ISSN 1063-7737, Astronomy Letters, 2010, Vol. 36, No. 8, pp. 533–539. © Pleiades Publishing, Inc., 2010.
Original Russian Text © S.A. Grebenev, R.A. Sunyaev, 2010, published in Pis'ma v Astronomicheskiĭ Zhurnal, 2010, Vol. 36, No. 8, pp. 563–569.

New Fast X-ray Transient IGR J18462−0223 Discovered by the INTEGRAL Observatory

S. A. Grebenev[1*] and R. A. Sunyaev[1,2]

[1]*Space Research Institute, Russian Academy of Sciences, Profsoyuznaya ul. 84/32, Moscow 117997, Russia*
[2]*Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, Postfach 1317, D-85741 Garching, Germany*
Received March 16, 2010

Abstract—Details of the discovery of a new X-ray source, IGR J18462−0223, on October 12, 2007, during a short (several hours), intense (∼35 mCrab at the peak) outburst of hard radiation by the IBIS/ISGRI gamma-ray telescope onboard the INTEGRAL observatory are given. The detection of another earlier outburst from this source occurred on April 28, 2006, in the archival data of the telescope is reported. We present the results of the source's localization and our spectral/timing analysis of the observational data. The source may turn out to be yet another representative of the continuously growing population of fast X-ray transients, which are the focus of attention because of the identification of their optical counterparts with early-type supergiants.

DOI: 10.1134/S1063773710080013

Key words: *X-ray sources, fast transients, X-ray pulsars, accretion from stellar wind.*

INTRODUCTION

In October–November 2007, the INTEGRAL international orbital gamma-ray observatory was measuring the spectral shape and distribution profile of the Galactic ridge hard X-ray emission in the Scutum Arm tangent. During the observation on October 12, the IBIS/ISGRI gamma-ray telescope detected a hitherto unknown X-ray source named IGR J18462−0223 (Grebenev et al. 2007). The emission from the source was detected with confidence for at least 5 h (out of the 8 h during which it was in the telescope's field of view). The source was detected neither before (27 h earlier) nor after (12 h later) this observation.

The communication by Grebenev et al. (2007) contained only brief information about the discovery of IGR J18462−0223. Here, we present the results of a more detailed spectral/timing analysis of the INTEGRAL data obtained during this outburst of the source and report the detection of another earlier (occurred on April 28, 2006) X-ray outburst from it.

The source is interesting in that it could be a new representative of the continuously growing population of fast X-ray transients, which are the focus of attention because of the identification of their optical counterparts with early-type supergiants (Smith 2004; Negueruela et al. 2006b). The fast transients are characterized by short (less than one day) intense (with a peak luminosity of $\sim 10^{36}$–10^{37} erg s^{-1}) outbursts separated by long (tens and hundreds of days) periods of quiescence, during which their luminosity falls by three or four orders of magnitude. The population already numbers at least eleven sources: IGR J08408−4503 (Götz et al. 2007), IGR J11215−5952 (Lubinski et al. 2005; Negueruela et al. 2005; Sidoli et al. 2007), IGR J16465−4507 (Lutovinov et al. 2004, 2005; Zurita Heras and Walter 2004; Smith 2004), IGR J16479−4514 (Molkov et al. 2003; Sguera et al. 2006; Chaty et al. 2008), XTE J1739−302 (Smith et al. 1998, 2006; Negueruela et al. 2006a), AX J1749.1−2733 (Sacano et al. 2002; Grebenev and Sunyaev 2007; Karasev et al. 2009), IGR J17544−2619 (Sunyaev et al. 2003; Grebenev et al. 2004; in't Zand 2005; Pellizza et al. 2006), SAX J1818.6−1703 (in't Zand et al. 1998; Grebenev and Sunyaev 2005; Sguera et al. 2006; Negueruela and Smith, 2006), AX J1841.0−0536 (Bamba et al. 2001; Sguera et al. 2006; Negueruela et al. 2006b), AX J1845.0−0433 (Yamauchi et al. 1995; Sguera et al. 2007), and IGR J18483−0311 (Chernyakova et al. 2003; Molkov et al. 2004; Rahoui and Chaty 2008). It is beyond doubt that the compact object in these sources is a neutron star with a strong magnetic field (pulsar) accreting matter from a supergiant's dense stellar

