RXTE observations of X-ray transients IGRJ17091-3624 and IGRJ18539+0727

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We present results of analysis of observations of two transient sources IGR J17091-3624 and IGR J18539+0727 in April 2003 with RXTE observatory. Obtained energy spectra of sources, and also power spectra of their flux variations give us a possibility to classify them as X-ray binary systems in low/hard spectral state. Parameters of power spectrum of IGR J18539+0727 indicates that this source is a black hole candidate.

Introduction

X-ray sources IGR J17091-3624 and IGR J18539+0727 were discovered by INTEGRAL observatory during deep survey of the Galactic central radian and routine scans of the Galactic plane in April 2003 (Kuulkers et al. 2003, Lutovinov et al. 2003a).

The first source was detected on April 14, 2003 with IBIS telescope aboard INTEGRAL observatory in the energy band 40-100 keV. The source flux was measured to be 20 mCrab. In softer energy band 15-40 keV only upper limit on the source flux was obtained at that time <10 mCrab. Following observations of this source by INTEGRAL showed that the source flux increased up to 40 and 25 mCrab in energy bands 15-40 and 40-100 keV respectively, that indicated that the spectrum of the source probably softened (Kuulkers et al. 2003).

Analysis of archived data of the TTM telescope of the “Roentgen” observatory aboard KVANT module of the MIR space station and WFC telescope of the BeppoSAX observatory revealed sporadic appearances of this source during period 1994–2001 (Revnivtsev et al. 2003, in’t Zand et al. 2003). Observations of the source in radio band, performed by VLA telescopes after the source discovery in April 2003, revealed the presence of possible radio companion (Rupen et al. 2003).

After several days, on April 17-18, 2003, during the Galactic plane scan and observations of microquasar GRS 1915+105 the second source was discovered. The source flux was measured to be 20 mCrab in energy bands 15-40 and 40-100 keV (Lutovinov et al. 2003a).

In order to try to understand the nature of the newly discovered sources almost immediately after INTEGRAL discovery the RXTE observations were performed. RXTE observatory have high sensitivity in the energy band 3-20 keV and can be successfully used for spectral and timing analysis of the sources. In this paper we present the results of analysis of these observations.

Observations, data analysis and results

X-ray sources IGR J17091-3624 and IGR J18539+0727 were observed by the RXTE observatory (Bradt, Rothschild, Swank 1993) on April 20.5 and 26.1, 2003 respectively. Effective exposures of performed observations were 2 and 3.2 ksec.

For RXTE data reduction we used standard programs of FTOOLS/LHEASOFT 5.2 package. For estimation of the PCA background we used "L7240"-based model. In order to increase our sensitivity to photons with energies higher than 10-15 keV we used data of all layers of PCA detectors. Because of weakness of sources they were not detected by HEXTE spectrometer (15-250 keV). For approximation of the sources spectra we used XSPEC package (http://xspec.gsfc.nasa.gov).

Spectrometer PCA of the RXTE observatory collects all photons from sky area around 1 sq.deg without any possibility to distinguish between the background photons and the photons from the source of our interest. During observations of X-ray sources located close to the Galactic plane the X-ray flux measured by PCA can contain significant contribution from "background" Galactic ridge emission. In the Galactic center region at the Galactic latitude ~ 2° (where IGR J17091-3624 is located) contribution of the Galactic ridge emission to the measured PCA flux should be at the level of ~ 0.5–0.6 mCrab in 3-20 keV energy band (e.g. Valinia, Marshall 1998, Revnivtsev 2003). At the same time, the flux detected from the source approximately equals to 4 mCrab, or only 8 time higher than the "background" flux from the Galactic ridge. Because of that we should be very careful in our following data analysis. At the distance around ~40° from the Galactic plane, the "background" contribution can be more significant.
center and at the Galactic latitude $\sim 3^\circ$, where IGR J18539+0727 is located, the contribution from the ridge emission is significantly lower ($\sim 2\%-5\%$ of the source flux).

