ISSN 1063-7737, Astronomy Letters, 2006, Vol. 32, No. 3, pp. 145–148. © Pleiades Publishing, Inc., 2006.
Original Russian Text © M.G. Revnivtsev, S.Yu. Sazonov, S.V. Molkov, A.A. Lutovinov, E.M. Churazov, R.A. Sunyaev, 2006, published in Pis'ma v Astronomicheskiĭ Zhurnal, 2006, Vol. 32, No. 3, pp. 163–167.

Hard X-ray Survey of the Galactic Plane Region in Crux: A Catalog of Sources

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Received July 25, 2005

Abstract—This paper belongs to a series of papers devoted to a hard X-ray survey of the sky. We analyze a large set of observations of the Galactic plane region in Crux with the IBIS telescope onboard the INTEGRAL observatory. We have detected 47 sources. There are 12 active galactic nuclei and 11 and 6 galactic binary systems with high-mass and low-mass optical companions, respectively, among the identified objects. Thirteen objects remain unidentified.

PACS numbers: 95.85.Nv; 95.85.Pw; 98.70.Qy
DOI: 10.1134/S1063773706030017

Key words: *X-ray and gamma-ray sources.*

INTRODUCTION

The INTEGRAL observatory (Winkler et al. 2003) devotes much of its time to the observations of objects in the Galactic plane. The wide field of view ($\sim 29° \times 29°$) and large effective area (~ 2400 cm^2) of IBIS, the main telescope of the observatory, make it possible to survey large areas of the sky as well as to study individual compact sources. In particular, a record-breaking sensitivity was achieved in the surveys of the Galactic Center region (Revnivtsev et al. 2004b), the Sagittarius Arm tangent (Molkov et al. 2004), and the region of the Coma cluster of galaxies (Krivonos et al. 2005a). A survey of the Galactic plane with a lower sensitivity was presented by Bird et al. (2004).

The great penetrating power of the hard X rays recorded by the IBIS telescope allow objects that have previously been virtually inaccessible to observation to be studied in the soft and standard X-ray ranges. In particular, a number of Galactic binary systems with large internal photoabsorption have been discovered (see, e.g., Schartel et al. 2003; Revnivtsev 2003; Kuulkers 2004; Lutovinov et al. 2005). The companions of the compact objects in such binaries are high-mass young stars with an intense stellar wind that forms an absorbing envelope around the compact object. The INTEGRAL observations have increased considerably the number of known high-mass X-ray binaries.

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A deep survey (the observations of series 0320102) of the Galactic plane region in Crux, which was covered by previous INTEGRAL observations rather poorly, was carried out in 2005. This allowed a record-breaking sensitivity of 0.8–1.0 mCrab in the energy range 17–60 keV to be achieved. Here, we present a catalog of sources that were detected during this survey. This catalog can be used to identify and study them in other energy ranges.

OBSERVATIONS

In this paper, we used data from all of the available IBIS/INTEGRAL observations in a $50° \times 50°$ field of view centered on the point with Galactic coordinates $l = 305°$ and $b = 0.^{\circ}0$. The observations of series 0320102 (a deep survey of the spiral arm region in Crux) and the publicly accessible scans of the Galactic plane made as part of the Main program of the INTEGRAL observatory in 2003–2004 give a major contribution to the exposure. At the edges of the region under study, a considerable increase in the sensitivity is achieved through the observations of the regions of the Large Magellanic Cloud and SN 1006. The total exposure time of the observations used was $\sim 2 \times 10^6$ s.

We analyzed the data and searched for sources using a technique described by Revnivtsev et al. (2004b) and Molkov et al. (2004). The quality of the images obtained allows us to lower the detection threshold

List of sources detected during a deep survey of the Galactic plane in Crux. The sources are arranged in order of decreasing detection significance