*E-mail: sergei@hea.iki.rssi.ru

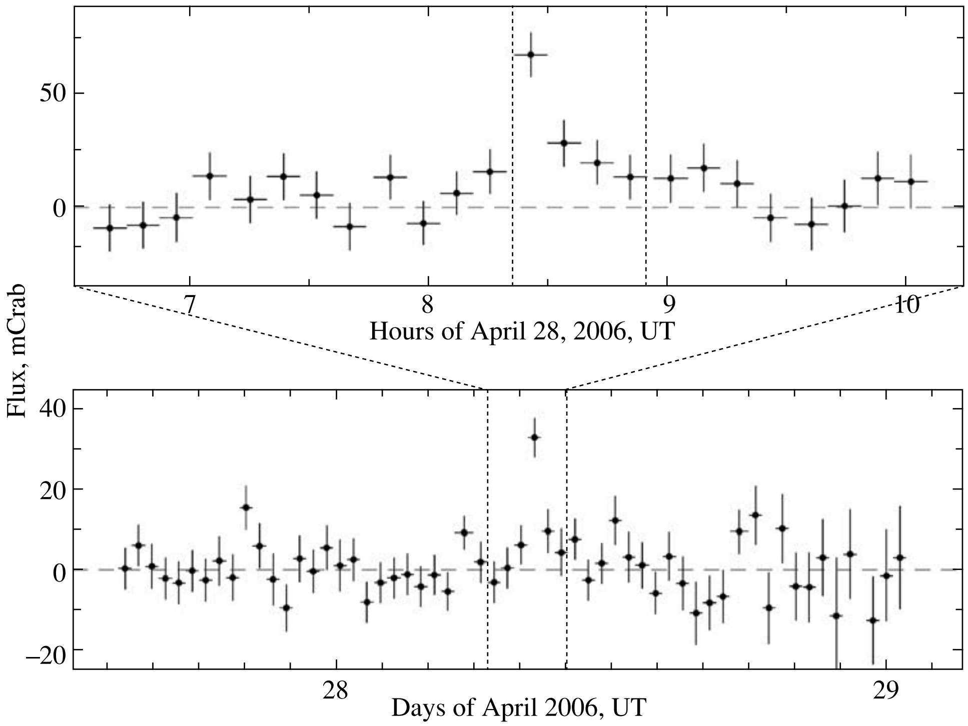

Fig. 1. Light curve of IGR J18462−0223 in the 20−60 keV energy band obtained by IBIS/ISGRI on April 27−28, 2006 (at the bottom). Each point of this curve corresponds to a separate INTEGRAL pointing ∼2000 s in duration. The segment of the curve near the source's outburst (in the interval marked by the vertical dotted lines) is shown at the top with a 500-s resolution. The dotted lines in the upper panel indicate the interval used to measure the outburst spectrum.

wind. X-ray pulsations have already been detected from five sources of the group. The remaining sources may be considered pulsars, because their radiation spectra are similar. The only question is why the accretion is episodic and so short in duration.

However, irrespective of the answer to this question, the discovery of fast transients itself provided a wealth of information about the variety of observational manifestations of high-mass X-ray binaries with supergiants. This discovery also advances noticeably our understanding of the problem of observing a very limited number of (quasi)persistent sources of this type compared to theoretical expectations (Illarionov and Sunyaev 1975; Grebenev and Sunyaev 2007).

OBSERVATIONS

The INTEGRAL observatory (Winkler et al. 2003) was placed in a high-apogee orbit by a PROTON launcher on October 17, 2002 (Eismont et al. 2003). It is equipped with four telescopes capable of carrying out simultaneous gamma-ray, X-ray, and optical observations. This work is based on data from the ISGRI detector (Lebrun et al. 2003) of the IBIS gamma-ray telescope (Ubertini et al. 2003).[1] This telescope, which uses the principle of a coded aperture, allows one to image the sky in a $30° \times 30°$ field of view (the fully coded zone is $9° \times 9°$) with an angular resolution of $12'$ (FWHM) and to investigate the properties of the detected point sources. ISGRI is a position-sensitive detector that consists of 128×128 CdTe semiconductor elements efficiently operating in the energy range 18−200 keV. The total area of the elements reaches 2620 cm^2; the effective area for sources at the center of the field of view is ~ 1100 cm^2 (one half of the detector is shadowed by the opaque aperture elements). The detector provides an energy resolution $\Delta E/E \sim 7\%$ (FWHM).

