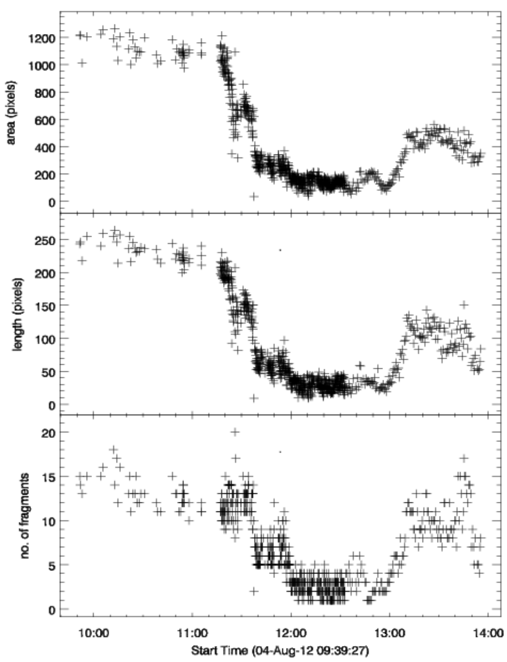
Report on the work done under the GI program during June-July, 2013 by Nandita Srivastava

1.Temporal relationship between the onset time of eruptive filaments, associated flare and CMEs

Abstract: We analysed observations of a long filament that underwent recurrent partial eruptions on August 4, 6, and 8, 2012. The filament reappeared in the subsequent rotation of the Sun, and disappeared completely on August 31, 2012. We implemented an automated filament detection algorithm developed by us for estimating different attributes of these filaments few hours prior to its disappearance in H**α** and studied their evolution. Based on these attributes, we determine the onset time of the disappearance of H**α** filaments. We then compared these onset times with that of the associated CMEs observed by LASCO coronagraphs. This is also useful to understand temporal relationship of EUV, X-ray flux variation using observations made by LYRA instrument aboard Proba2 associated with H**α** filament disappearances (observed from ground-based telescopes). Our results show importance of such studies in understanding the mechanism of CME initiation, particularly the role of eruptive filaments.

Introduction: Coronal Mass Ejections are the key drivers of space weather and are known to be the main cause of major geomagnetic storms at the earth (Gosling,1993). They are often associated with flares and eruptive filaments or EFs (Webb et al. 1976; Webb and Hundhausen, 1987). Munro et al. (1979) found that more than 70% of the CMEs were associated with EFs. Those originating from around centre of solar disc are potential candidates for geo-effective CMEs as shown by Srivastava & Venkatakrishnan (2004). CMEs associated with flares and eruptive prominences differ in their properties. A recent study by Joshi and Srivastava (2011) has shown that flare associated CMEs show bimodal acceleration while filament associated CMEs do not. As per our present understanding, same mechanism drives all CMEs, and the two types of CMEs, lie at the two extreme range of energies that drive them. One of the major constraints in investigating the driving force of CMEs is the difficulty in estimating their correct onset time. The onset time is currently estimated by back extrapolating the projected height-time plot of the leading edge of a CME using LASCO/SoHO observations (http://cdaw.gsfc.nasa.gov). In the events where the source region involves a filament, monitoring its activation is crucial for forewarning of its disappearance in H**α**, in EUV and also associated soft X-ray (SXR) flare and CME lift off. Determining precise temporal relationship between the eruption of H**α** and EUV filament, SXR emission and appearance of CME leading edge (in white light) is therefore of utmost importance in understanding the CME initiation mechanism. To achieve this objective, we examined, recurrent eruptions of a single large filament and the associated CMEs that occurred on August 4, 6, 8 and in the next rotation of the sun on August 31.



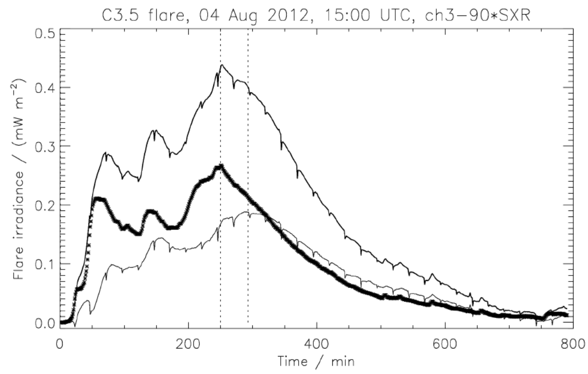


Figure 1: (left) The area, length and number of fragments of eruptive filament on August 4, 2012. On implementing the automatic detection technique, the time of onset of disappearance in H-alpha is found during 11:15 UT. Complete disappearance occurs at 12:20 UT

Figure 2: The observations from LYRA instrument plotted for entire duration of eruptive filament on August 4, 2012. The SXR flux (bold black line) peak for August 4 eruption shows that its precedes EUV flux (light black curve) peak by 40 minutes. These peaks occur much later than the time of complete disappearance of filament in H-alpha approximately 2 hours earlier.

