The Role of “Magnetic Dips” and “Bald Patches” for a Filament Observed by SOHO and GBO

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Abstract. The studied filament was observed on Sept. 25, 1996, in Hα with the MSDP on the German VTT, Tenerife, as well as in Si IV with SOHO/SUMER. The 3-D magnetic configuration of the filament channel is reconstructed, using linear magnetohydrostatic (lmhs) extrapolations from a SOHO/MDI magnetogram, which is modified by a background magnetic component constraining a twisted flux-tube.

This flux-tube is deformed by the magnetic polarities observed with SOHO/MDI. The shape and location of the computed “dipped field lines” are in good agreement with the shape of the filament and its feet observed in Hα. Some “bald patches” (BPs) are present where the distribution of dips reaches the photosphere. We find observational signatures in Si IV brightenings of energy release at the locations of computed “bald patch separatrices”, defined by field lines which are tangent to the photosphere. We propose that the plasma is there heated by ohmic dissipation from the expected currents in the BP separatrices. The results show the importance of “dipped field lines” and “bald patches” in filament channels.

1. Observations of the filament channel

On September 1996, a quiescent filament channel was observed in the decaying remnant of AR 7986. The observations were obtained during a coordinated campaign between space instruments aboard SOHO, Yohkoh and ground-based instruments, in the context of the Joint Observing Program JOP 17 concerning the study of the “Dynamics of Solar Active Regions”.

The filament channel was simultaneously observed, in Si IV (EUV) with SOHO/SUMER at 11:23-11:52 UT, as well as in Hα with the MSDP spectograph on the German VTT in Tenerife at 12:14 UT (see Figure 1,b,c). The filament itself does not clearly appear in Si IV, however, some elongated brightenings are present in the filament channel. Some of them can be easily associated

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with magnetic polarities observed in the network at 12:53 UT with SOHO/MDI, while some others do not appear to be related to photospheric magnetic fields.

These elongated non-network EUV brightenings are nearly parallel to the inversion line above which the filament is observed in Hα. This reveals that they may be associated with highly sheared field lines in the filament channel. We try here to give an explanation for the UV emission of the plasma in these fine structures.

2. Magneto hydrostatic model

We have developed a model for filament and filament channels which describes the magnetic field in equilibrium. In this section we summarize our hypotheses and main result from previous work (Aulanier et al., 1999), and provide a short description of their application to the present problem.

2.1. What are “bald patches”?

Apart from the presence of magnetic null in the corona, separatrices can only be present in a magnetic volume when some field lines are tangential to the boundary. This is a particularly interesting case of separatrices which, so far, was not looked at systematically in magnetic configurations derived from observations. A theoretical study of the conditions for the appearance of field lines that present a dip which is tangent to the photosphere has been completed by Titov et al. (1993). They named the line formed by such tangent points as a “bald patch” (BP). Bungey et al. (1996) studied their 3-D topology, and have proposed that they could be related to low altitude (photospheric or chromospheric) reconnection.

2.2. The relationship between ‘bald patches” and filament feet

In Aulanier et al. (1998) a magnetic field configuration was extrapolated in the linear force-free field (lfff) assumption from a theoretical magnetogram, recon-
structured from a SOHO/MDI magnetogram which was combined with a sheared bipolar background field imposing a twisted flux-tube. The results were in accordance with many observational evidences, summarized in the review of Démoulin (1998).

The model was compared to the same filament channel observed on Sept. 25, 1996 in Hα with the MSDP. The lateral feet (or “barbs”) have been shown to be formed by a set of dipped field lines which are connected to the photosphere in small areas of parasitic polarities in the main background bipolar vertical field, forming BPs. The topology of the magnetic field in these regions derived from the model is summarized in Figure 2,a.

2.3. Model of the filament channel

The magnetic field is computed with the same method as in Aulanier et al. (1998), except that the extrapolation is made with the linear magnetohydrostatic (lmhs) assumption, using the analytical equations derived by Low (1992). This method takes into account the effects of plasma pressure and gravity, which is more relevant of the physical conditions in the chromosphere, especially for BPs. Using this method, the 3-D distribution of the computed dipped field lines has successfully been compared to the shape of the filament and its lateral feet, as well as some dark fibrils in the filament channel. Further developments can be found in Aulanier et al. (1999).

