Ginga Observation of a Recurrent Soft X-Ray Transient Source 1RXS J170930.2−263927

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Abstract

A transient X-ray source was detected in scanning observation in the Galactic bulge region in 1990 March (source D in Yamauchi & Koyama 1990). Using scan data obtained with Ginga in 1990 March and 1990 April, the source position was re-determined. The revised sky position is in agreement with that of a recurrent soft X-ray transient source 1RXS J170930.2−263927=XTE J1709−267. The spectrum is similar to those obtained with RXTE, Beppo SAX, and MAXI. The flux in 1990 March is estimated to be more than 100 mCrab. The Ginga results indicate that 1RXS J170930.2−263927=XTE J1709−267 was in outburst in 1990 March.

Key words: stars: individual (1RXS J170930.2−263927) — X-rays: spectra

1. Introduction

1RXS J170930.2−263927 is an X-ray transient source, first discovered in the ROSAT all-sky survey in 1990 August (Voges et al. 1999). After its discovery, outbursts in 1997, 2002, 2004, and 2007 have been reported (Marshall et al. 1997; Jonker et al. 2003, 2004; Markwardt & Swank 2004; Remillard 2007). In addition, recently, MAXI/GSC detected a new outburst in 2010 July (Negoro et al. 2010). Based on these results, a 2–3 year recurrence time is suggested (Markwardt & Swank 2004; Remillard 2007; Negoro et al. 2010). The detection of type I X-ray bursts (Cocchi et al. 1998; Jonker et al. 2003, 2004) demonstrates that 1RXS J170930.2−263927 is a low-mass X-ray binary containing a weakly magnetized neutron star.

The Ginga satellite, launched in 1987 (Makino & the Astro-C Team 1987), discovered a transient X-ray source with a flux of >10 mCrab in the scanning observation of the Galactic bulge region in 1990 March (Yamauchi & Koyama 1990). The error region of the Ginga transient source was included 1RXS J170930.2−263927, but the error region derived from the one-dimensional scan data is so large ($4^\circ \times 0^\circ.2$) that it is unclear whether the Ginga transient source and 1RXS J170930.2−263927=XTE J1709−267 are identical.

In 1990 April, another scanning observation near the transient source was carried out. The scan paths in 1990 March and April crossed each other. Thus, using the scan data obtained in 1990 March and April, we re-determined the source position. In this paper, we present the results obtained from the reanalysis of the Ginga data.

2. Observations and Results

Scanning observations were carried out with the Large Area Counters (LAC) onboard Ginga. The total effective area and the energy range of the LAC were 4000 cm^2 and 1–37 keV, respectively. The FWHM of the LAC field of view (FOV) was about 1° and 2° along and perpendicular to the scan path, respectively. Details concerning Ginga and the LAC were given in Makino & the Astro-C Team (1987) and Turner et al. (1989), respectively.

The Galactic bulge region was observed on 1990 March 24–27, while the observation around Ophiuchus cluster of galaxies was carried out on 1990 April 7–10. The scan speed was set to 0.64 degree min^{-1} and all the data were taken in the MPC-1 mode.

In order to obtain a high signal-to-noise ratio, scan data were folded azimuthally. The scan profiles in the 1.1–20.9 keV energy band obtained on 1990 March 24–25 (scan A), April 8–9 (scan B), and April 9–10 (scan C) are shown in figure 1. The non-X-ray background was subtracted using a method given in Awaki et al. (1991). The profile of scan A clearly shows two bright X-ray sources at the scan angles of $\sim -0.^\circ6$ and $\sim +2.^\circ5$. The former is Ophiuchus cluster of galaxies and the latter is the Ginga transient source=source D in Yamauchi & Koyama (1990). On the other hand, in the profiles of scan B and C, Ophiuchus cluster of galaxies is clearly seen at the scan angle of $\sim 0^\circ$. In addition, the X-ray counts increase near to the terminal points at the scan angle of $+2.^\circ5$

