PROCEEDINGS OF SCIENCE

XMM-Newton observations of five INTEGRAL sources located towards the Scutum Arm

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Results are presented for *XMM-Newton* observations of five hard X-ray sources discovered by *INTEGRAL* in the direction of the Scutum Arm. Each source received $\gtrsim$20 ks of effective exposure time. We provide refined X-ray positions for all five targets enabling us to pinpoint the most likely counterpart in optical/infrared archives. Spectral and timing information (much of which are provided for the first time) allow us to give a firm classification for IGR J18462$-$0223 and to offer tentative classifications for the others. For IGR J18462$-$0223, we discovered a coherent pulsation period of 997$\pm$1 s which we attribute to the spin of a neutron star in a highly-obscured ($N_{\mathrm{H}} = 2 \times 10^{23}\,\mathrm{cm}^{-2}$) high-mass X-ray binary (HMXB). This makes IGR J18462$-$0223 the seventh supergiant fast X-ray transient (SFXT) candidate with a confirmed pulsation period. IGR J18457+0244 is a highly-absorbed ($N_{\mathrm{H}} = 8 \times 10^{23}\,\mathrm{cm}^{-2}$) source in which the possible detection of an iron line suggests an active galactic nucleus (AGN) of type Sey-2 situated at $z = 0.07(1)$. A periodic signal at 4.4 ks could be a quasi-periodic oscillation which would make IGR J18457+0244 one of a handful of AGN in which such features have been claimed, but a slowly-rotating neutron star in an HMXB can not be ruled out. IGR J18482+0049 represents a new obscured HMXB candidate with $N_{\mathrm{H}} = 4 \times 10^{23}\,\mathrm{cm}^{-2}$. We tentatively propose that IGR J18532+0416 is either an AGN or a pulsar in an HMXB system. The X-ray spectral properties of IGR J18538$-$0102 are consistent with the AGN classification that has been proposed for this source.

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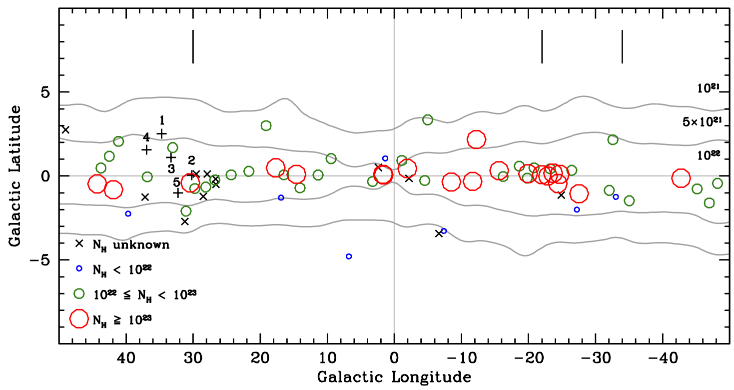

Figure 1: The spatial distribution of HMXBs in Galactic coordinates with symbol size proportional to the X-ray measured column density as reported in the literature. The contours represent cumulative line-of-sight absorption levels of 10^{21}, 5×10^{21}, and 10^{22} cm^{-2} [8]. The vertical bars denote the tangents to the (left to right) Scutum, Inner Perseus, and Norma arms from [9]. The five targets in this study (which are unclassified or tentatively classified) are labeled with crosses and are numbered 1 through 5 in order of increasing R.A.

1. Introduction

The spatial distribution of obscured HMXBs (those with $N_{\rm H} \geq 10^{23}$ cm^{-2}) appears to be asymmetric about the Galactic Center (GC) [1]. In the inner quadrant of the Galactic Plane (Fig. 1), there are 37 *INTEGRAL*-detected HMXBs (with and without $N_{\rm H}$ measurements) at positive longitudes, and an equivalent number (34) at negative longitudes. Among HMXBs whose $N_{\rm H}$ values are known to be less than 10^{23} cm^{-2}, the left-right distribution is also symmetrical about the GC: 21 vs. 18. Thus, the asymmetry is only evident for the obscured systems: there are around half as many obscured HMXBs (7) at positive longitudes as there are at negative longitudes (13).

