MAGNETIC CANCELLATION AND SMALL-SCALE ACTIVITY IN AN AR FILAMENT

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ABSTRACT

A long set of observations obtained with the VTT/MSDP spectrograph in September 1998 (8 to 11) allows us to follow the formation of a complex filament in and around a nest of active regions during its disk passage. Continuous shear of magnetic field in this region can explain the formation and the relative stability of the filament structure before the occurrence of a flare which leads to important changes in the magnetic configuration. The corona overlying the region and the flare, as well, is observed by TRACE.

The studied filament is stable on long time scale. However, high spatial and temporal observations obtained in LaPalma (SVST) show high Doppler shifts and strong transverse motions of absorbing blobs along the filament. These velocities are directly related to magnetic activity as observed with the SVST. A small scale magnetic analysis shows emergence of MMFs (Moving Magnetic Features) around a decaying sunspot and canceling flux with the neighbor network. Magnetic reconnection could occur and explain the ejection of blobs along the new magnetic field lines. Formation of the transient blobs is discussed.

Key words: Solar magnetic field, Filament.

1. INTRODUCTION

The formation of filaments is initially related to global as well as to local magnetic configuration. Filaments lie above and along magnetic field inversion lines. The dynamics of the small-scale structure appears to be an important feature of the prominence plasma (Tandberg-Hanssen, 1994). The apparent flowing of the plasma horizontally, as well as vertically (Schmieder \textit{et al.}, 1984, 1991; Zirker \textit{et al.}, 1998), is thought to be an important and significant element in process of prominence formation and maintenance.

The small-scale and medium-scale structures of prominences and filament outline the topology of the magnetic field. One also notices that the typical length of medium-scale filament segments is compatible with the size of supergranules. An association between the filament feet or “barbs” and parasitic magnetic polarities is inferred from studies by Martin \textit{et al.} (1994), Aulanier \textit{et al.} (1999) and Wang (2001).

We focus our observations on September 9 1998 when the filament is well formed and study its dynamics using mainly the SVST data related to the magnetic activity of its environment.

2. OBSERVATIONS

2.1. Instruments

The majority of the observations were obtained with Lockheed tunable filter (Title \textit{et al.}, 1992) mounted in the Swedish Vacuum Solar Telescope (SVST) on La Palma (Scharmer \textit{et al.}, 1985). Nine narrow-band filtergrams, recorded sequentially with a time step of 1 min, at the following wavelength positions; two exposures in the wing of Fe i 6302.5Å (\(\Delta \lambda = -0.06\)Å) at, respectively, left and right circular polarization (LCP, RCP), then one filtergram was recorded at \(\Delta \lambda = -0.35\)Å from the same iron line and followed by six filtergrams in the Hα line (center, \(\pm 0.25\)Å, \(\pm 0.45\)Å and \(+0.7\)Å). The filter passband was 72 mÅ at \(\lambda 6302.5\)Å. The longitudinal magnetic field in the photosphere is computed from LCP and RCP (Deng \textit{et al.}, 2002). The Doppler shifts are computed by the bisector method after reconstruction of the Hα profile as defined by the 5 observed wavelength points. The pixel size of the rebinned images is 0.18 Å, the spatial resolution is estimated to 0.4 Å.

TRACE (Handy \textit{et al.}, 1999) was observing this AR during two periods (12:00 to 16:00 and 17:00 to 18:00.)

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UT on September 9, 1998) with its filters centered at, respectively, Fe \textit{ix/x} 171\textit{Å}, Fe \textit{xii} 195\textit{Å} and in the broad band 1600\textit{Å}, at a cadence of 1 min per set. The camera pixel size was 0.5 arc sec. The French Multi-channel Subtractive Double Pass (MSDP) spectrograph (Mein 1991) which was mounted on the German VTT solar telescope in Tenerife observed the AR from 12:23 to 18:01 UT with a cadence of 30 min (Schmieder \textit{et al.}, 2002)

2.2. Filament between active regions

On September 9, the AR 8329 consists of a leading sunspot with positive polarity and a following, dispersed negative polarity corresponding to faculae and some intense magnetic network. This region appears to be 'squeezed' between two active regions; the AR 8326 on its northern edge and new emerging flux developing at its south border (see also Schmieder \textit{et al.}, 2002). The left-most part of the active region filament shown in Figure 1 consists of three separate segments, denoted F1, F2 and F3 in Figure 2. The filament is located at N18 E10 on September 9, 1998. It was formed the previous day in the decaying AR 8329 around an intrusion of positive polarity represented by a small sunspot (called C in Figure 2) inside this following polarity (Figure 3). The resulting magnetic inversion line became irregular and complex. This is the signature of a high shear favoring the stability of the filament in its channel (Martin, 1998).

The filament was observed during four hours with the SVST telescope. The seeing was variable and images of poor resolution have been discarded from the data set. Consequently, the cadence is reduced and varying between 1 and 7 minutes. The three segments of the Hα filament are separated by regions where mixed magnetic polarities are strong and evolving; here denoted region R1 between F1 and F2, and region R2 between F2 and R3. One observes also repeated interruptions of filament section F2 in the region R3, that seems to result from intrusion of a weak positive polarity in the negative polarity network (Figure 2).

