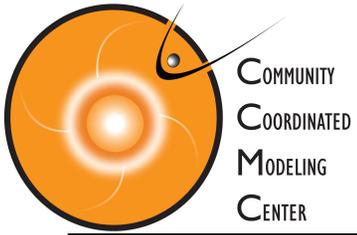


# Flares and CMEs

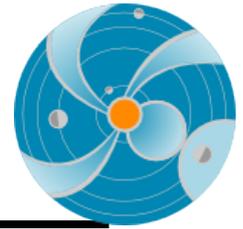
*A. Taktakishvili*

**CCMC, SWRC**

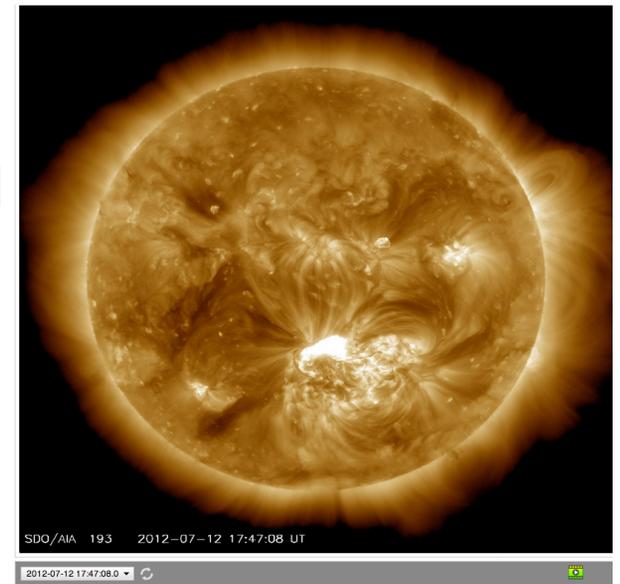
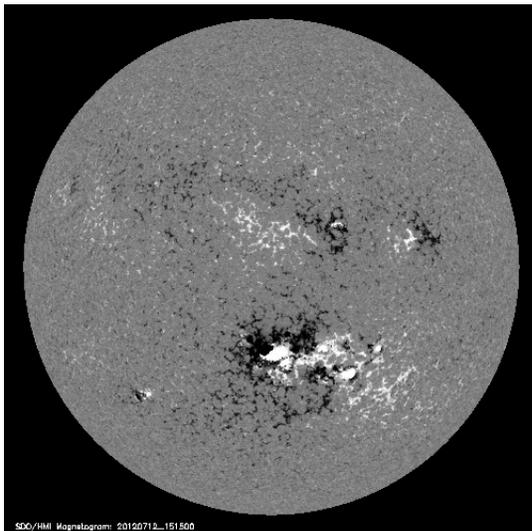
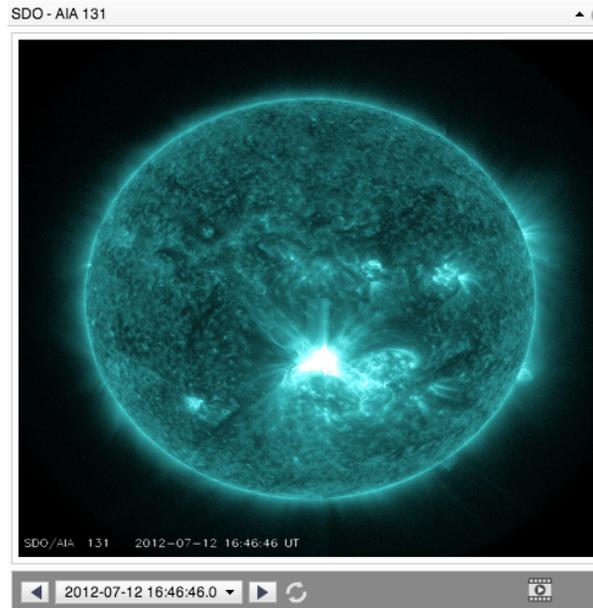
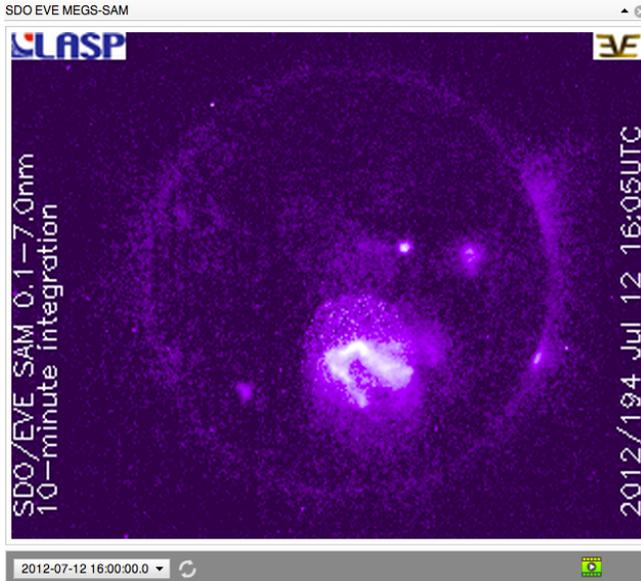
**NASA Goddard Space Flight Center**

