Kinematics of solar eruptive prominences according to space-based observations

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Outline

We tracked the behavior of the prominence bodies during the eruptive process. Observations, obtained by two space-based instruments were used to study the plasma kinematics - Solar Dynamics Observatory/Atmospheric Imaging Assembly (SDO/AIA) on heights up to 1.3 solar radii and Solar and Heliospheric Observatory/Large Angle and Spectrometric Coronagraph (SOHO/LASCO) white-light coronagraph C2 on heights up to 6 solar radii. The presented height-time profiles of the eruptions show changes of the velocity of the prominence material.

Observations & Prominences

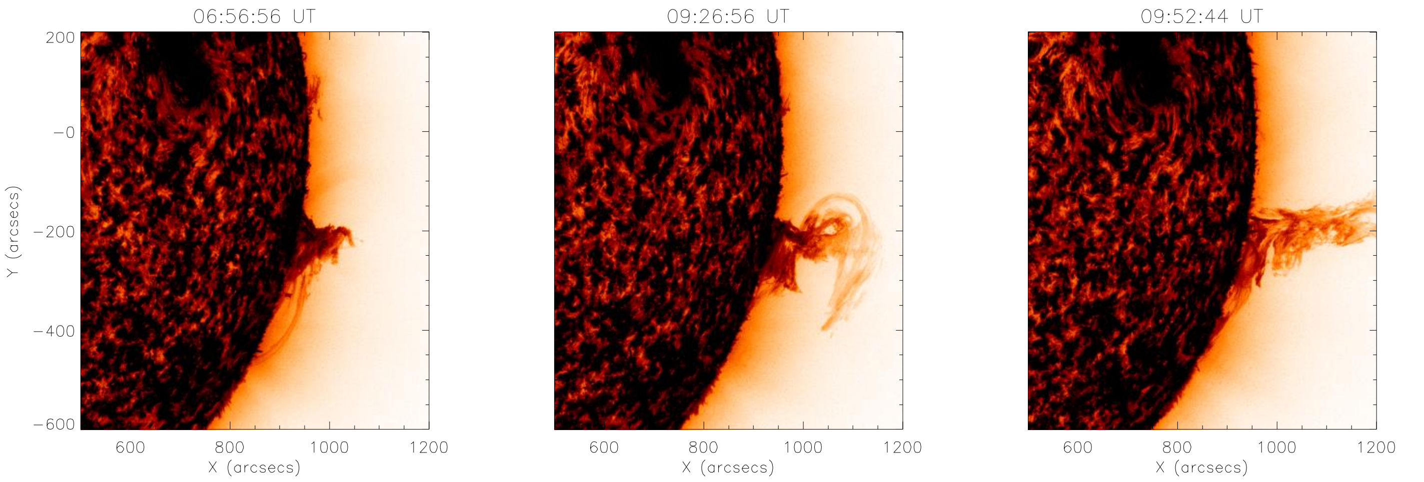
The current study stands on space-based observations and presents velocity distributions of five solar prominences. We analyzed images obtained in the He II 304 Å channel of AIA/SDO taken with an average cadence of about 5 min. To track the prominence body on higher altitudes and to search for a possible association of the eruptive prominences (EPs) with coronal mass ejections (CMEs), the LASCO/SOHO C2 coronagraph (covering the distance range of 1.5 to 6 solar radii with cadence – 12-15 min) data was also used, where available.