No.	Source	R.A.	Dec.	σ	Flux (17–60 keV), mCrab	Comments
1	GX 301–2	186.65	−62.77	690.48	96.9 ± 0.2	HMXB, P
2	XTE J1550–564	237.75	−56.45	405.01	73.1 ± 0.2	LMXB, BH
3	Cen A	201.36	−43.01	189.12	37.6 ± 0.2	AGN
4	Cen X-3	170.30	−60.62	172.20	26.4 ± 0.2	HMXB, P
5	A1145.1–6141	176.87	−61.95	131.99	19.1 ± 0.2	HMXB, P
6	4U 1538–522	235.58	−52.37	111.37	18.3 ± 0.2	HMXB, P
7	Circinus galaxy	213.28	−65.34	70.14	11.9 ± 0.2	AGN
8	NGC 4945	196.37	−49.46	61.79	12.2 ± 0.2	AGN
9	4U 1516–569	230.17	−57.17	61.02	11.4 ± 0.2	LMXB, B
10	PSR 1509–58	228.47	−59.14	43.67	8.6 ± 0.2	PSR
11	4U 1323–619	201.64	−62.13	37.93	5.4 ± 0.2	LMXB
12	4U 1626–67	248.06	−67.47	27.07	12.5 ± 0.5	LMXB, P
13	NGC 4507	188.90	−39.91	25.45	8.3 ± 0.4	AGN
14	4U 1344–60	206.89	−60.61	23.50	3.6 ± 0.2	AGN
15	IGR J12346–6434	188.71	−64.56	22.34	3.2 ± 0.2	Symb. star (1, 2)
16	4U 1246–588	192.39	−59.08	22.35	3.2 ± 0.2	XB
17	X 1145–619	176.99	−62.20	20.82	3.1 ± 0.2	HMXB, P
18	IGR J11435–6109	175.99	−61.12	18.68	2.7 ± 0.2	HMXB, P (3)
19	IGR J11305–6256	172.77	−62.94	16.26	2.5 ± 0.2	– (4)
20	2S1254–690	194.41	−69.29	12.18	2.3 ± 0.2	LMXB
21	1RXP J130159.6–635806	195.50	−63.96	11.74	1.7 ± 0.2	HMXB, P (5)
22	IGR J12026–5349	180.67	−53.83	11.72	2.1 ± 0.2	AGN:WKK 0560
23	4U 1543–624	236.94	−62.55	11.59	2.7 ± 0.3	LMXB, NS
24	IGR J14579–4308	224.44	−43.14	11.11	1.8 ± 0.2	AGN:IC 4518
25	XTE J1543–568	236.01	−56.75	9.97	1.8 ± 0.2	HMXB, P
26	NGC 6300	259.20	−62.79	9.61	3.1 ± 0.4	AGN
27	ESO 323–G077	196.60	−40.42	7.58	1.7 ± 0.2	AGN
28	XSS J12270–4859	186.99	−48.90	7.60	1.8 ± 0.3	–
29	IGR J13109–5552	197.69	−55.86	7.14	1.1 ± 0.2	–
30	IGR J15360–5750	234.00	−57.84	6.33	1.2 ± 0.2	–
31	IGR J14175–4641	214.30	−46.68	6.11	1.2 ± 0.2	–
32	IGR J16185–5928	244.63	−59.47	5.70	1.2 ± 0.2	AGN:WKK 6471
33	IGR J10109–5746	152.71	−57.78	5.57	1.3 ± 0.3	–
34	IGR J14493–5534	222.29	−55.60	5.56	1.0 ± 0.2	–
35	IGR J10252–6829	156.30	−68.46	5.42	1.6 ± 0.3	–
36	IGR J14552–5133	223.81	−51.55	5.37	1.0 ± 0.2	AGN:WKK 4338
37	1ES 1210–646	183.24	−64.84	5.15	0.8 ± 0.2	–
38	IGR J08023–6954	120.57	−69.91	5.14	1.7 ± 0.4	–
39	IGR J14471–6319	221.78	−63.33	5.09	0.9 ± 0.2	–
40	IGR J15094–6649	227.32	−66.85	5.02	1.1 ± 0.2	–
41*	IGR J11321–5311	173.03	−53.18	10.5	27 ± 2.6	–(6)
42*	IGR J11215–5952	170.42	−59.90	8.42	1.8 ± 0.2	HMXB (7, 8)
43*	HD 101379	174.88	−65.33	7.07	1.6 ± 0.2	RS CVn
44*	PSR B1259–63	195.70	−63.83	6.36	0.9 ± 0.2	HMXB, P
45*	IGR J11085–5100	167.14	−51.01	5.64	1.9 ± 0.4	–
46*	4U 1022–55	159.45	−56.74	5.54	1.3 ± 0.3	HMXB
47*	IGR J12415–5750	190.35	−57.84	5.00	1.0 ± 0.2	AGN:WKK 1263