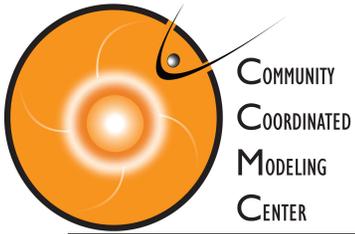


# Solar Flare

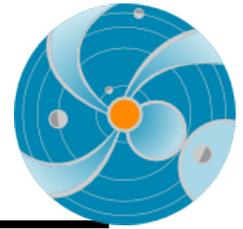


2012 July 12 X1.4 class flare

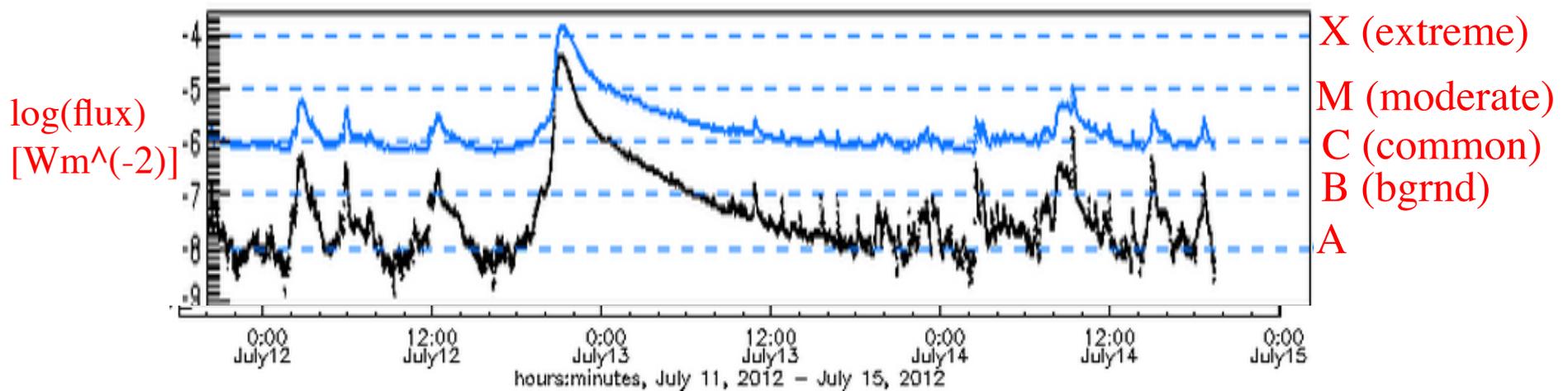
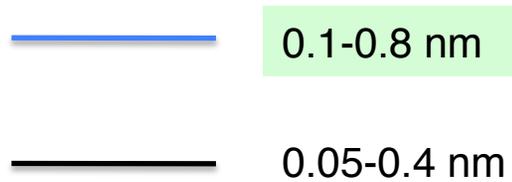




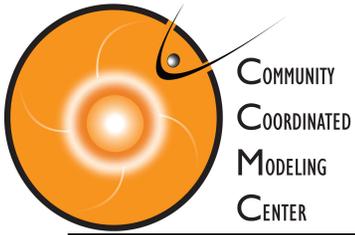
# Solar Flare Class



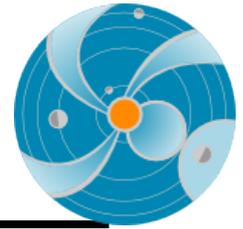
2012 July 12 X1.4 class flare



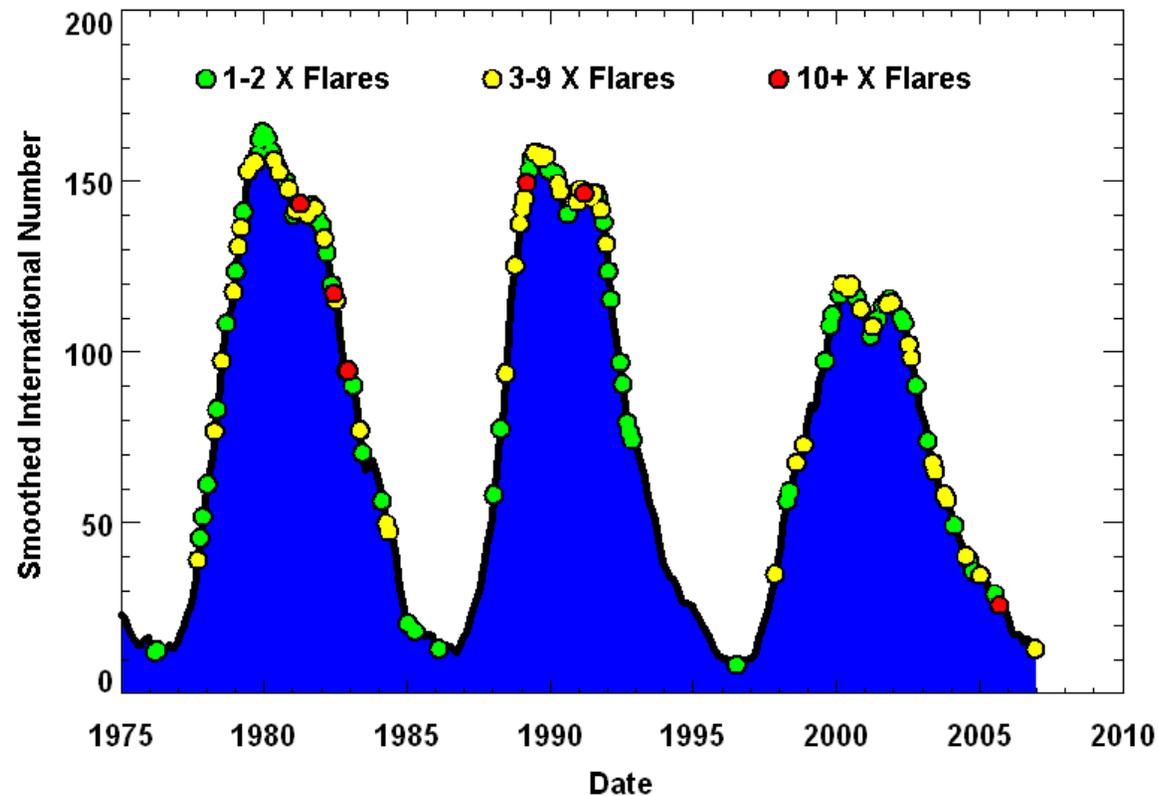
$$\text{X1.4 class: flux}(0.1\text{-}0.8\text{nm})[\text{Wm}^{(-2)}]=1.4*10^{(-4)}$$

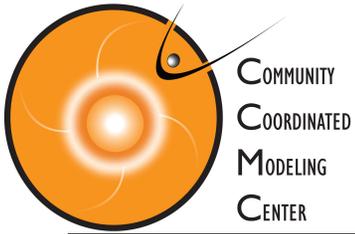


# Flares over the Solar cycle

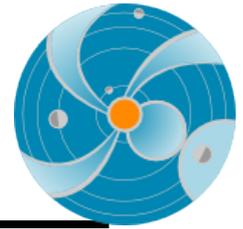


Solar flares have been monitored by x-ray detectors on GOES satellites since 1976. The number of X-Class flares per month increases with the number of sunspots but **big flares can occur anytime sunspots are present.**

