EVOLUTION OF FLARE SOURCE INFERRED FROM HARD X-RAY AND RADIO OBSERVATION: Solar Burst on 27 October 1992

T. Takakura [1] and the HXT group : M. Nishio [2] and the Radioheliograph group

[1] *Department of Astronomy, School of Science, University of Tokyo, Tokyo 113, Japan*
[2] *Nobeyama Radio Observatory, National Astronomical Observatory, Minamisaku, Nagano 384-13, Japan*

Summary

The flare on 27 October 1992 was observed simultaneously with the hard X-ray telescope on board the Yohkoh satellite and the Nobeyama Radioheliograph at 17 GHz.

The time profiles in four energy bands of the X-ray burst are shown in figure 1. The radio time profile at 17 GHz is similar to the profile of the M1 band.

The X-ray images are shown in figure 2, in which the last one is the radio image shown for comparison. If we compare the X-ray images with the magnetogram observed at the Okayama Observatory of the NAO, the two peaks in the contour maps lie on the regions with opposite magnetic polarity. Consequently, the double source is probably footpoints of a single coronal loop.

In the very early phase, the X-ray source spreads from the loop top, seen at time 1, towards the footpoints as frequently observed in the simple flares (Takakura et al. 1993), with a speed above 6×10^3 km/s.

At time 3 the X-ray maps are available in three energy bands. Therefore, we can estimate the spectrum based on the ratio of brightness (counts/s/pixel) in the three energy bands, $R_1 = L/M_1$ and $R_2 = M_1/M_2$. The X-ray spectral indexes Γ_1 and Γ_2 for the northern footpoint, A, are both about 3.4, indicating nonthermal spectrum with the electron spectral index of 4.9, while Γ_2 is much greater than Γ_1 at both the southern foot point, B, and the loop top, C, indicating quasi-thermal spectrum of about 8.0×10^7K ($n_e = 2.1 \times 10^7 cm^{-3}$) and 7.5×10^7K ($n_e = 2.8 \times 10^9 cm^{-3}$), respectively.

The radio contour maps are shown in figure 3. The map center coincides with that of the X-ray maps shown in figure 2, though the map size is bigger, 157.2" square. As shown in this figure, the image is always single and larger than the X-ray images. These are, however,

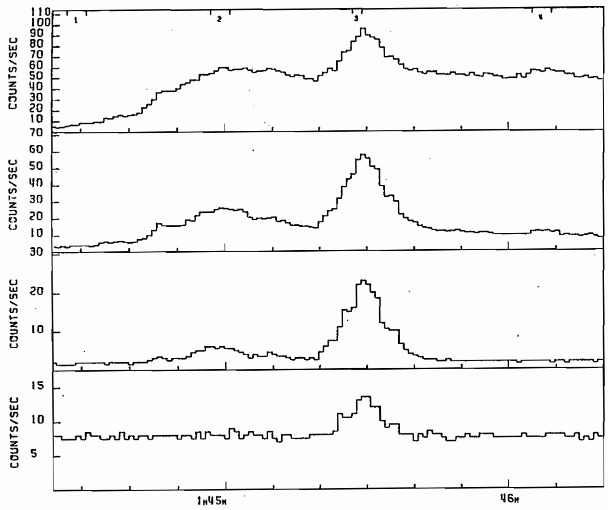

Fig.1 Time profiles of the X-ray burst on 1992 October 27 in four energy bands from top to bottom: L, 13.9-22.7 keV; M1, 22.7-32.7 keV; M2, 32.7-52.7 keV; H, 52.7-92.8 keV. The numbers on the curve in the top panel give the times of the snapshots of the X-ray maps shown in figure 2.

