ACTIVE-REGION TRANSIENT BRIGHTENINGS AND THE HEATING OF ACTIVE REGION CORONA

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Abstract

We examine the possibility that active-region transient brightenings contribute to the heating of active region corona. The energy involved in a transient brightening is estimated to range from 10^{25} to 10^{29} ergs. The frequency distribution as a function of energy can be represented with a single power law with an index $1.5 \sim 1.6$ in the energy range greater than 10^{27} ergs, although the distribution deviates from the power law in the energy range smaller than 10^{27} ergs due to the dead time and/or the obscuration by bright background features. In addition, the total energy supplied by the power law distribution of transient brightenings, assuming that the power law continues to lower energy, is of one order of magnitude smaller than the heating rate required in active region corona.

1. Introduction

It is well known that the number (N) of solar flares falls off with increasing peak flux or energy (W) as a flat power law,

$$dN = AW^{-\alpha}dW, \tag{1}$$

with the index (α) of about $1.5 \sim 1.8$ (e.g., Drake 1971; Datlowe, Elcan, & Hudson 1974; Dennis 1985; Crosby, Aschwanden & Dennis 1992). Hard X-ray microflares may also have similar power law distribution but with the larger index about 2 (Lin *et al.* 1984). The total power P in the flare distribution can be represented as

$$P = \int_{W_{min}}^{W_{max}} (dN/dW)WdW = \frac{A}{-\alpha+2}\, W^{-\alpha+2}\Big|_{W_{min}}^{W_{max}}. \tag{2}$$

¿From this equation, $\alpha \geq 2$ implies that microflares may be able to contribute to the heating of active region corona, if W_{min} is low enough, as suggested by Lin *et al.* (1984).

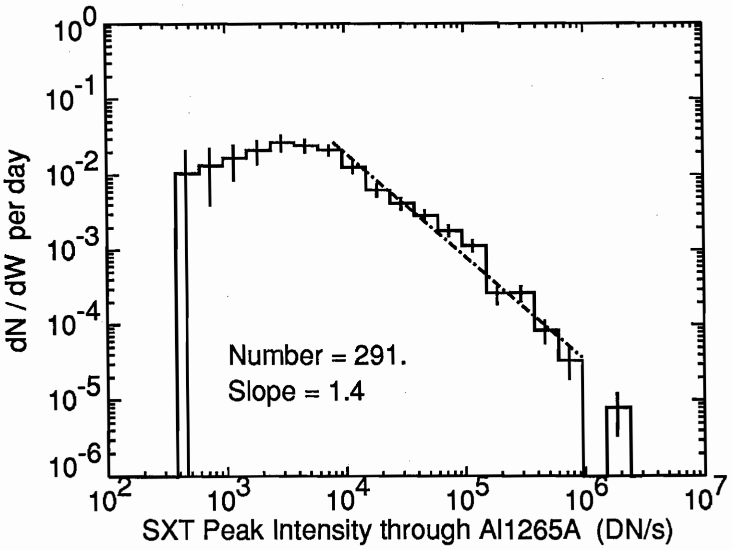

Fig. 1. Frequency distribution of transient brightenings as a function of the soft X-ray peak flux measured at the SXT focal plane through Al 1265Å filter. The error bars represent $\pm 1\sigma$ uncertainties based on Poisson statistics. The distribution can be fitted by a power law with the index 1.4 (dash-dotted line) in the range of 8×10^3 to 10^6 DN s^{-1}.

Soft X-ray imaging observations carried out by the Soft X-ray Telescope (SXT; Tsuneta *et al.* 1991) on the *Yohkoh* spacecraft (Ogawara *et al.* 1991) are sensitive enough to verify the microflare coronal heating hypothesis (Parker 1988). The SXT has revealed that active regions show frequent flare-like brightenings (transient brightenings, hereafter TBs) (Shimizu *et al.* 1992; 1994, Shimizu 1994). Intense TBs are suggested to be soft X-ray counterpart of the hard X-ray microflares (Tsuneta & Lemen 1993).

In this paper, we examine the data taken from 15 through 20 August 1992 to study the energetics and the occurrence rate of TBs: An active region NOAA 7260 was continuously observed during this period (Nitta *et al.* 1994; Leka *et al.* 1994), unless the observations are interrupted by flare observations.

2. Collection of Transient Brightenings

All the features which show small enhancements in brightness in the images are regarded as TBs in this study. Some morphological examples of TBs, although not observed in this region, are presented in Shimizu *et al.* (1994). In order to obtain accurate distribution of occurrence rate of TBs, we need to find TBs without missing as weak TBs as possible. TBs are, therefore, searched with two independent methods: visual inspection method and macro pixel method.

In the visual inspection method, we searched all the features with small enhancements in brightness. This method may miss faint TBs which appear in the bright diffuse backgrounds of the active region. We, thus, developed a macro pixel method to verify that the visual inspection method does not miss faint TBs. We divides 128×128 partial frame images into macro pixels, for instance, consisting of 32×32 pixels, and then systematically pick up enhancements of the macro-pixel brightness. In this paper, results obtained with the visual inspection method are mainly presented, although both results differ only slightly.

