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Multi-wavelength Study of the Triggering of an M1.2 Class Solar Flare in AR1069 on 5 May 2010

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Abstract: We analyze the multiwavelength observations to study an M-1.2 class solar flare occurred in NOAA AR1069 on 05 May 2010 between 17:00 UT-18:30 UT. A twisted and very faint flux-tube is most likely activated in the flaring region, which further reconnects with the overlying coronal loop systems and trigger an M1.2 class solar flare. We report the observational scenario of the most probable activation of a faint and twisted flux-tube, its reconnection with overlying loops, and flare energy release, and also discuss its implications in the triggering of the observed solar eruptive event.

INTRODUCTION

Solar flares and the associated dynamical processes are well studied in the modern era of the space borne and ground based observations. These processes may contribute to the mass and energy supply through the various layers of the solar atmosphere even into the interplanetary space and causing the space weather effects. Such eruptive phenomena are the explosive large-scale events in the solar atmosphere that release enormous amount of energy ($\sim 10^{32}$ ergs) on the timescale of hours, and contribute significantly to the heating of plasma, mass ejection, and high energy particle acceleration (Shibata and Magara, 2011, and references cited there). Several mechanisms have been proposed about the solar flares and associated dynamical processes, however, there is still a need to fully understand these energetic processes in the solar atmosphere (Benz et al., 2008, and references cited there). The key physical processes for producing such eruptive phenomena are the flux emergence, formation of a current sheets, and magnetic reconnection that causes shock heating, mass ejection, and particle acceleration (Shibata and Magara, 2011).

Inspite of the above mentioned classical processes, recently the various types of instabilities have been explored both in the observations and theory as a driver of the solar flares and associated eruptive phenomena. Recently, Srivastava et al. (2010) have found the first evidence of the kink unstable and highly twisted loops in AR10960 on 4 June 2010, which leads to the recurrent flares. Foullan et al. (2011) have reported the first observational evidence of the Kelvin-Helmholtz instability in the solar active regions that leads the flare and associated eruptions. Kumar et al. (2011) have also reported the first observational evidence of the loop-loop interaction due to coalescence instability and the triggering of an M-class flare. Recently, Innes et al. (2012) have found the observational evidence of Ralyeighi-Jeans instability in the solar corona, which leads the dynamical plasma processes. In conclusion, the modern era of high resolution observations from space and ground is shedding new light on the role of such crucial plasma processes in the evolution of eruptive and energetic events in the solar atmosphere.

The flux-emergence may also play a key role in flaring regions in the solar atmosphere. Kumar et al. (2011) have found the rare observational evidence of the emergence of a flux-rope that was failed in the eruption due to a remnant filament, though triggered an M-class flare in the active region AR11045 on 12 February 2010 via its reconnection with the low lying closed loops. Shen et al. (2011) have found the evidence of successive failing of a filament that later erupts and gives a coronal mass ejection in the same active region during C-class flare energy release. On contrary, the emerged and unstable flux-ropes may also generate the full solar eruptions (e.g, CMES) in the outer solar atmosphere (e.g., Shen et al., 2012, Jian et al., 2012, and references cited there). These recent examples were associated with the flare triggering in the active regions associated with the enhanced magnetic field complexity and flux emergence (e.g., Dwivedi et al., 2012).

In the present paper, we discuss the preliminary observations of the triggering of an M-1.2 class solar flare on 5 May 2010 in NOAA AR1069 during 17:00 UT-19:00 UT due to the most likely activation of a twisted flux-rope and its reconnection with the overlying coronal loops. In Sec 2., we describe the observational results, and in the last section we outline the discussions and conclusions.

