Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS **470,** 512–516 (2017) doi:10.1093/mnras/stx1276
Advance Access publication 2017 May 23

New hard X-ray sources discovered in the ongoing *INTEGRAL* Galactic plane survey after 14 yr of observations

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Accepted 2017 May 19. Received 2017 May 17; in original form 2017 April 11

ABSTRACT

The International Gamma-Ray Astrophysics Laboratory (*INTEGRAL*) continues to successfully work in orbit after its launch in 2002. The mission provides the deepest ever survey of hard X-ray sources throughout the Galaxy at energies above 20 keV. We report on a catalogue of new hard X-ray source candidates based on the latest sky maps comprising 14 yr of data acquired with the IBIS telescope onboard *INTEGRAL* in the Galactic Plane ($|b| < 17.5^{\circ}$). The current catalogue includes in total 72 hard X-ray sources detected at S/N $> 4.7\sigma$ and not known to previous *INTEGRAL* surveys. Among them, 31 objects have also been detected in the on-going all-sky survey by the BAT telescope of the *Swift* observatory. For 26 sources on the list, we suggest possible identifications: 21 active galactic nuclei, two cataclysmic variables, two isolated pulsars or pulsar wind nebulae and one supernova remnant; 46 sources from the catalogue remain unclassified.

Key words: surveys – X-rays: general.

1 INTRODUCTION

X-ray surveys play a key role in our understanding of energetic phenomena in the Universe. Detailed investigations of the physics and evolution of X-ray selected sources are usually based on systematic studies of their properties. Observations in recent decades have revealed a variety of X-ray point sources beyond the Solar system in the Milky Way and Magellanic Clouds. Although the bright X-ray sources in the Milky Way can be effectively studied, many of them are not observable due to the heavy obscuration by the Galactic disc. Studies of nearby galaxies with modern sensitive soft X-ray telescopes are relatively free from the obscuration problem and can provide us uniform samples of X-ray binaries in different environments (see Fabbiano 2006; Fabbiano & White 2006, for a review). As a result, we may know better the properties of X-ray source populations and structure of the nearby galaxies, than of our own Milky Way.

X-ray observations of our Galaxy at energies above 10 keV are free from the obscuration bias. However, due to the large extent of the Milky Way across the sky, a systematic survey of the Galactic X-ray source population and discovery of new X-ray emitters require wide-angle instruments. This makes the IBIS coded-mask telescope (Ubertini et al. 2003) onboard the *INTEGRAL* observatory (Winkler et al. 2003) unique and most suitable for surveying the Galaxy in the hard X-ray domain.

The *INTEGRAL* observatory has been successfully operating in orbit since its launch in 2002 October. Over the past years, *INTEGRAL* acquired a huge data set, which allowed us to construct high quality X-ray catalogues in the Galactic Plane (GP), starting from our early papers by Revnivtsev et al. (2004, 2006); Molkov et al. (2004), to more recent surveys (see Krivonos et al. 2012, 2015; Bird et al. 2016, and references therein). These works were subsequently used for many relevant studies, including systematic discoveries of strongly absorbed high-mass X-ray binaries (HMXBs) and the study of their luminosity function and distribution in the Galaxy (Lutovinov et al. 2005, 2013b; Bodaghee et al. 2007, 2012; Chaty et al. 2008; Coleiro et al. 2013), the statistics of low-mass X-ray binaries (LMXBs) (Revnivtsev et al. 2008b) and cataclysmic variables (CVs) (Revnivtsev et al. 2008a; Scaringi et al. 2010).