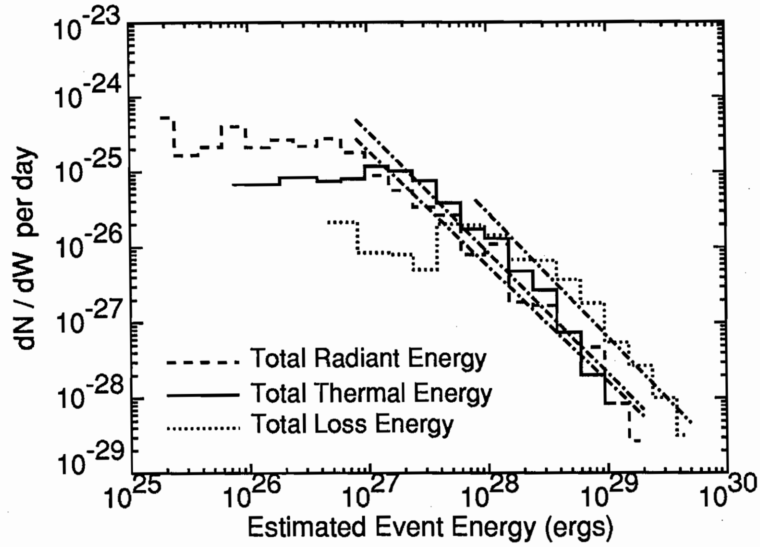

Fig. 2. Frequency distribution of transient brightenings as a function of the total energy estimated with three different methods: the total radiant energy (dashed line), thermal energy content (solid line), and total radiative and conductive loss energy (dotted line). Each distribution can be represented by a single power law with the index 1.5 $\sim$ 1.6 (dash-dotted lines), although the distribution deviates from the power law at the lower end of energy range.

3. Occurrence Rate of Transient Brightenings

The differential distribution of the occurrence rate of TBs obtained with the visual inspection method is shown in Figure 1. It is apparent that tiny TBs more frequently appear than intense ones. The distribution of the peak flux of TBs can be represented by a power law with the index 1.4 ± 0.1 over 2 orders of magnitude. The deviation from the power law at the low end is presumably due to the dead time and/or the obscuration by the bright background features in the active region. Note that the results obtained with the macro pixel method show that the power law distribution continues down to lower peak flux.

In order to examine the hypothesis that the active region corona is heated by TBs, the total energy released into active region corona is more meaningful than the observed peak flux. The estimation of the total released energy, however, has ambiguity, because of the uncertainty of conduction loss. We, thus, estimate the total energy with three different methods; the total radiant energy obtained from an empirical conversion formula described in Hudson(1991), thermal energy content, and total loss energy due to radiative and conductive loss. [Note that Hudson(1991) has a misprint in the conversion formula and $L_{SXR}/L_{total} = 2/30$ is correct (Hudson 1993).]

Figure 2 shows the frequency distribution as a function of the total released energy estimated with three different methods. All the estimation can be represented by a single power law with the index 1.5 $\sim$ 1.6, which is flatter than the slope of the hard X-ray microflares (Lin *et al.* 1984). This value is also flatter than that of the distribution of hard X-ray peak flux of major flares (1.7 $\sim$ 1.8, eg., Dennis 1985), but it is in good agreement with that of the total flare energy of major flares calculated by integrating the thick-target energy rate over the flare duration (1.53, Crosby, Aschwanden, & Dennis 1993). The total energy estimated with three different methods is as follows; The energy range of the total radiant energy is from

10^{25} to 10^{29} ergs, the range of thermal energy content from 10^{26} to 10^{29} ergs, and the range of the total loss energy due to the radiative and conductive loss from 5×10^{26} to 5×10^{29} ergs. The discrepancy between the total radiant energy and the total loss energy may come from uncertainty in the assumptions used. The conversion formula used in the estimation of the total radiant energy may not be accurate enough. Heat conduction flux along cylindrical coronal loops is applied with the classical Spitzer theory in the estimation of the total loss energy. The convergence of the coronal loops may significantly reduce the heat conduction from the corona. Another uncertainty in the energy estimation is that of filling factors. Here we have assumed a filling factor of unity.

4. Energy Input by Transient Brightenings

The energy input by the sum of TBs can be easily estimated with Figure 2. Here we adopt the power law distribution of the total loss energy, that will give larger value than other estimation, as an exercise and assume that this distribution continues from 10^{32} ergs downward to the nanoflare energy ($< 10^{24}$ ergs) range. The estimated total loss energy is 2.7×10^{27} erg s^{-1}. To compare this energy with the energy input required for the active region, we estimate the radiative and conductive losses in the active region 7260. The temperature of the active region is 5.7 MK and the emission measure 1.5×10^{28} cm^{-5} on average. Assuming the line of sight to be the diameter of the region, the electron density can be derived to be 9.9×10^{8} cm^{-3}. The radiative loss rate is estimated to be 2.1×10^{26} ergs s^{-1} and the conductive loss rate 1.4×10^{28} ergs s^{-1}. The energy input into this active region should be roughly 1.5×10^{28} ergs s^{-1}. Therefore, the total energy supplied by the transient brightenings is of one order of magnitude smaller than the energy input required for the heating of the active region corona.

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