Astron Astrophys Rev (2015) 23:2
DOI 10.1007/s00159-015-0082-6

REVIEW ARTICLE

High-mass X-ray binaries in the Milky Way

A closer look with *INTEGRAL*

Roland Walter[1] · **Alexander A. Lutovinov**[2] ·
Enrico Bozzo[1] · **Sergey S. Tsygankov**[3]

Received: 30 October 2014 / Published online: 5 August 2015

Abstract High-mass X-ray binaries are fundamental in the study of stellar evolution, nucleosynthesis, structure and evolution of galaxies and accretion processes. Hard X-rays observations by *INTEGRAL* and *Swift* have broadened significantly our understanding in particular for the super-giant systems in the Milky Way, whose number has increased by almost a factor of three. *INTEGRAL* played a crucial role in the discovery, study and understanding of heavily obscured systems and of fast X-ray transients. Most super-giant systems can now be classified into three categories: classical/obscured, eccentric and fast transient. The classical systems feature low eccentricity and variability factor of $\sim 10^3$, mostly driven by hydrodynamic phenomena occurring on scales larger than the accretion radius. Among them, systems with short orbital periods and close to Roche-Lobe overflow or with slow winds appear highly obscured. In eccentric systems, the variability amplitude can reach even higher factors because of the contrast of the wind density along the orbit. Four super-giant systems, featuring fast outbursts,

---

✉ Roland Walter
Roland.Walter@unige.ch

Alexander A. Lutovinov
aal@iki.rssi.ru

Enrico Bozzo
Enrico.Bozzo@unige.ch

Sergey S. Tsygankov
stsygankov@gmail.com

[1] ISDC, Geneva Observatory, University of Geneva, Ch. d'Ecogia 16, 1290 Versoix, Switzerland

[2] Space Research Institute of the Russian Academy of Science, Profsoyuznaya Str. 84/32, 117997 Moscow, Russian Federation

[3] Tuorla Observatory, Department of Physics and Astronomy, University of Turku, Väisäläntie 20, 21500 Piikkiö, Finland

very short orbital periods and anomalously low accretion rates, are not yet understood. Simulations of the accretion processes on relatively large scales have progressed and reproduce parts of the observations. The combined effects of wind clumps, magnetic fields, neutron star rotation and eccentricity ought to be included in future modelling work. Observations with *INTEGRAL* in combination with other observatories were also important for detecting cyclotron resonant scattering features in spectra of X-ray pulsars, probing their variations and the geometry of the accretion column and emission regions. Finally, the unique characteristics of *INTEGRAL* and its long life time played a fundamental role for building a complete catalogue of HXMBs, to study the different populations of these systems in our Galaxy and to constrain some of the time scales and processes driving their birth and evolution.

Keywords X-ray binaries · Pulsars · Mass loss and stellar winds

1 Introduction

Neutron stars and stellar mass black holes stand out as luminous X-ray sources in the Galaxy when they are accreting matter from nearby stars. When these companions have masses above $\sim$10 $M_\odot$, the systems are known as high-mass X-ray binaries (HMXB). Such systems can be formed when one of the initial member stars loses a significant part of its mass, through stellar wind or mass transfer, before the first supernova explosion occurs (van den Heuvel and Heise 1972). They are young (several dozen million years old), in contrast to the low-mass X-ray binary systems (LMXBs) that are several billion years old.

In most HMXBs, the compact objects capture a very small fraction of the stellar wind of their companions and the resulting accretion rates are low (Bondi and Hoyle 1944; Davidson and Ostriker 1973; Lamers et al. 1976). High X-ray luminosities ($>10^{35}$ erg/s) are observed in two situations. Strong and transient X-ray flares, reaching the Eddington luminosity, occur when the compact object crosses a dense component of the stellar wind, usually expelled by a fast rotating main sequence star (featuring emission lines in the optical and hence identified as “Be” systems). High accretion rates are also observed in close systems where the companion is practically filling its Roche lobe (giant and super-giant systems). These systems become very luminous (up to 10^{40} erg/s; Bachetti et al. 2014) when the donor is close to the Roche limit and the accretion becomes dominated by a tidal stream. Roche-lobe overflow is rarely observed as the compact object is quickly enshrouded, unless the radial expansion of the companion is slow.

The very large majority of the HMXB systems harbour accreting pulsars (Liu et al. 2006; Lutovinov and Tsygankov 2009). In such systems, the plasma approaching the neutron star is stopped by the pressure of the dipolar magnetic field and forced to move along the field lines toward the magnetic poles, where the captured matter releases its gravitational energy in the form of X-rays. The X-ray continuum of accreting pulsars is characterised by a power law of photon index 0.3–2 with a high-energy exponential cutoff (7–30 keV, White et al. 1983; Filippova et al. 2005), sometimes modified by absorption and emission lines in the soft X-rays and by cyclotron resonance scattering features (CRSF) at higher energies (Coburn et al. 2002; Filippova et al. 2005; Caballero and Wilms 2012). The plasma falls in the accretion column at almost the speed of light and heats to 10^8K close to the neutron star surface (see, e.g. Basko and Sunyaev 1976; Nagel 1981; Meszaros and Nagel 1985; Araya-Góchez and Harding 2000; Nishimura 2008; Mushtukov et al. 2015). Bulk and thermal Comptonization plays a key role in the formation of the non thermal X-ray emission (Becker and Wolff 2007).

CRSFs are caused by the scattering of hard X-ray photons on electrons whose energy is quantized by the magnetic field according to the Landau levels (Gnedin and Sunyaev 1974; Truemper et al. 1978; Araya-Góchez and Harding 2000). This electron energy can be measured from the source spectra and hence the magnetic field strength in the scattering region. Variability of the CRSF energy with luminosity on long and spin period time scales indicate that the accretion flow is not uniform nor stationary (Mihara et al. 1998; Mowlavi et al. 2006; Staubert et al. 2007; Tsygankov et al. 2006, 2010; Klochkov et al. 2011).

Emission lines and absorption observed in the soft X-ray band are the imprints of the companion stellar wind. Photo-ionisation and other effects of the pulsar on the wind structure, as well as inhomogeneities of the wind, either genuine or induced by the compact object, lead to additional variability.

The HMXBs of the Milky Way include three microquasars and black-hole candidates and three gamma-ray loud binaries. Because of their peculiarities, these six sources will not be discussed in this review. Their high-energy emission and variability patterns are very different from those described above and dominated by inverse Compton scattering of electron accelerated close to the black-hole or in the interaction regions between the companion stellar winds and pulsar winds or microquasar jets (Dubus 2013).

The INTernational Gamma-Ray Astrophysics Laboratory (*INTEGRAL*), a medium size mission from the European Space Agency (Winkler et al. 2003), observes the Universe in the hard X-ray and soft gamma-ray band. The wide field of view ($\sim 30°$) of its main instruments, its unique energy coverage and its frequent scans of the galactic plane allowed *INTEGRAL* to observe the Galaxy in a parameter space not well studied before and to discover strongly absorbed and transient HMXBs with low duty cycles.

110 HMXB systems were known in the Milky Way before the launch of *INTEGRAL* (Liu et al. 2000): 13 super-giant, 52 Be and 45 systems of unclear or other types. The serendipitous discovery by *INTEGRAL* of many new HMXB systems, in particular 23 likely of super-giant type, came as a surprise. The mere fact that these new systems had not been identified in the past indicates that the HMXB phenomenology is more diverse and rich than anticipated. This review concentrates on these new aspects.

HMXBs are generally concentrated towards the Galactic plane, close to their birthplace (Fig. 1; see also, e.g. Grimm et al. 2002). The X-ray luminosity of normal star forming galaxies, dominated by HMXBs and by the hot ionised inter-stellar gas, correlates well with the star formation rate (Grimm et al. 2003; Ranalli et al. 2003; Lehmer et al. 2010; Mineo et al. 2012a, b; Lutovinov et al. 2013b). The discovery by *INTEGRAL* of many new HMXBs close to the tangent directions to the inner galactic arms also allowed to understand better their distribution in the Milky Way and their relation with star forming regions (Lutovinov et al. 2005a; Bodaghee et al. 2012c; Coleiro and Chaty 2013). Finally, the small fraction of black-hole HMXB systems, probably orig-

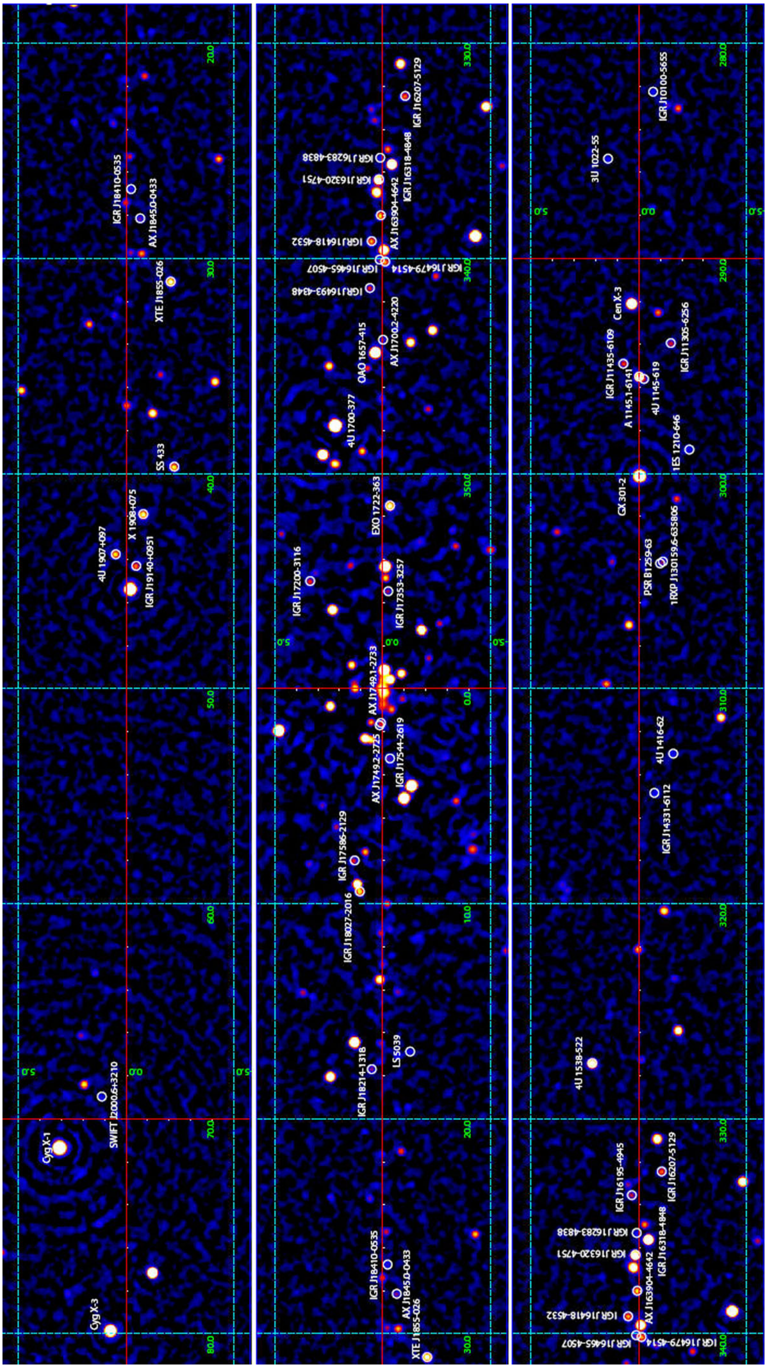


Fig. 1 Image of the inner part of the Galactic plane, obtained with INTEGRAL/IBIS in the 17–60 keV energy band. Persistent HMXBs are identified with circles (Lutovinov et al. 2013b). *The horizontal red line* is the Galactic equator

inating from very high mass stars, and their higher masses when compared to neutron stars, can be related to the physics of supernova explosions (Belczynski et al. 2012).

Sections 2 and 3 review the new observations, source discoveries and catalogue and the properties of the various classes of HMXBs in the light of the new observations. In Sects. 4 and 5, we discuss several new aspects of the phenomenology of wind accretion revealed by the individual objects and the global properties of their population at the scale of the Galaxy. Finally a summary of the new results is presented in Sect. 6.

2 Observations and source catalogue

2.1 Hard X-ray sources and their identification

The large field of view, hard X-ray coded mask imagers on board *INTEGRAL* and *Swift* are observing the full sky regularly; *INTEGRAL* focussing more on the galactic plane. The observations consist of numerous short pointings of $(1-5)\times 10^3$ s, enhancing the sensitivity to flaring activities on such time scales. Many new sources and flares were detected and about a thousand Astronomer's Telegrams were issued.

The value of any sky survey to study the properties of a population of sources (in particular HMXBs) depends on the survey completeness and on the identification of the nature of the detected sources. Surveys performed with *INTEGRAL* and *Swift* have a very high identification completeness, reaching 92 % in the Galactic plane (Krivonos et al. 2012). Such a high identification completeness results from follow-up observations performed by several research groups in the soft X-rays ($<$10 keV), optical, infrared and radio wavelengths (see, e.g. Walter et al. 2003; Bikmaev et al. 2006, 2008; Masetti et al. 2006b, 2009, 2012b; Tomsick et al. 2006a, 2008, 2009a; Rahoui et al. 2008; Burenin et al. 2008; Chaty et al. 2008; Lutovinov et al. 2012b; Karasev et al. 2012).

As the source localization accuracy provided by the imagers on board *INTEGRAL* and *Swift* (about 2–5 arcmin depending on the source significance) is not enough for an unambiguous optical identification, a significant improvement of the localization accuracy is required as a first step. This is achieved by follow-up observations (or archival studies) carried out with focussing X-ray telescopes such as *Swift/XRT*, *XMM-Newton* or *Chandra*. In densely populated regions, such as the inner part of the Galaxy, sub arcsecond resolution is required and only follow-up observations with *Chandra* can help to identify a hard X-tray source.

In the case of HMXBs, an accurate X-ray position is usually good enough to identify the likely counterpart in optical and infrared surveys or catalogues (such as *DSS*, *USNO-A2*(*B1*), *2MASS*, *UKIDSS*, or *VVV*). The photometry obtained from these surveys together with the high-energy spectra and lightcurves allow us to make first assumptions on the nature of the sources. In particular, the presence of X-ray absorption together with a counterpart well detected in the infrared and much weaker in the optical is a good indication for the massive nature of the binary system. The detection of X-ray pulsations unambiguously points at a rotating neutron star with a strong magnetic field.

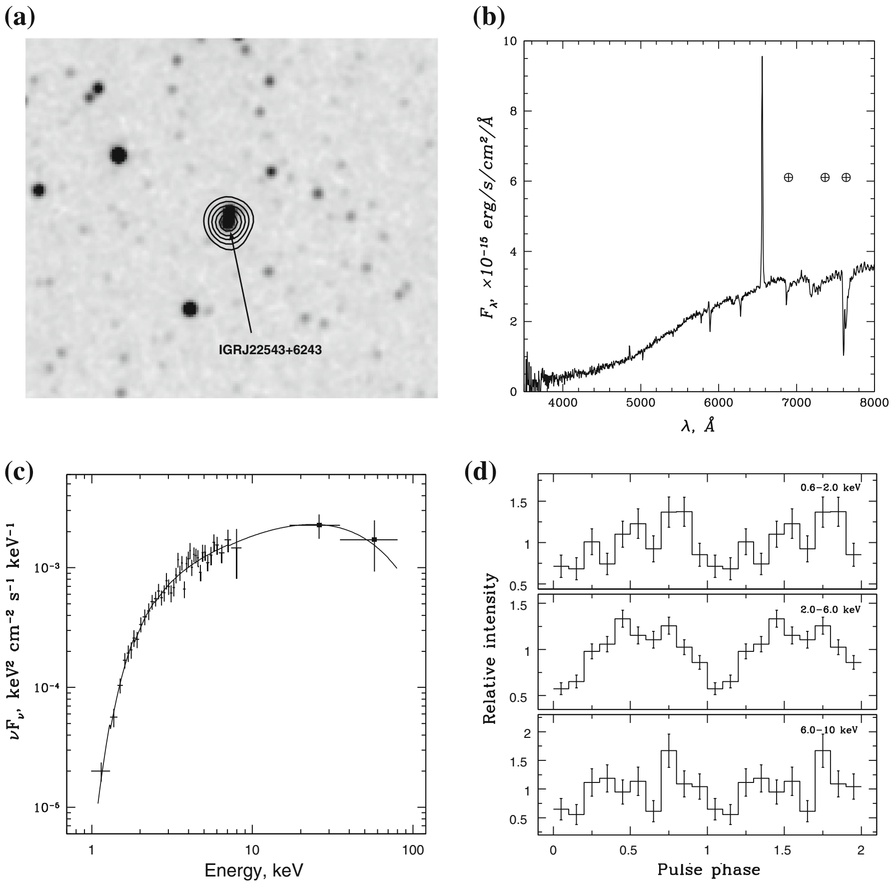


Fig. 2 **a** Sky field around the source IGR J22534+6243 in the *J*-band (*2MASS* survey). *Contours* indicate levels of the source intensity in the X-rays, obtained by *Swift/XRT*. The infrared counterpart is indicated by the *arrow*. **b** Optical spectrum of the source. **c** Broadband energy spectrum of IGR J22534+6243. The best-fit model is indicated by the *solid line*. **d** Pulse profile in three energy bands, folded with the period of 46.675 s. See Lutovinov et al. (2013a) for details

A final confirmation of the nature of the sources can only be obtained from infrared/optical spectroscopic observations with low to medium resolution ($\lambda/\Delta\lambda \simeq 500-3000$). Several classification parameters are used: the reddening, different absorption and emission lines typical for different object classes, line flux ratios, line width and their redshift.

The identification process is illustrated in Fig. 2 for IGR J22534+6243, a hard X-ray source discovered by *INTEGRAL*. An infrared image in the J-band around the position obtained by a follow-up observation with *Swift/XRT* is shown in Fig. 2a. Two close (4.4 arcsecond separation) relatively bright ($m_J \simeq 11.64$ and $m_J \simeq 11.78$) objects are detected in the X-ray error circle. The optical spectrum of the most central object obtained with the Russian-Turkish Telescope *RTT-150* is typical for an early-type star (Fig. 2b). The broadened $H\alpha$ emission line, together with the $H\beta$ and HeI

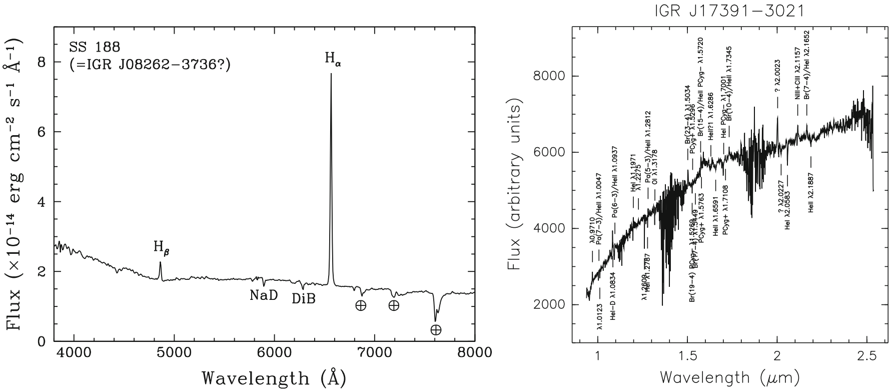


Fig. 3 An example of optical and infrared spectra of two high mass X-ray binary systems IGR J08262-3736 (*left*) and IGR J17391-3021 (*right*), discovered by *INTEGRAL*. The spectra are from Masetti et al. (2010b) and Chaty et al. (2008)

emission lines, is often observed for Be stars, which have a fast-rotating equatorial disc. The broadband X-ray spectrum of IGR J22534+6243 obtained with *Chandra* and *INTEGRAL* is typical for an accreting neutron star with a cutoff power law model and photo-absorption at low energies (Fig. 2c). Finally, X-ray pulsations with a period of $P_s \simeq 46.67$ s were detected from this source (Fig. 2d). These observations allow to classify IGR J22534+6243 as a new X-ray pulsar in a Be high-mass X-ray binary system (Lutovinov et al. 2013a). Other examples of the optical and infrared spectra of high-mass X-ray binaries, discovered by *INTEGRAL* are shown in Fig. 3.

2.2 Source catalogue

Our catalogue of HMXBs in the Milky Way includes a total of 87 sources listed in Table 1, organised per source category as commonly known in the literature. For each source we list coordinates, spin and orbital periods, spectral type, distance, system type (cl: classical; abs: obscured; SFXT: transients; ?: unclear type; e: eccentric orbit; P: pulsar; BH: black-hole) and the average 17–60 keV flux in units of 10^{-11} erg s^{-1} cm^{-2} (taken from Krivonos et al. 2007, 2012). If the source is missing in these catalogues, then its flux was taken from other papers (appropriate references and energy bands are mentioned). The system type is based on our analysis of the available data presented in this review and can be different from the previously published ones.

The Milky-Way HMXBs can be categorized as follows:

- 24 systems have super-giant companions and are persistent at hard X-rays. These are the classical systems. Six of them are characterised by high obscuration. Seven of them are known in the literature as super-giant fast X-ray transients but can be understood as classical systems.
- 10 systems are super-giant fast X-ray transients detected above 10 mCrab only for short periods and with a low ($\lesssim$10 %) duty cycle. They feature likely super-giant companions and show impressive variability factors in the range 10^{2-5}. Most of

Table 1 Catalogue of high-mass X-ray binaries

Source name	RA	DEC	l	b	P_s	P_orb	ST	kpc	Type	F_{17-60}
Super-giant persistent systems										
1A 0114+650	19.516	65.289	125.723	2.571	9475[1]	11.59[2]	B0.5I[2]	7.2[3]	cl,P	9.40
Vela X-1	135.531	−40.555	−96.933	3.930	283[4]	8.964[4]	B0.5Ib	1.7–2.1[5]	cl,P	214.77
1E 1145.1-6141	176.870	−61.956	−64.509	−0.027	297[6]	14.365[7]	B2Iae[8]	8.2[8]	cl,P	18.99
GX 301-2	186.651	−62.772	−59.891	−0.031	675–700[9]	41.492[10]	B1 Ia+[9]	3–4[9]	cl,P	181.21
4U 1538-522	235.600	−52.385	−32.581	2.177	528–530[11]	3.728[12]	B0I[13]	5.5[13]	cl,P	16.38
IGR J16318-4848	247.951	−48.817	335.616	−0.448			sgB[e][14]	0.9–6.2[14]	abs,cl	24.63
IGR J16320-4751	248.007	−47.875	336.329	0.169	1309[15]	8.986[16]	O8I[17]	3.5[17]	abs,cl,P	14.23
IGR J16393-4641	249.772	−46.704	336.001	0.075	912.0[18]	4.24[19]	OB?[20]	> 10?[20]	abs,cl,P	5.9
IGR J16493-4348	252.362	−43.819	−18.629	0.603	1093[21]	6.782[21]	B0.5 Ib[32]	> 6[22]	cl,P	1.81
OAO 1657-415	255.199	−41.656	−15.631	0.324	38.2[23]	10.448[24]	Ofpe/WN9[24]	4–8[24]	cl,P	65.44
4U 1700-37	255.986	−37.844	347.7544	2.173	–	3.412[25]	O6.5 Iaf+[26]	1.9[27]	cl,BH?	209.4
EXO 1722-363	261.297	−36.283	351.497	−0.354	413.89[28]	9.742[28]	B0-B1Ia[29]	6–10.5[29]	abs,cl,P	7.72
IGR J18027-2016	270.666	−20.283	9.430	1.039	139.612[30]	4.469[30]	B1 Ib[31]	12.4[32]	abs,cl,P	4.21
XTE J1855-026	283.870	−2.601	31.082	−2.085	360.7[33]	6.0724[34]	B0 Iaep[35]		cl,P	10.34
4U 1907+097	287.406	9.833	43.752	0.488	437–440[36]	8.375[36]	O8.5Iab[37]	< 8[37]	cl,P	13.36
4U 1909+07	287.701	7.595	41.896	−0.810	605[38]	4.4[39]	O7.5-9.5sg[40]	7[40]	cl,P	12.68
IGR J19140+0951	288.526	9.885	44.298	−0.461		13.55[41]	B0.5Ia/d[42]	2–5[42]	cl,P	8.93
Super-giant fast X-ray transients										
IGR J08408-4503	130.199	−45.058	264.040	−1.950	–	–	O8.5Ib(f)[43]	2.7[44]	?	0.4
IGR J11215-5952	170.445	−59.863	291.893	1.073	186.78[45]	165[45]	B0.5Ia[46]	6.4–8.0[46]	e,cl,P	0.15
IGR J16195-4945	244.884	−49.742	333.557	0.339	–	16(?)[47]	O,B,A[48]	5[48]	cl	1.66
IGR J16207-5129	245.193	−51.502	332.459	−1.050	–	9.726(?)[49]	B0I[50]	6[51]	cl	2.74

Table 1 continued

Source name	RA	DEC	l	b	P_s	P_{orb}	ST	kpc	Type	F_{17-60}
IGR J16328-4726	248.158	−47.395	336.749	0.422	–	10.07[52]	O8Iaf[53]	–	cl	3[54]
IGR J16418-4532	250.462	−45.540	339.189	0.489	1212[55]	3.73886[56]	O8.5[57]	13[57]	cl,abs,P	3.40
IGR J16465-4507	251.647	−45.118	340.053	0.135	228[58]	30.32[59]	B0.5-O9.5Ia[60]	3.8–23.6[61]	cl,P	4.64
IGR J16479-4514	252.027	−45.202	340.163	−0.124	–	3.3193[86]	O8.5Ib[63]	1.1–7.7[63]	SFXT	3.62
IGR J17354-3255	263.854	−32.938	355.447	−0.269	–	8.452[64]	–	–	cl	1.01
XTE J1739-302	264.798	−30.344	358.068	0.445	–	51.47[65]	O8.5Iab(f)[66]	2.3[66]	eSFXT	0.945
IGR J17544-2619	268.605	−26.331	3.236	−0.336	–	4.926[67]	O9Ib[68]	2.1–4.2[69]	eSFXT,P	0.68
SAX J1818.6-1703	274.658	−17.047	14.080	−0.704	–	30.0[70]	B0.5Iab[71]	2.0–2.2[71]	eSFXT	1.31
AX J1820.5-1434	275.125	−14.573	16.473	0.068	152.26[72]	54.0[73]	O9.5-B0Ve[74],	–	?,P	1.29
AX J1841.0-0536	280.252	−5.596	26.764	−0.239	–	6.45[75]	B1Ib[76]	1.7–5.2[76]	SFXT	0.94
AX J1845.0-0433	281.259	−4.565	28.140	−0.660	–	5.7[77]	O9Ia[78]	6.4[79]	SFXT	1.46
IGR J18462-0223	281.553	−2.375	30.223	0.079	997	–	sg(?)	–	?,P	0.4[54]
IGR J18483-0311	282.071	−3.171	29.750	−0.745	(21.05)[80]	18.518[81]	B0.5Ia[82]	3–4	eSFXT,P	4.11
Be systems										
4U 0115+63	19.625	63.746	125.924	1.026	3.61[83]	24.3[83]	B0.2Ve[84]	7[84]	P	125.50
IGR J01363+6610	24.060	66.188	127.447	3.699		160(?)[85]	B1IV-Ve[86]	2.0		15.44
RX J0146.9+6121	26.744	61.351	129.553	−0.785	1400[87]		B1Ve[88]	2.5[89]	P	1.19
IGR J01583+6713	29.577	67.223	129.352	5.188	(469.2?)[90]		B2IVe[90]	4.0[90]	P(?)	0.4[54]
V 0332+53	53.751	53.172	146.052	−2.194	4.375[91]	34.67[91]	O8-9Ve[92]	7.0[92]	P	393.29
4U 0352+309	58.849	31.036	163.084	−17.144	835[93]	250[94]	B0Ve[95]	0.95[95]	P	30.07
RX J0440.9+4431	70.270	44.530	159.858	−1.258	202.5[96]	155[97]	Be[98]	3.3[99]	P	0.95
A 0535+262	84.735	26.324	−178.575	−2.625	103[100]	111.1[101]	B0IIIe[102]	2[102]	P	223.49
IGR J06074+2205	91.861	22.097	188.385	0.814			B0.5Ve[103]	4.5[103]		0.3

Table 1 continued

Source name	RA	DEC	l	b	P_s	P_{orb}	ST	kpc	Type	F_{17-60}
2E 0655.8-0708	104.557	−7.218	−139.871	−1.784	160.7[104]	101.2[105]	O9.7Ve[106]	3.9[107]	P	3.26
GRO J1008-57	152.447	−58.298	−77.018	−1.821	93.6[108]	249.46[109]	B1-B2 Ve[110]	5[111]	P	13.62
3U 1022-55	159.401	−56.801	−74.647	1.496	860[112]		B0 V-IIIe[113]	5[113]	P	8.66
1A 1118-615	170.238	−61.917	292.499	−0.892	405–407[114]	24.0[114]	O9.5IV-Ve[115]	3–7[115]	P	4.75
IGR J11305-6256	172.779	−62.947	293.945	−1.485	–	–	B0IIIe[116]	3[116]		2.58
IGR J11435-6109	176.001	−61.127	294.881	0.686	161.76[117]	52.46[118]	B0Ve/B2Ve[119]	$\gtrsim$6–10[119]	P	2.83
4U 1145-619	177.000	−62.207	−64.389	−0.240	292[120]	187.5[121]	B1Vne[122]	0.5–3.1[123]	P	2.30
GX 304-1	195.322	−61.602	−55.897	1.247	272[124]	132.5[125]	B2 Vne[126]	2.4[127]	P	1.38
2RXP J130159.6-635806	195.495	−63.969	−55.912	−1.121	~700[128]		B0.5Ve[53]	4–7[128]	P	1.79
4U 1416-62	215.303	−62.698	−46.979	−1.598	17.64[129]	42.12[130]	B1Ve[131]	1.4–11[132]	P	0.78
XTE J1543-568	236.011	−56.748	−35.036	−1.450	27.12[133]	75.56[134]	Be(?)		P	10.47
AX J1700.2-4220	255.105	−42.316	343.8034	−0.030	54[135]	44.0[136]			P	1.61
GRO J1750-27	267.300	−26.647	2.368	0.508	4.45[137]	29.806[138]			P	1.23
GS 1843+00	281.404	0.868	33.065	1.694	29.5[139]		B0-B2IV-Ve[140]	≥10[140]	P	3.23
A 1845-024	282.048	−2.426	30.395	−0.404	94.8[141]	241[142]			P	9.66
XTE J1858+034	284.673	3.437	36.820	−0.066	221[143]	380[144]			P	52.68
4U 1901+03	285.917	3.207	37.187	−1.248	2.763[145]	22.58[145]	B0III?[146]		P	80.54
IGR J19294+1816	292.350	18.267	53.441	0.205	12.4[147]	117.2[148]	Be(?)		P	11[149]
XTE J1946+274	296.410	27.366	63.206	1.399	15.8[150]	169.2[151]	B0-1V-IVe[152]	8–10[152]	P	5.38
KS 1947+300	297.397	30.211	66.099	2.092	18.7[153]	40.415[154]	B0Ve[155]	9.5[156]	P	5.56
EXO 2030+375	308.062	37.638	77.153	−1.231	42[157]	46.016[158]	B0 Ve[159]	7.1[160]	P	88.59
SAX J2103.5+4545	315.901	45.753	87.134	−0.681	358.6[161]	12.68[162]	B0Ve[163]	4.5–7[164]	P	9.19
IGR J22534+6243	343.365	62.723	109.875	2.881	46.67[165]		Be[166]		P	0.60

Table 1 continued

Source name	RA	DEC	l	b	P_s	P_{orb}	ST	kpc	Type	F_{17-60}
Giant and main sequence systems										
IGR J00370+6122	9.286	61.386	121.242	−1.468	359[167]	15.663[167]	BN0.5II-III[168]	3.3	P	0.47
1ES 1210-646	183.269	−64.917	−61.143	−2.277		6.7[169]	B2V[170]	2.8[170]		0.83
IGR J21343+4738	323.625	47.614	92.179	−3.147			B3V[170]			1.40
4U 2206+543	331.992	54.513	100.612	−1.102	5559[171]	9.568[172]	O9.5Vp[173]	2.6[173]	P	8.59
Roche-lobe overflow systems										
Cen X-3	170.306	−60.628	−67.905	0.352	4.82[174]	2.087[174]	O6.5II-III[175]	5–8[175]	P	47.58
Gamma-ray loud binaries										
LSI 61 +303	40.090	61.222	135.661	1.069		26.496[176]	B0Ve[175]	2.0[177]		1.22
PSR B1259-63	195.699	−63.836	−55.816	−0.992	0.047[178]	1236.7[179]	B2e[179]	2.3[180]	P	0.82
LS 5039	276.554	−14.861	16.934	−1.192		3.906[181]	O6.5Vf[184]	2.5[183]		0.64
Black-hole systems										
SS 433	287.957	4.979	39.698	−2.235	–	13.1	A3-7	5.5	BH	8.12
Cyg X-1	299.588	35.202	71.342	3.068	–	5.6	O9.7Iab	1.86	BH	845.64
Cyg X-3	308.108	40.959	79.851	0.709	–	0.2	WNe+	11.3	BH	132.21
Unclear types										
IGR 08262-3736	126.557	−37.620	256.438	0.285			OBV[184]		?	0.3[54]
IGR J10101-5654	152.529	−56.914	−77.765	−0.676			sgB[e][53]		?	0.86
AIGR J14331-6112	218.285	−61.261	314.846	−0.764	–	–	BIII/BV[31]	–	?	0.64
IGR J14488-5942	222.180	−59.704	317.234	−0.129	–	49.5(?)[185]	Oe/Be(?)[53]	–	?	0.4[54]
IGR J17200-3116	260.022	−31.294	−4.981	3.343	328.18[186]				P	1.67
AX J1749.1-2733	267.275	−27.550	1.583	0.062	132[187]		B1-3[188]	13–16[188]	?,P	1.19
AX J1749.2-2725	267.292	−27.421	1.701	0.116	217[189]		B3[188]	14[188]	?,P	1.00

Table 1 continued

Source name	RA	DEC	l	b	P_{s}	P_{orb}	ST	kpc	Type	F_{17-60}
IGR J17586-2129	269.654	−21.382	7.997	1.322	–		sgOB[53]	–	?	0.2
IGR J18151-1052	273.790	−10.880	19.111	2.964			OB[190]		CV(?)[191]	0.45
IGR J18179-1621	274.468	−16.359	14.600	−0.219	11.82[193]				?,P	6–12[193]
IGR J19173+0747	289.349	7.785	42.821	−2.172			early BV[194]		?	0.56[195]
SWIFT J2000.6+3210	300.101	32.166	68.986	1.134	1056[47]		BV/BIII[31]	8[31]	?,P	2.15

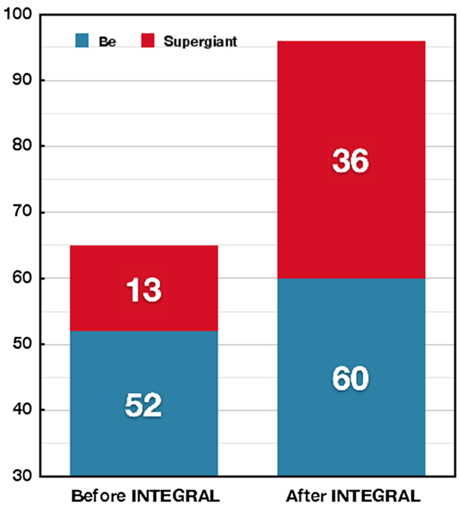
[?] Marginal detection

[1] Wang (2011), [2] Crampton et al. (1985), [3] Reig et al. (1996), [4] Quaintrell et al. (2003), [5] Nagase et al. (1986), [6] White et al. (1980), [7] Ray and Chakrabarty (2002), [8] Densham and Charles (1982), [9] Kaper et al. (2006), [10] Koh et al. (1997), [11] Clark (2000), [12] Clark et al. (1994), [13] Reynolds et al. (1992), [14] Filliatre and Chaty (2004), [15] Lutovinov et al. (2005c), [16] Manousakis and Walter (2012), [17] Rahoui et al. (2008), [18] Bodaghee et al. (2006), [19] Pearlman et al. (2011), [20] Bodaghee et al. 2012a, [21] Pearlman et al. (2013), [22] Nespoli et al. (2010b), [23] White and Pravdo (1979), [24] Mason et al. (2012), [25] Corbet et al. (2010c), [26] Jones et al. (1973), [27] Ankay et al. (2001), [28] Manousakis and Walter (2011), [29] Mason et al. (2009), [30] Mason et al. (2011), [31] Masetti et al. (2008), [32] Torrejón et al. (2010), [33] Corbet et al. (1999b), [34] Corbet and Mukai (2002), [35] Negueruela et al. (2008a), [36] in't Zand et al. (1998b), [37] Nespoli et al. (2008), [38] Morel and Grosdidier (2005), [39] Wen et al. (2000), [40] Morel and Grosdidier (2005), [41] Corbet et al. (2004), [42] Hannikainen et al. (2007), [43] Barba et al. (2006), [44] Leyder et al. (2007), [45] Romano et al. (2009c), [46] Negueruela (2010), [47] Morris et al. (2009) inferred from the fraction of time spent in outburst, [48] Tomsick et al. (2006a), [49] Jain et al. (2011) not confirmed, [50] Negueruela et al. (2007a), [51] Nespoli et al. (2008), [52] Corbet et al. (2010a), [53] Coleiro et al. (2013), [54] Bird et al. (2010) in the 20–40 keV band, [55] Sidoli et al. (2012), [56] Levine et al. (2011), [57] Rahoui et al. (2008), [58] Lutovinov et al. (2005a), [59] Clark et al. (2010), [60] Nespoli et al. (2008); Rahoui et al. (2008), [61] Heras and Walter (2004), [62] Romano et al. (2009b), [63] Nespoli et al. (2008), [64] D'Ai' et al. (2010), [65] Drave et al. (2010), [66] Negueruela et al. (2006a), [67] Clark et al. (2009), [68] Pellizza et al. (2006), [69] Pellizza et al. (2006), [70] Bird et al. (2009), [71] Torrejón et al. (2010), [72] Kinugasa et al. (1998), [73] Segreto et al. (2013), [74] Liu et al. (2006) counterpart could be two blended sources, [75] González-Galán (2014), [76] Nespoli et al. (2008), [77] Goossens et al. (2013), [78] Coe et al. (1996), [79] Coleiro and Chaty (2013), [80] Sguera et al. (2007); Ducci et al. (2013a), [81] Romano et al. (2010b), [82] Rahoui et al. (2008), [83] Rappaport et al. (1978), [84] Negueruela and Okazaki (2001), [85] Corbet and Krimm (2010), [86] Reig et al. (2005b), [87] La Palombara and Mereghetti (2006), [88] Reig (2011), [89] Tapia et al. (1991), [90] Kaur et al. (2008), [91] Zhang et al. (2005), [92] Negueruela et al. (1999), [93] White et al. (1976), [94] Delgado-Martí et al. (2001), [95] Telting et al. (1998), [96] Reig (2011), [97] Tsygankov et al. (2012), [98] Motch et al. (1997), [99] Reig et al. (2005a), [100] Rosenberg et al. (1975), [101] Finger et al. (1996b), [102] Steele et al. (1998), [103] Reig et al. (2010), [104] Morgan et al. (2003), [105] Yan et al. (2012), [106] Pakull et al. (2003), [107] McBride et al. (2006), [108] Stollberg et al. (1993), [109] Kuehnel et al. (2012), [110] Coe et al. (2007), [111] Coe et al. (1994a), [112] Reig (2011),

Table 1 continued

[113] Motch et al. (1997), [114] Staubert et al. (2011), [115] Janot-Pacheco et al. (1981), [116] Masetti et al. (2006a), [117] Revnivtsev et al. (2005), [118] Corbet and Remillard (2005), [119] Negueruela et al. (2007b), [120] White et al. (1978), [121] Watson et al. (1981), [122] Jones et al. (1974), [123] Clark and Dolan (1999); Stevens et al. (1997), [124] Huckle et al. (1977), [125] Priedhorsky and Terrell (1983), [126] Parkes et al. (1980), [127] Parkes et al. (1980), [128] Chernyakova et al. (2005), [129] Kelley et al. (1981), [130] Finger et al. (1996a), [131] Reig (2011), [132] Grindlay et al. (1984), [133] Marshall et al. (2000), [134] in't Zand et al. (2001), [135] Markwardt et al. (2010), [136] Corbet et al. (2010c), [137] Shaw et al. (2009), [138] Shaw et al. (2009), [139] Koyama et al. (1990a), [140] Israel et al. (2001), [141] Makino and GINGA Team (1988a), [142] Zhang et al. (1996), [143] Takeshima et al. (1998), [144] Doroshenko et al. (2008), [145] Galloway et al. (2005), [146] Jones et al. (1974), [147] Rodriguez et al. (2009), [148] Corbet and Krimm (2009), [149] Turler et al. (2009) in the 20–40 keV band, [150] Smith and Takeshima (1998), [151] Wilson et al. (2003), [152] Verrecchia et al. (2002a), [153] Chakrabarty et al. (1995), [154] Galloway et al. (2004), [155] Negueruela et al. (2003), [156] Tsygankov and Lutovinov (2005b), [157] Parmar et al. (1985), [158] Stollberg et al. (1999), [159] Coe et al. (1988), [160] Wilson et al. (2002), [161] Hulleman et al. (1998), [162] Baykal et al. (2000), [163] Reig (2011), [164] Baykal et al. (2007), [165] Halpern (2012a), [166] Lutovinov et al. (2013a), [167] in't Zand et al. (2007), [168] Reig et al. (2005b), [169] Corbet and Mukai (2008), [170] Masetti et al. (2009), [171] Reig et al. (2009), [172] Corbet and Peele (2001), [173] Blay et al. (2006), [174] van der Meer et al. (2007), [175] Day and Tennant (1991), [176] Casares et al. (2005a), [177] Frail and Hjellming (1991), [178] Johnston et al. (1992), [179] Johnston et al. (1994), [180] Negueruela et al. (2011), [181] Casares et al. (2005b), [182] Clark et al. (2001a), [183] Casares et al. (2005b), [184] Masetti et al. (2010b), [185] Corbet et al. (2010b), [186] Nichelli et al. (2011), [187] Karasev et al. (2008), [188] Karasev et al. (2010a), [189] Torii et al. (1998), [190] Burenin et al. (2009), [191] Lutovinov et al. (2012b); Masetti et al. (2013), [192] Halpern (2012b), [193] Bozzo et al. (2012a) in the 20–50 keV band, [194] Masetti et al. (2012b), [195] Pavan et al. (2011) in the 20–40 keV band,

Fig. 4 Number of HMXBs identified as Be or super-giant systems in the Galaxy, before and after the discoveries triggered by the *INTEGRAL* mission



them have been discovered by INTEGRAL (some had been discovered previously but not identified as super-giant systems).

- Cen X-3, the only Roche Lobe Overflow giant system identified in the Galaxy.
- 57 systems have likely a Be stellar companion (32 detected by *INTEGRAL*).
- 3 gamma-ray loud binaries (of Be type as well).
- 3 black-hole systems (2 are super-giant systems).
- 4 giant and main sequence systems (two of them discovered by *INTEGRAL*).
- 12 systems of unclear type, 4 among them have likely a main sequence or giant companion, and their identification is, therefore, more difficult. IGR J10101-5654 is a sgB[e] system which was detected in outburst for two months in 2004 and has been faint otherwise.

The galactic plane observations of *INTEGRAL* had an important impact on our knowledge of super-giant systems. They tripled the number of these systems identified in the Galaxy (Fig. 4) and new types of behaviour were discovered, in particular systems featuring strong and persistent obscuration or high variability and low duty cycles (respectively, 6 and 13 sources). Even while pulsations have not yet been detected in 12 of these systems, their hard X-ray spectra are typical of accreting pulsars. Not a single new high-mass black-hole system has been discovered.

There are about 20,000 O stars in the galaxy and 33 % of them are double systems evolving through envelope stripping (Sana et al. 2012). Assuming that half of these systems will survive the supernova kicks, about one HMXB forms every 1500 years. The larger number of super-giant HMXBs discovered by *INTEGRAL* points to a lifetime of $\sim 10^5$ years for the HXMB phase which may support the enhanced wind and stripped H-burning scenario of Ziolkowski (1977).

There are some additional unidentified *INTEGRAL* sources that have been suggested as HMXB candidates: the X-ray spectra of IGR J18325-0756, IGR J16283-4843 and IGR J18219-1347 show significant absorption; IGR J13186-6257 and XTE J1824-141

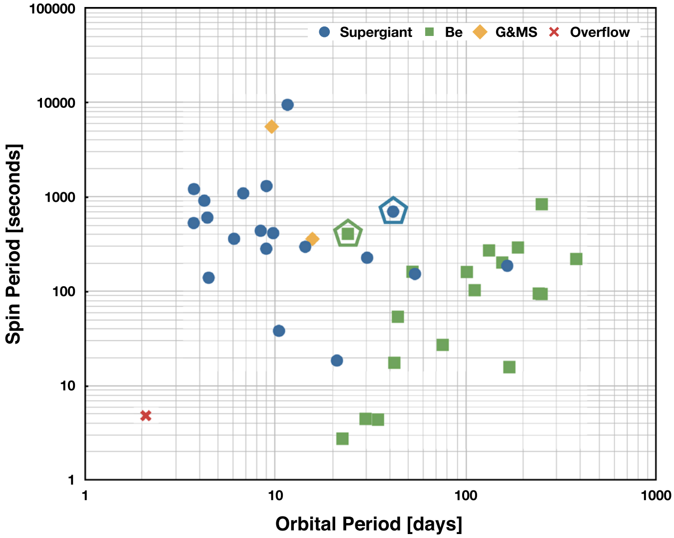


Fig. 5 The Corbet diagram for the systems in our sample of HMXB with both orbital and spin periods available. *Green squares* are Be systems; *blue circles* are super-giant systems; *yellow diamonds* are main sequence systems and the *red cross* is the Roche lobe overflow system Cen X-3. *Pentagons* identify systems discussed in the text

have periods of 20 days and 120 s, respectively. We decided not to include them here as the evidence for high mass companions remains too vague.

2.3 Corbet diagram

The Corbet diagram (Corbet 1984), presenting HMXB as a function of spin and orbital periods, is a powerful tool to understand the nature and the evolution of the systems. Figure 5 displays the members of our catalogue for which both orbital and spin periods are available.

The Be systems (green squares) are well aligned on the usual sequence (Corbet 1984), excepting for the outlier 1A 1118-615 (green pentagon). Staubert et al. (2011) suggested that the long quiescence time between the outbursts of this system could cause the pulsar to spin down to a period characteristic of wind-fed systems.

The super-giant systems (blue circles) have spin periods independent from their orbital periods, as expected for wind accretion. The supergiant with the longest orbital period, IGR J11215-5952 reaches the Be sequence. It features very regular outbursts and it has been suggested to be an evolutionary link with the Be systems (Liu et al. 2011). GX 301-2 (blue pentagon) remains persistently wind-fed by its hypergiant stellar companion, despite its eccentric orbit. The few super-giant fast X-ray transients which cannot be explained as classical systems appear in two groups that will be further discussed in Sect. 3.2: the short orbital period transient systems (for which no spin periods are available) and eccentric systems with orbital periods comparable to that of GX 301-2.

