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HAKUCHO OBSERVATIONS OF X-RAY BURSTS FROM 4U 1702 − 42

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ABSTRACT

X-ray bursts were observed with the *Hakucho* satellite from a source designated XB 1702−429, which coincides in position with a medium intensity *Uhuru* source 4U/2S 1702−429 within an accuracy of about 0°.2. In 1979 this burst source was burst active. Its activity was much lower in 1980. Brief descriptions are given of the properties of bursts and persistent X-ray emissions from this source. Its relation to previous X-ray burst observations in the same sky region is discussed.

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

I. INTRODUCTION

Although more than 20 cosmic X-ray burst sources have been discovered (Lewin and Joss 1981; Oda 1981), the identification with persistent X-ray sources has remained uncertain for some burst sources because of their insufficient positional accuracy. An example is a burster currently known as XB 1702−429 (Lewin and Joss 1981).

The existence of a burst source near $\alpha \approx 17^h04^m$, $\delta \approx -43°.5$ was first noticed by *OSO 8* (Swank *et al.* 1976). Subsequently, *SAS 3* observed X-ray bursts from this sky region and gave the designation of MXB 1706−43 (Marshall, Li, and Rappaport 1977). This burster was tentatively identified with the *OSO 8* burster. A medium intensity *Uhuru* source 4U 1702−42 = 2S 1702−429, although lying ~ 0°.5 outside the error box for MXB 1706−43 (~ 0.3 deg^2 in area), was suggested as the persistent counterpart of this burster (Lewin and Clark 1979). However, there has been no published result, at least to our knowledge, that explains the identification of 4U 1702−42 with the burst source.

Based on the *Hakucho* observations in 1979, we have established the existence of a burst source, named XB 1702−429 (Oda 1981), which has a close positional coincidence ($\lesssim$ 0°.2) with 4U 1702−42. In this *Letter*, we report the location and properties of XB 1702−429 and discuss its relation to the *OSO 8* and *SAS 3* bursters.

II. OBSERVATIONS

The observations were carried out using the CMC system on board *Hakucho* (Kondo *et al.* 1981). In brief, the CMC system consists of a pair of rotating modulation collimators (CMC-1 and CMC-2) with a common field of view of 17°.6 FWHM. The two CMCs are arranged so that their modulation phases are exactly 180° apart. The occurrence of an X-ray burst in the CMC field of view can be detected by monitoring the count rate sum of the two CMCs, which acts as a simple wide-field-of-view detector, while the location of the observed burst can be determined with ~ 0°.5 accuracy by analyzing the count rate difference between the two CMCs.

The source 4U 1702−42 was in the CMC field of view for five periods in 1979 (April 7–14, April 22–May 12, May 21–26, June 24–July 9, and July 25–August 5). The gross exposure to the source was thus about 55 days, with a net exposure time of 300–450 minutes a day. During these observations, 14 X-ray bursts were detected with the CMC from the close vicinity of 4U 1702−42. Their occurrences are listed in Table 1. The locations of these 14 bursts are in good agreement with one another, within the positional accuracy of the CMC as mentioned above, which indicates that they were actually from the same source.

Figure 1 represents the 90% confidence error region for this burst source obtained as a weighted mean over

TABLE 1

X-RAY BURSTS OBSERVED FROM XB 1702−429 WITH *HAKUCHO*

Burst Name	Year	Date	Onset Time (UT)
412−0410	1979	Apr 12	04:10:13
(501−0742)	1979	May 1	07:42:06
501−0752	1979	May 1	07:52:57
502−1833	1979	May 2	18:33:52
(502−1838)	1979	May 2	18:38:27
(503−1451)	1979	May 3	14:51:30
(503−1842)	1979	May 3	18:42:56
510−1532	1979	May 10	15:32:10
511−2223	1979	May 11	22:23:16
523−0312	1979	May 23	03:12:00
624−1429	1979	Jun 24	14:29:06
624−2351	1979	Jun 24	23:51:05
626−1652	1979	Jun 26	16:52:49
630−1600	1979	Jun 30	16:00:01
728−0128	1979	Jul 28	01:28:05
728−1133	1979	Jul 28	11:33:26
728−2345	1979	Jul 28	23:45:36
729−0943	1979	Jul 29	09:43:56
0421−0728	1980	Apr 21	07:28:50
0715−1227	1980	Jul 15	12:27:29

