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ASYMMETRIC FILAMENT ERUPTION FOLLOWED BY TWO-RIBBON FLARE

KOSTADINKA KOLEVA, PETER DUCHLEV and MOMCHIL DECHEV

Institute of Astronomy with National Astronomical Observatory,
Bulgarian Academy of Sciences
E-mail: koleva@astro.bas.bg, pduchlev@astro.bas.bg, mdechev@astro.bas.bg

Abstract. We report the first results from the study of an asymmetric eruptive prominence (EP) that appeared on 01 Nov 2014 and was followed by a two-ribbon solar flare. The ejection triggered a fast coronal mass ejection (CME) that was well visible in the LASCO C2 field of view. The morphology and kinematics of the EP and two-ribbon flare were examined by multi-channel observations from AIA/SDO and SoHO/LASCO. Initially, the EP slowly rose and then it sharply ejected up with a strong acceleration producing the CME bright core. The evolution of two-ribbon flare is morphologically characterized by separation of the two ribbons in the chromosphere. The ribbons' separation showed two-stage evolution: first one with relatively fast decelerating motion and very slow second one with low constant velocity. Such separating motion is believed to provide a signature of the reconnection process occurring progressively higher up in the corona.

1. INTRODUCTION

Solar filaments (or prominence when observed on the limb) are relatively cool (10^4 K) and dense (10^{10} –10^{11} cm^{-3}) plasma objects embedded in the hot (10^6 K) and tenuous (10^9 cm^{-3}) solar corona (Tandberg-Hanssen 1995). Very often filaments displays eruptive motions. Solar prominence eruptions is one of the most energetic active phenomena of the Sun, during which about 10^{12} kg plasma can be thrown out from the chromosphere and low corona to the interplanetary space. Hence, the prominence eruptions has an important impact for the space weather manifestations. Filament eruptions are closely associated with CMEs.

Filaments are often observed to erupt asymmetrically. During the so called asymmetric eruption one of the prominence leg remains fixed to the photosphere, while the other undergo rising motions until its position becomes almost perpendicular to the solar limb (Liu et al. 2009).

Filament/prominence eruption are frequently accompanied by a two-ribbon solar flare, which are observed to expand (separate) in the chromosphere. It is widely accepted that two-ribbon flares are triggered by magnetic reconnection between coronal field lines that has been forced to open by erupting filaments (Svestka & Cliver 1992).

In this work we present the kinematic and morphological analysis of the asymmetric filament eruption that was followed by a two ribbon solar flare. The set of observations used for our analysis are described in Sect. 2. In Sect. 3 and Sect. 4 are presented the morphology and kinematics of the filament eruption and solar flare, respectively. In Sect. 5 some details of the associated CME are given. The main results and conclusions are summarized in Sect. 6.

2. OBSERVATIONS

The asymmetric prominence eruption was observed at 01 Nov 2014 in a quiet solar region close to the east limb. The eruption started at 04:26 UT and ended at 05:28 UT. The ejection of the prominence material was followed by a two ribbon solar flare, located at heliographic coordinates S22E52.

For event analyzed here we used observations from Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Observatory (SDO) (*Lemen, et al.* 2012). The AIA consists of seven Extreme Ultra-Violet field (EUV) and three Ultra-Violet (UV) channels, which provide an unprecedented view of the solar corona with an average cadence of ~12 s. The AIA image field-of-view reaches 1.3 solar radii with a spatial resolution of ~ 1.5". The eruption kinematics was studied by images taken with 1 min cadence in He II 304 Å passband. To trace the flare ribbon kinematics the data in Fe XIII 131Å, Fe IX 171 Å and C IV 1600 Å channels from SDO/AIA were also used.

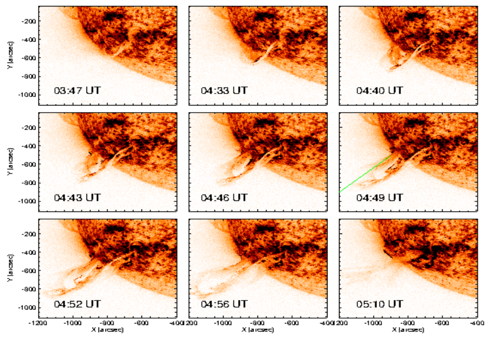


Figure 1: The EP evolution in AIA/SDO FOV in He II 304 Å channel (reversed colors). The green line marks the slice position used for obtaining the height-time evolution.