In the previous paper (Krivonos et al. 2012), we presented a GP survey ($|b| < 17.5^{\circ}$) based on 9 yr of *INTEGRAL* operations. The survey catalogue lists 402 sources detected in the 17–60 keV energy band and time-average sky maps at more than 4.7σ significance, including 253 Galactic sources of known or tentatively identified nature, and 34 unidentified sources. The upper panel of Fig. 1 illustrates the limiting flux of the *INTEGRAL* 9-yr survey over the Galactic longitude, demonstrating that the survey's

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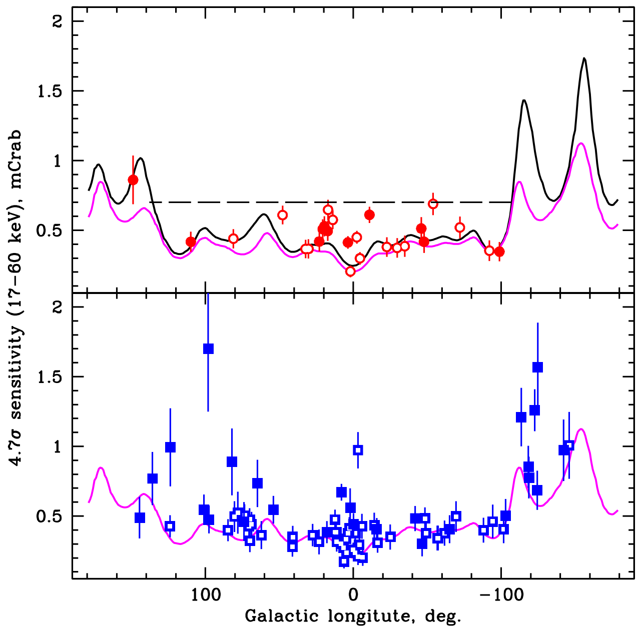

Figure 1. Sensitivity of the Galactic plane surveys over the Galactic longitude averaged within $|b| < 5°$ in the 17–60 keV energy band (4.7σ, 1 mCrab = 1.43×10^{-11} erg s^{-1} cm^{-2}), based on the actual exposure time. Black solid line corresponds to the 9-yr survey Krivonos et al. (2012), magenta line shows the sensitivity curve from the current work. Upper panel: open and filled red circles show the positions and fluxes of 26 non-identified persistent sources (Krivonos et al. 2012; Lutovinov et al. 2013b). Filled circles denote objects identified up to now. Long dashed line represents the flux limit used by Lutovinov et al. (2013b) to achieve full completeness of the survey in the inner part of the Galaxy (there are no unidentified sources above the line). Bottom panel: blue open squares denote 46 non-identified sources detected in the current survey. Filled squares show 26 sources with tentatively identified nature.

completeness in the inner part of the Galaxy raises to 100 per cent above the flux limit of 0.7 mCrab (shown in the figure with the dashed line). The sample of 26 persistent unidentified sources is shown by red circles (see Lutovinov et al. 2013b, for details). A number of multiwavelength follow-up observations were initiated to unveil the nature of these unclassified objects (Karasev et al. 2012; Lutovinov et al. 2013a, 2015; Masetti et al. 2013; Revnivtsev et al. 2013; Tomsick et al. 2015, 2016a,b; Zolotukhin & Revnivtsev 2015; Burenin et al. 2016; Clavel et al. 2016; Rahoui, Tomsick & Krivonos 2017) which led to the classification of 11 sources (shown by solid red circles in Fig. 1), raising the total survey identification completeness from ~92 per cent to ~94 per cent.

The 9-yr *INTEGRAL* Galactic survey by Krivonos et al. (2012) and the all-sky survey by Bird et al. (2016) were based on similar data sets, available by January 2011 and by the end of 2010, respectively. Over about 6 yr that have passed since then, *INTEGRAL* accumulated an additional ~80 and ~50 Ms of exposure (dead-time corrected) over the whole sky and in the GP ($|b| < 17.5°$), respectively. The increased sensitivity of the currently available *INTEGRAL* data set allows us to make a next iteration in the process of finding previously unknown hard X-ray sources. Mereminskiy et al. (2016) recently released a 17–60 keV deep survey of three extragalactic fields (M81, Large Magellanic Cloud and 3C 273/Coma), based on 12 yr of observations (2003–2015) with the detection of 147 sources at S/N > 4σ, including 37 sources observed in hard X-rays for the first time.

In this short report we present a catalogue of newly discovered hard X-ray sources detected in the latest maps of the GP comprising 14 yr of data acquired with *INTEGRAL*/IBIS.

