

Quantifying Magnetic Energy Storage and Release in Active Regions with Emerging Flux

Solar Physics REU, Summer 2011

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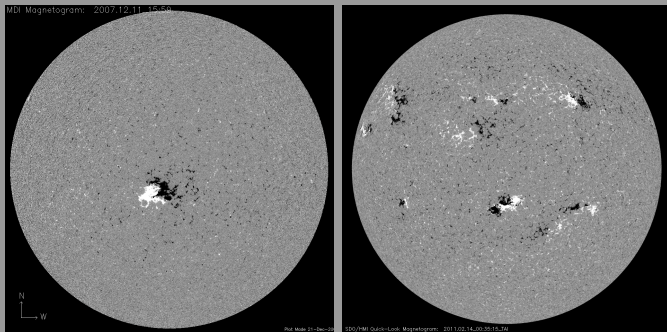
August 4, 2011

Overview

- Ultimately, trying to come up with a baseline estimate for the amount of energy released during a solar flare
 - Solar flares occur when magnetic reconnection takes place
 - Flux emergence plays a part in this
- Looking at a set of magnetograms of active regions around the time of a solar flare, break the region up into smaller subregions
 - Done through a mix of automatic algorithms, and by hand
- Estimate free energy build up due to emergence and movement of active regions

Magnetograms

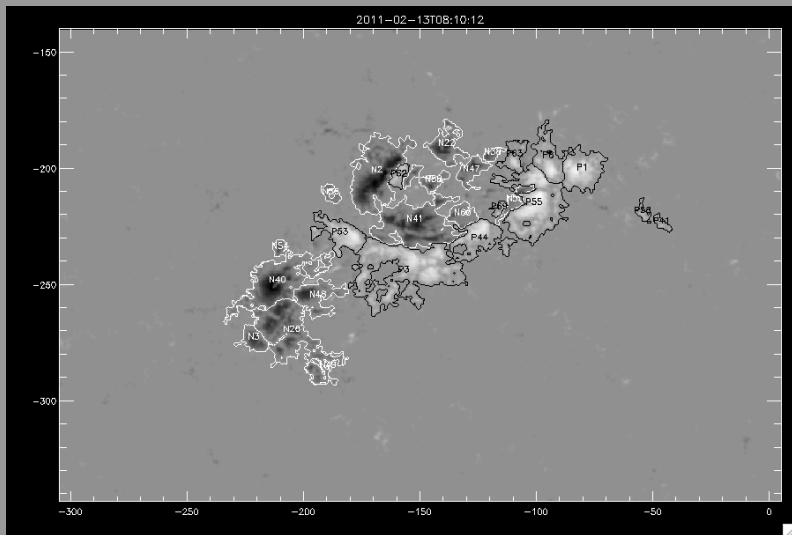
- A way of looking at magnetic fields on the Sun
- By measuring the spectral line splitting, the Zeeman effect can be used to find the magnetic field
- The magnetograms I used came from MDI (SOHO), and HMI (SDO)



Partitioning

- Use a downhill tessellation to partition each magnetogram into distinct regions
- A couple different settings that can be changed:
 - **Saddle** value gives a threshold value for the difference between two peaks
 - **B_{thr}** is the minimum value for an individual pixel, usually around ± 50 Gauss
 - The **height** is the distance above the photosphere that you view the image—this is basically just a smoothing function
 - **Minimum size** of a region, can be set either by pixels or total flux in that region

Partitioning



Centroids and Time Correlation

- After a time series of magnetograms are masked, we try to associate sub-regions between timesteps
- First, find the flux of each region:

$$\psi = \int_{\mathcal{R}} B_z(x, y) dx dy$$

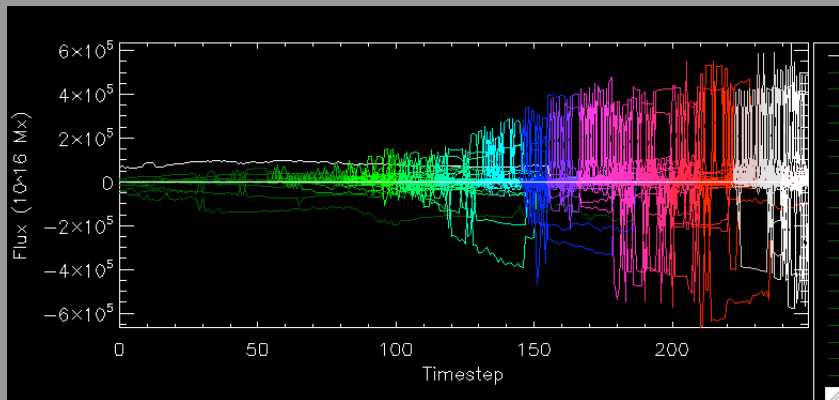
- Use this to find the location of the centroid (pole) :

$$\bar{x} = \psi^{-1} \int_{\mathcal{R}} x B_z(x, y) dx dy$$

- If the distance between two poles is less than the threshold value 10Mm, the two poles are merged

Time Correlation

- Unfortunately, this doesn't actually work very well.

