Proc. VI Serbian-Bulgarian Astronomical Conference, Belgrade 7-11 May 2008,
Eds. M. S. Dimitrijević, M. Tsvetkov, L. Č. Popović, V. Golev
Publ. Astr. Soc. "Rudjer Bošković", No. 9, 2009, 189-198

H-ALPHA BRIGHTNESS EVOLUTION DURING THE ERUPTION OF PROMINENCES OF 7 MAY 1979 AND 8 JUNE 1980

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Abstract. In this study the evolution of two eruptive prominences with a reconnection of magnetic field is investigated. The main goal is to examine the Hαα brightening in different parts of the prominence body as eruption precursor signatures, as well as their relation to the prominence destabilization and eruption.

1. INTRODUCTION

Prominences are relatively cool, dense objects embedded in the hotter corona and they are most commonly observed at the solar limb in emission of Hα hydrogen line. The prominences have magnetically organized geometry and they present a variety of such cool objects ranging from long-lived quiescent prominences to short-lived active region prominences. Their evolution depends on the properties and on the evolution of the magnetic fields supporting and insulating the cool prominence plasma in the corona.

The quiescent prominences, as well as active region prominences sometimes undergo eruptions. It is believed that eruptive prominences (EP) are physically connected to magnetic field line reconnection (e.g. Rompolt, 1990; Švestka and Cliver, 1992; Tandberg-Hanssen, 1995; Tsuneta, 1996).

There are observations made at X-ray, EUV, UV, and Hα that infer the brightening at these wavelengths as signatures of magnetic reconnection processes (Yurchyshyn, 2002; Sterling and Moore, 2003; Moon et al., 2004; Attrill et al., 2005; Chifor et al., 2006). A recent study (Chifor et al., 2006) of the yearly evolution of a prominence eruption, showed precursor brightening in the X-ray, EUV and microwave emission with respect to possible mechanisms that might be responsible for the prominence destabilization and acceleration. These observations suggest that reconnection events localized beneath the erupting footpoint may eventually destabilize the entire prominence, causing the eruption.

In this work we used a Hα diagnostic to detect the signatures of the magnetic reconnection that took place during the eruption of two prominences on 8 June 1980 and on 7 May 1979. Measurements and analysis of Hα brightening in parts of the prominence body was performed. A comparison between Hα light-curves and pre-eruption and eruption evolution of the prominences was made. The main purpose is to study spatial and temporal dependence between Hα brightening and prominence activation and eruption, as well as the process of magnetic reconnection leading to a re-forming of the magnetic field configuration in the vicinity of the prominences.

2. OBSERVATIONS

The EP of 8 June 1980 (Carrington Rotation 1696) was observed in Hα between 07:06:30 UT and 09:02:55 UT on the eastern limb at a mean latitude S18. The EP evolution is shown in Fig.1.

The EP of 8 June 1980 was identified with the western end of filament in decaying active region on Meudon synoptic map for Carrington Rotation 1696. The western filament end crosses the solar limb under an angle of about of 45°. The eruption was registered during second rotation of the filament lifetime.

The event with confined eruption processes on 7 May 1979 was registered between 13:50 UT and 14:27 UT in the Hα hydrogen line. A series of 20 Hα filtergrams was obtained. The exposure time used for the filtergram obtaining was 1/8 of second. Fig.2 shows the evolution of the prominence eruption. The filtergrams have an average cadence of about 1.5 minutes.

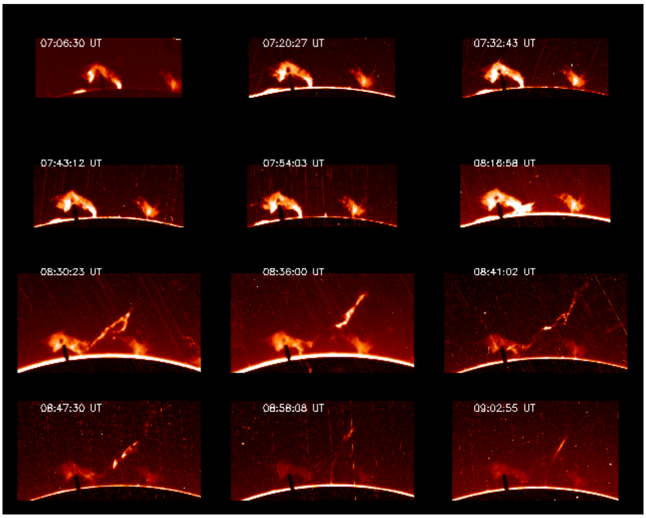

Figure 1: The evolution of EP of 8 June 1980 between 07:06 UT and 09:03 UT.

