High-mass X-ray binaries in the inner part of the Galaxy

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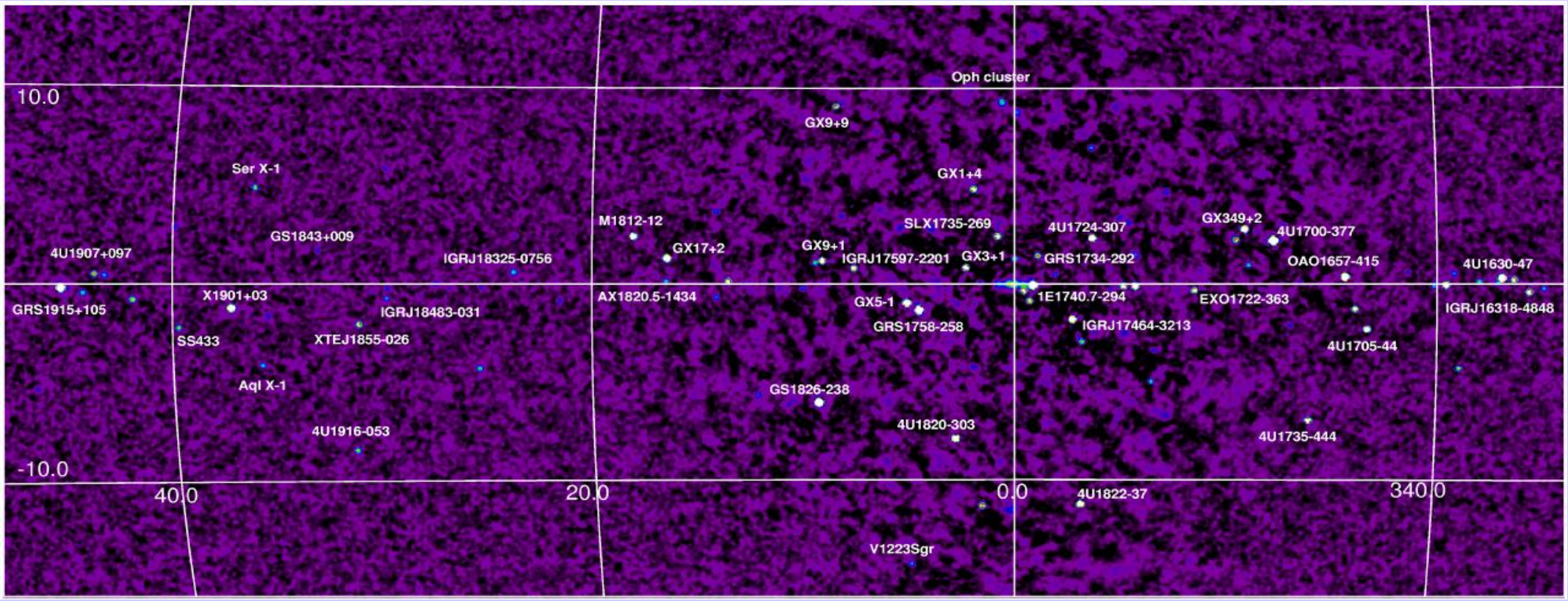


The inner part of the Galaxy :
from the Norma arm to the Sagittarius arm

325<l<50, |b|<5

Previous results

Grimm, Gilfanov, Sunyaev (2002)

1-12 keV ASM/RXTE data

Total sample of HMXB in the Galaxy with the limiting sensitivity of ~6×10^{-11} erg/s/cm2 is about 50, in the inner part of the Galaxy < 10

LMXB concentrated towards the Galactic Center (old population)
HMXB concentrated towards the spiral arms (young population)

Current study (INTEGRAL)

Energy band: 20-60 keV

Inner part of the Galaxy ~>5 Msec
(public data + RAS part of General Program)

We choose a limiting uniform sensitivity
~1.5 mCrab (~1.8×10^{-11} ergs/s/cm^2) ->
maximal area with the best possible sensitivity

Totally detected 89 sources of the different nature (flux ~> 1.5 mCrab): 49 LMXB, 22 HMXB, 2 AGN, several SNR and single pulsars, 10 - unidentified + IGRJ16465-4507

