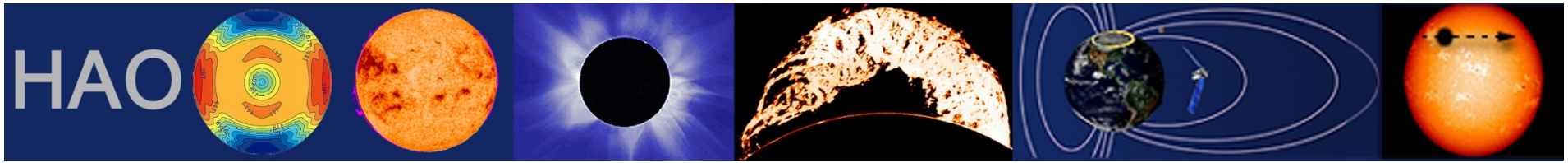


# Big Flare Hunting

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and

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High Altitude Observatory (HAO) – National Center for Atmospheric Research (NCAR)

NCAR

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August 2, 2013

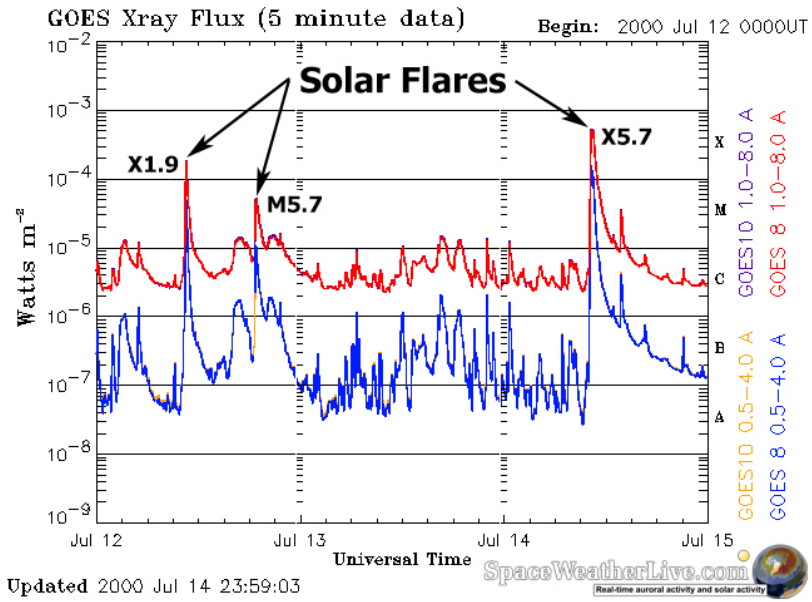
# Solar Flares

- A sudden eruption of energy in the solar atmosphere lasting minutes to hours, from which radiation and particles are emitted.

Source:NASA

# Big Flares: How Big is Big?

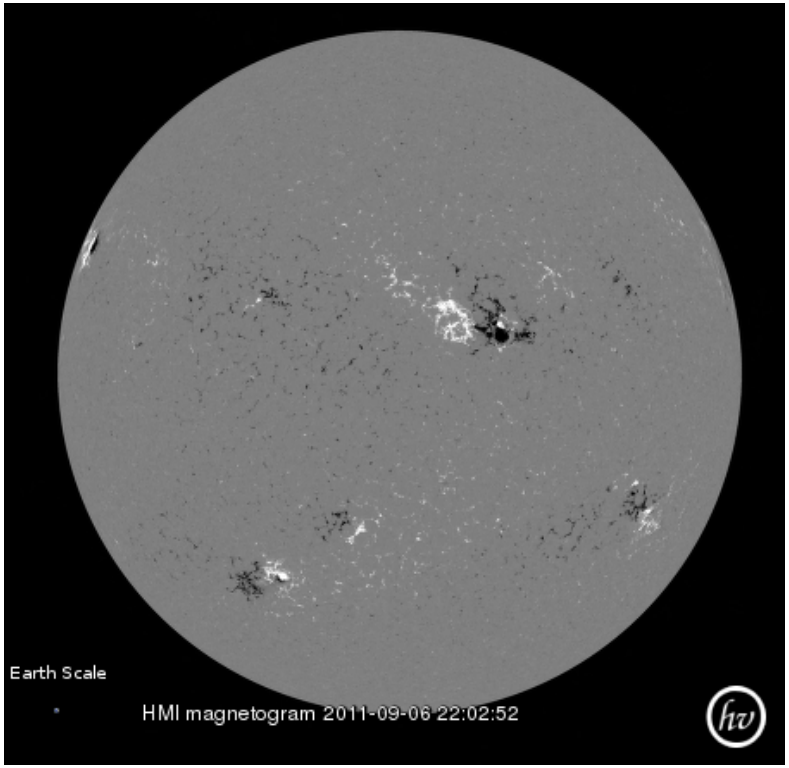
- Peak Bust Intensity (I), 0.1 to 0.8 nm flux (W $m^{-2}$):
  - B $I < 10^{-6}$
  - C $10^{-6} <= I < 10^{-5}$
  - M $10^{-5} <= I < 10^{-4}$
  - X $I >= 10^{-4}$