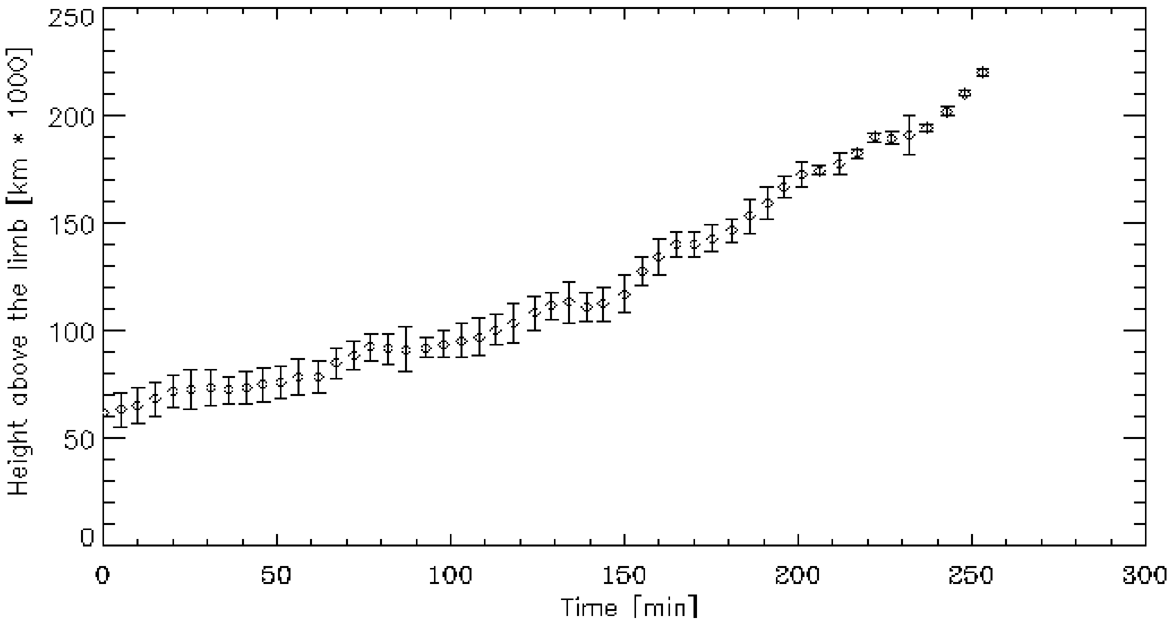
Some basic information for the three explored prominences is summarized in Table 1.

	EP I	EP II	EP III	EP IV	EP V
Date and Time [UT]	7 August 2010 06:00 – 16:00	25 August 2010 00:00 – 04:30	30 September 2010 18:30 – 00:30	28/29 July 2012 15:30 – 02:30	27 February 2013 00:00 – 07:30
First Appearance [UT]	4 August 2010 03:00	23 August 2010 15:00	30 September 2010 13:30	27 July 2012 01:00	25 February 2013 00:00
Position	W limb	S limb	NW limb	SE limb	SW limb
Eruption type	Partial	Confined	Confined	Partial	Full
Visibility in LASCO C2 FOV	No	No	No	Yes	Yes
Association with ARs	No	No	No	11532	No

Table 1: Basic data for the explored prominences.