List of detected HMXB

Source	α(2000)	δ(2000)	N_H,10^{22} cm^{-2} Observed	N_H,10^{22} cm^{-2} Galactic	Flux, mCrab[a]	Comments[b]
4U 1538-522	235.584	-52.376	1.6[1]	0.96	16.5±0.2	P
AXJ161929-4945	244.871	-49.758	14	2.19	2.0±0.2	
IGR J16318-4848	247.953	-48.801	310	2.07	21.8±0.2	
AX J163159-4752[d]	248.009	-47.859	18	2.13	13.0±0.2	P
IGR J16358-4726	248.990	-47.407	40	2.20	3.11±0.21	P
AX J163904-4642	249.757	-46.676	58	2.18	4.63±0.21	P
IGR J16465-4507	251.648	-45.118	72	2.12	8.8±0.9	P
IGR J16479-4514[e]	252.032	-45.206	12	2.14	3.22±0.20	
OAO 1657-415	255.199	-41.653	40[2]	1.76	68.2±0.2	P
4U 1700-377	255.982	-37.841	2-100[3]	0.74	185.0±0.2	
EXO 1722-363	261.286	-36.280	50[4]	1.50	7.18±0.13	P
IGR/XTE J17391-3021	264.802	-30.329	1-1.5[5]	1.37	1.50±0.11	
AX J1749.2-2725	267.335	-27.511	10[6]	1.62	1.51±0.11	P
IGR/SAX J18027-2016	270.677	-20.278	1-1.5[7]	1.04	4.06±0.14	P
AX J1820.5-1434	275.131	-14.553	13[8]	1.65	2.94±0.20	P
AX J1838.0-0655	279.523	-6.921	9	1.86	2.36±0.24	
GS 1843+00	281.412	0.891	2.3[9]	1.01	4.49±0.20	P
XTE J1855-026	283.873	-2.597	15[10]	0.73	11.4±0.2	P
4U 1901+03	285.914	3.215	7[f]	1.03	75.5±0.2	P
4U 1907+097	287.401	9.843	3-8 [11]	1.75	13.2±0.2	P
X1908+075	287.699	7.598	10-50[12]	1.48	13.4±0.2	P
SS 433	287.950	4.990	–[g]	0.76	14.2±0.2	BH
XTE J1858+034	284.693	3.429	6 [13]	1.89	15±1	P

Criteria of HMXB: 1) optical identification 2) pulsations 3) strong intrinsic absorption

Pulsations

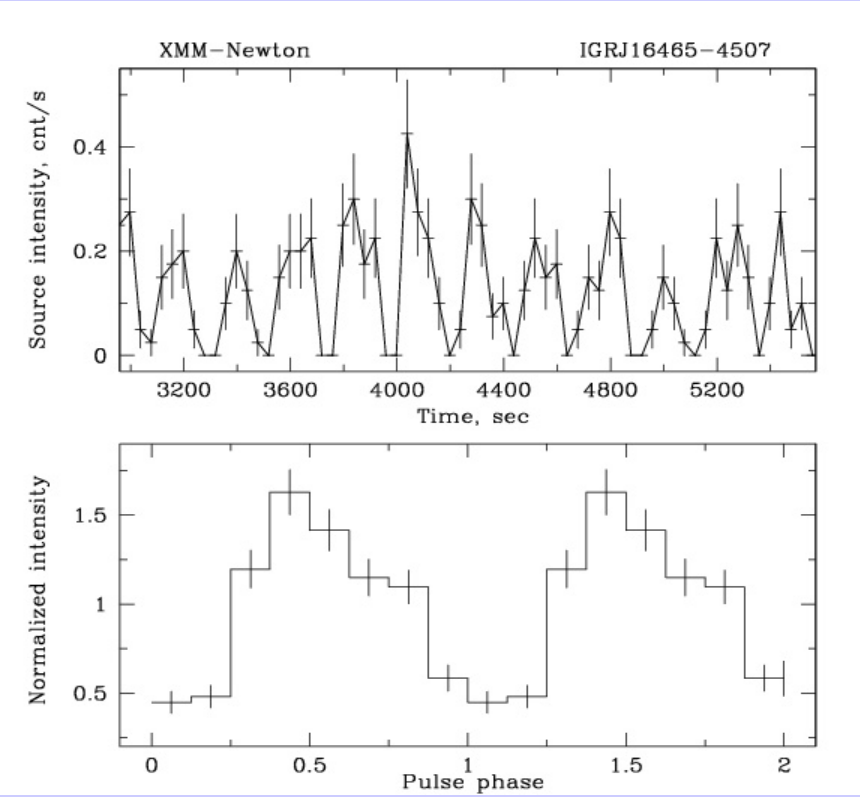
16 of 23 - are X-pulsars, 4 of them – new