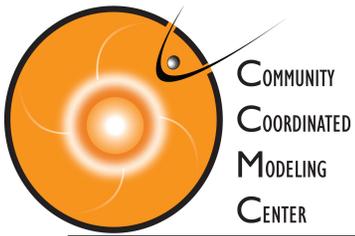




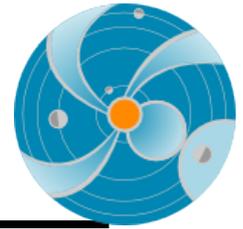
## Flare: SWx impacts



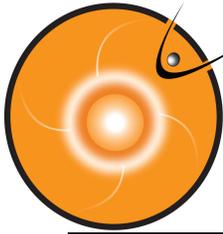
- Cause radio blackout through changing the structures/composition of the ionosphere (sudden ionospheric disturbances) – x ray and EUV emissions, **lasting minutes to hours**
- Affect radio communications, GPS, directly by its radio noises at different wavelengths
- Contribute to SEP – proton radiation, **lasting a couple of days**



# Flare Characteristics

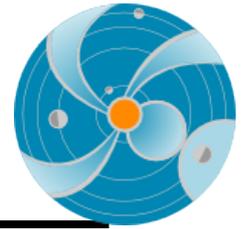


- Flares tend to occur in isolation, localized in space and time but with strong correlations; typically one active region will produce dozens of flares, especially during periods of flux emergence (often near the beginning of the lifetime of a given region, but not always). **The most powerful events usually occur in active regions.**

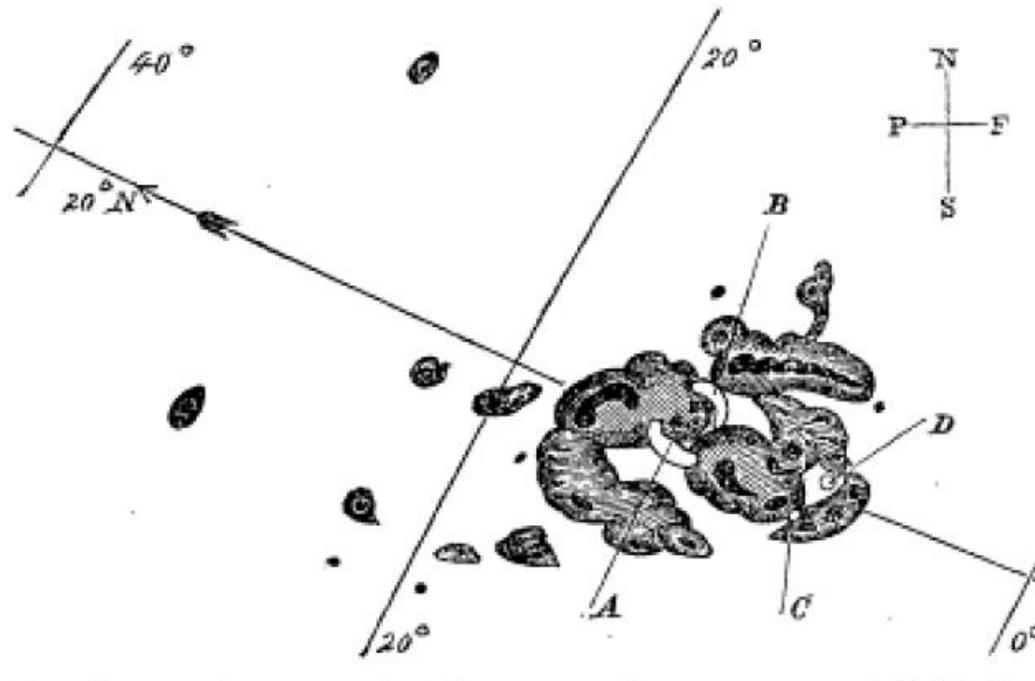


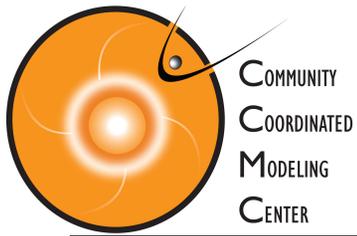
COMMUNITY  
COORDINATED  
MODELING  
CENTER

# Solar Flare Discovered

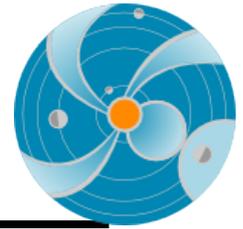


In 1859 Richard Carrington reported observing a large sunspot group on the afternoon of September 1<sup>st</sup> when “...*two patches of intensely bright and white light broke out...*”

