A filament eruption with an apparent reshuffle of endpoints

Boris Filippov

Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation of the Russian Academy of Sciences (IZMIRAN), Troitsk, Moscow 142190, Russia

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ABSTRACT

A filament eruption during 2010 April 30–May 1, which shows the reconnection of one filament leg with a region far away from its initial position, is analysed. Observations from three viewpoints are used for measurements of endpoint coordinates as precise as possible. The northern leg of the erupting prominence loop ‘jumps’ laterally to a latitude lower than the latitude of the original southern endpoint. Thus, the endpoints have reshuffled their positions in the limb view. Although this behaviour could be interpreted as an asymmetric ‘zipping-like’ eruption, it does not look very likely. It seems more likely to represent reconnection of the flux-rope field lines in the northern leg with ambient coronal magnetic field lines rooted in a quiet region far from the filament. From calculations of coronal potential magnetic field, we found that the filament before the eruption was stable to vertical displacements, but was liable to violation of horizontal equilibrium. This is an unusual initiation of an eruption, with a combination of initial horizontal and vertical flux-rope displacements, showing a new and unexpected possibility for the start of an eruptive event.

Key words: magnetic reconnection – Sun: activity – Sun: filaments, prominences – Sun: magnetic fields.

1 INTRODUCTION

Many solar filaments (or prominences when they are observed above the solar limb) end their life with a sudden rapid rise called an eruption. Sometimes a filament rises like an enlarging loop lying in a plane containing filament endpoints anchored in the chromosphere and the centre of the Sun (Gopalswamy & Hanaoka 1998). A famous example suggestive of such behaviour is the eruption of the giant prominence on 1945 June 28 (‘Granddaddy’) observed at the High Altitude Observatory. Some eruptive prominences deviate significantly from this plane and move in a non-radial direction (Gopalswamy, Hanaoka & Hudson 2000; Filippov, Gopalswamy & Lozhechkin 2001, 2002; Sun et al. 2012). Moreover, the loop may not be flat but rather the apex may exhibit a writhing motion as it rotates about the direction of ascent (Ji et al. 2003; Romano, Contarino & Zuccarello 2003; Williams et al. 2005; Zhou et al. 2006; Green et al. 2007; Mughlach, Wang & Kliem 2009; Kliem, Török & Thompson 2012).

There are also partial filament eruptions when only a section of a long filament starts to ascend, while other parts of the filament are observed unchanged (Tripathi et al. 2009). Usually a prominence stretched along the limb consists of a number of arches with feet (also called barbs) connected to the chromosphere like a long road bridge with several spans. After the start of ascension, the feet break successively, except for the filament endpoints for a full eruption or the feet of the undisturbed filament sections for a partial eruption. Of course, in a real solar environment, events are often asymmetric. One leg of an eruptive prominence may be fixed to the chromosphere at the prominence endpoint, while the other part of the prominence with the chromosphere changes its position following the successive breaking of intermediate feet. Liu, Alexander & Gilbert (2009) identified two types of asymmetric filament eruption: whipping-like, where the active leg whips upward, occasionally extending high into the corona, and zipping-like, where the visible end of the active leg moves along the polarity inversion line (PIL) like the unfastening of a zipper. It should be noted that the visibility of a filament depends on the loading of its magnetic skeleton with dense plasma. During an asymmetric filament eruption, the active leg can either whip upward, if it is anchored at the location where the eruption initiates, or ‘zip’ away from the visible end of the active leg, where the eruption initiates, towards the ‘invisible’ end of the active leg. The ‘invisible’ end later becomes visible during the zipping process, with mass draining down along axial filament field lines.

