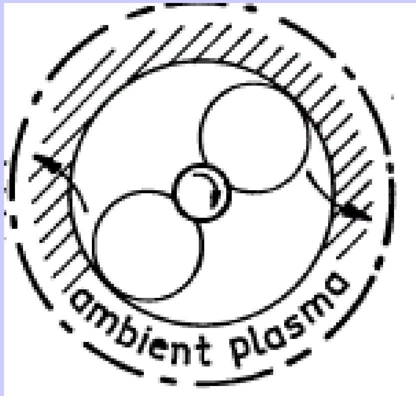
High-mass X-ray binary systems through the eyes of INTEGRAL

Lutovinov A.

Walter, Lutovinov, Bozzo, Tsygankov AAR, 23, 2 (2015)

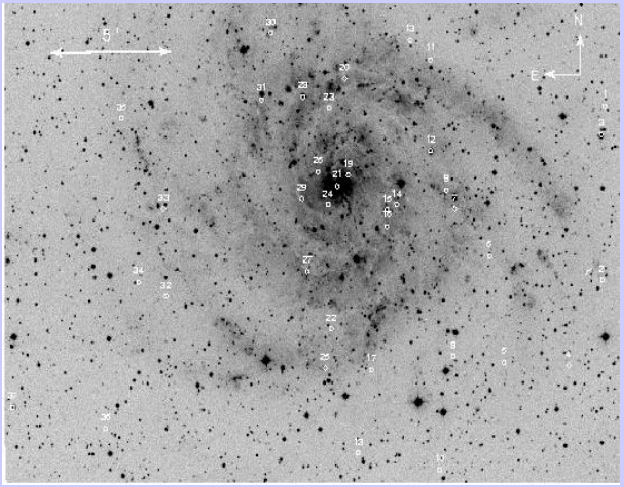
Understanding of HMXB population:

1) Properties of compact objects (NS magn. field, magnetosphere interactions, spin period, etc)



2) Formation and evolution of binaries, spatial distribution, luminosity function

3) Application for cosmological surveys (distant galaxies, contribution of HMXBs to observed X-ray luminosities)



Nature of a vast majority of XRBs in other galaxies are unknown. Only investigations in our Galaxy can help to answer to above questions about XRBs.

It is not possible to trace the "history" of one system, it is needed to study the population as a whole.

Surveys with the high coverage, sensitivity, completeness of the detection and identifications are required.

ROSAT, ASCA, Chandra, XMM-Newton, ASM/RXTE have limitations.

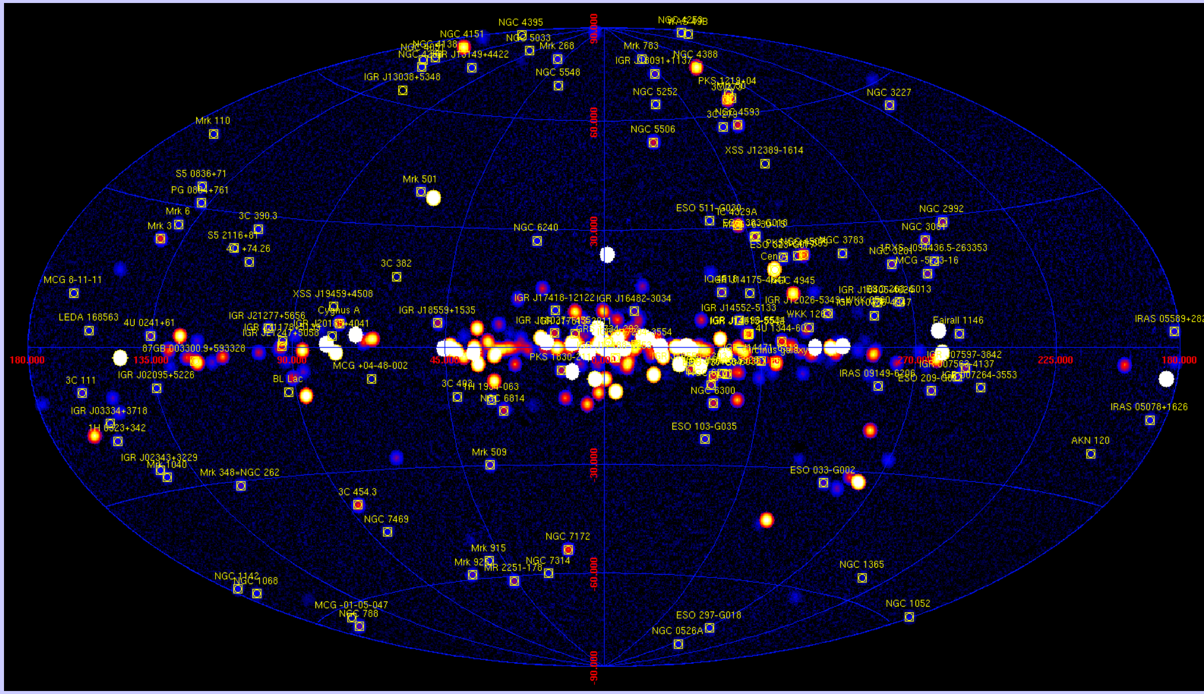
INTEGRAL or Swift have certain advantages

INTEGRAL/IBIS
All-sky survey

(Krivonos et. al., 2010, current state)

~830 detections (42% IGRs):

- ~50% Galactic (45% IGRs)
- ~40% ExtraGal.
- ~10% Unident.

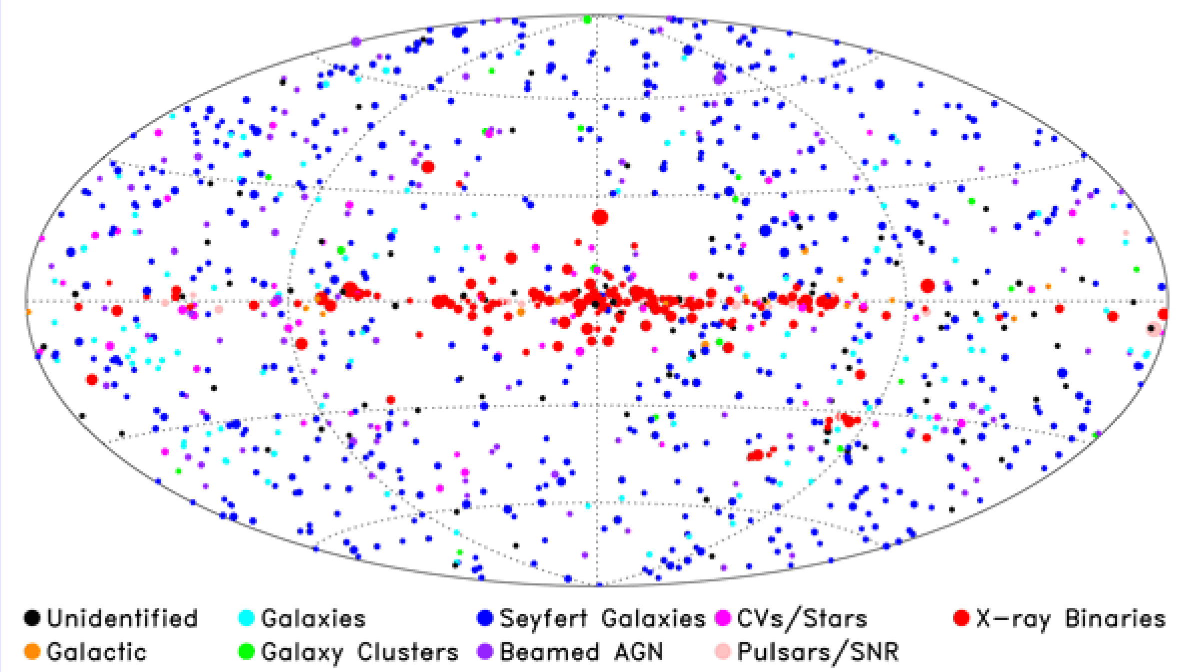


SWIFT/BAT 70 m all-sky survey

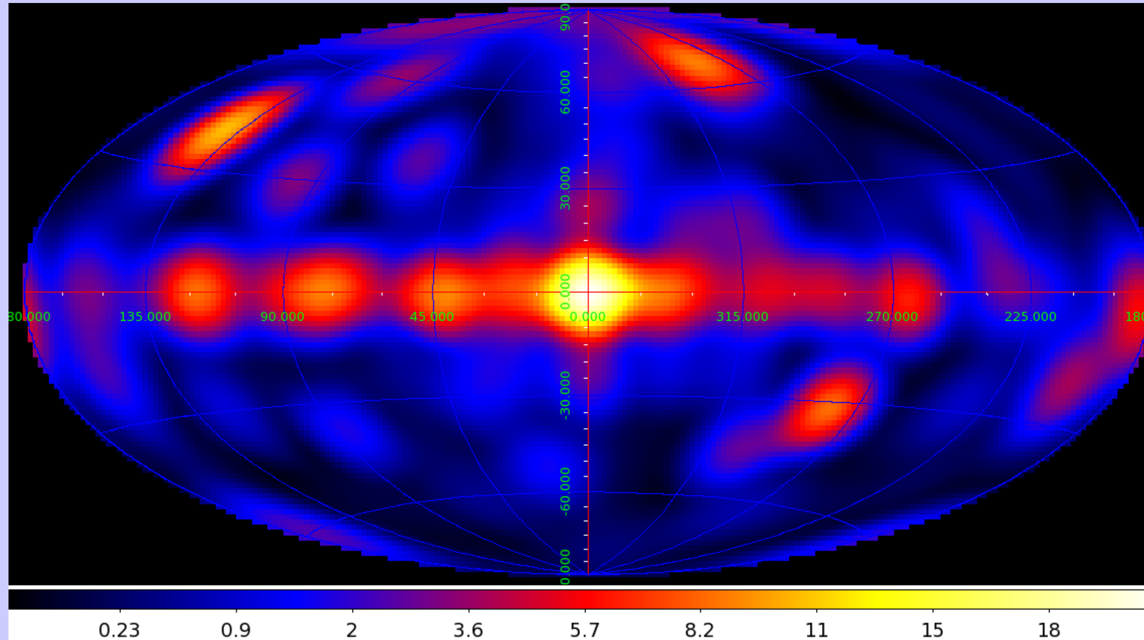
(Baumgartnet et al., 2013)

~1200 detections:

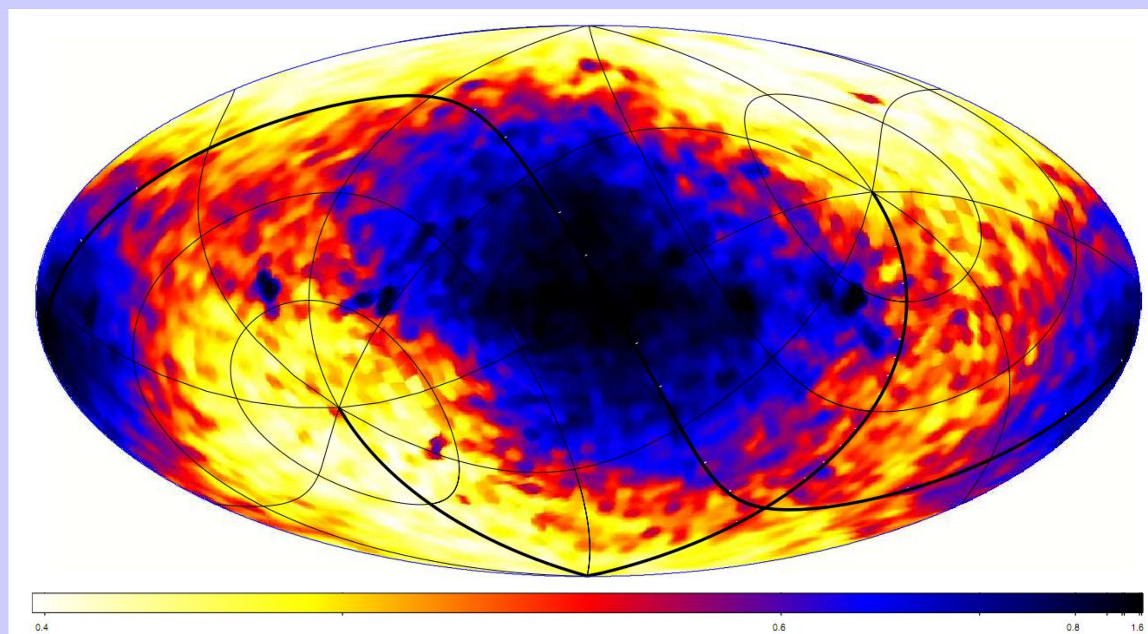
- ~21% Galactic
- ~60% ExtraGal.
- ~ 19% Unident.



