Studying Solar Active-Region Magnetic Evolution Leading to a Confined Eruption

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Introduction & Background

It is currently believed that there exists a continuum of solar eruptions, from the comparatively small, such as coronal jets, to extremely large eruptions that produce coronal mass ejections (CMEs) and solar flares, all triggered by magnetic flux cancellation. On the smaller end of currently studied solar eruptions are solar coronal jets, which have been observed to be driven by the eruption of small filaments, or minifilaments (Sterling 2015). These minifilaments and their corresponding eruptions are relatively small and short lived, only approximately 10,000km in length and lasting for about 10 minutes. Panesar (2016), further investigated these minifilaments, specifically their trigger mechanism. They examined ten randomly selected solar-quiet region coronal jets with flux values ranging from 10^{19} - $2.0\text{x}10^{19}$ Maxwells, tracking their evolution across the solar disc from emergence until eruption. In all cases the minifilaments were along the magnetic neutral line, between emergent flux. As the regions progressed they observed positive and negative polarity flux merging along the neutral line, resulting in flux cancellation. This cancellation continued until the time of the eruption, when between 21% and 50% total flux cancellation was observed. It was concluded that this magnetic flux cancellation is the primary trigger mechanism of minifilament eruptions.

It is also favorable to examine large scale eruptions, in order to form a more complete picture of the solar eruption continuum. It however, remains infeasible to examine many large scale, CME and solar flare producing eruptions. The filaments that produce these eruptions, which are 3x104-1.1x105 km in size, are found in active regions which must evolve over several weeks before an eruption occurs. This combined with the rotational period of the Sun ~27 days, means that an AR of interest cannot be observed from emergence until eruption on the solar disc, i.e. an AR that produces an eruption visible on the solar disc will have emerged on the far side of the Sun. In light of this it is not possible with currently available instrumentation to observe most large ARs in their entirety, which is necessary in order to form an adequate understanding of the buildup and triggering process.

In order to overcome this issue, Sterling (2018) examined two small scale, magnetically isolated active regions, dissimilar only in size to larger regions, that could be observed on the solar disc from emergence until eruption. In each of the two regions, they observed the emergence of flux(~$2\text{X}10^{21}$ Mx), followed by an initial period of separation, and finally a contraction back towards the neutral line, resulting in cancellation. At the time of the eruption the active regions were observed to have experienced 30--50% flux cancellation. These findings are consistent with earlier findings for smaller scale eruptions; again suggesting a consistent eruption mechanism over a wide range of solar eruptions. However, in the case of larger active regions examined by Sterling (2018), more data is required before drawing firm conclusions.

Based on these conclusions, we seek to examine an additional active region, similar to those in Sterling (2018). The active region that we selected, emerged approximately 15°W of solar center on, 8 September 2014 at 18:00 UT, relatively isolated, though it is smaller (<10^{21} Mx) and along the neutral line of an overarching old weak-field magnetic arcade. Producing a confined eruption approximately 3 days later at 18:45 UT.