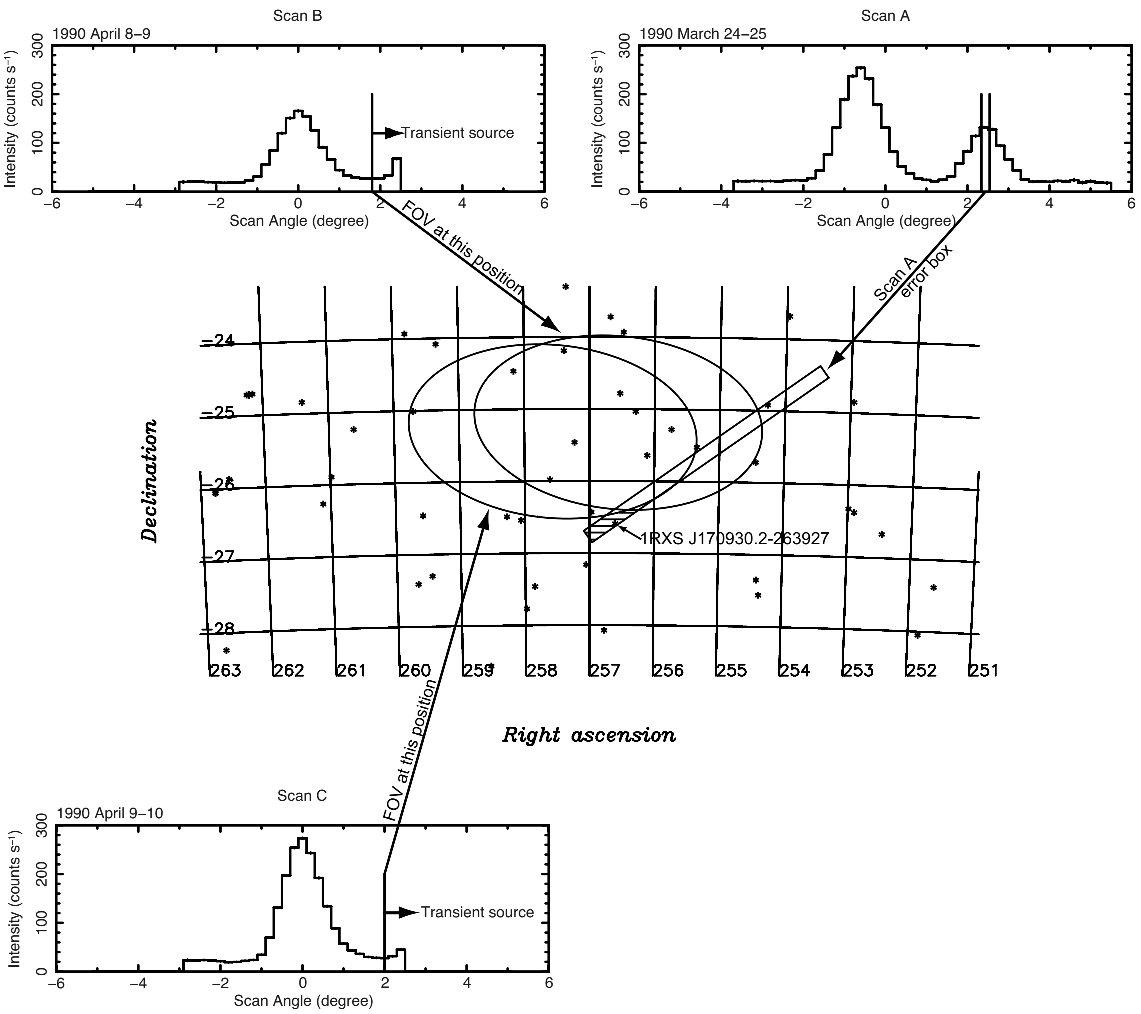

Fig. 1. Scan profiles obtained with the Ginga LAC on 1990 March 24–25 (scan A), April 8–9 (scan B) , and 9–10 (scan C) and the sky map around the Ginga transient source. Asterisks show the positions of cataloged X-ray sources (Forman et al. 1978, Warwick et al. 1981, Wood et al. 1984, Warwick et al. 1988, Voges et al. 1999, Sugizaki et al. 2001) and supernova remnants (Green 2006). The sky coordinates are B1950. The shaded region shows the probable source position derived from the three scan profiles.