INTEGRAL/IBIS
exposure map



SWIFT/BAT
sensitivity map:

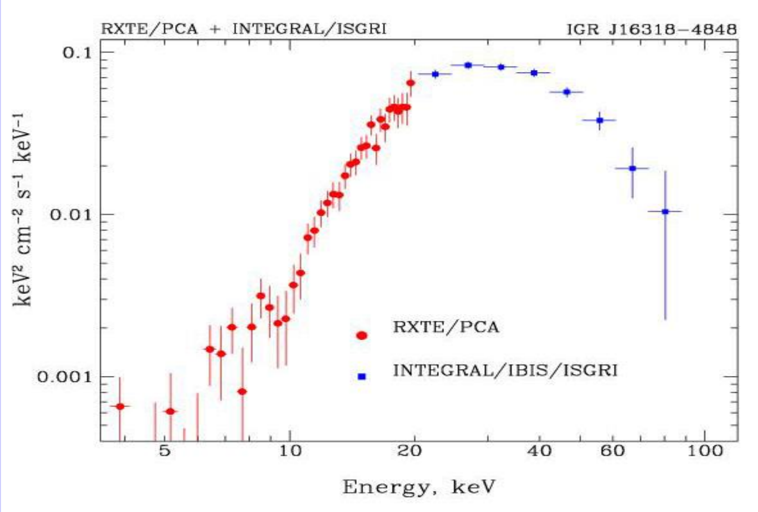


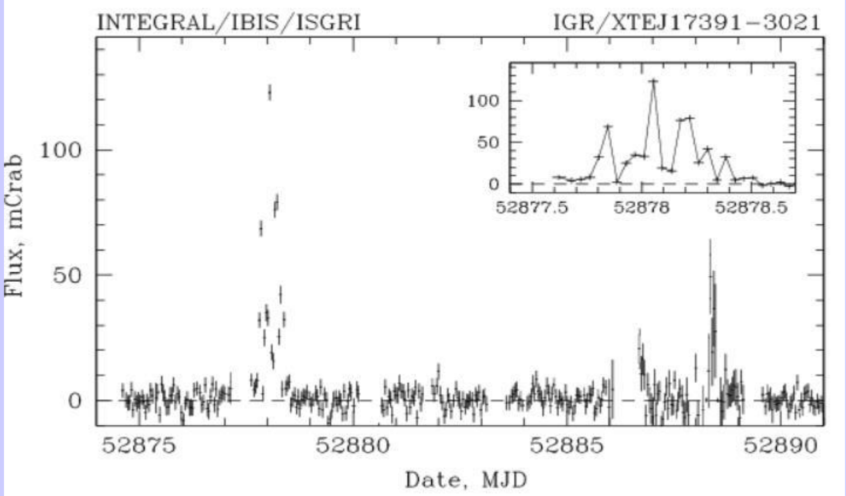
Highlights of INTEGRAL in the Galaxy

Discovery more than hundred new sources

New population of HMXBs

Heavily absorbed systems Supergiant fast X-ray transients





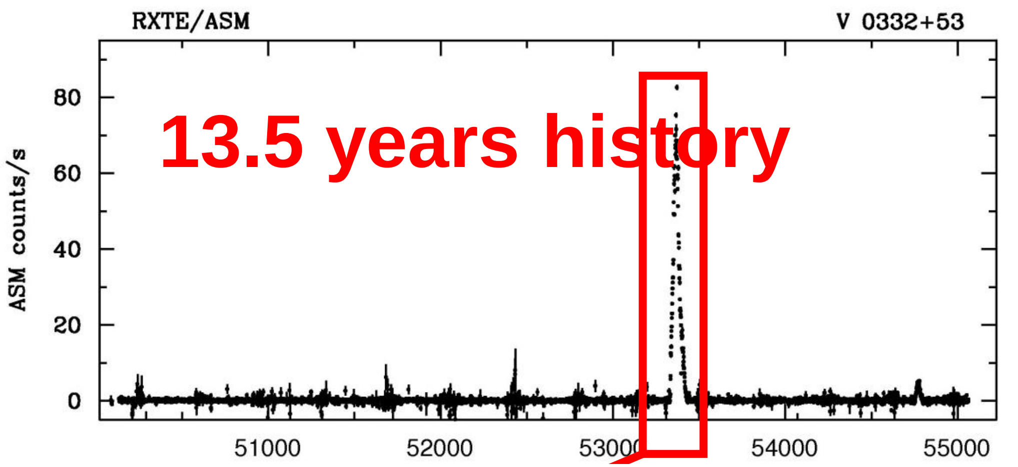
Broadband spectroscopy of XRBs

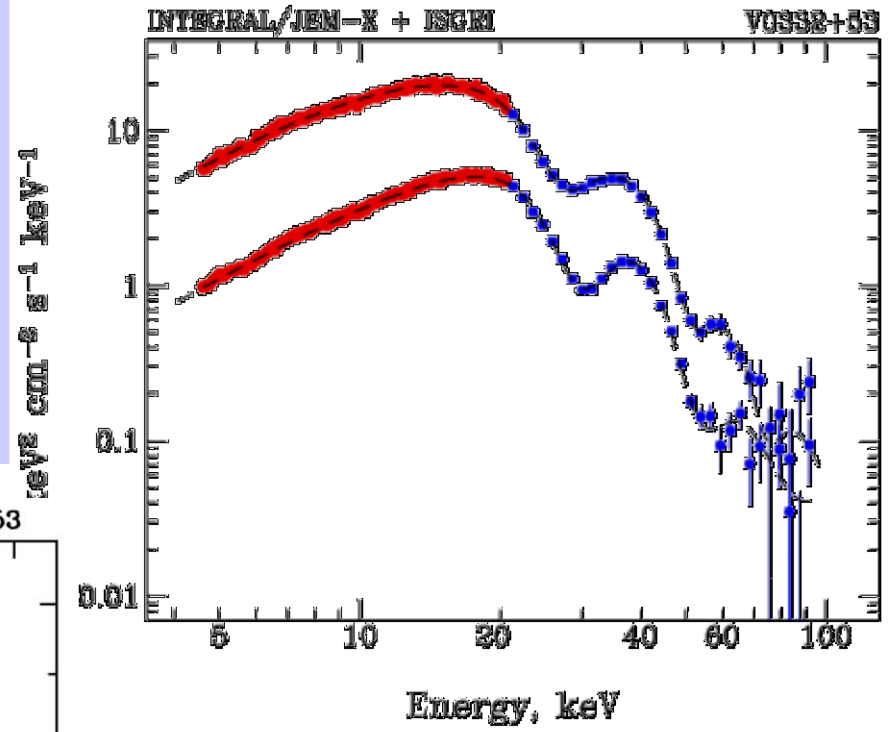
Discovery and detailed study cyclotron lines

Long term studies of accreting black holes

Populations study of XRBs

V0332+53 – natural laboratory





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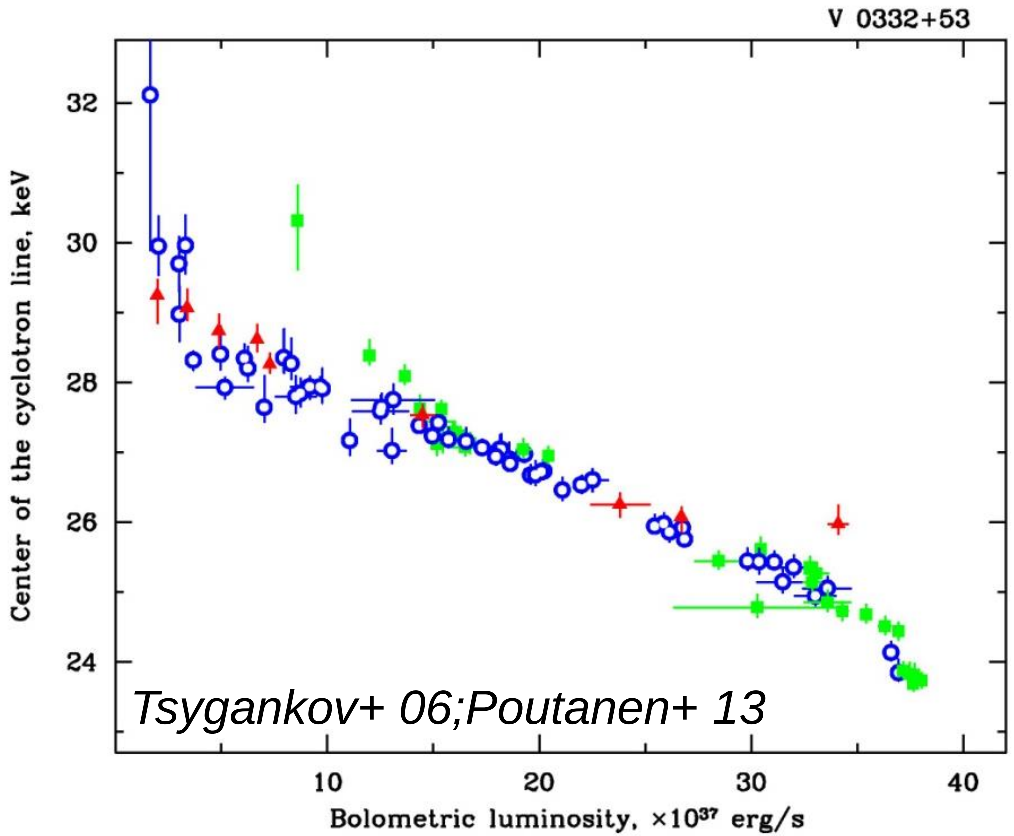