2 DATA ANALYSIS

For this work, we selected all publicly available *INTEGRAL* data from 2002 December to 2017 March (spacecraft revolutions 26-1790). Prior to actual data analysis we applied the latest energy calibration (Caballero et al. 2013) for the registered Imager on Board the Integral Satellite/Integral Soft Gamma-Ray Imager (IBIS/ISGRI) detector events with the *INTEGRAL* Offline Scientific Analysis version 10.2 provided by INTEGRAL Science Data Centre (ISDC) Data Centre for Astrophysics up to the COR level. Then events were processed with a proprietary analysis package developed at IKI[1] (details available in Krivonos et al. 2010a, 2012; Churazov et al. 2014) to produce a 17–60 keV sky image of every individual *INTEGRAL* observation with a typical exposure time of 2 ks (usually referred as *Science Window*, or *ScW*). The flux scale in each *ScW* sky image was renormalized using the flux of the Crab nebula measured in the nearest observation. This procedure was used to account for the loss of sensitivity at low energies $E \lesssim 23$ keV caused by ongoing detector degradation.

In total, we obtained 124 727 *ScW* images covering the whole sky, comprising ~220 Ms of the effective (dead time-corrected) exposure. For the purposes of this work we selected 79234 *ScW*s (~130 Ms) within the GP ($|b| < 17.5°$). Following Krivonos et al. (2012) we constructed six overlapping $70° \times 35°$ Cartesian projections centred at the GP ($|b| = 0°$) and Galactic longitudes $l = 0°$, $\pm 50°$, $\pm 115°$ and $l = 180°$.

Based on the actual exposure, the peak sensitivity of the survey is 2.2×10^{-12} erg s^{-1} cm^{-2} (~0.15 mCrab[2] in the 17–60 keV energy band) at a 4.7σ detection level. The survey covers 90 per cent of the geometrical area (12680 degrees) down to the flux limit of 1.3×10^{-11} erg s^{-1} cm^{-2} (~0.93 mCrab) and 10 per cent of the total area down to the flux limit of 3.8×10^{-12} erg s^{-1} cm^{-2} (~0.26 mCrab). Given the added exposure in the GP, the achieved improvement in sensitivity with respect to the 9-yr survey is in the range of 10–30 per cent. The updated sensitivity of the current survey over the Galactic longitude is shown in the bottom panel of Fig. 1. Note that the overall improvement in sensitivity makes it possible to probe deeper into the Galaxy. Fig. 2 shows a face-on schematic view of the Galaxy and the distances at which we can detect a hard X-ray source of a given luminosity L_{HX} in the 17–60 keV band. One can see that (i) we can now detect all sources with the luminosity $L_{HX} > 2 \times 10^{35}$ erg s^{-1} at the far end of the Galaxy in the direction towards the Galactic Centre (GC), (ii) the distance range for the luminosity $L_{HX} > 10^{35}$ erg s^{-1} covers most of the Galactic stellar mass and (iii) the Galactic central bar is fully reachable at luminosities $L_{HX} > 5 \times 10^{34}$ erg s^{-1}.

Following Krivonos et al. (2012), we adopted a conservative detection threshold of $(S/N)_{lim} > 4.7\sigma$ to ensure that the final catalogue contains no more than one spurious source assuming Poisson statistics. The regions around bright sources, such as Crab, Sco X-1, Cyg X-1, Cyg X-3, Vela X-1, GX 301-2 and GRS 1915+105 were excluded from the automated excess selection to prevent false

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[2] 1 mCrab corresponds to 1.43×10^{-11} erg s^{-1} cm^{-2} assuming a spectral shape $10(E/1\,\mathrm{keV})^{-2.1}$ photons cm^{-2} s^{-1} keV^{-1}.

