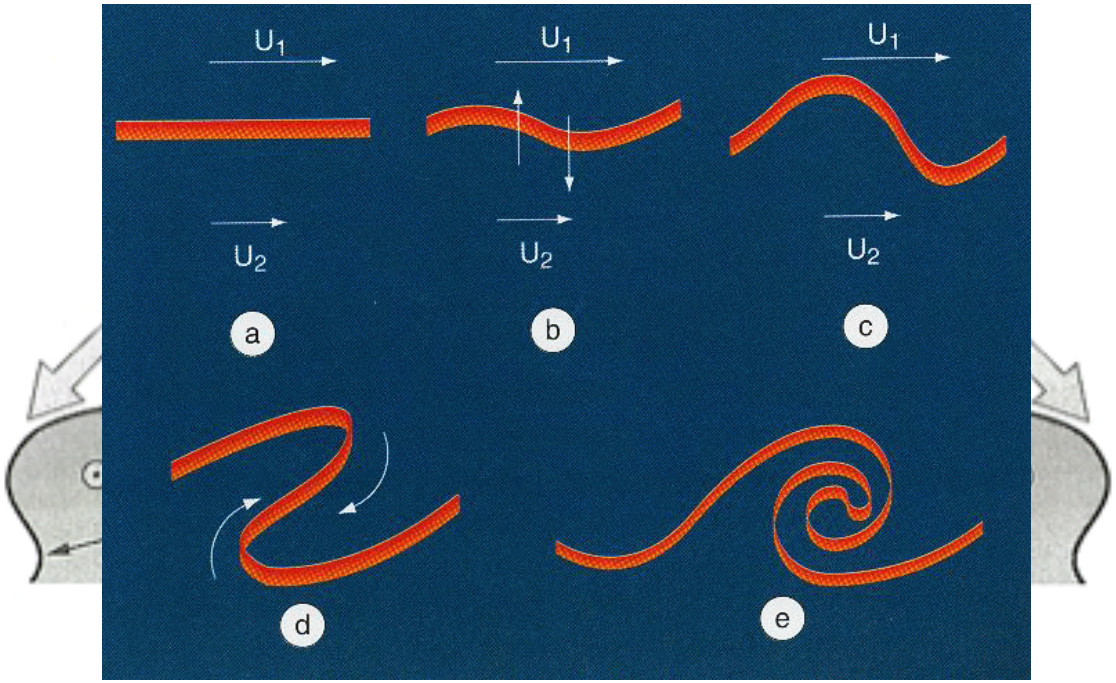
Watch the video

iSWA Layout:
07/12/2012

http://goo.gl/V0JjxV

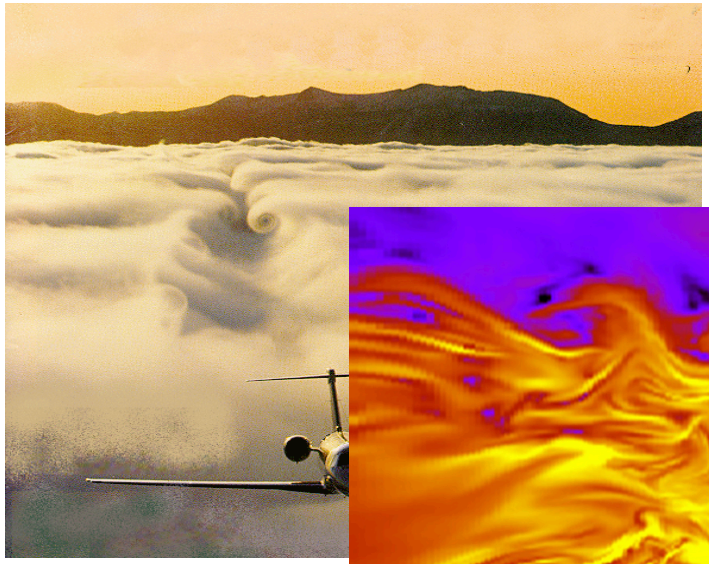
Magnetosphere Physics Research

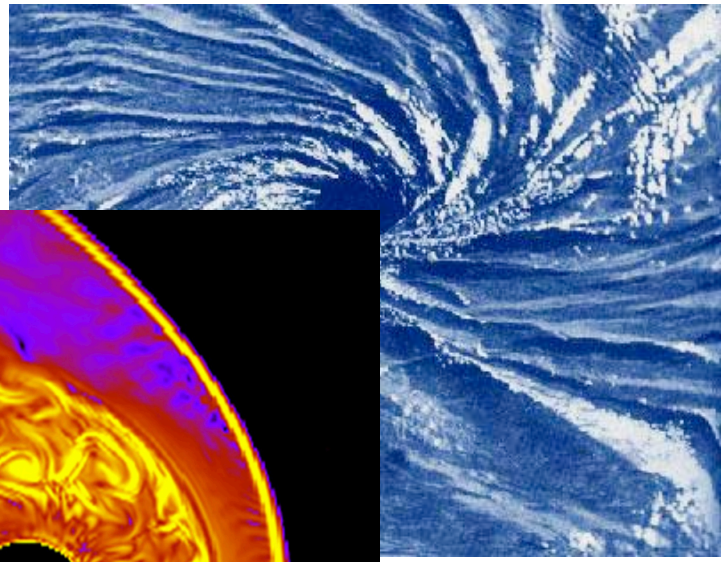
Kelvin-Helmholtz Instability

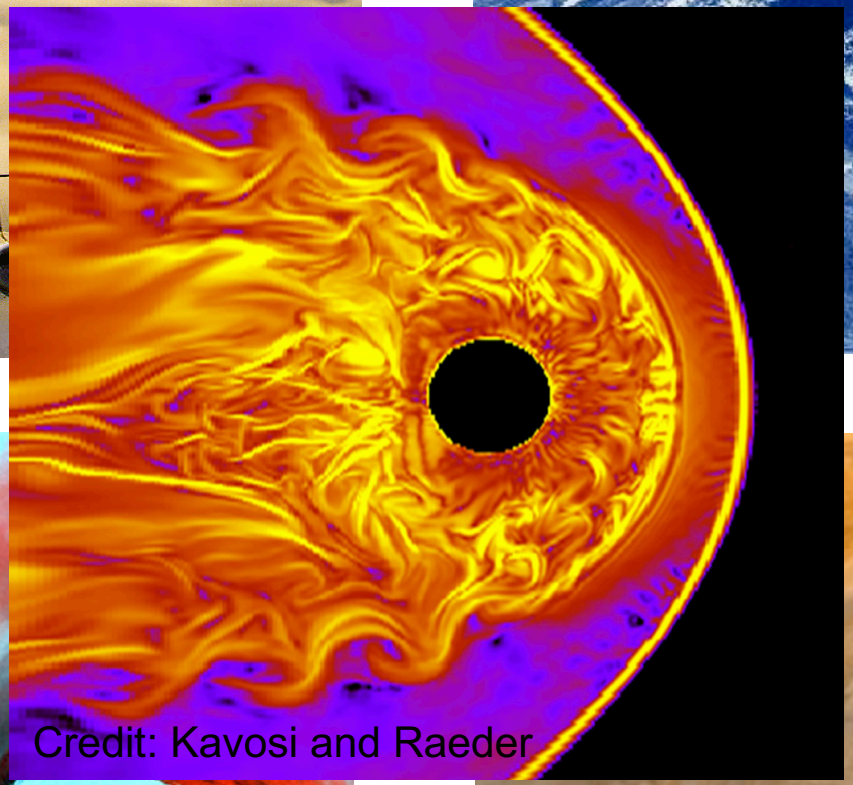


- Waves that occur between the velocity shear of two fluids.
- It creates vortices on the magnetopause, specially on the flanks.
- Predominantely at high solar wind velocities and northward IMF (positive Bz) component.
- Many scientific models have been created to study these two parameters: the flow velocity and the magnetic field.

