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CENTER

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



**Space  
Weather  
Research  
Center**

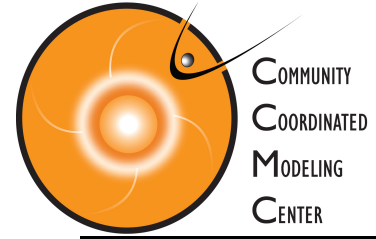
Presented by:  
Dr. Yaireska (Yari) Collado-Vega

**CCMC/SWRC**

**NASA Goddard Space Flight Center**

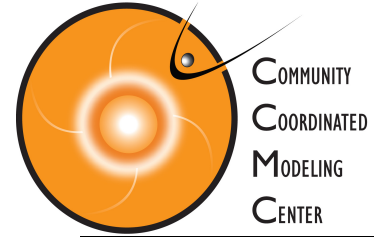
**Thanks to the CCMC/SWRC team**

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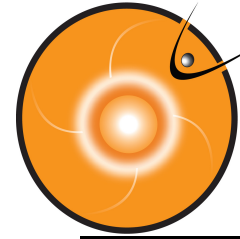
# The Sun



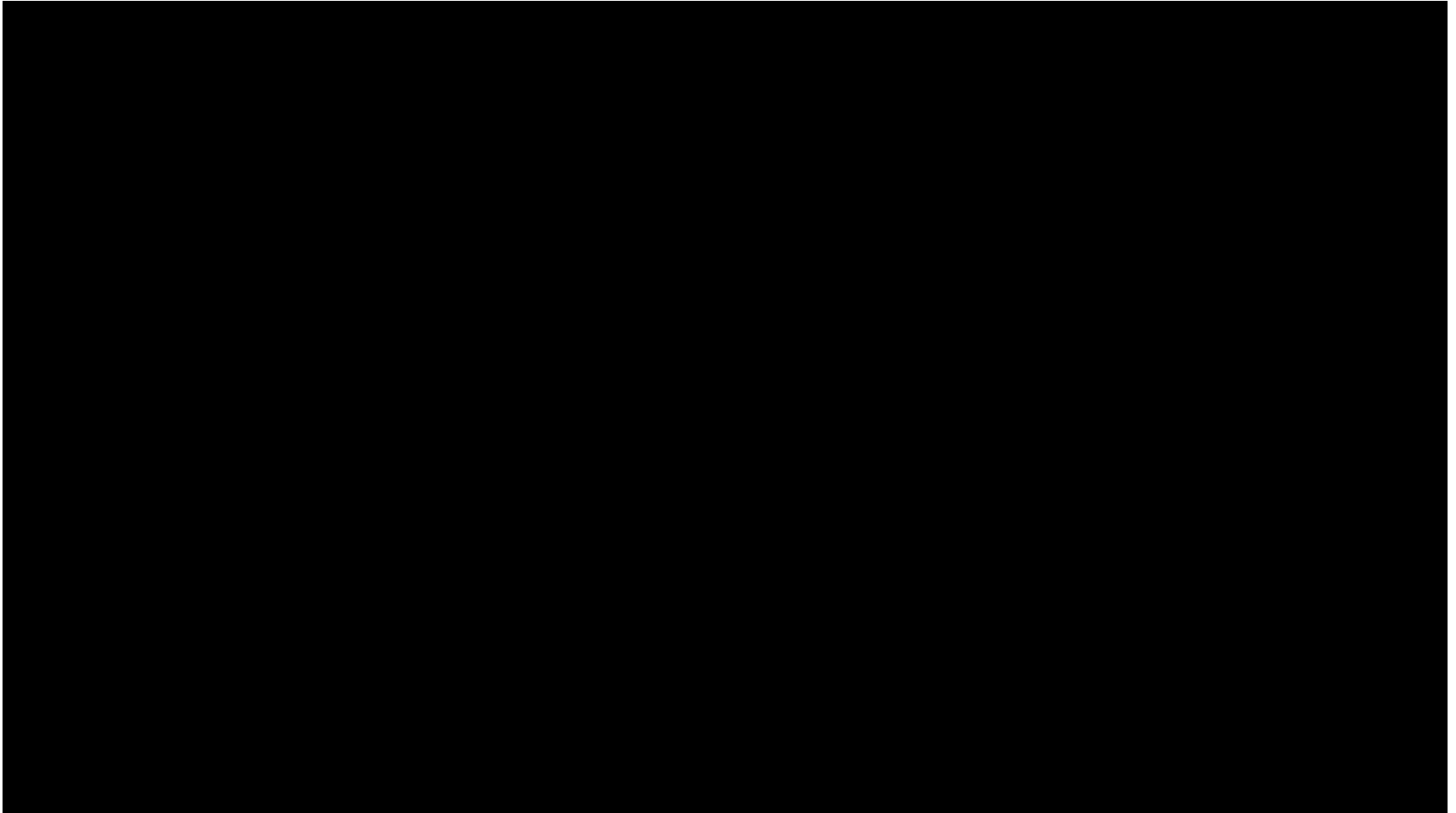


# The Sun's Rainbow



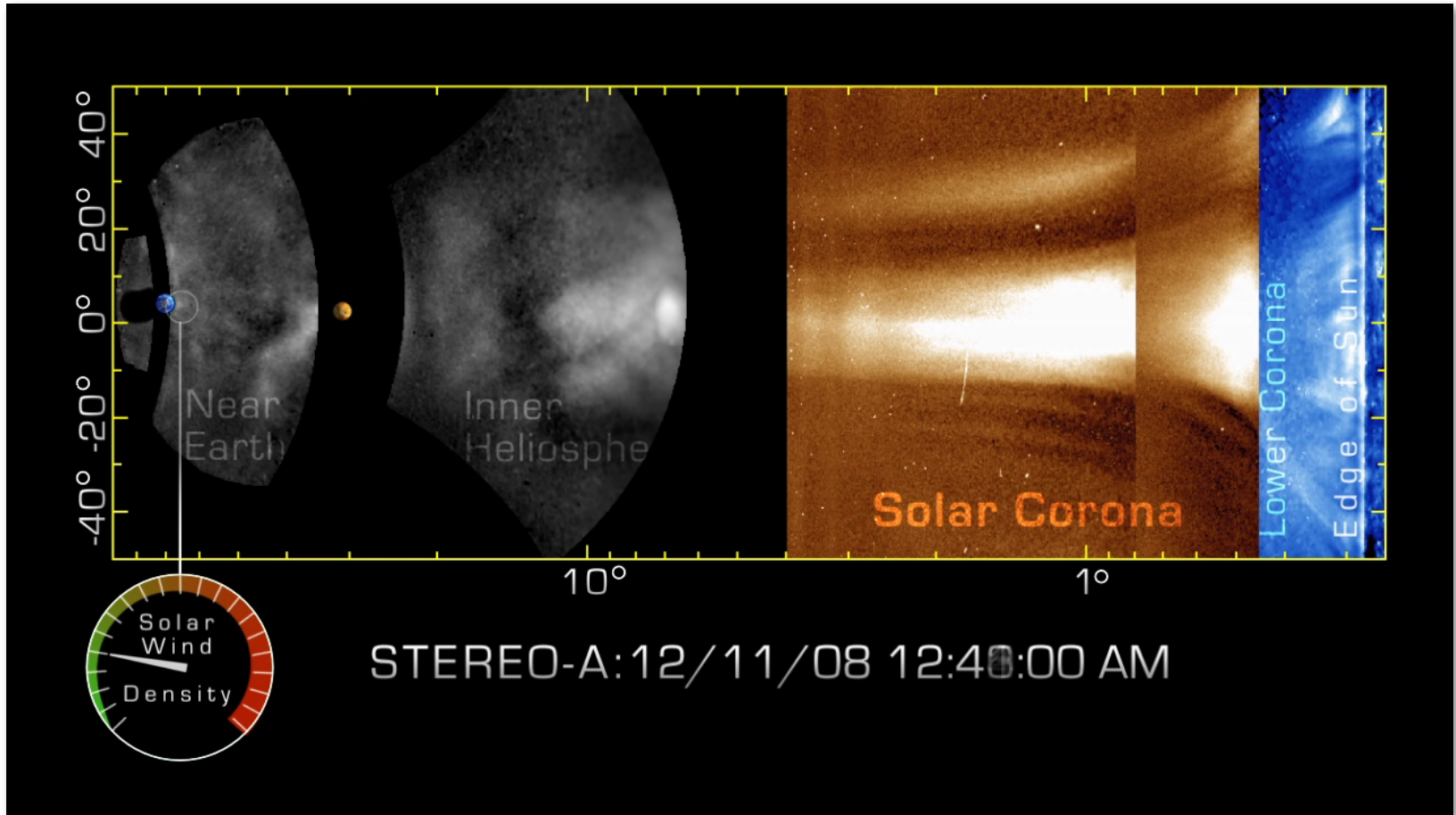


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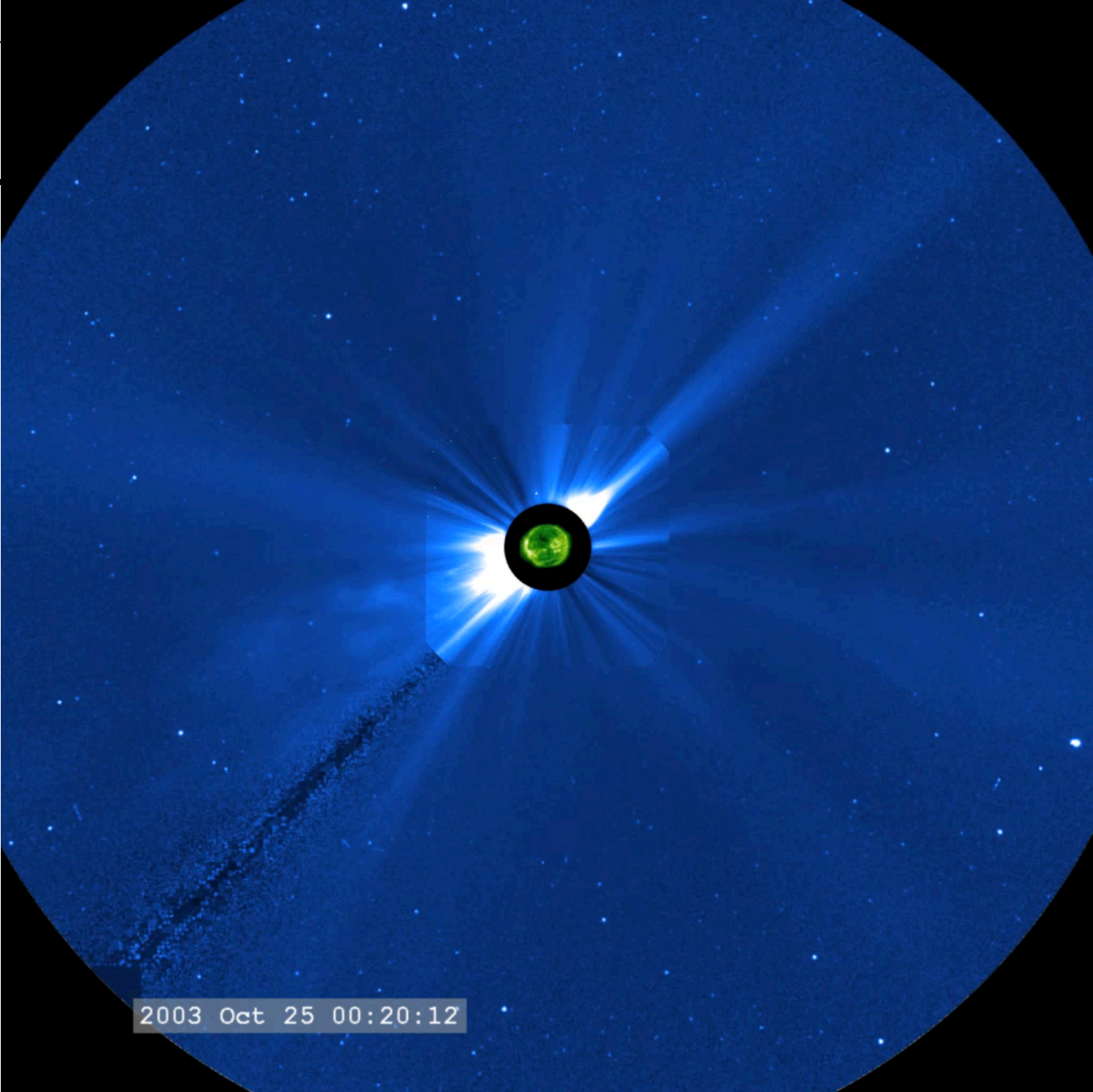
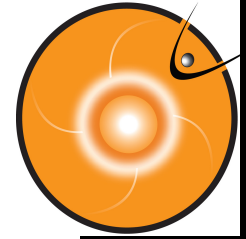




