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A VERY LONG X-RAY BURST WITH A PRECURSOR FROM XB 1715 − 321

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ABSTRACT

The *Hakucho* satellite observed a very long X-ray burst with a precursor from XB 1715 − 321 on 1982 July 20. The precursor precedes the onset of the main burst in the 1–9 keV range by about 7 s and lasts a few seconds. The main burst lasts about 300 s; in the first half of this period, the spectral hardness increases gradually up to that corresponding to the blackbody temperature of 3 keV, while the bolometric luminosity for the assumed blackbody spectrum stays nearly constant for about 100 s. The event is interpreted as a single burst with the expansion and contraction of the envelope.

Subject heading: X-ray: bursts

I. INTRODUCTION

XB 1715 − 321 has been identified with a relatively weak (~ 1/30 the Crab nebula intensity), persistent X-ray source, 2S 1715 − 321 (Jernigan *et al.* 1978; also designated MX 1716 − 31 by Markert, Backman, and McClintock 1976). This source was confirmed in 1979 by Makishima *et al.* (1981) as an X-ray burster which emits typical type I bursts, although rather infrequently. In 1982 July, this source emitted an unusually long X-ray burst with a precursor. The burst is quite similar to two earlier events which were called fast transient events by Hoffman, Marshall, and Lewin (1978). This *Letter* describes observed properties of the burst and shows that, although the burst is unusual, it can be accounted for in terms of the expansion and contraction of the neutron star envelope in a single burst.

II. OBSERVATIONS AND RESULTS

The burst monitor system aboard the *Hakucho* (Kondo *et al.* 1980) pointed to the region in the vicinity of XB 1715 − 321 during 1982 April 25–May 13 and July 20–August 8.

Only one X-ray burst was detected, on July 20, from XB 1715 − 321 in 29 days of observation (the effective observation time was ~ 120 hr). The count rate versus time in the 1–22 keV, 3–6 keV, 6–10 keV, and 9–22 keV energy bands for FMC-2 are shown in Figure 1. The record was interrupted by telemetry failure at about 270 s after the onset of the burst and then contaminated by radiation belt particles after the recovery of telemetry. The termination of the burst was therefore unobservable.

During the observation, the persistent X-ray flux of XB 1715 − 321 was weaker than the minimum detection limit, which was approximately 1/50 of the Crab nebula intensity, consistent with that in earlier observations (Markert *et al.* 1977; Jernigan *et al.* 1978; Makishima *et al.* 1981).

The position of the burst was determined by the correlation map analysis of the modulation collimator data to be

$$\alpha(1950) = 258\overset{\circ}{.}97 \pm 0\overset{\circ}{.}20, \quad \delta(1950) = -32\overset{\circ}{.}16 \pm 0\overset{\circ}{.}20$$

which is consistent with the position measured by Reid *et al.* (1980):

$$\alpha(1950) = 258\overset{\circ}{.}88 \pm 0\overset{\circ}{.}06, \quad \delta(1950) = -32\overset{\circ}{.}13 \pm 0\overset{\circ}{.}06.$$

In Figure 1, a precursor is clearly seen in the 1–22 keV, 3–6 keV, and 6–10 keV bands, preceding by about 7 s the main burst in the 3–6 keV band. Table 1 summarizes the basic properties of the precursor and the main burst. The rise time of the precursor of ≤ 0.75 s is common with typical type I bursts (Lewin and Joss 1981), but that of the main burst indicates a relatively slow rise and a strong energy dependence. The duration of the main burst (the time length between half maxima in each band) is about 2 minutes. The peak intensities of the precursor and the main burst are, respectively, 0.9 ± 0.1 and 2.2 ± 0.1 times that of the Crab nebula flux. The ratio of the total integrated counts of the precursor and the main burst is $(6.3 \pm 0.9) \times 10^{-3}$.