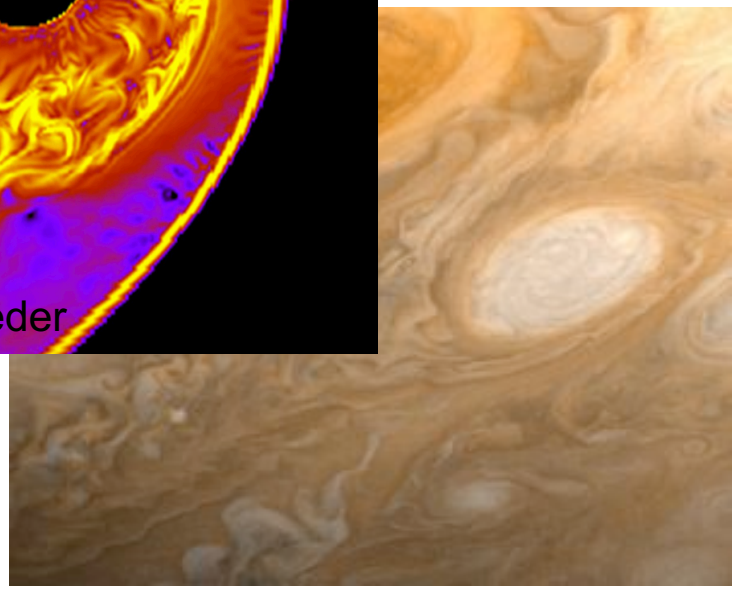
Examples of Kelvin-Helmholtz Instability