While falling back to the chromosphere, eruptive prominence material can move along pre-existing magnetic flux tubes, possibly highly stretched and deformed, which belong to the magnetic skeleton of the prominence. There are also indications that sometimes prominence plasma returns to the chromosphere along trajectories that were formed by reconnection of the prominence magnetic field with the ambient coronal magnetic field. Grechnev et al. (2008)
reported an explosive filament eruption on 2004 July 13, in which one part of the ejecta escaped as a coronal mass ejection (CME) and another part fell back on to the Sun. The latter part consisted of fragments of the filament dispersed into a cloud covering almost the whole north-west quadrant of the solar disc. Obviously, some areas where filament fragments landed had not been connected with the filament by field lines. On 2011 June 7, an active region filament near the west solar limb rose and erupted, hurling an enormous amount of material into the solar atmosphere (Innes et al. 2012; Gilbert et al. 2013; Carlyle et al. 2014; van Driel-Gesztelyi et al. 2014). The diagonal scale of the ejecta appears at least an order of magnitude larger than the initial footpoint separation and suggests that the filament carried a very large amount of mass. A significant fraction of the prominence mass was observed falling back to the solar surface along newly reconfigured magnetic field lines. van Driel-Gesztelyi et al. (2014) consider this event as clear evidence that large-scale reconfiguration of the coronal magnetic field takes place during solar eruptions via the process of magnetic reconnection. Manoharan et al. (1996) reported a disc event on 25 October 1994, which provided evidence for a large-scale magnetic reconnection occurring between the expanding twisted loops and overlying the trans-equatorial loops that interconnect quiet solar regions.

In this work, we analyse observations of the eruptive filament on 2010 April 30–May 1, which shows reconnection of one filament leg with a region far away from its initial position. In contrast to the above-mentioned examples of coronal reconnection, the erupting filament loop does not disintegrate but keeps the shape of a rather thin loop even after a fast ‘jump’ of the endpoint over a distance of 0.7 $R_\odot$, where $R_\odot$ denotes the solar radius. We calculated the parameters of the coronal potential magnetic field and found that the eruption began with instability not in the vertical direction, as is typical for eruptive filaments, but after violation of horizontal equilibrium.

2 OBSERVATIONS OF THE ERUPTIVE FILAMENT ON 2010 APRIL 30–MAY 1 FROM THREE VIEWPOINTS

A quiescent filament, located close to National Oceanic and Atmospheric Administration (NOAA) active region 11064 and to the north-west from it (Fig. 1), started to rise rapidly after 2300 UT on 2010 April 30. The eruption was observed on the disc in the H{$\alpha$} line at the Mauna Loa Solar Observatory with a cadence of 3 min (Fig. 2) and at Culgoora Solar Observatory with a cadence of 1 min, as well as on the eastern limb by the Solar Terrestrial Relations Observatory – Ahead (STEREO A) and close to the western limb by the Solar Terrestrial Relations Observatory – Behind (STEREO B) with a cadence of 10 min (Figs 3 and 4). The event was also observed on the disc with the Project for On-Board Autonomy 2 (PROBA2)/Sun Watcher using APS and Image Processing (SWAP) extreme ultraviolet (EUV) solar telescope in a spectral bandpass centred on 174 Å with a cadence of about 1 min (Halain et al. 2013; Seaton et al. 2013). At first, it looked like a typical eruption of a filament, showing an expanding loop with anchored endpoints (movie 1). At 2346 UT, the top of the loop folded over in images obtained by the Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI) Extreme Ultraviolet Imager (EUVI) (Wuelser et al. 2004; Howard et al. 2008) on board STEREO A, showing writhing of the filament axis. The apex of the eruptive filament (prominence) deflected to the south during the ascension. At 0006 UT, it was over the southern endpoint of the prominence. This endpoint became wider and consisted of several strands of threads after 0000 UT. The southernmost strand faded out after 0030 UT, while the northern strand became narrower with fine threads. The behaviour of the northern endpoint of the filament was more dramatic. Before the eruption, the filament axis entered the chromosphere at this endpoint, inclined slightly to the south from the vertical. From 2330–0000 UT, the axis was nearly vertical; then it...
inclined to the south. At about 0030 UT, the northern leg of the erupting prominence loop ‘jumped’ laterally to a position further south than the southern endpoint of the prominence. The loop proceeded to expand and ascend; however, the endpoints reshuffled their positions in STEREO A images. The original southern endpoint is now in the north, while the original northern endpoint is in the south. Further evolution of the eruptive prominence in STEREO A images looks like that of a typical prominence eruption with endpoints anchored in the chromosphere, if one forgets that the endpoints have exchanged roles. The top of the prominence left the STEREO A field of view at 0040 UT and after 0140 UT all the structure faded and flew away from the field of view. After half an hour of acceleration (∼ 2300–2330 UT), the top of the prominence rose with an approximately constant speed of 90 km s$^{-1}$ (Fig. 5).