OBSERVATIONAL RESULTS

The active region NOAA AR 1069 appeared on the solar disk with an emergence of photopsheric magnetic field. It was located in the North-West (N42 W40) on 05 May 2010 and having the âã-sunspot group configuration. As per Hinode/EIS flare catalog (http://msslxr.mssl.ucl.ac.uk:8080/SolarB/eisflarecat.jsp), during the release of M1.2-class flare energy between 17:00 UT-18:00 UT, the flare started at 17: 13 UT, maximizes at 17:19 UT, and ended at 17:22 UT. GOES integrated X-ray light curves (Figure 1) generated by the GOES observational data base and Solar Soft, indicate that the M1.2 class flare started on 17:00 UT, peaks on 17:20 UT, and ended completely around 18:30 UT. The flare was an impulsive one with a steep rise of the soft X-ray fluxes as evident in Figure 1 in both 1.0-8.0 Å and 0.5-4.0 Å. Figure 2 shows the full-disk EIT map, which displays the position of the active region NOAA AR 1069 when flare was started as per Hinode/EIS EUV flare catalog. Other active regions are also shown in the full disk SoHO/EIT map on 5 May 2010.

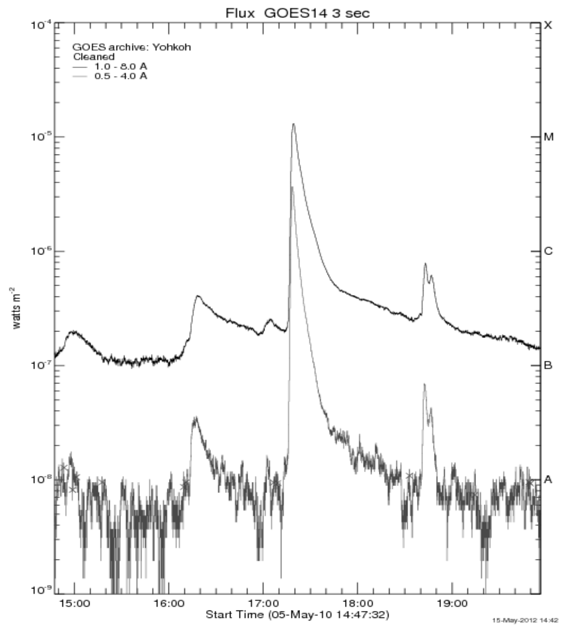

Fig. 1. GOES integrated X-ray light curves (red for 0.5-4.0 Å, and black for 1.0-8.0 Å) showing the evolution of M1.2 class solar flare during 17:00-18:30 UT on 5 May 2010.

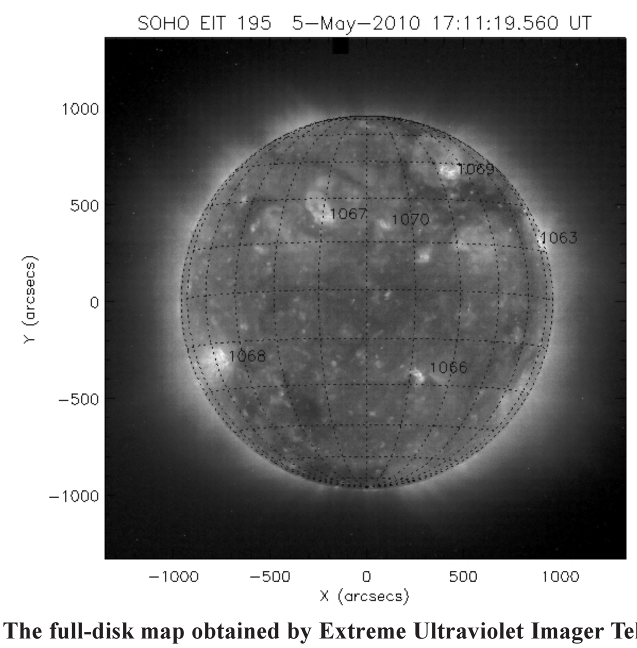

Fig. 2. The full-disk map obtained by Extreme Ultraviolet Imager Telescope (EIT) onboard Solar and Heliospheric Observatory (SoHO) in 195 Å showing the position of NOAA AR 1069 at the time of M1.2 class solar flare on 05 May 2010.

