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EVOLUTION OF ACTIVE REGIONS LEADING TO FLARES

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Abstract

We model observed longitudinal magnetic fields obtained in Potsdam, Meudon, MSFC Hunstville by a series of magnetic sources located below the photosphere. Hα flare kernels are found situated on intersecting separatrices (surfaces delimiting regions of different magnetic connectivities). We deduce that energy release occurs mainly at the separator by magnetic reconnection. Evidence for both neutralized and un-neutralized currents are observed in different flaring regions. Moreover we have found two photospheric currents of opposite sign, linked in the corona by field lines, at the border of flare kernels.

1. Introduction

The occurence of flares is related to the presence of various special irregularities in the magnetic field configuration such as strong magnetic shear, emerging, cancelling flux, parasitic polarity, interaction of sunspot groups. More recently the importance of the magnetic topology has been pointed out (Baum and Brathenal 1980, Hénoux and Somov 1987). Then Gorbachev and Somov (1988) investigated the link between observed flare ribbons and the magnetic topology of the corresponding active region. Since then, an increasing number of investigations have clearly related the separatrices with the location of Hα flare ribbons. Moreover we have found in such configurations concentrated electric currents near the separatrices. Here we will show how currents may be formed, then we discuss special cases showing the topological relationship between Hα kernels and current density cells and separatrices.