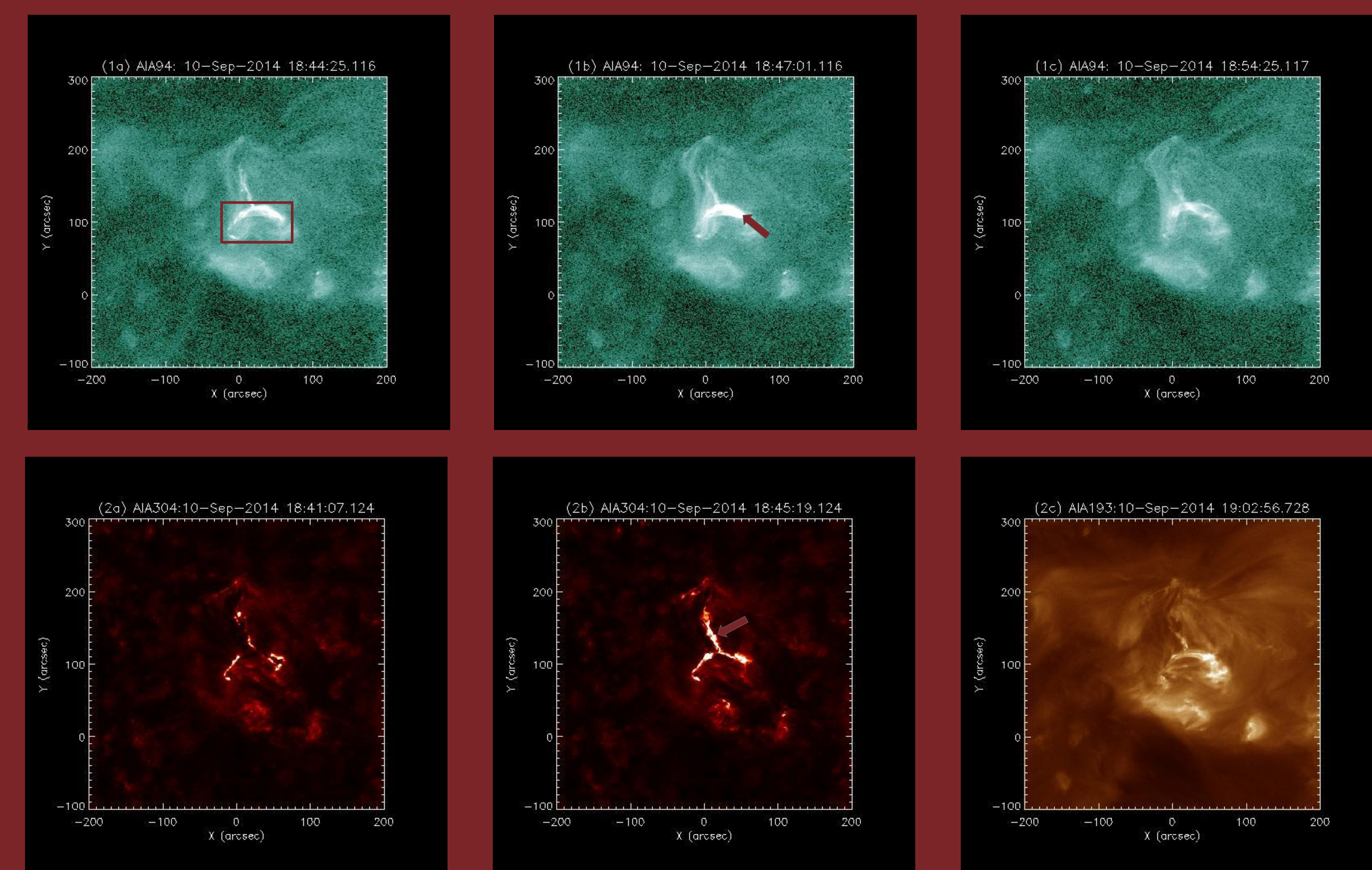
Methods

For our investigation we used a method similar to that of Sterling (2018). We examined several candidate active regions (ARs), using data from the Solar Dynamics Observatory (SDO) in 94 angstroms and corresponding HMI magnetograms. 94 angstroms was selected simply because most candidate ARs were easily visible at this wavelength. Our selection criteria were:

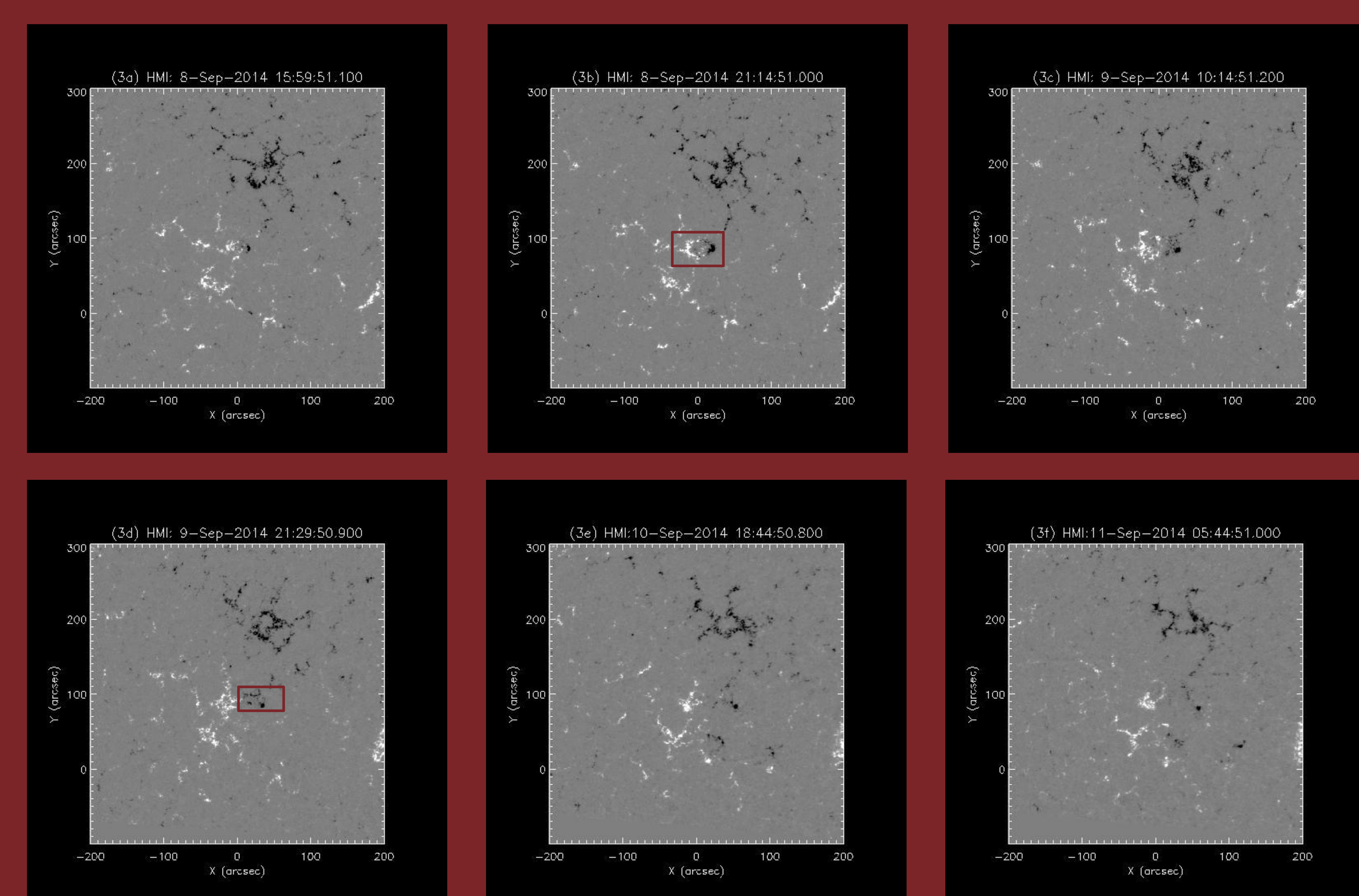
- AR was small enough that it emerged and erupted on disc
- Remained relatively magnetically isolated during its entire lifetime
- Emerges and erupts as far as possible from the solar limb

We examined five candidate ARs and selected one that best fit these criteria. Then using data from JSOC's cutout service we produced rough cadence films, 6 minutes derotated to a common time, of the entire AR lifetime in AIA: 94, 171, 193, and 304 angstroms as well as HMI magnetograms. Additionally we produced high cadence, 12 second films also derotated, in all of the aforementioned wavelengths. The movies produced in the AIA wavelengths were used for visual analysis of the region. The HMI magnetograms, were first used to select a favorable polarity for for flux calculations. We selected negative, because it experienced less movement and maintained better isolation throughout the lifetime of the AR. Using the region of negative flux, we computed fluix change throughout the lifetime of the AR and plotted this using a flux correction factor. Additionally, we used the entire region of interest to produce two time distance plots, to analyse the spatial movements of the flux, the second plot used a smaller exposure range in order to better view weaker flux patches.