# CME propagation

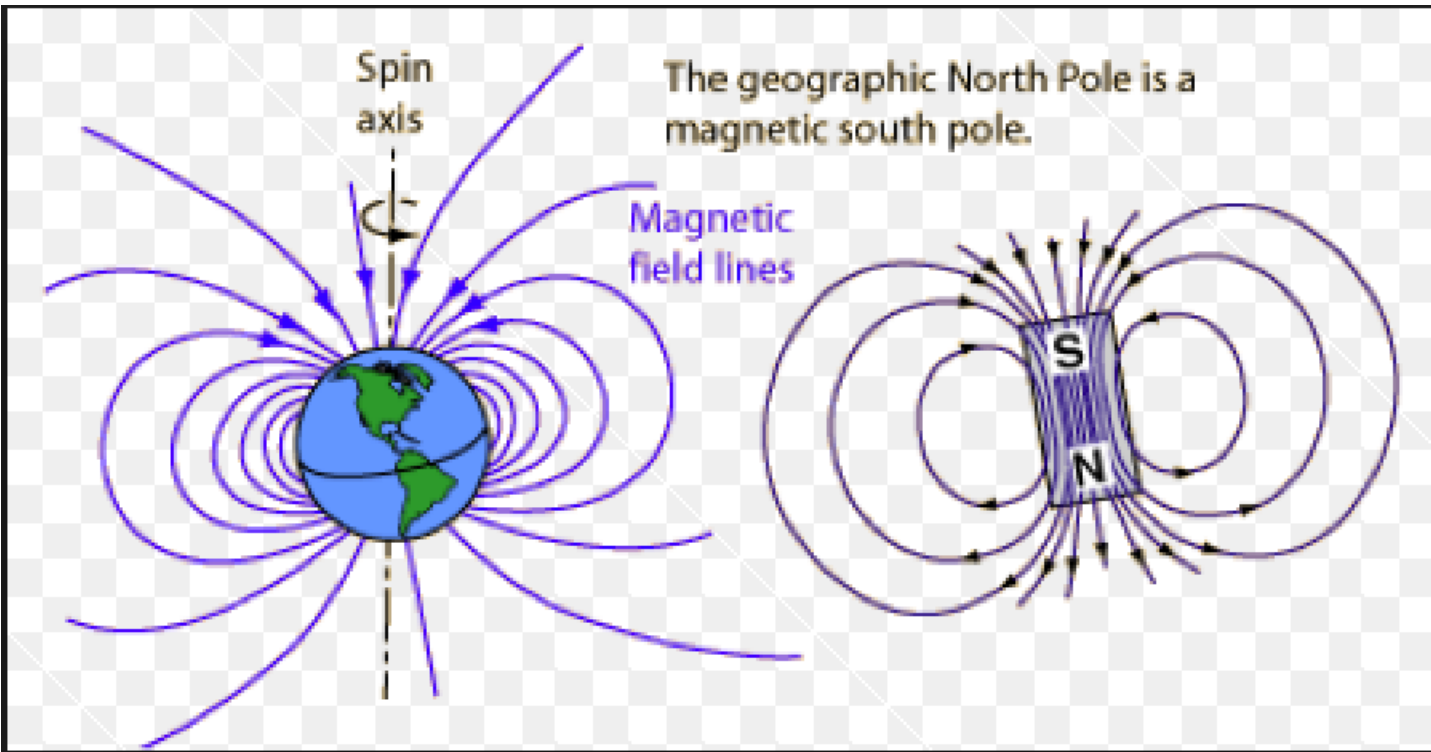


CME propagation to the Earth takes typically 2-4 days.



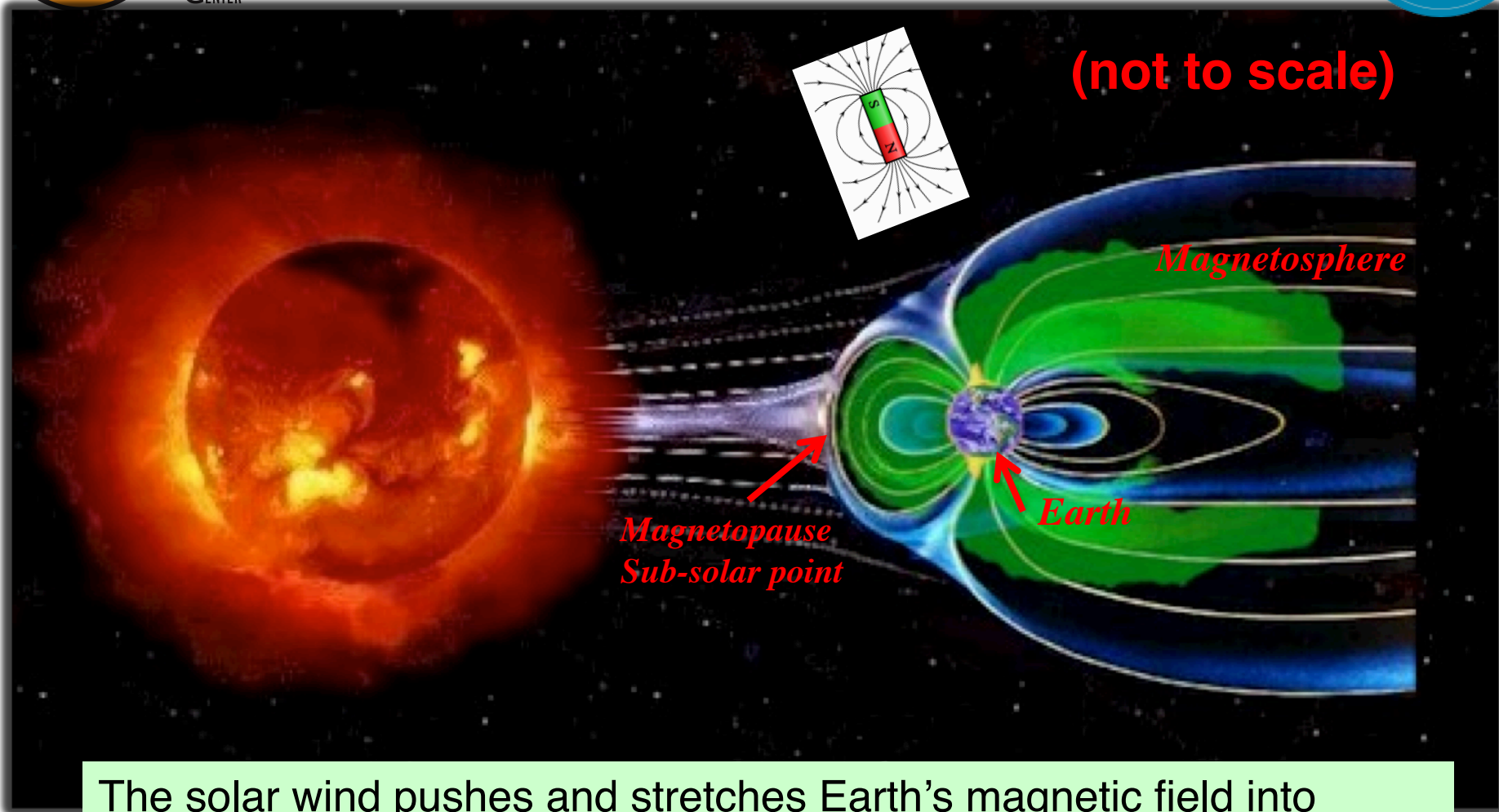
2003 Oct 25 00:20:12

# Magnetic Field of the Earth



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

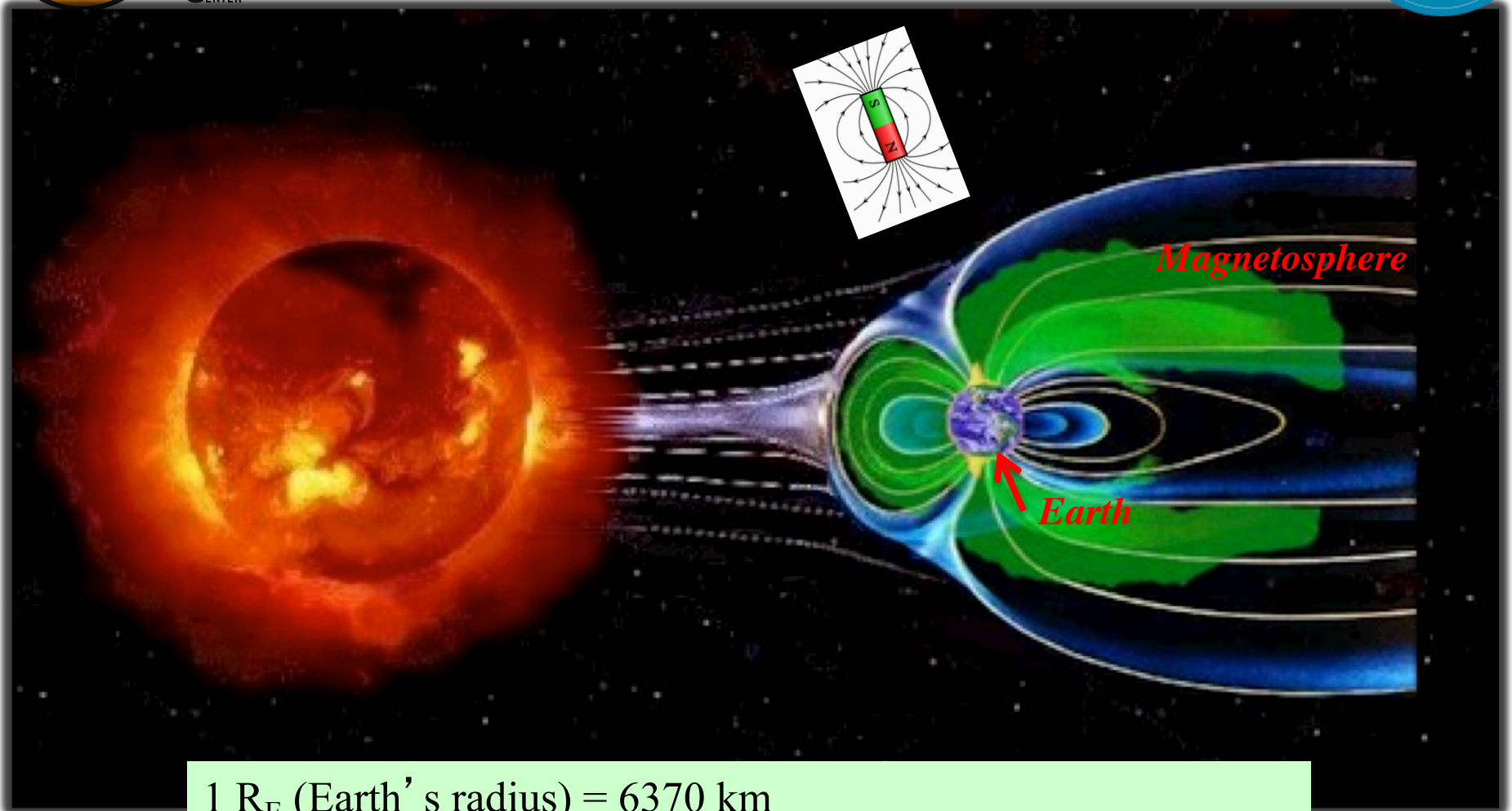
# Earth's Magnetic Field



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

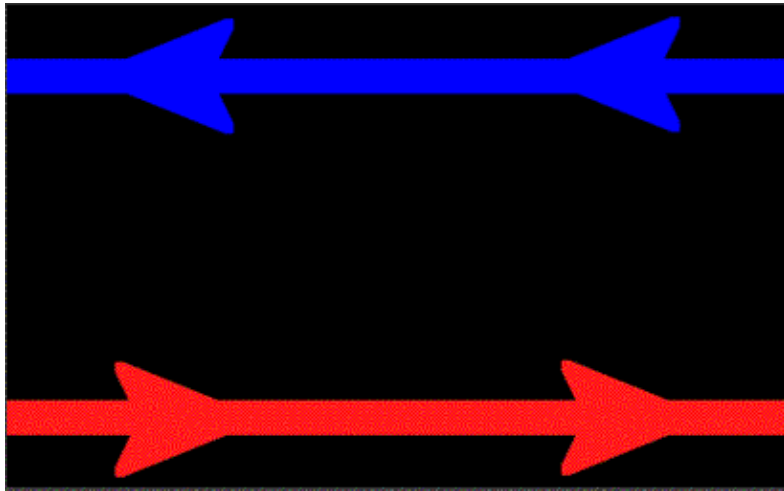


1  $R_E$  (Earth's radius) = 6370 km

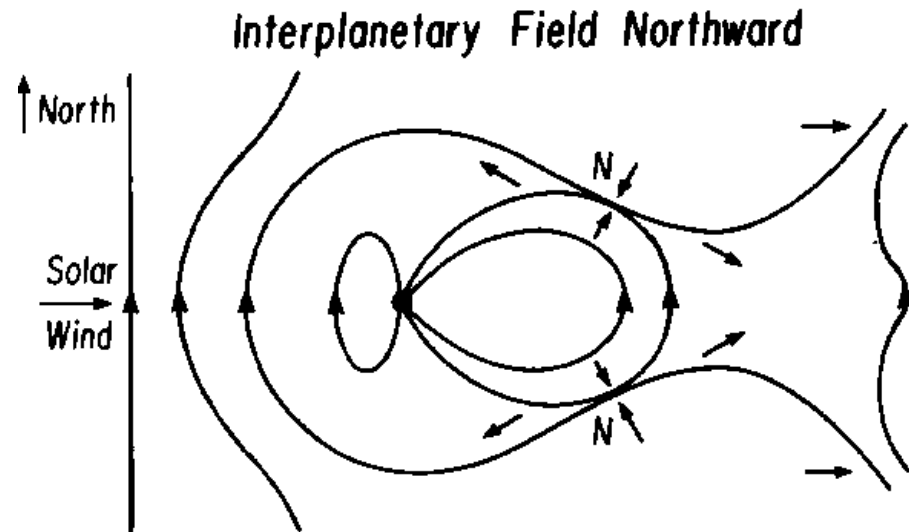
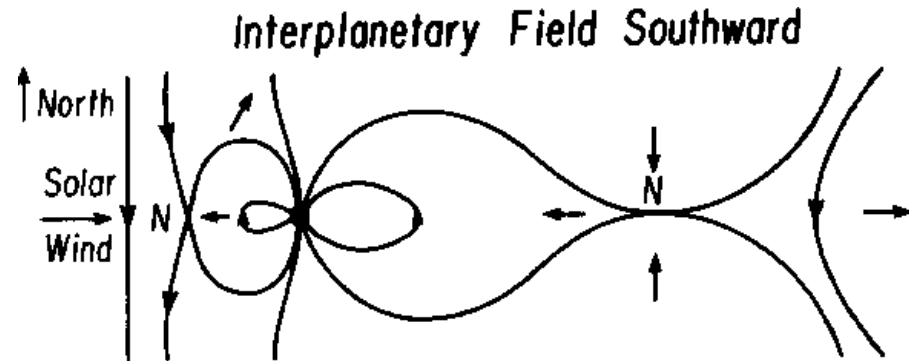
1  $R_S$  (Solar radius)  $\sim$  110  $R_E$