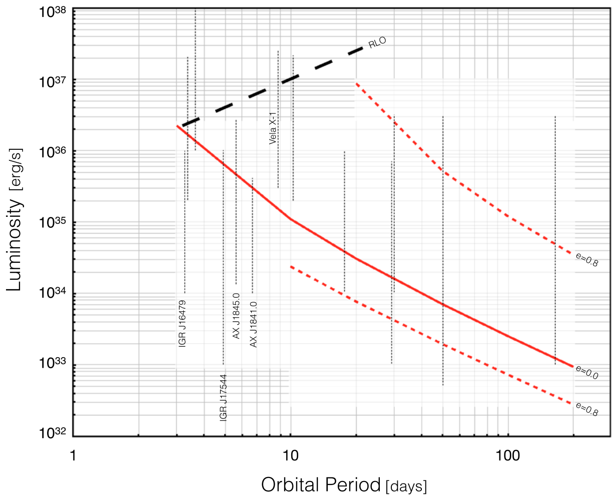


Fig. 6 X-ray luminosity expected from a sgHMXB for a smooth stellar wind ($V_\infty = 10^3$ km/s, $\beta = 0.8$, $\dot{M} = 10^{-6}$ $M_\odot$/year, $M_\star = 20$ $M_\odot$) as a function of the orbital period for eccentricities of 0 (*continuous line*) and 0.8 (*short dashed lines*). *The long dashed line* indicates the Roche-lobe overflow limit. The range of observed variability (minimum and maximum connected by *dotted lines*) is indicated for a number of sources discussed in this review

The few giant and main sequence systems (yellow diamonds), lacking emission lines, are in the wind-fed region of the diagram. The only galactic Roche-lobe overflow system Cen X-3 (red cross) has spun-up to very short period.

2.4 Expected X-ray luminosity of super-giant systems

The X-ray luminosity of an accreting neutron star (i.e. the mass accretion rate) is determined mainly by the density and velocity of the stellar wind near the compact object. Assuming a smooth stellar wind and a mass to luminosity conversion factor of 0.1 mc^2, the range of X-ray luminosities reachable by a system (with a specific companion and wind velocity) depends mostly on the orbital period and eccentricity (see, e.g. Castor et al. 1975; Lamers and Cassinelli 1999; Vink et al. 2000) as schematized in Fig. 6. The main secondary parameter driving the luminosity is the wind velocity. An increase of the terminal velocity by a factor of 3 pushes the red lines in Fig. 6 downwards by a factor of 50 and could explain part of the outlier luminosities.

Persistent systems (i.e. $L_X > 10^{35}$ erg/s) are expected at short orbital periods. Eccentric systems generate variations by factors up to 100 and can appear as transitory. Systems with short orbital periods and reaching low luminosities require a mechanism quenching accretion. Hydrodynamical effects of the neutron star on the stellar wind (Blondin et al. 1991; Manousakis and Walter 2015a) can generate variability by a factor >100. Intrinsic clumping of the stellar wind (Walter and Zurita Heras 2007) or magnetic gating mechanisms (Bozzo et al. 2008b) can have even larger effects.

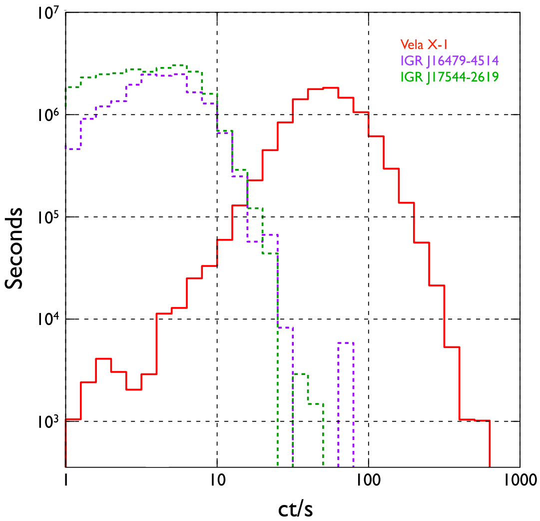


Fig. 7 Histogram of the effective time during which a given count rate is observed for Vela X-1 (*INTEGRAL/ISGRI* 17–80 keV). *Eclipses* have been removed and the distribution has been corrected for the statistical noise. The total exposure time is 11.8 Ms; time bins span from 24 to 720 s depending on the source strength; the average count rate statistical uncertainty is 4 ct/s. The distributions for two bright SFXTs are shown as well

3 Types of high-mass X-ray binaries

3.1 Persistent super-giant systems

INTEGRAL discovered 13 new persistent sgHMXB in addition to the ten classical wind-fed systems previously known in the Galaxy. Six of them, featuring absorbing column densities persistently $\gtrsim 10^{23}$ cm^{-2}, are known as “obscured systems”. The classical systems also display strong absorption close to eclipse but are less absorbed ($N_H \sim 10^{22}$ cm^{-2}) at the inferior conjunction. Obscured and classical systems are very similar and the distinction between them is mostly due to the fact that the former were first identified at hard X-rays. One of the obscured system, IGR J16318-4848, is peculiar and deserves a special category. Note that several SFXTs (see Sect. 3.2) turn out to be classical systems as well.

3.1.1 Classical super-giant systems

Several of the classical sgHXMB are bright enough to allow long and meaningful lightcurves to be obtained at hard X-rays:

- Vela X-1 is the prototype of the classical sgHMXB. It has been observed continuously by *INTEGRAL* with several orbits at high temporal resolution. Its 17–80 keV luminosity (outside of eclipses) varies in the range $(0.6 - 25) \times 10^{36}$ erg/s for an average of 1.4×10^{36} erg/s. The brightest flares are short (down to 0.5 h) and sequences of flares, separated by ~2 h have been observed. The pulsed fraction does not vary significantly during the flares, indicating that the mass inflow rate through the accretion column varies considerably. The flare rate is decreasing smoothly with luminosity (Fig. 7) suggesting that the variability is driven by a single mechanism. Low luminosities are observed during short (fraction of an

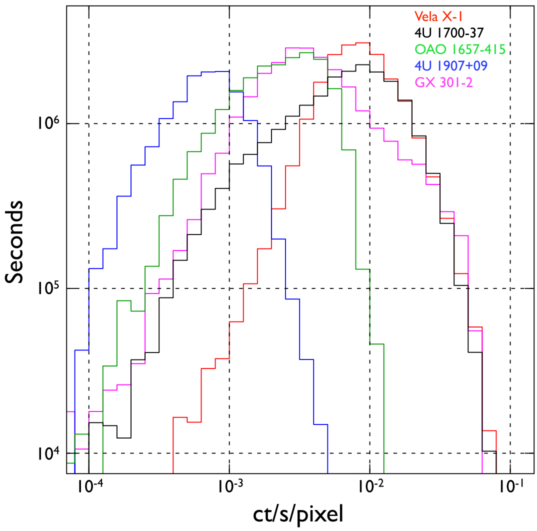


Fig. 8 Histogram of the effective time during which a given count rate is observed for four classical HMXB (*Swift/BAT*). *Eclipses* have been removed. *The right-hand side* of the distribution is much steeper for OAO 1657-415, which is dominated by very long activity periods rather than by narrow spikes as observed in the other sources

hour) periods. Even if they have been named "off-states", accretion goes on but at a reduced rate (during the five off-states presented by Kreykenbohm et al. (2008), the average *INTEGRAL/ISGRI* count rate was 10 ± 0.7 ct/s, i.e. 3×10^{35} erg/s). Figure 7 indicates that the luminosity distribution extends smoothly towards low values before slightly bending up, suggesting that a distinct variability mechanism is required. Suzaku observations confirmed that this bending is indeed related to the "off-states" (Doroshenko et al. 2011).

- 4U 1700-37 is characterised by very short flares (with duration down to 250 s) reaching $\gtrsim 10^{37}$ erg/s. *XMM-Newton* observed it in quiet state at 2×10^{35} erg/s (van der Meer et al. 2005). Its luminosity distribution follows an asymmetric log normal, peaking at 10^{36} erg/s (Fig. 8).
- The variability of OAO 1657-415 (Fig. 8) is shaped as an highly asymmetric log-normal distribution. Periods of enhanced activity are very long (10 to 120 days, i.e. 1–12 orbits) reaching $\gtrsim 10^{37}$ erg/s. Periods of low activity ($\lesssim 2 \times 10^{35}$ erg/s) are also relatively long (several days). The variability is dominated by stellar wind density/velocity variations that extend over the complete orbit ($\sim 2R_\star$) and varies on time scales of months or by low velocity clumps corotating with the neutron star. It is interesting to note that the companion is a peculiar O star, (possibly a Wolf–Rayet), that can generate highly structured winds.
- Figure 8 shows clearly that an additional component is required in GX 301-2 to explain its high flux activity: the dense accretion stream forming close to periastron. Short flares (fraction of an hour) are superimposed. In about half of the orbits long secondary flares can be observed during the less active part of the orbit, indicating that the tidal stream generates a spiral structure.

Short "off-states" have been observed in Vela X-1, GX 301-2 (Göğüş et al. 2011) and 4U1907+09 (Doroshenko et al. 2012a). The "off-states" of 4U1907+09 are particularly frequent ($\gtrsim 20$ % duty cycle) and are missing close to periastron. Figure 8 indicates that classical sgHMXB, such as 4U 1700-37 and OAO 1657-415, features an intense activity at low count rate, similar to that observed in 4U 1907+09, and that Vela X-1 is more rarely is such a state.

Variability amplitude and off-states The variability of the accretion rate by a factor 10–100 in wind-fed systems in circular orbits was successfully explained by hydrodynamical simulations (Blondin et al. 1990). When the system is close to Roche-lobe overflow, the tidal stream further increases the wind density in the direction of the compact object (Blondin et al. 1991), explaining enhanced variability in eccentric systems (such as GX 301-2). Photo-ionisation of the wind by the compact object also generates wind inhomogeneities in the form of additional streams (Blondin 1994) and obscuration at late orbital phases. Large and rapid variations of the mass accretion rate have interesting consequences for the formation of the hard X-ray spectrum that can be probed on short time scales with *NuStar* (Fürst et al. 2014b). A number of explanations was put forward to explain variability factors as large as $\sim 10^3$ in classical sgHMXB and in particular in Vela X-1 (Fig. 8):

- *Wind clumping* Line driven instability can in principle generate huge density variations in the stellar wind of massive stars but the details and the geometry are not yet understood. Besides multiple observational evidence (Bouret et al. 2005; Fullerton et al. 2006; Prinja and Howarth 1986; Lépine and Moffat 1999; Markova et al. 2005; Lupie and Nordsieck 1987; Davies et al. 2007; Cassinelli and Olson 1979; Oskinova et al. 2006), wind clumping is still poorly constrained. If huge density variations can in principle be accounted for by wind clumps (in't Zand 2005; Walter and Zurita Heras 2007), it is unclear if: (i) the density contrasts will propagate to the magnetosphere, (ii) how clumps interplays with the hydrodynamic effects in the wind induced by the presence of the compact object, (iii) if a reasonable clump model can generate the observed luminosity distribution (Fig. 8), and (iv) if clumps are created early enough to influence close binaries (Sundqvist and Owocki 2013).
- *Hydrodynamics* Manousakis and Walter (2015a, b) have included the effect of photo-ionisation on the wind acceleration in the hydrodynamical model of Vela X-1. Even with a very simplified treatment, the model allowed to probe the dynamics of the region surrounding the neutron star and in particular the collision between the primary stellar wind, slowed down by photo-ionisation and flowing outwards and a gas stream flowing inwards from the tidal stream towards the neutron star. A shock front is generated and moves inwards and outwards regularly creating low-density bubbles expanding to $\sim 10^{11}$ cm before crashing on the accretion radius. This "breathing" mechanism generates instantaneous accretion rates 10 times lower than predicted previously, global luminosity variations by a factor of 10^3 and transient modulations with a characteristic time-scale of ~ 6500 s (for the geometry of Vela X-1). Interestingly such transient modulations have been detected in Vela X-1 (Kreykenbohm et al. 2008). The model predicts a luminosity distribution that is slightly too narrow when compared to the observations. The identification of a mechanism that can explain both the observed variability and quasi-periods is, however, encouraging.

  Shakura et al. (2013) have shown that two regimes of subsonic accretion are possible at the boundary of the magnetosphere depending on whether or not the plasma

is cooled by Compton processes (high vs low accretion rate). The different cooling times determine the fall-down velocity, i.e. the accretion rate at the boundary of the magnetosphere. At low luminosity the X-ray photons are directed perpendicular to the neutron star surface, inverse Compton cooling is less efficient and a change of the pulse profile could be observed (Doroshenko et al. 2011). This mechanism increases the luminosity ratio produced by an externally driven mass accretion variability.
  These two mechanisms will work together. The breathing mode that occurs high above the magnetosphere will be amplified by the change of geometry of the accretion column and of the cooling mechanism. The amplification might not be so effective, nor needed, if the seed density variations are strong enough.
- *Magnetic gating* Doroshenko et al. (2011) have investigated the possibility for the variability of Vela X-1 to be generated by Kelvin–Helmholtz instability at the magnetospheric boundary, leading to "magnetic gating" of the accretion (opening and closing the gate) (Bozzo et al. 2008b). The required magnetic field of $(2-10)\times10^{13}$ G can in principle be accommodated if the CRSF would be generated close to the top of the accretion column at high flux level. However, *NuStar* observations (Fürst et al. 2014b) recently revealed that the CRSF harmonic energy is correlated to the X-ray luminosity down to 10^{36} erg/s (this is not the case for the fundamental), which was interpreted with a surface magnetic field of 2×10^{12} G. The spectrum of an off-state of Vela X-1, presented in the same paper, did not show any CRSF possibly pointing to a higher magnetic field, but the relatively low signal to noise obtained is not yet conclusive.

The X-ray variability of classical sgHMXB systems is complex but most of the behaviour seems to be reproducible by hydrodynamical effects (even if this has not been done effectively for all systems). It is not obvious that additional physical mechanisms such are clumping or magnetic gating are required to explain the observations. OAO 1657-415 features variability on very long ($\gg P_{\mathrm{orb}}$) time scales that can only be related to global wind structures but these variations have not been studied in detail so far.

3.1.2 Obscured super-giant systems

The five super-giant HMXBs featuring persistently high obscuration ($\gtrsim10^{23}$ cm^{-2}) harbour pulsars orbiting in 3.7–9.7 days around O8-B1 companions. In three of them (IGR J16393-4611, IGR J16418-4532, IGR J18027-2016), the orbital periods are very short (<4.4 days) and the pulsars orbit close to the surface of their companion stars. Two classical sgHXMB have similarly short periods:

- 4U1700-37: *EXOSAT* spectra obtained along the orbit have shown a phase-dependent absorbing column density with a minimum $\sim0.5\times10^{23}$ cm^{-2} (Haberl et al. 1989). High Fe Kα equivalent width and important scattered and soft X-ray excess emission (van der Meer et al. 2005) indicate that the absorbing column density was underestimated. A minimum value of $\sim2\times10^{23}$ cm^{-2} was reported, matching our definition for an obscured source.

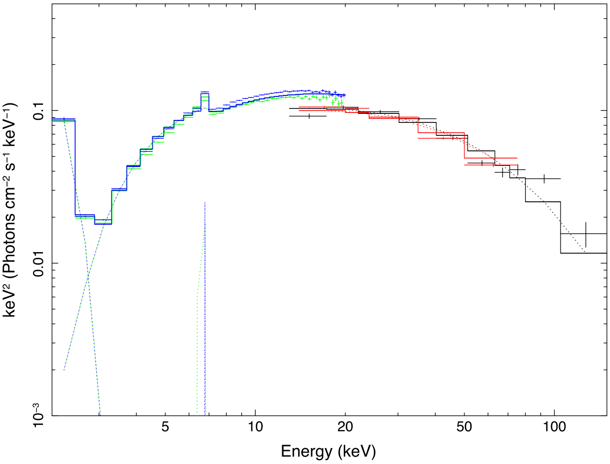


Fig. 9 *RXTE PCA, INTEGRAL/ISGRI* and *Swift/BAT* spectra of 4U 1909+07 fitted with an absorbed cutoff power law plus Fe Kα and soft X-ray excess

- 4U 1909+07: A low absorption was reported but the spectrum is fairly complex showing an Iron Kα line and a soft X-ray excess. The value of the absorbing column density in this object is not settled but the combined spectrum built from *RXTE, INTEGRAL* and *BAT* data are reasonably represented with $N_H \sim 1.3 \times 10^{23}$ cm^{-2} and an Fe Kα equivalent width of 100 eV (Fig. 9).

It is, therefore, plausible to assume that all persistent systems with $P_{\text{orb}} < 5$ days become obscured and are in transition towards Roche lobe overflow. As a matter of fact they all have $L \gtrsim 10^{36}$ erg/s with IGR J16418-4532 reaching up to 10^{38} erg/s (see also Sect. 3.2). The two remaining obscured systems have longer orbital periods ($\approx$10 days) and other explanations have been found for their obscuration:

- EXO 1722-363: Comparison of observations with hydrodynamic simulations indicate that the large absorbing column density and its variability with orbital phase can be understood if the wind terminal velocity is low and if the neutron star is massive enough ($>1.8\ M_\odot$) to strongly perturb the stellar wind (Manousakis et al. 2012).
- IGR J16320-4751: The absorbing column density is pretty constant at $\approx 10^{23}$ cm^{-2} (the exact value is model dependent; Rodriguez et al. 2006) along the orbit and increased to 5×10^{23} cm^{-2} at one occasion (Zurita-Heras et al. 2009). The infrared reddening towards IGR J16320-4751 is exceptional and significantly larger than what can be expected from the 21-cm measurements (Chaty et al. 2008). This indicates the presence of large amount of dust in the vicinity of the source that can explain a fraction of the constant X-ray obscuration. IGR J16320-4751 might well be a classical system obscured by the environment and not by intrinsic processes.

Obscured sgHMXBs can, therefore, be understood as classical systems in transition to Roche lobe overflow or with relatively low-velocity winds. As the neutron stars can cut off wind acceleration via ionisation (Stevens and Kallman 1990), the wind can be slower in binaries than in isolated stars. For instance GX 301-2, 4U 1907+09 and EXO 1722-363 feature high absorbing column densities and low wind terminal velocities of 500, 1000 and 600 km/s (Kaper et al. 2006; Kostka and Leahy 2010; Manousakis et al. 2012). Even the companion of Vela X-1 has a wind terminal velocity less than what would be expected from its high luminosity (Kudritzki and Puls 2000). Once the companion is close to overflowing its Roche lobe, deep spiral-in is unavoidable (van den Heuvel and De Loore 1973) and results in a Common Envelope phase (Taam et al. 1978).

Obscured systems account for ∼20 % of the persistent sgHMXBs detected at hard X-rays. This suggests that the systems remain, on average, for about 20,000 years close to Roche lobe overflow.

3.1.3 *IGR J16318-4848*

IGR J16318-4848, the most obscured persistent sgHMXB, is almost Compton thick with an absorbing column density varying in the range $(1.2-2.2) \times 10^{24}$ cm^{-2} (de Plaa et al. 2003; Ibarra et al. 2007). The X-ray absorption is much larger than that of the infrared counterpart (Revnivtsev et al. 2003). Walter et al. (2003) and Barragán et al. (2009) did not find any significant Fe Kα Compton shoulder indicating that the absorbing column density averaged isotropically is several times lower than observed on the line of sight. IGR J16318-4848 has been detected continuously with *INTEGRAL/ISGRI* and *Swift/BAT* for more than 10 years. During this period, the hard X-ray luminosity, averaged over two months or over a year, has shown variability by a factor of only three, respectively two, around an average value of 10^{35} erg/s. This corresponds to the typical behaviour of a classical system with a close to circular orbit and excludes scenarios involving a high eccentricity or a Be system. Flares and low flux states reaching 100 mCrab and <2 mCrab, respectively, are observed on time scales of some days very regularly. No period is detected.

Walter et al. (2006) suggested that the compact object is orbiting within the dense equatorial outflow of its B[e] super-giant companion. The thickness of the disk was evaluated as ∼0.7 R_* (Chaty and Rahoui 2012) and densities $>10^{13}$ cm^{-3} are mentioned in such disks (Levesque et al. 2014), which would correspond to a Hydrogen column density through the disk of $\sim 10^{24}$ cm^{-2}. If this interpretation is correct the inclination angle of the system on the line of sight should be ∼15° to explain the absence of a Compton shoulder. Such a geometry does not generate any eclipse if the orbital period is $\gtrsim$40 days. Thanks to the high-density wind, the accretion rate on the compact object remains large enough even far away from the companion star. The variability is probably related to hydrodynamic instabilities that the compact object will not fail to be produce. The fate of IGR J16318-4848 is unclear. Chaty and Rahoui (2012) estimated the size of the infrared emitting disk to ∼70 R_*. If the compact object orbits in the external regions of that disk, the system may end up in a BH/NS binary (Taam and Sandquist 2000).

3.2 Super-giant fast X-ray transients

Super-giant fast X-ray transients (SFXTs) were identified as a new class of sources in 2005 (Sguera et al. 2005; Negueruela et al. 2006b) thanks to the long-term monitoring program of the Galactic plane carried out with *INTEGRAL*. These hard X-ray transients produce short and bright flares with typical durations of a few hours and peak fluxes of few tens to hundred mCrab (in the energy band ∼20–100 keV). Given the short and sporadic nature of these events, the large field of view of the *IBIS/ISGRI* imager on-boad *INTEGRAL* proved to be particularly well suited to search for SFXT sources (Sguera et al. 2006; Walter and Zurita Heras 2007). So far, about 15 objects have been identified among the SFXTs (Falanga et al. 2011). Outside the short bright events, these sources are hardly detectable with *INTEGRAL*. Their average persistent X-ray flux is a factor of $\sim 10^2$–10^5 lower than the one at the peak of the bright flares. This is much below the sensitivity level of any presently available large FoV X-ray instrument and thus deep pointed observations with focusing high sensitivity X-ray telescopes are required to study their persistent emission (e.g. *XMM-Newton, Chandra, Suzaku, Swift/XRT*; Romano et al. 2009b; Sidoli et al. 2008; Romano et al. 2010c; Bozzo et al. 2010; Sidoli et al. 2010; Bodaghee et al. 2011; Bozzo et al. 2012b; Sidoli et al. 2013).

Since 2005, SFTXs have been monitored regularly in the X-rays and a relatively large effort was devoted to perform observations of these sources in different energy domains, spanning from the far IR to γ-rays (Walter 2007) and up to the very high energies (∼GeV; Sguera et al. 2009, 2011). It was soon understood that all SFXT systems were hosting a compact object accreting from the wind of a massive companion, typically a super-giant O-B star (Tomsick et al. 2006a, 2008, 2009a; Chaty et al. 2008; Masetti et al. 2008; Negueruela et al. 2008b; Chaty 2010; Bodaghee et al. 2012a). SFXTs were thus classified as a subclass of wind-accreting super-giant X-ray binaries. Accurate spectroscopic classifications of super-giant stars in SFXTs made it possible to establish in a few cases the mass and radius of the star, together with its wind properties (i.e. mass loss rate and terminal velocity; see, e.g. Rahoui et al. 2008 and references therein). The detection of X-ray pulsations in a few sources, with periods ranging from few up to thousand seconds, led to the conclusion that compact objects in SFXTs should be relatively young neutron stars, with magnetic field (at least) as high as 10^{11}–10^{12} G (Grebenev and Sunyaev 2007; Bozzo et al. 2008b; Sguera et al. 2010). In several SFXTs, long-term observations carried out with *INTEGRAL* and *Swift* also permitted to measure their orbital periods. Reported values span from 3.3 up to 57 days, the only exception being the source IGR J11215-5952 with an orbital period of ∼168 days (see Table 1). The similarity between sgHMXBs and SFXTs in terms of constituent stars and orbital properties makes it difficult to understand the peculiar behaviour displayed by the latter in the X-ray domain (Bozzo et al. 2013).

A large number of X-ray flares has been recorded so far from the SFXTs and thus the flaring state of these sources is known in fairly good detail (see, e.g. Romano et al. 2013, for recent reviews). *INTEGRAL* and *Swift* observations permitted to carry out broad band spectral analysis of these events and it is now established that flares can occur at different luminosity levels, spanning from a few times 10^{35} to 10^{37} erg/s.

The brightest flares (peaking at $>10^{36}$ erg/s) are sometimes called "outbursts" to distinguish them from the lower luminosity events. In four sources flares and outbursts showed evidence of clustering at preferred orbital phases. In the other sources they have been detected at any time during the neutron star revolution around the companion.

The spectral model generally used to fit X-ray spectra of the flares is an absorbed cutoff power-law (e.g. Romano et al. 2011a). The measured parameters are on average very similar to those observed in other classes of young accreting X-ray pulsars: (i) the absorption column density is higher than the Galactic value in the direction of the source due to locally distributed dense material from the stellar wind; (ii) the power-law photon index ranges from 0.5 to 2.0; (iii) the cutoff energy (if any) is between 10 and 30 keV (Sidoli et al. 2009b, c; Ducci et al. 2010). Some flares are accompanied by remarkable increases in the absorption column density, indicative of possible local enhancement in the accreting material around the compact object. Many flares, however, do not show such a feature and are accompanied by relatively modest variations (if any) in the spectral photon index. Thermal spectral components during SFXT flares are rare, at odds with other classes of highly accreting neutron stars. So far, the best examples are these of IGR J08408-4503 (Sidoli et al. 2009a) and AX J1845.0-0433 (Zurita Heras and Walter 2009), where prominent black-body spectra were observed with temperature and emission radius comparable to those expected for a hot spot on the neutron star surface, similar to what is detected in other classes of accreting X-ray pulsars. Long-term observations with wide field instruments also permitted to accurately investigate the duty cycle of SFXTs. The general finding is that these sources spend only a small fraction of their time ($\lesssim$5–10 %) in the flaring states (i.e. at luminosities $\gtrsim 10^{35}$ erg/s; Paizis and Sidoli 2014) and on-average display a much lower persistent luminosity that ranges from 10^{32} (very low state) to 10^{34} erg/s (intermediate state).

In contrast with the flaring state, the intermediate and the very low luminosity states of the SFXTs are still poorly known. In these states, the low X-ray luminosity of the SFXTs implies that deep pointed observations lasting several tens of ks (typically about 10–30 ks with *XMM-Newton*) are required to measure accurately the spectral properties and investigate their time variability with sufficient accuracy. Such long integration times challenge our understanding of processes occurring on the most relevant time scales that are comparable to dynamical processes occurring close to the neutron stare magnetosphere and typically range from a few to hundred seconds. These observations are usually also limited in time to a maximum total exposure time of $\ll$100 ks per source, and they can only probe a relatively small fraction of the neutron star orbit around the companion. The picture that was achieved so far of the low emission states of SFXTs thus remains fragmented.

A XMM-Newton observation of IGR J16479-4514 revealed in 2008 that part of the X-ray variability of this source was due to an extended X-ray eclipse, lasting about 0.6 day (Bozzo et al. 2008c). X-ray eclipses were later discovered in IGR J16418-4532 (Drave et al. 2013) and possibly in IGR J16207-5129 and IGR J17354-3255 (Bodaghee et al. 2010; Ducci et al. 2013b). *XMM-Newton* and *Suzaku* observations of

XTE J1739-302, IGR J17544-2619, IGR J16328-4726 and IGR J08408-4503 revealed the presence of pronounced X-ray variability also during "quiescence". This variability comprises small flares that occur on the same time scales as the brightest outbursts but reaches peak luminosities that are a factor of 10^2–10^3 lower. Some of these flares are also accompanied by modest changes in the spectral slope and/or in the value of the local absorption. X-ray dips have been observed in two sources (Bozzo et al. 2012b; Drave et al. 2013). Due to the relatively low statistics of the corresponding data, their nature is still debated but they seem to have a different origin with respect to dips usually observed in low mass X-ray binaries. The latter are usually ascribed to the presence of geometrically thick material on the rim of the accretion disk surrounding the neutron star (Kuulkers et al. 1998). Soft spectral components, dominating the X-ray emission at energies $\lesssim$2 keV, have been detected in SFXTs much more often in quiescence than during flaring states (Zurita Heras and Chaty 2009; Bozzo et al. 2010; Sidoli 2010). In the case of XTE J1739-302 and AX J1845.0-0433 these components have been mainly ascribed to the reprocessing of the X-ray emission from the neutron star by the surrounding wind material (Hickox et al. 2004), but in the case of IGR J08408-4503 it was argued that the soft X-ray emission could have been produced within the super-giant wind itself. The temperature and luminosity of this component resembled, indeed, that of close-by isolated super-giant stars (see, e.g. the case of ζ-Puppis; Nazé et al. 2012 and references therein). If confirmed, this would suggest that accretion during the lowest luminosity periods displayed by some SFXTs might be strongly inhibited: X-ray observations of SFXTs in these states could then be used to directly probe the properties of their super-giant companions' wind.

Interesting spectral and timing behaviours have thus been revealed from "quiescent" SFXTs (i.e. outside the flaring states), but it is not clear yet if such phenomena occur in all sources or if they are peculiar of a few specific systems. As we argue later in this section, the latter seems so far the most reliable conclusion and thus SFXTs might need to be divided in a number of sub-classes.

Early models proposed to interpret the peculiar X-ray variability of the SFXTs ascribed the fast flaring behaviour to the presence of very pronounced eccentricities coupled with inhomogeneous super-giant winds (Negueruela et al. 2008b; Chaty 2010). This hypothesis was severely challenged already in 2009 when short orbital periods were measured in a few SFXTs (e.g. IGR J16479-4514 and IGR J17544-2619). As these systems display similar properties as those with much longer orbital periods (e.g. XTE J1739-302; Drave et al. 2010), it is unlikely that the separation between the neutron star and the companion is playing a central role in triggering the SFXT variability. In analogy with classical HMXBs, different possibilities have been considered to explain the SFXT behaviour, including large inhomogeneities in the wind ("clumps"), magnetic/centrifugal gates due to the magnetic field and rotation of the neutron star and hydrodynamical effects. At odds with the classical HMXBs, all these possibilities require extreme values of the involved parameters to match the SFXT dynamical range in the X-ray luminosity. The orbital characteristics of these sources mostly affect the way in which different effects combine to give rise to the pronounced variability (see Sect. 4). We summarized in Table 2 the most relevant properties of all known confirmed and can-

Table 2 Super-giant fast X-ray transient candidates: variability of the hard X-ray luminosity and orbital parameters

Source name	P_{orb} (days)	e	$L_{10\,\mathrm{keV}}$ (10^{35} erg/s)	Remark
Classic-like systems				
IGR J16418-4532	3.7	–	10–1000	Short flares, obscured, variations similar to these of Vela X-1
IGR J17354-3255	8.4	–	2–20	The variability amplitude is less than a factor 100, excepting a deep minimum at a specific orbital phase, that could be an eclipse
IGR J16207-5129	10	–	0.6–5	Low variability amplitude
IGR J16328-4726	10	–	0.8–8	Low variability amplitude, only a few flares detected. A distance of 5 kpc was assumed
AX J16195-4945	16	–	0.5–3	Low variability amplitude, flares are short, quiescent state at $L \approx 0.1$
IGR J16465-4507	30	–	0.1–7	Low variability amplitude
IGR J11215-5952	168	Large	0.01–30	Flares are long (days) and occur at periastron. Similar to GX 301-2
Fast transients reaching anomalously low luminosities				
IGR J16479-4514	3.3	–	0.1–6	Flares are short (h) and frequent (∼week)
IGR J17544-2619	5	–	0.1–30	Flares are clustered in orbital phase, rare low states with $L < 0.01$ have been reported
AX J18410-0536	6.4	–	0.1–10	Flares are short (h)
AX J18450-0433	5.7	<0.4	0.1–15	Flares are short and frequent (∼weeks)
Eccentric transients				
IGR J18483-0311	18	0.4	0.6–10	Flares are short and clustered in orbital phase. The luminosity far from periastron is ∼0.1
SAX J18186-1703	30	0.4	0.01–30	Flares are short and clustered in orbital phase. $L < 0.001$ has been measured once at apastron, an outlier value
XTE J1739-302	51	<0.8	0.07–30	Flares are short and frequent, not clustered in orbital phase. Minimum luminosity ∼0.005
Unclear systems				
IGR J08408-4503		–	0.03–50	Flares are short, very rare (∼year) and structured
IGR J18462-0223		–	0.04–3	Flares are short and very rare
AX J18205-1434	54	–	0.2–2	Low variability amplitude, unknown distance, possibly not a super-giant

The smallest luminosity given is an average value, lower instantaneous values are observed. The maximum luminosity corresponds to the peak of a flare

didate SFXT sources. By taking advantage of all information published in the past ∼10 years on these sources, we organised the SFXTs in the four sub-groups listed below.

1. *Classic-like systems:*

These are variable systems behaving very much like classical sgHMXB:

- IGR J16418-4532 is the most distant SFXT and the only one persistently detected above 10^{36} erg/s and reaching the Eddington luminosity during flares. This suggests that the system is close to Roche lobe overflow (Sidoli et al. 2012). The absence of strong orbital modulation indicates that its transient nature is likely related either to some hydrodynamic properties of the accretion stream (Manousakis et al. 2012) and/or that a temporary accretion disk might form around the neutron star (see also Ducci et al. 2010, and references therein). The range of luminosity is similar to that observed in Vela X-1.
- The five sources IGR J17354-3255, IGR J16207-5129, IGR J16328-4726, AX J16195-4945 and IGR J16465-4507, with intermediate orbital periods, feature a low variability amplitude with flares reaching a flux a few tens of times the average source level. The hard X-ray luminosities are in the range 10^{35-36} erg/s. These characteristics are comparable to those of some classical sgHMHB.
- The source IGR J11215-5952 is the only one displaying a long period of activity at periastron, most likely related to its anomalously large orbit and eccentricity (for an HMXB). The duration of the pronounced activity at periastron is much shorter than that usually observed from Be-systems, thus suggesting that accretion is never mediated through a stable accretion disk. The variability properties of IGR J11215-5952 more likely resemble those of GX 301-2, a classical sgHMXBs displaying a remarkably peaked X-ray activity around periastron.

2. *Fast transients reaching anomalously low luminosities:*

The four sources IGR J16479-4514, IGR J17544-2619, AX J18410-0536 and AX J18450-0433 display short orbital periods and large variability with average and minimal luminosities ($\lesssim 10^{34}$ erg/s) and typical flare luminosities $\gtrsim 10$ times lower (see Fig. 7) than expected in classical systems with such orbits (Oskinova et al. 2012).

- IGR J16479-4514: Sidoli et al. (2013) analysed a Suzaku observation covering an almost complete orbit of the system. Apart from the eclipse-related variability, the luminosity remained at a level of $\sim 10^{34}$ erg/s with a variability less than a factor of 10. Flares at two specific orbital phases and an $N_H \approx 10^{23}$ cm^{-2} suggest the presence of accretion streams comparable to these found in obscured systems. Flares up to a level of 10^{36} erg/s were detected by *Swift/XRT* (La Parola et al. 2010b) while the source remained below 10^{34} erg/s for 20 % of the time (Romano et al. 2014a). Note that the distance to the source is uncertain and that the luminosities quoted above could be significantly larger. No spin period is available.
- IGR J17544-2619: Drave et al. (2014) and Romano et al. (2014a) observed that its X-ray luminosity varies mostly in the range 10^{33-35} erg/s with some flares reaching few 10^{36} erg/s. The source activity shows a clear peak at periastron, reminiscent of the building up of a tidal stream, and a minimum at apastron. The average source luminosity of 10^{34} erg/s is well below the expectation for such a short orbital period. The detection of a CRSF indicating a magnetic field of 10^{12} G (Bhalerao et al. 2015) speaks against magnetic gating.

- AX J1845.0-0433: Zurita Heras and Walter (2009) caught an outburst of the source with XMM-Newton and concluded that it was likely related to the accretion of a clump with a mass of $\sim 10^{22}$ g. The flare spectrum was steep and included a soft component with an absorption corrected luminosity (0.2–10 keV) of 10^{36} erg/s (and $\approx 10^{35}$ erg/s at hard X-rays). The spectra observed by *INTEGRAL/ISGRI* and *Swift/BAT* averaged over the missions are 10 times fainter. The X-ray lightcurves indicate that the source can shut down in a few minutes, corresponding to the free fall time at the accretion radius. A minimum luminosity of 0.5×10^{34} erg/s (0.7–10 keV) was reported by Yamauchi et al. (1995). No spin period is available.
- AX J1841.0-0536: Bozzo et al. (2011b) studied an outburst of the source well-sampled by XMM-Newton. A luminosity of the source (1–10 keV) was $\approx 4 \times 10^{32}$ erg/s in quiescence and reached $\approx 4 \times 10^{35}$ at the flare peak. The flare characteristics, in particular the evolution of the absorption, could be well explained by the ingestion of a wind clump with a mass of $\sim 10^{22}$ g. *Suzaku* detected a similar flare and a quiescent luminosity of 10^{34} erg/s (1–10 keV; Kawabata Nobukawa et al. 2012). The source is found to be 28 % of the time below a luminosity of 10^{34} erg/s by *Swift/XRT* (Romano et al. 2014a). An average luminosity (20–100 keV) of $\sim 10^{34}$ erg/s can be derived from *ISGRI* and *BAT* data. No spin period is available.

The behaviour of this sub-class of SFXT systems could be related to abnormal low mass-loss rates, high wind velocities or gating mechanisms (Bozzo et al. 2013). The flares with a duration of a few hours are probably frequent ($\sim P_{\mathrm{orb}}$) but not that often detected (in particular in AX J18410-0536, where the hard X-ray flares are at the limit of sensitivity, but for which a flare was detected by chance when observed by *XMM-Newton*).

3. *Eccentric transients:*

The three sources IGR J18483-0311, SAX J18186-1703 and XTE J1739-302 display large X-ray variability and short flares clustered at a specific orbital phase. The maximum luminosities reach few 10^{36} erg/s. The minimum (and average) luminosities detected decrease with the orbital period. The range of luminosities observed are not far from those expected by orbital modulation, if the intrinsic variability observed in classical systems is taken into account (Fig. 6). Note that the minimum observed in SAX J18186-1703 was detected only once and could be an outlier (Bozzo et al. 2008a; Zurita Heras and Chaty 2009).

4. *Unclear systems:*

The last three sources IGR J08408-4503, IGR J18462-0233 and AX J18205-1434 are difficult to categorize, mostly because of a lack of good observations. IGR J08408-4503 and IGR J18462-0233 have unknown orbital periods and only a few flares were observed. Their average luminosities are very low, which may indicate eccentric orbits. AX J18205-1434 could be an eccentric classical sgHMXB; however, the high-mass nature of its companion was not firmly established yet.

According to our classification above, it appears that the SFXT class comprises seven systems with variability properties relatively similar to classical sgHMXBs (one in Roche-lobe overflow) and seven more extreme fast transients. The main peculiar property of the latter group is not the luminosity of the flares, but rather their low persistent luminosity which is on average much lower than expected when compared to classical systems. As we discuss further in Sect. 4, the spread in the properties of winds from super-giant stars and their intrinsic inhomogeneity can be invoked to interpret reasonably well the X-ray variability of the "classic-like systems".

For the "fast transients reaching anomalously low luminosities", featuring short orbital periods, additional mechanisms are required to explain their behaviour in the X-ray domain. As the average luminosity of these systems is significantly lower than expected (i.e. when comparing with classical systems with similar orbital periods), the additional mechanisms need to account for a substantial reduction of the mass accretion rate along the orbit of the compact object. In Sect. 4 we show that efficient "gating" mechanisms to inhibit the accretion onto the compact objects can be realized by taking into account the neutron star rotation and magnetic field. The need for gating mechanisms in the "eccentric transients" is somehow less critical than in the previous subclass, as the eccentric and elongated orbits of these systems also contribute to enhance their dynamic range in the X-ray luminosity and decrease its average value over each orbital revolution.

3.3 Be systems, X-ray pulsars and properties of cyclotron absorption lines

Binary systems with Be stars as secondaries constitute a substantial part of all HMXBs. By definition, Be stars are non super-giant B-type stars that have shown emission lines in their spectra, originating from a circumstellar disk expelled by a rapidly rotating star (Porter and Rivinius 2003). A majority of these systems are transient sources exhibiting two type of outbursts. Type I outbursts are caused by the enhanced mass accretion rate close to periastron, last for 0.2–0.3 $P_{\rm orb}$ and peak to $\sim 10^{37}$ erg s^{-1}. The rare type II outbursts, reaching the Eddington luminosity, can last for several orbital periods and are probably related to events of stellar activity that may finally lead to the disappearance of the circumstellar disc.

Observing transient X-ray pulsars in bright outburst is essential to understand the physical processes at play close to the neutron star surface and in particular the response of the "neutron star–magnetosphere" system to the variability of the mass accretion rate on different time scales.

As Reig (2011) wrote a detailed review of the observational properties of Be systems and related models, we are concentrating here only on some recent results obtained at hard X-rays.

Thanks to the number of wide field of view X-ray telescopes operating during the past decade (*RXTE/ASM*, *Swift*, *INTEGRAL*, *MAXI*), practically all major Be outbursts in this period could be detected and 8 new galactic BeXBs were discovered increasing the sample of these sources to 60; before INTEGRAL's launch this number was 52 (Liu et al. 2006).

The Be nature was confidently established for six of the newly discovered sources. Five systems feature pulsations with periods ranging from 12 to $\sim$700 s (IGR J01583+6713, IGR J11435-6109, IGR J13020-6359, IGR J19294+1816, IGR

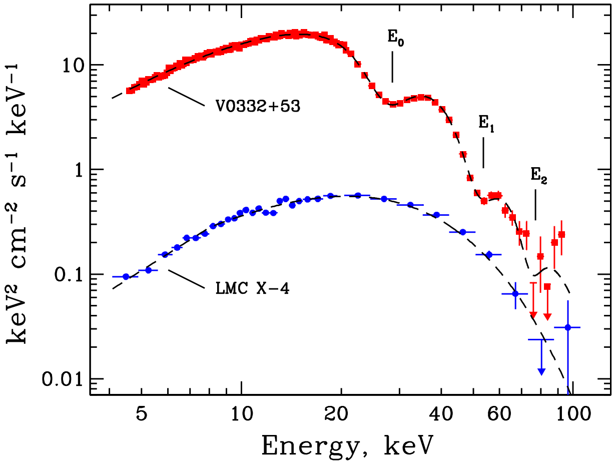


Fig. 10 Energy spectra of two X-ray pulsars: V 0332+53 (*red squares*) with three harmonics of the cyclotron absorption line and LMC X-4 (*blue circles*) without such a feature (*INTEGRAL* data)

J22534+6243) and orbital periods have been determined for four systems (IGR J01363+6610, IGR J11305-6256, IGR J11435-6109, IGR J19294+1816). More details on these systems can be found in Table 1.

INTEGRAL was able to promptly observe dozens of bright type I and type II outbursts. As a result, comprehensive studies of spectral and timing properties of these transients were performed in a wide energy band for different time scales and source luminosities. In particular new CRSFs were discovered in the spectra of several X-ray pulsars (e.g. RX J0440.9+4431, EXO 2030+375, see Table 3).

Broad CRSF features are detected in a subset of the accreting X-ray pulsars. The first CRSF was detected in the spectrum of the X-ray pulsar Her X-1 (Truemper et al. 1978), a low-mass X-ray binary. By now cyclotron absorption lines were detected in the spectra of more than two dozens accreting pulsars. In four of them higher harmonics (up to the fifth!) were detected as well. Typical spectra detected by *INTEGRAL* for X-ray pulsars are shown on Fig. 10 for V 0332+53 (Tsygankov et al. 2006), which includes a CRSF with two higher harmonics, and LMC X-4 (Tsygankov and Lutovinov 2005a) which does not.

The list of X-ray pulsars with confirmed cyclotron absorption lines in their spectra is presented in Table 3. Many CRSF were discovered with data from *Ginga* and *RXTE*. *INTEGRAL* contributed to new detections and to detailed studies of known lines thanks to its large effective area and high sensitivity in the energy range where most of CRSFs are located (10–70 keV).

The emission spectra of X-ray pulsars are usually approximated by phenomenological power law models modified by an exponential cutoff at energies above 15–30 keV (White et al. 1983). Physical spectral models (see, e.g. Nagel 1981; Meszaros and Nagel 1985; Becker and Wolff 2005, 2007) were constructed only for specific configurations of the emitting regions and are not able to explain in a self-consistent manner the variety of the observations.

Table 3 List of X-ray pulsars with known cyclotron lines

Source name	Cyclotron energy (keV)
4U 0115+63	11.5[1], 20.1[2,*], 33.6[3,*], 49.5[4,*], 53[5,*]
V 0332+53	28[6], 53[6,*], 74[7,*]
4U 0352+309 (X Per)	29[8]
RX J0440.9+4431	32[9]
RX J0520.5-6932	31.5[10]
A 0535+262	50[11], 110[12,*]
MXB 0656-072	36[13]
Vela X-1	27[14],54[14,*]
GRO J1008-57	88[15,?], 75.5[16]
1A 1118-61	55[17]
Cen X-3	28[18]
GX 301-2	37[19], 48[20]
GX 304-1	50.8[21]
4U 1538-52	20[22], 47[23,*]
Swift J1626.6-5156	10[24]
4U 1626-67	37[25]
Her X-1	42[26]
OAO 1657-415	36[27]
GRO J1744-28	4.7[28]
IGR J18179-1621	21[29]
GS 1843+00	20[30]
4U 1907+09	19[31],40[32,*]
4U 1909+07	44[33,?]
XTE J1946+274	36[34]
KS 1947+300	12.5[35]
EXO 2030+375	11[36,?], 36[37,?], 63[38,?]
Cep X-4	30[39]

[*] Higher harmonics

[?] Marginal detection

[1] White et al. (1983), [2] Wheaton et al. (1979), [3] Heindl et al. (1999), [4] Santangelo et al. (1999), [5] Ferrigno et al. (2009), [6] Makishima et al. (1990), [7] Coburn et al. (2005), [8] Coburn et al. (2001), [9] Tsygankov et al. (2012), [10] Tendulkar et al. (2014), [11] Kendziorra et al. (1994), [12] Grove et al. (1995), [13] Heindl et al. (2003), [14] Kendziorra et al. (1992), [15] Shrader et al. (1999), [16] Yamamoto et al. (2013), [17] Doroshenko et al. (2010b), [18] Nagase et al. (1992); Santangelo et al. (1998), [19] Makishima and Mihara (1992), [20] Filippova et al. (2005), [21] Mihara et al. (2010), [22] Clark et al. (1990), [23] Rodes-Roca et al. (2009), [24] DeCesar et al. (2013), [25] Orlandini et al. (1998), [26] Truemper et al. (1978), [27] Orlandini et al. (1999), [28] D'Aì et al. (2015), [29] Tuerler et al. (2012), [30] Mihara (1995), [31] Makishima and Mihara (1992), [32] Cusumano et al. (1998), [33] Jaisawal et al. (2013), [34] Heindl et al. (2001), [35] Fürst et al. (2014a), [36] Wilson et al. (2008), [37] Reig and Coe (1999), [38] Klochkov et al. (2008), [39] Mihara et al. (1991)

The interaction of the radiation with the accreted matter in strong magnetic and gravitational fields is a complex problem. A number of authors attempted to simulate the shape of the continuum and CRSFs as a function of the pulse phase, source luminosity, geometry of the emission regions, etc (see, e.g. Araya and Harding 1999; Araya-Góchez and Harding 2000; Schönherr et al. 2007; Harding and Lai 2006; Nishimura 2008 and references therein).

The comparison of the model predictions with the observations, however, still fails to provide strong constrains on the physical parameters of the accretion regions due both to the limitations of the present-day hard X-ray telescopes and the complexity of the models.

An important result of *INTEGRAL* is the discovery of an anti-correlation between the cyclotron energy and the X-ray luminosity in the transient X-ray pulsars V 0332+53 (Tsygankov et al. 2006; Mowlavi et al. 2006) and 4U 0115+63 (Nakajima et al. 2006; Tsygankov et al. 2007; but see Müller et al. 2013; Boldin et al. 2013 for the influence of the continuum spectral shape). This result initiated a systematic study of the cyclotron energy properties as a function of the source luminosity.

This behaviour was interpreted with a change of the geometry of the accretion column, which is rising above the neutron star surface at luminosities higher than the critical one (Basko and Sunyaev 1976; Mushtukov et al. 2015). Nishimura (2008, 2014) modelled the cyclotron line by the sum of the contributions emerging from individual line-forming regions along the accretion column with different magnetic field strength, temperature and density. An increase of the mass accretion rate causes the emergence of additional line-forming regions with lower magnetic fields that lead to a decrease of the cyclotron energy.

Another recent model (Poutanen et al. 2013) suggests that a significant part of the accretion column radiation is intercepted and reflected by the neutron star surface because of relativistic beaming. Variations of the accretion column height lead to a shift of the illuminated part of the neutron star surface toward the equator where the magnetic field is weaker. This naturally causes the observed anti-correlation of the cyclotron line energy with luminosity. Moreover, this model is able to explain the amplitude of the cyclotron energy variability which is smaller than would otherwise be anticipated for the corresponding luminosity changes.

