RXTE observations of strongly absorbed sources IGR J16318-4848 and IGR J16358-4726

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Results of analysis of RXTE observations of strongly absorbed X-ray sources IGR J16318-4848 and IGR J16358-4726 are presented. Careful subtraction of Galactic ridge emission contribution to the observed spectra of RXTE/PCA allowed us to obtain the spectra of the sources in 3–25 keV energy band. Spectra of the sources could be well described by a power law with photoabsorption. It is shown that the value of absorption column in the case of RXTE observation of IGR J16318-4848 performed on March 14.1, 2003 is somewhat higher that that obtained by XMM observatory on Feb 10.7 2003. This could imply that the source has variable absorption, presumably connected with an orbital phase of the binary system. It is noted, that all three X-ray sources, discovered by INTEGRAL observatory in the sky region of \((l, b) \sim (336, 0)\) (IGR J16318-4848, IGR J16320-4751 and IGR J16358-4726) have large intrinsic photoabsorption and could be high mass X-ray binaries. This hypothesis has indirect support from the fact that their are located close to the Norma spiral arm tangent, i.e. in the region of enhanced concentrations of young massive stars. If they are reside within this spiral arm some rough estimation of the sources distance could be made \(- D \sim 6-8\) kpc.

Introduction

During first several months of Galactic plane scans of INTEGRAL observatory there were discovered a few sources which X-ray spectrum has high photoabsorption - IGR J16318-4848 (Courvoisier et al. 2003, Murakami et al. 2003), IGR J16320-4751/AX J1631.9-4752 (Tomsick et al. 2003), IGR J16358-4726 (Revnivtsev et al. 2003a,b).

Shortly after discovery of IGR J16318-4848, the source was observed by XMM (Schartel et al. 2003, de Plaa et al. 2003), that allowed one to make precise position determination and identify its infrared and optical companion (Foschini et al. 2003, Revnivtsev et al. 2003c). Analysis of infrared and optical measurements of the counterpart showed that X-ray binary IGR J16318-4848 likely contains supergiant companion, which powerful stellar wind could lead to the observed properties of the source - very strong photoabsorption and very powerful fluorescent emission lines of neutral iron - very similar to that of long period pulsar GX301-2 (Revnivtsev et al. 2003c).

Observations of IGR J16320-4751 and IGR J16358-4726 with XMM and CHANDRA satellites (Rodriguez et al. 2003, Kouveliotou et al. 2003) have not resulted in unambiguous identification of their infrared counterparts, however, in both cases companion stars are likely to be bright, and possibly massive.

In the present Letter we present results of analysis of RXTE observations of IGR J16318-4848 and IGR J16358-4726.

Data analysis and results

IGR J16318-4848 and IGR J16358-4726 were observed by RXTE on March 14.1, 2003 and March 25.9, 2003 respectively. Effective exposure times of these observations were 6.5 ksec and 3.1 ksec. Because sources are located in highly populated area of the sky and the field of view of RXTE/PCA instrument is 1°, the orientation of the observatory in both cases had some offset with respect to the real source positions, in order to exclude possible contribution of nearby known bright sources. Map of the sky around sources with overplotted fields of view of RXTE/PCA during two observations is presented in Fig.1.

For the data reduction we used standard programs of package FTOOLS/LHEASOFT 5.2. Because the sources of our interest are rather weak and they were observed with offset pointings, that diminishes the flux detected from them, we have paid special attention to the correct PCA background subtraction. First of all we have excluded the data from PCU0, because from May 2000 this detector lacks propane veto layer, that leads to the worse quality of background subtraction. Besides, we have used data from upper layer of anodes (LR1) only, because it has lower systematic uncertainties of the background estimation. For the background modelling we used model "L7_240".

 Galactic Ridge emission very strongly contributes to the X-ray emission detected by RXTE/PCA, that complicates the analysis of weak sources close to the Galactic
plane. For example, the X-ray flux, detected by PCA from IGR J16318-4848 in 2-10 keV energy range is not more than 0.1-0.2 mCrab however Galactic ridge emission, integrated over PCA field of view, gives X-ray flux at the level of approximately 3–5 mCrab (Valinia, Marshall 1998, Revnivtsev 2003).

