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HARD X-RAY IMAGING OBSERVATION OF FLUCTUATING BURSTS

K. Ohki

Tokyo Astronomical Observatory
Mitaka Tokyo, 181 Japan

M. Harada

Science University of Tokyo
Tokyo, Japan

Measurement has been done to obtain one-dimensional sizes of rapidly fluctuating bursts with fast spikes whose rise times are typically about one second, and in some extreme cases less than 0.1 seconds. The results of two bursts with fast spikes are presented here. One has a soft spectrum, and the other has a very hard spectrum. The measured one-dimensional size of both events indicates relatively a small size and simple structure. We can say, however, the source size is not so small as expected from its rapid time variations. Therefore, a thermal explanation of these bursts seems to be excluded.

1. Introduction

Among various electromagnetic radiations, the hard X-ray shows most complex temporal variations during the impulsive phase of flares as well as radio waves. This fact may simply indicate that both type of radiations come from most violently activated regions in the flare or the vicinity of them where energy is created from the nearby magnetic field. Then, a question may be naturally raised what causes the short time fluctuations. Do they indicate many different loops flaring up successively, or the repeated activations within the same loop?

It takes about 8 seconds to obtain two-dimensional flare images with the hard X-ray imaging telescope aboard the Hinotori (hereafter called SXT). However, if we restrict ourselves within one dimensional scan images, the temporal resolution to make a single scan image is only about 100 milliseconds depending on the position angle of the scan. So,hard X-ray source location, size, and their time variation up to 100 millisec can be observed by using this one dimensional scan data.

2. Data Selection

To obtain the one-dimensional size of hard X-ray events with fast spikes, we searched for relatively intense events which contain at least several spikes with a total duration of well less than one second.

Another criterion of event selection is that the events should have fast spikes even in the lowest energy channel of the hard X-ray spectrometer, usually at 17 - 40 keV, because the SXT always observed at this energy range. Many hard X-ray bursts observed with the Hinotori show rather slow and broad spikes in the lowest energy channel in spite of fast and sharp spikes in the higher energies. Even in the case where fast spikes exist in the lowest channel, they are usually embedded in the gradual components, and the flux due to fast spikes seems relatively small as compared with those due to the gradual ones. Therefore we intentionally searched for those events in which the fast spike components constitute the major part of the total flux in the lowest energy channel.

Two typical events with such characteristics as above are found in the events of March, 1981. Mar 21 and Mar 24 event seem to be very similar in their appearance of the time history of the lowest channel. But the spectral characteristics of the two events are very different each other. Mar 21 event has a very hard spectrum, while Mar 24 has a rather soft one. In other words, these two events would show two extreme examples among similar events with fast spikes. Therefore, we will exclusively analyze these two events in this paper.

3. Method of Data Analysis

As indicated in Makishima(1982), the telescope SXT has the intrinsic roundness of the triangular beam pattern which is less than seven arcsec. Pre-launch calibration data also show five arcsec for the roundness of the beam pattern. Therefore, it would not be so implausible to start from a rigorous triangular pattern to analyze the one-dimensional data , if our goal of this analysis is restricted to 10 arcsec for the minimum detectable size of the hard X-ray sources.

Then, first we assume a triangular shape with FWHM of 28 arcsec as the SXT 2 (the name of the two SXT collimators) beam pattern. Second, we assume a gaussian profile as the structure of a single source. Then, the convolution between the triangular beam pattern and the gaussian profile of the source will give a calculated pattern after the transmission through an ideal collimator to be compared with the observed one-dimensional scan data.

Figure 1 shows the relationship between the FWHM of the assumed gaussian profile and the FWHM after convolution calculation described above. We can easily obtain the one-dimensional size by measuring the FWHM of the observed one-dimensional scan curve and by comparing it to the calculated FWHM in Figure 1, as far as the assumption of the gaussian profile is not so absurd.

