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YOHKOH BRAGG CRYSTAL SPECTROMETER (BCS) OBSERVASIONS OF THE 6-FEB-1992 LIMB FLARE

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Abstract

We present *Yohkoh* BCS observations of a near-limb solar flare of 6 Feb 1992. SXT images show that the event was composed of at least two flaring loops. The first of these to flare had a maximum Fe XXV temperature of about 19 MK and no substantial Fe XXVI component, while the second flaring loop achieved a Fe XXV temperature in excess of 21 MK and had a superhot (30–40 MK) Fe XXVI component.

1. Introduction

Previous observations using Bragg crystal spectrometers (BCS) have shown that solar flare plasmas chiefly consist of gas around 20 MK (e.g., Doschek 1990). Although many events appear not to have a substantial amount of gas at hotter temperatures, there is a subset of flares which do contain gas in the range of 30–40 MK. Such flares are said to have a "superhot" component (Lin et al. 1981, Tanaka 1986). Data from the BCS on *Yohkoh*, indicate that an event which occurred on 6 Feb 1992 was a composite of both types of flares, i.e., one without a superhot component and one with a superhot component. This event was also well observed by *Yohkoh*'s soft X-ray telescope (SXT) and hard X-ray telescope (HXT), affording an excellent opportunity for detailed comparative studies. Here we present a brief summary of the observations of this event from BCS, and a description of results from SXT. A description of the HXT data, and more information on SXT data from this event are presented in the paper by Kosugi et al. (1994a) in this same volume. A full study of this event combining results from all instruments will be presented elsewhere (Kosugi et al. 1994b).

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2. The *Yohkoh* BCS

The Bragg crystal spectrometer (BCS) experiment on *Yohkoh* observes the Sun in four narrow spectral bands in the soft X-ray region. These four bands cover the resonance lines and associated satellite lines of H-like iron (Fe XXVI, near 1.78 Å), He-like iron (Fe XXV near 1.85 Å), He-like calcium (Ca XIX, near 3.18 Å), and He-like sulfur (S XV, near 5.04 Å). The three highest energy channels only observe flares, while the S XV channel is capable of observing both flares and non-flaring active regions. Both iron channels share a single detector, while the calcium and sulfur channels share a second detector. The *Yohkoh* BCS is about an order of magnitude more sensitive than BCS experiments that have flown on the *P78-1, SMM,* and *Hinotori* satellites. Lang et al. (1992) describe the performance of the *Yohkoh* BCS.

For the work presented here, we measure temperatures in the two iron channels. For Fe XXV temperature measurements, we make use of the temperature-sensitive ratio of the dielectronic line at 1.866 Å ($1s^22p\ ^2P_{3/2} - 1s2p^2\ ^2D_{5/2}$, line j in the notation of Gabriel 1972) and the Fe XXV resonance line ($1s^2\ ^1S_0 - 1s2p\ ^1P_1$, line w) at 1.8499 Å. For Fe XXVI, we estimate a temperature by using the ratio of the sum of the intensities of the Lyα lines near 1.778 Å and 1.785 Å, and the intensity of the Fe XXV resonance line. Doschek et al. (1990) give a relationship between this ratio and Fe XXVI temperature.

For the *Yohkoh* BCS, virtually all flares smaller than the GOES mid-M class produce usable spectra in all BCS channels, except Fe XXVI. Flares larger than mid-M class saturate the sensitive BCS detectors. Many flares that are potentially large enough to generate detectable Fe XXVI spectra saturate the iron channel detector before Fe XXVI is strong enough to be detected. Therefore only a limited number of flares seen by the *Yohkoh* BCS display Fe XXVI spectra (Pike et al. 1994). One example is an event seen on 16 Dec 1991 (Culhane et al. 1994). Below we discuss the Fe XXVI event of 6 Feb 1992.

3. BCS and SXT Observations of the 6 FEB 1992 Flare

On 6 Feb 1992 near 3:12 UT, a flare occurred on the near-earth side of the West solar limb. Although the event eventually reached GOES level M7.6, BCS was able to make good observations up until about 3:22 UT, after which time the BCS detectors saturated. Plotting the Fe XXV temperature, $T_e(He)$, as a function of time shows the following characteristics: At the beginning of the observations near 3:11 UT $T_e(He) \approx$ 14 MK. After 3:11 $T_e(He)$ steadily rises until achieving a peak at about 3:16 UT of $\approx$ 19 MK. Then $T_e(He)$ decreases, reaching a minimum of about 18 MK near 3:18 UT, and then starts to rise again. Near 3:22 UT, $T_e(He)$ is near 22 MK and still rising when the BCS observations end due to saturation.

As indicated above, this event also displays prominent Fe XXVI spectra prior to saturation. The intensity of the Fe XXVI spectrum is very weak or non-existent until about 3:18 UT, and it becomes strong after about 3:20 UT. Using the method discussed in Section 2, we derive a corresponding Fe XXVI temperature, $T_e(H)$, of about 30 – 40 MK, indicating the presence of a superhot component.

SXT images of this event show what appears to be a single loop-like structure from before 3:16 UT until about 3:20 UT. Moreover, that loop is brightest in a localized region near the top of the loop. This is typical of many flares, i.e., after an initial footpoint brightening, loop-top brightenings are characteristic of many flares observed by SXT (Acton et al. 1992, Hudson et al. 1994). From about 3:21 UT, what appears to be a second loop, a few arcseconds to the north of the first loop, begins to brighten. The brightening in the northern loop appears to proceed from a single footpoint, and expands to fill the entire loop by about 3:26 UT. The loop-filling motion has an apparent velocity of about 200 km s^{-1}, which is consistent with the ion sound speed given our ignorance of the angle of projection of the motion. By 3:32 UT, the intensity of the northern loop completely dominates that of the first, southernmost loop.

One possible interpretation of these observations is the following: The southern loop in the SXT images is a flare which has a maximum Fe XXV temperature of around 19 MK, no substantial Fe XXVI spectral signature, and a prominent loop-top brightening seen in SXT images after onset. In contrast, the northern loop, which appears later, has a maximum Fe XXV temperature in excess of 21 MK, a substantial Fe XXVI emitting component with temperatures of 30 – 40 MK, and appears to be a loop gradually filling with hot plasma in SXT images. If this interpretation is correct, the 6 Feb 1994 event is, to the best of our knowledge, the first of its kind ever analyzed.

Previous and current studies indicate that the presence or absence of a superhot component does not appear to be correlated with $T_e(He)$ values in general (Tanaka 1986, Pike et al. 1994). There is as yet no information on the relationship between flares containing superhot components and their appearance in high resolution soft X-ray images.

4. Summary

Our preliminary studies of the 6 Feb 1994 flare indicate that it is composed of (at least) two different flaring loops, one lacking a superhot component and appearing as a single bright kernel at the loop top in SXT images, the second loop containing a superhot component and appearing to fill from one end in SXT images. Combining observations from various instruments on *Yohkoh* will potentially allow us to compare directly properties of the two different types of flaring loops. Studies such as these utilizing data from various instruments promise to increase further our understanding of solar flares.

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