AN EXAMPLE OF THE CANCELLATION OF MAGNETIC FIELDS DURING THE DECAY OF AN ACTIVE REGION

J. I. GARCÍA DE LA ROSA,* M. A. ABALLE, and M. COLLADOS*

Instituto de Astrofísica de Canarias, 38200 – La Laguna, Tenerife, Spain

(Received 20 October, 1988; in revised form 1 August, 1989)

Abstract. A case of cancellation of magnetic fields is observed during the decay of a small active region. Three different sources of information were simultaneously used: high resolution magnetograms, chromospheric CaII filtergrams and transverse velocity fields.

A magnetic structure is apparently dragged to the network by the supergranular velocity field while it splits into two. There, they meet another structure with opposite magnetic polarity. After a period of coexistence, the magnetic pairs vanish, leaving no trace of either magnetic or chromospheric structures.

1. Introduction

Although large scale measurements indicate that magnetic flux is massively removed from the photospheric level, at a rate of $10^{22}$ Mx day$^{-1}$ (Howard and Labonte, 1981), unquestionable observations of the removal process are insufficient to account for the large detected rate of flux disappearance. Several mechanisms have been proposed to explain the removal of magnetic flux from the photospheric level (Zwaan, 1978). Except for the pure submergence, the others basically rely on the probably frequent encounter between opposite polarity fields, both above and below the surface. According to Spruit, Title, and Van Ballegooijen (1987), the subphotospheric encounter leads to the formation of a U-loop, which develops kinds that float to the surface where they decay and disappear.

Another possibility of flux disappearance takes place after the reconnection of opposite polarity field lines in or above the solar surface. This leaves a flux loop, which can be pulled back below the photosphere (submergence) by hydromagnetic forces (Priest, 1987). This mechanism would explain the observed collision and further cancellation of opposite polarity fragments of varied origins: network elements, halves of ephemeral regions and intra-network fields (Martin, 1988). However, the previous observations mainly refer to the quiet Sun and, therefore, it remains questionable if this same mechanism is relevant during the decay of active regions, where larger magnetic elements are involved. So far, two observations have been reported on the disappearance of magnetic flux on decaying active regions (Zirin, 1985; Martin, Livi, and Wang, 1985). In both cases, parts of the active region itself were cancelled with fragments of the network. The present observation shows a further example of magnetic field cancellation during the decay of an active region: random collision between opposite polarity

* Visiting astronomer, Sacramento Peak Observatory, operated by the Association of Universities for Research in Astronomy, Inc. under contract AST-78-17292 with the National Science Foundation.

fragments and further slow disappearance of the pair. Our evidence derives from a triple set of high resolution observations: magnetic, dynamic (transverse photospheric motions), and chromospheric.

2. Observations

Observations were carried out at Sacramento Peak Observatory (U.S.A.) on October 31, 1984 on the decay of the small active region NOAA 4588 which had an estimated flux of $3 \times 10^{20} \text{ Mx}$. The observation period runs from 15:15 UT to 23:30 UT with a gap of almost 1.5 hours from 16:13 UT. A modified set up of the Universal Birefringent Filter of the Vacuum Tower Telescope (November, 1984) was used to obtain the raw data. Bursts of five pairs of simultaneous filtergrams, $A$ and $B$, were obtained every minute on the magnetic line 6102.7 Å. Their addition ($A + B$) produces a continuum intensity picture and their subtraction ($A - B$) a magnetogram. This rather tedious reduction process, involving digitization, correlation and operation of pairs of images, was carried out at the Instituto de Astrofísica de Canarias. An improvement of the magnetic signal was performed by comparing two contiguous magnetograms (5 s apart) to eliminate spurious structures. It is worth mentioning that this kind of observations produces strictly simultaneous magnetic and photospheric intensity data.

In occasional moments of superb seeing, the short exposures (0.1 s) allowed us to approach the diffraction limit of the telescope ($\sim 0.2''$). As it is usual for the magnetographs using the Leighton technique, the high spatial resolution is not accompanied by a proper magnetic calibration. The resulting poor magnetic sensitivity prevents us to carry out a quantitative study.

The local cross-correlation of successive (1 min interval) photospheric pictures, following the method by November and Simon (1988) was also used to find the superficial velocity field, which manifests itself through its drag upon the granules.

Complementary CaII-K filtergrams were also simultaneously obtained of the same region with a 1 minute interval.

3. Description of the Data

The preceding part of the active region is made of a decaying pore of + polarity which feeds an enhanced network. Large scale magnetograms (Solar Geophysical Data reports) show this $p$-part located in an opposite polarity magnetic background to which magnetic inclusion $A$ (Figure 1(a)) probably belongs.