We analyze the SoHO/EIT for the study the M1.2 class solar flare in the NOAA AR 1069 on 05 May 2010 during 17"00-18:30 UT. We use the standard subroutines of Solar Soft to calibrate and reduce the SoHO/EIT temporal image data of 195 Å. The images are scaled further in intensity, and the negative color snapshots have been produced. Figure 3 shows the temporal conditions of the active region NOAA 1069 during the time of M1.2 class solar flare on 5 May 2010 as observed by SoHO/EIT. The top two snapshots show the maximization of the M1.2 class solar flare, while the images in the bottom panel are shown in the decay phase of the flare. It is clear from the top-two panels that the well evolved loop systems were presented during the rising phase of the flare, which diminished in the due course of the time during and after the peaking of the flare. Although, the less spatial resolution of the EIT images and 195 Å filter response do not provide the clue about the presence of very faint and twisted flux-rope in the flaring region.

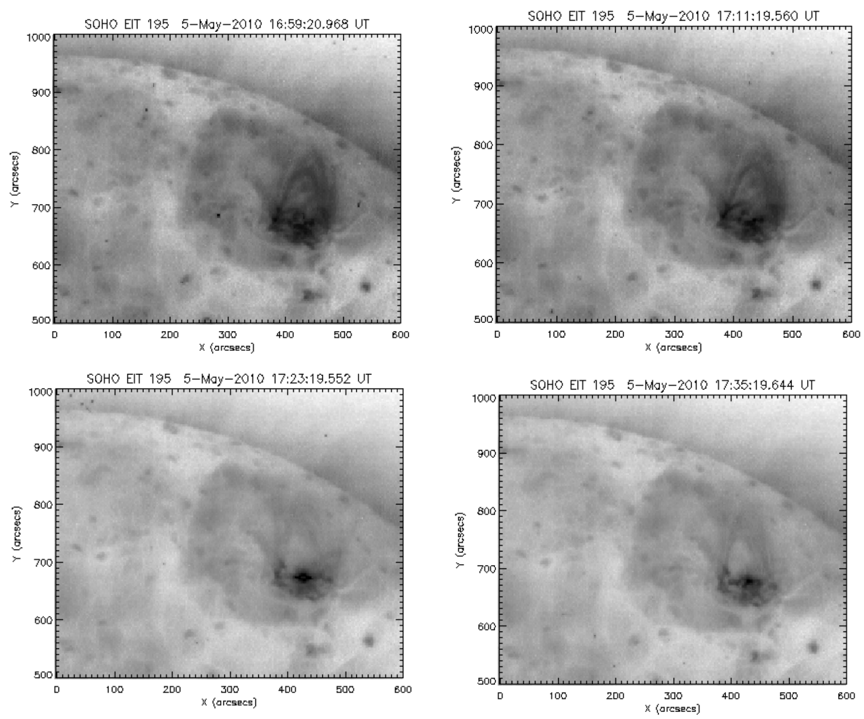

Fig. 3. The active region NOAA 1069 during the episode of M1.2 class solar flare on 05 May 2010 as observed in SoHO/EIT 195 Å. The top two snapshots show the maximization of the flare, while the images in the bottom panels are shown in the decay phase of the flare.