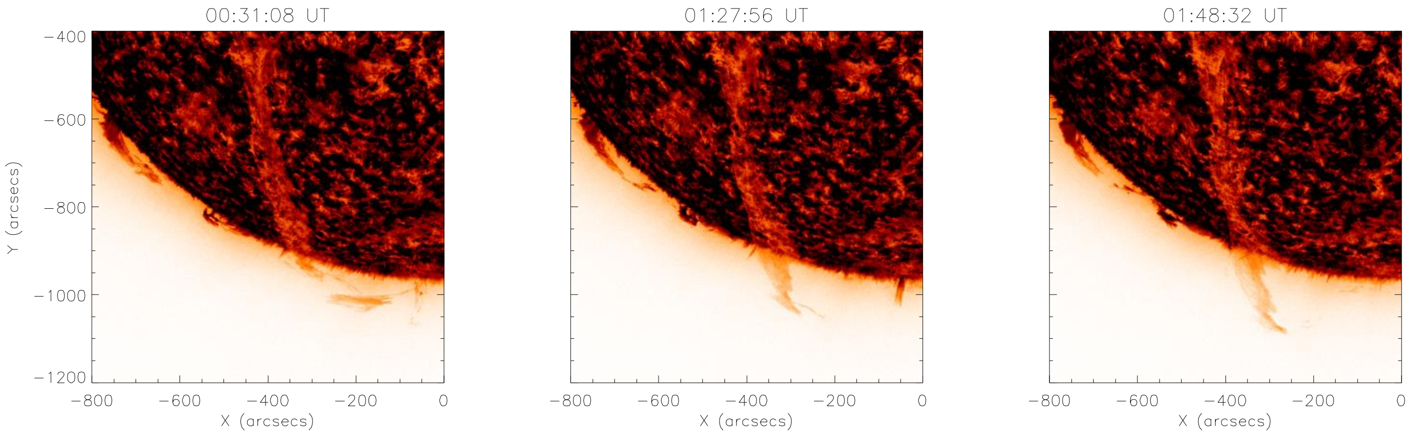
EP I 7 Aug 2010



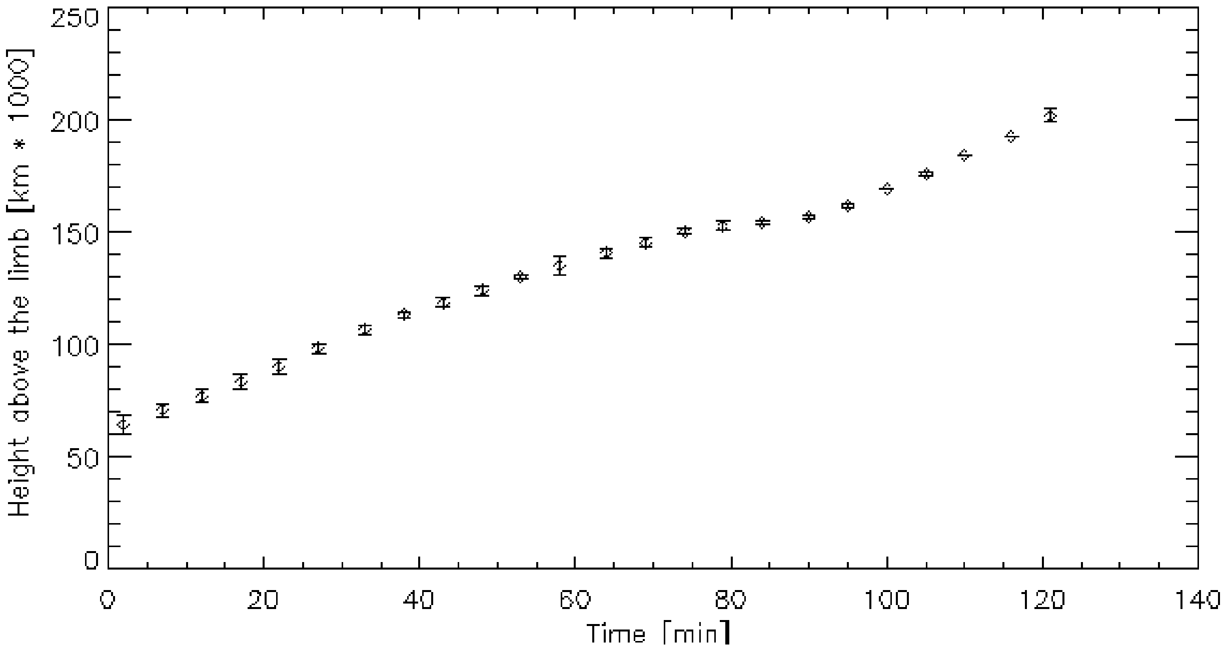


The first appearance of the EP I happened on 2010 Aug 4 around 3:00 UT as a small quiescent prominence on the W limb. Approximately 3 days later, it erupted ejecting a part of its matter into the heliosphere. Measuring the height of the prominence during the eruption allowed us to build a height-time diagram and to track its behavior while rising from 62 500 km to 220 000 km in the AIA field of view (FOV).

