A&A 448, L49–L52 (2006)
DOI: 10.1051/0004-6361:200500233

Astronomy & Astrophysics

Identification of four RXTE Slew Survey sources with nearby luminous active galactic nuclei

M. Revnivtsev[1,2], S. Sazonov[1,2], E. Churazov[1,2], and S. Trudolyubov[3,2]

[1] Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, 85740 Garching bei München, Germany
e-mail: mikej@mpa-garching.mpg.de
[2] Space Research Institute, Russian Academy of Sciences, Profsoyuznaya 84/32, 117997 Moscow, Russia
[3] Institute for Geophysics and Planetary Physics, University of California, Riverside, CA 92521, USA

Received 15 November 2005 / Accepted 23 December 2005

ABSTRACT

Based on RXTE scans and observations with the SWIFT/XRT telescope and INTEGRAL observatory, we report the identification of four X-ray sources discovered during the RXTE Slew Survey of the $|b| > 10°$ sky with nearby ($z \sim 0.017-0.098$) luminous ($L_{2-10\ \rm keV} \sim 5 \times 10^{42}-10^{44}$ erg s^{-1}) active galactic nuclei. Two of the objects exhibit heavily intrinsically absorbed X-ray spectra ($N_{\rm H} \sim 10^{23}$ cm^{-2}).

Key words. surveys – galaxies: Seyfert – X-rays: general

1. Introduction

Shallow large-area X-ray surveys are essential for studying the local population of active galactic nuclei (AGN) and complement deep small-area X-ray surveys, which probe AGN at high redshift. Recently, significant progress has been made in scanning the extragalactic sky at photon energies above 2 keV, where circumnuclear obscuration does not affect the detectability of nearby AGN as severely as in the soft X-ray regime. In particular, a serendipitous survey of the high Galactic latitude ($|b| > 10°$) sky in the 3–20 keV band was performed with the PCA instrument of the RXTE observatory – the RXTE Slew Survey (XSS, Revnivtsev et al. 2004), in which a total of ~300 sources with fluxes down to ~0.5−1 mCrab were detected, including ~100 identified AGN. This survey is now being nicely complemented in the standard X-ray band by the XMM-Newton Slew Survey (e.g. Saxton et al. 2005), which will cover a significant fraction of the sky with higher sensitivity and much better source localization accuracy than the XSS, and in hard X-rays (above 15 keV) by all-sky surveys performed with INTEGRAL (e.g. Beckmann et al. 2005; Sazonov et al. 2005) and SWIFT (Markwardt et al. 2005), which are somewhat more sensitive to strongly obscured ($N_{\rm H} \gtrsim 10^{23}$ cm^{-2}) AGN compared to the XSS.

About 30 XSS sources remain unidentified (most of them located in the southern hemisphere), and this presents some uncertainty for statistical studies based on the XSS AGN sample (Sazonov & Revnivtsev 2004; Heckman et al. 2005). The main reason for the missing identifications is the poor localization of XSS sources. The positions of weak XSS sources are known only to ~1° accuracy, which practically precludes their identification through observations with X-ray and optical telescopes.

A number of steps have therefore been undertaken to improve the completeness of identification of the XSS source catalog. First, several unidentified XSS sources were recently detected in hard X-rays with INTEGRAL, resulting in sufficiently accurate positions (~5′) for initiating observations of these sources with Chandra. This led to the identification of two sources (XSS J12389−1614 and XSS J19459+4508) with nearby galaxies, implying that they are AGN (Sazonov et al. 2005). Secondly, we obtained RXTE/PCA scans over the positions of a set of XSS sources, which allowed us to improve these positions to 6–20′. Some of these sources together with a few other XSS sources for which there is a likely soft X-ray counterpart from the ROSAT all-sky survey (RASS, Voges et al. 1999) were recently observed by the X-Ray Telescope (XRT) aboard SWIFT, providing accurate localizations and X-ray spectral information. Finally, XSS sources with relatively well known positions as well as INTEGRAL detected sources make up the input sample for an ongoing program of optical identification of northern objects on the Russian-Turkish 1.5-m Telescope (Bikmaev et al. 2006).

The continuation of all these efforts should soon lead to a highly complete identification of the XSS catalog. Here we report the association of 4 previously unidentified XSS sources with nearby luminous AGN, based on RXTE, SWIFT and INTEGRAL observations.

