The outburst of the X-ray nova GRS 1739-278 in September, 2016

I.A. Mereminskiy\textsuperscript{1}, E.V. Filippova\textsuperscript{1}, R.A. Krivonos\textsuperscript{1}, S.A. Grebenev\textsuperscript{1}, R.A. Burenin\textsuperscript{1} and R.A. Sunyaev\textsuperscript{1,2}

\textsuperscript{1}Space Research Institute, Russian Academy of Sciences, Profsoyuznaya 84/32, 117997 Moscow, Russia
\textsuperscript{2}Max Planck Institute for Astrophysics, Karl-Schwarzschild-Strasse 1, D-85741 Garching, Germany

During the scanning observations of the Galactic Center region in August – September 2016 we detected the new outburst of the historical X-ray nova GRS 1739-278, the black hole candidate LMXB system. In this letter we present results of INTEGRAL and Swift-XRT observations taken during the outburst. In hard X-ray band (20–60 keV) the flux from the source raised from \( \sim 11 \) to \( \sim 30 \) mCrab between 3 and 14 of September. For nearly 8 days the source has been observed at this flux level and then faded to \( \sim 15 \) mCrab. The broadband quasi-simultaneous spectrum obtained during the outburst is well described by the absorbed powerlaw with the photon index \( \Gamma = 1.86 \pm 0.07 \) in broad energy range 0.5–150 keV, with absorption corresponding to \( N_H = 2.3 \times 10^{22} \text{ cm}^{-2} \) assuming solar abundance. Based on this we can conclude that the source was in the low/hard state. From the lightcurve and spectra we propose that this outburst was ‘failed’, i.e. amount of accreted matter was not sufficient to achieve the high/soft spectral state with dominant soft blackbody component as seen in normal outbursts of black hole candidates.

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*Corresponding author <i.a.mereminskiy@gmail.com>
1. Introduction

The X-ray nova GRS 1739-278 was discovered by SIGMA telescope onboard GRANAT space observatory during its bright outburst in 1996 (Paul et al., 1996). Later GRANAT continued observations of this source (Vargas et al., 1997) along with other X-ray telescopes: ROSAT (Greiner et al., 1996), RXTE and TTM/Kvant (Borozdin et al., 1998). The optical counterpart was found in observations carried out by ESO telescopes (Marti et al., 1997). The peak flux was about \( \sim 800 \) mCrab in 2–10 keV (ASM/RXTE) (Borozdin et al., 1998). During the outburst GRS 1739-278 demonstrated typical behavior of the black hole candidate (BHC, see e.g. Grebenev et al., 1993, 1997; Tanaka and Shibazaki, 1996; Remillard and McClintock, 2006; Belloni, 2010). The lightcurve could be described with a FRED-like (fast rise, exponential decay) shape, at the beginning of the outburst the source was in a typical low/hard state, with spectrum dominated by a power-law component with exponential cutoff at high (\( \geq 100 \) keV) energies followed by a high/soft state with a strong blackbody component (Borozdin et al., 1998). Observations at VLA (Durouchoux et al., 1996) revealed presence of variable radio emission, which could be caused by jets. Borozdin and Trudolyubov (2000) found QPO at 5 Hz in RXTE observations conducted while the source was in the very high/soft state.

Since the discovery of the source in 1996, the Galactic Center region has been regularly monitored by RXTE/ASM and INTEGRAL (since 2003) missions. According to Krivonos et al. (2012a) GRS 1739-278 remained in quiescence until 2013, the upper limit on 20–60 keV flux was 0.12 mCrab (3\( \sigma \), 1 mCrab corresponds to \( 12.3 \times 10^{-12} \) erg cm\(^{-2} \) s\(^{-1} \)).

