Active-Region Transient Brightenings in NOAA 7260

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Abstract

In this paper, we discuss transient brightenings appeared in an active region NOAA 7260 from the point of view of their morphology and spatial distribution. In this region, more than half of transient brightenings show simple brightening structures with a single loop, although one third of them are simultaneous brightenings of multiple loops. This result is different from the result of transient brightenings appeared in NOAA 6891. This difference may be due to the dominance of small-size brightenings in NOAA 7260. Transient brightenings are observed to be localized in two areas in NOAA 7260. One of them is a growing emerging magnetic flux region embedded in the following plage area, suggesting that some transient brightenings are associated with the emergence of the magnetic flux. Other transient brightenings appear around the outer boundary of the penumbra of a preceding well-developed spot.

1. Introduction

Soft X-ray Telescope (SXT) aboard the *Yohkoh* satellite (Ogawara et al. 1991) has found that active regions show many tiny flare-like brightenings (Shimizu et al. 1992). Intense brightenings are believed to be soft X-ray counterparts of hard X-ray "microflares" observed by hard X-ray balloon-borne observations with high sensitivity (Lin et al. 1984). The SXT observes fainter brightenings which are not detectable with other instruments, such as the *GOES* soft X-ray full-sun monitors. Transient brightenings appear on average every a few minutes in active regions of high activity. In relatively quiet active regions, the frequency of their occurrence falls down to once every 1 hour.

Transient brightenings appear in forms of single or multiple loops, although some brightenings are point-like. Shimizu et al. (1994a) statistically investigate the morphology of transient brightenings appeared in the active region NOAA 6891, which is the most energetic active region since the *Yohkoh* launch (*Solar Geophysical Data*), and find that simultaneous brightenings of multiple loops are more often seen than brightenings of single and point-like structures. In this paper, we investigate transient brightenings appeared in another active region NOAA 7260 from the point of view of their morphology and physical states, and then make a comparison between the morphological results in NOAA 7260 and NOAA 6891. We also discuss the spatial distribution of transient brightenings in NOAA 7260.

2. Observation and Data Analysis

The SXT is a grazing incidence X-ray telescope covering the 3 to 60 Å wavelength equipped with a 1024×1024 charge coupled device (CCD) detector. Two filter wheels and a mechanical shutter are mounted in front of the CCD detector to choose energy band and exposure time. The CCD camera, shutter, and filter wheels are controlled by on-board microprocessors. The detailed description of the instrument is given by Tsuneta et al. (1991).

The data used in this analysis are obtained from 15 to 20 August, 1992. During this period, partial CCD images with two different X-ray filters (Al 1265Å filter, Al 12μ filter) are available every 32 sec. The target region of the partial images is NOAA 7260, which is located at the disk center on 18 August, 1992, with the 5×5 arcmin field of view. The pixel size of the images is 2.46 arcsec. The exposure durations are controlled by an on-board automatic exposure control logic. We selected the sequence of images which had a time coverage of more than 25 min. The total time coverage of all the selected data is about 10 hours.

We examined the data by visually inspecting images and picked up those events that were observed throughout their lifetime and events observed from beginning up to maximum phase. 291 transient brightenings are selected in total. By applying the spline fitting function to light curves of a transient brightening, the peak X-ray fluxes, the background X-ray fluxes, and the lifetimes are obtained for each filter. Here the peak flux is meant to be the maximum enhancement in excess of the background flux.

The background flux is assumed to be the minimum flux just prior to the rising phase. The lifetime is defined as the duration above half maximum intensity. The length and width of a brightening feature are determined from the image showing the brightening in peak phase. The heliocentric address of a transient brightening is also calculated. These physical parameters are obtained after the CCD corrections (dark subtraction, decompression from 8 bit to 12 bit and so on) and the removal of the satellite jitter motions. Morphological properties are determined by visually inspecting the images and are then classified following the categories of Shimizu et al. (1994a).