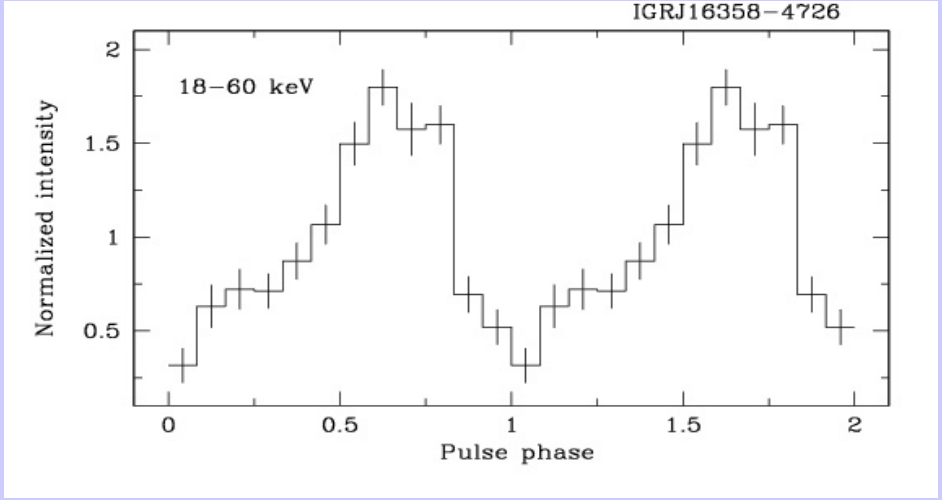
IGRJ16358-4726 P=5980±22 sec (INTEGRAL, Chandra)
(Lutovinov, Revnivtsev, Glifanov et al. 2004, Patel et al. 2004)

IGRJ16320-4751 P~1300 sec (XMM, ASCA)
(Lutovinov, Rodriguez, Revnivtsev, Shtykovskiy 2004)

IGRJ16465-4507 P=228±6 sec (XMM) (Lutovinov et al. 2004)

AXJ163904-4642 P~900 sec (XMM) (Walter et al. 2004)