The observations of the Scutum Arm tangent in mid-October 2007, during which IGR J18462−0223 was discovered, were carried out in the accordance with the proposal of R.A. Sunyaev. The observatory was successively pointed at points with a fixed Galactic longitude $l \simeq 24°$ ($l \simeq 22°$ at the next passage) and a latitude changing from $b = 30°$ to $-30°$ at 2°

[1] The JEM-X monitor onboard INTEGRAL could give data in a softer X-ray band than that of ISGRI, but IGR J18462-0223 was far from the center of its field of view (narrower than the IBIS one) and was observed with a low sensibility.

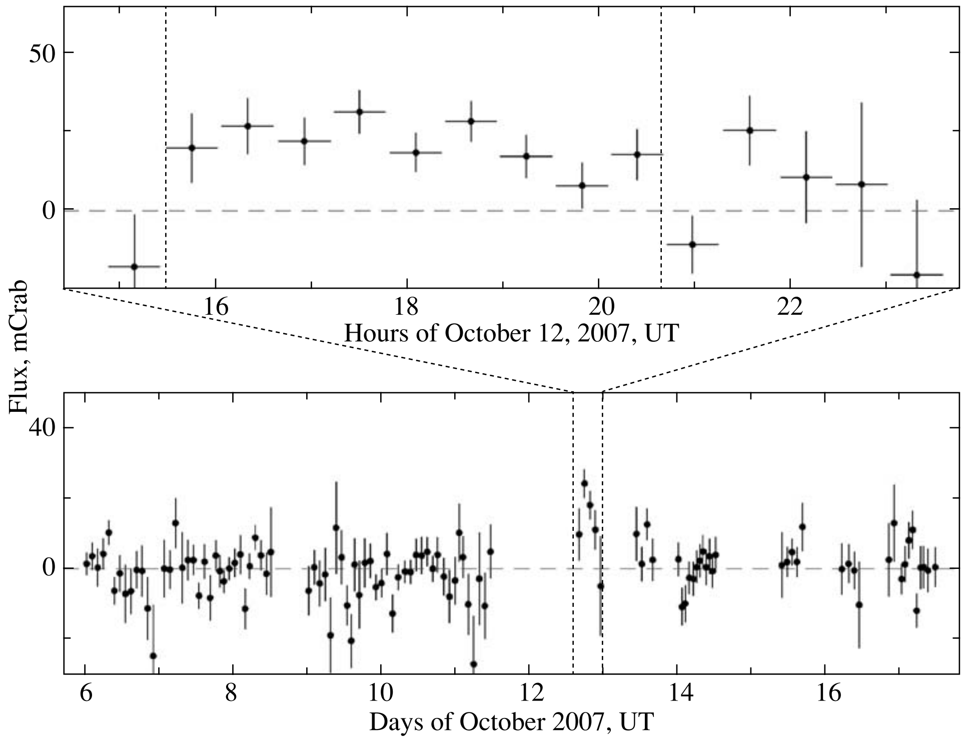

Fig. 2. The same light curve as that in Fig. 1 but obtained in the period October 6–17, 2007, with a resolution of ∼6000 s (at the bottom). The profile of the outburst recorded in this period from IGR J18462–0223 is shown at the top with a resolution of ∼2000 s corresponding to the duration of separate INTEGRAL pointings. The dotted lines in the upper panel indicate the interval used to measure the outburst spectrum.

steps. Another outburst of the source, which was revealed already after its discovery when the archival data were analyzed, was recorded in late April 2006. At this time, INTEGRAL was scanning the Galactic plane within the framework of the Core observational program (Winkler et al. 2003). The observatory was pointed at points in the band $b = \pm 4^\circ$ at 2° steps. Depending on the pointing, the exposure efficiency for IGR J18462–0223 (its Galactic coordinates are $l \simeq 30\overset{\circ}{.}2$ and $b = 0\overset{\circ}{.}06$) changed. The duration of each pointing was $\sim$ 2000 s in both cases.