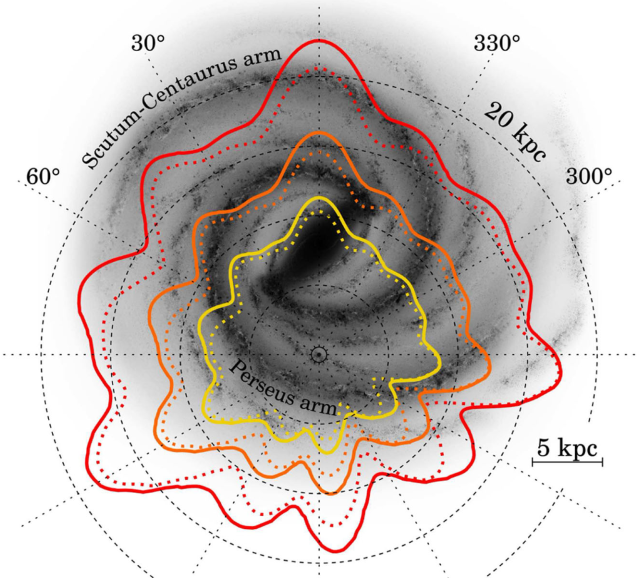

Figure 2. Face-on view of the Galaxy shown along with the distance range at which an X-ray source of a given luminosity $L_{\rm HX}$ (or more) can be detected according to the 17–60 keV sensitivity of the current 14-yr *INTEGRAL* survey (solid lines), compared to the 9-yr GP survey (Krivonos et al. 2012; dotted lines). Red, orange and yellow contours correspond to $L_{\rm HX} = 2 \times 10^{35}$, 10^{35} and 5×10^{34} erg s^{-1}, respectively. The background image is a sketch of the Galaxy adopted from Churchwell et al. (2009).

detections triggered by high systematic noise. However, manual inspection of these regions was performed to select possible source candidates (properly marked as being detected in noisy environment).

Special care was taken for the source detection in the region of ∼17 degrees around the GC due to enhanced systematics (see e.g. Krivonos et al. 2010a). False detections were revealed by a distorted excess shape that differs significantly from the instrumental point-spread function, which is a symmetric two-dimensional Gaussian ($\sigma = 5'$). One can reduce IBIS/ISGRI false detections by using additional information from the BAT coded-mask telescope (Barthelmy et al. 2005) onboard the *Swift* observatory (Gehrels et al. 2004) working at hard X-ray energies. Since BAT has a different coded-mask design compared to IBIS, it suffers different systematics, which allows one to suppress the non-statistical uncertainties known to IBIS (the idea on which the combined *Swift-INTEGRAL* survey by Bottacini, Ajello & Greiner 2012, is based). We assume that finding a hard X-ray counterpart in the ongoing *Swift*/BAT surveys (Cusumano et al. 2010; Baumgartner et al. 2013) of a suspected IBIS/ISGRI systematic excess adds more evidence that the excess is a real source.

3 RESULTS

Our analysis of 14-yr averaged sky images of the GP ($|b| < 17.5°$) led to the detection of 522 hard X-ray sources at significance $S/N > 4.7\sigma$, which is ∼30 per cent more compared to 402 sources detected in the 9-yr survey (Krivonos et al. 2012) with the same detection threshold. Note that 14 weak sources[3] listed in the 9-yr survey with fluxes of 0.2–0.5 mCrab are not detected in the current study, probably due to an intrinsic variability. Among 134 newly added sources (522−402 + 14), we identified 62 previously known X-ray emitters, including 17 known sources that experienced transient events after 2010 (Table 1). A detailed analysis of the survey's catalogue will be presented elsewhere. For the current report, we selected those 72 (out of 134) newly detected hard X-ray sources that have not been listed in the *INTEGRAL* surveys based on the data acquired before 2010 (Bird et al. 2004, 2006, 2007, 2010, 2016; Krivonos et al. 2007, 2010b, 2012), i.e. those sources whose detection is mainly determined by the ∼6-yr increased *INTEGRAL* survey sensitivity.

Table 2[4] lists new *INTEGRAL* sources detected in the current work with significances between 4.7σ and 15σ and fluxes between 0.17 and 1.7 mCrab (2.5×10^{-12} to 2.4×10^{-11}erg s^{-1} cm^{-2}). We searched for source counterparts within a 3.6 arcmin error circle (90 per cent confidence), as typical for the *INTEGRAL* sources detected at $S/N = 5$–6σ (Krivonos et al. 2007). As seen from Table 2, 31 source candidates are also detected in the ongoing *Swift*/BAT all-sky hard X-ray survey (Cusumano et al. 2010; Baumgartner et al. 2013). No hard X-ray counterparts were found for 41 sources, thus they have been detected in hard X-rays for the first time.

We utilized also the SIMBAD[5] and NED[6] data bases to perform a preliminary identification of the detected source candidates within 3.6 arcmin of the *INTEGRAL* position. However, usually unique optical/IR counterparts and hence firm astronomical classification can only be obtained based on arcsecond positions provided by soft X-ray focusing telescopes. Therefore, we paid a special attention for finding soft X-ray counterparts in the HEASARC[7] data base, *Swift*/XRT point source catalogue (1SXPS; Evans et al. 2014) and the third *XMM–Newton* serendipitous source catalogue (3XMM-DR5; Rosen et al. 2016). As a result, we suggest classification for 26 sources from the list, with two (IGR J00555+4610 and IGR J18184−2352) being most likely CVs and 21 probably being active galactic nuclei (Table 2 and filled squares in the bottom panel of Fig. 1). The remaining 46 unclassified sources are shown by open squares in the bottom panel of Fig. 1. Note, that most of them are detected close to the limiting flux of the survey below ∼0.5 mCrab (except for IGR J16459−2325 with a measured flux of 1.0 ± 0.1 mCrab). Twenty out of the 46 non-identified sources are located in the Galactic bulge at $|l| < 15°$.

4 CONCLUDING REMARK

Regular observations of the GP with *INTEGRAL* are consistently improving the sensitivity of the hard X-ray survey and allowing us to extend our knowledge of the Galactic X-ray source population, both for weak and nearby sources (mostly CVs, see e.g. Lutovinov et al. 2010; Clavel et al. 2016; Tomsick et al. 2016a), and more distant objects located at the far end of the Galaxy (Lutovinov et al. 2016; Rahoui et al. 2017). The presented catalogue opens the path to a large programme of follow-up observations, dedicated both to unveil

[3] IGR J17315−3221, IGR J17331−2406, Swift J2113.5+5422, IGR J18175−1530, IGR J17448−3231, XTE J1543−568, IGR J16293−4603, IGR J17197−3010, IGR J16358−4726, IGR J18497−0248, XTE J1751−305, AX J1753.5−2745, IGR J09189−4418 and IGR J20107+4534.

[4] Table 2 is only available in the online version of the paper.

[5] http://simbad.u-strasbg.fr/simbad

[6] http://ned.ipac.caltech.edu

[7] https://heasarc.gsfc.nasa.gov

Table 1. The list of known X-ray transients detected in the 14-yr time averaged map at S/N > 4.7σ mainly due to outburst event(s) that occurred between 2010 and 2016.

No.	Name	RA (J2000) (deg)	Dec. (J2000) (deg)	$\text{Flux}_{17\text{–}60\,\text{keV}}$ 10^{-11} erg s^{-1} cm^{-2}	S/N	Type^a	Outburst (year)
1	GS 0834−430	128.979	−43.185	0.99 ± 0.08	12.6	HMXB	2012
2	GS 1354−64	209.562	−64.733	3.94 ± 0.09	45.2	LMXB	2015
3	IGR J17177−3656	259.424	−36.880	0.32 ± 0.06	4.9	LMXB	2011
4	GRS 1716−249	259.903	−25.020	4.03 ± 0.06	65.2	LMXB	2016
5	Swift J1734.5−3027	263.652	−30.399	0.87 ± 0.05	17.2	LMXB	2013
6	GRS 1739−278	265.661	−27.748	2.11 ± 0.05	42.5	LMXB	2014, 2016
7	GRO J1744−28	266.138	−28.741	4.51 ± 0.05	91.8	LMXB	2014, 2017
8	Swift J174510.8−262411	266.297	−26.401	30.74 ± 0.05	607.7	LMXB	2012
9	IGR J17498−2921	267.482	−29.323	0.72 ± 0.05	14.6	LMXB	2011
10	1RXS J180408.9−342058	271.036	−34.356	5.80 ± 0.06	99.5	LMXB	2012
11	SAX J1806.5−2215	271.634	−22.233	3.31 ± 0.06	54.7	LMXB	2011
12	IGR J18179−1621	274.477	−16.481	0.38 ± 0.08	4.7	HMXB	2012
13	IGR J18245−2452	276.106	−24.879	1.29 ± 0.07	19.3	LMXB	2013
14	MAXI J1828−249	277.238	−25.041	1.23 ± 0.07	17.3	BHC	2013
15	MAXI J1836−194	278.937	−19.314	2.17 ± 0.09	24.5	XRB	2011
16	XTE J1859+083	284.753	8.239	0.60 ± 0.07	8.3	HMXB	2015
17	V404 Cyg	306.019	33.867	9.70 ± 0.08	119.8	LMXB	2015