3. DYNAMICS

3.1. Period of activity

The velocities of the \textit{bulk} flowing material are determined by means of a time-slice technique developed by Lin \textit{et al.} (2002) for measurements of transverse motions in filaments. Enhanced flowing of the absorbing plasma are observed at different times, and in both directions, with velocities ranging typically between 5 and 10 km s\textsuperscript{-1} (Deng \textit{et al.}, 2002). In region R1 between 16:15-35 UT, 16:41-17:03 UT, a blob (a) jumps from F1 to F2 with a transverse velocity of about 10 km s\textsuperscript{-1}, leaving the filament segment F1 nearly empty. It later reforms and one sees a returning flow (b) in the opposite direction with velocities of 14 km s\textsuperscript{-1} (16:54-17:07 UT), which is close to the sound velocity. The blob (d) appears, subsequently, to be returning material in region R3. The blobs could be followed over distances around 20
arc sec but not along whole a section of the filament (50 arc sec).

Considering the signs of the transverse and line-of-sight motions, for the 'blobs', it seems to show that the 'blob a' moving from segment F1, across the gap (R1), into the next segment are red shifted \(~7\) km s\(^{-1}\). This implies that the flow follows downward bending field lines. Similarly, the same goes for the fan of threads belonging to region F1 and stretching towards R1 during this time period.

The magnetic activity is caused by the decaying, small sunspot C which is surrounded by Moving Magnetic Features (MMFs), expelled away from the C spot towards the network polarities (MMFs are discussed in the paper by Harvey and Harvey (1973). The MMFs cancel as they reach opposite polarities. This occurs mainly in region R1, which is characterized by a break in the filament seen in H\(\alpha\) absorption, and by mixed polarities in the filament channel belonging to the network (Figure 2).

3.2. Quiet periods

Doppler images show generally higher contrast and finer structural details than the corresponding images in H\(\alpha\) intensity. The structures in the Doppler images outline both 'spines' and the branching threads. The 'Doppler channel' is generally larger than the H\(\alpha\) filament with aligned threads, alternating blue and red shifted (Figure 4). The measured amplitudes of the line-of-sight motions are generally less than 2 km s\(^{-1}\). The transverse field could not be measured during more quiet periods.

4. CONCLUSION

What can tell us the present data:

- Magnetic topology:
  In the quiet periods the velocities can mainly be measured from Doppler shifts. The transverse field velocities are below the detection level limited by seeing and lengths of the time series. Counterstreaming of the prominence plasma suggests that the fine structures are generally horizontal in the non-activated parts of the filament. The filament plasma is supported in nearly horizontal fields or in weak 'dips' of magnetic field lines, as suggested Aulanier and Démoulin (1998).

Figure 2. Filament observed in H\(\alpha\), and magnetic field map of the same region observed with the SVST on September 9, 1998. Black and white signals are, respectively, positive and negative longitudinal magnetic polarity. In order to show the network magnetic field, the maps are saturated at \(\pm\) 400 G. Contours of the filament segments F1, F2, F3 and the regions R1, R2, R3, and the sunspot C. The upper right panel shows the same region as observed by TRACE at 195\(\ Å\). Here the filament appears as a large dark channel. North is up. (Deng et al., 2002)

Figure 3. Formation of the filament: (left panel) the sunspot with fibril turning clockwise observed on September 8 with the MSDP, (right panel), the continuous filament turning around the sunspot observed on September 9 with the SVST.
• Transient, absorbing 'blobs'
  During periods of activation the 'blobs' are expelled at high velocities from the filament segment F1. The combined transverse motion and Doppler shifts seem to imply velocities between 10 and 14 km s\(^{-1}\). One sees evidence of either twisted motions or strong down flows in the fans of threads ("foot" of F1). The dynamics of both the blobs and the fine threads could suggest that the structures are inclined towards lower levels. The blobs jump over the apparent gap between two separate filament sections into the next segment (Filament F2). It is not known whether the field line that served to guide the blobs across the gap existed prior to the activation, or were formed as a result of the reconnection. We observed canceling flux close to the footprints of the filaments which could favor reconnection.

• Formation of the transient blobs
  One envisions three alternative scenarios concerning the formation of blobs; either (1) condensation out of thin, hot coronal material (theoretical models by Poland and Mariska (1986), Antiochos et al. (2000), (2) injection of 'cool' chromospheric matter from the chromosphere below, this mechanism would predict locations of up-welling plasma, which, however, are not observed in the present data, or (3) an increase in density in initially optically thin (in H\(\alpha\), 'cool' matter by compressions or by changing of direction of the horizontal fibrils. If the magnetic field lines are becoming inclined, the material falls towards low levels (as we have noticed in the observations). The blobs are expelled downwards in the field of gravity.

References: