

POPULATION OF HMXB IN THE GALAXY

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ABSTRACT

We study populations of High-Mass X-ray Binaries in the Galaxy using data of the INTEGRAL observatory in a hard X-ray energy band. More than two hundreds of sources were detected with INTEGRAL near the galactic plane ($|b| < 5$ deg), most of them have a galactic origin and belong to high (HMXB) and low mass (LMXB) X-ray binaries. We investigated properties and spectra of a large sample of HMXBs and concluded that most of them are belong to X-ray pulsars. We also build the distribution of HMXBs for the whole Galaxy and showed that its peaks are practically coincident with spiral arm tangents. The obtained results are discussed in terms of some model estimations of the density of different components of the Galaxy.

Key words: Galaxy; high mass X-ray binaries; population.

1. INTRODUCTION AND PREVIOUS WORKS

The INTEGRAL observatory is successfully operating on the orbit about 3.5 years since its launch in 2002 [1]. For this period more than 35 million seconds of data were provided and analyzed. One of the most interesting results obtained by INTEGRAL for this period are surveys of different parts of the sky and especially the Galactic center and plane ([2, 3, 4, 5]). These surveys as well as other INTEGRAL observations allowed to discover several dozens sources of different nature, mostly galactic X-ray binaries. These objects are brightest X-ray emitters in the Galaxy and their positions in the Galaxy connected with the origin of their optical star. Based on the RXTE/ASM sky survey in the 2 – 10 keV energy band Grimm et al. [6] showed that the spatial distribution of high mass X-ray binaries (HMXB) and low mass X-ray binaries (LMXBs) is significantly different. HMXBs being the young X-ray population of the Galaxy should trace the star formation (SF) regions, while LMXBs should be more concentrated in the regions of high stellar mass density, particularly in the Galactic center region (see also [7]).

INTEGRAL observations and discoveries of a large num-

ber of X-ray sources in a hard energy range (> 20 keV) where the photoabsorption doesn't play any role allowed to significantly move in the study of different populations of X-ray binaries, their properties and spatial distribution. In our first paper devoted to this problem [8] we were focused on a sample of Galactic sources located in the Galactic plane between the Norma and Sagittarius spiral arms (the inner part of the Galaxy). The following investigations used more than 24 Msec of publicly available data of INTEGRAL observations and were extended to the whole Galactic plane [9].

In frame of work dedicated to the all-sky survey in hard X-rays [10] we analyzed all available at the moment data of the INTEGRAL observatory and studied the population of X-ray binaries in the Galaxy. Some preliminary results concerned HMXBs are briefly presented in the current paper.

2. INDIVIDUAL SOURCES, THEIR PROPERTIES AND SPECTRA

There is a large population of highly photoabsorbed Galactic X-ray sources among newly discovered ones with the INTEGRAL observatory. The prominent feature of such sources is a strong intrinsic absorption ($\sim 10^{23} - 10^{24} \text{ cm}^{-2}$), that made difficult their detection in a soft energy band (< 10 keV). Remarkably these sources were confined in relatively small regions of the sky, close to the tangents of the Galactic spiral arms (e.g. [8, 9]). The analysis of their properties showed that they are high mass X-ray binaries with early type companion stars (giant or supergiant) with a strong stellar wind (e.g. [11]). The usage of hard X-ray energy band > 20 keV (IS-GRI detector of the INTEGRAL/IBIS telescope, [12]) allowed one to reconstruct spectra of such heavily absorbed sources and showed that most of them are very similar to spectra of X-ray pulsars and can be fitted the powerlaw model with a cutoff([8]). The following studies of these sources performed with XMM-Newton, RXTE, Chandra observatories revealed coherent pulsations from some of them (e.g. [13, 14, 15]).

As an example in Fig.1 spectra of new heavily absorbed sources IGR/AX J16320-4752 and IGR J16479-4514 obtained with INTEGRAL (> 20 keV) and XMM-Newton

