SRG/ART-XC: Galactic Bulge deep survey

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Space Research Institute RAS

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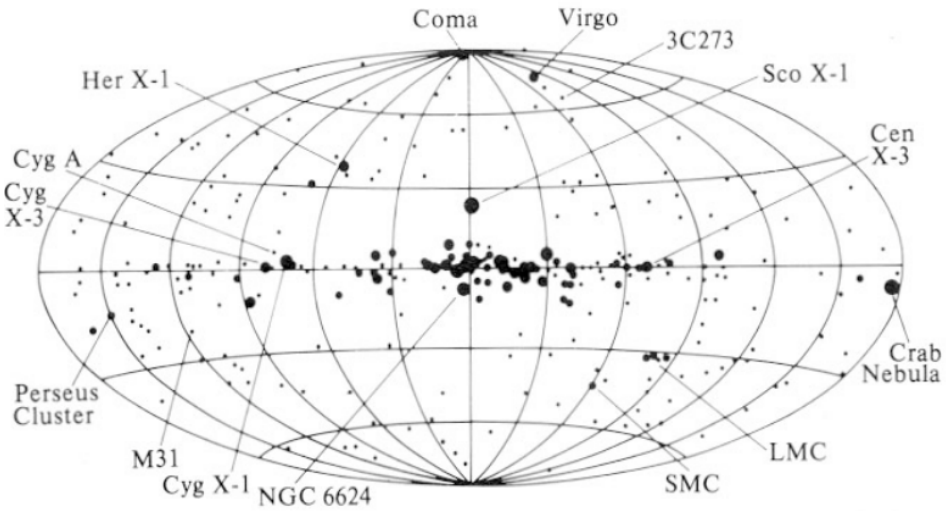
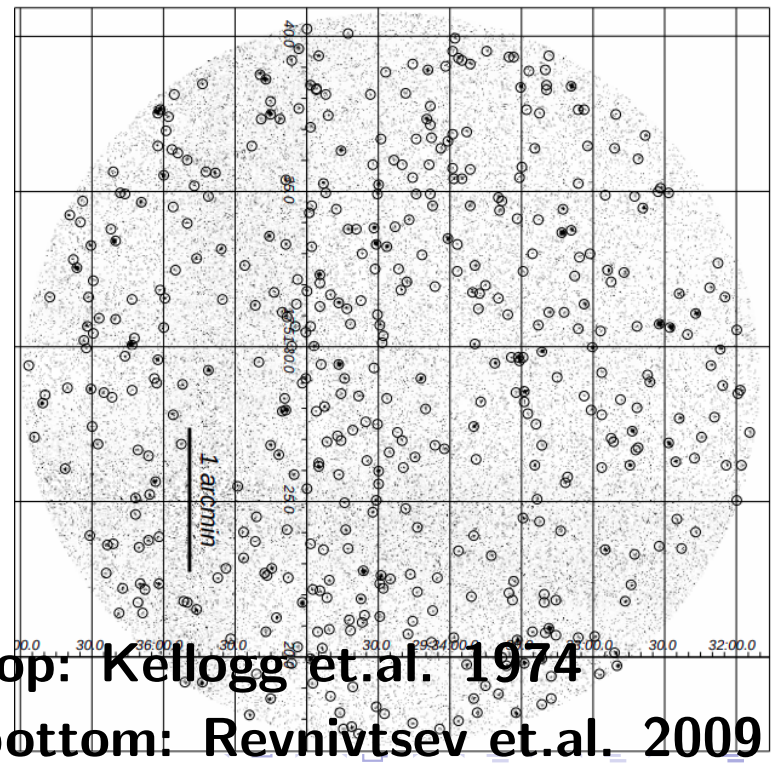
galactic X-ray sources

- *accretion driven X-ray sources
  - *CVs
  - *LMXBs
  - *HMXBs
- *wind fed systems
  - *WR-WR binaries
  - *Symbiotic and Symbiotic
- X-ray binaries
  - *HMXBs
- *transient
  - *active stars
  - *novae and bursters
  - *HMXBs, LMXBs, CVs

