LONG DURATION EVENTS OBSERVED WITH THE NOBEYAMA RADIOHELIOGRAPH

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Abstract

The long duration events are extensively observed with the Nobeyama Radioheliograph. The radio images show the existence of polarized bright footpoints of the flare loops, which is due to thermal electrons, and the temperature structure in the LDE loops in conjunction with the soft X-ray images.

1. Introduction

Long duration events have been mainly observed as the results of prominence eruptions, and explained by the application of the models by Carmichael (1964), Sturrock (1968), Hirayama (1974), and Kopp and Pneuman (1976) (CSHKP model). The SXT on board the *Yohkoh* satellite observed various LDE's, of which the size ranges from 10^5km to 10^6km (see Tsunata's review, 1992). The study of LDE's is very important because it gives the clues not only for the flare physics but also for the development of the global coronal sturcture.

The Nobeyama Radioheliograph has also observed various long duration events. These are the first extensive observations of LDE's in radio wavelengths with a combination of high time and spatial resolutions, and a high sensitivity. In this preliminary description of the LDE's observed with the radioheliograph, We give the results about (1) the nature of the polarized bright footpoints, and (2) comparison between the images of flare loops at 17 GHz and those in soft X-rays.

2. Polarized Footpoints

The SXT images and the radio images of the events on 1992 June 25-26 and on 1993 March 11 are shown in Figures 1 and 2. We can find intense brightenings at the footpoints in the radio images, besides the flare loops in the radio images show similar structures to those in the SXT images. The footpoints are strongly polarized and they coincide with sunspots.

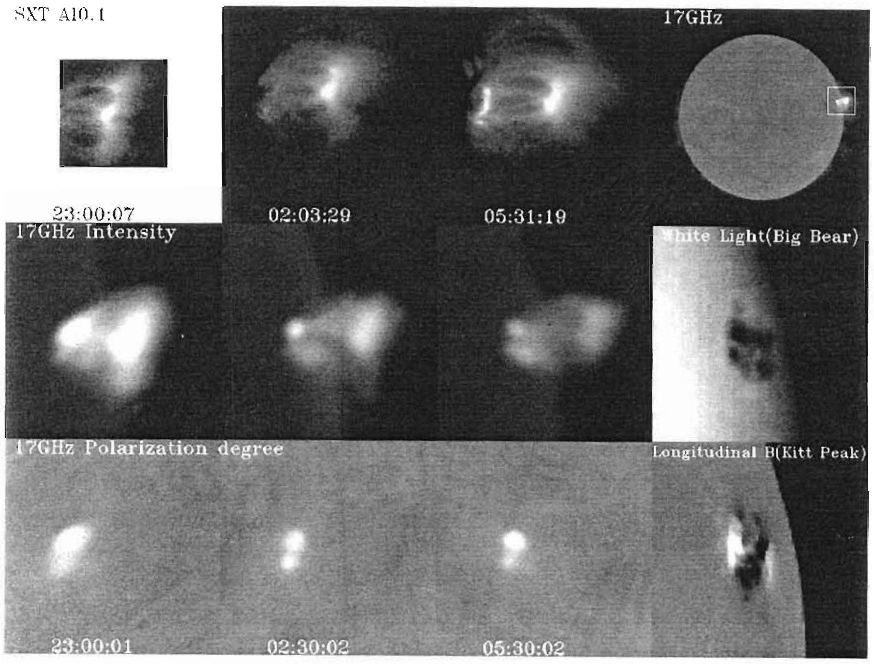

Fig. 1. A long duration event on 1992 June 25-26 occurred in the region NOAA7206 near the west limb. Developing (post) flare loops are seen in the SXT pictures and the radio pictures. Strongly polarized bright footpoints which are seen in the radio images correspond to two sunspots of positive magnetic field.