The observational data were analyzed using the software developed for the IBIS/ISGRI telescope at the Space Research Institute, the Russian Academy of Sciences. Its general description can be found in Revnivtsev et al. (2004). In our spectral analysis, we used the response matrix of the standard OSA package, which proved to be efficient in fitting the spectra of the Crab Nebula. The spectrum of the Nebula was assumed to be $dN(E)/dE = 10E^{-2.1}$ phot cm^{-2} s^{-1} keV^{-1}, where the energy E is given in keV.

RESULTS

The lower panels in Figs. 1 and 2 show the light curves of IGR J18462–0223 obtained by the IBIS/ISGRI telescope in the 20–60 keV energy band on April 27–28, 2006, and October 6–17, 2007, respectively. In these time intervals, the outbursts of its hard radiation were recorded.[2] The outburst profiles with an improved time resolution are presented in the upper panels of the figures. Whereas the first outburst has a total duration of ∼1 h, being characterized by an intense (∼65 mCrab) narrow ($\lesssim$20 min) initial emission peak, the second outburst has a duration of ∼5 h at an almost flat profile corresponding to a flux of ∼35 mCrab with evidence of a beginning decline by the end of the observations. The detection confidence (S/N ratio) is ≃7.3 and 9.5, respectively, for the first and second outbursts. The time intervals indicated by the dotted lines in the upper panels of the figures were used for its determination.

Figure 3 presents the X-ray image (S/N map) of the region near IGR J18462–0223 obtained by

[2]Note that the ASM monitor of the RXTE observatory did not see the source at the time of the outbursts.

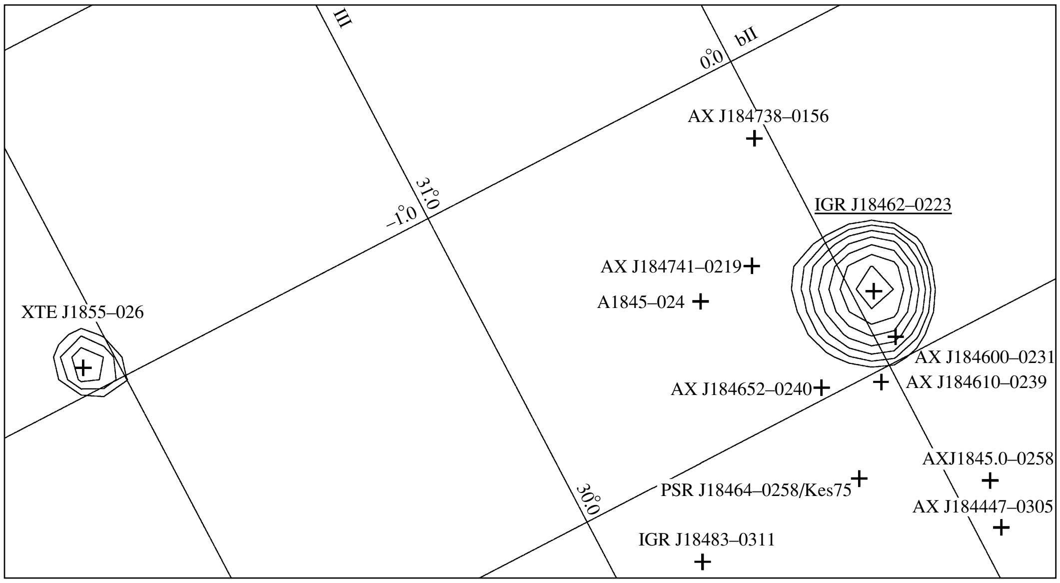

Fig. 3. Image of the region near the X-ray transient IGR J18462−0223 obtained by the IBIS/ISGRI telescope from the sum of observations of the 2006 and 2007 X-ray outbursts. The contours indicate the regions of confident detection of the sources in the energy range 20–60 keV and are given at S/N ratios of 3.5, 4.2, 5.0, 6.0, 7.2, 8.7, 10.4, 12.5, . . . (on a logarithmic scale). The image size is approximately $1^\circ\!.5 \times 3^\circ$.