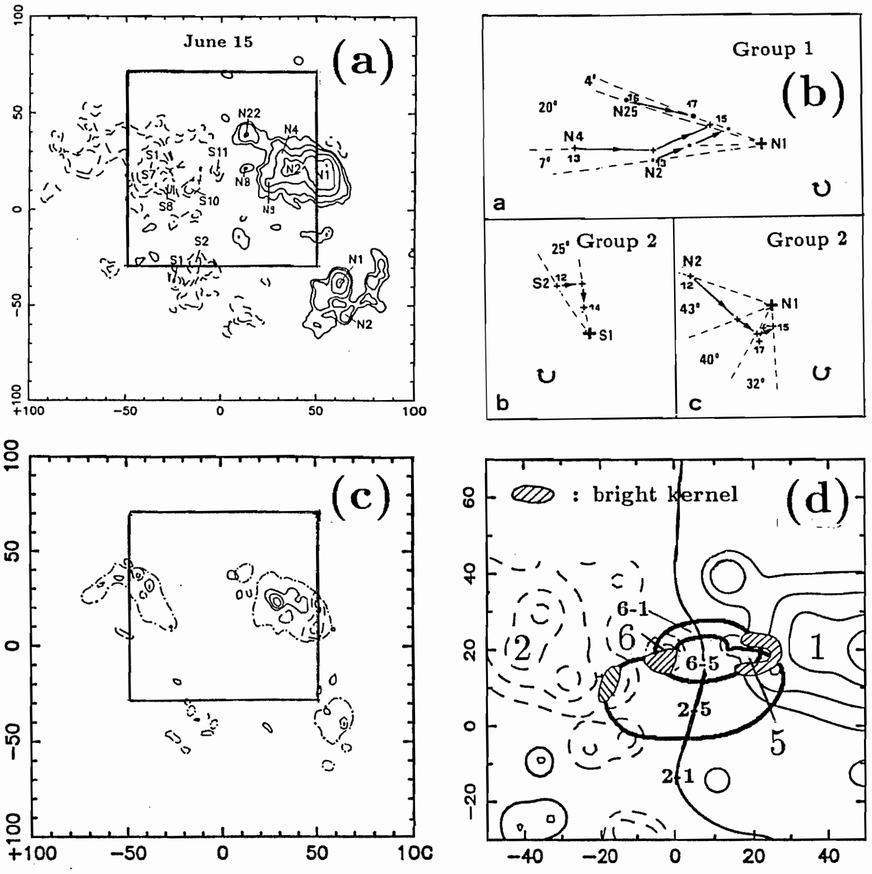

Fig. 1. (a) Meudon longitudinal magnetic map of AR 2511 and 2512 observed on June 15 1980 at 06:07 UT. The isocontour levels are ±100, 200, 500, 1000G. (b) Relative motions of the satellite spots versus the main spots showing twisting motions (van Driel-Gesztelyi *et al.* 1991). (c) Density of the vertical current computed from MSFC magnetograms (isocontour levels ± 3, 6, 10 mA/m^2). In the leading spot we notice the presence of positive and negative currents. (d) Longitudinal magnetic field for a model using subphotospheric magnetic charges (they form two bipoles: 1-2, 5-6). The new emerging flux (bipole 6-5 corresponding to spots S11 and N8 in (a)) is at the origin of the flare. The main Hα kernels are related to the two drawn separatrices. We have the configuration (− −/++).

2. How the currents are formed?

Magnetic energy can be accumulated in the corona by several mechanisms. Firstly twisted flux tubes can emerge from the convection zone; Van-Driel *et al.* (1994a) show the importance of such a possibility in a particular case. Secondly photospheric large scale motions can store progressively energy in the corona; the rotation of sunspots during few days is given as an exemple in Fig.1.b. Large scale shearing motions as it was observed in the AR 6659 of June 1991 (Schmieder *et al.* 1994) are also good conditions to create currents. In case of emerging twisted flux, we have neutralized currents and the configuration near the neutral line is nearly potential (Fig.1). With large scale motions we have un-neutralized currents (Melrose 1991). According to the observations (Figs.1, 2), both cases can occur. Finally it is worth to note that this study is limited by the accuracy of the transverse field measurements and the 180^0 ambiguity and that Faraday rotation has to be taken into account.

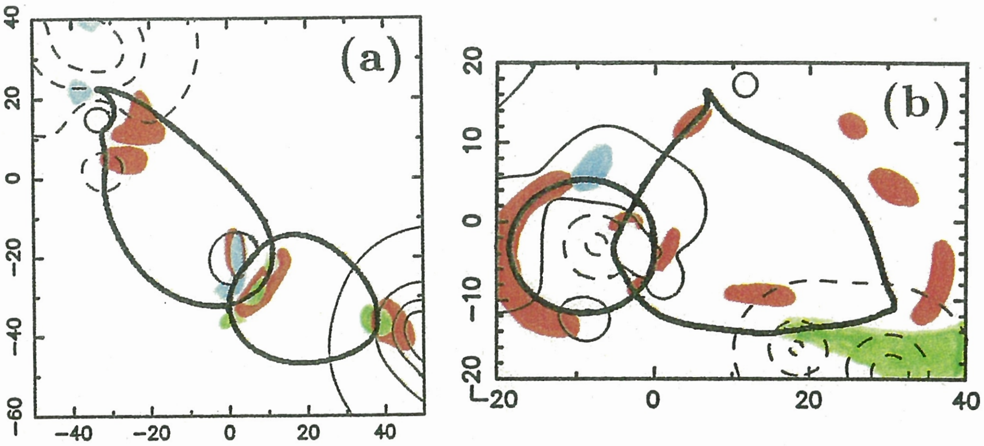

Fig. 2. Vertical currents ($J_z > 0$ blue, $J_z < 0$ green), Hα flare kernels (red) and their location versus separatrices (thick lines) on (a) April 7, 1980 with the configuration (−/+/−/+) (Mandrini *et al.* 1993, Wilkinson *et al.* 1992), (b) June 23, 1989 with a configuration in S shape (van Driel *et al.* 1994b)

