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# Morphological and Kinematical Study of Causally- Linked Filament Eruptions

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**Abstract**

In this study we present the multi-wavelength observations of three linked filament eruptions occurring on 2015 July 19. The events were observed in UV/EUV wavelengths by Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO) and GONG in H-alpha wavelength. The third filament eruption was associated with GOES C2.1 class flare and coronal mass ejection (CME). These three filament eruptions are successive and sympathetic in nature. Using the time-distance analysis technique, we have discussed the kinematics of the erupting filaments.

**Introduction**

Eruptive prominences (EPs) (or filaments if observed on the solar disk) are large-scale phenomena occurring in the solar atmosphere. They are frequently associated and physically related to coronal mass ejections (CMEs) and flares (Tandberg-Hanssen, 1995; Munro et al., 1979; Chandra et al., 2017). Such close relationship between EPs and the other eruptive solar occurrences (Lin et al, 2003; Priest and Forbes, 2002) suggests that the three eruptive events are different manifestations of a same huge physical process, whose energy source is the free energy stored in coronal magnetic fields (Forbes, 2000). Observations show that prominences display a wide range of eruptive activity. For example, according to observational definition of Gilbert et al. (2007) three basic types of the filaments/prominences eruptions exist, based on the relation between the filament mass and the corresponding supporting magnetic structure: full, partial, and failed.

Among the variety of solar eruptions there are cases when two and more filaments erupt in a close temporal and spatial correlation with linkage between them. Such eruptions are so-called “sympathetic” eruptions. Sympathetic filament eruptions are defined as consecutive linked eruptions occurring within a relatively short time period in different but physically related locations (Moon et al., 2002; Yang et al., 2012; Joshi et al., 2016; Wang et al., 2016). Observational and numerical research point that the physical linkages between the sympathetic eruptions have a magnetic nature (Ding et al., 2006; Wang et al., 2007; Jiang et al., 2008; Török et al., 2011; Wang et al., 2016). Török et al. (2011) did 3-dimensional MHD simulations of sympathetic eruptions, observed on 2011 October 01, and suggested two possible magnetic trigger mechanism. One possibility is the presence of a separator above closed flux system and second possibility is the presence of an adjacent closed flux system overlying a flux rope.

In this work we present the study of the successive sympathetic eruptions of three quiet filaments, namely F1, F2 and F3, that occurred on 2015 July 19 in the western solar hemisphere. The used data, morphology and events timing are described in Section 2. The kinematics is presented in Sections 3. Finally the summary is given in Section 4.

## 2. Observations

### *2.1 Data Sets*

In the present work we used high spatial and temporal resolution data in Extreme Ultraviolet (EUV) channels from the Atmospheric Imaging Assembly (AIA; Lemen et al., 2012) on board the Solar Dynamics Observatory (SDO, Pesnell et al., 2012). The filament eruption kinematics and morphology are studied by data in He II 304 Å channel of AIA/SDO. H-alpha images from Global Oscillation Network Group (GONG; Harvey et al. 2011) were used to investigate the location and chromosphere nature of filament eruption. In order to search for a possible association with CMEs, data from LASCO/SoHO CME catalog were also used: https://cdaw.gsfc.nasa.gov/CME_list/ (Gopalswamy et al., 2009).