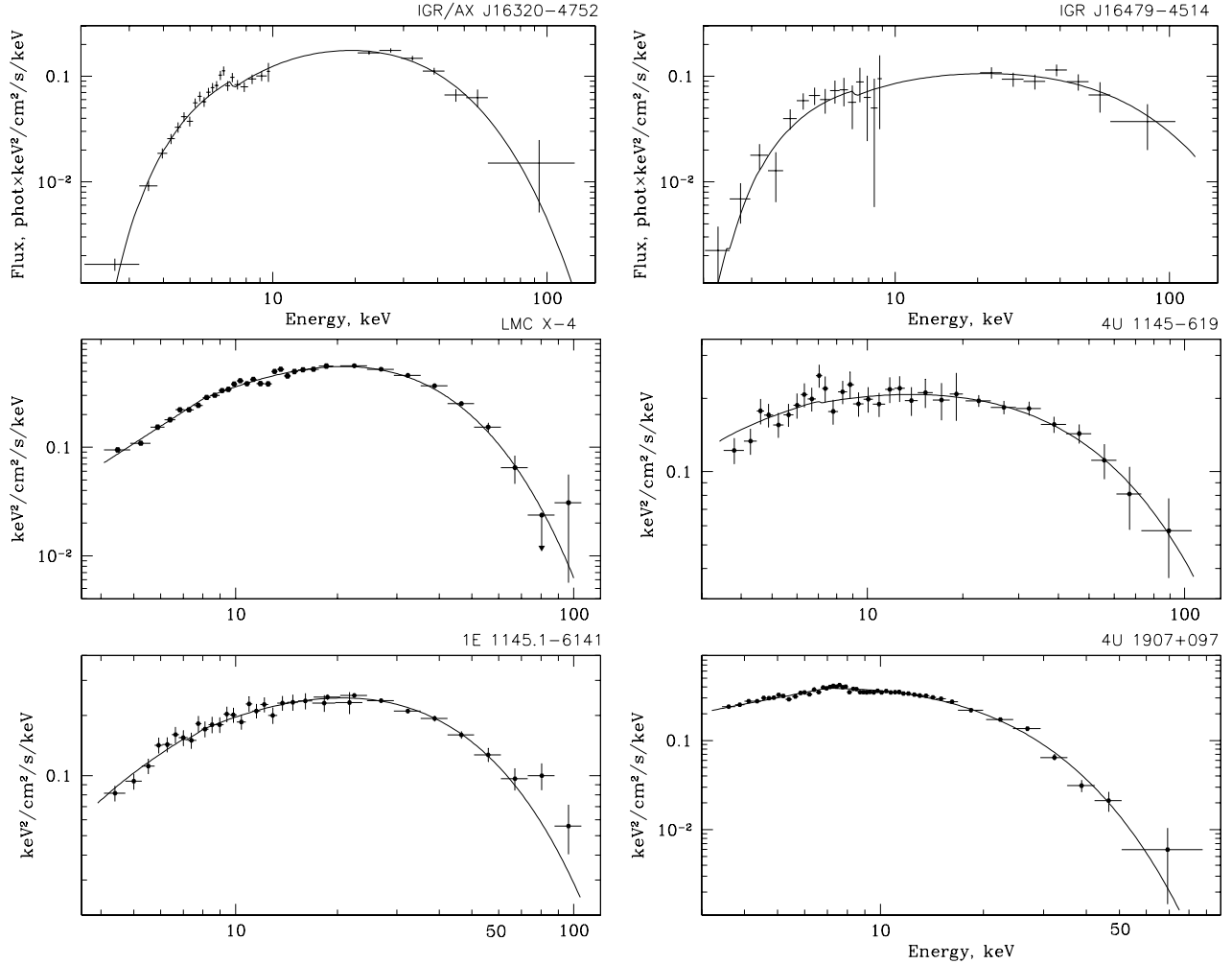


Figure 1. (Two upper panels) Broadband energy spectra of two new absorbed sources IGR/AX J16320-4752 and IGR J16479-4514, obtained by XMM-Newton and INTEGRAL observatories. (Bottom panels) Typical broadband spectra of four known X-ray pulsars obtained by the JEM-X monitor and IBIS telescope of the INTEGRAL observatory (see [16] for details). The best-fit models are shown by solid lines.

(1–10 keV) observatories are presented. The spectra of 4 known X-ray pulsars obtained in a wide energy band (4–100 keV) with the JEM-X and IBIS telescopes of the INTEGRAL observatory are shown in Fig.1 for the comparison. It is clearly seen that spectra of INTEGRAL sources and X-ray pulsars are very similar. The subsequent study with using data of the XMM-Newton observatory and archival data of the ASCA observatory actually revealed pulsations from IGR/AX J16320-4752 with the period of ~ 1300 s ([15]). Thus X-ray pulsars constitute a significant part of high-mass X-ray binaries as among newly discovered sources as among those observed with INTEGRAL. In particular, most of HMXBs observed with the INTEGRAL observatory in the inner part of the Galaxy (16 of 23) are accretion-powered X-ray pulsars ([8]). In total the INTEGRAL observatory significantly detected and allowed to reconstruct spectra of 35 X-ray pulsars ([16]).

Note, that despite of the general similarity of spectra of new sources and X-ray pulsars the more strong absorption in new sources is obviously seen (Fig.1).