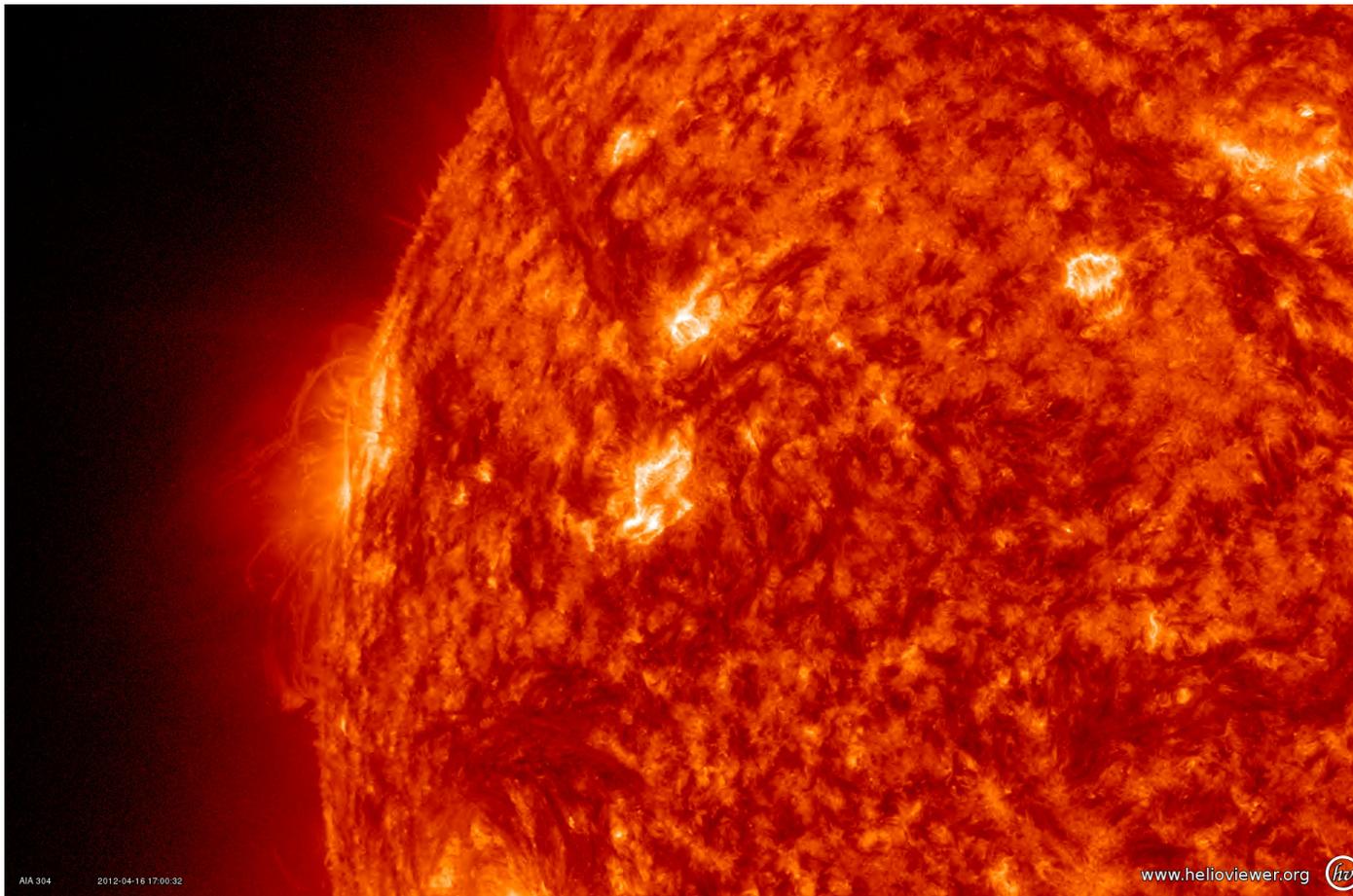


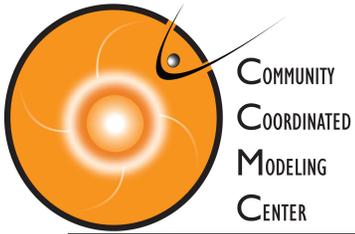


# Coronal Mass Ejection

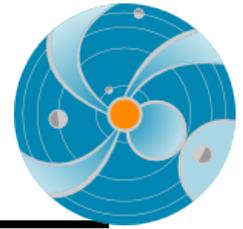


Coronal Mass Ejection – Reaches the Earth in 1-3 days

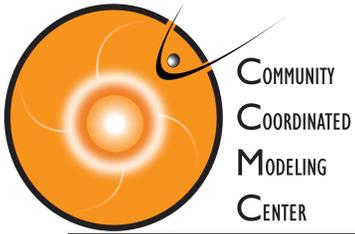




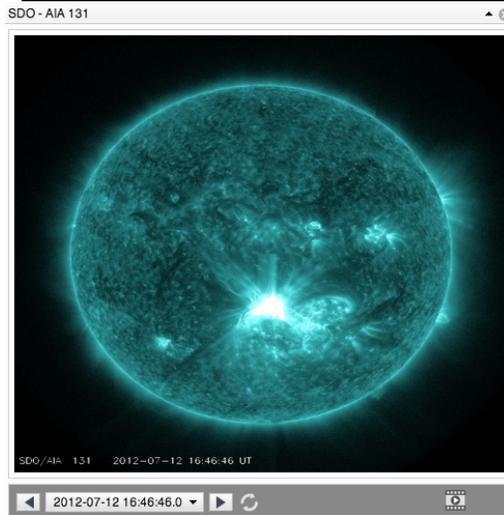
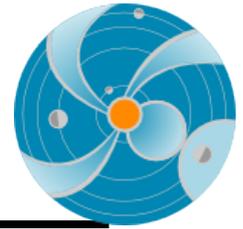
## CME/flare