Since three energy bands are effectively available, we can derive two spectral parameters. Assuming the blackbody spectrum, we obtain the blackbody temperature ($kT_{\rm bb}$) and the

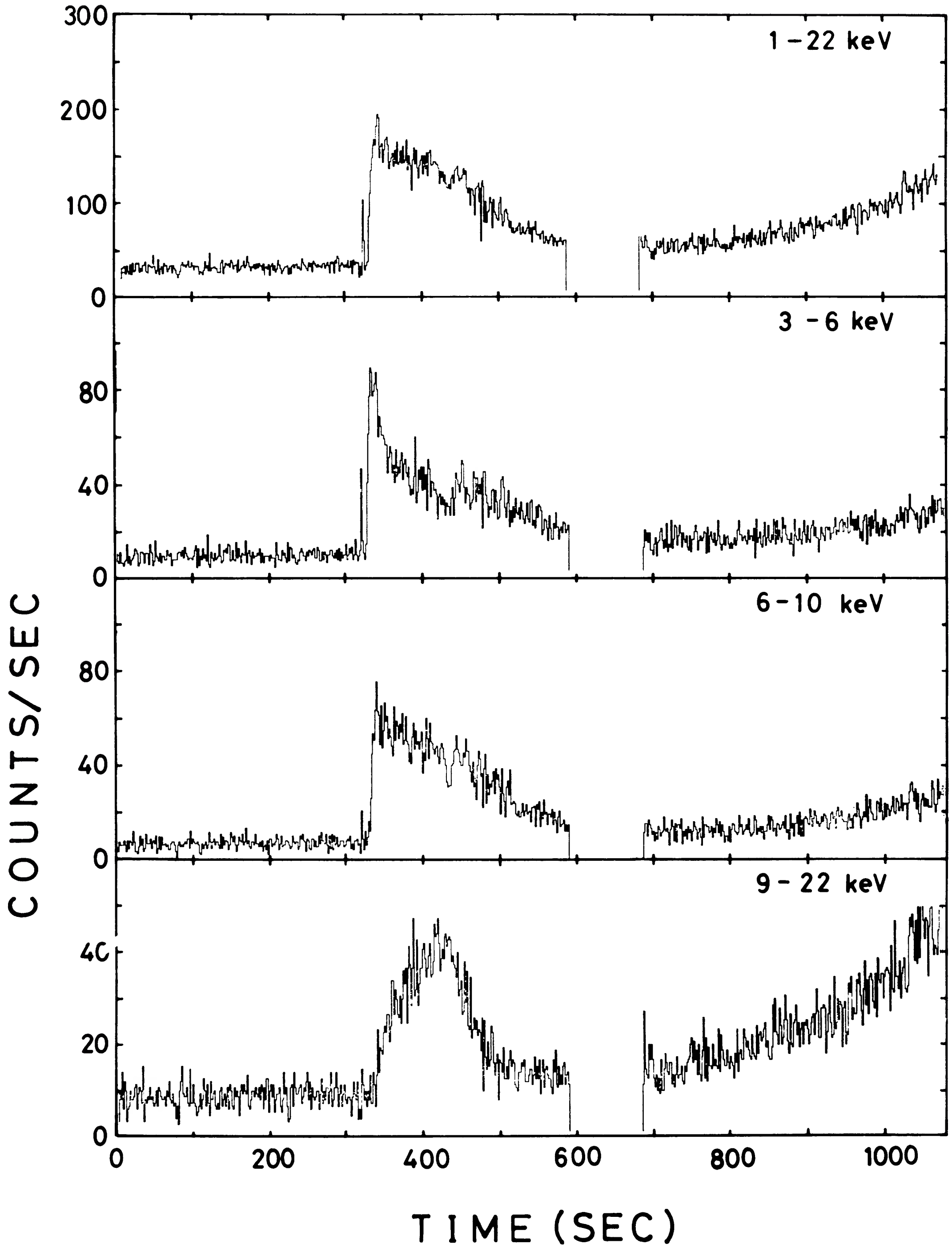

FIG. 1.—Raw count rate profiles (1.5 s bin) of the very long X-ray burst with a precursor from XB 1715−321 observed in the 1–22 keV, 3–6 keV, 6–10 keV, and 9–22 keV energy bands by the FMC-2 detector onboard *Hakucho*. The record was interrupted by telemetry failure at about 270 s after the onset of the burst and then contaminated by radiation belt particles after the recovery of telemetry.

absorption measure which is represented by the hydrogen column density (N_H). Results of this analysis show that kT_{bb} ranges from 1.1 keV to 3.0 keV and $N_H = (0\text{–}10) \times 10^{22}$ H atoms cm^{-2}. Since N_H is not supposed to change during the burst, we fix this as $N_H = 2 \times 10^{22}$ H atoms cm^{-2} (the value of N_H does not essentially affect the following analysis). From these quantities, we can derive the bolometric correction and, consequently, the bolometric luminosity and the blackbody radius if spherical emission and the source distance D are assumed.