the IBIS/ISGRI telescope in the 20–60 keV energy band from the sum of observations of the two outbursts. The source was detected at a level of S/N = 11.7. Its position on the map, R.A. = $18^h46^m16^s\!.6$ and Decl. = $-02^\circ23'35''$ (epoch 2000.0, $1'\!.5$ uncertainty), slightly (by $24''$) differs from the position based on the data for only one (second) outburst (Grebenev et al. 2007). We see from Fig. 3 that the source lies in a densely populated region. This is natural, because it is close to the Galactic plane and because the X-ray sources from the Galactic arm (the bases of the Scutum–Centaurus arm) are projected onto this region. It is quite likely that IGR J18462−0223 itself is located in this arm; the distance to it is then $d \simeq 6$ kpc. Most of these sources were detected during the ASCA survey of the Galactic plane (Sugizaki et al. 2001), although the fast X-ray transient IGR J18483−0311 discovered previously by the INTEGRAL observatory (Chernyakova et al. 2003; Molkov et al. 2004), the unique schizophrenic pulsar PSR J18464−0258 in the supernova remnant Kes 75 (Kuper and Hersmen 2009), and the transient pulsar A 1845−024/GS 1843−02 (Finger et al. 1999) are also seen here. None of the sources in the vicinity of IGR J18462−0223 indicated in Fig. 3 was detected in the image accumulation time. The closest detected source, the well-known 361-s X-ray pulsar XTE J1855−026, is at a distance of $\sim 2^\circ$ from IGR J18462−0223. It should be specially noted that AX J184600−0231 closest to IGR J18462−0223 is $9'$ away from it, which exceeds noticeably the uncertainty in localizing this new transient.

Figure 4 shows the spectrum of IGR J18462−0223 obtained from the sum of observations of the 2006 and 2007 outbursts and the spectra of each individual outburst. These were measured during the time intervals highlighted in Figs. 1 and 2 by the vertical dotted lines. The corresponding mean luminosities during the outbursts calculated for an assumed distance of 6 kpc are listed in the table. We see that the source's emission is recorded at least up to ~ 80 keV; a gradual drop is observed at energies above 60 keV. The spectra of the two outbursts are similar; the first is harder than the second but mainly through the energy range $\gtrsim$60 keV, where the points of the spectrum are statistically not very significant. Fitting the average spectrum of the outbursts by the law of bremsstrahlung from an optically thin thermal plasma (see the table, the TB model) yields a temperature $kT \sim 40$ keV. Spectra of such shape and hardness are typical of X-ray pulsars in high-mass X-ray binaries and, in particular, fast X-ray transients. To illustrate this assertion, we provided the spectrum of the well-known fast X-ray transient IGR J16479−4514 (Grebenev 2009), which is actually very similar to that of IGR J18462−0223 with the same temperature $kT \simeq 38 \pm 6$ keV, in the upper panel of Fig. 4.

Note that the average spectrum of the outbursts can be fitted by a power law (PL in the table) with

Results of fitting the X-ray spectrum of IGR J18462−0223 during the outbursts recorded by the INTEGRAL observatory

Date	Model[a]	kT, keV	α[b]	L_X^c, $\times 10^{36}$, erg s^{-1}	$\chi^2(N)$[d]
Apr. 28, 2006	PL		2.08 ± 0.37	2.65 ± 0.38	1.18 (23)
	TB	81 ± 28		2.75 ± 0.40	1.22 (23)
Oct. 12, 2007	PL		2.66 ± 0.35	1.40 ± 0.15	1.39 (23)
	TB	32 ± 4		1.37 ± 0.15	1.47 (23)
2006 + 2007	PL		2.48 ± 0.28	1.61 ± 0.15	1.28 (23)
	TB	39 ± 5		1.60 ± 0.14	1.39 (23)
	TB + CA	30 ± 7		1.61 ± 0.14	1.07 (21)

[a] PL—power law, TB—thermal bremsstrahlung, CA—cyclotron absorption (one harmonic);
[b] photon index;
[c] 20−100 keV luminosity for an assumed distance of $d = 6$ kpc;
[d] χ^2 value of the best fit normalized to N (N is the number of degrees of freedom).