The second outburst of GRS 1739-278 was detected by Filippova et al. (2014) in 2014. It’s 2–20 keV flux was measured at the level of \( \sim 200 \) mCrab\(^1\) with MAXI experiment (Matsuoka et al., 2009). Fig. 1 shows the source lightcurve during the second outburst as measured by Swift-BAT telescope (Gehrels et al., 2004) in 25-50 keV. One can notice that although the second outburst apparently ended after \( \sim 150 \) days after the beginning, the source flux has not lowered down to zero and remained on 5–15 mCrab level. As shown in Fig. 1 in the beginning of September the flux from GRS 1739-278 started to increase. This allowed us to report an onset of the new outburst using INTEGRAL observations (Mereminskiy et al., 2016). In this work we used all publicly available INTEGRAL data, including monitoring observations of the Galactic Bulge (Kuulkers et al., 2007) and private data from scanning observations of the Galactic Center (as described in Krivonos et al., 2012b). We also used two Swift-XRT observations performed on September 21 and 24 as well as follow-up observations by Russian-Turkish 1.5-m telescope (RTT-150) on September, 26.

2. Observations

Main results were obtained with IBIS/ISGRI telescope (Ubertini et al., 2003) onboard INTEGRAL observatory (Winkler et al., 2003). IBIS/ISGRI is a wide-field (30\( ^\circ \) \times 30\( ^\circ \) FWZR) coded mask telescope working in the hard X-ray range 20–300 keV. The angular resolution of about 13’ FWHM allows a confident detection of GRS 1739-278 despite its location in the Galactic Bulge, a region crowded by a large number of bright point X-ray sources (Krivonos et al., 2012a, see also Fig. 2 for illustration). We also used JEM-X telescope onboard INTEGRAL, which is sensitive in the standard X-ray range 3–35 keV (Lund et al., 2003) and has field of view of 13.2\( ^\circ \) in diameter. The field around the source was observed by INTEGRAL from 29 August until 27 September 2016 which corresponds to 1719-1729 INTEGRAL orbits, with exception for 1723 and 1724 revolutions, when INTEGRAL observed Crab nebulae for calibration purposes.

For IBIS/ISGRI data we performed energy calibration (processing of event lists up to the COR level) with use of OSA 10.1 (Courvoisier et al., 2003). IBIS/ISGRI is a wide-field (30\( ^\circ \) \times 30\( ^\circ \) FWZR) coded mask telescope working in the hard X-ray range 20–300 keV. The angular resolution of about 13’ FWHM allows a confident detection of GRS 1739-278 despite its location in the Galactic Bulge, a region crowded by a large number of bright point X-ray sources (Krivonos et al., 2012a, see also Fig. 2 for illustration). We also used JEM-X telescope onboard INTEGRAL, which is sensitive in the standard X-ray range 3–35 keV (Lund et al., 2003) and has field of view of 13.2\( ^\circ \) in diameter. The field around the source was observed by INTEGRAL from 29 August until 27 September 2016 which corresponds to 1719-1729 INTEGRAL orbits, with exception for 1723 and 1724 revolutions, when INTEGRAL observed Crab nebulae for calibration purposes.

For IBIS/ISGRI data we performed energy calibration (processing of event lists up to the COR level) with use of OSA 10.1 (Courvoisier et al., 2003). Then we used the proprietary analysis package developed at IKI (Revnivtsev et al., 2004; Krivonos et al., 2010; Churazov et al., 2014) to reconstruct sky images and extract source fluxes. JEM-X data were reduced with the standard software OSA 10.1 to obtain sky images (IMA level) and then processed according to Grebenev and Mereminskiy (2015).

\(^1\)http://maxi.riken.jp/top/index.php?cid=1&jname=J1742-277
Fig. 1: Swift-BAT lightcurve in 25–50 keV range taken between January, 2014 and September, 2016. The second large outburst (denoted as ‘2d’) and onset of the third outburst (denoted as ‘3d’) are clearly visible. During outbursts time bin was chosen as 6 days and between outbursts as 2 months.
Fig. 2: The image of the Galactic Center region in 20–60 keV band obtained with IBIS/ISGRI (Galactic coordinates, shown in term of significance). The square-root color map ranges from 0 to 25. The mosaic was made using observations conducted from 14 to 21 September 2016.

