Two Different Cases of Filament Eruptions Driven by Kink Instability

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Abstract. In this work we present a comparative analysis of two filament/prominence eruptions (EP) driven by helical kink instability. First EP on 2010 March 30 presented a kink induced confined eruption of a single magnetic flux rope (FR) followed of partial FR reformation, which was associated with coronal mass ejection (CME). The second EP on 2014 May 4 represented kink induced eruptions of two coupled FRs of the same filament that were interacting and splitting during the eruption. The first FR underwent a confined eruption followed of FR reformation while the second FR underwent a successive partial eruption, which was associated with CME. The physical processes in the EPs environments, such as magnetic emergence, cancellation or shearing, reconnection signatures, overlaying magnetic arcades and the activity events accompanying the eruptions were analyzed. This work laid special emphasis on specific conditions, which are crucial for the type of the filament eruptions and their kinematics and evolution.
Key words: Sun; Solar Prominence Eruptions; Coronal Mass Ejections; Magnetic Fields; Multiwavelengt Observations

Introduction

The kink instability is one of the basic physical mechanisms that drive filament eruptions (e.g., Bi et al., 2011; Liu et al., 2007). Recent observations of kinking filament eruptions, including full, partial, and failed eruptions reveal that the type of eruption depends on the interactions of the filament with its magnetic environment (Gilbert et al., 2007). The EP on 2010 March 30 evolved as a height-expanding left-handed twisted loop with both legs anchored in a chromospheric plage region. The EP reached a maximum height of 526 Mm before contracting to its primary location, where it was partially reformed in the same place two days later. Nevertheless, this eruption triggered a CME observed in LASCO C2 (Koleva et al., 2012). The EP on 2014 May 4 consisted of two coupled filament FRs (FR1 and FR2) located along the same polarity inversion line, i.e. in the same filament channel in a quiet solar region. Only the FR1 eruption was associated with CME (Dechev et al., 2018). First event was observed as an EP above the limb from AIA/SDO, while in the EUVI/STEREO B field-of-view (FOV) it was viewed as a filament eruption (FE). Second event was well observed as an EP above the limb from AIA/SDO and EUVI/STEREO-B, while in the EUVI/STEREO-A FOV, it was observed as a FE (Fig. 1). The associated CMEs were well observed in LASCO C2 FOV.

1.Analysis and Results

The EP on 2010 March 30 revealed three distinct phases: prominence activation, an eruption with acceleration, and an eruption with a constant velocity (Fig. 2a). Its kinematic parameters given in Table 1 are typical for a single FR failed eruption.

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Kink-induced full and failed eruptions of two coupled flux tubes of the same filament

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HIGHLIGHTS

- The EP source was two coupled filament segments in a quiet solar region.
- Eruption belongs to the class of causally linked eruptions of two coupled segments.
- EUV signatures suggest magnetic flux and current transfer between filament segments.
- The segments have same helicity over the critical values for kink instability to act.
- Two segments produced successive (partial) and failed kink-induced eruptions.

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ABSTRACT

In this work, we report results from the study of a filament/prominence eruption on 2014 May 4. This eruption belongs to the class of rarely reported causally linked eruptions of two coupled flux tubes (FTs) of a quiet region filament. We made a comparative analysis based on multiwave observations from Solar Dynamics Observatory (SDO) and Solar Terrestrial Relations Observatory (STEREO) A and B combining the high temporal and spatial data taken from three different viewpoints. The main results of the study are as follows: (1) The source of the eruptive prominence consists of two coupled FTs located near the eastern limb: top-located one (FT1) and bottom-located one (FT2). (2) FT1 and FT2 had the same helicity, i.e. left-handed twist and writhe. Their untwisting motion during eruption suggests that kink instability seems to act. (3) The kinematic evolution of the FT1 suggests a slow successful eruption that was associated with a slow CME. (4) The FT2 exhibited failed kinked eruption with a non-radial propagation followed by its reformation. This eruption was accompanied of apparent mass draining in the legs, flare-ribbons and post-flare EUV arcade.

1. Introduction

It has been widely accepted that the filament/prominence eruptions, coronal mass ejections (CMEs), and flares, are three different manifestations of a large single physical process, whose energy source is derived from the free energy contained in sheared or twisted coronal magnetic fields (e.g. Forbes, 2000; Lin et al., 2003; Su et al., 2011). Observationally, the eruptive prominences (EPs) are frequently associated and physically related to CMEs and flares (Tandberg-Hanssen, 1995; Forbes, 2000; Priest and Forbes, 2002; Lin et al., 2003) and some of them are followed by two ribbon flares (Choudhary and Moore, 2003; Chandra et al., 2011).

Observed in white light, CMEs are often seen as a three-part structure of a bright CME leading front (rim), followed by a dark cavity, and a bright core (e.g. Illing and Hundhausen, 1986; Gibson et al., 2006; Chen et al., 1997; Chen, 2011; Vourlidas et al., 2013). The cavity is suggested to be the upper portion of a helical flux rope with an EP at its bottom that is a white-light counterpart of the CME bright core (e.g. Munro et al., 1979; House et al., 1981; Low, 1996; 2001; Chen et al., 2006; 2014). In recent years, the typical rim-cavity-prominence coronal mass ejection (CME) morphology has been hypothesized to be the result of underlying magnetic flux-rope (FR) geometry. This hypothesis has been applied to the description of prominences, CMEs, and to combined FR-Prominence-CME structures (see e.g. Krall and Sterling, 2007; Green and Kliem, 2009, for detailed reviews).

An outstanding question about CMEs and EPs structures is whether they are driven by a pre-existing FR through ideal processes, such as loss of equilibrium or magnetohydrodynamic (MHD) instabilities (e.g. kink or torus), or by non-ideal (resistive) processes, i.e., magnetic reconnections, which either lead to expul-

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Homologous prominence non-radial eruptions: A case study

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HIGHLIGHTS

- A sequence of four homologous prominence eruptions of confined type is analysed.
- Homologous behaviour during the pre-eruptive phase is found in 17 GHz radio data.
- A new (fourth) criterion for homology is defined.
- Maximum height increase of each consecutive eruption-an important homology feature.

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ABSTRACT

The present study provides important details on homologous eruptions of a solar prominence that occurred in active region NOAA 10904 on 2006 August 22. We report on the pre-eruptive phase of the homologous feature as well as the kinematics and the morphology of a forth from a series of prominence eruptions that is critical in defining the nature of the previous consecutive eruptions. The evolution of the overlying coronal field during homologous eruptions is discussed and a new observational criterion for homologous eruptions is provided. We find a distinctive sequence of three activation periods each of them containing pre-eruptive precursors such as a brightening and enlarging of the prominence body followed by small surge-like ejections from its southern end observed in the radio 17 GHz. We analyse a fourth eruption that clearly indicates a full reformation of the prominence after the third eruption. The fourth eruption although occurring 11 h later has an identical morphology, the same angle of propagation with respect to the radial direction, as well as similar kinematic evolution as the previous three eruptions. We find an important feature of the homologous eruptive prominence sequence that is the maximum height increase of each consecutive eruption. The present analysis establishes that all four eruptions observed in Hα are of confined type with the third eruption undergoing a thermal disappearance during its eruptive phase. We suggest that the observation of the same direction of the magnetic flux rope (MFR) ejections can be consider as an additional observational criterion for MFR homology. This observational indication for homologous eruptions is important, especially in the case of events of typical or poorly distinguishable morphology of eruptive solar phenomena.

1. Introduction

The relationship between eruptive prominences (EPs) and other eruptive solar phenomena such as CMEs and flares (e.g. St. Cyr and Webb, 1991; Subramanian and Dere, 2001; Schrijver et al., 2008; Chandra et al., 2010) suggests that the three eruptive events often occur in the same large-scale coronal magnetic field configuration (e.g. Forbes, 2000) in which the EP occupies a limited volume at its base. It is commonly accepted that solar prominence (filament) eruptions frequently accompany coronal mass ejections (CMEs). Thus, studying the pre-eruption phase, origin and evolution of EPs gives additional information relevant to CMEs' launch and propagation.

The observations and studies of early stages of prominence eruptions, i.e. prominence pre-eruptive activation, are crucial for the understanding of the signatures and pre-cursors of forthcoming solar eruptions. The observations of prominence motions before and near the eruption onset can provide information for the coronal magnetic field evolution during the pre-eruptive stages (e.g. Sterling et al., 2012). Multi-wavelength studies of the precursor signatures for eruptions, such as pre-eruptive brightenings in microwave, extreme ultraviolet (EUV), and X-ray emission changes are necessary to reveal the processes involved in the prominence destabilisation. In particular, microwave observations can show the full temporal and spatial prominence (filament)

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Hα spectroscopy and multiwavelength imaging of a solar flare caused by filament eruption⋆

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ABSTRACT

Context. We study a sequence of eruptive events including filament eruption, a GOES C4.3 flare, and a coronal mass ejection.