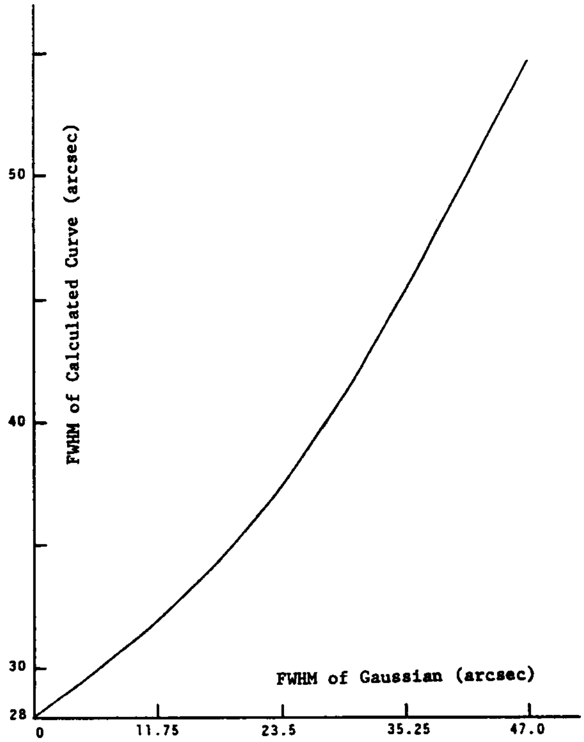


Fig.1. The relationship between the FWHM of the assumed gaussian profile and the FWHM of the calculated scan curve.

4.1. March 24, 1981 Event

In Figure 2(a), time histories of four energy bands are shown. Although this event has a moderate count rate at the lowest energy channel, the count rate at the third channel is very small and the highest channel shows almost no increase above the back-ground level, indicating a fairly soft spectrum of this event.

Figure 3 shows a detail time history with 0.125 sec temporal resolution and three examples of FWHM fitting of one-dimensional scan data. For comparison, the first scan data are accompanied by a standard scan profile taken from October 12, 1981 event which has an excellent single point source with the smallest size we have ever observed, with two-dimensional images for this event being obtained because this event has a smooth and gradual time variation. Generally, the March 24 event consists of a relatively small single source throughout the event. Exceptionally, a halo component is seen in the early phase of the event as can be seen in Figure 3(a1), though the brightness of this halo is less than 10 % of the main source. The measured FWHM sizes of the main source at various times are summarized in Table 1.

4.2. March 21,1981 Event

This event has the main source with larger size than March 24 event as shown in Figure 4. Especially, in the first half of the event, it contains intense halo components or some secondary weaker sources. Any way, it has a complex spatial structure. It should be noted here that a clear secondary source can be seen in a early phase of this first half period as shown in

