Complex Eruptive Dynamics Leading to a Prominence Eruption and a Partial-Halo Coronal Mass Ejection

M. Dechev, K. Koleva and P. Duchlev
Institute of Astronomy with NAO, Bulgarian Academy of Sciences, Bulgaria

Background

The filament eruptions (FEs) are often closely associated with flares and a coronal mass ejections (CMEs). All these phenomena are different manifestations of the release of magnetic energy stored in the corona prior to the event. One of the mechanisms that can lead to the instability and trigger the energy release is the MHD ideal instability (kink or torus) of a twisted coronal flux rope (FR). Such instabilities may be caused by the evolution of the external magnetic field (cancellation or emergence), shearing motion and the change of loops topology overlying the filament. The interactions between two nearby filaments can also cause their eruptions and can lead to a flare and/or CME. Moreover, the threads of a filament can also interact and rapidly change the magnetic connectivity in the filament structure upon magnetic reconnection.

We present very rarely reported case of an eruptive prominence (EP) composed by both hot, bright flux rope (BFR) and cool massive flux ropes (MFR) that was involved in sympathetically linked chain of events on 2014 March 14, which finished with a partial-halo coronal mass ejection (CME) with a bi-components bright core.

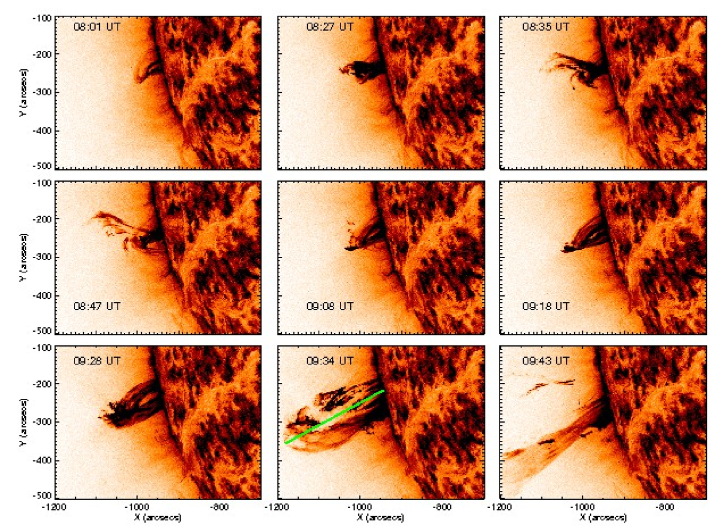

Fig.1. The EP evolution in reversed color SDO/AIA 304 Å images. The green line marks the slice position used for height determination.

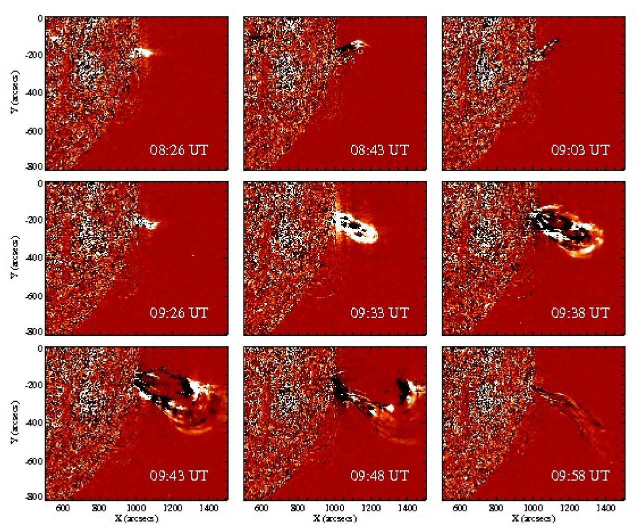

Fig.2. The EP evolution on 2014 March 14 in STEREO A/EUVI 304 Å difference images.

Observations

Two nearby filament FRs erupted between 07:33 UT and 11:48 UT on 2014 March 14 that was observed as an eruptive prominence (EP) above the eastern limb by SDO/AIA (Fig. 1), above the western limb by STEREO A/EUVI (Fig.2) and as a FE near the western limb in the STEREO B field-of view (FOV).

The observations were taken with the following instruments:

- SDO/AIA images in the 304 Å, 335 Å, 211 Å, 171 Å, 131 Å, and 94 Å channels at a 12 s cadence.
- EUVI images of STEREO/A in 304 Å channel and STEREO/B in 195 Å channel at a cadence of 10 min.
- SOHO/LASCO C2 and C3 white-light images

All the data were reduced and co-aligned by standard procedures.

Results: pre-eruptive activity *(04:30-08:00 UT)*

The filament was overlaid by a common arcade of the unipolar-bipolar-unipolar streamer belt (multiarcade streamer) that is a favorable magnetic configuration for producing sympathetic events.