Table 1. Identification of XSS sources.

RXTE Name	RXTE α, δ (2000)	Err	Identification	AGN Class[a]	Position[b] α, δ (2000)	Redshift
XSS J05054−2348	76.414 −23.906	6′	2MASX J05054575−2351139	Sy2	05 05 45.7 −23 51 14	0.0350[c]
XSS J12303−4232	187.567 −42.541	60′	1RXS J123212.3−421745			
			IRAS F12295−4201?			
			USNO-B1.0 0477-0336688		12 32 12.0 −42 17 51	0.098[d]
XSS J16151−0943	243.796 −09.724	60′	1RXS J161519.2−093618			
			6dF J1615191−093613	Sy1	16 15 19.1 −09 36 13	0.0650[c]
XSS J18236−5616	275.703 −56.348	20′	IGR J18244−5622			
			IC 4709		18 24 19.4 −56 22 09	0.0169

[a] From Bikmaev et al. (2006). [b] The quoted optical positions are consistent with those measured by SWIFT/XRT or INTEGRAL/IBIS. [c] The quoted NED values are confirmed by Bikmaev et al. (2006). [d] Inferred from the X-ray spectrum.

2. Observations

Dedicated RXTE/PCA scans performed on June 23, 2004 and March 28, 2005 allowed us to significantly improve the positions of two sources, XSS J05054−2348 and XSS J18236−5616. In two other cases, XSS J12303−4232 and XSS J16151−0943, a likely bright (~0.6 and ~0.4 cnt s^{-1}, respectively) soft X-ray counterpart from the RASS was previously proposed based on the original XSS localization (Sazonov & Revnivtsev 2004), with the positions of the RASS sources known to ~10″ accuracy. During the period August–October 2005 three of the aformentioned sources (XSS J05054−2348, XSS J12303−4232 and XSS J16151−0943) were observed with the SWIFT/XRT telescope for exposure times ranging from 3 to 26 ks.

We analyzed the SWIFT/XRT observations using standard tasks of HEADAS 6.0.1 package following SWIFT Guest Observer Facility recommendations (`http://legacy.gsfc.nasa.gov/docs/swift/analysis/`) and found a single bright X-ray (0.5−10 keV) source in the ~20′ × 20′ XRT image for each XSS source. For XSS J12303−4232 and XSS J16151−0943 the XRT detected source coincides with the proposed RASS counterpart. If more than one X-ray source was present in the XRT field of view, the positions of weaker X-ray sources were correlated with the optical and infrared images of the region to calculate astrometric corrections to the XRT image. By applying this correction we were then able to improve the positions of the bright X-ray sources to ~1−2″ (without astrometric correction the localization accuracy is ~5″). Cross-correlation of the XRT images with optical sky surveys (see Table 1 and Fig. 1) revealed that XSS J05054−2348 and XSS J16151−0943 are each associated with a known galaxy. Optical spectroscopy further demonstrated (Bikmaev et al. 2006) that these galaxies can be classified as Seyfert 2 and Seyfert 1, respectively.

The XRT position of XSS J12303−4232 coincides with a relatively bright (R ~ 14) stellar-like object (see Fig. 1), which has a likely infrared counterpart from the IRAS catalog (see Table 1). As will be shown below, the X-ray spectrum of XSS J12303−4232 obtained with XRT is typical for AGN and contains a strong emission line at ~5.8 keV that can be identified with a redshifted $K\alpha$ line of neutral iron. These facts suggest that XSS J12303−4232 is a nearby QSO at $z \sim 0.1$.

The fourth source of the present sample (XSS J18236−5616) has not yet been observed by SWIFT/XRT but is clearly detectable (at 3.5σ) on the summed hard X-ray map accumulated by INTEGRAL/IBIS so far (Revnivtsev et al., in preparation). This yields us a significantly improved position (~5′) for this source. The INTEGRAL confidence region contains a known nearby galaxy (see Table 1 and Fig. 1), which together with the broad-band X-ray spectrum taken by RXTE and INTEGRAL (see below) strongly suggests that this source too is an AGN.

