

# Calculating the Magnetic Free Energy Using the Minimum Current Corona Model in Evolving Active Regions



Lucas Tarr & Dana Longcope

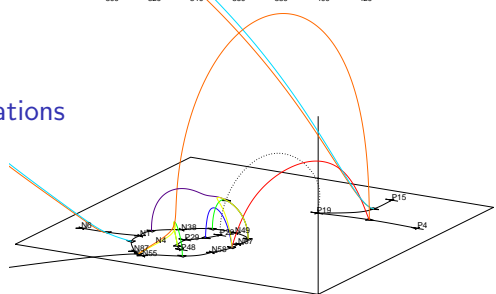
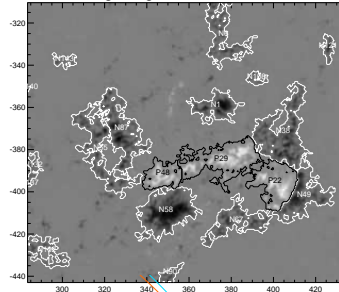
MSU Solar Physics

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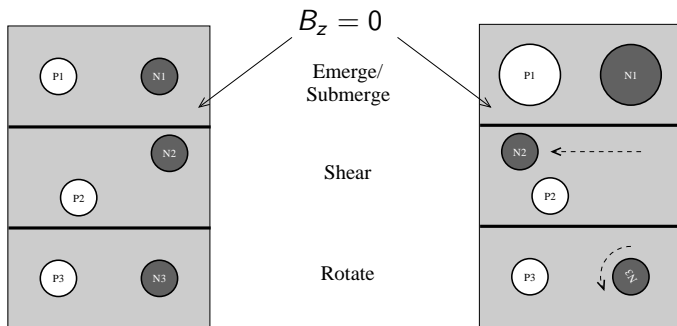
- 1 Modeling Photospheric Sources
- 2 Coronal Topology
- 3 AR11112 Energetics
- 4 MCC informing AIA observations

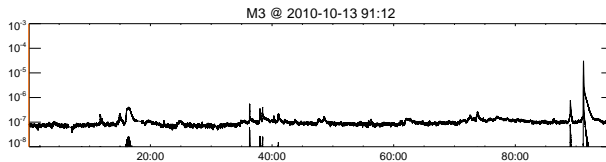
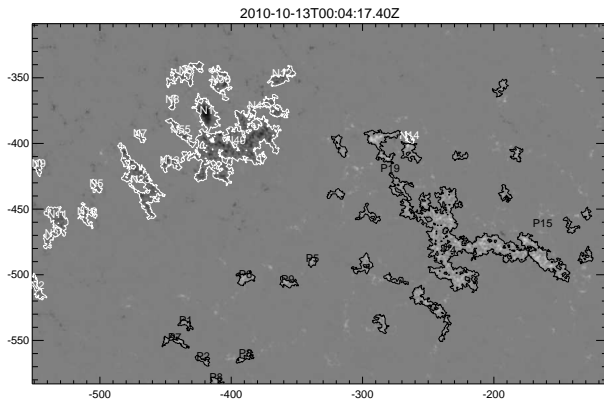
HMI Magnetogram: 2010-10-16 18:53



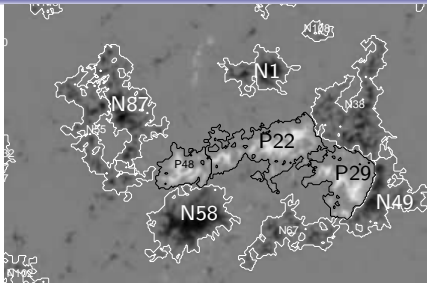
## Minimum Current Corona (MCC) Model of Coronal Field Evolution:

- Concentrated flux evolves in a  $|B_z| = 0$  photospheric sea
- Amount of flux linking each pair of regions is fixed during evolution