The EP of 7 May 1979 was associated with a long-lived filament with coordinates 36N 302 on Meudon synoptic map for Carrington rotation 1681. The EP appeared during second rotation of the filament lifetime that lasting 6 solar rotations, which suggests that the associated EP was manifestation of a temporary instability of a part of the filament structure. Such temporary instability the filament underwent in fifth rotation of its existing when a partial DB was observed on the solar disk. The filament crossed the limb plane under very small angle so that its long axis almost coincides with the line-of-sight and the EP represents a segment of the middle part of the filament observed in edge-on position.

Both registrations were made with Small Coronagraph (130/3450 mm) at the Astronomical Institute of the University of Wroclaw, Poland. The Hα filtegrams were taken through a 3Å Hα filter. All filtegrams were obtained with exposure time of 1/15 of second.

The plates were digitized with the automatic Joyce-Loeble MDM6 microdensitometer at the NAO Rozen, Bulgaria. The two-dimensional scans have resolution of 20 μm per pixel and step of 20 μm in both directions. The spatial resolution is a little larger than 1 arcsec.

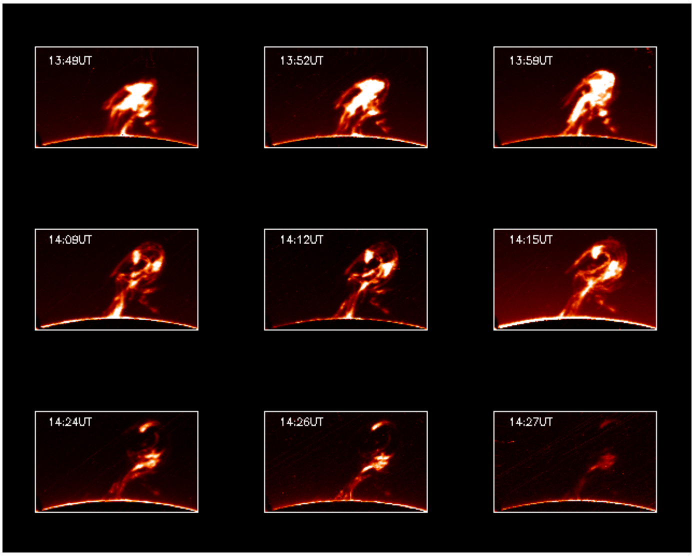

Figure 2: The evolution of EP of 7 May 1979 between 13:50 UT and 14:27 UT.

2. MORPHOLOGY AND KINEMATICS

The EP of 8 June 1980 consisted of two arches (Rompolt, 1994). The observations of the prominence covered four phases of its evolution: quiet state (quiescent prominence), activation, eruption, and post-eruptive phase.

A sketch of the EP body is presented in this Fig. 3. The points of measurements that were used to trace kinematics and morphology of prominence eruption are marked on the sketch.

At 08:03:00 UT a strong enhancement of brightness in Hα was registered in the central leg (point 3) of the prominence body. About ten minutes later a loop structure has been ejected from this leg. Most likely the ejection was a result of magnetic reconnection process in the prominence leg. According to Rompolt (1994) the reconnection took place between two adjacent bunches of the fine filament structure with different polarities.

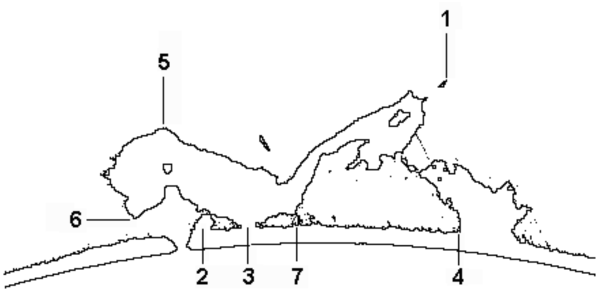

Figure 3: A simplified sketch of EP of 8 June 1980 with points of measurements.

The height variation of the upper point of the right-hand prominence arch (point 1) with time is presented in Fig.4. The method used to obtain kinematic parameters of the prominence during the eruption was described in Koleva et al., (2005).

The activation of the prominence started at 07:55 UT, 48 minutes after the observation onset and the apparent prominence eruption started at 08:17 UT, about 70 minutes after the observation onset. After 08:45 UT when the EP reached a maximum height of about 220 000 km, the post-eruption started. During the post-eruptive phase the prominence plasma flowed back to the chromosphere.