**IGR J17091-3624**

Light curves of the source measured during observation on April 20, 2003 is shown in Fig. 1(left). As it is seen from the figure the source flux was relatively stable at the level of $\sim 4$ mCrab (estimated contribution of the Galactic ridge emission is subtracted). The fractional rms amplitude of its aperiodic variability equals to $27 \pm 3\%$ in the frequency range 0.01-10 Hz.

No QPO-like features is seen on the power spectrum (Fig. 2(left)). In general the power spectrum could be well approximated by standard model of band limited noise. But the increase of sensitivity in a comparison with previous case allowed us to detect the second component of the noise. Approximation of the power spectrum with the model $dP \propto 1/(1 + (f/f_0)^2)df$ gives the break frequency $f_0 = 0.31 \pm 0.04$ Hz.

In Fig. 3(left) we present the energy spectrum of IGR J17091-3624, averaged over all observation. Solid line shows the model used for spectral approximation $(dN/dE \propto E^{-\Gamma})$. Dashed line denotes the estimated contribution of the Galactic ridge emission to the spectrum collected by RXTE/PCA. Estimations based on measurements of Revnivtsev (2003). Approximation of the power spectrum with the model $dP_{1,2} \propto 1/(1 + (f/f_{1,2})^2)df$ gives the break frequencies $f_1 = (5.3 \pm 0.5) \cdot 10^{-2}$ Hz and $f_2 = 1.3 \pm 0.2$ Hz. The rms amplitude of aperiodic variability contained in lower frequency component is $\sim 33\%$, in higher frequency component $\sim 30\%$. Total source flux variability in frequency range 0.005-20 Hz equals to $45 \pm 2\%$.

Energy spectrum of the source, averaged over whole observation, is shown in Fig. 4(right). Because IGR J18539+0727 is significantly further from the Galactic center and by more than half a degree further from the Galactic plane in comparison with previous source, the contribution of the Galactic ridge emission to the flux detected by RXTE/PCA is almost negligible. As it was noted before its contribution does not exceed 2-5\% of the IGR J18539+0727 flux.

For the approximation of the spectrum of the source we used the same model - power law with neutral absorption. Apparent presence of the emission line at the energy $\sim 6.4$ keV probably caused by the reprocessing the hard X-ray emission from the innermost parts of the accretion flow by cold optically thick outer parts of the accretion disk (see e.g. Basko et al. 1974). However, the weakness of the source and low exposure of the used observation result in the low sensitivity of our spectral analysis to the presence of the reflected/reprocessed component itself (continuum). Upper limit on the possible amplitude of the reflected component ($\text{model pexrav of XSPEC package; Magdziarz, Zdziaski 1995}$) in the spectrum of IGR J18539+0727 is $\Omega/2\pi < 0.3$, where $\Omega$ is the solid angle subtended by the reflector with respect to the source of hard X-ray pho-
during approximation of the IGR J17091-3624 energy spectrum the estimated contribution of Galactic ridge emission was subtracted. Normalization of the ridge emission was taken to give 3-20 keV flux at the level of \( \sim 1.9 \times 10^{-11} \) erg/s/cm\(^2\)/(in the field of view of PCA), that is corresponds to result of Revnivtsev (2003)

\[ b \] Influence of the Galactic ridge emission does not allow us to state the presence of the emission line in the spectrum of the source.

**Table 1.** Best fit parameters of spectral approximations of IGR J17091-3624 and IGR J18539+0727.

| Parameter                        | IGR J17091-3624 \(^a\) | IGR J18539+0727 |
|----------------------------------|-------------------------|-----------------|
| Neutral absorption \( N_H L \), \( 10^{22} \) cm\(^{-2}\) | < 1                     | 1.5 ± 0.4       |
| Photon index, \( \Gamma \)       | 1.43 ± 0.03             | 1.47 ± 0.05     |
| Energy of the emission line, keV | \(-\)                  | 6.4 ± 0.1       |
| Width of the line, keV           | \(-\)                  | < 0.3           |
| Equivalent width of the line, EW, eV | \(-\)              | 135 ± 25        |
| Flux (3-25 keV), \( 10^{-10} \) erg/s/cm\(^2\) | 1.0                     | 1.8             |

\(^a\) During approximation of the IGR J17091-3624 energy spectrum the estimated contribution of Galactic ridge emission was subtracted. Normalization of the ridge emission was taken to give 3-20 keV flux at the level of \( \sim 1.9 \times 10^{-11} \) erg/s/cm\(^2\)/(in the field of view of PCA), that is corresponds to result of Revnivtsev (2003)

\[ b \] Influence of the Galactic ridge emission does not allow us to state the presence of the emission line in the spectrum of the source.