Is this asymmetry the signature of an evolutionary difference between the massive binary populations of the Galactic arms? To test this hypothesis, we need a more complete sample of obscured HMXBs. Indeed, there are unclassified IGRs (including HMXB candidates) at positive longitudes, and if these can be shown to be obscured HMXBs, then we might reject an evolutionary origin for the asymmetry and point instead to an observational bias. We obtained *XMM-Newton* observations of five unclassified (or tentatively classified) IGRs[1] that are located in the direction of the Scutum Arm: IGR J18457+0244, IGR J18462−0223, IGR J18482+0049, IGR J18532+0416, and IGR J18538−0102. Each source was observed for ~25 ks by *XMM-Newton* during April, 2011.

2. IGR J18457+0244: an AGN candidate with a possible QPO

The coordinates we obtain for IGR J18457+0244 are R.A. = 18:45:40.30 and Dec. = +02:42:11.2, i.e., consistent with the *Swift*-XRT position [2]. There are no known IR or radio sources inside the XMM-Newton error circle of 2.5″-radius (90% confidence). A power law fit to the X-ray spectrum yields a photon index $\Gamma = 2.3(7)$, and a large column density ($N_{\rm H}$

[1]a comprehensive list of IGRs and their properties can be found at `http://irfu.cea.fr/Sap/IGR-Sources`

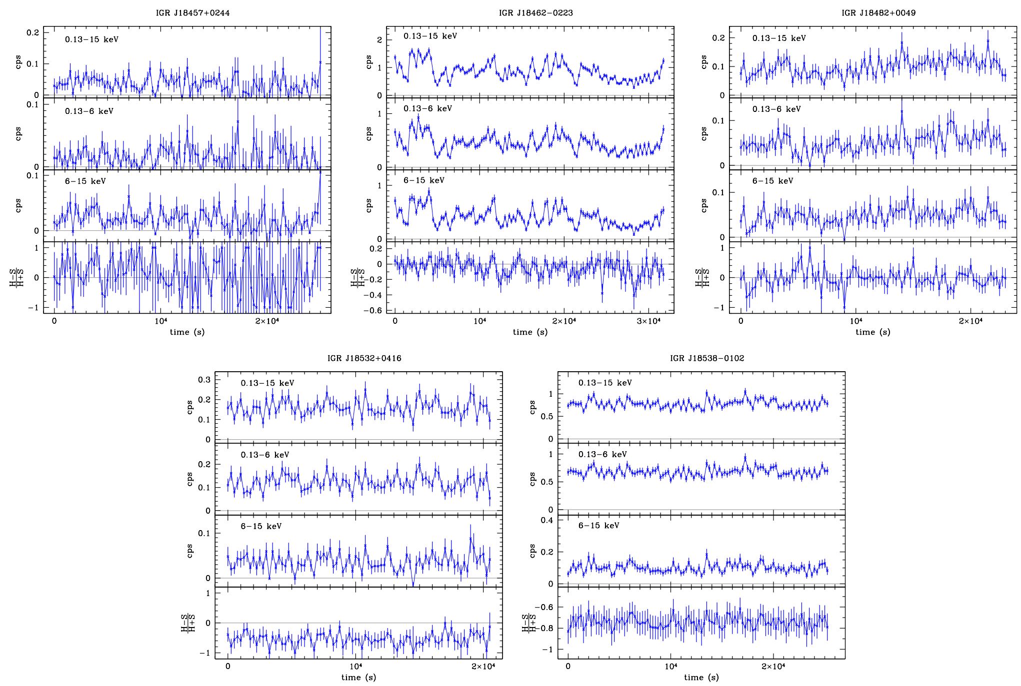

Figure 2: Background-subtracted and exposure-corrected light curves of the five target sources taken with EPIC-pn in the full energy range (0.13–15 keV), and in the soft (S: 0.13–6 keV) and hard bands (H: 6–15 keV). The time resolution is 250 s. The hardness ratio is defined as $\frac{H-S}{H+S}$.

