Populations of High Energy Sources in Galaxies
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High-Mass X-ray Binaries population in the Galaxy

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Abstract. We study high mass X-ray binaries (HMXBs) in the Galaxy using data of the INTEGRAL observatory. High sensitivity survey of the whole Galaxy with a possibility to detect absorbed sources significantly enlarged our sample of HMXBs in a comparison with the previous studies. Large fraction of detected high mass X-ray binaries is highly photoabsorbed. We investigated the HMXBs distribution along the Galactic plane and found their strong concentrations toward Galactic spiral arms, confirming previous results of Grimm *et al.* (2002) obtained using smaller sample of sources. We conclude that the mapping of Galactic HMXBs should be important tool to trace the star formation regions at the opposite side of the Galaxy.

Keywords. Galaxy: structure, X-rays: galaxies, X-rays: binaries.

1. Introduction

High- and low-mass binaries (LMXBs and HMXBs) harboring compact objects (neutron stars or black holes) are the brightest X-ray emitters in the Galaxy. At the moment more than 130 HMXBs and 200 LMXBs ever observed during last 35–40 years are known (Liu *et al.* 2000, 2001). Their positions in the Galaxy intimately connected with the origin of their optical star. The HMXBs being the younger X-ray population of the Galaxy (massive stars which are companion stars in HMXBs can not live longer than ~10–100 Myr) should trace the star formation (SF) regions, while LMXBs (live time much more then ~Gyr) should be more concentrated in the regions of high stellar mass density.

Using the RXTE/ASM survey of the sky (the 2–10 keV energy range) Grimm *et al.* (2002) found significant differences in the spatial distribution of HMXBs and LMXBs. The luminosity functions of LMXBs and HMXBs were found to be also quite different. Luminosity function of HMXBs essentially is a power law from $\sim 10^{39}$ erg/s down to $\sim 10^{33}$ erg/s where indications of some flattening were obtained by Shtykovskiy & Gilfanov (2005). The LMXB luminosity function is much flatter on lower luminosities end (Gilfanov 2004). It is interesting that the behavior of luminosity functions of LMXBs and HMXBs might be generally understood considering the mass trasfer mechanisms in these binary systems. It was shown that the shape of the HMXB luminosity function is governed by the properties of the massive star mass loss via stellar wind (Postnov 2003), while the luminosity function of low mass X-ray binaries (in which the Roche lobe overflow is the dominant way to supply the matter to the accretor) contains imprints of magnetic and gravitational braking of the binary system (Postnov & Kuranov 2005).

Below we describe some general properties of high and low mass X-ray binaries from a sample of sources obtained with latest INTEGRAL/IBIS survey of the Galaxy.

HMXB	LMXB
young population ($\times 10^7$ yr)	old population ($\times 10^9$ yr)
$M_c > 10 M_\odot$	$M_c \sim 1 M_\odot$
type: late $O - B[e]$ stars	type: $K - M$ stars
strong stellar wind	no stellar wind
intrinsic absorption	no intrinsic absorption
trace the SF regions	trace stellar mass
Vela X-1, 4U1700-37, GX301-2, Cyg X-1, most X-ray pulsars	1E1740-294, GRS1915+105, X-ray bursters and BHC

2. Inner part of the Galaxy

In the recent paper (Lutovinov *et al.* 2005) we focused on a sample of Galactic sources located in the Galactic plane in between the Norma and Sagittarius spiral arms (the inner part of the Galaxy). This Galactic region was selected because it had the best statistics of the available INTEGRAL data to that date. Using a ∼5 Msec exposure we constructed a flux limited sample of sources in this region and detected about 90 sources with a flux more than 1.5 mCrab in the 20–60 keV energy band. Most of them (49) were identified with LMXBs, but 23 were HMXBs. The usage of hard X-ray energy band (INTEGRAL/IBIS telescope) allowed one to reveal a considerable population of absorbed sources and significantly increase the number of known HMXBs in the inner part of the Galaxy. Most of detected HMXBs proved to be accreting X-ray pulsars with a strong intrinsic photoabsorption. As an example in Fig. 1 we present spectra of new heavily absorbed sources IGR J16318-4848 and IGR J16358-4726 obtained with INTEGRAL (>20 keV) and RXTE (3–20 keV) observatories.