The eruption of the prominence was followed by a CME, which was observed from all three viewpoints (Fig. 6). Due to the geometrical factor, it was brightest in the field of view of the STEREO A COR2 coronagraph (Howard et al. 2008). At the late stage, the legs of the CME connecting the core with the Sun show noticeable twisted structure (not visible in the difference image in Fig. 6). The Large Angle and Spectrometer Coronagraph (LASCO) C2 (Brueckner et al. 1995) on board the Solar and Heliospheric Observatory (SOHO) and the STEREO B COR2 coronagraph registered only
faint features, which became perceptible enough only in difference images. The CME propagated in the east-south-east direction for STEREO A and SOHO, but in the west-south-west direction for STEREO B. The bright core in the STEREO A COR2 field of view moved with a speed of about 100 km s$^{-1}$. The frontal CME structure, of course, moved faster. According to the SOHO/LASCO CME Catalog (http://cdaw.gsfc.nasa.gov/CME_list/), the CME appeared first in the field of view of C2 at 0712 UT on May 1 at a polar angle of 111$^\circ$, had an angular width of 108$^\circ$ and reached a final speed of 380 km s$^{-1}$.

In H$\alpha$ images obtained with ground-based telescopes, the filament rotates counterclockwise about its southern endpoint like a nearly straight structure (Fig. 2, see also movie 2). It passed over AR 11064 in projection and faded when it stretched in a nearly longitudinal direction. Two short faint flaring ribbons appeared at 2350 UT at the location of the most curved and widest section (an elbow in Fig. 1) of the pre-eruptive filament (Fig. 2).

Brightening below the ascending filament in STEREO B images arose at 2336 UT soon after the start of the eruption (Figs 3 and 4, movie 3). Later on, two discontinuous ribbons became very prominent in the images and a system of post-eruptive loops was observed in 171-Å channels of both STEREO A and STEREO B spacecrafts. The beginning of the event in STEREO B observations also looks like a typical filament eruption. Between 0026 and 0036 UT, the attachment of the filament to the northern endpoint tore, while the filament end jumped a large distance in both latitude and longitude and found a new, more or less stable, position in projection on the disc. In order to understand what happened to the connectivity of the filament, what was a real displacement and what was a projection effect, let us examine the position of the filament endpoints in detail.

### 3 FILAMENT ENDPOINT COORDINATES

We used images in JPEG format from the websites of the STEREO mission and ground observatories. All images are rotated in such a way that the projection of the solar rotation axis is vertical and heliographic north is at the top of the images. In the vertical plane containing the line of sight, the rotation axis is inclined by an angle $B_0$ from the sky plane. Usually $B_0$ is indicated as the heliolatitude of the centre of the solar disc in an image of the Sun. We will use the heliocentric Earth equatorial coordinate system (HEELQ), with $Oz$ directed along the solar rotation axis, $Ox$ pointed towards the intersection of the solar equator and solar central meridian as seen from the Earth and $Oy$ completing the right-handed system. After measurements of the coordinates $y'$ (horizontal) and $z'$ (vertical) relative to the disc centre in units of the solar radius $R_\odot$ (since the scale is different in different observational data), we should rotate the $Ox'y'z'$ coordinate system by the angle $B_0$ around the $Oy'$ axis and transform the Cartesian coordinates $x$, $y$, $z$ into spherical heliocentric coordinates $\varphi$ and $\lambda$, assuming that all points of interest are located on the spherical surface $r = R_\odot$:

\begin{align}
  x &= x' \cos B_0 - z' \sin B_0, \\
  y &= y', \\
  z &= x' \sin B_0 + z' \cos B_0, \\
  \sin \varphi &= \frac{z}{R_\odot} = \frac{z'}{R_\odot} \cos B_0 + \sin B_0 \sqrt{1 - \frac{y'^2 + z'^2}{R_\odot^2}}, \\
  \sin \lambda &= \frac{y'}{R_\odot \cos \varphi}.
\end{align}

The results of the measurements are shown in Figs 7 and 8. The grey (red) curves and symbols correspond to the southern endpoint, the black (blue) curves and symbols to the northern endpoint. Triangles (squares) show data from STEREO A (STEREO B) images.