We analyze the STEREO-A/SECCHI/EUVI for the study of the M1.2 solar flare (Wuelser et al., 2010). The EUVI 195 Å filter is sensitive to the plasma maintained around 1.0 MK, and thus suitable to capture the dynamics and plasma processes in the inner corona. We use the standard subroutines of Solar Soft to calibrate and reduce the EUVI 195 Å image data. The images are scaled further in intensity, and the negative color images have been produced. Figure 4 shows the temporal conditions of the active region NOAA 1069 during the time of M1.2 class solar flare on 05 May 2010 as observed by STEREO-A/SECCHI. The observations of AR1069 with STEREO ahead provide the new angle to understand the active region dynamics during the flare process. The top two snapshots show the maximization of flare, while the images in the bottom panels are shown in the decay phase of the flare. It is clear from the top two panels that the well evolved loop systems are presented during the rising phase of the flare, which diminished in the due course of the time during and after the peaking of the flare. The most likely activation of the faint and twisted flux-rope, its interaction with overlying loops, and the breaking of coronal loops are clearly evident during the various stages of the flare (Figure 4). The faint and twisted flux-rope interacts with the well evolved overlying loop arcades that reconnect further with each other (cf., top-left panel on 17:06 UT). The overlying loop threads break during this reconnection process in the corona, and the flare energy maximizes (cf., top-right panel on 17: 11 UT). After the flare maximum and energy release, the flux-rope still reconnects with the overlying loops and breaks them, while the flare goes in its decay phase. This is the standard reconnection scenario and occurrence of the flare.

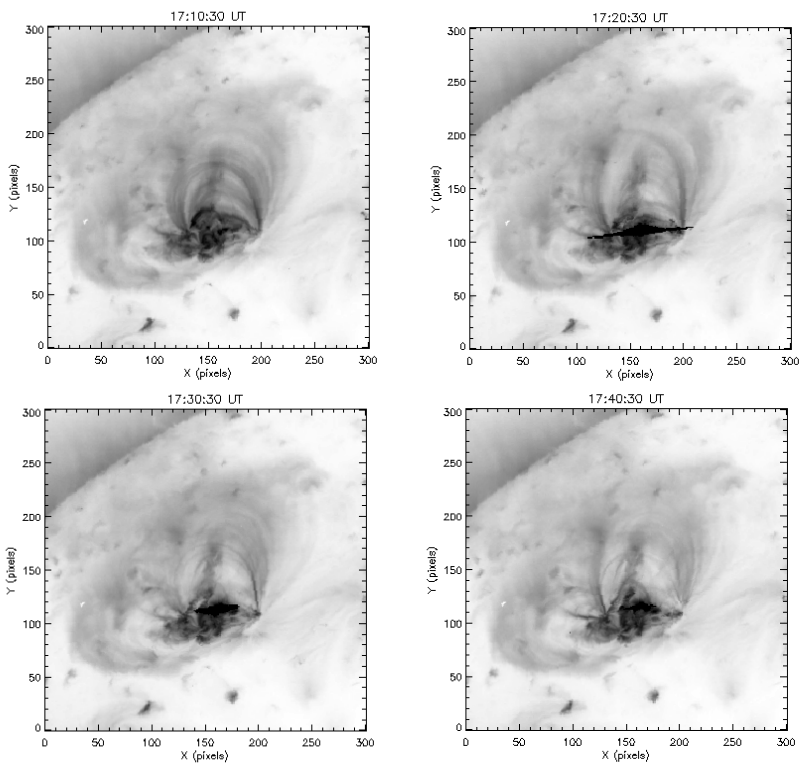

Fig. 4. The active region NOAA 1069 during the episode of M1.2 class solar flare on 05 May 2010 in STEREO/SECCHI 195 Å . The top two snapshots show the maximization of flare, while the images in the bottom panels are shown in the decay phase of the flare. The most likely activation of the faint and twisted flux-rope, its interaction with overlying loops, and the breaking of coronal loops are clearly evident during the various stages of the flare.

We analyze the STEREO/SECCHI 304 Å to study the low atmospheric views of M1.2 solar flare in AR1069. The EUVI 304 Å filter is sensitive to the plasma maintained around 0.1 MK, and thus suitable to capture the dynamics and plasma processes in the upper chromosphere and transition region. We use the standard subroutines of Solar Soft to calibrate and reduce the EUVI 304 Å images. The images are scaled further in intensity, and the negative color images have been produced. Figure 5 shows the temporal conditions of the active region NOAA 1069 during the time of M1.2 class solar flare on 5 May 2010 in STEREO-A/SECCHI. The observations of AR1069 with STEREO ahead provide the new angle to understand the active region dynamics during the flare process. The top two snapshots show the maximization of flare, while the images in the bottom panel are shown in the decay phase of the flare. The most likely activation of the faint and twisted flux-tube is also evident during the various stages of the flare (Figure 5). The flare energy release, and the evidence of the formation of its ribbons are visible in the lower solar atmosphere.