1 AU (Distance between the Sun and the Earth)  $\sim$  215  $R_S$

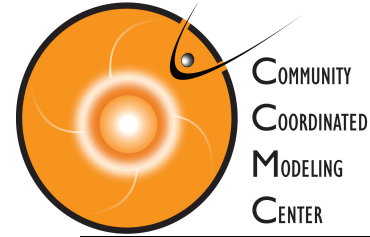
# Magnetosphere for Southward and Northward IMF Orientation



Magnetic Reconnection







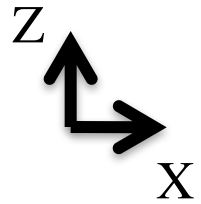
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# Magnetosphere: Northward IMF

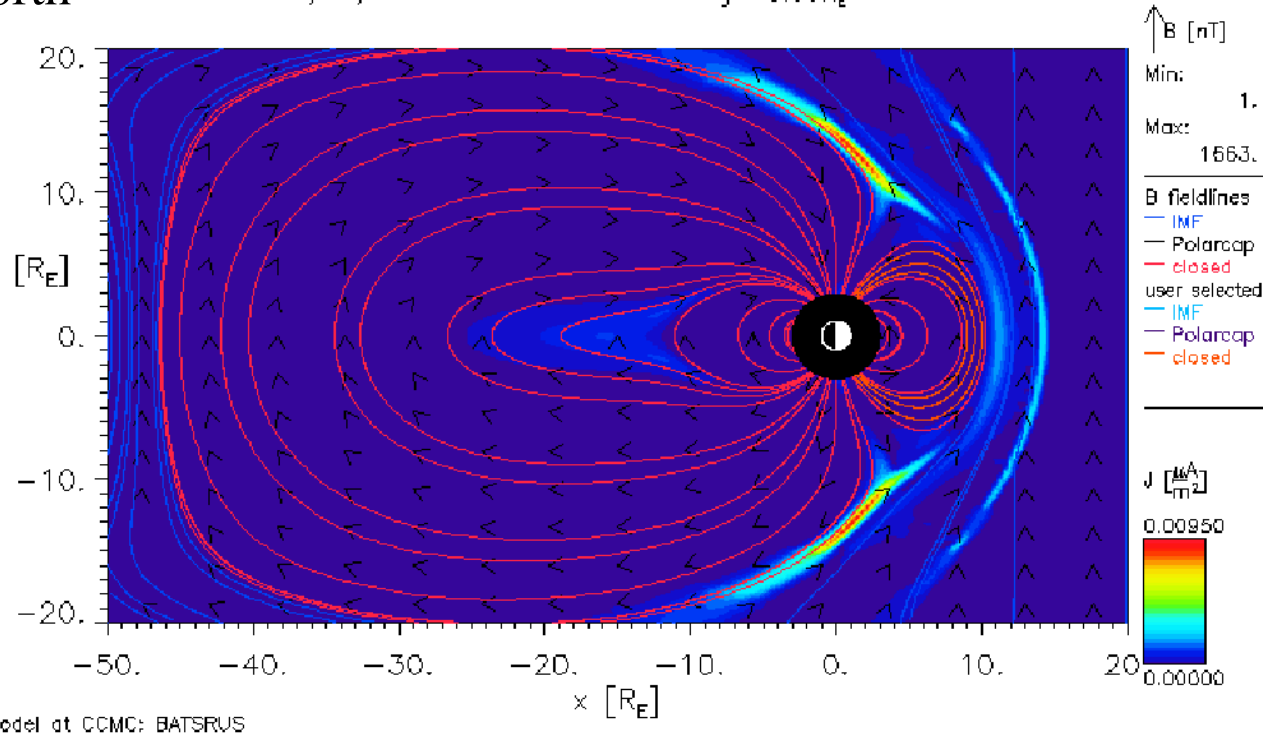


X: Earth to Sun

Z: South to North



01/01/2000 Time = 02:04:00 UT  $y = 0.00R_E$



Sun

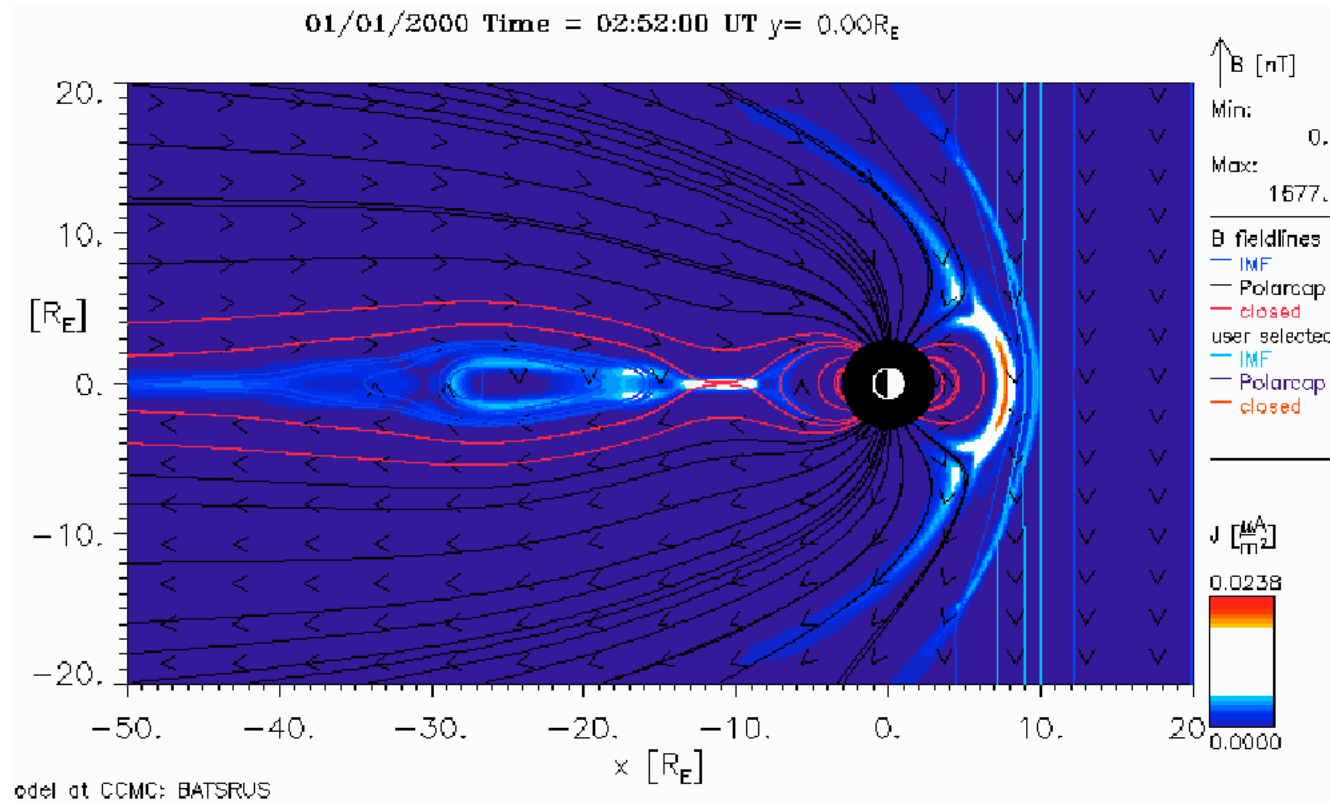
**Red lines** (closed): Magnetic field (MF) lines with both ends connected to the Earth

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

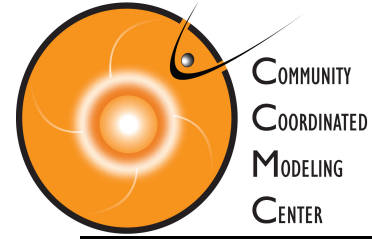
**Blue lines** (interplanetary): MF lines with both ends in the interplanetary space



# 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 at the Earth
- Blue lines** (interplanetary): MF lines with both ends in the interplanetary space



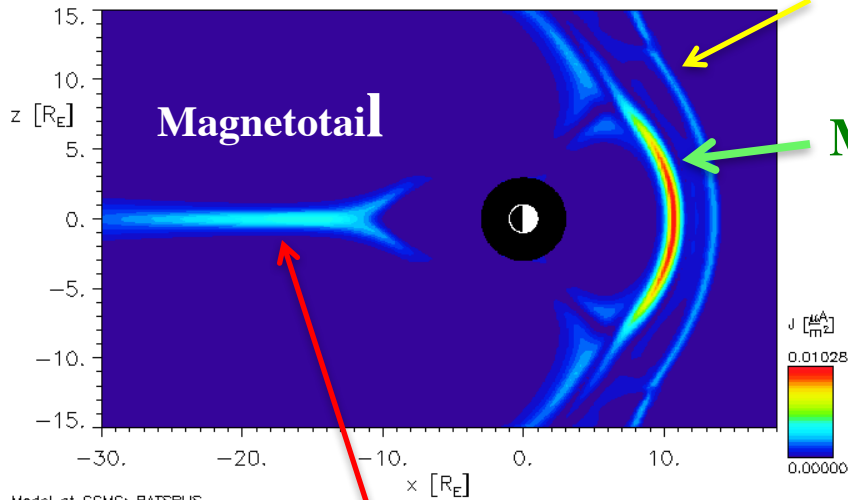
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# Magnetosphere in Different Cut Planes



meridional cut  $Y=0$

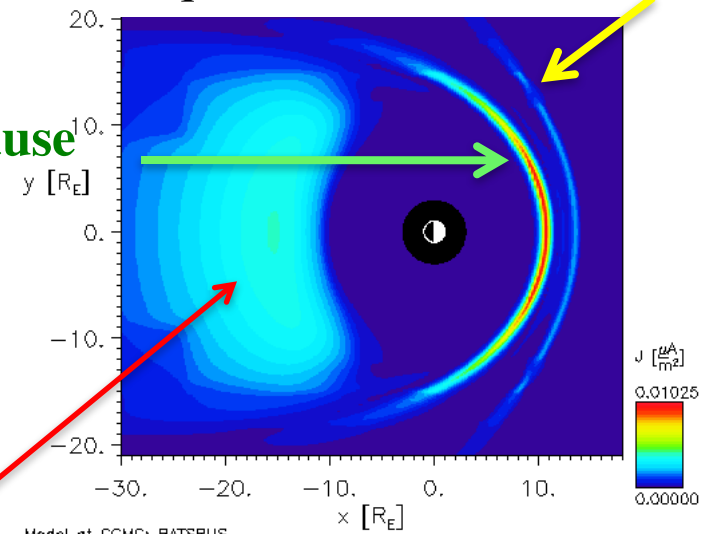
Bow shock



Model at CCMC: BATSRUS

equatorial cut  $Z=0$

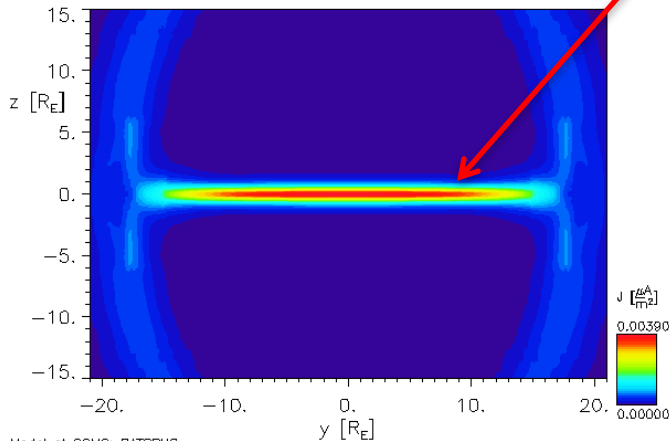
Bow shock



Model at CCMC: BATSRUS

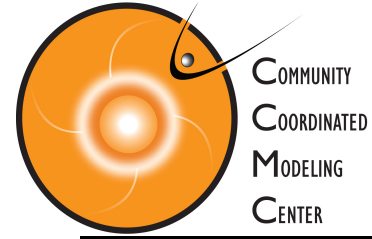
Magnetotail current sheet

01/01/2000 Time = 02:00:00 UT  $x = -15.0R_E$



Model at CCMC: BATSRUS

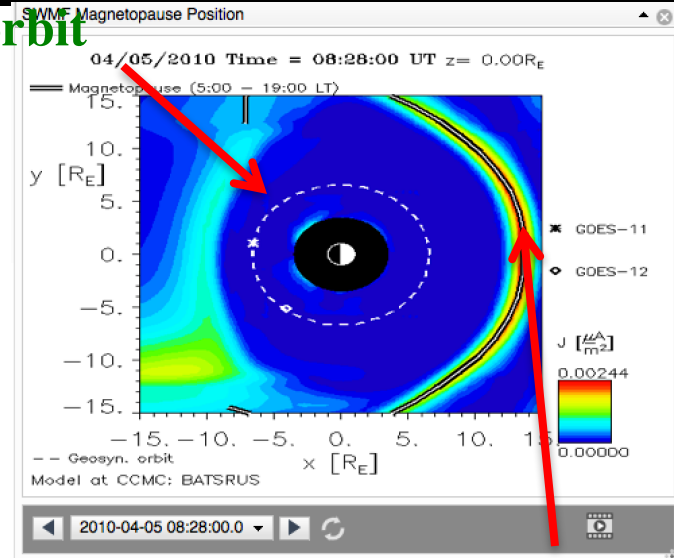
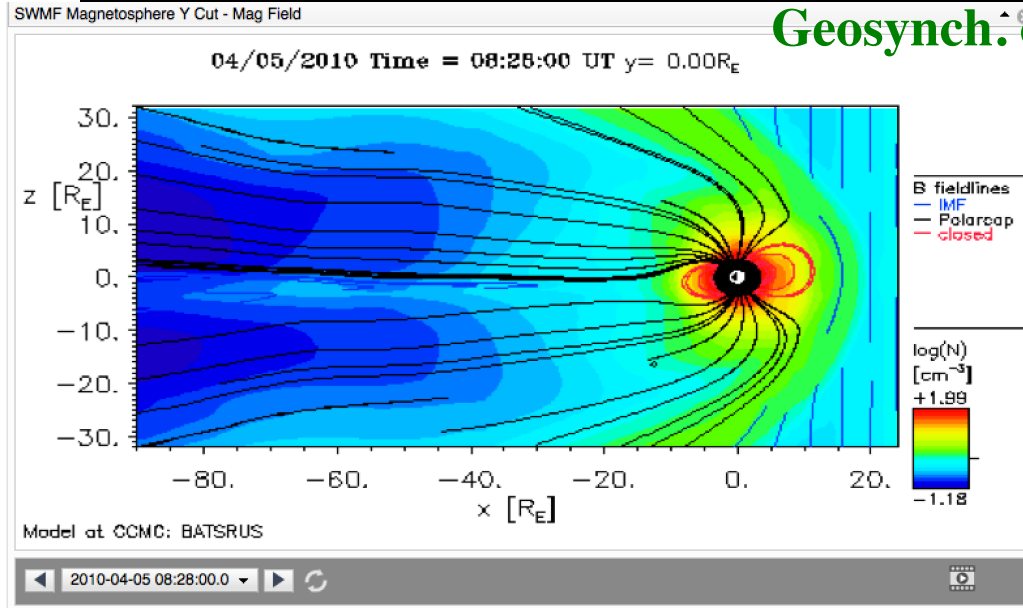
cross-tail cut  $X = -15 R_E$