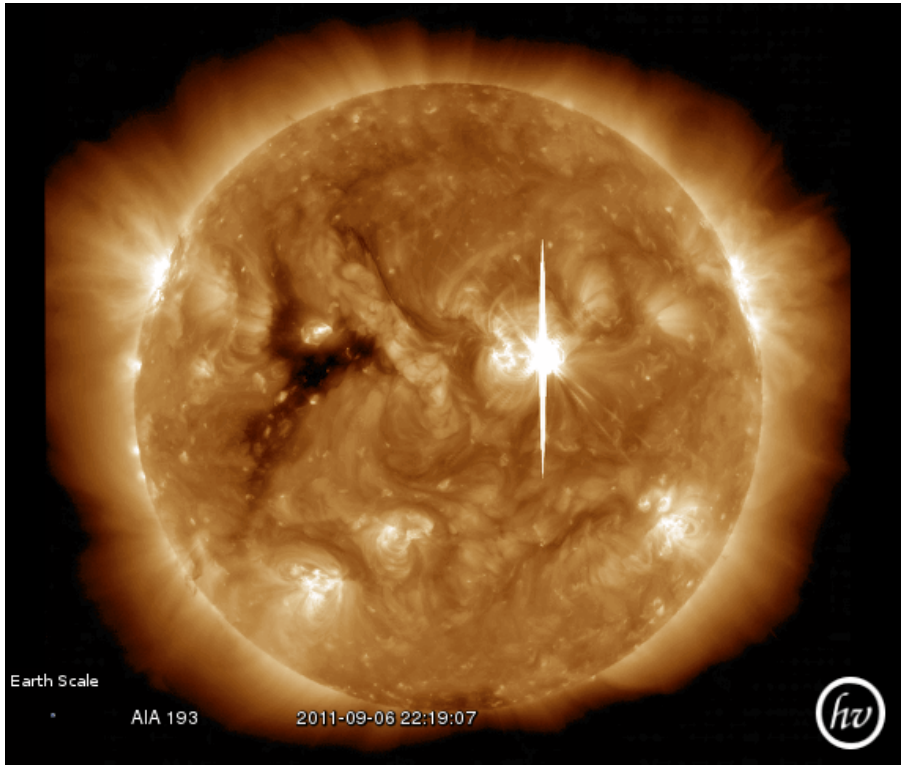



A multiplicative factor is appended to the end of the class (e.g. M8 = 8 x $10^{-5}$ W $m^{-2}$)

# The Goal

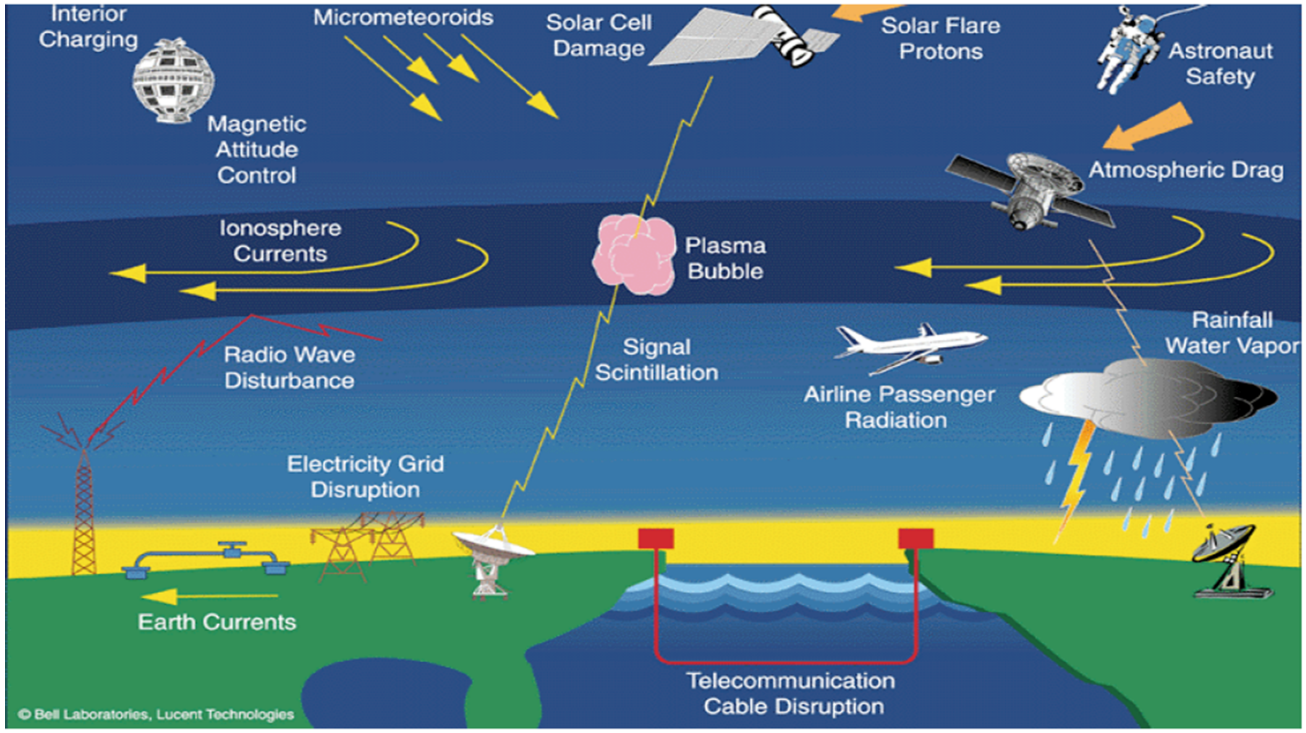
- Understand formation of the biggest flare from magnetic field data by studying emergence of new magnetic flux before the Flare



# Motivation
## Why do we care?

- Solar Flares and Coronal Mass ejections (CMEs) are one of the most explosive events in the solar system.
- Main drivers of Space Weather
- Modern society is dependent on technologies that can be vulnerable to space weather.