Figure 2 shows the time profiles of the bolometric luminosity L_x, the blackbody radius R_{bb}, and the blackbody temperature kT_{bb}, referring to the normalized distance of 10 kpc. The source distance is not yet available because no optical counter-

TABLE 1

X-RAY BURSTS FROM XB 1715−321

	ENERGY BAND (keV)			
	Precursor		Main Burst	
PARAMETER	1–9	9–22	1–9	9–22
Rise time (s)	< 0.75	...	8	74
Duration (s)	3	...	137	121
Peak flux (counts s^{-1}) ...	192 ± 26	...	500 ± 18	128 ± 9
Total flux (counts)	450 ± 48	...	57400 ± 4200	14200 ± 2500
Hardness ratio	0.11 ± 0.08		0.04 ± 0.01 (min) 0.61 ± 0.06 (max)	
	Precursor		Main Burst	
Peak luminosity[a] (ergs s^{-1})	(4.9 ± 0.9) × 10^{38}		(8.0 ± 0.5) × 10^{38}	
Total energy[a] (ergs)	(7.0 ± 1.3) × 10^{38}		(1.19 ± .09) × 10^{41}	
Blackbody temperature (keV)	(1.2 ± 0.3)[b]		1.1 ± 0.1 (min) 3.0 ± 0.2 (max)	
Blackbody[a] radius (km)	30 ± 3		63 ± 7 (max) 9.2 ± 0.5 (min)	

[a]Assuming the blackbody spherical emission for the assumed distance to the source is 10 kpc.

[b]Results from 3–6/6–10 keV data.

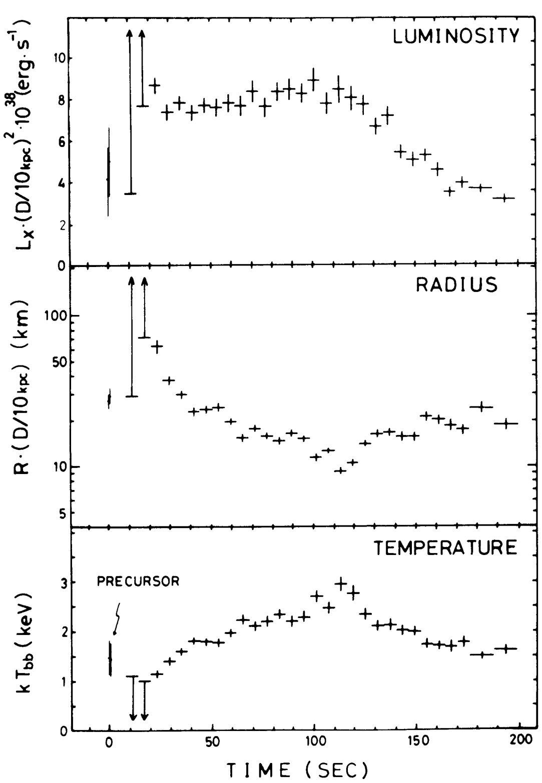

FIG. 2.—The bolometric energy flux and the blackbody radius for the assumed distance of 10 kpc and the blackbody temperature plotted vs. time from $5^h33^m20^s$ (UT) on 1982 July 20.

part has been identified, and its direction is near the galactic center (l = 354°.1, b = 3°.1).

In Figure 2, we can clearly see that the blackbody temperature increases gradually from 1.1 keV up to 3.0 keV in the first half of the main burst, while the bolometric luminosity L_x stays nearly constant, (8.0 ± 0.5) × 10^{38} × $(D/10 \text{ kpc})^2$ ergs s^{-1}, thus resulting in a rapid decrease of the blackbody radius from (63 ± 7) × (D/10 kpc) km to (9.2 ± 0.5) × (D/10 kpc) km.