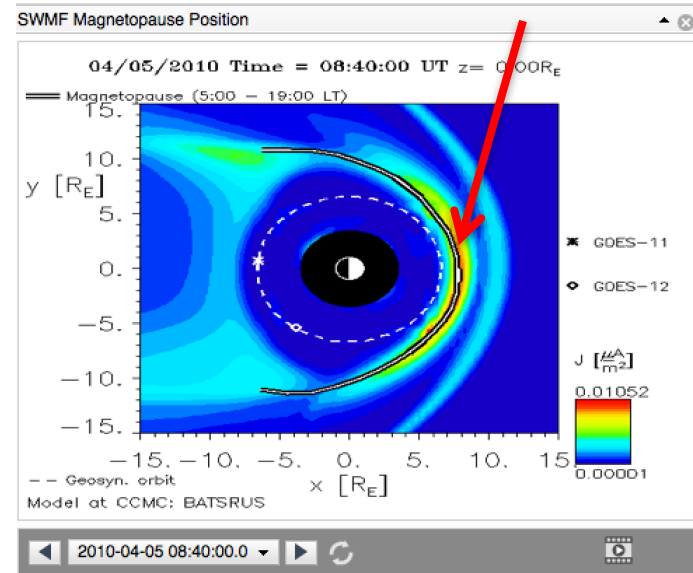
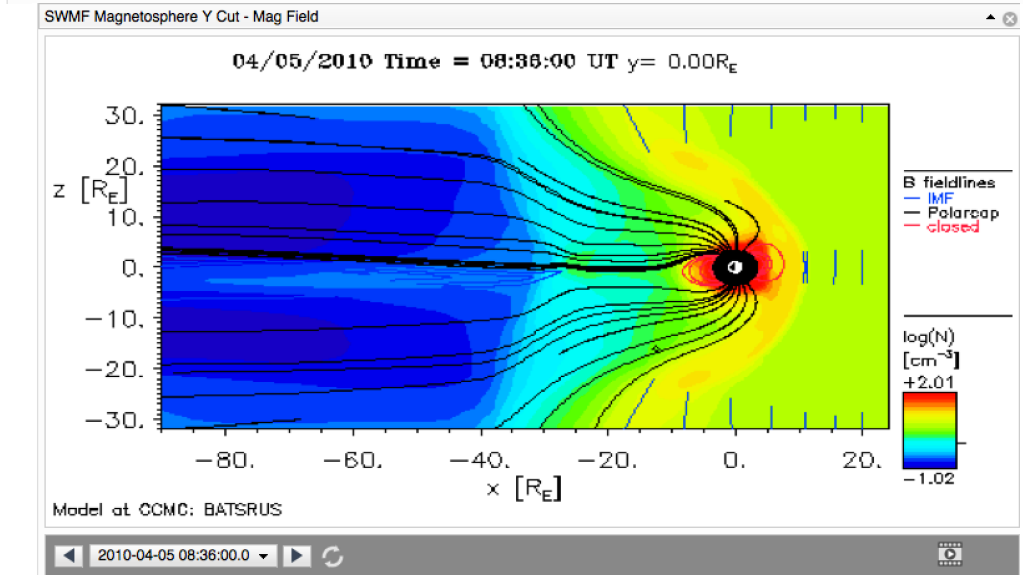
# Magnetosphere: Quiet vs. Compressed

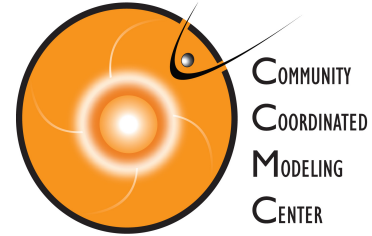


Geosynch. orbit



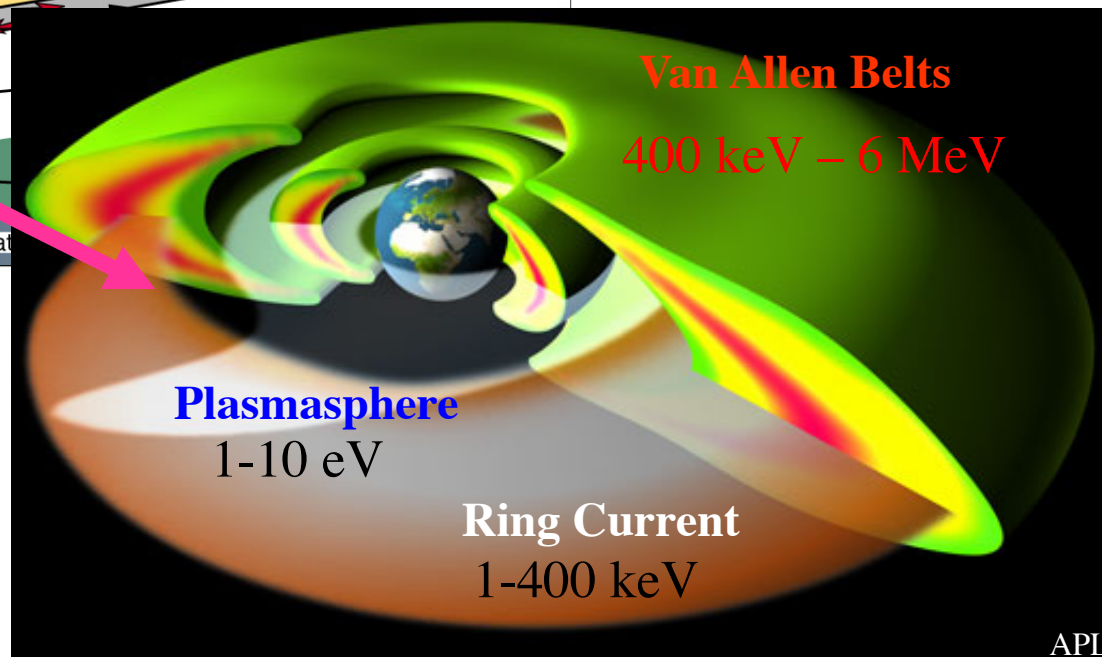
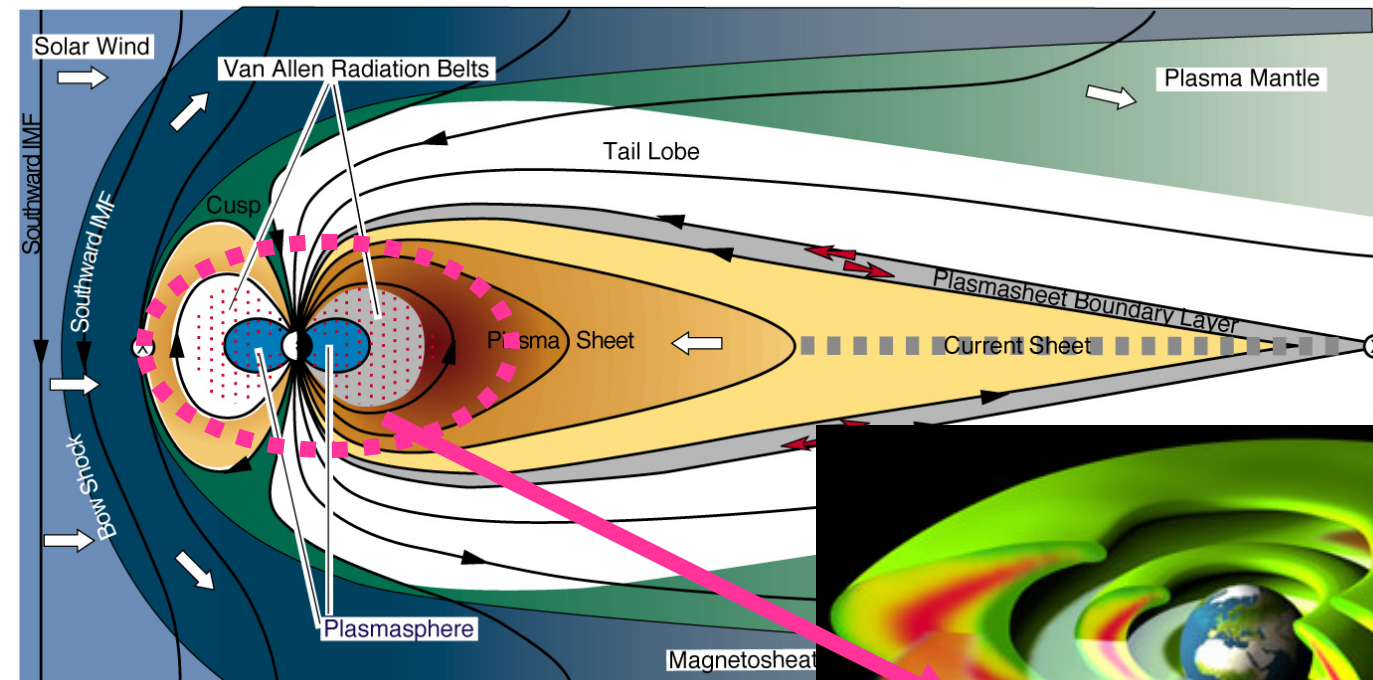
Magnetopause





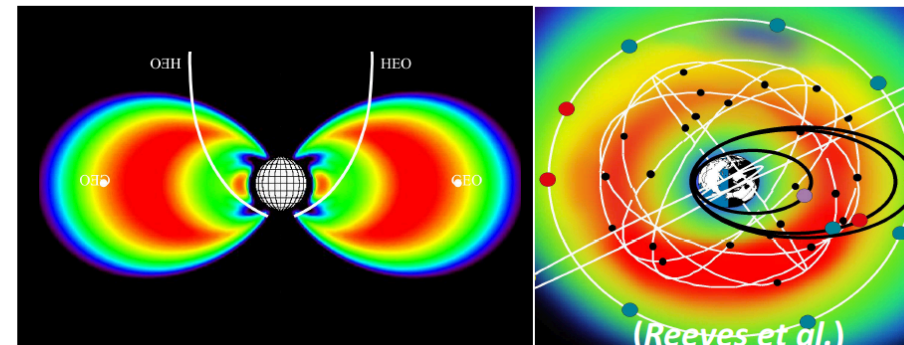
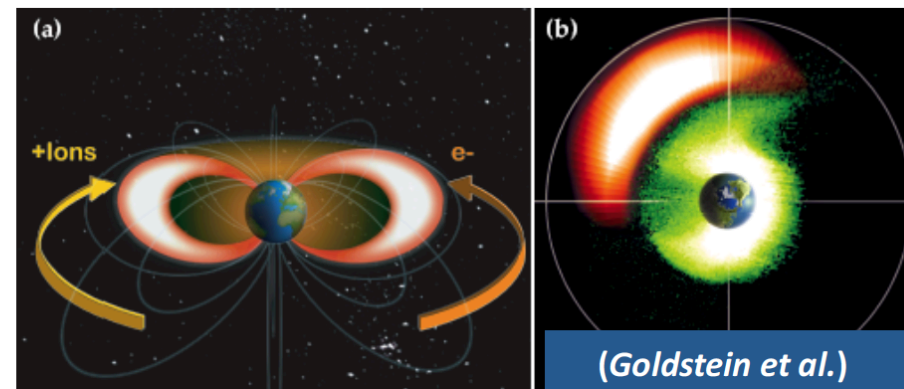
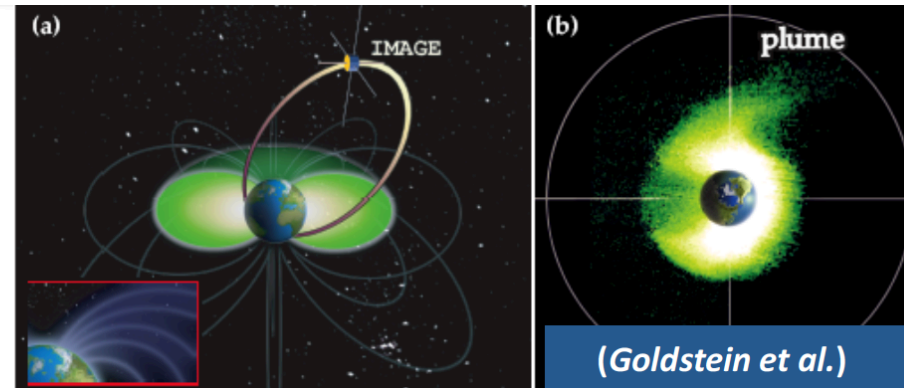
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# Inner Magnetosphere (up to ~ 10 RE)