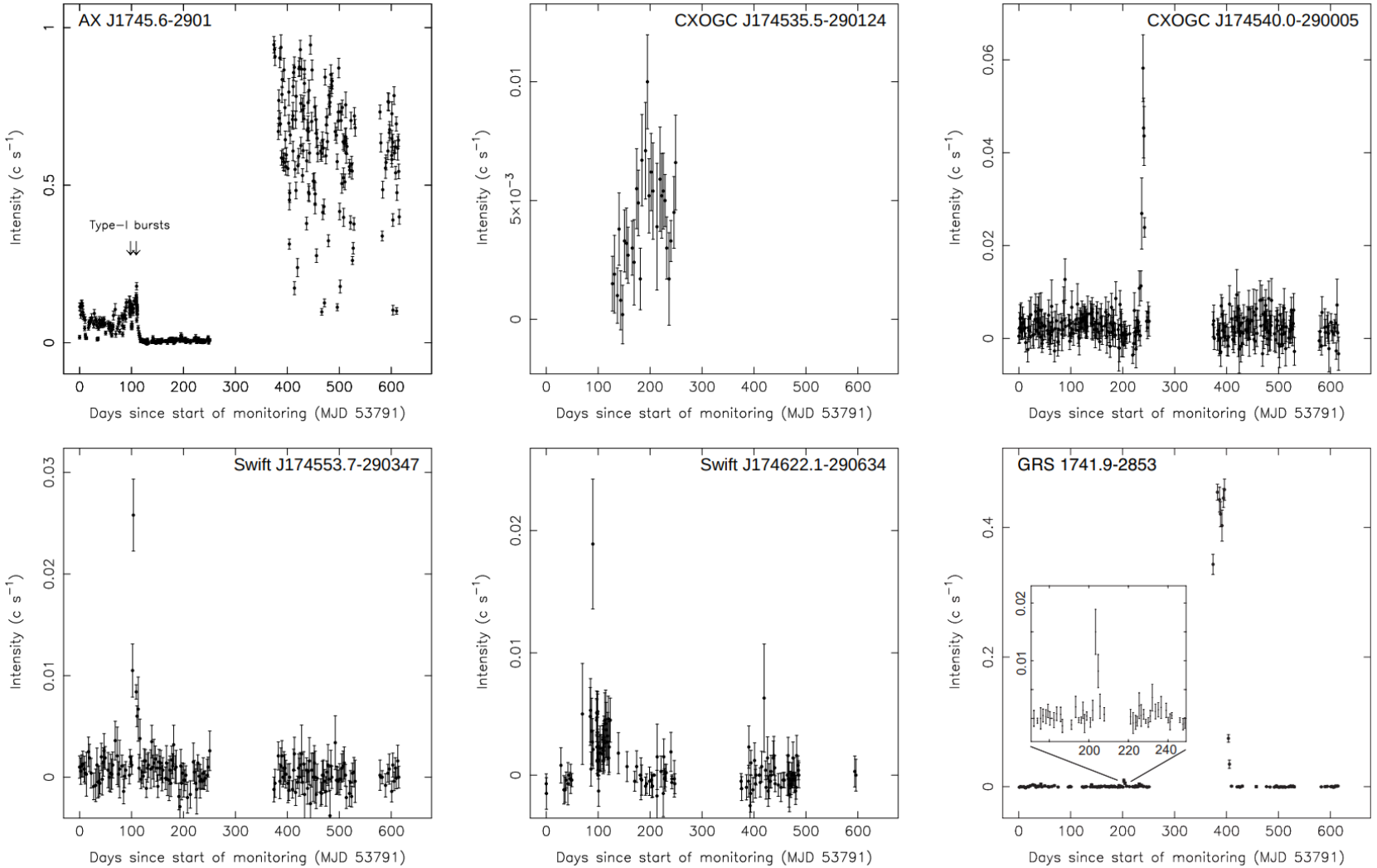




top: Kellogg et.al. 1974

bottom: Revnivtsev et.al. 2009

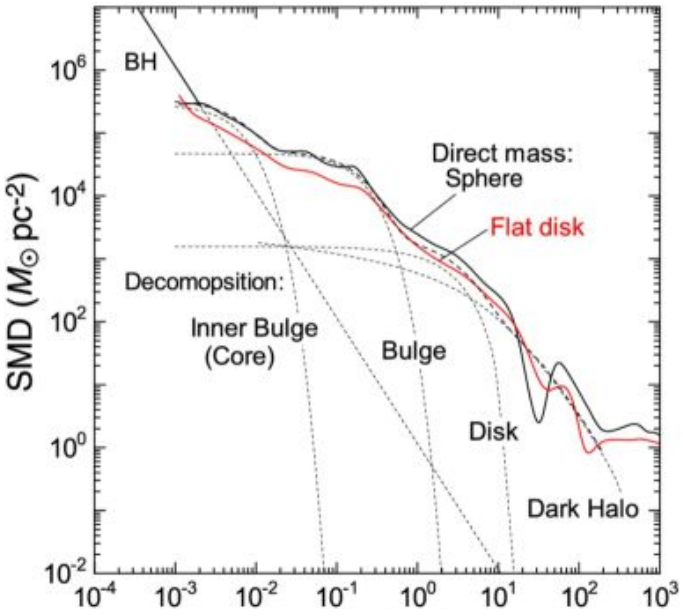
Hidden population, revealed through outburst

