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Small-scale magnetic and velocity inhomogeneities in a sunspot light bridge

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Abstract

High resolution spectro-polarimetric observations of a sunspot light bridge by *Hinode*, reveal small-scale inhomogeneities in the magnetic field and velocity. These inhomogeneities arise as a consequence of a weak, secondary lobe in the Stokes *V* profile which have a polarity opposite that of the sunspot and very large (>5 km s^{-1}) Doppler velocities of both signs, suggesting two distinct types of magnetic anomalies. These two sets of inhomogeneities are highly time-dependent and appear exclusively in the upper half of the light bridge and only after the light bridge is completely formed. Both sets of inhomogeneities appear as patches and can be present independent of the other, next to one another, or spatially separated in a single scan. A two-component inversion of the corresponding spectral profiles indicates that the inhomogeneities occupy a very small fraction, amounting to less than 10%, of the resolution element. These structures are likely driven by small-scale magneto-convection where they could further interact with the overlying sunspot magnetic field to produce reconnection jets in the chromosphere.

Keywords: Sunspots; Light bridges; Magnetic fields; High resolution; Photosphere; Spectro-polarimetry

1. Introduction

Light bridges (LBs) are conspicuous, bright structures in the umbrae of sunspots and pores and are typically present during the formation or fragmentation of spots (Garcia de La Rosa, 1987). LBs can be regarded as either field-free intrusions of hot plasma in the gappy umbral magnetic field (Parker, 1979; Choudhuri, 1986), or manifestations of large-scale magneto-convection (Rimmele, 2008) in umbrae. The latter scenario is now widely, although not universally, accepted as being responsible for the fine structure and energy transport in sunspots. This in particular has been made possible from the advancement in numerical simulations (Schüssler and Vögler, 2006; Cheung et al., 2010), as well as high resolution observations from both ground and space (Ortiz et al., 2010; Rouppe van der Voort et al., 2010; Ruiz Cobo and Asensio Ramos, 2013; Scharmer et al., 2013; Pozuelo et al., 2015). The interaction between umbral dots and intruding penumbral filaments, typically seen during light bridge formation (Katsukawa et al., 2007; Louis et al., 2012), lends further credence to magneto-convection in sunspots. In this sense, LBs represent a natural location where convective disruptions are more vigorous and apparent than in other parts of a sunspot. Such a disruption could produce magnetic inhomogeneities that might explain the pronounced chromospheric activity in LBs as reported in Louis et al. (2008) and recently in Louis et al. (2014a). In this paper I analyse small-scale magnetic anomalies in a sunspot LB using high resolution observations from *Hinode* (Kosugi et al., 2007).

2. Observations

High resolution observations of NOAA AR 11271 were acquired by the *Hinode* spectropolarimeter (SP; Ichimoto

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et al., 2008; Lites et al., 2013) on 2011 August 18–19. During these two days the SP took 14 scans (nine scans on August 18 and five scans on August 19) of the active region in the fast mode, each scan covering a field of view (FOV) of nearly 75″ × 82″. On August 18, the scans were taken at 11:00–11:16 UT, 11:20–11:36 UT, 11:40–11:56 UT, 18:12–18:28 UT, 18:32–18:48 UT, 18:52–19:08 UT, 19:12–19:28 UT, 19:32–19:48 UT, and 19:52–20:08 UT. The five SP scans on August 19 have a similar scan time of 16 min starting at 08:05 UT and ending at 10:21 UT. In the fast mode, the SP recorded the four Stokes profiles of the Fe I lines at 630 nm with a spectral sampling of 2.15 pm, a step width of 0″.29, and a spatial sampling of 0″.32 along the slit. The Level 0 data were reduced using standard routines included in the Solar-Soft package (Lites and Ichimoto, 2013). The active region traversed heliocentric angles of 42° to 30° between August 18 and 19.