NOTE.—The identification for the four bursts in parentheses is uncertain due to their large (about 2°) positional uncertainty. The burst onset time refers to the first 0.75 s time bin in which the count rate exceeds 3 σ above background.

the individual burst positions. We designate this burster XB 1702−429, based on its location: $\alpha = 17^h02^m \pm 01^m$, $\delta = -42.^\circ9 \pm 0.^\circ2$ (1950.0). As shown in Figure 1, 4U 1702−42 = 2S 1702−429 (Forman *et al.* 1978; Jernigan *et al.* 1978) lies almost at the center of this error region of ~ 0.1 deg^2. We thus conclude with a sufficient confidence that 4U 1702−42 and XB 1702−429 are actually one and the same celestial object. This is the first concrete report that relates this persistent source with burst activities.

During these observations, four more bursts may have been observed from XB 1702−429. They are also listed in Table 1 in parentheses. Although the occurrences of these four bursts were statistically significant, their error regions were exceptionally large ($\sim 2°$ in diameter) because their flux was relatively weak. All we can say is that their positions are consistent with XB 1702−429 within this error.

In 1980, we again observed XB 1702−429 with the CMC for four periods: April 7–21, June 16–27, July 10–18, and July 23–August 1. The gross exposure this time was about 40 days in total. Although the exposure efficiency was almost the same as in 1979, only two bursts (as listed in Table 1) were observed from XB 1702−429 in 1980 as compared to 14 (or possibly 18) bursts in 1979. This implies that the average rate of burst detection from this source was ~ 5 times smaller in 1980 than in 1979.

III. PROPERTIES OF XB 1702−429

In Figure 2, we present several examples of burst profiles from XB 1702−429 observed in 1979. They are expressed as the sum of the two CMCs in which the signal modulation vanishes. The bursts observed in 1980, although not shown here, have no significant difference in profile from those of 1979.

The X-ray bursts from XB 1702−429 have a typical peak X-ray flux of 1.0–1.8 times the Crab Nebula flux in 3–10 keV. The burst rise time is a few seconds or less. The burst duration (defined as the time interval in which 70% of the total photon counts were received) is 10–15 s for XB 1702−429, which is roughly intermediate among bursters.

To see the average burst properties of XB 1702−429, we superposed the intensity profiles in two energy bands of bursts (d) to (i) in Figure 2 by fitting their onset times, as defined in Table 1. The result is shown in Figure 3. There we also show the time evolutions of the burst temperature T and luminosity L, both derived from the composite intensity profiles in the 3–6 and 6–10 keV bands, assuming a blackbody spectrum with $N_H = 5 \times 10^{22}$ cm^{-2}. There we can see that the temperature decreases in time from its peak value of ~ 2.5 keV, and that the time evolutions of T and L roughly follow the relation $L \propto T^4$, implying that the surface area of

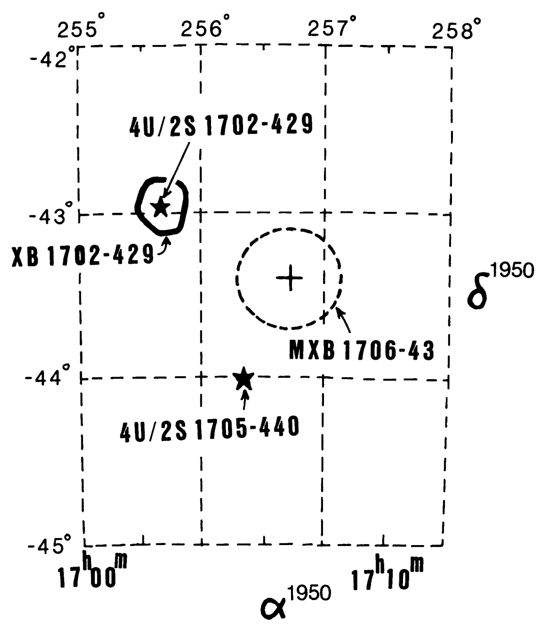

FIG. 1.—The location of XB 1702−429 (the 90% confidence error box) determined by *Hakucho* in 1979. The 14 bursts, listed in Table 1 without parentheses, were used. The two stars indicate the *SAS 3* positions for 4U/2S 1702−429 and 4U/2S 1705−440 (Jernigan *et al.* 1978). The dotted circle shows the position and approximate error region for MXB 1706−43 (Marshall, Li, and Rappaport 1977).

