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DISCOVERY OF TWO NEW X-RAY BURST SOURCES IN THE GLOBULAR CLUSTERS TERZAN 1 AND TERZAN 5

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ABSTRACT

Two new X-ray burst sources were discovered in the galactic-bulge region from the *Hakucho* observations. These sources are most likely in the globular clusters Terzan 1 and Terzan 5. Including these two, there are at least eight burst sources associated with globular clusters, of which six lie within 10° of the galactic center. These cases enhance the evidence for the Population II nature of the burst sources and for their strong concentration toward the galactic center. The burst activity of the Terzan 5 source appears episodic.

Subject headings: Clusters: globular — X-rays: bursts

I. INTRODUCTION

Of ~50 so-called galactic-bulge X-ray sources, 8 are known to lie in globular clusters. About 30 of these sources are X-ray burst sources, in which at least 6 are associated with globular clusters (Lewin and Clark 1979, and references therein). High association of the burst sources with globular clusters indicates their Population II nature (Lewin and Clark 1979).

We recently discovered two new X-ray burst sources in the galactic-bulge region from the *Hakucho* satellite. Locations of these two burst sources are within experimental uncertainties coincident with the globular clusters Terzan 1 and Terzan 5. These globular clusters lie within 5° of the galactic center. The present results further enhance the evidence for the association of burst sources with globular clusters as well as for the high concentration of burst sources near the galactic center.

II. OBSERVATIONAL RESULTS

The burst monitor on board the X-ray astronomy satellite *Hakucho* consists of the coarse modulation collimator system (CMC-1, 2) with a wide field of view (17° FWHM) and the fine modulation collimator system (FMC-1) with a smaller field of view (5°.8 FWHM). Another tubular-collimator counter (FMC-2) of 5°.8 (FWHM) field of view is also included. Details of the instruments are given elsewhere (Inoue *et al.* 1979; Kondo *et al.* 1980).

Our search for X-ray bursts in the galactic center region this year spanned the period of 1980 July 15 through early September. The celestial field of 5° radius from the galactic center has always been in the field of view of the CMC system.

a) XB 1733−30

On 1980 July 15 and 22, two X-ray bursts were observed from a source whose location did not coincide with any of the cataloged X-ray sources. The source location was determined with reference to bright bulge sources 1758−250 (GX 5−1), 1735−444, 1742−294 (GCX−1), 1702−363 (GX 349+2), and 1642−455 (GX 340+0), which were simultaneously in the field of view.

The burst source position thus obtained is

$$\alpha(1950) = 17^{h}32^{m}05^{s} \pm 50^{s} \quad (263^{\circ}.02 \pm 0^{\circ}.22)$$

$$\delta(1950) = -30^{\circ}.4 \pm 0^{\circ}.3.$$

The finding chart of the source XB 1733−30 is shown in Figure 1(*a*). The globular cluster Terzan 1 (α[1950] = $17^{h}32^{m}35^{s}$, δ[1950] = −30°26′.3) (Terzan 1966) lies near the center of the error region.

The first burst was observed with the CMC system only, in the 3–6 and 6–10 keV bands. The second burst was also observed with the FMC system in the 1–9 and 9–22 keV bands, with a better signal-to-noise ratio. The profile of the second burst is shown in two energy bands in Figure 2(*a*). Both bursts are noted to rise and decay rather slowly. The count rate in the higher

energy band falls faster than that in the lower energy band, indicating that the spectrum softens during the burst decay. This feature is characteristic of the type I X-ray bursts, according to the classification by Hoffman, Marshall, and Lewin (1978). The peak flux is estimated to be roughly 7×10^{-8} ergs cm^{-2} s^{-1}.

It is not known when XB 1733−30 became burst active. No burst from XB 1733−30 was observed after July 22, although the source was continuously in the field of view. The persistent component of this source was not detectable above the detection limit of the FMC system which was about 1/50 of the Crab Nebula intensity in the range 1–22 keV.

b) XB 1745−25

Another source in the galactic center region was discovered to become burst active on 1980 August 5. Fourteen bursts were observed from this source. The location of this burst source was determined relative to the positions of bright bulge sources 1702−363 (GX 349+2), 1744−265 (GX 3+1), and 1758−250 (GX 5−1). The best position determined with the FMC system is

$$\alpha(1950) = 17^h45^m23^s \pm 33^s \quad (266\overset{\circ}{.}35 \pm 0\overset{\circ}{.}14)$$
$$\delta(1950) = -24\overset{\circ}{.}7 \pm 0\overset{\circ}{.}1.$$

No known X-ray sources are in the vicinity consistent with this location. However, the error box includes the globular cluster Terzan 5 whose coordinates are $\alpha(1950) = 17^h45^m00^s$, $\delta(1950) = -24°45\overset{'}{.}9$ (Terzan 1968). The finding chart of this new burst source is shown in Figure 1(*b*). The observed 14 bursts occurred in the period of 1980 August 5–21, with an average frequency of $\sim$0.2 hr^{-1} for the net observation time. Before and after this period, no burst from this source was detected. It appears, therefore, that the burst activity of this source is either temporary or possibly intermittent. An example of burst profiles for XB 1745−25 observed with the FMC system is shown in two energy bands, 1–9 and 9–22 keV, in Figure 2(*b*). The burst profiles look similar to those for XB 1733−30

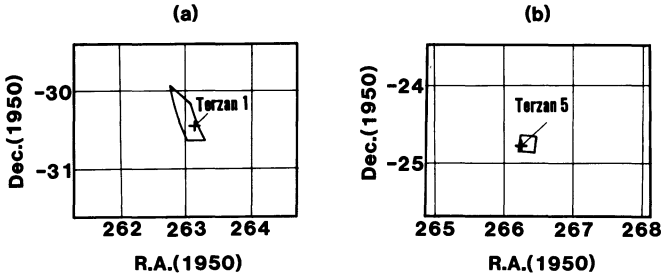

FIG. 1.—Finding charts for (*a*) XB 1733−30 and (*b*) XB 1745−25. Positions of the globular clusters Terzan 1 and Terzan 5 are indicated.