In order to determine the source positions, we applied the same process as that used in Yamauchi (2005) and Yamauchi et al. (2007). We fitted the scan profile to a model consisting of contribution of point sources and the sky brightness [the Cosmic X-ray background (CXB) and the Galactic diffuse X-ray emission (GDXE)]. In the profile of scan A, three X-ray sources, Ophiuchus cluster of galaxies, 1RXS J171236.3−241445, and the transient source, were included to the model. The scan angle of 1RXS J171236.3−241445 was fixed to the value calculated from the cataloged position (Voges et al. 1999), because it is a faint source. The surface brightness distribution of Ophiuchus cluster of galaxies was assumed to be the Gaussian function. The best-fit scan angle of Ophiuchus cluster of galaxies was $0.^\circ 64$, while the scan angle of the Ginga transient source was determined to be $2.^\circ 44$. The typical uncertainty along the scan path was estimated to be $0.^\circ 1$. On the other hand, since the source positions were determined from the one-dimensional scan data, an uncertainty perpendicular to the scan path was $\pm 2^\circ$ (bottom-to-bottom of the collimator response function). The error region of the Ginga transient source is shown in figure 1.

The same process was applied to the scan profiles of scan B and C. We included the same three X-ray sources to the model. The scan angle of Ophiuchus cluster of galaxies is in agreement with that calculated from the cataloged position within the error. However, since the peak of the Ginga transient source was not seen in the scan profiles, the scan angle of the Ginga transient source was not constrained well.

The profiles of scan B and C in figure 1 show that the X-ray counts from the Ginga transient source are found at the scan angles of $> +1.^\circ 8$ of scan B and $> +2.^\circ 0$ of

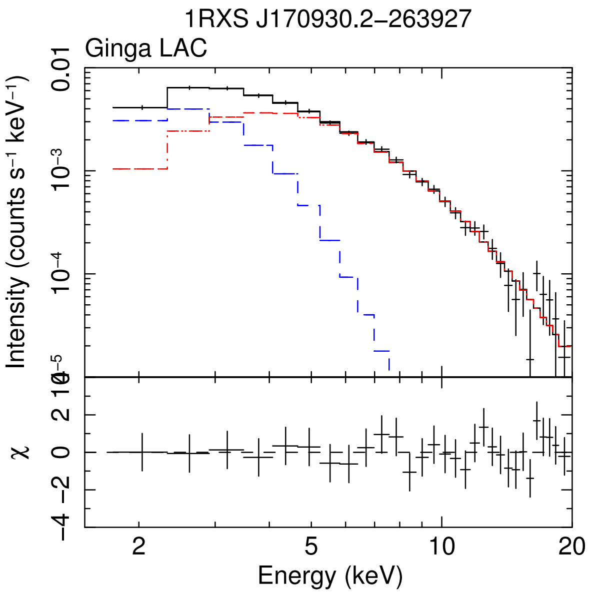

Fig. 2. The X-ray spectrum of 1RXS J170930.2−263927 obtained with the Ginga LAC on 1990 March 24–25 (upper panel) and the residuals from the best-fit model (lower panel). The histograms display the best-fit multicolor disk (dashed line) + comptonized blackbody with $kT_e = 10$ keV (dash-dotted line) model (see table 1).

scan C. This means that the sky position of the Ginga transient source should be outside the FOV at the scan angle=+1.°8 of scan B and +2.°0 of scan C (as shown by arrows in the scan profiles in figure 1). The FOVs at the scan angles (+1.°8 of scan B and +2.°0 of scan C) are displayed in figure 1. The three scan data lead the conclusion that the probable source position is the shaded region shown in figure 1. The region includes 1RXS J170930.2−263927.

The X-ray spectrum of the Ginga transient source was extracted from the scan A data. X-ray counts were accumulated from the scan angle of +2.°3 – +2.°7. The non-X-ray background was subtracted using the method given in Awaki et al. (1991). The spectrum of CXB was evaluated from blank sky data with $|b| > 40°$, while contributions of GDXE and X-ray counts from nearby unresolved faint sources were estimated from data with the scan angle of +3.°5–+4.°1. Figure 2 shows the background-subtracted X-ray spectrum.

We fitted the spectra to single-component models, a bremsstrahlung model or a power-law model, taking into account the interstellar absorption. The cross sections of the photoelectric absorption were taken from Morrison & McCammon (1983). The best-fit parameters are listed in table 1. Next, we applied two-component models, a multicolor disk (diskbb model in XSPEC, Mitsuda et al. 1984) plus blackbody model or a multicolor disk

Table 1. Results of a spectral analysis for the 1RXS J170930.2−263927 spectrum obtained on 1990 March 24–25.