3. Morphology

Transient brightenings are classified into three categories: (1) simultaneous brightenings of multiple loops, (2) brightenings of single loop, and (3) point-like brightenings. The classification of transient brightenings appeared in NOAA 7260 is presented in Table 1. As a reference, Table 1 has the classification of transient brightenings in NOAA 6891, which comes from Shimizu et al. (1994a).

Table 1. Morphological Classification of Transient Brightenings.

NOAA 7260

classification	number	percentage
Total analyzed event	291	
POINT-like event	32	11.0%
SINGLE-loop event	184	63.2%
MULTIPLE-loop event	75	25.8%

NOAA 6891

classification	number	percentage
Total analyzed event	142	
POINT-like event	26	18.3%
SINGLE-loop event	59	41.5%
MULTIPLE-loop event	57	40.2%

(From Shimizu et al. 1994a)

In NOAA 7260, more than half of transient brightenings show quite simple brightening structures with a single loop. A quarter of transient brightenings is simultaneous brightenings of multiple loops. On the other hand, in NOAA 6891, the percentage of multiple-loop brightenings is comparable to that of single-loop brightenings. The percentage of multiple-loop brightenings in NOAA 7260 is smaller than that in NOAA 6891. Reversely, the percentage of single-loop brightenings in NOAA 7260 is larger than that in NOAA 6891. This means that there is apparent difference in the morphology of transient brightenings between the active regions, although we cannot find any significant difference in the percentage of point-like brightenings between them.

It is concluded in Shimizu et al. (1994a) that some of single-loop and point-like brightenings could have multiple-loop structures on sub-loop scales and that most of transient brightenings may consist of multiple loops. This conclusion comes from the fact that the size of the loops in single-loop and point-like brightenings is smaller than that of the loops in multiple-loop brightenings. To discuss the difference in the morphology of transient brightenings between the active regions, we should know the distribution of the size of the loops in NOAA 7260 (Figure 1). Comparing Figure 1 with that in NOAA 6891 (Figure 2 of Shimizu et al. 1994a), we find that single-loop and point-like brightenings have similar distributions in both regions. The size distribution of multiple-loop brightenings in NOAA 7260 is, however, quite different from that in NOAA 6891. NOAA 7260 is lacking in the long-size part of multiple-loop brightenings. This means that transient brightenings with small size are dominant in NOAA 7260, so that many transient brightenings can be regarded as single-loop brightenings which may have multiple-loop structures on sub-loop scales. In addition, the driving forces of transient brightenings might be different in both active regions.

Even in NOAA 7260, the initial brightenings at the footpoints of the loops are observed in many multiple-loop brightenings as well as in single-loop brightenings. Enhanced emission at the sites where