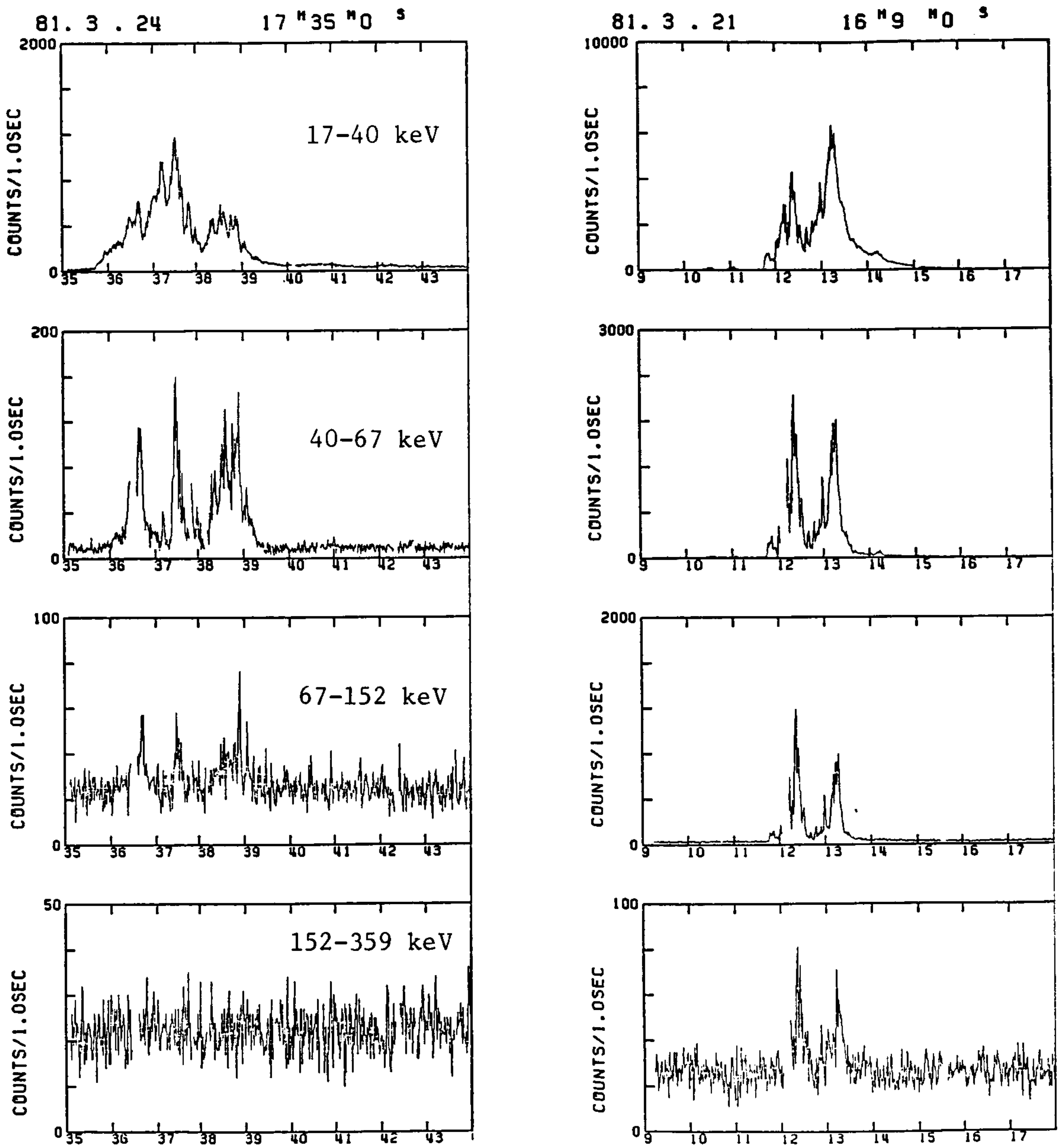


Fig.2. Time histories of March 24 and March 21, 1981 events. One division of the horizontal time axis