Note. [a]General astrophysical type of the object: LMXB (HMXB) – low- (high-) mass X-ray binary; BHC – black hole candidate; XRB – X-ray binary.

new classes of objects and to increase the overall completeness of the source sample, needed for many Galactic population studies.

ACKNOWLEDGEMENTS

This work is based on observations with *INTEGRAL*, an ESA project with instruments and the science data centre funded by ESA member states (especially the PI countries: Denmark, France, Germany, Italy, Switzerland, Spain), and Poland, and with the participation of Russia and the USA. This research has made use of: data obtained from the High Energy Astrophysics Science Archive Research Center (HEASARC) provided by NASA's Goddard Space Flight Center; the SIMBAD database operated at CDS, Strasbourg, France; the NASA/IPAC Extragalactic Database (NED) operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration; the Palermo BAT Catalogue and data base operated at INAF–IASF Palermo. The data were obtained from the European[8] and Russian[9] *INTEGRAL* Science Data Centers. The authors are grateful to E. M. Churazov, who developed the *INTEGRAL*/IBIS data analysis methods and provided the software, and thank the Max Planck Institute for Astrophysics for computational support. This work was financially supported by Russian Science Foundation grant 14-22-00271.

REFERENCES

Barthelmy S. D. et al., 2005, Space Sci. Rev., 120, 143
Baumgartner W. H., Tueller J., Markwardt C. B., Skinner G. K., Barthelmy S., Mushotzky R. F., Evans P. A., Gehrels N., 2013, ApJS, 207, 19
Bird A. J. et al., 2004, ApJ, 607, L33
Bird A. J. et al., 2006, ApJ, 636, 765
Bird A. J. et al., 2007, ApJS, 170, 175
Bird A. J. et al., 2010, ApJS, 186, 1
Bird A. J. et al., 2016, ApJS, 223, 15
Bodaghee A. et al., 2007, A&A, 467, 585
Bodaghee A., Tomsick J. A., Rodriguez J., James J. B., 2012, ApJ, 744, 108
Bottacini E., Ajello M., Greiner J., 2012, ApJS, 201, 34
Burenin R. A. et al., 2016, Astron. Lett., 42, 295
Caballero I. et al., 2013, Proc. Sci., INTEGRAL IBIS/ISGRI energy calibration in OSA 10. SISSA, Trieste, PoS(INTEGRAL 2012), 142
Chaty S., Rahoui F., Foellmi C., Tomsick J. A., Rodriguez J., Walter R., 2008, A&A, 484, 783
Churazov E. et al., 2014, Nature, 512, 406
Churchwell E. et al., 2009, PASP, 121, 213
Clavel M. et al., 2016, MNRAS, 461, 304
Coleiro A., Chaty S., Zurita Heras J. A., Rahoui F., Tomsick J. A., 2013, A&A, 560, A108
Cusumano G. et al., 2010, A&A, 524, A64
Evans P. A. et al., 2014, ApJS, 210, 8
Fabbiano G., 2006, ARA&A, 44, 323
Fabbiano G., White N. E., 2006, in Lewin W., van der Klis M., eds, Compact Stellar X-ray Sources in Normal Galaxies. Cambridge Univ. Press, Cambridge, p. 475.
Gehrels N. et al., 2004, ApJ, 611, 1005
Karasev D. I., Lutovinov A. A., Revnivtsev M. G., Krivonos R. A., 2012, Astron. Lett., 38, 629
Krivonos R., Revnivtsev M., Lutovinov A., Sazonov S., Churazov E., Sunyaev R., 2007, A&A, 475, 775
Krivonos R., Revnivtsev M., Tsygankov S., Sazonov S., Vikhlinin A., Pavlinsky M., Churazov E., Sunyaev R., 2010a, A&A, 519, A107
Krivonos R., Tsygankov S., Revnivtsev M., Grebenev S., Churazov E., Sunyaev R., 2010b, A&A, 523, A61
Krivonos R., Tsygankov S., Lutovinov A., Revnivtsev M., Churazov E., Sunyaev R., 2012, A&A, 545, A27
Krivonos R., Tsygankov S., Lutovinov A., Revnivtsev M., Churazov E., Sunyaev R., 2015, MNRAS, 448, 3766
Lutovinov A., Revnivtsev M., Gilfanov M., Shtykovskiy P., Molkov S., Sunyaev R., 2005, A&A, 444, 821
Lutovinov A. A., Burenin R. A., Revnivtsev M. G., Suleimanov V. F., Tkachenko A. Y., 2010, Astron. Lett., 36, 904
Lutovinov A. A., Mironov A. I., Burenin R. A., Revnivtsev M. G., Tsygankov S. S., Pavlinsky M. N., Korobtsev I. V., Eselevich M. V., 2013a, Astron. Lett., 39, 513
Lutovinov A. A., Revnivtsev M. G., Tsygankov S. S., Krivonos R. A., 2013b, MNRAS, 431, 327
Lutovinov A. A. et al., 2015, Astron. Lett., 41, 179