Swift-XRT observational campaign was initiated immediately (Neilsen et al., 2016) after discovery of the new outburst. The first observation (ObsID. 00033812055, hereafter we use only two last digits of the ObsID.) was performed on 21 September (57652 MJD), XRT observed GRS 1739-278 in Photon Counting mode for ∼1 ks. The second observation (ID. 56) took place on 24 September (57656 MJD). We processed all data using the standard pipeline XRTPIPELINE v.0.12.6 (Burrows et al., 2005). The exposure map was build by XRTEXPOMAP and was used to produce ARF files. XRT observed GRS 1739-278 at nearly 1.5 cts s⁻¹ (0.5–10 keV) rate. For the spectral analysis we had rebinned data in order to have at least 100 photons per bin. Unfortunately, the source count rate was too low to study its variability at timescales of minutes or seconds.

On 26 September (16:50 UTC) we performed a search for an optical/IR emission with RTT-150 telescope with the focal reducer and TFOSC spectrograph. Observational conditions were poor because of the large zenith angle, the image quality was about 2.5″. We got direct images in r’ and i’ band, the exposure time was 300 s.

3. Results

Fig. 2 shows the significance map of the field around GRS 1739-278 obtained with IBIS/ISGRI in 20–60 keV range on September 2016 (spacecraft revolutions 1725-1727). The source is detected at 34σ significance level, the exposure on the source is 62 ksec. Several other bright X-ray sources in the Galactic Bulge are also marked.

In Fig. 3 we present the lightcurve of the source in 20–60 keV band taken with IBIS/ISGRI for all available data. The first significant detection of the source occurred on 3 September, the flux was 11.1 ± 3.1 mCrab. Several features are clearly seen on the figure: the slow and steady increase of the flux for about 10 days, the “plateau” at ∼30 mCrab level that lasted for a week, and, then, the decline to ∼15 mCrab. The source remained at this stage until the end of our observations. This behaviour is completely different from that in the previous outburst of the source, during which intensity in 15–50 keV band increased tenfold in the course of 8 days and reached ∼300 mCrab at maximum as Swift-BAT data
Fig. 3: The hard X-ray lightcurve (20–60 keV) of GRS 1739-278 during the third outburst as seen by INTEGRAL. Arrows show coordinated Swift-XRT observations, the dotted line represents time of our optical/IR follow-up.

Table 1: The best-fit spectral parameters for IBIS/ISGRI observations of GRS 1739-278

| Revolution     | Obs. start MJD | Obs. end MJD | Exposure, ks | Flux 20-100 keV, $10^{-10}$ erg cm$^{-2}$ s$^{-1}$ | $\Gamma$ | $N_H$, 10$^{22}$ cm$^{-2}$ |
|----------------|----------------|--------------|--------------|-----------------------------------------------|--------|------------------|
| 1725           | 57645.8        | 57647.0      | 21           | 5.8±2.6                                       | 1.73±0.12 |
| 1726           | 57648.5        | 57649.7      | 23           | 5.6±2.6                                       | 1.98±0.12 |
| 1727           | 57651.9        | 57653.1      | 19           | 5.2±2.8                                       | 1.84±0.14 |
| 1728-1729      | 57653.7        | 57658.3      | 37           | 3.0±1.9                                       | 1.81±0.16 |

show (Krimm et al., 2014) (see also Fig. 1).

We reconstructed and studied spectra obtained by IBIS/ISGRI in 1725, 1726 and 1727 orbits, during which the source was bright. We also built the overall spectrum for 1728-1729 revolutions. To fit spectra we used wabs*powerlaw model from XSPEC package (Arnaud, 1996). All spectra are well-fitted by the powerlaw with the slope of $\sim$1.7–2.0 (Table 1), no high-energy cut-off is seen up to 150 keV.