2.1. X-ray spectra

We then performed a spectral analysis based on SWIFT/XRT data in the 0.5−10 keV band for XSS J05054−2348, XSS J12303−4232 and XSS J16151−0943, and RXTE/PCA scans data in the 3−20 keV band for XSS J05054−2348 and XSS J18236−5616. For the last source, there is also a measurement of its 17−60 keV flux by INTEGRAL. Combining all these data we obtain the source spectra presented in Fig. 2.

All four spectra are well fit by a power law modified by photoabsorption along the line of sight (see Table 2). The photon indexes are well constrained by the data and are typical for Seyfert galaxies and QSOs ($\Gamma \sim 1.8$). The spectra of XSS J05054−2348 and XSS J18236−5616 exhibit heavy photoabsorption ($N_{\rm H} \sim 10^{23}$ cm^{-2}), while in the other two cases (XSS J12303−4232 and XSS J16151−0943) the measured absorption column density is consistent with the Galactic absorption toward the sources. The high and low absorpiton columns measured for XSS J05054−2348 and XSS J16151−0943 are in accord with their optical classification as Seyfert 2 and Seyfert 1 galaxy, respectively. We also note the good agreement between the spectra of XSS J05054−2348 obtained by SWIFT/XRT and RXTE/PCA. Similarly the hard X-ray flux measured with INTEGRAL for XSS J18236−5616 is consistent (within the 90% uncertainties) with the extrapolated best-fit model of RXTE/PCA data. The fact that the fluxes reported here differ by up to a factor of 2 from those measured during

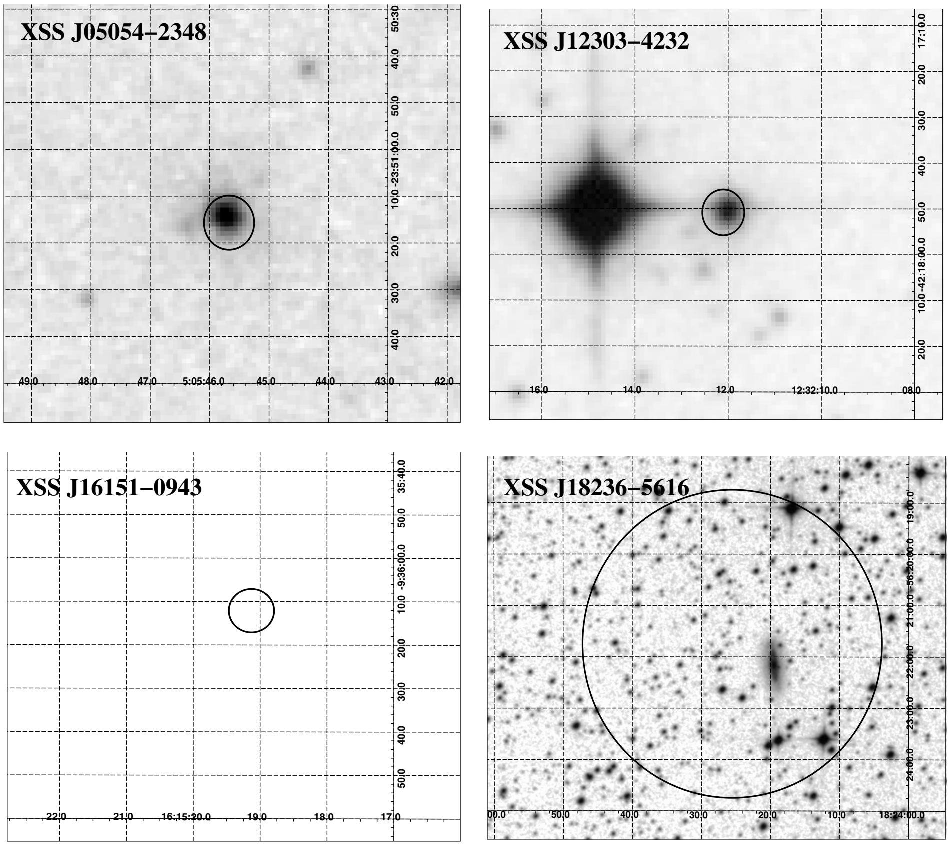

Fig. 1. SWIFT/XRT localizations (∼5″-radius circles) and an INTEGRAL/IBIS 1σ confidence region (∼3′-radius circle in the lower right panel) for the studied XSS sources, plotted against the DSS optical images.