Further observations of X-ray pulsars during bright outbursts are needed to discriminate between the models.

For low-luminosity sources an opposite behaviour of the cyclotron energy with the luminosity has been observed (Staubert et al. 2007; Yamamoto et al. 2011; Klochkov et al. 2012). This has been explained by a squeeze of the emitting region towards the neutron star surface (where the magnetic field is higher) triggered by the ram pressure of the in-falling matter (Staubert et al. 2007).

The measurements of the cyclotron line energy as a function of luminosity are presented in Fig. 11 for the sources with known positive and negative correlations (shown by blue and red points, respectively). Finally, it is worth to note that for some transient pulsars no dependence of the cyclotron energy on luminosity has been detected for a wide range of luminosities (see, e.g. Caballero et al. 2013, for A 0535+26).

Apart from the transient BeXBs, Reig and Roche (1999) pointed out the existence of persistent sources of the same Be/X type, but with low luminosities ($10^{34}-10^{35}$ erg/s). Such objects are usually characterised by wide ($P_{\rm orb} \gtrsim 200$ days) and low-eccentricity ($e \lesssim 0.2$) orbits, suggesting small natal kick (Pfahl et al. 2002), and by thermal excesses with a temperature of about $kT \simeq 1$ keV for a small emission region ($R < 0.5$ km).

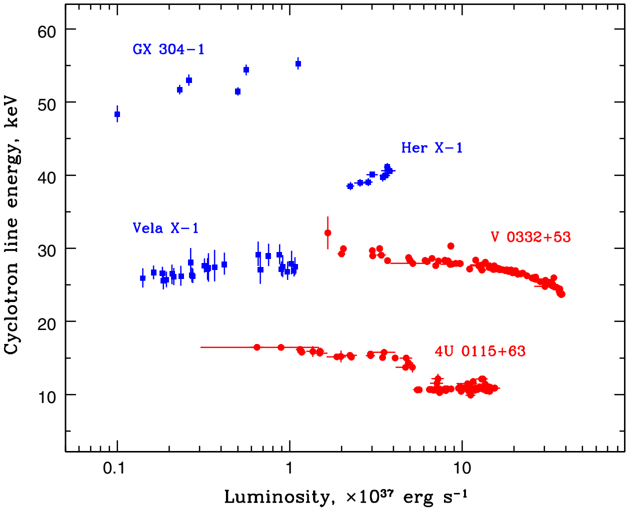


Fig. 11 Cyclotron line energy dependence on the luminosity for the X-ray pulsars V 0332+53 (from Tsygankov et al. 2010), 4U 0115+63 (from Tsygankov et al. 2007), GX 304-1 (from Klochkov et al. 2012), Her X-1 (from Staubert et al. 2007) and Vela X-1 (the energy of the first harmonic divided by two is used; from Fürst et al. 2014b). Sources with positive and negative correlations of the cyclotron line energy with luminosity are shown by *blue* and *red points*, respectively

INTEGRAL detected very hard spectra in some of these systems. In particular, X Persei and RX J0440.9+4431 were detected significantly up to ∼160 keV (Doroshenko et al. 2012b; Lutovinov et al. 2012a) and ∼120 keV (Tsygankov et al. 2012), respectively. Broadband spectra of both sources are shown in Fig. 12 for illustration. Both cyclotron absorption lines and hard X-ray emission can be clearly seen.

4 Wind accretion: a chaotic process

4.1 Slick winds

In the simplest approximation, the wind of a massive star is considered to be spherically symmetric and its properties are described by the so-called "CAK" model (from the initials of its three inventors; Castor et al. 1975). This model predicts that symmetric and homogeneous winds stream outward from the stars as their atmospheres are not in hydrostatic equilibrium and gravity is overcome by gas and radiation pressure. The latter is generated by the high luminosity of the star, reaching $\sim 10^6\ \mathrm{L}_\odot$ in super-giants. The absorption of radiation in spectral lines provides the means to transfer energy and momentum to the out-flowing material and thus accelerates the wind up to velocities of $v_\infty \simeq 1000{-}3000$ km/s, following a β-law (Lamers and Cassinelli 1999):

$$v_w = v_\infty (1 - R_0/r)^\beta, , \tag{1}$$

where $R_0 = R_*[1 - (v_0/v_\infty)^{1/\beta}]$, R_* is the radius of the super-giant star, $v_0/v_\infty \simeq 0.01$ and v_∞ is the terminal wind velocity. Typical mass loss rates carried away by these fast winds are in the range $\dot{M}_w \simeq 10^{-7}{-}10^{-5}\ \mathrm{M}_\odot$/year.

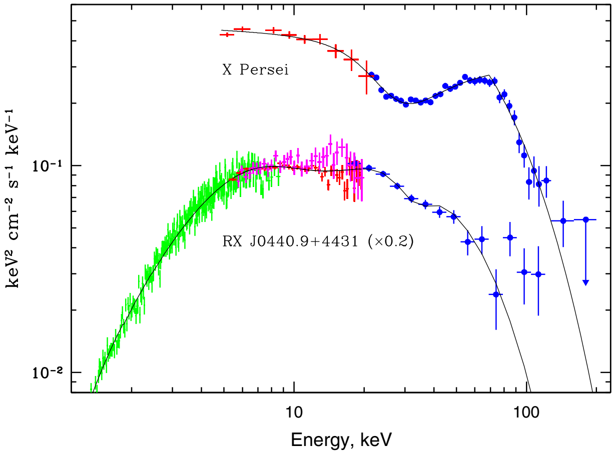


Fig. 12 Broadband energy spectra of X Persei and RX J0440.9+4431 obtained with *JEM-X* (*red crosses*) and *IBIS* (*blue circles*) on board *INTEGRAL*, *RXTE/PCA* (*magenta crosses*) and *Swift/XRT* (*green crosses*). Broad cyclotron absorption lines $\simeq$30 keV and the hard X-ray emission above 100 keV are clearly visible in both sources. The spectrum of RX J0440.9+4431 is multiplied by a coefficient 0.2 for clarity

According to the classical wind accretion scenario, the wind material flowing at supersonic velocities from the super-giant companion is shocked at a certain distance from the neutron star and then freely falls toward the surface of the compact object where it is accreted (see, e.g. Frank et al. 1992 and references therein). The distance of the (bow-) shock from the NS is usually termed the "accretion radius" and can be estimated as

$$R_{\mathrm{acc}} = 2GM_{\mathrm{NS}}/v_{\mathrm{rel}}^2 \simeq 2GM_{\mathrm{NS}}/v_w^2 = 3.7 \times 10^{10} v_8^{-2} \text{ cm}. \tag{2}$$

In the above equation we neglected the NS orbital velocity and approximated $v_w \sim v_\infty$ (v_8 corresponds v_∞ in units of 10^8 cm/s). A NS mass of 1.4 $\mathrm{M}_\odot$ is considered throughout this section. R_{acc} also defines the typical NS cross-section with respect to the wind material flowing around and thus determines the effective fraction of the mass lost from the super-giant that the NS is able to capture at any time. If we assume as a first-order approximation that the wind from the super-giant star is spherically symmetric, then we can express the mass loss rate at a distance r from the star as $\dot{M}_w = 4\pi\rho_w(a)a^2 v_w$ and the NS mass capture rate as $\dot{M}_{\mathrm{acc}} = \pi\rho_w(a)R_{\mathrm{acc}}^2 v_w$, where a is the orbital separation between the NS and its companion. It is thus clear that only a tiny fraction of the total mass loss rate from the super-giant star can be effectively accreted onto the NS:

$$\frac{\dot{M}_{\mathrm{acc}}}{\dot{M}_w} \simeq \frac{1}{4}\left(\frac{R_{\mathrm{acc}}}{a}\right)^2 \sim 2 \times 10^{-5} v_8^{-4} a_{10\mathrm{d}}^{-2}. \tag{3}$$

We have assumed in the equation above a circular orbit a binary orbital period of 10 days and a total mass for the two stars of 30 $\mathrm{M}_\odot$, i.e.

$$a = 4.2 \times 10^{12} P_{10\mathrm{d}}^{2/3} M_{30}^{1/3} = 4.2 \times 10^{12} a_{10\mathrm{d}}. \tag{4}$$

The accretion of all the captured material onto the neutron star gives rise to a total X-ray luminosity of

$$L_X = \frac{G M_{\mathrm{NS}} \dot{M}_{\mathrm{acc}}}{R_{\mathrm{NS}}} \simeq 2 \times 10^{35} \dot{M}_{-6} a_{10\mathrm{d}}^{-2} v_8^{-4}, \tag{5}$$

where $\dot{M}_{-6}$ is the super-giant mass loss rate in units of 10^{-6} $\mathrm{M}_\odot$ year^{-1}. This regime, in which all the mass captured by the NS is accreted onto its surface, is usually called "direct accretion regime".

Despite the initial success of the CAK model and the smooth wind accretion scenario described above (Vink et al. 2000), observational results proved in the past few years that these calculations are oversimplified as massive star winds are inherently inhomogeneous and the inhomogeneities play an important role in the accretion process.

4.2 Take the rough with the smooth

The most direct evidence for the presence of inhomogeneities in stellar winds is provided by the detection of peculiar features in the spectra of Wolf–Rayet and O-stars (Eversberg et al. 1998; Lépine and Moffat 1999). Linear stability analyses already proved in the early 80s (Lucy and White 1980) that line-driven winds are unstable for velocity perturbations. During the non-linear growth of the instability, high-speed material steepens into strong reverse shocks that compress most of the wind mass into finite dense "clumps" and leave the surroundings filled up with a lower density medium (Owocki et al. 1988). Initial 1D hydrodynamic simulations showed that clumps merge and grow in size while moving away from the stellar surface, leading to large variations in the local density (up to 4 orders of magnitude) and velocity (a factor of few). In these simulations, collisions between clumps were also shown to be able to produce a remarkable amount of X-rays (Feldmeier 1995; Feldmeier et al. 1997; Cohen et al. 2010; Oskinova et al. 2011, 2012; Leutenegger et al. 2013). 2D hydrodynamical simulations later questioned the formation of large clumps, as in the multi-dimensional approach these structures are disrupted by the thin-shell and Rayleigh–Taylor instabilities (Dessart and Owocki 2002, 2003, 2005). At present, a general agreement on the formation and characteristics of the clumps is still missing (Puls et al. 2008; Sundqvist et al. 2012; Šurlan et al. 2013).

The debate on the clump properties intensified in the early 2000s due to the suggestion that the enhanced density of these structures could be the main driver of the pronounced X-ray variability displayed by many high mass X-ray binaries. Starting from the initial investigations presented by Sako et al. (2003), several studies adopted this interpretation and used detailed X-ray timing and spectroscopic observations of classical super-giant HMXBs to infer the properties of clumps (i.e. mass, density, size and velocity). The effect of clumps on the high-energy emission from these sources is twofold. Clumps simply passing in front of the X-ray source cause source dimming or even obscuration and display the signatures of photoelectric absorption. In addition to these phenomena, clumps that lead to increased accretion also give rise to large variations of the X-ray luminosity (qualitatively speaking, the instantaneous mass accretion rate onto the NS is proportional to the density of the surrounding wind material) and thus the encounter with a clump can lead to an immediate increase of the X-ray luminosity by a factor of $\sim$10–100 for a few thousand seconds; see Eq. 5). Under these assumptions, the masses (radii) of clumps derived from the currently available X-ray data would be in the range $10^{18}-10^{20}$ g ($10^{10}-10^{11}$ cm), in agreement with what is expected from simulations and observations of isolated super-giant stars (Kreykenbohm et al. 2008). Fürst et al. (2010) analysed in details a long INTEGRAL data-set of Vela X-1 and showed that the X-ray count-rate recorded from this source typically follows a log-normal distribution. They demonstrated through a MonteCarlo approach that such differential distribution would be expected in case wind accretion onto a neutron star occurs from a highly-structured clumpy medium. A similar result was found for a number of other classical sgHMXBs by exploiting the usage of cumulative luminosity distributions (Paizis and Sidoli 2014). These studies thus seemed to provide a strong support in favour of clumps being the key ingredient triggering the X-ray variability displayed by classical sgHMXBs.

This conclusion is challenged by new hydrodynamic simulations of accreting neutron stars in sgHXMBs (Manousakis and Walter 2015a), in which the required level of X-ray variability in Vela X-1 is reproduced by assuming only smooth winds and including the development of hydrodynamic instabilities and the effects of photo-ionisation to modulate the mass accretion rate onto the compact object. The collision between the primary stellar wind, slowed by photo-ionisation and flowing outwards and a gas stream flowing inwards from the tidal stream generates a shock front that moves inwards and outwards regularly creating transient low-density bubbles. This "breathing" mechanism generates instantaneous accretion rates 10 times lower than predicted previously, log normal luminosity distributions with variations by a factor of 10^3 and transient modulations. The identification of a mechanism that can explain both the observed variability amplitude and distribution and quasi-periods is encouraging. Log normal distributions are the signature of a self-organised criticality. In our case the criticality condition is the angular momentum of the shock front discussed above which could alternatively lead or trail the neutron star.

When an accretion stream can develop in a classical system, the hydrodynamical effects of the neutron star are strong enough to explain the observed variability. An important question that is currently under investigation is whether intrinsically clumped winds would survive and have significant additional effect when compared to these of the neutron star. The observability through absorption of the presence of strong tidal streams matching the results of simulations based on CAK winds (Manousakis et al. 2012) indicate that line driven instability plays a minor role in forming the global structure of the wind close to the surface of the star.

In 2005, the discovery of the super-giant fast X-ray transients (SFXT) opened new questions regarding physical processes at work during wind accretion onto NSs. As reported in Sect. 3.2, the SFXTs are far from being a homogeneous class of sources and thus we shall discuss them separately.

For the SFXTs that we classified as relatively similar to "classical systems", the observed variabilities are not larger than these observed in Vela X-1 (or GX 301-2, in the case of IGR J11215-5952 that has a very eccentric orbit). The X-ray dynamic range in these sources could tentatively be associated with hydrodynamically generated small-scale inhomogeneities. The additional variability observed in “eccentric transients” can be accommodated for by the variation of the wind density along the orbit.

For the four SFXTs that we classified as “fast transients” the above explanations are not viable and other mechanisms have to be invoked. In these four systems, the compact objects orbit close to their companions and should generate tidal streams but feature anomalously low luminosities ($<10^{34}$ erg/s) in quiescence. Despite the uncertainties still affecting our knowledge of the mass loss rates from OB super-giants (Puls et al. 2008; Vink et al. 2000), Eq. 5 shows that sgHMXBs with periods of 4–5 days should have typically an average luminosity of $\gtrsim 10^{36}$ erg s^{-1}. The flares, therefore, roughly reach the luminosities expected on average for smooth winds but the minimal luminosities are much too low (Romano et al. 2014b), suggesting a mechanism quenching accretion most of the time rather than generating inhomogeneities. The wind clump scenario (Walter and Zurita Heras 2007) can perhaps explain density ratios up to 10^{3-5} (Runacres and Owocki 2005) between the clump and inter-clump medium. Such density contrasts are, however, predicted relatively far from the surface ($\sim 10R_*$) of the companion and low and large densities are expected i.e. flares and low states. This is not matching the observations.

4.3 Magnetic gating

Grebenev and Sunyaev (2007) and Bozzo et al. (2008c) proposed that such inhibition of accretion can occur due to centrifugal and/or magnetic gates related to the pulsar magnetic field and rotation. It is known since the early 70s that direct accretion onto a magnetized neuron star can occur only if the rotation of the compact object is slow enough to allow its magnetospheric boundary R_m to reside within the so-called corotation radius:

$$R_{\rm co} = 3.7 \times 10^9 P_{s2}^{2/3} \text{ cm} \tag{6}$$

(here P_{s2} is the NS spin period in units of 100 s). $R_{\rm co}$ represents the distance from the NS at which a particle attached to its corotating magnetic field lines would reach a velocity comparable with the local Keplerian velocity; the condition $R_m < R_{\rm co}$ thus ensures that the accreting flow is not pushed outward (rather than accreted) by the rapidly rotating compact object. In case of wind accretion, the NS magnetospheric boundary R_m can be roughly estimated by equating the magnetic to the free-fall pressure of the accreting material:

$$R_m = 3.3 \times 10^9 \dot{M}_{-6}^{-1/6} a_{10\rm d}^{1/3} v_8^{-1/6} \mu_{30}^{1/3}. \tag{7}$$

Here, $\mu = B_{\rm NS} R_{\rm NS}^3$ is the neutron star magnetic moment and $\mu_{30} = \mu/(10^{30})$ G cm^3, for typical parameters (i.e. $R_{\rm NS} = 10^6$ cm and $B_{\rm NS} = 10^{12}$ G). By using Eqs. (6) and (7), we thus conclude that direct accretion cannot occur in case of (i) strongly magnetized ($\mu_{30} \gg 1$) and/or rapidly rotating ($P_{s2} \ll 1$) NSs, (ii) very slow wind velocities ($v_8 \ll 1$) and/or low mass accretion rates ($\dot{M}_{-6} \ll 1$). When $R_m \gtrsim R_{\rm co}$, the centrifugal gate closes and the so-called "propeller" regime sets-in (Illarionov and Sunyaev 1975), inhibiting a large fraction of the accretion. A precise estimate of the expected drop in the mass accretion rate is difficult to be provided, due to the occurrence of numerous physical processes and instabilities that cannot be taken into account in a simplified theoretical calculation. More sophisticated multi-dimensional simulations of the propeller regime have been carried out in the past years, supporting the above findings. However, these simulations could not include yet all relevant 3D magneto-hydrodynamic instabilities that dramatically affect plasma entry into the NS magnetosphere and thus the mass accretion rate (see, e.g. Toropin et al. 1999; Romanova et al. 2003 and references therein).

Accretion can also be inhibited by invoking a magnetic, rather than a centrifugal barrier. The magnetic barrier sets-in when $R_m \gtrsim R_{\rm acc}$. In this condition, the inflowing material from the super-giant star cannot be gravitationally focused toward the compact object and it gets deflected away (rather than accreted) by the NS magnetosphere. For typical parameters, the expected drop in the mass accretion rate compared to the direct accretion regime can be as large as a factor of $\gtrsim$100. By using the Eqs. 2 and 7, the condition $R_m \gtrsim R_{\rm acc}$ can be written as

$$\dot{M}_{-6} \lesssim 4.5 \times 10^{-7} \mu_{30}^2 a_{10\rm d}^2 v_8^{11}. \tag{8}$$

It can thus be easily deduced that the magnetic gating requires strong NS magnetic fields ($B \gg 10^{12}$ G) to be applicable in the SFXT case.

The magnetic and centrifugal gates can also operate simultaneously when both the conditions $R_m \gtrsim R_{\rm co}$ and $R_m \gtrsim R_{\rm acc}$ are satisfied. As $R_{\rm acc} \sim 10^{10}$ cm for typical parameters, the latter case is realized only when the corotation radius is also of the same order, i.e. in case of NS endowed with long spin periods ($\gtrsim$1000 s, see Eq. 6). If both magnetic and centrifugal gates are at work together, the lowest X-ray luminosity regime can be achieved with a total drop in the mass accretion rate by a factor of 10^4-10^5. Gating models thus suggest that the peculiar X-ray variability of the SFXTs could be related to different values of the magnetic field and spin period of the NS hosted in these systems compared to classical sgHMXBs. In particular, the longer spin periods and more intense magnetic fields of the SFXTs could permit to achieve easily a dynamic range in the X-ray luminosity of 10^4-10^5, by assuming only the presence of moderately dense clumps in the wind of the super-giant star.

Even though large magnetic fields are not always required for the gating models to be applicable to the SFXTs, the recent discovery of a possible cyclotron line at $\sim$17 keV in the X-ray spectrum of one of the most highly variable SFXTs raised questions on the possibility of having very strongly magnetized NSs in these sources (Bhalerao et al. 2015). Such spectral feature would, indeed, indicate a NS magnetic field as low as $\sim 10^{12}$ G.

4.4 Cooling switch

A different mechanism to halt the mass accretion flow in sgHMXBs and SFXTs was proposed by Shakura et al. (2012). These authors developed in details the previously proposed idea of the so-called "subsonic accretion regime" (Davies and Pringle 1981; Ikhsanov 2007). According to Elsner and Lamb (1977), the wind material halted at R_{acc} is able to fall freely and accrete at the rate indicated by Eq. (3) only if it can be rapidly cooled below a critical temperature. The latter is determined by the operating condition of the Rayleigh–Taylor instability (RTI), the main mechanism allowing material to penetrate the NS magnetosphere and to get accreted onto the surface of the compact object. The wind material at the accretion radius is cooled by Compton scattering with lower energy photons produced close to the neutron star as a consequence of the on-going accretion. Shakura et al. (2012) demonstrated that systems endowed with an X-ray luminosity $\lesssim 4 \times 10^{36}$ erg s^{-1} cannot cool rapidly enough the material at R_{acc}, and thus a hot envelope is formed around the NS in which the radial velocity of the inflowing material is significantly lower than the free-fall value. In these conditions, material can be cooled down sufficiently for the RTI to operate only close to the inner magnetospheric boundary R_m, and detailed calculations show that the reduced mass accretion rate corresponds to roughly 30 % of the value given in Eq. (3).

In sources with even lower X-ray luminosities ($\ll 10^{36}$ erg/s), Compton cooling is not efficient enough to cool material located even in the closest proximity of the NS magnetospheric boundary and the system enters a radiatively (bremsstrahlung) cooling regime. In this case, only $\lesssim 10$ % of the mass flow rate given by the Eq. (3) is allowed to penetrate the NS magnetosphere and be accreted onto the surface of the compact object. On the one hand, Shakura et al. (2013) suggested that a switch from the Compton to the radiatively cooling dominated settling regime could be invoked to explain the off-states displayed by several sgHMXBs (see also Sect. 3.1.1). Such switch would be caused by the change from the fan to the pencil-beam emission typically observed in young accreting X-ray pulsars at luminosities $\lesssim 10^{36}$ erg/s. Indeed, due to geometrical constraints, the pencil-beamed emission cannot illuminate sufficiently the inner boundary of the NS magnetosphere with the X-rays emitted from the compact objects, thus largely inhibiting the RTI and leading to the onset of the radiatively dominated settling accretion regime. On the other hand, Shakura et al. (2014) also suggested that a similar mechanism could be responsible for the peculiar X-ray variability displayed by the SFXTs. As these sources are typically characterised by an average X-ray luminosity $\lesssim 10^{34}$ erg/s, the authors proposed that SFXTs are in the radiatively dominated regime for most of the time. According to this interpretation, the bright SFXT flares/outbursts would correspond to peculiar episodes of enhanced accretion during which the hot envelope around the NS magnetospheric boundary collapses and is accreted at once onto the NS. In their model, the collapse is induced by sporadic reconnections between rare magnetized clumps (transporting both the radial and tangential components of the super-giant star magnetic field) and the NS magnetic field lines close to R_m.

Although Shakura et al. (2014) showed that the accretion of the entire mass contained in the hot envelope would produce the required amount of X-rays to explain the emission recorded during SFXT flares/outbursts, the model still fails to explain why SFXTs should be characterised a priori by a lower averaged mass accretion rate than all other sgHMXBs. If no gating mechanism is at work to maintain an accretion rate low enough to sustain the formation of a hot envelope around the NS, the only remaining alternative to explain the low average luminosity of the SFXTs would be that their super-giant stars have systematically faster and/or less dense winds compared to other OB super-giants in classical sgHMXBs. This hypothesis seems, however, unlikely given the fact that the spectroscopic classifications of OB super-giants in SFXTs and classical sgHMXBs show no systematic differences (Bozzo et al. 2013).

5 Populations of HMXBs

The properties of individual X-ray binaries in nearby galaxies have been studied for more than a decade, in particular after the launch of the *Chandra* X-ray observatory (see, e.g. Trudolyubov et al. 2001; Pence et al. 2001; Kong 2003; Swartz et al. 2003). This requires to establish the nature of all X-ray sources, which remains difficult as the spatial resolution of *Chandra* and of the *Hubble Space Telescope* are not sufficient to unambiguously identify the counterparts and the nature of most sources. Therefore indirect methods, such as the construction of X-ray luminosity functions (LF), are needed to study of properties of populations of sources located in different regions of a galaxy (see, e.g. Gilfanov 2004; Mineo et al. 2012a).

Observing our Galaxy and, for some aspects, the Large and Small Magellanic Clouds is, therefore, necessary to study the global properties of X-ray binaries. As it is impossible to track the evolution of individual sources, it is necessary to investigate the full population of X-ray binaries to understand their evolution, including its dependence on the companion mass or on the binary parameters. Catalogue of sources, collected with many different instruments (e.g. Liu et al. 2006), are also not well suited for statistical and physical studies of populations because of their non-uniformity.

A systematic survey of the Galaxy with *INTEGRAL* at hard X-ray energies ($>$17 keV) with a moderate angular resolution ($\sim 12'$) allowed for the first time to overcome these difficulties and to obtain a virtually unbiased list of X-ray binaries in the Milky Way with an unprecedented sensitivity of $\simeq 3 \times 10^{-12}$ erg/s cm^2. An image of the inner ($|l| \lesssim 80°$) Galactic plane obtained by *INTEGRAL* is shown in Fig. 1.

5.1 Distribution of HMXBs and its correlation with the spiral structure

High-mass X-ray binaries are a young galactic population and cannot migrate far from their birthplace, tracing regions of enhanced stellar formation. A spatial correlation between HMXBs and spiral arms was clearly established by Grimm et al. (2002), using data from *RXTE/ASM*.

As *INTEGRAL* observed the complete galactic plane and discovered many new high-mass X-ray binaries, several studies of their distribution were published (Lutovinov et al. 2005a, 2007; Dean et al. 2005; Bodaghee et al. 2007, 2012c; Coleiro and Chaty 2013).

The distributions of HMXBs and LMXBs along the Galactic plane are shown in Fig. 13. The overwhelming majority of the low-mass X-ray binaries is located in the Galactic bulge, while high-mass X-ray binaries are concentrated in the spiral arms. The HMXB distribution differs from a uniform or LMXB one with a probability $>$99.9 % (Lutovinov et al. 2005a, 2007).

A detailed comparison of the HMXBs distribution with the spiral structure shows that the correlation is not exact. In particular, the maxima of the HMXB angular

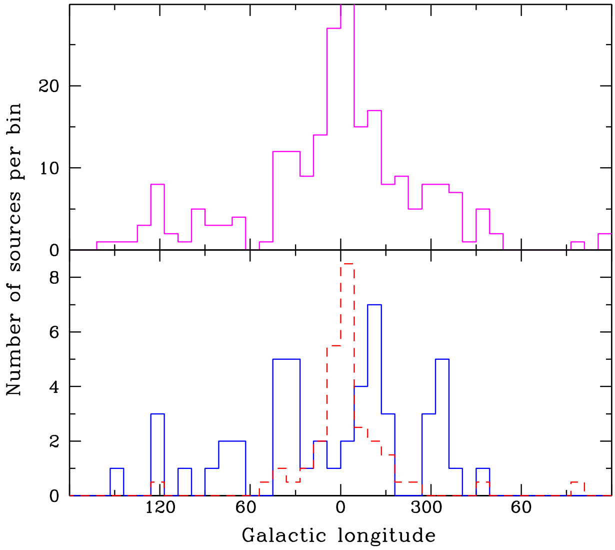


Fig. 13 Distributions along the Galactic plane of all X-ray sources detected by *INTEGRAL* at low galactic latitude ($|b| < 5°$, *top*) and of high-mass (*dark blue solid histogram*) and low-mass (*red dashed histogram*; divided by two) X-ray binary systems (*bottom*)

distribution do not coincide with the tangents to the spiral arms. Although the distances of the majority of the systems and, therefore, their exact positions with respect to the spiral arms are uncertain, it has been argued that the displacement of the HMXB distribution when compared to the spiral arms is real and corresponds to a delay of several of $\sim 10^7$ years expected between the star formation and their appearance as bright X-ray sources.

Several observations support this interpretation. Galactic molecular clouds with very intensive star formation feature many young hot stars, but no high-mass X-ray binary systems (see, e.g. Feigelson et al. 2003; Nakajima et al. 2003). A small displacement between the massive X-ray binary systems and the position of the spiral arms was also detected in M83 (see Fig. 17 from Soria and Wu 2003). Moreover, Shtykovskiy and Gilfanov (2005a) have shown, that the population of HMXBs does not correlate with the current regions of stellar formation in the LMC and found that they could be connected assuming an interval which can be estimated as $\simeq(1-2) \times 10^7$ years.

The spiral waves of the Galaxy (see, e.g. Lin et al. 1969) rotate with angular velocities varying between $\Omega \sim 20-60$ rad/Gyr, in the outer and inner galactic regions, respectively (Bissantz et al. 2003). The inner part of the spiral galactic structure is probably corotating with the stars up to a distance of ~3.4 kpc, corresponding approximately to the inner extremity of the Norma arm.

During the lifetime of massive stars and stars of average masses whose evolution can lead to the formation of HMXBs (see, e.g. Tutukov and Yungelson 1973, 1993; Massevitch et al. 1976), the position of the spiral arms will change considerably with respect to the stars, and their tangent directions appear displaced with respect to the

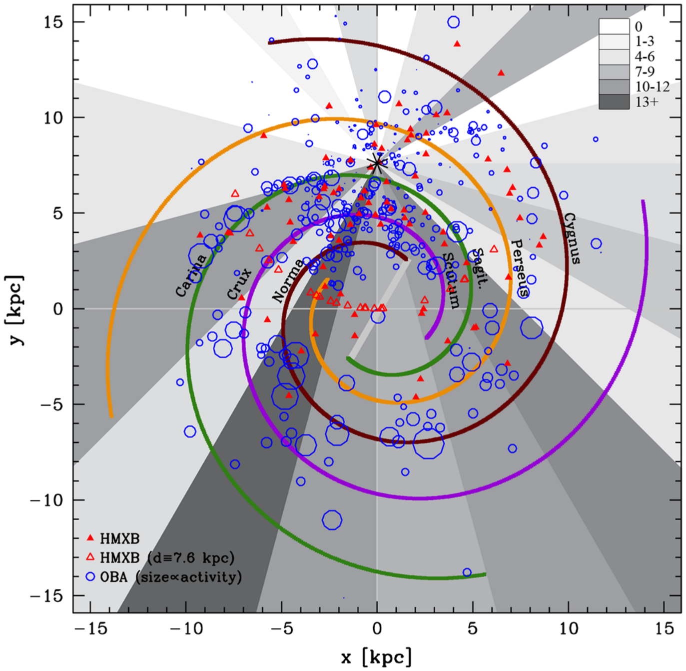


Fig. 14 Galactic distribution of HMXBs (*filled triangles*—with known distances, *open triangles*—with unknown distances, placed at 7.6 kpc) and the locations of OB associations (*circles*, with a size proportional to the amount of activity in the association). As in Fig. 13 the *shaded sectors* represent the distribution of HMXBs along the Galactic plane (Bodaghee et al. 2012c)

maxima of the HMXB population. The inner part of the Norma arm was at the position of the observed HMXB peak density approximately ∼15–20 million years ago which is in agreement with the model of Shtykovskiy and Gilfanov (2007).

A significant two-dimensional clustering between HMXBs and OB associations was also found in the Milky Way (see Fig. 14 and Bodaghee et al. 2012c). The two populations were found not perfectly aligned, confirming the above (1-D) analysis. An average offset of 0.4 ± 0.2 kpc was derived between a given HMXB and its nearest OB association, a distance consistent with natal kicks of $\sim 100 \pm 50$ km/s (Bodaghee et al. 2012c). The observed distribution of HMXBs in the Milky Way contains, therefore, information on the evolutionary history of massive binaries. Similar results were obtained by Coleiro and Chaty (2013), who found the correlation between HMXB distribution and the distribution of star forming complexes. Note that this was done using of a new approach for estimating of the distance and absorption for HMXBs, by spectral energy distribution fitting.

5.2 Luminosity function and surface density of HMXBs

The X-ray luminosity function is an important tool for the study of the formation and evolution of binary systems and of their dependence on the type of galaxy. The differential luminosity function of HXMBs in galaxies of different types is proportional to their star formation rate (SFR) (see, e.g. Grimm et al. 2002, 2003) and has an universal power law shape: $\frac{dN}{dL} \propto \mathrm{SFR} \times L^{-\alpha}$, with an index of $\alpha \simeq (1.6 \pm 0.1)$ in a wide luminosity range $10^{35}-10^{40}$ erg/s, that can be explained by the fundamental mass–luminosity and mass–radius relations for high-mass stars (Postnov 2003). There are also some indications for a flattening (Bhadkamkar and Ghosh 2012) of the HMXBs luminosity function at low luminosities both for sources in our Galaxy (Voss and Ajello 2010) and for objects in the Small Magellanic Cloud (Shtykovskiy and Gilfanov 2005b). The luminosity function at low luminosities is very important for the predictions of the number of sources that can be expected in future, more sensitive, surveys (Pavlinsky et al. 2009) and for estimating the contribution of HMXBs to the total X-ray luminosity of outer galaxies.

Luminosity functions can be straightforwardly constructed for outer galaxies as the distance to all sources is known and as focusing X-ray telescopes provide a rather uniform sensitivity. In the case of our Galaxy it is necessary to correct for the unequal sensitivity of the survey along the galactic plane. The simplest way to make such a correction is to assume a density distribution of HMXBs over the Galaxy. The latter can be done in different ways—in particular, Grimm et al. (2002) parametrised it as a disk with certain parameters, Voss and Ajello (2010) expected that HMXBs are distributed like the stellar mass in the Galaxy.

INTEGRAL observations allowed us to measure the HMXBs' density distribution and to calculate their luminosity function using fewer assumptions (Lutovinov et al. 2013b). It was first shown that the most numerous population of persistent HMXBs in our Galaxy are the wind-fed systems as other types of HMXBs indeed have only a few representatives. Then an axisymmetric distribution of HMXBs was assumed, i.e. that the Galaxy could be divided into several annuli of constant HMXBs surface density and luminosity function. A model of the latter in the form of a broken power law (with slopes α_1 and α_2 below and above the break at the luminosity L_*) was then adjusted to the data. The best fit luminosity function is presented in Fig. 15 and the parameters are listed in Table 4.

It is clearly seen that the luminosity function of HMXBs in a wide range of luminosities ($10^{34}-10^{37}$ erg/s) cannot be described by a simple power law. It features a break or a curvature at luminosities around $(0.4-2) \times 10^{36}$ erg/s and a flattening at low luminosity, confirming previous results (Shtykovskiy and Gilfanov 2005b; Voss and Ajello 2010).

The normalizations of the luminosity function can be used to calculate the surface density of HMXBs in each annulus. The results are presented in Table 4 and Fig. 16. The distribution of the surface density of HMXBs in the Galaxy has a maximum at galactocentric distances of 2–8 kpc, as is also observed for the galactic SFR.

A comparison of the surface density of HMXBs with that of the star formation rate in the Galaxy (Guesten and Mezger 1982; Lyne et al. 1985; Chiappini et al. 2001) shows a very good correlation that can be expressed as

$$N(\mathrm{HMXB}, L_\mathrm{x} > 10^{35} \mathrm{erg\ s^{-1}})/\mathrm{kpc}^2 \approx 5.5 \times 10^{-2}\ \mathrm{SFR}/\mathrm{SFR}_\odot$$

where $\mathrm{SFR}_\odot$ is the star formation rate near the Sun.

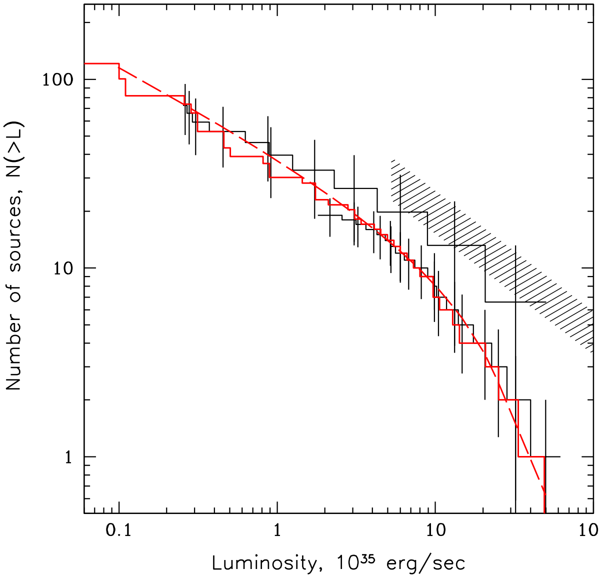


Fig. 15 Luminosity functions of HMXBs accreting from the stellar wind (*red histogram*). *Red dashed line* represents the best fit model of the luminosity function with parameters from Table 4. *Two black solid histograms* represent luminosity functions within volume limited samples (see Lutovinov et al. 2013b, for details). *Hatched area* shows the number-luminosity function of all classes of HMXBs in our Galaxy from Grimm et al. (2002)

Table 4 Best fit parameters of the luminosity function of HMXBs and their spatial density distribution

Parameter	Value and 1σ error
α_1	1.40 ± 0.13 (stat.) $\pm$ 0.06 (syst.)
α_2	>2.2
L_*, 10^{36} erg/s	$2.5^{+2.7}_{-1.3}$ (stat.) $\pm$ 1.0 (syst.)
R_g, kpc	$N(L > 10^{35}$ erg/s) kpc^{-2}
0–2	0.0 ± 0.05 (syst.)
2–5	$0.11^{+0.05}_{-0.04}$ (stat.) $\pm$ 0.02 (syst.)
5–8	$0.13^{+0.04}_{-0.03}$ (stat.) $\pm$ 0.01 (syst.)
8–11	$(3.8^{+2.1}_{-1.2}) \times 10^{-2}$ (stat.) $\pm 6.5 \times 10^{-3}$ (syst.)
11–14	$(6.2^{+7.2}_{-4.3}) \times 10^{-3}$ (stat.) $\pm 4.8 \times 10^{-3}$ (syst.)

Finally, the observations from *INTEGRAL* allow us to calculate the scale of the HMXBs vertical distribution as $\simeq 85-90$ pc which is significantly larger (by about $\sim$50 pc) than that of massive stars. This indicates that HMXBs should have travelled some distance from their birth places, similar to what was discussed above for the spatial correlation between HMXBs and OBAs. Assuming that HMXBs receive a systematic kick 50–90 km/s during supernova explosions, the kinematic age of the population of HMXBs with wind-fed neutron stars after the supernova explosion can be estimated as $\tau \simeq 0.5-1$ Myr.

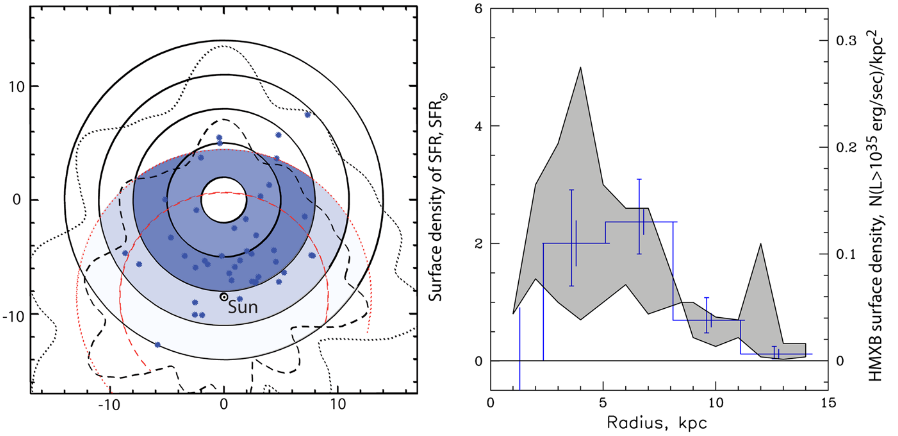


Fig. 16 (*left*) Surface density of HMXBs in the Galaxy (a darker color of the annulus corresponds to a higher surface density of HMXBs, see Table 4). *Blue points* indicate positions of persistent HMXBs. *Different lines* correspond to different sensitivity levels of the *INTEGRAL* survey (Lutovinov et al. 2013b). (*right*) Dependence of the HMXBs surface density (*histogram*, *right axis*) and star formation rate surface density (upper and lower bounds, *solid curve*, *left axis*) on the galactocentric distance

6 Summary

Our knowledge of high-mass X-ray binaries, and in particular of super-giant ones, has improved significantly since the launch of the wide field of view hard X-ray imagers on board *INTEGRAL* and *Swift* in 2002 and 2004, respectively. The discoveries of 23 new super-giant systems, increasing their population in the Galaxy by a factor 2.6 and of new X-ray variability patterns came as a surprise, challenging our understanding of stellar wind accretion around neutron stars.

In this review we have tried to make some sense of the observed phenomenology, keeping in mind that wind accretion is a stochastic process (Sect. 2). The super-giant HMXB population was classified as follows:

Classical super-giant systems feature a low orbital eccentricity and variability by a factor of $\sim 10^3$ on time scales much longer than the free fall time at the accretion or Alfvén radius. It is likely that most of that variability can be explained by hydrodynamic effects driven by the gravitational field of the neutron star. This variability can be enhanced by magnetic gating or a cooling switch on short time scales but it is not yet clear if such mechanisms are operative or needed. Several SFXTs belong to this category.

Obscured super-giant systems are similar to classical system, but characterised by persistently high X-ray absorption ($\sim 10^{23}$ cm^{-2}). Most of them are luminous systems with orbital periods of less than 5 days, in transition to Roche lobe overflow. Strong absorption can also be related to particularly slow stellar winds or by the presence of large amount of interstellar material on the line of sight. The extreme obscuration observed in IGR J16318-4848 has a different nature and probably originates in the equatorial outflow of its B[e] companion.

Fast transients reaching anomalously low luminosities (IGR J16479-4514, AX J18410-0536, AX J18450-0433 and IGR J17544-2619) have very short orbital periods ($<$5 days) and display average and minimal luminosities of $\sim 10^{34}$ erg/s and typical flare luminosities ten times lower than expected in classical systems with similar orbits. Several mechanisms to quench the accretion have been discussed (low mass loss rates, high wind velocities, magnetic gating, cooling switch) but no univocal process has been identified. Note that no spin periods are available for any of these sources.

Eccentric transients (IGR J18483-0311, SAX J18186-1703 and XTE J1739-302) are SFXTs with orbits sufficiently eccentric to explain the range of observed X-ray fluxes. The short flares require specific hydrodynamic processes (or structured winds), possibly similar to those observed in classical systems.

So far, several attempts have been made to study either the combined effects of wind clumps, neutron star magnetic field/spin rotation or the effect of eccentricity on the accretion from a smooth wind. A more complete theoretical study including all these effects is still missing. Our currently poor knowledge of the orbital parameters of many SFXTs and the lack of spin periods and magnetic field measurements still make the comparison between the outcome of such extended study with the constraints obtained through the currently available data (Sect. 4) challenging.

Hard X-ray observations of *INTEGRAL* in combination with other observatories were also unique to probe the variations of the CRSFs and of the geometry of the accretion column as a function of the accretion rate. The impact of observing Be systems flares with sensitive hard X-ray instruments is very important and has led to several geometrical interpretations, new ideas and theories (Sect. 3) that should be tested in the future.

The clustering of HXMBs near star formation regions in the Galaxy, that could be determined for the first time thanks to deep observations of the Galactic plane, has allowed us to constrain their formation rate and, in addition, the average natal kicks of neutron stars (Sect. 5). Furthermore, the fraction of HXMBs of different classes has allowed us to constrain some of the time scales and processes driving their evolution.

The low flux population of HXMBs remains undetected. The Spectrum-RG survey (Pavlinsky et al. 2009; Doroshenko et al. 2014) should soon unveil it and help constraining further the evolution of these systems and populations. Thousands of normal galaxies will also be detected by Spectrum-RG opening a new window on their recent star formation and compact object population.

Acknowledgments Based on observations with INTEGRAL, an ESA project with instruments and science data centre funded by ESA member states (especially the PI countries: Denmark, France, Germany, Italy, Switzerland, Spain) and with the participation of Russia and the USA. This work was supported by a grant from the Scientific & Technological Cooperation Programme Switzerland-Russia. AAL acknowledges support by the grant of the Russian Science Foundation 14-22-00271. We thank Ed. van den Heuvel for carefully reading our manuscript and providing detailed comments.

Appendix: Notes on individual sources

IGR J00370+6122 was discovered in 2003 during the deep observations of the Cassiopeia region with the *INTEGRAL* observatory (Hartog et al. 2004). Studying the nature of the source Reig et al. (2005b) found that the optical counterpart is neither a Be star nor a supergiant star (the most adequate classification was to be B0.5 II-III at the distance of ∼3 kpc) and so IGR J00370+6122 appears difficult to fit within the classical classification scheme of HMXBs (see, however, González-Galán et al. 2014 for the recent classification of the source as a BN0.7Ib and discussion its possible supergiant nature). Later Hartog et al. (2006) and in't Zand et al. (2007) showed that the source is a recurrent transient X-ray pulsar (with a spin period of $P_{\rm spin} \simeq 359$ s) in an eccentric orbit (with the orbital period $P_{\rm orb} = 15.667$ days), demonstrating s flaring behaviour within a dynamic range about 10–20.

1A 0114+650 has been shown to be a rather unusual source. It was discovered by the *SAS-3* observatory during the galactic plane survey and was identified with a bright early type optical star (Dower et al. 1977), exhibiting properties consistent with both Be and supergiant X-ray binaries. The source nature was debated several years until Crampton et al. (1985) classified the optical star as B0.5 with the luminosity class I or II, i.e. as a supergiant at the distance 7.2 kpc (Reig et al. 1996). Using the optical data Crampton et al. (1985) determined also an orbital period of the system $P_{\rm orb} \simeq 11.6$ days, which was confirmed later in X-rays by Corbet et al. (1999a). 1A 0114+650 is the X-ray pulsar with one of the longest known pulse periods $P_{\rm spin} \simeq 2.65$ h (Farrell et al. 2008), which evolved on the time scale of several years (Wang 2011). In addition to pulse and orbital variabilities in the system there is a superorbital periodicity with the period of 30.7 days (Farrell et al. 2006).

IGR J01363+6610 was discovered with the *INTEGRAL* observatory during galactic plane scans (Grebenev et al. 2004b). The follow-up observations with the *XMM-Newton* observatory revealed a faint variable X-ray source inside the *INTEGRAL* error box. This source has a hard power law spectrum with a photon index of 1.4 ± 0.3 and, based on the optical data, was associated with the Be-star as an optical companion in the binary system (Tomsick et al. 2011). The distance estimate ∼2 kpc indicates a very low quiescent X-ray luminosity of the source $\simeq 10^{32}$ erg/s. A possible ≃160 days orbital period was found in the *Swift/BAT* data (Corbet and Krimm 2010).

RX J0146.9+6121 belongs to the class of low-luminosity persistent systems with Be-companions (see Reig 2011, for details). Similarly to other such systems its spectrum is characterised by a presence of the soft thermal component with the temperature of $kT \sim 1$ keV and the power-low tail at higher energies (La Palombara and Mereghetti 2006). The source is the X-ray pulsar with a quite long pulse period of $P_{\rm spin} \simeq 25$ min, which was discovered by the *EXOSAT* observatory and erroneously related to the nearby source 4U 0142+614 (White et al. 1987; Reig 2011). The system is located in the open cluster NGC 663 at a distance of 2.5 kpc (Tapia et al. 1991).