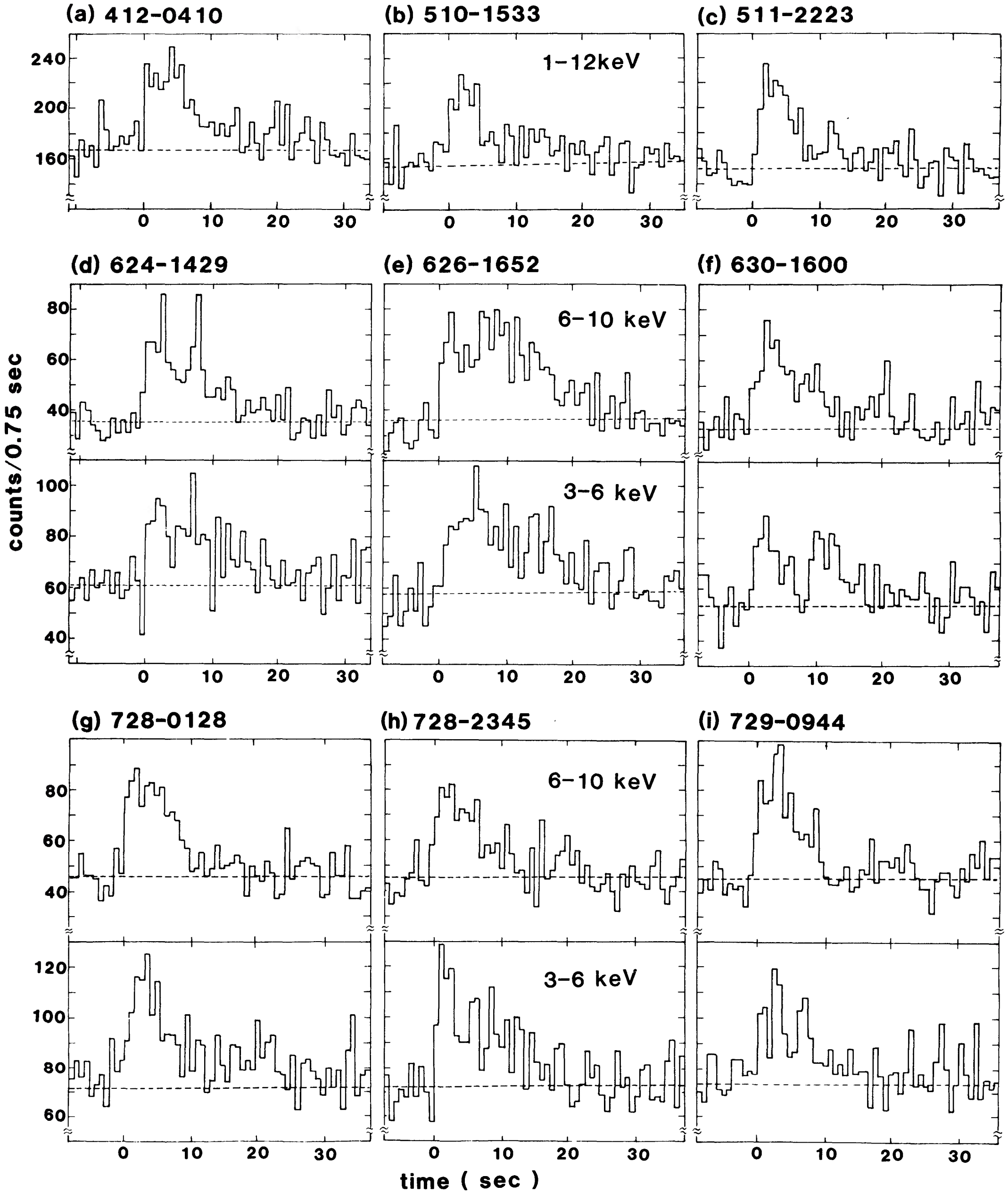

FIG. 2.—Examples of burst profiles of XB 1702−429 observed with the *Hakucho* CMC system in 1979. Count rates are not corrected for the aspect. Dashed line indicates the background level. The onset time (= time 0) of each burst is defined in Table 1. The CMC was operated with one energy channel (1–12 keV) in 1979 April and May and with two channels (3–6 and 6–10 keV) after 1979 June.

the burst emission region remains approximately constant during the burst decay (van Paradijs 1978). In this way the average burst characteristics for XB 1702−429 are quite similar to those found in other burst sources.

However, we sometimes noticed peculiar substructures in the burst profile, as represented by bursts (d), (f), and (i) in Figure 2. These substructures have time scales of ~ 5 s and are often out of phase in the two energy channels. Hence, it is suggested that the condition of constant surface area of the emission region may be violated in some individual bursts from XB 1702−429.