a photon index $\alpha \simeq 2.5 \pm 0.3$ as successfully as by a thermal bremsstrahlung law. In general, however, a good fit (with normalized to the degree of freedom $\chi^2 \simeq 1$) cannot be achieved with such simple models, because there is a feature in absorption near ∼30 keV or, possibly, an additional soft emission component at energies $\lesssim$25 keV in all spectra. This feature can result from the resonance cyclotron absorption of emission in a neutron star's strong magnetic field (see, e.g., Tsygankov et al. 2007). Adding a cyclotron harmonic in the form of a factor,

$$\exp\left[-\tau_c\left(\frac{E}{E_c}\right)^2\frac{\Delta E_c^2}{(E-E_c)^2+\Delta E_c^2}\right]$$

to the bremsstrahlung model actually improves noticeably the fit (see the table), although this line cannot be said to be present with certainty due to the overall low statistical significance of the spectrum points (according to the $\Delta\chi$-statistics the probability of the line appearance by chance is 8×10^{-3}). The width of the cyclotron line was recorded at its best value of $\Delta E_c = 8$ keV, with its optical depth and energy being $\tau_c = 1.4 \pm 0.4$ and $E_c \simeq 26 \pm 2$ keV, respectively. The value of E_c obtained allows the neutron star's magnetic field in the region of main energy release to be estimated, $B = (1+z)\,E_c/(11.6\text{ keV}) \times 10^{12}\text{ G} \simeq 2.2 \times 10^{12}(1+z)$ G, where z is the redshift in the neutron star's gravitational field.

CONCLUSIONS

The short (several hours), intense X-ray outbursts of IGR J18462−0223, their hard spectrum similar to the spectrum of bremsstrahlung from an optically thin plasma with $kT \sim 30$−40 keV, the long (years) intervals between the outbursts, and, finally, the source' location in the Galactic plane and, possibly, in a Galactic arm, where intensive star formation takes place, all allow us to consider IGR J18462−0223 as a new candidate for fast X-ray transients with a massive companion or even a supergiant. Its more accurate localization (in soft X-rays) and optical identification are needed. Hard X-ray observations of new outbursts from IGR J18462−0223 will allow the question about the presence of a cyclotron absorption line in its spectrum to be solved. The number of pulsars whose radiation spectra exhibit such lines is still small, while the importance of such observations, which allow direct measurements of a neutron star's magnetic field to be made, is great.

Note that the outbursts of IGR J18462−0223 are shorter than those for most other fast transients. What is this—a characteristic feature of this source or an observational effect related to its fairly large distance ($d \sim 6$ kpc) and its location at the edge of the telescope's field of view during the outbursts, in the region where the effective area of the telescope decreases? The measured flux from IGR J18462−0223 during the outbursts was comparable to that from such fast transients as IGR J16465−4507, IGR J16479−4514, and several others, while its