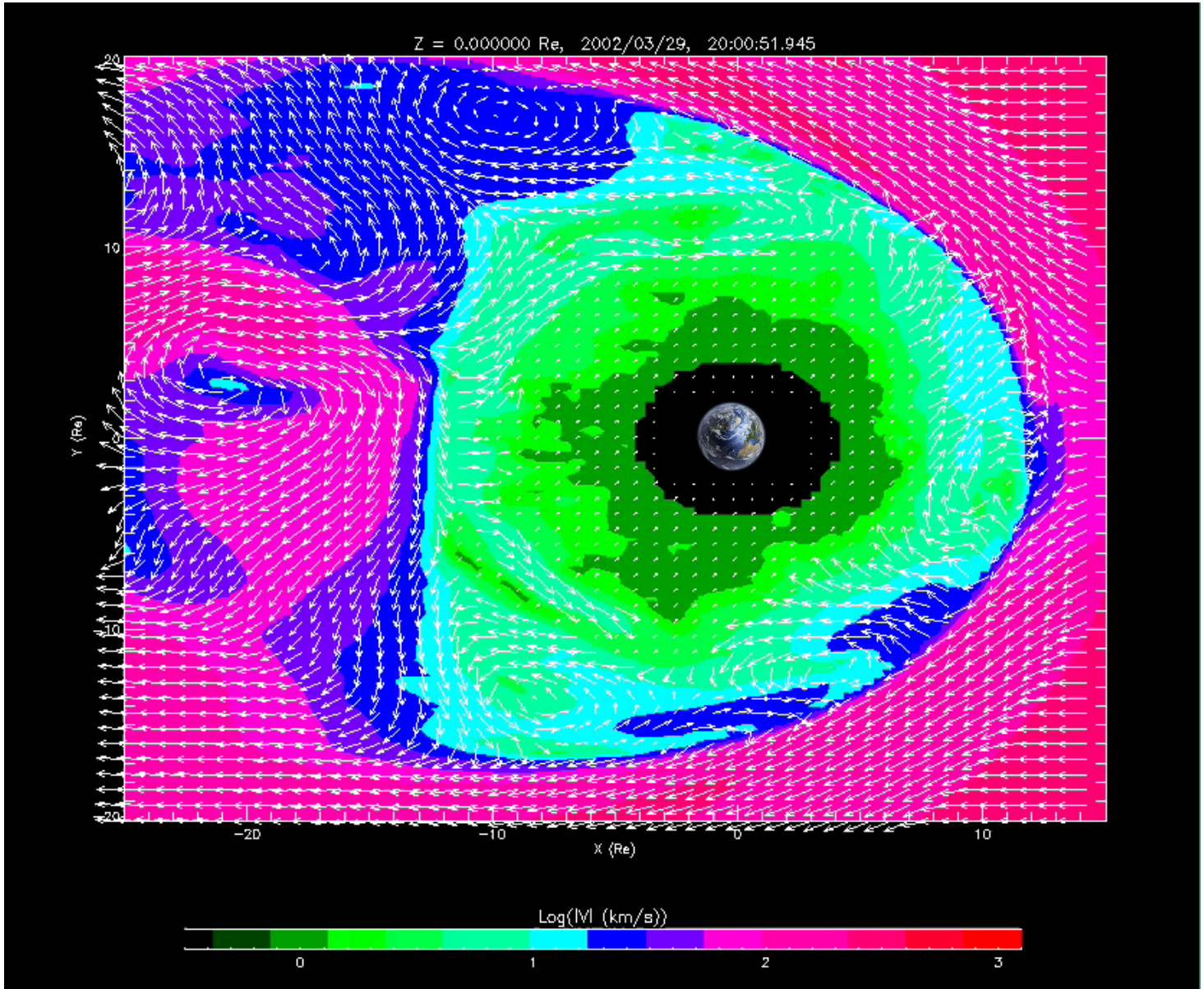


Credit: Kavosi and Raeder



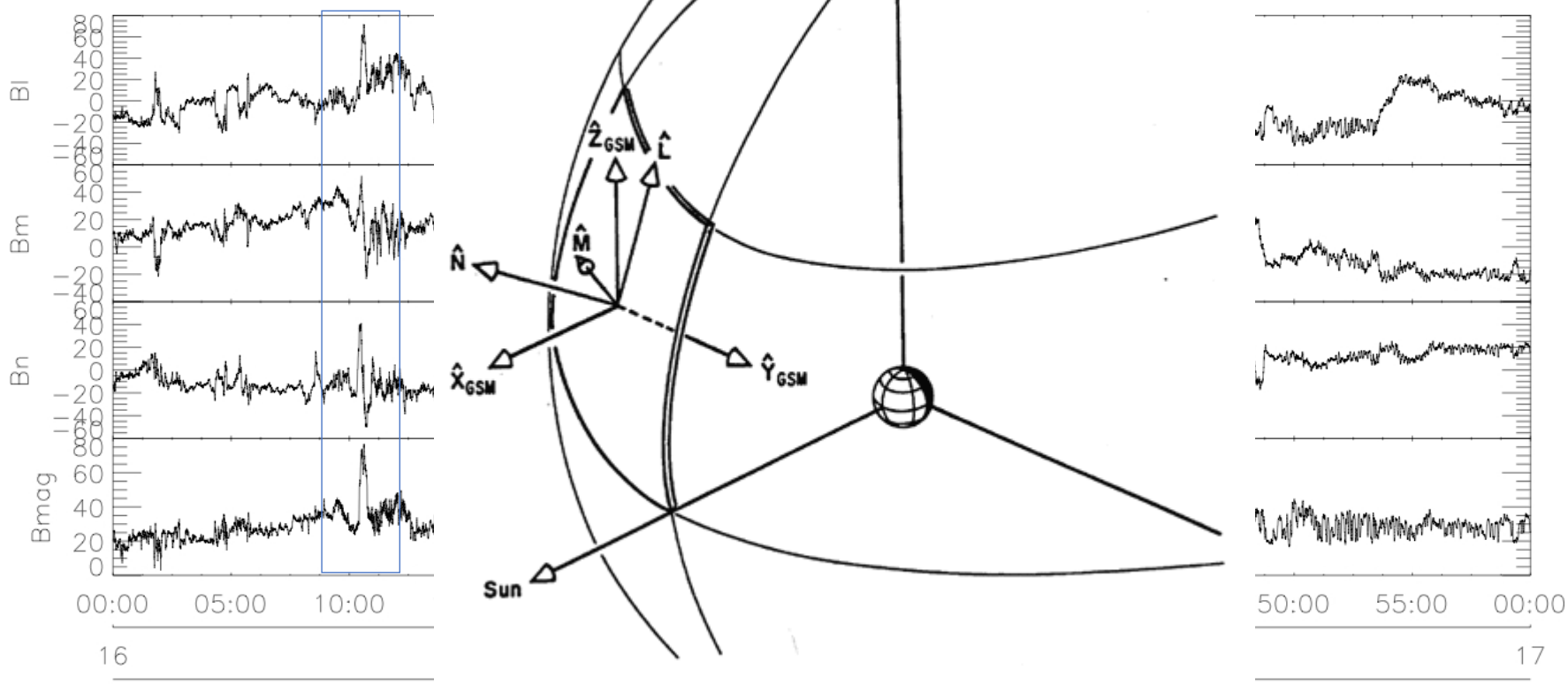
Magnetosphere Physics Research

Collado-Vega, Y. M., et al., JGR, 2007 and 2013



Flux Transfer Events (FTEs)