The multipolar photospheric magnetic field around the filament, nearby young AR still in the emergence phase, and the gradual EUV emission under the slow rising filament as a precursor of slow magnetic reconnection suggest a complex, multi-step process that produced a chain of a casually related events.

The continuous flux emergence in the young AR, as well as the associated flare suggest that the flux emergence could supply sufficient energy to trigger the surge appearance at 08:16 UT by generation of low-altitude reconnection, which was suggested by increasing of 195 Å brightening before surge onset (Fig. 7).

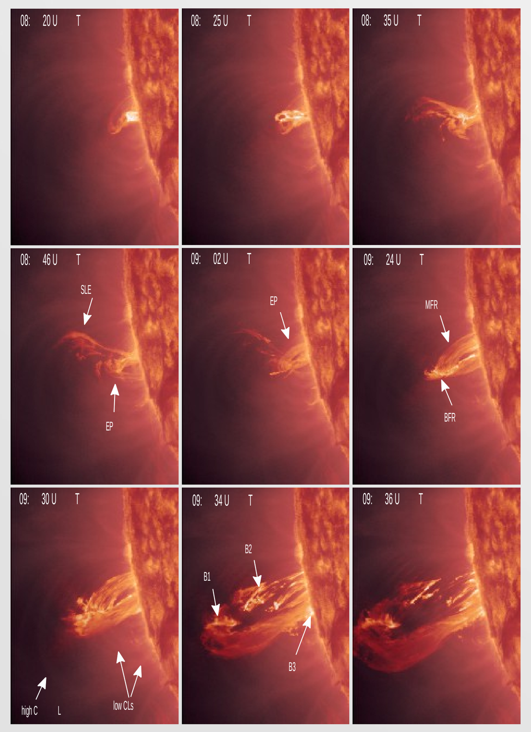

Fig. 3. Basic stages in the EP evolution in SDO/AIA 304 Å and 211 Å combined images and its coronal environment.

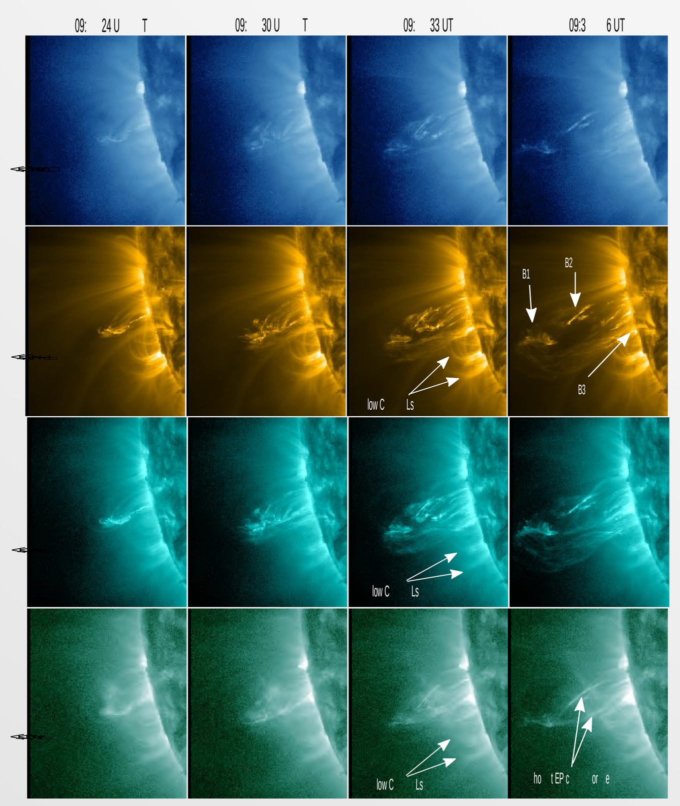

Fig. 4. The EP structure evolution and brightening presented in the SDO/AIA 335 Å, 171 Å , 131 Å, and 94 Å high temperature channels.