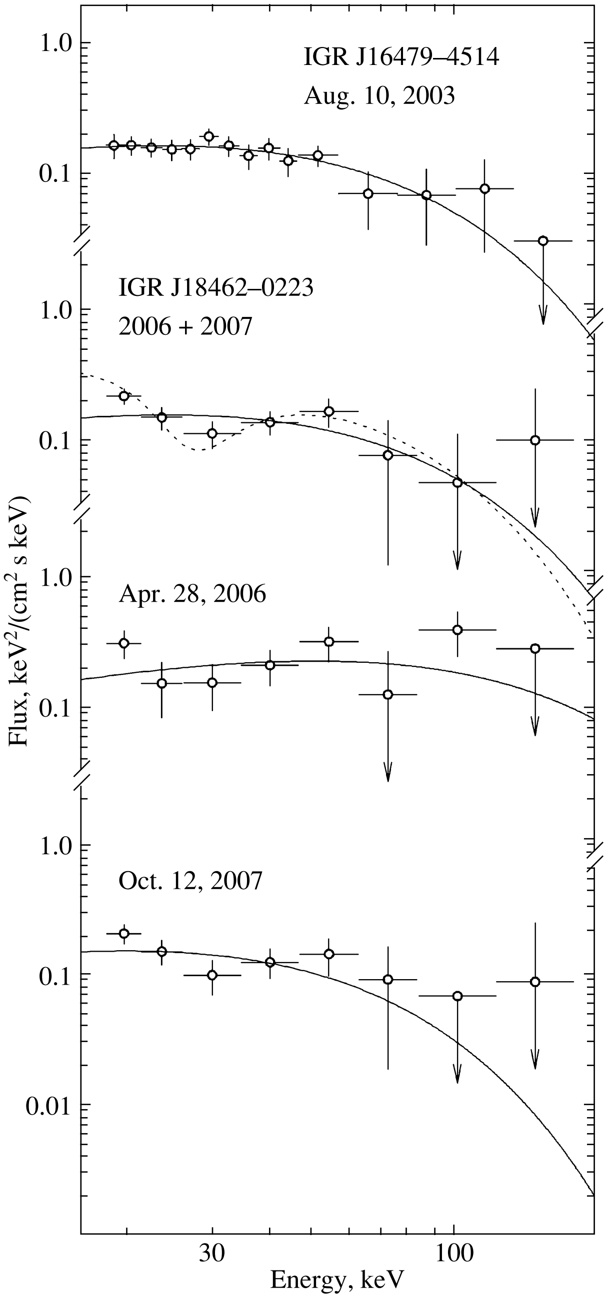

Fig. 4. Average X-ray spectrum of IGR J18462−0223 obtained by the IBIS/ISGRI telescope from the sum of observations of the 2006 and 2007 outbursts and spectra of each individual outburst. The spectra are hard, with the characteristic temperature being $kT \simeq 30-80$ keV (solid line) when fitted by the law of bremsstrahlung from optically thin plasma. The dotted line indicates the result of including the cyclotron absorption line in the fit (see the text). For comparison, the spectrum of the well-known fast X-ray transient IGR J16479-4514 is shown at the top.

detection confidence was lower. Since the profiles of outbursts from many fast transients contain several individual intense bursts standing out above the average level (see the selection of light curves for fast transients in Grebenev 2009), the possibility of observational (selective) effects due to which we see only the tops of such bursts in the case of IGR J18462−0223 seems quite real. Therefore, the following question is natural: How many unknown fast transients similar to IGR J18462−0223 still wait for their "lucky" (direct and timely) hard X-ray telescope pointing to be detected?

ACKNOWLEDGMENTS

This work is based on the observational data from the INTEGRAL observatory[3] retrieved via the Russian and European INTEGRAL Science Data centers. We used some of the programs developed by E.M. Churazov to analyze the data. We are grateful to R.A. Krivonos for access to the results of the all-sky survey conducted by him based on INTEGRAL data. The study was supported by the Russian Foundation for Basic Research (project no. 10-02-01466), the Program of the Russian President for Support of Leading Scientific Schools (grant no. NSh.-5069.2010.2), and the "Origin and Evolution of Stars and Galaxies" Program of the Presidium of the Russian Academy of Sciences.

REFERENCES

1. A. Bamba, J. Yokogawa, M. Ueno, et al., Publ. Astron. Soc. Jpn. **53**, 1179 (2001).
2. S. Chaty, F. Rahoui, C. Foellmi, et al., Astron. Astrophys. **484**, 783 (2008).
3. M. Chernyakova, A. Lutovinov, F. Capitanio, et al., Astron. Telegram 157 (2003).
4. N. A. Eismont, A. V. Ditrikh, G. Janin, et al., Astron. Astrophys. **411**, L37 (2003).
5. M. H. Finger, L. Bildsten, D. Chakrabarty, et al., Astrophys. J. **517**, 449 (1999).
6. D. Götz, M. Falanga, F. Senziani, et al., Astrophys. J. **655**, L101 (2007).
7. S. A. Grebenev, in *Proc. of the Workshop on The Extreme sky: Sampling the Universe above 10 keV, Otranto/Lecce, Italy, Oct. 13–17, 2009,* Ed. by P. Ubertini, PoS **96**, 60 (2009).
8. S. A. Grebenev and R. A. Sunyaev, Pis'ma Astron. Zh. **31**, 754 (2005) [Astron. Lett. **31**, 672 (2005)].
9. S. A. Grebenev and R. A. Sunyaev, Pis'ma Astron. Zh. **33**, 175 (2007) [Astron. Lett. **33**, 149 (2007)].
10. S. A. Grebenev, J. Rodriguez, and N. J. Westergaard, Astron. Telegram 252 (2004).
11. S. A. Grebenev, M. G. Revnivtsev, and R. A. Sunyaev, Astron. Telegram 1319 (2007).

[3]An ESA satellite with scientific instruments provided by France, Italy, Germany, Switzerland, Denmark, Spain, Czech Republic, and Poland, launched into orbit by Russia, and operated by ESA with participation of the USA.