Aims. We aim to identify the possible trigger(s) and precursor(s) of the filament destabilisation, investigate flare kernel characteristics, flare ribbons/kernels formation and evolution, study the interrelation of the filament-eruption/flare/coronal-mass-ejection phenomena as part of the integral active-region magnetic field configuration, and determine Hα line profile evolution during the eruptive phenomena.

Methods. Multi-instrument observations are analysed including Hα line profiles, speckle images at Hα – 0.8 Å and Hα + 0.8 Å from IBIS at DST/NSO, EUV images and magnetograms from the SDO, coronagraph images from STEREO, and the X-ray flux observations from *Fermi* and GOES.

Results. We establish that the filament destabilisation and eruption are the main triggers for the flaring activity. A surge-like event with a circular ribbon in one of the filament footpoints is determined as the possible trigger of the filament destabilisation. Plasma draining in this footpoint is identified as the precursor for the filament eruption. A magnetic flux emergence prior to the filament destabilisation followed by a high rate of flux cancellation of 1.34×10^{16} Mx s^{-1} is found during the flare activity. The flare X-ray lightcurves reveal three phases that are found to be associated with three different ribbons occurring consecutively. A kernel from each ribbon is selected and analysed. The kernel lightcurves and Hα line profiles reveal that the emission increase in the line centre is stronger than that in the line wings. A delay of around 5–6 min is found between the increase in the line centre and the occurrence of red asymmetry. Only red asymmetry is observed in the ribbons during the impulsive phases. Blue asymmetry is only associated with the dynamic filament.

Key words. Sun: activity – Sun: flares – Sun: filaments, prominences – line: profiles

1. Introduction

Solar flares are powerful solar phenomena that are believed to be driven by magnetic reconnection resulting in plasma heating and particle acceleration. They can be observed as emission enhancements across the entire electromagnetic spectrum, from radio to γ-ray wavelengths. Flares are considered as phenomena initiated in the corona since radio and hard X-ray emission at flaring sites were discovered (Shibata & Magara 2011, and the references therein). For decades, the chromospheric response to flares has been investigated by using Hα filtergrams. Flaring sites observed in Hα show spectacular phenomena such as filament (prominence) eruptions and flare ribbons (bright regions in the chromosphere along the magnetic neutral line); Hα kernels, which are very bright and compact Hα emission sources embedded in flare ribbons, are also common features appearing during a flare. They are believed to be the locations of high-energetic particle precipitation. More details about solar flares can be found in several reviews (e.g. Hudson 2007; Benz 2008; Shibata & Magara 2011; Fletcher et al. 2011).

Although flares have been observed at chromospheric temperature since the Hα filter was invented in the 1930s, the precise mechanism(s) by which energy release in the corona drives chromospheric emission bursts, called ribbons or kernels, has not been well established. A two-dimensional magnetic reconnection model called CSHKP (Carmichael 1964; Sturrock 1966; Hirayama 1974; Kopp & Pneuman 1976), suggests that the plasma surrounding a null point in the corona is heated such that high coronal pressure, thermal conduction, and non-thermal particles (mostly electrons) can efficiently carry energy from the magnetic reconnection site in the corona to the lower solar atmosphere along the magnetic field lines (Magara et al. 1996). Thermal radiation from soft X-rays, EUV, and UV can also contribute to this process, but this contribution was found to be very small (Allred et al. 2005). Other more recent works have raised questions about the viability of this mechanism in the light of recent observations (Fletcher & Hudson 2008) and suggested Alfvén wave propagation as an alternate energy transport mechanism from the corona to chromosphere during flares (Russell & Fletcher 2013).

Although Hα filtergrams provide a wealth of information on the dynamic morphological evolution of the flare in the chromosphere (Hudson 2007, and references therein), full Hα line profiles have powerful diagnostic potential for understanding the physical mechanism driving solar flares. Based on a static model, Canfield et al. (1984) calculated Hα profiles of flare chromospheres produced by different mechanisms (see the previous

⋆ Appendix A and movie associated to Fig. A.4 are available in electronic form at http://www.aanda.org

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

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Abstract. 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) and associated partial-halo coronal mass ejection (CME). Using SDO and STEREO A and B multi-wavelength observations, we examined in detail the eruption of EP flux ropes (FRs) and their associated activities in a complex magnetic configuration located beneath a multiarcade helmet streamer. We establish the sequence of activities appearance involved in casually linked chain of events on 2014 March 14: short-lived active region, surge eruption, EP BFR rising, EP BFR and MFR merging and interacting, EP common FR fast rise, flare, EP FR bifurcation, partial-halo CME with bi-component bright core, impulsive flare, post-flare loop arcade. A surge-like event in the northern EP footpoints is determined as the possible trigger of the bright FR appearance beneath the cool, massive FR. Plasma draining in this footpoints is identified as the precursor for the EP eruption. We find that the EP FRs merging at the fast-rise onset and their splitting in the phase of strong acceleration are the main triggers for the flaring activity. Studying the eruptions of EP hot and cool FRs with their associated CME, we find that they are co-spatial with the CME bright core, i.e. the hot and cool EP FRs produced bi-component CME bright core.
Key words: Sun; Solar Prominence Eruptions; Flares; Coronal Mass Ejections; Multi-wavelengt Observations

Introduction

The solar prominences (known as filaments, when they are observed on the disk) are dense and cool material suspended in the hot and thin solar corona along polarity inversion lines (PILs). They are found in magnetic dip regions located in two main magnetic configurations: a sheared arcade and a flux rope. In the sheared arcade configuration, the arcade connects the opposite polarities on either sides of a PIL, whereas in the case of the flux rope configuration the magnetic field has helical magnetic structure (Mackay et al., 2010). It is commonly accepted to divide filaments into three types according to their locations on the solar disk: active-region, intermediate, and quiescent filaments (e.g. Engvold, 1998; Mackay et al., 2010).

It is widely accepted that prominence/filament eruptions are often one aspect of a more general single eruption that can produce a solar flare and a coronal mass ejection (CME) (e.g., Hirayama, 1974; Shibata et al., 1995; Moore et al., 2001; Forbes, 2000; Priest & Forbes, 2002). These three eruptive phenomena are usually considered to be connected with each other, and they may be different manifestations of the same magnetic energy release process in the corona (e.g. Shibata et al., 1995; Forbes, 2000; Moore et al., 2001; Priest & Forbes, 2002; Sterling et al., 2012). Many studies of the relationship between eruptive prominences (EPs), solar flares and CMEs (e.g.,

Sub- and Quasi-Centurial Cycles in Solar and Geomagnetic Activity Data Series

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Abstract. The subject of this paper is the existence and stability of solar cycles with durations in the range of 20–250 years. Five types of data series are used: 1) the Zurich series (1749–2009 AD), the mean annual International sunspot number *Ri*, 2) the Group sunspot number series *Rh* (1610–1995 AD), 3) the simulated extended sunspot number from Extended time series of Solar Activity Indices (ESAI) (1090–2002 AD), 4) the simulated extended geomagnetic *aa*-index from ESAI (1099–2002 AD), 5) the Meudon filament series (1919–1991 AD). Two principally independent methods of time series analysis are used: the T-R periodogram analysis (both in standard and "scanning window" regimes) and the wavelet-analysis. The obtained results are very similar. A strong cycle with a mean duration of 55–60 years is found to exist in all series. On the other hand, a strong and stable quasi 110–120 years and ∼200-year cycles are obtained in all of these series except in the *Ri* one. The high importance of the long term solar activity dynamics for the aims of solar dynamo modeling and predictions is especially noted.
Key words: solar activity; solar cycles; methods - indices, extended solar data series

Introduction

It is usually accepted that the length of the so called "secular" (centurial) or Gleissberg solar cycle is about 7 or 8 Schwabe-Wolf's sunspot cycles, i.e. $\sim$ 80-90 years. The corresponding oscillation has been detected by different methods since the middle of 1940ies in the instrumental sunspot data series (see e.g. Gleissberg, 1944; Vitinskii, 1973) and until present days (e.g. Kane, 2008). Using tree rings ^{14}C data series (INTCAL93), Damon and Sonett (1991), Peristykh and Damon (2003) found that ∼88 year solar cycle exists and could be traced during the last 11–12000 years (post-glacial epoch, Holocene). It has been also found in these studies that such quasi-centurial oscillation is modulated by other longer bi-millennial 2000–2500 year cycle (usually called "Hallstadtzeit").