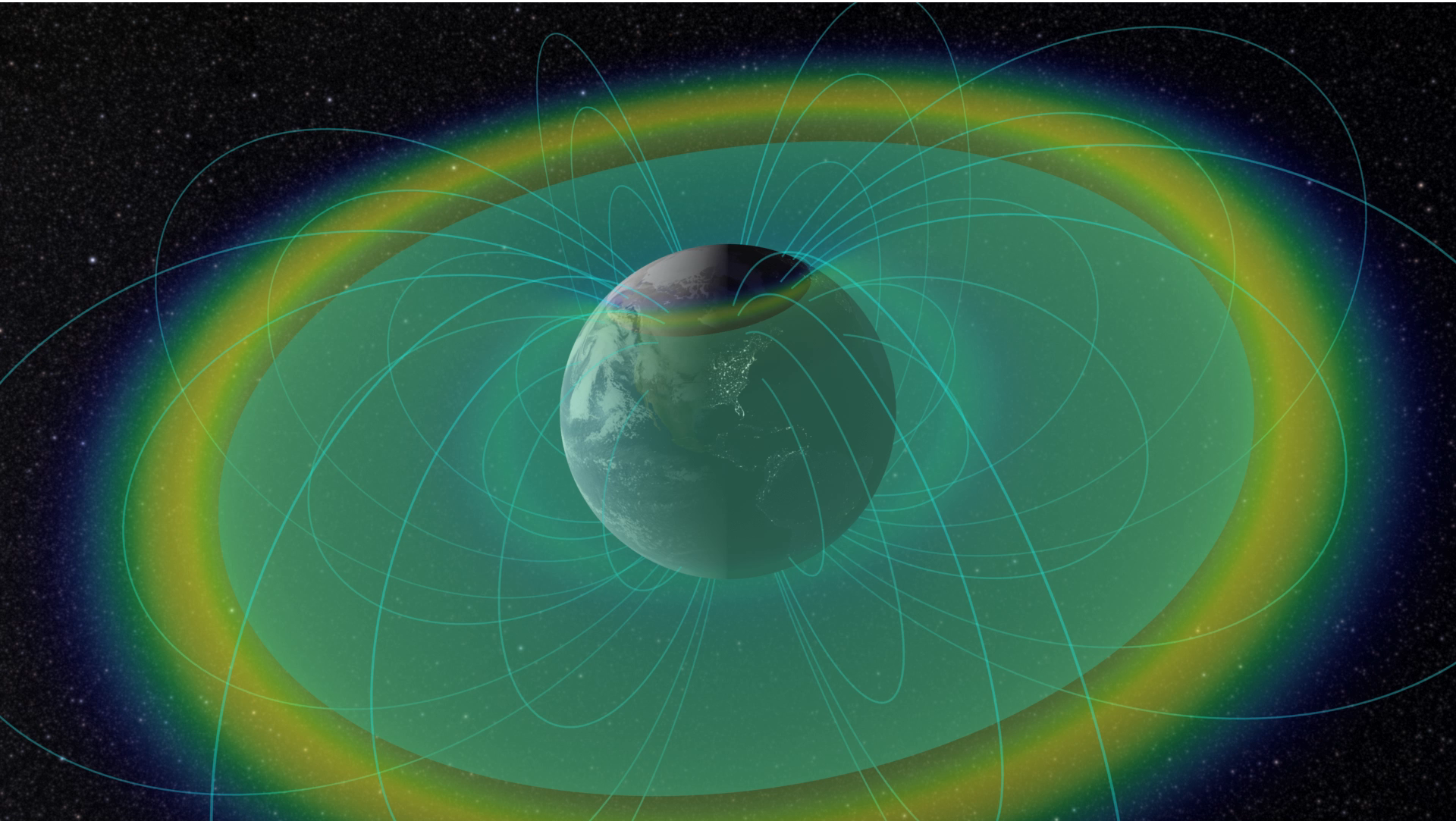
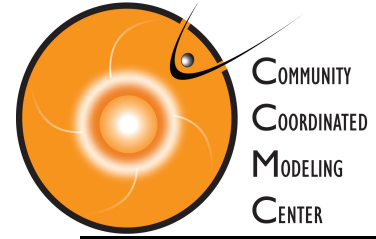


- Plasmasphere
  - 1-10 eV ions
  - ionospheric origin
- Ring current
  - 1-400 keV ions
  - both ionospheric and solar wind origin
- Outer radiation belt
  - 0.4-10 MeV electrons
  - magnetospheric origin

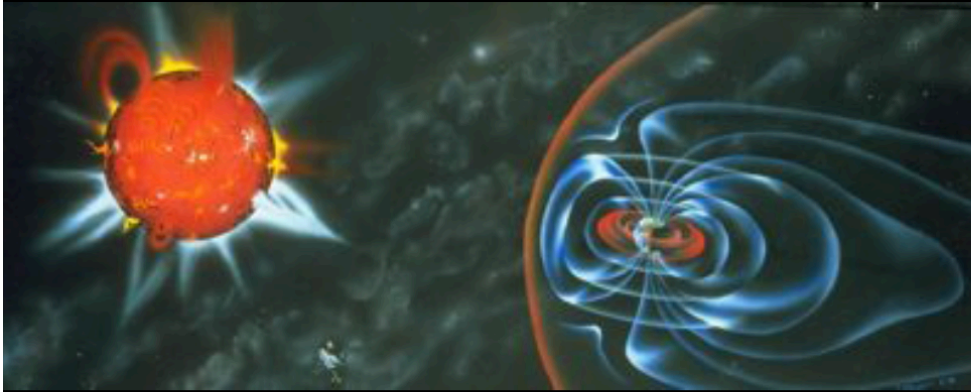
Inner magnetosphere: Gigantic Particle accelerator





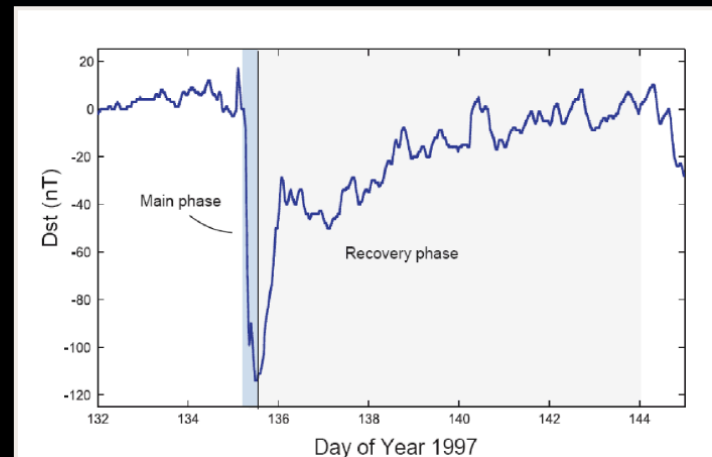


# Magnetic Storms



- 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

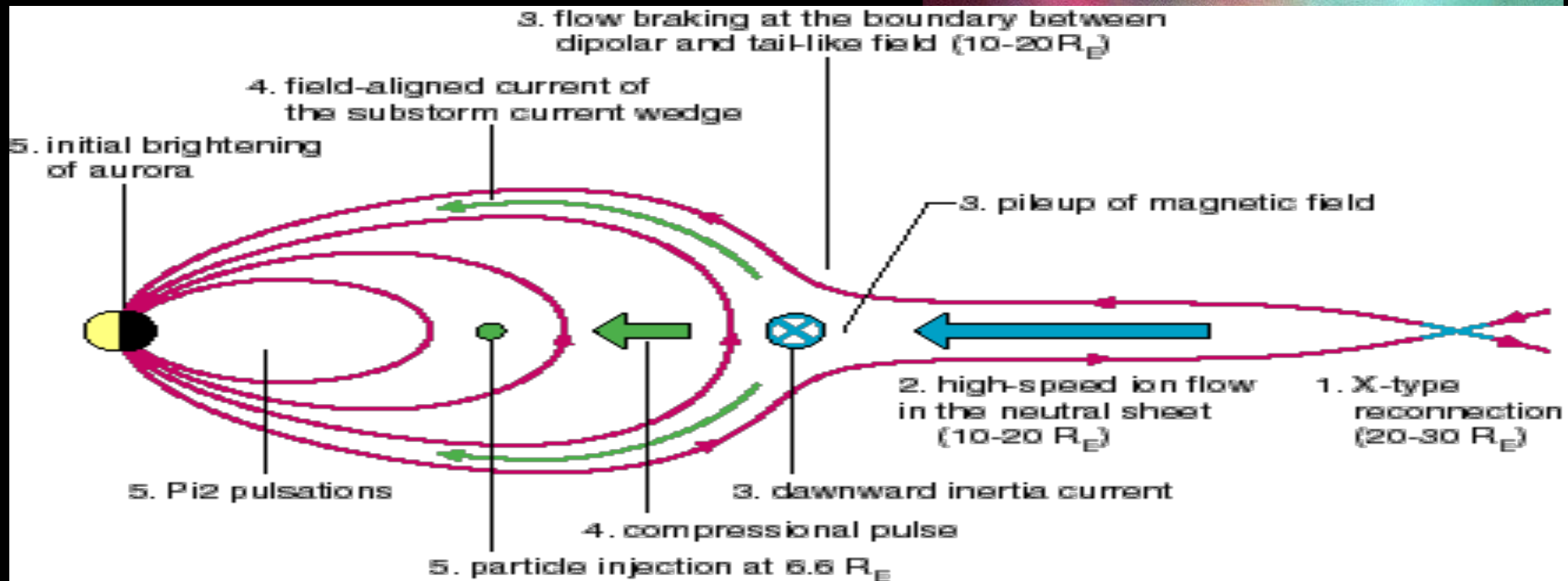
- Dst measures ring current development
  - Storm sudden commencement (SSC), main phase, and recovery phase
  - Duration: days



# Substorms



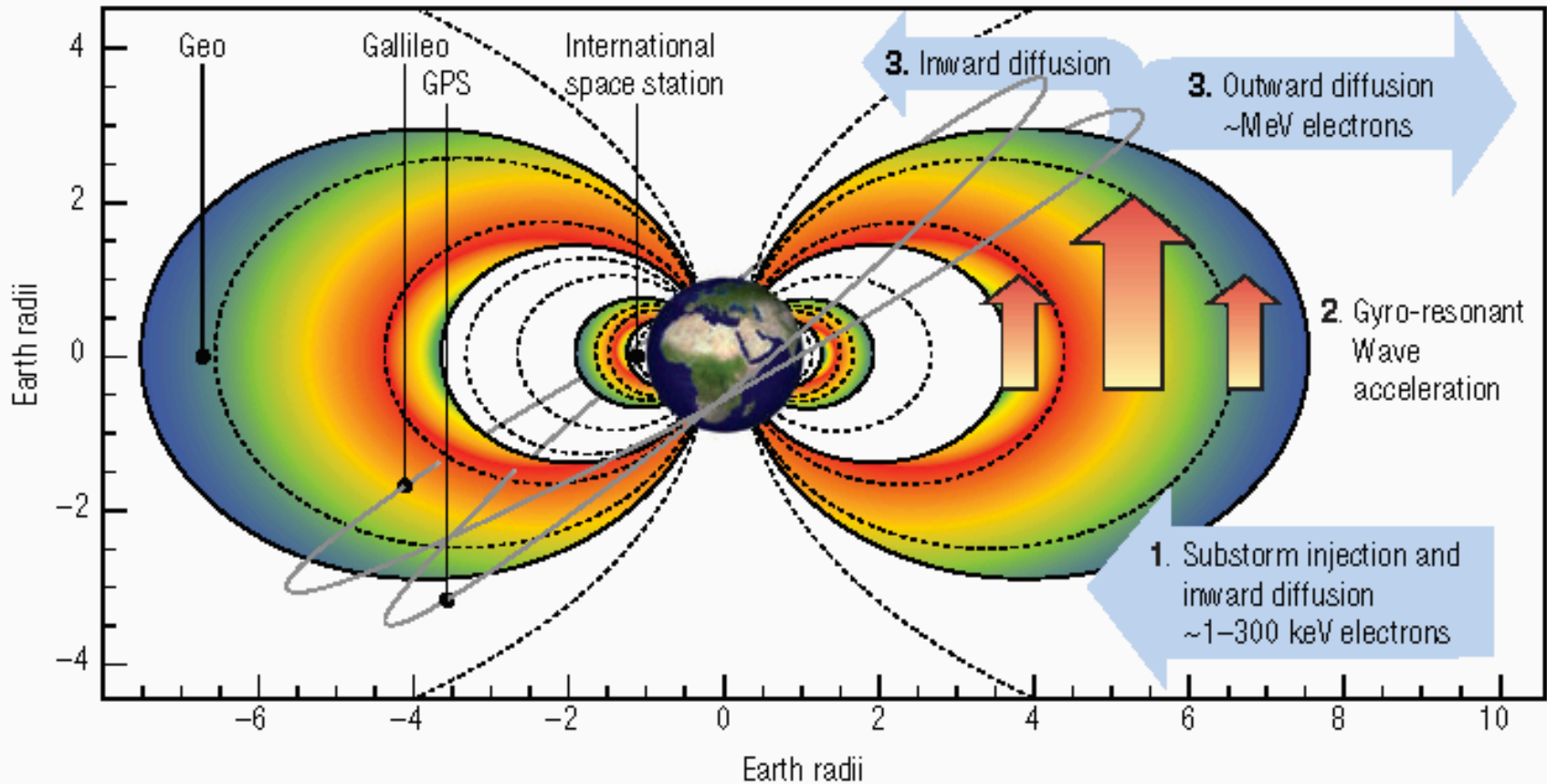
- Instabilities that abruptly and explosively release solar wind energy stored within the Earth's magnetotail.
- manifested most visually by a characteristic global development of auroras
- Last ~ hours