In Swift-XRT observations the source was already in fading phase, yet still confidently detected at $1.28±0.04$ cts s$^{-1}$ ($S/N \simeq 30$). Spectra obtained by Swift-XRT show no obvious peculiarities and can be described with the absorbed powerlaw. The measured absorption column $\sim2.3\times10^{22}$ cm$^{-2}$ is in agreement with previous estimates (Greiner et al., 1996; Miller et al., 2015). The best-fit models are presented in Table 2. The slope of the powerlaw is measured with large errors due to narrow width of the energy range and strong correlation with the absorption.

We then constructed broadband X-ray spectra of GRS 1739-278 using quasi-simultaneous observations made by INTEGRAL and Swift. To achieve better statistics for INTEGRAL JEM-X and IBIS/ISGRI data we used the spectrum averaged over 1725-1727 (“plateau”) revolutions. We performed simultaneous

Table 2: The best-fit spectral parameters of GRS 1739-278 from Swift-XRT spectra

| ID | Obs. start MJD | Exposure, s | Unabsorbed flux (0.1-10 keV), 10$^{-10}$ erg cm$^{-2}$ s$^{-1}$ | $\Gamma$ | $N_H$, 10$^{22}$ cm$^{-2}$ |
|----|----------------|-------------|-------------------------------------------------|--------|------------------|
| 55 | 57652          | 968.9       | 2.4±0.6                                         | 1.74±0.24 | 2.14±0.43 |
| 56 | 57656          | 939         | 1.6±0.2                                         | 1.5±0.3 | 1.52±0.19 |
fitting of three spectra (XRT 0.3–10 keV, JEM-X 5–20 keV, and IBIS/ISGRI 20–150 keV) using simple $\text{const} \times \text{wabs} \times \text{powerlaw}$ model. To account for non-simultaneity of observations and differences in absolute calibrations we introduced cross-calibration coefficients ($\text{const}$ $C_{\text{XRT}}$ and $C_{\text{JEM-X}}$), using IBIS/ISGRI data as a reference. The obtained spectrum is presented in Fig. 4. For 1728–1729 revolutions we performed the similar analysis, but without using JEM-X data.

The best-fit model parameters are presented in Table 3. The spectrum obtained in the course of “plateau” is well described by a simple model with reasonable $\chi^2_{\text{red}} = 0.51$ (12 d.o.f.). The surface density of the neutral hydrogen column $N_H$ which accounts for the absorption seen in spectra, was measured as $(2.3 \pm 0.2) \times 10^{22}$ cm$^{-2}$ (assuming solar abundance) during the “plateau” and as $(1.7 \pm 0.2) \times 10^{22}$ cm$^{-2}$ at the decline. Both values are close to previously measured $N_H \simeq 2.1 \times 10^{22}$ cm$^{-2}$ [Grebenev et al. 1996, Miller et al. 2015], however they are significantly different from each other. On the other hand, although data in Table 3 show some spectral hardening (from $\Gamma = 1.86 \pm 0.19$ to $\Gamma = 1.73 \pm 0.05$) this is not reliable enough. There are no traces of the blackbody radiation or Fe K$\alpha$ fluorescent line. Unlike the NuSTAR observations from previous outburst [Miller et al. 2015, Fuerst et al. 2016] there is no cut-off at 40–50 keV in the powerlaw component, which we traced up to $\sim 150$ keV, thanks to IBIS/ISGRI energy coverage. We shall note, that observations performed by different telescopes were non-simultaneous and the source showed variability of at least order of 2 during the individual IBIS/ISGRI observations on the “plateau”. This can explain cross-calibration coefficients of 0.44 and 0.33 for JEM-X and XRT, respectively. This showed variability of at least order of 2 during the individual IBIS/ISGRI observations on the “plateau”. We shall note, that observations performed by different telescopes were non-simultaneous and the source showed variability of at least order of 2 during the individual IBIS/ISGRI observations on the “plateau”. This can explain cross-calibration coefficients of 0.44 and 0.33 for JEM-X and XRT, respectively. This showed variability of at least order of 2 during the individual IBIS/ISGRI observations on the “plateau”.