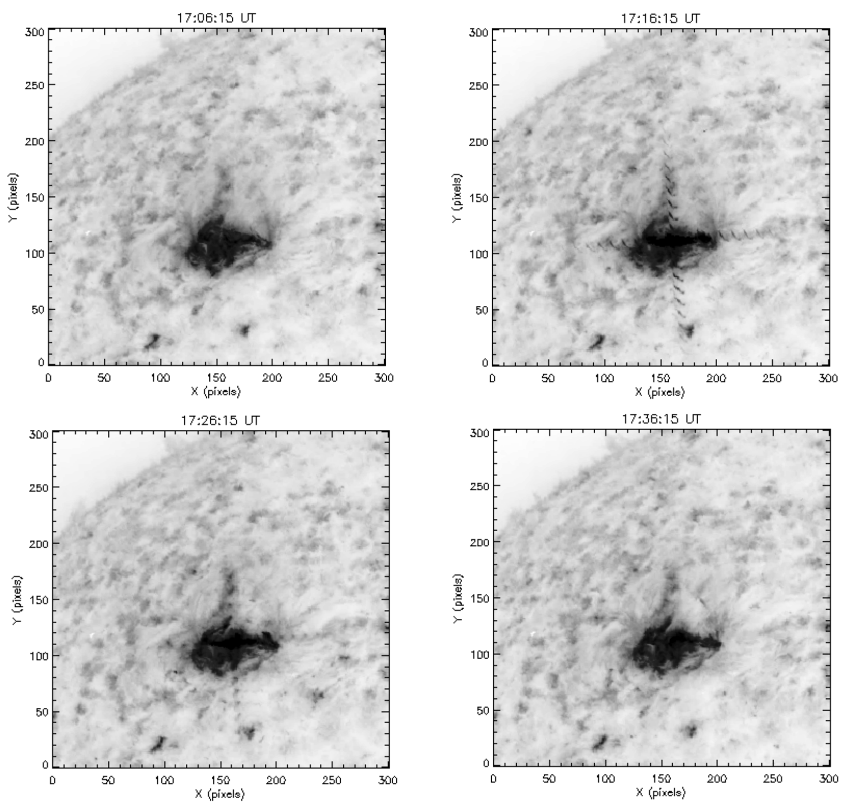

Fig. 5. The active region NOAA 1069 during the time of M1.2 class solar flare on 5 May 2010 in STEREO/SECCHI/EUVI 304. The top two snapshots show the maximization of flare, while the images in the bottom panel are shown in the decay phase of the flare. The most likely activation of the faint and twisted flux-rope foot-point traces, and low atmospheric view are clearly evident during the various stages of the flare.