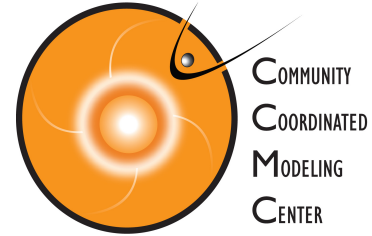




### Electron acceleration in the outer radiation belt



Horne et al., 2007, Nature Physics

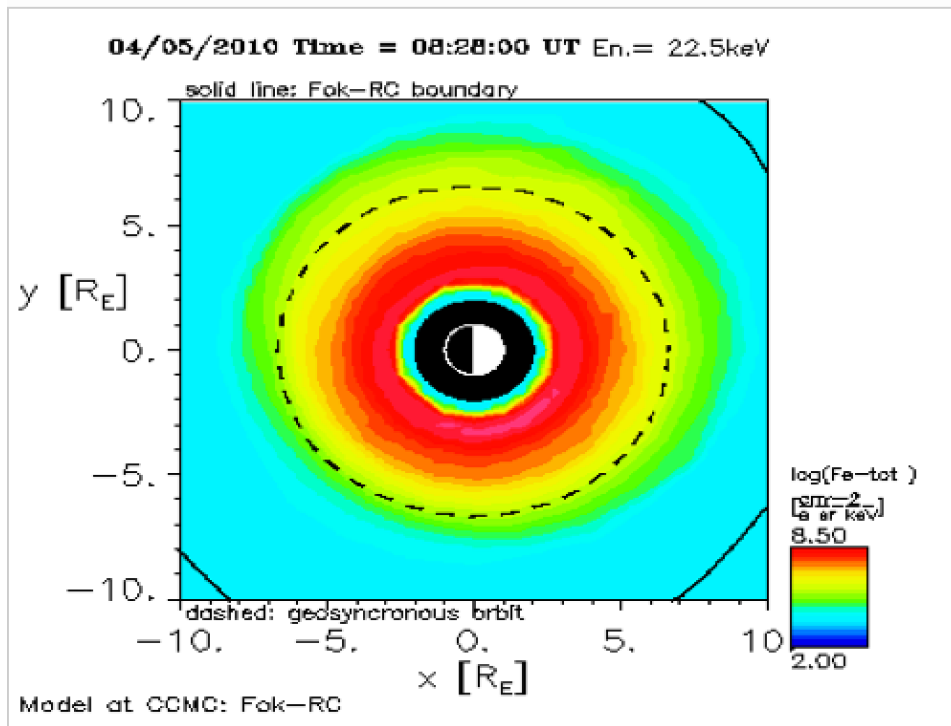


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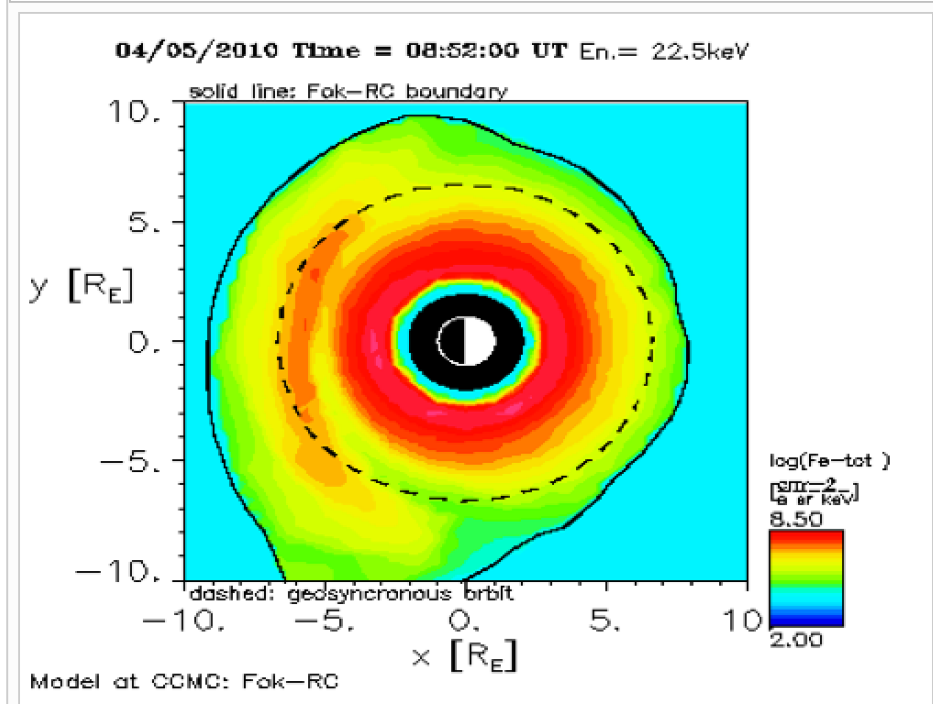
# Ring Current: Quiet vs. Active



Fok Ring Current electrons at 22.5 keV



Fok Ring Current electrons at 22.5 keV



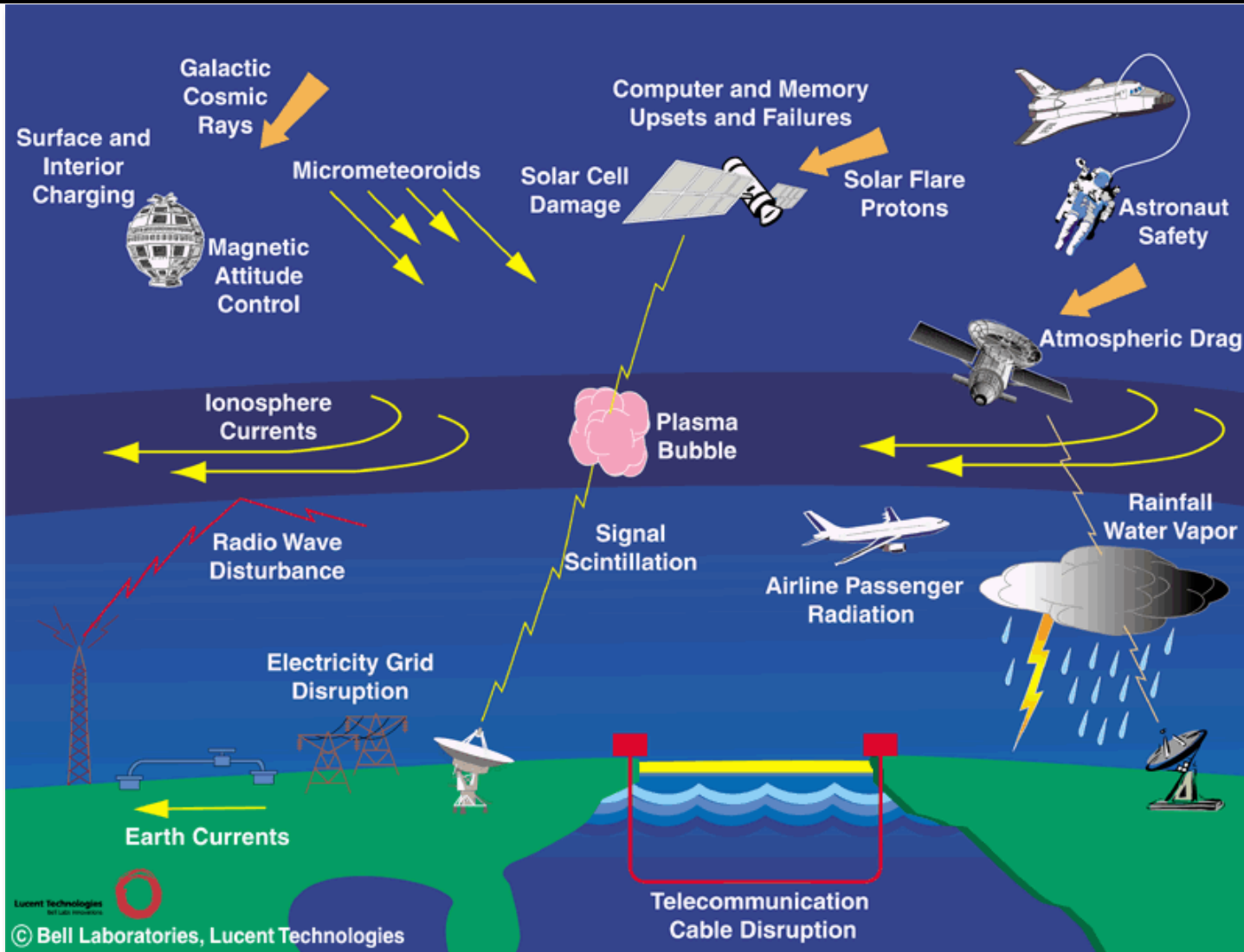
2010-04-05 08:28:00.0



2010-04-05 08:52:00.0

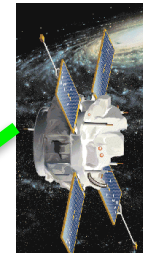
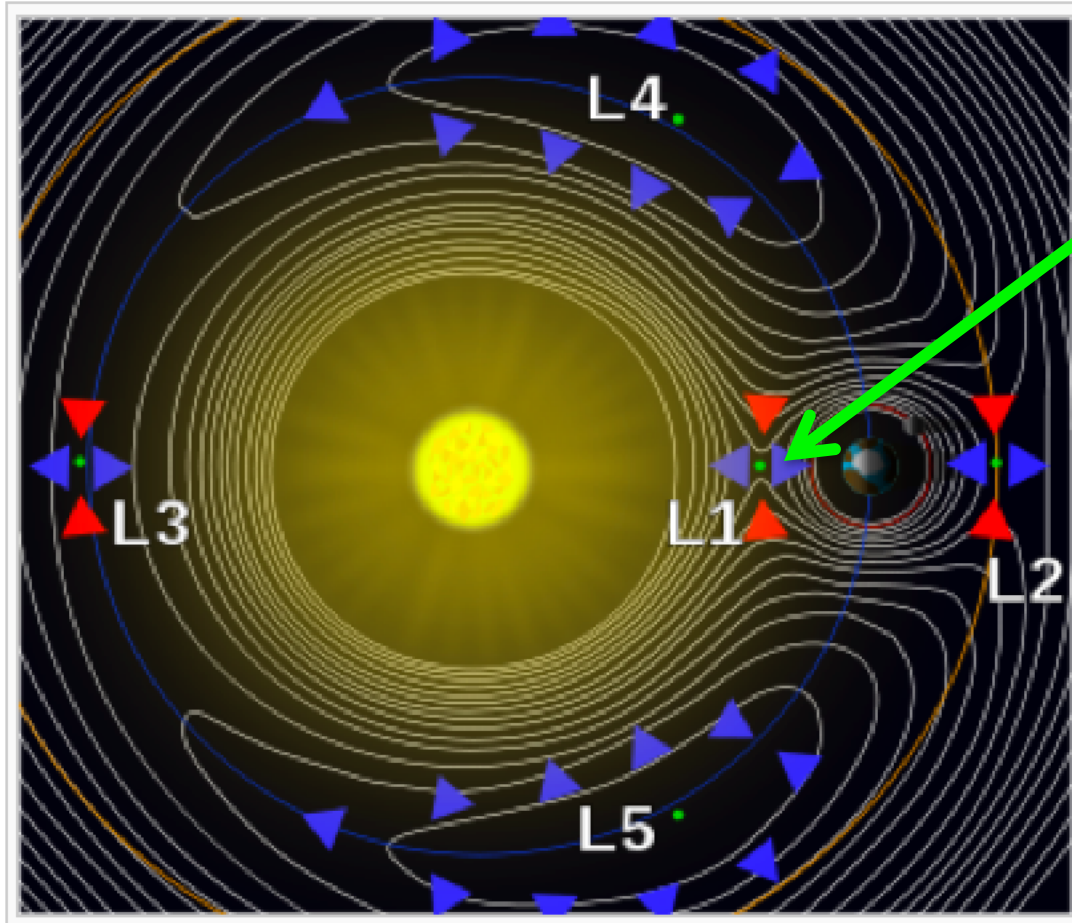


# Space Weather Impacts



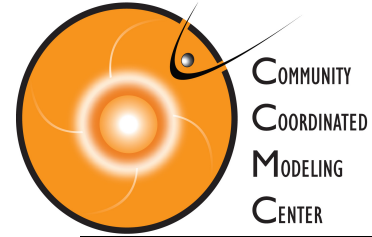
Space weather impacts (credit: L. Lanzerotti/Bell Labs)

# Lagrange Point – L1



Advanced  
Composition  
Explorer

**L1** (Solar Wind Monitor ACE location):  $\sim 200 R_E$  sunward  
You can fit 1 Sun between the Earth and L1.  
 $2 R_S$  (Solar diameter)  $\sim 220 R_E$