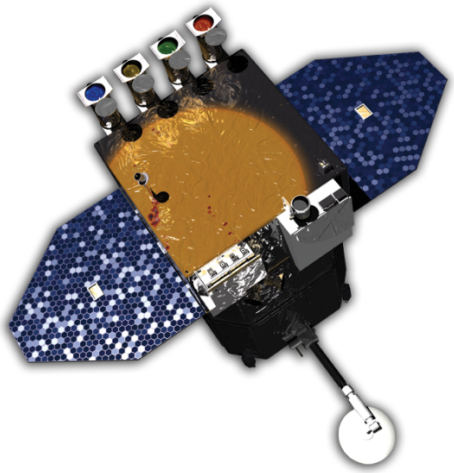


# NOAA Scale

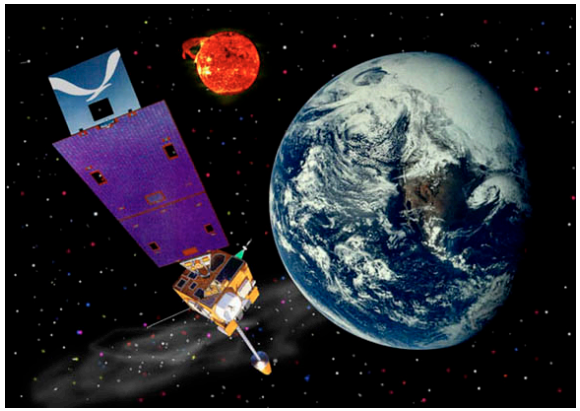
| Category | | Effect | Physical measure | Average Frequency (1 cycle=11 years) |
|---|---|---|---|---|
| Scale | Descriptor | Duration of event will influence severity of effects | | |
| **Radio Blackouts** | | | GOES X-ray peak brightness by class and by flux* | Number of events when flux level was met; (number of storm days) |
| R 5 | Extreme | **HF Radio:**Complete HF (high frequency**) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector.<br><br>**Navigation:** Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side. | X20 ($2 \times 10^{-3}$) | Less than 1 per cycle |
| R 4 | Severe | **HF Radio:** : HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time.<br><br>**Navigation:** Outages of low-frequency navigation signals cause increased error in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth. | X10 ($10^{-3}$) | 8 per cycle (8 days per cycle) |
| R 3 | Strong | **HF Radio:** Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth.<br><br>**Navigation:** Low-frequency navigation signals degraded for about an hour. | X1 ($10^{-4}$) | 175 per cycle (140 days per cycle) |
| R 2 | Moderate | **HF Radio:** Limited blackout of HF radio communication on sunlit side, loss of radio contact for tens of minutes.<br><br>**Navigation:** Degradation of low-frequency navigation signals for tens of minutes. | M5 ($5 \times 10^{-5}$) | 350 per cycle (300 days per cycle) |
| R 1 | Minor | **HF Radio:** Weak or minor degradation of HF radio communication on sunlit side, occasional loss of radio contact.<br><br>**Navigation:** Low-frequency navigation signals degraded for brief intervals. | M1 ($10^{-5}$) | 2000 per cycle (950 days per cycle) |

# Data

- Solar Dynamics Observatory (SDO)
  - HMI (Helioseismic and Magnetic Imager)



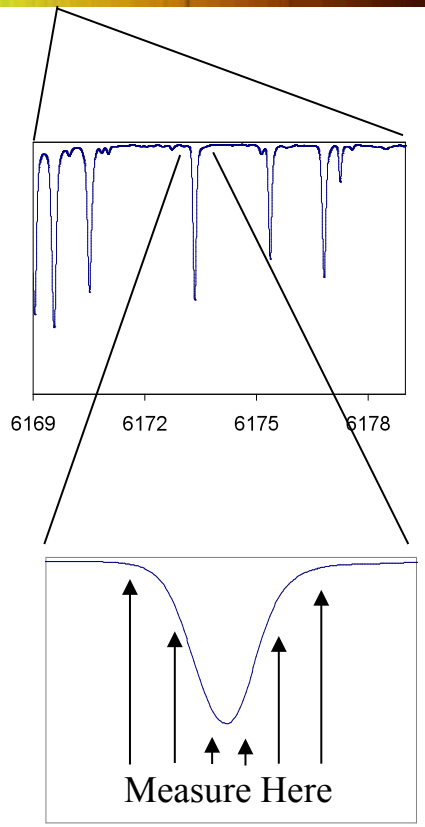
- Geostationary Operational Environmental Satellites (GOES)
  - X-Ray Imager

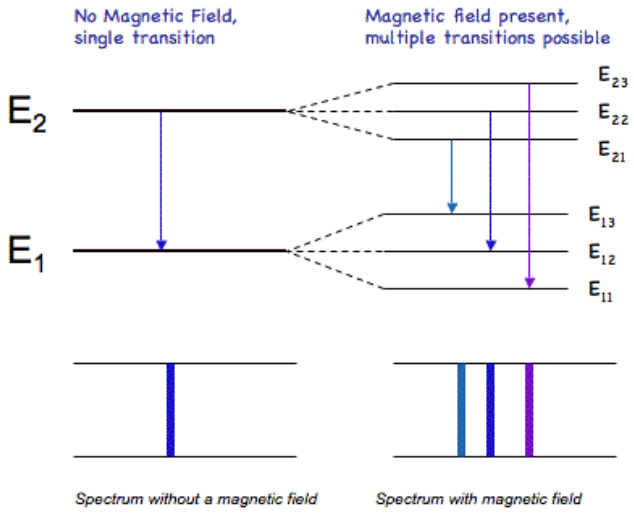


# September, 2011

# HMI

- HMI measures magnetic fields by sampling the Zeeman split line in four polarizations at six wavelengths across a spectral line.
- Gives the Line-of-Sight Magnetic Flux

