THE HOW AND WHY OF BIG SOLAR FLARES

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Abstract

It is generally understood that the peak soft X-ray flux of solar flares emanating from active regions follows a power-law spectrum of magnitudes; however, it is not understood why the flares from some active regions do not obviously exhibit this distribution. We take here an approach to understand why this occurs, by combining modeling and observation to study the energy reservoirs within a solar active region and the pathway the energy takes to produce solar events. We consider a complex active region, AR 11793 from July 19th, 2013, that was expected to produce larger flares than the actual C-flares observed. We modeled the coronal magnetic field using the CFITS nonlinear force-free extrapolation code, then identified individual coronal current systems by starting from photospheric concentrations of high vertical current density and propagating those through the extrapolation volume. We estimated the energy-release prospects of each current system as a measure of how much energy might be released in a single reconnection event. We used different thresholds and similar selection parameters to select the current systems and investigated the sensitivity of the results to the choice of such parameters. We present here results comparing the energy associated with the individual current systems with the magnitude of the flares originating from our region.

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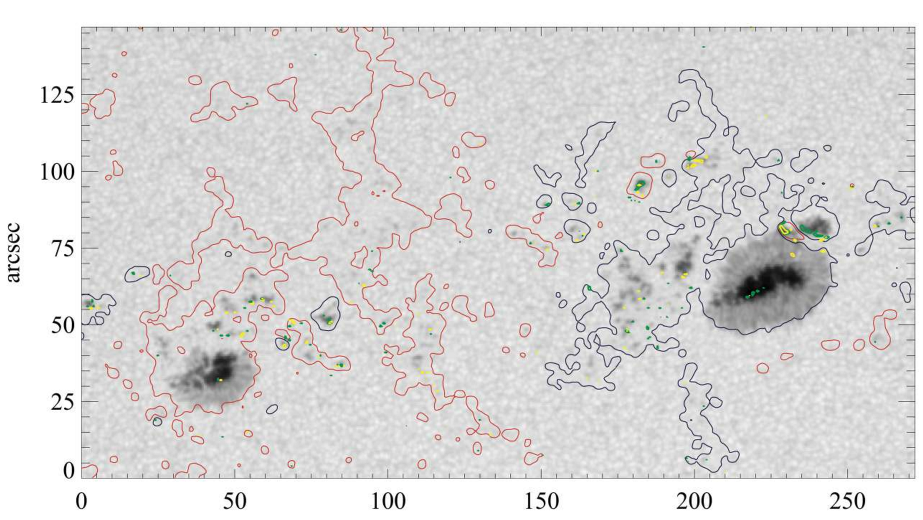
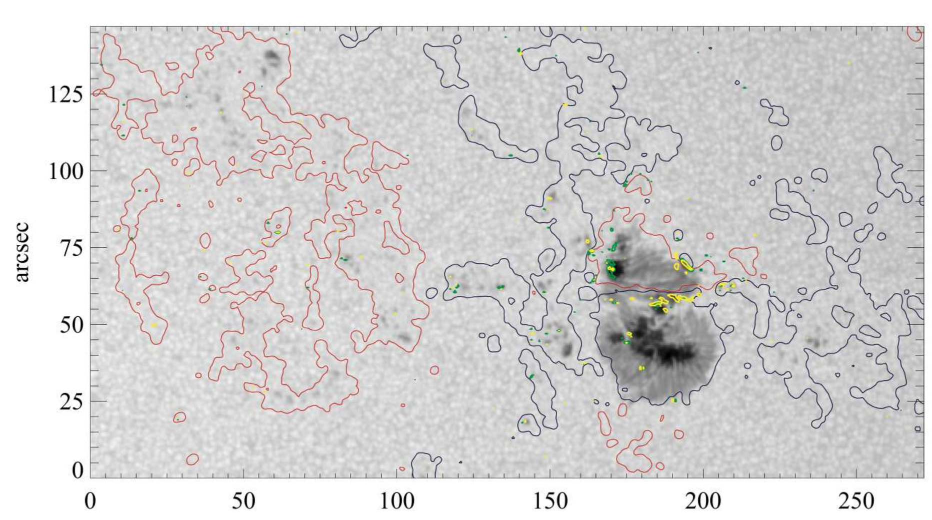
We consider solar active regions with similar properties, yet diferent magnitudes of flares:

AR 11793 on 2013.07.19 at 20:00 TAI

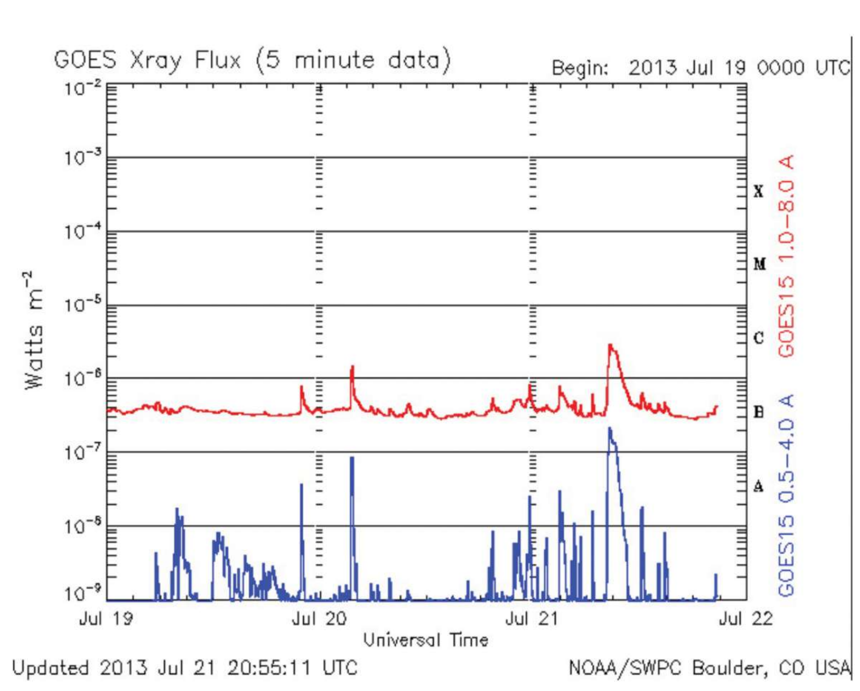


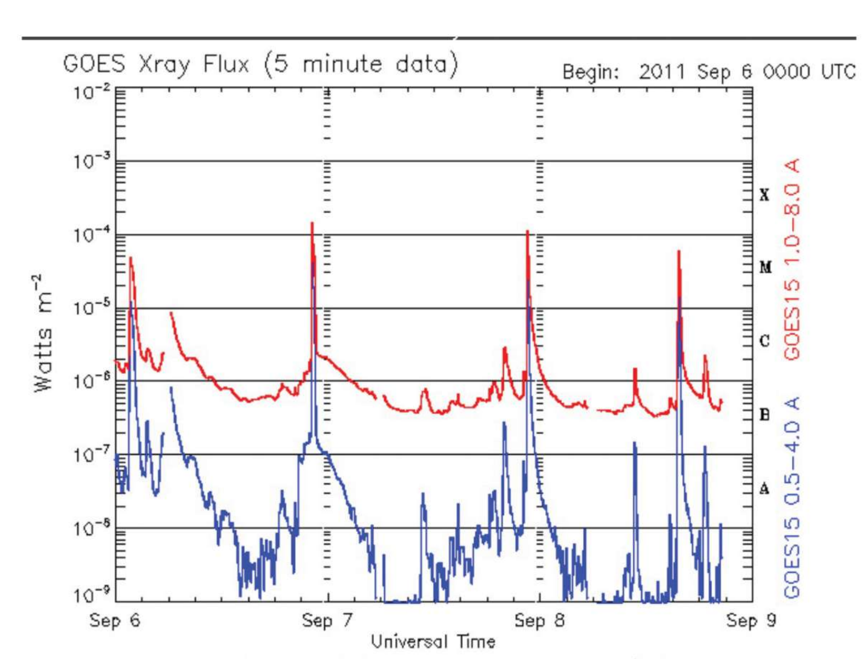
AR 11283 on 2011.09.06 at 00:48 TAI



Images are in continuum intensity (greyscale) with contours of radial magnetic field (red, blue, G) and radial current density (green, yellow, mA^{-2}).