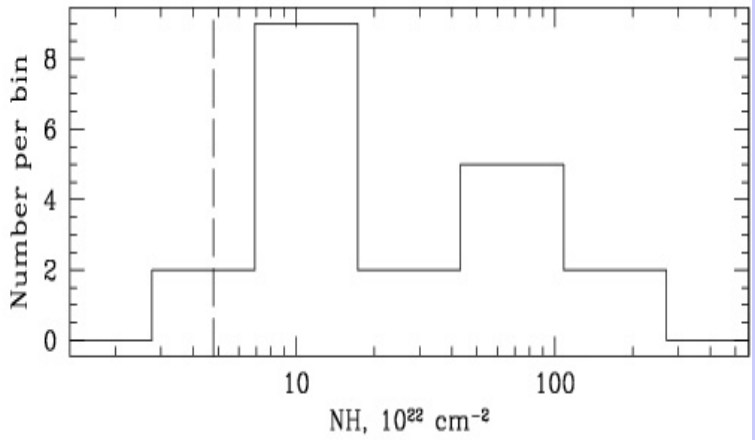


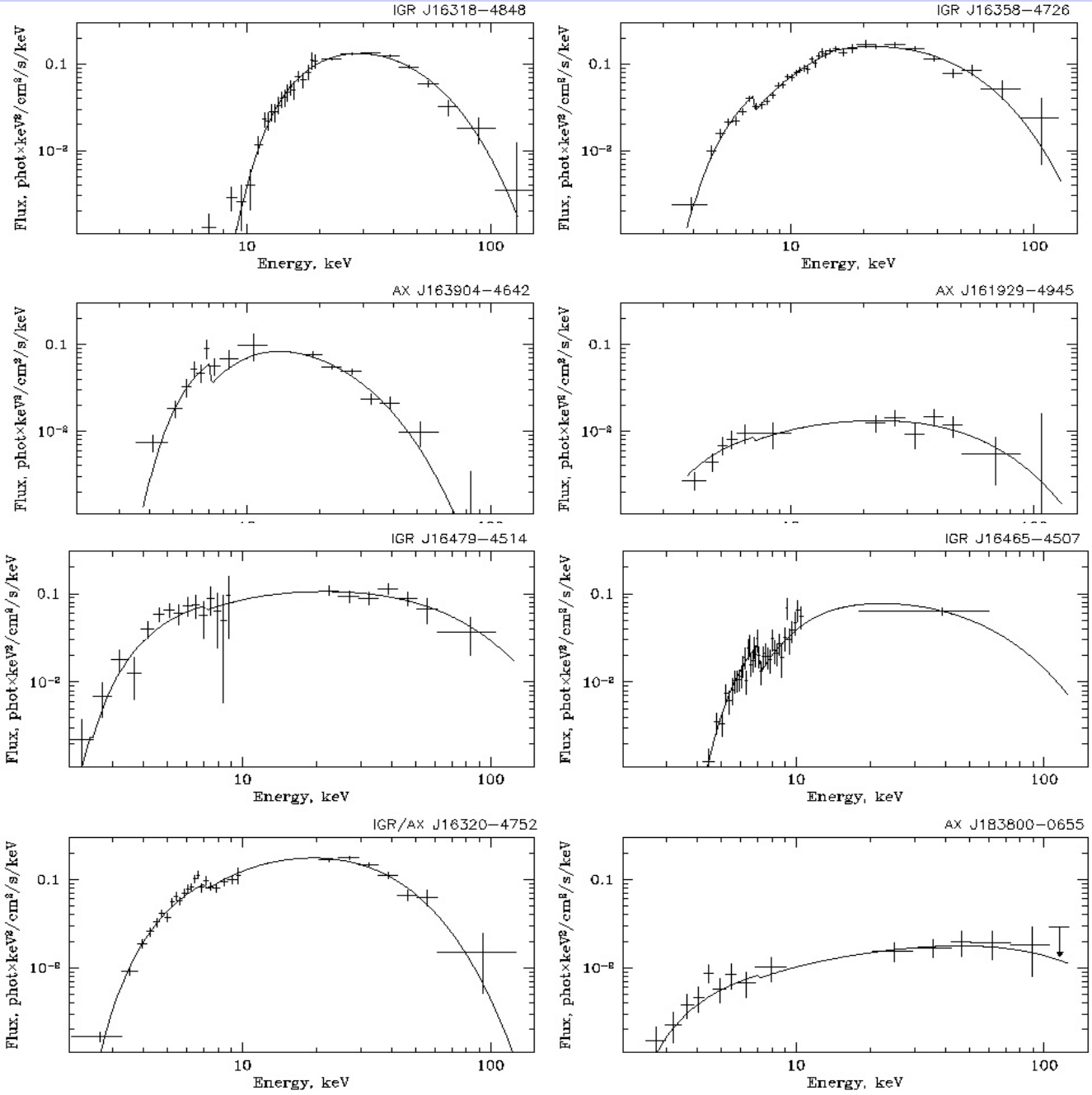