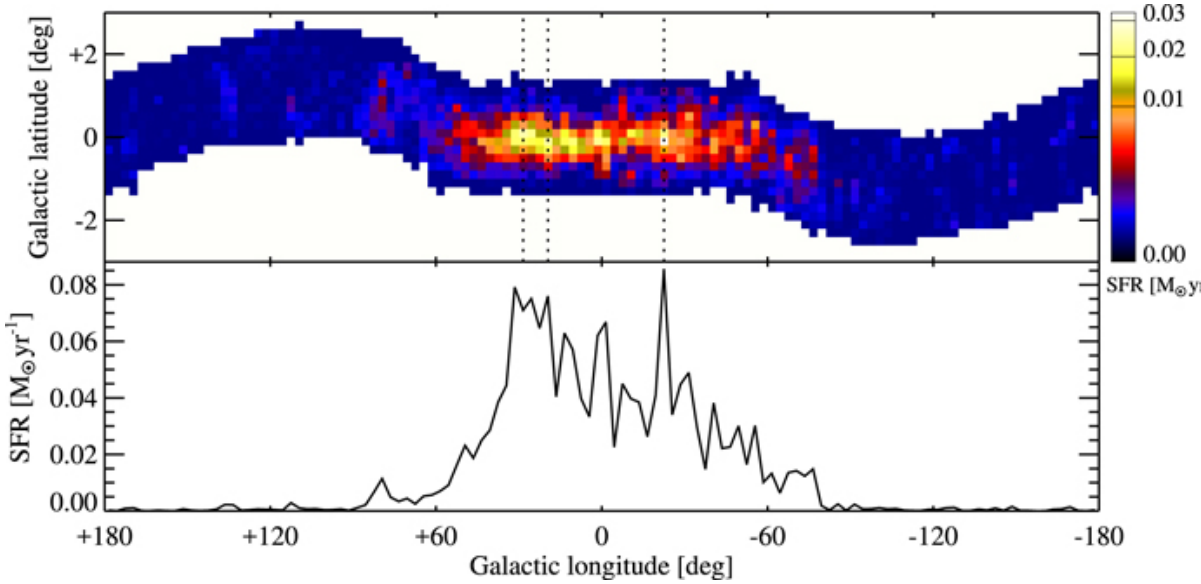


VFXT - a population of the faint and transient X-ray sources revealed in the galactic center, see **Muno et.al 2005, Degenaar & Wijnands 2009, Baharmian et.al. 2020**

Follow the mass

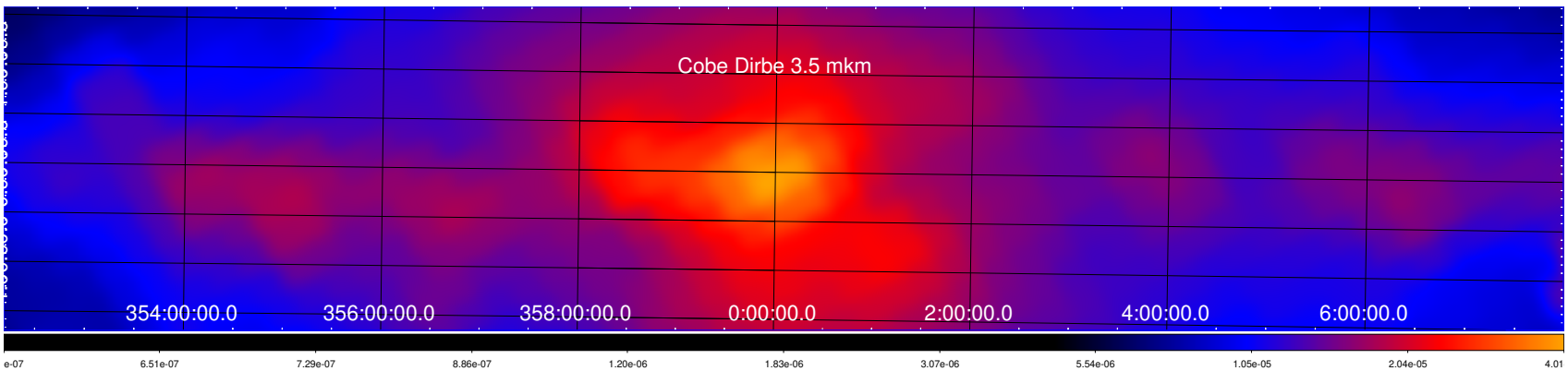
Most of the Milky Way mass is accumulated in the Galactic Center