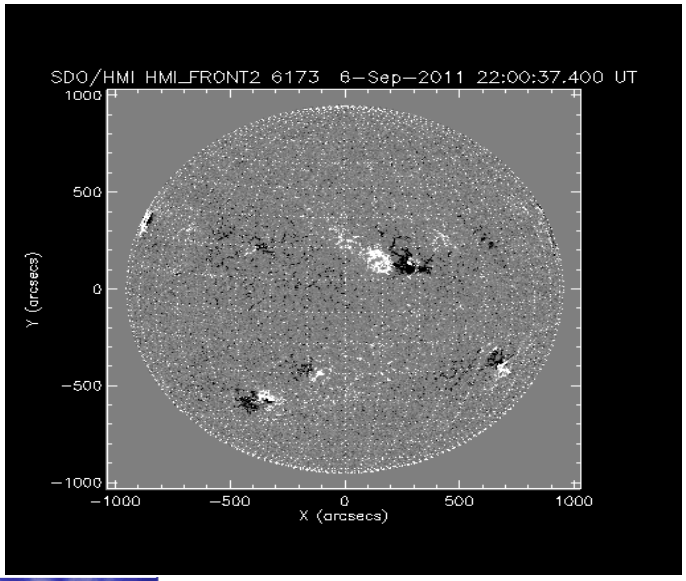


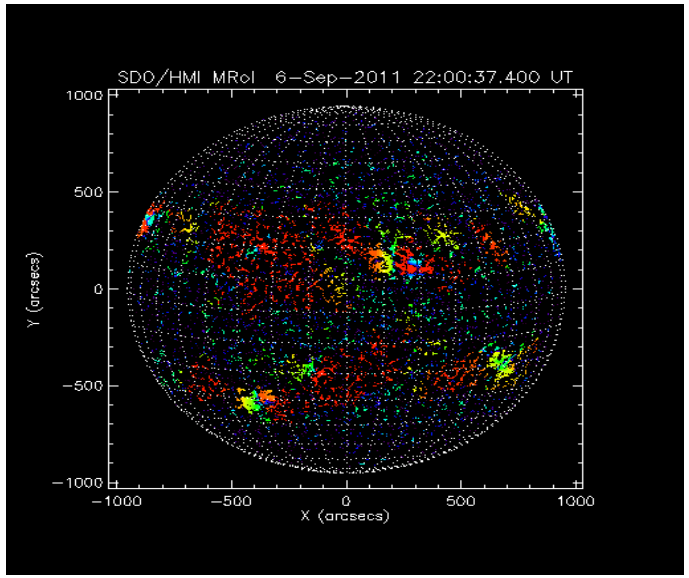




Source:www.hmi.stanford.edu

# Method
## Magnetic Range of Influence
## (MROI)

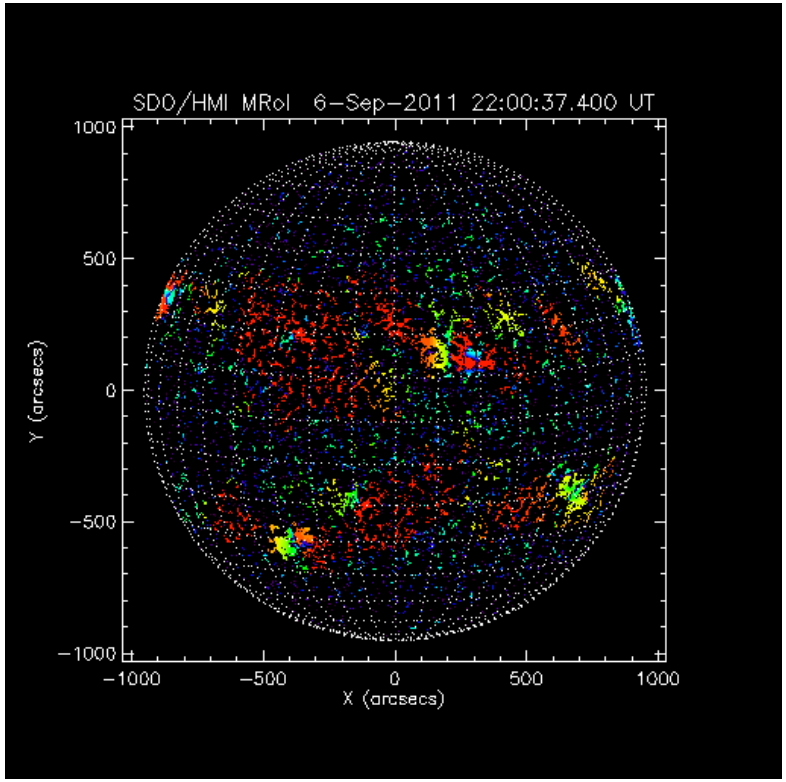
- Reflects the radial distance required to balance the magnetic field
- Small values represent locally “closed” regions
- Large values values represent unbalanced and “open” regions