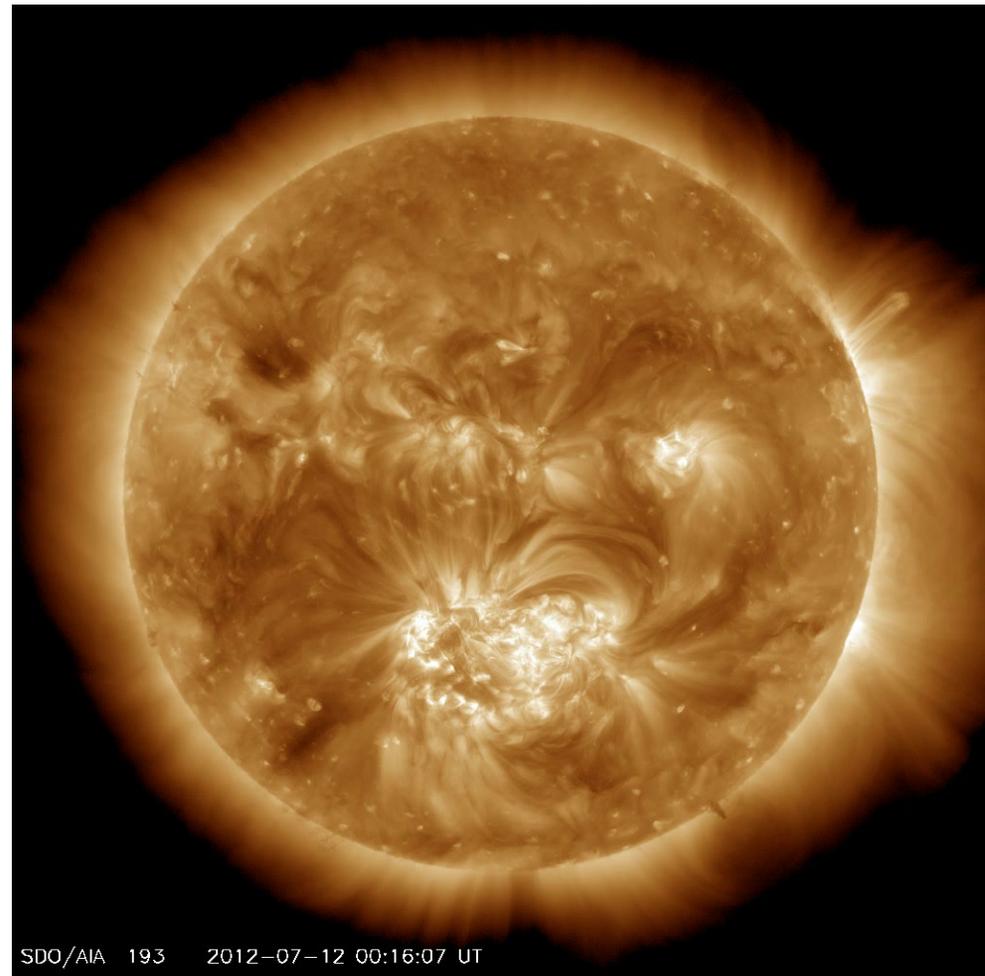
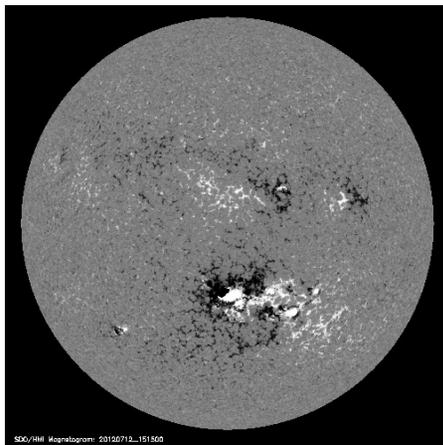
- **The most energetic CMEs occur in close association with powerful flares.** Nevertheless large-scale CMEs do occur in the absence of major flares even though these tend to be slower and less energetic.
- When strong flare/CME occurs, it gives off emission across the whole electromagnetic spectrum, at the same time energetic particles

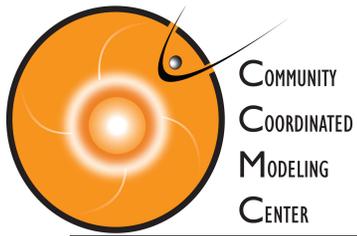


# Most of the CMEs Originate From the Active Regions

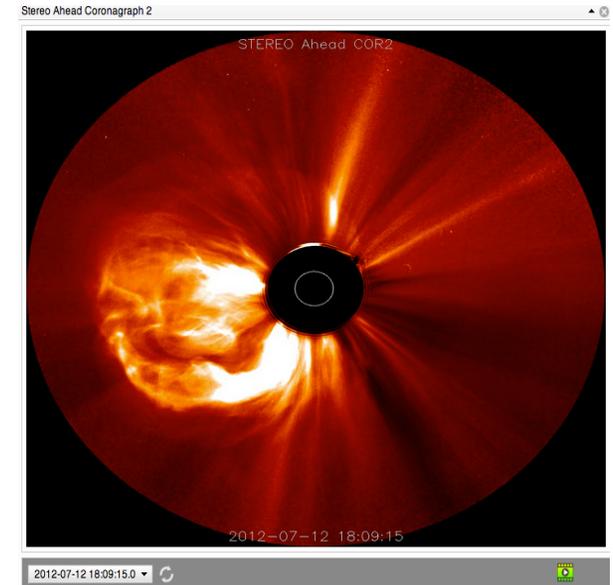
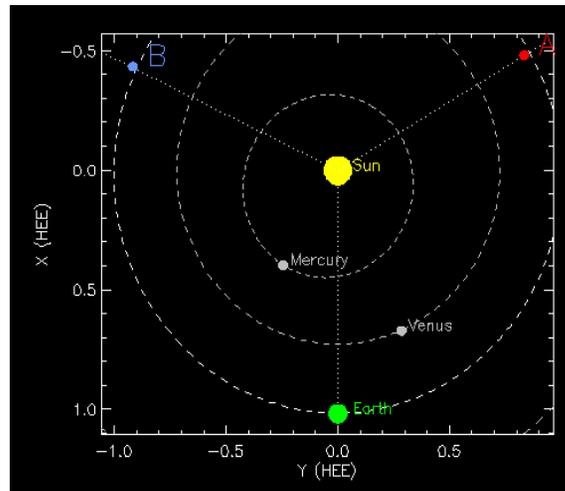
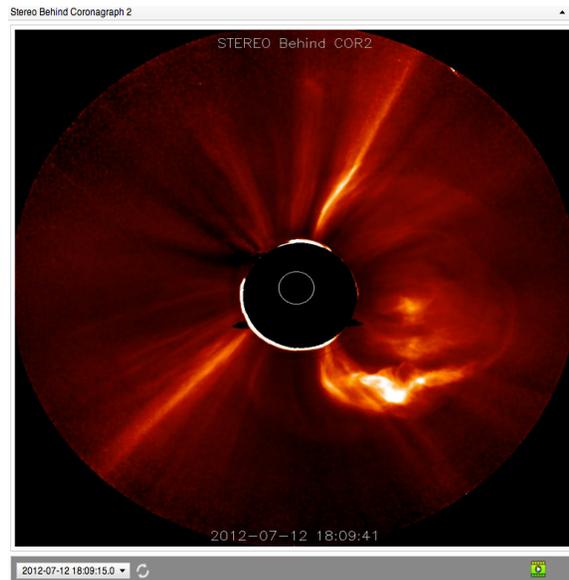
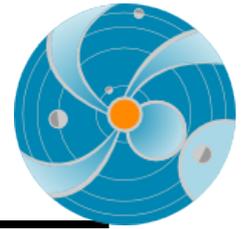