EP II 25 Aug 2010

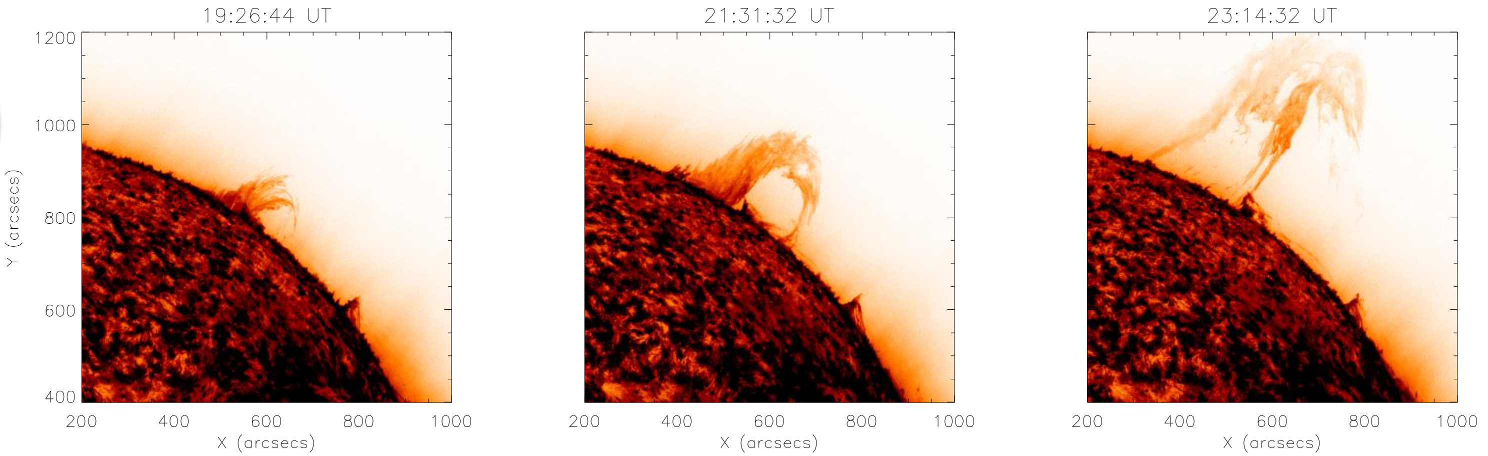


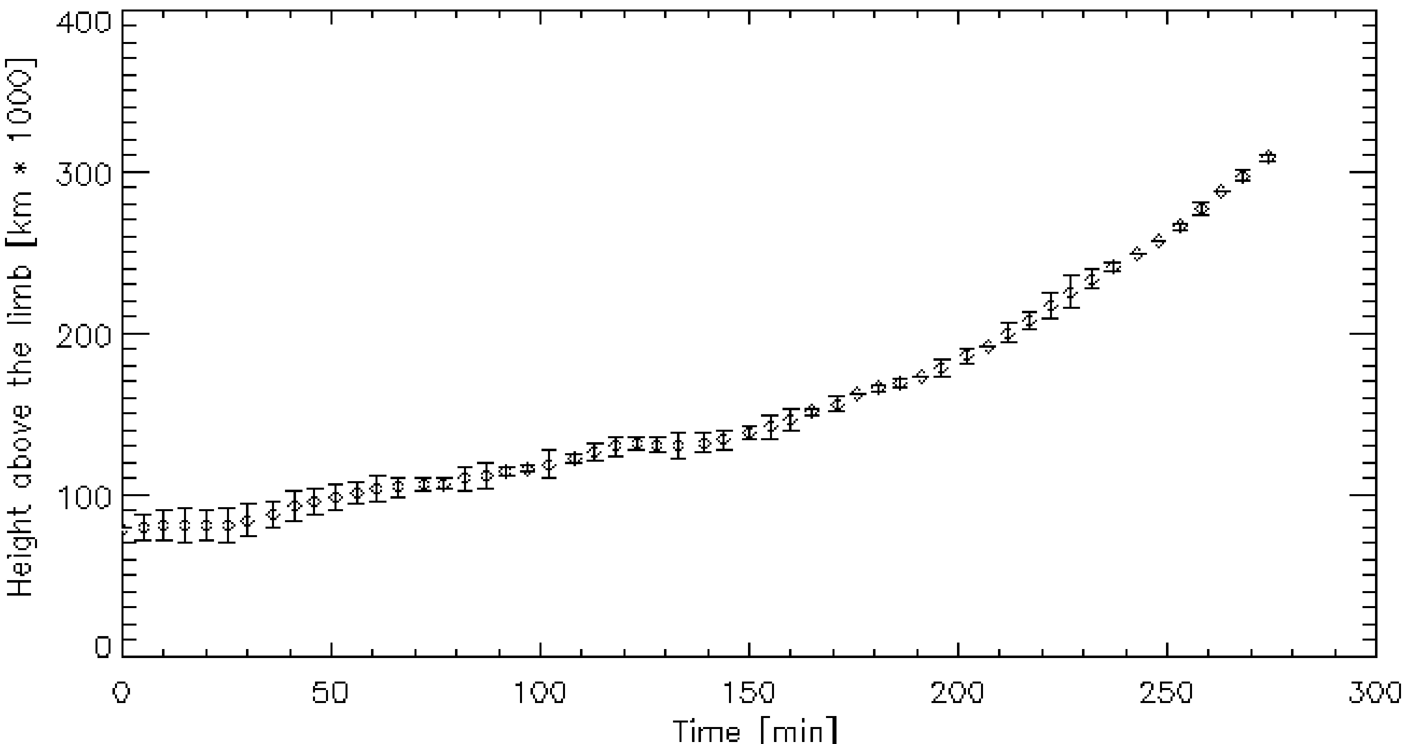
The height of the EP II above the limb was also determined from AIA images. We built the height-time profile of the eruption, which showed that it was relatively slow one as the height of the EP changes from 65 000 to 205 000 km for about 4.5 hours of observations. Because of the visibility of the EP only until 3:00 UT (in the AIA FOV), we were unable to continue measurements.