High state

α = -0.09+/-0.01

E_{cut} = 9.15+/-0.03 кэВ

E_{cyc1} = 26.21+/-0.15 кэВ

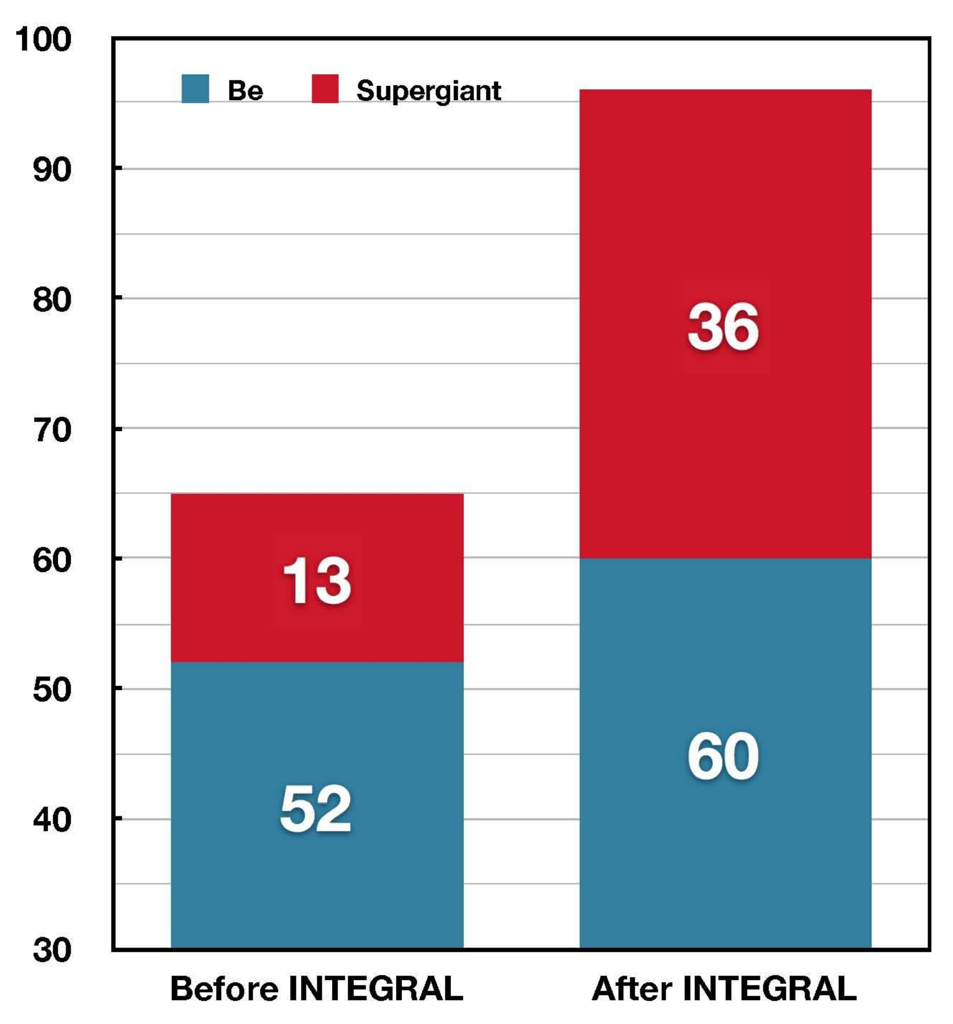
E_{cyc2} = 50.66+/-0.30 кэВ

E_{cyc3} = 73.8+/-1.8 кэВ

$E_{cyc1}/E_{cyc2}/E_{cyc3}$= 1/1.93/2.82

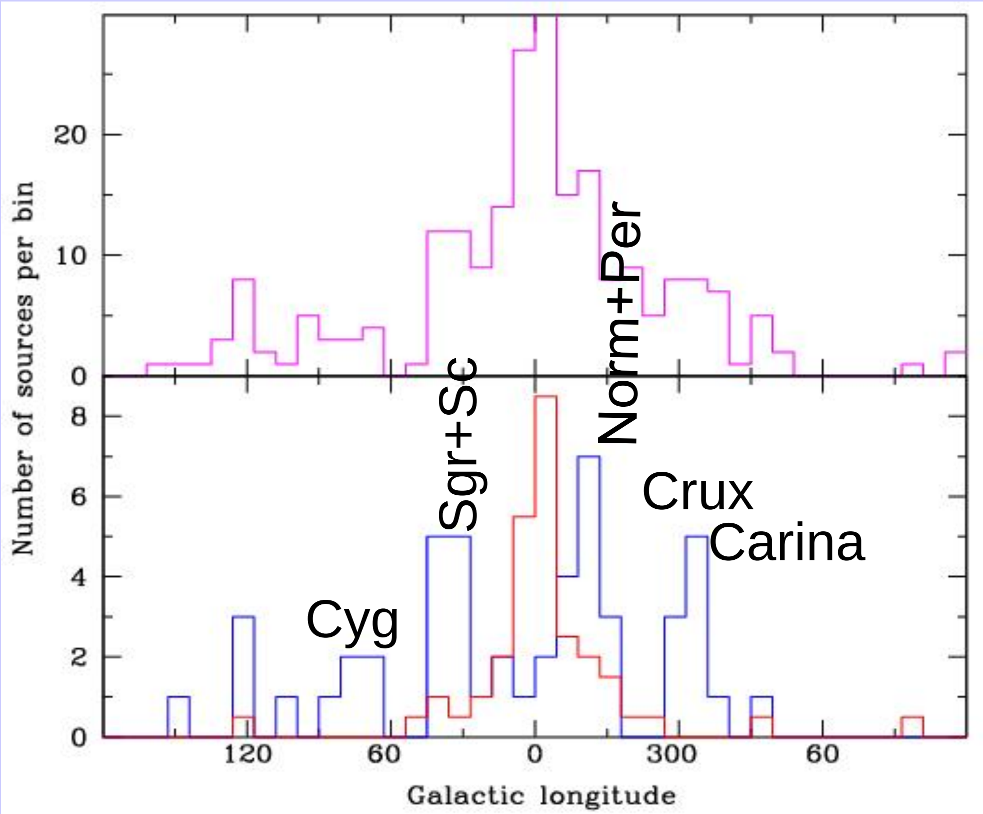
Kreykenbohm et al. 2005

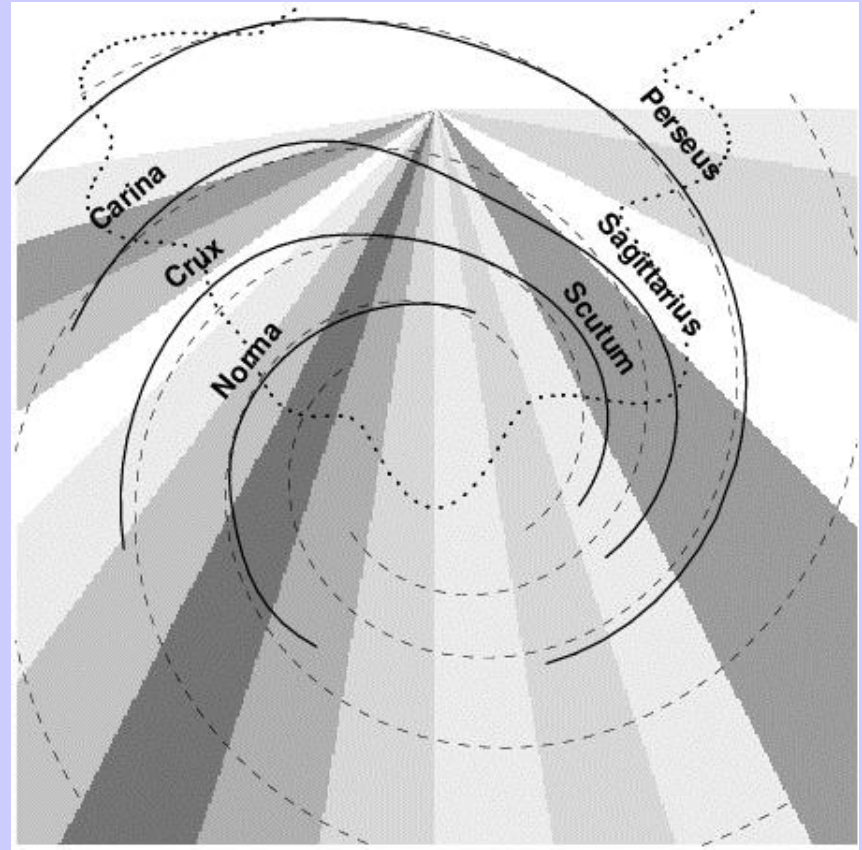
Number of known HMXBs is increased significantly
Population study at new level



Walter et al. 2015

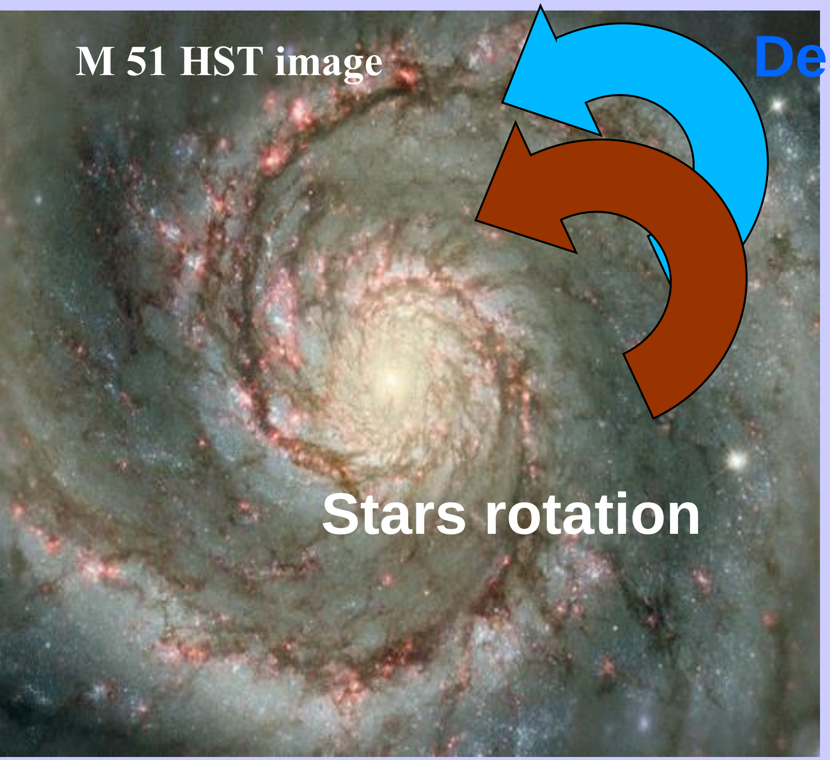
HMXBs distribution (face-on view)

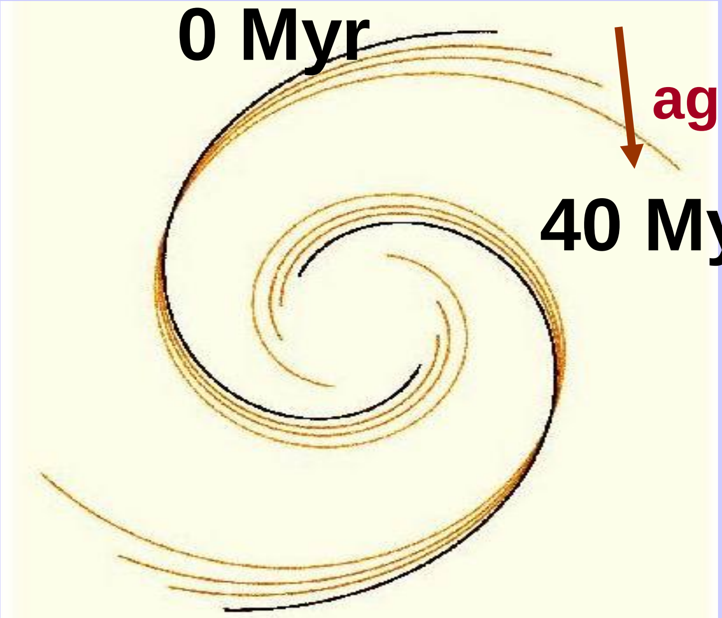




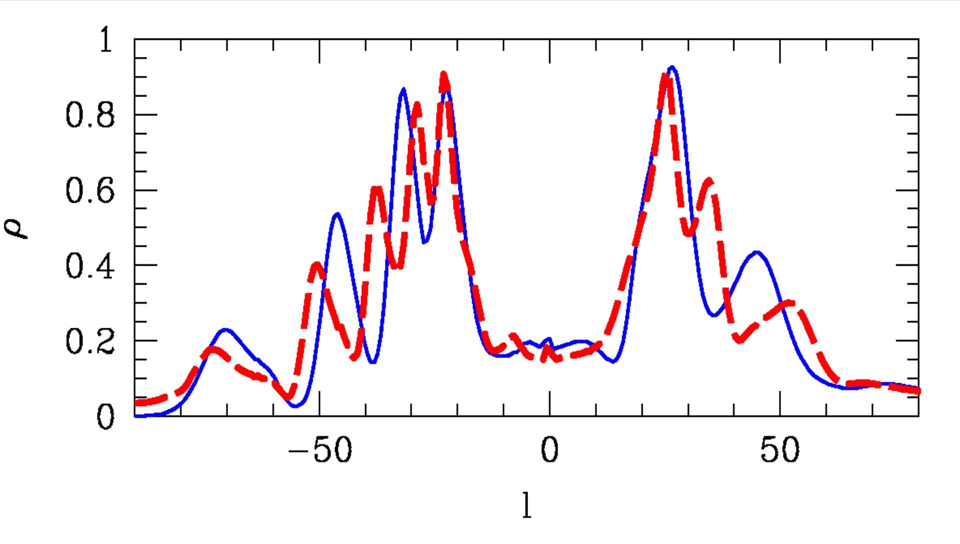
Lutovinov et al. (2005, 2007)

HMXB peaked away of the Galactic Center and concentrated towards the spiral arms, but not one-to one. Possible reasons: Active HMXBs – few Myr to 20-30 Myr -> current SF regions are displaced in a relation to HMXBs due to different angular velocities of stars and spiral arm structure**!**





$$\Delta\Theta = (\Omega(r) - \Omega_p)\tau$$

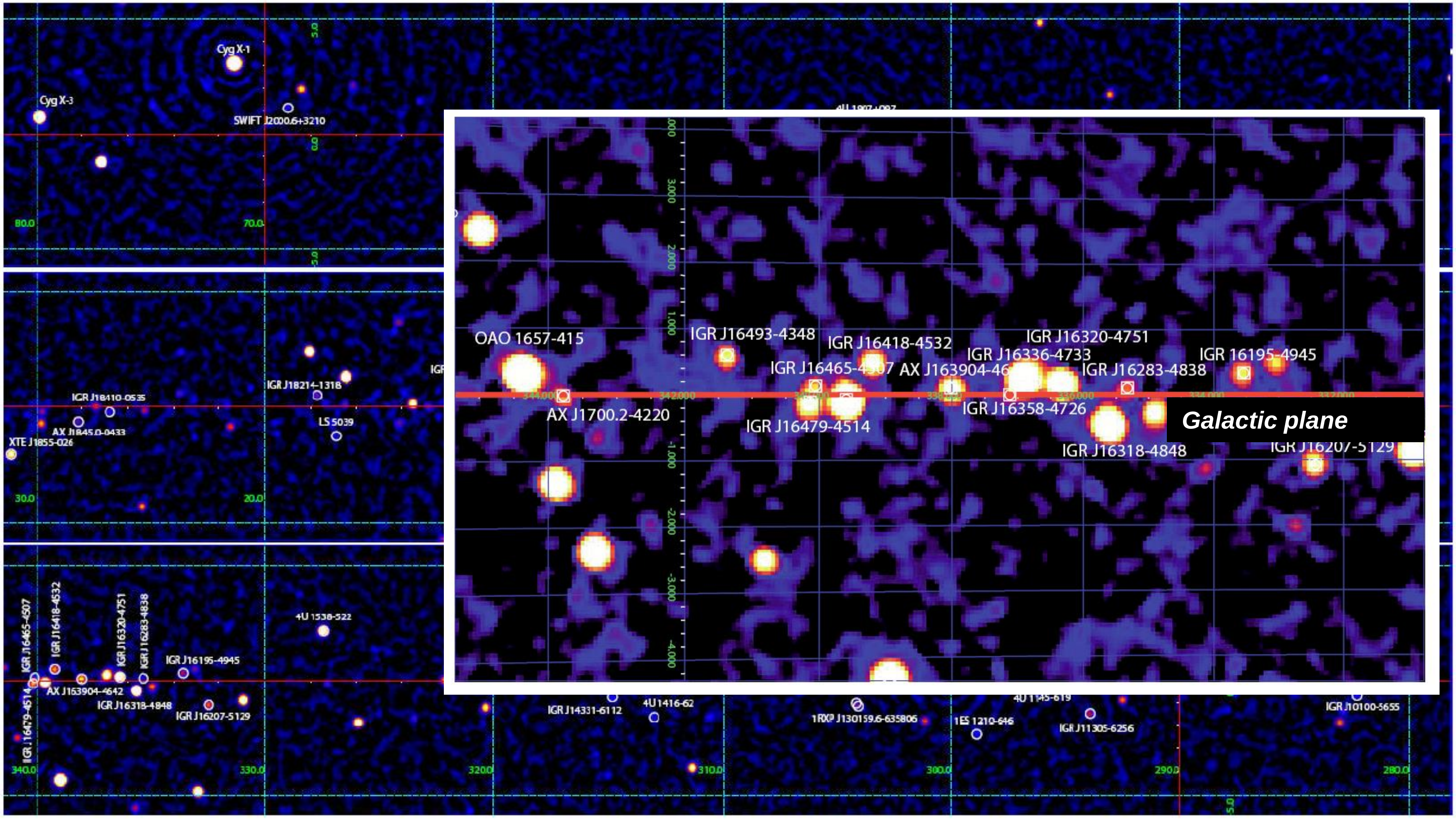


Young systems

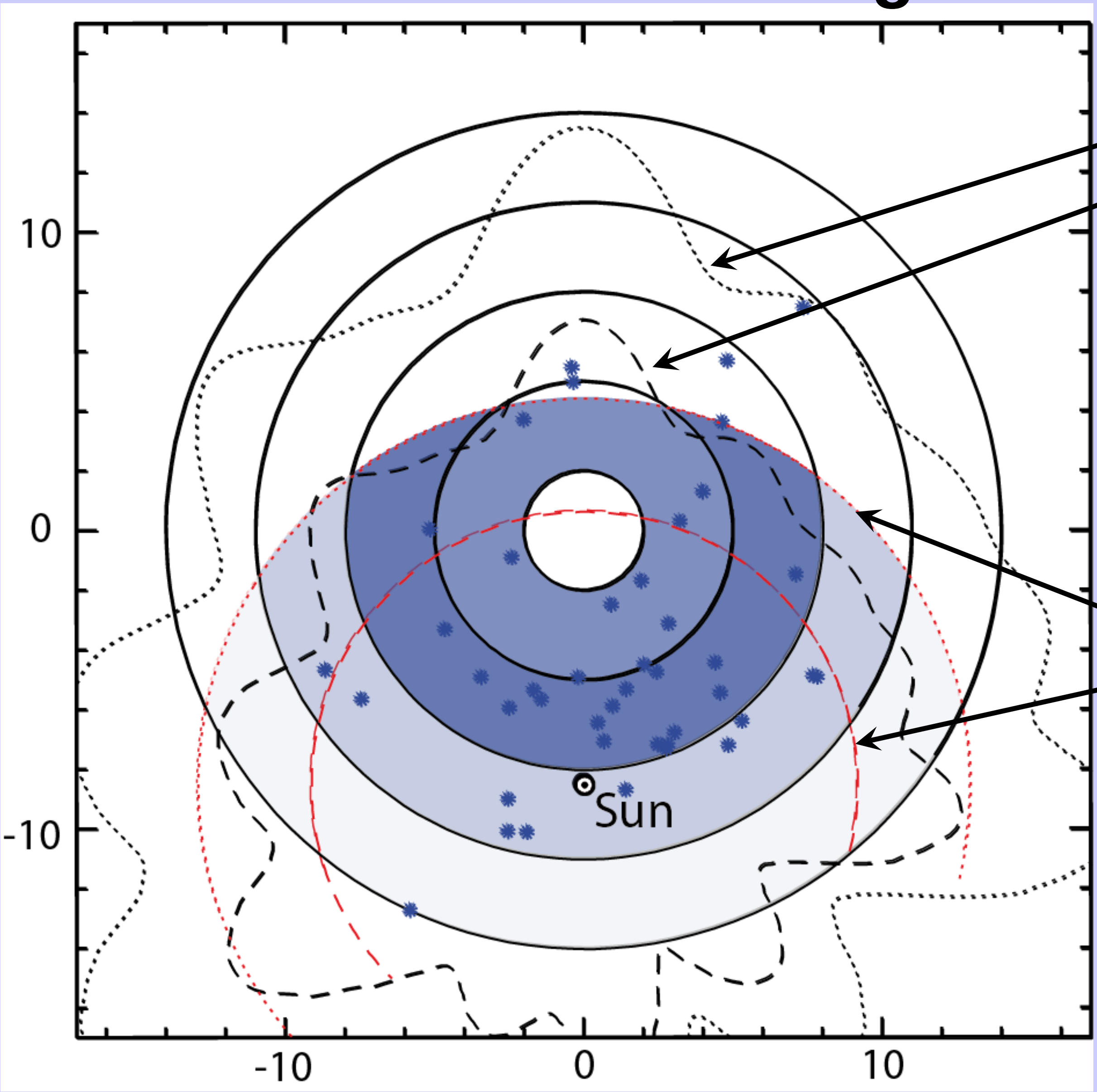
40 Myr

Shtykovskiy & Gilfanov 2007

HMXBs in the Galaxy



INTEGRAL view through the whole Galaxy



Real sensitivity:

$2x10^{35}$ erg/s

10^{35} erg/s

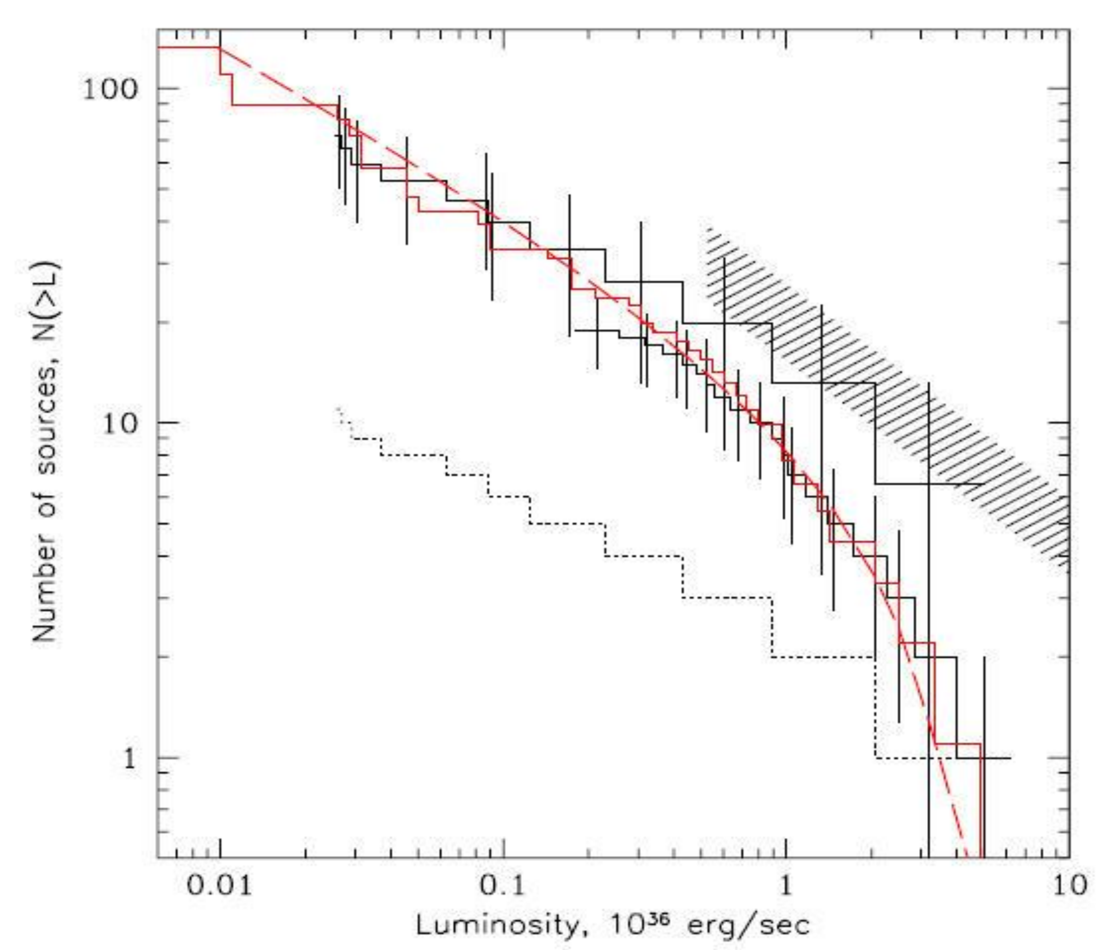
Limited flux
0.7 mCrab
(10^{-11} erg/s/cm^{2})

$2x10^{35}$ erg/s

10^{35} erg/s

The Galaxy was divided into 5 rings
0-2,2-5,5-8,
8-11 and 11-14 kpc

Key tasks: 1) LF and 2) Surface density



Luminosity function

> 2x10[35] erg/s completeness 13 kpc

$$\gamma_{\text{bright}} = 2.0 \pm 0.3$$

> 2x10[34] erg/s completeness 4.1 kpc

$$\gamma_{\text{faint}} = 1.49 \pm 0.21$$

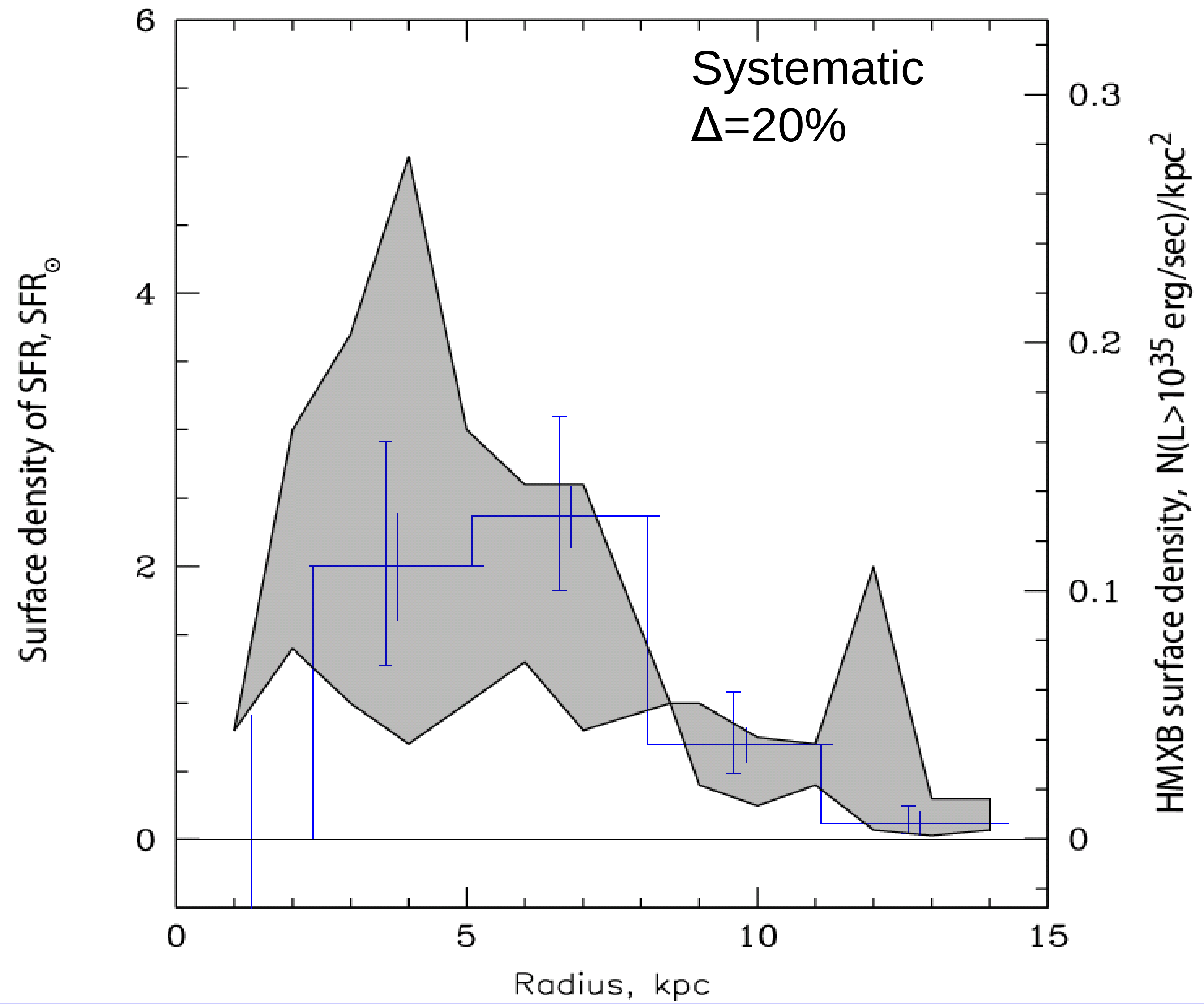
$$\frac{dN}{dL} = \begin{cases} A_j (L/L_*)^{-\alpha_1} & \text{if } L < L_* \\ A_j (L/L_*)^{-\alpha_2} & \text{if } L > L_* \end{cases}$$

$$C = 2 \sum_j \left(\int \phi(L) S_{\max,j}(L) dL - \sum_{i=1}^{N_j} \ln\left[\phi(L_{i,j}) S_{\max,j}(L_{i,j})\right] \right)$$

$$\phi(L) = dN/dL$$

Cash (1979)

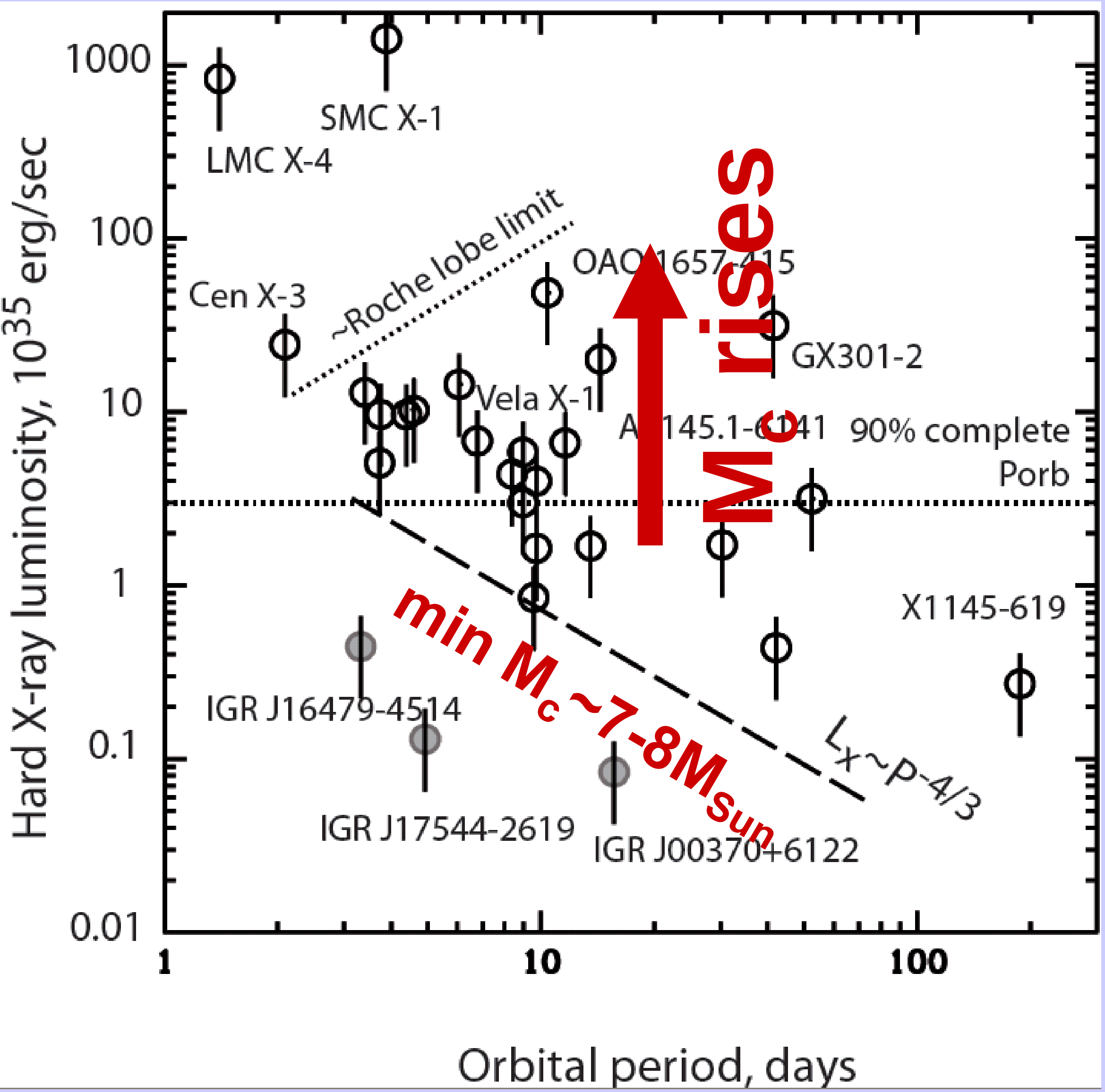
Density distribution of the HMXBs vs SFR



$N \approx 5 \times 10^{-2}\ SFR/SFR_{\odot}$

Guesten & Mezger 1982; Lyne, Manchester, & Taylor 1985; Chiappini, Matteucci, & Romano 2001