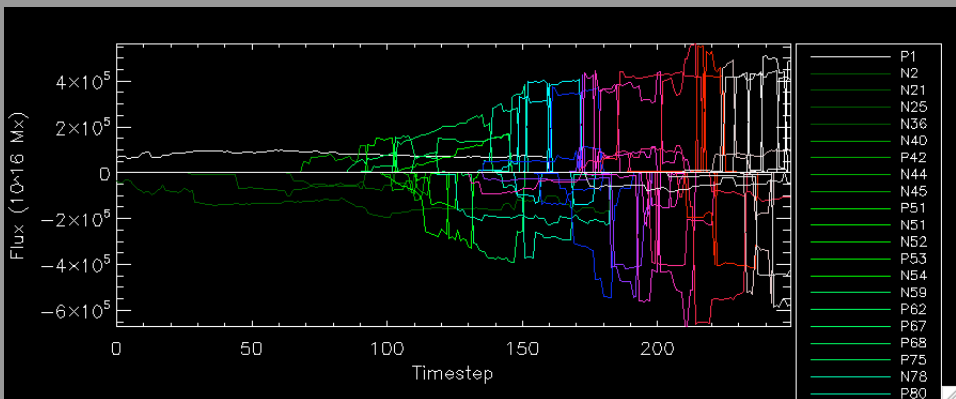


rmv_flick and rmv_vanish

- Two automatic procedures to try to smooth this out:
 - rmv_flick
 - Looks at regions that exist for only a single timestep
 - Compares the pixels in single timestep region to those in the timestep before, after and relabels it if there is considerable overlap with another region
 - rmv_vanish
 - Looks at regions where the label randomly changes
 - Again uses a three timestep window, but looks for regions that disappear in the middle timestep, and compare its area to regions in the timesteps before, after

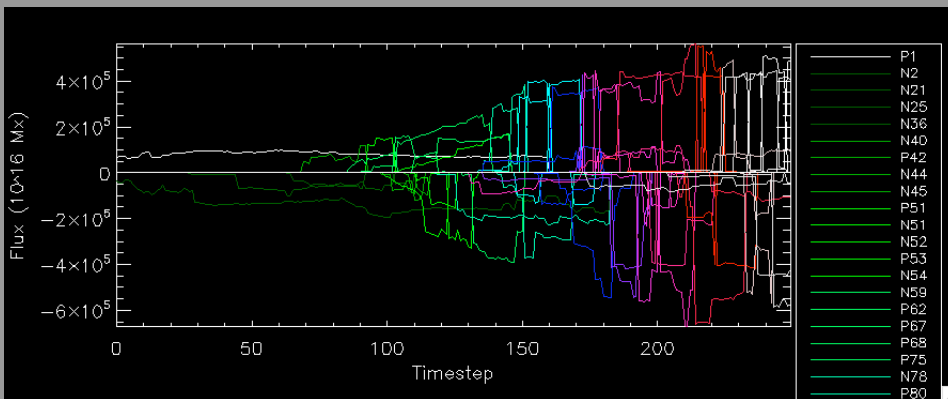
rmv_flick and rmv_vanish

- An improvement, but still not perfect:



rmv_flick and rmv_vanish

- An improvement, but still not perfect:

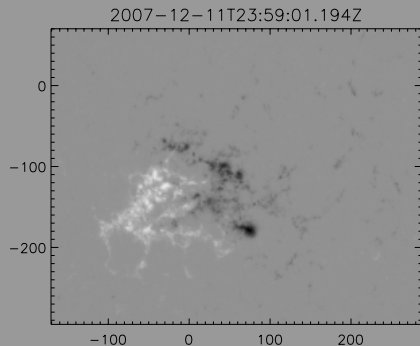


- The rest is done manually

AR10978 and AR11158

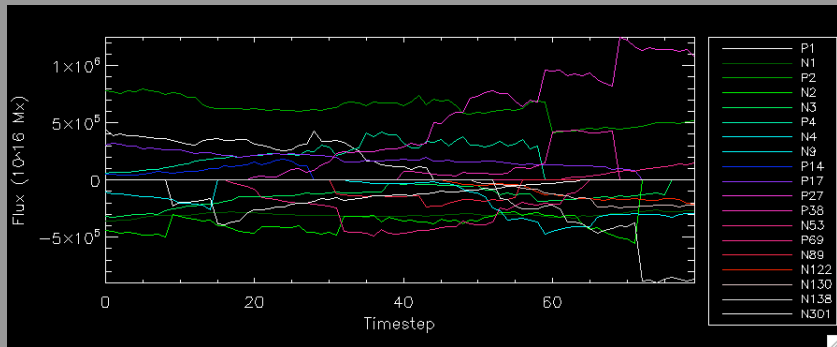
The regions I worked on were:

- AR10978
 - C-class flare in Dec. of 2007
 - Data from MDI, at 96 minute cadence
 - Threshold=50G, Height=3Mm, Minimum Size=22 pixels, Saddle=400