Observations, Analysis and Results:
A long filament appeared on the Sun on August 1 at the SE limb as seen from the Hα images. On August 4, it showed activations leading to its disappearance in Hα at around 12:20 UT. This was associated with C3.5 class flare observed by GOES and as an enhancement in EUV flux observed by LYRA aboard PROBA2 (Dominique et al. 2013). The filament eruption was associated with a white light halo CME with projected speed of 850 km/s as observed by LASCO-C2 coronagraph at 13:22 UT. Following this, the filament reformed and underwent subsequent eruptions on August 6 and 8 accompanied by C-class flares and slow and accelerating CMEs. It may be noted that all the three eruptions were not powerful enough to drive a geomagnetic storm although the location of the filaments was favourable (Srivastava and Venkatakrishnan, 2004). In the next rotation of the Sun, the filament reappeared on August 30, on the SE limb and erupted completely on August 31 at 19:40 UT in Hα with an associated C8.4 class flare and EUV flux peaking around 20:43 UT and 21:13 UT. Concurrently, LASCO-C2 observed a partial halo CME with a speed of 1440 km/s. Although this CME was in SE direction, it gave rise to a moderate geomagnetic storm on September 3 (Dst~ -78 nT). As described above, the chain of recurrent eruptions of a long quiescent filament at intervals of few days, provides an excellent data-set to understand the initiation, and propagation of slowly accelerating CMEs during the minimum phase of the solar cycle, which under suitable circumstances may prove to be geoeffective. We implemented an algorithm developed by Joshi, Srivastava and Mathew (2010) on the full disk Hα images obtained for all the 4 events. This algorithm detects, tracks and estimates the location, length, area and number of fragments of disappearing filaments (Figure 1, left). From the temporal evolution of these attributes, we estimated the time of start and end of Hα filament disappearance, compared these with the time of SXR flux peak, EUV flux peak and CME lift off (Figure 1 right) obtained from LYRA instrument and LASCO coronagraphs. Our analysis shows that the start time of the filament disappearance precedes the time of peak of SXR flux by more than 1.5 hr. The EUV flux peaks 15 to 30 min after the SXR flux. Further, the Hα filament disappearance starts at least an hour earlier than the onset time of CME. These clearly demonstrate the usefulness of implementation of the automated filament detection technique to forewarn a potential geo-effective eruptions, based on full disk Hα observations, prior to the launch of a CME. A manuscript based on the above study is currently under preparation.

2.Slow Ascent phase of a CME and its tracking through heliosphere : Case study of 7 October 2010 CME

Abstract: Studies of eruptive prominences observed in H-alpha have been made by several authors in the past, for example, Smith and Ramsey (1964), Tandberg-Hanssen (1980), Kahler (1988), Wang and Sheeley (1999) Filippov and Den (2001, 2002, 2003), Sterling et al. (2007). With the new observations available in extreme ultraviolet wavelength in 304 A, we have attempted to study the pre-eruptive phase in more detail using EIT/SOHO (Joshi and Srivastava, 2007). These EIT images were used to estimate the range of heights above the solar surface at which eruptive prominences attain maximum acceleration and velocity. Also comparison of the height and velocity profiles of the eruptive prominence with those of the associated CME was made to aid in understanding the basic driving mechanisms in both cases (Joshi and Srivastava, 2011).

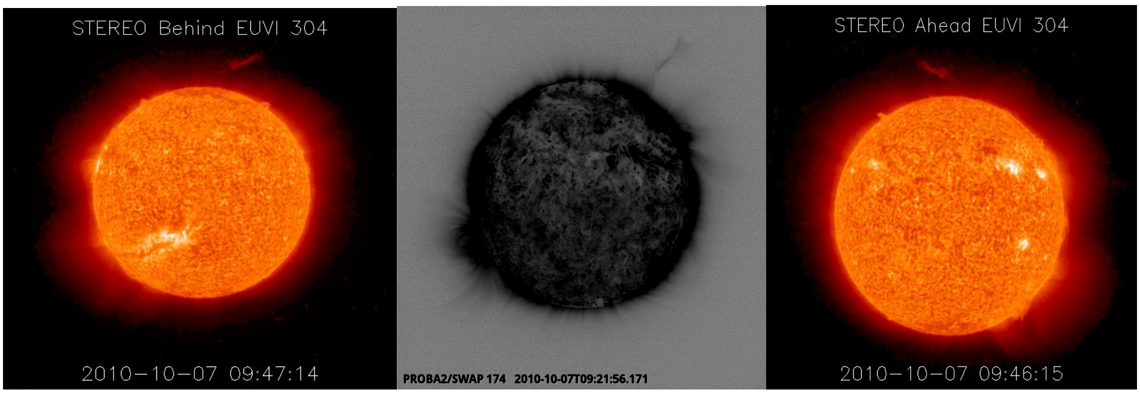


Figure 3: Slow eruptive feature observed on 7 October 2010 by EUVI B (30.4 nm), SWAP (17.4 nm) and EUVI A (30.4 nm). Tracking and identification of features is possible in the EUVI A & B pair and EUVI A and SWAP pair for 3D reconstruction.

