HARD AND SOFT X-RAY OBSERVATIONS OF A SUPER-HOT THERMAL FLARE OF 6 FEBRUARY, 1992

T. Kosugi [1], T. Sakao [1], S. Masuda [1], H. Hara [2], T. Shimizu [2], and H. S. Hudson [3]

[1] *National Astronomical Observatory, Mitaka 181, Japan*
[2] *Institute of Astronomy, University of Tokyo, Mitaka 181, Japan*
[3] *Institute for Astronomy, University of Hawaii, Honolulu, HI 96822, U.S.A.*

Extended Abstract

The flare of 6 February, 1992 at 03:10 UT is the first flare that showed typical characteristics of a super-hot thermal flare (type A flare) and was imaged simultaneously in both the hard and soft X-ray ranges with sufficient spatial resolution. The observations were made with the Hard X-ray Telescope (HXT; Kosugi *et al.* 1991) and the Soft X-ray Telescope (SXT; Tsuneta *et al.* 1991) on board *Yohkoh.* The flare occurred in the active region NOAA 7030 near the west limb (N05W82), which is a suitable condition for us to obtain a hint as for where and how the flare energy is released and transported in a flaring loop.

Time histories of the flare in soft X-rays (from *GOES*), microwaves at 17 GHz (from Nobeyama), and hard X-rays (from HXT) are compared in figure 1. It is clear from this figure that the flare consists of two distinctly different stages from each other.

In the first stage, the flare seems to be a normal impulsive flare. It began at about 03:10 UT and peaked at 03:16 UT. The hard X-ray (above $\sim$ 25 keV) spike lasted for only $\sim$ 1 min (FWHM), showed a relatively hard spectrum that can be fitted by a power-law spectrum with a spectral index of $\sim$ 4, and was associated with an intense microwave burst. In this stage, the hard X-ray emission originated from the two footpoints of a soft X-ray emitting loop (figure 2, top left), which is typical for impulsive flares (e.g., Sakao *et al.* 1994; Sakao 1994).

Then, in the second stage, a new flaring loop began to brighten at the north of the first-stage flaring loop (figure 2), although the two loops seem to share one footpoint in common. This second stage, peaking at about 03:25 UT in hard X-rays, is characterized by quite different properties from those of the first stage: a gradual broad peak lasting for longer than 10 min, a quite soft hard X-ray spectrum that is dominated by thermal emission from a super-hot plasma with temperatures of 30 – 40 millions K, and lack of associated microwave burst, all of which are typical for super-hot thermal flares or type A flares (e.g., Tsuneta *et al.* 1984; Kosugi *et al.* 1988). The existence of super-hot thermal plasma is confirmed by

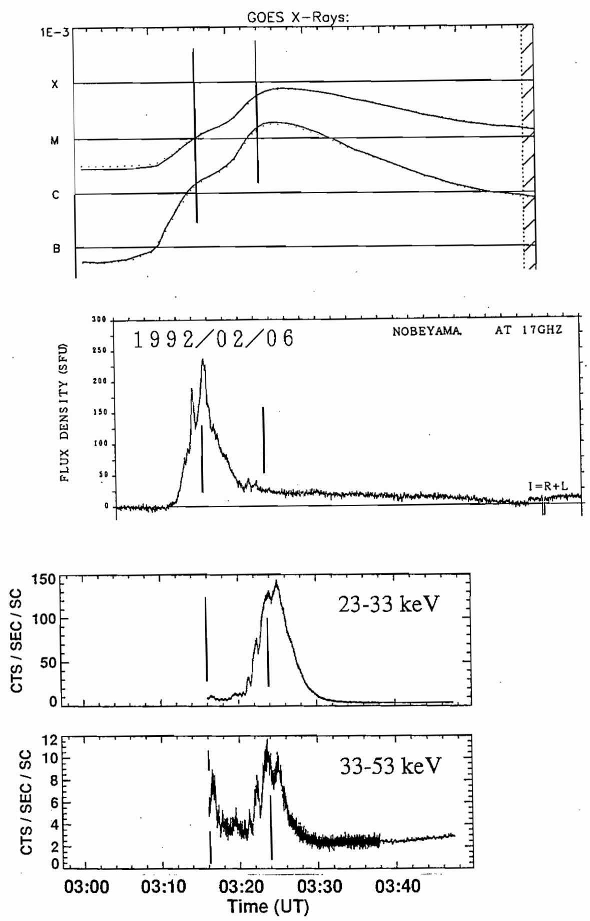

Fig. 1. Time histories of the 6 February, 1992 flare in soft X-rays (top: from *GOES*), microwaves at 17 GHz (middle: from Nobeyama), and hard X-rays (bottom: from *Yohkoh* HXT). The second peak at ~ 03:25 UT shows typical characteristics of a super-hot thermal flare.

detection of Fe XXVI line emissions with the Bragg Crystal Spectrometer (BCS) on board *Yohkoh* (Sterling 1994).