	AR 11793	AR 11283
Total Unsigned Flux:	$\Phi \sim 4.9 \times 10^{22}$ Mx	$\Phi \sim 4.8 \times 10^{22}$ Mx
Total Unsigned Current:	$I \sim 1.8 \times 10^{13}$ A	$I \sim 1.4 \times 10^{13}$ A





Hypothesis: The energy released during a magnetic reconnection event (flare) is a fraction of the the total energy stored.

- Active regions whose current systems store little energy will produce flares of lesser magnitudes, and vice versa

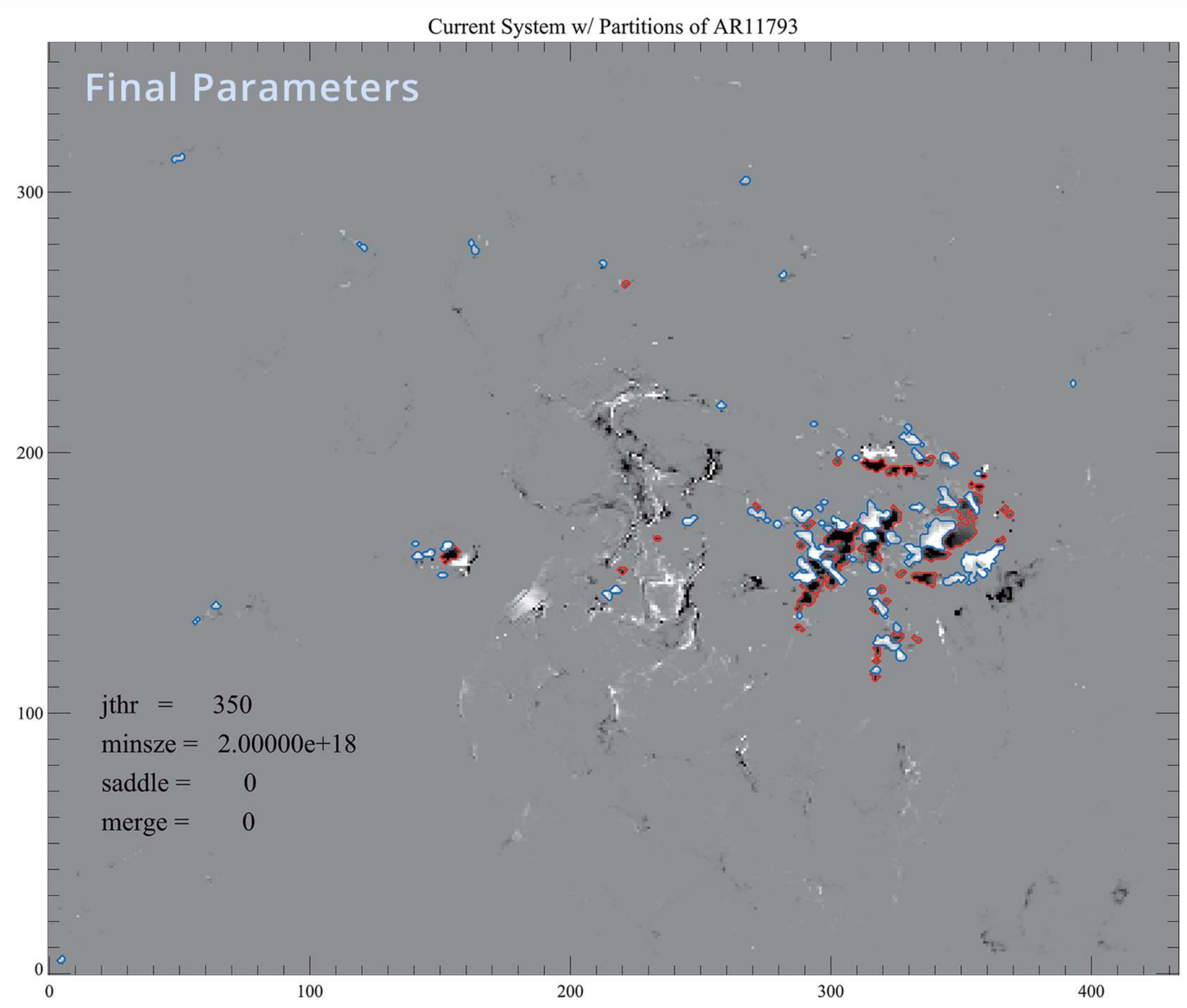
Methods

1. Identified concentrations of the radial current systems at the photosphere
2. Propagated these currents through a model of the corona (CFITS) to get field lines
3. Used the Biot-Savart law to compute the coronal magnetic field, *B*, due to each identified coronal electric current system
4. Computed the energy from a volume integral due to that identified curent system

1 Identifying Current Systems