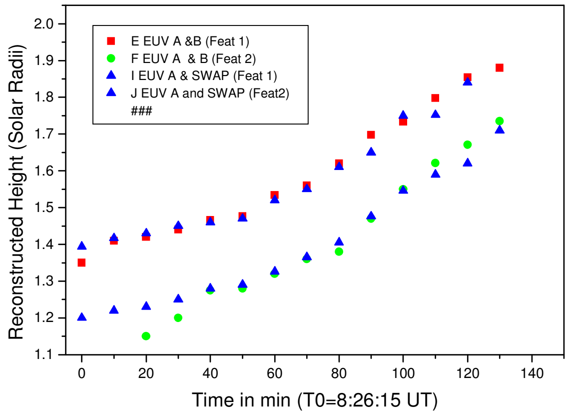


Figure 4: Evolution of true height of two identifiable points on the erupting feature (Feat1 & Feat2) obtained from 3D reconstruction

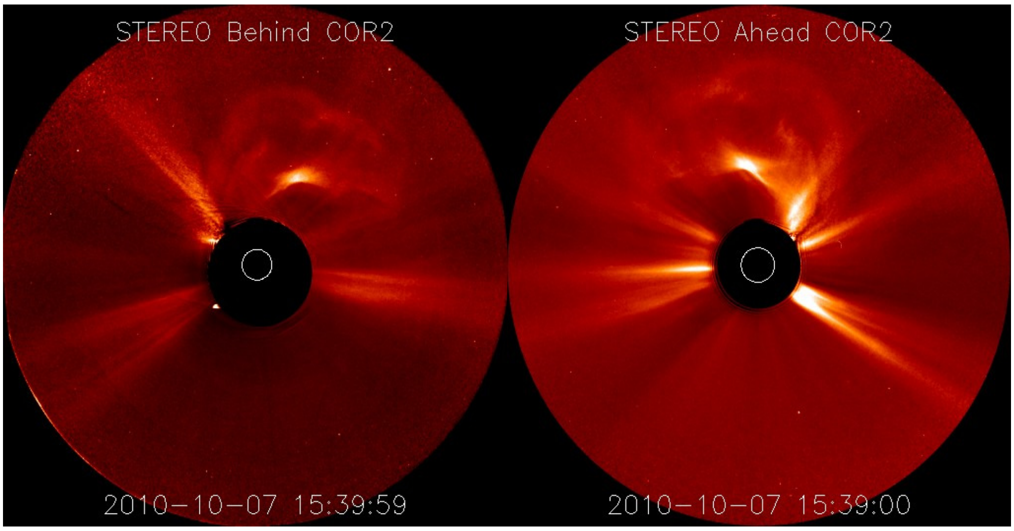


Figure 5: Evolution of CME as observed in COR2 coronagraphs in white light.

Our earlier studies show that erupting prominences evolve through 2 distinct phases, a pre-eruptive phase and an eruptive phase, which respectively are characterized by low velocities of several km s^{-1} and eruptive velocities of several tens to hundreds of km s^{-1}, respectively.

We studied a slow CME observed on 7 October 2010, when the separation angle between two STEREO spacecraft was 161deg . The CME was tracked in the lower corona in EUV using the EUVI instrument aboard STEREO in 30.4 nm and using the SWAP instrument in 17.4 nm. This event allowed us to compare the different temperature plasma associated with the CME in the lower corona and their dynamics. The slow eruption phase was observed for a long duration in SWAP field of view for more than two hours in the north-west limb. Using the EUVI A & B images, we reconstructed the 3D locations of various eruptive features and estimated their true speeds. We also carried out 3D reconstruction of these erupting features using SWAP (17.4 nm) and one of the EUVI images (A/B) as stereoscopic pair obtained at approximately same time. Thus, using SWAP images as third eye on the sun, we gain interesting insights on the initiation and propagation of the slow CME. The 3D reconstruction was carried out using STEREO pair (2 vantage points) and SWAP as the third vantage point, and we find that SWAP images provide a complete view of the erupting feature while the EUVI images show only a part (mid-section) of the erupting feature. The combined plot of 3D height-time variation obtained by application of tie-pointing of common features identified in (i)STEREO A & B images and (ii) SWAP & one of STEREO A/B images provides evidence of co-spatial multi-temperature plasma as shown in Figure 2. The 3D reconstruction also gives reconstructed speed of this erupting CME to lie in the range of 60-400 km/s, indicating that the CME accelerated in the same way as gradual CMEs or blobs in the slow solar wind. Generally, these gradual CMEs rise with very slow speeds (less than 50 km/s) up to a distance of $2R_\odot$ and then are accelerated to higher speeds until $5R_\odot$. From a distance of about $20R_\odot$, they attain almost a constant speed ranging between 300 and 500 km/s which were projected speeds obtained from LASCO. In the present case, the 3D study reveals that most of the acceleration experienced by the CME is between the outer edge of the COR1fov and the inner edge of the COR2 fov . The detailed analysis of this event is currently under progress.