It is noteworthy that the super-hot, hard X-ray source appeared first near the loop top and gradually expanded downwards. At the same time, a bright soft X-ray source appeared first at the northern footpoint of the loop and gradually expanded upwards (figure 2). This is in contrast to the tendency that hard X-ray source appears as double footpoint sources in impulsive flares, which is actually seen in the first stage of this flare.

This unusual behavior in hard and soft X-ray sources in the second stage or the super-hot thermal flare can be explained as follows: In super-hot thermal flares the flare energy, released near the loop top, is mainly consumed for creation of super-hot plasma there and is transported via heat conduction towards the footpoints, resulting in evaporation of chromospheric material seen as upward motion in soft X-rays. On the contrary, in normal impulsive flares, the main product of the primary energy release is nonthermal electrons, which precipitate towards the two footpoints of a loop, resulting in the double footpoint hard X-ray sources. Maybe the energy release mechanism is similar to, but the efficiency of particle

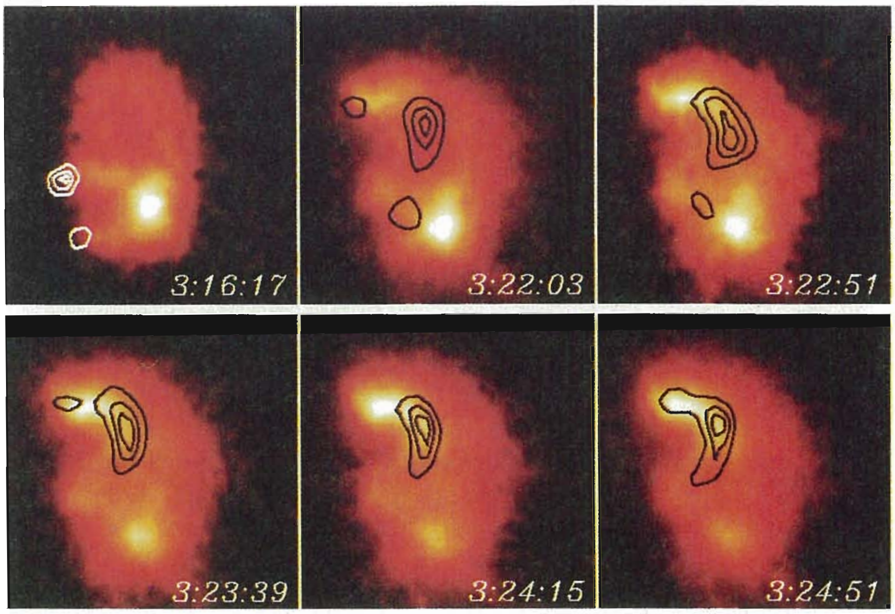

Fig. 2. Hard X-ray (33–53 keV: contours) and soft X-ray (Be filter: grey scale) images of the 6 February, 1992 flare. The flare occurred near the west limb at N05W82, so that we see vertical structures in projection. The solar north is to the top, west to the right. Each map covers 78 ×78 arcsec. In the first stage at 03:16:17 UT (top left), the double footpoint hard X-ray sources are clearly seen. In the second stage after 03:22 UT, a new flaring loop brightens with the hard X-ray source appearing near the top.

acceleration differs critically from each other. Since the first and the second stages originate from different loops and also since the hard X-rays above ~ 30 keV, maybe of nonthermal origin, are emitted from the loop top portion in the second stage, it is suggested that a high density inside the second-stage flaring loop is responsible for this inefficiency of particle acceleration. A further study is in progress.

References

1. Kosugi, T., Dennis, B. R., and Kai, K., 1988, *Astrophys. J.*, **324**, 1118.
2. Kosugi, T. *et al.*, 1991, *Solar Phys.*, **136**, 17.
3. Sakao, T., 1994, Ph.D. thesis, University of Tokyo.
4. Sakao, T. *et al.*, 1994, in these proceedings.
5. Sterling, A. C., 1994, in these proceedings.
6. Tsuneta, S. *et al.*, 1984, *Astrophys. J.*, **284**, 827.
7. Tsuneta, S. *et al.*, 1991, *Solar Phys.*, **136**, 37.