MICROFLARING AT THE FEET OF LARGE ACTIVE REGION LOOPS

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Abstract

By superposing Yohkoh SXT images on an MSFC magnetogram of an active region, we find that the brightest loops in the bipolar magnetic envelope spanning the active region are rooted near a compact site of mixed polarity and microflaring. Apparently, the enhanced coronal heating in these high loops is a consequence of the microflaring and/or related magnetic activity at this end site.

1. Introduction

There are many examples in the literature of observations of substantial energy transfer out of compact flaring loops into adjacent, more extended structures (either open or closed loops). For example, Machado and Moore (1986) noted that a filament associated with a large active region loop remained undisturbed throughout a flare involving that loop and a compact loop lying near one of its footpoints. This was evidence that the main release of energy was in the compact loop, so that an Hα brightening at the remote footpoint of the larger loop was the result of energy transfer between the structures rather than internal release within the larger loop.

Martin and Svestka (1988) examined similar loop interactions and gave the name "flaring arches" to the larger loops involved (37,000 and 57,000 km). The short time lag between initial X-ray bursts at the primary footpoints and Hα brightenings at the remote footpoints of the arches is evidence for the injection of high speed electron streams into the flaring arches, while Hα and X-ray emission enhancements propagating more slowly along the arch show that there is bulk injection of material from the primary footpoint. Svestka, Farnik and Tang (1989) described similar injection of material into open structures to produce surges, and noted that the base of these structures are associated with "magnetic intrusions or polarity islands". Fontenla et al. (1991) reported the injection of multi-temperature material into a 300,000 km flaring arch, evidence that a pressure pulse from heating low in the loop drove low-lying plasma along the loop, rather than that energy release high in the corona drove chromospheric evaporation. The base of the flaring arch in this study was also associated with an island of included polarity in the active region.

There is evidence that similar loop interactions may occur apart from flares and subflares. For example, Webb and Zirin (1980), examining Skylab data, noted that the footpoints of X-ray bright loops within active regions corresponded to sites of persistent Hα brightenings. These were also sites of rapidly changing magnetic fields.

In the course of examining Yohkoh SXT data for a correlative study with magnetograms (reported elsewhere in these proceedings by Moore et al.) we found an apparent example of the transfer of energy from active low-lying loops into higher, more extended loops. In this paper we compare SXT images with a Marshall Space Flight Center (MSFC) magnetogram to describe the magnetic structure of the interacting loop system, then examine some of the intensity variations at the footpoint sites and in the larger loops. These observations suggest that the coronal heating energy from the compact low-loop site is injected into the neighboring loops, not in the form of coronal plasma or energetic particles, but as waves that dissipate in the body of the high loops.

2. Observations and Discussion

Coaligned white-light images were obtained with both the MSFC and Yohkoh data. These were used to make an accurate superposition of the magnetogram and the X-ray images. Figure 1 shows the result of adjusting the scales and rotations of the two white light images for best fit. We estimate that the superposition is good to a few arcsec.

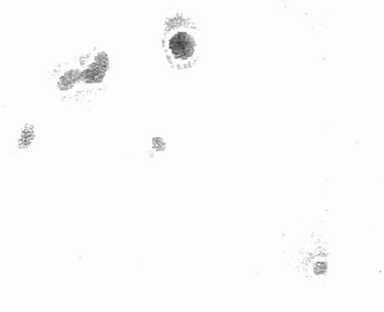

Fig. 1. White light images used for superposing the X-ray and magnetic field data for AR 6982. Contours of Yohkoh white light intensity at 18:05 UT, 26 December 1991 are superposed on an MSFC white light image taken at 18:24 UT. Solar north is up, and west is to the right.

In figure 2(a), the derived relative scalings and rotations have been used to superpose a Yohkoh SXT image and the MSFC magnetogram. The main features in the X-ray image are (1) a bright region along the northern portion of the main neutral line (a region of high magnetic shear - see Moore et al., these proceedings), (2) a compact bright region spanning a

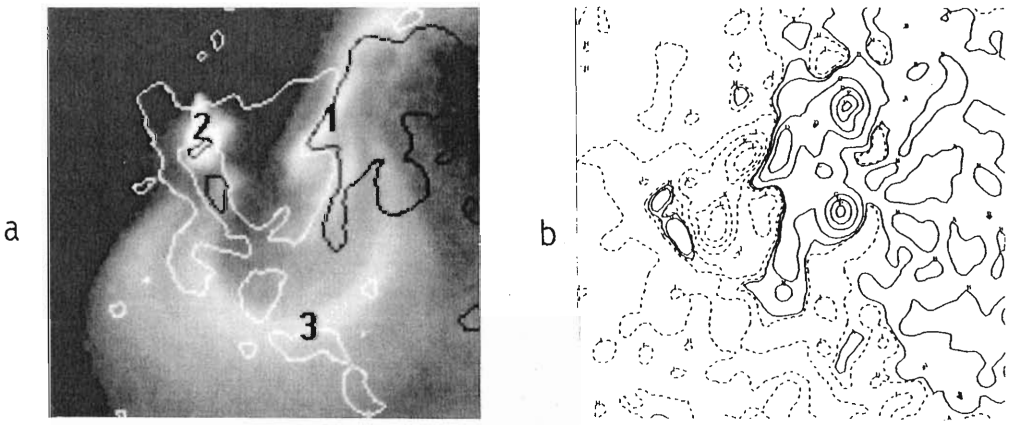

Fig. 2. (a) Contours of longitudinal field strength (- 150 G - white, +150 G - black, from an MSFC magnetogram at 18:24 UT 26 December 1991) superposed on a Yohkoh SXT image of AR 6982 taken at 18:07 UT. The X-ray image is the result of a 3.778 s exposure through the thick Al filter. Solar north is up, and west is to the right. (b) The same MSFC magnetogram represented by the minimal contours in (b), now with contours at +/- 10, 100, 500, 1000, and 1500 G and at +2000 G.

secondary neutral line north of an island of included positive polarity within the main negative polarity region, and (3) several bright loops having one end rooted in the main patch of positive polarity, with the other lying in negative polarity near the included positive island. This image is the earliest obtained of the X-ray brightening at (2), which is associated with the beginning of an Hα subflare (class SF, 18:06 - 18:20 UT, Solar Geophysical Data). However, the high loops (3) showed enhanced emission for more than an hour prior to the start of the subflare, and continued to do so for more than an hour after it ended, with no evidence of the enhancement evolving to higher loops during this time. This argues against heating of the high loops by flare-like internal release of energy triggered by the subflare near their footpoints.

Figure 2(b) shows more detail from the magnetogram of the region. Comparison with (a) shows that the west end of the enhanced loops lies in a broad region of moderately high positive field strength, of order 500 G, lying between the two main positive flux concentrations. However, the east end is rooted in negative flux near the island of positive flux. Now, why should these particular loops, out of all the magnetic loops filling space in and about the active region, show enhanced X-ray emission? A plausible answer is that some special activity near their feet drives enhanced coronal heating in only these loops. The obvious candidate for the seat of this localized anomalous activity is the east-end island of reversed polarity.

Figure 3 shows a sequence of four X-ray images taken during the hour after the image shown in Figure 2(a). White is used for the brightest areas, green for the faintest. The first frame was taken about a minute after the one in Figure 2(a), and still shows the subflare brightening. There was also a later, less intense brightening involving the other (southern) lobe of the included polarity island that is not shown in this sequence. The high loops and the fainter, more extended structures shown in green exhibit brightness fluctuations throughout this time, superimposed on a general decline after the end of the subflare. In the last frame, the northern lobe of the included polarity island brightens again, but the amplitude is much less than during the subflare. Throughout the sequence, there is a clear emission gap separating the subflaring/microflaring low loops rooted in the included polarity island and the associated high loops rooted near this island.

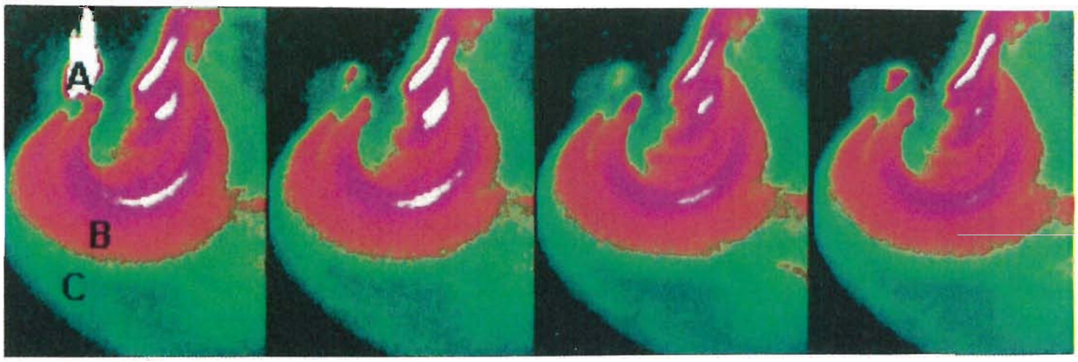

Fig. 3. X-ray brightness fluctuations in AR 6982. Times of these frames are 18:08, 18:28, 18:42, and 18:51 UT. The images are corrected for differing exposures (168 or 338 ms), but all used the thin Al filter. Variations at sites A, B, and C are plotted in Figure 4.

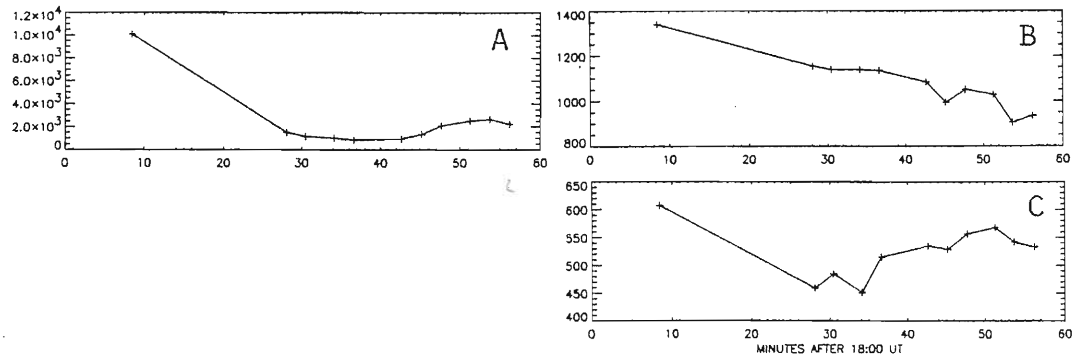

Fig. 4. X-ray brightness variations (corrected for variable exposure) at sites A, B, and C of Figure 3. For site A, the values are those at the brightest pixel within the microflare. Values for B and C are averages over blocks of four pixels.

The light curves in Figure 4 show the general decline of the "outer loop" (B) and the extended structure in the green "boundary layer" (C) fringing the active region. However, there are substantial increases in emission within this trend, particularly in the highest structures. One of these, a bump about 10 minutes in duration around 18:50 UT, is seen at both B and C. This may be a response to the reactivation of A just before 18:50 UT.

What can be inferred about the form of the energy transfer between the low and high loops from these observations? First, the emission gap between the low and high structures argues against direct transfer or generation of energetic particles and hot coronal plasma at an interface between the low loops and the feet of the high loops, the mechanism suggested for most of the observations of energy transfer during larger events cited in the introduction. Since recent work has shown that the emission from small microflares is cooler than that from large microflares and subflares (Porter, Fontenla, and Simnett 1994), and further, that even very large mass motions and ejections can occur with no simultaneous heating signature visible to SXT (Sime, these proceedings), we make the following suggestion. The enhanced emission in the higher structures obviously responds to nearby members of the flare family as large as subflares (see decline, 18:08 - 18:30) and appears to respond to much smaller events (18:45 - 18:55). The heating leading to this enhanced emission may be maintained at other times via a series of still smaller events whose energy first goes preferentially into motion, generating waves, rather than directly heating plasma to coronal temperatures. Observations of transition region emission (e.g. Porter, Toomre, and Gebbie 1984) have shown that some sites in active regions display almost continuous activity at that temperature. Such microflares, or perhaps microeruptions is a better name for events at such low temperature, might generate waves which propagate into and dissipate along the nearby high loops, but still have little or no signature themselves in SXT observations.

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