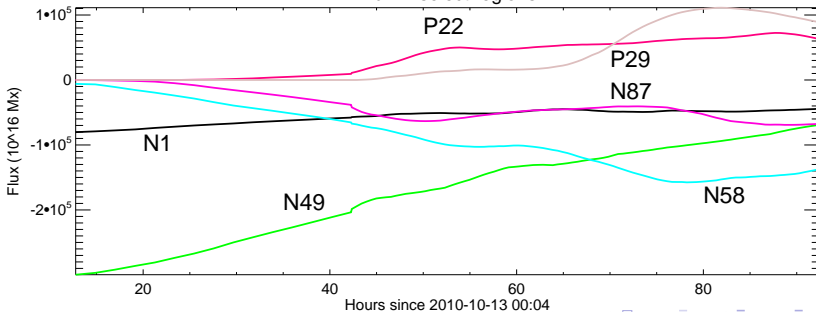




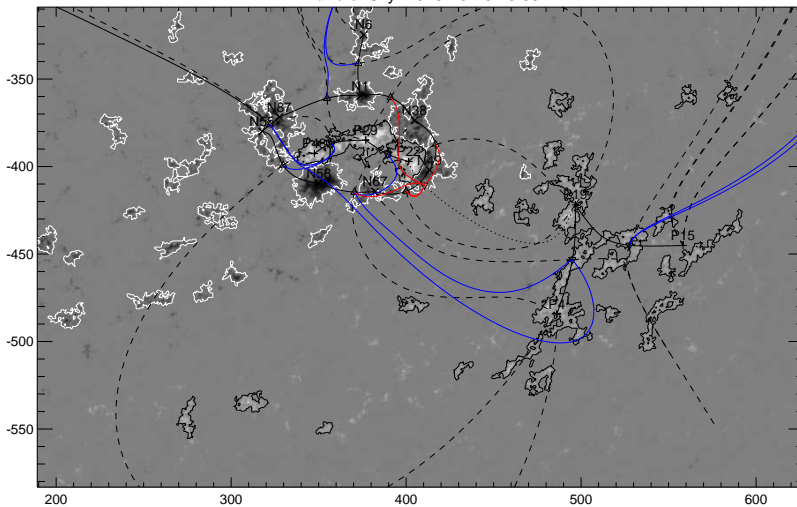
Magnetogram  
subsection:  
2010-10-16,  
18:53 UT

