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DISCOVERY OF AN X-RAY BURST SOURCE XB 1715−321

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ABSTRACT

A new X-ray burst source, XB 1715−321, was discovered with the *Hakucho* satellite. Three type I X-ray bursts were observed from this source in 1979. The error region for XB 1715−321, about 0.3 square degrees in area, includes a persistent X-ray source MX/2S 1715−321 which has been suspected to be the source of several fast transient events. Those bursts detected by *Hakucho* are characterized by a slow rise time (5–10 s) and a relatively long burst interval.

Subject headings: X-rays: bursts — X-rays: sources

I. INTRODUCTION

In 1979, an extensive sky survey for cosmic X-ray bursts was performed along the galactic plane with the Japanese X-ray astronomy satellite *Hakucho* (Inoue *et al.* 1979; Tanaka 1979; Oda 1980). In this observation, several previously suspected bursters were confirmed, and a few sources of X-ray bursts were discovered. This *Letter* describes one of them, the burster XB 1715−321.

Two aspects of XB 1715−321 are of interest. One is that all the bursts from this source exhibited a slow rise time. The second is that XB 1715−321 is, with little doubt, identified with a persistent X-ray source, MX/2S 1715−321, which has drawn attention as a candidate source for "fast transient" events (Markert, Backman, and McClintock 1976; Hoffman *et al.* 1978; Lewin and Clark 1979).

II. OBSERVATIONS

A region of the sky near $\alpha = 17^h$, $\delta = -32°$ was observed with the burst monitor system aboard *Hakucho* during four separate periods in 1979: April 22–26, May 10–12, July 20–25, and August 5–19. In addition to the well-established bursters (MXB 1730−335, MXB 1728−337, and MXB 1659−298) and several bright bulge sources, the X-ray source MX/2S 1715−321 was almost continuously in the field of view of the CMC system during these periods. The CMC system, consisting of a push-pull pair of coarse rotating modulation collimators of 4°.7 pitch angle (CMC 1 and CMC 2), performs a panoramic sky survey in the spin axis direction with a wide field of view (17°.6 FWHM). The count rate sum of CMC 1 and CMC 2, free from modulation, represents the time variation of X-ray intensity, and the difference between the two provides positional information, for steady X-ray sources as well as for variable or transient X-ray emissions whose duration is not much shorter than the satellite spin period (about 10 s). Detailed accounts of the instrumentation and method of observation may be found elsewhere (Inoue *et al.* 1979; Kondo *et al.* 1980).

An X-ray burst in May, and two more in July, were detected with the CMC from the vicinity of MX/2S 1715−321. Their count rate profiles are presented in Figure 1. In April and May, the CMC was operated in a single-energy-band mode (1–12 keV), whereas in July and August two spectral channels (3–6 and 6–10 keV) were available.

The third event occurred near the direction of the spin axis and, hence, was also observed with the FMC system. The FMC system is composed of a fine modulation collimator of 0°.54 pitch angle (FMC 1) and a tubular-field-of-view detector (FMC 2), both having a smaller field of view (5°.8 FWHM). The FMC 2 usually provides a better signal-to-noise ratio than the CMC.

Here, it must be noted that the data coverage of *Hakucho* is neither continuous nor uniform in time, intermitted by Earth occultation of the source, the South Atlantic Anomaly, the limited data recorder capacity, and so on. The net exposure for a source in