$= 8\times10^{23}$ cm^{-2}) indicating intrinsic absorption. Adding a Gaussian to the model to account for a possible iron line improves the fit and gives a line energy of 6.01(6) keV suggesting an AGN ($z \sim 0.07$). Analysis of the light curve reveals a potential signal at a period of 4400 s (8 bins per trial period) with χ^2 = 56 (6σ significance, not corrected for the number of trials) and a pulse fraction of 32%±7%. This weak periodicity could be a QPO which is a common feature of the power spectrum of black hole binaries, but which has been confirmed in one AGN thus far (RE J1034+396) [3].

3. IGR J18462−0223: a new obscured SFXT pulsar

For IGR J18462−0223, we obtained X-ray coordinates of R.A. = 18:46:12.68 and Dec. = −02:22:29.3. This is the most precise X-ray position known for this SFXT candidate, and the 2.5″-radius error circle (90% confidence) excludes all catalogued objects from other wavelengths. The X-ray spectrum of IGR J18462−0223 features a large column density ($N_{\mathrm{H}} = 2\times10^{23}$ cm^{-2}), a hard power law continuum ($\Gamma \sim -0.8$), an iron Kα line at 6.41(5) keV, and a cutoff energy at around 3 keV. This spectral shape is typical of wind-accreting X-ray pulsars. Indeed, our timing analysis revealed a coherent pulsation at a period of 997±1 s (pulse fraction of 12%±2%) with $\chi^2 = 162$ for 10 bins per trial period (∼12σ significance, not corrected for the number of trials). Thus, the compact object hosted by IGR J18462−0223 is an accreting neutron star whose magnetic and spin axes are misaligned. Overall, the timing and spectral characteristics of IGR J18462−0223 suggest that this system is an obscured (and probably distant) SFXT pulsar, and one of the few examples

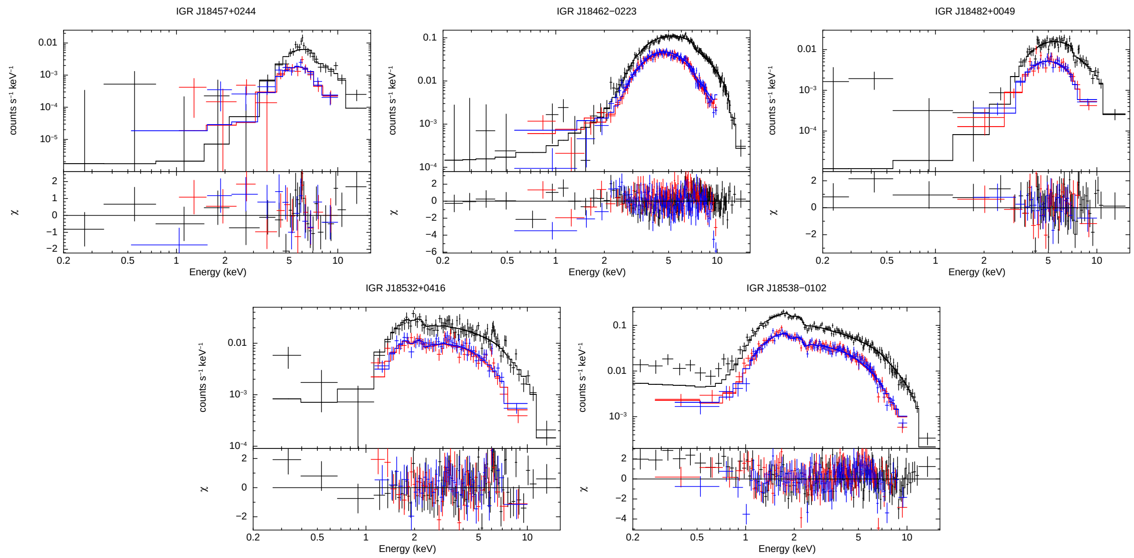

Figure 3: Spectra (corrected for the background) in the 0.13–15-keV band of the five sources as gathered with pn (black), MOS1 (red), and MOS2 (blue). Each bin collects a minimum of 20 counts, and the spectra have been modeled with an absorbed power law.

of a highly-obscured HMXB in the direction of the Scutum Arm. This makes IGR J18462−0223 the seventh (out of $\sim$20 known SFXT candidates) to have a measured spin period.