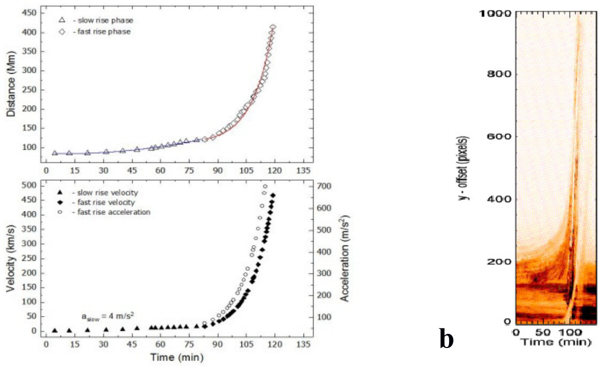
The ejection triggered a coronal mass ejection (CME). Images obtained by the Large Angle and Spectrometric Coronagraph (LASCO)/C2 on board SOHO, whose field-of-view extends from 2 to 6 solar radii (Brueckner et al. 1995) were also analyzed in order to trace the CME properties.

The evolution of prominence eruption in 304 channel of AIA/SDO in reversed colors is presented in Figure 1. With green line is marked the slice position used for kinematic study of the eruption.

3. PROMINENCE MORPHOLOGY AND KINEMATICS

The prominence body consisted of helically clockwise twisted flux robe (FR). The FR twist (a measure of the number of turns of the magnetic field lines) can be visually estimated after 04:43 UT at 3π (Fig. 1), which is above the critical value of 2π required for the kink instability to act (Hood & Priest 1981). At about 05:02 UT the left handed twist was transformed to the left-handed writhe. The same sign of the FR helical twisting and writhing is a basic condition for the kink instability presence (Hood & Priest 1981). That allow us to suggest that the eruptive prominence from 01 Nov 2014 was possibly subjected to a kink instability, although other instabilities may also have acted.

The prominence eruption started at about 03:47 UT. The eruption clearly showed two phases. During the first, slow-rise phase, which lasted at about 24 min the prominence body rose with velocities from 1.2 km/s to ~20 km/s. The second fast-rise phase lasted until 05:00 UT when the top of the prominence body quit the AIA field of view (FOV). During this phase the prominence ascended with increasing speed and acceleration. At the same time the prominence body underwent an untwisting motion. The fast rise phase velocity and acceleration reached 468 km/s and 700 m/s^2, respectively. After 05:09 UT the northern leg disconnected from the solar chromosphere.



a b

Figure 2: Height-time profile of prominence evolution (top) and eruption velocities and acceleration (bottom) - (**a**). The start time is 01 Nov 2014 03:00 UT. Time-distance diagram – (**b**).

The height-time profile of prominence evolution and eruption velocities and acceleration are shown in Fig. 2a, while Fig 2b presents the time-distance diagram, used for height determination.

4. SOLAR TWO-RIBBON FLARE KINEMATICS

The prominence eruption form 01 Nov 2014 was followed by a C2.7 Goes class two-ribbon solar flare. The flare started at 04:44 UT, 12 minutes after the start of the EP fast-rise phase. It's peak intensity was registered at 05:43 UT. In Fig. 3 are presented the flare images in four AIA/SDO channels with different temperature formation, He II 304 Å (log(T)=4.7), Fe IX 171 Å (log(T)=5.8), C IV 1600 Å (log(T)=5.0) and Fe VIII 131 Å (log(T)=7.2). At such a way the flare evolution can be traced in different regions of solar atmosphere, such as chromosphere (304 Å), quiet corona and upper transition region (171 Å), upper photosphere (1600 Å) and hot flaring regions (131 Å).

It is widely accepted that the evolution of the two-ribbon solar flares is morphologically characterized by separation of the ribbons in the solar chromosphere. Such separating motion is believed to provide a signature of the reconnection process occurring in the corona (Cheng et al. 2003, Wang et al. 2003). In this paper we studied the separation of the flare ribbons observed at the chromosphere as a function of time. The ribbons' separation showed two-stage evolution. During the first stage which lasted about 43 minutes, the two ribbons moved away from each other with relatively fast decelerating velocity from 35 km/s to several km/s. The second stage was characterized by a motion with a low constant velocity of 1.4 km/s and lasted for more than 1.5 hr when flare emission decayed. The results are presented in Fig. 4.

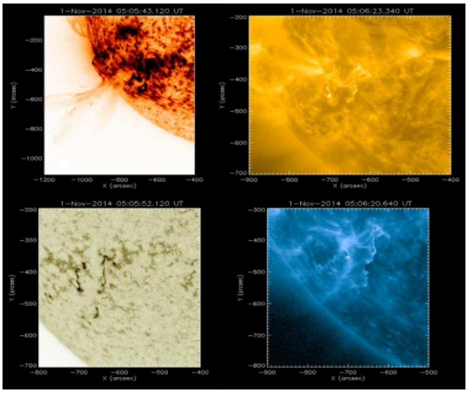


Figure 3: Two ribbons flare as viewed in AIA 304 Å, 171 Å, 1600 Å and 131 Å channels at temperature formation: log (T) = 4.7, 5.8, 5.0 and 7.2, respectively.