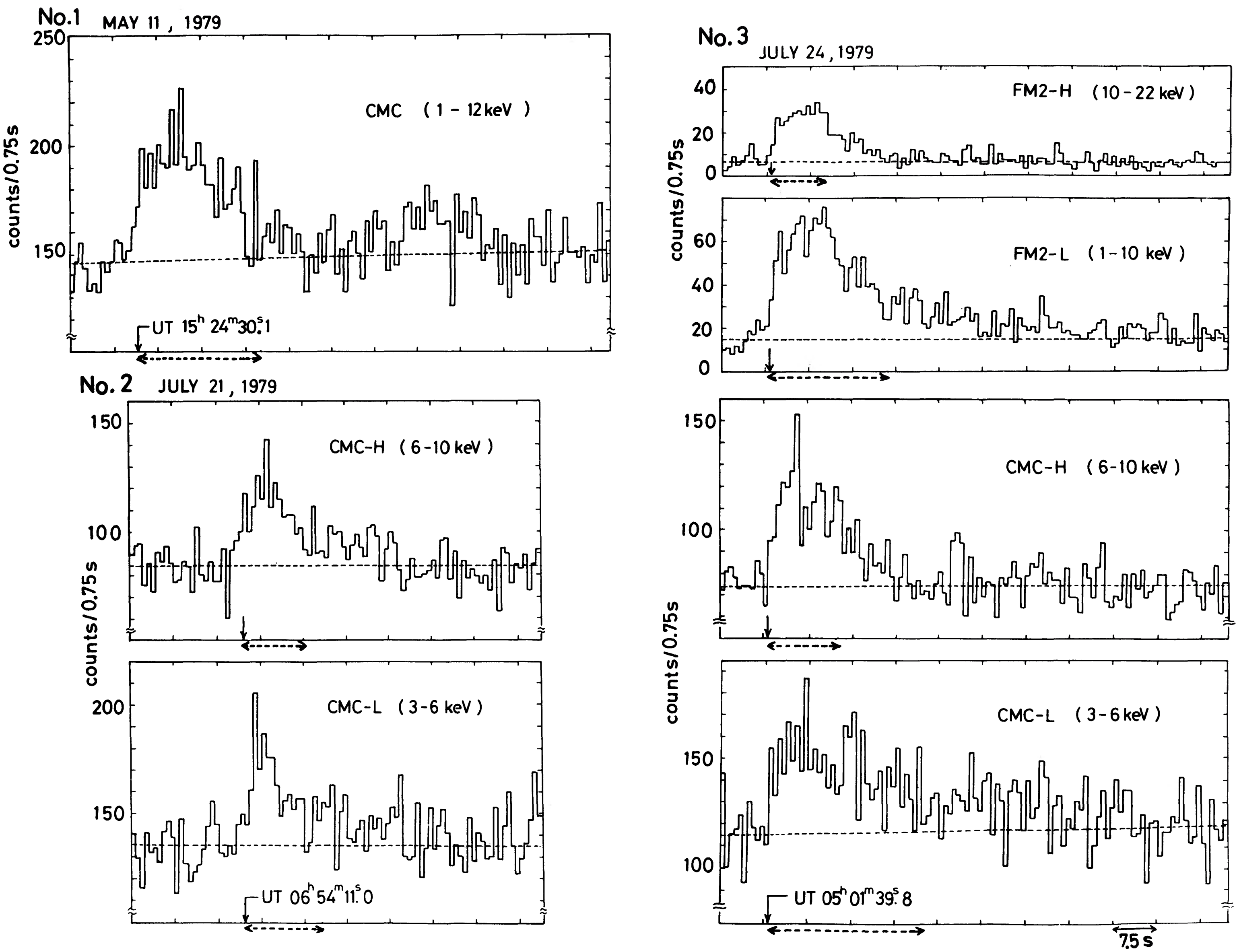

FIG. 1.—Count rate profiles (0.75 second bin) of three X-ray bursts from XB 1715−321 detected with *Hakucho* *z*-axis detectors. Data are not corrected for the aspect. Background levels are indicated by dashed lines. The onset time of each burst (*solid arrow*) and measure of its duration (*dashed arrow*) are defined in Table 1.

the spin axis direction is typically 300–450 minutes a day. This fact complicates the estimation of intervals of X-ray bursts. In general the true burst occurrence would be about 3–5 times more frequent than is inferred from the face value of *Hakucho* observations if the bursts take place in a sufficiently random way.

III. RESULT

Through the correlation map analysis (Tanaka 1979; Jernigan 1977; Schnopper *et al.* 1970) of the CMC data, the locations of these bursts were determined by reference to the positions of bright bulge sources GX 340+0, GX 339−4, GX 349+2, 4U 1735−444, and GX 5−1 which were simultaneously in the field of view. The locations of the three bursts thus determined are in good agreement with one another within the positional accuracy of the CMC ($\lesssim 0\overset{\circ}{.}5$). This indicates that they are from the same source. The combined error region for this burst source, about 0.3 square degrees in area, is presented in Figure 2. The most likely position is

$$\alpha = 17^h15^m, \quad \delta = -32\overset{\circ}{.}1 \quad (1950.0),$$

leading to the designation of XB 1715−321.

