OBSERVATIONAL EVIDENCE FOR VARIOUS MODELS OF MOVING MAGNETIC FEATURES

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Abstract. We present new measurements of Moving Magnetic Features (MMFs) based on the observations of the active region NOAA 5612 made at Big Bear Solar Observatory (BBSO) on 2 August, 1989. We check the existing theoretical models against our new observations and discuss the origin of MMFs conjectured from the deduced observational constraints.

1. Introduction

Moving Magnetic Features (MMFs) are small magnetic elements which move out continuously from sunspots and appear in both polarities. Only a few theoretical interpretations have been proposed on their real identity. Harvey and Harvey (1973) first suggested that MMFs could be field lines detached from a decaying spot. As they move out, they are undulated by granulation and their rising and submerging parts are observed as bi-polarity. A competing view is that MMFs are closed magnetic loops rather than twisted field lines and thus their bi-polarity is due to the pairs of apparent opposite polarities of closed loops (Wilson, 1975, 1986; Spruit, Title, and van Ballegooijen, 1987). Obviously high-resolution observations of MMFs will be critical to such theoretical interpretations.

In the present paper, we report new observational information on MMFs and check the proposed theoretical schemes against our observation. In Section 2, we summarize and discuss the recent high-resolution observations of MMFs. Discussions of the nature of MMFs will follow in Section 3.

2. Observation

The data obtained are the high-resolution magnetograms (resolution ≤ 2") of the sunspot in active region NOAA 5612 obtained at Big Bear Solar Observatory (BBSO) on 2 August, 1989. The position was 30° E 378° S, and hence the heliocentric angle of 22° has been taken into account in correcting the projection effect on the velocity-measurement. This spot was so large (diameter ≈ 20000 km) that a detailed dynamic configuration of MMFs could be obtained together with that of Evershed flow. Figure 1 shows two magnetogram pictures of the active region taken with a time interval of two-and-half hours. We marked MMFs with ovals and specified them by numbers to identify and trace them in the subsequent frames. As seen in the figure, most of the magnetic elements occurred in pairs of opposite polarity which are closely spaced. In

Fig. 1. Two frames of NOAA 5612 in longitudinal magnetic field taken at 17:17:43 UT and 19:54:03 UT on August 2, 1989. Only a section in the limbward side of the active region is shown together with the linear scale of the magnetogram. We mark some MMFs with ovals and indicate their paths with dashed arrows. They are observed to appear in pairs of opposite polarity and to flow out of the penumbral boundary, mostly along the dark filaments.

In the following, we would like to concentrate our discussion on the four pieces of observational information which are most relevant to the theoretical interpretation of the MMFs (see, for other details, Zirin and Wang, 1991).

First, on a large field of view, the bipolar pairs are observed to be randomly oriented. If these bipolarity pairs were the footpoints of a long field line as suggested by Harvey and Harvey (Figure 3(b)), they would appear to lie in a radial direction. On the other hand, loop models proposed by Wilson (1975) and Spruit, Title, and van Ballegooijen (1987) may explain this fact rather naturally, because the closed loops are all separated from each other and thus can be oriented randomly. If the closely-spaced pairs of opposite polarity MMFs are really closed loops, then the loops must be of a size comparable to their spacing and of a thickness represented by the size of each magnetic element in a polarity. When MMFs show up very near the penumbral edge, they have a thickness comparable to the width of filaments (~1"–2"). As they move outward, the thickness of a magnetic element soon expands to about 2"–5" (Figure 1). There are, though, a few monopoles in Figure 1, in the sense that their pairs cannot be found nearby. These would then be thought of as the occasional appearances of only one end of a loop at the seeing level of a magnetogram, as the loop is slightly displaced around that level.

Second, most MMFs are seen to flow out from the penumbral edge along dark filaments. The examples are the MMFs numbered 1, 2, 3, and 4 in the first frame of Figure 1, as indicated by the dashed arrows. Here we note that due to the apparent polarity reversal of the penumbral fields, the dark feature in the outer penumbral region