EP III 30 Sept 2010

The EP III (2010 Sept 30) erupted quickly after showing up (6 hours later) on the NW limb. Its activation led to an arch formation from a rising plasma. The eight-hours long eruption (18:30-00:30) was relatively slow. The maximal height reached, before the material to start falling back down to the Sun and define a confined eruption, was ≈ 305 000 km (AIA).

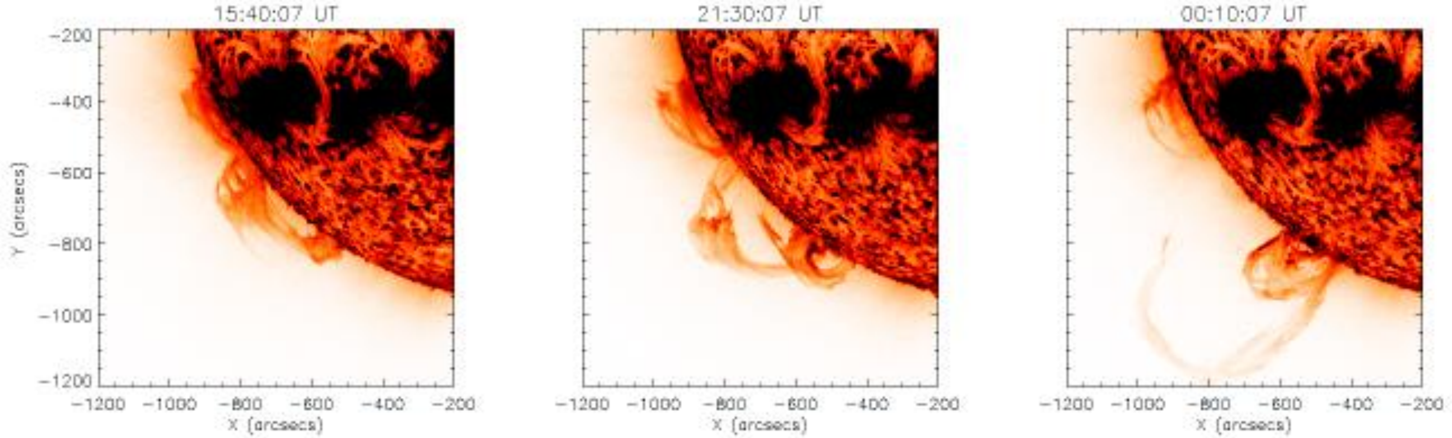




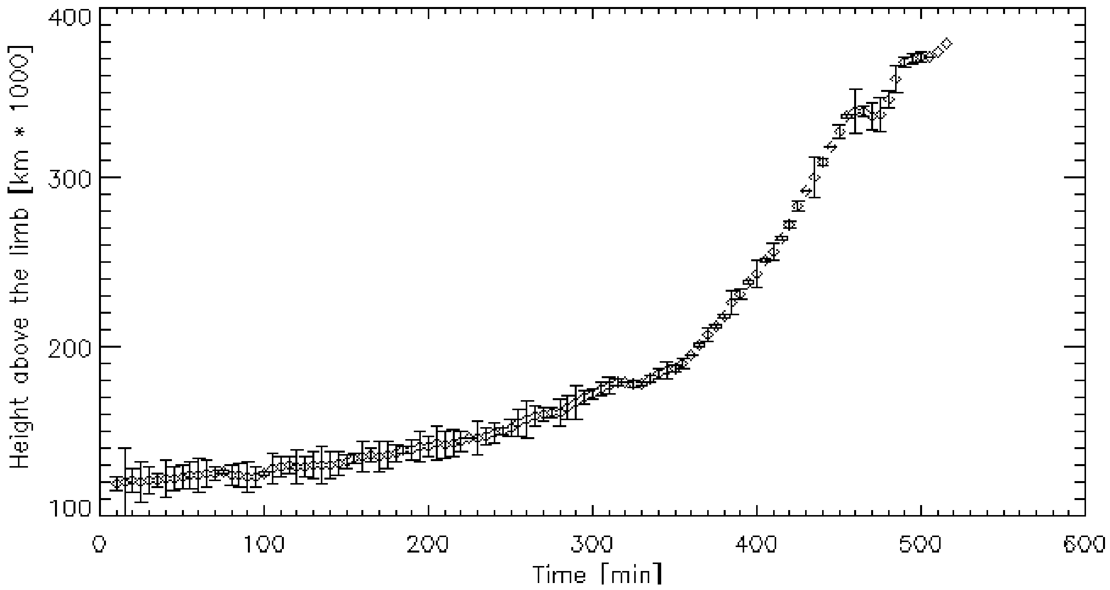
EP IV 28 July 2012

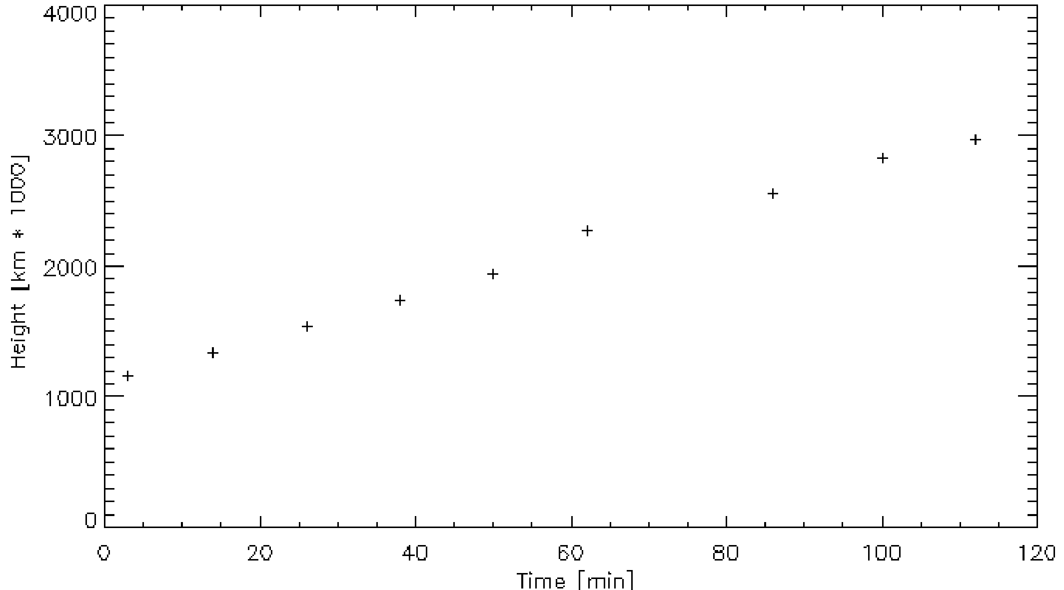