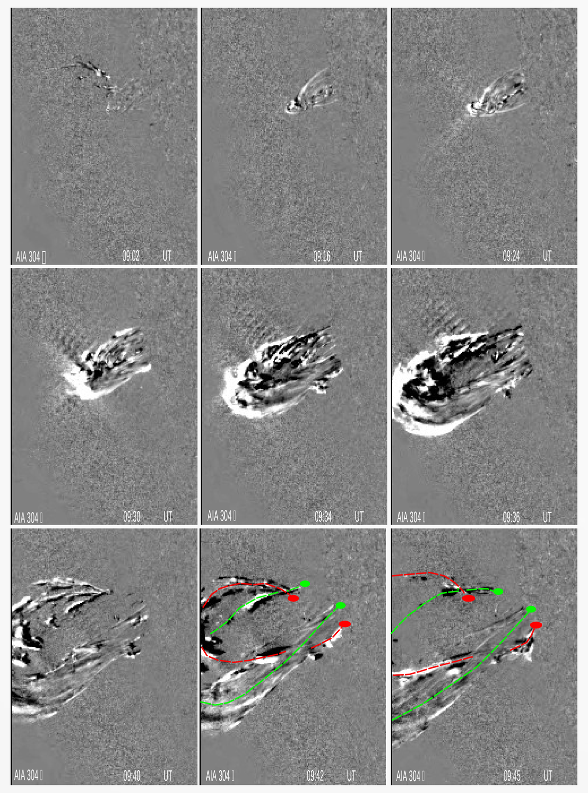

Fig. 5. SDO/AIA 304 Å running difference images presenting the main stages of the EP evolution. The dashed lines trace the two EP FRs: green - MFR and red - BFR. The green and red circles indicate the MFR and BFR footpoints.

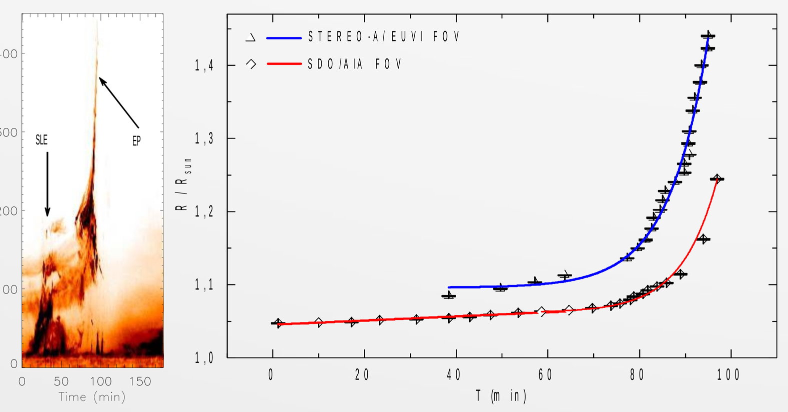

Fig. 6. left: Time-slice diagram used for height determination. right: Height-time diagram of prominence eruption as observed in AIA/SDO and STEREO A FOV.

Results: filament activation *(08:01-09:16 UT)*

The surge is most reliable trigger of the EP BFR and its slow rising bellow the arch-like MFR. Moreover, the EUV brightening in all AIA channels responds at the same time and have similar decay times (Fig. 3 and 4), which is an observational signature supporting the dominant role of the plasma compression over reconnection.

The BFR slowly rose beneath the MFR that accompanied by an apparent plasma drainage observed in the threads of MFR and BFR. Just before the EP fast-rise onset, the BFR was already visible as bright loop, which was merged with the MFR inner edge forming in this way a single common EP FR in the AIA FOV (Fig. 3 and 4).

In the AIA FOV the EP slowly rose with an average speed of ~3 km s-1 vs ~6 km s-1 in the EUVI FOV (Fig. 6).

Results: prominence eruption *(09:16-10:00 UT)*

The EP fast rise is consisted of two specific stages: first one of coherent, rapid rising of a single EP FR between 09:16 UT and 09:32 UT, and second one of sharp EP rising and splitting of the single FR between 09:32 UT and 09:41 UT. Main feature of this stage is dynamic EUV brightening that spread from top to bottom covering whole EP FR at 09:30 UT. The second stage started with brightening fragmentation due to EUV dimming in different part of EP FR and at 09:34 UT only three regions of strong EUV emission remained in FR: at the top (B1), in the middle part of northern leg (B2), and at FR footpoints (B3) (Fig. 3 and 4).

Just after the strong acceleration onset of EP the upper part of the single FR began to split laterally and at 09:41 UT the massive and bright FRs were again visible, but well separated, with propagations in quite different directions (Fig. 5). During the EP fast rising the velocities exponentially increased from ~3.5 km s-1 to ~280 km s-1. in the AIA FOV, while in the EUVI FOV they incresed from 12 km s-1 to 470 km s-1 (Fig. 6).

Results: partial halo CME and ribbon flare*(10:00 UT - 20:49 UT)*

The late EP evolution beneath the CME and multiarcade streamer surrounded it affect on the CME three-parts structure. The CME bright core presented a specific bi-component structure produced by the upper parts of cool MFR and hot BFR, which had quite different asymmetrical positions in the cavity (Fig 8).

The impulsive flare started in this stage at 09:52 UT, just after the EP splittng and almost simultaneously with the CME appearance (10:02 UT) in the LASCO C2 FOV. It reached maximum at the time when extensive strong EUV brightening in the bipolar region containing BFR was observed (Fig 7).