Table 2. Results of spectral fitting, source fluxes and luminosities.

Source	Instrument	Γ	$N_{\rm H}$ ($N_{\rm H,Gal}$[a]) 10^{22} cm^{-2}	Line E (keV)	χ^2/ d.o.f	F (2–10 keV) 10^{-11} erg/cm^2/s	L (2–10 keV)[b] 10^{43} erg/s
XSS J05054−2348	XRT+PCA	1.81 ± 0.12	5.7 ± 0.4 (0.02)	–	1.03/145	1.5 ± 0.1	3.7 ± 0.2
XSS J12303−4232	XRT	1.56 ± 0.07	0.07 ± 0.02 (0.07)	5.82 ± 0.03	0.99/256	0.46 ± 0.04	9.8 ± 0.9
XSS J16151−0943	XRT	1.98 ± 0.15	0.14 ± 0.05 (0.13)	–	0.77/33	0.40 ± 0.04	3.6 ± 0.4
XSS J18236−5616	PCA	2.00 ± 0.13	12 ± 2 (0.08)	–	1.2/17	1.1 ± 0.1	0.62 ± 0.06

[a] Galactic absorption column based on Dickey & Lockman (1990). [b] Observed luminosity, assuming $(H_0, \Omega_{\rm m}, \Omega_\Lambda)$ = (75 km s^{-1} Mpc^{-1}, 0.3, 0.7).

the XSS several years ago indicates some intrinsic variability of the studied AGN.

Very interesting is the case of XSS J12303−4232, whose spectrum contains a bright narrow emission line at energy ∼5.8 keV (detected at >99.9% confidence). It is natural to interpete this feature as a redshifted 6.4 keV iron fluorescence line, often observed in high-quality AGN spectra. The measured equivalent line width (280 ± 40 eV) is not unusual for AGN, including unobsured ones (e.g. Nandra & Pounds 1994; Reynolds 1997). The determined line energy then suggests that XSS J12303−4232 is an AGN at a redshift of ∼0.1.

The determined luminosities of our objects (see Table 2) are typical for Seyfert galaxies and fall near the peak of the X-ray luminosity function of local AGN (Sazonov & Revnivtsev 2004).

3. Conclusion

We presented evidence that an additional 4 XSS sources are nearby (z = 0.017−0.098) AGN. Two of them are characterized by strong intrinsic absorption ($N_{\rm H} \sim 10^{23}$ cm^{-2}). This seems to continue the tendency of finding (Compton thin) obscured objects almost exclusively on the low-luminosity ($\lesssim 10^{43.5}$ erg s^{-1}) branch of the X-ray luminosity function of local AGN, as first clearly noticed in the XSS (Sazonov & Revnivtsev 2004) and now also in the SWIFT and INTEGRAL surveys (Markwardt et al. 2005; Sazonov et al. 2005).

This study fills some of the remaining gaps in the XSS catalog. We hope that the final catalog, consisting of up to ∼130 X-ray bright ($\gtrsim$0.5−1 mCrab), mostly nearby ($z < 0.1$), AGN, will serve as a useful input sample for detailed studies of the local AGN population. In addition, efforts put into the