Figure 3 indicates that the average burst peak luminosity for XB 1702−429 is about $5 \times (D/10 \text{ kpc})^2$

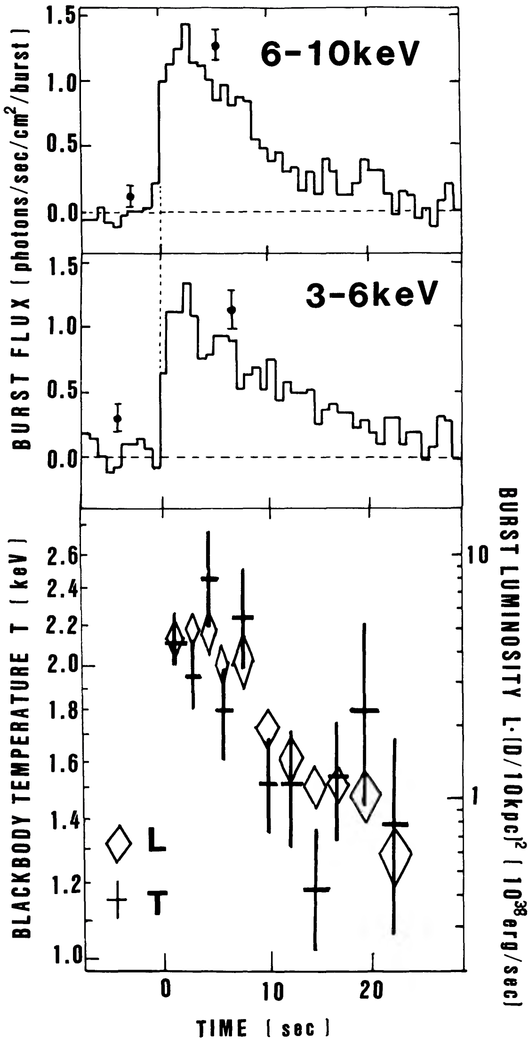

FIG. 3.—A composite burst profile for XB 1702−429 obtained by superposing six bursts (bursts (d) to (i) in Fig. 2). The flux is corrected for the aspect. Time evolutions of the burst temperature T and luminosity L (both derived assuming a blackbody spectrum with $N_H = 5 \times 10^{22}$ cm^{-2}) for the composite profile are also shown. Note that the L axis is exactly 4 times as compressed as the T axis, so that the "constant surface area" condition ($L \propto T^4$) can be examined easily.

$\times 10^{38}$ ergs s^{-1}, with D the source distance. Since this value is quite similar to those found for burst sources which lie within $\sim 5°$ of the galactic center (Inoue *et al.* 1981), it is indicated that XB 1702−429 is also at a distance roughly corresponding to the galactic center.