![Figure 6. Difference images of the CME associated with the filament eruption in the field of view of three coronagraphs. (Courtesy of the STEREO/SECCHI Consortium and the SOHO/LASCO Consortium, ESA and NASA.)](https://academic.oup.com/mnras/article-abstract/442/4/2892/1338272)

![Figure 7. Filament endpoint latitude derived from observations from different points of view. The grey (red) lines and symbols correspond to the southern endpoint, the black (blue) lines and symbols to the northern endpoint. The upper-right short grey (magenta) curve shows the latitude of the crossing point of the prominence leg with the STEREO-B limb.](https://academic.oup.com/mnras/article-abstract/442/4/2892/1338272)

![Figure 8. Filament endpoint longitude derived from observations from different points of view. The grey (red) lines and symbols correspond to the southern endpoint, the black (blue) lines and symbols to the northern endpoint.](https://academic.oup.com/mnras/article-abstract/442/4/2892/1338272)
and circles represent data from Hα observations. In general, data from all points of view are in good agreement with each other. Uncertainties and discrepancies appear to be due to difficulties in identification of the same features in different projections, because of the complicated internal structure of the filament. In particular, bifurcation of the southern filament leg leads to the appearance of an additional (higher latitude) branch in the southern endpoint position data of STEREO A (Fig. 7). In the late phase of the eruption, the original southern endpoint cannot be recognized in STEREO-B images. Only material projected on the sky plane above the limb as a prominence indicates the position of the original southern section of the filament. The lowest part of the prominence, indicated by the light grey (magenta) arrow in Fig. 9, is the nearest visible section of the filament to the southern endpoint. The upper-right short grey (magenta) curve in Fig. 7 shows the latitude of the crossing point of the prominence leg with the STEREO-B limb. Due to the curved shape of the erupting filament, the latitude of the crossing point is greater than the latitude of the southern endpoint derived from STEREO A observations (short grey (red) curve with triangle symbols in Fig. 7), but the difference is not very significant. There is a wide jump of more than 30° in the northern endpoint latitude during the changing of its ‘connectivity’.

The longitude of the northern endpoint also changes at about 30° (Fig. 8). The exact position of this endpoint is less definite in longitude than in latitude, because the northern section of the filament has nearly longitudinal orientation (Fig. 1); while this section is rather faint in Hα images and its visibility varies in time (compare Figs 1 and 2). This is the main reason for a steeper decrease of the northern endpoint longitude derived from the Hα data. We fix the visible northern end of the filament in Hα images; however, this is not the endpoint of the flux rope anchored in the photosphere but the middle part of the moving flux rope, with the northern endpoint still anchored at the same place (compare Fig. 2 or, better still, movie 2 with the difference images at 2356–0006 UT, 0026–0016 UT in Figs 3 and 4 and movie 3).

Formulae (4)–(5) and the results shown in Figs 7 and 8 assume that selected points are located on the solar surface. This is correct for the southern endpoint, which is observed to be connected with the chromosphere on the limb till the last phase of the event. The situation with the northern endpoint is more intricate. We have no information about the height of the filament loop end above the chromosphere observed by STEREO B. Since the final position of the moving loop end is not far from the disc centre in the STEREO B images, the real coordinates more or less correspond to the values shown in Figs 7 and 8. We can only estimate an upper bound on the height of the filament end point seen by STEREO B. The difference STEREO A image in Fig. 9 shows that at 0106 UT the former northern (now eastern) endpoint must have a height lower than the line of sight tangent to the limb for STEREO A, because the prominence material extends down to the limb in the STEREO A view (see also movie 3). At this time, the eastern (former northern) endpoint in STEREO B images finds its final position.

The height of the line of sight above a point on the solar surface with coordinates ϕ and λ (or the length of the radial segment from a given point to the intersection with a tangent to the limb) is

\[ h = R_\odot \left( \frac{1}{\cos y} - 1 \right), \]

where \( y \) is the angle between the radius passing through the given point and the sky plane. This angle is given by

\[ \cos y = \sqrt{\sin^2 \varphi + \cos^2 \varphi \sin^2 \lambda}. \]

For STEREO A images, we should use a coordinate system related to them. For this purpose, the HEEQ system should be rotated by the separation angle between the Earth and STEREO A of 70° around the \( O\zeta \) axis and by the angle of inclination of the solar rotational axis from the sky plane \( B_0 = 4.12 \) around the \( O\gamma \) axis. According to equations (1)–(5),

\[ \sin \varphi_A = \sin \varphi \cos B_0 + \cos \varphi \cos(\lambda + \Delta \lambda) \sin B_0, \]

\[ \sin \lambda_A = \frac{\cos \varphi}{\cos \varphi_A} \sin(\lambda + \Delta \lambda). \]

