Fe XXV Temperatures in Flares Determined from the *Yohkoh* BCS Experiment

Alphonse C. Sterling
Computational Physics Inc.
2750 Prosperity Ave., Suite 600
Fairfax, Virginia 22031 USA *

January 10, 1994

Abstract

The Bragg crystal spectrometer (BCS) experiment on board *Yohkoh* is more sensitive than similar instruments flown on earlier satellites. This increased sensitivity allows us to study flares from very early periods after onset. In this report we briefly introduce the instrument. We also describe observations of a unique flare that was well observed by both BCS and the soft X-ray telescope (SXT) on board *Yohkoh.* Studies such as these combining data from different *Yohkoh* instruments promises to vastly increase our understanding of solar flare phenomena.

1 The *Yohkoh* BCS

The Bragg crystal spectrometer (BCS) experiment on board *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.

Among the scientific objectives of the BCS is to measure thermal and non-thermal flare temperatures, bulk plasma motions, and elemental abundances. A standard procedure for measuring thermal temperatures is to use the ratio of intensities of a dielectronic recombination line to the corresponding resonance line. This ratio is well known to be temperature-sensitive. In Fe XXV spectra, appropriate lines are the Fe XXIV dielectronic line at 1.866 Å ($1s^2 2p\ ^2P_{3/2} - 1s2p^2\ ^2D_{5/2}$) and the Fe XXV resonance line ($1s^2\ ^1S_0 - 1s2p\ ^1P_1$) at 1.8499 Å. For Fe XXVI, useful lines are the Lyα lines near 1.778 Å and 1.785 Å, and the associated satellite lines in the region around 1.79 – 1.793 Å. It is also possible to estimate the Fe XXVI temperature by measuring the ratio of the intensities

*Current address: Institute for Space and Astronautical Science, Yoshinodai 3-1-1, Sagamihara, Kanagawa 229, Japan of the sum of the Lyα lines and the Fe XXV resonance line. Doschek *et al.* (1990) give a relationship between this ratio and Fe XXVI temperature. Flares generally have maximum Fe XXV temperatures of about 18 – 27 MK, while Fe XXVI temperatures are comparable or a little higher (e.g., Doschek 1990). There is also a category of flares that have very hot Fe XXVI spectral signatures (Lin *et al.* 1981, Tanaka 1986), as high as about 35 MK. These events are referred to as having a "superhot" component.

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. Most flares that are large enough to generate detectable Fe XXVI spectra saturate the iron channel detector before Fe XXVI is strong enough to be detected. Only relatively small flares which have a superhot component display Fe XXVI spectra in the *Yohkoh* BCS. So far, only a small number of flares seen by *Yohkoh* satisfy these conditions. One example is an event seen on 16-Dec-1991 (Culhane *et al.* 1994). In the next section we discuss a second such event.

2 BCS Observations of the 6 Feb 1992 Flare

Around 3:12 UT on 6-Feb-1992, a flare reaching GOES class M7.6 occurred near the solar west limb. Although it was too large for continuous BCS observations, we did obtain good data throughout much of the rise phase of the event. An analysis of the Fe XXV spectra shows that the flare has a complicated Fe XXV temperature time evolution, first rising to a first maximum, then decreasing, and then increasing again, heading toward a second maximum. The first maximum is about 19 MK and occurs near 3:15 UT, and then the temperature decreases to below 18 MK, reaching a minimum at about 3:18 UT before starting to increase again. Near 3:22 UT the Fe XXV temperature is near 21 MK and still increasing, at which point the intensity of the flare saturates the BCS detectors.

This event displays a prominent Fe XXVI spectrum prior to saturation. The intensity of this spectrum is very weak or non-existent until about 3:18 UT, and it becomes strong after about 3:20 UT. The ratio of the sum of the intensity of the Lyα lines and the intensity of the Fe XXV resonance line indicates that the emitting plasma has a temperature of about 30 – 40 MK. Thus this event does indeed possess a superhot component.

Images from the *Yohkoh* soft X-ray telescope (SXT) of this event also show some interesting features. Up until about 3:20 UT, there is what appears to be one single flaring loop. Moreover, that loop is brightest in a localized region near the top of the loop. 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 one 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}. 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 relatively "standard," frequently observed flare which has a maximum Fe XXV temperature of around 19 MK, no substantial Fe XXVI spectral signature, and a loop-top brightening seen in SXT images after onset. In contrast, the northern loop, which occurs 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, this event is, to the best of our knowledge, the first of its kind ever analysed. A full report on this event, including observations from the *Yohkoh* hard X-ray telescope (HXT), will appear at a later date (Kosugi *et al.* 1994).

3 Future Prospects

Combining BCS data with observations from the *Yohkoh* SXT can give insights into flare dynamics not previously possible. In the same way, in the future work will be done combining results from all *Yohkoh* instruments. Such studies promise to further increase our understanding of solar flares.

References

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