During the middle and the second half of the 20th century quasi-periodic oscillations, which are comparable with the Glessberg's sunspot cycle have been established in many solar, geophysical, climatic, and other environmental processes (see e.g. Schove 1955, 1983; Rubashev, 1963; Javaraiah et al., 2005). On the other hand, it has been also found that in many cases there is not a clear 80–90 year solar cycle (SC), but rather one or more quasi-cyclic oscillations, which are slightly shorter or longer than the "classic" Gleissberg cycle. Still in the middle of 1950ies, Schove (1955) has found that in the auroral activity during the last ∼2600 years there is not a single 78 year cycle, but rater few oscillations with sub- and quasi-centurial

Three successive eruptions of a prominence observed by the coronagraph in NAO - Rozhen

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Abstract. A study of a rare event of three successive prominence eruptions observed with the $H\alpha$ coronagraph at the National Astronomical Observatory (NAO) – Rozhen is presented. The eruptive prominence is situated in active region NOAA 10904 and is associated with a narrow coronal mass ejection. The kinematics of the successive eruptions was analysed and compared. The obtained results suggest that the evolution of the eruptive prominence and the kinematic parameters of its successive eruptions are consistent with the so-called "homologous" eruptive events on the Sun.

Key words: solar eruptive prominences

1. Introduction

Solar prominences (or filaments, when observed on the disk) are formed and maintained above the magnetic polarity inversion line (PIL), in a magnetic structure called a filament channel, in which the filament can be supported by the magnetic field (see for review Martin, 1998). In terms of the magnetic environment of the PILs, there are three essential cases of prominence formation: **(i)** in weak magnetic fields at high latitudes (called polar crown prominences); **(ii)** in active regions (ARs), and **(iii)** at the borders of ARs or between two closely situated ARs (e.g. Leroy, 1989 for review). The final stage of a prominence is almost always an eruption (Filippov and Den, 2001) or in the case of a filament, the so-called "disparition brusque" (Raadu et al., 1987; Schmieder et al., 2000), when the filament faints away and disappears.

The relationship between eruptive prominences (EPs), large-scale eruptive phenomena such as CMEs and flares (Subramanian and Dere, 2001; Schrijver et al., 2008; Chandra et al., 2010; Yan et al., 2011), suggests that the three eruptive events occur in the same large-scale coronal magnetic field (e.g. Forbes, 2000; Li and Zhang, 2013). A three-part structure of a bright loop (helmet streamer), a dark cavity, and a prominence core often exists in the quiet corona (e.g., Gibson et al., 2006). The cavity is suggested to be the upper portion of a helical flux rope with cool filament material suspended at its bottom (e.g., Low 1996, 2001). CMEs exhibit an equivalent three-part structure: the bright core (EP), the dark cavity and the leading edge (e.g., Illing and Hundhausen, 1986). Thus, a detailed study of the origin and evolution of EPs is essential for a good understanding of their role in triggering CMEs (Schmieder et al., 2013), which will lead to a good ability to forecast CMEs and associated space weather.

Various studies indicate that prominences can erupt in many different ways depending on the prominence magnetic environment at all levels of the solar atmosphere and the physical processes occurring there (e.g. Joshi and Srivastava, 2011 for reviews). Solar prominences exhibit a range of eruptive behaviours,

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UBVRI observations of the flickering of RS Ophiuchi at quiescence★

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ABSTRACT

We report observations of the flickering variability of the recurrent nova RS Oph at quiescence on the basis of simultaneous observations in five bands ($UBVRI$). RS Oph has a flickering source with $(U-B)_0 = -0.62 \pm 0.07$, $(B-V)_0 = 0.15 \pm 0.10$ and $(V-R)_0 = 0.25 \pm 0.05$.

We find for the flickering source a temperature $T_{\rm fl} \approx 9500 \pm 500$ K, and luminosity $L_{\rm fl} \sim$ 50–150 $L_\odot$ (using a distance of $d = 1.6$ kpc).

We also find that on a $(U-B)$ versus $(B-V)$ diagram, the flickering of the symbiotic stars differs from that of the cataclysmic variables. The possible source of the flickering is discussed.

The data are available upon request from the authors.

Key words: binaries: symbiotic – stars: individual: RS Oph – novae, cataclysmic variables.

1 INTRODUCTION

In the symbiotic recurrent nova RS Ophiuchi (HD 162214), a near-Chandrasekhar-mass white dwarf (WD) accretes material from a red giant companion (e.g. Hachisu & Kato 2001; Sokoloski et al. 2006). It experiences nova eruptions approximately every 20 yr (Evans et al. 2008), with the most recent eruption having occurred on 2006 February 12 (Narumi et al. 2006). Fekel et al. (2000) found that RS Oph has an orbital period of 455 d and give red giant and WD masses of 2.3 $M_\odot$ and close to 1.4 $M_\odot$, respectively, with a separation of $a = 2.68 \times 10^{13}$ cm between the components. For the range of spectral types suggested (Worters et al. 2007) for the red giant in the RS Oph system, its radius is smaller than its Roche lobe, and accretion on to the WD may occur only from the red giant wind.

The flickering (stochastic light variations on time-scales of a few minutes with an amplitude of a few × 0.1 mag) is a variability observed in the three main types of binaries that contain WDs accreting material from a companion mass-donor star: cataclysmic variables (CVs), supersoft X-ray binaries and symbiotic stars (Sokoloski 2003). The flickering of RS Oph has been detected by Walker (1977). The systematic searches for flickering variability in symbiotic stars and related objects (Dobrzycka, Kenyon & Milone 1996a; Sokoloski, Bildsten & Ho 2001; Gromadzki et al. 2006) have shown that among ∼200 symbiotic stars known, only nine present flickering – RS Oph, T CrB, MWC 560, Z And, V2116 Oph, CH Cyg, RT Cru, o Cet and V407 Cyg.

Here, we investigate the flickering variability of RS Oph in the *UBVRI* bands and discuss its possible origin.

2 OBSERVATIONS

On the night of 2008 July 6, we observed RS Oph simultaneously with four telescopes equipped with CCD cameras. The 2-m RCC telescope of the National Astronomical Observatory (NAO) Rozhen equipped with a dual channel focal reducer was observed in U and V bands. In the U band, a Photometrics CCD (1024 × 1024 pixels, field of view of 4.9 × 4.9 arcmin^2) has been used, and in the V band a VersArray 1330B CCD (1340 × 1300 pixels, field of view of 6.3 × 6.3 arcmin^2). The 60 cm Rozhen telescope was observed in the R band (equipped with an FLI PL09000 CCD with 3056 × 3056 pixels and field of view of 5.7 × 5.7 arcmin^2), the 50/70 cm Schmidt telescope of NAO Rozhen in the B band (SBIG STL11000M CCD, 4008 × 2672 pixels and field of view of 16 × 24 arcmin^2) and the 60 cm telescope of the Belogradchick Astronomical Observatory in the I band (SBIG ST8 CCD, 1530 × 1020 pixels and field of view of 6.4 × 4.2 arcmin^2).

On the night of 2009 July 21, we observed RS Oph simultaneously with three telescopes. The 50/70 cm Schmidt telescope was observed in the U band, the 60 cm Rozhen telescope in repeating B

★Based on data from Bulgarian observatories Rozhen and Belogradchik.
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TECHNIQUE FOR TRACKING AND VISUALIZATION OF MOTION IN SEQUENCE OF IMAGES OF THE SOLAR CORONA

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Abstract. The material represents specialized methodology for tracking and visualization of the motions in sequence of pictures of the solar corona. The performance includes:

1. Preliminary processing of each frame: initial analysis and elimination of atmospheric scattering of light, image improvement using Gaussian filtering and a sharpen filtering for emphasizing of the contours;
2. Processing to the series: clipping the area from the currently processed frame, alignment of the clipping area with the same area in the initial frame, forming an image from the maximal brightness for each pixel of each picture of the sequence, calculation of the time-spatial gradient, determining of the direction of gradient changes and visualization of the motion by transfer to saturation and colour hue for each pixel.

This technique is used for development of a special computer program working with pictures in FITS and JPG graphic formats.

The results from testing the technique on the sequences of images from solar coronagraph of NAO Rozhen are shown.

1. INTRODUCTION

The term Solar prominences (SP) is used to describe a variety of objects, ranging from relatively stable structures with lifetimes of many months, to transient phenomena that last hours or less. Most commonly they are observed at the solar limb in the time of total solar eclipses or through solar telescope – coronagraph. The prominences are wonderful demonstration of that part of the local magnetic fields that affect to our life penetrating by the earth atmosphere. The form and movement of prominences trace the configuration and evolution of the local magnetic fields. During its evolution the prominences could be disturbed by external factors that affect on the plasma movement. These disturbances varied from temporal ac-

Optimization of a motion tracking and mapping method based on images of the solar corona

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Abstract. The study presents the current stage of development and application of a motion tracking and mapping method, based on solar corona images. The object of discussion is the problem of image processing during the extraction of features of interest in the sequence of solar prominences images. At first the method requires calculating techniques that ensure processing time-period commensurable with the time-period of the fastest developing part of the prominence body. That defines the necessity of optimization of the basic algorithms. The paper describes results of test procedures on accepted approaches for reducing the operation time by parallel processing of the images. The method also requires presentation of the lightness information independently of the sensor of particular coronagraph and image file format. This investigation proposes two techniques for achievement the identity of images from different instruments/sensors.
Key words: image processing; solar images; parralel programming; image exchange

Introduction

The method for motion tracking and mapping, based on solar corona images (Pavlova, Koleva, 2008; Pavlova et al., 2010) proposes an ability for modeling the dynamical changes in solar prominences during its evolution. However, to obtain a correct model for image processing we have to ensure an optimal accuracy and reliability of the extracted features, fixed as 2D compass directions of layers. The test has been conducted on sequences of images that include several elements - an artificial moon visible as a black half circle, the solar corona with bright prominences above the moon and near them - background of a shining Earth atmosphere. A correction for Earth rotation was also applied, using some static elements in the images as a reference.