4U 0115+63 was discovered by the *UHURU* observatory in the early 1970s by Giacconi et al. (1972), Forman et al. (1978). During the *SAS-3* observations in 1978, Cominsky et al. (1978) found a pulsation period of 3.61 s. Rappaport et al. (1978) determined the binary's main parameters: orbital period of ∼24.3 days, orbital eccentricity 0.34,and projected semimajor axis of the relativistic object $a_x \sin i \sim 140$ light seconds (see also Tamura et al. 1992; Lutovinov et al. 1994, for an improvement of the parameters). Optical observations of the star V635 Cas (Hutchings and Crampton 1981; Kholopov et al. 1981), which is the counterpart associated to the X-ray source 4U0115+63, were performed by Negueruela and Okazaki (2001). These data allowed the authors to firmly classify this object as a B0.2Ve star and estimated a distance to the source of 7–8 kpc. The X-ray pulsar 4U 0115+63 is unique in its spectral characteristics. At present, it is the only object in which a cyclotron line was detected in the X-ray spectrum together with its higher harmonics up to the fourth order. Properties of this cyclotron feature were studied in detail using data of many observatories (Wheaton et al. 1979; White et al. 1983; Mihara et al. 1998; Heindl et al. 1999; Santangelo et al. 1999; Lutovinov et al. 2000). Particularly, Mihara et al. (1998, 2004) found that the position of the fundamental cyclotron line in the energy spectrum depends on the pulsar luminosity. Later, this effect was confirmed using the *RXTE* and *INTEGRAL* data (Nakajima et al. 2006; Tsygankov et al. 2007; Klochkov et al. 2011; Boldin et al. 2013). Such a behaviour can be explained either by the modification of the emitting regions in the vicinity of the neutron star or by artificial effects due to poor knowledge of the spectral continuum (Ferrigno et al. 2009; Müller et al. 2013; Boldin et al. 2013).

IGR J01583+6713 is a high mass X-ray binary with the Be companion star (type B2IVe) located at a distance about 4 kpc (Kaur et al. 2008). The sources was discovered by the *INTEGRAL* observatory during observations of the Cas A region in 2005 (Steiner et al. 2005). The follow-up observations with the *XRT* telescope of the *Swift* observatory revealed a strong absorption in the source spectrum $N_H \simeq 10^{23}$ cm^{-2} (Kennea et al. 2005) and a presence of possible pulsations in its light curve with the period $P_{\rm spin} \simeq 469.2$ s (Kaur et al. 2008). Note, that the latter result was not confirmed by Tomsick et al. (2011) based on the *XMM-Newton* and *Chandra* data.

V0332+53 was first detected by the Vela 5B observatory in 1973 (Terrell et al. 1982) during an outburst when its intensity reached ∼1.4 Crab in the 3−12 keV energy band. During subsequent outbursts in 1983–1984 and 1989, observed with the *EXOSAT* and *Ginga* observatories, respectively, the spin (∼4.4 s) and orbital (∼34.25 days) periods were determined by Stella et al. (1985). The cyclotron resonance scattering feature with an energy of $E_{\rm cyc} = 28.5 \pm 0.5$ keV was detected in its spectrum Makishima et al. (1990). Based of the results of long-term monitoring campaign of Be/X-ray binaries with the Southampton/Valencia/SAAO, Negueruela et al. (1999) determined the spectral class of BQ Cam—the normal companion of the X-ray pulsar V 0332+53—as O8–9Ve and estimated the distance to the system at ∼7 kpc. The last leads to the maximum source luminosity of $\sim 4 \times 10^{38}$ erg/s observed during outbursts, that make it one of the brightest X-ray sources in the Galaxy. The next powerful outburst of V 0332+53 began at the end of 2004 (Swank et al. 2004). An analysis of the follow-up observations performed with the *RXTE* and *INTEGRAL* observatories showed that beside the absorption feature at an energy of ∼26 keV, there are two additional similar features in the source spectrum at energies of ∼49 and ∼75 keV, which were interpreted as the second and third harmonics of the main cyclotron frequency (Kreykenbohm et al. 2005; Pottschmidt et al. 2005). A good coverage of the whole outburst (including rising and declining parts) with the *RXTE* observations allowed to Tsygankov et al. (2006,

2010) to make a detailed spectral analysis and to show that the cyclotron line energy is not a constant but negatively correlated with the source luminosity and to obtain constraints on the magnetic field in the source as $B_{\rm NS} \simeq 3.5 \times 10^{12}$ G. Moreover, the line energy as well as its width and depth are also strongly variable on the pulse period scale (Lutovinov et al. 2015).

4U 0352+309/X Persei is a classical persistent Be/X-ray binary system, consisting of an X-ray pulsar and a Be-star companion optically identified with the star HD 24534 (spectral type B0Ve). It was discovered during a high X-ray intensity state in 1972 and pulsations with the period of $P_{\rm spin} \simeq 835$ s were detected by the *Copernicus* observatory (White et al. 1976). A distance to the source is estimated by different authors in the range of 700 to 1300 pc, but more often the value of 950 ± 200 pc is used (Telting et al. 1998). Adopting this distance the source peak luminosity $L_X \simeq 2 \times 10^{35}$ erg/s was registered in 1975, 2003 and 2010 (Lutovinov et al. 2012a). Delgado-Martí et al. (2001) succeeded in determining orbital parameters for X Persei and showed that it is in a moderately eccentric orbit ($e \simeq 0.11$) with a very long $P_{\rm orb} \simeq 250$ days orbital period. Deep observations performed with the *INTEGRAL* observatory allowed to detect the hard X-ray emission from X Persei up to ≃160 keV (Doroshenko et al. 2012b; Lutovinov et al. 2012a) that is non-typical for X-ray pulsars. In the X Persei spectrum there is also a strong absorption feature near the energy of ≃30 keV. It was discovered by Coburn et al. (2001) based on the *RXTE* data and interpreted as a cyclotron resonance scattering feature that allowed to estimate a magnetic field on the neutron star surface $B_{\rm NS} \simeq (2.4 - 2.9) \times 10^{12}$ G, (Lutovinov et al. 2012a). This line was found to be significantly broader than is typically observed in X-ray pulsars (Coburn et al. 2002) that allowed other authors interpreted it as an artificial deficit of photons in the region where the different spectral components overlap (Salvo et al. 1998; Doroshenko et al. 2012b). Due to a source proximity, it is extremely bright in the optical and infrared wavebands ($m_{V,B} \simeq 6$) that is allowing to investigate and modeling the physical properties and behaviour of Be-systems at different time scales (see, e.g. Roche et al. 1993; Clark et al. 2001b; Okazaki and Negueruela 2001).

RX J0440.9+4431 was found during the *ROSAT* Galactic plane survey with the optical companion BSD 24-491/LS V +44 17 classified as a Be star (Motch et al. 1997). Distance to the system was estimated as 3.3 ± 0.5 kpc (Reig et al. 2005a). For the first time RX J0440.9+4431 was detected in the hard X-ray energy band by the *INTEGRAL* observatory during the Type I outburst in September 2010 (Krivonos et al. 2010; Tsygankov et al. 2012). Before this the source belonged to the small population of persistent low-luminosity binaries with Be companions and a slowly rotating neutron star (the pulse period is ∼202.5) . Based of a set of equally spaced in time Type I outbursts (each of them have the 3−100 keV luminosity about few $\times 10^{36}$ erg/s) in 2010–2011 (Morii et al. 2010; Krivonos et al. 2010) it became possible to estimate the orbital period of RX J0440.9+4431 as ∼155 days (Tsygankov et al. 2011). The spectral analysis of the *INTEGRAL* data revealed a ∼32 keV cyclotron resonant scattering feature in the source spectrum, that corresponds to the magnetic field strength of the neutron star surface $B \simeq 3.2 \times 10^{12}$ G (Tsygankov et al. 2012). Moreover, the source spectrum is rather hard and its emission is clearly detected above 100 keV (Krivonos et al. 2015).

A 0535+262 is a typical Be/XRP transient discovered with *Ariel V* during a giant (Type II) outburst (Rosenberg et al. 1975). Besides giant outbursts not related to the specific orbital phase, the source demonstrates also normal (Type I) outbursts linked to the periastron passages of the neutron star (see, e.g. Giovannelli and Graziati 1992). The binary system consists of a B0IIIe star HDE 245770 at the distance of ∼2 kpc (Steele et al. 1998) and a neutron star rotating with a spin period ∼103 s. The orbit is highly eccentric ($e \sim 0.47$) with a period of ∼111.1 days (Finger et al. 1996b). The energy spectrum of A 0535+262 is modified by two absorption features at ∼45 and ∼100 keV, which are interpreted as a cyclotron absorption line and its first harmonic. The magnetic field strength on the neutron star surface can be estimated as $B \sim 4 \times 10^{12}$ G (Kendziorra et al. 1994; Grove et al. 1995). A comprehensive analysis of the *INTEGRAL*, *RXTE* and *Suzaku* spectral data does not reveal variations of the cyclotron energy during outbursts (Caballero et al. 2013).

IGR J06074+2205 was discovered in 2003 with the *JEM-X* telescope on board the *INTEGRAL* observatory (Chenevez et al. 2004). A number of studies were dedicated to the search of the optical counterpart of this source (Halpern and Tyagi 2005; Tomsick et al. 2006b; Masetti et al. 2006a; Reig and Zezas 2009; Reig et al. 2010). Finally Reig et al. (2010) identified it with a relatively bright ($V = 12.3$) B0.5Ve star located at a distance of ∼4.5 kpc.

2E 0655.8-0708 (better known as MXB 0656-072) is a transient X-ray source in the Galactic plane discovered in 1975 with the *SAS-3* observatory (Clark et al. 1975). Pulsations of the X-ray flux with a period ∼160.7 s were found with *RXTE/PCA* (Morgan et al. 2003). An optical companion was identified with a O9.7Ve star (Pakull et al. 2003) at the distance of 3.9 ± 0.1 kpc (McBride et al. 2006). An orbital period was estimated from *SWIFT/BAT* and *RXTE/ASM* data as ∼101.2 days (Yan et al. 2012). During the strong Type II outburst in 2003 the detailed spectral analysis of MXB 0656-072 was performed using *RXTE* data (Heindl et al. 2003). To describe the source spectrum the standard model of power law with the high-energy cutoff was modified by an iron and cyclotron absorption lines. Best fit parameters were: photon index 1.09 ± 0.01, cutoff energy $E_{\rm cut} = 16.8 \pm 0.1$ keV, exponential folding energy $E_{\rm fold} = 11.5 \pm 0.3$ keV, cyclotron line energy $E_{\rm cycl} = 36 \pm 1$ keV. A slightly different parametrisation of the spectral model gives the cyclotron line energy $32.8^{+0.5}_{-0.4}$ keV which is stable through the outburst and over the pulsar spin phase (McBride et al. 2006).

IGR J08408-4503 was discovered in the Vela region on 15 May 2006 with INTEGRAL during a short flare lasting less than 1000 s (Götz et al. 2007). Its optical counterpart was later identified as the supergiant star HD 74194 located at 3 kpc, thus confirming that this source belongs to the SFXT class (Götz et al. 2007; Masetti et al. 2006a). IGR J08408-4503 was observed in outburst several times with *INTEGRAL* and *Swift* (Götz et al. 2007; Leyder et al. 2007; Sidoli et al. 2009c; Barthelmy et al.

2009). Observations of the source in the lower X-ray activity state were performed with *Swift*, *XMM-Newton* and *Suzaku* (Kennea and Campana 2006; Bozzo et al. 2010; Sidoli et al. 2010). These revealed the presence of a peculiar soft ($<$2 keV) spectral component possibly associated with the X-ray emission from the supergiant wind itself. IGR J08408-4503 is the best suited SFXT to study soft spectral components as it is on average the less absorbed one.

Vela X-1 is the archetype of the persistent classical sgHMXBs. The pulsar (1.86 $M_\odot$; spin 283 s) orbits a B0.5Ib supergiant in 8.964 days on an almost circular ($e \approx 0.09$; $R = 1.76R_*$) trajectory (Quaintrell et al. 2003), see however Koenigsberger et al. (2012). The strong and continuous X-ray variability observed (Kreykenbohm et al. 2008) has been explained by wind clumping (Fürst et al. 2010), self-criticality of the wind-fed accretion flow (Manousakis et al. 2012), magnetic gating (Doroshenko et al. 2011) or transition of cooling mechanism (Shakura et al. 2013). Vela X-1 is one of the few systems where the influence of photo-ionisation can be studied (Watanabe et al. 2006; Krtička et al. 2012; Manousakis and Walter 2015a). The pulse profile changes with energy and variable cyclotron absorption features are detected (Doroshenko et al. 2011; Fürst et al. 2014b). Small variations of the spin period have been observed on various time scales (Bildsten et al. 1997). Vela X-1 is a runaway system accompanied by a bow shock (Kaper et al. 1997).

GRO J1008-57 was discovered during the bright outburst in 1993 with *CGRO/BATSE* as an X-ray source pulsating with a period 93.587 ± 0.005 s (Stollberg et al. 1993). An optical counterpart was identified with a B1-B2 Ve star (Coe et al. 2007) at a distance of $\sim$5 kpc (Coe et al. 1994a). Orbital parameters were determined using data from different observatories as follows: $P_{\rm orb} = 249.46 \pm 0.10$ days, $a_x \sin i = 530 \pm 60$ lt-s, $\omega = -26 \pm 8$ deg, $e = 0.68 \pm 0.02$ (Levine and Corbet 2006; Coe et al. 2007; Kuehnel et al. 2012). The combined spectrum from the *CGRO* and *ASCA* observations can be well approximated by a power law with the high-energy cutoff and a 6.4-keV iron emission line (Shrader et al. 1999). An approximation of the *INTEGRAL* data results in the following spectral parameters: photon index 1.4 ± 0.1, cutoff energy $E_{\rm cut} = 8.0 \pm 1.0$ keV, exponential folding $E_{\rm fold} = 21 \pm 2$ keV (Coe et al. 2007). Based on the *Suzaku* data Yamamoto et al. (2013) discovered a cyclotron line in the source spectrum at $E_{\rm cyc} = 75.5^{+2.5}_{-1.5}$ keV. This detection reconfirms the previously suggested spectral feature around $\sim$80 keV (Shrader et al. 1999).

IGR J10101-5654 was detected by the *INTEGRAL* observatory at high energies ($>$20 keV) in 2004 during observations of the Carina region (Kuiper et al. 2006). The NIR spectrum is very rich with many strong emission lines, originating from different media, that suggests the presence of a stratified circumstellar environment. This allowed Coleiro et al. (2013) to suggest the companion star to be a sgB[e]. *Chandra* observations revealed a significant change in the mass accretion rate onto the compact object and determined spectral parameters as: photon index $1.0^{+0.5}_{-0.4}$, photo-absorption $N_H = 3.2^{+1.2}_{-1.0} \times 10^{22}$ cm^{-2} (Tomsick et al. 2008).

3U 1022-55 (also known as 4U 1036-56 and RX 1037.5-5647) appeared in the *Uhuru* catalogue (Giacconi et al. 1972). The optical counterpart of the system is a B0 V-IIIe star LS 1698 at the distance of ∼5 kpc (Motch et al. 1997). Timing analysis of the *RXTE* data revealed pulsations in the source flux with a period of $P \simeq 860$ s and it was suggested that the system belongs to the subclass of persistent Be/X-ray systems with slowly rotating neutron stars (Reig 2011). A possible association of 4U 1036-56 with the unidentified transient gamma-ray source AGL J1037-5708 was discussed by Li et al. (2012a). It is interesting to note that the black body component with $kT_{\rm BB} = 1.26^{+0.16}_{-0.09}$ keV and $R_{\rm BB} = 128^{+13}_{-21}$ m (La Palombara et al. 2009) is present in the source spectrum in addition to the typical pulsars components—power law and the high-energy cutoff (White et al. 1983). This thermal emission suggests its polar-cap origin and can be characteristic of all low-luminosity Be systems (see, e.g. La Palombara and Mereghetti 2006; La Palombara et al. 2009; Tsygankov et al. 2012).

Cen X-3 is the first X-ray pulsar discovered with a spin period of 4.8 s (Giacconi et al. 1971). It orbits an O6.5 II-III supergiant, located at 5–8 kpc (Day and Tennant 1991; Krzeminski 1974), in 2.1 days with a small eccentricity, if any (van der Meer et al. 2007; Falanga et al. 2015). Mass transfer probably occurs through a combination of wind and disk accretion (Petterson 1978; Tsunemi et al. 1996; Tjemkes et al. 1986; Kohmura et al. 2001; Suchy et al. 2008). A cyclotron absorption feature is detected (Nagase et al. 1992; Santangelo et al. 1998; Heindl and Chakrabarty 1999). Iron line variability indicate fluorescence on several components (Devasia et al. 2010).

1A 1118-615 is a peculiar Be system with a long spin period (406 s, Staubert et al. 2011) for a short orbital period (24 days, Staubert et al. 2011). Three type II outbursts have been detected in 38 years featuring correlated X-rays and Hα fluxes (Coe et al. 1994b). A cyclotron absorption feature at 55 keV (Doroshenko et al. 2010b) and QPOs (Nespoli and Reig 2011) have been detected leading to the magnetic field estimations of $(7-8) \times 10^{12}$ G. The companion is a O9.5IV-Ve star located at 3–7 kpc (Janot-Pacheco et al. 1981).

IGR J11215-5952 is an SFXT displaying a regular outbursting activity during the periastron passage (Sidoli et al. 2007). The system geometry could be well understood through the long-term monitoring performed with *Swift*/XRT and the orbital period has been measured at ∼165 days (Romano et al. 2009c). This source has been observed in outburst many times with *INTEGRAL* and *Swift*, and it is known to host a ∼186 s spinning NS (Swank et al. 2007). Due to the peculiar regularity in the occurrence of its outburst, IGR J11215-5952 is suggested to be an evolutionary link between SFXTs and BeXRBs (Liu et al. 2011). A detailed study of the supergiant star hosted in this system was presented by Lorenzo et al. (2014). This study did not reveal any particularly relevant peculiarity from the star that is classified as a normal B0.5 Ia supergiant.

IGR J11305-6256 was discovered by *INTEGRAL* in 2004 (Produit et al. 2004). The companion star was identified as the B0IIIe star HD100199 located at about 3 kpc (Masetti et al. 2006a). The broad-band X-ray spectrum, moderate absorption and transient X-ray activity led La Parola et al. (2013) to classify the source as a Be X-ray binary. These authors also reported on the discovery of the source orbital period at 120.83 days and noticed that the average orbital modulation of the X-ray emission from IGR J11305-6256 is relatively low compared to other sources in the same class. No X-ray pulsations have been detected so far.

IGR J11435-6109 was discovered by *INTEGRAL* in 2004 (Grebenev et al. 2004a). Pulsations at a period of ∼166 s were first reported by Swank and Markwardt (2004) and later confirmed by Revnivtsev et al. (2005). The orbital period of the source is 52.5 days (Corbet and Remillard 2005). The precise X-ray localization of IGR J11435-6109 obtained through a *Chandra* observation (Tomsick et al. 2007) permitted to identify the companion star in this object as a B0Ve/B2Ve located at $\gtrsim$6–10 kpc (Negueruela et al. 2007b). The source is thus a distant Be X-ray binary (see also Coleiro et al. 2013).

4U 1145-619 was first mentioned in the second *UHURU* catalogue (Giacconi et al. 1972). Subsequent examination of its localization error box in optics revealed inside a relatively bright star ($V \simeq 9$) with a spectral type B1Vne (Jones et al. 1974). These optical identification and spectral classification were later confirmed by Dower et al. (1978) and Hutchings et al. (1981). In the meantime, two close X-ray periodicities with periods of ∼292 and ∼297 s were discovered from the vicinity of 4U 1145-619 (White et al. 1978). The situation was clarified with the discovery of another X-ray source 1E 1145.1-614 located only 15′ away from 4U 1145-619 and demonstrated pulsations with the period of ∼298 s, while pulsations with the period ≃290 s were attributed to 4U 1145-619 (Lamb et al. 1980). Long-term observations of 4U 1145-619 with the *Ariel V* observatory revealed outbursts from the source, which occurred at regular intervals of ≃187.5 days and which were interpreted as a motion of a neutron star in a highly eccentric $e > 0.6$ orbit with the corresponding period (Watson et al. 1981). Further observations of the source performed by different observatories allowed to trace its pulse period history (see, e.g. Lutovinov et al. 1994; Bildsten et al. 1997 and references therein), to measure for the first time the source spectrum up to 100 keV (Filippova et al. 2005), etc. It is necessary to note that distance estimations from spectroscopic observations $d = 3.1 \pm 0.5$ kpc (Stevens et al. 1997) are several times larger than that from the parallax measurements $d = 0.51 \pm 0.24$ kpc (Clark and Dolan 1999). But for the latter measurement authors indicate that the 90 % confidence interval on the Hipparcos parallax measurement of 4U 1145-619 extends to a distance of 2.3 kpc and thus spectroscopic and astrometric parallaxes practically overlap.

1E 1145.1-6141 is a persistent sgHMXB with a pulsar (297 s spin) orbiting a companion in 14.365 days with an eccentricity of 0.2. The spectrum features constant intrinsic absorption (10^{23} cm^{-2}). Both spin-up and spin-down have been observed (Ray and Chakrabarty 2002; Ferrigno et al. 2008).

1ES 1210-646 is a poorly studied X-ray source, which was found during the *Einstein* Slew Survey (Elvis et al. 1992). Based on optical spectroscopy the system was classified as a HMXB (Masetti et al. 2009). An orbital modulation with a period of about

6.7 days was found by Corbet and Mukai (2008) in the *RXTE/ASM* data. The source spectrum near its maximum flux can be well approximated by a power law continuum with a photon index $\simeq$1.41, high-energy cutoff ($E_{\mathrm{cut}} = 6.0$ keV, $E_{\mathrm{fold}} = 5.7$ keV) and an Fe K line at 6.56 keV with an equivalent width $\simeq$300 eV (Corbet and Mukai 2008). Later Masetti et al. (2010a) using data from the *SWIFT/XRT* telescope showed that the iron line has a transient nature and is tied to the orbital motion of the neutron star.

GX 301-2 is among the brightest HMXB ($L_X \sim 10^{37}$ erg/s), thanks to the slow (3–400 km/s) and very dense stellar wind of its hyper giant companion (Kaper et al. 1995, 2006). The highly eccentric ($e \sim 0.5$) pulsar orbit (Sato et al. 1986; Koh et al. 1997) generates a strong orbital modulation of the accretion rate with a broad maximum at phase 0.95 linked with a circumstellar disk or an accretion stream (Leahy and Kostka 2008). The absence of eclipse constrains the inclination angle in the range ($44^\circ - 78^\circ$). A deep and variable cyclotron resonance feature is observed at hard X-rays (Kreykenbohm et al. 2004; Filippova et al. 2005; Fürst et al. 2011b). Spin-up episodes have been observed and explained by the formation of transient accretion disks (Koh et al. 1997). Fast spin-down episodes have been interpreted as evidence for a 10^{14} G surface magnetic field (Doroshenko et al. 2010a) or as accretion of magnetised material (Ikhsanov and Finger 2012). Off-states were detected (Göğüş et al. 2011; Suchy et al. 2012), similar to the ones observed in Vela X-1. The soft X-ray spectrum is affected by variable partial coverage of two different absorbers (Watanabe et al. 2003; Suchy et al. 2012).

GX304-1 was discovered during a high-energy X-ray balloon observations in 1967. A pulsar nature of the source was established with the detection of ~272 s pulsations (Huckle et al. 1977; McClintock et al. 1977). Later a long-term study with the *Vela 5B* satellite revealed a 132.5-day periodicity of flaring events (Priedhorsky and Terrell 1983), attributable to the binary period. An optical companion in the system is a Be star (Mason et al. 1978) at a distance of 2.4 ± 0.5 kpc (Parkes et al. 1980). Recently, it was shown that additionally to the standard X-ray pulsar spectrum model an inclusion of the cyclotron absorption line with energy $E_{\mathrm{cyc}} = 50.8 \pm 0.5$ keV, width $\sigma = 8.2 \pm 1.4$ keV and depth $\tau = 0.76 \pm 0.05$ is required for the correct approximation of the source spectrum (Mihara et al. 2010). Later, Yamamoto et al. (2011) and Klochkov et al. (2012) using the data from different observatories (including *INTEGRAL*) revealed a positive correlation between the cyclotron line energy and the source flux (see Fig. 11). Observations with the *Fermi/GBM* instruments showed that a strong outburst activity of the source is accompanied by significant changes in the source pulse period. The latter can be explained in the frame of the quasi-spherical settling accretion onto the neutron star (Postnov et al. 2015).

2RXP J130159.6-635806 is a faint X-ray source, discovered by the *ROSAT* observatory during all sky survey (sometimes this source is named IGR 13020-6359 as well, due to its first detection in hard X-ray with *INTEGRAL*). The sky field around the source was observed several times in different epochs by different observatories (*ASCA, BeppoSAX, XMM-Newton*), but only after the source detection with the *INTE-*

GRAL observatory (Chernyakova et al. 2004) the detailed analysis of the archival and follow-up data was done. This analysis allowed Chernyakova et al. (2005) to discover pulsations from the source with the period $P_{\rm spin} \simeq 700$ s and trace its evolution up to ∼10 years before. The study of a set of observations has shown that the pulse period changed from ∼735 s in 1994 to ∼704 s in 2004. (Chernyakova et al. 2005) proposed also a possible optical counterpart of the source as a Be-star and obtained a tentative estimate of the distance to the binary system as 4–7 kpc. Subsequent infrared spectral observations confirmed suggestions about the source nature and allowed Coleiro et al. (2013) to constrain its spectral type to B0.5Ve. Recent observations with the *N*uSTAR observatory revealed an unusually steady long-term spin-up in this system, when the pulse period was dramatically changed of about 100 s during ∼20 years (Krivonos et al. 2015).

4U 1416-62/2S 1417-624 is a well-known transient X-ray pulsar in a binary system with a Be-companion star, which was discovered with the *SAS-3* observatory. Using these data Apparao et al. (1980) found pulsations from the source with the period $P_{\rm spin} \simeq 17.64$ s. Based on the accurate measurements of the source position with the *Einstein* observatory and following optical observations it was shown that an optical counterpart in the system is a Be star (Grindlay et al. 1984) with a spectral type B1Ve (Reig 2011). Long observations performed with the *BATSE* instrument on board the *Comptom-GRO* observatory in 1994 allowed to determine orbital parameters of the system and showed that a neutron star is orbiting in a highly eccentric orbit (eccentricity $e = 0.446$) with the period $P_{\rm orb} = 42.12$ days (Finger et al. 1996a). Estimates of the distance to the system have still a large uncertainty, 1.4–11.1 kpc (Grindlay et al. 1984).

IGR J14331-6112 was discovered by *INTEGRAL* in 2003 (Keek et al. 2006). The soft X-ray counterpart was detected first with *Swift*/XRT and later confirmed by *Chandra* (Tomsick et al. 2009a). Masetti et al. (2008) suggested that the spectral type of the companion star is BIII/BV, but this classification is still a matter of debate (Coleiro et al. 2013).

IGR J14488-5942 was presented for the first time in the 4th *IBIS* catalogue (Bird et al. 2010) as a transient source. Inside the *INTEGRAL/IBIS* error circle two X-ray sources were detected with the *Swift* observatory (Landi et al. 2009; Rodriguez et al. 2010). One of them, Swift J144843.3-594216, was suggested to be a true counterpart of IGR J14488-5942. A modulation of the hard X-ray flux (15−100 keV) with period around 49 days has been discovered using *Swift/BAT* data (Corbet et al. 2010b). Based on the NIR spectroscopy Coleiro et al. (2013) concluded that this HMXB is more likely an Oe/Be HMXB than a supergiant one.

4U 1538-522 is an eclipsing persistent sgHMXB (spin 530.4 s) with a short orbital period of 3.728 days and an eccentricity >0.08 (Davison et al. 1977; Becker et al. 1977; Makishima et al. 1987; Corbet et al. 1993; Clark et al. 1994; Clark 2000). The companion is a B0I star located at 5.5 kpc (Becker et al. 1977; Reynolds et al. 1992). Variability of the absorption at eclipse egress allows to measure the stellar wind parameters (Clark et al. 1994). The X-ray spectrum (Robba et al. 1992) displays two cyclotron absorption features (Clark et al. 1990; Robba et al. 2001; Rodes-Roca et al. 2009). Emission lines from an extended ionised region have been detected during eclipses (Rodes-Roca et al. 2011). Small spin-up and down have been detected (Rubin et al. 1997).

XTEJ1543-568 was discovered as a transient X-ray pulsar with the pulse period $P_{\text{spin}} = 27.12$ s with the *PCA/RXTE* spectrometer (Marshall et al. 2000). A long-term observational program during about a year allowed in't Zand et al. (2001) to determine the orbital parameters of the system, in particular, its orbital period $P_{\text{orb}} = 75.56$ days. Taking into account the source position on the pulse period–orbital period diagram and its temporal behavior these authors suggested that XTEJ1543-568 is a Be system with an unusually low eccentricity ($e = 0.03$). No optical counterpart has been reported to the date.

IGRJ16195-4945 was discovered by *INTEGRAL* in 2003 (Walter et al. 2004) and associated with the ASCA source AXJ161929-4945 (Sugizaki et al. 2001; Sidoli et al. 2005b). The fast flaring activity detected from this source with *INTEGRAL* led Sguera et al. (2006) to associate this source with the SFXT class (see also Morris et al. 2009). A *Chandra* observation performed in the direction of the source permitted to identify the supergiant companion and provide further support to this association (Tomsick et al. 2006a; Rahoui et al. 2008).

IGRJ16207-5129 was discovered by *INTEGRAL* in 2003 (Walter et al. 2004). The companion star (Masetti et al. 2006a; Negueruela et al. 2007a) was classified as a B1 Ia star at ~6.1 kpc by Nespoli et al. (2008). Due to its relatively high persistent flux a and the lack of prominent outbursts, Walter and Zurita Heras (2007); Tomsick et al. (2009b) suggested that IGRJ16207-5121 belong to the class of the highly absorbed HMXBs, rather than to the SFXT class. This is supported by the results of *XMM-Newton* and *Chandra* observations, which measured an absorption column density of $\gtrsim 10^{23}$ cm^{-2} (Tomsick et al. 2009b; Bodaghee et al. 2010). The classification of this source is, however, still a matter of debate.

IGRJ16318-4848 is the first source discovered with INTEGRAL (Courvoisier et al. 2003; Walter et al. 2003). XMM-Newton observation indicated that the source is Compton thick with $N_H \approx 2 \times 10^{24}$ cm^{-2} (Matt and Guainazzi 2003; Walter et al. 2003). Archive and further X-ray observations indicated a persistently bright and Compton thick source (Revnivtsev et al. 2003; Revnivtsev 2003; Ibarra et al. 2007). The hard X-ray flux detected by INTEGRAL varies by a factor of up to 10 with doubling timescale of the order of 1 hour. The absorbing column density varies significantly by a factor of two Ibarra et al. (2007). The weakness of the Iron 6.4 keV fluorescence line Compton shoulder suggests that the absorption column density is larger on the line of sight than on average (Matt and Guainazzi 2003; Barragán et al. 2009), pointing towards a disk like geometry. The source was associated with an infrared counterpart (Foschini et al. 2003) of spectral type sgB[e] (Filliatre and Chaty 2004), indicating a very rare system surrounded by dense circumstellar gas and dust (Kaplan et al. 2006) that could be the signature of an equatorial disk (Rahoui et al. 2008; Chaty and Rahoui 2012) or of a close to LBV phase (Moon et al. 2007). No period has been detected in the system.

IGR J16320-4751 is a persistent source (in't Zand et al. 2003) serendipitously discovered with INTEGRAL (Tomsick et al. 2003). The source is highly absorbed with $N_H \approx (1{-}2) \times 10^{23}$ cm^{-2} (Rodriguez et al. 2003). X-ray pulsations with a period of (1309 ± 40) s (Lutovinov et al. 2005c) and an orbital period of 8.986 days (Corbet et al. 2005a; Manousakis and Walter 2012) (but no eclipse) have been detected. The hard X-ray flux detected by *INTEGRAL* varies by a factor larger than 10 and can do so in a few hours. The most likely companion star is an highly reddened O8I supergiant located at ~3.5 kpc (Rahoui et al. 2008). We note that IGR J16320-4751 is not related to the pulsar wind nebula HESS J1632-478 (Balbo et al. 2010).

IGR J16328-4726 was discovered with *INTEGRAL* by Bird et al. (2007). The source is also classified as an hard X-ray transient in the *INTEGRAL*/ISGRI and *Swift*/BAT catalogues (Bird et al. 2010; Cusumano et al. 2010). The first study of the source in the soft X-ray domain was performed as a follow-up to the bright outburst from the source caught with the *Swift*/BAT in 2009 (Grupe et al. 2009). In this occasion, the *Swift*/XRT could follow the evolution of the X-ray flux from the source up to 4 days after the onset of the outburst and revealed a typical behaviour of the SFXT sources (Fiocchi et al. 2010). Corbet et al. (2010a) reported on the discovery of the source orbital period at ~10 days using archival *Swift*/BAT data. A devoted *XMM-Newton* observation also evidenced a pronounced flaring activity during faint X-ray states (Bozzo et al. 2012b), a behaviour already observed in a number of SFXTs. A similar flaring activity was also found in archival *Beppo-SAX* data (Fiocchi et al. 2013). The companion star hosted in this system is classified as a O8Iafpe supergiant (Coleiro et al. 2013).

IGR J16393-4643 is a likely persistent sgHMXB. The source is a highly absorbed ($N_H \approx 2.5 \times 10^{23}$ cm^{-2} Bodaghee et al. 2006) pulsar with a spin period of 911 s (Bodaghee et al. 2006). The orbital period is under debate with a most likely value of 4.24 days (Pearlman et al. 2011; Thompson et al. 2006; Islam et al. 2015). The companion is not yet identified (Bodaghee et al. 2012a) but its dynamical mass is estimated as >7.5 M$_\odot$ (Pearlman et al. 2011; Nespoli et al. 2010a; Chaty et al. 2008).

IGR J16418-4532 was discovered by *INTEGRAL* in 2003 (Tomsick et al. 2004) and later classified as an SFXT on the basis of its fast flaring activity (Sguera et al. 2006). The discovery of the orbital period of the source at 3.75 days, together with some hint for the presence of an X-ray eclipse, was reported by (Corbet et al. 2006). The presence of an X-ray eclipse was later confirmed and analysed in detail by Drave et al. (2013). The source was detected in outburst few times with *Swift* (Romano et al. 2011c, 2012c) and monitored along its orbit with both the *Swift*/XRT (Romano et al. 2012d) and *XMM-Newton* (Sidoli et al. 2012). The observations confirmed the presence of prominent flaring activity in different X-ray luminosity states and led to the discovery of pulsations at a period of ~1212 s (see also Walter et al. 2006). Drave et al. (2013) showed that the apparent transient behaviour of the source is most likely due to its large distance (and the consequently low intrinsic X-ray flux). When the latter is taken into account, the source behaviour in X-rays is similar to that of classical sgHMXBs (see also Bozzo et al. 2015). IGR J16418-4532 is one of the few sources for which a superorbital modulation has been detected (the period of the modulation is 14.7 days; Corbet and Krimm 2013).

IGR J16465-4507, discovered with *INTEGRAL* (Lutovinov et al. 2004), is a transient X-ray pulsar (spin period ∼228 s, Lutovinov et al. 2005a) which displays on average properties very similar to those of the highly absorbed HMXBs (Walter et al. 2006) but was tentatively associated with the SFXT class due to the detection of fast flaring activity with *INTEGRAL* (Walter and Zurita Heras 2007). The supergiant companion was first identified by Smith (2004) and then confirmed by Negueruela et al. (2005). The measured orbital period of the source is 30.3 days (Clark et al. 2010; La Parola et al. 2010a). Despite the initial association with the SFXT class, the long-term monitoring of the source carried out with *Swift* showed that its X-ray flux variability is fairly limited and the X-ray behaviour is close to that of classical sgHMXBs (Romano et al. 2014a; Bozzo et al. 2015).

IGR J16479-4514 is a confirmed SFXT source. It was discovered with *INTEGRAL* (Molkov et al. 2003b) and observed in outburst several times with *Swift* and *INTEGRAL* (Romano et al. 2008c, b; Sguera et al. 2008). This object is known to have at present the shortest orbital period among the other sources of the same class (3.3 days, Romano et al. 2009b) and is the only one displaying X-ray eclipses (Bozzo et al. 2008c). The source undergoes regularly a peculiar flaring activity close to the periastron passage, which has been reported first by (Bozzo et al. 2009) and then studied in detail through a nearly complete orbital monitoring performed with *Suzaku* (Sidoli et al. 2013). The latter observation also did not reveal strong variation in the spectral parameters in different orbital phases, at odds with the behaviour displayed by other SFXT sources. IGR J16479-4514 is one of the few sources for which a superorbital modulation has been detected (the period of the modulation is 11.88 days; Corbet and Krimm 2013).

IGR J16493-4348 is an eclipsing sgHMXB system with a 6.78-day orbital period and a 1093-s spin period (Pearlman et al. 2013). The X-ray spectrum shows signatures for intrinsic absorption ($5{-}9\times10^{22}$ cm^{-2}) and for a cyclotron absorption feature (Morris et al. 2009; D'Aì et al. 2011a). The companion star is a B0.5 Ib supergiant (Nespoli et al. 2010b). IGR J16493-4348 is one of the few sources for which a superorbital modulation has been detected (the period of the modulation is 20.07 days; Corbet and Krimm 2013).

OAO 1657-415 is a persistent eclipsing sgHMXB with a pulsar (spin 37 s) orbiting a O or WR companion in 10.448 days on an eccentric ($e = 0.11$) orbit (Mason et al. 2012). The absorbing column density is $\geq 2\times10^{22}$ cm^{-2}. The accretion mode alternates between disk and wind accretion (Jenke et al. 2012). The wind density profile could be constrained by the hard X-ray eclipse profile (Denis et al. 2010).

4U 1700-37 is an eclipsing X-ray source associated with a very massive companion of type O6.5Iaf+ (Jones et al. 1973). The orbital parameters have been reconstructed and the most likely mass of the compact object is 2.4 $M_{\odot}$ (Corbet et al. 2010c). The detection of QPOs and the absence of pulsation (Dolan 2011) favour a black hole compact object while the hard X-ray spectral shape is typical for an accreting pulsar. The binary may have escaped the Sco OB1 association 2 millions years ago (Ankay et al. 2001). High-ionisation lines have been observed also during eclipses, indicating that the stellar wind is very inhomogeneous (Boroson et al. 2003). The hard X-ray flux varies by a factor of several hundreds. The absorbing column density increases around eclipses as expected for a spherical wind plus a stream trailing the neutron star (Haberl et al. 1989).

AX J1700.2-4220 was discovered as a faint ASCA source. RXTE and Swift monitoring of the source allowed to characterise it as a Be system ($P_S = 54$ s; $P_{\rm orb} = 44$ days). The optical counterpart is not yet identified.

IGR J17200-3116 was discovered during a deep observation of the Galactic Center with the *INTEGRAL* observatory in 2003 (Revnivtsev et al. 2004; Walter et al. 2004). The exact class of the optical counterpart and distance to the source are still unknown. Based on the *XRT/Swift* data, Nichelli et al. (2011) discovered pulsations from the source with the period $P_{\rm spin} \simeq 328$ s that allowed to suggest this source as a X-ray pulsar in the high-mass X-ray binary system. More observations are required to determine the spectral type of this HMXB.

EXO 1722-363 was discovered with EXOSAT (Warwick et al. 1988) and identified as an highly obscured X-ray pulsar with Ginga (Makino 1988; Tawara et al. 1989; Takeuchi et al. 1990). The source position was refined with INTEGRAL (Lutovinov et al. 2003a; Walter et al. 2004) and further with XMM-Newton, which allowed an association with an infrared counterpart (Zurita Heras et al. 2006). Its infrared spectrum was identified with that of a supergiant B0-B1Ia star, located at a distance of 7.1−7.9 kpc (Chaty et al. 2008; Mason et al. 2009, 2010). The orbital period of 9.742 days, determined with RXTE (Markwardt and Swank 2003; Corbet et al. 2005b) and refined with INTEGRAL (Manousakis and Walter 2011) thanks to the presence of X-ray eclipses, established the system as a sgHMXB. The orbital eccentricity is smaller than 0.15. Outside of the X-ray eclipses, the X-ray (2–10 keV) luminosity varies in the range $(0.25-2) \times 10^{36}$ erg/s and a soft component is detected at a level of 3×10^{33} erg/s. The spectrum is typical for an accreting pulsar with $\Gamma \sim 0$ and a cutoff energy of $E_C \sim 8.2$ keV. An Iron line is detected with an equivalent width of ∼100 eV, generated by material very close to the neutron star. The X-ray pulsar features a spin period of 413.89 s (with short time scale variability as large as 1 μs/s) and a persistently high obscuration, with an absorbing column density varying along the orbit and averaging to 2×10^{23} cm^{-2} (Walter et al. 2006; Manousakis and Walter 2011). Detailed hydrodynamic simulations of EXO 1722-363 indicated that its high obscuration is linked with the low velocity (∼500 km/s) of the companion stellar wind and constrained the neutron star mass to 1.75–2.15 (Manousakis et al. 2012), a value slightly larger but compatible with the kinematic value of 1.5 ± 0.4 (Mason et al. 2010).

IGR J17354-3255 was discovered with *INTEGRAL* in 2006 (Kuulkers et al. 2006). The source only sporadically displays relatively short flares with duration from few hours to ~1 day (Vercellone et al. 2009; Tomsick 2009) and has an orbital period of 8.4 days. For these reasons it was associated with the SFXT class (D'Aì et al. 2011b; Sguera et al. 2011). The source is also positionally coincident with the high-energy AGILE transient AGL J1734-3310, even though the localization uncertainties are still too large to claim a firm association (Vercellone et al. 2009). An *XMM-Newton* observation aimed at the source failed to detect it (Bozzo et al. 2012b) and set a lower limit to the dynamic range of its X-ray luminosity of $\gtrsim 10^4$. An orbital monitoring of the source with *Swift* suggested the presence of a possible X-ray eclipse (Ducci et al. 2013b).

XTE J1739-302 (other name IGR J17391-3021) was discovered with *RXTE* during a bright outburst in 1997 (Smith et al. 1998). Several outbursts from this source were detected with ASCA (Sakano et al. 2002), RXTE (Smith et al. 2006), *INTEGRAL* (Sunyaev et al. 2003a; Lutovinov et al. 2005b; Sguera et al. 2005, 2006; Blay et al. 2008) and *Swift*/BAT (Sidoli et al. 2009a, c; Romano et al. 2009b, 2011b). The source was also observed during faint X-ray states by *Chandra* and *XMM-Newton*, revealing the typical variability of the SFXT sources (Smith et al. 2006; Bozzo et al. 2010; Bodaghee et al. 2011). The discovery of the source orbital period at 51.47 days was reported by Drave et al. (2010). The identification of the supergiant companion of XTE J1739-302 was reported by (Rahoui et al. 2008).

AX J1749.1-2733 and AX J1749.2-2725 are two closely spaced (angular distance is about 7′) faint X-ray sources discovered by the *ASCA* observatory in the direction to the Galactic Center (Sakano et al. 2002; Torii et al. 1998). The latter one was initially recognized as an X-ray pulsar with the period $P_{\rm spin} \simeq 220$ s (Torii et al. 1998); pulsations with the period $P_{\rm spin} \simeq 132$ s from AX J1749.1-2733 were detected later, based on the *XMM-Newton* and *INTEGRAL* data (Karasev et al. 2007, 2008). The *INTEGRAL* observatory detected these sources in hard X-rays: AX J1749.1-2733 during the outburst (Grebenev and Sunyaev 2007) and on the average map (Krivonos et al. 2012), AX J1749.2-2725 on the average map (Krivonos et al. 2012). Spectra of both sources demonstrate a presence of the strong photo-absorption, which significantly exceeds the interstellar one and indicates the massive nature of their companions. An optical identification of both sources was problematic a long time. The infrared data from the *NTT/SOFI* telescope allowed Karasev et al. (2010a) to determine optical counterparts in both systems and estimate their spectral classes as B1-3 and B3 for AX J1749.1-2733 and AX J1749.2-2725, respectively. Moreover, based on the currently developed methods of distance estimation according to the position of red clump giants on the color-magnitude diagram (Karasev et al. 2010b), Karasev et al. (2010a) also estimated the distances to the sources as $13-16$ and ~14 kpc, respectively.

GRO 1750-27 is a transient X-ray pulsar with a pulse period $P_{\rm spin} = 4.45$ s. It was discovered by the *BATSE* instrument on board the *Comptom-GRO* observatory during a strong outburst in 1995 (Scott et al. 1997). Besides the pulse period a strong modulation of the source flux was found on a time scale of 29.8 days and interpreted as the orbital period in the binary system (Scott et al. 1997). A second outburst from the system was detected in 2008 by the *Swift* observatory (Krimm et al. 2008) and was monitored by several instruments. These observations allowed to measure the broadband X-ray spectrum of the source and trace the evolution of its hardness, which demonstrated a gradual softening during the outburst (Shaw et al. 2009). Moreover, the accuracy of the determination of the orbital period was improved to $P_{\rm orb} = 29.806 \pm 0.001$ days (Shaw et al. 2009). Based on the source behaviour and on a relation between pulse and orbital periods (Scott et al. 1997) assumed a Be-nature of its optical counterpart and estimated a distance to the system as $\sim$18 kpc; however this result still needs to be confirmed.

IGR J17544-2619 , discovered with *INTEGRAL* (Sunyaev et al. 2003b), is one of the most extreme and well-studied SFXT sources (in't Zand 2005). The companion star was spectroscopically identified by Pellizza et al. (2006) (but see also Rahoui et al. 2008) and the orbital period was measured at 4.92 days (Clark et al. 2009). A possible indication of pulsations from the direction of the source at 71 s was reported by Drave et al. (2012) by using the RXTE/PCA, but then retracted (Drave et al. 2014). The deepest observation available was performed with the XIS on-board Suzaku (Rampy et al. 2009). In these data, the authors found evidence for the presence of clumps using hardness ratio measurements, caused by variations of the local absorption. The source was also monitored with Swift/XRT for more than two years (Romano et al. 2011a), during which a number of typical SFXT outbursts were identified. Enhanced variability in the X-ray domain was also evidenced in two relatively short observations performed with *XMM-Newton* in 2003 (González-Riestra et al. 2004). An unprecedentedly bright outburst was detected by the source in 2014, leading to the suggestion that temporary accretion disks might form around the neutron star hosted in this system. A possible detection of pulsations at 11.6 s (Romano et al. 2015) and of a cyclotron line at 17 keV (Bhalerao et al. 2015) were also reported.

IGR J17586-2129 was first reported by Bird et al. (2007). Using follow-up observations with the Chandra observatory Tomsick et al. (2009a) improved an accuracy of the source coordinates and determined the infrared 2MASS counterpart. In addition, these authors found a significant absorption ($\simeq 10^{23}$ cm^{-2}) in the IGR J17586-2129 spectrum and stated that the source is a candidate to the absorbed HMXB. The infrared spectroscopic measurements revealed only the Br(7-4) emission line, that in combination with the measured spectral energy distribution points toward a supergiant companion star (Coleiro et al. 2013).

IGR J18027-2016 is a persistent eclipsing X-ray pulsar detected by *INTEGRAL* (Revnivtsev et al. 2004; Lutovinov et al. 2005b) and BeppoSAX (Augello et al. 2003). With a spin period of 139.612 s and an orbital period of 4.4696 days, its orbit could be reconstructed (Hill et al. 2005; Mason et al. 2011). Its X-ray continuum, typical of an accreting pulsar, is moderately absorbed with $N_H \approx 0.9 \times 10^{23}$ cm^{-2} and the presence for an Iron line (Walter et al. 2006). The companion star is likely a supergiant B1Ib located at a distance of $\sim$12.4 kpc (Masetti et al. 2008; Chaty et al. 2008; Torrejón et al. 2010).

IGR J18151-1052 was discovered by the *INTEGRAL* observatory during the Galactic plane survey (Krivonos et al. 2009). Follow-up observations of the source, performed with the *XRT* telescope aboard the *Swift* observatory, revealed a significant photo-absorption in its spectrum—up to 3.4×10^{22} cm^{-2}, that is much higher than that in the Galactic interstellar medium. A strong H_α emission line at zero redshift was detected in the spectrum of its optical counterpart. This suggests that the object is definitely an X-ray binary in our Galaxy, probably an absorbed OB-star (Burenin et al. 2009). The further detailed analysis showed that the identification of the system as a cataclysmic variable cannot be fully ruled out and might be preferable (Lutovinov et al. 2012b; Masetti et al. 2013).