Formation and evolution



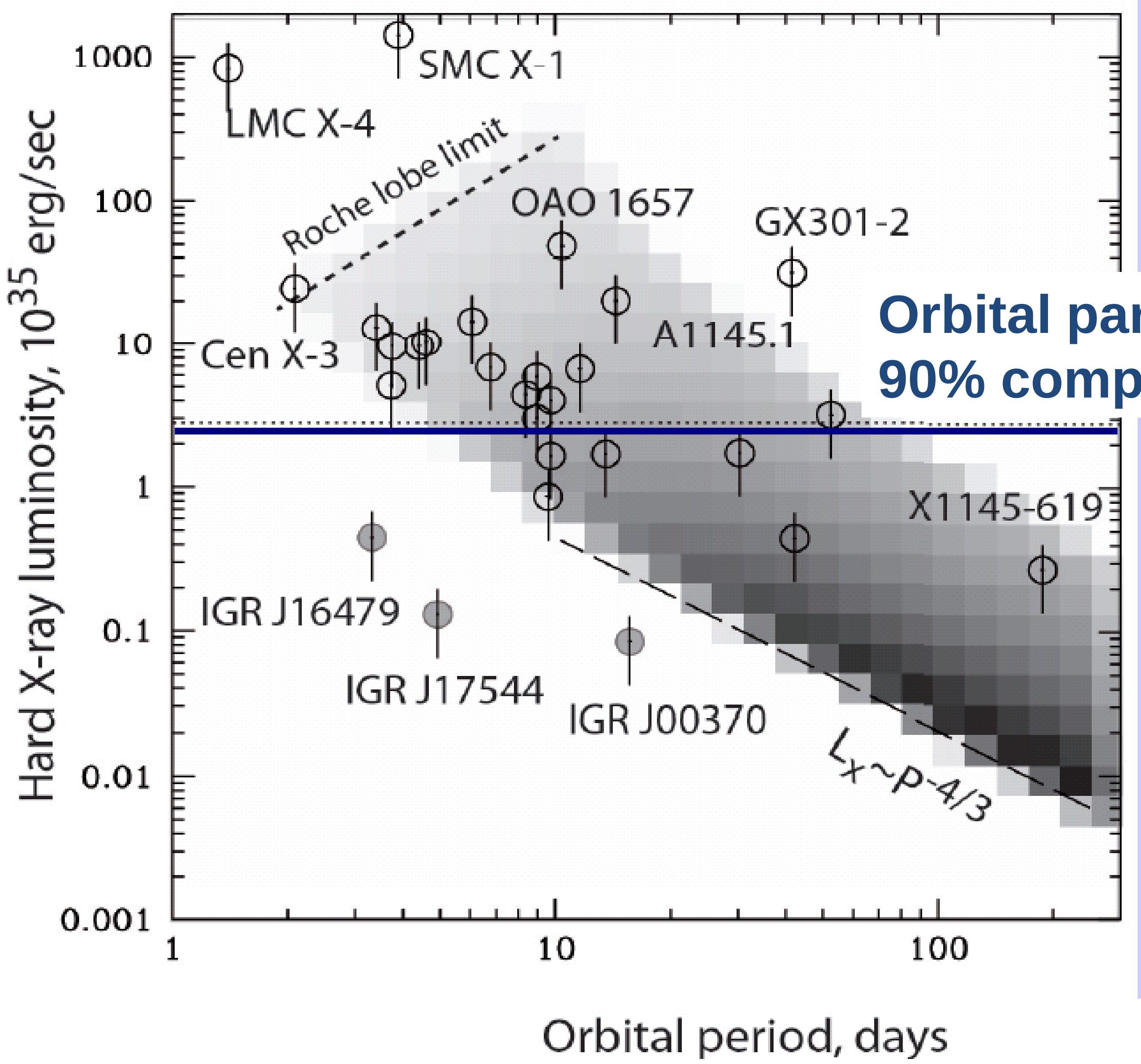
Our statistically complete flux-limited sample provides clues –

what determines the HMXB population

1)P_{orb} distribution
2)M_c distribution

$dN/dM_c \sim M_c^{-2.35}$ (Salpeter)

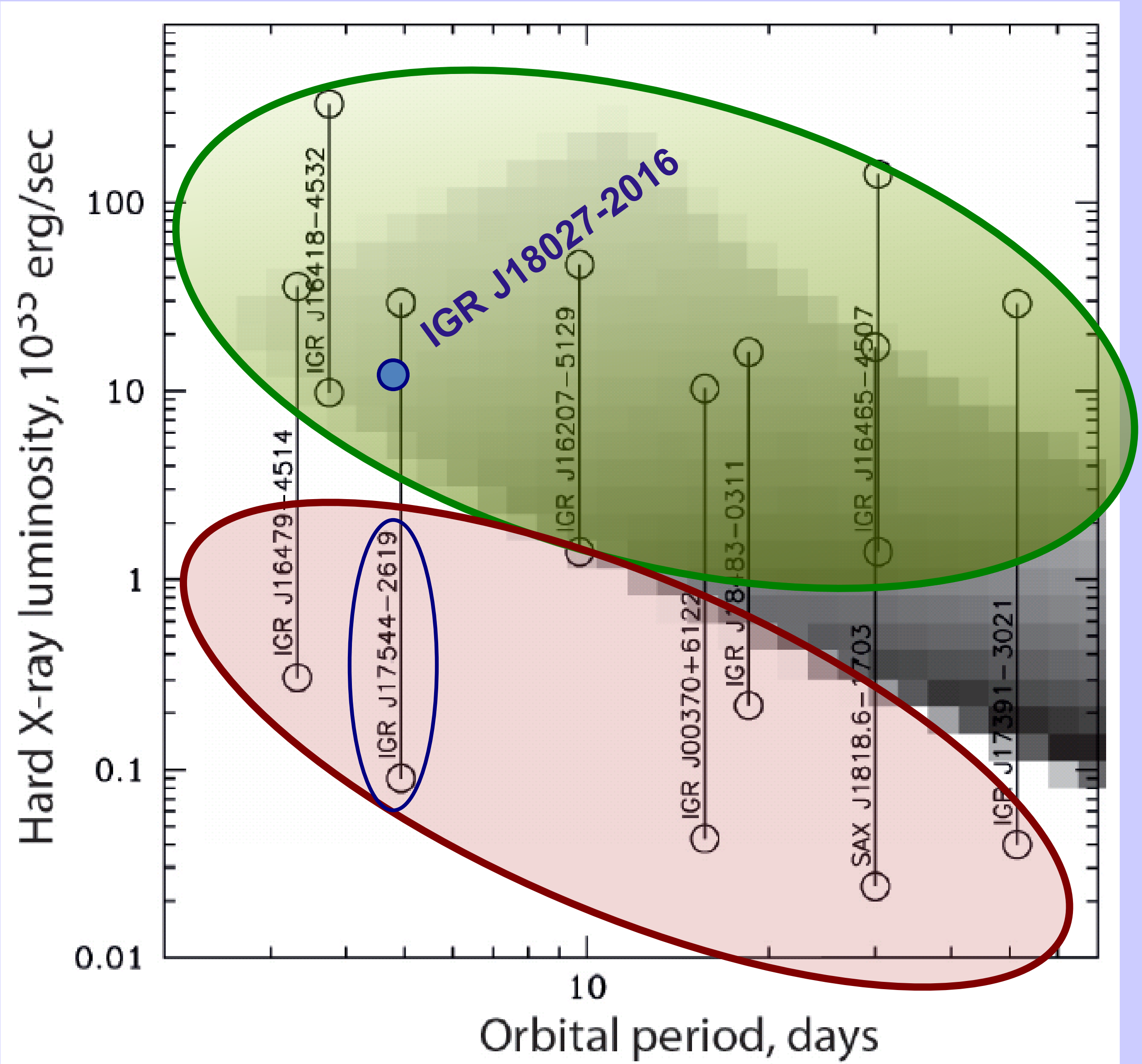
$dN/d\log P = const$ *(Bhattacharia, Ghosh, 2012)*



Orbital parameters
90% completeness

Lutovinov et al. (2013)

SFXT (outbursts mechanisms)



Clumpy wind

(Walter et al. 2006, Sidoli et al. 2011)

Inhibition of the accretion

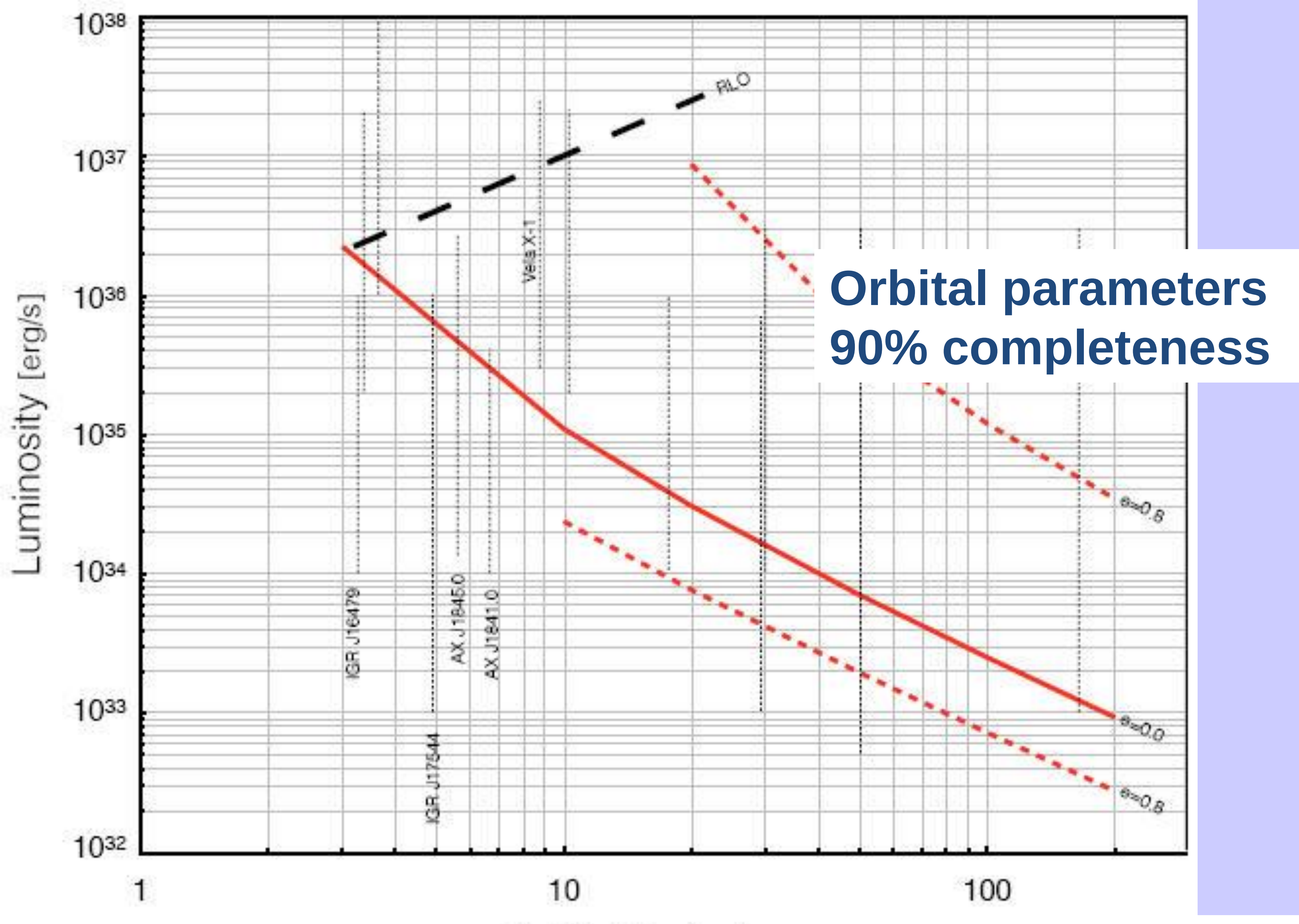
(Grebenev & Sunyaev 2007, Bozzo et al. 2008)

Flaring activity due to transition from (stable) radiative cooling to (unstable) Compton cooling *(Shakura et al. 2013, 2014)*

see talk P.Romano!