Although no known X-ray burst source is found at this location, the persistent X-ray source MX/2S 1715−321 lies near the center of this error region (Fig. 2). This source was first discovered with *OSO 7* (Markert, Backman, and McClintock 1976), and its location was subsequently refined with *SAS 3* (Jernigan *et al.* 1978). In view of the close positional coincidence, there is little doubt that MX/2S 1715−321 and XB 1715−321 are the same celestial object. These previous observations recorded a persistent X-ray flux of about 1/30 the Crab flux from this source. In the present observation, the persistent X-ray emission from XB 1715−321 was undetectable with a 3 σ upper limit of about 1/10 the Crab intensity (3–10 keV).

Table 1 summarizes the basic properties of the three X-ray bursts from XB 1715−321. A characteristic feature of them is their long rise time (5–10 s; see Fig. 1), in contrast to familiar type I bursts whose rise time is typically $\lesssim 2$ s. The peak intensity of the present bursts is about 1.5 times the Crab flux (3–10 keV). Their durations are of the order of 10–25 s. As presented in Figure 3, a spectral softening is evident for the third burst and is suggested by the data for the second one. If a blackbody spectrum is assumed, the observed hardness ratio indicates a burst peak temperature of (2.5–3) keV.

The observed spectral softening, together with a slow burst recurrence, classifies these events as type I X-ray

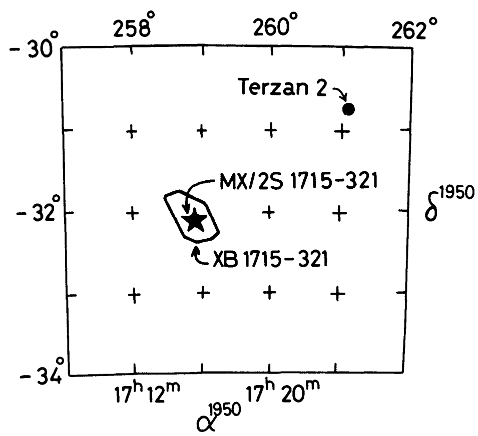

FIG. 2.—The 90% confidence-level contour for the location of XB 1715−321. Positions of MX/2S 1715−321 (*star*) and Terzan 2 = XB 1724−30 (*filled circle*) are also indicated.

TABLE 1

X-RAY BURSTS FROM XB 1715−321

Onset Time[a] (1979 UT)	Distance to Spin Axis	Detector	Energy Range (keV)	Burst Peak[b] Flux (counts per s)	Integrated[b] Photon Counts	Burst[c] Duration (s)
May 11, $15^h24^m30^s$	$11\overset{\circ}{.}3$	CMC 1+2	1–12	225±30	3900±150	21±1
July 21, $06^h54^m11^s$	$5\overset{\circ}{.}7$	CMC 1+2	3–6	93±15	1040±45	14±1
			6–10	90±15	810±40	11±1
July 24, $05^h01^m40^s$	$3\overset{\circ}{.}7$	CMC 1+2	3–6	74±15	1950±65	27±2
			6–10	112±17	1150±50	11±2
		FMC 2	1–10	207±20	4100±100	20±2
			10–22	83±12	1060±60	9±1

[a] Defined as the first 0.75 s bin in which the total count rate exceeds 3 σ above background.

[b] After correcting for aspect. FMC 2 has an effective area 1.20 times larger than that of CMC 1 + 2. The approximate Crab count rates are: 165 counts per s (CMC 1–12 keV), 78 counts per s (CMC 3–6 keV), 40 counts per s (CMC 6–10 keV), 190 counts per s (FMC 1–10 keV), and 27 counts per s (FMC 10–22 keV).

[c] Defined as the time interval from the burst onset until that time at which 70% of the total burst photon counts have been received.

