THE ELECTRON DENSITY IN THE LOCALIZED BRIGHT REGIONS AT THE TOPS OF FLARE LOOPS

G. A. Doschek

E. O. Hulburt Center for Space Research, Naval Research Laboratory, Washington, DC 20375-5352, U.S.A.

Abstract

A technique for determining the electron density in the localized bright regions at the tops of flare loops is discussed, and some preliminary results are given. The technique utilizes SXT flare images obtained with the Be filter, and S XV spectra obtained by the BCS. The densities are derived under the assumption of a filling factor of unity, and are therefore lower limits.

1. Introduction

One of the most interesting discoveries with Yohkoh are the bright knots of emission that occur at the tops of flare loops (e.g., Feldman et al. 1994). These are best seen in "simple" appearing flares that occur above the limb, such as the event on 13 January 1992 near 17 UT. These emission knots are difficult to understand in terms of traditional models of magnetic flux tubes, and many possible theoretical explanations for the knots are being considered. It is therefore interesting to determine the physical characteristics of the plasma in the knots, such as the electron density. In this paper one possible technique is described, and a few results are given. This work is still ongoing, and a more extensive publication will be prepared.

2. Technique

One obvious way to determine the electron density is to use SXT images alone. First, the emission measure of the localized bright region is determined using SXT_PREP and SXT_TEEM. The density is then derived by dividing this emission measure by the estimated volume of the bright region, determined from inspection of the SXT images. The extent of the bright regions is quite small, usually of the order of one to three pixels for most flares. (Long duration events are an exception.) If the bright region is assumed to be a sphere with a diameter of two SXT pixels, then the volume is 2.2×10^{25} cm^3.

An independent, and therefore valuable, way to estimate the density is to combine the SXT and BCS data, and use the S XV BCS spectra to determine the emission measure of the bright region. The volume is still determined from the SXT images. The rationale for this method is the observed fact that the S XV BCS flare light curves have very similar shapes to the SXT light curves obtained from Be filter images. The implication is that the SXT Be filter image is essentially what the flare would look like if an image were available in S XV radiation. This seems like a reasonable assumption because the Be filter response is quite high near 5 Å, close to the wavelengths of the S XV lines. The technique is best applied to limb flares because, a) the localized bright region is well-defined, and b) blue-shifted S XV emission is absent, giving a much simpler spectrum than observed for many disk flares during the rise phase.

First, the S XV spectra are fit by theoretical synthetic spectra. The electron temperature, averaged over the whole flare, and the total emission measure of the flaring region, are determined from the fits. Although BCS also "sees" other active regions on the Sun, this background emission is usually small compared to the flare emission, except at the flare onset and far into the flare decay phase. Second, the fraction of the total flare emission due to the localized bright regions is determined from inspection of the SXT images. There are a number of ways to do this systematically, e.g., select a cutoff intensity that is some fraction of the brightest pixel in the bright knot. Third, the BCS total S XV emission measure is multiplied by the fraction of the total SXT emission in the bright knot. This gives the S XV emission measure of the bright knot. Implicit in this procedure is the assumption that the average S XV temperature is the same in the bright region as in the legs of the flare loop. The effect of violating this assumption is under investigation. Finally, the S XV bright knot emission measure is divided by the volume of the bright knot, determined using the same technique used to determine the fraction of SXT emission in the bright knot. The square root of this quantity is the electron density of the bright knot, assuming a filling factor of unity. The density is therefore a lower limit.

It is desirable to use the above procedure to determine the density in the bright knot of a flare as a function of time, and then to use the total S XV emission measure to determine a corresponding average electron density in the legs of the loop, using the same technique as described above for the bright knot. It is also possible to make assumptions such as that all of the Fe XXV emission arises in the bright knot, and then use the total Fe XXV emission measure to determine a density for comparison to the S XV results. This type of work is still in progress and no results are given here.

3. Preliminary Results

The results given below are for flares that have very small bright localized regions. The volume assumed is a sphere with a two pixel diameter, as mentioned above.

- 17 February 1992 flare: The derived density is 3.2×10^{11} cm^{-3} at 15:41:25 UT and 1.2×10^{12} cm^{-3} at 15:46:05 UT. The latter density is for times near peak S XV emission in the flare; the former density pertains to a time during the rise phase of the flare.

- 13 January 1992 flare: A density of 2.9×10^{11} cm^{-3} is derived for 17:28:34 UT, a time during the rise phase of the flare.

- 2 December 1991 flare: A density of 3.4×10^{11} cm^{-3} is derived for 04:52:20 UT, a time during the rise phase of the flare.

The above electron densities pertain to plasma at temperatures between about 10 and 20×10^6 K. The densities are high, but are consistent with results obtained from the S082-A slitless spectrograph on Skylab. The densities are higher if the filling factor is less than 1.

The total emission measures obtained from S XV and from SXT using SXT_TEEM are within a factor of 2 for two flares for which checks have been made, but I note that there is a more substantial discrepancy in the derived electron temperatures. For one flare, a temperature of about 8×10^6 K is obtained from SXT but the temperature derived from S XV is about 16×10^6 K. The source of this discrepancy is unclear and is under investigation.

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References

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