No IR source was detected at the position reported by Marti et al. 1997) in images obtained with RTT-150. We estimated $5\sigma$ upper limits as $m(r') \simeq 22.0$ and $m'(r') \simeq 20.8$. In Fig. 5 we plotted these limits alongside with the spectrum from Fig. 1. Earlier Grebenev et al. 2013, 2014, 2016) showed that IR and optical observations of some X-ray novae are well described by the powerlaw extrapolation of their hard X-ray spectra, with respect to the absorption by the dust, corresponding to the photoabsorption by the neutral gas which can be measured from a soft X-ray spectrum. It is interesting to note that observations of X-ray novae in radio bands also suggest single powerlaw [Russell et al. 2000]. From Fig. 5 it is seen, that due to severe absorption in direction to the GRS 1739-278 obtained upper limits are much higher than powerlaw extrapolation of the hard X-ray spectrum, as well as possible blackbody contribution from outer and cooler parts of the accretion disk around the black hole. In Fig. 5 spectra corresponding to the critical Eddington accretion rate onto $10 M_\odot$ black hole are also presented: red lines show spectrum arising from an accretion disk, extended up to the last stable orbit radius ($3 R_g$), blue lines show the same disk but with $30 R_g$ inner radius. Both models give equal contribution to the IR band, although the first disk can not be present in this system, because of lack of the soft X-ray emission. We should also note that, under reasonable assumptions, the irradiation can not significantly increase the blackbody disk contribution to the IR emission [Grebenev et al. 2016].

Based on both spectra and the estimated luminosity we can assume that the source stayed in the canonical low/hard black hole state. Therefore, it turns out that this outburst is failed, at least yet, i.e. amount of accreted matter is not high enough to reach the high/soft state with the prominent blackbody component, that is usual for developed outbursts. Forthcoming NuSTAR and Chandra observations [Heilesen et al. 2016] could shed additional light on this question.

We carried out several additional observations of GRS 1739-278 with IBIS/ISGRI in 1730-1732 revolutions after the paper was accepted. The source remains active with 20–60 keV flux about 15 mCrab.

### Table 3: The best-fit parameters of broadband X-ray spectra of GRS 1739-278

| INTEGRAL revolutions | ObsID | $N_H$, $10^{22}$ cm$^{-2}$ | $\Gamma$ | Flux, $10^{-12}$ cm$^{-2}$ s$^{-1}$ | $C_{\text{JEM-X}}$ | $C_{\text{IBIS}}$ | $\chi^2_{\text{red}}$ |
|----------------------|-------|---------------------------|---------|-----------------------------|-----------------|-----------------|----------------|
| 1725-1727            | 55    | 2.33±0.20                 | 1.86±0.07 | 8.61±2.3                   | 5.3±1.4         | 0.44±0.06       | 0.32±0.05       | 6.1(12)       |
| 1728-1729            | 56    | 1.68±0.19                 | 1.73±0.05 | 1.8±0.1                     | 3.0±0.2         | -               | 0.56±0.18       | 12.1(10)      |
Fig. 4: The broadband X-ray spectrum of GRS 1739-278. Swift-XRT data are shown in black (ID. 00033812055), JEM-X and IBIS/ISGRI data averaged over 1725-1727 revolutions are shown in red and blue.

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Fig. 5: Same spectra as in Fig. 4 but with upper limits from IR observations. The powerlaw extrapolation of hard X-ray spectra shown in black (solid lines denote true spectrum and dashed one show absorbed). The powerlaw extrapolation with addition of an Eddington-limited cold blackbody disk is shown in red (corresponds to disk with inner radius of $3 \ R_g$) and in blue (with $30 \ R_g$).
References

Arnaud, K. A.: 1996, in G. H. Jacoby and J. Barnes (eds.), *Astronomical Data Analysis Software and Systems V*, Vol. 101 of *Astronomical Society of the Pacific Conference Series*, p. 17

Belloni, T. M.: 2010, in T. Belloni (ed.), *Lecture Notes in Physics, Berlin Springer Verlag*, Vol. 794 of *Lecture Notes in Physics, Berlin Springer Verlag*, p. 53