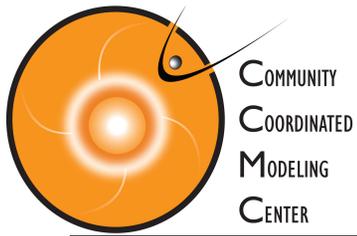
2012 July 12 X1.4 class flare and a following CME



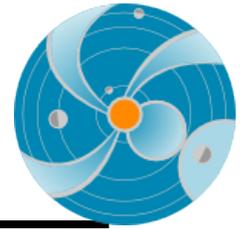


# July 12, 2012 CME Viewed by Coronagraph Imagers

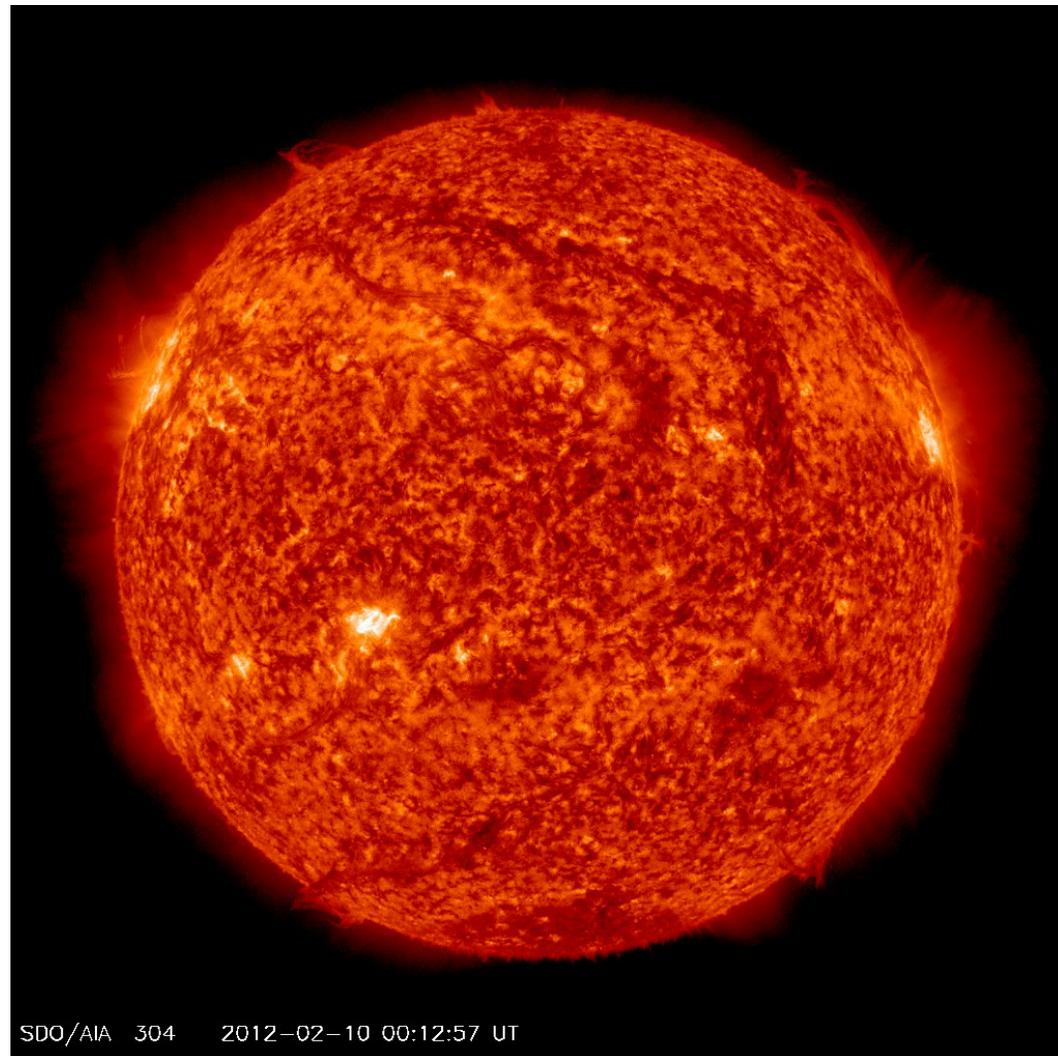


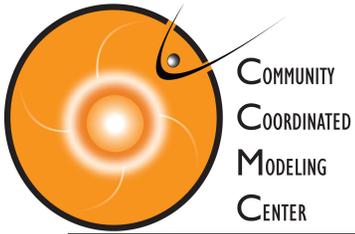


# CME from a Filament Eruption

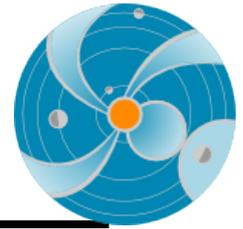


Northeast (upper left) quadrant starting around 19:00 UT on Feb 10, 2012





# CME Properties



- Mass:  $\sim 10^{15-16}$  g
- Speed: few hundred - 3000km/s

..or

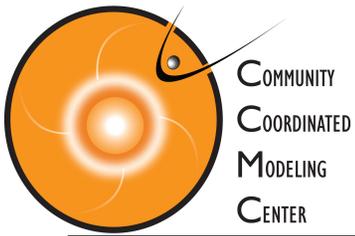
- Mass:  $\sim 1$  million Nimitz-class aircraft carriers
- Speed: 1.5 -10 million km/hour



Earth?