Since the object of interest are only the moving prominences' parts, the background shining was removed before the main process of the compass directions extraction. The method supposes a usage of calculating techniques that ensure at first - an optimal time-period for image sequences processing commensurable with the time period of the fastest developing parts of the prominence (several minutes), and second - a presentation of the lightness information independent from the sensor of particular coronagraph and image file format.

For this purpose all the processing is executed by specially developed software. We used images from two different instruments - Small Coronagraph (130/3450 mm) at the Astronomical Institute of Wroclaw University, Poland and 15-cm Lio-coronagraph mounted at NAO Rozhen. The sequences were registered with H_α filter. All filtegrams from Wroclaw coronagraph were degitized with the automatic Joyce-Loebl microdensitometer at National Astronomical Observatory Rozhen, Bulgaria to fits format files. The images from NAO were obtained with digital camera Canon EOS 305D ($8Mpxs$) in jpg file format.

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ASYMMETRIC FILAMENT ERUPTION FOLLOWED BY TWO-RIBBON FLARE

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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

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HARD X-RAY DIAGNOSTIC OF PROTON PRODUCING SOLAR FLARES COMPARED TO OTHER EMISSION SIGNATURES

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Abstract. We present results on the correlation analysis between the peak intensity of the in situ proton events from SOHO/ERNE instrument and the properties of their solar origin, solar flares and coronal mass ejections (CMEs). Starting at the RHESSI mission launch after 2002, 70 flares well-observed in hard X-rays (HXRs) that are also accompanied with in situ proton events are selected. In addition to HXRs, flare emission at several other wavelengths, namely in the soft X-ray (SXR), ultraviolet (UV) and microwave (MW), is used. We calculated Pearson correlation coefficients between the proton peak intensities from one side, and, from another, the peak flare flux at various wavelengths or the speed of the accompanied CME. We obtain the highest correlations with the CME speed, with the SXR flare class and with MWs, lower ones with the SXR derivative, UV and 12–50 keV HXRs and the lowest correlation coefficients are obtained with the 50–300 keV HXRs. Possible interpretations are discussed.

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MULTI-WAVELENGTH OBSERVATIONS OF AN ERUPTIVE PROMINENCE ON 7 AUGUST 2010

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Abstract. We aim to investigate the morphology and kinematic evolution of a helically-twisted quiescent prominence. The kinematic pattern during the main stages of prominence eruption were studied, using data from both ground-based and space born observatories. The prominence environment and related activity was also considered.

1. INTRODUCTION

The observations show that the eruptive phenomena, such as prominence/filament eruptions, coronal mass ejections (CMEs) and flares are often physically related to each other by the same magnetic flux rope (MFR) occurring in the solar atmosphere (e.g., Gilbert et al. 2000; Gopalswamy et al. 2003; Schrijver et al. 2008; Filippov and Koutchmy 2008). This relation is better expressed between eruptive prominences (EPs) and CMEs. Being one of the earliest known forms of mass ejections from the Sun, EPs started to receive attention in the late 1800s (see Tandberg-Hanssen 1995). Coronagraph observations reveal that CMEs generally have a three-part structure: a bright leading front, a dark cavity, and an inner bright core (e.g. Illing and Hundhausen 1983; Chen et al. 2011). The cavity is usually believed to be a helical flux rope (e.g., Gibson et al. 2006; Riley et al. 2008) and the bright core is thought to be cool prominence/filament matter that is suspended in magnetic dips of a flux rope configuration (e.g., Guo et al. 2010; Jing et al. 2010).

The aforementioned specific physical relationship between EPs and CMEs suggests that the study of the EPs can provide critical clues not only to the prominence activity, but also to the physics of CMEs. Moreover, their study has indicated that the triggering mechanism is related to an unstable MFR (Rubio da Costa et al. 2012 for a review). The observations indicate that the temporal evolution of these phenomena and especially the role played by prominence activation and eruption can be significantly different from event to event (e.g. Sterling and Moore 2005; Wang et al. 2007; Liu et al. 2009; Zuccarello et al. 2009). Therefore, a detailed examination of the kinematic patterns of EP and its triggering mechanism may advance our ability to predict the launch of CME, will the CME be fast or slow etc. Such prediction is

THE WHITE-LIGHT FLARE AND CME ON NOVEMBER 6, 1997 AND THE EARTH MAGNETOSPHERE RESPONSE

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ABSTRACT

We analyse the WLF registered on 6 of November 1997 near the western solar limb, as well as, the local magnetic field morphology and the accompanying active phenomena. Particular attention is paid to the CME observed after 13:00 UT. An attempt is maid to construct model scenario of CME formation and evolution. We study, as well, the earth magnetosphere response to this phenomenon using magnetometric data from Interball Auroral Probe and Interball Tail Probe satellites.

1. INTRODUCTION

In the solar-terrestrial influences studies of particular interest is the better knowledge of the structure and physical parameters of CME treated as "initial conditions". It is supposed that the magnetic field and plasma parameters distribution in the circumterrestrial space and earth magnetosphere response will depend strongly on these initial conditions.

In this work we examine the active events preceding the CME on November 6 to construct a model of CME formation and evolution. Than we trace the CME propagation and behaviour at one AU and the provoked earth magnetosphere response.

2. SOLAR OBSERVATIONS

A white-light flare (WLF) has been visually registered in Haskovo Observatory on 6 of November 1997 between 11:45 UT and 11:50 UT very close to the W-S solar limb in the leading spot ($17° \leq B \leq 23°$; $L \approx 301.1$) of a sunspot group in active region (AR) 81008 (Figure 1, upper left panel). The sunspot group has been traced several days starting from 27.10.97, when it appeared first near the E-S limb and ending 07.11.97, one day after the WLF event.

Vector magnetograms of the solar area containing the AR 81008, taken it three consecutive days (Figure 1, upper right and lower panels) at the Okayama Astrophysical Observatory show that at 05:27:44 UT on 06.11.97 new magnetic flux emerged near the position where the WLF appears about 6 hours later.

AR 81008 has δ-type spot configuration and a large number of CMEs and flares associated its passage on the disk. According to Solar Geophysical Data, on November 6 two H-alpha flares of importance 2B in the time interval 11:22 - 11:49 UT have been registered. The first one was accompanied by a high-speed dark filament. Very close to the active region had been registered a dark surge on the disk starting before 11:24 UT; a bright surge on disk starting at 11:53 UT and two X-ray flares, one at 11:31 UT with importance C 4.7 and other one at 11:49 UT with optical brightness B and X-ray class X9.4.

Nancay radioheliograph do not registered type II burst. However after 1152:57 UT a group of fast moving type III-like bursts lasting until 1153:30 UT has been observed. The sources at two highest frequencies exhibit two components tracing a loop like structure with the 164 MHz emission located at the top. A southward drift of this positions suggests that the structure is expanding with velocity of 3000 km/s. Later, only the western component remains visible.

On 6 of November 1997 a loop-like CME has been registered by LASCO/SOHO. This event is well studied by Maia et al. (1999). One of the loop's footpoints has been located in AR 81008. Initially a semicircular loop has been registered in the field of view of C1 coronagraph at 11:52 UT in the light of FeXIV. The frames taken between 11:54 and 11:56 UT in FeX and continuum show that the loop expands with velocity 2000 km/s. This is a very "impulsive" start after which the velocity of the leading edge of the loop decreases, but it propagates in the field of view of C3 coronagraph with an almost constant speed of about 1700 km/s.

For such large velocity the formation of CME driven shock front is expected.

According to LASCO CME List the first loop in the field of view of C2 coronagraph appears at 12:10 UT, when velocity of 1560 km/s is measured for its leading edge. The loop expands with constant velocity, it has angular span of 135^0 and position angle 261^0 of the central axis. The CME safes the loop-like shape in its later states of development. After 12:30 UT the CME

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METHOD FOR TRACKING AND MAPPING A MOTION BASED ON IMAGES OF THE SOLAR CORONA

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Abstract. This work continues our investigations on possibilities of presentation the time development of eruptive solar protuberance and related magnetic field. The aim of this work is mapping the direction of movement of different layers of protuberance. The map construction is based on compass directions dividing them to 8 possible – North, South, West, East, North-West, North-East, South-West, South-East. The tests in this investigation are carried on sequences of images obtained from 15 cm Lio coronagraph-telescope of NAO Rozhen, used for observation of protuberance of low solar corona.

