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Force-Free Models of a Filament Channel In Which a Filament Forms

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Abstract. Over the years few examples of the formation of filament channels or filaments have been observed. One such example was recently seen by Gaizauskas et al. (1997). This paper constructs force-free models of the main stages of formation.

1. Introduction

The formation of the filament channel and filament occurred when a small activity complex emerged near to and interacted with an old remnant region. One day after the complex emerged a system of curved fibrils surrounded it (Figure 1a). The alignment signified the formation of the channel. On the fifth day of development flux from the complex cancelled with flux from the remnant region and a filament formed (Gaizauskas et al. (1997), Figures 2–4). Force-free models of the main stages of formation are now constructed (Mackay et al. 1997).

2. Fibrils Around the Activity Complex

To model the fibrils around the activity complex a numerical, constant-α , force-free field will be constructed from the magnetogram of the complex. A contour plot of the magnetogram is shown in Figure 1b. In the area considered there is good flux balance ($\sim 0.1\%$). Since there is such good flux balance and the patches of flux emerged together, this suggests that the activity complex in its early stages of development may be an isolated system. The initial modelling will, therefore, not include the remnant region. The best comparison between the field lines and fibrils (Figure 1b) was obtained for $\alpha = 3.0$. On the left-hand side the field lines bend around from the positive region to the negative region in a north-south direction and give a very good comparison to the fibrils. This topological agreement shows that the C-shaped arc of fibrils and, therefore, the filament channel is aligned with, and due to, the extended non-potential field of the complex. The channel is of sinistral type, since the magnetic field points to the left (when viewed from the +ve polarity side). The formation of a sinistral channel is due to currents that are parallel to the field (α +ve). If

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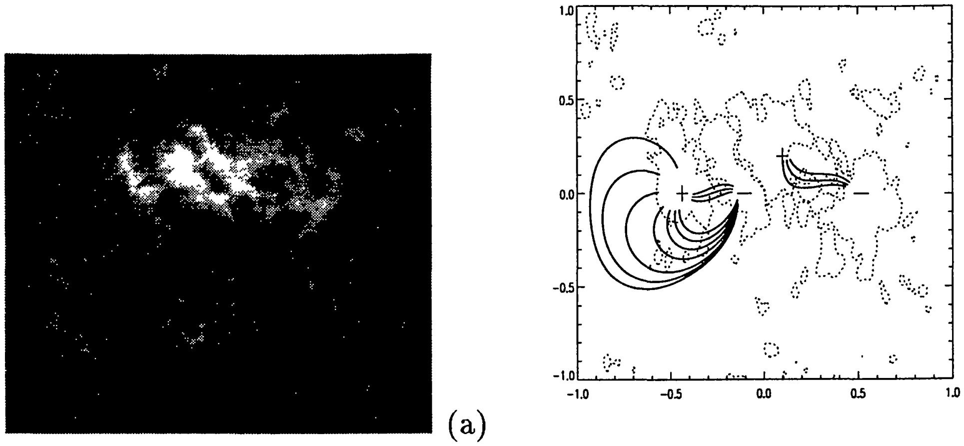


(a) (b)

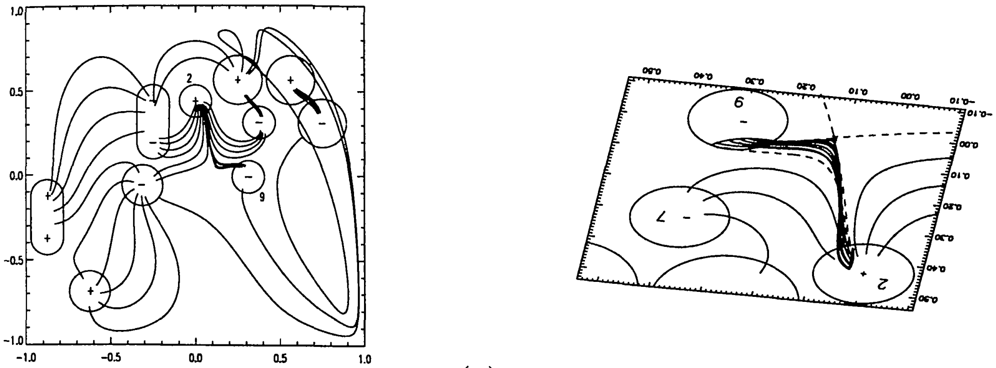
Figure 1. (a) Fibrils around activity complex in Hα. (b) Field lines deduced by model plotted on a contour of the magnetogram.

α had been negative the fieldlines would have closed south-north and a dextral channel produced.

3. Magnetic Structure of the Filament

On the fifth day of formation the remnant region and new region interacted. To model the magnetic structure of the filament, both of the regions are included. The field lines in the channel are computed for various values of α and the best representation of the filament is for $\alpha = 2.3$ (Figure 2(a)). The field lines that represent the filament form a thin straight structure that runs down the channel parallel to the polarity inversion line. Near one end there is a steep bend to the right as they enter a region of negative plage. The separatrix surface that encloses the flux connecting regions 2 and 9 is shown in Figure 2(b). The flux that represents the path of the filament forms a thin vertical sheet structure. Near source 2 the sheet is inclined at an angle to the vertical and becomes more vertical as it reaches further down the channel. It fattens out near the neutral point at $x = 0.12, y = 0.02$. Since the angle of inclination of the sheet changes, this gives the appearance of twist of the field lines. However, this is a projection effect and there is no twist in the structure.