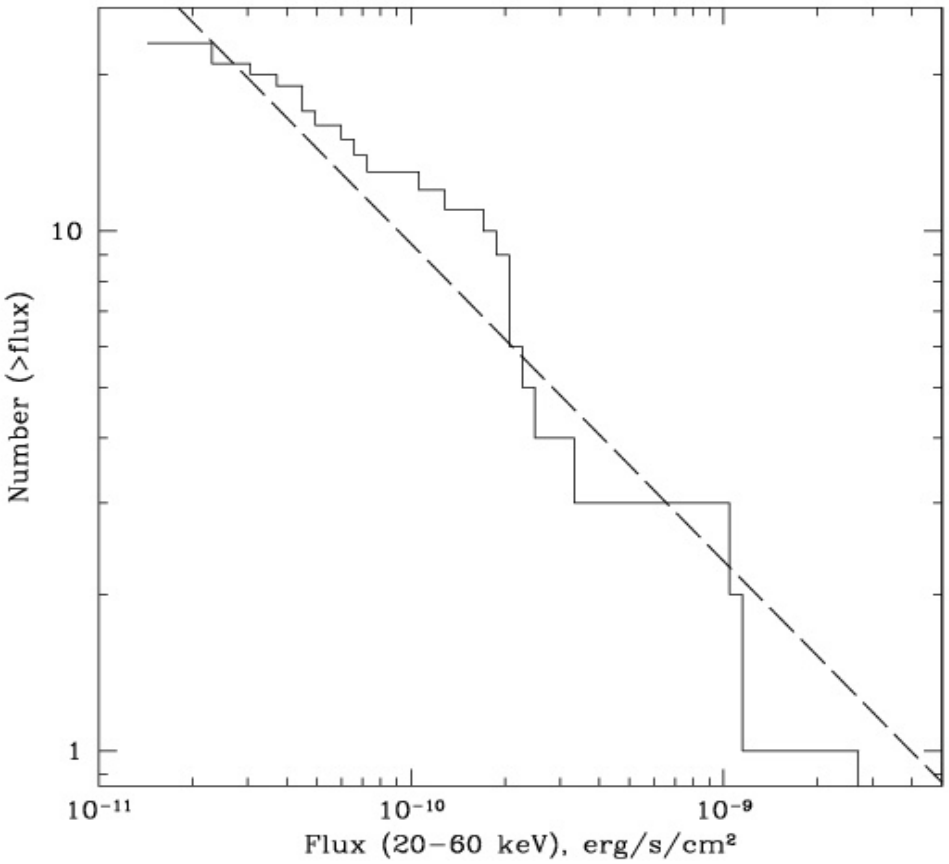
PF_{16465} ~ 50-60 %
PF_{16358} = 70±10 %
PF_{16320} ~30%