Our magnetograms show the straight motion of feature $A$ over a long distance (some 5000 km) to meet the opposite polarity structure $B$, located at the network. After a period of coexistence, they completely disappeared. Although our observations do not allow quantitative magnetic measurements, the size of both features $A$ and $B$, slightly larger than 1", suggests to us to consider them as magnetic knots with a flux content of $10^{19}$ Mx (Beckers and Schröter, 1968).
Fig. 1. Evolution of the decaying active region NOAA 4588 on October 31, 1984. Below are four magnetograms (black = + polarity) where features A and B have been labeled. Above is a simultaneous Ca II filtergram. Superimposed on the first magnetogram is the velocity field. The corresponding time for each pair is: 1a, 16:00 UT; 1b, 17:45 UT; 1c, 20:11 UT; and 1d, 23:04 UT.
Fig. 1c.
Fig. 1d.
The long distance journey of $A$ towards $B$ is almost entirely justified in terms of the observed photospheric velocity fields. As shown in Figure 1(a), arrows locally corresponding to the velocity vectors at the photosphere outline a supergranular cell centered slightly below and to the left of the pore. Near-magnetic feature $A$ the velocity vector pointing towards the network has the following components: $v_x = 0.3 \text{ km s}^{-1}$ and $v_y = 0.7 \text{ km s}^{-1}$ ($v = 0.76 \text{ km s}^{-1}$). As can be seen in the magnetograms, the velocity of feature $A$ closely agrees, both in direction and amplitude, with that photospheric velocity, strongly suggesting that the $A$ feature was dragged to the network by the supergranular motions.

At the network, feature $B$ remains in a fixed position, or even moves slightly towards $A$, despite the clear motion in the opposite direction of the large structure to which it formerly belonged. The behaviour of pole $B$ and its persistent attachment to pole $A$ (Figure 1(b)), observed during at least 3 hours, is difficult to explain in terms of the measured average photospheric velocity. However, departures from the average velocity are possible and they would eventually explain the behaviour of pole $B$. By 17:45 UT, pole $A$ shows some degree of fragmentation which precedes its later disappearance, in agreement with Martin, Livi, and Wang (1985). Lastly, around 22:00 UT, some 4.5 hours after the arrival of pole $A$ to the network, the features have completely disappeared, both from the magnetograms and filtergrams (Figure 1(d)). The inspection of the Ca I ff filtergrams show no signal of activity at the chromospheric level during the whole period.

4. Discussion

A possible scenario to explain the mentioned observations is the following: an isolated magnetic feature of the pre-existing background field is convectively dragged to a supergranular border. There, it eventually collides with an opposite polarity element of the enhanced network, produced by the decay of a small active region. The first collision and reconnection between the fields, possibly takes place high in the corona, when the magnetic poles (footpoints) are still far apart. Priest (1987) suggests that the neutral point of the reconnection is at a height of the order of the separation of the poles and, as long as the footpoints approach, this level moves towards the chromosphere. In the frame of the present study the concept of reconnection at high levels is purely speculative and unsupported by our own observations. It is however sustained, both by theoretical arguments and by more appropriate observations, like those of Marsh (1978) who observed Hα microflares from where he inferred reconnection.

The failure of Martin, Livi, and Wang (1985) to detect chromospheric fibrils joining cancelling features casts doubts on the process of submergence or rather suggests a lower level (some hundred kilometers above the photosphere) for the reconnection (Martin, 1989).

As a result of the reconnection, $\Omega$-loops connect pole $B$ to both poles $A$. The further approach of the footpoints proceeds until the magnetic tension of the curved line ($B^2/\mu R_c$; $R_c$: curvature radius) surpasses the buoyancy force ($B^2/2\mu A$; $A$: scale height),
and the submergence starts. At that moment, the distance between the footpoints at the photospheric level: \( L \approx 2R_e \), is of the order of \( \sim 4A \). With \( A_{\text{phot}} \approx 500 \text{ km} \), the value of \( L \) roughly agrees with the observed distance between the poles (Figure 1(c)). The process of subsequent fading and disappearance of the poles could be explained as a progressive inclination and complete submergence of the loops.

Despite the variety of data supporting this interpretation, there are some missing clues which prevent us to reach a final conclusion: (i) The observation of coronal activity (X-ray bright points) or microflares associated with the reconnection; (ii) the observation of photospheric downflows between the magnetic poles, associated with the submergence of the \( \Omega \)-loop; and (iii) the observation of chromospheric fibrils joining cancelling features.

Further observations including Dopplergrams and Hα filtergrams would help to clarify the role played by submergence on the removal of magnetic flux from the photosphere. As suggested by García de la Rosa (1989) the best candidate place to look for massive removal of magnetic flux is at the intermediate active regions of a Complex of Activity (of the kind described by Bumba and Howard, 1965).

**Acknowledgements**

The authors gratefully acknowledge the staff of the VTT (Sacramento Peak) and specially Dr L. J. November for their help during the observations.

This work has been partly funded by the CAICYT under project 84/0905.

**References**