1. INTRODUCTION

This work continues the investigations on possibilities of presentation the time development of eruptive solar prominence and related magnetic field described in "Technique for tracking and visualization of motion in sequence of images of the solar corona".

The aim of the work is mapping the direction of movement of different layers of prominence and tracking its positions in the sequence of images.

The movement produces any displacement that follows some direction. The direction shows possible changes in different layers of prominence and its estimation gives information about the magnetic field behavior. There are two questions of interest:

- Available inhomogeneous is the whole prominence from the point of view of dynamics of eruption?
- What are directions of movement available in prominence?

A simple technique that uses spatial gradients, gives a possibility to estimate the directions in angular interval. The differences between positions of layers could be obtained using sequences of computer images of prominence. Pixel based image processing [3] calculates the time-spatial gradient on the area of four neighbor pixels with same positions into sequenced frames [1]. The ratio between

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PROMINENCE ERUPTION ON 22 AUGUST 2006 OBSERVED WITH THE H_α CORONAGRAPH IN NAO ROZHEN

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Abstract. An eruptive prominence (EP) on 22 August 2006 was observed with the Hα coronagraph in the National Astronomical Observatory (NAO) – Rozhen, Bulgaria. The kinematic pattern of the EP was studied and the basic parameters of its eruption were determined. The associations of the EP with the filament oh the solar disc and solar radio events are presented.

1. BACKGROUND

The EP occurred at the southwestern solar limb (S16° W) between 04:28 UT and 11:00 UT. The eruptive event presents seven successive eruptions during that time interval (Table 1). Each eruption, after first one, reaches smaller maximum height than previous one. The eruptions run at an angle of 45° about the limb and show two distinctive phases: rising phase and post-eruptive phase, when the prominence plasma flow back to the chromosphere by the same trajectory (Fig.1).

The eruptions are associated with a filament located at the western end of an active region NOAA 10904 at approximately the same place. The EP is associated with some activity events in solar radio emissions at 164 MHz (Nancay Radioheliograph) and 17 GHz (Nobeyama Radioheliograph).

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KINEMATICS OF A LOOP-LIKE ERUPTIVE PROMINENCE AS OBSERVED BY AIA/SDO

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Abstract. We examined the kinematic and helicity pattern, as well as the morphological and geometrical evolution of an EP on 2010 March 30. We used the He II 304 A AIA/SDO and EUVI/STEREO B observations. The unique combination of high-resolution limb observations of the EP in AIA and a central meridian position in EUVI permitted a view from significantly different perspectives and detailed analysis of the prominence eruption. The eruption process consists of prominence activation, acceleration, and a phase of constant velocity. The prominence body was composed of left-hand twisted threads around the main prominence axis. The twist during the eruption was estimated at 3 turns (6 pi). The prominence reformed in the same place two days after its eruption. The same sign of the prominence body twist and writhe, as well as the amount of twisting above the critical value of 2pi after the activation phase indicate that the conditions for kink instability were present. The fact that the erupted filament re-formed at the same place two days after the eruption implies a confined type of eruption.

1. INTRODUCTION

Prominence eruptions are large-scale eruptive phenomena, which occur in the low solar atmosphere. Eruptive prominences (EP), in contrast to active ones, could be defined as prominences in which all or some of the prominence material appears to escape the solar gravitational field (Gilbert et al., 2000). Gilbert et al. (2007) summarize three types of prominence eruptions: a full eruption, when all of the material is expelled; a partial, when only a part of the mass erupts; or a failed eruption, if the material resettles or falls back to the surface. The observations show that prominence/filament activations include a wide range of eruptive-like dynamic activity, from the full eruption (Plunkett et al., 2000) through partial eruption (Zhou et al. 2006; Liu et al., 2008) to failed eruption. Several studies

AN ACTIVITY PATTERN OF AR NOAA 9026 DURING THE LAST HALF OF ITS EVOLUTION

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***Abstract**:*

We have studied the evolution of active region NOAA 9026 by processing and analysis of white-light images and H_α filtergrams obtained in Astronomical Institute in Wroclaw (Poland). For determination of the full picture of activity events during the active region evolution the data from BBSO, GOES and Palma Reports were used. The sunspot evolution, filament and flare activities were summarized. The analysis of LASCO and EIT (SoHO) data suggests possible interrelations between associated with active region coronal mass ejections and filament eruption, as well as some X-flares in this region.

Introduction

The active region (AR) NOAA 9026 was observed on the solar disk from 02 to 12 June 2000. For the first time during this solar cycle, the Sun display a spectacular fireworks of many flares going off in close succession from one and the same active region.

The AR 9026 was observed in Wroclaw Astronomical Institute (Poland) from June 7, 2000 when it was located near the central meridian, to June 11, 2000. The registrations in white light and H-alpha were made. The observational data was processed with the Joyce Loeble microdencitometer in NAO Rozhen (Bulgaria).

For more detailed study of the active region evolution from its first appearance to its decay the BBSO Solar Activity Reports, GOES event list, and Palma Reports data were used.

Our aim was obtain a full picture of activity events, as well as some possible interrelations between them during the evolution of AR NOAA 9026.

Sunspot evolution:

The AR 9026 was observed for the first time at the E-limb on June 2, 2000. Its location was near N19E75. At the moment of its appearance the AR was observed as two well shaped sunspots with distinct penumbra. The

Emission line variability in the spectrum of V417 Centauri ⋆

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Abstract. We report high resolution ($\lambda/\Delta\lambda \sim 48000$) spectral observations of the yellow symbiotic star V417 Cen obtained in 2004. We find that the equivalent widths of the emission lines decreased, while the brightness increased. The FWHMs and wavelengths of the emission lines do not change.

We estimated the interstellar extinction towards V417 Cen as $E_{B-V} = 0.95 \pm 0.10$, using the KI interstellar line.

Using the [O III] lines, we obtain a rough estimation of the density and the temperature in the forbidden lines region $\log N_e \approx 4.5 \pm 0.5$ and $T_e = 100000 \pm 25000$ K. Tidal interaction in this binary is also discussed.

Key words: stars: individual: V417 Cen – binaries: symbiotic

Introduction

Symbiotic stars (SSs) are thought to comprise a compact object (usually a white dwarf) accreting from a cool giant. They offer a laboratory in which to study such processes as (1) mass loss from cool giants and the formation of nebulae, (2) accretion onto compact objects, radiative transfer in gaseous nebulae, (3) jets and outflows (i.e. Corradi, Mikolajewska & Mahoney 2003).

V417 Centauri (HV 6516, Hen 3-977) is a poorly studied D'-type (yellow) symbiotic system surrounded by a faint asymmetric nebula. The symbiotic nature of the object was proposed by Steiner, Cieslinski & Jablonski (1988). The cool component is a G2 Ib-II star, with $\log(L/L_\odot) = 3.5$ and $T_{eff} = 5000$ K (van Winckel et al. 1994). Pereira, Cunha & Smith (2003) found atmospheric parameters $T_{eff} = 6000$, $\log g = 3.0$, and spectral type F9 III/IV.

The binary period is not defined. Van Winckel et al. (1994) found a 245.68 day periodicity with an amplitude of 0.5 mag using Harvard and Sonneberg plates. Gromadzki et al. (2011) using optical photometric observations covering 20 years detected strong long term modulation with a period of about 1700 days and amplitude about 1.5 mag in V-band, in addition to variations with shorter time-scales and lower amplitudes. However, the long period seems to be non-coherent and the nature of light variations and the length of the orbital period remain unknown.

⋆ based on data from ESO (program 073.D-0724) and AAVSO

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Filament Eruptions Associated with Flares, Coronal Mass Ejections and Solar Energetic Particle Events

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Abstract

We present analysis of three cases of filament eruptions (FEs) that occurred on 04 Aug 2011, 09 Nov 2011 and 05 Apr 2012 and their associations with flares as sources of solar energetic particles (SEPs) and coronal mass ejections. The associated FEs and SEP-related solar flares were selected by simultaneous observations in X-ray, EUV and radio wavelengths.

Introduction

The aim of this work is to investigate the various pre- and eruptive signatures that were observed during three complex events, including filament eruptions (FEs), solar energetic particles (SEPs) related solar flares, coronal waves (CWs) and coronal mass ejections (CMEs). We focus on the filament helical morphology and kinematic evolution (heights, velocities, accelerations) in order to determine their eruption mechanisms and the rate of their connections with the associated flares, CMEs and SEPs, as well.

Data

We used data from AIA/SDO (*Lemen, et al.* 2012) in He II 304 Å channel to study the eruptions kinematics.

The analyzed events were observed in hard X-ray (HXR), extreme ultraviolet (EUV) and radio wavelengths, and had associated SEP fluxes observed at 1 AU.

We used data from RHESSI (Lin et al. 2002) to trace the flare properties in HXRs.