The approximate coordinates of the eastern endpoint \( \varphi = 8°, \lambda = -52° \) in the HEEQ system transform to \( \varphi_A = 10°, \lambda_A = -121° \). Then \( \gamma_A = 31° \) and \( h = 116 \text{ Mm} \) (megametres). This height is much less than the height of the prominence top, about 500 Mm at this time (Fig. 5). Therefore, the shape of the prominence axis in the later stage of the eruption is a loop with low endpoints. The eastern (former northern) filament extremity is definitely located below \( \sim 100 \text{ Mm} \) and possibly finds a connection with the chromosphere at a new point after coronal reconnection.

### 4 MAGNETIC FIELD AND FILAMENT STABILITY

It is widely accepted now that filaments represent cold dense plasma contained within magnetic flux ropes embedded into the coronal magnetic field. A flux rope can exist in equilibrium in an ambient magnetic field for a rather long time before an eruption. Van Tend & Kuperus (1978) first showed that there is a critical height for stable flux-rope equilibria, above which the background coronal magnetic field decreases faster than the inverse height. The transition from stability to instability was later named catastrophic loss of equilibrium and was assumed to be the cause of sudden eruptive events (Priest & Forbes 1990; Forbes & Isenberg 1991; Lin et al. 1998; Schmieder, Démoine & Aulanier 2013). Van Tend & Kuperus (1978) modelled a flux rope with the magnetic field created by a straight line current. If a flux rope is curved, an additional force called the ‘Lorentz self-force’ or ‘hoop force’ is present (Bateman 1978). It is directed away from the curvature centre. In the presence of an ambient magnetic field, the curved flux rope can be in either stable or unstable equilibrium depending on the properties of the external field. Kliem & Török (2006) called the related instability ‘torus instability’ and showed, following Bateman (1978), that it occurs when the background magnetic field decreases along the major radius \( R \) of the expanding flux rope faster than \( R^{-1.5} \). Démoine & Aulanier (2010) carefully compared the two types of models and came to the conclusion that the same physics is involved in the instabilities of circular and straight current channels. The stability of the flux-rope equilibrium in both models depends on the rate of...
Filament eruption with apparent reshuffle

**Figure 10.** Fragment of the SOHO/MDI magnetogram on 2010 April 30 at 2227 UT and (b)–(i) distributions of the decay index and PILs (thick grey (red) lines) at different heights indicated at upper right corners. The thickest grey (green) line in (b) shows the section of the PIL line initially occupied by the filament. The small light grey (green) circles in (b) and (f) show the final position of the new filament end region before the filament fades. Shaded areas show the regions where $n > 1$. (Courtesy of the SOHO/MDI consortium.)

The background field decrease, quantified by the so-called decay index,

$$n = -\frac{\partial \ln B_t}{\partial \ln h},$$

where $B_t$ is the horizontal magnetic field component perpendicular to the flux-rope axis and $h$ is the height above the photosphere. Filippov & Den (2000, 2001) pioneered work in applying this index to the analysis of filament stability. Démoulin & Aulanier (2010) found that, for the typical range of current-channel thickness expected in the corona and used in many MHD simulations (Török & Kliem 2007; Schrijver et al. 2008; Fan 2010; Lugaz et al. 2011) and for a current channel expanding during an upward perturbation, the critical decay index $n_c$ has similar values for both circular and straight current channels in the range 1.1–1.3.

To analyse the equilibrium conditions of the flux rope associated with the filament, we calculated the shape of PILs and the distribution of the decay index of the potential magnetic field at different heights in a region surrounding the filament (see Filippov 2013 for details). Fig. 10(a) represents a fragment of the magnetogram taken by the Michelson Doppler Imager (MDI: Scherrer et al. 1995) on board SOHO on 2010 April 30 at 2227 UT, which was used as a boundary condition for the potential magnetic field calculations. In Fig. 10, thin lines show isocontours of $n = 0.5$, 1, 1.5, while thick grey (red) lines indicate the positions of PILs at the respective heights. Areas where $n > 1$ are shaded. A PIL is a place where a coronal electric current (a flux rope) can find horizontal equilibrium. The thickest grey (green) line in Fig. 10(b) shows the section of the PIL occupied by the filament as seen in the Hα line. The filament lies over the PIL separating the area of predominantly negative network polarity in the upper right corner of the frame from active region 11064 near the centre of the frame. The left part of the magnetogram contains a mixture of faint small-scale opposite polarities, producing numerous closed PIL contours (Fig. 10b–e).