corresponds to one minute. Four energy bands are illustrated.

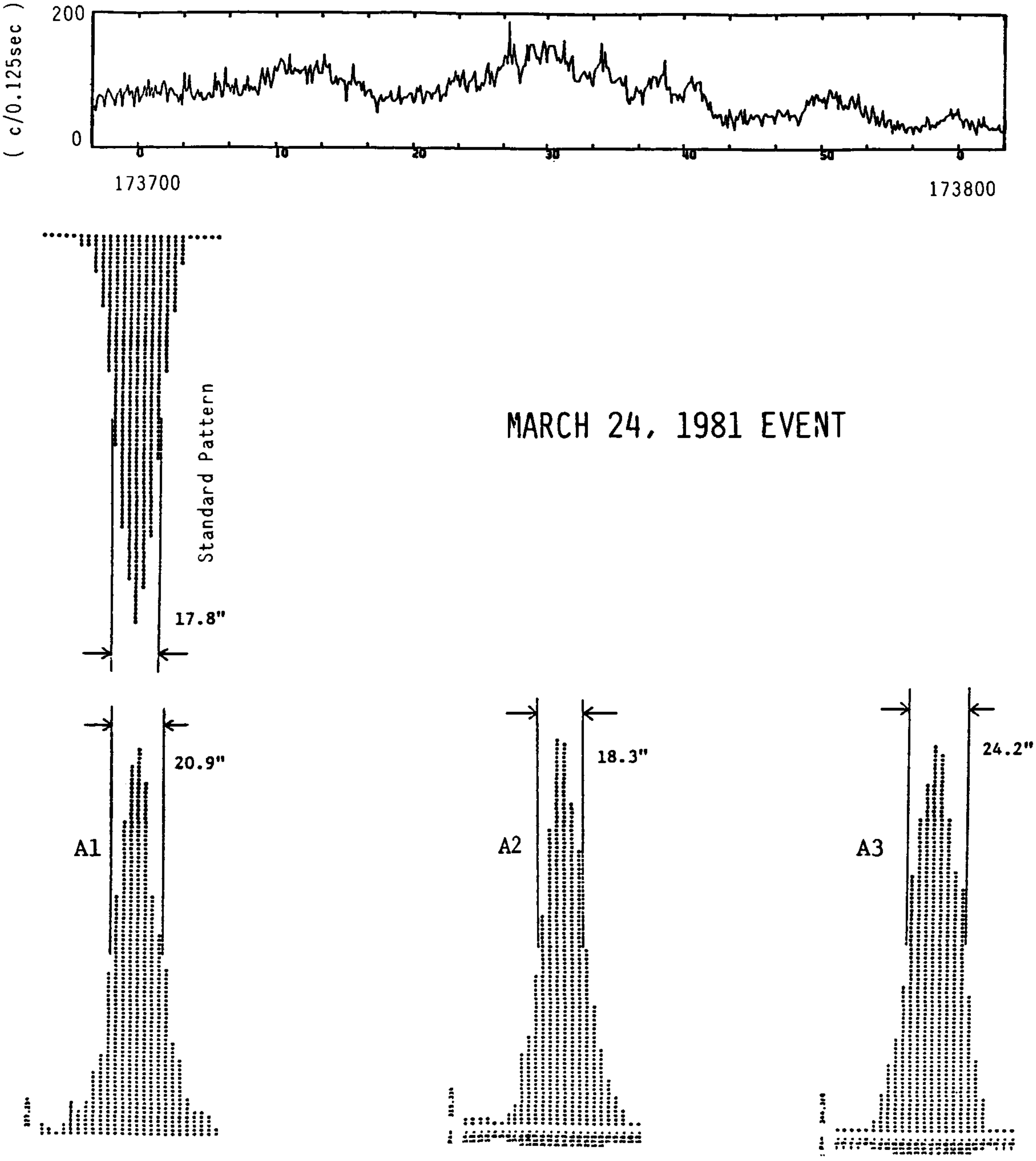
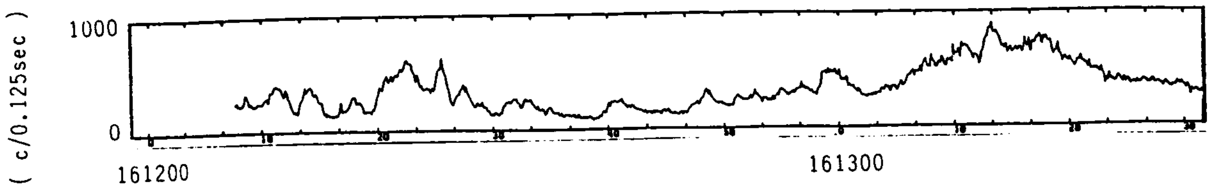