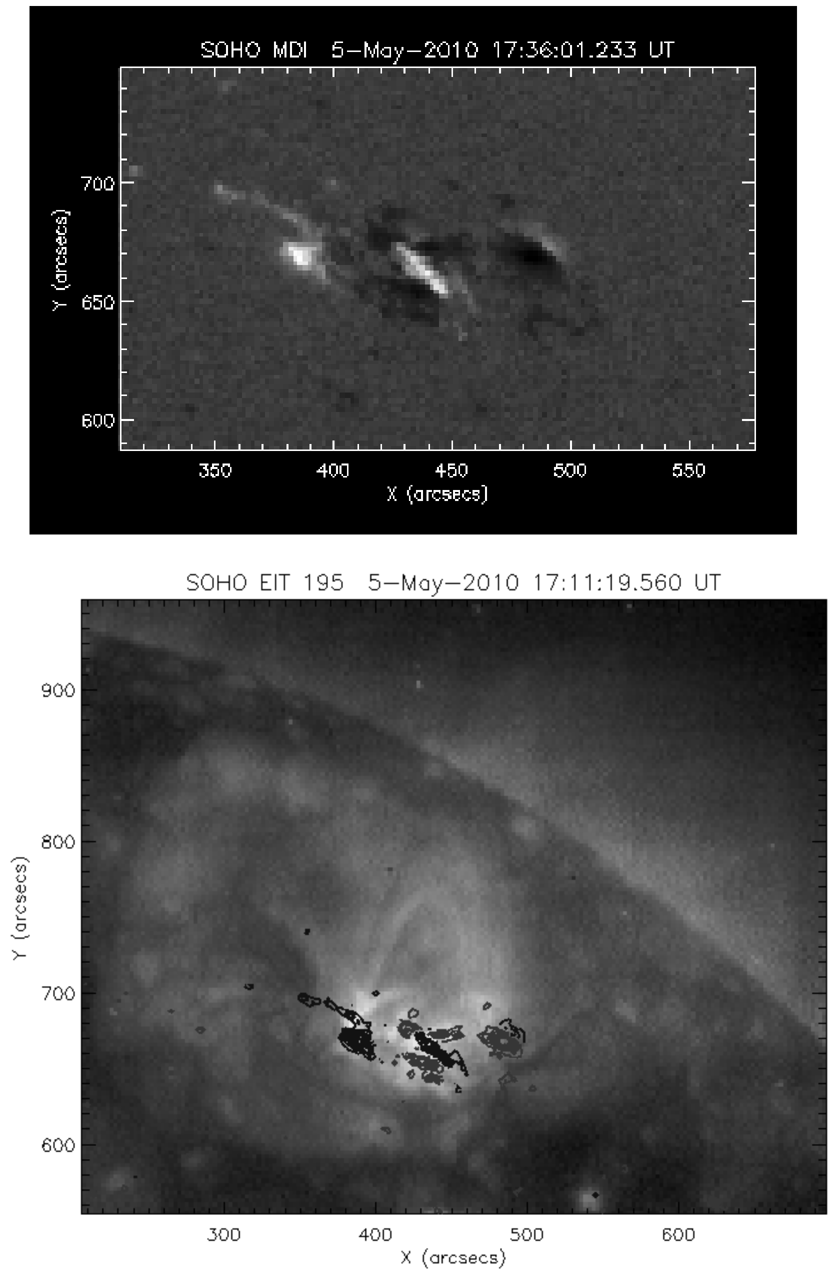

Fig. 6. Left panel : The SoHO/MDI image of the magnetic field of AR1069 on 5 May 2010. The black represents the negative polarities, while white represent the positive polarities. Right Panel : The overplotted magnetic field polarity contours (blue = +ve, red = –ve) over the SoHO/EIT snapshot neat the flare maximum.

The SoHO/MDI image of the magnetic field of AR1069 on 5 May 2010 is shown in the left panel of Figure 6 (The black represents the negative polarities, while white represents the positive polarities). We calibrate and analyzed the magnetogram full disk data obtained by Michelson Doppler Imager (MDI) onboard SoHO (Scherrer et al., 1995). The overplotted magnetic field polarity contours (blue=+ve, red= - ve) over the SoHO/EIT snapshot neat the flare initiation time, are displayed in the right panel of Figure 6. It is clearly evident that overlying loops are anchored as bipolar loops in the positive and negative polarities respectively lying at western and eastern boundaries of the active region. While, the twisted flux-rope most probably emerges at the centre of the active region where the magnetic field distribution is rather complex.