Intrinsic absorption

19 of 23 sources have a significant (>5x10^{22} cm^{-2}) intrinsic absorption

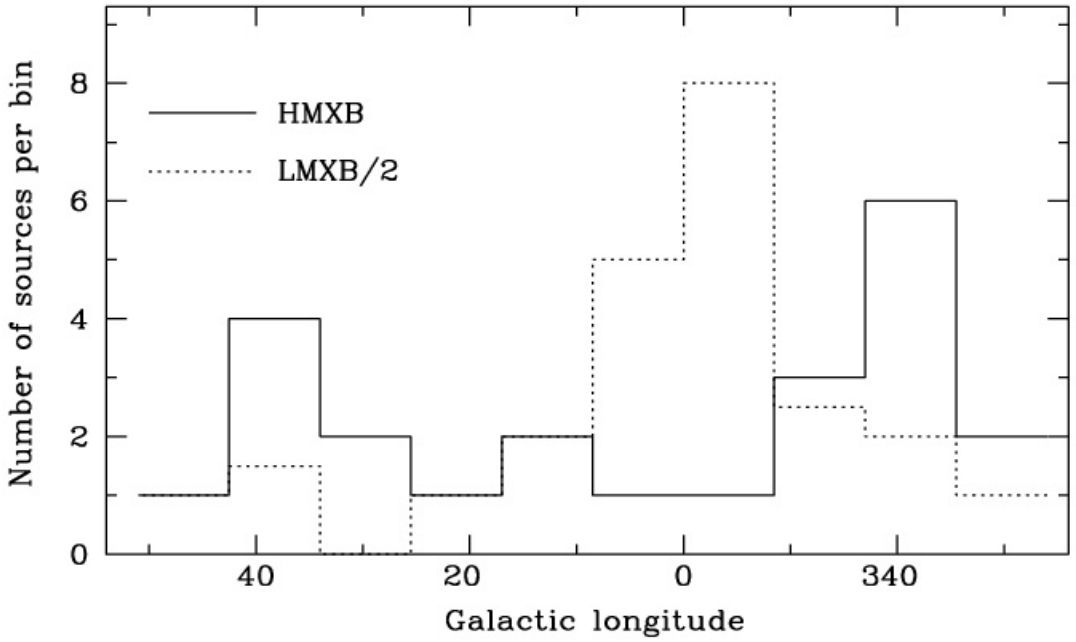




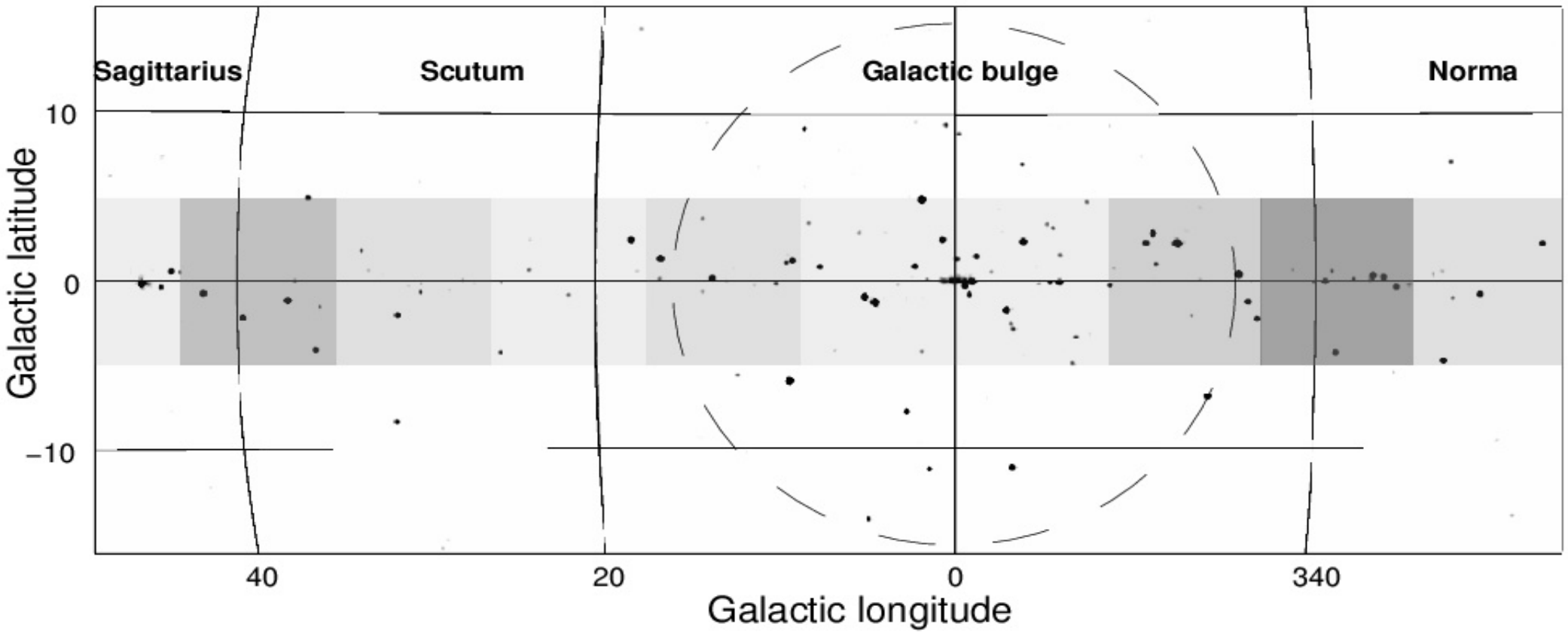


Number-flux function of HMXB
Dashed line represents a shape of this function obtained by Grimm et al. (2002) with ?=0.64