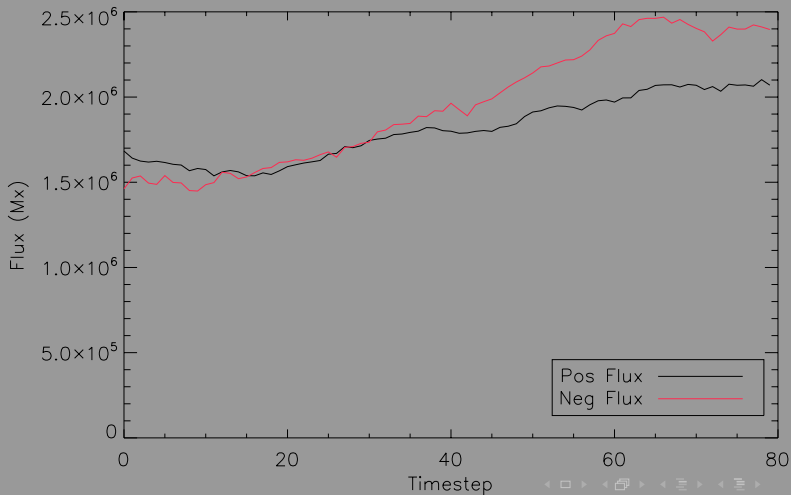
AR10978 and AR11158

AR10978, from Dec. 2007



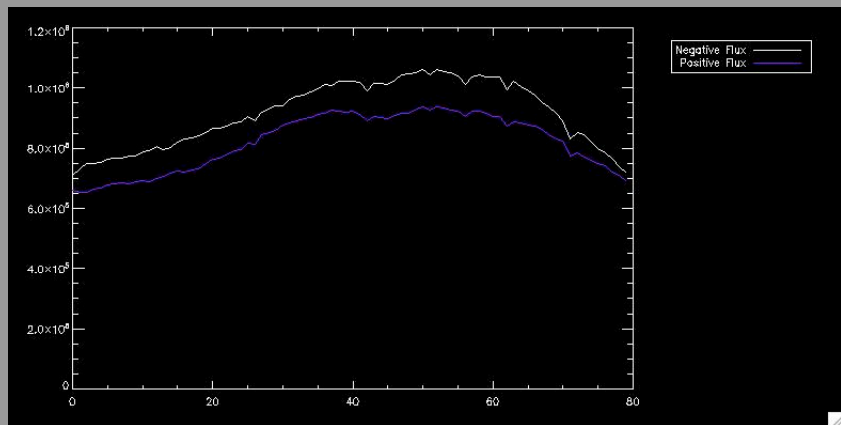
AR10978 and AR11158

AR10978, from Dec. 2007



AR10978 and AR11158

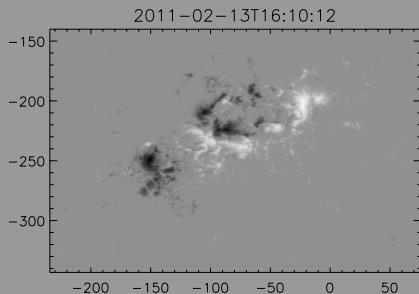
AR10978, from Dec. 2007



AR10978 and AR11158

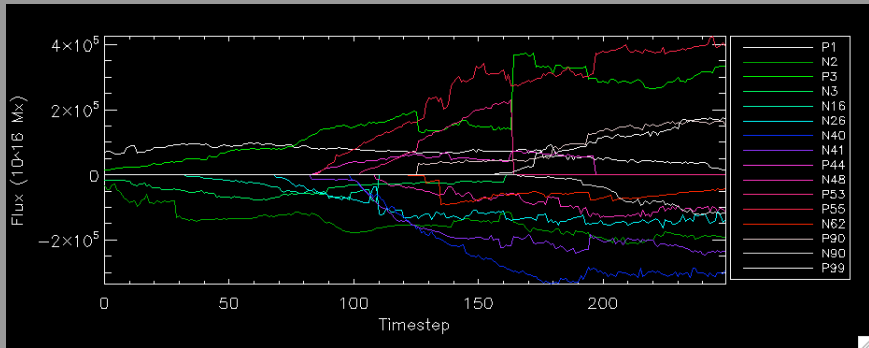
The regions I worked on were:

- AR11158
 - X-class flare in Feb. 2011 (Valentine's Day Flare)
 - Data from HMI, at 24 minute cadence
 - Threshold=75G, Height=3Mm, Saddle=700



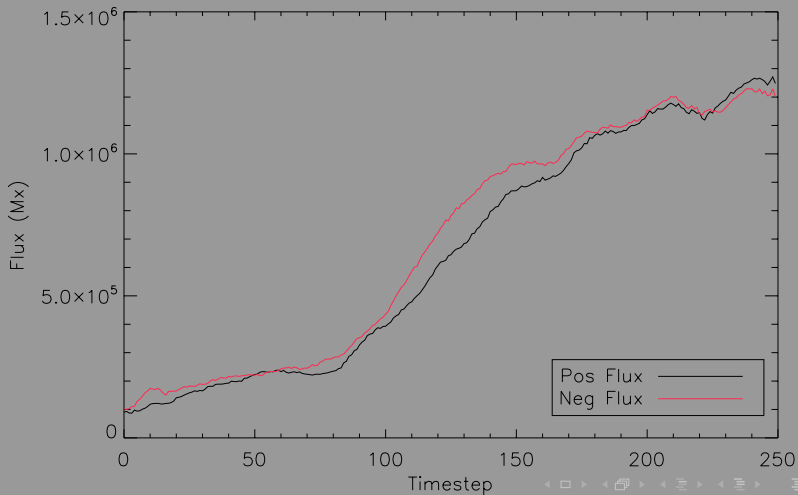
AR10978 and AR11158

AR11158, from Feb. 2011

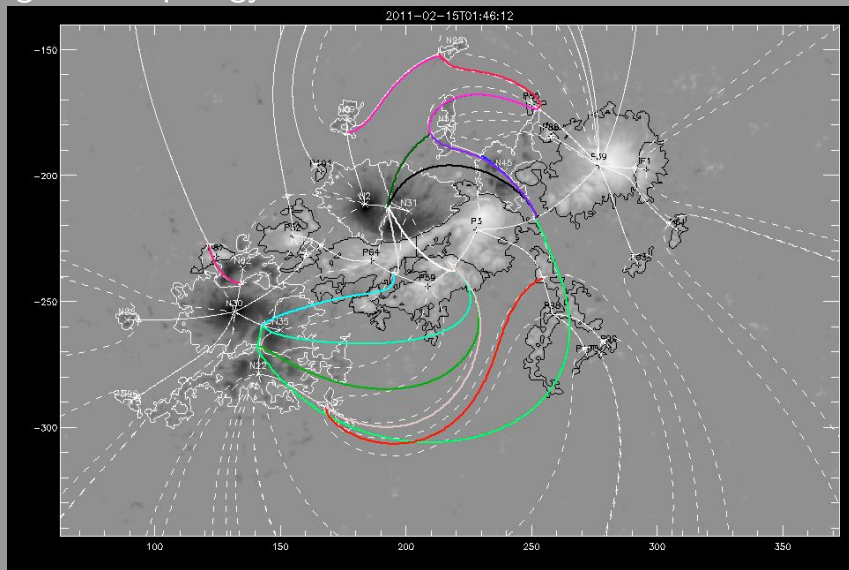


AR10978 and AR11158

AR11158, from Feb. 2011



Magnetic Topology



Potential Field

- There always exists a potential field: a minimum energy configuration
- We assume no current in the corona, so that

$$\nabla \times \mathbf{B} = 0, \text{ or } \mathbf{B} = \nabla\phi$$

- Combine with $\nabla \cdot \mathbf{B} = 0$ (from Maxwell's Eqns):