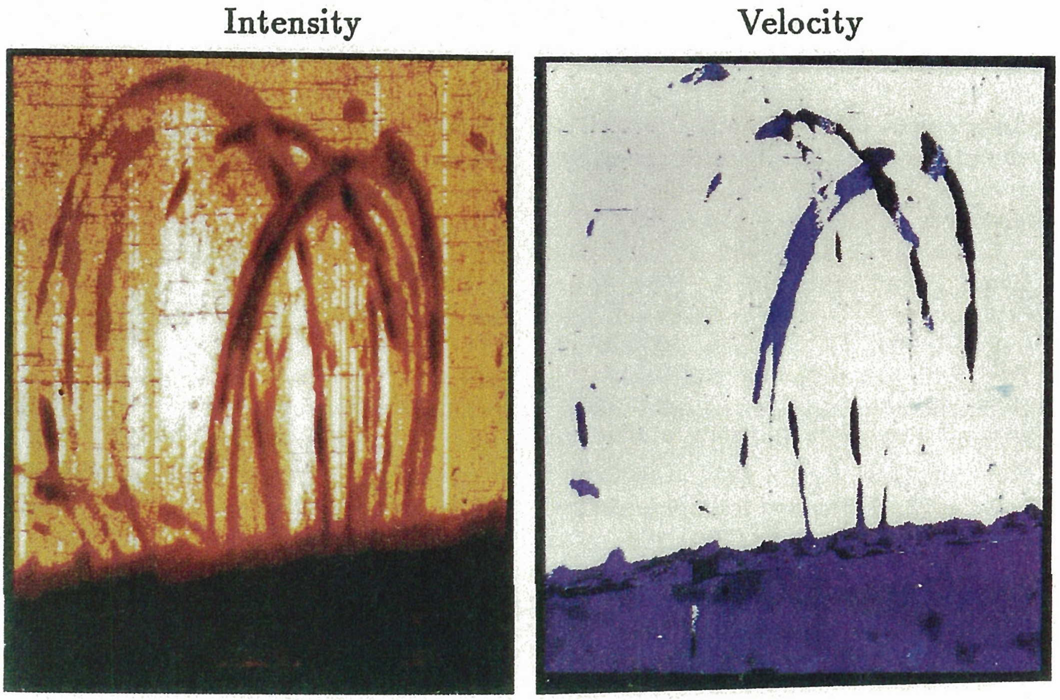

Fig. 3. Arcades of post-flare loops (MSDP images obtained at Pic du Midi on June 26, 1992).

3. Magnetic Topology of Active Region

Flare models have to explain how and where magnetic energy is released in solar flares. Post-flare loops are formed between the flare ribbons during the development of flares and show directly the link between ribbons even when they are distant by more than 100 Mm (Fig.3). The 2D model of reconnection based on the Kopp and Pneuman configuration and proposed by Forbes and Malherbe (1986) has been generalized to 3D (Démoulin *et al.* 1993). To the X reconnection point in 2D corresponds in 3D the separator which is the intersection of 2 separatrix surfaces separating topologically distinct magnetic flux. Because of the frozen-in condition current sheets are created on the separatrix surfaces or twisted flux tubes are approaching the separator when the magnetic configuration is deformed. At the separator, field lines of 4 connectivity cells can interact, therefore it is a privilege location of magnetic energy release (Fig.1.d). This is obvious for 3D quadrupolar regions (Fig.2.a-similar to theoretical 2D configuration) but it is also possible for a bipolar region with a S shaped inversion line (Fig.2.b). Even for bipolar regions with a near potential field and a straight inversion line where a simple arcade topology seems at first more appropriate and where flaring is not expected (Fig.1), magnetic interaction can take place in the separator region.

4. Conclusion

We have shown the importance of the magnetic topology in active regions for the occurence of flares. Current sheets or twisted flux tubes created by subphotospheric motions accumulate energy which is released by reconnection of magnetic field lines at the separator. As the time is going on, the two ribbons are going away from each other and the post-flare loops increase in extension. It seems that the separatrices move, occupying a certain volume during the whole flare. 3D MHD analysis versus time of such configuration does not exist presently. The extrapolation is limited to linear force-free field valid in moderately sheared configurations.

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