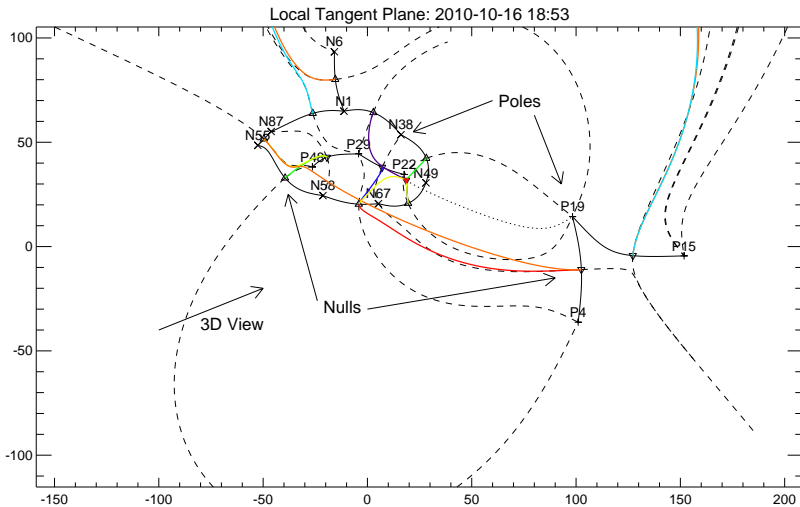


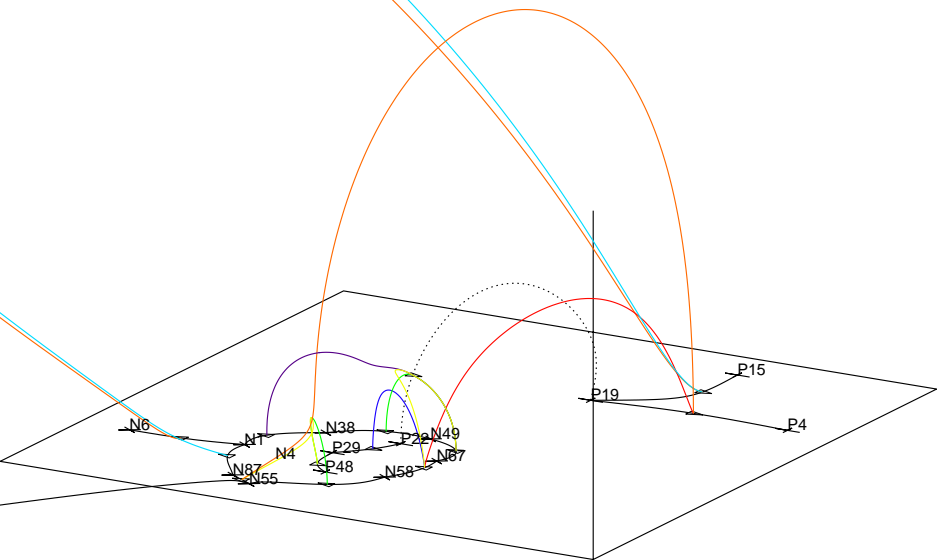
Flux in select regions



Plane of Sky: 2010-10-16 18:53









MCC asserts that, barring reconnection, domain fluxes are fixed over time. Current therefore develops along separators (Longcope&Magara, 2004):

$$\psi_{\sigma}^{(cr)i} \equiv \psi_{\sigma}^i - \psi_{\sigma}^{(v)i} = \frac{IL}{4\pi} \ln\left(\frac{eI^*}{|I|}\right)$$

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$$\psi_{\sigma}^{(cr)i} \equiv \psi_{\sigma}^i - \psi_{\sigma}^{(v)i} = \frac{IL}{4\pi} \ln\left(\frac{eI^*}{|I|}\right) \quad (1)$$

which yields an energy in excess of the potential field:

$$\Delta W_{MCC}(I) = \frac{1}{4\pi} \int_{\Psi_{potl}}^{\Psi} Id\Psi = \frac{LI^2}{32\pi^2} \ln\left(\frac{\sqrt{e}I^*}{|I|}\right) \quad (2)$$

Invert the current/separatrix–flux relation:

$$I(\psi_{\sigma}^{(cr)i}) = I^* \Lambda^{-1}(4\pi\psi_{\sigma}^{(cr)i} / LI^*) \quad (3)$$

with  $\Lambda(x) \equiv x \ln(e/|x|)$

... and solve for the work:

$$\Delta W_{MCC}(I) \longrightarrow \Delta W_{MCC}(\psi_{\sigma}^{(cr)i}) \quad (4)$$

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We must now explicitly calculate the separatrix fluxes  $\psi_{\sigma}^{(cr)i}$

# Under the hood

- Initial generation of consistent partitions
- Inconsistent boundaries between regions
- Quantifying submergence and emergence (Partnering emerging pairs)
- Determining all domains linked by each separator (fast algorithm using Gauss Linking Number)