**Discussion**

During several months from the start of operations of INTEGRAL observatory several sources, which could be called weak hard transients, with roughly similar properties were discovered: IGR J17091-3624 (Kuulkers et al. 2003), IGR J18539+0727 (Lutovinov et al. 2003a), IGR J18325-0756 (Lutovinov et al. 2003b), IGR17597-2201 (Lutovinov et al. 2003c), IGR J18483-0311 (Chernyakova et al. 2003). “Hard” in this case denotes that transients, in spite of being quite weak, were still detected by INTEGRAL in a hard X-ray energy band 40-100 keV.

In this work we presented the results of spectral and timing analysis of two sources - IGR J17091-3624 and IGR J18539+0727, that were observed by RXTE satellite after the INTEGRAL discovery of them.

Spectra of these sources could be well approximated by power law model (\( dN(E) \propto E^{-\alpha} dE \)). Because of proximity of IGR J17091-3624 to the Galactic center and, consequently, significant contribution of the Galactic ridge emission to the flux detected by RXTE/PCA, we can not measure the parameters of possible fluorescent emission line of the source. In the case of IGR J18539+0727 such analysis is possible and we see the fluorescent line at energy \( \sim 6.4 \) keV (Fig\(^a\) Table 1). Such fluorescent emission line is often observed in spectra of X-ray binaries in low/hard spectral state. This line likely originates as a re-
Fig. 3. (left) Energy spectrum of IGR J17091-3624. Points with error bars (1σ) represent the spectrum observed by RXTE/PCA, solid line shows the model of observed spectrum, that consist of source spectrum and the spectrum of the galactic ridge emission (dashed line). (right) Energy spectrum of IGR J18539+0727. Points with error bars (1σ) represent the observed spectrum, solid line shows the used model. Contribution of the ridge emission is small.

result of reprocessing of hard X-ray emission of innermost parts of the accretion flow by outer cold parts of optically thick accretion disk (see e.g Basko et al. 1974, Gilfanov et al. 1999)

Both sources demonstrate strong flux variability on time scales from tenths to tens of seconds. Characteristics of energy spectra of sources and power spectra of their light curves allow us to classify them as X-ray binary systems in low/hard spectral state. Significant activity of IGR J17091-3624 in radio (Rupen et al. 2003) indirectly confirms such classification (Fender, Hendry 2000)

For quite a long time the parameters of power spectra of sources light curves are under discussion in the view of possibility of determination of the nature of the compact object in the X-ray binary system (e.g. Wijnands & van der Klis 1999, Sunyaev & Revnivtsev 2000). It was demonstrated a number of times that the light curves of neutron star X-ray binaries in the low spectral state typically contain higher frequency variability than that of back hole X-ray binaries. Power spectra of X-ray binaries allow one to apply strict criterion to distinguish neutron star systems from back holes binaries (Sunyaev & Revnivtsev 2000), however lower frequency band power spectra parameters do not allow one to do so.

Investigations of X-ray binaries show that neutron star systems usually do not demonstrate the lowest break frequency lower then ~0.1 Hz (Wijnands & van der Klis 1999). In our case, the power spectrum of IGR J18539+0727 has the break frequency lower then that. Therefore we can tentatively suggest that this source is a black hole candidate.

Parameters of power spectrum of IGR J17091-3624 do not allow us to do so, however significant flux of the source in radio band observed by VLA (Rupen et al. 2003) also hints that the source could be a black hole candidate (Fender et al. 2001). In spite of that, for real determination of the nature of compact objects in these systems one need more observations, especially in the optical spectral band, that would allow to identify optical companions of X-ray sources and measure the mass functions of the binaries.

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