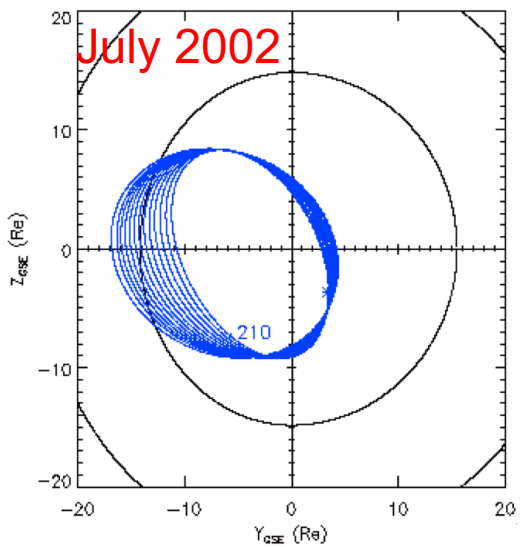
Flux Transfer Events (FTE's) are magnetopause signatures that result from the passage of flux ropes produced by reconnection.

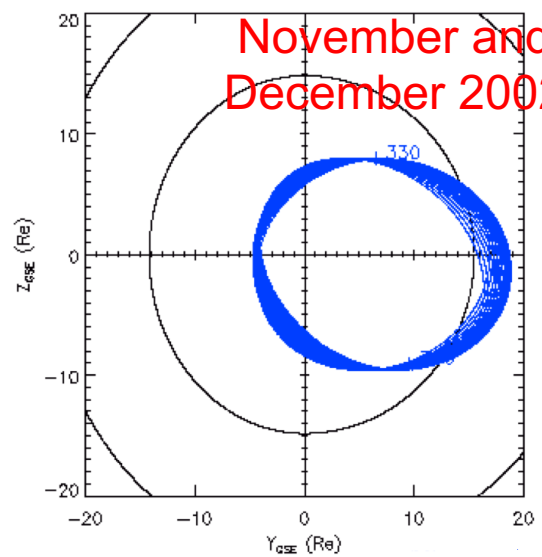