High-energy particles related to the studied events are analyzed in different energy channels using proton data from SoHO/ERNE instrument (Torsti et al. 1995) and electron data from ACE/EPAM DE (Gold et al. 1998).

In order to search for a possible association with CMEs, data from SoHO/LASCO CME catalog (https://cdaw.gsfc.nasa.gov/CME_list/) and STEREO (Wuelser et al. 2004) were also used.

Results

a) The event from 4 Aug 2011:

The filament eruption was observed on 4 Aug 2011 close to the AR 11261 with heliographic coordinates N16W51. The eruption started at about 03:30 UT in the AIA field-of-view (FOV) and lasted about 5h. It was an asymmetric full type eruption with well pronounced twist. Its evolution is shown in base-difference images in Figure 1 (a).

The eruption clearly showed two evolution phases: The initial phase lasted about 44 min. During this phase the velocity rose from 10.4 km/s to 49.4 km/s with a constant acceleration of 23.2 m/s2. During the second phase the filament rose with a constant velocity of about v = 65.1 km/s. The height-time profile of prominence evolution and eruption velocities and acceleration are shown in Figure 1 (b).

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Hard X-ray, EUV, and radio signatures in relation to solar energetic particles

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In this report we present analysis of well-observed electromagnetic signatures related to solar energetic particles (SEPs). We selected cases with simultaneous observations in hard X-ray, EUV and radio wavelengths of the SEP-related solar flares and analyzed the properties of the emission (light curves, spectrum and temporal evolution). The non-thermal potential of solar flares is tested in terms of correlation studies between the particle intensities (protons and electrons) and the flare flux at various wavelengths. The results are compared with the outcomes when using GOES soft X-ray flare class. The solar origin of SEP events in terms of solar flares is discussed.

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Initiation, Interaction and Eruption of Filament Flux Ropes from the Perspective of Their Magnetic Twist and Environment

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Abstract.

We present two prominence/filament eruptions (FEs) that belong to the class of rarely reported eruptions of two near-by flux ropes (FRs) of the same filament. The FRs (FR1 and FR2) of the FE on 2014 May 4 with the same helicity, i.e. left- handed twist and writhe, interact during the eruption. Their kinematics indicate a slow successful eruption of FR1 associated with a slow coronal mass ejections (CME) and a failed kinked FR2 eruption with a strong non-radial propagation followed by its reformation. The second FE on 2014 March 14 is composed by both hot, bright flux rope (BFR) and cool massive flux ropes (MFR) that underwent merging followed by splitting during the eruption. This FE produced a partial-halo CME with a bi-component bright core and an impulsive flare and post-flare loop arcade, as well. The comparative analyses of two eruptive prominences (EPs) suggest that the character of FR's interaction in each of them play a crucial role for both the driver of eruption (kink or torus instability) and the type of eruption - failed, partial or successful.

Introduction

Magnetic flux rope (FR) eruptions in the solar atmosphere play a key role in eruptive activities of the Sun, such as filament eruptions, CMEs, and flares. Prominences/filaments occur frequently as major precursors of coronal mass ejections (CMEs) as indicated by the observed close association between their eruptions and CMEs [*Munro R.H. et al.*, 1979, *Webb D. F. and Hundhausen A. J.*, 1987]. Several basic mechanisms that can disrupt the FRs include both ideal processes such as helical kink instability and torus instability of twisted coronal FRs and the non-ideal (resistive) process of the fast magnetic reconnections in current sheets [*Aulanier G.*, 2013, for a review].

It is known that two adjacent filaments sometimes approach each other and interact. There are four fundamental types of interaction: bounce, merge, slingshot, and tunnel [*Jiang Y. et al.*, 2013, *Joshi, N. C. et al.*, 2016]. The interacting filaments studies can contribute for verifying different filament models and for better understanding the coronal magnetic field structures and their dynamics, as well. However, such observational reports are still rare.

There are cases, when both branches belonging to a single filament FR are separated later that results into two ropes with the same handedness. According to previous observations and simulations, such splitting often occurs during the eruption or, in some cases, just before the filament eruption (FE) [*Liu, R. et al.*, 2012, *Kliem B. et al.*, 2014, for a review]. Such cases are very rarely reported.

The aim of this work is the comparison of two eruptive prominences (EP) that belongs to afore-mentioned last class of very rarely reported eruptions. The FRs (FR1 and FR2) of the first EP on 2014 May 4 with the same helicity interact during the eruption. The FR1 presents a slow successful eruption associated with a slow CME and the FR2 underwent a failed kinked eruption with a strong non-radial propagation followed by its reformation [*Dechev M. et al.*, 2018a]. The second EP on 2014 March 14 is composed by both hot, bright flux rope (BFR) and cool massive flux ropes (MFR) that underwent merging followed by its splitting during the eruption. This EP produces a partial-halo CME with a bi-component bright core and an impulsive flare and post-flare loop arcade, as well [*Dechev M. et al.*, 2018b].

HELICAL INTERNAL STRUCTURES IN ERUPTIVE PROMINENCES

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Introduction

Helical structures have been observed in many active prominences on the Sun. These structures can be roughly divided in two classes: internal (or microscopic) and external (or macroscopic). In the case of internal twist two or more fine threads with different helix radii are observed within the body of the prominence tube. In the second case, the whole body of a prominence tube shows helical twist or two or more tubes are intertwined in a rope-like structure.

Observation of twisted prominences have been reported by Jockers and Engvold [1], Rompolt [2], Wang [3], Vrsnak et al. [4] and Vrsnak et al. [5].

Twisted, helical-like patterns are more frequent in active region prominences. All these configurations can be represented by an axial current and so are equivalent to a simple twisted magnetic flux tube.

In the eruption phase, the morphology of a prominence often changes dynamically. In the late phases of the eruption usually a rather simple arch remains, frequently exposing helical-like structure. Such a behavior is described in Tandberg-Hanssen [6] and Vrsnak et al. [7].

A more detailed classification of the prominences exposing helical-like structures is made in Vrasnak et al. [5]. The authors described four main classes (Figure 1):

DYNAMIC CHARACTERISTICS OF THREE ERUPTIVE PROMINENCES

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Abstract:
The kinematics and dynamics of eruptions of three prominences was studied. The properties of their dependence of the height on time, as well as of horizontal expansion on time during the eruption was analyzed and compared.

1. Introduction

The eruption process of the prominences develops in two main phases. In the first pre-eruptive phase, the prominence slowly rises with approximately constant velocity of several km/s (Rompolt, 1990). At some critical height the prominence erupts and a large part of its material is lifted into the corona and into the planetary space. The velocity of the ejected prominence ranges from several km/s at the beginning phase of the eruption to several hundreds km/s at the late phase of the eruption (Rompolt, 1990).

Besides the eruption in the vertical direction, some eruptive prominences (EPs) exhibit expansion in the horizontal direction. Most of them show constant velocity (Rompolt, 1984; Rudawy et al., 1994). The velocities of the horizontal expansion are in the range from 15 to 80 km/s (Rompolt, 1998).

According to Vršnak's classification (Vršnak, 1998), there are three classes of EPs in dependence of the fine structure of the eruptive phase. Class **A** when the prominence material often remains constant after the initial acceleration. Class **B** when after the acceleration and the constant velocity follow deceleration of the EP material. Class **C** when the initial acceleration of the EP continues up to the prominence disappearing in H_{α}.

There are two basic types of EPs according to Rompolt's classification (Rompolt, 1990). Both types EPs are embedded in the lower part of huge magnetic system (HMS). The EPs of type I have shape of a large arch at the bottom of the HMS that rising up into the corona during the eruption. The EPs

БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ

ЦЕНТРАЛНА ЛАБОРАТОРИЯ ПО СЛЪНЧЕВО-ЗЕМНИ ВЪЗДЕЙСТВИЯ
ГЕОФИЗИЧЕН ИНСТИТУТ
ИНСТИТУТ ПО АСТРОНОМИЯ
ИНСТИТУТ ЗА КОСМИЧЕСКИ ИЗСЛЕДВАНИЯ
СЪЮЗ ПО ЕЛЕКТРОНИКА, ЕЛЕКТРОТЕХНИКА И СЪОБЩЕНИЯ

ОСМА НАЦИОНАЛНА КОНФЕРЕНЦИЯ
С МЕЖДУНАРОДНО УЧАСТИЕ
ПОСВЕТЕНА НА 40-ГОДИШНИНАТА ОТ
ПОЛЕТА НА ПЪРВИЯ ЧОВЕК В КОСМОСА

СЪВРЕМЕННИ ПРОБЛЕМИ НА СЛЪНЧЕВО-ЗЕМНИТЕ ВЪЗДЕЙСТВИЯ

CONTEMPORARY PROBLEMS OF SOLAR-TERRESTRIAL INFLUENCES

СОФИЯ, 6-7 ДЕКЕМВРИ 2001
ИЗДАНИЕ НА ЦЛСЗВ – БАН

ИЗХВЪРЛЯНЕ НА КОРОНАЛНА МАТЕРИЯ ОТ СЛЪНЦЕТО НА 6 ЮНИ 2000 Г. И ВЪЗДЕЙСТВИЕТО ВЪРХУ МАГНИТОСФЕРАТА НА ЗЕМЯТА

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Резюме. Тази рабата представлява предварително изследване на необикновеното CME от 6 Юни 2000 г., с проследяване на основните моменти на процеса: (1) стартирането на CME в слънчевата корона; (2) магнитната конфигурация в междупланетното пространство, в която преминава CME; (3) реакцията на магнитосферата, респ. геомагнитната буря и (4) съпоставка с предишни изследвания.