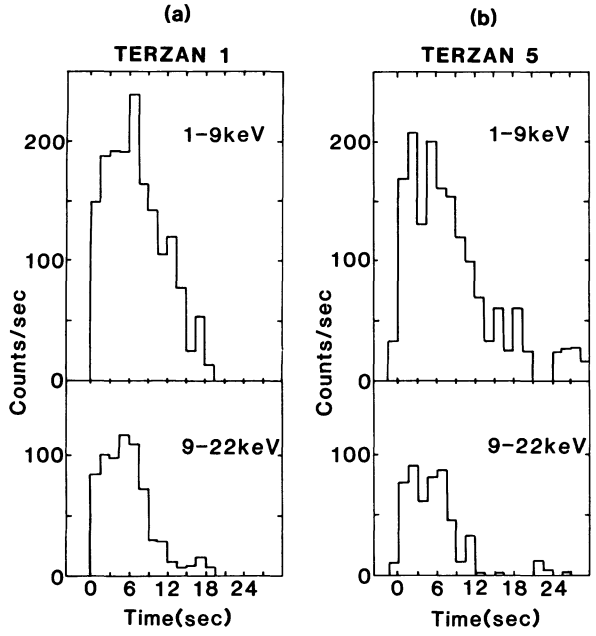

FIG. 2.—Examples of X-ray bursts from (*a*) XB 1733−30 (Terzan 1) and (*b*) XB 1745−25 (Terzan 5) with FMC-2 in two energy bands, 1–9 and 9–22 keV, both corrected for the aspect and the background.

in that they are clearly of type I and, in general, rise and decay slowly. The peak fluxes of the XB 1745−25 bursts are distributed in the range 2.0–6.1 × 10^{-8} ergs cm^{-2} s^{-1}.

The persistent flux from this source was never detectable above the detection threshold of the FMC system (∼1/50 of the Crab Nebula) during the present observations.

III. DISCUSSION

Globular clusters Terzan 1 and Terzan 5 are found within the error boxes of newly discovered burst sources XB 1733−30 and XB 1745−25, respectively. The present positional accuracy (0.08 deg^2 for XB 1733−30 and 0.05 deg^2 for XB 1745−25) is insufficient for an unambiguous identification with an optical counterpart. However, in view of the circumstantial evidence that previous observations revealed a high probability of association of burst sources with globular clusters, it is most probable that XB 1733−30 and XB 1745−25 lie in the globular clusters Terzan 1 and Terzan 5, respectively. Positional coincidence with a known globular cluster by mere chance is less than 1%. Taking for granted the present identification, we now have eight burst sources which are associated with globular clusters.

Four globular-cluster burst sources, Terzan 1, Terzan 2 (Swank *et al.* 1977; Grindlay *et al.* 1980), Terzan 5, and Liller I (for the rapid burster), out of eight in total lie within 5° of the galactic center. Terzan 1, 2, and 5, and Liller I are all heavily obscured in the visible band (Terzan 1966, 1968; Liller 1977) and are considered to be located near the galactic center. Adding NGC 6624 and NGC 6441, six out of eight are all within 10° of the galactic center. The error box of an *OSO 8* burster (Swank *et al.* 1976) contains the globular cluster NGC 6553. If this tentative identification is correct, seven globular-cluster bursters are concentrated within 10° of the galactic center. Their distribution is in qualitative accordance with that of globular clusters themselves near the center of our Galaxy (Harris 1976; Oort 1977). This point is discussed in more detail in a separate paper (Inoue *et al.* 1981).

It is interesting to note that X-ray bursts from neither XB 1733−30 nor XB 1745−25 have been reported in the past. As a matter of fact, *Hakucho* was pointed to this direction for about a month in 1979, but no bursts from these sources were recorded. Since the peak flux for these bursts are well over the Crab Nebula flux, similar bursts from these sources would surely have been detected if they were burst active. Therefore, the burst activity of the Terzan 1 and Terzan 5 sources may be rare. The Terzan 5 source produced 14 bursts in a period of 17 days, whereas no bursts were observed before or after this period. This shows that the burst activity of the Terzan 5 source is clearly episodic.

So far, few globular-cluster sources are found to be reliable burst sources. As a matter of fact, we have observed NGC 6624 from time to time in 1979 and 1980 for more than 30 days, and NGC 6441, NGC 6553, and Terzan 2 for a total of about 3 months, but no bursts were recorded. Although an occasional dormancy seems common to many burst sources, whether the globular cluster burst sources are less reliable than the isolated burst sources is an interesting question in connection with the genetics of burst sources.

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