3-D MODELLING OF A FILAMENT OBSERVED IN Hα AND WITH SOHO

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ABSTRACT

In a previous paper (Aulanier and Démoulin 1998) we have shown that a twisted flux-tube is the most probable magnetic configuration supporting prominences. The model is in agreement with many observations, in particular the magnetic fields and the chirality properties in prominences. Moreover, prominence feet appear as a direct consequence of the parasitic polarities present in the filament channel. The aim of our paper here is to investigate further the link between the feet and parasitic polarities by modelling explicitly these polarities. We show that the prominence lateral feet appear naturally, above secondary photospheric inversion lines and we describe the observed morphological change of the feet as the parasitic polarities evolve.

This approach is applied to an Hα filament observed with the MSDP spectrograph on the German VTT in Tenerife and with SOHO/SUMER spectrometer, when SOHO/MDI magnetograms are available. We show that the shape of the filament is defined by the 3-D distribution of the dips in the computed magnetic configuration. Then we analyse the topology of the magnetic field. We find some correspondence between chromospheric brightenings, observed around the feet of the filament in the Ca II (8542 Å) line and the locations of the computed quasi-separatrix layers (QSLs), and between Si IV line brightenings and the footpoints of the field lines associated to the QSLs. This confirms the magnetic configuration we derived and shows that at a low level energy release is present in the complex topology of the filament configuration.

1. Filament Observations 25 September 1996

On Sept. 25, 1996, in the framework of SOHO SUMER/CDS JOP 017 (Dynamics of Solar Active Structures, DYNAC) Si IV (1393.76 Å), O V (1371.29 Å), Hα and CaII (8542 Å) observations of a filament have been obtained with the MSDP/VTT instrument (Mein 1991, Mein et al., 1998) and with SUMER (Wilhelm et al., 1995, 1997). The filament was observed in the dispersed bipolar remnant of NOAA 7986 close to disc center and went through repeated Disparition Brusques connected to CME events (Schmieder et al., 1997, van Driel-Gesztelyi et al., 1998).

We co-aligned the MSDP images with the MDI full-disc magnetograms. The MDI cadence was 90 minutes but between 07:40 UT and 12:53 UT no MDI map is available (Scherrer et al., 1995). In spite of this data gap during the MSDP observing hours (08:43 - 17:04 UT), we find that the evolution of the filament feet in the vicinity of moving and cancelling parasitic polarities is just as predicted by the model (Fig. 1). Not only the location of feet, but even the chromospheric structure along the filament channel (e.g. plages) show likeness between observation and model (see section 2).

We have a good series of SUMER images (90 arc sec × 75 arc sec) covering one footpoint of the filament during 5 hours (07:00- 12:00 UT). The scanning of this field of view was obtained in 30 minutes. We co-aligned these images with CaII and Hα images obtained with the MSDP (Fig. 2). Network brightenings in CaII and Si IV show a good correspondence. The Si IV bright feature close to or underlying the filament footpoint evolves during the observation time. It can be resolved as bright parallel fibrils.

2. Overview of the model

The filament is modelled with the assumption of a highly sheared linear force-free field \( \mathbf{B} \) (Aulanier & Démoulin, 1998). The main assumption of the model is to claim that dense plasma fills magnetic dips in the filaments, and consequently appears dark in absorption on the disk in Hα (Fig. 1). So the model deals with 3-D magnetic configurations that present some dips, at least above the main inversion line,
Figure 1. MSDP Hα and Ca II (8542 Å) observations (top and middle panels) co-aligned with SOHO/MDI magnetic maps overlaid by a Hα filament contour (bottom panel) show that the shape and orientation of the filament feet depend on the presence of parasitic polarities in the filament channel. Note the change in orientation of the middle-right foot and the changes in position and strength of the underlying polarities. North is 30 degrees to the left.

Figure 2. Co-aligned images of a section of the filament observed on Sept 25 1996 in Ca II, Hα lines (MSDP) and in Si IV line (SUMER) show brightenings around the filament foot, where magnetic polarities are present. The Si IV intensity image is overlaid by a Hα filament isocontour. North is up.
Figure 3. Observation and model of a filament. (a) MSDP observation in the Hα line center of a filament taken at 12:14 on Sept. 25, 1996 (b, c, d) are different views of the modelled filament (b) from the top, (c) from the south-east direction and (d) from the side as if it were observed at the limb. Full (resp. dashed) lines represent positive (resp. negative) photospheric vertical field. The scale of the axes is given in Mm. Thicker lines represent 1 Mm deep "dip" portions of field lines which can be filled with dense plasma and thus can hold the material of the filament, plages and dark fibrils along the filament channel. Note that the filament material is supported in a great number of very flat magnetic field line dips (c), which lie at different heights, thus it is not surprising that observers cannot "see" dips in filaments.

Figure 4. Comparison of the location of Quasi Separatrix Layers (QSLs) with chromospheric brightenings (a) MSDP Ca II (8542 Å) image with brightness enhanced – arrows point to weak brightenings associated with QSLs (b) top view of the modelled prominence including the QSL locations.
where the filament is supposed to be present. The plasma influence is not taken into account, as its effect on the magnetic field is supposed to be of second order. It is only considered as a tracer of the magnetic configuration. The dips are assumed to be filled up to a given height (1,000 km), which is consistent with a few pressure scale heights for typical physical parameters in filaments. Hence the morphology of a filament is likely to be driven essentially by the spatial distribution and the shape of magnetic dips.

For several reasons, it has been shown by the model that the best configuration for different observational aspects of filament channels is a slightly twisted flux tube. Parasitic polarities in the main bipolar filament channel lead to a perturbation of the highly sheared twisted flux tube. Some lateral dips appear at low heights, on each side of the main inversion line. They stand right above secondary inversion lines at the edge of these parasitic polarities. Their shape and their distribution lead to lateral and underlying foot structures, to some small isolated groups of dips which could be interpreted as dark fibrils or plages.

Using the method developed by Aulanier et al. (1998), we implement a theoretical background field, in order to impose the presence of a twisted flux tube. It is added to the observed magnetic polarities in the filament channel (SOHO/MDI), which we modelled by magnetic charges (Démoulin & Priest, 1992). The 3-D distribution of dipped field lines is in agreement with the shape of the filament observed in Ca II (see Fig. 3). The elongated brightenings observed in Ca II (MSDP) may be related to the quasi-separatrix layers (QSLs) associated with the filament topology (see Fig. 4). Si IV (SOHO/SUMER) faint elongated brightenings lying parallel to the filament axis may be interpreted as the heated footpoints of field lines anchored in the photosphere in the vicinity of the QSLs (Figs. 2 and 5) where the presence of high currents (Démoulin et al., 1996) and consequently Joule heating are expected.

3. Results

1. Bright regions observed in the Ca II and in Si IV match with the magnetic network.
2. Using extrapolation of the magnetic field we find a good match between computed the distribution of 3-D magnetic dips and Hα morphology.
3. The model based on quasi-separatrices suggests that much fainter flare-ribbon-like brightenings appear where quasi-separatrix layers intersect with the chromosphere, e.g. around parasitic polarities. The signature of such brightenings in Ca II is weak, but appears significant.
4. Some parallel brightenings also appear in Si IV (SUMER/CDS) in the vicinity of a parasitic/anomalous polarity (Fig. 2). These could be interpreted as parts of the field lines of the filament structure, close to low dips, heated by ohmic dissipation at the QSLs.

REFERENCES


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