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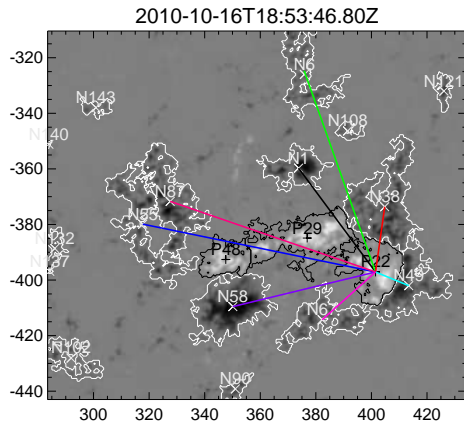
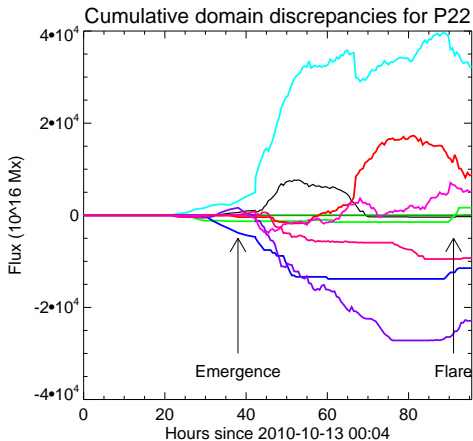
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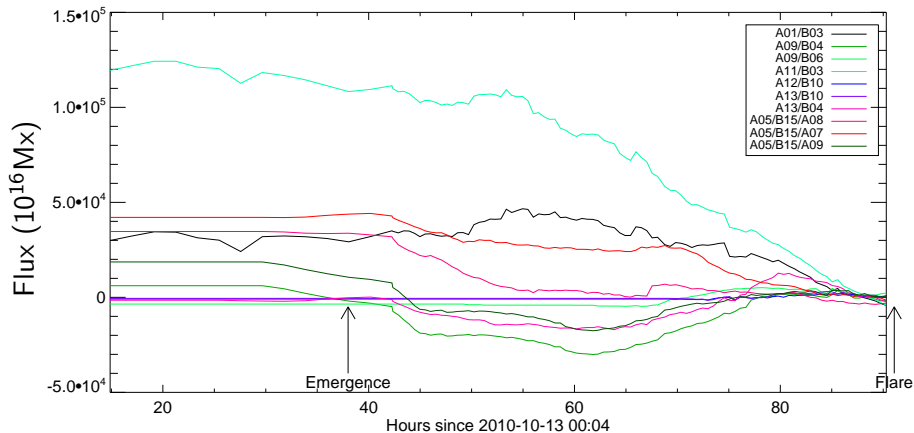
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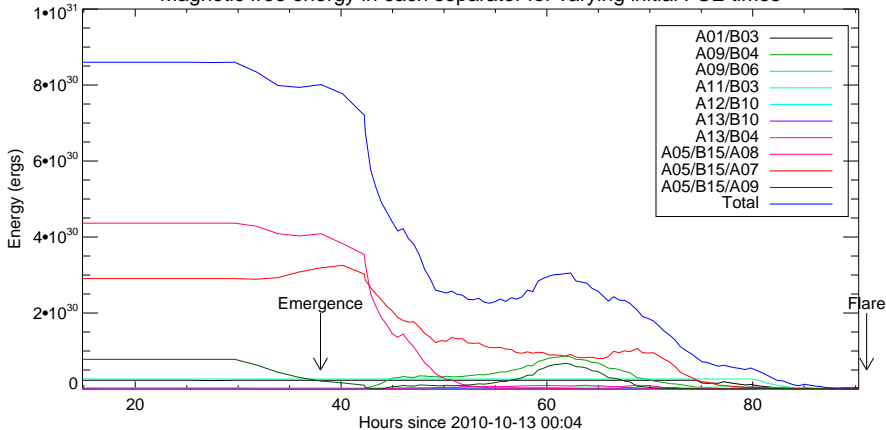
# Domains for a single region: P22



