Multi-spacecraft Analysis and modeling of a solar eruption on August 14, 2010

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Abstract

A central question regarding solar eruptions is exactly how magnetic reconnection converts stored magnetic energy into heat, radiation, and kinetic energy. A second important question is what mechanisms trigger such eruptions and initiate the reconnection that drives them. Several models offer an explanation for these triggers. One of the proposed mechanisms is solar flux emergence, which assumes that an initial flux rope equilibrium breaks down as a reaction to the injection of magnetic energy when additional flux emerges on the nearby solar surface. The flux cancellation mechanism, on the other hand, explains the loss of equilibrium by the disappearance of magnetic flux near the neutral line that separates regions of opposite magnetic polarity.

On August 14, 2010 a striking eruption occurred on the NW limb of the sun. SDO/HMI magnetogram observations show a significant amount of flux emergence in the eruption region, which suggested that this played a role in triggering this eruption. In this poster, we will offer a first interpretation of this event combining observations made by STEREO, SDO/AIA and PROBA2/SWAP. We discuss ongoing efforts on the modeling of this event.

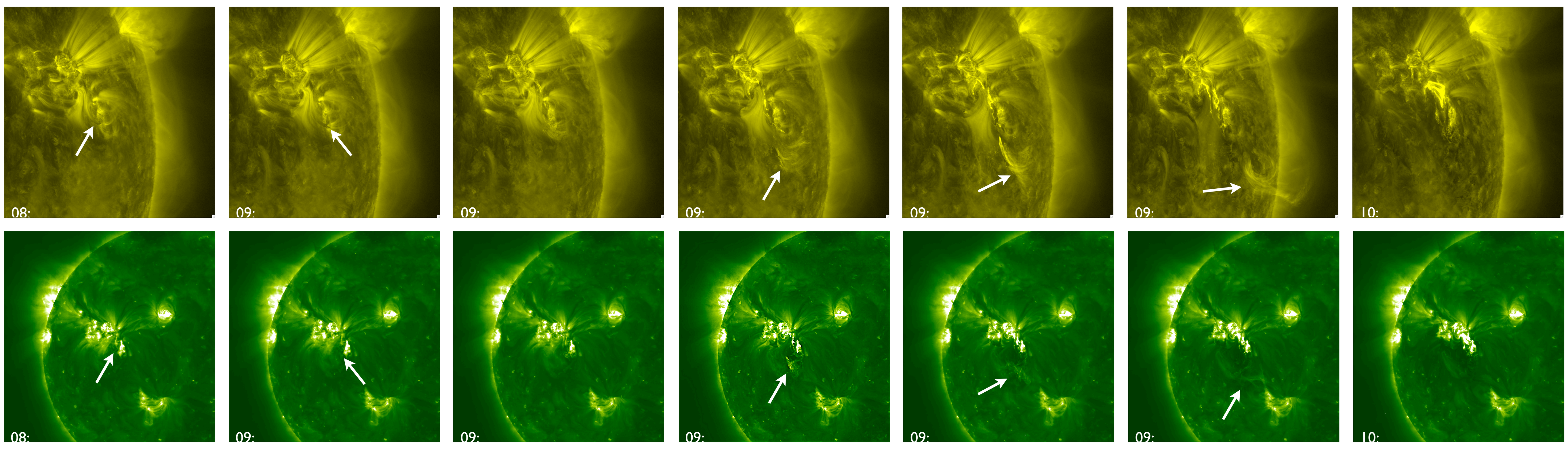

Fig. 1: SDO/AIA 171 Å and STEREO-A/EUVI 195 Å images of the filament eruption on August 14, 2010. The arrows in de images on the left indicate the location and destabilization of the filament. Later in time, the arrows emphasize to untwisting motion that is observed as the erupting filament unwinds.

The filament eruption

On 14 August 2010 SDO, PROBA2, and STEREO-A observed a filament eruption that occurred on the north-west limb of the sun starting around 08:50 UT. Two separate active regions, linked by a filament, were involved: NOAA AR 1099 (north) and NOAA AR 1093 (south). Both regions showed flaring activity up to B-level in the days before and after the eruption, but the eruption itself was measured by GOES as a C4.4 flare with a peak time of 10:05 UT (Fig. 2). The rising phase of the flare in the GOES flux curve contains a shoulder (blue arrow) around 09:30 UT which appears to correspond to the start of the filament eruption in the southern region. However, the flare peak occurs only after the northern part of the filament erupts.