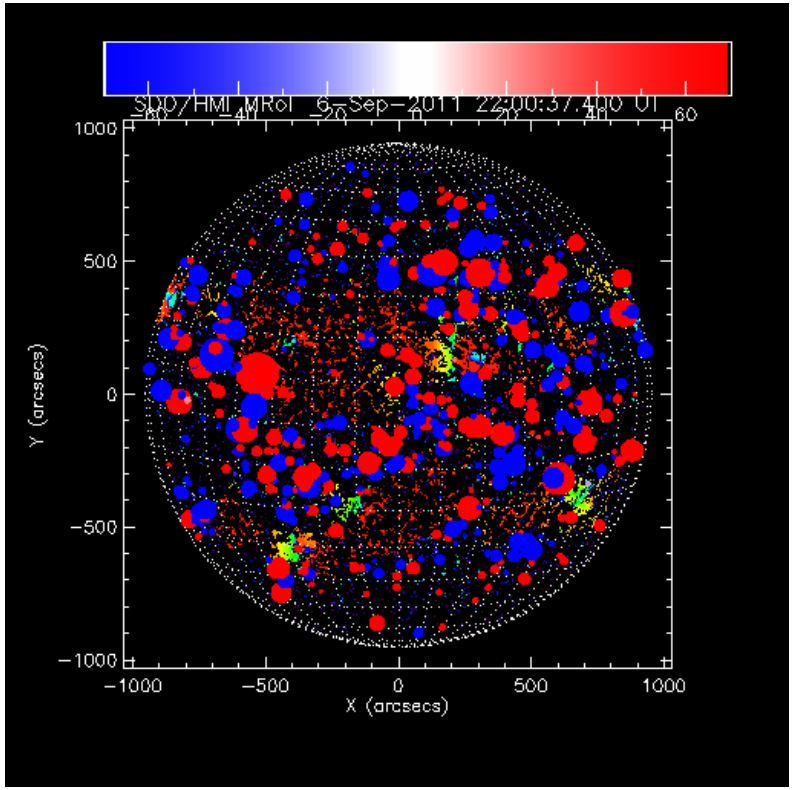


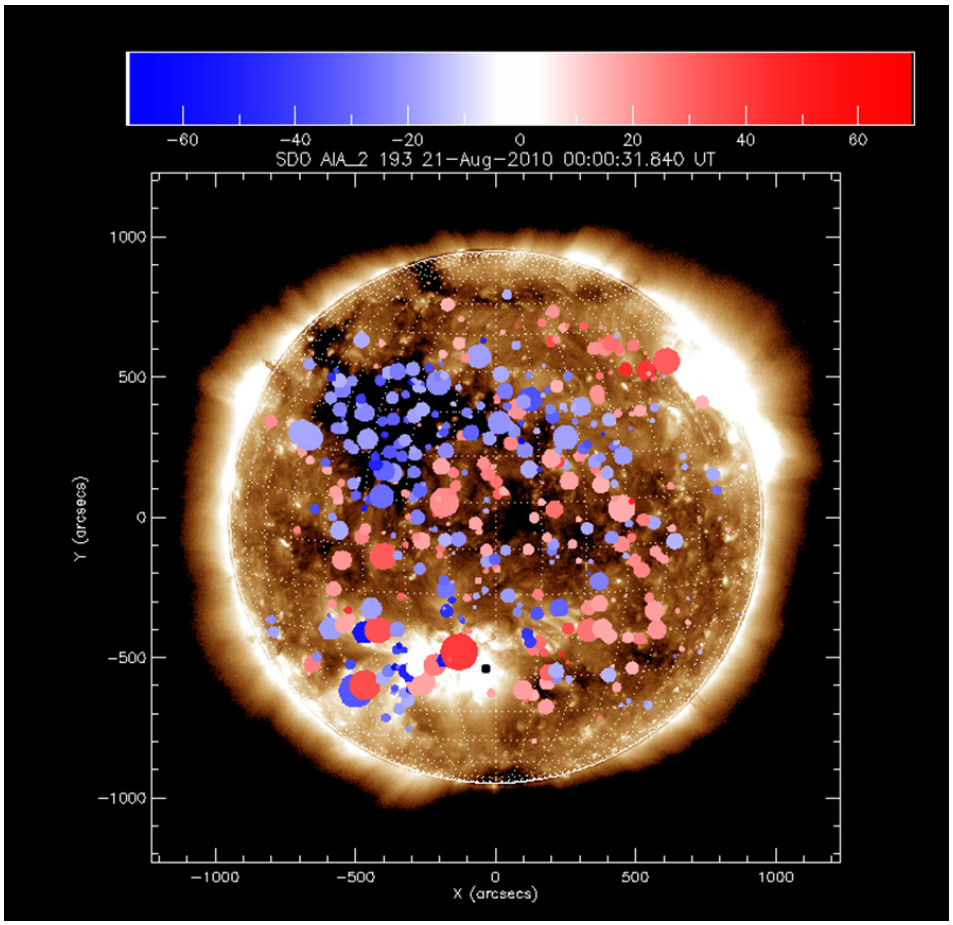
# Method

## G-nodes



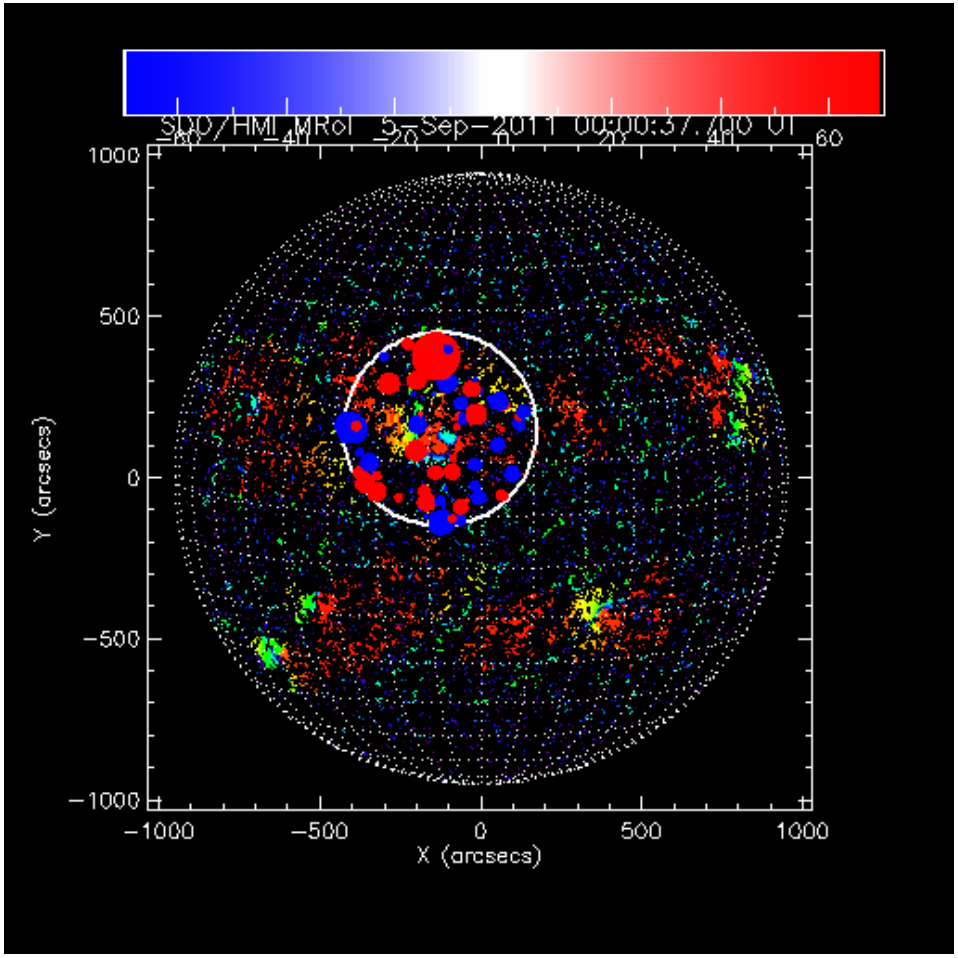



# G-nodes?



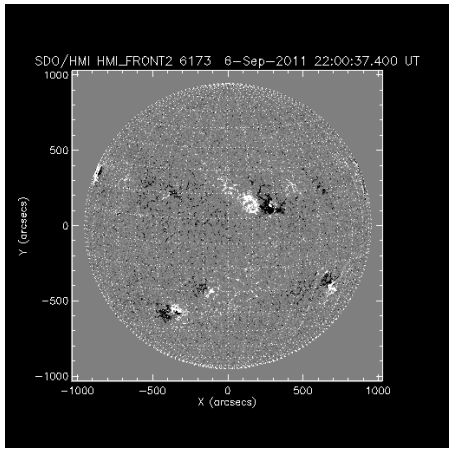

- Regions of about 150-250 Mm MROI scale
- G-gnodes represent the magnetic elements of a very large (and potentially deep) scale of magneto-convection
- Related to the Solar cycle and Coronal Holes. Here we investigate their relation to Solar Flares.

# Tracking the G-nodes

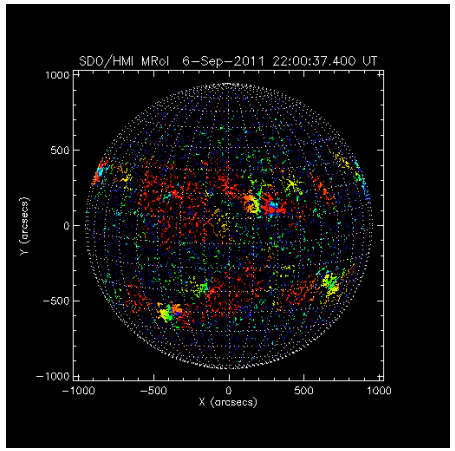



- Active Region:
  - 3 major flares (M53, X21, X18)
  - Radius 300” at (280”, 150”)
- 76 hours (30 min steps)
  - 46 hours before X21 Flare
- 3 test regions:
  - NE (-250”,400)
  - SW (250,-400)
  - SE (-250,-400)