# Separator fluxes: Different initial constraint times compared to flare-time potential field

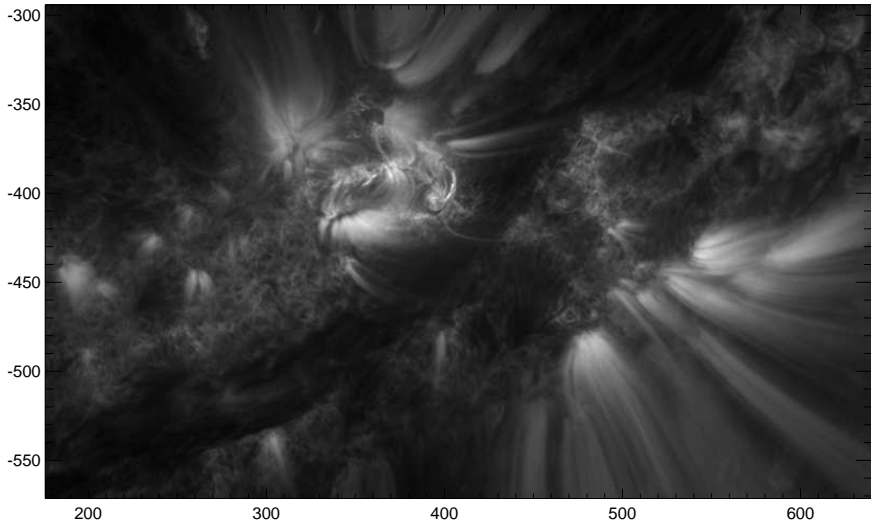


Magnetic free energy in each separator for varying initial FCE times

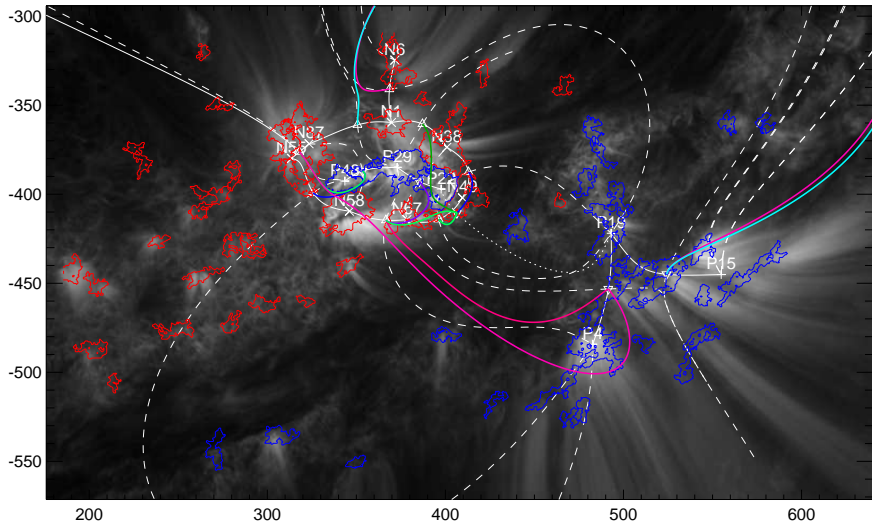


Free energy build up of  $\sim 8.5 \times 10^{30}$  ergs over 3 days leading up to the flare, or  $\approx 5\%$  of the potential field energy.

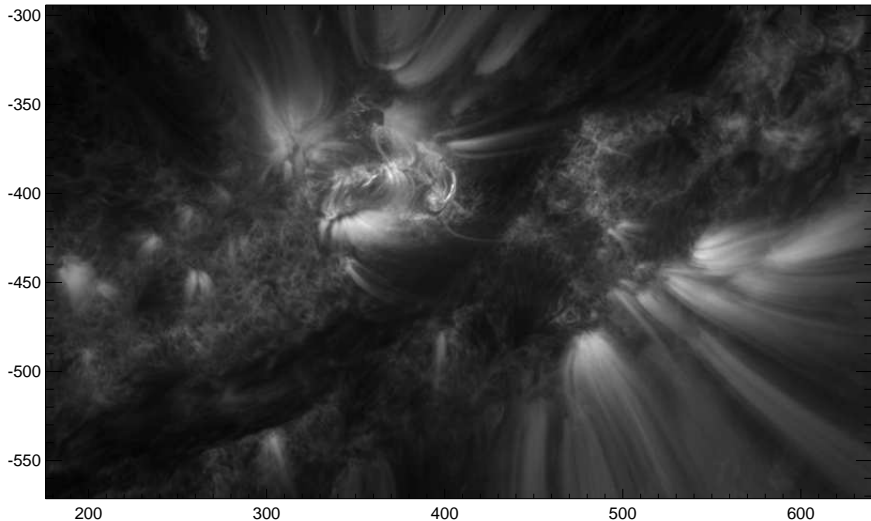
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# Conclusions

We have extended the Minimum Current Corona model to deal explicitly with emerging flux, and applied this to the case of AR11112, which underwent an M3.0 flare.

Free Energy MCC:  $0.85 \times 10^{31}$  ergs

Free Energy MC-Voronoi:  $0.23 \times 10^{31}$  ergs

(see poster 106: Longcope, Malanushenko, Tarr)

Total Potential Energy:  $16.7 \times 10^{31}$  ergs

GOES Radiated Energy:  $0.03 \times 10^{31}$  ergs