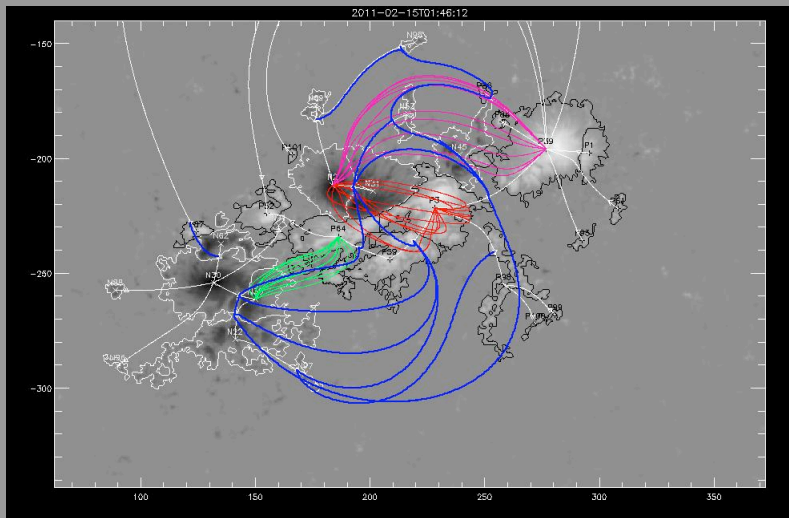
$$\nabla^2\phi = 0$$

- So by solving Laplace's equation we can find the (unique) potential field

Potential Field

- So, designate one timestep as being in the potential field configuration, and constrain flux to that arrangement
- Also find the potential field configuration at every timestep after
- Use the poles (flux weighted centroids) from the mask array to figure out the magnetic topology at each timestep

Magnetic Topology

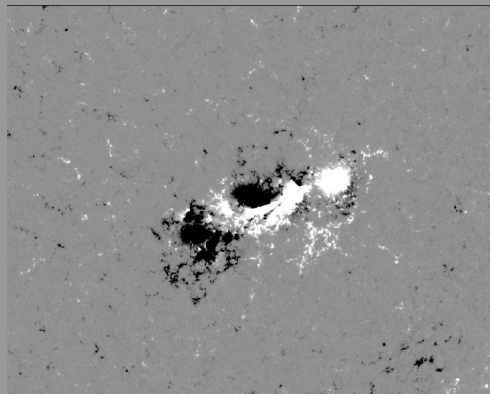


Potential Field

- So, designate one timestep as being in the potential field configuration, and constrain flux to that arrangement
- Also find the potential field configuration at every timestep after
- Use the poles from the mask array to figure out the magnetic topology
- The discrepancy between the “actual” field should hopefully give a lower bound for the energy

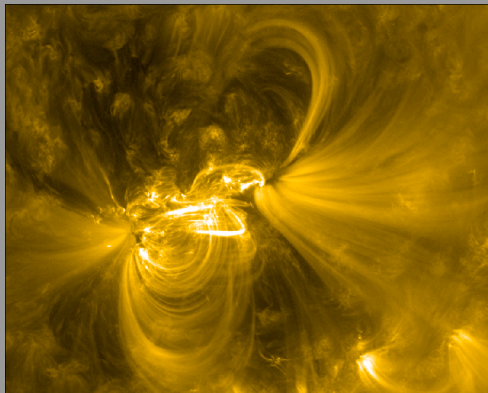
Conclusion

- The work I did was just the beginning of a long process
- Compare the free energy estimates to X-ray emission data from flares