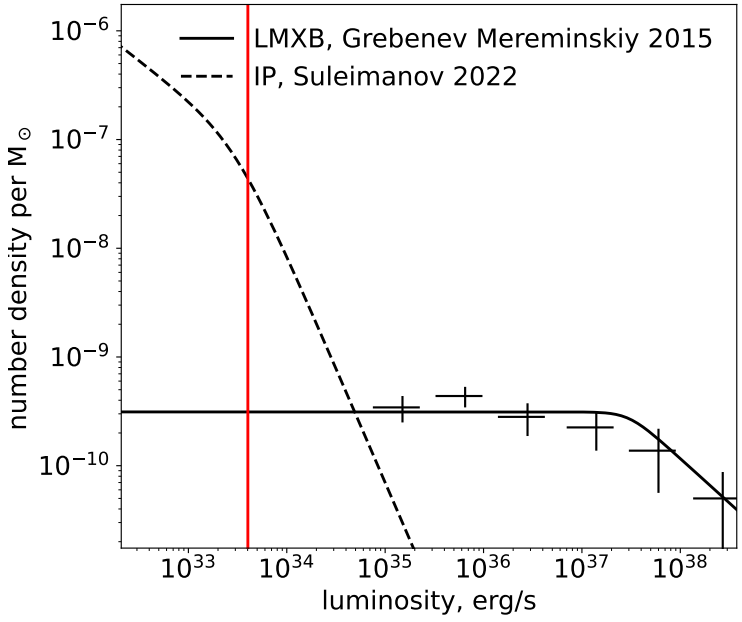


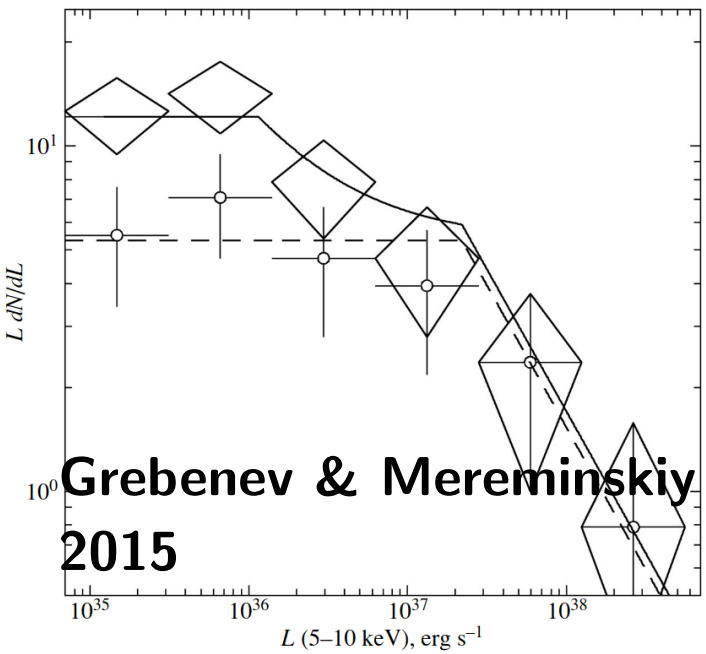
Sofue Y. 2017PASJ...69R...1S

Elia 2022ApJ...941..162E

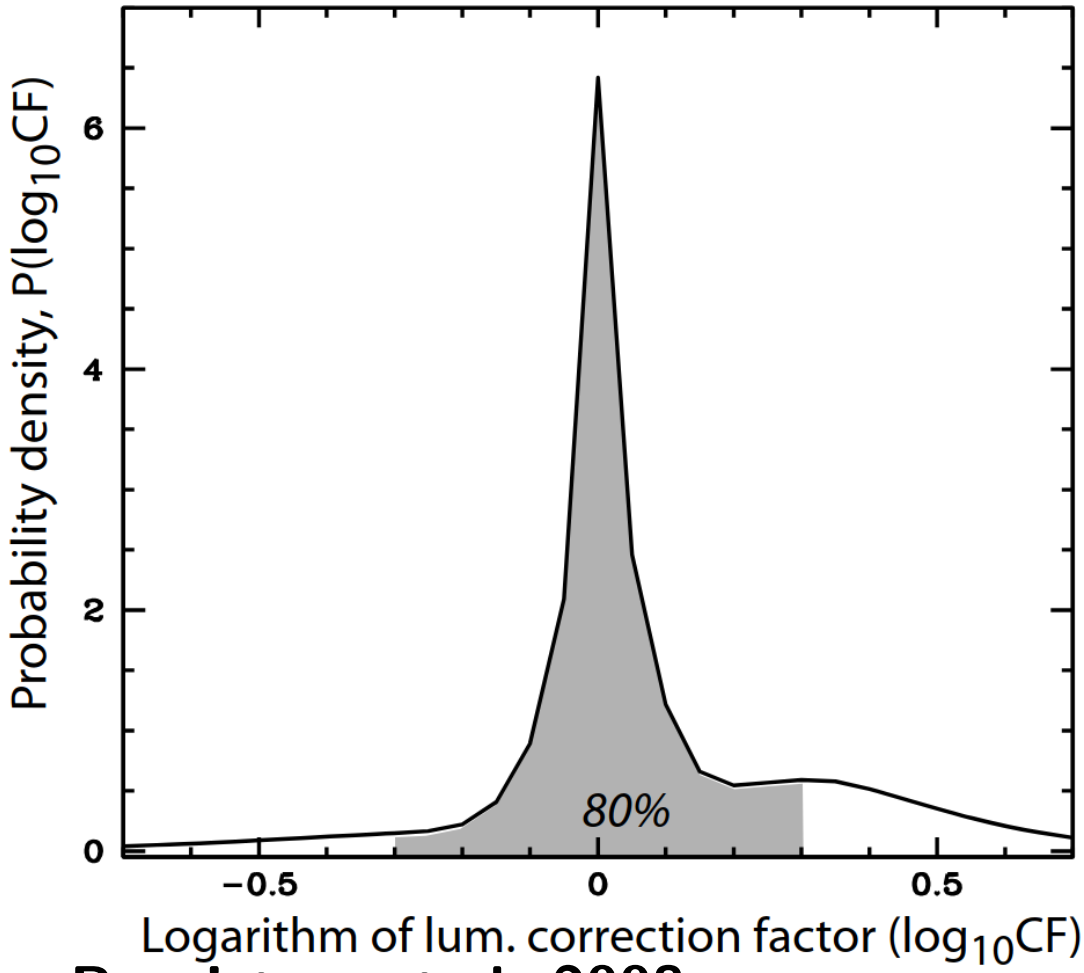


Who will we find?