From Collado-Vega, Y. M., Ph.D. Thesis, 2013

Largest – 386 km/s

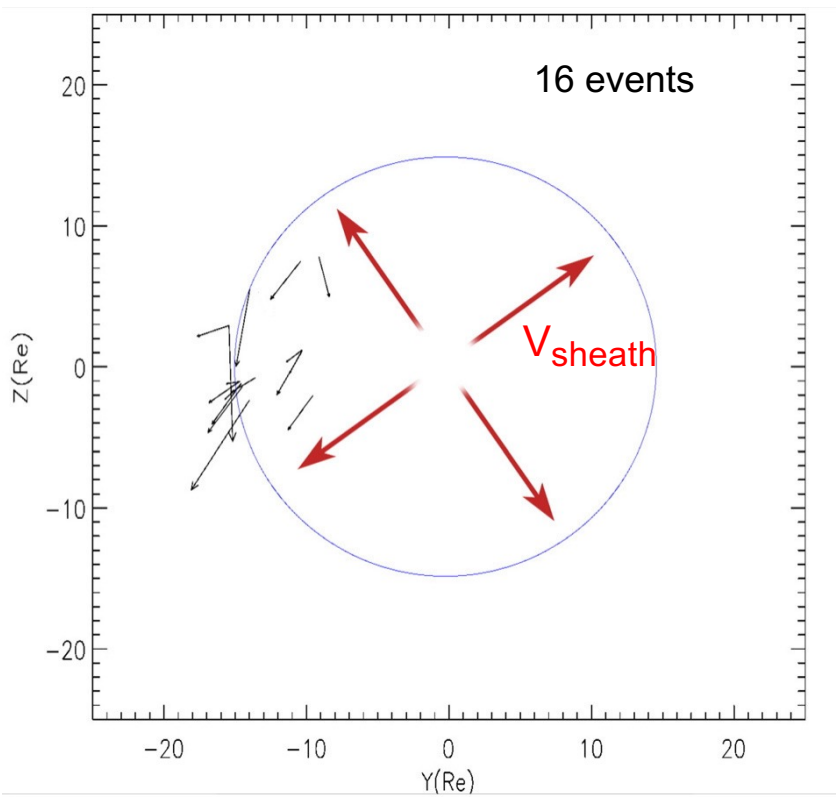
Smallest – 90 km/s

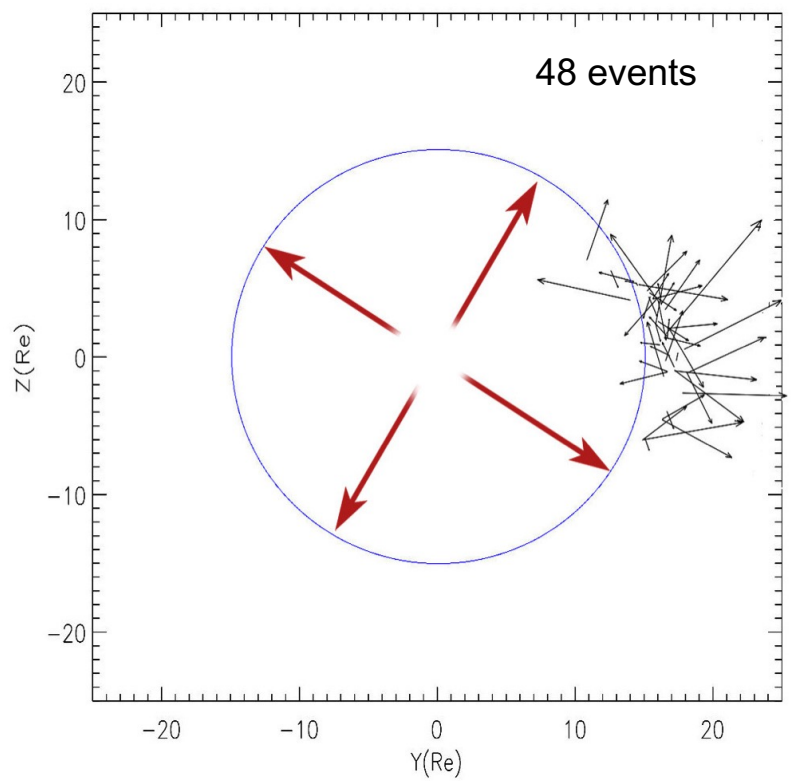




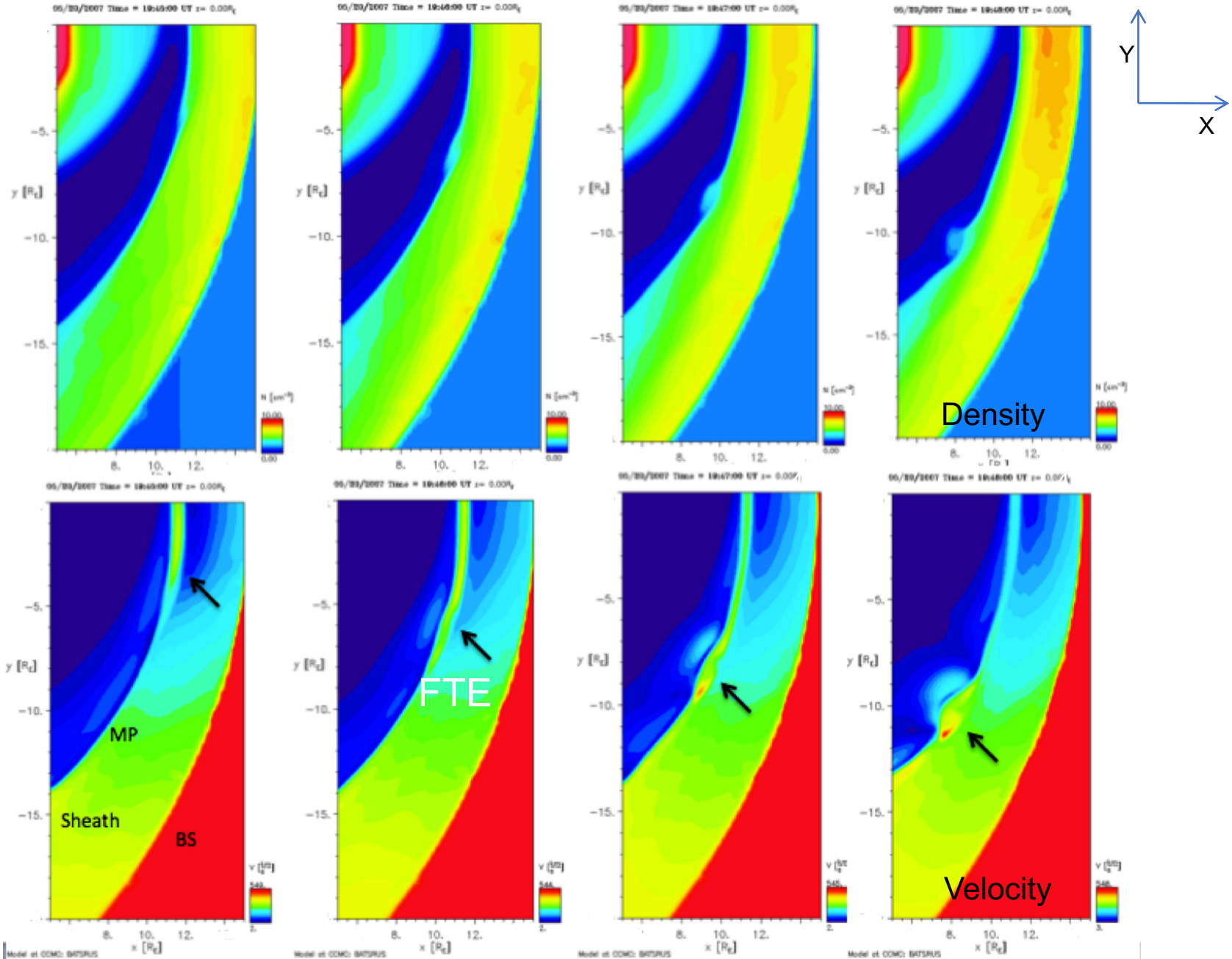