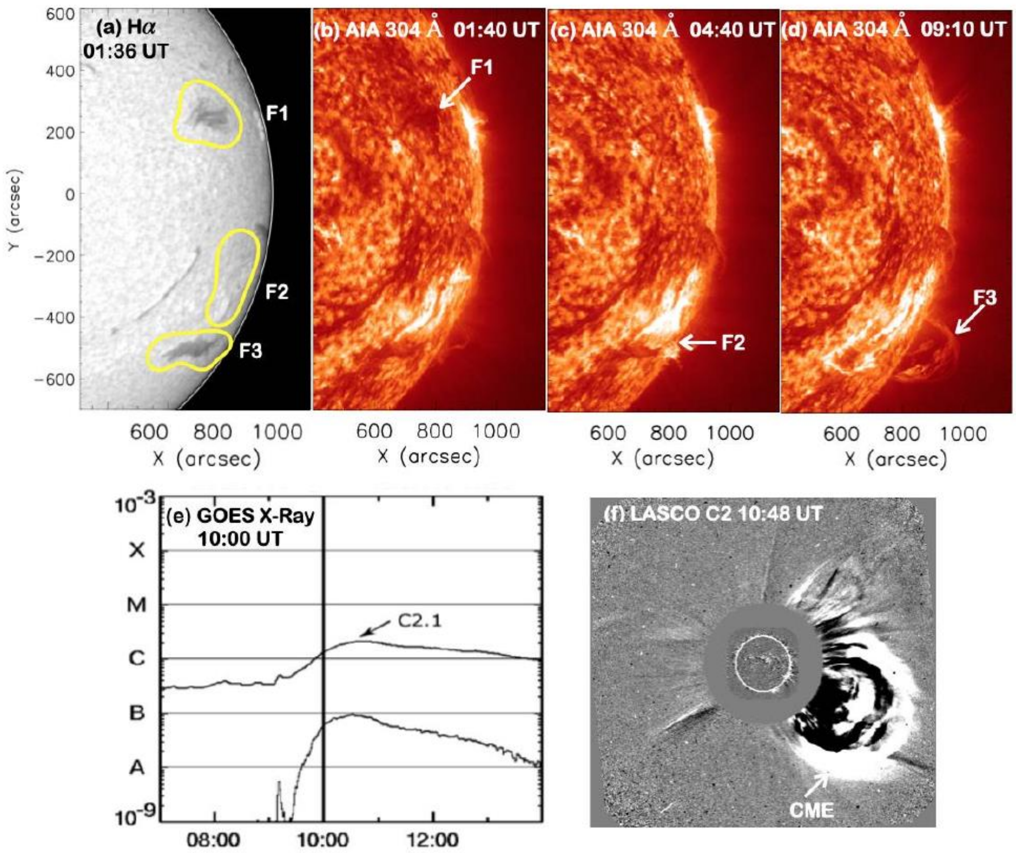


*Figure 1: (a) Yellow contours indicate the location of filament F1, F2 and F3 before the eruption on H-alpha image. (b-d) AIA 304 Å images during the three filament eruption. (e, d) GOES flare and CME associated with F3 filament eruption.*

### *2.2 Morphology and events timing*

On 2015 July 19, we have observed the successive eruptions of three quiet filaments from the western hemisphere. Afterwards, we will refer them as F1, F2 and F3 respectively. Based on the eruptions evolution and the closeness in time of the erupting filaments, we can interpret them as sympathetic eruptions. The location of filaments before the eruptionis is labeled in Figure 1a.

Initially the quiet filament F1 located in northern hemisphere stared to erupt around 01:00 UT. We found some part of the filament was erupted mostly radiallyin the north-west direction. However, the eruption could not evolved into CME. Together with this eruption some part of the filament was observed to fall back towards the south direction, where F2 filament was located. Due to the fall back of this material, the filament F2 located in southern hemisphere becomes unstable and starts to erupt in west-south direction. Afterward some part of this filament falls down to the solar surface. The downfall material of the filament F2 again triggered another filament F3, which is located very close to the filament F2 (about 50 arcsec). As a result of this trigger, the filament F3 started to erupt and the filament material is gone in the west direction. The F3 eruption produced a pair of long flare ribbons, which became a gradual GOES C2.1 class flare. The Figure 1(b-d) shows the images of filament eruption in AIA 304 A.

Further the eruption of filament F3 was associated with a partial halo CME, observed by the Large Angle and Spectrometric Coronagraphs (LASCO) aboard SOHO. The angular width and the speed of the CME are 194 deg and 782 km/s, respectively. The morphological evolution of these eruptions is displayed in Figure 1 in H-alpha and UV/EUV wavelengths. The associated GOES flare and the CME are also depicted in same figure.

## 3. Eruption Kinematics

To explore the temporal relation between these sympathetic eruptions, we tracked the eruption kinematics using the slice-time plots. For this, we have selected three artificial slices viz. S1, S2 and S3 respectively. The direction of the slices are selected according to the direction of filament material ejection. The location of slices and the results of this analysis as a time-distance plots are shown in Figure 2 and 3 respectively.