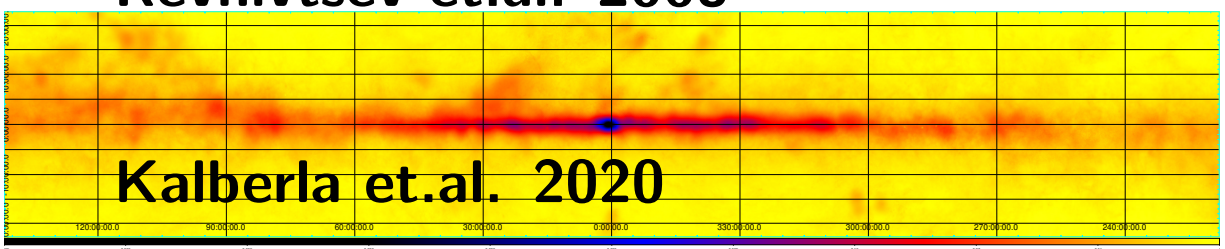




Grebenev & Mereminskiy 2015



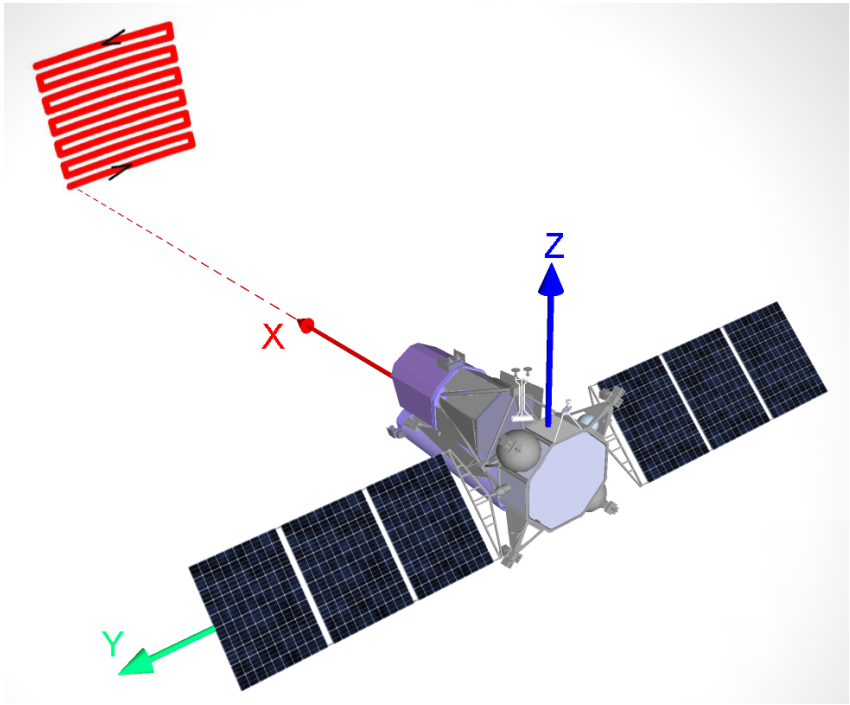
Revnivtsev et.al. 2008



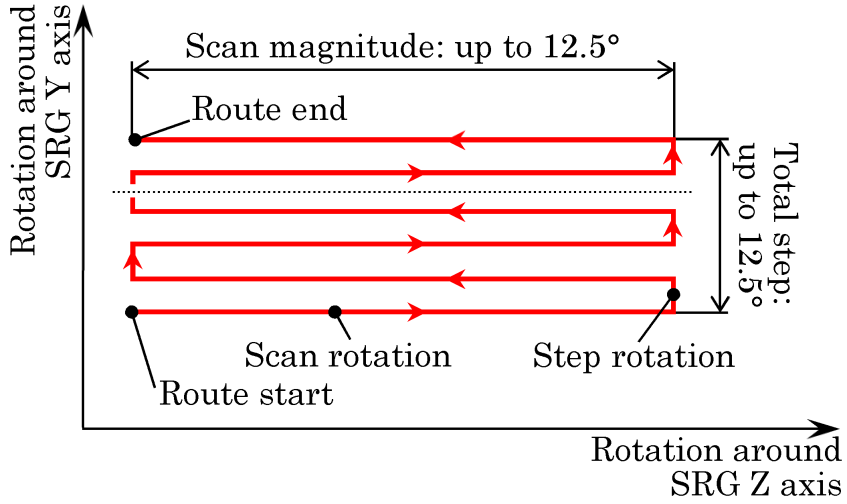