At 08:03:00 UT the footpoint of the central leg of the prominence (point 3 in Fig. 3) strongly brightened up and the first registration of ejection from the northern end of this leg was made. Fifteen minutes later the ejection was transformed in loop-like structure that propagated upward and rightward at an angle of about 45° toward the limb. During that time interval, Hα brightening spread all over the ejection and almost 1/3 of prominence body move away from this leg. After 08:19 UT the central leg gradually faded and at 08:28:05 UT it completely disappeared in Hα line. According to Rompolt (1994) it was transformed by magnetic reconnection into a "hanging" leg. A few minutes later the leg between two arches has been completely rebuilt by the material flowing down from the top part of both arches.

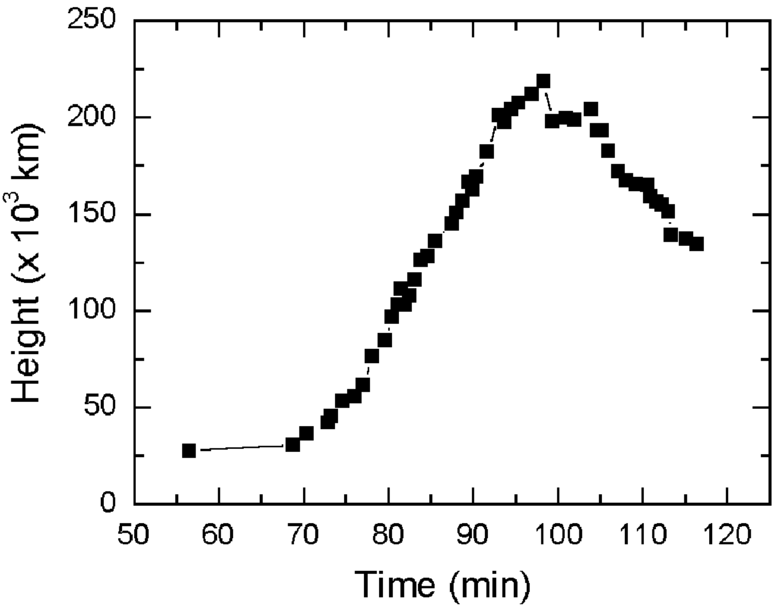

Figure 4: The height variations of the upper point of the right-hand prominence arch (point 1) with time. The zero at the time scale corresponds to 07:06:30 UT.

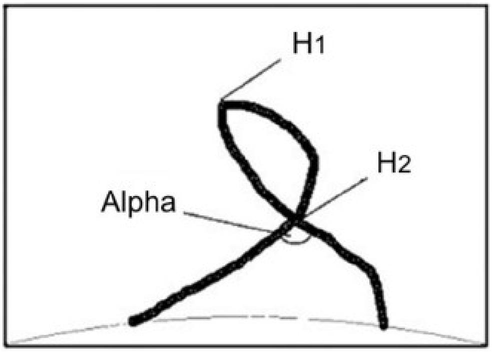

Figure 5: A simplified sketch of EP of 7 May 1979 with points of measurements.

The projection on the sky plane of the EP of 7 May 1979 represents a helically writhed loop with intricate internal structure. In Fig.5 is shown a sketch of the simplified prominence loop. The points of measurements that were used to trace kinematics and morphology of prominence eruption are marked on the sketch. H_1 is the height of the summit of prominence loop projected on the sky plane. H_2 is the sky plane projection of the height of the crossing point of the loop legs.

The observed prominence eruption started at a height of about 120 000 km and stopped at a height of about 180 000 km. The average rising velocity estimated by least-square fit is about 28 km/s. In 13:59 UT the height H_2 reach a maximum height of 100 000 km. After that time, the projection of the crossing point began move downwards up to the end of the eruption process.

The EP structure remained complicated up to 14:02 UT and from that time up to the end of the eruption a simplification of the structure was registered. After 14:18 UT the EP loop faded and it almost disappeared in Hα line to the end of the observations.

The height-time profile of H_2 shows two different phases. First one between 13:52 UT and 14:11 UT when the H_2 remained relatively high at heights of about 95 000 km and second one between 14:12 UT and 14:26 UT when the H_2 remained at heights of about 70 000 km.

The EP rose in relatively narrow interval of heights during 40-min time interval. The height-time profile of the summit of the EP loop (H_1) shows only linear increasing of velocity of several km/s, that is typical for the late phase of prominence's eruptions. This fact, as well as the relatively big height at the observation onset suggests that most probably the observations start later when the eruption was in progress, omitting its accelerating phase.

In the time of eruption the EP undergo morphological changes leading to the helical writhing of the prominence loop. The results are presented in Fig. 6.