In order to take into account the Galactic ridge emission we have used results of analysis, presented in papers of Valinia, Marshall (1998) and Revnivtsev (2003). Besides, in our analysis we used RXTE/PCA data obtained during observation of the point, close to IGR J16318-4848 and IGR J16358-4726, and namely - observations of SGR 1627-41 in a quiescent state (Nov. 19-20, 2001). As the shape of the spectrum of Galactic ridge emission does not depend on the position on the sky, except for changing value of interstellar photoabsorption (Yamasaki et al. 1997, Valinia, Marshall 1998, Tanaka 2002, Revnivtsev 2003), we can use its spectrum obtained in an empty field as a template in order to subtract its contribution to the observations of IGR J16318-4848 and IGR J16358-4726.

**IGR J16318-4848**

Spectrum of IGR J16318-4848, averaged over whole observation is presented in Fig.2. In the figure we also present total spectrum, detected by RXTE/PCA, that consists of the spectrum of the source and the spectrum of Galactic ridge emission. Note, that normalization of the source spectrum is in ~ 2.22 times smaller than the real one because of ~ 0.55° offset pointing of RXTE/PCA.

For the source spectral approximation we have used simplest model – a power law \( dN(E) \propto E^{-\alpha}dE \) with neutral photoabsorption (\( wabs \) model is XSPEC package). This model was successfully used for spectral approximation of XMM and ASCA data (de Plaa et al. 2003, Revnivtsev et al. 2003c). It is worth to note, that in spite of known presence of prominent fluorescent emission lines at 6–7 keV (Schartel et al. 2003, de Plaa et al. 2003, Revnivtsev et al. 2003c) very strong influence of Galactic ridge emission at these energies precludes any analysis of these lines in RXTE/PCA data. Flux from the Galactic ridge emission, detected by RXTE/PCA at energies 6–7 keV is more than 10 times higher than that of IGR J16318-4848 (see. Fig.2). Obtained best fit parameters of the source spectrum are presented in Table 1. Note, that the parameter of neutral photoabsorption \( nH L \) is somewhat larger than that obtained by XMM on Feb 10.7, 2003 (de Plaa et al. 2003, Matt, Guainazzi 2003).

The lightcurve of the source over the whole observation is presented in Fig.3.

Analysis of the power spectrum of the obtained lightcurve have not shown any pulsations or highly coherent oscillations (Swank, Markwardt 2003). 2 \( \sigma \) upper limit on the amplitude of possible pulsations with a frequencies 0.01 Hz - 1 kHz in the energy band 10-20 keV is approximately 10-15%. Upper limit on an amplitude of pulsations with longer periods, like in the case of GX301-2 (670 sec) or IGR J16358-4726 (5860 sec, Kouveliotou et al. 2003) is even larger, ~20-50%. It is not possible to study the light curve of the source at energies lower than ~10 keV because of the source weakness with respect to the Galactic ridge emission.
Table 1. Best fit parameters of the spectra of IGR J16318-4848 and IGR J16358-4726, obtained with RXTE/PCA

| Parameter                   | IGR J16318-4848 | IGR J16358-4726 |
|-----------------------------|-----------------|-----------------|
| Absorption column $N_H$, $10^{22}$ cm$^{-2}$ | $310 \pm 70$    | $40 \pm 10$     |
| Photon index $\alpha$      | $1.0 \pm 0.5$   | $1.1 \pm 0.2$   |
| Observed flux$^a$ (3-25 keV), $10^{-10}$ erg/s/cm$^2$ | $1.1$           | $5.4$           |

$^a$ Observed flux of the source was corrected for the collimator response

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**Fig. 3.** Lightcurve of IGR J16318-4848 and IGR J16358-4726. Contribution of the galactic ridge emission is subtracted.

**Fig. 4.** Spectrum of IGR J16358-4726. Crosses denotes the spectrum, observed by RXTE/PCA, open circles - spectrum of IGR J16358-4726 after subtraction of Galactic ridge emission. Solid curve represents the model of RXTE/PCA observed spectrum, that consists of model of Galactic ridge emission (dotted curve) and model of the source spectrum (dashed curve).

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**IGR J16358-4726**

Spectrum of the source, averaged over whole observation is presented in Fig. 4. Similar to the case of IGR J16318-4848 on the Fig.4 we present total spectrum, detected by RXTE/PCA, that consist of the source spectrum and the spectrum of Galactic ridge emission.