- Arrives to Earth in 1-2 days

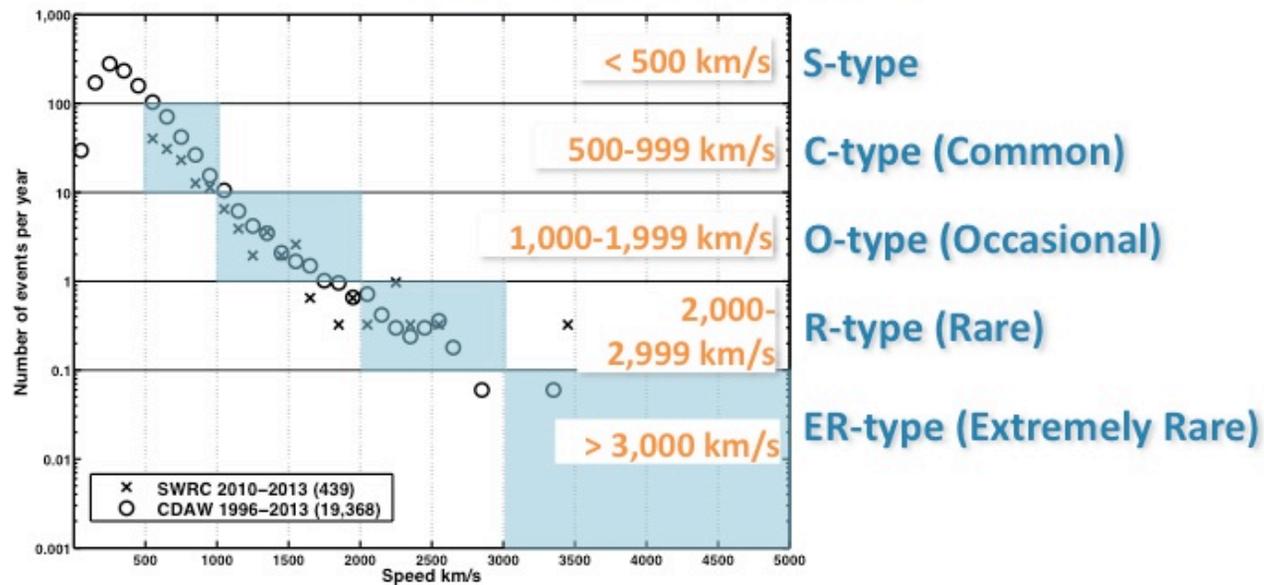


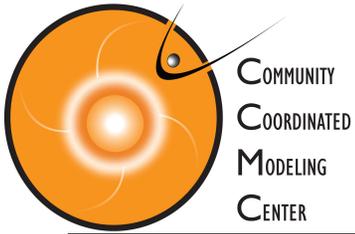
# CME SCORE



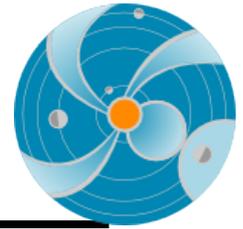
- A simple new category system for CMEs based on frequency of detection and speed
- Complements Flare Classes
- Applicable in space weather operations and research

## Space Weather Research Center CME SCORE Scale





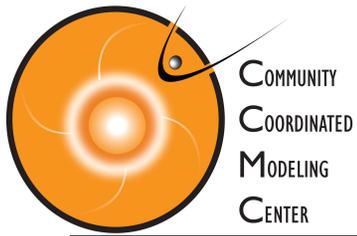
## SWx impacts of CME



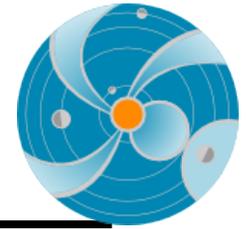
- Contribute to SEP (particle radiation): 20-30 minutes from the occurrence of the CME/flare
- Result in a geomagnetic storm: takes 1-2 days arriving at Earth
- Result in electron radiation enhancement in the near-Earth space: takes 1-3 days

Affecting spacecraft electronics – surfacing charging/  
internal charging:

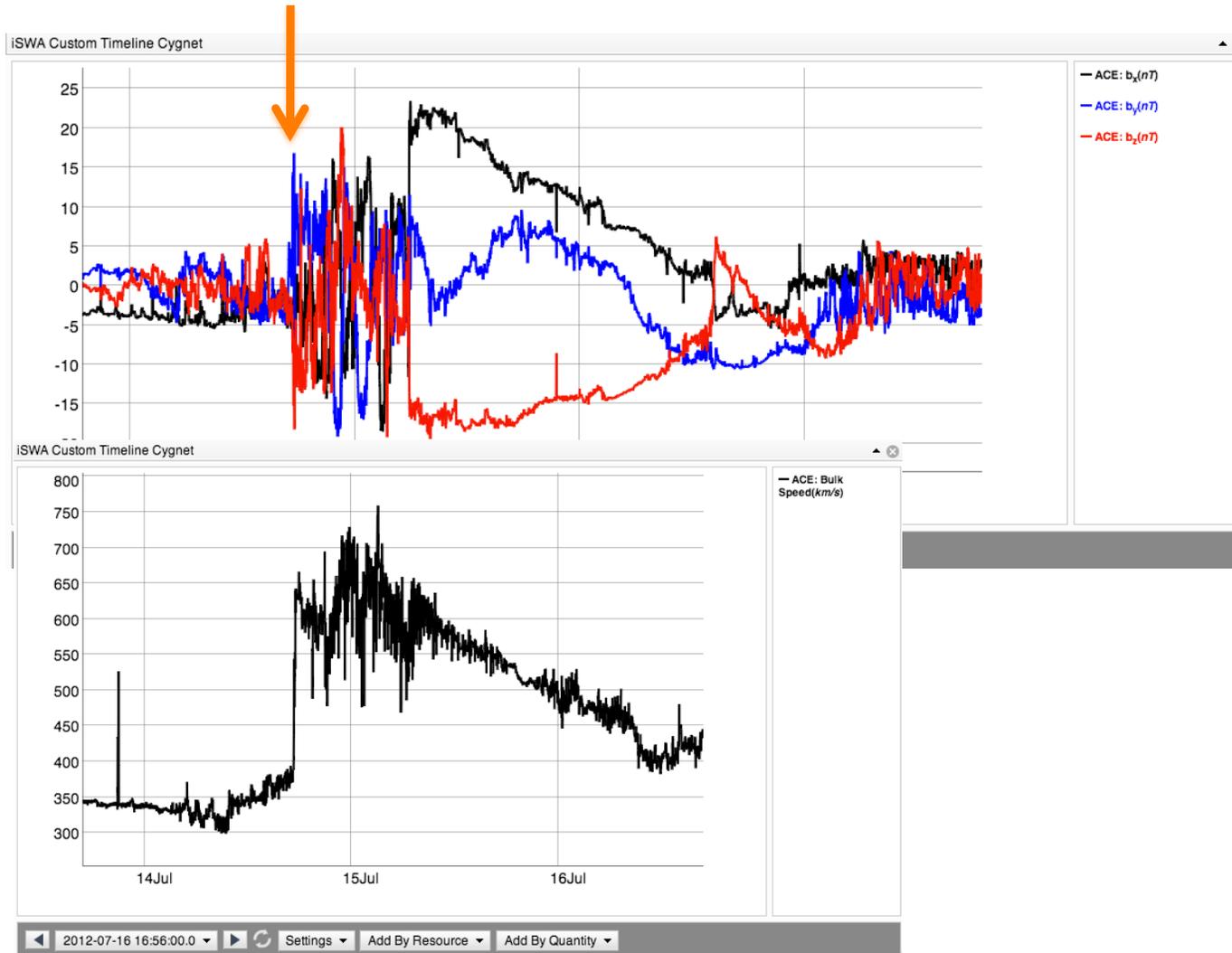
Radio communication, navigation, power grids, pipelines,  
and so on