IGR J18179-1621 is a hard X-ray transient source discovered during the inner Galactic disk observations in February 2012 (Tuerler et al. 2012). X-ray pulsations with a period of $P_{\rm spin} \simeq 11.82$ s were discovered immediately in the source light curve during follow-up observations with the *XRT/Swift* telescope (Halpern 2012b). The broadband spectrum of the source can be described by a power law model modified by a high-energy cutoff and strong photo-absorption ($N_H \simeq 12 \times 10^{22}$ cm^{-2}) at low energies (Li et al. 2012b). Thus, it can be concluded that IGR J18179-1621 is a new heavily absorbed X-ray pulsar in a HMXB. Finally, note that a type of its optical companion is still not determined.

SAX J1818.6-1703 is one of the confirmed SFXT sources and was discovered in 1998 by *Beppo-SAX* (in't Zand et al. 1998a). Several outbursts from the source were detected with *INTEGRAL* and *Swift* (see, e.g. Sidoli et al. 2009b and references therein). Bird et al. (2010) and Zurita Heras and Chaty (2009) determined the best orbital period of the source at 30 ± 0.1 days. Zurita Heras and Chaty (2009) also found that most of the discovered outbursts took place close to the periastron passage and that the source usually remains relatively bright in X-rays for about ~6 days around this orbital phase. Outbursts in several periastron passages were missing. SAX J1818.6-1703 was also observed twice with *XMM-Newton* close to the apastron, but not detected Bozzo et al. (2008a, 2012b).

AX J1820.5-1434 is a faint X-ray pulsar with the neutron star spin period $P_{\rm spin} \simeq 152$ s, discovered by the *ASCA* observatory during the Galactic plane survey (Kinugasa et al. 1998). These observations revealed also a strong absorption in the X-ray spectrum ($N_H \sim 10^{23}$ cm^{-2}). It was interpreted as an indication that AX J1820.5-1434 is a high-mass X-ray binary system, but a clear optical identification and determination of the spectral class of the optical star are still problematic (Negueruela and Schurch 2007). A detection of the hard X-ray emission from AX J1820.5-1434 with the *INTEGRAL* observatory (Lutovinov et al. 2003b) allowed to reconstruct the source spectrum up to ~70 keV and to show that it is typical for X-ray pulsars in HMXB (Filippova et al. 2005). This source is also tentatively associated with the SFXT class due to the detection of fast flaring activity with *INTEGRAL* (Walter and Zurita Heras 2007). A timing analysis of the long-term observations with the *S*wift observatory revealed the detection of a coherent signal at $P_{\rm orb} = 54.0 \pm 0.4$ days, which was interpreted as the orbital period of the binary system (Segreto et al. 2013).

IGR J18410-0535 (other name AX J1841.0-0536) was discovered with *ASCA* in 1994 (Bamba et al. 2001), while undergoing two bright flares lasting about 1 h each. Similar SFXT-like flaring activity was also recorded several times with MAXI and *INTEGRAL* (Rodriguez et al. 2004; Sguera et al. 2006; Walter and Zurita Heras 2007). Hours-long outbursts were also detected by *Swift*/BAT and followed up a few times by *Swift*/XRT (de Pasquale et al. 2010; Romano et al. 2010a, 2011b, 2012a, b). This behaviour led to the association of IGR J1841.0-0536 with the SFXT class. This association was strengthened by the identification of the supergiant companion through infrared observations (Nespoli et al. 2008). A 45-ks long *XMM-Newton* observation performed in 2011 in the direction of IGR J1841.0-0536 caught the source undergoing a bright X-ray flare, which could be interpreted in terms of sudden "ingestion" of accreting material from the dense wind environment. This observation could not confirm the presence of pulsations at ∼4.7 s, as suggested by the analysis of previous data (Bamba et al. 2001; Sidoli et al. 2008). A possible association between IGR J18410-0535 and the transient MeV EGRET source 3EG J1837-0423 was suggested by Sguera et al. (2009). The discovery of the source orbital period at 6.5 days was reported by González-Galán (2014).

GS 1843+00 is a transient X-ray pulsar discovered in 1988 by the *Ginga* observatory during a galactic plane scan (Makino and GINGA Team 1988b). A pulse period of 29.5 s was measured shortly (Koyama et al. 1990a). Spectroscopic and photometric data indicate a B0-B2 IV-Ve star located at a distance of $\geq$10 kpc as an optical counterpart (Israel et al. 2001).

IGR J18450-0435 (other name AX J1845.0-0433) was discovered by Yamauchi et al. (1995) in 1993 with the *ASCA* observatory and classified as a transient X-ray source. It exhibited a few hours-long flaring activity and spectral properties similar to those displayed by the SFXTs. The supergiant companion was identified by Coe et al. (1996). The source has been observed several times during periods of enhanced X-ray activity with *INTEGRAL* (Molkov et al. 2004; Halpern and Gotthelf 2006) and *Swift* (Sguera et al. 2007; Romano et al. 2009a, 2012a). In all cases, the X-ray flares displayed similar properties with respect to those detected originally with *ASCA*. IGR J18450-0435 was also observed with *XMM-Newton* and caught during the transition from a flaring to a quiescent state (Zurita Heras and Walter 2009). The *XMM-Newton* observation also revealed the presence of a soft spectral component at energies $\lesssim$2 keV, similar to that already detected from a number of SFXTs and interpreted in terms of X-ray emission from the supergiant wind itself or reprocessing of the NS X-rays within the wind material. The discovery of the source orbital period was reported by Goossens et al. (2013).

A 1845-024 was initially found by *Ariel-5* (Seward et al. 1976). Later *Ginga* discovered a pulsating source GS 1843-024 with the period of 94.8 ± 0.1 s (Makino and GINGA Team 1988a) at the same position. Soffitta et al. (1998) identified these two sources with a hard X-ray object GRO J1849-03, which was discovered by *CGRO/BATSE* and demonstrated recurrent hard X-ray outbursts with a period of ∼241 days (Zhang et al. 1996). Assuming this periodicity to be orbital one Soffitta et al. (1998) classified this source as Be/XRP system using the Corbet diagram. The source spectrum is typical for X-ray pulsars, but modified by a large absorption at low energies $N_H = (1.5 - 3) \times 10^{23}$ cm^{-2} (Koyama et al. 1990b). According to the *INTEGRAL* data the source spectrum above 20 keV can be approximated by a simple power-law (Doroshenko et al. 2008).

IGR J18462-0223 was discovered by *INTEGRAL* during a few hours-long outburst very reminiscent of the event usually recorded from the SFXTs (Grebenev and Sunyaev 2010). The source was also observed later with *XMM-Newton* (Bodaghee et al. 2012b), which provided an improved X-ray position within a few arcsec accuracy. The infrared counterpart is, however, not securely identified yet. The *XMM-Newton* observation also led to the measurement of a strong absorption in X-rays local to the source, which is reminiscent of what is usually observed in the highly absorbed HMXBs, and the identification of X-ray pulsations at a period of 997 s. This confirmed the presence of a neutron star accretor in IGR J18462-0223 as expected for an SFXT source. The NIR counterpart of IGR J18462-0223 was identified by Sguera et al. (2013) and suggested to be a supergiant star located at ∼11 kpc.

IGR J18483-0311 was discovered in 2003 by Chernyakova et al. (2003). The 18.5-day orbital period of the system was first identified by Levine and Corbet (2006) using *RXTE* archival data and later confirmed with *INTEGRAL* (Sguera et al. 2007). *INTEGRAL* data also showed that IGR J18483-0311 sporadically displays a few days-long X-ray active states (∼3 days), during which fast flares with typical timescales of a few hours can be observed (Krimm et al. 2011; Romano et al. 2010b; Ducci et al. 2013a). Pulsations with a period of ∼21 s were first reported by Sguera et al. (2007). Giunta et al. (2009) discussed the possible detection of pulsations during the low X-ray intensity states of the source. These detections of pulsations were later questioned by Ducci et al. (2013a). The supergiant companion of IGR J18483-0311 was identified by Rahoui et al. (2008).

XTE J1855-026 was discovered during *RXTE* scans along the Galactic plane (Corbet et al. 1999b). The source exhibited pulsations with a period of $P_{\rm spin} \simeq 360.7$ s and also a flux modulation with a period of $P_{\rm orb} \simeq 6.07$ days, which was interpreted as the orbital period in the binary system (Corbet and Mukai 2002). In the same paper other orbital parameters were determined as well: $a_x \sin i = 80.5 \pm 1.4$ lt-s, $\omega = 226 \pm 15$ deg, $e = 0.04 \pm 0.02$. An optical counterpart of XTE J1855-026 was identified as a B0 Iaep luminous supergiant star (Verrecchia et al. 2002b; Negueruela et al. 2008a). The source spectrum has a typical form for X-ray pulsars (White et al. 1983) modified by a significant photo-absorption $N_H \simeq (4-15) \times 10^{22}$ cm^{-2} (Corbet et al. 1999b; Romano et al. 2008a).

XTE J1858+034 is a hard X-ray transient pulsar discovered by *RXTE/ASM* in February 1998 (Remillard et al. 1998). The pulse period was measured with using of *RXTE/PCA* data to be 221.0 ± 0.5 s (Takeshima et al. 1998). The transient behaviour, hard X-ray spectrum and pulsations suggest the Be/XRP nature of the source (Takeshima et al. 1998). An orbital period value was estimated to be ∼380 days

(Doroshenko et al. 2008). The hard X-ray spectrum obtained by the *INTEGRAL* observatory can be well described by a power law model with the high-energy cutoff and photo-absorption at low energies: photon index 1.26 ± 0.08, $E_{\rm cut} = 26.7 \pm 0.7$ keV, $E_{\rm fold} = 6.6 \pm 0.3$ keV, $N_H = (9.0 \pm 1.3) \times 10^{22}$ cm^{-2} (Doroshenko et al. 2008).

4U 1901+03 was detected by the All Sky Monitor of the *RXTE* observatory in January 2003 (Galloway et al. 2003). It was only a second appearance of this source on the X-ray sky after its discovery with the *UHURU* observatory (Forman et al. 1976). The follow-up observations, performed with the *PCA/RXTE* spectrometer, allowed to discover a coherent signal with the period $P_{\rm spin} \simeq 2.763$ s in the source light curve. This discovery was confirmed soon with the *INTEGRAL* observatory, which observed this region of the sky (Molkov et al. 2003a). Moreover, these observations allowed to obtain for the first time a source broadband spectrum and demonstrate that it can be well approximated by a power law model with a photon index $\Gamma \sim 1.9$ and a high-energy cutoff ($E_{\rm cut} \simeq 12$ and $E_{\rm fold} \simeq 13.5$ keV) that is typical for X-ray pulsars. Using data of the *RXTE* observatory (Galloway et al. 2005) determined orbital parameters of the system and showed that it has a very small eccentricity ($e \simeq 0.036$) and moderate orbital period $P_{\rm orb} \simeq 22.58$ days. The outburst has lasted for about 5 months. There are not firmly established optical counterpart of the source, nor consolidated estimates of its distance. There are only tentative suggestions that the neutron star in 4U 1901+03 accretes from the wind of a main-sequence OB star (Galloway et al. 2005, but see also the association of 4U1901+03 with an early type giant star B0III by Jones et al. 1974).

4U 1907+097 is a persistent sgHMXB with a pulsar (437.5 s spin) orbiting an O8-9 Ia supergiant (located at 2–6 kpc) in 8.37 days with an eccentricity of 0.28 (Makishima et al. 1984; in't Zand et al. 1998b; Cox et al. 2005; Nespoli et al. 2008). Its X-ray emission is highly variable and feature cyclotron absorption features (Mihara et al. 1995; Cusumano et al. 1998; Rivers et al. 2010; Fürst et al. 2011a; Hemphill et al. 2013). The source spends ~60 % of the time in X-ray off-states that can last from minutes to hours (in't Zand et al. 1998b; Roberts et al. 2001; Rivers et al. 2010; Şahiner et al. 2012). Pulsations are detected during the off-states (Roberts et al. 2001; Doroshenko et al. 2012a). Limited random-walk spin period variations have been observed (Şahiner et al. 2012). The X-ray absorption is modulated by the orbit (Şahiner et al. 2012, but remains $<10^{23}$ cm^{-2}) and could be modelled with an accretion stream trailing the neutron star (Kostka and Leahy 2010). 4U 1907+097 is a runaway system accompanied by a bow shock (Gvaramadze et al. 2011).

4U 1909+07 is a persistent X-ray pulsar discovered by the *UHURU* observatory (Forman et al. 1978) (also known as X 1908+075). An orbital periodicity of 4.4 days has been found in the *RXTE/ASM* data (Wen et al. 2000). Morel and Grosdidier (2005) reported a near-infrared identification of the counterpart consistent with a late O-type supergiant star lying at a distance of ~7 kpc. Using *RXTE/PCA* data Levine et al. (2004) found the pulse period of the neutron star of ~605 s and determined the binary orbit parameters $P_{\rm orb} = 4.4007 \pm 0.0009$ days, $e = 0.021 \pm 0.039$, $a_x \sin i = 47.83 \pm 0.94$ lt-s, $f(M) = 6.07 \pm 0.35\ M_{\rm sun}$. A very strong stellar wind in the system leads to the substantial photo-absorption in the energy spectrum of X 1908+075, which consists of a power law continuum modified by a turnover at high energies. The orbital phase resolved spectroscopy reveals an increase of the photo-absorption by a factor of 3 or more reaching values of $N_H \sim$ few $\times\, 10^{23}$ cm^{-2} around orbital phase 0 (Levine et al. 2004). Possible detection of the cyclotron scattering feature at 44 keV was reported by Jaisawal et al. (2013) based on the *Suzaku* data. 4U 1909+07 is one of the few sources for which a superorbital modulation has been detected (the period of the modulation is 15.18 days; Corbet and Krimm 2013).

IGR J19140+0951 is a persistent sgHMXB featuring a 13.55 days orbital period. The counterpart is a B0.5 supergiant located at 2–5 kpc (Hannikainen et al. 2007). Its accreting pulsar X-ray spectrum features absorption (10^{23-24} cm^{-2}) modulated by the orbital period and a variable soft X-ray excess (Prat et al. 2008).

IGR J19173+0747 was discovered by the *INTEGRAL* observatory during deep observations of the Sagittarius arm region (Pavan et al. 2011). Follow-up observations with the *XRT/Swift* telescope allowed to refine the source position, which was coincident with that of the *ROSAT* source 1RXS J191720.6+074755, and determine its optical counterpart. Based on the overall optical spectral shape and characteristics of an early-type star Masetti et al. (2012b) classified the object IGR J19173+0747 as a candidate to the high-mass X-ray binary.

IGR J19294+1816 was discovered in 2009 with the *INTEGRAL* observatory (Turler et al. 2009). Indications of coherent pulsations with a period of about 12.4 s were found with *Swift/XRT* data (Rodriguez et al. 2009). Corbet and Krimm (2009) have found an orbital modulation of the hard X-ray flux with a period of 117 days. The relation between orbital and pulsation periods, as well as transient nature, leads to the identification of this source as a Be binary system with the X-ray pulsar. The source broadband spectrum could be well fitted by a cut off power law with photo-absorption: photon index 0.4 ± 0.3, $E_{\rm cut} = 8.0^{+1.2}_{1.0}$ keV, $N_H = (3.1 \pm 0.7) \times 10^{22}$ cm^{-2} (Bozzo et al. 2011a).

XTE J1946+274 is the X-ray pulsar ($P_{\rm spin} = 15.83$ s) discovered simultaneously with the *RXTE* observatory and *BATSE* instrument in 1998 (Smith and Takeshima 1998). A strong outburst activity of the source in 1998–2001 allowed Wilson et al. (2003) to measure the orbital period of the system $P_{\rm orb} = 169.2$ days and its eccentricity $e = 0.33$. Such long orbital periods in a combination with a relatively high eccentricity are typical for Be/X-ray binaries. In the case of XTE J1946+274, its optical counterpart has a spectral class B0-1V-IVe and is located at a distance of 8–10 kpc (Verrecchia et al. 2002a). Based on the *RXTE* data Heindl et al. (2001) found a cyclotron resonance scattering feature in the source hard X-ray spectrum near 36 keV. Such an energy corresponds to a magnetic field strength of $\simeq 3.1 \times 10^{12}$ G.

KS 1947+300 is a transient X-ray pulsar, which was discovered in June 1989 by the *TTM* telescope aboard the *KVANT* module of the *Mir* space station (Borozdin et al. 1990). Later the *BATSE* monitor of the *Compton-GRO* observatory revealed the X-ray pulsar GRO J1948+32 with a period of 18.7 s in the same region of the sky (Chakrabarty et al. 1995). Subsequently, KS 1947+300 and GRO J1948+32 were found to be the same object (Swank and Morgan 2000). Based on the association of the optical counterpart with a B0Ve star the distance to the source was estimated as $\sim$10 kpc (Negueruela et al. 2003). Later, using *INTEGRAL* and *RXTE* data a similar value for the distance to the source ($\sim$9.5 kpc) was derived from the spin-up rate of the neutron star (Tsygankov and Lutovinov 2005b). Measurements of the orbital Doppler shift of the pulse period allowed Galloway et al. (2004) to determine the orbital parameters of the binary system: the orbital period $P_{\rm orb} = 40.415 \pm 0.010$ days, the projected semimajor axis of the relativistic object $a_x \sin i = 137 \pm 3$ light seconds and the eccentricity $e = 0.033 \pm 0.013$. The spectrum of KS 1947+300 in the $3-100$ keV energy range can be described by a power law with a high-energy cutoff. Spectral parameters are slightly dependent on the source luminosity and in average consistent with a photon index of $\Gamma \sim 1.1$, $E_{\rm cut} \sim 10$ keV and $E_{\rm fold} \sim 25$ keV (Tsygankov and Lutovinov 2005b). According to the NuSTAR observations an emission continuum is modified by the pulse phase dependent cyclotron scattering feature at $\sim$12.5 keV Fürst et al. (2014a).

SWIFT J2000.6+3210 was recently discovered by the *Swift/BAT* telescope (Tueller et al. 2005) and optically identified with an early BV or mid BIII star (Halpern 2006; Burenin et al. 2006; Masetti et al. 2008). During one of two *Suzaku* observations a period of 1056 s was found and interpreted as the spin period of the neutron star (Morris et al. 2009). Spectral analysis of these data revealed a significant photo-absorption $N_H \simeq \times 10^{23}$ cm^{-2} (Morris et al. 2009).

EXO 2030+375 is a transient accreting X-ray pulsar with a spin period of $\sim$42 s discovered with the *EXOSAT* observatory during a giant outburst in 1985 (Parmar et al. 1985). The optical counterpart in the binary system is a B0Ve star (Motch and Janot-Pacheco 1987; Coe et al. 1988), and the distance to the system is estimated as $\sim$7.1 kpc (Wilson et al. 2002). Orbital parameters of the binary system were derived using *BATSE* data (Stollberg et al. 1999): the orbital period $P_{\rm orb} = 46.016 \pm 0.003$ days, $e = 0.36 \pm 0.02$, $a_x \sin i = 261 \pm 14$ lt-s. The energy spectrum of the source is typical for X-ray pulsars and can be fitted by a power-law model with the high-energy cutoff and iron line. Some authors reported about a tentative detection of the cyclotron absorption feature at $\sim$36 keV (Reig and Coe 1999), and $\sim$11 keV (Wilson et al. 2008) using *RXTE* data and at $\sim$63 keV using *INTEGRAL* data (Klochkov et al. 2008). However the existence of this feature in the source spectrum is still not proven reliably.

SAX J2103.5+4545 is a member of a high-mass Be binary system with a moderate eccentricity ($e \simeq 0.4$) and one of the shortest orbital period $P_{\rm orb} \simeq 12.68$ days known to date among such binaries (Baykal et al. 2000). The source was discovered as a X-ray pulsar with the period $P_{\rm spin} = 358.6$ s based on the data of the *BeppoSAX* observatory (Hulleman et al. 1998). A subsequent monitoring of the pulse period revealed its strong evolution and periods of a drastic acceleration of the neutron star rotation (Sidoli et al. 2005a; Baykal et al. 2007). The accurate X-ray coordinates of the source, obtained with the *XMM-Newton* observatory, allowed to determine unambiguously its optical counterpart, which turned out an O-B star with strong emission lines (Filippova et al. 2004). The spectral class of the optical star was determined as B0Ve (Reig 2011). A distance to the source is estimated as $\simeq$4.5−6.9 kpc (Baykal et al. 2007). The broadband spectrum of SAX J2103.5+4545, obtained with data of *RXTE* and *INTEGRAL* observatories, is typical for X-ray pulsars and can be described by a power law with high-energy cutoff (see, e.g. Baykal et al. 2002; Lutovinov et al. 2003c; Filippova et al. 2004; Ducci et al. 2008).

IGR J21343+4738 was discovered during deep observations at the *INTEGRAL* observatory (Krivonos et al. 2007; Bird et al. 2007). An optical companion is a $V = 14.1$ B1IVe shell star located at a distance of ~8.5 kpc (Reig and Zezas 2014a). X-ray pulsations with the period of $\simeq$320 s were discovered at the *XMM-Newton* observatory (Reig and Zezas 2014b).

4U 2206+543 appeared for the first time in the *UHURU* catalogue (Giacconi et al. 1972). The optical counterpart in the system is a peculiar O9.5V star with a high He abundance at a distance of ~2.6 kpc (Blay et al. 2006). A possible orbital modulation with a period of $\simeq$9.57 days was found in the *RXTE/ASM* data (Corbet and Peele 2001). Pulsations at a period of 5559 ± 3 s were discovered using observations of *RXTE/PCA* (Reig et al. 2009). Some models predict the system 4U 2206+543 to harbour a magnetar (see, e.g. Finger et al. 2010). In addition to the spectral model typical for X-ray pulsars (power law with high-energy cutoff), some evidence of a cyclotron resonance scattering feature at energies ~30 and ~60 keV were presented using *RXTE, BeppoSAX* (Torrejón et al. 2004) and *INTEGRAL* (Blay et al. 2005; Wang 2009) data. However, later an existence of such features in the source spectrum was not confirmed (Wang 2013).

IGR J22534+6243 was discovered as a faint hard X-ray source on the Galactic plane map averaging about 9 years of *INTEGRAL* observations (Krivonos et al. 2012). Based on *Chandra* and *Swift* archival data, Halpern (2012a) found pulsations of the X-ray emission with a period $P_{\text{spin}} \simeq 46.67$ s. The broad-band spectrum of IGR J22534+6243 obtained with *Chandra*, *Swift* and *INTEGRAL* observatories can be well described by a power law model with a cutoff energy of 25−30 keV, slightly higher than usually observed for X-ray pulsars (Lutovinov et al. 2013a). The proposed optical counterpart 2MASS J22535512+6243368 was observed later by Masetti et al. (2012a) and Lutovinov et al. (2013a), who revealed an optical spectrum typical for an early type star with superimposed $H\alpha$, $H\beta$ and HeI emissions at redshift zero. Based on these measurements it was concluded that IGR J22534+6243 is a X-ray pulsar in a Be high-mass X-ray binary system.

References

Ankay A, Kaper L, de Bruijne JHJ, Dewi J, Hoogerwerf R, Savonije GJ (2001) The origin of the runaway high-mass X-ray binary HD 153919/4U1700-37. A&A 370:170–175. doi:10.1051/0004-6361:20010192. arXiv:astro-ph/0102118

Apparao KMV, Naranan S, Kelley RL, Bradt HV (1980) 2S1417-624—a variable galactic X-ray source near CG312-1. A&A 89:249

Araya RA, Harding AK (1999) Cyclotron line features from near-critical magnetic fields: the effect of optical depth and plasma geometry. Astrophys J 517:334–354. doi:10.1086/307157

Araya-Góchez RA, Harding AK (2000) Cyclotron-line features from near-critical fields. II. On the effect of anisotropic radiation fields. Astrophys J 544:1067–1080. doi:10.1086/317224. arXiv:astro-ph/0007191

Augello G, Iaria R, Robba NR, Di Salvo T, Burderi L, Lavagetto G, Stella L (2003) BeppoSAX serendipitous discovery of the X-ray pulsar SAX J1802.7-2017. Astrophys J Lett 596:L63–L66. doi:10.1086/379092. arXiv:astro-ph/0308157

Bachetti M, Harrison FA, Walton DJ, Grefenstette BW, Chakrabarty D, Fürst F, Barret D, Beloborodov A, Boggs SE, Christensen FE, Craig WW, Fabian AC, Hailey CJ, Hornschemeier A, Kaspi V, Kulkarni SR, Maccarone T, Miller JM, Rana V, Stern D, Tendulkar SP, Tomsick J, Webb NA, Zhang WW (2014) An ultraluminous X-ray source powered by an accreting neutron star. Nature 514:202–204. doi:10.1038/nature13791. arXiv:1410.3590

Balbo M, Saouter P, Walter R, Pavan L, Tramacere A, Pohl M, Zurita-Heras JA (2010) HESS J1632-478: an energetic relic. A&A 520:A111. doi:10.1051/0004-6361/201014764. arXiv:1007.1970

Bamba A, Yokogawa J, Ueno M, Koyama K, Yamauchi S (2001) Discovery of a transient X-ray pulsar, AX J1841.0-0536, in the scutum arm region with ASCA. Publ ASJ 53:1179–1183. arXiv:astro-ph/0110423

Barba R, Gamen R, Morrell N (2006) HD 74194, a new binary supergiant fast X-ray transient?, possible optical counterpart of INTEGRAL hard X-ray source IGR J08408-4503. Astron Telegr 819:1

Barragán L, Wilms J, Pottschmidt K, Nowak MA, Kreykenbohm I, Walter R, Tomsick JA (2009) Suzaku observation of IGR J16318-4848. A&A 508:1275–1278. doi:10.1051/0004-6361/200810811. arXiv:0912.0254

Barthelmy SD, Romano P, Burrows DN, Esposito P, Evans PA, Gehrels N, Kennea JA, Krimm HA, La Parola V, Markwardt CB, Pagani C, Palmer DM, Sidoli L, Vercellone S (2009) Swift observations of a new outburst of the SFXT IGR J08408-4503. Astron Telegr 2178:1

Basko MM, Sunyaev RA (1976) The limiting luminosity of accreting neutron stars with magnetic fields. Mon Not RAS 175:395–417

Baykal A, Stark MJ, Swank J (2000) Discovery of the orbit of the transient X-ray pulsar SAX J2103.5+4545. Astrophys J Lett 544:L129–L132. doi:10.1086/317320. arXiv:astro-ph/0009481

Baykal A, Stark MJ, Swank JH (2002) X-ray spectra and pulse frequency changes in SAX J2103.5+4545. Astrophys J 569:903–910. doi:10.1086/339429. arXiv:astro-ph/0201080

Baykal A, Inam SÇ, Stark MJ, Heffner CM, Erkoca AE, Swank JH (2007) Timing studies on RXTE observations of SAX J2103.5+4545. Mon Not RAS 374:1108–1114. doi:10.1111/j.1365-2966.2006.11231.x. arXiv:astro-ph/0608653

Becker PA, Wolff MT (2005) Spectral formation in X-ray pulsars: bulk comptonization in the accretion shock. Astrophys J 630:465–488. doi:10.1086/431720. arXiv:astro-ph/0505129

Becker PA, Wolff MT (2007) Thermal and bulk comptonization in accretion-powered X-ray pulsars. Astrophys J 654:435–457. doi:10.1086/509108. arXiv:astro-ph/0609035

Becker RH, Swank JH, Boldt EA, Holt SS, Serlemitsos PJ, Pravdo SH, Saba JR (1977) A1540-53, an eclipsing X-ray binary pulsator. Astrophys J Lett 216:L11–L14. doi:10.1086/182498

Belczynski K, Wiktorowicz G, Fryer CL, Holz DE, Kalogera V (2012) Missing black holes unveil the supernova explosion mechanism. Astrophys J 757:91. doi:10.1088/0004-637X/757/1/91. arXiv:1110.1635

Bhadkamkar H, Ghosh P (2012) Collective properties of X-ray binary populations of galaxies. I. Luminosity and orbital period distributions of high-mass X-ray binaries. Astrophys J 746:22. doi:10.1088/0004-637X/746/1/22. arXiv:1111.3817

Bhalerao V, Romano P, Tomsick J, Natalucci L, Smith DM, Bellm E, Boggs SE, Chakrabarty D, Christensen FE, Craig WW, Fuerst F, Hailey CJ, Harrison FA, Krivonos RA, Lu TN, Madsen K, Stern D, Younes G, Zhang W (2015) NuSTAR detection of a cyclotron line in the supergiant fast X-ray transient IGR J17544-2619. Mon Not RAS 447:2274–2281. doi:10.1093/mnras/stu2495. arXiv:1407.0112

Bikmaev IF, Sunyaev RA, Revnivtsev MG, Burenin RA (2006) New nearby active galactic nuclei among INTEGRAL and RXTE X-ray sources. Astron Lett 32:221–227. doi:10.1134/S1063773706040013

Bikmaev IF, Burenin RA, Revnivtsev MG, Sazonov SY, Sunyaev RA, Pavlinsky MN, Sakhibullin NA (2008) Optical identifications of five INTEGRAL hard X-ray sources in the Galactic plane. Astron Lett 34:653–663. doi:10.1134/S1063773708100010. arXiv:0810.2018

Bildsten L, Chakrabarty D, Chiu J, Finger MH, Koh DT, Nelson RW, Prince TA, Rubin BC, Scott DM, Stollberg M, Vaughan BA, Wilson CA, Wilson RB (1997) Observations of accreting pulsars. Astrophys J Suppl 113:367. doi:10.1086/313060. arXiv:astro-ph/9707125

Bird AJ, Malizia A, Bazzano A, Barlow EJ, Bassani L, Hill AB, Bélanger G, Capitanio F, Clark DJ, Dean AJ, Fiocchi M, Götz D, Lebrun F, Molina M, Produit N, Renaud M, Sguera V, Stephen JB, Terrier R, Ubertini P, Walter R, Winkler C, Zurita J (2007) The third IBIS/ISGRI soft gamma-ray survey catalog. Astrophys J Suppl 170:175–186. doi:10.1086/513148 arXiv:astro-ph/0611493

Bird AJ, Bazzano A, Hill AB, McBride VA, Sguera V, Shaw SE, Watkins HJ (2009) Discovery of a 30-d period in the supergiant fast X-ray transient SAX J1818.6-1703. Mon Not RAS 393:L11–L15. doi:10.1111/j.1745-3933.2008.00583.x. arXiv:0810.5696

Bird AJ, Bazzano A, Bassani L, Capitanio F, Fiocchi M, Hill AB, Malizia A, McBride VA, Scaringi S, Sguera V, Stephen JB, Ubertini P, Dean AJ, Lebrun F, Terrier R, Renaud M, Mattana F, Götz D, Rodriguez J, Belanger G, Walter R, Winkler C (2010) The fourth IBIS/ISGRI soft gamma-ray survey catalog. Astrophys J Suppl 186:1–9. doi:10.1088/0067-0049/186/1/1 arXiv:0910.1704

Bissantz N, Englmaier P, Gerhard O (2003) Gas dynamics in the Milky Way: second pattern speed and large-scale morphology. Mon Not RAS 340:949–968. doi:10.1046/j.1365-8711.2003.06358.x. arXiv:astro-ph/0212516

Blay P, Ribó M, Negueruela I, Torrejón JM, Reig P, Camero A, Mirabel IF, Reglero V (2005) Further evidence for the presence of a neutron star in 4U 2206+54. INTEGRAL and VLA observations. A&A 438:963–972. doi:10.1051/0004-6361:20042207. arXiv:astro-ph/0502524

Blay P, Negueruela I, Reig P, Coe MJ, Corbet RHD, Fabregat J, Tarasov AE (2006) Multiwavelength monitoring of BD +53 2790, the optical counterpart to 4U 2206+54. A&A 446:1095–1105. doi:10.1051/0004-6361:20053951. arXiv:astro-ph/0510400

Blay P, Martínez-Núñez S, Negueruela I, Pottschmidt K, Smith DM, Torrejón JM, Reig P, Kretschmar P, Kreykenbohm I (2008) INTEGRAL long-term monitoring of the supergiant fast X-ray transient XTE J1739-302. A&A 489:669–676. doi:10.1051/0004-6361:200809385. arXiv:0806.4097

Blondin JM (1994) The shadow wind in high-mass X-ray binaries. Astrophys J 435:756–766. doi:10.1086/174853

Blondin JM, Kallman TR, Fryxell BA, Taam RE (1990) Hydrodynamic simulations of stellar wind disruption by a compact X-ray source. Astrophys J 356:591–608. doi:10.1086/168865

Blondin JM, Stevens IR, Kallman TR (1991) Enhanced winds and tidal streams in massive X-ray binaries. Astrophys J 371:684–695. doi:10.1086/169934

Bodaghee A, Walter R, Zurita Heras JA, Bird AJ, Courvoisier TJL, Malizia A, Terrier R, Ubertini P (2006) IGR J16393-4643: a new heavily-obscured X-ray pulsar. A&A 447:1027–1034. doi:10.1051/0004-6361:20053809. arXiv:astro-ph/0510112

Bodaghee A, Courvoisier TJL, Rodriguez J, Beckmann V, Produit N, Hannikainen D, Kuulkers E, Willis DR, Wendt G (2007) A description of sources detected by INTEGRAL during the first 4 years of observations. A&A 467:585–596. doi:10.1051/0004-6361:20077091. arXiv:astro-ph/0703043

Bodaghee A, Tomsick JA, Rodriguez J, Chaty S, Pottschmidt K, Walter R (2010) Broadband Suzaku observations of IGR J16207-5129. Astrophys J 719:451–458. doi:10.1088/0004-637X/719/1/451. arXiv:1006.1911

Bodaghee A, Tomsick JA, Rodriguez J, Chaty S, Pottschmidt K, Walter R, Romano P (2011) Suzaku observes weak flares from IGR J17391-3021 representing a common low-activity state in this supergiant fast X-ray transient. Astrophys J 727:59. doi:10.1088/0004-637X/727/1/59. arXiv:1012.0855

Bodaghee A, Rahoui F, Tomsick JA, Rodriguez J (2012a) Chandra observations of five INTEGRAL sources: new X-ray positions for IGR J16393-4643 and IGR J17091-3624. Astrophys J 751:113. doi:10.1088/0004-637X/751/2/113. arXiv:1203.0557

Bodaghee A, Tomsick JA, Rodriguez J (2012b) XMM-Newton observations of five INTEGRAL sources located towards the scutum arm. Astrophys J 753:3. doi:10.1088/0004-637X/753/1/3. arXiv:1204.3645

Bodaghee A, Tomsick JA, Rodriguez J, James JB (2012c) Clustering between high-mass X-ray binaries and OB associations in the Milky Way. Astrophys J 744:108. doi:10.1088/0004-637X/744/2/108. arXiv:1109.3466

Boldin PA, Tsygankov SS, Lutovinov AA (2013) On timing and spectral characteristics of the X-ray pulsar 4U 0115+63: evolution of the pulsation period and the cyclotron line energy. Astron Lett 39:375–388. doi:10.1134/S1063773713060029. arXiv:1305.6785

Bondi H, Hoyle F (1944) On the mechanism of accretion by stars. Mon Not RAS 104:273

Boroson B, Vrtilek SD, Kallman T, Corcoran M (2003) Chandra grating spectroscopy of the X-ray binary 4U 1700-37 in a flaring state. Astrophys J 592:516–531. doi:10.1086/375636. arXiv:astro-ph/0303277

Borozdin K, Gilfanov M, Sunyaev R, Churazov E, Loznikov V, Yamburenko N, Skinner GK, Patterson TG, Willmore AP, Emam O, Brinkman AC, Heise J, Int-Zand JJM, Jager R (1990) KS:1947+300—a new transient X-ray source in Cygnus. Sov Astron Lett 16:345

Bouret J-C, Lanz T, Hillier DJ (2005) Lower mass loss rates in O-type stars: spectral signatures of dense clumps in the wind of two Galactic O4 stars. Astron Astrophy 438(1):301–316. doi:10.1051/0004-6361:20042531

Bozzo E, Campana S, Stella L, Falanga M, Israel G, Rampy R, Smith D, Negueruela I (2008a) XMM-Newton and SWIFT observations of the supergiant fast X-ray transient SAXJ1818.6-1703. Astron Telegr 1493:1

Bozzo E, Falanga M, Stella L (2008b) Are there magnetars in high-mass X-ray binaries? The case of supergiant fast X-ray transients. Astrophys J 683:1031–1044. doi:10.1086/589990. arXiv:0805.1849

Bozzo E, Stella L, Israel G, Falanga M, Campana S (2008c) IGRJ16479-4514: the first eclipsing supergiant fast X-ray transient? Mon Not RAS 391:L108–L112. doi:10.1111/j.1745-3933.2008.00566.x. arXiv:0809.3642

Bozzo E, Giunta A, Stella L, Falanga M, Israel G, Campana S (2009) Swift observations of IGR J16479-4514 in outburst. A&A 502:21–25. doi:10.1051/0004-6361/200912131. arXiv:0906.0883

Bozzo E, Stella L, Ferrigno C, Giunta A, Falanga M, Campana S, Israel G, Leyder JC (2010) The supergiant fast X-ray transients XTE J1739-302 and IGR J08408-4503 in quiescence with XMM-Newton. A&A 519:A6. doi:10.1051/0004-6361/201014095. arXiv:1004.2059

Bozzo E, Ferrigno C, Falanga M, Walter R (2011a) INTEGRAL and Swift observations of IGR J19294+1816 in outburst. A&A 531:A65. doi:10.1051/0004-6361/201116729. arXiv:1105.2727

Bozzo E, Giunta A, Cusumano G, Ferrigno C, Walter R, Campana S, Falanga M, Israel G, Stella L (2011b) XMM-Newton observations of IGR J18410-0535: the ingestion of a clump by a supergiant fast X-ray transient. Astrophys J Suppl 531:A130. doi:10.1051/0004-6361/201116726. arXiv:1106.5125

Bozzo E, Ferrigno C, Türler M, Manousakis A, Falanga M (2012a) IGR J18179-1621: an obscured X-ray pulsar discovered by INTEGRAL. A&A 545:A83. doi:10.1051/0004-6361/201219344. arXiv:1207.4557

Bozzo E, Pavan L, Ferrigno C, Falanga M, Campana S, Paltani S, Stella L, Walter R (2012b) XMM-Newton observations of four high mass X-ray binaries and IGR J17348-2045. A&A 544:A118. doi:10.1051/0004-6361/201218900. arXiv:1207.3719

Bozzo E, Romano P, Ferrigno C, Esposito P, Mangano V (2013) Observations of supergiant fast X-ray transients with LOFT. Adv Space Res 51:1593–1599. doi:10.1016/j.asr.2012.12.001. arXiv:1212.0323

Bozzo E, Romano P, Ducci L, Bernardini F, Falanga M (2015) Supergiant fast X-ray transients as an underluminous class of supergiant X-ray binaries. Adv Space Res 55:1255–1263. doi:10.1016/j.asr.2014.11.012. arXiv:1411.4470

Burenin R, Mescheryakov A, Revnivtsev M, Bikmaev I, Sunyaev R (2006) Optical identification of four INTEGRAL sources. Astron Telegr 880:1

Burenin RA, Mescheryakov AV, Revnivtsev MG, Sazonov SY, Bikmaev IF, Pavlinsky MN, Sunyaev RA (2008) New active galactic nuclei among the INTEGRAL and SWIFT X-ray sources. Astron Lett 34:367–374. doi:10.1134/S1063773708060017. arXiv:0802.1791

Burenin R, Makarov D, Uklein R, Revnivtsev M, Lutovinov A (2009) Optical identification of a hard X-ray source IGR J18151-1052. Astron Telegr 2193:1

Caballero I, Wilms J (2012) X-ray pulsars: a review. Mem Soc Astron Ital 83:230 arXiv:1206.3124

Caballero I, Pottschmidt K, Marcu DM, Barragan L, Ferrigno C, Klochkov D, Zurita Heras JA, Suchy S, Wilms J, Kretschmar P, Santangelo A, Kreykenbohm I, Fürst F, Rothschild R, Staubert R, Finger MH, Camero-Arranz A, Makishima K, Enoto T, Iwakiri W, Terada Y (2013) A double-peaked outburst of A 0535+26 observed with INTEGRAL, RXTE, and Suzaku. Astrophys J Lett 764:L23. doi:10.1088/2041-8205/764/2/L23. arXiv:1301.4856

Casares J, Ribas I, Paredes JM, Martí J, Allende Prieto C (2005a) Orbital parameters of the microquasar LS I +61 303. Mon Not RAS 360:1105–1109. doi:10.1111/j.1365-2966.2005.09106.x. arXiv:astro-ph/0504332

Casares J, Ribó M, Ribas I, Paredes JM, Martí J, Herrero A (2005b) A possible black hole in the γ-ray microquasar LS 5039. Mon Not RAS 364:899–908. doi:10.1111/j.1365-2966.2005.09617.x. arXiv:astro-ph/0507549

Castor JI, Abbott DC, Klein RI (1975) Radiation-driven winds in of stars. Astrophys J 195:157–174

Cassinelli JP, Olson GL (1979) The effects of coronal regions on the X-ray flux and ionization conditions in the winds of OB supergiants and Of stars. Astrophys J (Part 1) 229:304–317. doi:10.1086/156956

Chakrabarty D, Koh T, Bildsten L, Prince TA, Finger MH, Wilson RB, Pendleton GN, Rubin BC (1995) Discovery of the 18.7 second accreting X-ray pulsar GRO J1948+32. Astrophys J 446:826. doi:10.1086/175839

Chaty S (2010) High energy phenomena in supergiant X-ray binaries. In: Martí J, Luque-Escamilla PL, Combi JA (eds) Astronomical society of the pacific conference series, vol 422, pp 277–284. arXiv:1005.1995

Chaty S, Rahoui F (2012) Broadband ESO/VISIR-spitzer infrared spectroscopy of the obscured supergiant X-ray binary IGR J16318-4848. Astrophys J 751:150. doi:10.1088/0004-637X/751/2/150. arXiv:1205.2225

Chaty S, Rahoui F, Foellmi C, Tomsick JA, Rodriguez J, Walter R (2008) Multi-wavelength observations of Galactic hard X-ray sources discovered by INTEGRAL. I. The nature of the companion star. A&A 484:783–800. doi:10.1051/0004-6361:20078768. arXiv:0802.1774

Chenevez J, Budtz-Jorgensen C, Lund N, Westergaard NJ, Kretschmar P, Rodriguez J, Orr A, Hermsen W (2004) IGR J06074+2205 a new X-ray source discovered by INTEGRAL. Astron Telegr 223:1

Chernyakova M, Lutovinov A, Capitanio F, Lund N, Gehrels N (2003) Igr J18483-0311. Astron Telegr 157:1

Chernyakova M, Shtykovsky P, Lutovinov A, Revnivtsev M, Courvoisier T, Walter R, Shaw S, Cocco G, Attie D, Budtz-Jorgensen C, Hermsen W, Much R (2004) Transition to a hard state of 1RXP J130159.6-635806. Astron Telegr 251:1

Chernyakova M, Lutovinov A, Rodríguez J, Revnivtsev M (2005) Discovery and study of the accreting pulsar 2RXP J130159.6-635806. Mon Not RAS 364:455–461. doi:10.1111/j.1365-2966.2005.09548.x. arXiv:astro-ph/0508515

Chiappini C, Matteucci F, Romano D (2001) Abundance gradients and the formation of the Milky Way. Astrophys J 554:1044–1058. doi:10.1086/321427. arXiv:astro-ph/0102134

Clark GW (2000) The orbit of the binary X-ray pulsar 4U 1538-52 from Rossi X-ray timing explorer observations. Astrophys J Lett 542:L131–L133. doi:10.1086/312926

Clark LL, Dolan JF (1999) The distance to eight X-ray sources derived from HIPPARCOS observations. A&A 350:1085–1088

Clark GW, Schmidt GD, Angel JRP (1975) Mx 0656-07. IAU Circ 2843:1

Clark GW, Woo JW, Nagase F, Makishima K, Sakao T (1990) Discovery of a cyclotron absorption line in the spectrum of the binary X-ray pulsar 4U 1538-52 observed by GINGA. Astrophys J 353:274–280. doi:10.1086/168614

Clark GW, Woo JW, Nagase F (1994) Properties of a B0 I stellar wind and interstellar grains derived from GINGA observations of the binary X-ray pulsar 4U 1538-52. Astrophys J 422:336–350. doi:10.1086/173729

Clark JS, Reig P, Goodwin SP, Larionov VM, Blay P, Coe MJ, Fabregat J, Negueruela I, Papadakis I, Steele IA (2001a) On the radio emitting high mass X-ray binary LS 5039. A&A 376:476–483. doi:10.1051/0004-6361:20010919

Clark JS, Tarasov AE, Okazaki AT, Roche P, Lyuty VM (2001b) Phase changes of the Be/X-ray binary X Persei. A&A 380:615–629. doi:10.1051/0004-6361:20011468

Clark DJ, Hill AB, Bird AJ, McBride VA, Scaringi S, Dean AJ (2009) Discovery of the orbital period in the supergiant fast X-ray transient IGR J17544-2619. Mon Not RAS 399:L113–L117. doi:10.1111/j.1745-3933.2009.00737.x. arXiv:0908.1041

Clark DJ, Sguera V, Bird AJ, McBride VA, Hill AB, Scaringi S, Drave S, Bazzano A, Dean AJ (2010) The orbital period in the supergiant fast X-ray transient IGR J16465-4507. Mon Not RAS 406:L75–L79. doi:10.1111/j.1745-3933.2010.00885.x. arXiv:1005.4763

Coburn W, Heindl WA, Gruber DE, Rothschild RE, Staubert R, Wilms J, Kreykenbohm I (2001) Discovery of a cyclotron resonant scattering feature in the Rossi X-ray timing explorer spectrum of 4U 0352+309 (X Persei). Astrophys J 552:738–747. doi:10.1086/320565. arXiv:astro-ph/0101110

Coburn W, Heindl WA, Rothschild RE, Gruber DE, Kreykenbohm I, Wilms J, Kretschmar P, Staubert R (2002) Magnetic fields of accreting X-ray pulsars with the Rossi X-ray timing explorer. Astrophys J 580:394–412. doi:10.1086/343033. arXiv:astro-ph/0207325

Coburn W, Kretschmar P, Kreykenbohm I, McBride VA, Rothschild RE, Wilms J (2005) Multiple cyclotron lines in V0332+53. Astron Telegr 381:1

Coe MJ, Payne BJ, Longmore A, Hanson CG (1988) The optical/IR counterpart to the newly-discovered X-ray source EXO 2030+375. Mon Not RAS 232:865–871

Coe MJ, Roche P, Everall C, Fabregat J, Buckley DAH, Smith RC, Reynolds AP, Jupp ID, MacGillivray HT (1994a) Discovery of the optical counterpart to the CGRO transient GRO:J1008-57. Mon Not RAS 270:L57

Coe MJ, Roche P, Everall C, Fishman GJ, Hagedon KS, Finger M, Wilson RB, Buckley DAH, Shrader C, Fabregat J, Polcaro VF, Giovannelli F, Villada M (1994b) Multiwaveband study of a major X-ray outburst from the Be/X-ray transient system A 1118-616. A&A 289:784–794

Coe MJ, Fabregat J, Negueruela I, Roche P, Steele IA (1996) Discovery of the optical counterpart to the ASCA transient AX 1845.0-0433. Mon Not RAS 281:333–338

Coe MJ, Bird AJ, Hill AB, McBride VA, Schurch M, Galache J, Wilson CA, Finger M, Buckley DA, Romero-Colmenero E (2007) Now you see it, now you don't—the circumstellar disc in the GRO J1008-57 system. Mon Not RAS 378:1427–1433. doi:10.1111/j.1365-2966.2007.11878.x. arXiv:0704.2589

Cohen DH, Leutenegger MA, Wollman EE, Zsargó J, Hillier DJ, Townsend RHD, Owocki SP (2010) A mass-loss rate determination for ζ Puppis from the quantitative analysis of X-ray emission-line profiles. Mon Not RAS 405:2391–2405. doi:10.1111/j.1365-2966.2010.16606.x. arXiv:1003.0892

Coleiro A, Chaty S (2013) Distribution of high-mass X-ray binaries in the Milky Way. Astrophys J 764:185. doi:10.1088/0004-637X/764/2/185. arXiv:1212.5460