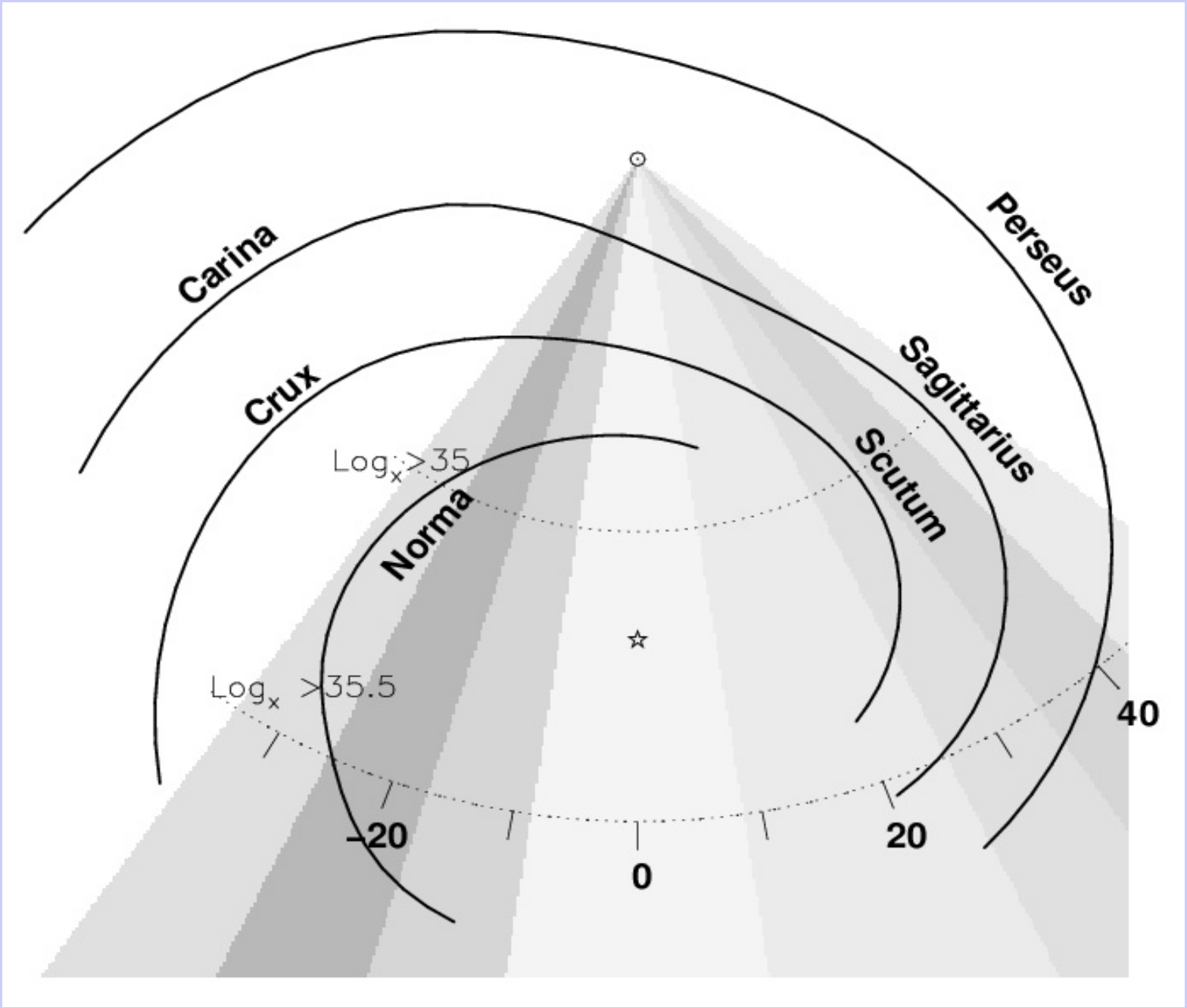
Angular distribution of HMXB and LMXB in the inner part of Galaxy



HMXB distribution



Spatial bin is 8.5x10 deg,
The gray scale -> change of the HMXB density (1-7)
HMXB peaked away of the Galactic Center and concentrated to the spiral arms, but not one-to one. Why?


Perseus
Carina
Crux
Sagittarius
Scutum
Norma
Log$_x$>35
Log$_x$ >35.5
−20
0
20
40

Active HMXB - few Myr to 20-30 Myr from the beginning of the star formation (SF).

Current SF regions ~ do not have HMXBs.