For the spectral approximation we used the same model as for the case of IGR J16318-4848 - power law with neutral photoabsorption. Best fit parameters of used model are presented in Table 1. Obtained values of parameters well agree with CHANDRA results (Kouveliotou et al. 2003)

As it was expected, the flux of the Galactic ridge emission in this observation is higher than in the case of IGR J16318-4848 (Fig.2,4) because the field of view of RXTE/PCA was $\sim 0.5^\circ$ closer to the Galactic plane (see Fig.1). The value of the flux of the Galactic ridge emission well agrees with the results of Valinia, Marshall (1998), Revnivtsev (2003).

Lightcurve of the source does not allow us to analyze pulsations with the period 5.86 ksec, detected by Kouveliotou et al. (2003), because the length of our observation is only 3.1 ksec. Pulsations or highly coherent oscillations with shorter periods was not detected. 2$\sigma$ upper limit on such oscillations at frequencies 0.01Hz – 1 kHz is $\sim 10^{-15}$%.

**Discussion**

In the previous chapter we presented results of analysis of RXTE observations of two strongly absorbed X-ray sources IGR J16318-4848 and IGR J16358-4726. In spite of faintness of sources, strong influence of the Galactic ridge emission and closeness of other bright X-ray binaries, the chosen observation strategy allowed us to obtain the spectra of sources in 3–25 keV energy band.

Spectra of considered sources could be well described by a power law with neutral photoabsorption (model wabs $\times$ power of XSPEC package). Because of large contribution of Galactic ridge emission (that contains a set of powerful lines in 6-7 keV energy band) to the spectra detected by RXTE/PCA, it is not possible to study the emission lines, that could be present in the spectra.
of IGR J16318-4848 and IGR J16358-4726. Obtained best fit parameters of our spectral approximation well agree with results of other observatories, except for somewhat higher value of absorption column $n_H L$ in the case of IGR J16318-4848 with respect to the value obtained with XMM observatory (de Plaa et al. 2003, Matt, Guainazzi 2003).

In spite of considerable complications that arises from strong contribution of Galactic ridge emission to the observed spectra of RXTE/PCA we still believe that our obtained best fit parameters of spectral approximations are more or less correct. Compatibility of best fit parameters of the spectrum of IGR J16358-4726 obtained by RXTE/PCA on March 25.9, 2003 (see Table 1) and obtained by CHANDRA on March 24.2, 2003 (Kouveliotou et al. 2003) could serve as a demonstration of correctness of our method of spectral analysis.

Therefore we suppose that higher value (with respect to the value obtained by XMM observatory on Feb. 10.7, 2003) of obtained absorption column in the case of IGR J16318-4848 could imply that the source has variable absorption, probably connected with the orbital phase of the binary system. Similar absorption variability was observed for a large set of high mass X-ray binary systems, in particular in the case of long period pulsar GX 301-2 (see e.g. Endo et al. 2002) which observational appearances are very similar to that of IGR J16318-4848.

It is interesting to note, that three X-ray sources, discovered by INTEGRAL observatory in the region of $(l, b) \sim (336, 0)$ (IGR J16318-4848, IGR J16320-4751 and IGR J16358-4726) have a lot of things in common. All three sources have strongly absorbed X-ray spectra, values of the absorption column strongly exceed the interstellar ones (e.g. Dickey, Lockman 1990). All three sources have rather hard X-ray spectra (photon index $\alpha \sim 1-1.3$), that is typical for X-ray pulsars and high mass binaries. For IGR J16318-4848 it was shown that its optical/infrared counterpart is bright, likely massive, star (Foschini et al. 2003, Revnivtsev et al. 2003c). For other two sources no unambiguous identification of counterparts were made yet, however it is likely that these sources also have bright companions, similar to IGR J16318-4848 (see, Rodriguez et al. 2003, Kouveliotou et al. 2003). Therefore it seems to be reasonable to assume that all three X-ary sources could be high mass binaries. Location of the sources on the sky could also be treated in the favor of described hypothesis. Sources are located at $(l, b) \sim (336, 0)$, close to the Norma spiral arm tangent, i.e. in the region of enhanced concentration of young massive stars (see e.g. Grimm et al. 2002). If our assumption is correct than the rough estimation of the sources distance could be made - 6–8 kpc.

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