One slow eleven-hour eruption (15:30-02:30), observed by AIA/SDO, shows asymmetric EP forming three arches. During the eruption the prominence reaches 380 000 km in AIA FOV.

The EP continues to rise up as a core of a CME observed by LASCO C2.



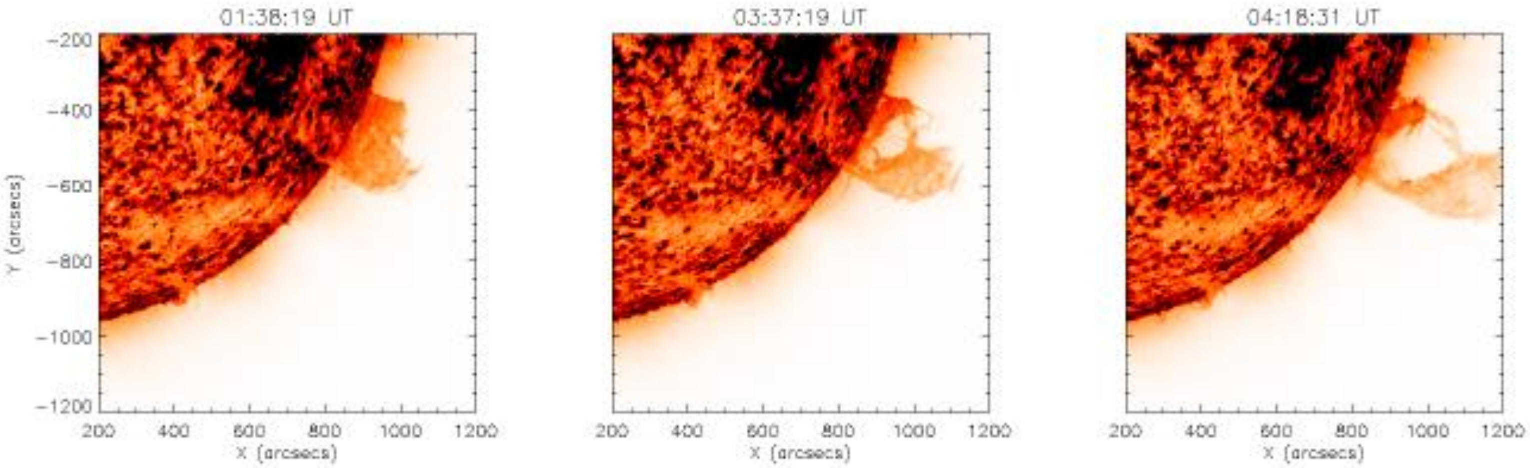
Part of the material is ejected in the corona and a small part flows down on the Sun. At the final moments of visibility in LASCO C2 FOV (12 hours after the start of the eruption) the outer segments of the prominence material were ≈ 2.970×10^6 km (≈ 4.3 solar radii) away from the solar limb.