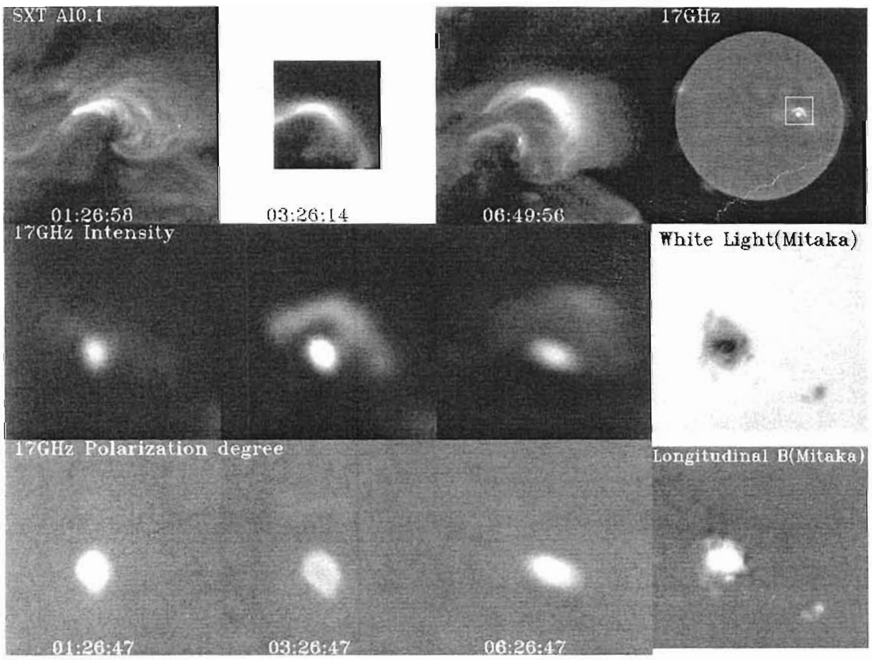

Fig. 2. A long duration event on 1993 March 11 occurred in the region NOAA7440. Flare loops and a polarized bright footpoint are also seen.

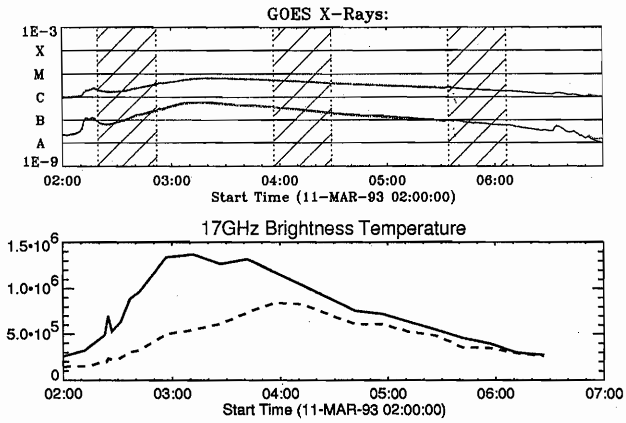

Fig. 3. Brightness temperature of the footpoint (solid line) and that at the loop top (dashed line) are shown with a GOES plot.

The footpoint brightenings are a common feature in the radio images of LDE's which occurred in active regions. The maps of the polarization degree show the central depression during the flare; this feature is also observed in the other LDE's.

The time profiles of the brightness at the footpoint and at the loop top in the event on 1993 March 11 are shown in Figure 3. The brightness of the footpoint changes nearly proportional to the X-ray brightness.

In usual impulsive flares, footpoint brightenings at 17 GHz, which are generally polarized, proceed the soft X-ray brightening, and the derivatives of the soft X-ray profiles are similar to the radio brightness profile (Neupert effect). Therefore the footpoint brightenings in impulsive flares is related with the heating rate. However, in LDE's, footpoint brightenings behave similarly to the soft X-ray intensities. They seem to be related to thermal energy contents rather than heating. Therefore the footpoint brightenings in the LDE's are probably due to gyration of thermal electrons. Strong thermal gyro-resonance radiations cannot be seen in impulsive flares. Therefore we cannot conclude that LDE's are the 'long durating' impulsive flares.

3. Temperature Structure

From the Skylab observations and an eclipse observation temperature structure of LDE loops is derived(MacCombie and Rust 1979, Hanaoka et al. 1986); the loops of which temperature ranges from 1×10^4 K to 5×10^6 K are stratified. The SXT observation shows similar structure (Tsuneta *et al.* 1992), but cooler loops ($< 10^6$ K) can not be seen because of the restriction of the SXT miller.

Besides the footpoint brightenings, the flare loops are brightened due to thermal free-free radiation at 17 GHz. According to Webb and Kundu (1978), radio flux S due to thermal free-free radiation from optically thin plasma of temperature T is expressed as

$$S = (3.4 \times 10^{-68})(N_e N_i V) T^{-1/2} g \quad \mathrm{Wm^{-2}Hz^{-1}} \quad , \tag{1}$$

where N_e and N_i are an electron density and an ion density, V is a volume, and g is a Gaunt factor. Because of the temperature dependence $T^{-1/2}$, the Radioheliograph is sensitive in lower temperature range where the SXT has only low sensitivity.