Увод. Явлението изхвърляне на коронална маса или Coronal mass ejection (CME) е открито през 70--те години в резултат на изследванията на слънчевата корона чрез коронографи на борда на СКАЙЛАБ (Gosling et al., 1976, вж. Delannee et al., 2000). Това явление се разглежда като друга форма на слънчевата активност, различна от слънчевите избухвания (flare) и вторичните им ефекти (нагряване на хромосферата и генериране на рентгеново, ултравиолетово и оптично излъчване, особено в ярката линия Hα; радиоизлъчване в различни диапазони; слънчеви енергийни частици - Solar Energetic Particle (SEP) event (в последно време, обаче, се поддържа идеята за генериране на SEP на съществено разстояние от Слънцето). CME изглежда да са главния слънчев аген, директно свързан с генерирането на геомагнитните бури (Gosling, 1993). CME се дефинира като изменение в короналната структура, което (1) става за време от няколко минути до няколко часа и (2) включва появяването на ново, блестащо в бялата светлина образувание в зрителното поле на коронографа (Hundhausen, 1993, вж. Delannee et al., 2000). Много спътникови експерименти в междупланетното пространство, особено в последно време, са регистрирали съществуването на необикновенни магнитни конфигурации (облаци) -Magnetic Clouds (MC) от плазма, корелиращи с геомагнитните бури (Burlaga et al., 1981; Huang, 1998; Thomsen et al., 1998; Frey et al., 1998 и др.), но малко за сега са изследванията върху твърде амбициозната задача - да се покаже, че CME директно преминава в конфигурацията магнитен облак (Burlaga et al., 1998; Klein, 1982; Dermendjiev et al., 1999). Магнитен облак е кратковременно изхвърляне в слънчевия вятър, характеризиращо се с относително силно магнитно поле, бавно въртене на $\boldsymbol{B}$ на $\approx 180^{\circ}$, ниско β (β е отношението на кинетичното към магнитното налягане $\beta = NkT/(B^2/8\pi)$, ниска температура на протоните и радиален размер $\approx$ 0.25 AU (Burlaga et al., 1981).

Тази рабата представлява предварително изследване на необикновеното CME от 6 Юни 2000 г., с проследяване на основните моменти на процеса: (1) стартирането на CME в слънчевата корона; (2) магнитната конфигурация в междупланетното пространство, в която преминава CME; (3) реакцията на магнитосферата, респ. геомагнитната буря и (4) съпоставка с предишни изследвания. За тази цел ще се възползуваме от безпрецедентните възможности, които ни предлага спътника Solar and Heliospheric Observatory (SOHO) и в частност изображенията от два важни уреда: (1) Телескоп за изображение в крайната ултра виолетова област - Extreme Ultra Violet Imaging Telescope (EIT), центриран към 195 A - линията на Fe XII, за изследване на ниската корона (Delaboudiniere et al.,1995, вж. Delannee et al., 2000) и (2) Спектрометричен коронограф с голямо зрително поле -Large Angle Spectrometric Coronograph (LASCO), центриран към линията 5800 A за изображения на короната в бялата светлина, чрез 3 коронографа, които общо покриват един сегмент около Слънцено с външен радиус 30 R_s, R_s - радиус на Слънцето(Brueckner et al., 1995, вж. Delannee et al., 2000). Използват се и други спътникови мисии: регистрации на магнитното поле MFE/WIND и на слънчевия вятър SWE/WIND, GEOS, SAMPEX както и наземни геофизически мрежи.

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EXPLORATIONS COSMIQUES

FORCING OF THE MAGNETOSPHERE AND IONOSPHERE BY STRONGLY MAGNETISED SOLAR PLASMOID ON 6–7 APRIL 2000

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(Submitted by Academician D. Mishev on June 1, 2000)

Solar event. A coronal mass ejection (CME) has been registered by SOHO /LASCO on 4 April 2000 from 15:18 UT to 19:42 UT. The phenomenon reached velocity up to 2000 km/s. The CME has been preceded by C9.7 flare (Fig. 1, Upper Panel) at 15:41 UT in active region 8933 (at heliographic coordinates N16W66) and soft X-ray emission starting at 15:12 UT, ending 16:05 UT with a maximum at 15:41 UT. The flare event was accompanied by an eruption of a filament (prominence on the disc) (Fig. 1, Botomn Panel), which probably was the source of the increase of energetic particles seen at GEOS spacecraft starting arround 17:00 UT [1]. Unfortunately, SOHO/EIT observations in Fe XII at 14:24, 14:40, 15:24 and 17:00 UT missed the time of the filament eruption and we could not trace the erupting arcade. The basic conclusion is that the CME material and magnetic field came mainly from the erupting filament. Consequently, the initial conditions of this CME formations differ significantly from the respective conditions of CME formation on 6 November 1997 when the CME material originated mainly from evaporated chromosphere due to a preceding white light flare [2].

Magnetic cloud at 1 AU. On 6 April the magnetised plasma of this CME encountered the Earth environment. A preliminary analysis of available data shows that this event differs with its very distinctive features which provoked our interest. No doubt that similar events occurred in the past, too, but now due to the ISTP Program, including INTERBALL mission the event can be traced beginning from the Sun, through the interplanetary space towards near Earth environment.

In this work we tried to describe the magnetic field **B** at one AU on 6-7 April in terms of its module B, elevation angle (δ), and azimuth (ϕ) [3]. In our opinion this is more convenient for representing the topology of the large magnetic field configurations. On the basis of WIND magnetic field data we calculated these parameters for 48 hours period starting at 00 UT on 6 April 2000 (Fig. 2). We identify the arrival of the leading edge of the plasmoid with a sudden strong magnetic field jump of 25 -30 nT at 16:15 UT (Panel 1, Fig. 2). Simultaneously with $|\mathbf{B}|$ increase, a sudden rotation of **B** towards the South takes place or δ turns abruptly from positive to negative. The field remains steady with these features until 24 UT, when its direction changed to positive (Fig. 2,

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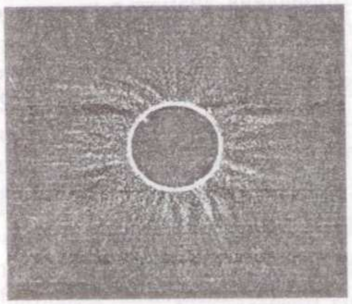

Фиг. 5. Слънчевата корона на 11 Февруари 1961г. Фина структура.

Заключение

В заключение може да се каже, че този съвременен анализ на фотографии на бялата корона правени от борда на самолет по време на пълното слънчево затъмнение от 15 Февруари 1961г разкрива интересна фина структура на короната, каквато наземните наблюдения (виж Sky and Telescope, vol. 21, N4, 1961) само загатват. Изследванията по този наблюдателен материал продължават. Те за нас са също една добра възможност за уточняване на изследователските цели по време на предстоящото пълно слънчево затъмнение на 11 Август 1999 година.

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ВЪРХУ ПРИРОДАТА НА ЯВЛЕНИЕТО БЯГАЩИ СЕНКИ ПО ВРЕМЕ НА ПЪЛНИ СЛЪНЧЕВИ ЗАТЪМНЕНИЯ

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Резюме: Обсъдени са физическите параметри на явлението бягащи сенки по време на пълни слънчеви затъмнения като основно се набляга на тези, получени от български екип по време на такова затъмнение през 1961г. Дискутират се възможните физически причини - флуктуации на плътността на земната атмосфера и потъмняването към края на слънчевия диск - водещи до формирането на бягащи сенки. Приведени са теоретични аргументи, показващи, че до голяма степен физическите характеристики на това явление зависят от фазата на 11-годишния цикъл на слънчевата активност. Това е един убедителен мотив за изпълнение на наблюдателен експеримент за регистриране на бягащи сенки по време на пълното слънчево затъмнение на 11 август 1999г (фаза максимум на цикъла) и сравнение на резултатите с тези от затъмнението на 15 февруари 1961г. (фаза минимум на цикъла).