3. Towards maping the whole Galaxy

Now (end of summer 2005) there is more than 24 Msec of publicly available data of INTEGRAL observations. These observations allow us to study large part of the sky including extragalactic (see Krivonos *et al.* 2005) and Galactic sources. At the moment more than 300 sources were detected in all data with a high statistical significance. About 60 from them are new sources discovered by INTEGRAL. X-ray binaries are concentrated towards the Galactic plane, however HMXBs and LMXBs have different vertical scale heights, reflecting the age of stellar companions of these sources: ∼150 pc for HMXBs

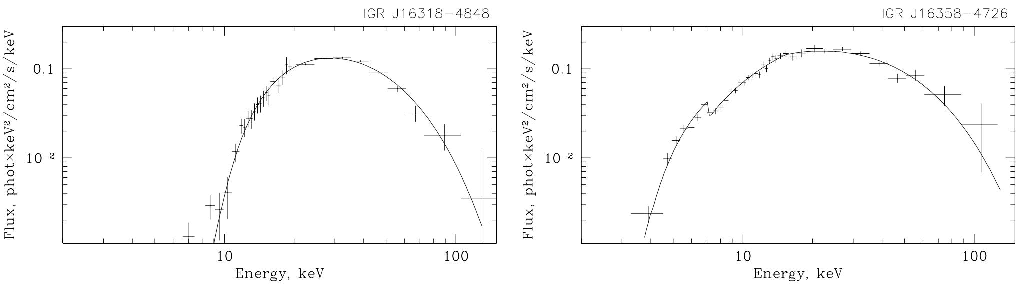

Figure 1. Broadband energy spectra of IGR J16318-4848 and IGR J16358-4726. The best-fit models are shown by solid lines.

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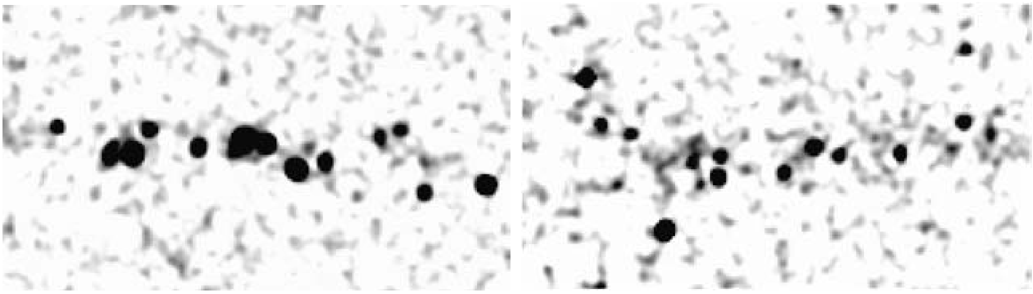

Figure 2. Maps of Norma (left) and Scutum-Sagittarius (right) spiral arm tangents obtained with IBIS/INTEGRAL.

and ∼400 pc for LMXBs (Grimm *et al.* 2002). At the Galactic Center distance from the Sun (assume 8.5 kpc) these scale heights correspond to angular scales of $\sim 1°$and $\sim 2.7°$, respectively. Below we present two current samples of sources with $|b| < 2°$ and $|b| < 5°$ from the Galactic plane.

All sky	
Total	300 sources
HMXB	49 sources
LMXB	68 sources
Galactic plane ($|b| < 5$, LMXB scale)	
Total	184 sources
HMXB	43 sources
LMXB	54 sources
Galactic plane ($|b| < 2$, HMXB scale)	
Total	115 sources
HMXB	36 sources
LMXB	33 sources

It is interesting to note that relative quantity of HMXBs and LMXBs changes considerably if we widen our selection region with the respect to the Galactic plane. Majority of absorbed sources, discovered by INTEGRAL, lies very close to the Galactic plane. On Fig. 2 one clearly sees a large number of sources near the Galactic plane and rapid drop of their surface density towards higher Galactic latitues.