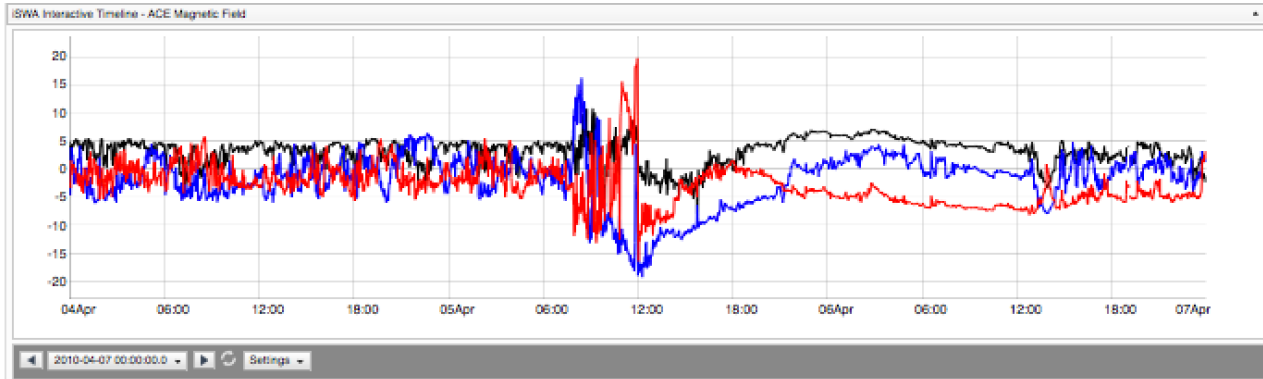
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# Solar Wind Parameters at ACE

on 04/05/2010



nT



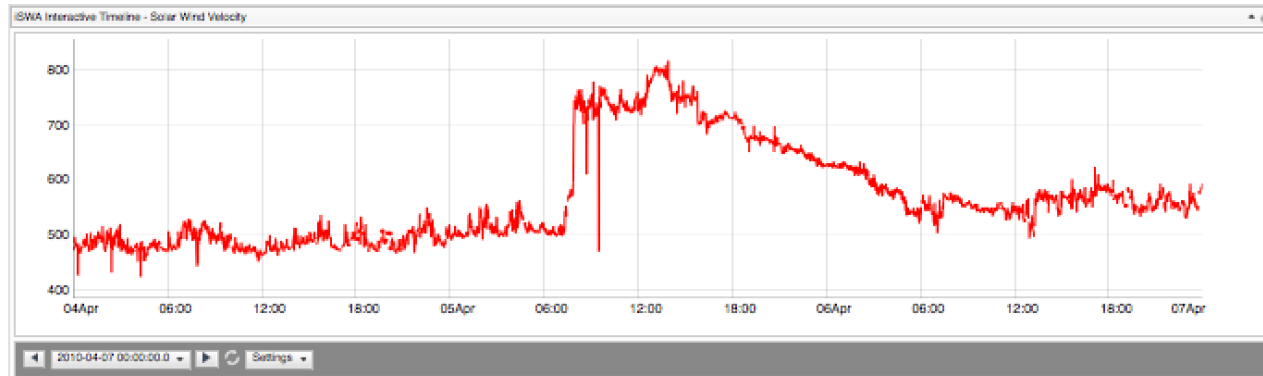
Magnetic field

$B_x$ ,  $B_y$ ,  $B_z$

X: Earth to Sun

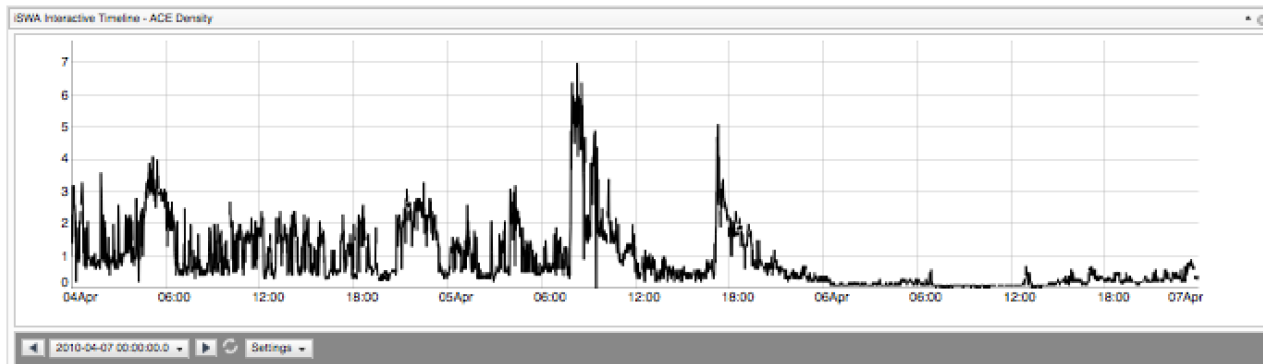
Z: North to South

km/s

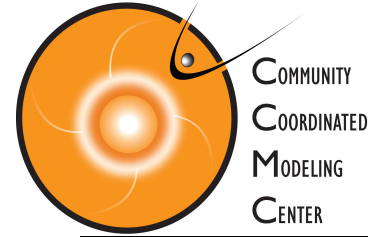


Velocity

part/cm<sup>3</sup>



Density

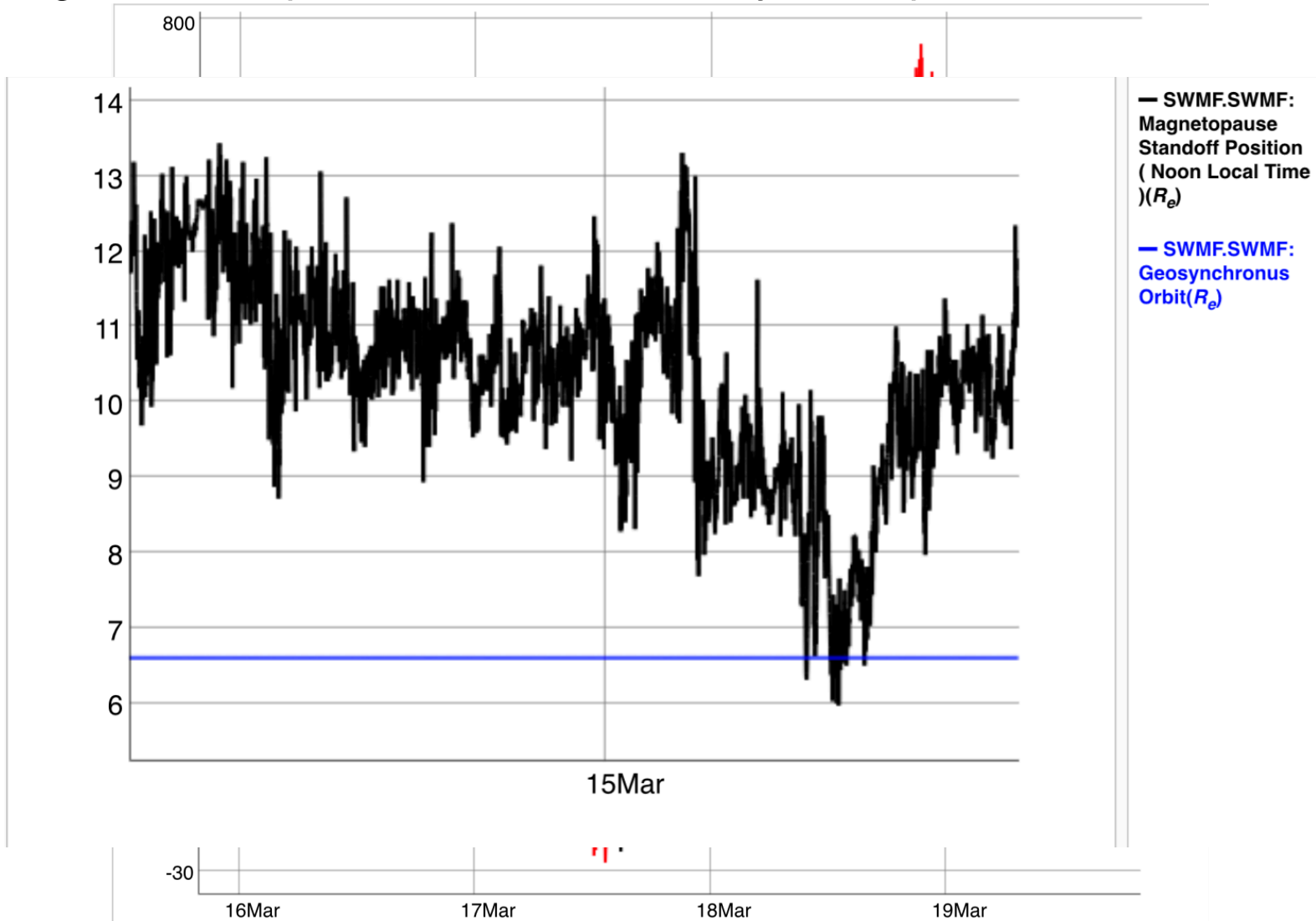


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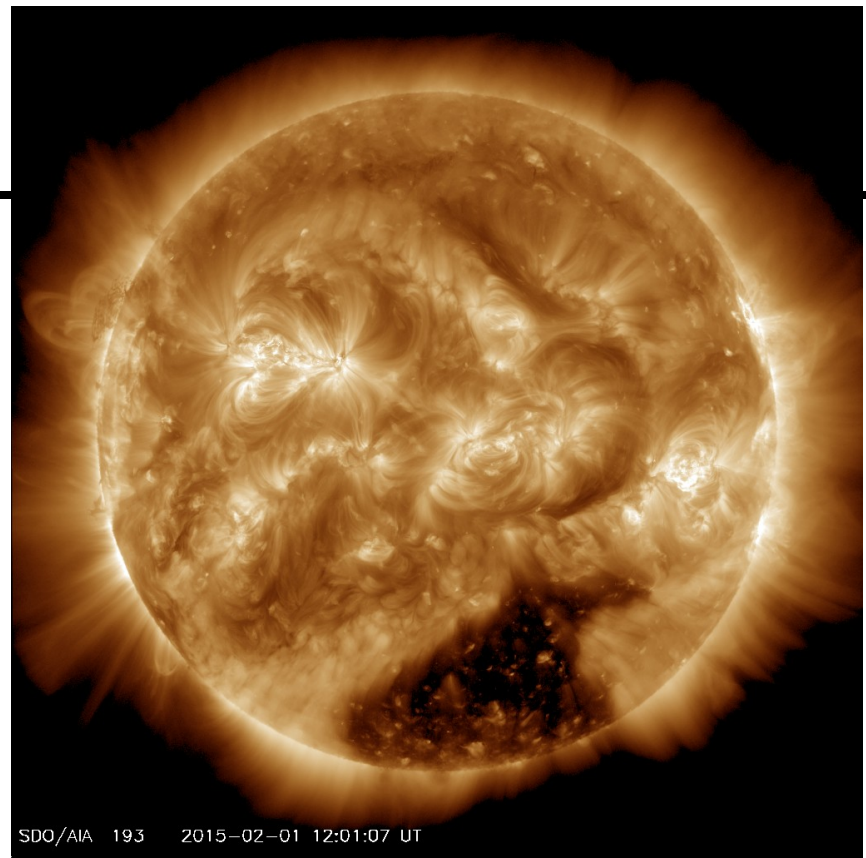
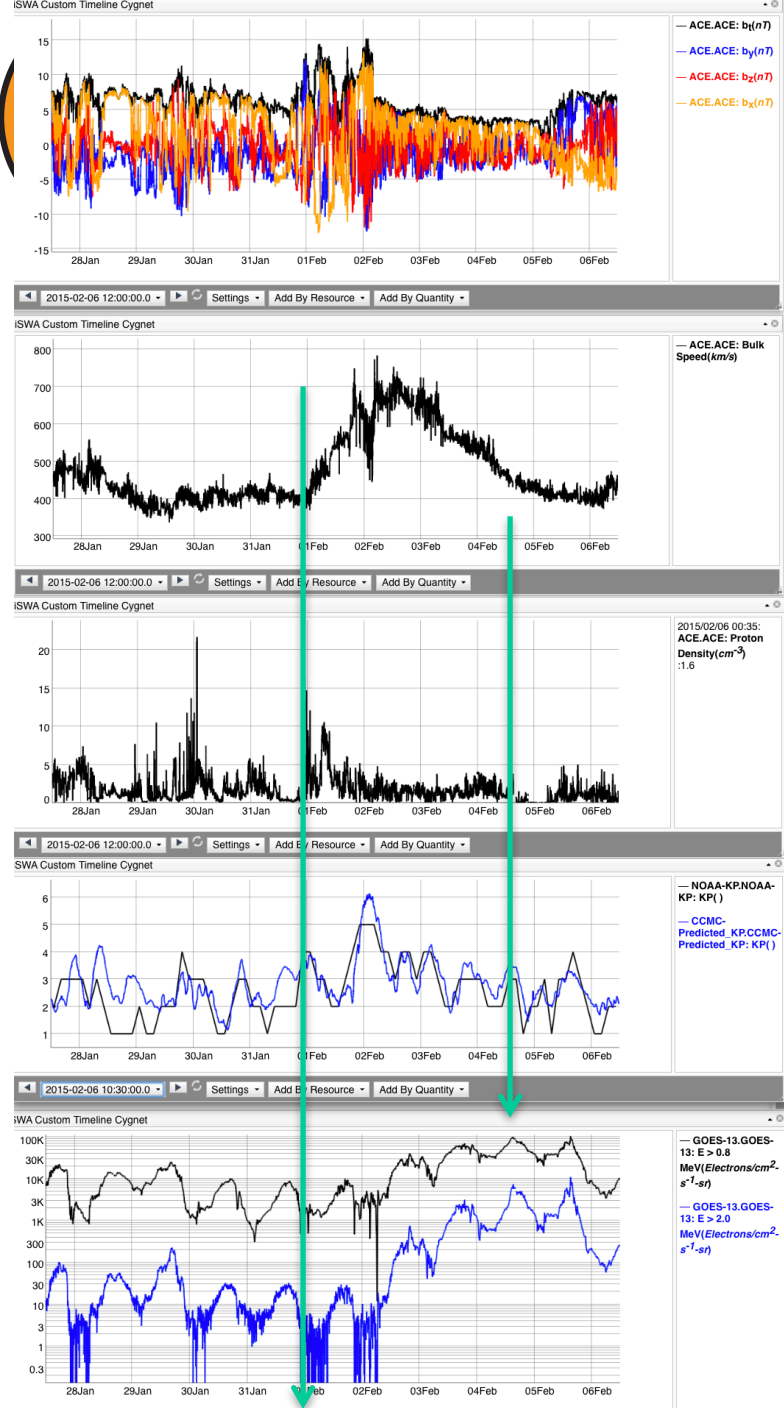
# Magnetopause Stand-off Distance