As in Aulanier et al. (1998,1999), we find that the lateral feet join the photosphere at BPs. The dips which join the photosphere are then the portion of some larger field lines (see Figure 2,b) which form arcades overlaying the twisted flux-tube (which has been imposed to model the filament body). These particular field lines form the separatrix surface associated with each BP.

3. Comparison of the model with observations

The coordinated observing campaign from which the data was obtained provided us with multi-wavelength observations of the filament channel. These have revealed that the features observed in Si IV for example were not the same as those observed in Hα. Moreover, some elongated EUV brightenings could not be related to magnetic network elements. As a consequence the necessity of using a magnetic model for interpreting these features was raised.

3.1. Heating of the plasma in “bald patch” separatrices

Unfortunately, our 3-D model of the magnetic field in the filament channel does not allow us to consider the thermodynamics. That’s why the thermal properties of the plasma have to be obtained from other models, in which the studied magnetic configurations are simpler (e.g. 2-D), but locally similar to ours.

Low & Wolfson (1988), Billinghamurst et al. (1993), Aly & Amari (1997) and Cheng & Choe (1998) have shown that strong currents can be generated at BP separatrices in 2.5-D magnetic configurations for typical coronal conditions. Their results clearly show that the distribution of the current density and the shape of the BP separatrix mainly depends on the applied photospheric footpoint motions as well as the heating or the cooling of the plasma in these regions.
Figure 2. Magnetic configuration associated with a "bald patch" (BP) in the filament channel. a) Sketch in 3-D of the model of the filament feet. The field lines tangent to the photosphere form the "bald patch" separatrix. The intersection of the separatrix and the local magnetic inversion line is the "bald patch" (BP). b) A view along the filament from above the photosphere, of the 3-D linear magneto-hydrostatic (lmhs) prominence model. The thin solid (resp. dashed) lines on the photospheric plane correspond to isocontours of the vertical magnetic field of 8 and 24 G (resp. negative values) taken from the SOHO/MDI magnetogram at 12:53 UT. The small thin lines correspond to the dipped portion of the field lines forming the filament, which are drawn up to a depth of 300 km. The long lines correspond to large sheared field lines forming arcades over the filament body, and rooted at bald patches (BPs). The portion of these lines lying between the photosphere and the altitude of 15 Mm are drawn thicker.

However, the physics of current accumulation and dissipation is expected to be significantly different at BP locations than in the corona, mainly due to the high density of the plasma at the photospheric/chromospheric level. One of these effects is to reduce the validity of line-tying at the BP. This point has been numerically studied by Karpen et al. (1991) and further discussed by Billingshurst et al. (1993). In a topological context, this effect broadens the BP separatrice, forming a less-concentrated current layer.

From all these studies, we expect that ohmic dissipation is likely to take place in BP separatrices.

3.2. An explanation of the non-network EUV brightenings

The shape and the orientation of the lower portions of the field lines which are associated with BPs (forming BP separatrices) can be correlated to Si iv elongated non-network brightenings observed with SOHO/SUMER (see Figure 3), while other field lines do not have any significant bright observational counterpart. The comparison of the model to the observations reveals that the length of these UV brightenings are in the order of 10 Mm. These UV features cannot be interpreted as a chromosphere-corona transition region (CCTR) as its width has been estimated to a few hundreds of km, theoretically (e.g. Vesecky et al.,
Bald Patches in a Filament

Figure 3. (a) Filament channel observed in Si IV by SOHO/SUMER, at 11:23-11:52 UT. (c) is a top view of the large field lines shown in Figure 2,b. The thickest parts (below 15 Mm) of some of these can be correlated to Si IV brightenings. The small circles show the computed BPs. (b) is an overlay of (a) and (c).

1979) as well as observationally (e.g. Vial, 1990).

As we have explained that high current densities can be present in BP separatrices (see previous Section), we propose that these elongated Si IV brightenings are formed by ohmic heating of the plasma along these sheared field lines, leading to a UV emission.

References