Then we compared an SXT image of the LDE on 1993 March 16 with a radio image. In Figure 4 an SXT image and maps of temperature and emission measure which are derived on the basis of the filter ratio method are shown. From these maps and the above equation we derived a map at 17GHz (Figure 4(d)). Since the spatial resolution of the Radioheliograph is

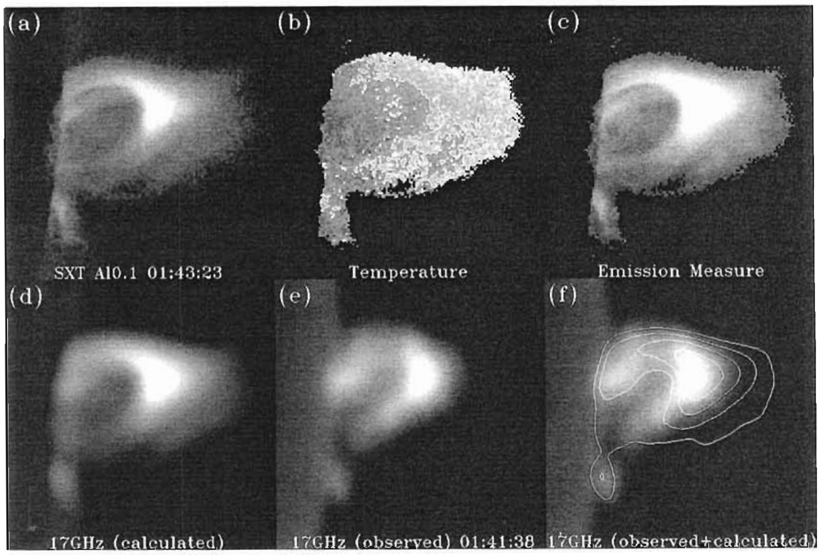

Fig. 4. (a) An SXT picture of the LDE on 1993 March 16. (b)(c) Temperature and emission measure maps derived from the SXT pictures. (d) Calculated intensity at 17GHz. (e) A radio picture of the LDE at 17GHz. (f) Comparison between the observed and calculated radio images.

lower than that of the SXT, Figure 4(d) is convolved with the beam of the Radioheliograph. The observed map at 17 GHz is shown in Figure 4(e), and they are superposed in Figure 4(f). If the SXT observed all the plasma in the loops, these two pictures should be coincide. However, these two are different. Please watch the outermost contour in Figure 4(f); along that contour the part lower than the brightest point in the observed map is brighter than the upper half. This fact means that there is cool matter which can not be observed with the SXT in the lower half of the loops. The combination of the SXT images and radio images gives us the temperature structure of the loops and true amount of plasma.

The author is grateful to the Mitaka Flare-Telescope group, Big Bear Observatory, and National Solar Observatory for providing optical data.

References

1. Carmichael, H. 1964, in *AAS-NASA Symposium on the Physics of Solar Flares, NASA SP-50*, ed. W. N. Hess, p.451.
2. Hanaoka, Y., Kurokawa, H., and Saito, S. 1986, *Solar Phys.*, **105**, 133.
3. Hirayama, T. 1974, *Solar Phys.*, **34**, 323.
4. Kopp, R. A., and Pneuman, G. W. 1976, *Solar Phys.*, **50**, 85.
5. MacCombie, W. J., and Rust, D. M. 1979, *Solar Phys.*, **61**, 69.
6. Sturrock, P. A. 1968, in *Structure and Development of Solar Active Regions, Proceedings of the IAU Symp. 35*, ed. K. O. Kiepenheuer (D. Reidel, Dordrecht-Holland), p.471.
7. Tsuneta, S. 1992, in *Magnetic and Velocity Fields of Solar Active Regions, Proceedings of IAU Colloquium No. 141*, eds. H. Zirin, G. Ai, and H. Wang (Astronomical Society of Pacific, San Francisco), p. 239.
8. Tsuneta, S., Hara, H., Shimizu, T., Acton L. W., Strong, K. T., Hudson, H. S., and Ogawara, Y. 1992, *Publ. Astron. Soc. Japan*, **44**, L63.