12. A. F. Illarionov and R. A. Sunyaev, Astron. Astrophys. **39**, 185 (1975).
13. D. Karasev, A. Lutovinov, S. Tsygankov, and R. Burenin, in *Proc. of the Workshop on The Extreme sky: Sampling the Universe above 10 keV, Otranto/Lecce, Italy, Oct. 13–17, 2009,* Ed. by P. Ubertini, PoS **96**, 103 (2009).
14. L. Kuiper and W. Hermsen, Astron. Astrophys. **501**, 1031 (2009).
15. F. Lebrun, J. P. Leray, P. Lavocat, et al., Astron. Astrophys. **411**, L141 (2003).
16. P. Lubinski, M. Cadolle Bel, A. von Kienlin, et al., Astron. Telegram 469 (2005).
17. A. Lutovinov, J. Rodrigues, C. Budtz-Jorgensen, et al., Astron. Telegram 329 (2004).
18. A. Lutovinov, M. Revnivtsev, M. Gilfanov, et al., Astron. Astrophys. **444**, 821 (2005).
19. S. Molkov, N. Mowlavi, A. Goldwurm, et al., Astron. Telegram 176 (2003).
20. S. V. Molkov, A. M. Cherepashchuk, A. A. Lutovinov, et al., Pis'ma Astron. Zh. **30**, 589 (2004) [Astron. Lett. **30**, 534 (2004)].
21. I. Negueruela and D. M. Smith, Astron. Telegram 831 (2006).
22. I. Negueruela, D. M. Smith, and S. Chaty, Astron. Telegram 470 (2005).
23. I. Negueruela, D. M. Smith, T. E. Harrison, and J. M. Torrejón, Astrophys. J. **638**, 982 (2006a).
24. I. Negueruela, D. M. Smith, P. Reig, et al., in *Proc. of the 5th INTEGRAL Workshop on The X-ray Universe, El Escorial, Spain, 26–30 Sept. 2005,* Ed. by A. Wilson, ESA **SP-604**, 165 (2006b).
25. L. J. Pellizza, S. Chaty, and I. Negueruela, Astron. Astrophys. **455**, 653 (2006).
26. F. Rahoui and S. Chaty, Astron. Astrophys. **492**, 163 (2008).
27. M. G. Revnivtsev, R. A. Sunyaev, D. A. Varshalovich, et al., Pis'ma Astron. Zh. **30**, 430 (2004) [Astron. Lett. **30**, 382 (2004)].
28. M. Sakano, K. Koyama, H. Murakami, et al., Astrophys. J. Suppl. Ser. **138**, 19 (2002).
29. V. Sguera, A. Bazzano, A. J. Bird, et al., Astrophys. J. **646**, 452 (2006).
30. V. Sguera, A. J. Bird, A. J. Dean, et al., Astron. Astrophys. **462**, 695 (2007).
31. L. Sidoli, P. Romano, S. Mereghetti, et al., Astron. Astrophys. **476**, 1307 (2007).
32. D. M. Smith, Astron. Telegram 338 (2004).
33. D. M. Smith, D. Main, F. Marshall, et al., Astrophys. J. **501**, L181 (1998).
34. D. M. Smith, W. A. Heindl, C. B. Markwardt, et al., Astrophys. J. **638**, 974 (2006).
35. M. Sugizaki, K. Mitsuda, H. Kaneda, et al., Astrophys. J. Suppl. Ser. **134**, 77 (2001).
36. R. A. Sunyaev, S. A. Grebenev, A. A. Lutovinov, et al., Astron. Telegram 190 (2003).
37. S. S. Tsygankov, A. A. Lutovinov, E. M. Churazov, and R. A. Sunyaev, Pis'ma Astron. Zh. **33**, 417 (2007) [Astron. Lett. **33**, 368 (2007)].
38. P. Ubertini, F. Lebrun, G. Di Cocco, et al., Astron. Astrophys. **411**, L131 (2003).
39. S. Yamauchi, T. Aoki, K. Hayashida, et al., Publ. Astron. Soc. Jpn. **47**, 189 (1995).
40. C. Winkler, T. J.-L. Courvoisier, G. Di Cocco, et al., Astron. Astrophys. **411**, L1 (2003).
41. J. J. M. in't Zand, Astron. Astrophys. **441**, L1 (2005).
42. J. In't Zand, J. Heise, M. Smith, et al., IAU Circ. **6840** (1998).
43. J. A. Zurita Heras and R. Walter, Astron. Telegram 336 (2004).

Translated by Shtaerman