Borozdin, K. N., Revnivtsev, M. G., Trudolyubov, S. P., Aleksandrovich, N. L., Sunyaev, R. A., and Skinner, G. K.: 1998, *Astronomy Letters* 24, 435

Borozdin, K. N. and Trudolyubov, S. P.: 2000, Astrophys. J. 533, L131

Burrows, D. N., Hill, J. E., Nousek, J. A., Kennea, J. A., Wells, A., Osborne, J. P., Abbey, A. F., Beardsmore, A., Mukerjee, K., Short, A. D. T., Chincarini, G., Campana, S., Citterio, O., Moretti, A., Pagani, C., Tagliaferri, G., Giommi, P., Capalbi, M., Tamburelli, F., Angelini, L., Cusumano, G., Bräuninger, H. W., Burkert, W., and Hartner, G. D.: 2005, Space Sci. Rev. 120, 165

Churazov, E., Sunyaev, R., Isen, J., Knödlseder, J., Jean, P., Lebrun, F., Chugai, N., S., Bravo, E., Sazonov, S., and Renaud, M.: 2014, *Nature* 512, 406

Courvoisier, T. J.-L., Walter, R., Beckmann, V., Dean, A. J., Dubath, P., Hudec, R., Kretschmar, P., Mereghetti, S., Montmerle, T., Mowlavi, N., Paltani, S., Preite Martinez, A., Produit, N., Staubert, R., Strong, A. W., Swings, J.-P., Westergaard, N. J., White, N., Winkler, C., and Zdziarski, A. A.: 2003, Astron. Astrophys. 411, L53

Durouchoux, P., Smith, I. A., Hurley, K., Schultz, A. S. B., Waters, L. B. F. M., van Paradijs, J., Wallyn, P., Hjellming, R. M., Rupen, M. P., Marti, J., Mirabel, F., and Rodriguez, L. F.: 1996, *IAU Circ.* 6383

Filippova, E., Kuulkers, E., Skådt, N. M., Alfonso-Garzon, J., Beckmann, V., Bird, A. J., Brandt, S., Chenevez, J., Del Santo, M., Domingo, A., Ebisawa, K., Jonker, P. G., Kretschmar, P., Markwardt, C. B., Oosterbroek, T., Paizis, A., Pottschmidt, K., Sanchez-Fernandez, C., Wijnands, R., Bozzo, E., and Ferrigno, C.: 2014, *The Astronomer’s Telegram* 5991

Fuerst, F., Tomsonick, J. A., Yamaoka, K., Dauser, T., Miller, J. M., Clavel, M., Corbel, S., Fabian, A. C., Garcia, J., Harrison, F. A., Loh, A., Kaaret, P., Kalmsci, E., Migliari, S., Miller-Jones, J. C. A., Pottschmidt, K., Rahoui, F., Rodriguez, J., Stern, D., Stuhlinger, M., Walton, D. J., and Wilms, J.: 2016, *ArXiv e-prints*

Gehrels, N., Chincarini, G., Giommi, P., Mason, K. O., Nousek, J. A., Wells, A. A., White, N. E., Barthelmy, S. D., Burrows, D. N., Cominsky, L. R., Hurley, K. C., Marshall, F. E., Mészáros, P., Roming, P. W. A., Angelini, L., Barbier, L. M., Belloni, T., Campana, S., Caraveo, P. A., Chester, M. M., Citterio, O., Cline, T. L., Cropper, M. S., Cummings, J. R., Dean, A. J., Feigelson, E. D., Fenimore, E. E., Frail, D. A., Fruchter, A. S., Garmire, G. P., Gendreau, K., Ghisellini, G., Greiner, J., Hill, J. E., Hunsberger, S. D., Krimm, H. A., Kulkarni, S., Kumar, P., Lebrun, F., Lloyd-Ronning, N. M., Markwardt, C. B., Mattson, B. J., Mushotzky, R. F., Norris, J. P., Osborne, J., Paczynski, B., Palmer, D. M., Park, H.-S., Parsons, A. M., Paul, J., Rees, M. J., Reynolds, C. S., Rhoads, J. E., Sasseen, T. P., Schaefer, B. E., Short, A. T., Smale, A. P., Smith, I. A., Stella, L., Tagliaferri, G., Takahashi, T., Tashiro, M., Townsley, L. K., Tueller, J., Turner, M. J. L., Vietri, M., Voges, W., Ward, M. J., Willingale, R., Zerbi, F. M., and Zhang, W. W.: 2004, Astrophys. J. 611, 1005