Coleiro A, Chaty S, Zurita Heras JA, Rahoui F, Tomsick JA (2013) Infrared identification of high-mass X-ray binaries discovered by INTEGRAL. A&A 560:A108. doi:10.1051/0004-6361/201322382. arXiv:1310.0451

Cominsky L, Clark GW, Li F, Mayer W, Rappaport S (1978) Discovery of 3.6-s X-ray pulsations from 4U0115+63. Nature 273:367–369. doi:10.1038/273367a0

Corbet RHD (1984) Be/neutron star binaries—a relationship between orbital period and neutron star spin period. A&A 141:91–93

Corbet RHD, Krimm HA (2009) A 117-day period in IGR J19294+1816. Astron Telegr 2008:1

Corbet RHD, Krimm HA (2010) A 160 day period in the Be star X-ray binary IGR J01363+6610 from Swift BAT observations. Astron Telegr 3079:1

Corbet RHD, Krimm HA (2013) Superorbital periodic modulation in wind-accretion high-mass X-ray binaries from Swift burst alert telescope observations. Astrophys J 778:45. doi:10.1088/0004-637X/778/1/45. arXiv:1309.4119

Corbet RHD, Mukai K (2002) The orbit and position of the X-ray pulsar XTE J1855-026: an eclipsing supergiant system. Astrophys J 577:923–928. doi:10.1086/342244. arXiv:astro-ph/0207181

Corbet RHD, Mukai K (2008) The orbital period of 4U 1210-64. Astron Telegr 1861:1

Corbet RHD, Peele AG (2001) 4U 2206+54: an unusual high-mass X-ray binary with a 9.6 day orbital period but no strong pulsations. Astrophys J 562:936–942. doi:10.1086/323849. arXiv:astro-ph/0107131

Corbet RHD, Remillard R (2005) The orbital period of IGR J11435-6109. Astron Telegr 377:1

Corbet RHD, Woo JW, Nagase F (1993) The orbit and pulse period of X:1538-522 from GINGA observations. A&A 276:52

Corbet RHD, Finley JP, Peele AG (1999a) Evidence for a very slow X-ray pulsar in 2S 0114+650 from Rossi X-ray timing explorer all-sky monitor observations. Astrophys J 511:876–884. doi:10.1086/306727. arXiv:astro-ph/9809216

Corbet RHD, Marshall FE, Peele AG, Takeshima T (1999b) Rossi X-ray timing explorer observations of the X-ray pulsar XTE J1855-026: a possible new supergiant system. Astrophys J 517:956–963. doi:10.1086/307235. arXiv:astro-ph/9901125

Corbet RHD, Hannikainen DC, Remillard R (2004) The orbital period of IGR J19140+098. Astron Telegr 269:1

Corbet R, Barbier L, Barthelmy S, Cummings J, Fenimore E, Gehrels N, Hullinger D, Krimm H, Markwardt C, Palmer D, Parsons A, Sakamoto T, Sato G, Tueller J, Team The Swift-Survey (2005a) Swift/BAT discovery of the orbital period of IGR J16320-4751. Astron Telegr 649:1

Corbet RHD, Markwardt CB, Swank JH (2005b) Rossi X-ray timing explorer observations of the X-ray pulsar EXO 1722-363: a candidate eclipsing supergiant system. Astrophys J 633:377–383. doi:10.1086/444610. arXiv:astro-ph/0507259

Corbet R, Barbier L, Barthelmy S, Cummings J, Fenimore E, Gehrels N, Hullinger D, Krimm H, Markwardt C, Palmer D, Parsons A, Sakamoto T, Sato G, Tueller J, Remillard R (2006) Swift/BAT and RXTE/ASM discovery of the orbital period of IGR J16418-4532. Astron Telegr 779:1

Corbet RHD, Barthelmy SD, Baumgartner WH, Krimm HA, Markwardt CB, Skinner GK, Tueller J (2010a) A 10 Day Period in IGR J16328-4726 from Swift/BAT observations. Astron Telegr 2588:1

Corbet RHD, Barthelmy SD, Baumgartner WH, Krimm HA, Markwardt CB, Skinner GK, Tueller J (2010b) A 49 day period in IGR J14488-5942/Swift J1448.4-5945 from Swift/BAT observations. Astron Telegr 2598:1

Corbet RHD, Krimm HA, Skinner GK (2010c) A 44 day period in AX J1700.2-4220 from Swift/BAT observations. Astron Telegr 2559:1

Courvoisier TJL, Walter R, Rodriguez J, Bouchet L, Lutovinov AA (2003) Igr J16318-4848. IAU Circ 8063:3

Cox NLJ, Kaper L, Foing BH, Ehrenfreund P (2005) Diffuse interstellar bands of unprecedented strength in the line of sight towards high-mass X-ray binary 4U 1907+09. A&A 438:187–199. doi:10.1051/0004-6361:20042340

Crampton D, Hutchings JB, Cowley AP (1985) The supergiant X-ray binary system 2S 0114 + 650. Astrophys J 299:839–844. doi:10.1086/163750

Cusumano G, di Salvo T, Burderi L, Orlandini M, Piraino S, Robba N, Santangelo A (1998) Detection of a cyclotron line and its second harmonic in 4U1907+09. A&A 338:L79–L82 arXiv:astro-ph/9809167

Cusumano G, La Parola V, Segreto A, Ferrigno C, Maselli A, Sbarufatti B, Romano P, Chincarini G, Giommi P, Masetti N, Moretti A, Parisi P, Tagliaferri G (2010) The palermo Swift-BAT hard X-ray catalogue. III. Results after 54 months of sky survey. A&A 524:A64. doi:10.1051/0004-6361/201015249. arXiv:1009.0522

D'Ai' A, Cusumano G, La Parola V, Segreto A (2010) Discovery of the orbital period in the Swift/Bat data of the highly absorbed HMXB IGR J17354-3255. Astron Telegr 2596:1

D'Aì A, Cusumano G, La Parola V, Segreto A, di Salvo T, Iaria R, Robba NR (2011a) Evidence for a resonant cyclotron line in IGR J16493-4348 from the Swift-BAT hard X-ray survey. A&A 532:A73. doi:10.1051/0004-6361/201117035. arXiv:1208.0169

D'Aì A, La Parola V, Cusumano G, Segreto A, Romano P, Vercellone S, Robba NR (2011b) The Swift-BAT survey reveals the orbital period of three high-mass X-ray binaries. A&A 529:A30. doi:10.1051/0004-6361/201016401. arXiv:1102.4546

D'Aì A, Di Salvo T, Iaria R, García JA, Sanna A, Pintore F, Riggio A, Burderi L, Bozzo E, Dauser T, Matranga M, Galiano CG, Robba NR (2015) GRO J1744-28: an intermediate B-field pulsar in a low-mass X-ray binary. Mon Not R Astron Soc 449(4):4288–4303. doi:10.1093/mnras/stv531

Davidson K, Ostriker JP (1973) Neutron-star accretion in a stellar wind: model for a pulsed X-ray source. Astrophys J 179:585–598. doi:10.1086/151897

Davies RE, Pringle JE (1981) Spindown of neutron stars in close binary systems. II. Mon Not RAS 196:209–224

Davies B, Figer DF, Kudritzki R-P, MacKenty J, Najarro F, Herrero A (2007) A Massive Cluster of Red Supergiants at the Base of the Scutum-Crux Arm. Astrophys J 671(1):781–801. doi:10.1086/522224

Davison PJN, Watson MG, Pye JP (1977) The binary X-ray pulsar 3U 1538-52. Mon Not RAS 181:73P–79P

Day CSR, Tennant AF (1991) Dust scattering in the high-state eclipse of CEN X-3. Mon Not RAS 251:76–83

de Pasquale M, Barthelmy SD, Baumgartner WH, Burrows DN, Holland ST, Kennea JA, Mangano V, Palmer DM, Romano P, Sbarufatti B, Starling RLC, Vetere L (2010) Swift detection of outburst from the SFXT IGR J18410-0535. Astron Telegr 2661:1

de Plaa J, den Hartog PR, Kaastra JS, in't Zand JJM, Mendez M, Hermsen W (2003) XMM-Newton followup of IGR J16318-4848. Astron Telegr 119:1

Dean AJ, Bazzano A, Hill AB, Stephen JB, Bassani L, Barlow EJ, Bird AJ, Lebrun F, Sguera V, Shaw SE, Ubertini P, Walter R, Willis DR (2005) Global characteristics of the first IBIS/ISGRI catalogue sources: unveiling a murky episode of binary star evolution. A&A 443:485–494. doi:10.1051/0004-6361:20053513. arXiv:astro-ph/0508291

DeCesar ME, Boyd PT, Pottschmidt K, Wilms J, Suchy S, Miller MC (2013) The Be/X-ray binary Swift J1626.6-5156 as a variable cyclotron line source. Astrophys J 762:61. doi:10.1088/0004-637X/762/1/61. arXiv:1211.3109

Delgado-Martí H, Levine AM, Pfahl E, Rappaport SA (2001) The orbit of X Persei and its neutron star companion. Astrophys J 546:455–468. doi:10.1086/318236. arXiv:astro-ph/0004258

den Hartog PR, Kuiper LM, Corbet RHD, in't Zand JJM, Hermsen W, Vink J, Remillard R, van der Klis M (2004) IGR J00370+6122—a new high-mass X-ray binary. Astron Telegr 281:1

den Hartog PR, Hermsen W, Kuiper L, Vink J, in't Zand JJM, Collmar W (2006) INTEGRAL survey of the Cassiopeia region in hard X rays. A&A 451:587–602. doi:10.1051/0004-6361:20054711. arXiv:astro-ph/0601644

Denis M, Bulik T, Marcinkowski R (2010) INTEGRAL observations of OAO 1657-415: gamma-ray tomography of a B super giant. Acta Astron 60:75–82

Densham RH, Charles PA (1982) Optical photometry and spectroscopy of the X-ray pulsar 1E 1145.1-6141. Mon Not RAS 201:171–178

Dessart L, Owocki SP (2002) Emission profile variability in hot star winds. A pseudo-3D method based on radiation hydrodynamics simulations. A&A 383:1113–1124. doi:10.1051/0004-6361:20011826

Dessart L, Owocki SP (2003) Two-dimensional simulations of the line-driven instability in hot-star winds. A&A 406:L1–L4. doi:10.1051/0004-6361:20030810

Dessart L, Owocki SP (2005) 2D simulations of the line-driven instability in hot-star winds. II. Approximations for the 2D radiation force. A&A 437:657–666. doi:10.1051/0004-6361:20052778. arXiv:astro-ph/0503514

Devasia J, Paul B, James M, Indulekha K (2010) Variations in the X-ray eclipse transitions of Cen X-3. Res A&A 10:1127–1136. doi:10.1088/1674-4527/10/11/005. arXiv:1006.1035

di Salvo T, Burderi L, Robba NR, Guainazzi M (1998) The two-component X-ray broadband spectrum of X Persei observed by BeppoSAX. Astrophys J 509:897–903. doi:10.1086/306525

Dolan JF (2011) Very low frequency QPO in 4U1700-37. arXiv:1107.1537 (e-prints)

Doroshenko VA, Doroshenko RF, Postnov KA, Cherepashchuk AM, Tsygankov SS (2008) A study of the X-ray pulsars X1845-024 and XTE J1858+034 based on INTEGRAL observations. Astron Rep 52:138–151. doi:10.1134/S1063772908020054

Doroshenko V, Santangelo A, Suleimanov V, Kreykenbohm I, Staubert R, Ferrigno C, Klochkov D (2010a) Is there a highly magnetized neutron star in GX 301-2? A&A 515:A10. doi:10.1051/0004-6361/200912951. arXiv:0907.3844

Doroshenko V, Suchy S, Santangelo A, Staubert R, Kreykenbohm I, Rothschild R, Pottschmidt K, Wilms J (2010b) RXTE observations of the 1A 1118-61 in an outburst, and the discovery of a cyclotron line. A&A 515:L1. doi:10.1051/0004-6361/201014858. arXiv:1005.4782

Doroshenko V, Santangelo A, Suleimanov V (2011) Witnessing the magnetospheric boundary at work in Vela X-1. A&A 529:A52. doi:10.1051/0004-6361/201116482. arXiv:1102.5254

Doroshenko V, Santangelo A, Ducci L, Klochkov D (2012a) Supergiant, fast, but not so transient 4U 1907+09. A&A 548:A19. doi:10.1051/0004-6361/201220085. arXiv:1210.4428

Doroshenko V, Santangelo A, Kreykenbohm I, Doroshenko R (2012b) The hard X-ray emission of X Persei. A&A 540:L1. doi:10.1051/0004-6361/201218878. arXiv:1202.6271

Doroshenko V, Ducci L, Santangelo A, Sasaki M (2014) Population of the Galactic X-ray binaries and eRosita. A&A 567:A7. doi:10.1051/0004-6361/201423766. arXiv:1405.0802

Dower R, Kelley R, Margon B, Bradt H (1977) 2S 0114+650. IAU Circ 3144:2

Dower RG, Bradt HV, Doxsey RE, Jernigan JG, Kulik J, Apparao KMV (1978) Positions of galactic X-ray sources—at longitudes /l-II/ of 55-320 deg. Nature 273:364–367. doi:10.1038/273364a0

Drave SP, Clark DJ, Bird AJ, McBride VA, Hill AB, Sguera V, Scaringi S, Bazzano A (2010) Discovery of the 51.47-d orbital period in the supergiant fast X-ray transient XTE J1739-302 with INTEGRAL. Mon Not RAS 409:1220–1226. doi:10.1111/j.1365-2966.2010.17383.x. arXiv:1007.3379

Drave SP, Bird AJ, Townsend LJ, Hill AB, McBride VA, Sguera V, Bazzano A, Clark DJ (2012) X-ray pulsations from the region of the supergiant fast X-ray transient IGR J17544-2619. A&A 539:A21. doi:10.1051/0004-6361/201117947. arXiv:1201.2284

Drave SP, Bird AJ, Sidoli L, Sguera V, McBride VA, Hill AB, Bazzano A, Goossens ME (2013) INTEGRAL and XMM-Newton observations of IGR J16418-4532: evidence of accretion regime transitions in a supergiant fast X-ray transient. Mon Not RAS 433:528–542. doi:10.1093/mnras/stt754. arXiv:1305.0430

Drave SP, Bird AJ, Sidoli L, Sguera V, Bazzano A, Hill AB, Goossens ME (2014) New insights on accretion in supergiant fast X-ray transients from XMM-Newton and INTEGRAL observations of IGR J17544-2619. Mon Not RAS 439:2175–2185. doi:10.1093/mnras/stu110. arXiv:1401.3570

Dubus G (2013) Gamma-ray binaries and related systems. A&A Rev 21:64. doi:10.1007/s00159-013-0064-5. arXiv:1307.7083

Ducci L, Sidoli L, Paizis A, Mereghetti S, Pizzochero PM (2008) INTEGRAL observations of the 2007 outburst of the Be transient SAX J2103.5+4545. In: Proceedings of the 7th INTEGRAL workshop. arXiv:0810.5453

Ducci L, Sidoli L, Paizis A (2010) INTEGRAL results on supergiant fast X-ray transients and accretion mechanism interpretation: ionization effect and formation of transient accretion discs. Mon Not RAS 408:1540–1550. doi:10.1111/j.1365-2966.2010.17216.x

Ducci L, Doroshenko V, Sasaki M, Santangelo A, Esposito P, Romano P, Vercellone S (2013a) Spectral and temporal properties of the supergiant fast X-ray transient IGR J18483-0311 observed by INTEGRAL. A&A 559:A135. doi:10.1051/0004-6361/201322299. arXiv:1310.4728

Ducci L, Romano P, Esposito P, Bozzo E, Krimm HA, Vercellone S, Mangano V, Kennea JA (2013b) Swift/XRT orbital monitoring of the candidate supergiant fast X-ray transient IGR J17354-3255. A&A 556:A72. doi:10.1051/0004-6361/201321635. arXiv:1306.6443

Elsner RF, Lamb FK (1977) Accretion by magnetic neutron stars. I—magnetospheric structure and stability. Astrophys J 215:897–913. doi:10.1086/155427

Elvis M, Plummer D, Schachter J, Fabbiano G (1992) The Einstein slew survey. Astrophys J Suppl 80:257–303. doi:10.1086/191665

Eversberg T, Lepine S, Moffat AFJ (1998) Outmoving clumps in the wind of the hot O supergiant zeta puppis. Astrophys J 494:799–805. doi:10.1086/305218

Falanga M, Bozzo E, Walter R, Sarty GE, Stella L (2011) Searching for orbital periods of supergiant fast X-ray transients. J Am Assoc Var Star Obs 39:110

Falanga M, Bozzo E, Lutovinov A, Bonnet-Bidaud JM, Fetisova Y, Puls J (2015) The ephemeris, orbital decay, and masses of 10 eclipsing HMXBs. arXiv:1502.07126 (e-prints)

Farrell SA, Sood RK, O'Neill PM (2006) Super-orbital period in the high-mass X-ray binary 2S 0114+650. Mon Not RAS 367:1457–1462. doi:10.1111/j.1365-2966.2006.10150.x. arXiv:astro-ph/0502008

Farrell SA, Sood RK, O'Neill PM, Dieters S (2008) A detailed study of 2S 0114+650 with the Rossi X-ray timing explorer. Mon Not RAS 389:608–628. doi:10.1111/j.1365-2966.2008.13588.x. arXiv:0710.1243

Feigelson ED, Gaffney JA III, Garmire G, Hillenbrand LA, Townsley L (2003) X-rays in the orion nebula cluster: constraints on the origins of magnetic activity in pre-main-sequence stars. Astrophys J 584:911–930. doi:10.1086/345811. arXiv:astro-ph/0211049

Feldmeier A (1995) Time-dependent structure and energy transfer in hot star winds. A&A 299:523–544

Feldmeier A, Puls J, Pauldrach AWA (1997) A possible origin for X-rays from O stars. A&A 322:878–895

Ferrigno C, Segreto A, Mineo T, Santangelo A, Staubert R (2008) INTEGRAL observation of the accreting pulsar 1E1145.1-6141. A&A 479:533–539. doi:10.1051/0004-6361:20078643. arXiv:0712.1274

Ferrigno C, Becker PA, Segreto A, Mineo T, Santangelo A (2009) Study of the accreting pulsar 4U 0115+63 using a bulk and thermal Comptonization model. A&A 498:825–836. doi:10.1051/0004-6361/200809373. arXiv:0902.4392

Filippova EV, Lutovinov AA, Shtykovsky PE, Revnivtsev MG, Burenin RA, Arefiev VA, Pavlinsky MN, Sunyaev RA (2004) Broadband observations of the transient X-ray pulsar SAX J2103.5+4545. Astron Lett 30:824–833. doi:10.1134/1.1833433. arXiv:astro-ph/0410590

Filippova EV, Tsygankov SS, Lutovinov AA, Sunyaev RA (2005) Hard spectra of X-ray pulsars from INTEGRAL data. Astron Lett 31:729–747. doi:10.1134/1.2123288. arXiv:astro-ph/0509525

Filliatre P, Chaty S (2004) The optical/near-infrared counterpart of the INTEGRAL obscured source IGR J16318-4848: an sgB in a high-mass X-ray binary? Astrophys J 616:469–484. doi:10.1086/424869. arXiv:astro-ph/0408407

Finger MH, Wilson RB, Chakrabarty D (1996a) Reappearance of the X-ray binary pulsar 2S 1417-624. A&A Suppl Ser 120:C209

Finger MH, Wilson RB, Harmon BA (1996b) Quasi-periodic oscillations during a giant outburst of A0535+262. Astrophys J 459:288. doi:10.1086/176892

Finger MH, Ikhsanov NR, Wilson-Hodge CA, Patel SK (2010) Spin-down of the long-period accreting pulsar 4U 2206+54. Astrophys J 709:1249–1256. doi:10.1088/0004-637X/709/2/1249. arXiv:0908.4042

Fiocchi M, Sguera V, Bazzano A, Bassani L, Bird AJ, Natalucci L, Ubertini P (2010) IGR J16328-4726: a new candidate supergiant fast X-ray transient. Astrophys J Lett 725:L68–L72. doi:10.1088/2041-8205/725/1/L68. arXiv:1010.3529

Fiocchi M, Bazzano A, Bird AJ, Drave SP, Natalucci L, Persi P, Piro L, Ubertini P (2013) The INTEGRAL source IGR J16328-4726: a high-mass X-ray binary from the BeppoSAX era. Astrophys J 762:19. doi:10.1088/0004-637X/762/1/19. arXiv:1210.3840

Forman W, Tananbaum H, Jones C (1976) UHURU observations of the galactic plane in 1970, 1971, and 1972. Astrophys J Lett 206:L29–L35. doi:10.1086/182126

Forman W, Jones C, Cominsky L, Julien P, Murray S, Peters G, Tananbaum H, Giacconi R (1978) The fourth Uhuru catalog of X-ray sources. Astrophys J Suppl 38:357–412. doi:10.1086/190561

Foschini L, Rodriguez J, Walter R (2003) Igr J16318-4848. IAU Circ 8076:2

Frail DA, Hjellming RM (1991) Distance and total column density to the periodic radio star LSI + 61 deg 303. AJ 101:2126–2130. doi:10.1086/115833

Frank J, King AR, Raine DJ (1992) Accretion power in astrophysics. Cambridge University Press, Cambridge

Fullerton AW, Massa DL, Prinja RK (2006) The discordance of mass-loss estimates for galactic O-type stars. Astrophys J 637(2):1025–1039. doi:10.1086/498560

Fürst F, Kreykenbohm I, Pottschmidt K, Wilms J, Hanke M, Rothschild RE, Kretschmar P, Schulz NS, Huenemoerder DP, Klochkov D, Staubert R (2010) X-ray variation statistics and wind clumping in Vela X-1. A&A 519:A37. doi:10.1051/0004-6361/200913981. arXiv:1005.5243

Fürst F, Kreykenbohm I, Suchy S, Barragán L, Wilms J, Rothschild RE, Pottschmidt K (2011a) 4U 1909+07: a well-hidden pearl. A&A 525:A73. doi:10.1051/0004-6361/201015636. arXiv:1011.5052

Fürst F, Suchy S, Kreykenbohm I, Barragán L, Wilms J, Pottschmidt K, Caballero I, Kretschmar P, Ferrigno C, Rothschild RE (2011b) Study of the many fluorescent lines and the absorption variability in GX 301-2 with XMM-Newton. A&A 535:A9. doi:10.1051/0004-6361/201117665. arXiv:1110.2700

Fürst F, Pottschmidt K, Wilms J, Kennea J, Bachetti M, Bellm E, Boggs SE, Chakrabarty D, Christensen FE, Craig WW, Hailey CJ, Harrison F, Stern D, Tomsick JA, Walton DJ, Zhang W (2014a) NuSTAR discovery of a cyclotron line in KS 1947+300. Astrophys J Lett 784:L40. doi:10.1088/2041-8205/784/2/L40. arXiv:1403.1901

Fürst F, Pottschmidt K, Wilms J, Tomsick JA, Bachetti M, Boggs SE, Christensen FE, Craig WW, Grefenstette BW, Hailey CJ, Harrison F, Madsen KK, Miller JM, Stern D, Walton DJ, Zhang W (2014b) NuSTAR discovery of a luminosity dependent cyclotron line energy in Vela X-1. Astrophys J 780:133. doi:10.1088/0004-637X/780/2/133. arXiv:1311.5514

Galloway D, Remillard R, Morgan E, Swank J (2003) Recurrent transient X1901+031. Astron Telegr 118:1

Galloway DK, Morgan EH, Levine AM (2004) A frequency glitch in an accreting pulsar. Astrophys J 613:1164–1172. doi:10.1086/423265. arXiv:astro-ph/0401476

Galloway DK, Wang Z, Morgan EH (2005) Discovery of pulsations in the X-ray transient 4U 1901+03. Astrophys J 635:1217–1223. doi:10.1086/497573. arXiv:astro-ph/0506247

Giacconi R, Gursky H, Kellogg E, Schreier E, Tananbaum H (1971) Discovery of periodic X-ray pulsations in centaurus X-3 from UHURU. Astrophys J Lett 167:L67. doi:10.1086/180762

Giacconi R, Murray S, Gursky H, Kellogg E, Schreier E, Tananbaum H (1972) The Uhuru catalog of X-ray sources. Astrophys J 178:281–308. doi:10.1086/151790

Gilfanov M (2004) Low-mass X-ray binaries as a stellar mass indicator for the host galaxy. Mon Not RAS 349:146–168. doi:10.1111/j.1365-2966.2004.07473.x. arXiv:astro-ph/0309454

Giovannelli F, Graziati LS (1992) A 0535 + 26/HDE 245770—a typical X-ray/Be system. Space Sci Rev 59:1–81. doi:10.1007/BF01262537

Giunta A, Bozzo E, Bernardini F, Israel G, Stella L, Falanga M, Campana S, Bazzano A, Dean AJ, Mendez M (2009) The supergiant fast X-ray transient IGRJ18483-0311 in quiescence: XMM-Newton, Swift and Chandra observations. Mon Not RAS 399:744–749. doi:10.1111/j.1365-2966.2009.15174.x. arXiv:0905.4866

Gnedin IN, Sunyaev RA (1974) Polarization of optical and X-radiation from compact thermal sources with magnetic field. A&A 36:379–394

González-Galán A (2014) Fundamental properties of High-Mass X-ray Binaries. PhD Thesis, University of Alicante. arXiv:1503.01087

González-Galán A, Negueruela I, Castro N, Simón-Díaz S, Lorenzo J, Vilardell F (2014) Astrophysical parameters and orbital solution of the peculiar X-ray transient IGR J00370+6122. A&A 566:A131. doi:10.1051/0004-6361/201423554. arXiv:1404.4341

González-Riestra R, Oosterbroek T, Kuulkers E, Orr A, Parmar AN (2004) XMM-Newton observations of the INTEGRAL X-ray transient IGR J17544-2619. A&A 420:589–594. doi:10.1051/0004-6361:20035940. arXiv:astro-ph/0402293

Goossens ME, Bird AJ, Drave SP, Bazzano A, Hill AB, McBride VA, Sguera V, Sidoli L (2013) Discovering a 5.72-d period in the supergiant fast X-ray transient AX J1845.0-0433. Mon Not RAS 434:2182–2187. doi:10.1093/mnras/stt1166. arXiv:1307.0709

Götz D, Falanga M, Senziani F, De Luca A, Schanne S, von Kienlin A (2007) IGR J08408-4503: a new recurrent supergiant fast X-ray transient. Astrophys J Lett 655:L101-L104. doi:10.1086/511818. arXiv:astro-ph/0612437

Göğüş E, Kreykenbohm I, Belloni TM (2011) Discovery of a peculiar dip from GX 301-2. A&A 525:L6. doi:10.1051/0004-6361/201015905. arXiv:1011.3899

Grebenev SA, Sunyaev RA (2007) The first observation of AX J1749.1-2733 in a bright X-ray state. Another fast transient revealed by INTEGRAL. Astron Lett 33:149–158. doi:10.1134/S1063773707030024

Grebenev SA, Sunyaev RA (2010) New fast X-ray transient IGR J18462-0223 discovered by the INTEGRAL observatory. Astron Lett 36:533–539. doi:10.1134/S1063773710080013. arXiv:1009.3440

Grebenev SA, Ubertini P, Chenevez J, Mowlavi N, Roques JP, Gehrels N, Kuulkers E (2004a) New X-ray transient IGR J11435-6109 discovered with INTEGRAL. Astron Telegr 350:1

Grebenev SA, Ubertini P, Chenevez J, Orr A, Sunyaev RA (2004b) New X-ray transient IGR J01363+6610 discovered by INTEGRAL. Astron Telegr 275:1

Grimm HJ, Gilfanov M, Sunyaev R (2002) The Milky Way in X-rays for an outside observer. Log(N)-Log(S) and luminosity function of X-ray binaries from RXTE/ASM data. A&A 391:923–944. doi:10.1051/0004-6361:20020826. arXiv:astro-ph/0109239

Grimm HJ, Gilfanov M, Sunyaev R (2003) High-mass X-ray binaries as a star formation rate indicator in distant galaxies. Mon Not RAS 339:793–809. doi:10.1046/j.1365-8711.2003.06224.x. arXiv:astro-ph/0205371

Grindlay JE, Petro LD, McClintock JE (1984) Optical identification of 2S 1417-62. Astrophys J 276:621–624. doi:10.1086/161650

Grove JE, Strickman MS, Johnson WN, Kurfess JD, Kinzer RL, Starr CH, Jung GV, Kendziorra E, Kretschmar P, Maisack M, Staubert R (1995) The soft gamma-ray spectrum of A0535+26: detection of an absorption feature at 110 keV by OSSE. Astrophys J Lett 438:L25–L28. doi:10.1086/187706

Grupe D, Kennea J, Evans P, Romano P, Markwardt C, Chester M (2009) Swift detection of a flare from IGR J16328-4726. Astron Telegr, 2075:1

Guesten R, Mezger PG (1982) Star formation and abundance gradients in the galaxy. Vistas Astron 26:159–224. doi:10.1016/0083-6656(82)90005-8

Gvaramadze VV, Röser S, Scholz RD, Schilbach E (2011) 4U 1907+09: an HMXB running away from the Galactic plane. A&A 529:A14. doi:10.1051/0004-6361/201016256. arXiv:1102.2437

Haberl F, White NE, Kallman TR (1989) An EXOSAT X-ray observation of one orbital cycle of 4U 1700-37/HD 153919. Astrophys J 343:409–425. doi:10.1086/167714

Halpern JP (2006) Optical classification of three swift BAT/XRT sources at low galactic latitude. Astron Telegr 847:1

Halpern JP (2012a) Discovery of 46.6 s X-ray pulsations from the candidate for IGR J22534+6243. Astron Telegr 4240:1

Halpern JP (2012b) Swift detection of 11.82 s pulsations from IGR J18179-1621. Astron Telegr 3949:1

Halpern JP, Gotthelf EV (2006) Igr J18450-0435 = AX J18450-0433. Astron Telegr 692:1

Halpern JP, Tyagi S (2005) Be star counterpart of X-ray transient IGR J06074+2205. Astron Telegr 682:1

Hannikainen DC, Rawlings MG, Muhli P, Vilhu O, Schultz J, Rodriguez J (2007) The nature of the infrared counterpart of IGR J19140+0951. Mon Not RAS 380:665–668. doi:10.1111/j.1365-2966.2007.12092.x. arXiv:0706.1129

Harding AK, Lai D (2006) Physics of strongly magnetized neutron stars. Rep Prog Phys 69:2631–2708. doi:10.1088/0034-4885/69/9/R03. arXiv:astro-ph/0606674

Heindl WA, Chakrabarty D (1999) New results on cyclotron lines and neutron star magnetic fields. In: Aschenbach B, Freyberg MJ (eds) Highlights in X-ray astronomy. Max-Planck-Institut für extraterrestrische Physik, Garching, p 25

Heindl WA, Coburn W, Gruber DE, Pelling MR, Rothschild RE, Wilms J, Pottschmidt K, Staubert R (1999) Discovery of a third harmonic cyclotron resonance scattering feature in the X-ray spectrum of 4U 0115+63. Astrophys J Lett 521:L49–L53. doi:10.1086/312172. arXiv:astro-ph/9904222

Heindl WA, Coburn W, Gruber DE, Rothschild RE, Kreykenbohm I, Wilms J, Staubert R (2001) Discovery of a cyclotron resonance scattering feature in the X-ray spectrum of XTE J1946+274. Astrophys J Lett 563:L35–L39. doi:10.1086/339017. arXiv:astro-ph/0112468

Heindl W, Coburn W, Kreykenbohm I, Wilms J (2003) Cyclotron line in XTE J0658-073. Astron Telegr 200:1

Hemphill PB, Rothschild RE, Caballero I, Pottschmidt K, Kühnel M, Fürst F, Wilms J (2013) Measurements of cyclotron features and pulse periods in the high-mass X-ray binaries 4U 1538-522 and 4U 1907+09 with the international gamma-ray astrophysics laboratory. Astrophys J 777:61. doi:10.1088/0004-637X/777/1/61. arXiv:1309.0875

Heras JAZ, Walter R (2004) IGR J16465-4507 counterpart. Astron Telegr 336:1

Hickox RC, Narayan R, Kallman TR (2004) Origin of the soft excess in X-ray pulsars. Astrophys J 614:881–896

Hill AB, Walter R, Knigge C, Bazzano A, Bélanger G, Bird AJ, Dean AJ, Galache JL, Malizia A, Renaud M, Stephen J, Ubertini P (2005) The 1–50 keV spectral and timing analysis of IGR J18027-2016: an eclipsing, high mass X-ray binary. A&A 439:255–263. doi:10.1051/0004-6361:20052937. arXiv:astro-ph/0505078

Huckle HE, Mason KO, White NE, Sanford PW, Maraschi L, Tarenghi M, Tapia S (1977) Discovery of two periodic X-ray pulsators. Mon Not RAS 180:21P–26P

Hulleman F, in 't Zand JJM, Heise J (1998) Discovery of the transient X-ray pulsar SAX J2103.5+4545. A&A 337:L25–L28. arXiv:astro-ph/9807280

Hutchings JB, Crampton D (1981) The optical counterpart of 4U 0115+63. Astrophys J 247:222. doi:10.1086/159028

Hutchings JB, Crampton D, Cowley AP (1981) The X-ray pulsars 2S 1145-619 and 1E 1145.1-6141: optical identifications and a nearby supernova remnant. Astron J 86:871–874. doi:10.1086/112959

Ibarra A, Matt G, Guainazzi M, Kuulkers E, Jiménez-Bailón E, Rodriguez J, Nicastro F, Walter R (2007) The XMM-Newton/INTEGRAL monitoring campaign of IGR J16318-4848. A&A 465:501–507. doi:10.1051/0004-6361:20066225. arXiv:astro-ph/0611343

Ikhsanov NR (2007) The origin of long-period X-ray pulsars. Mon Not RAS 375:698–704. doi:10.1111/j.1365-2966.2006.11331.x. arXiv:astro-ph/0611442

Ikhsanov NR, Finger MH (2012) Signs of magnetic accretion in the X-ray pulsar binary GX 301-2. Astrophys J 753:1. doi:10.1088/0004-637X/753/1/1. arXiv:1204.4975

Illarionov AF, Sunyaev RA (1975) Why the number of Galactic X-ray stars is so small? A&A 39:185

in't Zand JJM (2005) Chandra observation of the fast X-ray transient IGR J17544-2619: evidence for a neutron star? A&A 441:L1–L4. doi:10.1051/0004-6361:200500162. arXiv:astro-ph/0508240

in't Zand J, Heise J, Smith M, Muller JM, Ubertini P, Bazzano A (1998a) SAX J1818.6-1703 and KS 1741-293. IAU Circ 6840:2

in't Zand JJM, Baykal A, Strohmayer TE (1998b) Recent X-ray measurements of the accretion-powered pulsar 4U 1907+09. Astrophys J 496:386. doi:10.1086/305362. arXiv:astro-ph/9711292

in't Zand JJM, Corbet RHD, Marshall FE (2001) Discovery of a 75 day orbit in XTE J1543-568. Astrophys J Lett 553:L165–L168. doi:10.1086/320688. arXiv:astro-ph/0104468

in't Zand JJM, Ubertin P, Del Santo M (2003) Igr J16320-4751 and Igr J16318-4848. IAU Circ 8077:2

in't Zand JJM, Kuiper L, den Hartog PR, Hermsen W, Corbet RHD (2007) A probable accretion-powered X-ray pulsar in IGR J00370+6122. A&A 469:1063–1068. doi:10.1051/0004-6361:20077189

Islam N, Maitra C, Pradhan P, Paul B (2015) A Suzaku view of IGR J16393-4643. Mon Not RAS 446:4148–4154. doi:10.1093/mnras/stu2395. arXiv:1411.3108

Israel GL, Negueruela I, Campana S, Covino S, Di Paola A, Maxwell DH, Norton AJ, Speziali R, Verrecchia F, Stella L (2001) The identification of the optical/IR counterpart of the 29.5-s transient X-ray pulsar GS 1843+009. A&A 371:1018–1023. doi:10.1051/0004-6361:20010417. arXiv:astro-ph/0103421

Jain C, Paul B, Maitra C (2011) Detection of periodic X-ray modulation of SFXT IGR J16207-5129 in the Swift-BAT light curve. Astron Telegr 3785:1

Jaisawal GK, Naik S, Paul B (2013) Possible detection of a cyclotron resonance scattering feature in the X-ray pulsar 4U 1909+07. Astrophys J 779:54. doi:10.1088/0004-637X/779/1/54. arXiv:1310.0948

Janot-Pacheco E, Ilovaisky SA, Chevalier C (1981) A photometric and spectroscopic study of He 3-640 /equals A1118-61/. A&A 99:274–284

Jenke PA, Finger MH, Wilson-Hodge CA, Camero-Arranz A (2012) Orbital decay and evidence of disk formation in the X-ray binary pulsar OAO 1657-415. Astrophys J 759:124. doi:10.1088/0004-637X/759/2/124. arXiv:1112.5190

Johnston S, Manchester RN, Lyne AG, Bailes M, Kaspi VM, Qiao G, D'Amico N (1992) PSR 1259-63: a binary radio pulsar with a be star companion. Astrophys J Lett 387:L37–L41. doi:10.1086/186300

Johnston S, Manchester RN, Lyne AG, Nicastro L, Spyromilio J (1994) Radio and optical observations of the PSR:B1259-63/SS:2883 be-star binary system. Mon Not RAS 268:430

Jones C, Forman W, Tananbaum H, Schreier E, Gursky H, Kellogg E, Giacconi R (1973) Evidence for the binary nature of 2u 1700-37. Astrophys J Lett 181:L43. doi:10.1086/181181

Jones CA, Chetin T, Liller W (1974) Optical studies of UHURU sources. VIII. Observations of 92 possible counterparts of X-ray sources. Astrophys J Lett 190:L1. doi:10.1086/181488

Kaper L, Lamers HJGLM, Ruymaekers E, van den Heuvel EPJ, Zuiderwijk EJ (1995) Wray 977 (GX 301-2): a hypergiant with pulsar companion. A&A 300:446–452. arXiv:astro-ph/9503003

Kaper L, van Loon JT, Augusteijn T, Goudfrooij P, Patat F, Waters LBFM, Zijlstra AA (1997) Discovery of a bow shock around VELA X-1. Astrophys J Lett 475:L37–L40. doi:10.1086/310454. arXiv:astro-ph/9611017

Kaper L, van der Meer A, Najarro F (2006) VLT/UVES spectroscopy of Wray 977, the hypergiant companion to the X-ray pulsar GX301-2. A&A 457:595–610. doi:10.1051/0004-6361:20065393. arXiv:astro-ph/0607613

Kaplan DL, Moon DS, Reach WT (2006) Long-wavelength excesses in two highly obscured high-mass X-ray binaries: IGR J16318-4848 and GX 301-2. Astrophys J Lett 649:L107–L110. doi:10.1086/508369

Karasev D, Tsygankov S, Lutovinov A, Churazov E, Sunyaev R (2007) Discovery of X-ray pulsations from the HMXB AX J1749.1-2733. Astron Telegr 1245:1. arXiv:0711.4559

Karasev DI, Tsygankov SS, Lutovinov AA (2008) Discovery of X-ray pulsations from the HMXB source AXJ1749.1-2733. Mon Not RAS 386:L10–L14. doi:10.1111/j.1745-3933.2008.00449.x. arXiv:0801.3247

Karasev DI, Lutovinov AA, Burenin RA (2010) AXJ1749.1-2733 and AXJ1749.2-2725: the close pair of X-ray pulsars behind the Galactic Centre. Mon Not RAS 409:L69–L73. doi:10.1111/j.1745-3933.2010.00949.x. arXiv:1009.1229

Karasev DI, Revnivtsev MG, Lutovinov AA, Burenin RA (2010b) Investigation of the stellar population and determination of interstellar extinction toward the Chandra Bulge Field based on RTT-150 data. Astron Lett 36:788–795. doi:10.1134/S1063773710110046

Karasev DI, Lutovinov AA, Revnivtsev MG, Krivonos RA (2012) Accurate localization and identification of six hard X-ray sources from Chandra and XMM-Newton data. Astron Lett 38:629–637. doi:10.1134/S1063773712100039. arXiv:1209.2945

Kaur R, Paul B, Kumar B, Sagar R (2008) Multiwavelength study of the transient X-ray binary IGR J01583+6713. Mon Not RAS 386:2253–2261. doi:10.1111/j.1365-2966.2008.13233.x. arXiv:0803.1113

Kawabata Nobukawa K, Nobukawa M, Tsuru TG, Koyama K (2012) Suzaku observation of the supergiant fast X-ray transient AX J1841.0-0536. Publ ASJ 64:99. doi:10.1093/pasj/64.5.99

Keek S, Kuiper L, Hermsen W (2006) The discovery of five new hard X-ray sources in the Circinus region by INTEGRAL. Astron Telegr 810:1

Kelley RL, Doxsey RE, Jernigan JG, Rappaport S, Apparao KMV, Naranan S (1981) Discovery of X-ray pulsations from 2S 1417-624. Astrophys J 243:251–256. doi:10.1086/158591

Kendziorra E, Mony B, Kretschmar P, Maisack M, Staubert R, Doebereiner S, Englhauser J, Pietsch W, Reppin C, Truemper J (1992) Hard X ray observations of VELA X-1 and A0535+26 with HEXE: discovery of cyclotron lines. In: Shrader CR, Gehrels N, Dennis B (eds) NASA conference publication, vol 3137, p 217

Kendziorra E, Kretschmar P, Pan HC, Kunz M, Maisack M, Staubert R, Pietsch W, Truemper J, Efremov V, Sunyaev R (1994) Evidence for cyclotron line features in high energy spectra of A 0535+26 during the March/April 1989 outburst. A&A 291:L31–L34

Kennea JA, Campana S (2006) Swift/XRT observation of IGR J08408-4503. Astron Telegr 818:1

Kennea JA, Racusin JL, Burrows DN, Hunsberger S, Nousek JA, Gehrels N (2005) Swift/XRT detection and localization of IGR J01583+6713. Astron Telegram 673:1

Kholopov PN, Samus' NN, Kukarkina NP, Medvedeva GI, Perova NB (1981) 66th name-list of variable stars. Inform Bullet Var Stars 2042:1

Kinugasa K, Torii K, Hashimoto Y, Tsunemi H, Hayashida K, Kitamoto S, Kamata Y, Dotani T, Nagase F, Sugizaki M, Ueda Y, Kawai N, Makishima K, Yamauchi S (1998) Discovery of the faint X-ray Pulsar AX J1820.5-1434 with ASCA. Astrophys J 495:435. doi:10.1086/305291

Klochkov D, Santangelo A, Staubert R, Ferrigno C (2008) Giant outburst of EXO 2030+375: pulse-phase resolved analysis of INTEGRAL data. A&A 491:833–840. doi:10.1051/0004-6361:200810673. arXiv:0809.4190

Klochkov D, Staubert R, Santangelo A, Rothschild RE, Ferrigno C (2011) Pulse-amplitude-resolved spectroscopy of bright accreting pulsars: indication of two accretion regimes. A&A 532:A126. doi:10.1051/0004-6361/201116800. arXiv:1107.2202

Klochkov D, Doroshenko V, Santangelo A, Staubert R, Ferrigno C, Kretschmar P, Caballero I, Wilms J, Kreykenbohm I, Pottschmidt K, Rothschild RE, Wilson-Hodge CA, Pühlhofer G (2012) Outburst of GX 304-1 monitored with INTEGRAL: positive correlation between the cyclotron line energy and flux. A&A 542:L28. doi:10.1051/0004-6361/201219385. arXiv:1205.5475

Koenigsberger G, Moreno E, Harrington DM (2012) Tidal effects on the radial velocity curve of HD 77581 (Vela X-1). A&A 539:A84. doi:10.1051/0004-6361/201118397. arXiv:1201.4619

Koh DT, Bildsten L, Chakrabarty D, Nelson RW, Prince TA, Vaughan BA, Finger MH, Wilson RB, Rubin BC (1997) Rapid spin-up episodes in the wind-fed accreting Pulsar GX 301-2. Astrophys J 479:933. doi:10.1086/303929

Kohmura T, Kitamoto S, Torii K (2001) Delayed iron lines in centaurus X-3. Astrophys J 562:943–949. doi:10.1086/323848

Kong AKH (2003) XMM-Newton observation of the X-ray point source population of the starburst galaxy IC 342. Mon Not RAS 346:265–272. doi:10.1046/j.1365-2966.2003.07086.x. arXiv:astro-ph/0308106

Kostka M, Leahy DA (2010) Evidence for an accretion stream in 4U1907+09. Mon Not RAS 407:1182–1187. doi:10.1111/j.1365-2966.2010.16968.x

Koyama K, Kawada M, Takeuchi Y, Tawara Y, Ushimaru N, Dotani T, Takizawa M (1990a) Discovery of a peculiar X-ray pulsar GS 1843+00. Astrophys J Lett 356:L47–L50. doi:10.1086/185747

Koyama K, Kunieda H, Takeuchi Y, Tawara Y (1990b) Discovery of a new X-ray pulsar GS 1843-02. Publ ASJ 42:L59–L64

Kreykenbohm I, Wilms J, Coburn W, Kuster M, Rothschild RE, Heindl WA, Kretschmar P, Staubert R (2004) The variable cyclotron line in GX 301-2. A&A 427:975–986. doi:10.1051/0004-6361:20035836. arXiv:astro-ph/0409015

Kreykenbohm I, Mowlavi N, Produit N, Soldi S, Walter R, Dubath P, Lubiński P, Türler M, Coburn W, Santangelo A, Rothschild RE, Staubert R (2005) INTEGRAL observation of V 0332+53 in outburst. A&A 433:L45–L48. doi:10.1051/0004-6361:200500023. arXiv:astro-ph/0503028

Kreykenbohm I, Wilms J, Kretschmar P, Torrejón JM, Pottschmidt K, Hanke M, Santangelo A, Ferrigno C, Staubert R (2008) High variability in Vela X-1: giant flares and off states. A&A 492:511–525. doi:10.1051/0004-6361:200809956. arXiv:0810.2981

Krimm HA, Barthelmy SD, Cummings J, Fenimore E, Gehrels N, Markwardt C, Palmer D, Parsons A, Sakamoto T, Sato G, Skinner G, Stamatikos M, Tueller J (2008) Swift/BAT detects increased activity from the accreting Pulsar GRO J1750-27. Astron Telegram 1376:1

Krimm HA, Romano P, Barthelmy SD, Baumgartner W, Cummings J, Fenimore E, Gehrels N, Markwardt CB, Palmer D, Sakamoto T, Skinner G, Stamatikos M, Tueller J, Ukwatta T (2011) Swift/BAT reports increased activity from IGR J18483-0311. Astron Telegram 3780:1

Krivonos R, Revnivtsev M, Lutovinov A, Sazonov S, Churazov E, Sunyaev R (2007) INTEGRAL/IBIS all-sky survey in hard X-rays. A&A 475:775–784. doi:10.1051/0004-6361:20077191. arXiv:astro-ph/0701836

Krivonos R, Tsygankov S, Sunyaev R, Melnikov S, Bikmaev I, Pavlinsky M, Burenin R (2009) Two new hard X-ray sources IGR J18151-1052 and IGR J17009+3559 discovered with INTEGRAL. Astron Telegram 2170:1

Krivonos R, Tsygankov S, Lutovinov A, Turler M, Bozzo E (2010) The continued flaring activity of LS V+44 17/RX J0440.9+4431. Astron Telegram 2828:1

Krivonos R, Tsygankov S, Lutovinov A, Revnivtsev M, Churazov E, Sunyaev R (2012) INTEGRAL/IBIS nine-year Galactic hard X-ray survey. A&A 545:A27. doi:10.1051/0004-6361/201219617. arXiv:1205.3941

Krivonos R, Tsygankov S, Lutovinov A, Revnivtsev M, Churazov E, Sunyaev R (2015) INTEGRAL 11-year hard X-ray survey above 100 keV. Mon Not RAS 448:3766–3774. doi:10.1093/mnras/stv150. arXiv:1412.1051

Krtička J, Kubát J, Skalický J (2012) X-ray photoionized bubble in the wind of vela X-1 pulsar supergiant companion. Astrophys J 757:162. doi:10.1088/0004-637X/757/2/162. arXiv:1208.1827