Conclusion

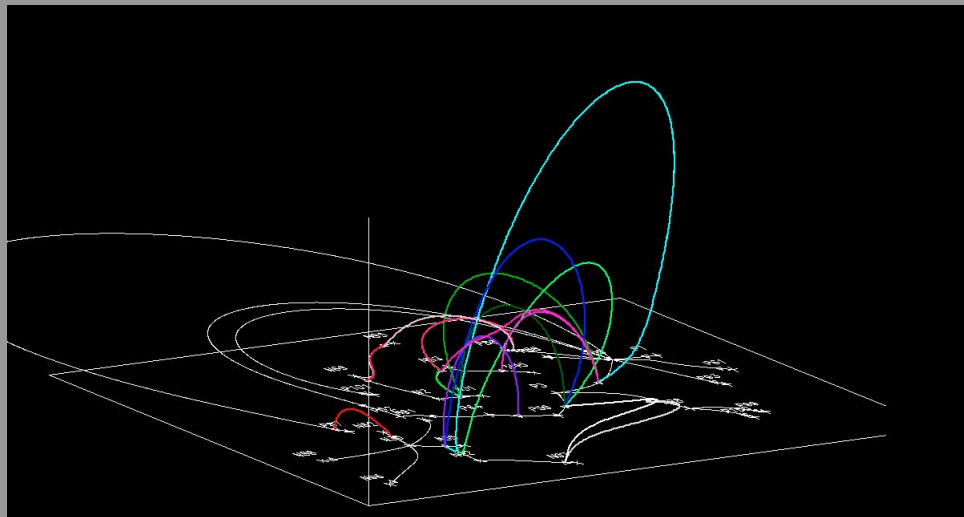
- The work I did was just the beginning of a long process
- Compare the free energy estimates to X-ray emission data from flares



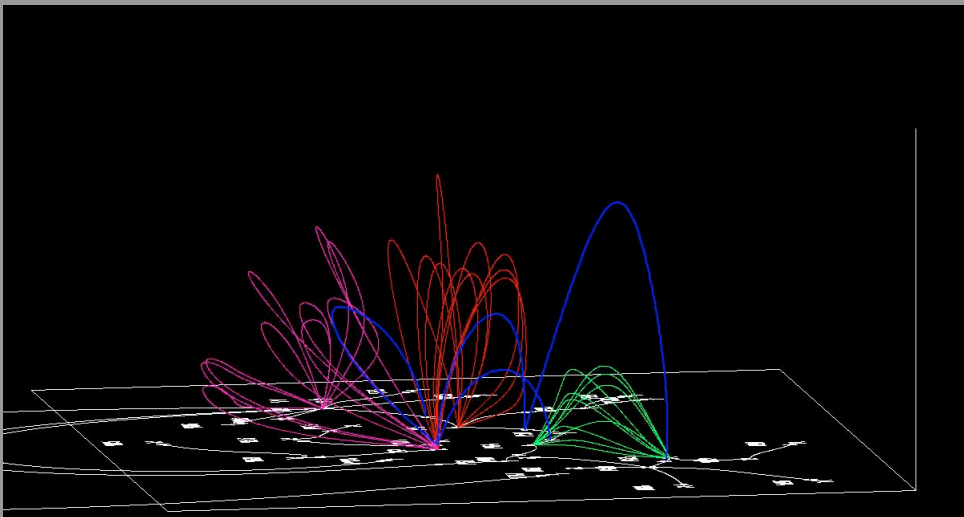
Acknowledgements

- Lucas Tarr
- Dana Longcope
- The entire MSU Solar Physics Group
- The REU advisors and students

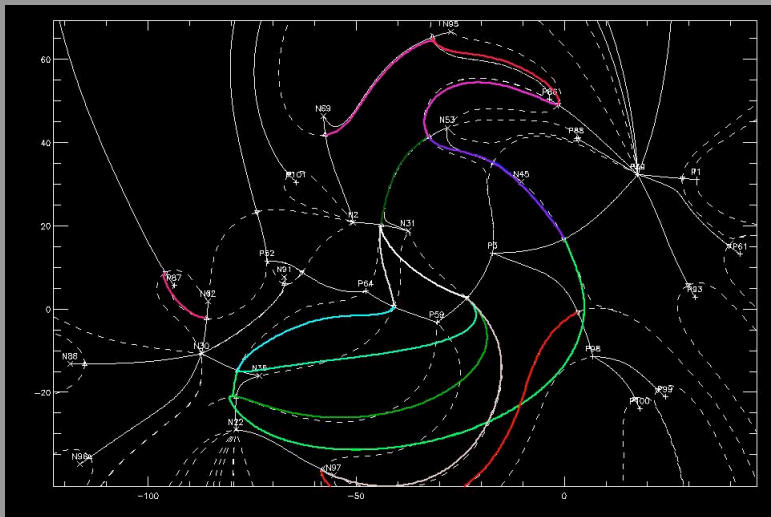
Magnetic Topology



Magnetic Topology



Magnetic Topology



A brief overview of magnetic topology terms

- Null Point:
 - Location (usually on photosphere) where the magnetic field is zero
- Seperator:
 - Field line connecting two nulls
- Pole:
 - Estimated point source at the flux weighted cenget of a mask region
- Spine:
 - Field lines connecting a pole to a null
- Domain:
 - The space connecting two poles