Grebenev, S., Sunyaev, R., Pavlinsky, M., Churazov, E., Gilfanov, M., Dyachkov, A., Khavenson, N., Sukhanov, K., Laurent, P., Ballet, J., Claret, A., Cordier, B., Jourdain, E., Niel, M., Pelaez, F., and Schnitz-Frayesse, M. C.: 1993, Astron. Astrophys. Suppl. Ser. 97, 281

Grebenev, S. A. and Mereminskiy, I. A.: 2015, *Astronomy Letters* 41, 765

Grebenev, S. A., Prosvetov, A. V., and Burenin, R. A.: 2014, *Astronomy Letters* 40, 171
Grebenev, S. A., Prosvetov, A. V., Burenin, R. A., Krivonos, R. A., and Mescheryakov, A. V.: 2016, *Astronomy Letters* **42**, 69

Grebenev, S. A., Prosvetov, A. V., and Sunyaev, R. A.: 2013, *Astronomy Letters* **39**, 367

Grebenev, S. A., Sunyaev, R. A., and Pavlinsky, M. N.: 1997, *Advances in Space Research* **19**, 15

Greiner, J., Dennerl, K., and Predehl, P.: 1996, Astron. Astrophys. **314**, L21

Krimm, H. A., Barthelmy, S. D., Baumgartner, W., Cummings, J., Gehrels, N., Lien, A. Y., Markwardt, C. B., Palmer, D., Sakamoto, T., Stamatikos, M., and Ukwatta, T.: 2014, *The Astronomer’s Telegram* 5986

Krivonos, R., Revnivtsev, M., Tsygankov, S., Sazonov, S., Vikhlinin, A., Pavlinsky, M., Churazov, E., and Sunyaev, R.: 2010, Astron. Astrophys. **519**, A107

Krivonos, R., Tsygankov, S., Revnivtsev, M., Churazov, E., and Sunyaev, R.: 2012a, *A&A* **545**, A27

Krivonos, R., Tsygankov, S., Revnivtsev, M., Sazonov, S., Churazov, E., and Sunyaev, R.: 2012b, Astron. Astrophys. **537**, A92

Kuulkers, E., Shaw, S. E., Paizis, A., Chenevez, J., Brandt, S., Courvoisier, T. J.-L., Domingo, A., Ebisawa, K., Kretschmar, P., Markwardt, C. B., Mowlavi, N., Oosterbroek, T., Orr, A., Ríosquez, D., Sanchez-Fernandez, C., and Wijnands, R.: 2007, Astron. Astrophys. **466**, 595

Lund, N., Budtz-Jørgensen, C., Westergaard, N. J., Brandt, S., Rasmussen, I. L., Hornstrup, A., Oxborrow, C. A., Chenevez, J., Jensen, P. A., Laursen, S., Andersen, K. H., Mogensen, P. B., Rasmussen, I., Omo, K., Pedersen, S. M., Polny, J., Andersson, H., Andersson, T., Kämäräinen, V., Vilhu, O., Huovelin, J., Maisala, S., Morawski, M., Juchnikowski, G., Costa, E., Feroci, M., Rubini, A., Rapisarda, M., Morelli, E., Carassiti, V., Frontera, F., Pelliciari, C., Loffredo, G., Martínez Núñez, S., Reglero, V., Velasco, T., Larsson, S., Svensson, R., Zdziarski, A. A., Castro-Tirado, A., Attina, P., Goria, M., Giulianelli, G., Cordero, F., Rezzagad, M., Schmidt, M., Carli, R., Gomez, C., Jensen, P. L., Sarri, G., Tiemon, A., Orr, A., Much, R., Kretschmar, P., and Schnopper, H. W.: 2003, *A&A* **411**, L231