Fig.3. High resolution time history and three examples of the observed one-dimensional scan curves of March 24,1981 event. Resultant gaussian FWHM derived from the measurement of the observed FWHM after fitting to the curve in Figure 1 is illustrated in each scan data. The observation times and other data for each scan is summarized in Table 1.



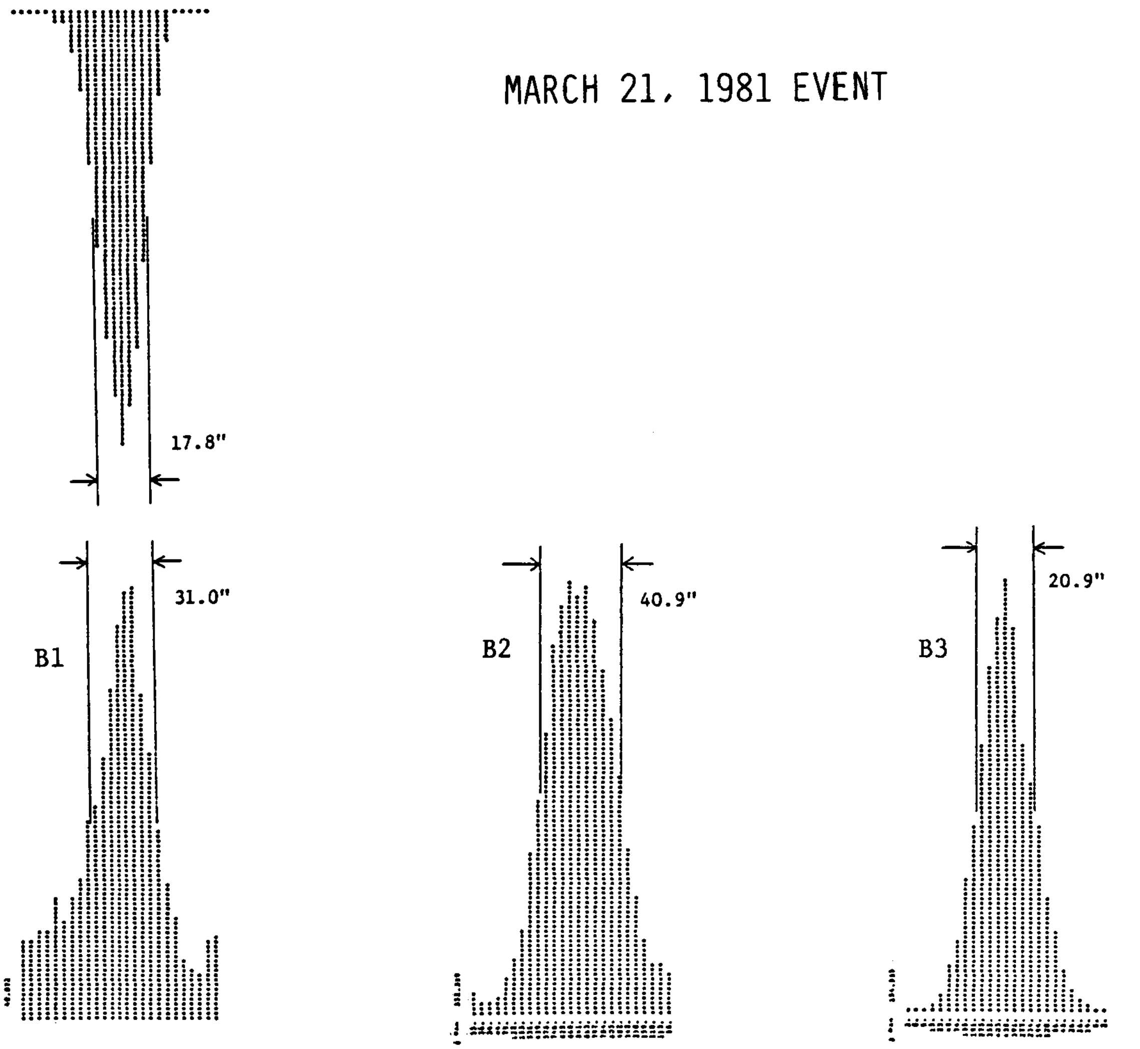


Fig.4. This is similar to Figure 3 but for the March 21, 1981 event. Above the scan data B1, a standard scan data from October 12, 1981 event is illustrated in upside-down position just for comparison. Note that all the observed FWHM of this event are larger than that of this standard scan data.

(continued)