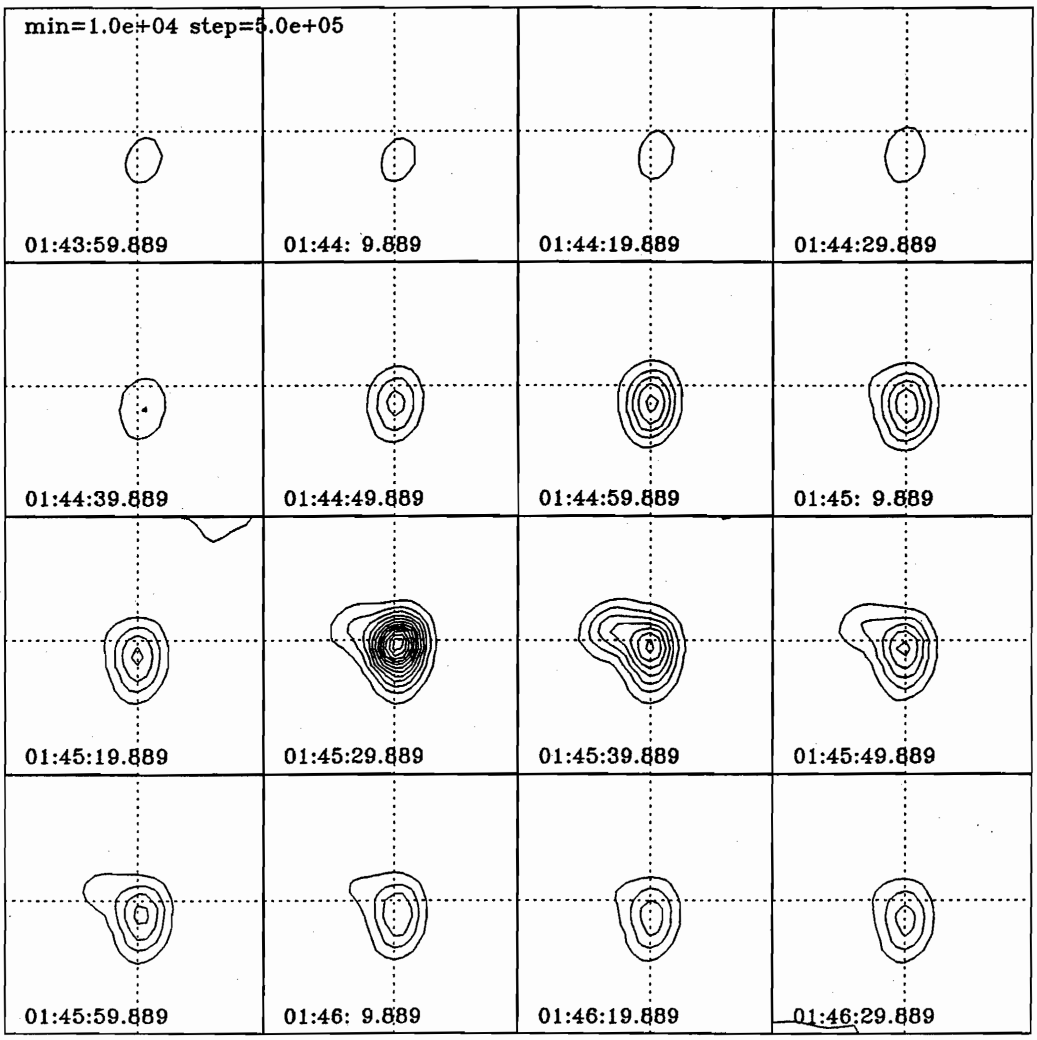

Fig.3 Radio contour maps. The map size is 157.2 arcsec square. The map center coincides with that of the X-ray maps shown in figure 2. The contour step is 0.5 million degrees.