4. IGR J18482+0049: an obscured HMXB candidate in the Scutum Arm

Our observation provides the most accurate X-ray position known for IGR J18482+0049: R.A. = 18:48:15.32 and Dec. = +00:47:34.9 (error radius of 2.5$''$ at 90% confidence). The only catalogued object consistent with the XMM-Newton position is 2MASS J18481540+0047332 which has magnitudes of 15.8, 14.0, and 13.9, respectively, in the J, H, and K bands [4]. An absorbed power law with $\Gamma = 2.0(3)$ provides an excellent fit to the X-ray spectrum. The column density ($N_{\rm H} = 4 \times 10^{23}$ cm^{-2}) is well in excess of the cumulative line-of-sight value. Given the large absorbing column, its location close to the Galactic Plane, and its persistent emission in the hard X-rays, we conclude that IGR J18482+0049 is probably a new obscured HMXB in the Scutum Arm. Many sources in this class feature pulsation periods in the X-rays, but we did not find conclusive evidence for a periodic signal in the 1–5000-s range. Confirmation of the HMXB nature of IGR J18482+0049 must await spectral analysis of the 2MASS counterpart proposed here.

5. IGR J18532+0416: an AGN candidate seen through the Galactic Plane

The XMM-Newton position for IGR J18532+0416 is the most accurate X-ray position known for this source: R.A. = 18:53:15.83 and Dec. = +04:17:48.5 (error radius of 2.5$''$ at 90% confidence). The nearest catalogued object is 2MASS J18481540+0047332 which is just outside the *XMM-Newton* error circle [4]. A power law with $\Gamma = 1.4(1)$ and moderate absorption ($N_{\rm H}$ $= 2 \times 10^{22}$ cm^{-2}) provides a good fit to the source spectrum. Residuals suggest the presence of an

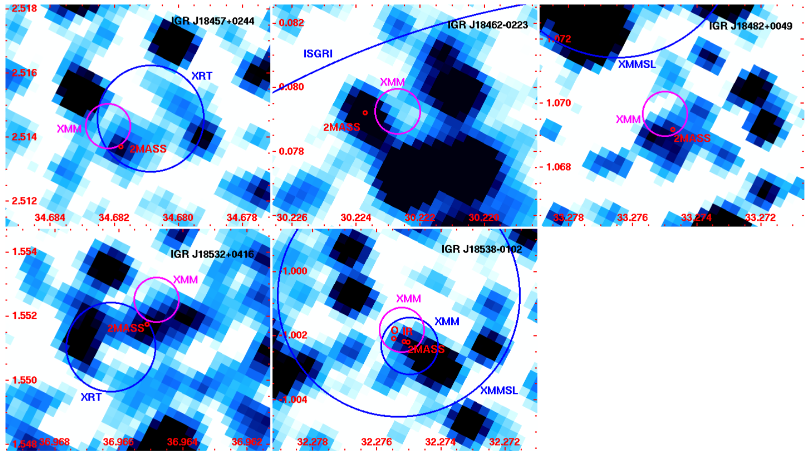

Figure 4: 2MASS *J*-band images of the fields of the five targets in Galactic coordinates [4]. The positions obtained with *XMM-Newton* (this work) are shown as magenta circles ($2''.5$ accuracy at 90% confidence), while the blue and red circles represent the error circles (90% confidence) of previously proposed X-ray and optical/infrared associations, respectively.

iron line, and its inclusion improves the fit. The line energy of 6.1(1) keV indicates an extragalactic origin (i.e., an AGN at $z \sim 0.05$). We cannot firmly establish the nature of IGR J18532+0416 because of the low signal-to-noise ratio of the iron line, as well as that of a possible periodicity at 1.4 ks. Confirmation (or refutation) of either of these observables will require additional X-ray observations.