3. SPATIAL DISTRIBUTION OF X-RAY BINARIES

At the moment (June of 2006) there are more than 35 Msec of publicly available data of INTEGRAL observations. These observations allow us to perform the all-sky survey in hard X-rays ([10]) and study both extragalactic ([17]) and Galactic sources. About 400 sources were detected in all data with a high statistical significance; about 140 from them are new sources discovered by INTEGRAL. As is known X-ray binaries are concentrated towards the Galactic plane, however HMXBs and

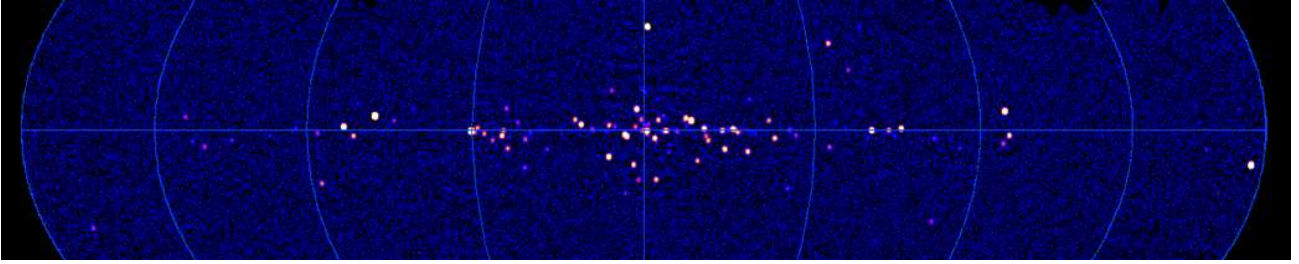


Figure 2. Map of the sky region near the Galactic plane obtained with ISGRI/IBIS/INTEGRAL in the 17 – 60 keV energy band.

LMXBs have different vertical scale heights, reflecting the age of stellar companions of these sources: ~ 150 pc for HMXBs and ~ 400 pc for LMXBs ([6]). At the galactic center distance from the Sun (assume 8.5 kpc) these scale heights correspond to angular scales of ~ 1 deg and ~ 2.7 deg, correspondingly. The part of the sky near the Galactic plane observed with the INTEGRAL observatory in the 17 – 60 energy band is shown in Fig.2. Following to [9] below we present two current samples of sources with $b < |2|$ deg and $b < |5|$ deg from the Galactic plane.

All sky	
Total	396 sources
HMXB	60 sources
LMXB	76 sources
Galactic plane ($b < 5 $, LMXB scale)	
Total	228 sources
HMXB	50 sources
LMXB	55 sources
Galactic plane ($b < 2 $, HMXB scale)	
Total	143 sources
HMXB	41 sources
LMXB	33 sources

It is interesting to note that relative numbers of HMXBs and LMXBs changes considerably if we widen our selection region with the respect to the Galactic plane, that reflects different vertical scales of distributions both type of sources. Note, that majority of absorbed sources, discovered by INTEGRAL, lies very close to the Galactic plane. In Fig.2 we can clearly see a large number of sources near the Galactic plane and rapid drop of their surface density towards higher Galactic latitudes. Another interesting point is that only 3 black hole candidates and 32 X-ray pulsars detected among 50 HMXBs inside of the 5-deg region from the Galactic plane; if we go down to the 2-deg region only 1 black hole candidate and 23 X-ray pulsars will be identified from 41 HMXBs in total.

Our Galaxy consists of four components – disk, bulge, spheroid and halo, the former two bring the main contribution to the mass of the Galaxy (e.g. [18]). Moreover, there is a clear spiral structure in the Galactic disk 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 the distribution of the surface density of HMXB along the Galactic plane is presented in comparison with the LMXB one. Note, that samples of sources considered here are not flux limited therefore ununiformity of exposure times should be take into account in the observed sources distributions. 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 the LMXBs distribution, that have a maximum near the Galactic center. To estimate the significance of this difference quantitatively we used a Kolmogorov-Smirnov test. We build cumulative

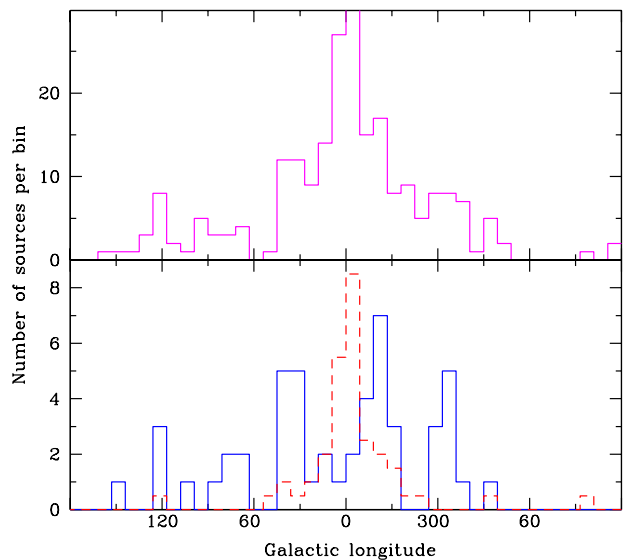


Figure 3. Angular distributions of all detected sources (upper panel), identified HMXBs and LMXBs (solid and dashed lines in bottom panel, respectively). The number of LMXBs are divided by 2.