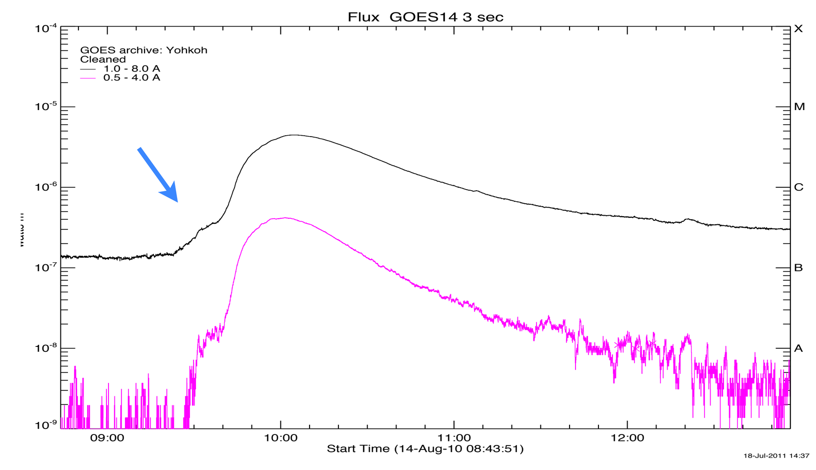

Fig. 2: The GOES X-ray flux measurements on August 14, 2010 show a C4,4 flare at the time of the eruption.

Prior to the eruption, the first signs of activity are seen in the form of flickering, bright points and small plasma flows, mainly in the northern active region. Around 08:54 UT, SDO/AIA 171 Å images show the rise of the filament that connects both active regions. As the filament unwinds the erupting plasma is hurled into space with an untwisting motion. At 10:12 UT the corresponding CME enters the SOHO/LASCO-C2 field-of-view.

Flux emergence versus flux cancellation

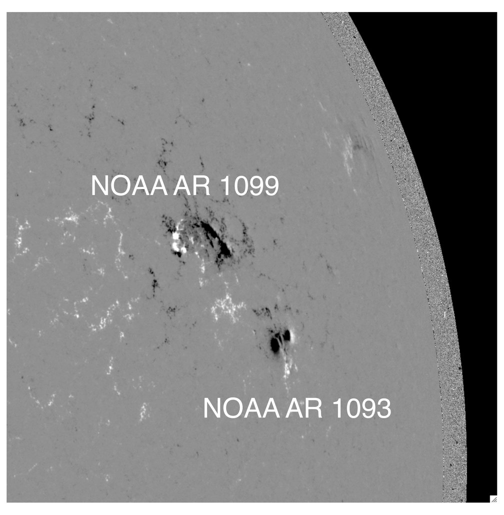

Fig. 3: SDO/HMI magnetogram taken at 08:30 UT showing the position of NOAA AR 1099 and NOAA AR 1093 on the solar disk just before the start of the eruption.

SDO/HMI magnetogram observations show a significant amount of flux emergence in the day and hours before the eruption, especially in the northern active region. This suggested that flux emergence played a role in triggering this eruption. To validate this assumption, we measured the evolution of the average flux in both active regions during seven hours around the time of the eruption. This revealed that while there is some increase in flux for the northern active region, the average flux in the southern region is decreasing considerably more at the same time. (Fig. 4) This suggests that the destabilization of the southern end of the filament by flux cancellation led to the eruption of the entire filament.

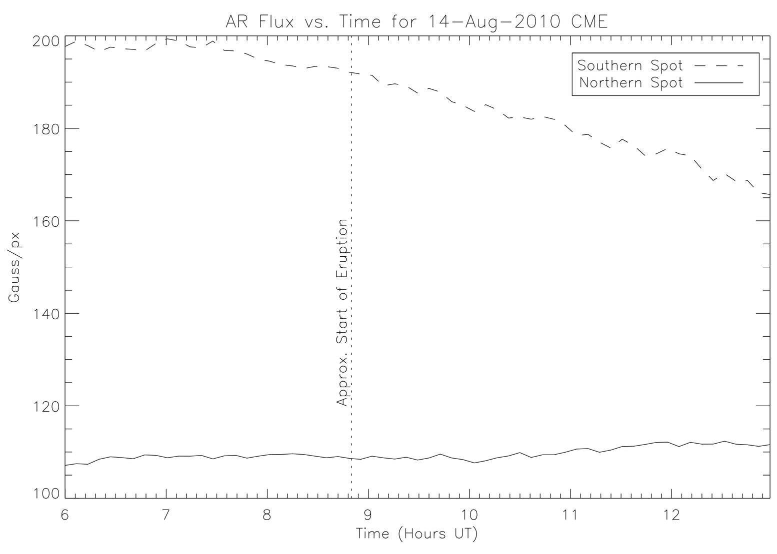

Fig. 4: Averaged flux in the northern and southern active region measured over time. The vertical line indicates the approximate start of the eruption.