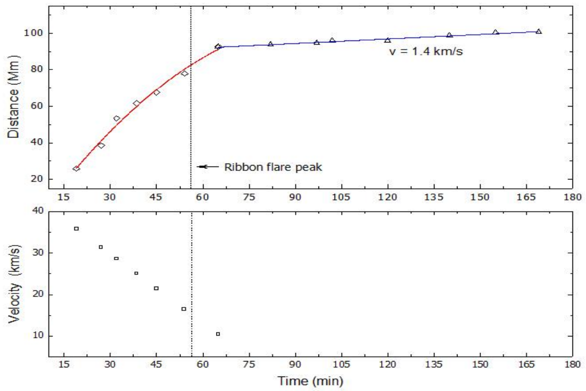


Figure 4: The distance between flare ribbons (top panel) and the separation velocity (bottom panel). The flare peak time is marked with dotted line.

5. THE ASSOCIATED CME

The prominence eruption was associated with a fast partial halo CME, which first appearance in LASCO/C2 FOV was at about 05:00 UT. The CME was located at position angle (PA) of 74° degrees and propagated with linear speed of 1624 km/s and acceleration of 7.3 m/s^2. The EP material could be traced in LASCO/C3 FOV up to 16 solar radii as the CME bright core. The CME evolution in LASCO C2 field of view is shown in Fig. 5, while in Fig. 6 the height-time profiles of EP and associated CME are presented together with Goes soft X-ray (SXR) flux in two energy channels.

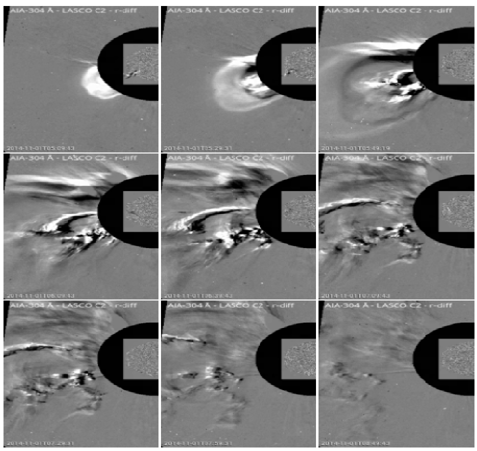


Figure 5: CME evolution sample in LASCO C2 field of view.

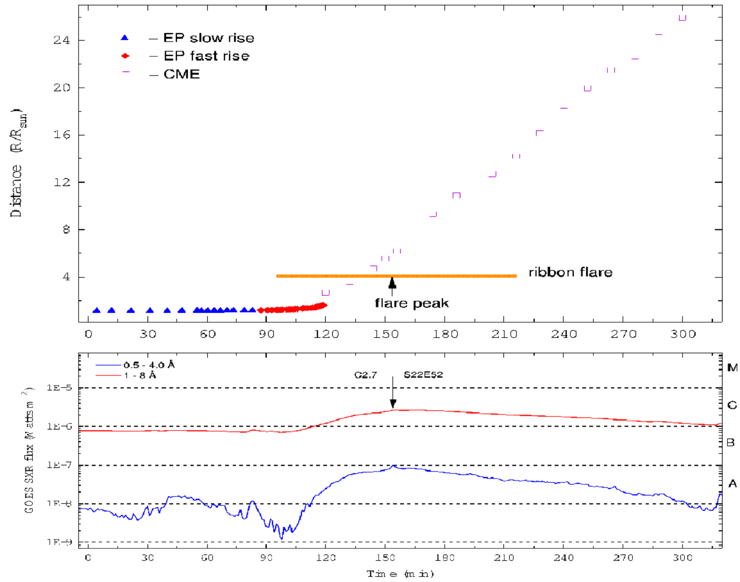


Figure 6: Height-time evolution of EP and associated CME (top panel) and Goes SXR flux (bottom panel). The start time is 03:00 UT. The time of flare peak is marked with black arrow.

6. SUMMARY

The prominence from 01 Nov 2014 underwent an asymmetric eruption with two clearly distinguish by its kinematic phases: slow-rise phase with a modest velocities and a phase of strong acceleration and very high speed. During the first phase the EP slowly rose with velocities from 1.2 km/s to ~18 km/s and then it underwent a strong acceleration (second phase) and rose with velocities from 20 km/s up to 468 km/s in the AIA/SDO field of view.

The two-ribbon flare underneath the EP most probably occurred due to reconnection processes in the coronal magnetic field in the wake of the prominence eruption. The ribbons' separation kinematics clearly shows two stages: first decelerating one with velocities from 35 km/s to several km/s and second very slow one with velocity of 1.4 km/s.

The EP produces a very fast halo CME, which propagates with velocity of 1624 km/s. The CME core formed by the EP can be traced up to 16 solar radii in the SOHO/LASCO C3 field of view.

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