Kalberla et.al. 2020

Large area surveys

Orientation and conduction



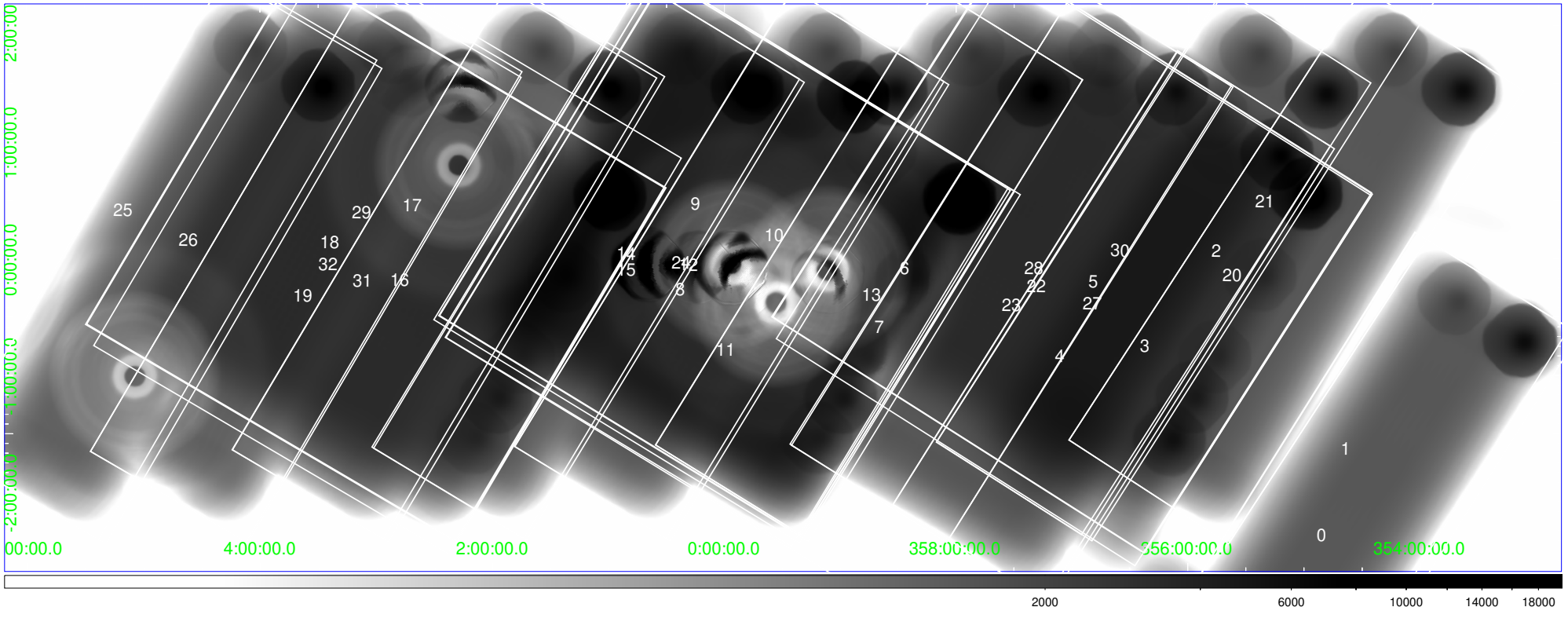
limiting area and duration



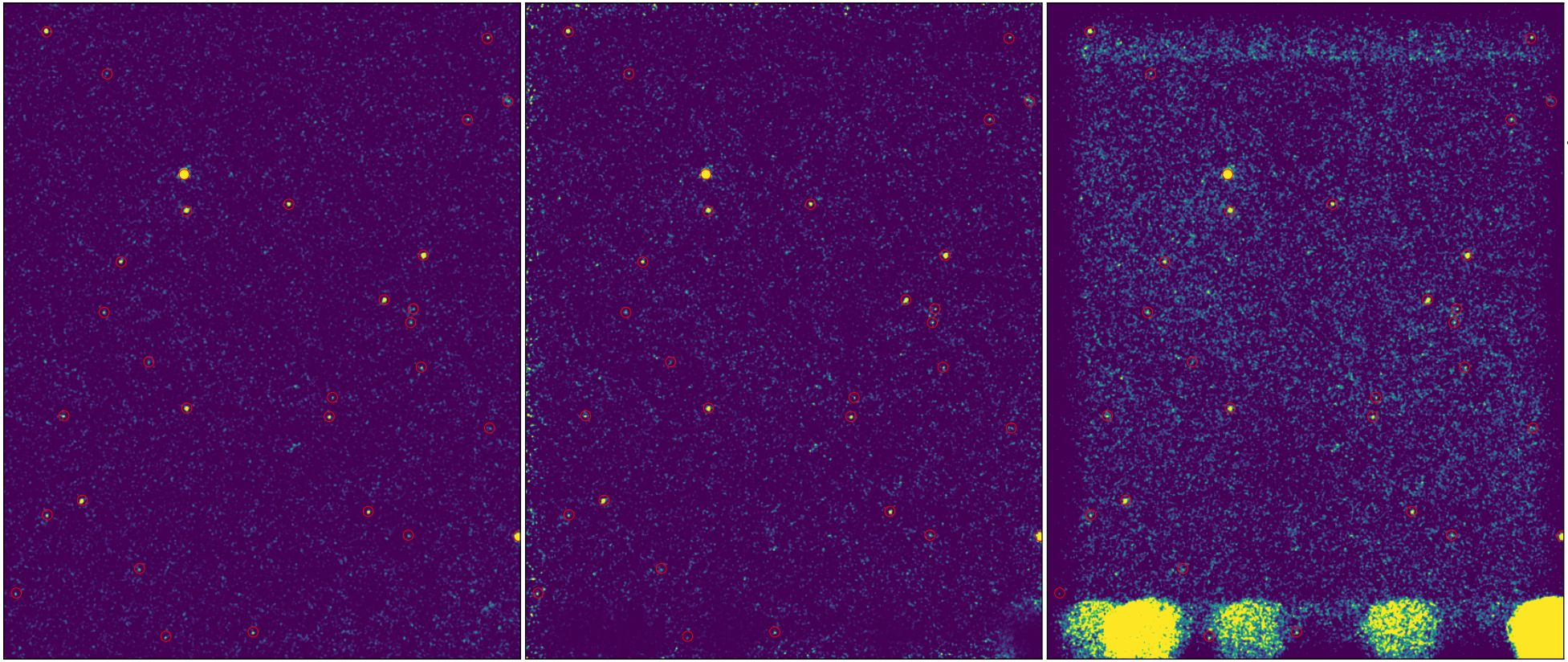
The scan area is limitted to $\sim$ 150sq.deg. and rotated in the Galactic coordinate system, therefore survey along l coordinate can not be performed in a single scan.