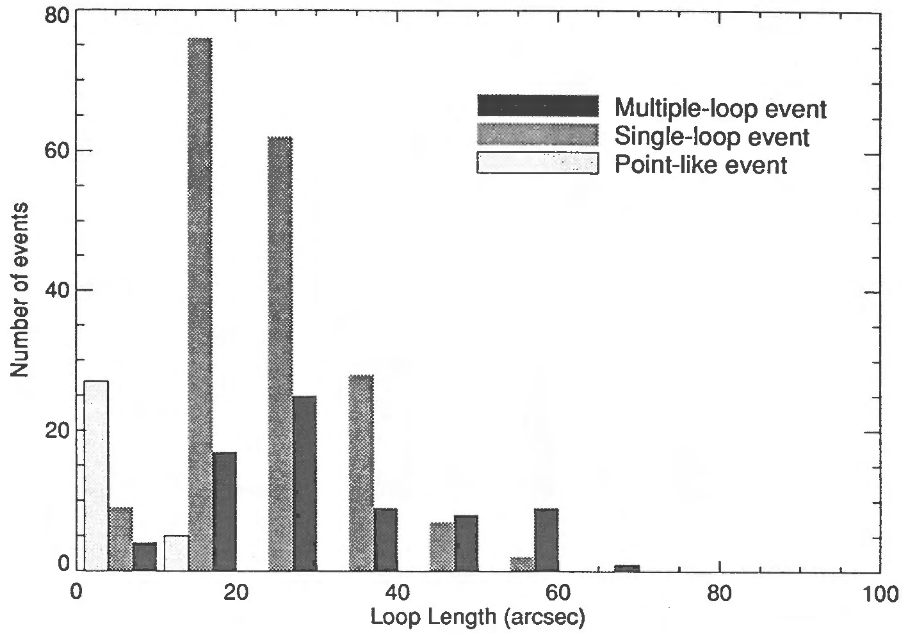

Fig. 1. The Distribution of the loop length of Transient Brightenings.

the loops are in contact is, however, rarely observed in NOAA 7260, although in NOAA 6891 we frequently observe enhanced emission at the contact points. The significant difference in the regions is that the diffuse background structures are relatively brighter in NOAA 6891 than in NOAA 7260. This implies that at the beginning of transient brightenings, the coronal plasma may have higher density or temperature in NOAA 6891 than in NOAA 7260, so that enhanced emission at the contact points is frequently observed in NOAA 6891. We also observe several X-ray jets (Shibata et al. 1991) associated with transient brightenings. Many X-ray jets appear around the following spots which have newly emerged during the observation.

4. Soft X-ray Peak Flux

Here the distribution of soft X-ray peak flux of transient brightenings is discussed with their morphology, to know how bright brightenings appear in NOAA 7260. Figure 2 is the histogram of soft X-ray peak flux (through Al 1265 Å filter) of transient brightenings appeared in the region. The horizontal axis is the total intensity of brightening features at the maximum phase, which is described in the unit of DN (data number) per sec. Note that there is a good correlation between soft X-ray peak flux and *GOES* high channel (0.5 $\sim$ 4 Å) flux for transient brightenings (Shimizu et al. 1994b): 10^5 and 10^6 DN s^{-1} roughly correspond to 10^{-9} (<B1 class) and 10^{-8} ($\sim$B3 class) W m^{-2} in the *GOES* high channel, respectively. We know that most of transient brightenings appear with the peak flux of 10^4 to 10^6 DN s^{-1}. There is no significant difference in distribution of the peak flux among three kind of morphological structures, except that multiple-loop brightenings are slightly brighter than single-loop or pointlike.

5. Spatial Distribution of Transient Brightenings

Finally we discuss the global distribution of the occurrence location of transient brightenings appeared in NOAA 7260. Figure 3 shows the locations of transient brightenings appeared in the period of 15 to 20 August, 1992. The asterisks show the locations of multiple-loop brightenings, the diamonds of single-loop, and the squares of point-like. They are marked on the center position of brightening structures. The projective locations of transient brightenings at 0 UT on 18 August are calculated with the assumption of the differential rotation of the active region. The shadows show umbrae and the dashed lines express