The height of the prominence in a stable state before the eruption is 17 Mm (Fig. 5). At this height, the filament is within the area of stability $n < 1$ (Fig. 9b–c). The location of the filament is stable in the vertical direction even at much greater heights, but at a height of 20 Mm the PIL occupied by the filament touches the PIL.
surrounding the negative polarity of AR 11064 and reconnects with it. A newly formed PIL (Fig. 10d) protrudes far to the east from the initial filament position. Since the flux rope can find horizontal equilibrium only on the PIL, it will be pushed to the east by the Lorentz force if it reaches a height greater than 20 Mm. Moreover, some sections of higher-altitude PILs are located within unstable (grey) areas. Therefore the flux rope, if it arrives at these sections, will be forced to rise.

PILs associated with small-scale magnetic sources disappear above a height of 60 Mm. Only a small annular PIL in the center of the domain remains at a height of 140 Mm and it also disappears at a height of 160 Mm.

5 DISCUSSION

It is widely believed that the most probable initial magnetic conﬁguration that accumulates dense prominence plasma and later hurls a CME into interplanetary space is a flux rope consisting of helical field lines (Chen 1989; Lin et al. 1998; Titov & Démoulin 1999; Amari et al. 2000; Low 2001; Kliem & Török 2006; Zuccarello, Meliani & Poedts 2012). An alternative conﬁguration of a CME source region is a sheared arcade (Moore & Roumeliotis 1992; Choe & Lee 1996; Antiochos, DeVore & Klimchuk 1999), which is converted into a flux-rope structure due to reconnection in the course of the eruption. Usually, initiation of filament eruptions is associated with instability of flux-rope equilibrium in the vertical direction. Our prominence was rather low before the eruption and it starts to ascend rapidly from a height of about 20 Mm. The maps of the decay index distribution (Fig. 10) show that the vertical equilibrium of a flux rope at the location of the filament can be stable even at heights several times greater. However, the topology of the magnetic field varies rapidly with height. At a height of about 20 Mm, the PIL where the flux rope sits touches the PIL surrounding the negative polarity of AR 11064 and reconnects with it. The horizontal equilibrium of the flux rope can easily be disturbed due to the proximity of another PIL. In principle, it could ﬁnd a new stable equilibrium over the changed PIL, but some sections of this PIL are unstable for vertical displacements, which leads to a filament eruption. This is an unusual initiation of an eruption, with a combination of initial horizontal and vertical flux-rope displacements never mentioned before, to the author’s knowledge.

The initial motion is slow, so it is not so easy to catch the beginning of the displacements in the horizontal and vertical directions. Taking into account changes in seeing conditions, some lateral displacement of the filament can be recognized between 2240 and 2258 UT in MLSO Hα images. However, internal motions within the filament can mask or emulate the real displacement of the filament as a whole. The same changes can be found in PROBA2/SWAP 174-Å images. Small changes in the height of the prominence are noticeable between 2236 and 2256 UT in STEREO A 304-Å images. It is also difﬁcult to distinguish the slow prominence rise from effects related to the solar rotation and prominence shape changes. Thus, it can be only stated that both motions start practically simultaneously. We can compare ﬁnite displacements of the filament in the horizontal and vertical directions at the beginning of the event over a period of time from 2306–2346 UT. Since the contrast of the filament is low in the Hα images (Fig. 2), in Fig. 11 we draw ﬁlament spines with the help of the time sequence (movie 2). The horizontal distance is about 150 Mm, while the change in height as evident from Figs 3 and 5 is about 150 Mm also. Thus, the deviation of the trajectory of the eruptive ﬁlament from the vertical is near 45°.

Figure 11. Filament spine at 2306 UT (dark grey (red) line) and 2346 UT (light grey (green) line), superposed on the Hα image at 2306 UT. The black (blue) arrow shows a horizontal displacement of about 150 Mm. The size of the frame is .5 R⊙ × .5 R⊙. (Courtesy of the Mauna Loa Solar Observatory, operated by the High Altitude Observatory, as part of the National Center for Atmospheric Research (NCAR). NCAR is supported by the National Science Foundation.)