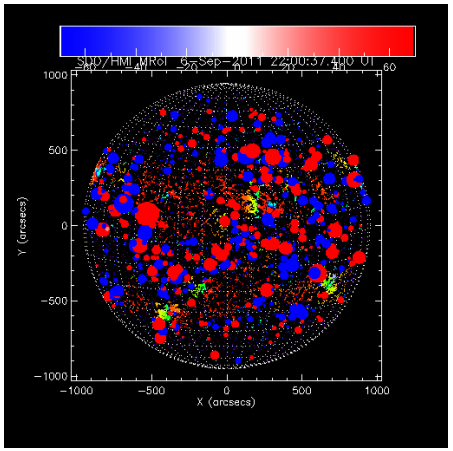
# The Process



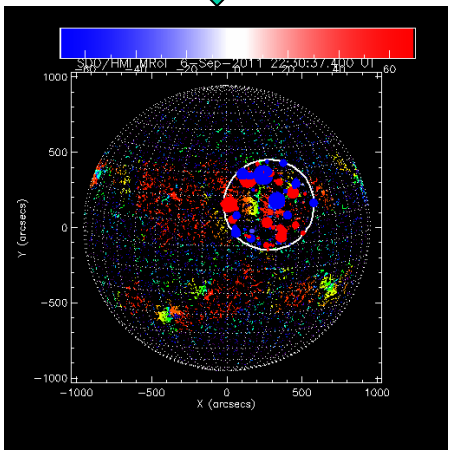

A



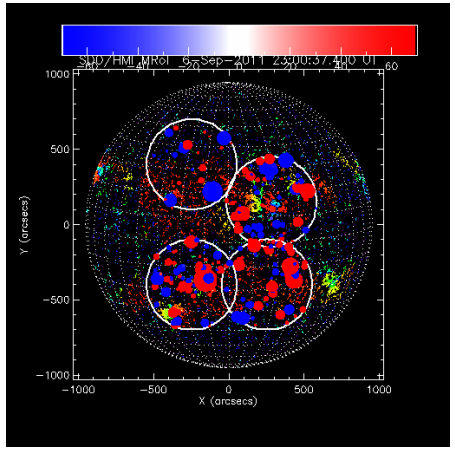

B




C




D

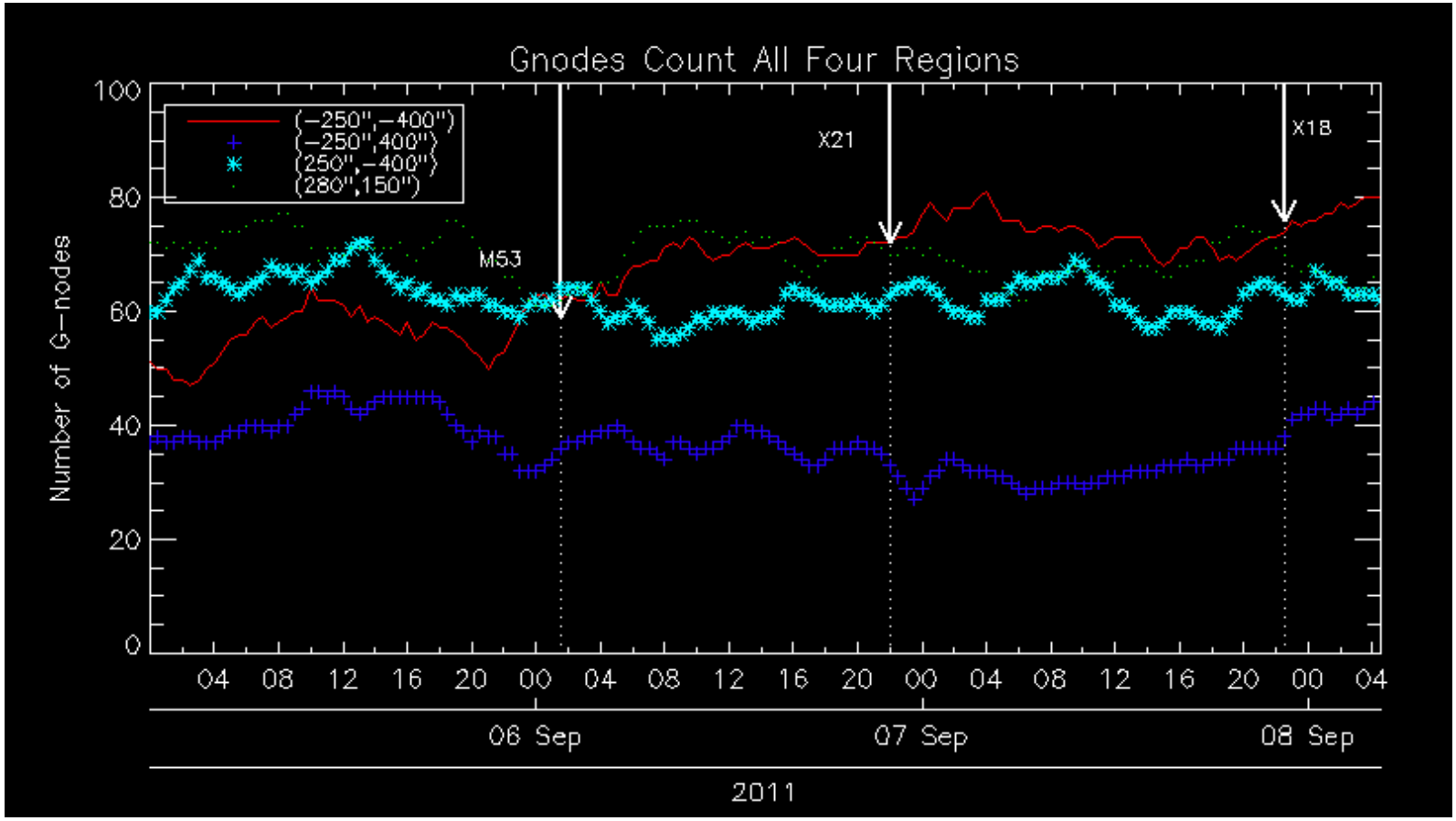



E

A. HMI
B. MROI
C. G-nodes
D. Active Region
E. Test Regions

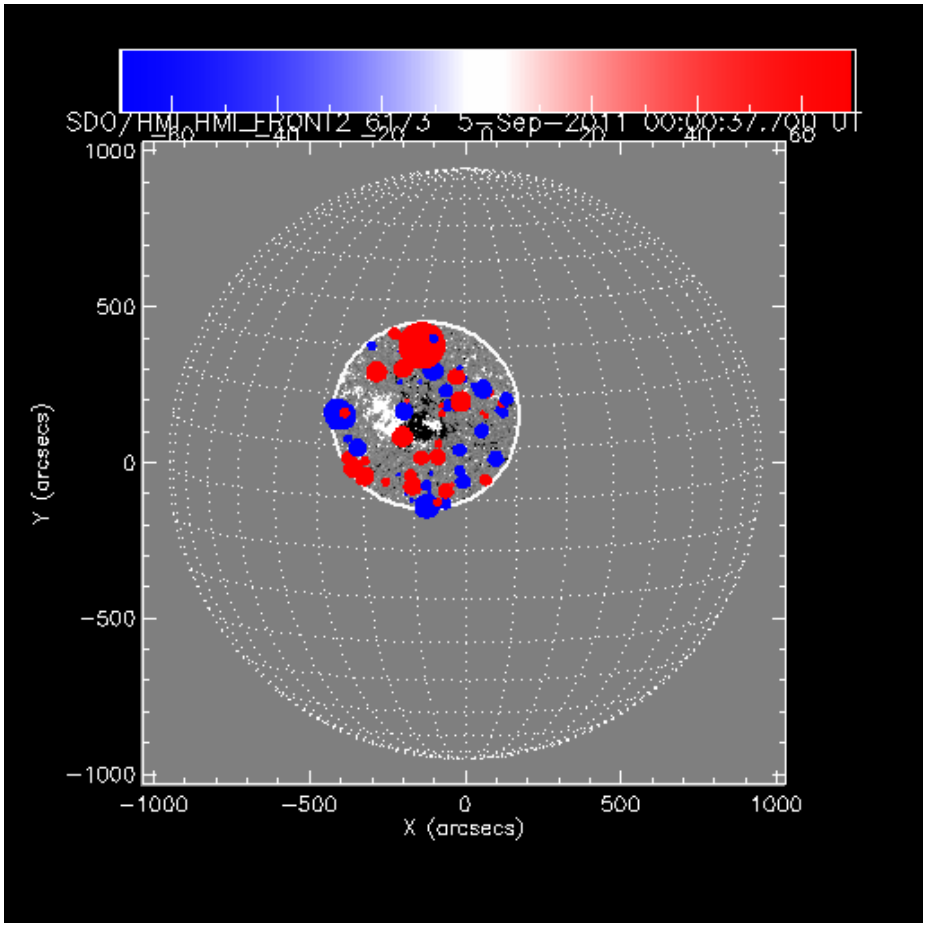
# Results

- No apparent significant correlation between G-nodes count and Flare events. Flare Region: (280”, 150”)



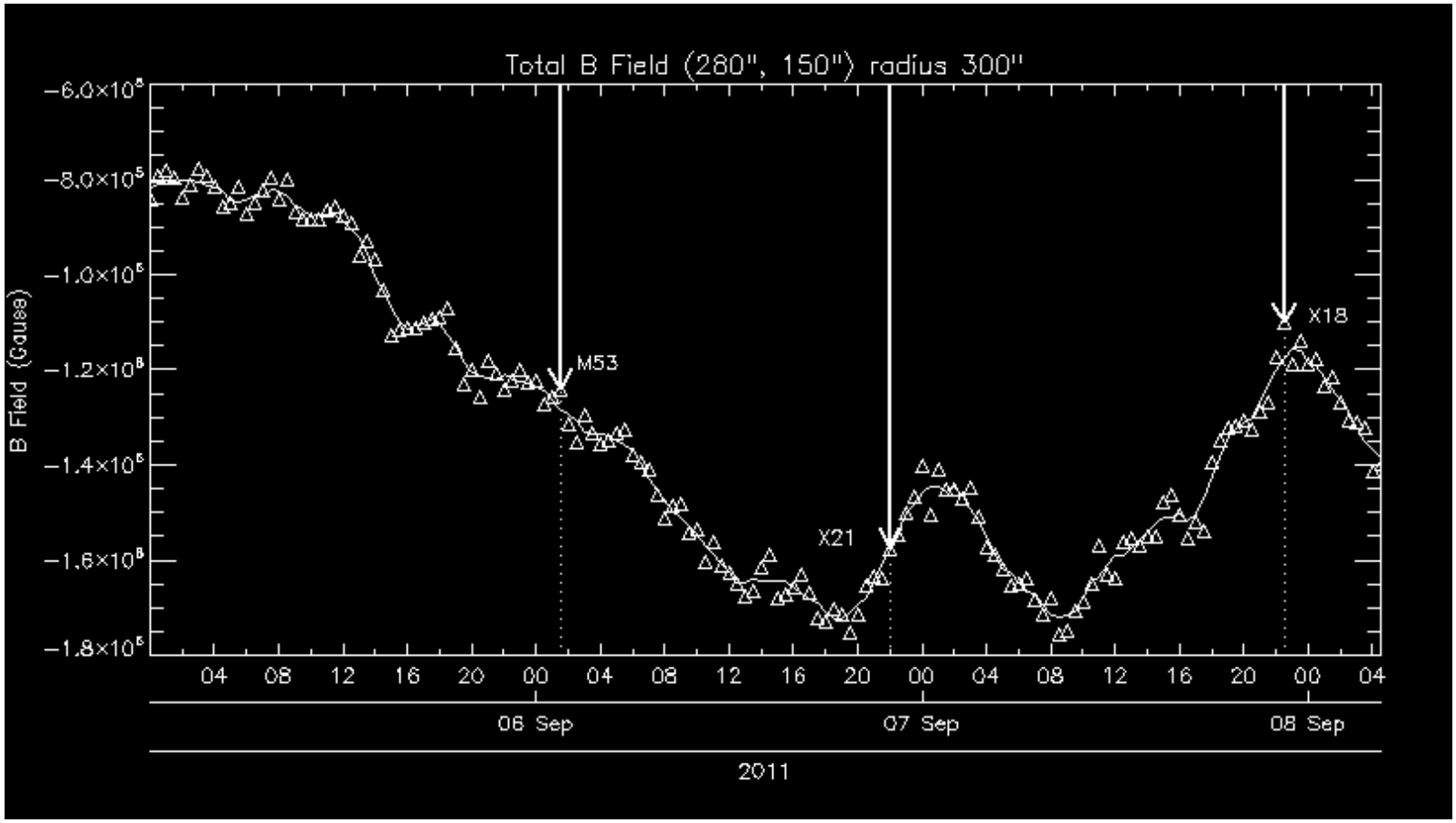
# Magnetic Field

- Do the same tracking but with HMI data



# Magnetic Field as a possible indicator?

- Flux imbalance of the active region as a function of time.



# Possible Future Work

- More data:
  - Extend the observation period
  - Decrease the time steps
- More Examples:
  - 15+ X-Class Solar Flares since SDO launch (4 in May 2013)
- MROI:
  - Change background subtraction for MROI
- Full vector field:
  - Look also at the behavior of horizontal field

# Discussion and Conclusions

- The signature of the emergence of new magnetic flux which we think is a vital component of the biggest flares was harder to detect than expected and more work is needed to understand the formation of these energetic events.

- Flux imbalance of the active region as a function of time

- It is hoped that this study sets the stage for further research into the formation and development of these powerful events

# Acknowledgment


- Special Thanks to:
  - Scott McIntosh
  - Rebecca Centeno
- 2013 REU in Solar and Space Physics:
  - Martin Snow
  - Erin Wood