The remnant region forms a necessary boundary on the east side of the channel on the day the filament forms. To show this only the activity complex and small plage region where the filament ends are included for this day. For no values of α do field lines connect between areas 2 and 9 along the path and height of the filament (Figure 3, $\alpha = 2.3$). The field lines have a geometry that represents the type of fibril structure that was seen on earlier days of formation. This suggests that the filament could not have formed in the channel with this same topology if the two regions had not interacted. Therefore, the remnant region and reconnections have an important role in the evolving topology of the channel on later days of formation.



(a) (b)

Figure 2. (a) Field lines in channel for $\alpha = 1.5 \times 10^{-8} m^{-1}$. (b) Separatrix surface of flux representing filament.

4. Hemispheric Pattern

The net helicity of the complex plays an important role in determining the chirality of the channel. A positive sign of α gave a sinistral channel. In the northern hemisphere 76% of active regions have net negative helicity (α -ve) and in the southern hemisphere 69% have net positive helicity (α +ve) (Pevstov et al. 1995). The channel analysed herein is now considered when the flux emerges on both the east and west side of the remnant region in each hemisphere. The sign of α is changed until a filament-type structure can be obtained as before. The results are shown in Figure 4. If the flux regions emerge to the west of the remnant region, a positive value of α is required to give the correct connectivity in the southern hemisphere and a negative value in the northern. Sinistral channels are produced in the southern hemisphere and dextral in the northern. If the opposite value of α is used in each case, a transverse structure is obtained across the channel and no filament channel created. On the east side a negative value of α is required in the southern hemisphere and gives a dextral channel; a positive value is required in the northern hemisphere to give a sinistral channel. Emergence on the west side needs the dominant sign of α in each hemisphere to get the correct structure while emergence on the east side needs the minority sign of α. The minority values of α give the wrong chirality, while the dominant values give the correct chirality for each hemisphere. Thus, statistically there is a much higher chance of having dextral filaments in the northern hemisphere and sinistral filaments in the southern hemisphere (Mackay et al. 1998).

5. Conclusions

In this paper force-free models of a filament channel and filament formation have been constructed. The modelling suggests that the formation of the filament channel is due to the emergence of the complex in a sheared state. Force-free models then give a good representation of the filament. The field lines that gave the best fit formed a thin vertical sheet of flux that connected down the channel.

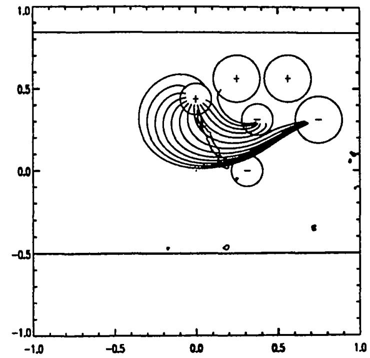


Figure 3. Field lines of filament channel when remnant region excluded.

A hemispheric pattern was then deduced, with dextral filaments dominating in the northern hemisphere and sinistral filaments in the southern. Helicity may, therefore, have an important effect on the hemispheric patterns of filaments.

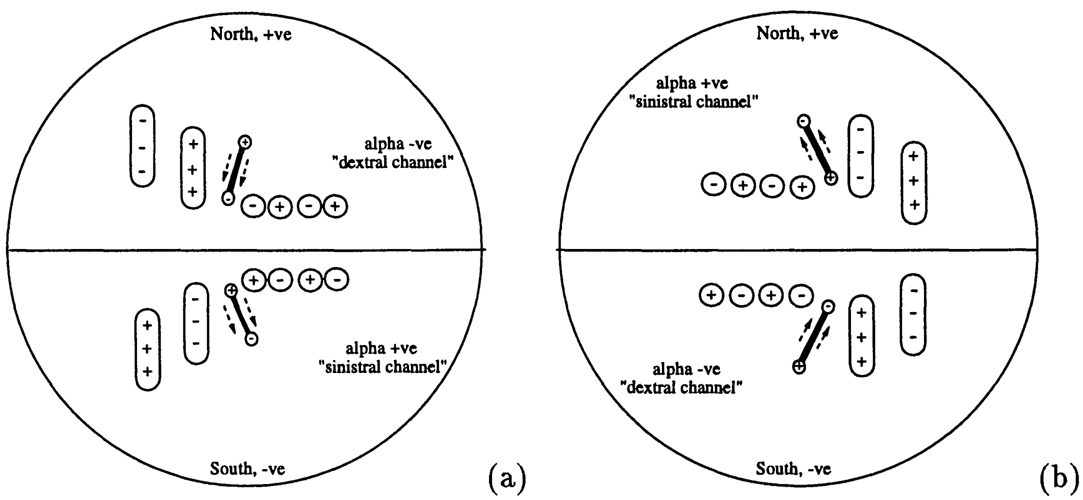


Figure 4. Filament channel formation (a) west and (b) east of remnant region.

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