1. Увод

Непосредствено преди и след пълната фаза на слънчево затъмнение върху земната повърхност се наблюдава вълноподобна картина от бързопреминаващи блещукащи и тъмни ивици. На това явление, наричано shadow bands, fleeting shadow, бегущих теней, най-много прилага названието "бягащи сенки". То е все още недостатъчно изучено, а проблемът за неговата физическа природа е все още дискусионен.

Анализът и интерпретацията на наблюдателните данни наложи схващането, че това явление се дължи на рязкото изменение на притока на слънчева радиация, което предизвиква динамични процеси в земната атмосфера, водещи до формирането на въздушни фронтове с определена

ОТКЛИК НА ЗЕМНАТА МАГНИТОСФЕРА НА WLF-CME НА 6 НОЕМВРИ 1997

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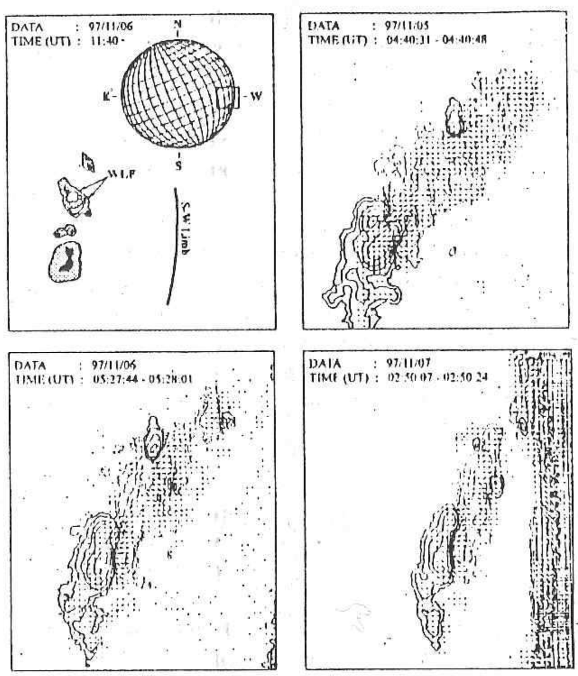
Резюме. Направен е анализ на избухването в бяла светлина (WLF) в 11:50 UT на 6 Ноември 1997 г. близо до западния лимб на Слънцето. То се появява близо до областта, където няколко часа преди това изплува интензивен магнитен поток. Отделено е внимание на последвалото изхвърляне на коронално вещество (CME) от същия район. Направен е опит да се конструира моделен сценарий на формирането и еволюцията на CME. Изследван е също така откликa на земната магнитосфера на това явление като са използувани магнитометрични данни от спътника ИНТЕРБОЛ - 2.

УВОД В изследването на слънчево -земните въздействия особен интерес представлява познаването на структурата и физическите параметри на явлението изхвърляне на коронална маса (CME), третирани като начални условия. Магнитното поле и параметрите на плазмата в околоземното пространство и земната магнитосфера зависят силно от тези начални условия. В тази работа ние изследваме активните явления, свързани със CME на 6 Ноември 1997 г. и правим опит да създадем един модел на формирането и еволюцията на CME. По -нататък трасираме разпространението на CME на разстояние 1 AU и разглеждаме откликa на земната магнитосфера

2. СЛЪНЧЕВИ НАБЛЮДЕНИЯ. На 6.11.1997 в Обсерватория Хасково е регистрирано избухване в бяла светлина (WLF) от 11:45 до 11:50 UT много близко до W -S слънчев лимб в активната област (AR) 81008 (Фиг. 1, горен ляв панел). Векторните диаграми, получени в Астрофизическата обсерватория Окаяма, показват изплуването на нов магнитен поток в тази област 6 часа преди WLF (Фиг. 1, горен десен и долни панели). В 12:10 UT от спътника СОХО е регистрирано CME и е измерена скорост 1600 км/сек за водещия му край. Единият край на арковидна структура на CME води началото си от AR 81008. CME запазва своята примкообразна форма като се разпространява по -бързо латерално, отколкото радиално и в 13:46 UT то има форма "закачалка" (Фигура 2).



Фигура 1. *WLF регистрирано у нас на 6 Ноември, 1997 г. между 11:45 UT и 11:50 UT (горен ляв панел). Векторни магнитограми от AR 81008 получени в Астрофизическа лаборатория Окаяма за три последователни дни. Вижда се добре появата на нов магнитен поток 6 часа преди WLF.*

ИНТЕРФЕРОМЕТРИЧНИ И МОНОХРОМАТИЧНИ НАБЛЮДЕНИЯ НА ОКОЛОСЛЪНЧЕВОТО ПРОСТРАНСТВО ОТ НЕБЕТО ПО ВРЕМЕ НА ПЪЛНОТО СЛЪНЧЕВО ЗАТЪМНЕНИЕ НА 11 АВГУСТ 1999 г.

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Съществуват две възможности за изследване на вътрешните области на междупланетния прахов облак, които не зависят от механизма на разсейване на фотосферното излъчване. Първата възможност се състои в регистриране на собственото топлинно излъчване на нагретите прахови частички в инфрачервената област на спектъра. Така беше открита топлинната или Т-корона (Peterson, 1967; MacQueen, 1968). Втората възможност, която според нас е по-перспективна, се състои в регистрирането на резонансно излъчване на атоми и нискозаредени йони на метали "отделящи се" при сублимиране на праховата компонента на слънчевата корона. Такива атоми и йони ще продължат да участват, за известно време, в общото движение на пораждащия ги прах, затова излъчваната от тях резонансна емисия ще показва доплерово изместване, съответсвуващо на компонентата на кеплеровата скорост по лъча на зрението.

За първи път успешен опит за регистриране на резонансно светене на Са II йони, с Фабри-Перо еталон и фотографска камера, беше осъществен по време на пълното слънчево затъмнение на 26 февруари 1998 г. (Gulyaev & Shcheglov, 1999а). На Фиг. 1. е показана интерферограма, получена по време на това затъмнение. На нея се вижда силно преекспонирано изображение на короната и слабо излъчване в K Ca II линията в западната част на околослънчевото пространство, на хелиоцентрично разстояние от 5 до 20 $R_{\odot}$. Измерените доплерови отмествания (от 170 до 280 км/сек), съответствуват на кеплеровата скорост на кръговото орбитално движение за разглежданите хелиоцентрични разстояния. Направен беше извода, че е регистрирана нова компонента на короналното излъчване (в допълнение на известните K-, E-, F-и Т-компоненти) и беше предложено тя да се нарича S-компонента на слънчевата корона (Gulyaev & Shcheglov, 1999в).

За затъмнението на 11 август 1999 г. беше поставена задачата да се повторят, с усъвършенствана апаратура, такива наблюдения с цел потвърждение или отхвърляне на резултатите от 1998 г. и евентуално получаването на нови данни за S-короната. За тази цел беше подготвена теоретично добре мотивирана наблюдателна програма в рамките на съвместен научно-изследователски проект "Регистриране на външната граница на безпраховата зона на слънчевата корона по време на пълното слънчево затъмнение на 11 август 1999 г." между ИЗМИРАН (координатор Р. Гуляев) и Института по астрономия при БАН (координатор В. Дерменджиев). Наблюденията бяха проведени на площадка "Полигона" край град Шабла. Цялата наблюдателна програма беше изпълнена успешно.

Разработената апаратура, която нарекохме интерферометрична камера, се състои от един Фабри-Перо еталон и интерференчен филтър центриран в линията K CaII ($\lambda=3933,7$ Å) с ивица на пропускане 60 Å. Линията H CaII, отстояща от K на 35 Å, попада в крилото на ивицата на пропускане на филтъра и е значително отслабена. Използван е обектив с фокусно разстояние 53 мм и фотокамера за 35 мм филм, с което стана възможно да се фотографира участък от небето до $80R_{\odot}$ в светлината на резонансните линии H и K на CaII.

При интерферометричните наблюдения беше използвана фотолента Kodak TMax P3200. При нейното проявяване беше избран режим, осигуряващ чувствителност 25 000 ISO. По време на пълната фаза бяха направени снимки с експозиции 1, 3, 10 и 60 сек. Оптимална се оказа експозиция 60 сек. Фотография от тази интерферограма е показан на Фиг. 2, където север е горе, а изток - на ляво. Центърът на системата от пръстени е разположен извън кадъра т.к. еталонът Фабри-Перо беше наклонен на 20^{0} спрямо нормалното положение.

На оригиналните негативи се виждат (макар и в по-малък обем, отколкото на снимките от 1998 г.) отделни емисионни фрагменти на K CaII с доплерово отместване. Най-забележимият детайл е разположен в област с позиционен ъгъл $\approx$-104^{0} и хелиоцентрично разстояние $20R_{\odot}$. Това до известна степен може да се счита за потвърждение на резултатите от затъмнението на 26 февруари 1998 г.

При сравнение на получените интерферограми от двете пълни слънчеви затъмнения може с голяма увереност да се направи заключението, че е регистрирано резонансно светене на йоните на CaII, показващо доплерово изместване. Този резултат ние интерпретираме