$dN/dM_c \sim M_c^{-2.35}$ (Salpeter)

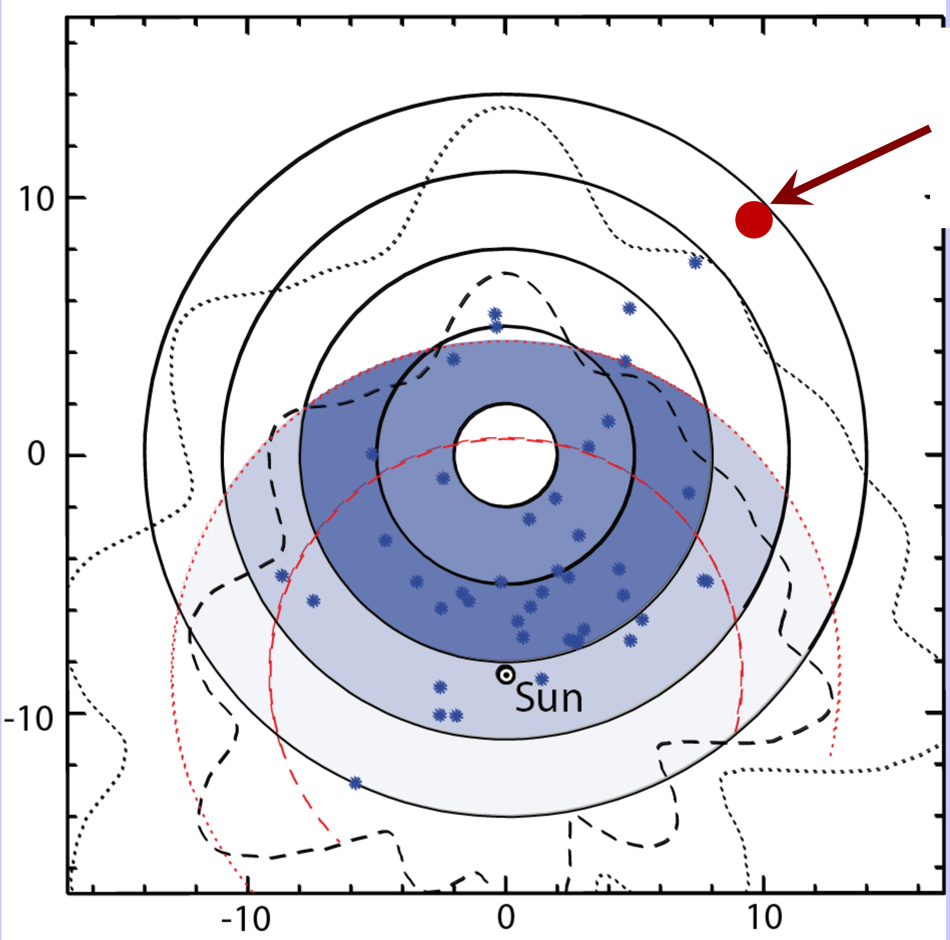
$dN/d\log P = const$ *(Bhattacharia, Ghosh, 2012)*



Walter et al. (2015)

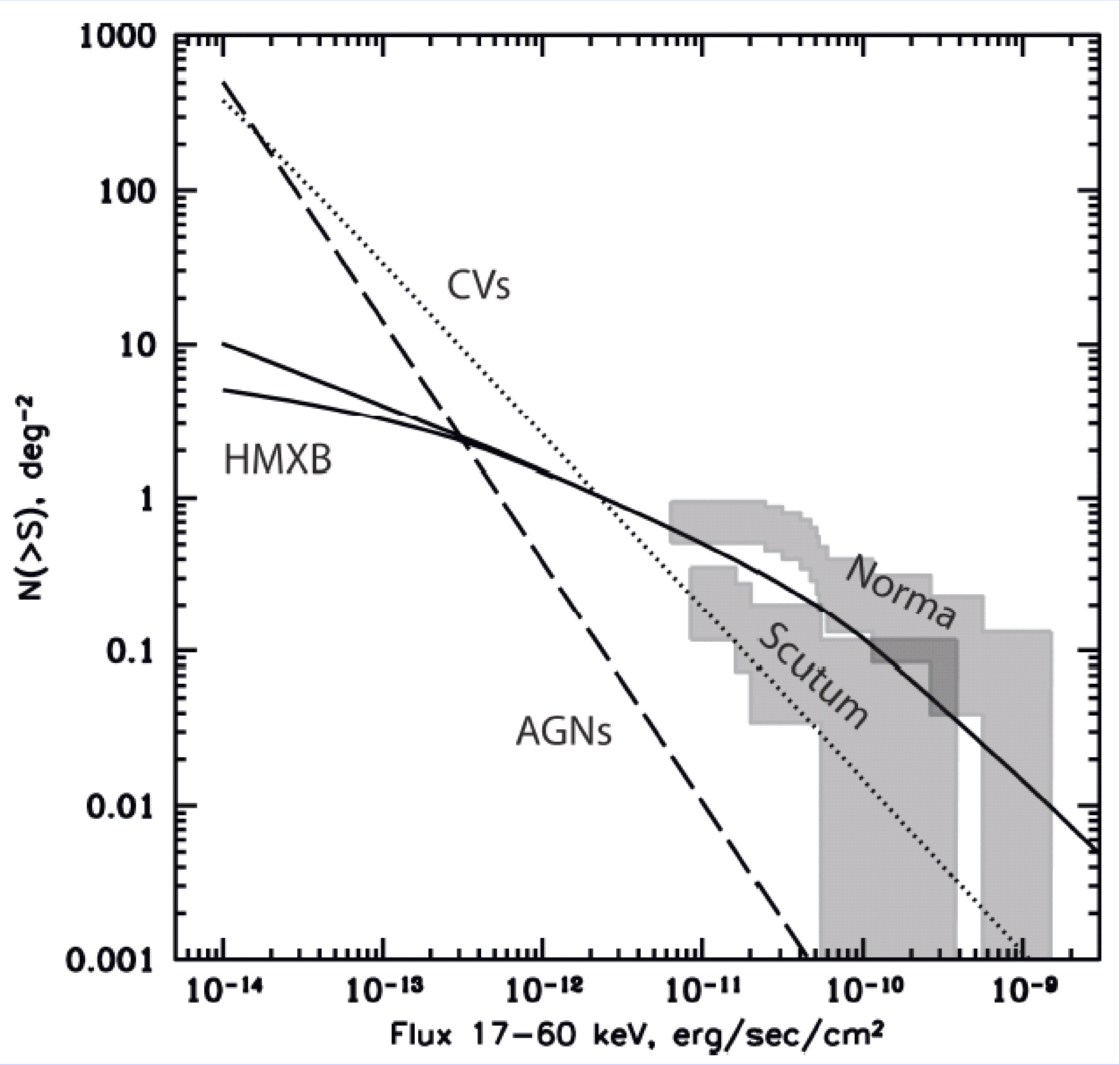
Open issues

- Determination of distances to HMXBs candidates in further part of the Galaxy
- Search for HMXBs in the Galactic bulge
- Total number of HMXBs in the Galaxy