3. Results

3.1. Anomalous Stokes profiles in the light bridge

Fig. 1 shows a small LB in the south-eastern half of the leading sunspot in AR 11271 that forms during the early part of August 18. There is also an indication of a pronounced intrusion of penumbral filaments at the northern part of the umbra-penumbra boundary (white rectangle in Fig. 1). The tip of these filaments extend into the umbra as diffuse umbral dots (left panel of Fig. 1). Nearly 6.5 h later a second LB forms, dividing the umbra into two nearly equal halves with one of its ends coinciding with the intruding penumbral filaments described above, while its other end connects to the smaller southern LB. The larger LB in the sunspot is the object of interest for this paper. There are frequent transitions between formation and fragmentation over a period of 3 days, but the LB remains intact between the latter half of August 18 to the end of August 19 (Fig. 8 of Louis et al., 2014b).

A smaller FOV consisting of the upper part of the LB is shown in Fig. 2, wherein the Stokes *V* profile at every pixel has been overlaid on the continuum map. Prior to the formation of the LB, the profiles consist of normal, anti-symmetric lobes (top left panel of Fig. 2). However, after the LB is formed, there is a clear indication of two different kinds of anomalous profiles present in it. These are indicated in blue and red colors in Fig. 2 and will henceforth be referred to as blue profiles (BPs) and red profiles (RPs). These anomalous profiles comprise a weak, but discernible, second component and their name serves to distinguish their position with respect to the primary lobes of the *V* profile. It is to be noted that, although both sets of profiles have opposite Doppler (velocity) signatures, their signs are opposite to the primary lobes of the *V* profile. This would suggest offhand that the BPs and RPs have a polarity opposite that of the sunspot (see Section 3.2).

The amplitude of the secondary lobe in Stokes *V*, corresponding to the weak component in the BPs and RPs, is less than 5% (e.g. bottom panels of columns 1 and 2 in Fig. 3). While the profiles indicated in the figure were selected by hand, it was verified that the amplitude of the weak lobe was at least four times the noise level of 1.5×10^{-3}. The peak corresponding to the BPs and RPs is, on an average, located at 17 pm and 22.5 pm, respectively from line center. This suggests that the features are associated with very large Doppler velocities. It is observed that the BPs and RPs are confined exclusively to the upper half of the LB throughout the observing period. These profiles appear in patches, sometimes as small as 0.2 arcsec^2 in area. The BPs and RPs can either appear (i) completely independent of each other (panels 2 and 3), or (ii) adjacent to each other (panels 4 and 5), or (iii) separated from each other (panel 6). Since there are only limited SP scans it is difficult to establish the lifetimes of these features. As they can be sometimes seen in successive scans at/near the same pixel, a lower limit of 20 min can be attributed to these features.

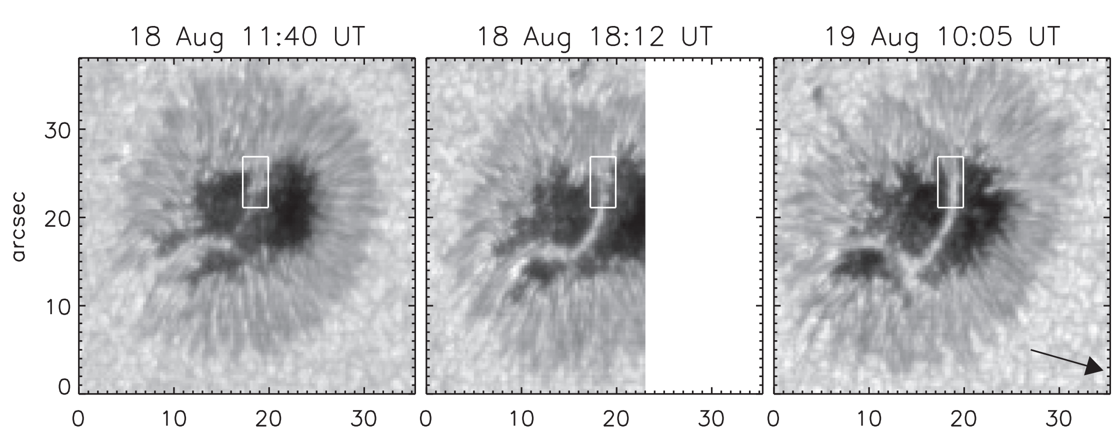

Fig. 1. Continuum images of the leading sunspot in AR 11271 on 2011 August 18 and 19. The white rectangle depicts a 10 × 19 pixel FOV shown in Fig. 2. The arrow in the right panel points to disk center.