6. IGR J18538−0102: a Sey-1 AGN viewed through the Galactic Plane

The X-ray position we obtained for IGR J18538−0102 is R.A. = 18:53:48.42 and Dec. = −01:02:28.3 (error radius of $2.5''$ at 90% confidence). This is the most precise position available for this source and it is compatible with previously-reported X-ray positions [5, 6], as well as with an optical counterpart whose spectrum suggests a Sey-1 AGN at $z \sim 0.145$ [7]. No periodic signal could be found in the 1–5000 s range. An absorbed power law with $\Gamma = 1.5(4)$ and $N_{\rm H} = 2 \times 10^{22}\,{\rm cm}^{-2}$ provides an adequate fit to the source spectrum. The spectral parameters that we measured are consistent with those from previous X-ray observations, and with the AGN classification.

7. Summary & Conclusions

Our results indicate that IGR J18462−0223 and IGR J18482+0049 are probably new heavily-absorbed ($N_{\rm H} > 10^{23}\,{\rm cm}^{-2}$) high-mass X-ray binaries (HMXBs). The former is a slow X-ray pulsar ($P = 997 \pm 1$ s) in a supergiant fast X-ray transient (SFXT) system. This makes IGR J18462−0223 a useful laboratory to test SFXT emission mechanisms which assume highly-magnetized ($B \gtrsim 10^{13}$ G) neutron stars [10, 11]. These two additional systems represent a 40% increase in the number of known obscured HMXBs in this region, helping to reduce (somewhat) the asymmetry that we continue to observe between the large number of obscured HMXB systems found towards the Norma Arm compared with the low number found in the direction of the Scutum Arm.

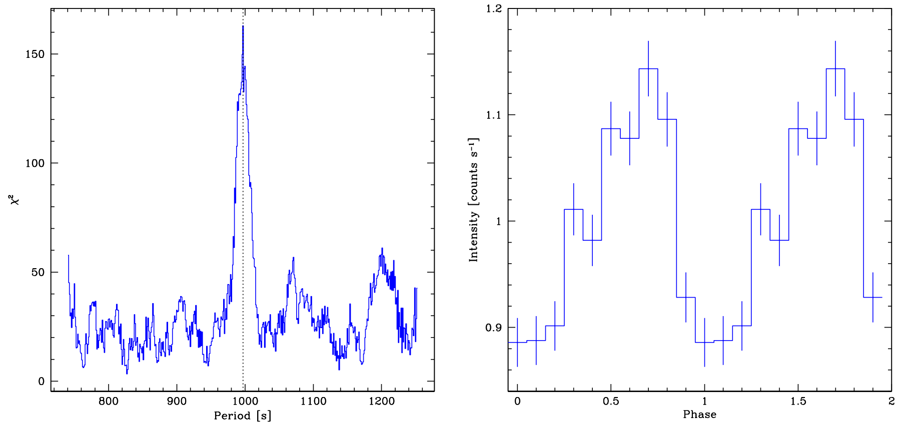

Figure 5: *Left*: Results from a periodicity search (χ^2 distribution) performed on the pn light curve (0.13–15 keV) of IGR J18462−0223 centered at 997 s (vertical line), with 10 bins per period, and a resolution of 1 s. *Right*: Pulse profile showing two phases of IGR J18462−0223 for a period of 997 s. The zero phase (phase in which the flux is at a minimum) corresponds to MJD 55669.00808.

We can not conclusively determine the nature of the other targets in our sample, IGR J18457+0244, IGR J18532+0416, and IGR J18538−0102. We propose that IGR J18457+0244 and IGR J18532+0416 are probably active galactic nuclei (AGN) viewed through the plane of the Milky Way, but Galactic X-ray binaries can not be ruled out. The spectral parameters of IGR J18538−0102 are consistent with an AGN interpretation. Confirmation of the classifications for all sources in this study will require further observations of the optical/infrared counterparts which we propose here. These results were published as Bodaghee et al. (2012), ApJ, 753, 3 [12].

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