PLASMA EJECTIONS FROM A LIGHT BRIDGE IN A SUNSPOT UMBRA

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ABSTRACT

We present conspicuous activities of plasma ejections along a light bridge of a stable and mature sunspot in NOAA Active Region 8971 on 2000 May 2. We found the ejections both in the Hα (104 K) images obtained with the Domeless Solar Telescope at Hida Observatory and in the 171 Å (Fe ix/Fe x; ∼105 K) images obtained with the Transition Region and Coronal Explorer. Main characteristics of the ejections are as follows: (1) Ejections occur intermittently and recurrently. (2) The velocities and the timings of the 171 Å ejections are the same as those of Hα ejections. (3) The appearance of the ejections are different from one another; i.e., the Hα ejections have a jetlike appearance, while the 171 Å ejections are like loops.

Subject headings: Sun: activity — Sun: chromosphere — Sun: corona — sunspots

1. INTRODUCTION

Characteristics of Hα surges have been studied for many years (e.g., Roy 1973) and are summarized by Bruzek & Durrant (1977) as follows: (1) Hα surges are straight or slightly curved spikes that are shot out of a small mound. (2) On the solar disk, they appear usually in absorption, but in their initial phase, sometimes in emission. (3) They also show strong tendency to recur. Kurokawa (1988) and Kurokawa & Kawai (1993) have reported that Hα surges are often found at the earliest stage of emerging flux regions (EFRs) and continue recurrently for many hours. They have also suggested that magnetic reconnection between a newly emerging flux and a pre-existing magnetic field is the essential mechanism of Hα surge production. Yokoyama & Shibata (1995) showed in their numerical simulation that such a reconnection really produces Hα surges in EFRs.

Roy (1973) found that Hα surges are also ejected from a light bridge of a sunspot umbra. However, no detailed study has been made of plasma ejections from a light bridge until now. We use the term “light bridge” to refer to a bright, long, and narrow feature penetrating or crossing a sunspot umbra. Light bridges are often seen in umbrae of mature and stable sunspots and have been considered to have the same magnetic polarity as that of the sunspot umbrae, while their field strength is much weaker (Beckers & Schröter 1969).

We found that conspicuous Hα surge activities occurred along the light bridge of the sunspot umbra in NOAA Active Region 8971 on 2000 May 2, with the 60 cm Domeless Solar Telescope (DST) at Hida Observatory, Kyoto University. Hα surge activities continued intermittently for about 6.5 hr, as long as the time span of our observation. Examining the extreme-ultraviolet (EUV) images obtained with the Transition Region and Coronal Explorer (TRACE; Handy et al. 1999; Schrijver et al. 1999), we found similar ejections from the light bridge in 171 Å (Fe ix/Fe x) images. Such ejections from a light bridge have never been reported before in the EUV wavelength. From now on, we refer to the ejection seen in 171 Å images obtained with TRACE as the “171 Å ejection.”

In this Letter, we report the morphological and the dynamical characteristics of the ejections from the light bridge, using the Hα and the 171 Å images of high spatial and temporal resolution obtained with DST and TRACE, respectively. In § 2, we summarize the observational data, and in § 3, we present observational results and discussion. In § 3.1, we report the features of the Hα surges obtained with DST, and in § 3.2, compare them with the 171 Å ejections. Then we discuss the magnetic configuration of this region and possible mechanisms for the surge activity in the light bridge in § 3.3. Our results are summarized in § 4.

2. OBSERVATIONAL DATA

We have observed the surge activities along the light bridge in NOAA AR 8971 (N20°, W55°) with DST from 23:00 UT on 2000 May 1 to 05:30 UT on May 2. The Hα monochromatic images were obtained with the Zeiss Lyot filter of the 0.25 Å passband and Sony laservideo disk recorder sequentially in three wavelengths: Hα ± 0.0, +0.6, and −0.6 Å. The successive wavelength change and recording were controlled with a personal computer, and the time capture for each wavelength was 12 s. In this study, we mainly used the Hα − 0.6 Å images, in which their ejecting motions are clearly seen.