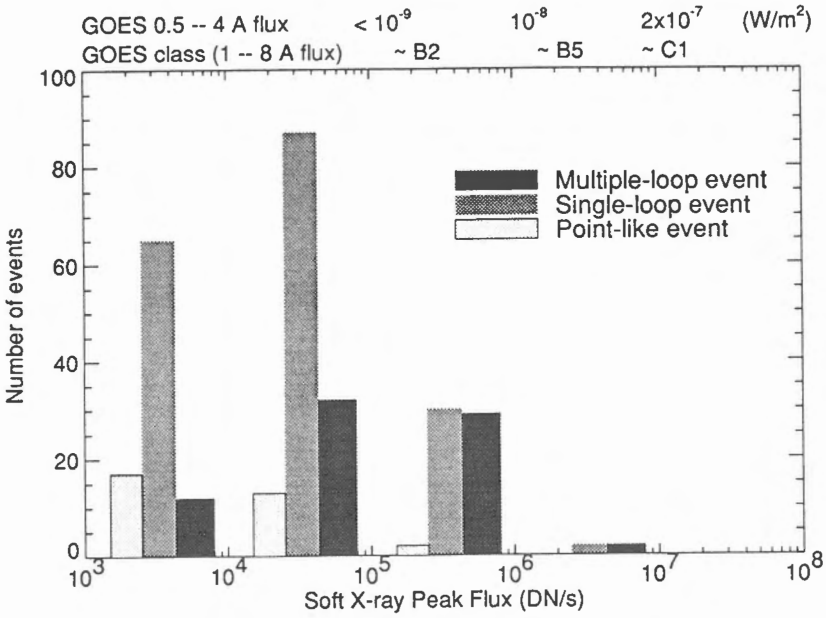

Fig. 2. Soft X-ray Peak Flux of Transient Brightenings.

the outer boundaries of penumbrae observed around 0 UT on 18 August.

We find that transient brightenings are localized in two areas: One is the outer boundary of the penumbra of a preceding spot and the other is a following area. The preceding spot is well-developed and the following area is an emerging flux region embedded in the following plage area during the observation (Jianqi 1993; Nitta et al. 1993). Transient brightenings in the following area are possibly associated with the growing emerging magnetic flux, because transient brightenings rarely appear before the appearance of the emerging flux region. A more interesting feature is frequent brightenings around the outer boundary of the well-developed sunspot. Near well-developed sunspots like this spot, many small magnetic bipolar features, or satellite spots are observed to movie outward from the outer boundaries of their penumbrae into network boundaries (Harvey and Harvey 1973). The moving magnetic loops due to the horizontal motions may approach each other and so have a magnetic reconnection in a current sheet between them. Moreover, some transient brightenings are observed to be located at a magnetic shear region near the eastern boundary of the preceding spot (Sakurai et al. 1993). To clarify the relationship between transient brightenings and the driving forces, we need to make a detailed comparison of transient brightenings with high spatial resolution Hα, continuum, and magnetic data and know their detailed correlation with the photospheric motions, magnetic shear, and other information from optical data.

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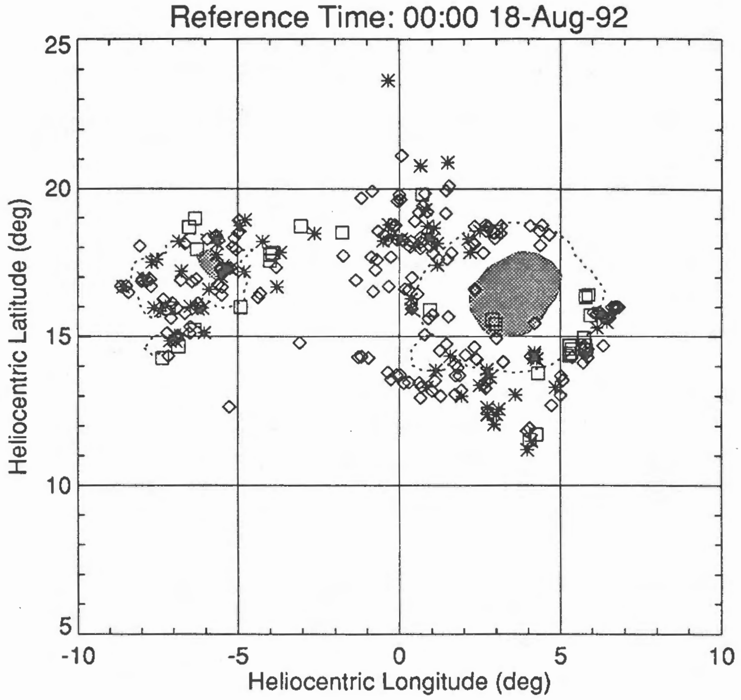

Fig. 3. Spatial Distribution of Transient Brightenings in NOAA 7260.

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