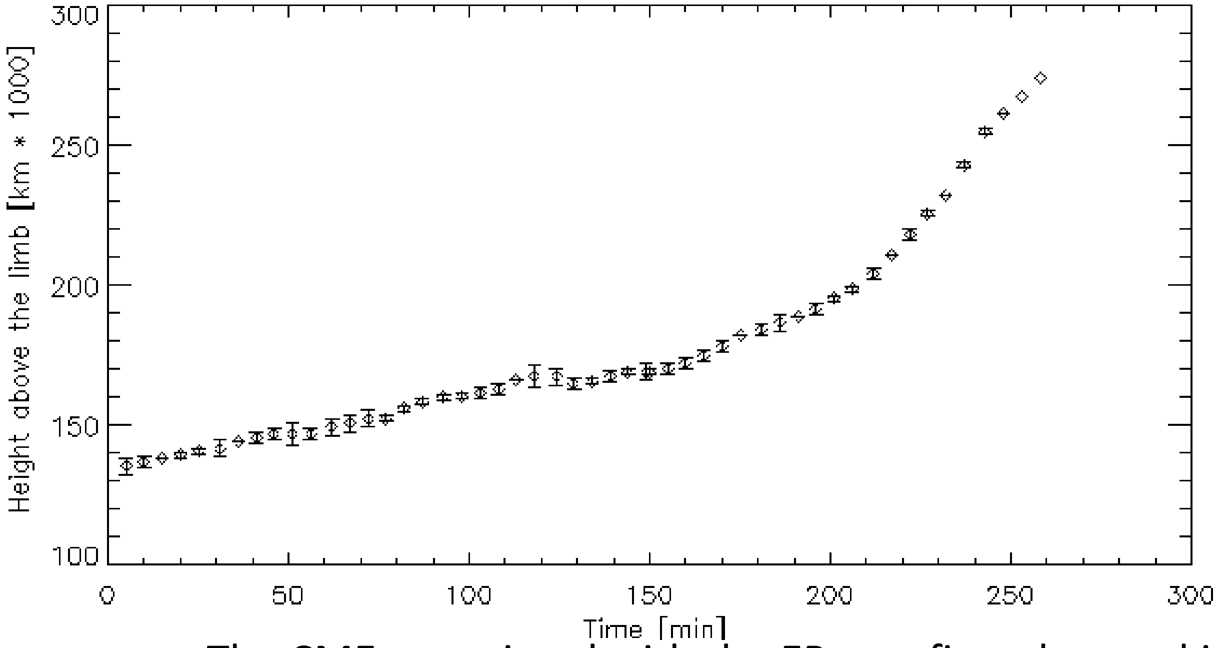


EP V 27 Feb 2013

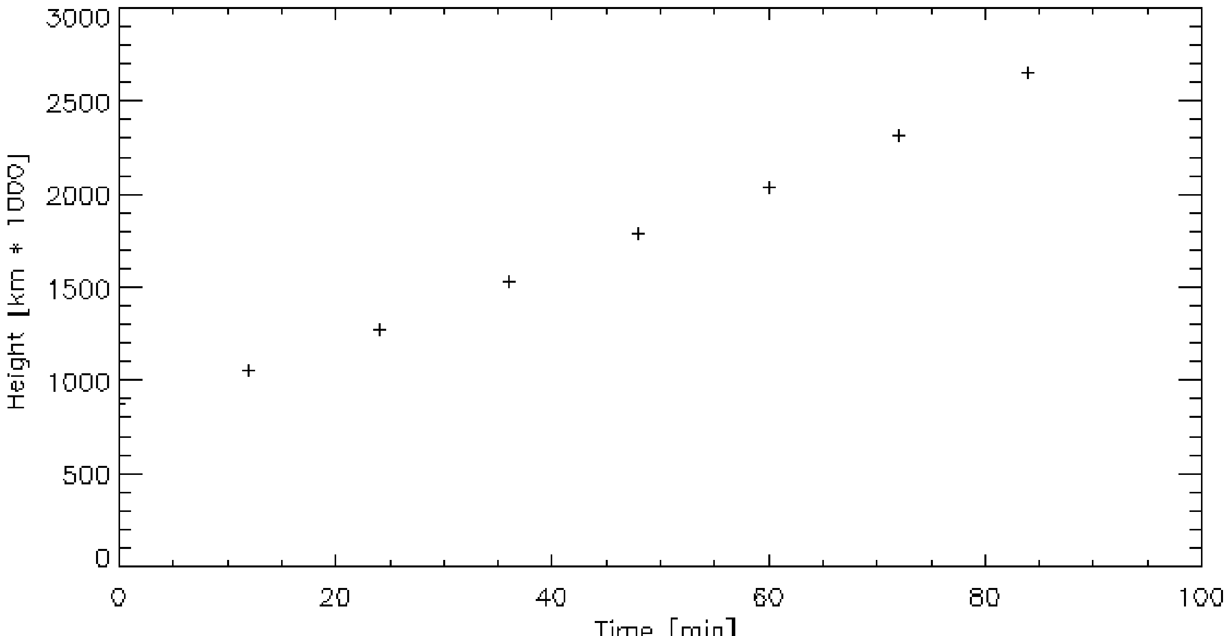
The last presented EP was observed on the SW limb on 2013 February 27, also not associated with an AR. The eruption was full and the CME associated with the EP was very week. Strong twisting motions were observed.



The height-time profile of the eruption showed that it was relatively slow (from 135 000 to 275 000 km for about 5.5 hours of observations). Unfortunately, the EP is visible in the AIA FOV only until 4:30 and despite the eruption continued, we were not able measure the highest point of the arch anymore.



The CME, associated with the EP, was first observed in the C2 FOV at about 05:00 UT, but the EP showed up half an hour later. The height-time profile seems linear, but still it may be due to the big cadence between the LASCO images.



Results

In all of the presented height-time diagrams some fluctuations of the curves can be noticed. Probably, because of the quite bigger cadence in LASCO/SOHO observations (12–15 minutes), they are visible only on the AIA plots.

The energy of the EPs used for the transfer of plasma in height gives a possible hypothesis that corresponds to our results. The plasma passes through separate arcade structures of the magnetic field and temporary delays due to weak magnetic reconnection. Then we see a significant acceleration of the mass, which is observed by the instruments of SOHO/LASCO. Passing through the open radial fields at altitudes higher than 2-2.5 solar radii, the mass reaches a height with free accelerating without oscillations, where such magnetic arcades are so insignificant that we are not able to report similar effects of periodic delay and acceleration.

As long as we do not have a statistically significant amount of explored prominences, a projection effect or wrong interpretation of the results is also a possible explanation.