[8] http://isdc.unige.ch
[9] http://hea.iki.rssi.ru/rsdc

Lutovinov A. A., Buckley D. A. H., Townsend L. J., Tsygankov S. S., Kennea J., 2016, MNRAS, 462, 3823
Masetti N. et al., 2013, A&A, 556, A120
Mereminskiy I. A., Krivonos R. A., Lutovinov A. A., Sazonov S. Y., Revnivtsev M. G., Sunyaev R. A., 2016, MNRAS, 459, 140
Molkov S. V., Cherepashchuk A. M., Lutovinov A. A., Revnivtsev M. G., Postnov K. A., Sunyaev R. A., 2004, Astron. Lett., 30, 534
Rahoui F., Tomsick J. A., Krivonos R., 2017, MNRAS, 465, 1563
Revnivtsev M. G. et al., 2004, Astron. Lett., 30, 382
Revnivtsev M. G., Sazonov S. Y., Molkov S. V., Lutovinov A. A., Churazov E. M., Sunyaev R. A., 2006, Astron. Lett., 32, 145
Revnivtsev M., Sazonov S., Krivonos R., Ritter H., Sunyaev R., 2008a, A&A, 489, 1121
Revnivtsev M., Lutovinov A., Churazov E., Sazonov S., Gilfanov M., Grebenev S., Sunyaev R., 2008b, A&A, 491, 209
Revnivtsev M. G., Kniazev A., Karasev D. I., Berdnikov L., Barway S., 2013, Astron. Lett., 39, 523
Rosen S. R. et al., 2016, A&A, 590, A1
Scaringi S. et al., 2010, MNRAS, 401, 2207
Tomsick J. A., Krivonos R., Rahoui F., Ajello M., Rodriguez J., Barrière N., Bodaghee A., Chaty S., 2015, MNRAS, 449, 597
Tomsick J. A., Rahoui F., Krivonos R., Clavel M., Strader J., Chomiuk L., 2016a, MNRAS, 460, 513
Tomsick J. A., Krivonos R., Wang Q., Bodaghee A., Chaty S., Rahoui F., Rodriguez J., Fornasini F. M., 2016b, ApJ, 816, 38
Ubertini P. et al., 2003, A&A, 411, L131
Winkler C. et al., 2003, A&A, 411, L1
Zolotukhin I. Y., Revnivtsev M. G., 2015, MNRAS, 446, 2418

SUPPORTING INFORMATION

Supplementary data are available at *MNRAS* online.

Table 2. The list of newly detected *INTEGRAL* hard X-ray sources based on 14 yr of observations.

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