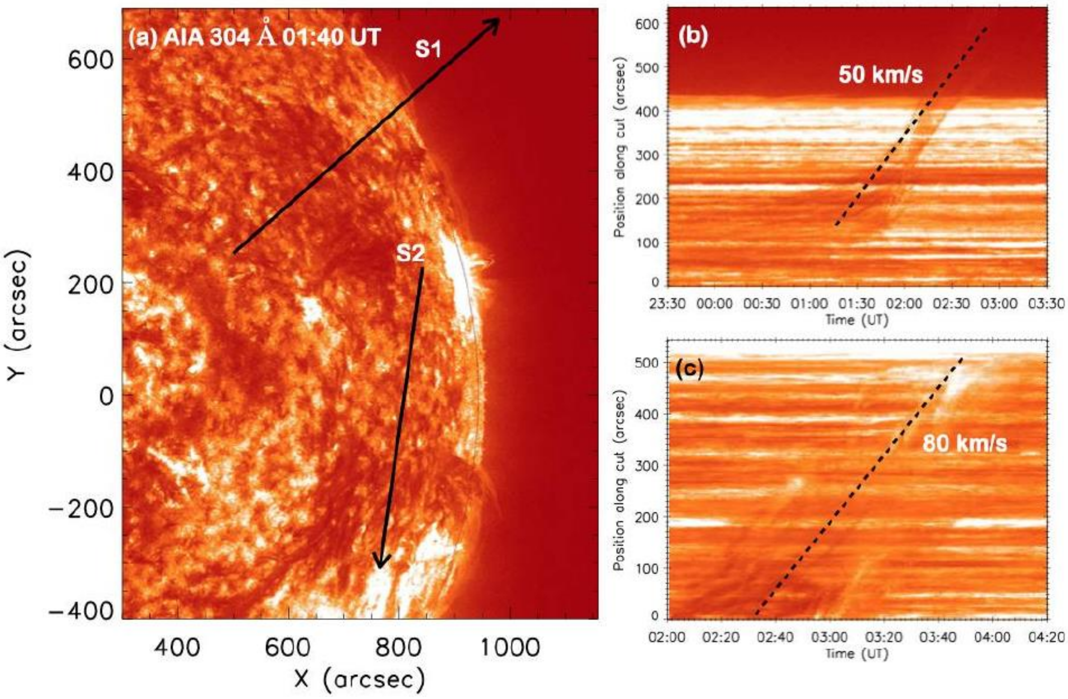


*Figure 2: (a) Location of the two slices selected for the height-time plot of F1 eruption in North-West direction and the filament material flow in south direction. (b, c) The height-distance plot along the slits S1 and S2 respectively.*

Eruption of F1 stared around 01:00 UT in the west direction as well as some material erupted in south direction. We have computed the speed of eruption in both the direction. The observed speed in north-west direction 50 km/s. While the observed speed in south direction computed along the slice S2 direction (see Figure 3) is about 80 km/s. From the time-distance plot and movie also, we found that the erupting material reached close to the location of filament F2 around 04:00 UT and made it unstable. The unstable F2 started to erupt towards west-south direction. Lateron some part of this filament falls down to the solar surface and this material made unstable the filament F3.

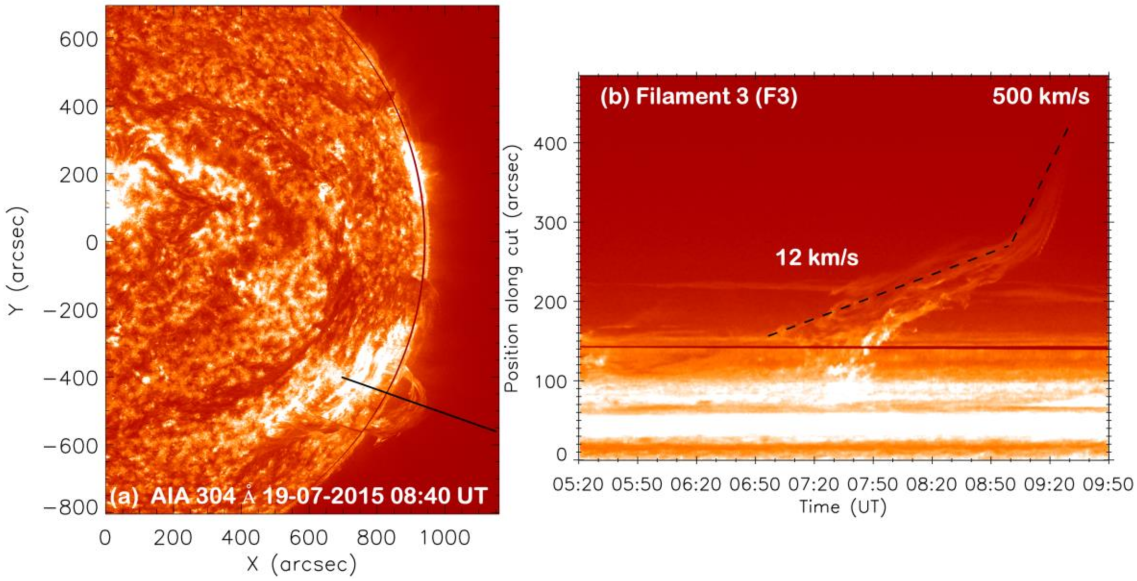


*Figure 3: (a) Location of time slice selected for the F3 eruption direction (b) Corresponding time-distance plot.*

Again, for the kinematics of filament F3 eruption, we have created a slice drawn in the left panel of Figure 3. The corresponding time-distance plot is presented in right panel of the same figure. From the time-distance plot, we have computed the eruption speed of F3 filament, which very clearly showed two eruptive phases (slow and fast). The speed of the slow phase is about 12 km/s, whereas the fast phase eruption speed is very fast and its average value is about 500 km/s. The two eruption phases are very clear and easily distinguishable. The slow rise phase is longer (about two hour), while the fast eruptive phase lasts about one hour.

## 5. Summary

We have studied three linked quiet filament eruptions that occurred on 2015 July 19, namely F1, F2 and F3. Initially the filament F1 starts to erupt due to some kind of instability, may be torus instability, and triggers the filament F2 eruption. The erupting F2 filament in turn causes the eruption of the filament F3. Finally F3 is fully erupted. The eruption of F3 filament was associated the a C2.1 solar flare and with a CME. This is a nice example of sympathetic eruption and can be explained by the MHD numerical simulation proposed by Tőrők et al,. (2011). In future we plan to explore these sympathetic eruptions in more detail.

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