Conclusions & Discussions

The velocity distribution of the plasma in height during prominence eruption shows quasi-periodic changes. They should not be considered as propagating waves or moving nodes in the meaning of MHD oscillation modes. We assume that the observed oscillations are due to magnetic loops overpassed by the prominence material. The surrounding magnetic structure of the filament defines the distribution of the velocity. When the plasma passes a single magnetic loop, the movement of the eruptive prominence slows down, which may be considered as a consequence of interaction between prominence material and the magnetic pressure of the surroundings.

According to the mass and the energy of the eruptive filament it is possible to observe an eruption when the plasma can completely get over the surrounding magnetic loops or reach certain height above the solar limb and flow back down to the Sun.

Our measurements show that heights in the range between 200 000 and 380 000 km above the solar limb might be critical, where the velocity of the erupting prominences rapidly raises and velocity oscillations stop. Presumably, these heights are different for filaments that undergo different eruption types. The highest critical height (380 000 km) from the studied prominences was observed at one of the two cases of partial eruptions. It is probably due to the lack of strong magnetic structures that can resist the free movement of material. Still, it can be connected to the low density of the corona, which cannot affect the distribution of the plasma velocity.

The current study contains only the very first results of our investigation. Its aim is to present some observational facts for the rising of the eruptive prominences. Future steps include exploring the causer of the veclocity variations in the height-time profiles.

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