Note: A 17–60 keV flux of 1 mCrab for a power-law spectrum with a photon index of $\Gamma = 2.1$ corresponds to a flux of 1.4×10^{-11} erg s^{-1} cm^{-2}. The classes of the sources are: HMXB—high-mass X-ray binary; LMXB—low-mass X-ray binary; RS CVn—active binary without a compact object; AGN—active galactic nucleus; P—pulsar; BH—black hole; NS—neutron star; B—burster. The numbers in the last column denote the following data sources: (1) Chernyakova et al. (2005); (2) Masetti et al. (2005); (3) Grebenev et al. (2004); (4) Produit et al. (2004); (5) Chernyakova et al. (2005, in press); (6) Krivonos et al. (2005a); (7) Lubinski et al. (2005); (8) Negueruela et al. (2005).

* These sources yield no significant detection on the averaged sky map, but they are detected at a statistically significant level in some of the series of observations. The fifth column gives the maximum recorded significance of the flux from the source.

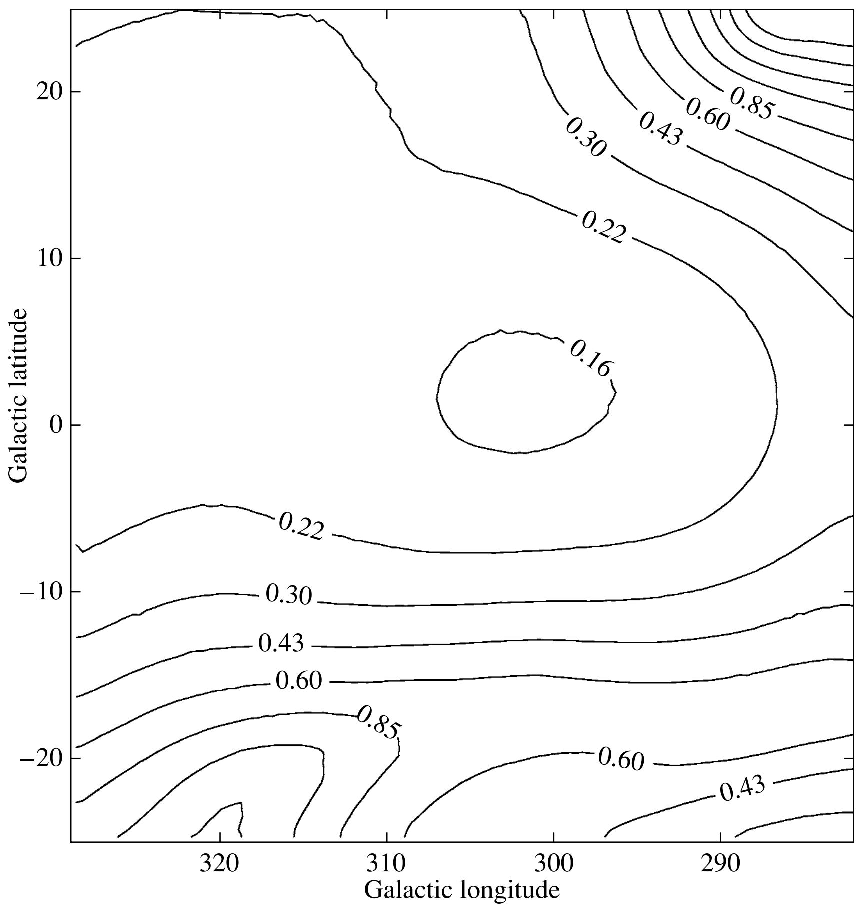

Fig. 1. Map of the sensitivity achieved in the observations used. The numbers on contours are 1σ uncertainties in the flux measurement inside the contour in mCrabs.

(the level of statistical significance at which the expected value of the number of false sources in the field under study is of the order of unity) in searching for new sources to $\sim 5\sigma$. The sensitivity map of the observations used is shown in Fig. 1.