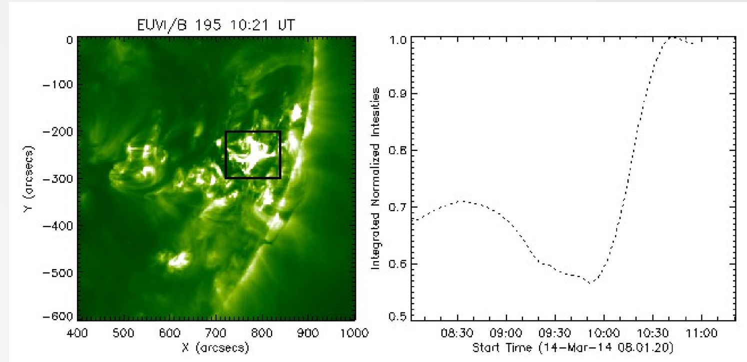

Fig. 7. left: EUVI B image in 195 Å channel; right: Integrated intensities in EUVI B 195 Å channel, obtained from the boxed region overplotted on the left panel.

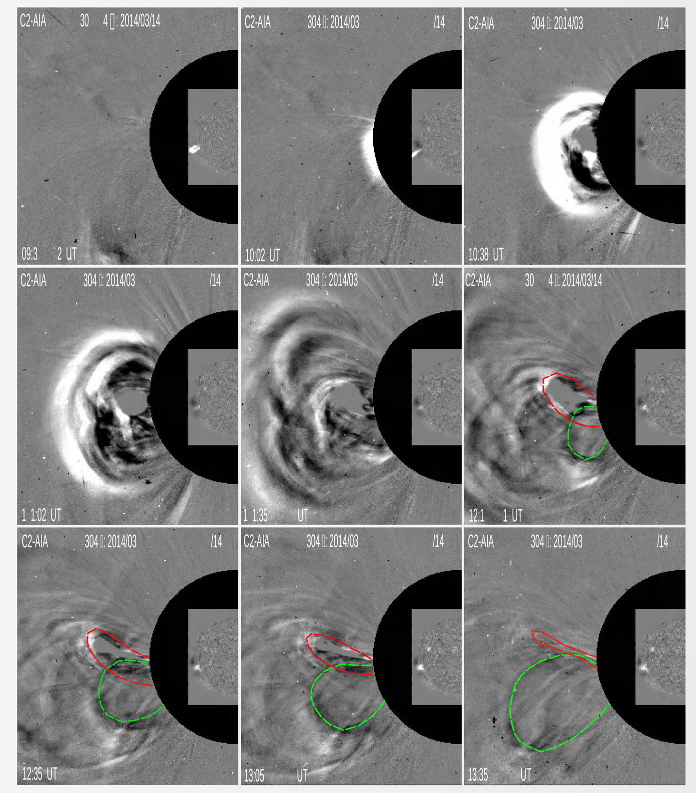

Fig. 8. A sequence of LASCO C2 and SDO/AIA 304 Å running difference images showing the progression of the 2014 March 14 prominence eruption as a bright core of partial-halo CME. The dashed lines in the last four frames trace the two EP FRs: green - MFR and red - BFR.

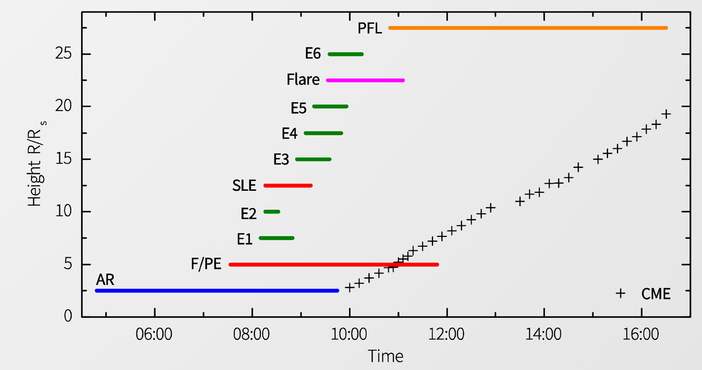

Fig. 9. Height-time diagram of the CME with overplotted exact durations of all associated events.

Conclusions

The EP was part of a chain of physically linked sympathetic events appearing in a single region below the multiarcade helmet streamer (Fig. 9).

The EP evolution on 2014 March 14 composed by both hot BFR and cool MFR, which involved a rare feature of interaction between the BFR and MFR that subsequently appeared as bi-component bright core in the associated partial-halo CME.

The dominant role of the BFR below the MFR suggests the torus instability as a most reliable driver of eruption.

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