Curent systems were identified by partitioning the vertical current density on the lower boundary using a series of parameters:

- Use a threshold on the current density to put each pixel to a local maximum (|*Jr*|)
- Remove partitions with insignifigant amounts of current
- Ignore pixels below a noise threshold
- Merge partitions at a small saddle point

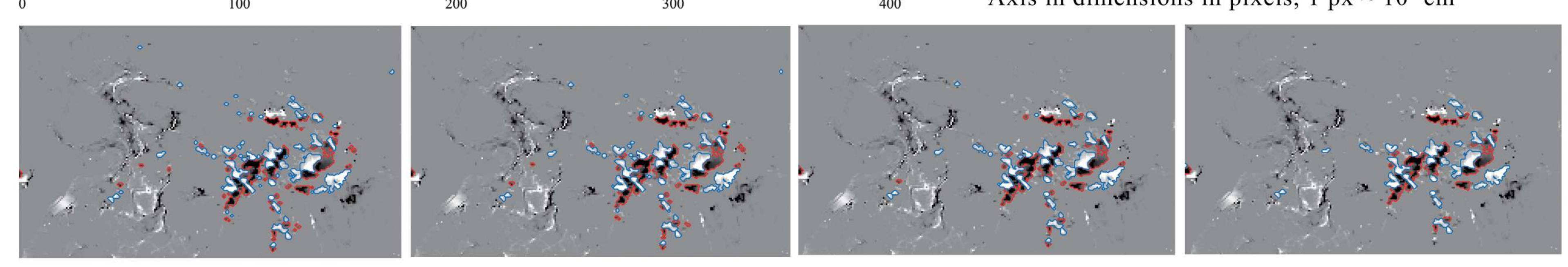


Identifying Current Systems (cont.)

Final set of parameters chosen:

- (Left) Photospheric vertical current density (*Jz*; greyscale) and current system with final chosen partitions for AR11793. Seen with radial current density footprint in the positive (outward) direction (blue), and radial current density in the negative (inward) direction (red).
- (Below) Current system of AR11793 with varying minimum |*Jr*| values, ranging from 1e18 to 1e19 statamps/m^2.