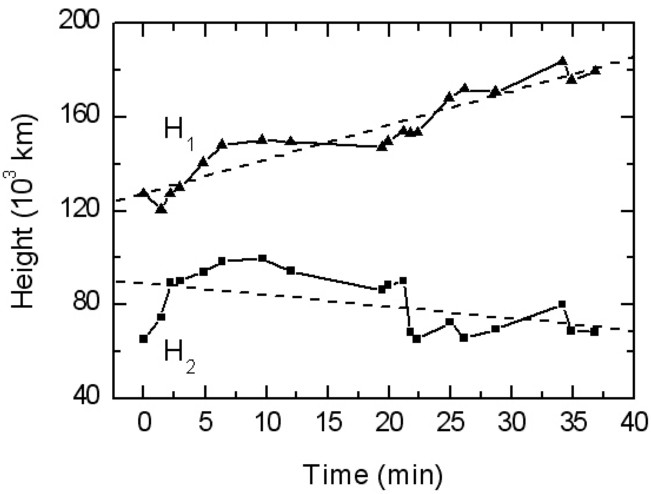

Figure 6: The height-time variations of heights H_1 and H_2. The zero at the time scale corresponds to 13:49 UT.

3. DATA ANALYSIS

The correlation between the processes of prominence activation and eruption and the brightness of Hα emission from the selected parts of the prominence body is discussed in the context of eruption trigger mechanisms, such as magnetic reconnection and the pre-eruptive brightening in Hα.

We analyzed the relative brightness in arbitrary units in 3 equal square areas with dimensions 60 x 60 px each. For EP of 8 June, 1980 this areas cover the central leg between the main prominence arches - the place where according to Rompolt (1994) the magnetic reconnection occurs and the part of the prominence "head" (between points 5 and 6, Fig. 3). For The EP of 7 May 1979 the respective area covers the projection of cross-point between the prominence legs (Fig. 5).

We used image statistics procedure to calculate the statistical properties of selected areas, such as mean and maximum pixel values, standard deviation, and variance of the pixel values in arbitrary units (Koleva, 2007).

4. RESULTS AND DISCUTION

For comparison of the processes of Hα brightening in the central leg of EP of 8 June, 1980 and the evolution of erupted prominence structure, the light curve of Hα brightness and the height-time profile of the eruption are shown in Fig. 7.

We trace the Hα brightening in selected areas during the four-phased evolution of the prominence: quiet state, activation, eruption, and post-eruption phase.

During the quiet state – we registered the first enhancement of brightening in the “head” of prominence body and in the leg between two arches at 07:28 UT. One can observe a gradual increase of prominence height until 07:54UT, the prominence activation starts. At 07:55 a strong brightening in the central leg was observed.

The first sign for the eruption occurred at the same time as the ejection from the northern end of this leg. The height of the ejection was about 27 500 km. This process was accompanied by detachment of the prominence leg from the chromosphere that suggests a development of magnetic reconnection process.

The Hα brightness in selected areas increased during time interval between 07:55 and 08:16 UT when the ejected structure accelerated. This process is most pronounced in the central leg. Moreover, the Hα brightening in this place was accompanied by its spreading over the bigger part of prominence body.

The erupted prominence structure rose with a constant velocity of about of 120 km/s at the same time when Hα dimming occurred in the area of central prominence leg.

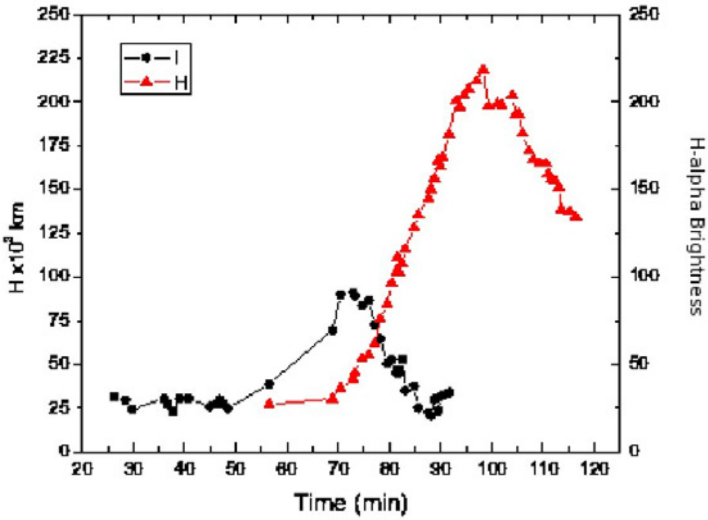

Figure 7: Height-time diagram of the EP of June 8, 1980 (triangles) and time profile of the mean pixel values of Hα brightness in the central prominence leg. The time scale is in minutes after 07:06 UT.