The precursor shows a very soft spectrum of $kT_{bb} \sim 1.2$ keV comparable to that at the rise of the main burst, and it has intermediate L_x and R_{bb} in comparison with those of the main burst. The total amounts of energy released for the main burst and the precursor are (1.19 ± 0.09) × 10^{41} $(D/10 \text{ kpc})^2$ and (7.0 ± 1.3) × 10^{38} $(D/10 \text{ kpc})^2$ ergs s^{-1}, respectively, so that the ratio of the former to the latter is (1.5 ± 0.4) × 10^2.

In the declining phase of the main burst, we observe spectral softening, typical of type I bursts, although the blackbody radius gradually increases.

III. DISCUSSION

It is worth noting that the two fast transient events observed earlier by Hoffmann *et al.* (1978) are very similar to the present burst in several respects: the presence of a precursor of short duration; the separation between the precursor and the onset of the main burst; the long duration of the main burst; and the spectral evolution in the rise and the decay phase. Although the identification of the burst sources with XB 1715−321 was not established, one was located in a long error box containing XB 1715−321, whereas the other hardly coincided with the same source.

In 1979, XB 1715−321 also emitted typical type I X-ray bursts whose durations are 10–25 s (Makishima *et al.* 1981). Furthermore, the present event shows properties common to the type I X-ray burst. These facts imply that the thermonuclear flash model, which is favored for the type I X-ray burst, may also be applied to the present event with very long duration and the precursor. Then the following questions have to be answered: On what condition does the X-ray burster emit a very long burst? What is the precursor in the context of the thermonuclear flash model?

In regard to the first question, we note that XB 1715−321 shows weak burst activity, only three bursts in 20 days in 1979 and a total of four bursts in 155 days during the last 4 years. This frequency is exceedingly low among the 30 known X-ray bursters. Hence the amount of fuel accumulated for triggering a burst is so large that the energy released by nuclear burning is much greater than usual.

Regarding the second question, we take into account the dynamical behavior triggered by thermonuclear flash. In the rising phase of the main burst, the blackbody temperature increases gradually from 1.1 keV to 3.0 keV, whereas the bolometric luminosity is nearly constant for about 100 s. If the variation of kT_{bb} is extrapolated prior to the rise of the main burst, the spectrum becomes too soft to be observed in the observable energy bands. We consider that the real onset of the burst is the onset of the precursor. The temperature begins to decrease because of a rapid increase of the radius, so that the X-ray intensity in the observable band diminishes. Then the temperature increases, as the radius decreases, and X-rays become observable again. The change in temperature is caused by the expansion of the envelope as a result of radiation pressure and by the subsequent infall of the heated envelope. This interpretation of the main burst and precursor as a single burst will be discussed in relation to the dynamical model of nuclear flash in a separate paper.

REFERENCES

Hoffman, J. A., Marshall, H. L., and Lewin, W. H. G. 1978, *Ap. J.* (*Letters*), **221**, L57.

Jernigan, J. G., Apparao, K. M. V., Bradt, H. V., Doxsey, R. E., Dower, R. G., and McClintock, J. E. 1978, *Nature*, **272**, 701.

Kondo, I., *et al.* 1980, *Space Sci. Instr.*, **5**, 211.

Lewin, W. H. G., and Joss, P. C. 1981, *Space Sci. Rev.*, **28**, 3.

Makishima, K., *et al.* 1981, *Ap. J.* (*Letters*), **244**, L79.

Markert, T. H., Backman, D. E., and McClintock, J. E. 1976, *Ap. J.* (*Letters*), **208**, L115.

Markert, T. H., Canizares, C. R., Clark, C. W., Hearn, D. R., Li, F. K., Sprott, G. F., and Winkler, P. F. 1977, *Ap. J.*, **218**, 801.

Reid, C. A., Johnston, M. D., Bradt, H. V., Doxsey, R. E., Griffith, R., and Schwarts, D. 1980, *A.J.*, **85**, 1062.

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