Marti, J., Mirabel, I. F., Duc, P.-A., and Rodriguez, L. F.: 1997, Astron. Astrophys. **323**, 158

Matsuoka, M., Kawasaki, K., Ueno, S., Tomida, H., Kohama, M., Suzuki, M., Adachi, Y., Ishikawa, M., Mihara, T., Sugizaki, M., Isobe, N., Nakagawa, Y., Tsunemi, H., Miyata, E., Kawai, N., Kataoka, J., Morii, M., Yoshida, A., Negoro, H., Nakajima, M., Ueda, Y., Chuo, H., Yamaoka, K., Yamazaki, O., Nakahira, S., You, T., Ishiwata, R., Miyoshi, S., Eguchi, S., Hiroi, K., Katayama, H., and Ebisawa, K.: 2009, Publ. Astron. Soc. Japan **61**, 999

Mereminskiy, I., Krivonos, R., Grebenev, S., Filippova, E., and Sunyaev, R.: 2016, *The Astronomer’s Telegram* 9517

Miller, J. M., Tomsick, J. A., Bachetti, M., Wilkins, D., Boggs, S. E., Christensen, F. E., Craig, W. W., Fabian, A. C., Grefenstette, B. W., Hailey, C. J., Harrison, F. A., Kara, E., King, A. L., Stern, D. K., and Zhang, W. W.: 2015, Astrophys. J. **799**, L6

Møller, J., Motta, S., Ponti, G., Coriat, M., Fender, R., and Corbel, S.: 2016, *The Astronomer’s Telegram* 9541

Paul, J., Bouchet, L., Churazov, E., and Sunyaev, R.: 1996, *IAU Circ.* 6348

Remillard, R. A. and McClintock, J. E.: 2006, Ann. Rev. Astron. Astrophys. **44**, 49

Revnivtsev, M. G., Sunyaev, R. A., Varshalovich, D. A., Zheleznjak, V. V., Cherepashchuk, A. M., Lutovinov, A. A., Churazov, E. M., Grebenev, S. A., and Gilfanov, M. R.: 2004, *Astronomy Letters* **30**, 382
Russell, D. M., Fender, R. P., Hynes, R. I., Brocksopp, C., Homan, J., Jonker, P. G., and Buxton, M. M.: 2006, Mon. Not. Roy. Astron. Soc. 371, 1334

Tanaka, Y. and Shibazaki, N.: 1996, Ann. Rev. Astron. Astrophys. 34, 607

Ubertini, P., Lebrun, F., Di Cocco, G., Bazzano, A., Bird, A. J., Broenstad, K., Goldwurm, A., La Rosa, G., Labanti, C., Laurent, P., Mirabel, I. F., Quadrini, E. M., Ramsey, B., Reglero, V., Sabau, L., Sacco, B., Staubert, R., Vigroux, L., Weisskopf, M. C., and Zdziarski, A. A.: 2003, Astron. Astrophys. 411, L131

Vargas, M., Goldwurm, A., Laurent, P., Paul, J., Jourdain, E., Roques, J.-P., Borrel, V., Bouchet, L., Sunyaev, R., Churazov, E., Gilfanov, M., Novikov, B., Dyachkov, A., Khavenson, N., Sukhanov, K., and Kuleshova, N.: 1997, Astrophys. J. 476, L23

Winkler, C., Courvoisier, T. J.-L., Di Cocco, G., Gehrels, N., Giménez, A., Grebenev, S., Hermsen, W., Mas-Hesse, J. M., Lebrun, F., Lund, N., Palumbo, G. G. C., Paul, J., Roques, J.-P., Schnopper, H., Schönfelder, V., Sunyaev, R., Teegarden, B., Ubertini, P., Vedrenne, G., and Dean, A. J.: 2003, Astron. Astrophys. 411, L1