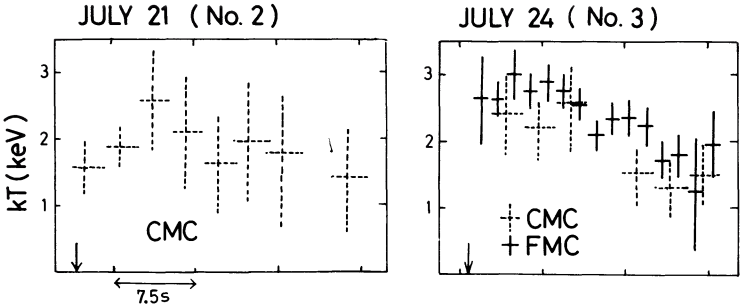

FIG. 3.—Spectral evolutions of the second and the third bursts from XB 1715−321. The temperature of the burst-emitting body was derived from the observed X-ray hardness ratio assuming a blackbody spectrum and N_H value of 1×10^{22} cm^{-2}. Solid vertical arrows indicate the burst onset time as defined in Table 1.

bursts (Hoffman, Marshall, and Lewin 1978), despite their slow-rise profiles.

IV. DISCUSSION

Hakucho observations revealed that a recurrent transient in Norma, 4U/XB 1608−522, produces X-ray bursts of notably long rise time as well as those of the fast-rise profile (Murakami *et al.* 1980). A similar behavior has been found in MXB 1636−536 (Tanaka 1979; Oda 1980; Hoffman, Lewin, and Doty 1977). In fact, there is a striking similarity of shapes among these slow-rise bursts from XB 1608−522, MXB 1636−536, and XB 1715−321. It is hence suggested that the slow-rise bursts are common to some bursters, rather than being exceptional, and that the rise time of X-ray bursts reflects a certain physical condition of the source.

The helium flash model (Joss 1978, and references therein) is one of the most favored theoretical explanations for type I X-ray bursts. However, this model does not predict the possibility of slow-rise bursts. Recently, Fujimoto, Hanawa, and Miyaji (1980) showed that the combined hydrogen-helium burning, which is reasonable under a condition of low persistent luminosity, results in slow-rise X-ray bursts. This model seems to give a better agreement with the present observation than the pure-helium-burning model.

Another important property of XB 1715−321 is its low burst frequency: only three bursts in about 30 days of gross exposure. This is significantly less frequent than the case of typical bursters even when the net exposure efficiency (300–450 minutes a day) is taken into account. This sparseness may account for the fact that XB 1715−321 has remained undiscovered so far. Probably the burst activity of this source is episodic. In fact, this sky region was studied again with *Hakucho* in 1980, but no bursts were observed from XB 1715−321 in more than 40 days of gross exposure (1980 April 14–19 and July 15–August 27). By use of the FMC 1, an upper limit to the persistent emission from XB 1715−321 of about 1/40 the Crab flux (1–10 keV) was obtained in 1980 April.

Markert, Backman, and McClintock (1976) observed two X-ray flares of 5–10 minutes durations with *OSO 7*, and one of them was assigned to MX/2S 1715−321. Later, *SAS 3* detected two unusual fast transient events with precursors from this vicinity (Hoffman *et al.* 1978; Lewin and Clark 1979). Their durations were 100 and 1500 s, and both showed the spectral softening. The error region for the shorter event included MX/2S 1715−321.

The present *Hakucho* results, in combination with these previous reports, suggest that some type I burst sources produce short-lived X-ray activities with a time scale considerably longer than that of typical X-ray bursts. Another example of this may be the neighboring burster XB 1724−30, optically identified with the globular cluster Terzan 2 (Grindlay 1978; Grindlay *et al.* 1980), from which a long (several minutes) burstlike event was detected with *OSO 8* (Swank *et al.* 1977). Incidentally, XB 1724−31 was in the field of view of the CMC during the present observation, but no bursts were detected from this source with *Hakucho*. The burst activity of Terzan 2 may be episodic or very irregular, too.

In conclusion, a new type I burst source XB 1715−321 was discovered. This source is distinguished among bursters by its slow-rise burst profile, a very sparse burst occurrence, a very weak persistent X-ray emission, and its possible association with the "fast-transient" events. However, physical interrelations among these facts are yet to be investigated.

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