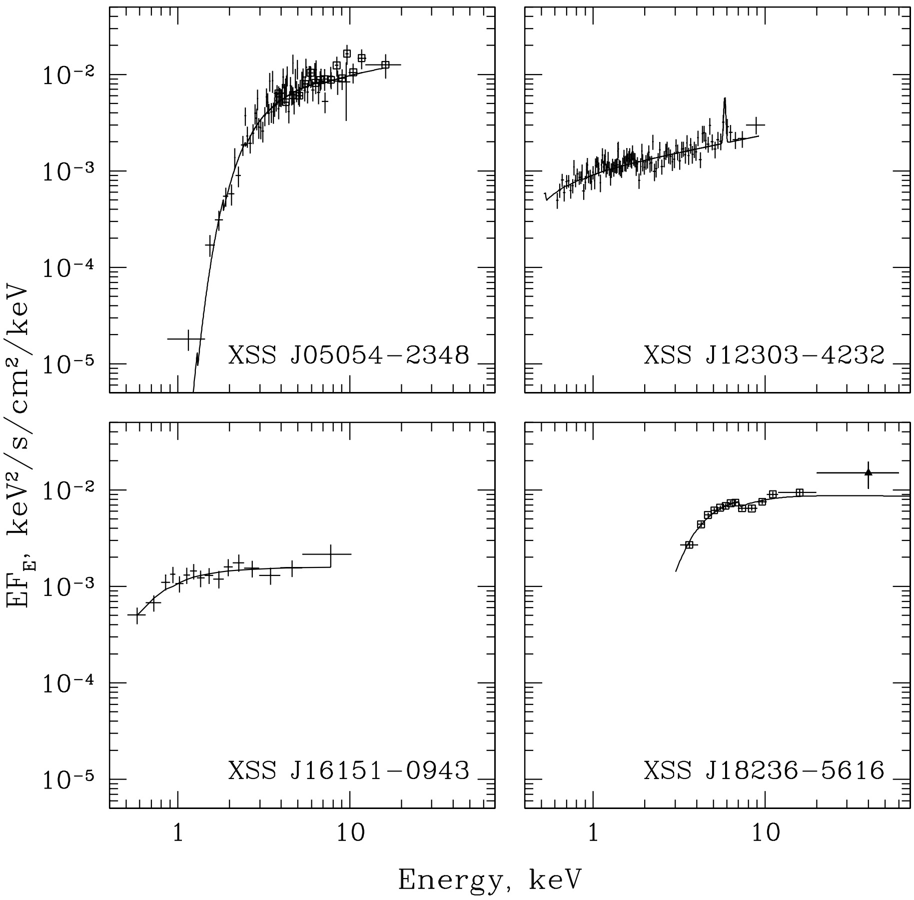

Fig. 2. X-ray spectra of the XSS sources. Shown are data from SWIFT/XRT (between 0.5 and 10 keV for XSS J05054−2348, XSS J12303−4232 and XSS J16151−0943) and from RXTE/PCA (between 3 and 20 keV for XSS J05054−2348 and XSS J18236−5616, open squares). For XSS J18236−5616 also the 17–60 keV flux measured by INTEGRAL is shown (solid triangle). The solid lines represent the best-fit models described in Table 2.

identification of XSS sources also help the continuing INTEGRAL and SWIFT hard X-ray all-sky surveys, since there is expected to be significant overlap between all three final catalogs of detected sources.

Acknowledgements. This research has made use of data obtained through the High Energy Astrophysics Science Archive Research Center Online Service, provided by the NASA/Goddard Space Flight Center. This research has also made use of the SIMBAD database (operated at CDS, Strasbourg) and NASA/IPAC Extragalactic Database (operated by the Jet Propulsion Laboratory, California Institute of Technology).

References

Beckmann, V., Gehrels, N., Shrader, C. R., & Soldi, S. 2005, ApJ, in press [arXiv:astro-ph/0510530]
Bikmaev, I., Sunyaev, R., Revnivtsev, M., & Burenin, R. 2006, Astron. Lett., in press [arXiv:astro-ph/0511405]
Dickey, J. M., & Lockman, F. J. 1990, ARA&A, 28, 215
Heckman, T. M., Ptak, A., Hornschemeier, A., & Kauffmann, G. 2005 [arXiv:astro-ph/0507674]
Markwardt, C. B., Tueller, J., Skinner, G. K., et al. 2005 [arXiv:astro-ph/0509860]
Nandra, K., & Pounds, K. A. 1994, MNRAS, 268, 405
Revnivtsev, M., Sazonov, S. Y., Jahoda, K., & Gilfanov, M. R. 2004, A&A, 418, 927
Reynolds, C. S. 1997, MNRAS, 286, 513
Saxton, R., Altieri, B., Read, A., et al. 2005, Proc. SPIE 2005 Conf., San Diego [arXiv:astro-ph/0509022]
Sazonov, S. Y., & Revnivtsev, M. G. 2004, A&A, 423, 469
Sazonov, S., Churazov, E., Revnivtsev, M., Vikhlinin, A., & Sunyaev, R. 2005, A&A, 444, L37
Voges, W., Aschenbach, B., Boller, Th., et al. 1999, A&A, 349, 389