Evolution of Small-scale Magnetic Features Streaming-out from a Pore

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Abstract. We present results from observations of Moving Magnetic Features (MMFs) of different types observed on region NOAA 11005. The analyses is based on spectro-polarimetric data obtained with the Interferometric Bidimensional Spectrometer (IBIS) at various spectral ranges. We present new evidences of bipolar MMFs observed to stream out from pores and show the temporal evolution of magnetic, dynamic and morphological properties of these features.

1. Introduction

Moving Magnetic Features (MMFs), the small-scale magnetic concentrations usually observed streaming out from penumbral regions, are thought to play an important role in the dispersal of the magnetic field during the decay phase of active regions. MMFs are classified into various types, depending on the magnetic and dynamic properties of the observed features. In particular, type I consists of bipolar structures, with typical velocities of \( \sim 0.5 - 1 \text{ km s}^{-1} \); type II of single magnetic elements, having the same polarity of the sunspot from where they are seen moving away, and having velocities of \( \sim 0.5 - 1 \text{ km s}^{-1} \); type III of single magnetic elements, having opposite polarity with respect to the relevant sunspot, and velocities in the range \( \sim 2 - 3 \text{ km s}^{-1} \) (Shine & Title 2001).

Recent analyses of MMFs characteristics have demonstrated that some MMFs are a manifestation of the penumbral Evershed flow in the sunspot moat, supporting earlier results about the magnetic connection between MMFs and the sunspot penumbra (see e.g. Zhang et al. 2003; Sainz Dalda & Martínez Pillet 2005; Cabrera Solana et al. 2005; Kubo et al. 2007). However, MMFs of different types were also observed streaming
out from naked spots, i.e. spots without penumbral regions (Harvey & Harvey 1973; Zuccarello et al. 2009).

Here we present results from observations of Moving Magnetic Features of different types observed streaming out of a pore.

2. Observations and data reduction

NOAA 11005 was observed on October 15th 2008 with the IBIS (Cavallini 2006) at DST/NSO at the beginning of its decay phase. The data set consists of 80 scans, taken in 70 min at the Fe I (617.3 nm) and Ca II (854.2 nm) lines, with a temporal cadence of 52 s. Both lines were sampled at 21 spectral points; 6 polarimetric states were acquired at each point for Fe I line. The Field of View (FOV) is \( \sim 80'' \times 40'' \) and the scale is 0.167''/pixel. White Light (WL) and G-Band (GB) counterparts were acquired imaging approximately the same FOV of the spectro-polarimetric data. The pixel scale of WL and GB images is 0.083'' and 0.051'', respectively. The data were reduced following standard procedures (Cauzzi et al. 2008; Viticchié et al. 2009). Atmospheric aberrations were estimated on WL and GB images through the MFBD technique and were then compensated for on spectro-polarimetric images through image de-stretching. The magnetic flux was estimated applying the Center of Gravity Method (COG) to left and right circular polarization signals. Line of Sight (LOS) velocities were computed from Doppler shifts of Stokes I profiles.

3. Results

The FOV includes the leading pore and part of a plage region (visible at the bottom right in Fig. 1) of NOAA 1105. Based on magnetic flux maps, we identified MMFs of various types streaming out from the pore; some of these features are shown in Fig.1 and are labeled P or N depending on their polarity. Features N have same polarity as the pore and migrate toward the plage region; features P have opposite polarity to the pore and migrate preferentially to the opposite direction, tracing the trajectory for new MMFs (cfr P1 and P2).

P1 feature shows characteristics that are common to the other observed features. As shown in Fig. 2, it originates in a region of strong polarity gradients, at the edge of the observed pore (1st and 2nd col.); increases in size and looses spatial coherence as it evolves (4th col.); brightening in Ca and G-band is delayed with respect to the occurrence of the MMF (5th col.); travels at a speed of \( \approx 1 \) km/s and it slowly dissolves (6th col); a new MMF (P2) streams out from the same location and follows a similar trajectory (7th col.). This is also illustrated in Fig. 3, which shows the temporal evolution of various quantities measured at the maximum value of magnetic flux of P1. We found that all the Stokes V profiles show asymmetric lobes and are mostly centered at line core; in agreement with this finding, Doppler analysis reveals modest LOS velocities (< 500 m/s).
Figure 1. Top Left: detail of MDI magnetogram imaging the AR analyzed and showing the FOV of IBIS. Top Right: 30″×30″ sub-field of the G-band data. Bottom Left: sub-field of Total Linear polarization signal derived from the Stokes profiles of the Fe I line. Bottom Right: sub-field of the COG magnetic flux map, saturated at ±100 Gauss, showing the MMFs analyzed.
Figure 2. Sub-fields derived from various data centered at feature P1 at different times. From top to bottom G-band, magnetic flux, total Circular and Linear Polarization signals, Ca II core and wing intensities.

Figure 3. Temporal evolution of analyzed properties of P1 (see text). Left panel: magnetic flux, total linear polarization, G-band and CaII wing contrast. Right panel: Stokes V profiles.
4. Conclusion

We have shown the temporal evolution of various quantities measured on type III MMFs observed to stream out from a pore on region NOAA 1105. The results are based on observations performed with the Interferometric Bidimensional Spectrometer (IBIS) in spectropolarimetric mode. They provide new evidences of features observed on regions lacking in penumbral filaments and new measurements of MMFs properties obtained with un-precedent temporal cadence. These results provide new observational inputs for improving current models of active regions evolution and decay.

References