Largest – 412 km/s

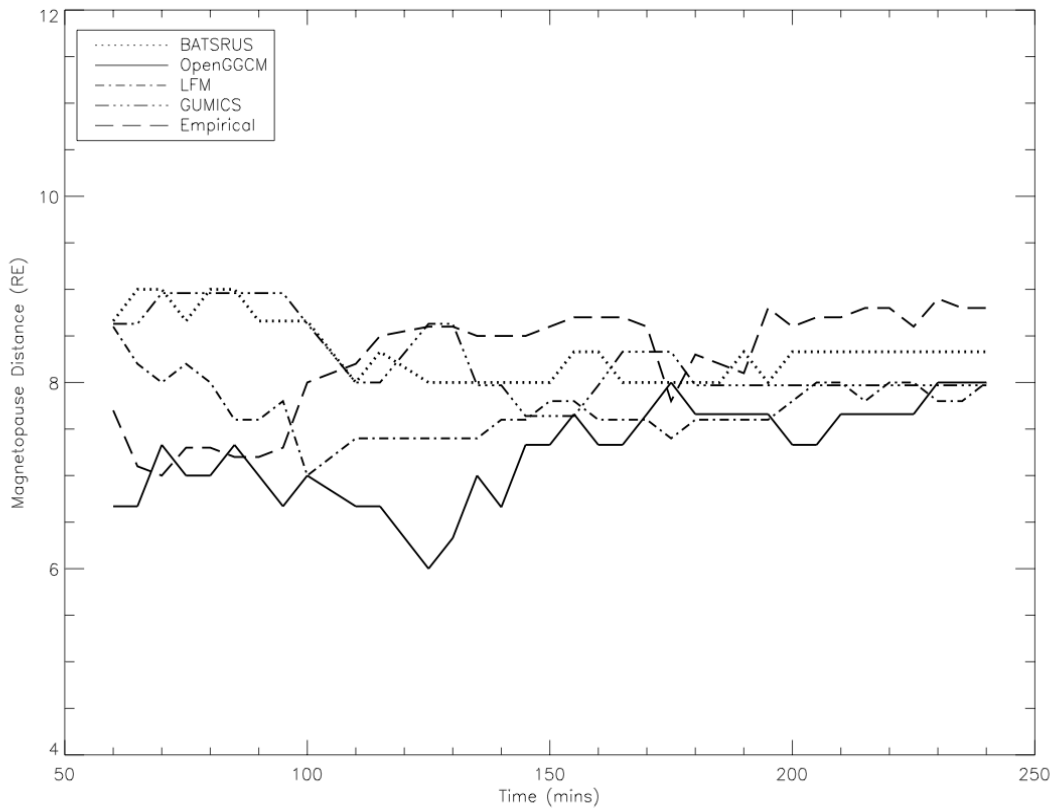
Smallest – 92 km/s





MHD Simulations (19:45-19:48 UT)



Magnetopause Stand-off Position

From Collado-Vega, Y. M., et al., In progress