The behavior of the ﬁlament endpoints is also unusual. The northern end of the ﬁlament during the eruption suddenly changes its anchoring to a position about 40° from the starting position. The process of ﬁlament endpoint change does not look very similar to either whipping-like or zipping-like asymmetric ﬁlament eruptions. The latter would imply the existence of a long ﬂux rope partly loaded with ﬁlament mass. During the eruption, internal plasma motions along the ﬂux-rope axis would reveal the previously invisible far endpoint of the ﬂux rope. In our case, it is difﬁcult to admit the existence of such a long ﬂux rope reaching the disc centre in the STEREO B images. The PIL with which the ﬁlament is associated runs to the north-east at all heights below 40 Mm. There is a high PIL stretched from the ﬁlament position to the south-east (Fig. 10f), but we have no manifestations of the presence of the ﬂux rope there. In principle, we can imagine the existence of an invisible (no mass load) ﬂux rope with one endpoint anchored at the bottom-left corner of the studied region, which extends over a height more than 40 Mm to the upper-right corner, where it is lowered to a height of 20 Mm and turns to the bottom of the region, providing conditions for ﬁlament formation. Only in this case could the observed prominence behaviour be interpreted as an asymmetric eruption.

Another possibility is reconnection of the ﬂux-rope ﬁeld lines somewhere along the northern half of the rising ﬁlament loop with ambient coronal magnetic ﬁeld lines rooted in a quiet region to the south-east from the ﬁlament. In contrast to examples of coronal reconnection, where the ﬁlament body disintegrates, the studied erupting ﬁlament loop keeps its shape, a rather thin loop. Reconnection of an erupting ﬂux rope with ambient coronal ﬂux has been seen in several numerical simulations of eruptions (Gibson & Fan 2006, 2008; Lugaz et al. 2011).

We found from comparison of STEREO A and STEREO B images that the observed ﬁnal height of the original northern leg (marked with dark grey (blue) arrows in Fig. 9) is at least lower than 100 Mm,
while the height of the prominence top at this time is about 500 Mm. Thus, the shape of the erupting filament axis is a loop with a high summit and low ends.

6 SUMMARY AND CONCLUSIONS

We studied the filament eruption on 2010 April 30–May 1, which shows the reconnection of one filament leg with a region far away from its initial position. Observations from three viewpoints were used, namely on-disc Hα observations by the Mauna Loa Solar Observatory and Culgoora Solar Observatory together with EUV observations by PROBA2 and on-limb observations by STEREO A and STEREO B. At the beginning of the event, the eruptive prominence looked like a typical one, i.e. an expanding loop with anchored endpoints. Then the top of the loop folded over, showing writhing of the filament axis, and deflected to the south during ascension. A little later, the endpoints reshuffled their positions in the limb view. The northern leg of the erupting prominence loop ‘jumps’ laterally to a latitude lower than the latitude of the former southern endpoint. This behaviour could be interpreted as an asymmetric zipping-like eruption, although it does not look very likely. Although there is a PIL stretched at a height above 40 Mm from the former filament position to the new eastern endpoint (Fig. 10f), no manifestations of the presence of the flux rope were observed there and flare-ribbon-like brightening along the path of this PIL was absent. Hence, observations do not support the interpretation of the event as a whipping-like or zipping-like asymmetric filament eruption. More probable seems the reconnection of the flux-rope field lines in the northern leg with ambient coronal magnetic field lines rooted in a quiet region far from the filament.

The eruption of the prominence was followed by a CME. Due to the geometrical factor, it was brightest in the field of view of the STEREO A COR2 coronagraph. At the late stage, the legs of the CME connecting its core with the Sun show a noticeably twisted structure.

We calculated the parameters of the coronal potential magnetic field and found that the eruption is likely to begin with an instability not in the vertical direction, as is typical for eruptive filaments, but after the violation of horizontal equilibrium. Observations show that the trajectory of the eruptive filament deviates from the vertical by an angle of about 45°. This is an unusual initiation of an eruption, with a combination of horizontal and vertical initial flux-rope displacements, showing a new and unexpected possibility for the start of eruptive events.

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