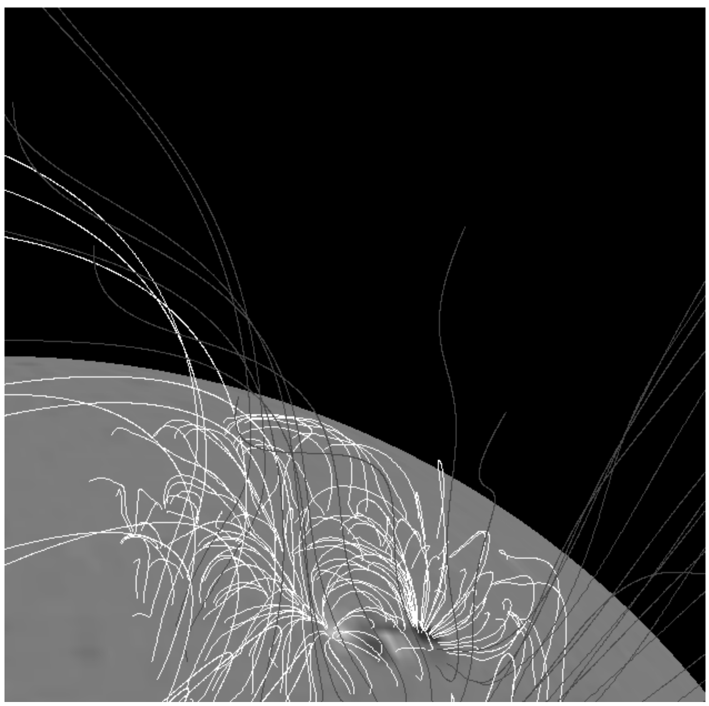

Fig. 7. The PFSS extrapolation of the magnetic field lines is overplotted on the SoHO/MDI image on 05 May 2010 at 12:04 UT. The white lines show the closed field lines, while the red lines show the open field lines.

The Potential Field Source Extrapolation (PFSS) of the active region field lines is shown in Figure 7 using the MDI data on 05 May 2010 at 12:04 UT to understand the pre-flare conditions of the magnetic field configuration. It is clear from the extrapolation that the closed lines create the coronal loop systems, while the dome shaped and whipped open flux-rope is created at the center of the active region. When plasma uploaded later on in the initial stage of the flaring event, then the flux-rope became visible in form of a faint but twisted flux-tube. Though, the filling of plasma is not enough, and the flux-rope appears very faint.

DISCUSSION AND CONCLUSIONS

In summary, we analyze the multiwavelength observations of an M1.2 class solar flare in NOAA AR 1069 during 17:00-19:00 UT on 05 May 2010. The observations indicate the most likely activation of the very faint and twisted flux-rope that interacts and reconnects with overlying loop arcades, and triggers theM1.2 class solar flare flare. The observations partially support the activation of the twisted flux-rope, and its reconnection with the pre-existing coronal arcades that causes the flare energy release due to the dissipation of the enhanced current (e.g., Fan and Gibson, 2003, and references cited there). The twisted flux-rope and its traces are through only visible in the STEREO-A, EUVI observations from a particular angle and under the responses of the 195 Å filter (Wuelser et al., 2010). The SDO/AIA EUV observations, which are not presented here, also does not capture the signature of this very faint flux-tube, and the most probable reason lies in the properties of its filter responses (O'Dwyer, 2011) giving the high background emissions especially in the EUV wavelengths. The full emergence scenario is also not clear about the flux-rope, and it seems that it was already presented at a particular angle with respect to the overlying arcades in the active region. The lateral movement of this flux-rope further causes some interaction with the loop arcades, which further leads reconnection and flare energy release. The detailed analyses using recent multiwavelength observations from various space borne observatories (e.g., SDO, SoHO, STEREO), magnetic field observations (SDO/HMI, SoHO/MDI), complementary ground based observations, and theoretical interpretations, will shed more light and will be published elsewhere.

In conclusion, the presented observations reveal the rare evidences of the reconnection scenario of a twisted flux-tube with the pre-existing coronal arcades that triggers the flare energy release. However, the detailed study should be performed using the forthcoming space and ground based observations, as well as stringent theoretical models to generate more understanding on the role of this type of reconnection hypothesis in the evolution of solar eruptive phenomena.

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