Krzeminski W (1974) The identification and UBV photometry of the visible component of the Centaurus X-3 binary system. Astrophys J Lett 192:L135–L138. doi:10.1086/181609

Kudritzki RP, Puls J (2000) Winds from hot stars. Annu Rev A&A 38:613–666. doi:10.1146/annurev.astro.38.1.613

Kuehnel M, Mueller S, Kreykenbohm I, Wilms J, Pottschmidt K, Fuerst F, Rothschild RE, Caballero I, Klochkov D, Staubert R, Suchy S, Kretschmar P, Ferrigno C, Torrejon JM, Martinez-Nunez S (2012) Improved orbital ephemeris of GRO J1008-57. Astron Telegram 4564:1

Kuiper L, Keek S, Hermsen W, Jonker PG, Steeghs D (2006) Discovery of four new hard X-ray sources in the Circinus and Carina region by INTEGRAL. Astron Telegram 684:1

Kuulkers E, Wijnands R, Belloni T, Mendez M, van der Klis M, van Paradijs J (1998) Absorption dips in the light curves of GRO J1655-40 and 4U 1630-47 during Outburst. Astrophys J 494:753

Kuulkers E, Shaw S, Paizis A, Gros A, Chenevez J, Sanchez-Fernandez C, Brandt S, Courvoisier TJL, Garau AD, Ebisawa K, Kretschmar P, Markwardt C, Mowlavi N, Oosterbroek T, Orr A, Oneca DR, Wijnands R (2006) New INTEGRAL source, IGR J17354-3255, and continuation of the INTEGRAL Galactic Bulge monitoring program. Astron Telegram 874:1

La Palombara N, Mereghetti S (2006) XMM-Newton observation of the Be/neutron star system RX J0146.9+6121: a soft X-ray excess in a low luminosity accreting pulsar. A&A 455:283–289. doi:10.1051/0004-6361:20065107. arXiv:astro-ph/0604193

La Palombara N, Sidoli L, Esposito P, Tiengo A, Mereghetti S (2009) XMM-Newton observation of the persistent Be/NS X-ray binary pulsar RX J1037.5-5647 in a low luminosity state. A&A 505:947–954. doi:10.1051/0004-6361/200912538. arXiv:0907.4239

La Parola V, Cusumano G, Romano P, Segreto A, Vercellone S, Chincarini G (2010a) Detection of an orbital period in the supergiant high-mass X-ray binary IGR J16465-4507 with Swift-BAT. Mon Not RAS 405:L66–L70. doi:10.1111/j.1745-3933.2010.00860.x. arXiv:1005.0684

La Parola V, Ducci L, Romano P, Sidoli L, Cusumano G, Vercellone S, Mangano V, Kennea JA, Krimm HA, Burrows DN, Gehrels N (2010b) The Swift SFXT monitoring campaign: the IGR J16479-4514 outburst in 2009. X-ray astronomy 2009; present status, multi-wavelength approach and future. Perspectives 1248:177–178. doi:10.1063/1.3475190. arXiv:1001.3588

La Parola V, D'Aì A, Cusumano G, Segreto A, Masetti N, Melandri A (2013) Timing and spectral study of the Be XRB IGR J11305-6256: swift discovers the orbital period and a soft X-ray excess. arXiv:1305:3916

Lamb RC, Markert TH, Hartman RC, Thompson DJ, Bignami GF (1980) Two X-ray pulsars: 2S 1145-619 and 1E 1145.1-6141. Astrophys J 239:651–654. doi:10.1086/158151

Lamers HJGLM, Cassinelli JP (1999) Introduction to stellar winds. Cambridge University Press, Cambridge

Lamers HJGLM, van den Heuvel EPJ, Petterson JA (1976) Stellar winds and accretion in massive X-ray binaries. A&A 49:327–335

Landi R, Masetti N, Capitanio F, Fiocchi M, Bird AJ (2009) A Swift/XRT follow-up observation of the INTEGRAL source IGR J14488-5942. Astron Telegr 2355:1

Leahy DA, Kostka M (2008) Stellar wind accretion in GX 301-2: evidence for a high-density stream. Mon Not RAS 384:747–754. doi:10.1111/j.1365-2966.2007.12754.x. arXiv:0709.0543

Lehmer BD, Alexander DM, Bauer FE, Brandt WN, Goulding AD, Jenkins LP, Ptak A, Roberts TP (2010) A chandra perspective on galaxy-wide X-ray binary emission and its correlation with star formation rate and stellar mass: new results from luminous infrared galaxies. Astrophys J 724:559–571. doi:10.1088/0004-637X/724/1/559. arXiv:1009.3943

Lépine S, Moffat AFJ (1999) Wind inhomogeneities in wolf-rayet stars. II Investigation of emission-line profile variations. Astrophys J 514:909–931. doi:10.1086/306958

Leutenegger MA, Cohen DH, Sundqvist JO, Owocki SP (2013) Constraints on porosity and mass loss in O-star winds from the modeling of X-ray emission line profile shapes. Astrophys J 770:80. doi:10.1088/0004-637X/770/1/80. arXiv:1305.5595

Levesque EM, Stringfellow GS, Ginsburg AG, Bally J, Keeney BA (2014) The peculiar balmer decrement of SN 2009ip: constraints on circumstellar geometry. Astrophys J 147:23. doi:10.1088/0004-6256/147/1/23

Levine AM, Corbet R (2006) Detection of additional periodicities in RXTE ASM light curves. Astron Telegr 940:1

Levine AM, Rappaport S, Remillard R, Savcheva A (2004) X1908+075: a pulsar orbiting in the stellar wind of a massive companion. Astrophys J 617:1284–1295. doi:10.1086/425567. arXiv:astro-ph/0404428

Levine AM, Bradt HV, Chakrabarty D, Corbet RHD, Harris RJ (2011) An extended and more sensitive search for periodicities in rossi X-ray timing explorer/all-sky monitor X-ray light curves. Astrophys J 196:6. doi:10.1088/0067-0049/196/1/6. arXiv:1009.0450

Leyder JC, Walter R, Lazos M, Masetti N, Produit N (2007) Hard X-ray flares in ASTROBJIGR J08408-4503/ASTROBJ unveil clumpy stellar winds. A&A 465:L35–L38. doi:10.1051/0004-6361:20066317

Li J, Torres DF, Zhang S, Papitto A, Chen Y, Wang JM (2012a) INTEGRAL and Swift observations of the be X-ray binary 4U 1036–56 (RX J1037.5-5647) and its possible relation with γ-ray transients. Astrophys J 761:49. doi:10.1088/0004-637X/761/1/49. arXiv:1210.1224

Li J, Zhang S, Torres DF, Papitto A, Chen YP, Wang JM (2012) INTEGRAL and Swift/XRT observations of IGR J18179-1621. Mon Not RAS 426:L16–L20. doi:10.1111/j.1745-3933.2012.01313.x

Lin CC, Yuan C, Shu FH (1969) On the spiral structure of disk galaxies. III. Comparison with observations. Astrophys J 155:721. doi:10.1086/149907

Liu QZ, van Paradijs J, van den Heuvel EPJ (2000) A catalogue of high-mass X-ray binaries. A&A Suppl Ser 147:25–49

Liu QZ, van Paradijs J, van den Heuvel EPJ (2006) Catalogue of Galactic high-mass X-ray binaries (Liu+, 2006). VizieR Online Data Catalog 345(51):165

Liu QZ, Chaty S, Yan JZ (2011) Be/X-ray binaries as the progenitors of the supergiant fast X-ray transients IGR J18483-0311 and IGR J11215-5952. Mon Not RAS 415:3349–3353. doi:10.1111/j.1365-2966.2011.18949.x

Lorenzo J, Negueruela I, Castro N, Norton AJ, Vilardell F, Herrero A (2014) Astrophysical parameters of the peculiar X-ray transient IGR J11215-5952. A&A 562:A18. doi:10.1051/0004-6361/201321913. arXiv:1312.5597

Lucy LB, White RL (1980) X-ray emission from the winds of hot stars. Astrophys J 241:300–305. doi:10.1086/158342

Lupie OL, Nordsieck KH (1987) Visible and infrared continuum spectropolarimetric observations of ten OB supergiant and O emission-line stars. Astron J 93:214–230. doi:10.1086/114302

Lutovinov AA, Tsygankov SS (2009) Timing characteristics of the hard X-ray emission from bright X-ray pulsars based on INTEGRAL data. Astron Lett 35(7):433–456. doi:10.1134/S1063773709070019

Lutovinov AA, Grebenev SA, Syunyaev RA, Pavlinskii MN (1994) Timing of X-ray pulsars from data obtained with the ART-P telescope of the GRANAT space observatory in 1990–1992. Astron Lett 20:538–564

Lutovinov AA, Grebenev SA, Sunyaev RA (2000) ART-P/GRANAT observations of the X-ray pulsar 4U0115+634 during the outburst in February 1990. Astron Lett 26:1–8. doi:10.1134/1.20363

Lutovinov A, Revnivtsev M, Molkov S (2003a) INTEGRAL detection and improved position of EXO 1722-363. Astron Telegr 178:1

Lutovinov A, Walter R, Belanger G, Lund N, Grebenev S, Winkler C (2003b) IGR17597-2201 and AX1820.5-1434. Astron Telegr 1:155

Lutovinov AA, Molkov SV, Revnivtsev MG (2003c) The first results of observations of the transient pulsar SAX J2103.5+4545 by the INTEGRAL observatory. Astron Lett 29:713–718. doi:10.1134/1.1624456. arXiv:astro-ph/0306289

Lutovinov A, Rodrigues J, Budtz-Jorgensen C, Grebenev S, Winkler C (2004) INTEGRAL discovered a new transient source IGRJ16465-4507. Astron Telegr 329:1

Lutovinov A, Revnivtsev M, Gilfanov M, Shtykovskiy P, Molkov S, Sunyaev R (2005a) INTEGRAL insight into the inner parts of the Galaxy. High mass X-ray binaries. A&A 444:821–829. doi:10.1051/0004-6361:20042392. arXiv:astro-ph/0411550

Lutovinov A, Revnivtsev M, Molkov S, Sunyaev R (2005b) INTEGRAL observations of five sources in the Galactic Center region. A&A 430:997–1003. doi:10.1051/0004-6361:20041677. arXiv:astro-ph/0407342

Lutovinov A, Rodriguez J, Revnivtsev M, Shtykovskiy P (2005c) Discovery of X-ray pulsations from IGR J16320-4751 = AX J1631.9-4752. A&A 433:L41–L44. doi:10.1051/0004-6361:200500092. arXiv:astro-ph/0411547

Lutovinov AA, Revnivtsev MG, Gilfanov MR, Sunyaev RA (2007) Population of HMXB in the Galaxy. In: ESA Special Publication, vol 622, p 241, arXiv:0801.3589

Lutovinov A, Tsygankov S, Chernyakova M (2012a) Strong outburst activity of the X-ray pulsar X Persei during 2001–2011. Mon Not RAS 423:1978–1984. doi:10.1111/j.1365-2966.2012.21036.x. arXiv:1204.0483

Lutovinov AA, Burenin RA, Revnivtsev MG, Bikmaev IF (2012b) Optical identification of six hard X-ray sources from the INTEGRAL and SWIFT all-sky surveys. Astron Lett 38:1–11. doi:10.1134/S1063773712010045

Lutovinov AA, Mironov AI, Burenin RA, Revnivtsev MG, Tsygankov SS, Pavlinsky MN, Korobtsev IV, Eselevich MV (2013a) Identification of four X-ray sources from the INTEGRAL and Swift catalogs. Astron Lett 39:513–522. doi:10.1134/S1063773713080069. arXiv:1307.2761

Lutovinov AA, Revnivtsev MG, Tsygankov SS, Krivonos RA (2013b) Population of persistent high-mass X-ray binaries in the Milky Way. Mon Not RAS 431:327–341. doi:10.1093/mnras/stt168. arXiv:1302.0728

Lutovinov AA, Tsygankov SS, Suleimanov VF, Mushtukov AA, Doroshenko V, Nagirner DI, Poutanen J (2015) Transient X-ray pulsar V 0332+53: pulse-phase-resolved spectroscopy and the reflection model. Mon Not RAS 448:2175–2176. doi:10.1093/mnras/stv125. arXiv:1502.03783

Lyne AG, Manchester RN, Taylor JH (1985) The galactic population of pulsars. Mon Not RAS 213:613–639

Makino F (1988) Supernova 1987A in the large magellanic cloud. IAU Circ 4530:2

Makino F, Team GINGA (1988a) GS 1843–024. IAU Circ 4661:2

Makino F, Team GINGA (1988b) Transient X-ray source. IAU Circ 4583:1

Makishima K, Mihara T (1992) Magnetic fields of neutron stars. In: Tanaka Y, Koyama K (eds) Frontiers science series. Universal Academy Press, Tokyo, p 23

Makishima K, Kawai N, Koyama K, Shibazaki N, Nagase F, Nakagawa M (1984) Discovery of a 437.5-s X-ray pulsation from 4U 1907 + 09. Publ ASJ 36:679–689

Makishima K, Koyama K, Hayakawa S, Nagase F (1987) Spectra and pulse period of the binary X-ray pulsar 4U 1538–52. Astrophys J 314:619–628. doi:10.1086/165091

Makishima K, Mihara T, Ishida M, Ohashi T, Sakao T, Tashiro M, Tsuru T, Kii T, Makino F, Murakami T, Nagase F, Tanaka Y, Kunieda H, Tawara Y, Kitamoto S, Miyamoto S, Yoshida A, Turner MJL (1990) Discovery of a prominent cyclotron absorption feature from the transient X-ray pulsar X0331 + 53. Astrophys J Lett 365:L59–L62. doi:10.1086/185888

Manousakis A, Walter R (2011) X-ray wind tomography of the highly absorbed HMXB IGR J17252–3616. A&A 526:A62. doi:10.1051/0004-6361/201015707. arXiv:1008.5362

Manousakis A, Walter R (2012) Personal communication

Manousakis A, Walter R (2015a) Origin of the X-ray off-states in Vela X-1. A&A 575:A58. doi:10.1051/0004-6361/201321414. arXiv:1412.5419

Manousakis A, Walter R (2015b) The stellar wind velocity field of HD 77581. A&A. arXiv:1507.01016

Manousakis A, Walter R, Blondin JM (2012) Neutron star masses from hydrodynamical effects in obscured supergiant high mass X-ray binaries. A&A 547(A20):7. doi:10.1051/0004-6361/201219717. arXiv:1210.2952

Markova N, Puls J, Scuderi S, Markov H (2005) Bright OB stars in the Galaxy. II. Wind variability in O supergiants as traced by Halpha. A&A 440(3):1133–1151. doi:10.1051/0004-6361:20041774

Markwardt CB, Swank JH (2003) Detection of orbital period of EXO 1722–363. Astron Telegr 179:1

Markwardt CB, Baumgartner WH, Skinner GK, Corbet RHD (2010) AX J1700.2-4220 is a 54 second X-ray pulsar. Astron Telegr, 2564:1

Marshall FE, Takeshima T, in't Zand J (2000) XTE J1543–568. IAU Circ 7363:2

Masetti N, Bassani L, Bazzano A, Bird AJ, Dean AJ, Malizia A, Norci L, Palazzi E, Schwope AD, Stephen JB, Ubertini P, Walter R (2006a) Unveiling the nature of INTEGRAL objects through optical spectroscopy. IV. A study of six new hard X-ray sources. A&A 455:11–19. doi:10.1051/0004-6361:20065111. arXiv:astro-ph/0604482

Masetti N, Morelli L, Palazzi E, Galaz G, Bassani L, Bazzano A, Bird AJ, Dean AJ, Israel GL, Landi R, Malizia A, Minniti D, Schiavone F, Stephen JB, Ubertini P, Walter R (2006b) Unveiling the nature of INTEGRAL objects through optical spectroscopy. V. Identification and properties of 21 southern hard X-ray sources. A&A 459:21–30. doi:10.1051/0004-6361:20066055. arXiv:astro-ph/0608394

Masetti N, Mason E, Morelli L, Cellone SA, McBride VA, Palazzi E, Bassani L, Bazzano A, Bird AJ, Charles PA, Dean AJ, Galaz G, Gehrels N, Landi R, Malizia A, Minniti D, Panessa F, Romero GE, Stephen JB, Ubertini P, Walter R (2008) Unveiling the nature of INTEGRAL objects through optical spectroscopy VI. A multi-observatory identification campaign. A&A 482:113–132. doi:10.1051/0004-6361:20079332 arXiv:1412.5419. arXiv:0802.0988

Masetti N, Parisi P, Palazzi E, Jiménez-Bailón E, Morelli L, Chavushyan V, Mason E, McBride VA, Bassani L, Bazzano A, Bird AJ, Dean AJ, Galaz G, Gehrels N, Landi R, Malizia A, Minniti D, Schiavone F, Stephen JB, Ubertini P (2009) Unveiling the nature of INTEGRAL objects through optical spectroscopy. VII. Identification of 20 Galactic and extragalactic hard X-ray sources. A&A 495:121–135. doi:10.1051/0004-6361:200811322. arXiv:0811.4085

Masetti N, Landi R, Sguera V, Capitanio F, Bassani L, Bazzano A, Bird AJ, Malizia A, Palazzi E (2010a) The peculiar high-mass X-ray binary 1ES 1210–646. A&A 511:A48. doi:10.1051/0004-6361/200913404. arXiv:1001.0568

Masetti N, Parisi P, Palazzi E, Jiménez-Bailón E, Chavushyan V, Bassani L, Bazzano A, Bird AJ, Dean AJ, Charles PA, Galaz G, Landi R, Malizia A, Mason E, McBride VA, Minniti D, Morelli L, Schiavone F, Stephen JB, Ubertini P (2010b) Unveiling the nature of INTEGRAL objects through optical spectroscopy. VIII. Identification of 44 newly detected hard X-ray sources. A&A 519:A96. doi:10.1051/0004-6361/201014852. arXiv:1006.4513

Masetti N, Jimenez-Bailon E, Chavushyan V, Parisi P, Bazzano A, Landi R, Bird AJ (2012a) Optical spectroscopy of X-ray source IGR J22534+6243. Astron Telegr 4248:1

Masetti N, Parisi P, Jiménez-Bailón E, Palazzi E, Chavushyan V, Bassani L, Bazzano A, Bird AJ, Dean AJ, Galaz G, Landi R, Malizia A, Minniti D, Morelli L, Schiavone F, Stephen JB, Ubertini P (2012b) Unveiling the nature of INTEGRAL objects through optical spectroscopy. IX. Twenty two more identifications, and a glance into the far hard X-ray Universe. A&A 538:A123. doi:10.1051/0004-6361/201118559. arXiv:1201.1906

Masetti N, Parisi P, Palazzi E, Jiménez-Bailón E, Chavushyan V, McBride V, Rojas AF, Steward L, Bassani L, Bazzano A, Bird AJ, Charles PA, Galaz G, Landi R, Malizia A, Mason E, Minniti D, Morelli L, Schiavone F, Stephen JB, Ubertini P (2013) Unveiling the nature of INTEGRAL objects through optical spectroscopy. X. A new multi-year, multi-observatory campaign. A&A 556:A120. doi:10.1051/0004-6361/201322026. arXiv:1307.2898

Mason KO, Murdin PG, Parkes GE, Visvanathan N (1978) The optical counterpart of GX 304–1. Mon Not RAS 184:45P–48P

Mason AB, Clark JS, Norton AJ, Negueruela I, Roche P (2009) Spectral classification of the mass donors in the high-mass X-ray binaries EXO 1722-363 and OAO 1657-415. A&A 505:281–286. doi:10.1051/0004-6361/200912480. arXiv:0907.3876

Mason AB, Norton AJ, Clark JS, Negueruela I, Roche P (2010) Preliminary determinations of the masses of the neutron star and mass donor in the high mass X-ray binary system EXO 1722-363. A&A 509:A79. doi:10.1051/0004-6361/200913394. arXiv:0911.4887

Mason AB, Norton AJ, Clark JS, Negueruela I, Roche P (2011) The masses of the neutron and donor star in the high-mass X-ray binary IGR J18027-2016. A&A 532:A124. doi:10.1051/0004-6361/201117392. arXiv:1106.5821

Mason AB, Clark JS, Norton AJ, Crowther PA, Tauris TM, Langer N, Negueruela I, Roche P (2012) The evolution and masses of the neutron star and donor star in the high mass X-ray binary OAO 1657-415. Mon Not RAS 422:199–206. doi:10.1111/j.1365-2966.2012.20596.x. arXiv:1102.3363

Massevitch AG, Tutukov AV, Iungelson LR (1976) Evolution of massive close binaries and formation of neutron stars and black holes. Ap&SS 40:115–133. doi:10.1007/BF00651192

Matt G, Guainazzi M (2003) The properties of the absorbing and line-emitting material in IGR J16318-4848. Mon Not RAS 341:L13–L17. doi:10.1046/j.1365-8711.2003.06658.x. arXiv:astro-ph/0303626

McBride VA, Wilms J, Coe MJ, Kreykenbohm I, Rothschild RE, Coburn W, Galache JL, Kretschmar P, Edge WRT, Staubert R (2006) Study of the cyclotron feature in MXB 0656-072. A&A 451:267–272. doi:10.1051/0004-6361:20054239. arXiv:astro-ph/0602113

McClintock JE, Nugent JJ, Li FK, Rappaport SA (1977) Discovery of a 272 second periodic variation in the X-ray source GX 304-1. Astrophys J Lett 216:L15–L18. doi:10.1086/182499

Meszaros P, Nagel W (1985) X-ray pulsar models. II—Comptonized spectra and pulse shapes. Astrophys J 299:138–153. doi:10.1086/163687

Mihara T (1995) Observational study of X-ray spectra of binary pulsars with Ginga. PhD thesis, Department of Physics, University of Tokyo (M95)

Mihara T, Makishima K, Kamijo S, Ohashi T, Nagase F, Tanaka Y, Koyama K (1991) Discovery of a cyclotron resonance feature at 30 keV from the transient X-ray pulsar Cepheus X-4. Astrophys J Lett 379:L61. doi:10.1086/186154

Mihara T, Makishima K, Nagase F (1995) Cyclotron lines and continuum spectra of X-ray binary pulsars with GINGA. In: American Astronomical Society meeting abstracts, Bulletin of the American Astronomical Society, vol 27, p #104.03

Mihara T, Makishima K, Nagase F (1998) Cyclotron line variability. Adv Space Res 22:987–996. doi:10.1016/S0273-1177(98)00128-8

Mihara T, Makishima K, Nagase F (2004) Luminosity-related changes in the cyclotron resonance structure of the binary X-ray pulsar 4U 0115+63. Astrophys J 610:390–401. doi:10.1086/421543

Mihara T, Yamamoto T, Sugizaki M, Yamaoka K (2010) Discovery of the cyclotron line at 51 keV from GX 304-1. Astron Telegr 2796:1

Mineo S, Gilfanov M, Sunyaev R (2012a) X-ray emission from star-forming galaxies—I. High-mass X-ray binaries. Mon Not RAS 419:2095–2115. doi:10.1111/j.1365-2966.2011.19862.x. arXiv:1105.4610

Mineo S, Gilfanov M, Sunyaev R (2012b) X-ray emission from star-forming galaxies—II. Hot interstellar medium. Mon Not RAS 426:1870–1883. doi:10.1111/j.1365-2966.2012.21831.x. arXiv:1205.3715

Molkov S, Lutovinov A, Grebenev S (2003a) First results from TOO observations of the Aql X-1 field with INTEGRAL. A&A 411:L357–L361. doi:10.1051/0004-6361:20031481. arXiv:astro-ph/0309630

Molkov S, Mowlavi N, Goldwurm A, Strong A, Lund N, Paul J, Oosterbroek T (2003b) Igr J16479-4514. Astron Telegr 176:1

Molkov SV, Cherepashchuk AM, Lutovinov AA, Revnivtsev MG, Postnov KA, Sunyaev RA (2004) A hard X-ray survey of the sagittarius arm tangent with the IBIS telescope of the INTEGRAL observatory: a catalog of sources. Astron Lett 30:534–539. doi:10.1134/1.1784495. arXiv:astro-ph/0402416

Moon DS, Kaplan DL, Reach WT, Harrison FA, Lee JE, Martin PG (2007) The rich mid-infrared environments of two highly obscured X-ray binaries: spitzer observations of IGR J16318-4848 and GX 301-2. Astrophys J Lett 671:L53–L56. doi:10.1086/524730. arXiv:0710.3351

Morel T, Grosdidier Y (2005) Near-infrared identification of the counterpart to X1908+075: a new OB-supergiant X-ray binary. Mon Not RAS 356:665–670. doi:10.1111/j.1365-2966.2004.08488.x. arXiv:astro-ph/0410178

Morgan E, Remillard R, Swank J (2003) XTEJ0658-073 (=MX0656-072) is a pulsar. Astron Telegr 199:1

Morii M, Kawai N, Sugimori K, Nakahira S, Yoshida A, Yamaoka K, Sugizaki M, Mihara T, Kohama M, Nakagawa YE, Yamamoto T, Saotome T, Negoro H, Nakajima M, Miyoshi S, Ozawa H, Ishiwata R, Tomida H, Matsuoka M, Kawasaki K, Ueno S, Suzuki M, Ishikawa M, Tsunemi H, Kimura M, Ueda Y, Isobe N, Eguchi S, Hiroi K, Daikyuji A, Uzawa A, Matsumura T, Yamazaki K (2010) MAXI/GSC detects a possible outburst of Be/X-ray binary LS V +44 17. Astron Telegr 2527:1

Morris DC, Smith RK, Markwardt CB, Mushotzky RF, Tueller J, Kallman TR, Dhuga KS (2009) Suzaku observations of four heavily absorbed HMXBs. Astrophys J 699:892–901. doi:10.1088/0004-637X/699/1/892. arXiv:0808.3141

Motch C, Janot-Pacheco E (1987) The optical counterpart of the X-ray transient EXO 2030+375. A&A 182:L55–L58

Motch C, Haberl F, Dennerl K, Pakull M, Janot-Pacheco E (1997) New massive X-ray binary candidates from the ROSAT Galactic Plane Survey. I. Results from a cross-correlation with OB star catalogues. A&A 323:853–875 arXiv:astro-ph/9611122

Mowlavi N, Kreykenbohm I, Shaw SE, Pottschmidt K, Wilms J, Rodriguez J, Produit N, Soldi S, Larsson S, Dubath P (2006) INTEGRAL observation of the high-mass X-ray transient V 0332+53 during the 2005 outburst decline. A&A 451:187–194. doi:10.1051/0004-6361:20054235. arXiv:astro-ph/0512414

Müller S, Ferrigno C, Kühnel M, Schönherr G, Becker PA, Wolff MT, Hertel D, Schwarm FW, Grinberg V, Obst M, Caballero I, Pottschmidt K, Fürst F, Kreykenbohm I, Rothschild RE, Hemphill P, Núñez SM, Torrejón JM, Klochkov D, Staubert R, Wilms J (2013) No anticorrelation between cyclotron line energy and X-ray flux in 4U 0115+634. A&A 551:A6. doi:10.1051/0004-6361/201220359. arXiv:1211.6298

Mushtukov AA, Suleimanov VF, Tsygankov SS, Poutanen J (2015) The critical accretion luminosity for magnetized neutron stars. Mon Not RAS 447:1847–1856. doi:10.1093/mnras/stu2484. arXiv:1409.6457

Nagase F, Hayakawa S, Sato N, Masai K, Inoue H (1986) Circumstellar matter in the VELA X-1/HD 77581 system. Publ ASJ 38:547–569

Nagase F, Corbet RHD, Day CSR, Inoue H, Takeshima T, Yoshida K, Mihara T (1992) GINGA observations of Centaurus X-3. Astrophys J 396:147–160. doi:10.1086/171705

Nagel W (1981) Radiative transfer in a strongly magnetized plasma—part two—effects of Comptonization. Astrophys J 251:288. doi:10.1086/159464

Nakajima H, Imanishi K, Takagi SI, Koyama K, Tsujimoto M (2003) X-ray observation on the Monoceros R2 star-forming region with the Chandra ACIS-I array. Publ ASJ 55:635–651. doi:10.1093/pasj/55.3.635. arXiv:astro-ph/0305323

Nakajima M, Mihara T, Makishima K, Niko H (2006) A further study of the luminosity-dependent cyclotron resonance energies of the binary X-ray pulsar 4U 0115+63 with the Rossi X-ray timing explorer. Astrophys J 646:1125–1138. doi:10.1086/502638. arXiv:astro-ph/0601491

Nazé Y, Flores CA, Rauw G (2012) A detailed X-ray investigation of ζ puppis. I. The dataset and some preliminary results. A&A 538:A22. doi:10.1051/0004-6361/201117387. arXiv:1112.0862

Negueruela I (2010) Stellar wind accretion in high-mass X-ray binaries. In: Martí J, Luque-Escamilla PL, Combi JA (eds) High energy phenomena in massive stars. Astronomical Society of the Pacific conference series, vol 422, p 57. arXiv:0907.2883

Negueruela I, Okazaki AT (2001) The Be/X-ray transient 4U 0115+63/V635 Cassiopeiae. I. A consistent model. A&A 369:108–116. doi:10.1051/0004-6361:20010146. arXiv:astro-ph/0011407

Negueruela I, Schurch MPE (2007) A search for counterparts to massive X-ray binaries using photometric catalogues. A&A 461:631–639. doi:10.1051/0004-6361:20066054. arXiv:astro-ph/0610006

Negueruela I, Roche P, Fabregat J, Coe MJ (1999) The Be/X-ray transient V0332+53: evidence for a tilt between the orbit and the equatorial plane? Mon Not RAS 307:695–702. doi:10.1046/j.1365-8711.1999.02682.x. arXiv:astro-ph/9903228

Negueruela I, Israel GL, Marco A, Norton AJ, Speziali R (2003) The Be/X-ray transient KS 1947+300. A&A 397:739–745. doi:10.1051/0004-6361:20021529. arXiv:astro-ph/0210465

Negueruela I, Smith DM, Chaty S (2005) Optical counterpart to IGR J16465-4507. Astron Telegr 429:1

Negueruela I, Smith DM, Harrison TE, Torrejón JM (2006a) The optical counterpart to the peculiar X-ray transient XTE J1739-302. Astrophys J 638:982–986. doi:10.1086/498935. arXiv:astro-ph/0510675

Negueruela I, Smith DM, Reig P, Chaty S, Torrejón JM (2006b) Supergiant fast X-ray transients: a new class of high mass X-ray binaries unveiled by INTEGRAL. In: Wilson A (ed) The X-ray Universe 2005, ESA Special Publication, vol 604, pp 165–170

Negueruela I, Smith DM, Torrejon JM, Reig P (2007a) Supergiant fast X-ray transients: a common behaviour or a class of objects? arXiv:astro-ph/0704.3224 (e-prints)

Negueruela I, Torrejón JM, McBride V (2007b) The correct optical counterpart to IGR J11435-6109. Astron Telegr 1239:1

Negueruela I, Casares J, Verrecchia F, Blay P, Israel GL, Covino S (2008a) XTE J1855-026 is a supergiant X-ray binary. Astron Telegr 1876:1

Negueruela I, Torrejón JM, Reig P, Ribó M, Smith DM (2008b) Supergiant fast X-ray transients and other wind accretors. In: Bandyopadhyay RM, Wachter S, Gelino D, Gelino CR (eds) A population explosion: the nature and evolution of X-ray binaries in diverse environments. American Institute of Physics conference series, vol 1010, pp 252–256. doi:10.1063/1.2945052. arXiv:0801.3863

Negueruela I, Ribó M, Herrero A, Lorenzo J, Khangulyan D, Aharonian FA (2011) Astrophysical parameters of LS 2883 and implications for the PSR B1259-63 gamma-ray binary. Astrophys J Lett 732:L11. doi:10.1088/2041-8205/732/1/L11. arXiv:1103.4636

Nespoli E, Reig P (2011) Discovery of a quasi-periodic oscillation in the X-ray pulsar 1A 1118-615: correlated spectral and aperiodic variability. A&A 526:A7. doi:10.1051/0004-6361/201015303. arXiv:1011.0564

Nespoli E, Fabregat J, Mennickent RE (2008) Unveiling the nature of six HMXBs through IR spectroscopy. A&A 486:911–917. doi:10.1051/0004-6361:200809645. arXiv:0806.0295

Nespoli E, Fabregat J, Mennickent RE (2010a) K-band spectroscopy of IGR J16358-4726 and IGR J16393-4643: two new symbiotic X-ray binaries. A&A 516:A94. doi:10.1051/0004-6361/200913410. arXiv:0910.0990

Nespoli E, Fabregat J, Mennickent RE (2010b) Unveiling the nature of IGR J16493-4348 with IR spectroscopy. A&A 516:A106. doi:10.1051/0004-6361/201014348. arXiv:1004.4101

Nichelli E, Israel GL, Moretti A, Campana S, Göz D, Stella L (2011) Swift discovery of 328s coherent pulsations from the HMXB IGR J17200-3116. Astron Telegr 3205:1

Nishimura O (2008) Formation mechanism for broad and shallow profiles of cyclotron lines in accreting X-ray pulsars. Astrophys J 672:1127–1136. doi:10.1086/523782

Nishimura O (2014) Variations of cyclotron line energy with luminosity in accreting X-ray pulsars. Astrophys J 781:30. doi:10.1088/0004-637X/781/1/30

Okazaki AT, Negueruela I (2001) A natural explanation for periodic X-ray outbursts in Be/X-ray binaries. A&A 377:161–174. doi:10.1051/0004-6361:20011083. arXiv:astro-ph/0108037

Orlandini M, Fiume DD, Frontera F, del Sordo S, Piraino S, Santangelo A, Segreto A, Oosterbroek T, Parmar AN (1998) BEPPOSAX observation of 4U 1626-67: discovery of an absorption cyclotron resonance feature. Astrophys J Lett 500:L163. doi:10.1086/311404. arXiv:astro-ph/9804241

Orlandini M, dal Fiume D, del Sordo S, Frontera F, Parmar AN, Santangelo A, Segreto A (1999) The broadband spectrum of OAO1657-415 with it BeppoSAX: in search of cyclotron lines. A&A 349:L9–L12 arXiv:astro-ph/9908094

Oskinova LM, Feldmeier A, Hamann W-R (2006) High-resolution X-ray spectroscopy of bright O-type stars. Mon Not R Astron Soc 372(1):313–326

Oskinova LM, Todt H, Ignace R, Brown JC, Cassinelli JP, Hamann WR (2011) Early magnetic B-type stars: X-ray emission and wind properties. Mon Not RAS 416:1456–1474. doi:10.1111/j.1365-2966.2011.19143.x. arXiv:1106.0508

Oskinova L, Hamann WR, Todt H, Sander A (2012) Macroclumping, magnetic fields, and X-rays in massive stars. In: Drissen L, Rubert C, St-Louis N, Moffat AFJ (eds) Proceedings of a scientific meeting in honor of Anthony F. J. Moffat, Astronomical Society of the Pacific conference series, vol 465, p 172

Owocki SP, Castor JI, Rybicki GB (1988) Time-dependent models of radiatively driven stellar winds. I—Nonlinear evolution of instabilities for a pure absorption model. Astrophys J 335:914–930. doi:10.1086/166977

Paizis A, Sidoli L (2014) Cumulative luminosity distributions of supergiant fast X-ray transients in hard X-rays. Mon Not RAS 439:3439–3452. doi:10.1093/mnras/stu191. arXiv:1401.6861

Pakull MW, Motch C, Negueruela I (2003) Be star counterpart of X-ray pulsar MX0656-072. Astron Telegr 202:1

Parkes GE, Murdin PG, Mason KO (1980) The shell spectrum of the optical counterpart of GX 304-1 /4U 1258-61/. Mon Not RAS 190:537–542

Parmar AN, Stella L, Ferri P, White NE (1985) EXO 2030+375. IAU Circ 4066:1

Pavan L, Bozzo E, Ferrigno C, Ricci C, Manousakis A, Walter R, Stella L (2011) AX J1910.7+0917 and three newly discovered INTEGRAL sources. A&A 526:A122. doi:10.1051/0004-6361/201015561. arXiv:1012.1164

Pavlinsky M, Sunyaev R, Churazov E, Vikhlinin A, Sazonov S, Revnivtsev M, Arefiev V, Lapshov I, Akimov V, Levin V, Buntov M, Semena N, Grigorovich S, Babyshkin V, Predehl P, Hasinger G, Böhringer H, Schmitt J, Santangelo A, Schwope A, Wilms J (2009) Spectrum-RG astrophysical project. In: Society of photo-optical instrumentation engineers (SPIE) conference series, vol 7437. doi:10.1117/12.837361

Pearlman AB, Corbet RHD, Pottschmidt K, Skinner GK (2011) The orbital parameters and nature of the X-ray pulsar IGR J16393-4643 using pulse timing analysis. In: AAS/High Energy Astrophysics Division, vol 12, p #42.06

Pearlman AB, Corbet R, Pottschmidt K (2013) Superorbital modulation and orbital parameters of the eclipsing high-mass X-ray pulsar IGR J16493-4348. In: American Astronomical Society meeting abstracts, vol 221, p #142.38

Pellizza LJ, Chaty S, Negueruela I (2006) IGR J17544-2619: a new supergiant fast X-ray transient revealed by optical/infrared observations. A&A 455:653–658. doi:10.1051/0004-6361:20054436. arXiv:astro-ph/0605559

Pence WD, Snowden SL, Mukai K, Kuntz KD (2001) Chandra X-ray sources in M101. Astrophys J 561:189–202. doi:10.1086/323240. arXiv:astro-ph/0107133

Petterson JA (1978) Twisted accretion disks. III—The time-dependent equations. Astrophys J 226:253–263. doi:10.1086/156604

Pfahl E, Rappaport S, Podsiadlowski P, Spruit H (2002) A new class of high-mass X-ray binaries: implications for core collapse and neutron star recoil. Astrophys J 574:364–376. doi:10.1086/340794. arXiv:astro-ph/0109521

Porter JM, Rivinius T (2003) Classical Be stars. PASP 115:1153–1170. doi:10.1086/378307

Postnov KA (2003) The universal luminosity function of binary X-ray sources in galaxies. Astron Lett 29:372–373. doi:10.1134/1.1579783. arXiv:astro-ph/0212568

Postnov KA, Mironov AI, Lutovinov AA, Shakura NI, Kochetkova AY, Tsygankov SS (2015) Spin-up/spin-down of neutron star in Be-X-ray binary system GX 304-1. Mon Not RAS 446:1013–1019. doi:10.1093/mnras/stu2155. arXiv:1410.3708

Pottschmidt K, Kreykenbohm I, Wilms J, Coburn W, Rothschild RE, Kretschmar P, McBride V, Suchy S, Staubert R (2005) RXTE discovery of multiple cyclotron lines during the 2004 December outburst of V0332+53. Astrophys J Lett 634:L97–L100. doi:10.1086/498689. arXiv:astro-ph/0511288

Poutanen J, Mushtukov AA, Suleimanov VF, Tsygankov SS, Nagirner DI, Doroshenko V, Lutovinov AA (2013) A reflection model for the cyclotron lines in the spectra of X-ray pulsars. Astrophys J 777:115. doi:10.1088/0004-637X/777/2/115. arXiv:1304.2633

Prat L, Rodriguez J, Hannikainen DC, Shaw SE (2008) Peering through the stellar wind of IGR J19140+0951 with simultaneous INTEGRAL/RXTE observations. Mon Not RAS 389:301–310. doi:10.1111/j.1365-2966.2008.13558.x. arXiv:0806.1973

Priedhorsky WC, Terrell J (1983) Long-term X-ray observations of CEN X-3, GX 301-2 (4U 1223-62), GX 304-1 (4U 1258–61) and 4U 1145-61. Astrophys J 273:709–715. doi:10.1086/161406

Prinja RK, Howarth ID (1986) Narrow absorption components and variability in ultraviolet P Cygni profiles of early-type stars. Astrophys J Suppl Ser 61:357–418. doi:10.1086/191117

Produit N, Ballet J, Mowlavi N (2004) New gamma-ray transient, IGR J11305-6256 discovered by INTEGRAL. Astron Telegr 278:1

Puls J, Vink JS, Najarro F (2008) Mass loss from hot massive stars. A&A Rev 16:209–325. doi:10.1007/s00159-008-0015-8. arXiv:0811.0487

Quaintrell H, Norton AJ, Ash TDC, Roche P, Willems B, Bedding TR, Baldry IK, Fender RP (2003) The mass of the neutron star in Vela X-1 and tidally induced non-radial oscillations in GP Vel. A&A 401:313–323. doi:10.1051/0004-6361:20030120. arXiv:astro-ph/0301243

Rahoui F, Chaty S, Lagage P, Pantin E (2008) Multi-wavelength observations of Galactic hard X-ray sources discovered by INTEGRAL. II. The environment of the companion star. A&A 484:801–813. doi:10.1051/0004-6361:20078774. arXiv:0802.1770

Rampy RA, Smith DM, Negueruela I (2009) IGR J17544-2619 in depth with Suzaku: direct evidence for clumpy winds in a supergiant fast X-ray transient. Astrophys J 707:243–249. doi:10.1088/0004-637X/707/1/243. arXiv:0904.1189

Ranalli P, Comastri A, Setti G (2003) The 2–10 keV luminosity as a star formation rate indicator. A&A 399:39–50. doi:10.1051/0004-6361:20021600. arXiv:astro-ph/0211304

Rappaport S, Clark GW, Cominsky L, Li F, Joss PC (1978) Orbital elements of 4U 0115+63 and the nature of the hard X-ray transients. Astrophys J Lett 224:L1–L4. doi:10.1086/182745

Ray PS, Chakrabarty D (2002) The orbit of the high-mass X-ray binary pulsar 1E 1145.1-6141. Astrophys J 581:1293–1296. doi:10.1086/344300. arXiv:astro-ph/0208367

Reig P (2011) Be/X-ray binaries. Ap&SS 332:1–29. doi:10.1007/s10509-010-0575-8. arXiv:1101.5036

Reig P, Coe MJ (1999) X-ray spectral properties of the pulsar EXO 2030+375 during an outburst. Mon Not RAS 302:700–706. doi:10.1046/j.1365-8711.1999.02179.x

Reig P, Roche P (1999) Discovery of two new persistent Be/X-ray pulsar systems. Mon Not RAS 306:100–106. doi:10.1046/j.1365-8711.1999.02473.x. arXiv:astro-ph/9902221

Reig P, Zezas A (2009) The spectral type of the optical counterpart to the high-mass X-ray binary IGR J06074+2205. Astron Telegr 2085:1

Reig P, Zezas A (2014a) Disc-loss episode in the Be shell optical counterpart to the high-mass X-ray binary IGR J21343+4738. A&A 561:A137. doi:10.1051/0004-6361/201321408. arXiv:1311.3093

Reig P, Zezas A (2014b) Discovery of X-ray pulsations in the Be/X-ray binary IGR J21343+4738. Mon Not RAS 442:472–478. doi:10.1093/mnras/stu898. arXiv:1405.1154

Reig P, Chakrabarty D, Coe MJ, Fabregat J, Negueruela I, Prince TA, Roche P, Steele IA (1996) Astrophysical parameters of the massive X-ray binary 2S 0114+650. A&A 311:879–888

Reig P, Negueruela I, Fabregat J, Chato R, Coe MJ (2005a) Long-term optical/IR variability of the Be/X-ray binary LS V +44 17 RX J0440.9+4431. A&A 440:1079–1086. doi:10.1051/0004-6361:20053124. arXiv:astro-ph/0506230

Reig P, Negueruela I, Papamastorakis G, Manousakis A, Kougentakis T (2005b) Identification of the optical counterparts of high-mass X-ray binaries through optical photometry and spectroscopy. A&A 440:637–646. doi:10.1051/0004-6361:20052684. arXiv:astro-ph/0505319

Reig P, Torrejón JM, Negueruela I, Blay P, Ribó M, Wilms J (2009) Discovery of slow X-ray pulsations in the high-mass X-ray binary 4U 2206+54. A&A 494:1073–1082. doi:10.1051/0004-6361:200810950. arXiv:0812.2365

Reig P, Zezas A, Gkouvelis L (2010) The optical counterpart to IGR J06074+2205: a Be/X-ray binary showing disc loss and V/R variability. A&A 522:A107. doi:10.1051/0004-6361/201014788. arXiv:1006.4935

Remillard R, Levine A, Takeshima T, Corbet RHD, Marshall FE, Swank JH, Chakrabarty D (1998) XTE J1858+034. IAU Circ 6826:2

Revnivtsev MG (2003) RXTE Observations of the Strongly Absorbed Sources IGR J16318–4848 and IGR J16358–4726. Astronomy Letters 29:644–648. doi:10.1134/1.1615332. arXiv:astro-ph/0304353

Revnivtsev MG, Sazonov SY, Gilfanov MR, Sunyaev RA (2003) IGR J16318-4848: an X-ray source in a dense envelope? Astron Lett 29:587–593. doi:10.1134/1.1607496. arXiv:astro-ph/0303274

Revnivtsev MG, Sunyaev RA, Varshalovich DA, Zheleznyakov VV, Cherepashchuk AM, Lutovinov AA, Churazov EM, Grebenev SA, Gilfanov MR (2004) A hard X-ray survey of the galactic-center region with the IBIS telescope of the INTEGRAL observatory: a catalog of sources. Astron Lett 30:382–389. doi:10.1134/1.1764884. arXiv:astro-ph/0402027

Revnivtsev M, Molkov S, Grebenev S (2005) New outburst of accreting X-ray pulsar IGR J11435-6109. Astron Telegr 531:1

Reynolds AP, Bell SA, Hilditch RW (1992) Optical spectroscopy of the massive X-ray binary QV Nor (4U 1538-52). Mon Not RAS 256:631–640

Rivers E, Markowitz A, Pottschmidt K, Roth S, Barragán L, Fürst F, Suchy S, Kreykenbohm I, Wilms J, Rothschild R (2010) A comprehensive spectral analysis of the X-ray pulsar 4U 1907+09 from two observations with the Suzaku X-ray observatory. Astrophys J 709:179–190. doi:10.1088/0004-637X/709/1/179. arXiv:0912.3023

Robba NR, Cusumano G, Orlandini M, dal Fiume D, Frontera F (1992) EXOSAT observations of the X-ray binary pulsar 4U 1538-52. Astrophys J 401:685–694. doi:10.1086/172096

Robba NR, Burderi L, Di Salvo T, Iaria R, Cusumano G (2001) The BeppoSAX 0.1-100 keV spectrum of the X-ray pulsar 4U 1538-52. Astrophys J 562:950–956. doi:10.1086/323841. arXiv:astro-ph/0109031

Roberts MSE, Michelson PF, Leahy DA, Hall TA, Finley JP, Cominsky LR, Srinivasan R (2001) Phase-dependent spectral variability in 4U 1907+09. Astrophys J 555:967–977. doi:10.1086/321487

Roche P, Coe MJ, Fabregat J, McHardy IM, Norton AJ, Percy JR, Reglero V, Reynolds A, Unger SJ (1993) Recent phase changes in X Persei—optical, infrared and X-ray behaviour. A&A 270:122–138

Rodes-Roca JJ, Torrejón JM, Kreykenbohm I, Martínez Núñez S, Camero-Arranz A, Bernabéu G (2009) The first cyclotron harmonic of 4U 1538-52. A&A 508:395–400. doi:10.1051/0004-6361/200912815. arXiv:0910.4464

Rodes-Roca JJ, Page KL, Torrejón JM, Osborne JP, Bernabéu G (2011) Detecting emission lines with XMM-Newton in 4U 1538-52. A&A 526:A64. doi:10.1051/0004-6361/201014324. arXiv:1012.0769

Rodriguez J, Tomsick JA, Foschini L, Walter R, Goldwurm A, Corbel S, Kaaret P (2003) An XMM-Newton observation of IGR J16320-4751 = AX J1631.9-4752. A&A 407:L41–L45. doi:10.1051/0004-6361:20031093. arXiv:astro-ph/0304139

Rodriguez J, Garau AD, Grebenev S, Parmard A, Roques J, Schonfelder V, Ubertini P, Walter R, Westergaard N (2004) INTEGRAL discovery of a possible new source IGR J18410-0535. Astron Telegr 340:1