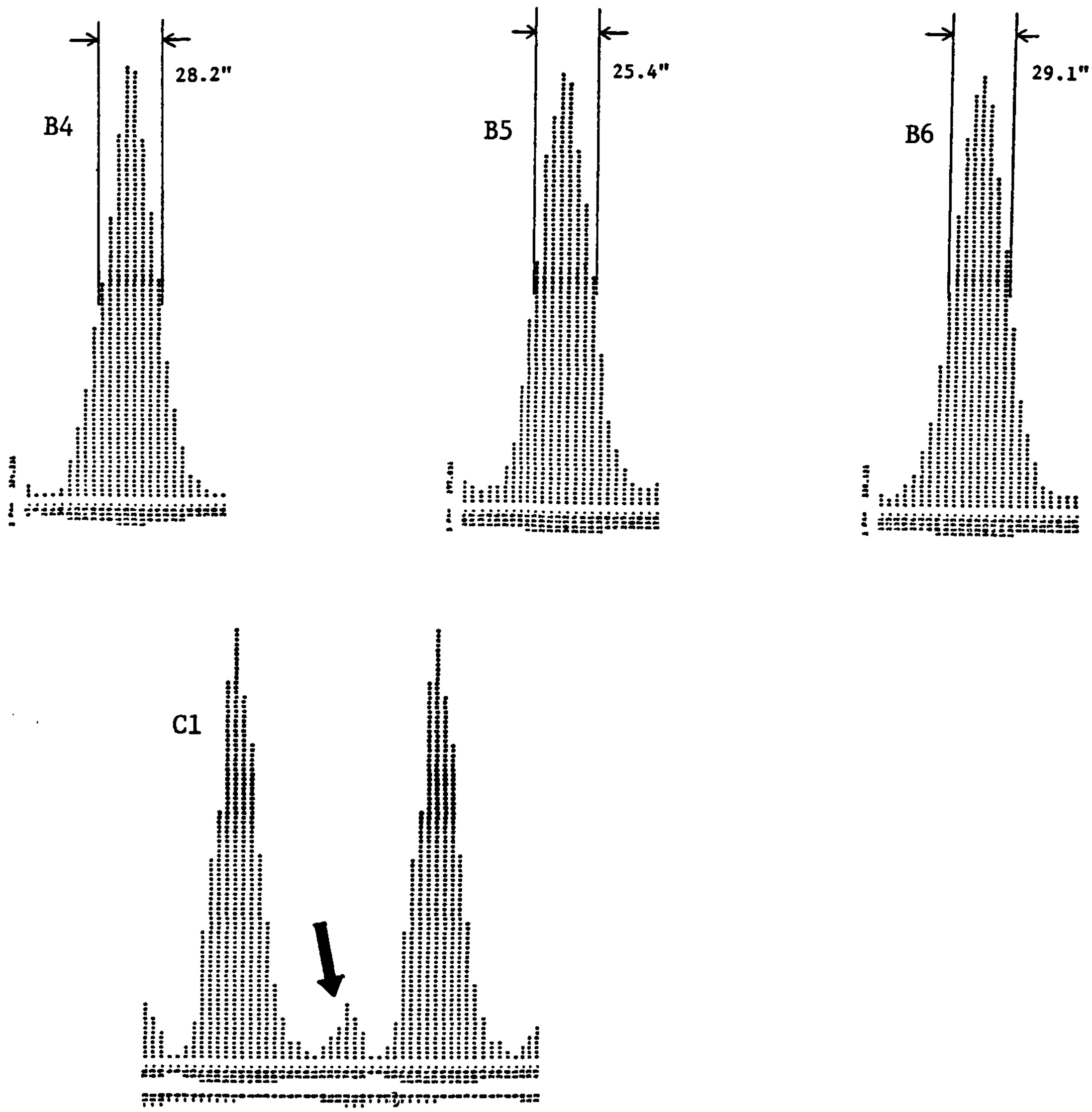


Fig.4 (continued) This again is similar to Figure 3. The bottom scan curve C1 is illustrated to show a small secondary source which is indicated by the thick arrow in the Figure. This scan data is specially given in two phases of scan in order to show the secondary source clearly.

Figure 4(C1). The spatial separation between this secondary source and the main source is as large as about one arcmin. Even in the second half, this event has a fairly large sized main source. The variation of the source sizes and the observed times are again summarized in Table 1.

Table 1. Summary of Observation

Date of Event	Scan No.	Obs.Time	Obs.FWHM (arcsec)	FWHM(arcsec) (gaussian)
MAR 24,1981	A1	17:37:13	35.9	20.9
	A2	17:37:25	34.7	18.3
	A3	17:37:39	37.8	24.2
MAR 21,1981	B1	16:12:24	42.1	31.0
	B2	16:12:26	49.5	40.9
	B3	16:13:04	35.9	20.9
	B4	16:13:12	40.2	28.2
	B5	16:13:13	38.4	25.4
	B6	16:13:15	40.9	29.1
	C1	16:12:19	——	——

5. Discussion

Many hard X-ray images of impulsive bursts has been already published. Among them, some images of spiky events were included, which showed relatively small and simple structures. For examples, two impulsive events on September 7, 1981 showed a small single source (Takakura et al. 1983). August 10, 1981 event also had a small source (Ohki et al. 1983).

However, we have had not hard X-ray images of rapidly fluctuating events composed of very fast spikes with total durations less than one second, since we can not reconstruct two-dimensional images for such events. About 8 seconds steady data are basically needed to obtain a two-dimensional image. Therefore, in this paper, we sought to have only one-dimensional informations of some fast spike events.

The observational results show relatively small single sources, in the case of March 24 event. One-dimensional sizes of March 21 event, however, show rather moderately sized, somewhat complex sources. The sizes are always larger than 20 arcsec, that is, more than 15000 km on the solar surface. If this size indicates the length of the flaring loop, 20 keV electrons take approximately 0.2 second to run through the entire loop. Since the energy generating region within the loop is localized in various flare models, a sharp spike with a rising time less than 0.1 second can not have a source size larger than 7500 km, that is, 10 arcsec.

If we take a thermally heated model for the fast spike burst, since the speed of heat conduction front is far less than the speed of 20 keV electrons, more difficulties would arise to be reconciled with the observed rapid time variations which should be originated from the 20 arcsec loop.

References

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