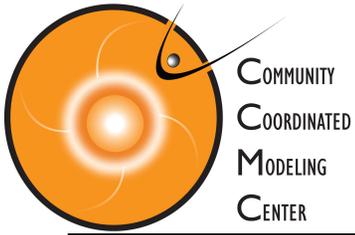


# Geomagnetic Storm Caused by the CME Arrival

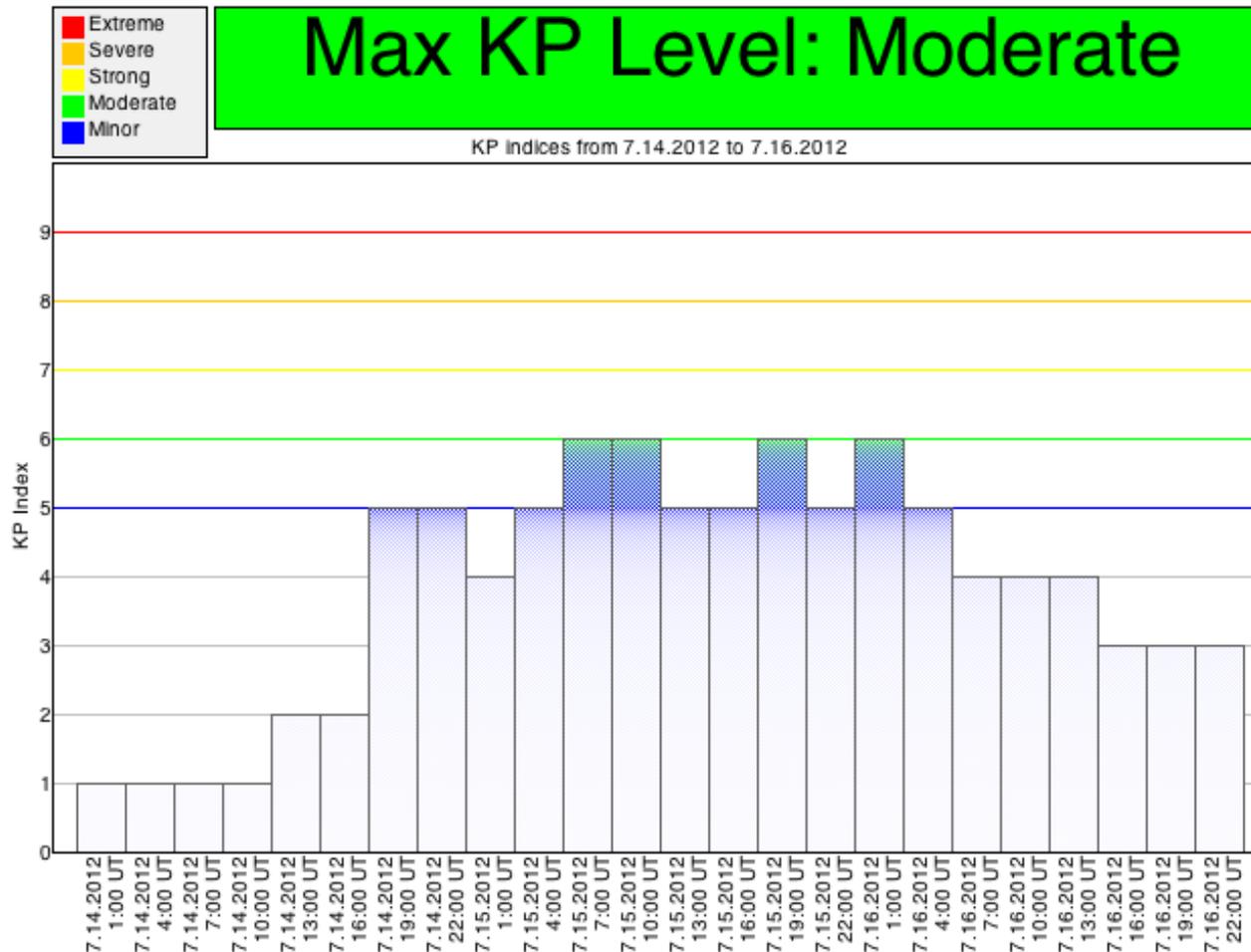
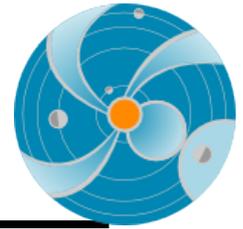


## CME Arrival at ACE

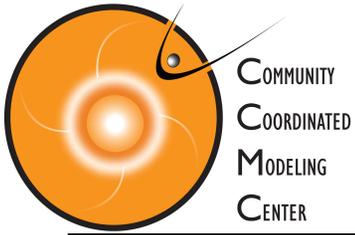




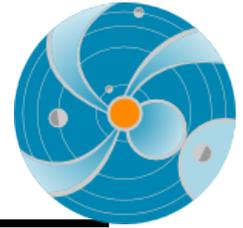
# Geomagnetic Storm Caused by the CME Arrival



Kp – index (German “Kennziffer” – characteristic digit)



# Physical Mechanism Behind the Flares and CMEs



It is believed that solar magnetic field, releases energy, accelerating solar plasma and causing flares and CMEs. Magnetic reconnection.



# CME Modeling



2012-07-12T00:00

2012-07-12T00 +0.00 day

- Earth
- Mars
- Mercury
- Venus
- Kepler
- MSL
- Spitzer
- Stereo\_A
- Stereo\_B