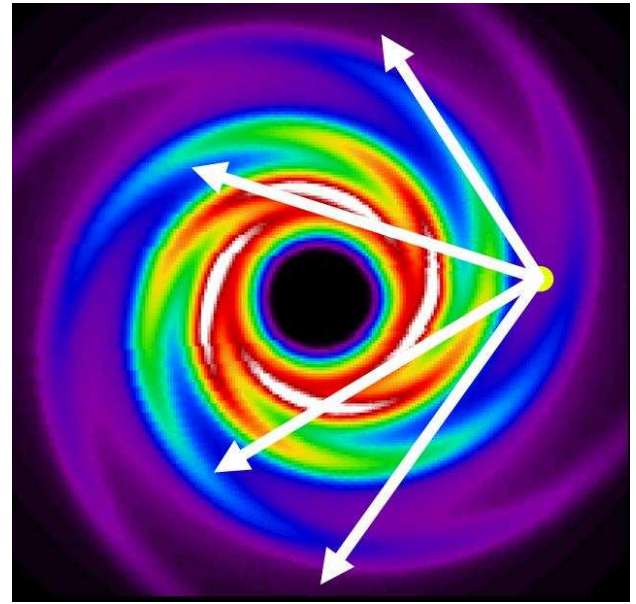
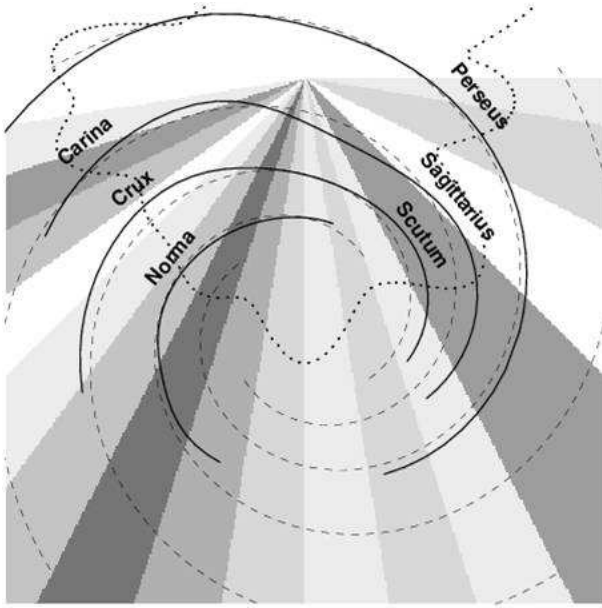


Figure 4. (Left) Face-on view of the Galaxy with overlaid densities of HMXBs shown in gray scale. Solid lines show the position of the spiral arms by [19]; the dashed line shows logarithmic spiral arms by [20]; the dotted line represents the current sensitivity of the survey at the level of $L_x = 10^{35}$ erg/s. (Right) The model mass distribution in the Galactic disk with the superimposed spiral structure. White arrows show the directions of peaks of the HMXBs concentration.

distributions for each of samples and found that probabilities that the HMXB distribution differs from LMXB and uniform ones are $> 99.9\%$ in both cases.

For the better visualization the observed distribution of HMXBs in the Galaxy is presented in Fig. 4 (left panel) with respect to the Galactic spiral structure. The number density of the sources is shown in gray scale; the spiral model of the Galaxy is based on optical and radio observations of HII regions ([19]) and logarithm spirals with pitch angle 12° adopted by ([20]). The dotted line shows maximal distances from the Sun at which the sensitivity of the IBIS telescope and current exposure allow us to detect X-ray sources with the luminosity $L_x = 10^{35}$ erg/s. Again, it is clearly seen that the HMXBs distribution strictly avoids the Galactic center and is concentrated towards Galactic spiral arms. Such result can be understood from the current knowledge of the Galactic structure. In Fig. 4 (right panel) the face-on distribution of the mass in the Galactic disk with the superimposed spiral arms structure is presented. The white arrows show the believed directions of the enhanced number of high-mass X-ray binaries, that are very close to the observed ones. Note, that despite of understanding of the HMXBs distribution in general, some subtle details are not clear yet. In particular, there is no exact coincidence of distribution peaks and spiral arm tangents, that was mentioned firstly for the inner part of Galaxy by ([8]) and confirmed here for the whole Galaxy.

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