Parameter	Value
Model: thermal bremsstrahlung×absorption	
$N_{\rm H}$ ($\times 10^{22}$ cm^{-2})	$0.4^{+0.3}_{-0.3}$
kT (keV)	6.2±0.5
χ^2_ν (d.o.f)	0.65 (27)
Model: power-law×absorption	
$N_{\rm H}$ ($\times 10^{22}$ cm^{-2})	2.1±0.4
α	$2.5^{+0.2}_{-0.1}$
χ^2_ν (d.o.f)	1.72 (27)
Model: (diskbb[1]+blackbody)×absorption	
$N_{\rm H}$ ($\times 10^{22}$ cm^{-2})	<1.4
$kT_{\rm in}$ (keV)	$2.6^{+0.3}_{-0.2}$
$kT_{\rm bb}$ (keV)	$0.62^{+0.10}_{-0.17}$
χ^2_ν (d.o.f)	0.77 (25)
Model: (diskbb[1]+compbb[2])×absorption	
$N_{\rm H}$ ($\times 10^{22}$ cm^{-2})	<3.4
$kT_{\rm in}$ (keV)	$0.63^{+0.47}_{-0.22}$
kT_0 (keV)	$1.3^{+0.6}_{-0.4}$
$kT_{\rm e}$ (keV)	10 (fixed)
τ	$1.5^{+0.5}_{-0.7}$
χ^2_ν (d.o.f)	0.62 (24)

Errors show single-parameter 90% confidence level.
[1] Multicolor disk model (Mitsuda et al. 1984)
[2] Comptonized blackbody model (Nishimura et al. 1986).

Table 2. Comparison of the spectral shape: the temperature of the thermal bremsstrahlung or the photon index.

Mission	kT (keV)	α	Reference
RXTE	4.7±0.2	3.06±0.06	1
Beppo SAX	5.77±0.63	2.67±0.13	2
MAXI	—	∼3	3
Ginga	6.2±0.5	$2.5^{+0.2}_{-0.1}$	4

References 1: Marshall et al. (1997), 2: Cocchi et al. (1998), 3: Negoro et al. (2010), 4: this work

plus comptonized blackbody (compbb model in XSPEC, Nishimura et al. 1986) model. These models explain the spectra of neutron star low-mass X-ray binaries (e.g., Barret 2001). Since we have no information on an electron temperature of the compbb model, kT_e, we assumed kT_e=10 keV. If kT_e=100 keV is assumed, then optical depth, τ, is 0.4, but the other parameters do not change significantly. The best-fit parameters are also listed in table 1.

3. Discussion

Using the scan data obtained in 1990 March and April, we re-determined the source position. The revised sky position, smaller than that of the previous report in Yamauchi & Koyama (1990), is in agreement with that of 1RXS J170930.2−263927. For a comparison, the best-fit spectral parameters of a thermal bremsstrahlung and a power-law model fits obtained in the RXTE (Marshall et al. 1997), Beppo SAX (Cocchi et al. 1998), MAXI (Negoro et al. 2010), and Ginga observations are listed in table 2. The parameters are similar to each other. Thus, the positional coincidence and the spectral similarity indicate that the Ginga transient source and 1RXS J170930.2−263927=XTE J1709−267 are identical.

Based on the spectral analysis, the flux with an aspect correction is calculated to be 2.3×10^{-9} erg s^{-1} cm$^{-2}\sim$110 mCrab on 1990 March 24–25, which is larger than that with ROSAT (∼13 mCrab, Marshall et al. 1997). Thus, the Ginga results indicate that 1RXS J170930.2−263927 was in outburst in 1990 March and was brighter than that in the ROSAT observation in 1990 August (Voges et al. 1999).

The results of the spectral fit for 1RXS J170930.2−263927 shows that the spectrum is well reproduced by the diskbb+compbb model. The spectral parameters are similar to those of X1608−522 in the high luminosity state (Mitsuda et al. 1989; Gierliński & Done 2002). X1608−522 is a well known a neutron star low-mass X-ray binary system The Ginga results support that 1RXS J170930.2−263927 is a neutron star low-mass X-ray binary system like X1608-522.

In order to detect outbursts and to study the physical process of the transient behavior, monitor observations are very important. MAXI, monitoring all the sky, is a suitable facility to investigate the physical process of recurrent soft X-ray transient sources.

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