RESULTS

A total of 47 sources were detected in the field under study (the field map is shown in Fig. 2) at a statistically significant level. Forty-one of them have statistically significant fluxes in the image averaged over the entire observing time. A number of objects (in our case, seven) appear with a flux above the detection threshold only temporarily. The sources are listed in the table. The location accuracy of the sources deteriorates with decreasing statistical significance of their detection: for the faintest sources, it is $\sim 6'$ (the radius of the 90% confidence contour).

To determine the nature of the source IGR J12026−5349, we used observational data from the CHANDRA observatory (see Sazonov et al. 2005). The accurate localization of the detected bright source ($0''.5$) allowed us to confidently associate it with the active nucleus in the galaxy WKK 0560.

In general, the search for correlations of the detected sources with existing catalogs of X-ray sources (e.g., with the catalogs of Galactic binary systems (Liu et al. 2000, 2001), the catalog of bright sources from the ROSAT all-sky survey (Voges et al. 1999), and the RXTE catalog (Revnivtsev et al. 2004a) as well as the catalog of galaxies allowed us to confidently identify 33 of the 47 sources. Twelve of them are active galactic nuclei, eleven sources are Galactic binary systems with high-mass optical companions, six are binaries with low-mass companions, one object is an RS CVn X-ray binary, and one is presumably a symbiotic star (RT Cru); twelve objects have remained unidentified. The survey revealed 15 new X-ray sources.

ACKNOWLEDGMENTS

This work was supported by the Ministry of Industry and Science (grant NSh-2083.2003.2 from the

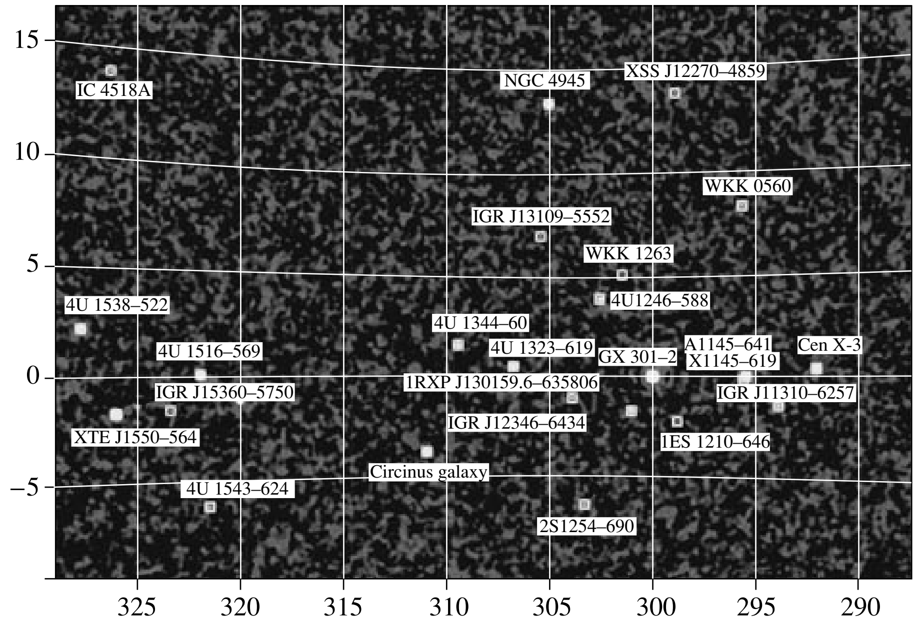

Fig. 2. Map of the Galactic plane region in Crux in the energy range 17–60 keV accumulated over the entire observing time. Only the brightest sources are labeled.

president of Russia), the "Nonstationary Phenomena in Astronomy" program of the Russian Academy of Sciences, and the Russian Foundation for Basic Research (project no. 04-02-17276). We are grateful to the International Data Center of the INTEGRAL observatory (Versois, Switzerland) and the Russian Data Center of the INTEGRAL observatory (Moscow, Russia). The results of this work are based on the observations of the INTEGRAL observatory, an ESA project with the participation of Denmark, France, Germany, Italy, Switzerland, Spain, the Czech Republic, Poland, Russia, and the United States.

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Translated by G. Rudnitskiĭ