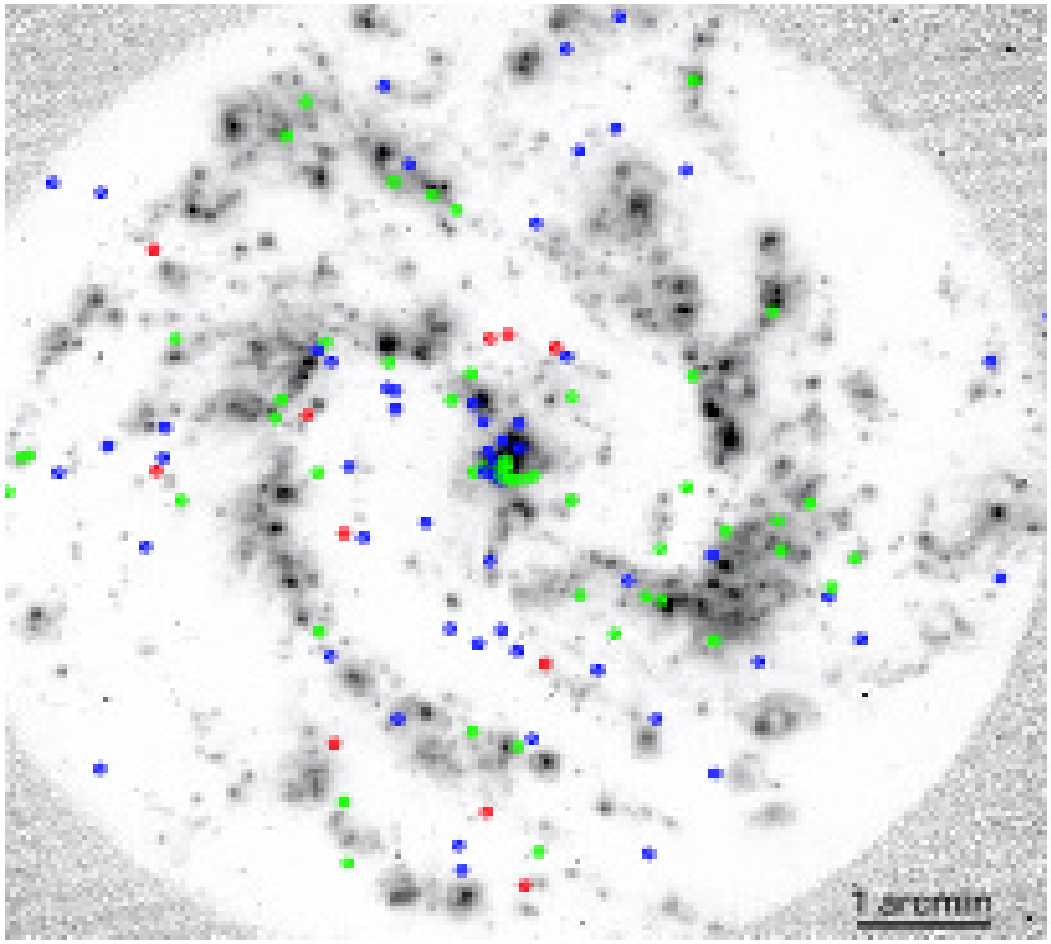
Examples:

1) molecular clouds (Feigelson et al. 2003, Nakajima et al. 2003**);**

2) LMC, there is a time delay about (1-2)x10^7 yr between epoch of the initial SF and epoch of HMXB (Shtykovskiy & Gilfanov 2004**);**

3) M83.

M83 (H_a image, CHANDRA)



- – supersoft sources (no correlation with HII regions)
- – soft sources, probably SNRs (mostly found in regions with high H_a)
- – XRB

(Soria & Wu, 2003)

Spiral arms = spiral density waves = enhanced SF

Spiral arm pattern moves :
~20 Gyr^{-1} to ~60 Gyr^{-1} (Bissantz et al. 2003)
Innermost part of arms (~3.4 kpc) and the bar corotates with stars (Bissantz et al. 2003)

Current positions of arms are displaced with the respect to the density maxima in the HMXB distribution. We need ~40° rotation of the spiral arms pattern.

Time delay ~10-12 Myr

Conclusions

New sample of HMXB in the inner part of the Galaxy is much larger than previous, reasons – we revealed a considerable part of the absorbed sources;

Majority of HMXB are significantly photoabsorbed;

Most of HMXBs – X-ray pulsars;

HMXB are concenrated towards spiral arms, but not one-to-one; reason – the dependence of number of HMXB on the age of the stellar population; the current maxima are observed where the SF was taking place ~10-12 Myr ago;

Continuation of observations is needed to increase the statistical significance of the observed displacement of HMXB