IV. PERSISTENT X-RAY COMPONENT FROM 4U 1702−42

During the present *Hakucho* observations, the persistent X-ray intensity of 4U 1702−42 was mostly uncertain because of the interference from a bright variable source, 4U 1705−44 = 2S 1705−440, which is only 1°2 away. We obtained one significant data point on 1980 July 14 using FMC-1 (a fine modulation collimator with 0°54 pitch angle and 5°8 FWHM field of view; Kondo *et al.* 1981) aboard *Hakucho*. At that time, the 1–10 keV X-ray flux from 4U 1702−42 and 4U 1705−44 was about 100 and 230 μJy, respectively. This value for 4U 1702−42 is not much different from those reported in the 4U catalog (30 *Uhuru* units; Forman *et al.* 1978) and by the *SAS 3* group (50 μJy in 2–11 keV; Jernigan *et al.* 1978).

X-ray burst sources commonly exhibit soft persistent X-ray spectra (typically kT = 3–7 keV) with the exception of MXB 1916−053 (Becker *et al.* 1977). Taking it for granted that 4U 1702−42 and XB 1702−429 are the same object, we notice that the persistent X-ray emission from this source, as observed by *Hakucho* on the above occasion, was rather hard for a burster; in fact, the FMC-1 spectral hardness ratio (defined as the photon flux ratio in 10–25 keV to 1–10 keV) was 0.25 ± 0.07 for 4U 1702−42, while the same quantity is in the range 0.05–0.13 for persistent X-ray emissions from typical "bright bulge" sources and bursters. Assuming a free-free spectrum with $N_H = 5 \times 10^{22}$ cm^{-2}, the hardness ratio for 4U 1702−42 would give kT = 8–17 keV. However, the *Uhuru* spectrum for this source (Jones 1977) is moderately soft (kT = 6–10 keV), suggesting a spectral variability.

V. DISCUSSION

In Figure 1, we notice that the error regions for XB 1702−429 and MXB 1706−43 do not intersect with each other, while the *OSO 8* error region (centered at $\alpha \approx 17^h04^m$, $\delta \approx -43°5$ with a typical uncertainty of several degrees; Swank *et al.* 1976) is consistent with either position. One possible explanation for this situation is to assume that *OSO 8*, *SAS 3*, and *Hakucho*, in fact, observed one and the same burster, and that the deviation of the *SAS 3* location is due to some systematic error. An alternative is to assume that there are actually two distinct bursters in this sky region, and that one of them (i.e., MXB 1706−43) was dormant during the present *Hakucho* observations. Such a dormancy would not be unusual, since most X-ray bursters exhibit variations in their burst activity on time scales of weeks, months, and years (Oda 1981). Indeed, the activity of XB 1702−429 itself did change in one year from its continuous activity in 1979 to rare burst occurrences in 1980.

An additional debate may arise from the observations of X-ray bursts with unusually short intervals from this sky region by both *OSO 8* ($\approx$ 8 minutes; Swank *et al.* 1976) and *SAS 3* ($\approx$ 24 minutes; Marshall, Li, and Rappaport 1977). Two similar cases are also found in our Table 1 (bursts 501−0742 and 501−0752, and bursts 502−1833 and 502−1838), although both cases include those bursts which were not clearly identified with XB 1702−429. At first sight, the cases of these short interval bursts would appear to support the hypothesis of two different bursters. Nevertheless, the other possibility (i.e., a single burst source) cannot be ruled out since successive bursts with ~ 10 minute intervals have been observed from some other bursters such as MXB 1743−28 (Lewin *et al.* 1976), XB 1608−522 (Murakami *et al.* 1980), Terzan 5 (Hayakawa 1981), and MXB 1636−536 (*Hakucho* team, in preparation). At present, we cannot further discriminate between these two possibilities.

In conclusion, we have established the existence of burst source XB 1702−429, which can be identified with 4U 1702−42. The average burst properties of this burster are quite similar to those of other bursters, but individual bursts may have complicated structures in their time profiles. The burst activity of this source is variable on an ~ 1 year time scale. 4U 1702−42 may be distinctive among bursters in that its persistent X-ray emission can be very hard. Finally, we suspect that this source occasionally emits X-ray bursts in a short succession, or that there may be another X-ray burster close to this source.

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