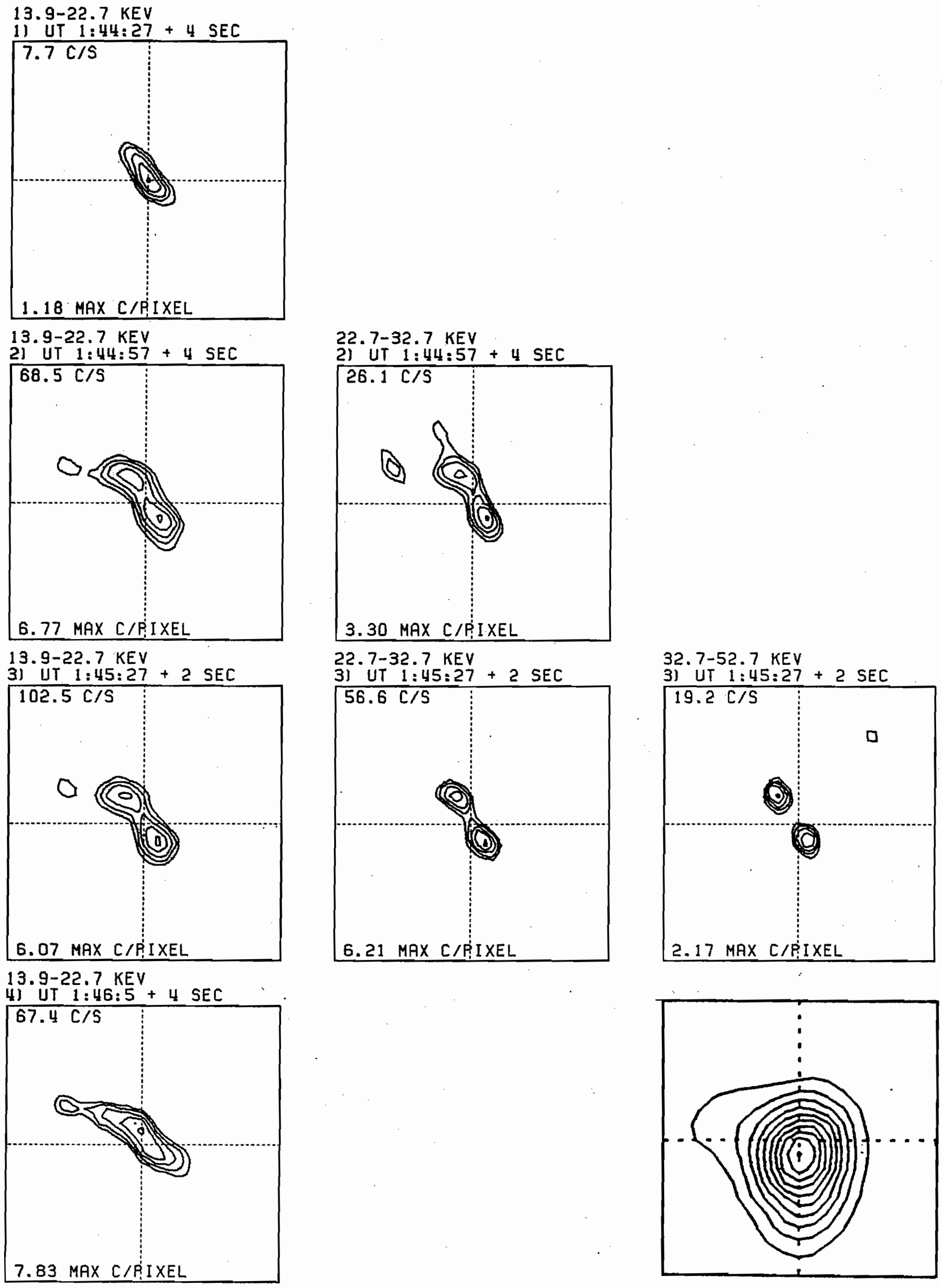

Fig.2 X-ray contour maps of the burst on 1992 October 27. The photon energy, the starting time and the integration time of the map are given in each panel. The panel number is identical with the number shown in figure 1, indicating the time of the snapshot. The minimum contour level is 0.1-times the peak brightness in each map and the contour step is square-root 3-times (i.e., logarithmic step). The map size is 96.4 arcsec square. The map center is 4.66 arcmin west and 8.03 arcmin south from the solar center. The solar north is upward (y-axis) in the maps. In each panel, the X-ray count/sec and count/pixel in the brightest pixel are shown. For comparison, a radio map at time (3) is shown in the last panel, in the same scale.

mainly ascribed to the wide beam width, 18" FWHM. Although the X-ray loop bridges a bipolar magnetic region, the radio images are everywhere highly polarized in L-sense, which corresponds to the magnetic field of footpoint A. This may be ascribed to the "limiting polarization"(e.g., Cohen, 1960).

The radio spectrum and polarization at four frequencies are given in table 1. At the main peak, the flux is maximum at 35 GHz. This emission may be attributed to the gyro-synchrotron from the footpoint A, in which electrons have nonthermal distribution. If we adopt the electron spectral index δ and n_e derived from the X- ray spectrum, as shown in table 1, we have the magnetic field of 1800 gauss, in order to satisfy that the thickness of the source is close to unity as to give the small polarization degree. Consequently, this source which is optically thick at the lower frequencies cannot give the observed fluxes at 17 and 9.4 GHz and also the high polarization degree at 17 GHz.

The radio emissions at and below 17 GHz are most probably ascribed to the thermal gyro emissions from the resonant layers, during his burst. If the gyro-resonance layer at 17 GHz is in the X-ray loop top, C, we have the magnetic field of 759 gauss (8th harmonic), to satisfy the observed flux and polarization degree as low as 30%, as given in table 1 . The radio sources at 9.4 and 3.75 GHz may mostly be outer resonance layers with lower electron temperatures and magnetic fields, as shown in table 1, as an example. In the same way, the radio spectrum and polarization at the first peak are explained by the parameters given in the last four columns of the table.

This observation is consistent with the "anomalous heat conduction model" presented by the simulation (Takakura, 1992) for the loop flares.

References

1. Cohen, M. 1960, *Astrophys. J.*, **131**, 664.
2. Takakura, T. 1992, *Solar Phys.*, **142**, 327.
3. Takakura, T. et al. 1993, *Publ. Astron. Soc. Japan*, **45**,737.

Table 1. Physical parameters in the radio source.

	main peak(01:45:30 UT)				1st peak (01:45:00 UT)			
frequency(GHz)	3.75	9.4	17	35	3.75	9.4	17	35
flux=R+L(sfu)	≤ 1	90	92	190	≤ 2	66	36	≤ 6
pol=(R-L)/(R+L)		0	-0.30	-0.10		0	-0.40	0
location*	OL	OL	C	A	OL	OL	C	A ?
emission**	Gth	Gth	Gth	Gsy	Gth	Gth	Gth	Gsy?
H (gauss)	> 446	671	759	1800	> 446	671	759	
N: harmonic numb.	3	5	8		3	5	8	
θ (degree)	> 50	> 60	65	100	> 50	> 70	75	
T_e (10^7 K)	0.15	3.0	7.5		0.15	2.2	5.5	
δ: electron sp. index				4.9				
n_e ($10^9 cm^{-3}$)	5.0	5.0	2.8	0.14 (> 10 keV)	5.0	5.0	4.6	
S ($10^{18} cm^2$)	7.0	2.5	0.42	0.27	7.0	2.5	0.27	
d (10^9cm)	2.0	1.0	0.73	1.0	2.0	1.0	0.73	

* C: loop top of X-ray source. A: footpoint A of X-ray source. OL: outer layer of X-ray source.

** Gth: thermal gyro emission. Gsy: gyro-synchrotron emission.