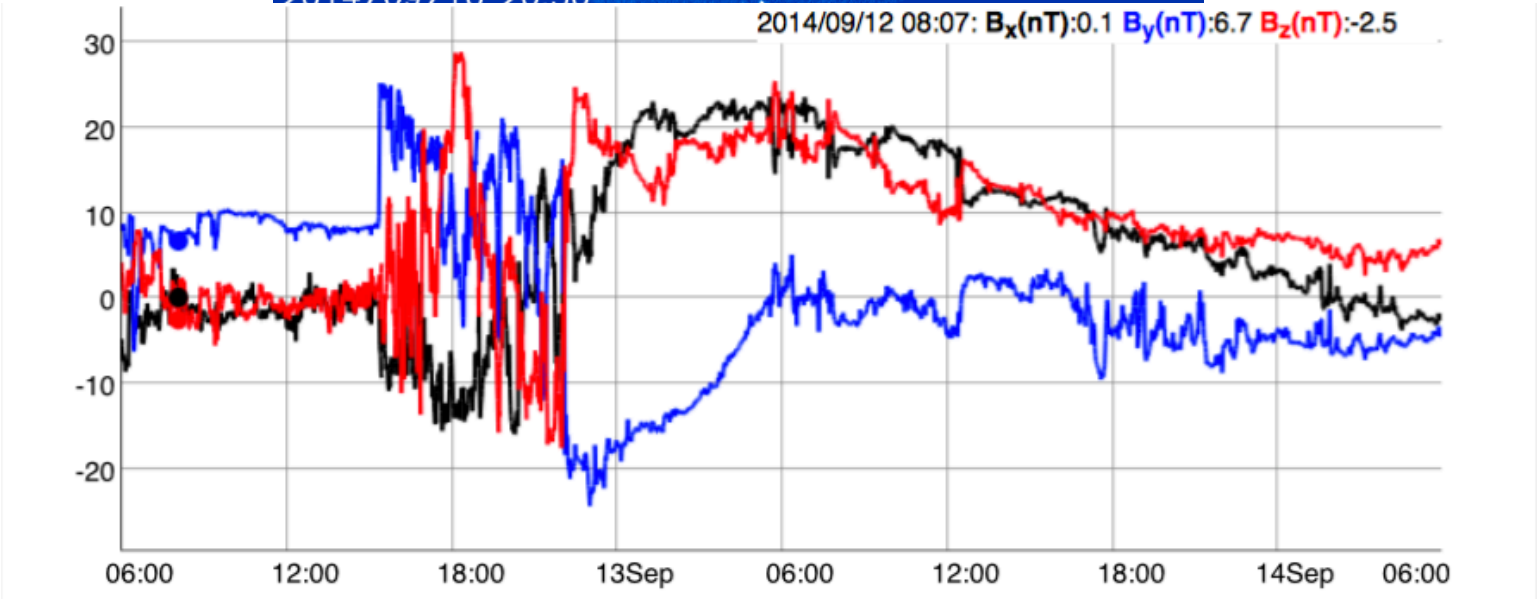
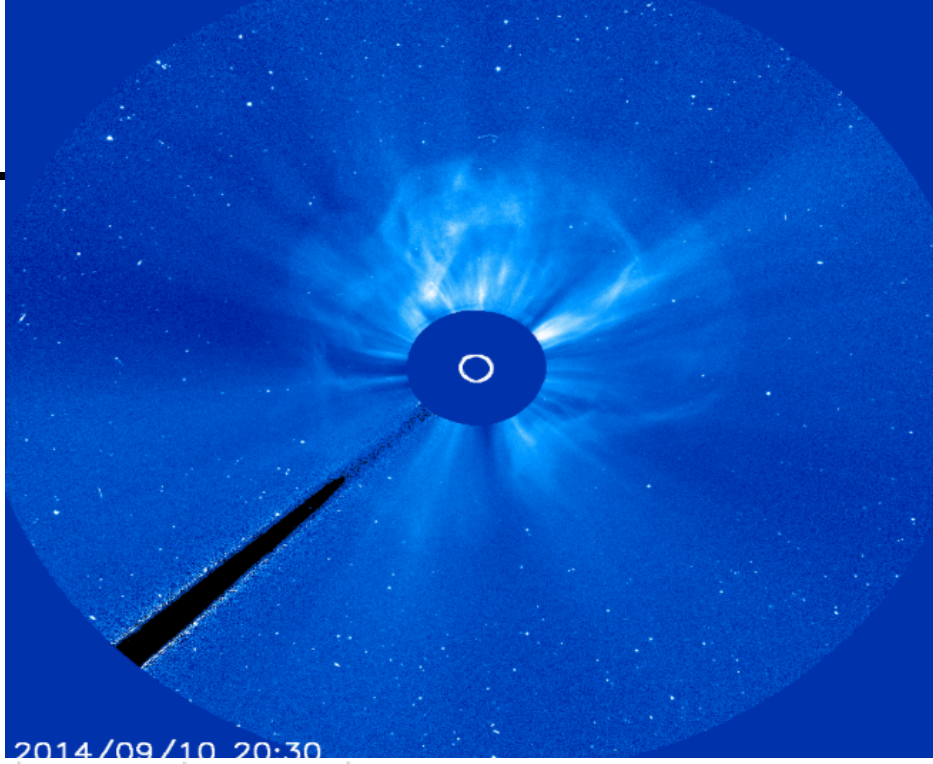
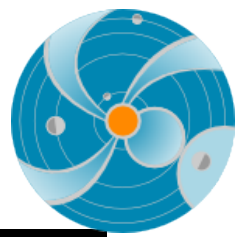
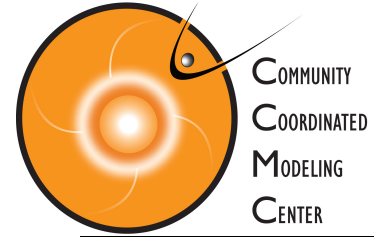
Degree of compression of MP due to dynamic pressure of solar wind







HSS and radiation belt electron flux enhancement



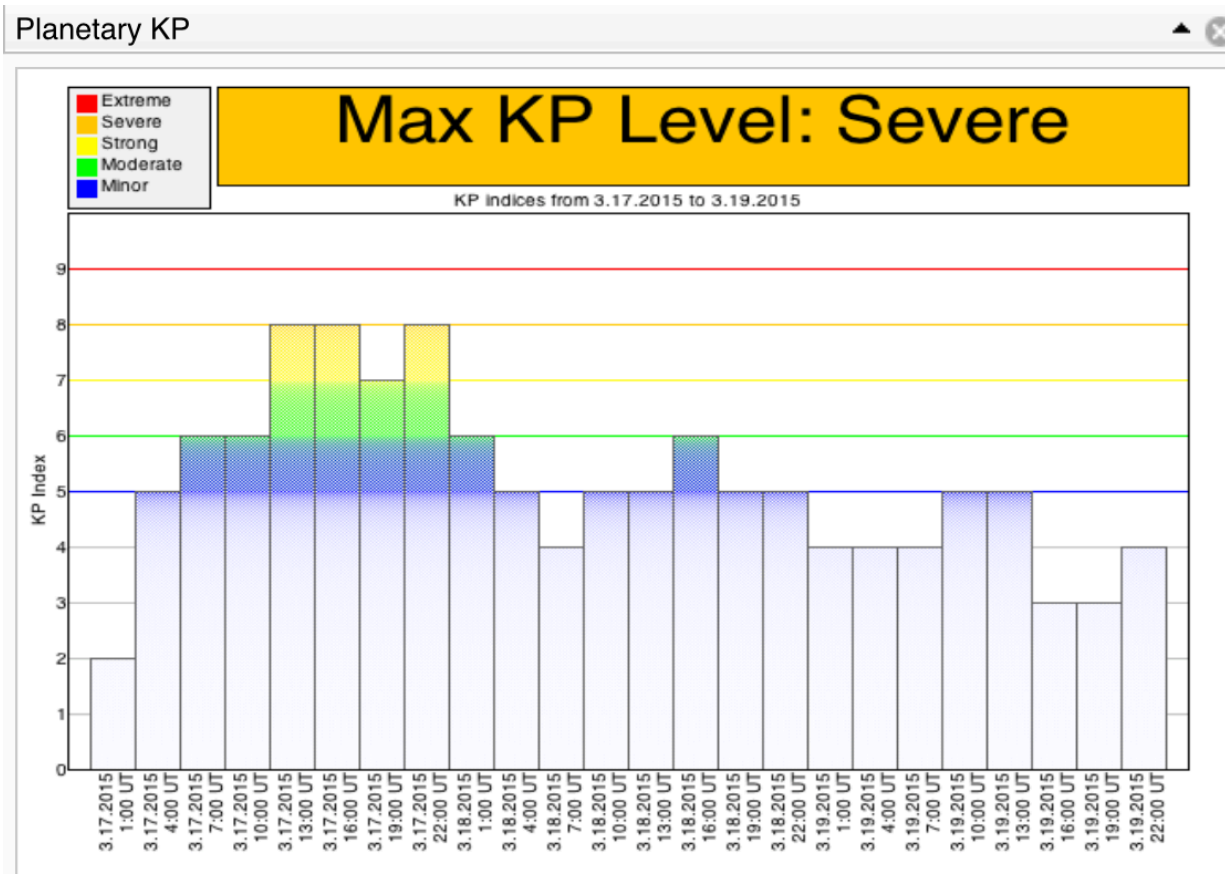


# Kp index



"planetarische Kennziffer" (= planetary index).

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



# Energetic Proton Flux

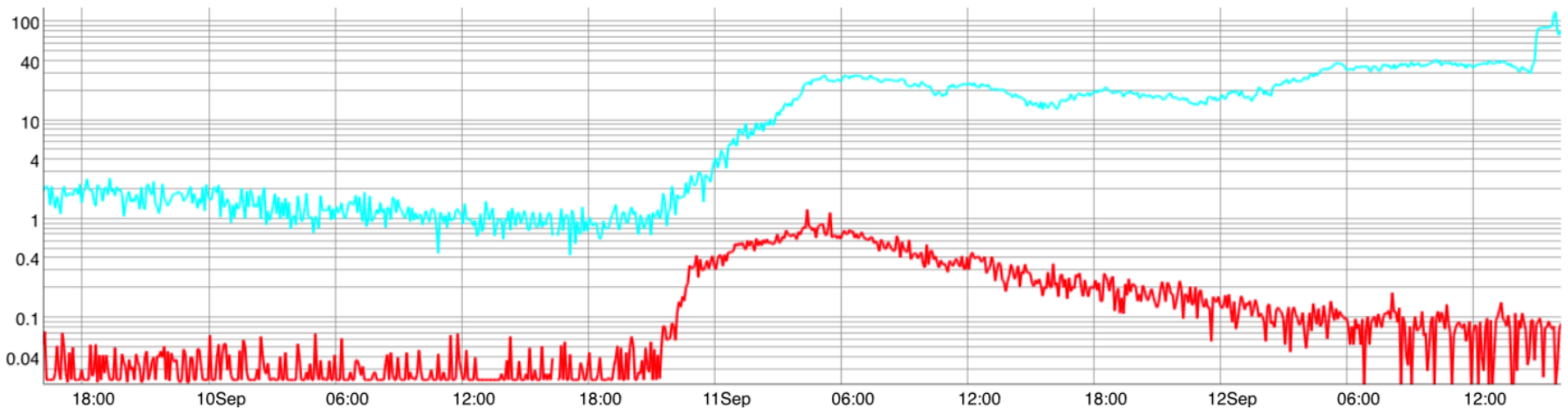
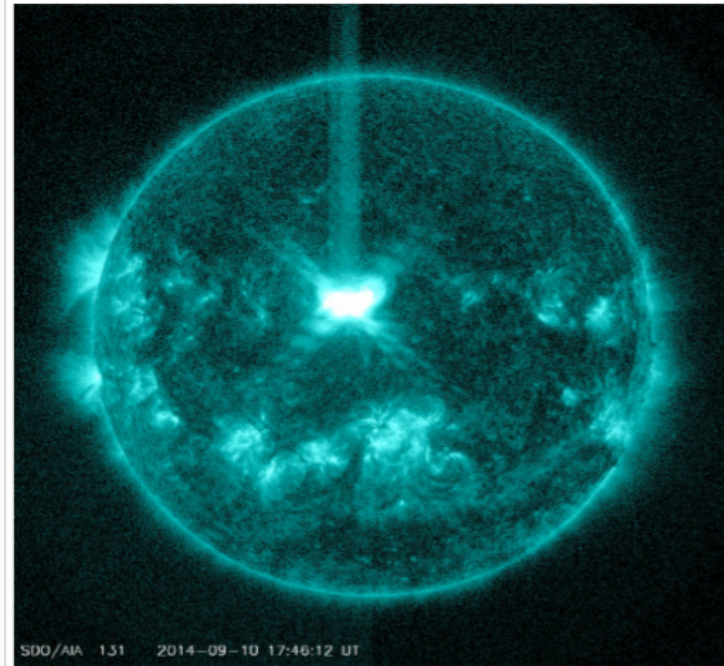


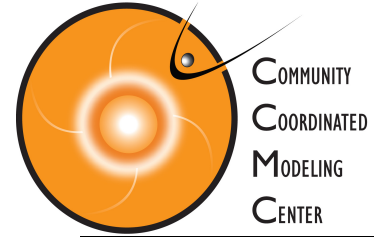
- $>10$  MeV flux by GOES spacecraft

Threshold: 10 pfu

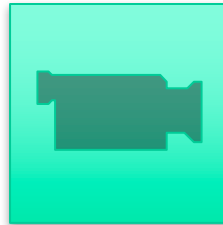
- $>100$  MeV flux by GOES spacecraft

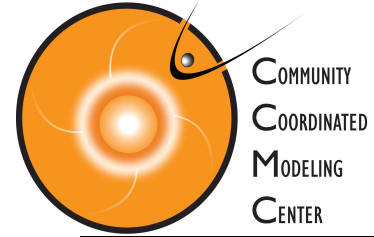
Threshold: 1 pfu





# Watch the video





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# **iSWA Layout:**

## **07/12/2012**

<http://goo.gl/V0JjxV>