Our Galaxy consists mostly of the disk and the bulge components (see e.g. Bahcall & Soneira 1980). In the Galactic disk there is a clear spiral structure which is believed to be a spiral density wave, initiating the intense star formation. Therefore we might naturally expect that increased number density of high mass X-ray binaries should be observed in spiral arms regions. In Fig. 3 we present distribution of surface density of LMXBs and HMXBs along the Galactic plane (note however, that the sample of sources considered here is not flux limited therefore some non-uniformity of exposure times should be imprinted in the observed sources distribution). It is obviously seen that there are concentrations of HMXB in the regions of tangents to the spiral arms, while it is much weaker in LMXB distribution.

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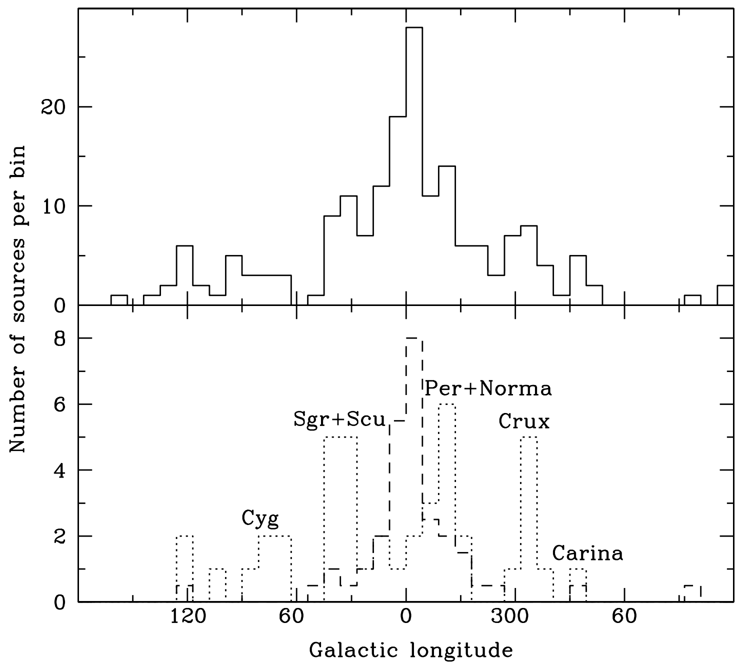

Figure 3. Angular distribution of all detected sources (upper panel), identified HMXBs and LMXBs (dotted and dashed lines in bottom panel, respectively). The number of LMXBs is divided by 2. The spiral arms are indicated by their names.

Note that the current sensitivity limit of the INTEGRAL/IBIS survey – $F_{\rm lim} \sim 10^{-11}$ erg/s/cm^2 in best places – corresponds to the detection sensitivity $L_{\rm lim} > 10^{35}$ erg/s till the end of the Galaxy. Therefore we might expect that with the INTEGRAL survey, which does not suffer from strong interstellar photoabsorption in the Galaxy, we should see all HMXB sources in the Galaxy brighter than the above limit. The position of newly discovered and will-be-discovered HMXBs should also fall into the region of intense star formation in the Galaxy. Consequently the mapping of HMXBs should be interesting tool to trace the star formation, especially at the opposite side of the Galaxy where most other methods to map the spiral structure fail (Vallee 1995).

Acknowledgements

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Discussion

Eracleous: Can you tell from the data if the HMXBs are powered by accretion from the stellar wind of the companion or by Roche lobe overflow?

Lutovinov: It is possible that some are powered by Roche lobe overflow but the majority are accreting from a stellar wind.

Ghosh: Would you say that the discrepancy between the spatial distribution of HMXBs and the positions of the spiral arms is already statistically significant, or that more work needs to be done?

Lutovinov: Really, the significance of this discrepancy is not enough. We obtained at the moment only some indications for the possible displacement between HMXBs and spiral arms. More observations are needed to make final conclusions.

Lipunov: One remark. Most of X-Ray massive binary systems belong to MS + Be systems. Due to selection effect we see only 1% percent of them. The real luminosity function can be determined after X-ray observations of 100's of galaxies.

Lutovinov: Yes, most of high mass X-ray binary systems include Be-stars. But they usually have quite small duty cycles, therefore at any given moment the probability to see the bright Be-system is low. This is confirmed by our sample, that doesn't contain any known Be-system.