2S1553-542, d≈20 kpc
Tsygankov+ 15,
Lutovinov+ 15

Number of HMXBs in Galaxy, predictions



Number of HMXBs, Norma Arm Survey by Chandra

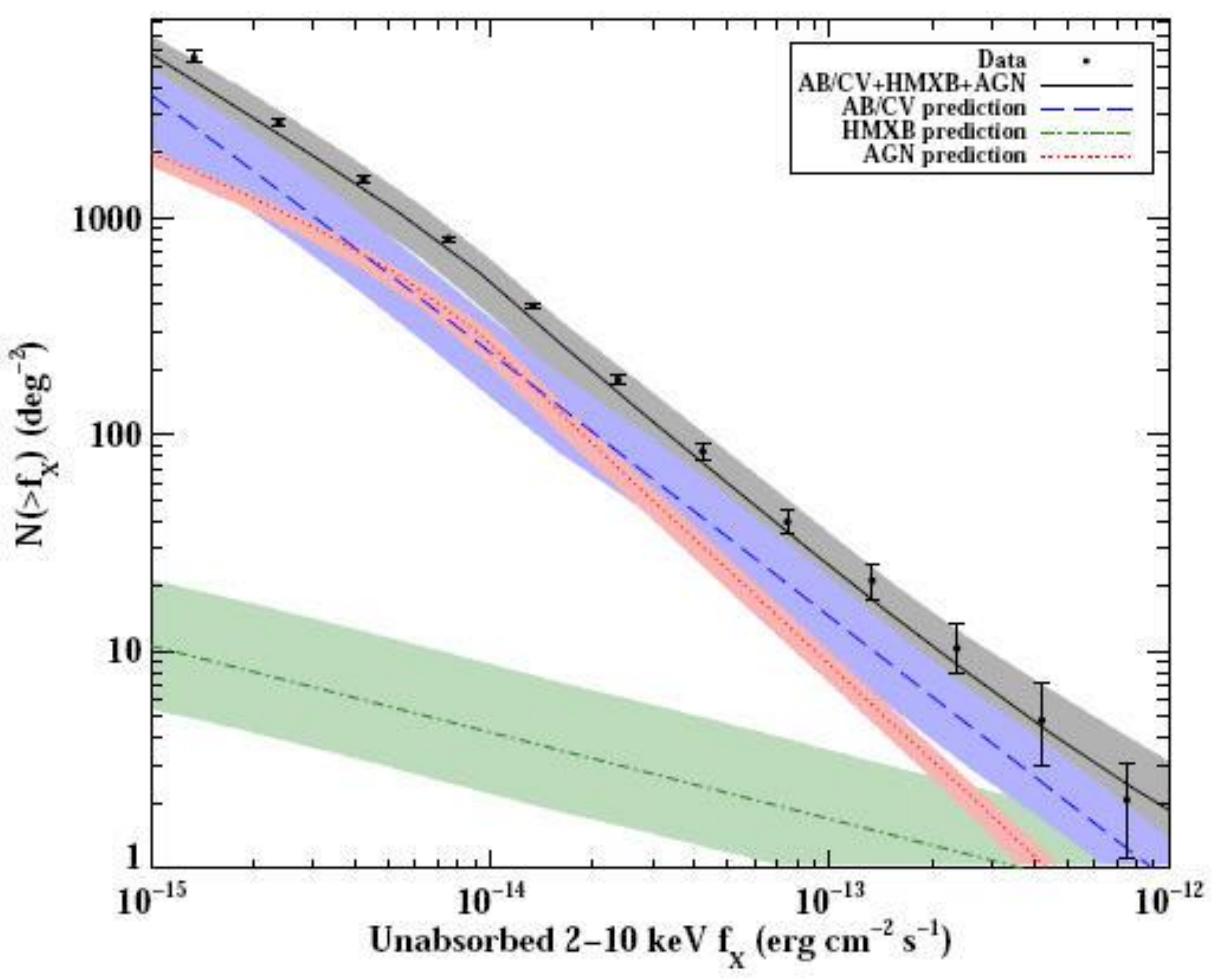
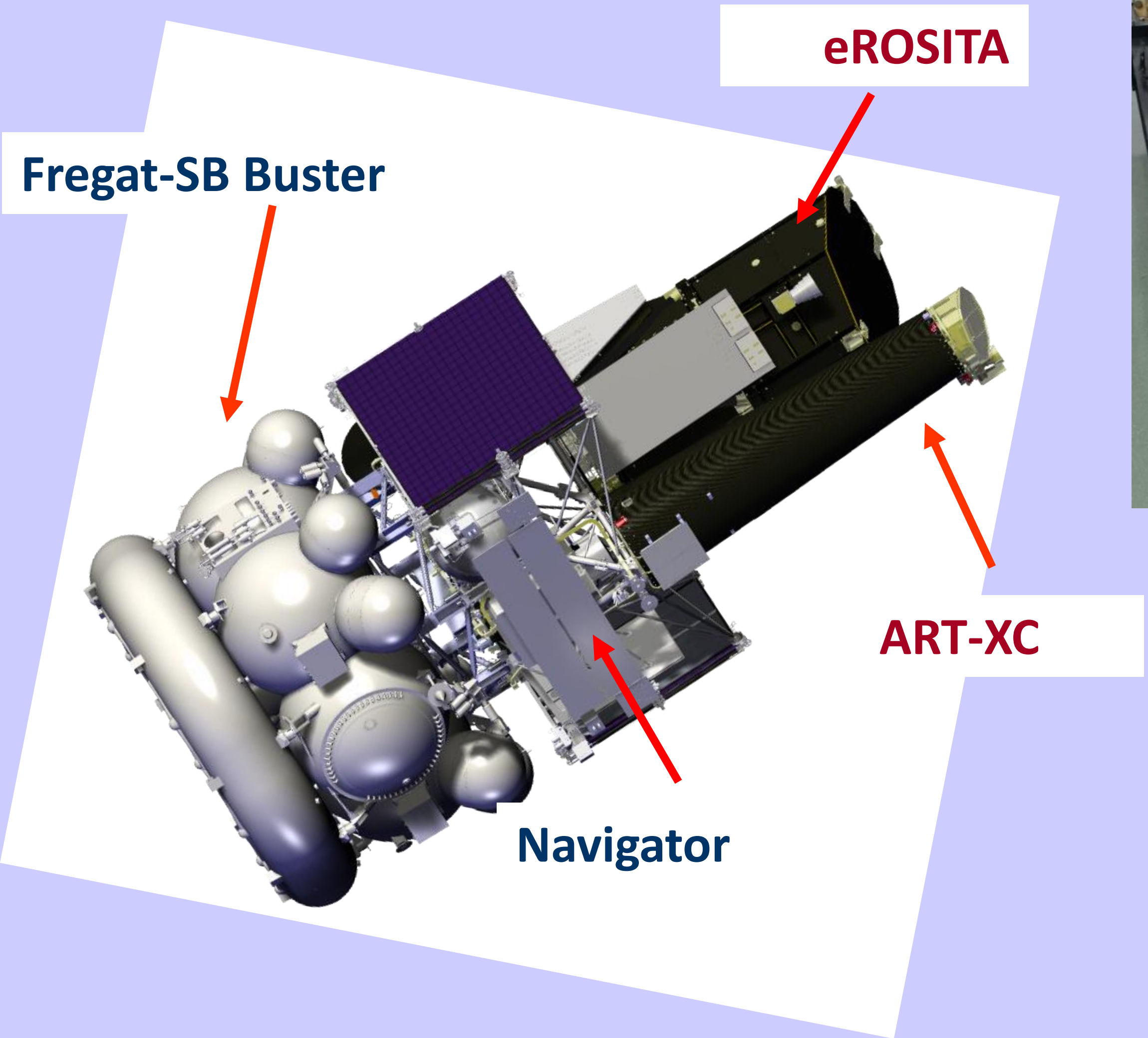
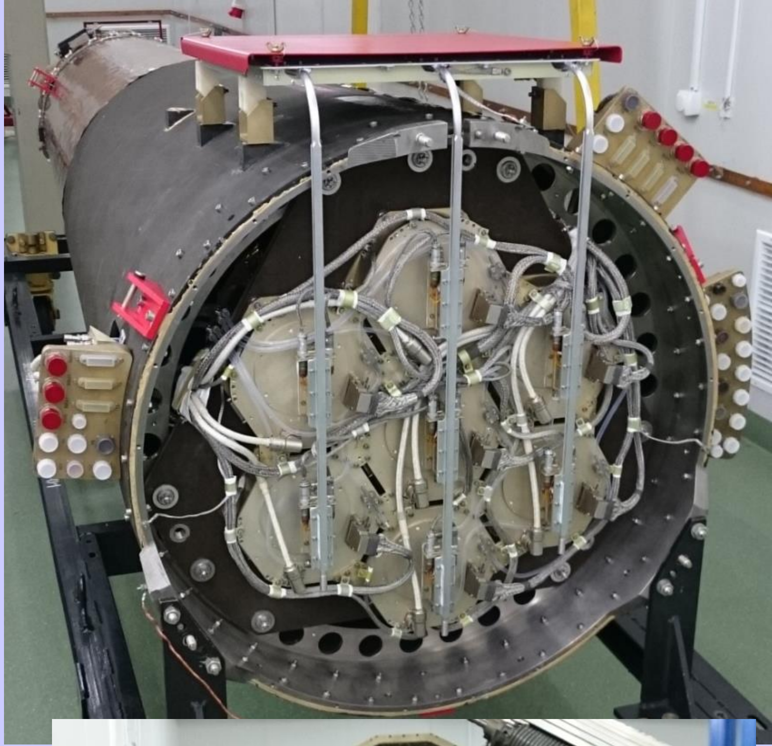


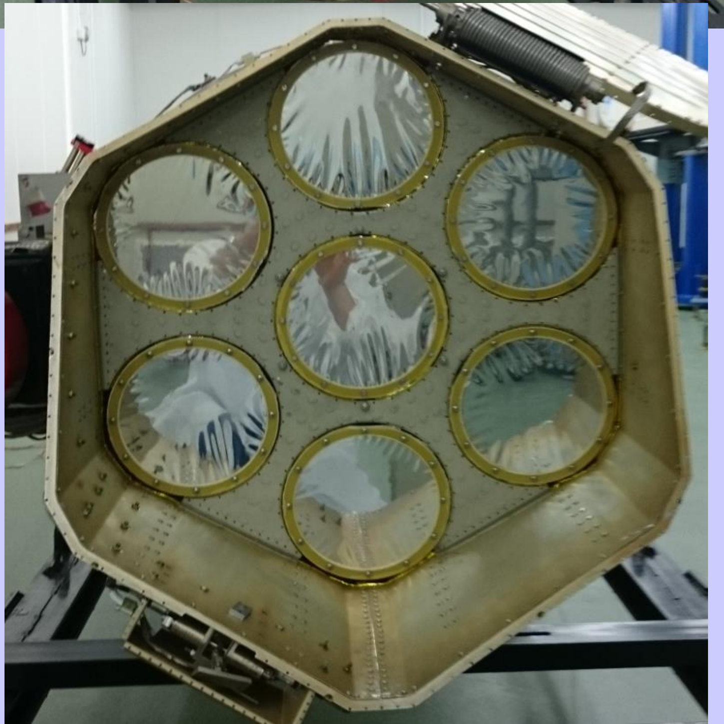
Figure 19. The observed number-flux distribution compared to the combined estimates of the expected AB/CV, HMXB, and AGN flux distributions based on the luminosity functions of these populations from other surveys. Esti-

Fornasini et al. 2014

Future surveys. Spectrum-Rentgen-Gamma

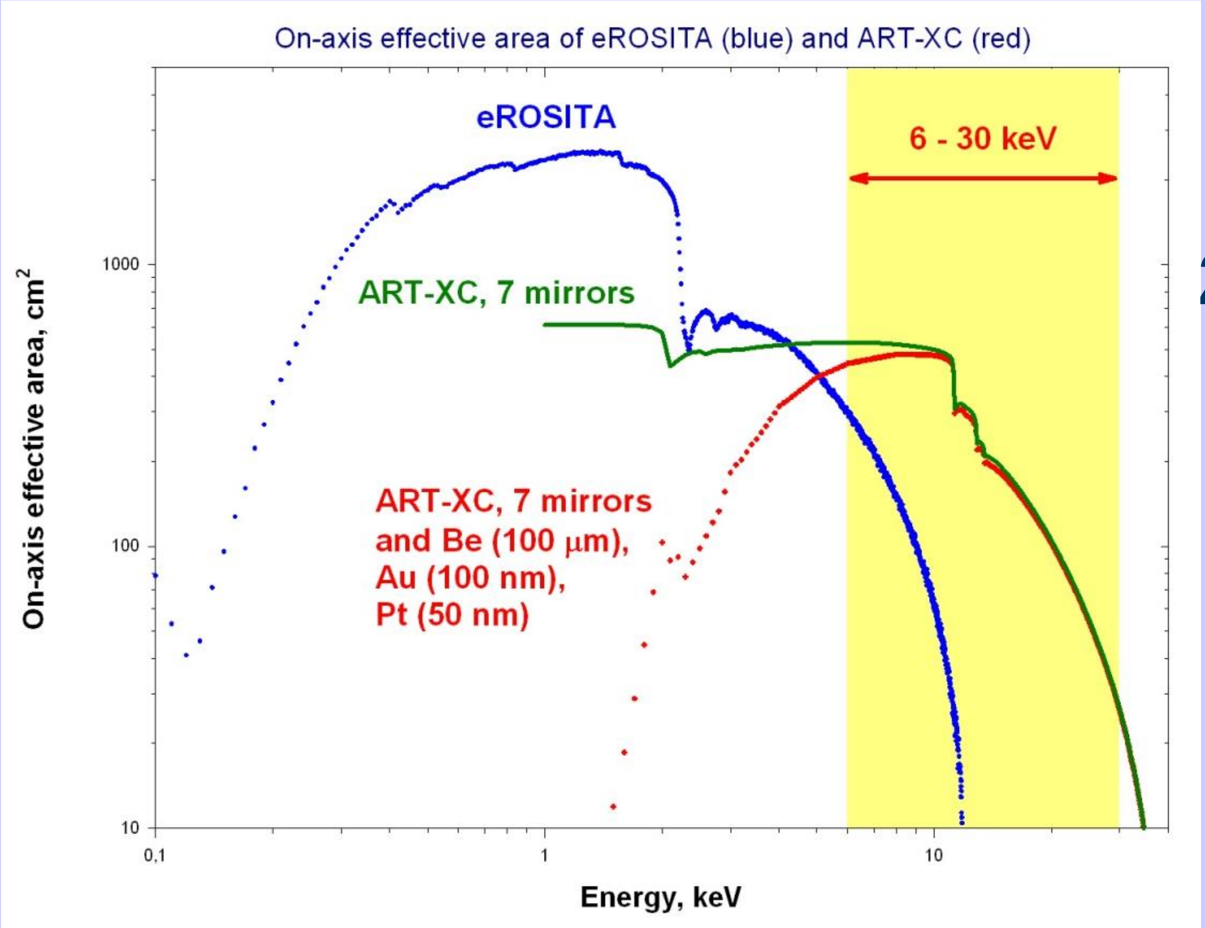






Launch 2017

Future surveys, SRG predictions



2500 cm^2 @ 1.4 keV

450 cm^2 @ 8 keV

Large area, sensitivity ~1.18×10^{-13} erg/s/cm^2

~130 persistent HMXBs in MW

Conclusions

1) INTEGRAL: first complete survey of HMXB in Milky Way (absorption ignorant)

2) Displacement between maximums of the HMXBs distribution and spiral structure

3) Curved shape of HMXB LF

4) Surface density distribution - > SFR

5) Predictions for future surveys, search for HMXBs in the Galactic bulge and large distances