Data

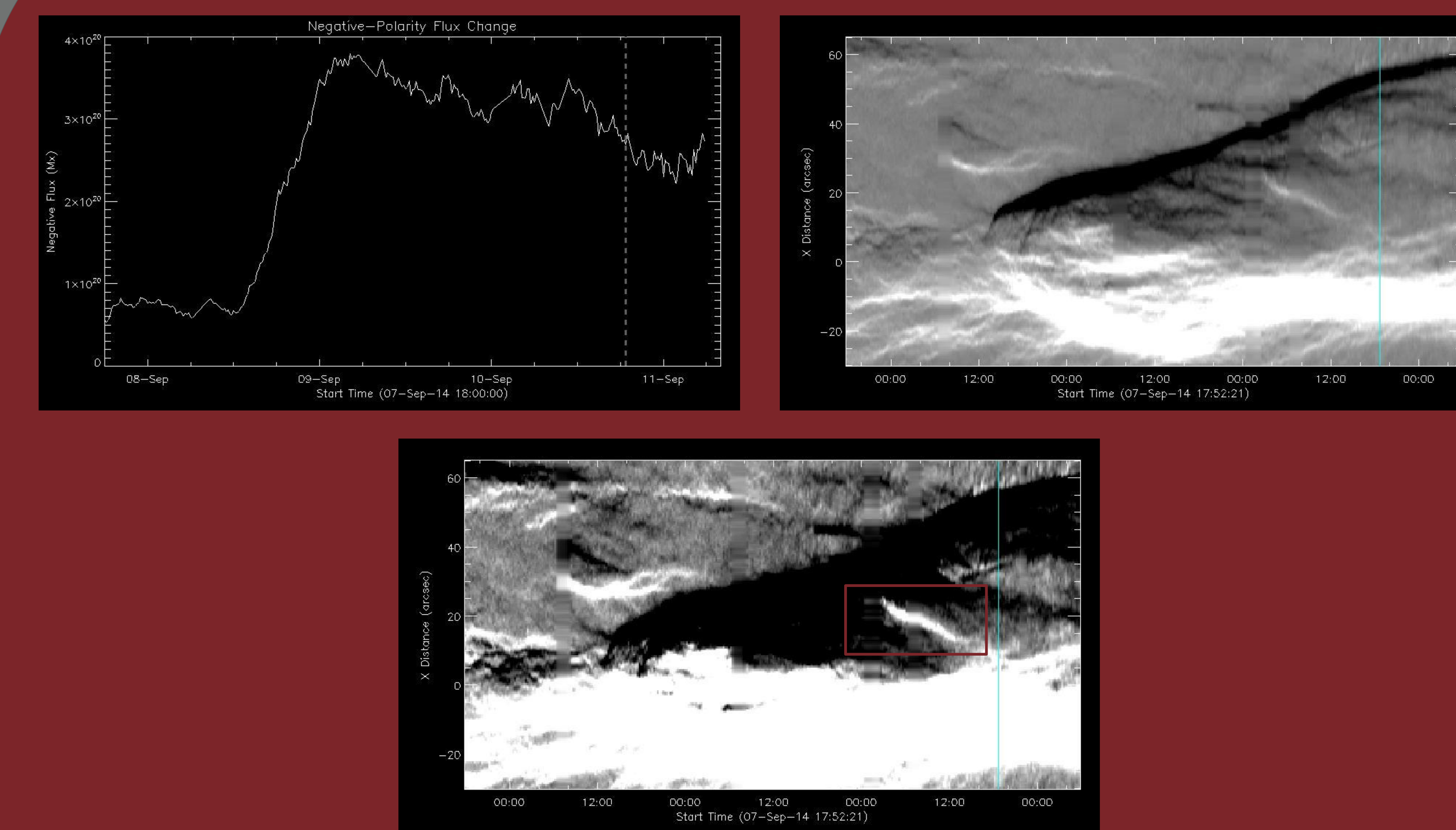


Pictured above, the first line (1a-1c) depicts the selected region in 94 angstroms. The first image (1a) depicts the region just before the eruption, with the box indicating the main eruption loop. The middle image (1b) is taken at the time of eruption, with an arrow pointing toward the main bright point of the eruption. The final image in the line (1c) is from just after the eruption. The second line (2a-2c), depicts the region in 304 angstroms (2a-2b) and 193 angstroms (2c). Again the middle image represents the AR at the time of eruption. The arrow in image 2b indicates the neutral line of the overarching weak-field magnetic arcade. This field brightens at the time of eruption but is not as prolonged as the main eruption which has a longer brightening as indicated by image 2c.



Above, images 3a-3f depict the region of interest in HMI magnetograms throughout its entire lifetime, white and black are positive and negative respectively. Image 3e depicts it at the time of eruption. The box in image 3b depicts the active region and area that was used for time distance plots. The larger areas of flux to the north and south represent the overarching old weak-field magnetic arcade. The box in 3d depicts the area that was used to calculate negative flux change.

Results and Conclusion



Using the region outlined in image 3d, we calculated the amount of negative polarity flux present over the lifetime of the active region and plotted using a correction factor to account for the rotation of the sun. The graph shows the emergence of flux and cancellation over the course of a day leading up to the filament eruption which occurred on 10 September 2014 at 18:45 UT and is denoted by the dotted grey line in the chart and the blue lines in the distance plots. We found ~20% flux cancellation had occurred at the time of eruption. The flux distance plots do not show as much recombination as those depicted in Sterling (2018). We believe that this is partially the result of weaker flux cancelling within the AR, this is seen better in the second distance plot which has a smaller exposure range to bring out weaker areas of flux. One area where this appears to be occurring is boxed in the second flux distance plot. Our observed flux cancellation of ~20% is notably lower than the 30-50% cancellation found by Sterling (2018). This, we believe, can be explained by several factors. First, this active region was smaller, less than 10^{21} Mx, than those examined by Sterling (2018). Additionally, this AR was along a portion of the neutral line of an overarching old weak-field magnetic arcade. As a result the filament that we examined underwent a confined eruption, not producing a CME, as opposed to the ejective eruptions observed by Sterling(20180). We believe this confined eruption given the smaller size of the filament, its presence within a larger arcade, and smaller cancellation, are consistent with previous observations.

References

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