The EUV images of this region obtained with TRACE are available from 04:30 to 06:00 UT on May 2. They also show conspicuous ejections along the light bridge. The TRACE 171 Å images were used to compare the features of the hot ejections of about 10⁵ K with those of Hα cool surges of about 10⁴ K. To co-align the Hα images with the EUV images, we used a TRACE 1600 Å image. There are a few soft X-ray images obtained with the soft X-ray telescope (SXT) aboard Yohkoh (Tsuneta et al. 1991) during the time interval from 05:20 to 05:30 UT on May 2. To process the TRACE and Yohkoh SXT images, we used the Interactive Data Language solar software.

In Figure 1, the times of Hα and EUV observations are summarized, where each time is represented by plus sign. The second and fourth rows show the times when the ejections along the light bridge are distinctly identified at Hα and 171 Å, respectively, and numbered thick lines in both rows show that they are especially “conspicuous” ejections. We mainly studied the event that occurred at 04:46 UT on May 2 (event 7 in Figs. 1 and 2 and Table 1), because the ejection was clearly seen both in Hα and in EUV.

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3. RESULTS AND DISCUSSIONS

3.1. Motions of Hα Surges

During the observation of DST, which was about 6.5 hr, Hα surges were ejected intermittently from the light bridge of the sunspot umbra in NOAA AR 8971 (see Fig. 1). Figure 2 shows eight surges that extended to larger than 11,000 km in apparent

| Event | Time (UT) | Apparent Velocity (km s⁻¹) | Apparent Maximum Length (Mm) |
|-------|-----------|----------------------------|------------------------------|
| Hα    | 00:40     | 37.1                       | 19.9                         |
| 2      | 02:38     | 32.3                       | 23.2                         |
| 3      | 02:50     | 41.0                       | 15.9                         |
| 4      | 03:19     | 57.3                       | 17.0                         |
| 5      | 03:57     | 44.0                       | 14.2                         |
| 6      | 04:27     | 28.3                       | 14.2                         |
| 7      | 04:46     | 40.4                       | 13.9                         |
| 8      | 05:32     | ...                        | 15.6                         |
| Mean value | ... | 38.5                       | 16.7                         |
| EUV 171 Å | 04:46 | 41.5                       | ...                          |

length. They are the largest among a number of surges observed in this light bridge. In Figure 2, the top left image is at Hα − 5.0 Å, and the others are at Hα − 0.6 Å. The mean apparent velocity of these surges is about 40 km s⁻¹, the mean apparent maximum length is about 17,000 km, and the mean lifetime is about 10 minutes. These features of the eight surges are listed in Table 1. We correct these values for the projection effect. Assuming that the surges are vertically ejected from the solar surface, we get the velocity of 50 km s⁻¹ and the max-
3.2. Comparison with TRACE and Yohkoh SXT Images

We also found ejections from the light bridge in 171 Å images obtained with TRACE. These 171 Å ejections have occurred intermittently just as Hα surges. For the event of 04:46 UT (event 7 in Figs. 1 and 2 and Table 1), we compared the Hα surge with the 171 Å ejections with respect to their morphological and dynamical characteristics.

Figure 3 shows the evolution of the ejection in Hα − 0.6 Å (top) and TRACE 171 Å (middle, negative). The bottom right panel is a Yohkoh SXT image overlaid with the contour of the sunspot umbra. The three panels in the bottom left box show the comparison of the appearance and the site of the ejections. The rightmost panel in the box gives the spatial relation among the sunspot umbra, the Hα surge, and the TRACE 171 Å loop, where they are displayed as dark gray, light gray, and a black curved line, respectively. The timing and location of the ejections in TRACE 171 Å images are almost the same as those of the surges at Hα − 0.6 Å. Furthermore, the velocity of the 171 Å ejection is about 40 km s⁻¹, and it is nearly equal to that of the Hα surge (see Table 1). However, the appearance of the ejections in the Hα images and the EUV images are different; that of the Hα surge is like a jet, while that of the 171 Å ejection looks like a reverse U-shaped loop.

The Hα surges seem to be ejected along some open magnetic field lines of about 5000 km in width and about 12,000 km in length. On the other hand, the 171 Å ejections (hot plasma) are reverse U-shaped loops that trace the edge of Hα surges (cool plasma; see the bottom middle cartoon in Fig. 3). The separation of two footpoints of the loop is about 5000 km, and the loop top is about 12,000 km in height. The growth of the reverse U-shaped 171 Å loops indicates the existence of some bipolar magnetic polarities in the light bridge of the sunspot umbra. In addition, as will be discussed below with the magnetograms (§ 3.3), the emergence of some new magnetic flux is probably occurring there. We examined soft X-ray images for the same region obtained with Yohkoh SXT, which provide information of the plasma of much higher temperature (more than 3 MK). However, we did not find any SXT ejections according to the locations of the Hα surges and EUV ejection in the light bridge. Such differences between the appearance of cool (about 10⁴ K) surges in Hα and hot plasma ejections at 171 Å (about 10⁶ K) and in soft X-ray (more than 3 MK) images indicate some dynamical and thermal characteristics of plasma ejection in the light bridge of the sunspot umbra. They should be explained by a proper model of the accelerating and heating mechanism.

3.3. Magnetic Configuration

The continuous surge activity, which was found in the light bridge of the sunspot umbra (§ 3.1), is considered to be evidence of emerging magnetic flux (e.g., Kurokawa & Kawai...
1993). The reverse U-shaped loop seen in TRACE images (§ 3.2) also suggests the emergence of a bipolar magnetic flux.

Figure 4 shows the magnetograms on April 27 (top; near the disk center) and on May 2 (bottom; near the northwest limb, N20°, W55°) obtained with the Michelson Doppler Interferometer (MDI) on board the Solar and Heliospheric Observatory (SOHO; Scherrer et al. 1995). The sunspot has negative polarity (black). The polarity of the light bridge is also negative, although its field strength is much weaker than the main sunspot umbra (April 27; top). On May 2 (bottom), positive polarity (white) is seen at the location on the light bridge.

Since the sunspot is located close to the solar limb (55°) on May 2, it is difficult to determine whether this opposite polarity is an indication of the newly emerging magnetic flux or whether it appears only due to the projection effect of the negative polarity field. We cannot exclude the possibility that some negative polarity that is inclined more than about 40° from the normal produces the fake positive polarity. Nevertheless, we suggest that unresolved and small newly emerging magnetic flux plays an essential role in the long-lasting surge activity. To conclude that new bipolar magnetic fluxes really emerge in light bridges and produce such surge activities by magnetic reconnection, we need more precise observations of magnetic fields of light bridges, near the disk center and with higher spatial resolution.

4. SUMMARY

We studied dynamical characteristics of Hα surges along a light bridge in a sunspot umbra with the DST at Hida Observatory. The surge activities continued intermittently for a long time, at least 6.5 hr. The apparent velocity of the surges was about 50 km s⁻¹ on average, and it is typical for that of an Hα surge. We also studied the ejections from the light bridge observed in the EUV coronal line at 171 Å with TRACE for the first time. The apparent velocities of 171 Å ejections were almost equal to those of Hα surges. We could not find any ejections from the light bridge in Yohkoh SXT images. This means that the temperature of the plasma ejected from the light bridge is lower than a few megakelvins. We found morphological differences between Hα surges and 171 Å ejections; the 171 Å ejections seem to be loops, while the Hα surges are like jets.

Examining the magnetogram obtained with SOHO MDI, we suggest that the emergence of new flux occurs in the region, although we cannot exclude the possibility that the opposite polarity is due to a projection effect. We need more precise observations of magnetic fields of light bridges.

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