Rodriguez J, Bodaghee A, Kaaret P, Tomsick JA, Kuulkers E, Malaguti G, Petrucci PO, Cabanac C, Chernyakova M, Corbel S, Deluit S, Di Cocco G, Ebisawa K, Goldwurm A, Henri G, Lebrun F, Paizis A, Walter R, Foschini L (2006) INTEGRAL and XMM-Newton observations of the X-ray pulsar IGR J16320-4751/AX J1631.9-4752. Mon Not RAS 366:274–282. doi:10.1111/j.1365-2966.2005.09855.x. arXiv:astro-ph/0511429

Rodriguez J, Tuerler M, Chaty S, Tomsick JA (2009) Swift archival observations of the field around the new INTEGRAL source IGR J19294+1816. Astron Telegr 1998:1

Rodriguez J, Tomsick JA, Bodaghee A (2010) Swift follow-up observations of 13 INTEGRAL sources. A&A 517:A14. doi:10.1051/0004-6361/200913967. arXiv:1003.3741

Romano P, Mereghetti S, Sidoli L, Evans PA (2008a) Swift/XRT localisation of XTE J1855-026. Astron Telegr 1875:1

Romano P, Sidoli L, Mangano V, Kennea JA, Burrows DN, Krimm H, Gehrels N, Vercellone S, Cusumano G, Paizis A (2008b) Swift catches a new outburst from the supergiant fast X-ray transient IGRJ16479-4514. Astron Telegr 1435:1

Romano P, Sidoli L, Mangano V, Vercellone S, Kennea JA, Cusumano G, Krimm HA, Burrows DN, Gehrels N (2008c) Monitoring supergiant fast X-ray transients with Swift. II. Rise to the outburst in IGR J16479-4514. Astrophys J Lett 680:L137–L140. doi:10.1086/590082. arXiv:0805.2089

Romano P, Barthelmy S, Margutti R, Guidorzi C, Sidoli L, Kennea JA, La Parola V, Burrows DN, Esposito P, Evans PA, Krimm HA, Gehrels N, Vercellone S (2009a) Swift observations of an outburst of the SFXT AX J1845.0-0433/IGR J18450-0435. Astron Telegr 2102:1

Romano P, Sidoli L, Cusumano G, La Parola V, Vercellone S, Pagani C, Ducci L, Mangano V, Cummings J, Krimm HA, Guidorzi C, Kennea JA, Hoversten EA, Burrows DN, Gehrels N (2009b) Monitoring supergiant fast X-ray transients with Swift: results from the first year. Mon Not RAS 399:2021–2032. doi:10.1111/j.1365-2966.2009.15356.x. arXiv:0907.1289

Romano P, Sidoli L, Cusumano G, Vercellone S, Mangano V, Krimm HA (2009c) Disentangling the system geometry of the supergiant fast X-ray transient IGR J11215-5952 with Swift. Astrophys J 696:2068–2074. doi:10.1088/0004-637X/696/2/2068. arXiv:0902.1985

Romano P, Cusumano G, Baumgartner WH, Krimm HA, Sakamoto T, de Pasquale M, Barthelmy SD, Burrows DN, Chester MM, Kennea JA, Evans PA, Esposito P, Gehrels N, Palmer DM, La Parola

V, Vercellone S (2010a) Analysis of Swift data of the June 5 outburst of the SFXT IGR J18410-0535/AX1841.0-0536. Astron Telegr 2662:1

Romano P, Sidoli L, Ducci L, Cusumano G, La Parola V, Pagani C, Page KL, Kennea JA, Burrows DN, Gehrels N, Sguera V, Bazzano A (2010b) Swift/XRT monitoring of the supergiant fast X-ray transient IGR J18483-0311 for an entire orbital period. Mon Not RAS 401:1564–1569. doi:10.1111/j.1365-2966.2009.15789.x. arXiv:0909.5109

Romano P, Sidoli L, Ducci L, Cusumano G, La Parola V, Pagani C, Page KL, Kennea JA, Burrows DN, Gehrels N, Sguera V, Bazzano A (2010c) Swift/XRT monitoring of the supergiant fast X-ray transient IGR J18483-0311 for an entire orbital period. Mon Not RAS 401:1564–1569. doi:10.1111/j.1365-2966.2009.15789.x. arXiv:0909.5109

Romano P, La Parola V, Vercellone S, Cusumano G, Sidoli L, Krimm HA, Pagani C, Esposito P, Hoversten EA, Kennea JA, Page KL, Burrows DN, Gehrels N (2011a) Two years of monitoring supergiant fast X-ray transients with Swift. Mon Not RAS 410:1825–1836. doi:10.1111/j.1365-2966.2010.17564.x. arXiv:1009.1146

Romano P, Mangano V, Cusumano G, Esposito P, Evans PA, Kennea JA, Vercellone S, La Parola V, Krimm HA, Burrows DN, Gehrels N (2011b) Confirmation of the supergiant fast X-ray transient nature of AX J1841.0-0536 from Swift outburst observations. Mon Not RAS 412:L30–L34. doi:10.1111/j.1745-3933.2010.00999.x. arXiv:1012.0028

Romano P, Mangano V, Esposito P, Kennea JA, Evans PA, Vercellone S, Burrows DN, Chester MM, Cusumano G, Farinelli R, Krimm H, La Parola V (2011c) Swift observations of a flare in IGR J16418-4532. Astron Telegr 3174:1

Romano P, Barthelmy SD, Chester MM, Oates SR, Burrows DN, Esposito P, Evans PA, Kennea JA, Krimm HA, Mangano V, Vercellone S, Gehrels N (2012a) Swift observes a new outburst from the supergiant fast X-ray transient AX J1845.0-0433. Astron Telegr 4095:1

Romano P, Barthelmy SD, Kennea JA, Esposito P, Evans PA, Mangano V, Palmer DM, Burrows DN, Chester MM, Krimm H, Ukwatta TN, Vercellone S, Gehrels N (2012b) Swift observes a new outburst from the supergiant fast X-ray transient AX J1841.0-0536. Astron Telegr 4176:1

Romano P, Barthelmy SD, Kennea JA, Esposito P, Evans PA, Mangano V, Palmer DM, Sakamoto T, Burrows DN, Chester MM, Krimm H, Vercellone S, Gehrels N (2012c) Swift detection of IGR16418-4532. Astron Telegr 4148:1

Romano P, Mangano V, Ducci L, Esposito P, Evans PA, Vercellone S, Kennea JA, Burrows DN, Gehrels N (2012d) Swift/X-ray telescope monitoring of the candidate supergiant fast X-ray transient IGR J16418-4532. Mon Not RAS 419:2695–2702. doi:10.1111/j.1365-2966.2011.19916.x. arXiv:1109.6165

Romano P, Mangano V, Ducci L, Esposito P, Vercellone S, Bocchino F, Burrows DN, Kennea JA, Krimm HA, Gehrels N, Farinelli R, Ceccobello C (2013) The Swift supergiant fast X-ray transients project: a review, new results and future perspectives. Adv Space Res 52:1593–1601. doi:10.1016/j.asr.2013.07.034. arXiv:1307.6969

Romano P, Ducci L, Mangano V, Esposito P, Bozzo E, Vercellone S (2014a) Soft X-ray characterisation of the long-term properties of supergiant fast X-ray transients. A&A 568:A55. doi:10.1051/0004-6361/201423867. arXiv:1406.6068

Romano P, Krimm HA, Palmer DM, Ducci L, Esposito P, Vercellone S, Evans PA, Guidorzi C, Mangano V, Kennea JA, Barthelmy SD, Burrows DN, Gehrels N (2014b) The 100-month Swift catalogue of supergiant fast X-ray transients. I. BAT on-board and transient monitor flares. A&A 562:A2. doi:10.1051/0004-6361/201322516. arXiv:1312.4955

Romano P, Bozzo E, Mangano V, Esposito P, Israel G, Tiengo A, Campana S, Ducci L, Ferrigno C, Kennea JA (2015) Giant outburst from the supergiant fast X-ray transient IGR J17544-2619: accretion from a transient disc? A&A 576:L4. doi:10.1051/0004-6361/201525749. arXiv:1502.04717

Romanova MM, Toropina OD, Toropin YM, Lovelace RVE (2003) Magnetohydrodynamic simulations of accretion onto a star in the ‘Propeller’ regime. Astrophys J 588:400–407. doi:10.1086/373990. arXiv:astro-ph/0209548

Rosenberg FD, Eyles CJ, Skinner GK, Willmore AP (1975) Observations of a transient X-ray source with a period of 104 S. Nature 256:628–630. doi:10.1038/256628a0

Rubin BC, Finger MH, Scott DM, Wilson RB (1997) Observation of a long-term spin-up trend in 4U 1538-52. Astrophys J 488:413. doi:10.1086/304679

Runacres MC, Owocki SP (2005) A pseudo-planar, periodic-box formalism for modelling the outer evolution of structure in spherically expanding stellar winds. A&A 429:323–333. doi:10.1051/0004-6361:20041281. arXiv:astro-ph/0405315

Şahiner Ş, Inam SÇ, Baykal A (2012) A comprehensive study of RXTE and INTEGRAL observations of the X-ray pulsar 4U 1907+09. Mon Not RAS 421:2079–2087. doi:10.1111/j.1365-2966.2012.20455.x. arXiv:1106.5957

Sakano M, Koyama K, Murakami H, Maeda Y, Yamauchi S (2002) ASCA X-ray source catalog in the galactic center region. Astrophys J Suppl 138:19–34. doi:10.1086/324020. arXiv:astro-ph/0108376

Sako M, Kahn SM, Paerels F, Liedahl DA, Watanabe S, Nagase F, Takahashi T (2003) Structure and dynamics of stellar winds in high-mass X-ray binaries. In: Invited review at the high-resolution X-ray spectroscopy workshop with XMM-Newton and Chandra, MSSL, Oct 24–25, 2002. arXiv:astro-ph/0309503 (e-prints)

Sana H, de Mink SE, de Koter A, Langer N, Evans CJ, Gieles M, Gosset E, Izzard RG, Le Bouquin JB, Schneider FRN (2012) Binary interaction dominates the evolution of massive stars. Science 337:444. doi:10.1126/science.1223344. arXiv:1207.6397

Santangelo A, del Sordo S, Segreto A, dal Fiume D, Orlandini M, Piraino S (1998) BeppoSAX detection of a cyclotron feature in the spectrum of Cen X-3. A&A 340:L55–L59

Santangelo A, Segreto A, Giarrusso S, dal Fiume D, Orlandini M, Parmar AN, Oosterbroek T, Bulik T, Mihara T, Campana S, Israel GL, Stella L (1999) A BEPPOSAX study of the pulsating transient X0115+63: the first X-ray spectrum with four cyclotron harmonic features. Astrophys J Lett 523:L85–L88. doi:10.1086/312249

Sato N, Nagase F, Kawai N, Kelley RL, Rappaport S, White NE (1986) Orbital elements of the binary X-ray pulsar GX 301-2. Astrophys J 304:241–248. doi:10.1086/164157

Schönherr G, Wilms J, Kretschmar P, Kreykenbohm I, Santangelo A, Rothschild RE, Coburn W, Staubert R (2007) A model for cyclotron resonance scattering features. A&A 472:353–365. doi:10.1051/0004-6361:20077218. arXiv:0707.2105

Scott DM, Finger MH, Wilson RB, Koh DT, Prince TA, Vaughan BA, Chakrabarty D (1997) Discovery and orbital determination of the transient X-ray pulsar GRO J1750-27. Astrophys J 488:831. doi:10.1086/304740

Segreto A, La Parola V, Cusumano G, D'Aì A, Masetti N, Campana S (2013) The 54-day orbital period of AX J1820.5-1434 unveiled by Swift. A&A 558:A99. doi:10.1051/0004-6361/201321892. arXiv:1305.3614

Seward FD, Page CG, Turner MJL, Pounds KA (1976) X-ray sources in the Aquila–Serpens–Scutum region. Mon Not RAS 175:39P–46P

Sguera V, Barlow EJ, Bird AJ, Clark DJ, Dean AJ, Hill AB, Moran L, Shaw SE, Willis DR, Bazzano A, Ubertini P, Malizia A (2005) INTEGRAL observations of recurrent fast X-ray transient sources. A&A 444:221–231. doi:10.1051/0004-6361:20053103. arXiv:astro-ph/0509018

Sguera V, Bazzano A, Bird AJ, Dean AJ, Ubertini P, Barlow EJ, Bassani L, Clark DJ, Hill AB, Malizia A, Molina M, Stephen JB (2006) Unveiling supergiant fast X-ray transient sources with INTEGRAL. Astrophys J 646:452–463. doi:10.1086/504827. arXiv:astro-ph/0603756

Sguera V, Hill AB, Bird AJ, Dean AJ, Bazzano A, Ubertini P, Masetti N, Landi R, Malizia A, Clark DJ, Molina M (2007) IGR J18483-0311: an accreting X-ray pulsar observed by INTEGRAL. A&A 467:249–257. doi:10.1051/0004-6361:20066762. arXiv:astro-ph/0702477

Sguera V, Bassani L, Landi R, Bazzano A, Bird AJ, Dean AJ, Malizia A, Masetti N, Ubertini P (2008) INTEGRAL and Swift/XRT observations of the SFXT IGR J16479-4514: from quiescence to fast flaring activity. A&A 487:619–623. doi:10.1051/0004-6361:20079195. arXiv:0805.0496

Sguera V, Romero GE, Bazzano A, Masetti N, Bird AJ, Bassani L (2009) Dissecting the region of 3EG J1837-0423 and HESS J1841-055 with INTEGRAL. Astrophys J 697:1194–1205. doi:10.1088/0004-637X/697/2/1194. arXiv:0903.1763

Sguera V, Ducci L, Sidoli L, Bazzano A, Bassani L (2010) XMM-Newton and INTEGRAL study of the SFXT IGR J18483-0311 in quiescence: hint of a cyclotron emission feature? Mon Not RAS 402:L49–L53. doi:10.1111/j.1745-3933.2009.00798.x. arXiv:0912.1730

Sguera V, Drave SP, Bird AJ, Bazzano A, Landi R, Ubertini P (2011) IGR J17354-3255 as a candidate intermediate supergiant fast X-ray transient possibly associated with the transient MeV AGL J1734-3310. Mon Not RAS 417:573–579. doi:10.1111/j.1365-2966.2011.19298.x. arXiv:1106.4209

Sguera V, Drave SP, Sidoli L, Masetti N, Landi R, Bird AJ, Bazzano A (2013) X-ray, optical, and infrared investigation of the candidate supergiant fast X-ray transient IGR J18462-0223. A&A 556:A27. doi:10.1051/0004-6361/201220785. arXiv:1305.1538

Shakura N, Postnov K, Kochetkova A, Hjalmarsdotter L (2012) Theory of quasi-spherical accretion in X-ray pulsars. Mon Not RAS 420:216–236. doi:10.1111/j.1365-2966.2011.20026.x. arXiv:1110.3701

Shakura N, Postnov K, Hjalmarsdotter L (2013) On the nature of ‘off’ states in slowly rotating low-luminosity X-ray pulsars. Mon Not RAS 428:670–677. doi:10.1093/mnras/sts062. arXiv:1209.4962

Shakura N, Postnov K, Sidoli L, Paizis A (2014) Bright flares in supergiant fast X-ray transients. Mon Not RAS 442:2325–2330. doi:10.1093/mnras/stu1027. arXiv:1405.5707

Shaw SE, Hill AB, Kuulkers E, Brandt S, Chenevez J, Kretschmar P (2009) The accretion powered spin-up of GRO J1750-27. Mon Not RAS 393:419–428. doi:10.1111/j.1365-2966.2008.14212.x

Shrader CR, Sutaria FK, Singh KP, Macomb DJ (1999) High-energy spectral and temporal characteristics of GRO J1008-57. Astrophys J 512:920–928. doi:10.1086/306785

Shtykovskiy P, Gilfanov M (2005a) High mass X-ray binaries in the LMC: Dependence on the stellar population age and the ‘propeller’ effect. A&A 431:597–614. doi:10.1051/0004-6361:20041074. arXiv:astro-ph/0404300

Shtykovskiy P, Gilfanov M (2005b) High-mass X-ray binaries in the small magellanic cloud: the luminosity function. Mon Not RAS 362:879–890. doi:10.1111/j.1365-2966.2005.09320.x. arXiv:astro-ph/0503477

Shtykovskiy PE, Gilfanov MR (2007) High-mass X-ray binaries and the spiral structure of the host galaxy. Astron Lett 33:299–308. doi:10.1134/S1063773707050039. arXiv:0710.3504

Sidoli L (2010) New galactic high mass X-ray binaries discovered with INTEGRAL. arXiv:1010.2070 (e-prints)

Sidoli L, Mereghetti S, Larsson S, Chernyakova M, Kreykenbohm I, Kretschmar P, Paizis A, Santangelo A, Ferrigno C, Falanga M (2005a) A large spin-up rate measured with INTEGRAL in the high mass X-ray binary pulsar SAX J2103.5+4545. A&A 440:1033–1039. doi:10.1051/0004-6361:20052961. arXiv:astro-ph/0505532

Sidoli L, Vercellone S, Mereghetti S, Tavani M (2005b) The soft X-ray counterpart of the newly discovered INTEGRAL source IGR J16195-4945. A&A 429:L47–L50. doi:10.1051/0004-6361:200400114. arXiv:astro-ph/0411610

Sidoli L, Romano P, Mereghetti S, Paizis A, Vercellone S, Mangano V, Götz D (2007) An alternative hypothesis for the outburst mechanism in supergiant fast X-ray transients: the case of IGR J11215-5952. A&A 476:1307–1315. doi:10.1051/0004-6361:20078137. arXiv:0710.1175

Sidoli L, Romano P, Mangano V, Pellizzoni A, Kennea JA, Cusumano G, Vercellone S, Paizis A, Burrows DN, Gehrels N (2008) Monitoring supergiant fast X-ray transients with Swift. I. Behavior outside outbursts. Astrophys J 687:1230–1235. doi:10.1086/590077. arXiv:0805.1808

Sidoli L, Romano P, Ducci L, Paizis A, Cusumano G, Mangano V, Krimm HA, Vercellone S, Burrows DN, Kennea JA, Gehrels N (2009a) Supergiant fast X-ray transients in outburst: new Swift observations of XTE J1739-302, IGR J17544-2619 and IGR J08408-4503. Mon Not RAS 397:1528–1538. doi:10.1111/j.1365-2966.2009.15049.x. arXiv:0905.2815

Sidoli L, Romano P, Esposito P, Parola VL, Kennea JA, Krimm HA, Chester MM, Bazzano A, Burrows DN, Gehrels N (2009b) The first broad-band X-ray study of the supergiant fast X-ray transient SAX J1818.6-1703 in outburst. Mon Not RAS 400:258–262. doi:10.1111/j.1365-2966.2009.15445.x. arXiv:0907.4041

Sidoli L, Romano P, Mangano V, Cusumano G, Vercellone S, Kennea JA, Paizis A, Krimm HA, Burrows DN, Gehrels N (2009c) Monitoring supergiant fast X-ray transients with Swift. III. Outbursts of the prototypical supergiant fast X-ray transients IGR J17544-2619 and XTE J1739-302. Astrophys J 690:120–127. doi:10.1088/0004-637X/690/1/120. arXiv:0808.3085

Sidoli L, Esposito P, Ducci L (2010) The longest observation of a low-intensity state from a supergiant fast X-ray transient: Suzaku observes IGRJ08408-4503. Mon Not RAS 409(2):611–618. doi:10.1111/j.1365-2966.2010.17320.x. arXiv:1007.1091

Sidoli L, Mereghetti S, Sguera V, Pizzolato F (2012) The XMM-Newton view of supergiant fast X-ray transients: the case of IGR J16418-4532. Mon Not RAS 420:554–561. doi:10.1111/j.1365-2966.2011.20063.x. arXiv:1110.5218

Sidoli L, Esposito P, Sguera V, Bodaghee A, Tomsick JA, Pottschmidt K, Rodriguez J, Romano P, Wilms J (2013) A Suzaku X-ray observation of one orbit of the supergiant fast X-ray transient IGR J16479-4514. Mon Not RAS 429(3):2763–2771. doi:10.1093/mnras/sts559. arXiv:1212.0723

Smith DM (2004) Circumstantial evidence for a blue supergiant companion of IGR J16465-4507. Astron Telegr 338:1

Smith DA, Takeshima T (1998) XTE J1946+274 transient 15.8-s pulsar (= 3A 1942+274 ?). Astron Telegr 36:1

Smith D, Remillard R, Swank J, Takeshima T, Smith E (1998) XTE J0421+560. IAU Circ 6855. http://cdsads.u-strasbg.fr/cgi-bin/nph-bib_query?bibcode=1998IAUC.6855....1S&db_key=AST

Smith DM, Heindl WA, Markwardt CB, Swank JH, Negueruela I, Harrison TE, Huss L (2006) XTE J1739-302 as a supergiant fast X-ray transient. Astrophys J 638:974–981. doi:10.1086/498936. arXiv:astro-ph/0510658

Soffitta P, Tomsick JA, Harmon BA, Costa E, Ford EC, Tavani M, Zhang SN, Kaaret P (1998) Identification of the periodic hard X-ray transient GRO J1849-03 with the X-ray pulsar GS -1843-02 = X1845-024: a new Be/X-ray binary. Astrophys J Lett 494:L203. doi:10.1086/311189. arXiv:astro-ph/9712282

Soria R, Wu K (2003) Properties of discrete X-ray sources in the starburst spiral galaxy M 83. A&A 410:53–74. doi:10.1051/0004-6361:20031074. arXiv:astro-ph/0307217

Staubert R, Shakura NI, Postnov K, Wilms J, Rothschild RE, Coburn W, Rodina L, Klochkov D (2007) Discovery of a flux-related change of the cyclotron line energy in Hercules X-1. A&A 465:L25–L28. doi:10.1051/0004-6361:20077098. arXiv:astro-ph/0702490

Staubert R, Pottschmidt K, Doroshenko V, Wilms J, Suchy S, Rothschild R, Santangelo A (2011) Finding a 24-day orbital period for the X-ray binary 1A 1118-616. A&A 527:A7. doi:10.1051/0004-6361/201015737. arXiv:1012.2459

Steele IA, Negueruela I, Coe MJ, Roche P (1998) The distances to the X-ray binaries LSI +61 deg 303 and A0535+262. Mon Not RAS 297:L5. doi:10.1046/j.1365-8711.1998.01593.x. arXiv:astro-ph/9803113

Steiner C, Eckert D, Mowlavi N, Decourchelle A, Vink J (2005) IGR J01583+6713, a new hard X-ray transient discovered by INTEGRAL. Astron Telegr 672:1

Stella L, White NE, Davelaar J, Parmar AN, Blissett RJ, van der Klis M (1985) The discovery of 4.4 second X-ray pulsations from the rapidly variable X-ray transient V0332 + 53. Astrophys J Lett 288:L45–L49. doi:10.1086/184419

Stevens IR, Kallman TR (1990) X-ray illuminated stellar winds—ionization effects in the radiative driving of stellar winds in massive X-ray binary systems. Astrophys J 365:321–331. doi:10.1086/169486

Stevens JB, Reig P, Coe MJ, Buckley DAH, Fabregat J, Steele IA (1997) Multiwavelength observations of the Be/X-ray binary 4U1145-619. Mon Not RAS 288:988–994. arXiv:astro-ph/9706110

Stollberg MT, Finger MH, Wilson RB, Harmon BA, Rubin BC, Zhang NS, Fishman GJ (1993) GRO J1008-57. IAU Circ 5836:1

Stollberg MT, Finger MH, Wilson RB, Scott DM, Crary DJ, Paciesas WS (1999) BATSE observations and orbit determination of the BE/X-ray transient EXO 2030+375. Astrophys J 512:313–321. doi:10.1086/306733

Suchy S, Pottschmidt K, Wilms J, Kreykenbohm I, Schönherr G, Kretschmar P, McBride V, Caballero I, Rothschild RE, Grinberg V (2008) Pulse phase-resolved analysis of the high-mass X-ray binary Centaurus X-3 over two binary orbits. Astrophys J 675:1487–1498. doi:10.1086/527042. arXiv:0711.2752

Suchy S, Fürst F, Pottschmidt K, Caballero I, Kreykenbohm I, Wilms J, Markowitz A, Rothschild RE (2012) Broadband spectroscopy using two Suzaku observations of the HMXB GX 301-2. Astrophys J 745:124. doi:10.1088/0004-637X/745/2/124. arXiv:1111.2088

Sugizaki M, Mitsuda K, Kaneda H, Matsuzaki K, Yamauchi S, Koyama K (2001) Faint X-ray sources resolved in the ASCA galactic plane survey and their contribution to the galactic ridge X-ray emission. Astrophys J Suppl 134:77–102. doi:10.1086/320358. arXiv:astro-ph/0101093

Sundqvist JO, Owocki SP (2013) Clumping in the inner winds of hot, massive stars from hydrodynamical line-driven instability simulations. Mon Not RAS 428(2):1837–1844. doi:10.1093/mnras/sts165

Sundqvist JO, Owocki SP, Cohen DH, Leutenegger MA, Townsend RHD (2012) A generalized porosity formalism for isotropic and anisotropic effective opacity and its effects on X-ray line attenuation in clumped O star winds. Mon Not RAS 420:1553–1561. doi:10.1111/j.1365-2966.2011.20141.x. arXiv:1111.1762

Sunyaev R, Lutovinov A, Molkov S, Deluit S (2003a) Possible new source IGR J17391-3021 or an outburst from XTE J1739-302. Astron Telegr 181:1

Sunyaev RA, Grebenev SA, Lutovinov AA, Rodriguez J, Mereghetti S, Gotz D, Courvoisier T (2003b) New source IGR J17544-2619 discovered with INTEGRAL. Astron Telegr 190:1

Šurlan B, Hamann WR, Aret A, Kubát J, Oskinova LM, Torres AF (2013) Macroclumping as solution of the discrepancy between Hα and P v mass loss diagnostics for O-type stars. A&A 559:A130. doi:10.1051/0004-6361/201322390. arXiv:1310.0449

Swank J, Morgan E (2000) KS 1947+300 = GRO J1948+32. IAU Circ 7531:4

Swank JH, Markwardt CB (2004) IGR J11435-6109: faded, but variable—possibly ~66 s pulsations. Astron Telegr 359:1

Swank J, Remillard R, Smith E (2004) Transient pulsar V0332+53 in outburst. Astron Telegr 349:1

Swank JH, Smith DM, Markwardt CB (2007) RXTE PCA pointed observations of IGR J11215-5952. Astron Telegr 999:1

Swartz DA, Ghosh KK, McCollough ML, Pannuti TG, Tennant AF, Wu K (2003) Chandra X-ray observations of the spiral galaxy M81. Astrophys J Suppl 144:213–242. doi:10.1086/345084. arXiv:astro-ph/0206160

Taam RE, Sandquist EL (2000) Common envelope evolution of massive binary stars. Annu Rev A&A 38:113–141. doi:10.1146/annurev.astro.38.1.113

Taam RE, Bodenheimer P, Ostriker JP (1978) Double core evolution. I—A 16 solar mass star with a 1 solar mass neutron-star companion. Astrophys J 222:269–280. doi:10.1086/156142

Takeshima T, Corbet RHD, Marshall FE, Swank J, Chakrabarty D (1998) XTE J1858+034. IAU Circ 6826:1

Takeuchi Y, Koyama K, Warwick RS (1990) Further GINGA observations of the new X-ray pulsar X1722-36. Publ ASJ 42:287–293

Tamura K, Tsunemi H, Kitamoto S, Hayashida K, Nagase F (1992) The X-ray outburst from X0115 + 634 in 1990 February. Astrophys J 389:676–684. doi:10.1086/171240

Tapia M, Costero R, Echevarria J, Roth M (1991) Near-infrared and Stromgren photometry of the open clusters NGC 663, NGC 1502 and NGC 1893. Mon Not RAS 253:649–661

Tawara Y, Yamauchi S, Awaki H, Kii T, Koyama K, Nagase F (1989) Discovery of 413.9-second X-ray pulsation from X1722-36. Publ ASJ 41:473–481

Telting JH, Waters LBFM, Roche P, Boogert ACA, Clark JS, de Martino D, Persi P (1998) The equatorial disc of the Be star X Persei. Mon Not RAS 296:785–799. doi:10.1046/j.1365-8711.1998.01433.x

Tendulkar SP, Fürst F, Pottschmidt K, Bachetti M, Bhalerao VB, Boggs SE, Christensen FE, Craig WW, Hailey CA, Harrison FA, Stern D, Tomsick JA, Walton DJ, Zhang W (2014) NuSTAR discovery of a cyclotron line in the Be/X-ray binary RX J0520.5-6932 during outburst. arXiv:1409.5035 (e-prints)

Terrell J, Belian RD, Conner JP, Evans WD, Priedhorsky WC (1982) X-ray transients, 1969–1976 (the movie). In: Bulletin of the American Astronomical Society, vol 14, p 619

Thompson TWJ, Tomsick JA, Rothschild RE, in't Zand JJM, Walter R (2006) Orbital parameters for the X-ray pulsar IGR J16393-4643. Astrophys J 649:373–381. doi:10.1086/506251. arXiv:astro-ph/0605657

Tjemkes SA, van Paradijs J, Zuiderwijk EJ (1986) Optical light curves of massive X-ray binaries. A&A 154:77–91

Tomsick JA (2009) A Chandra X-ray localization, spectrum, and IR identification for IGR J17354-3255. Astron Telegr 2022:344–353

Tomsick JA, Lingenfelter R, Walter R, Rodriguez J, Goldwurm A, Corbel S, Kaaret P (2003) Igr J16320-4751. IAU Circ 8076:1

Tomsick JA, Lingenfelter R, Corbel S, Goldwurm A, Kaaret P (2004) Two new INTEGRAL sources: IGR J15479-4529 and IGR J16418-4532. Astron Telegr 224:1

Tomsick JA, Chaty S, Rodriguez J, Foschini L, Walter R, Kaaret P (2006a) Identifications of Four INTEGRAL sources in the galactic plane via Chandra localizations. Astrophys J 647:1309–1322. doi:10.1086/505595. arXiv:astro-ph/0603810

Tomsick JA, Chaty S, Rodriguez J, Walter R, Kaaret P (2006b) IGR J06074+2205 is a Be X-ray binary. Astron Telegr 959:1

Tomsick JA, Chaty S, Rodriguez J, Walter R, Kaaret P (2007) Chandra position and optical/IR identification for IGR J11435-6109. Astron Telegr 1231:1

Tomsick JA, Chaty S, Rodriguez J, Walter R, Kaaret P (2008) Chandra localizations and spectra of INTEGRAL sources in the galactic plane. Astrophys J 685:1143–1156. doi:10.1086/591040. arXiv:0807.2278

Tomsick JA, Chaty S, Rodriguez J, Walter R, Kaaret P (2009a) Chandra localizations and spectra of integral sources in the galactic plane: the cycle 9 sample. Astrophys J 701:811–823. doi:10.1088/0004-637X/701/1/811. arXiv:0906.2577

Tomsick JA, Chaty S, Rodriguez J, Walter R, Kaaret P, Tovmassian G (2009b) An XMM-Newton spectral and timing study of IGR J16207-5129: an obscured and non-pulsating HMXB. Astrophys J 694:344–353. doi:10.1088/0004-637X/694/1/344. arXiv:0812.2975

Tomsick JA, Heinke C, Halpern J, Kaaret P, Chaty S, Rodriguez J, Bodaghee A (2011) Confirmation of IGR J01363+6610 as a Be X-ray binary with very low quiescent X-ray luminosity. Astrophys J 728:86. doi:10.1088/0004-637X/728/2/86. arXiv:1012.2817

Torii K, Kinugasa K, Katayama K, Kohmura T, Tsunemi H, Sakano M, Nishiuchi M, Koyama K, Yamauchi S (1998) Discovery of a 220 second X-ray pulsar, AX J1749.2-2725. Astrophys J 508:854–858. doi:10.1086/306455

Toropin YM, Toropina OD, Savelyev VV, Romanova MM, Chechetkin VM, Lovelace RVE (1999) Spherical Bondi accretion onto a magnetic dipole. Astrophys J 517:906–918. doi:10.1086/307229. arXiv:astro-ph/9811272

Torrejón JM, Kreykenbohm I, Orr A, Titarchuk L, Negueruela I (2004) Evidence for a neutron star in the non-pulsating massive X-ray binary 4U2206+54. A&A 423:301–309. doi:10.1051/0004-6361:20035743. arXiv:astro-ph/0405182

Torrejón JM, Negueruela I, Smith DM, Harrison TE (2010) Near-infrared survey of high mass X-ray binary candidates. A&A 510:A61. doi:10.1051/0004-6361/200912619. arXiv:0910.5603

Trudolyubov SP, Borozdin KN, Priedhorsky WC (2001) Bright X-ray transients in the andromeda galaxy observed with Chandra and XMM-Newton. Astrophys J Lett 563:L119–L122. doi:10.1086/338592. arXiv:astro-ph/0108477

Truemper J, Pietsch W, Reppin C, Voges W, Staubert R, Kendziorra E (1978) Evidence for strong cyclotron line emission in the hard X-ray spectrum of Hercules X-1. Astrophys J Lett 219:L105–L110. doi:10.1086/182617

Tsunemi H, Kitamoto S, Tamura K (1996) Long-term behavior of Centaurus X-3 observed with the all sky monitor on board GINGA. Astrophys J 456:316. doi:10.1086/176652

Tsygankov SS, Lutovinov AA (2005a) Long-term INTEGRAL and RXTE observations of the X-ray pulsar LMC X-4. Astron Lett 31:380–387. doi:10.1134/1.1940110. arXiv:astro-ph/0504601

Tsygankov SS, Lutovinov AA (2005b) Observations of the transient X-ray pulsar KS 1947+300 by the INTEGRAL and RXTE observatories. Astron Lett 31:88–97. doi:10.1134/1.1862348. arXiv:astro-ph/0501080

Tsygankov SS, Lutovinov AA, Churazov EM, Sunyaev RA (2006) V0332+53 in the outburst of 2004–2005: luminosity dependence of the cyclotron line and pulse profile. Mon Not RAS 371:19–28. doi:10.1111/j.1365-2966.2006.10610.x. arXiv:astro-ph/0511237

Tsygankov SS, Lutovinov AA, Churazov EM, Sunyaev RA (2007) 4U 0115+63 from RXTE and INTEGRAL data: pulse profile and cyclotron line energy. Astron Lett 33:368–384. doi:10.1134/S1063773707060023. arXiv:0704.2874

Tsygankov SS, Lutovinov AA, Serber AV (2010) Completing the puzzle of the 2004–2005 outburst in V0332+53: the brightening phase included. Mon Not RAS 401:1628–1635. doi:10.1111/j.1365-2966.2009.15791.x. arXiv:0909.5379

Tsygankov S, Lutovinov A, Krivonos R (2011) New outburst from the X-ray pulsar RX J0440.9+4431 and discovery of a possible $\sim$ 155 days orbital period. Astron Telegr 3137:1

Tsygankov SS, Krivonos RA, Lutovinov AA (2012) Broad-band observations of the Be/X-ray binary pulsar RX J0440.9+4431: discovery of a cyclotron absorption line. Mon Not RAS 421:2407–2413. doi:10.1111/j.1365-2966.2012.20475.x. arXiv:1201.0616

Tueller J, Barthelmy S, Burrows D, Falcone A, Gehrels N, Grupe D, Kennea J, Markwardt CB, Mushotzky RF, Skinner GK (2005) SWIFT/BAT detections of hard X-ray sources II. Astron Telegr 669:1

Tuerler M, Chenevez J, Bozzo E, Ferrigno C, Tramacere A, Caballero I, Rodriguez J, Cadolle-Bel M, Sanchez-Fernandez C, Del Santo M, Fiocchi M, Tarana A, den Hartog PR, Kreykenbohm I, Kuehnel M, Paizis A, Puehlhofer G, Watanabe K, Weidenspointner G, Zhang S (2012) A new hard X-ray transient discovered by INTEGRAL: IGR J18179-1621. Astron Telegr 3947:1

Turler M, Rodriguez J, Ferrigno C (2009) INTEGRAL discovers the new hard X-ray source IGR J19294+1816. Astron Telegr 1997:1

Tutukov A, Yungelson L (1973) Evolution of massive close binaries. Nauchnye Informatsii 27:70

Tutukov A, Yungelson L (1993) Formation of neutron stars in binary systems. Astron Rep 37:411–431

van den Heuvel EPJ, De Loore C (1973) The nature of X-ray binaries III. Evolution of massive close binaries with one collapsed component - with a possible application to Cygnus X-3. A&A 25:387–395

van den Heuvel EPJ, Heise J (1972) Centaurus X-3, possible reactivation of an old neutron star by mass exchange in a close binary. Nat Phys Sci 239:67–69. doi:10.1038/physci239067a0

van der Meer A, Kaper L, di Salvo T, Méndez M, van der Klis M, Barr P, Trams NR (2005) XMM-Newton X-ray spectroscopy of the high-mass X-ray binary 4U 1700–37 at low flux. A&A 432:999–1012. doi:10.1051/0004-6361:20041288. arXiv:astro-ph/0412021 van der Meer A, Kaper L, van Kerkwijk MH, Heemskerk MHM, van den Heuvel EPJ (2007) Determination of the mass of the neutron star in SMC X-1, LMC X-4, and Cen X-3 with VLT/UVES. A&A 473:523–538. doi:10.1051/0004-6361:20066025. arXiv:0707.2802

Vercellone S, D'Ammando F, Striani E, Tavani M, Sabatini S, Bulgarelli A, Gianotti F, Trifoglio M, Feroci M, Lazzarotto F, Del Monte E, Pittori C, Verrecchia F, Pellizzoni A, Pilia M, Chen A, Giuliani A, Piano G, Pucella G, Vittorini V, Costa E, Donnarumma I, Pacciani L, Soffitta P, Evangelista Y, Lapshov I, Rapisarda M, Argan A, Trois A, de Paris G, Marisaldi M, Di Cocco G, Labanti C, Fuschino F, Galli M, Caraveo P, Mereghetti S, Perotti F, Fiorini M, Zambra A, Barbiellini G, Longo F, Moretti E, Vallazza E, Picozza P, Morselli A, Prest M, Lipari P, Zanello D, Cattaneo P, Rappoldi Santolamazza P, Colafrancesco S, Giommi P, Salotti L, Romano P, Burrows DN, Gehrels N (2009) Swift detection of an X-ray transient possibly associated with IGR J17354-3255. Astron Telegr 2019:1

Verrecchia F, Israel GL, Negueruela I, Covino S, Polcaro VF, Clark JS, Steele IA, Gualandi R, Speziali R, Stella L (2002a) The identification of the optical/IR counterpart of the 15.8-s transient X-ray pulsar XTE J1946+274. A&A 393:983–989. doi:10.1051/0004-6361:20021087. arXiv:astro-ph/0207587

Verrecchia F, Negueruela I, Covino S, Israel G (2002b) The optical counterpart to XTE J1855-026. Astron Telegr 102:1

Vink JS, de Koter A, Lamers HJGLM (2000) New theoretical mass-loss rates of O and B stars. A&A 362:295–309. arXiv:astro-ph/0008183

Voss R, Ajello M (2010) Swift-BAT survey of galactic sources: catalog and properties of the populations. Astrophys J 721:1843–1852. doi:10.1088/0004-637X/721/2/1843. arXiv:1009.1397

Walter R (2007) New INTEGRAL sources and TeV emission. Astrophys Space Sci 309:5–9. doi:10.1007/s10509-007-9477-9

Walter R, Zurita Heras J (2007) Probing clumpy stellar winds with a neutron star. A&A 476:335–340. doi:10.1051/0004-6361:20078353. arXiv:0710.2542

Walter R, Rodriguez J, Foschini L, de Plaa J, Corbel S, Courvoisier TJL, den Hartog PR, Lebrun F, Parmar AN, Tomsick JA, Ubertini P (2003) INTEGRAL discovery of a bright highly obscured galactic X-ray binary source IGR J16318-4848. A&A 411:L427–L432. doi:10.1051/0004-6361:20031369. arXiv:astro-ph/0309536

Walter R, Bodaghee A, Barlow EJ, Bird AJ, Dean A, Hill AB, Shaw S, Bazzano A, Ubertini P, Bassani L, Malizia A, Stephen JB, Belanger G, Lebrun F, Terrier R (2004) 14 New unidentified INTEGRAL sources. Astron Telegr 229:1

Walter R, Zurita Heras J, Bassani L, Bazzano A, Bodaghee A, Dean A, Dubath P, Parmar AN, Renaud M, Ubertini P (2006) XMM-Newton and INTEGRAL observations of new absorbed supergiant high-mass X-ray binaries. A&A 453:133–143. doi:10.1051/0004-6361:20053719

Wang W (2009) Evidence for a magnetic neutron star in high-mass X-ray binary 4U 2206+54 with INTEGRAL/IBIS observations. Mon Not RAS 398:1428–1434. doi:10.1111/j.1365-2966.2009.15200.x. arXiv:0906.2591

Wang W (2011) Long-term hard X-ray monitoring of 2S 0114+65 with INTEGRAL/IBIS. Mon Not RAS 413:1083–1098. doi:10.1111/j.1365-2966.2010.18192.x. arXiv:1012.3211

Wang W (2013) Spin and spectral variations of a peculiar high-mass X-ray binary 4U 2206+54. Mon Not RAS 432:954–966. doi:10.1093/mnras/stt516. arXiv:1303.5507

Warwick RS, Norton AJ, Turner MJL, Watson MG, Willingale R (1988) A survey of the galactic plane with EXOSAT. Mon Not RAS 232:551–564

Watanabe S, Sako M, Ishida M, Ishisaki Y, Kahn SM, Kohmura T, Morita U, Nagase F, Paerels F, Takahashi T (2003) Detection of a fully resolved compton shoulder of the iron Kα line in the Chandra X-ray spectrum of GX 301-2. Astrophys J Lett 597:L37–L40. doi:10.1086/379735. arXiv:astro-ph/0309344

Watanabe S, Sako M, Ishida M, Ishisaki Y, Kahn SM, Kohmura T, Nagase F, Paerels F, Takahashi T (2006) X-ray spectral study of the photoionized stellar wind in Vela X-1. Astrophys J 651:421–437. doi:10.1086/507458. arXiv:astro-ph/0607025

Watson MG, Warwick RS, Ricketts MJ (1981) 2S1145-619—an X-ray pulsar in an eccentric binary system. Mon Not RAS 195:197–203

Wen L, Remillard RA, Bradt HV (2000) X1908+075: an X-ray binary with a 4.4 day period. Astrophys J 532:1119–1123. doi:10.1086/308604. arXiv:astro-ph/9907424

Wheaton WA, Doty JP, Primini FA, Cooke BA, Dobson CA, Goldman A, Hecht M, Howe SK, Hoffman JA, Scheepmaker A (1979) An absorption feature in the spectrum of the pulsed hard X-ray flux from 4U0115 + 63. Nature 282:240–243. doi:10.1038/282240a0

White NE, Pravdo SH (1979) The discovery of 38.22 second X-ray pulsations from the vicinity of OAO 1653-40. Astrophys J Lett 233:L121–L124. doi:10.1086/183089

White NE, Mason KO, Sanford PW, Murdin P (1976) The X-ray behaviour of 3U 0352+30 (X Per). Mon Not RAS 176:201–215

White NE, Parkes GE, Sanford PW, Mason KO, Murdin PG (1978) Two X-ray periodicities from the vicinity of 4U1145-61. Nature 274:664–666. doi:10.1038/274664a0

White NE, Becker RH, Pravdo SH, Boldt EA, Holt SS, Serlemitsos PJ (1980) The X-ray pulsars 4U 1145-61 and 1E 1145.1-6141. Astrophys J 239:655–660. doi:10.1086/158152

White NE, Swank JH, Holt SS (1983) Accretion powered X-ray pulsars. Astrophys J 270:711–734. doi:10.1086/161162

White NE, Mason KO, Giommi P, Angelini L, Pooley G, Branduardi-Raymont G, Murdin PG, Wall JV (1987) A 25 min modulation from the vicinity of the unusually soft X-ray source X0142+614. Mon Not RAS 226:645–654

Wilson CA, Finger MH, Coe MJ, Laycock S, Fabregat J (2002) A decade in the life of EXO 2030+375: a multiwavelength study of an accreting X-ray pulsar. Astrophys J 570:287–302. doi:10.1086/339739. arXiv:astro-ph/0201227

Wilson CA, Finger MH, Coe MJ, Negueruela I (2003) XTE J1946+274 = GRO J1944+26: an enigmatic Be/X-ray binary. Astrophys J 584:996–1007. doi:10.1086/345791. arXiv:astro-ph/0211124

Wilson CA, Finger MH, Camero-Arranz A (2008) Outbursts large and small from EXO 2030+375. Astrophys J 678:1263–1272. doi:10.1086/587134. arXiv:0804.1375

Winkler C, Courvoisier TJL, Di Cocco G, Gehrels N, Giménez A, Grebenev S, Hermsen W, Mas-Hesse JM, Lebrun F, Lund N, Palumbo GGC, Paul J, Roques JP, Schnopper H, Schönfelder V, Sunyaev R, Teegarden B, Ubertini P, Vedrenne G, Dean AJ (2003) The INTEGRAL mission. A&A 411:L1–L6. doi:10.1051/0004-6361:20031288

Yamamoto T, Sugizaki M, Mihara T, Nakajima M, Yamaoka K, Matsuoka M, Morii M, Makishima K (2011) Discovery of a cyclotron resonance feature in the X-ray spectrum of GX 304-1 with RXTE and Suzaku during outbursts detected by MAXI in 2010. Publ ASJ 63:751. arXiv:1102.4232

Yamamoto T, Mihara T, Sugizaki M, Sasano M, Makishima K, Nakajima M (2013) Discovery of cyclotron-line feature at 76 keV from Be/X-ray binary pulsar, GRO J1008-57. Astron Telegr 4759:1

Yamauchi S, Aoki T, Hayashida K, Kaneda H, Koyama K, Sugizaki M, Tanaka Y, Tomida H, Tsuboi Y (1995) New transient X-ray source in the scutum region discovered with ASCA. Publ ASJ 47: 189–194

Yan J, Zurita Heras JA, Chaty S, Li H, Liu Q (2012) Multi-wavelength study of the Be/X-ray binary MXB 0656-072. Astrophys J 753:73. doi:10.1088/0004-637X/753/1/73. arXiv:1205.0063

Zhang SN, Harmon BA, Paciesas WS, Fishman GJ, Finger MH, Robinson CR, Rubin BC, Grindlay JE, Barret D, Tavani M, Kaaret P, Bloser P, Ford E (1996) Periodic transient hard X-ray emission from GRO 1849-03. A&A Suppl Ser 120:C227

Zhang S, Qu JL, Song LM, Torres DF (2005) Recovery of the orbital parameters and pulse evolution of V0332+53 during a huge outburst. Astrophys J Lett 630:L65–L68. doi:10.1086/462415. arXiv:astro-ph/0507468

Ziolkowski J (1977) Origin and present evolution of massive X-ray binaries. In: Papagiannis MD (ed) Eighth Texas symposium on relativistic astrophysics, annals of the New York Academy of Sciences, vol 302, p 47. doi:10.1111/j.1749-6632.1977.tb37036.x

Zurita Heras JA, Chaty S (2009) Discovery of an eccentric 30 day period in the supergiant X-ray binary SAX J1818.6-1703 with INTEGRAL. A&A 493:L1–L4. doi:10.1051/0004-6361:200811179. arXiv:0811.2941

Zurita Heras JA, Walter R (2009) INTEGRAL and XMM-Newton observations of AX J1845.0-0433. A&A 494:1013–1019. doi:10.1051/0004-6361:200810219. arXiv:0811.0983

Zurita Heras JA, de Cesare G, Walter R, Bodaghee A, Bélanger G, Courvoisier TJL, Shaw SE, Stephen JB (2006) IGR J17252-3616: an accreting pulsar observed by INTEGRAL and XMM-Newton. A&A 448:261–270. doi:10.1051/0004-6361:20053876. arXiv:astro-ph/0511115

Zurita-Heras JA, Chaty S, Prat L, Rodriguez J (2009) Spectral evolution along the orbit of igr j163204751 with xmmnewton. AIP Conf Proc 1126(1):313–315. doi:10.1063/1.3149440