At 08:28 when the erupted structure almost reaches a maximum height, the leg had completely disappeared in Hα line.

The results of the analysis of Hα brightness at the projected crossing-point of the kinked legs of the EP on 7 May1979 are presented in Fig. 8. The EP on 7 May1979 is very similar by morphology and evolution to those one investigated of Ji et al. (2003) and recently revisited by Alexander et al. (2006).

Alexander et al. (2006), simulating the confined eruption of a filament on 27 May 2002 investigate the temporal and spatial relationship between the filament dynamics and the production of hard X-ray emission in the corona above the filament. They confirm the presence of two X-ray sources in the corona: First one above the filament prior to the main activation phase that was found of Ji et al. (2003) and second one that occurs under the apex of the filament during the eruption phase. The authors argue that this second source of a hard X-ray emission implies ongoing magnetic reconnection in a current sheet formed via a kink instability resulting from the interaction of the two adjacent legs underneath the writhing filament. They suggest that the enhanced emission indicates the possible interaction of the adjacent filament legs at their projected crossing-point, brought together by the kinking action of the eruption.

The confirmation of a second coronal source of a hard X-ray emission that occurs under the apex of the filament on 27 May 2002 during the erupting phase when the filament was clearly strongly kinked provides us the motivation for a study of the Hα brightness in the region of the projected crossing point during the evolution of the EP of 7 May 1979.

The time profiles of the Hα brightness, the height of the projected crossing point (H_2), and the normalized difference of H_1 and H_2 are given in Figure 8. Six minutes after the start of observations the Hα brightness reached maximum suggesting a process of Hα brightening, which most probably began before the observation onset. At the moment of its maximum (13:55 UT), H2 reached maximum height and the difference of H1 and H2 has a minimum value, respectively. After 13:55 UT H2 began downward motion and the difference H1-H2 increased to a maximum value at the end of the observations inferring increasing of the rate of the EP writhing (or kinking). These two processes of morphological changes were accompanied of decreasing of the relative Hα intensity, i.e. Hα dimming at the region of the projected crossing point.

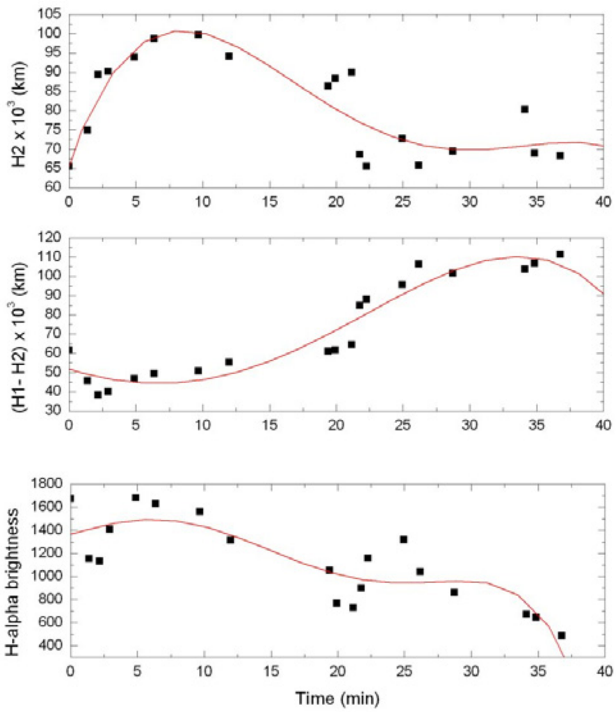

Figure 8: Height-time diagram of the EP of May 7, 1979 for the sky plane projection of the height of the crossing point (top panel), for the distance (H1-H2) (middle), and time profile of the mean pixel values in the crossing point (bottom). The time scale is in minutes after 13:50 UT.

The Hα brightening may be used as an indirect signature of magnetic reconnection process (e.g. Attrill et al. 2005, Chifor et al. 2006). The brightening seen in Hα is due to the heating of the plasma. Such intense heating is a by-product of magnetic reconnection process. Even though the filament failed to erupt, significant energy release occurred in association with the complex filament dynamics. This release of energy may be a consequence of enhanced emission in X-ray, EUV and H-alpha. In this context our results infer that Hα brightening in different parts of the prominence body could be considered as eruption precursor signatures.

Acknowledgements

The National Scientific Foundation of Bulgaria under Grants F1510/2005 and D0-406/2005 supported this study.

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