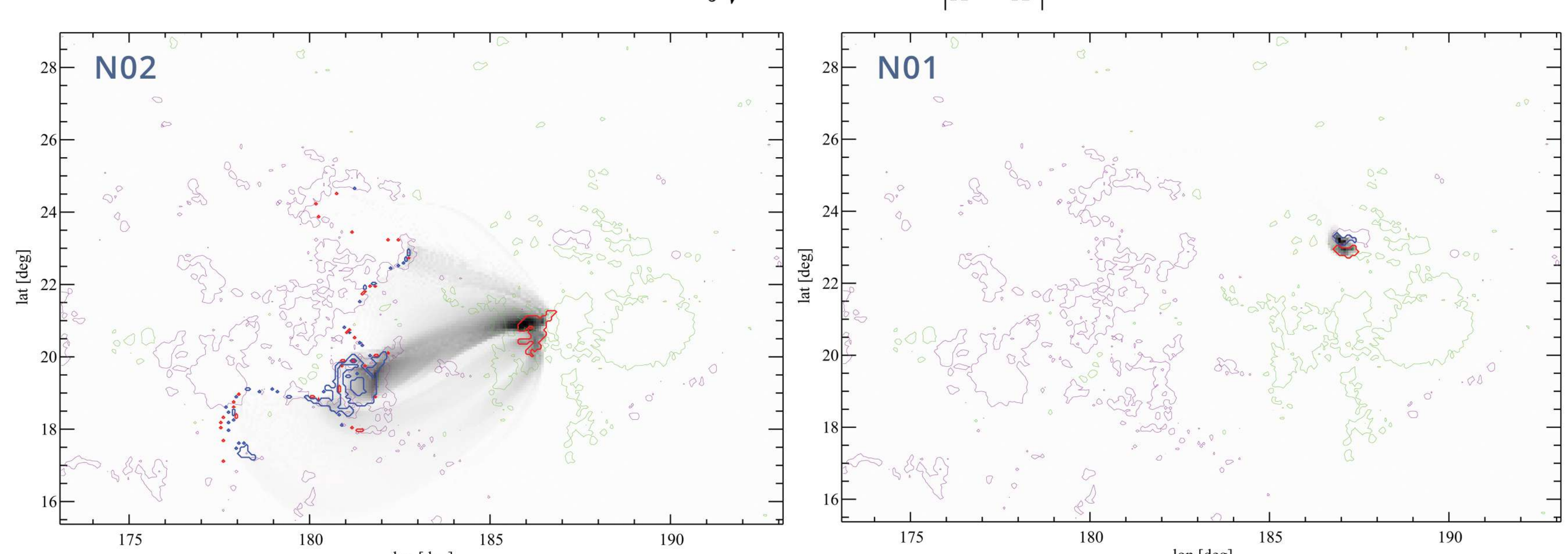
Axis in dimensions in pixels, 1 px ~ 10^8 cm



2 3 Determining the Magnetic Field

Using the Biot-Savart law, coronal magnetic field was determined due to each current system:

$$B'(x) = \frac{1}{c}\int_{V'} d^3x' \, J(x') \times \frac{(x - x')}{|x - x'|^3}$$



(Above) Examples of two current systems of AR11793, with current density (red, blue) and positive and negative ploarity of Br (purple, green), and connecting field lines (greyscale).

4 Calculating the Energy

Magnetic energy for each current system defined as:

$$E' = \frac{1}{8\pi}\int_{V} d^3x' \, [2B(x') - B'(x')] \cdot B'(x')$$

This is the energy available to be released in a reconection event due to the coronal current system modeled in steps 1-3

Results

Partition	I_{tot} (10^{20} statamp)	E (erg)
N01	-6.71	-3.18e29
N02	-8.75	3.85e30
P01	6.78	1.03e30
P08	3.11	1.66e30

- If energies remain similar, what else could vary? Next step in this project is to quanitfy the potential that this energy can be released
- See poster by A.Cavins in this session for results from AR 11283

Acknowledgments

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References

Barnes, G., D. W. Longcope, and K. D. Leka: 2005, 'Implementing a Magnetic Charge Topology Model for Solar Active Regions'. ApJ 629, 561–571.

Gilchrist, S. A. and M. S. Wheatland: 2014, 'Nonlinear Force-Free Modeling of the Corona in Spherical Coordinates'. Sol. Phys. 289, 1153.

Wheatland, M. S. and S. Régnier: 2009, 'A Self-Consistent Nonlinear Force-Free Solution for a Solar Active Region Magnetic Field'. ApJ 700, L88–L91.

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