Modeling Efforts and Plans

To simulate this eruption we start with a stationary magnetic field configuration, which we can then evolve by introducing artificial magnetic sources. To model this background magnetic field, we used the Versatile Advection Code in combination with a PFSS extrapolation for August 12, 2010, when the active regions involved were at the center of the solar disk. This global magnetic field simulation will be the starting point for the modeling of the eruption.

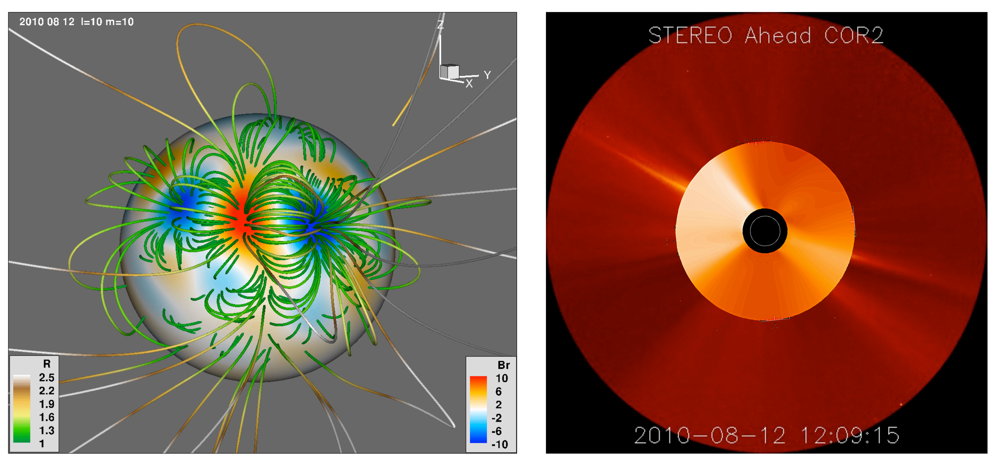

Fig. 5: Left: Magnetic field in the lower corona on August 12, 2010. Right: Simulated (1.5-6 Rs) and observed (6-15 Rs) white-light corona from the viewpoint of STEREO-A.

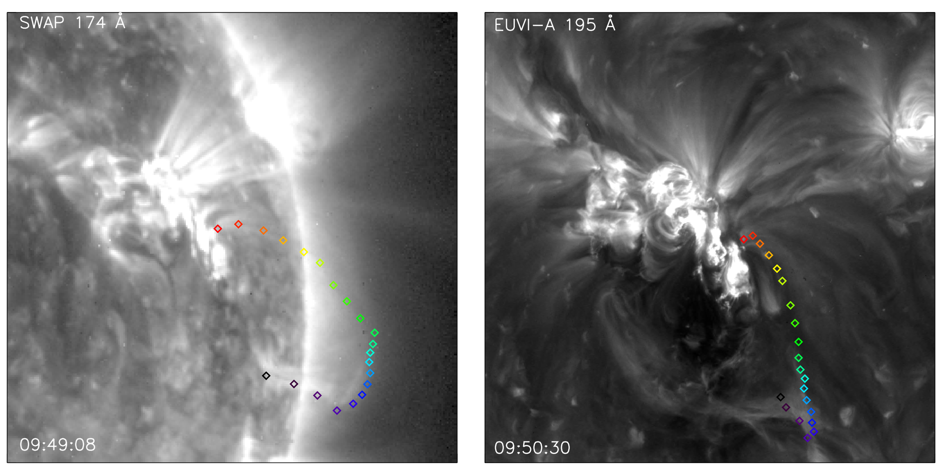

Fig. 6: 3D reconstruction of the eruption at 09:50 UT using PROBA2/SWAP 174 Å (left) and STEREO-A/EUVI 195Å (right)

The simulated white-light corona can be compared to observations made by SOHO/LASCO and STEREO/COR 1 and 2 (Fig. 5, right panel). As the fine structure of the magnetic field is not included in our simulation, this match is not perfect. However, the global features of the magnetic field are already well represented in this simulation. In a next step, we will evolve this result to obtain the magnetic field on August 14.

In order to derive a height-time diagram for the erupting prominence, we started a 3D reconstruction of this feature using STEREO-A/EUVI 193 and PROBA2/SWAP 174 Å images (Fig. 6). Fitting this height-time diagram with a power-law polynomial can give us a clue about which eruption mechanism is at work here. We hope to use this as input for our future model results.

Conclusions, questions and outlook

- Our analysis suggests that flux cancellation in the southern active region caused the southern end of the filament to become unstable, which led to the eruption of the entire filament.
- We plan to model this eruption with AMRVAC, using the background magnetic field on August 12 as a starting point.
- We are making a 3D reconstruction of this eruption using SDO/AIA, SWAP and STEREO-A/EUVI images to extract height-time diagrams.
- A similar eruption took place on August 7, 2010 involving the same active regions. What can we learn from a comparison of both events?