SRG/ART-XC Galactic center survey

The survey provides quasy uniform coverage of the central $-5^\circ < l < 5^\circ$deg and $-2^\circ < b < 2^\circ$ area of the Milky Way.



Optimal source detection



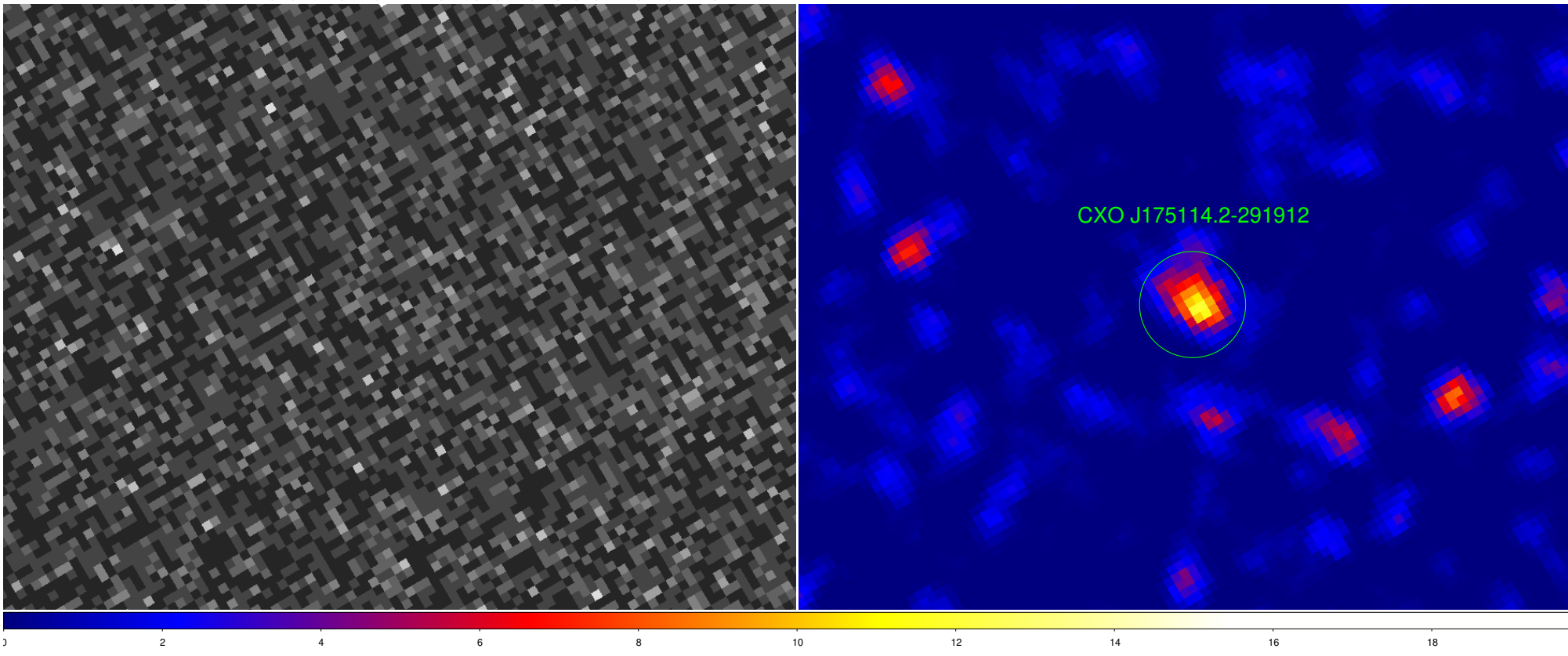
$\Delta \ln L$ ((Data - BKG) $*$ PSF)/EXPOSURE Data $*$ PSF

The likelihood ratio algorithms solves the problem off nonuniform exposure and background, there is no need to exclude parking or avoid edegs of the scan.

Semena et.al. 2024 2024MNRAS.533..313S

Source detection algorithm

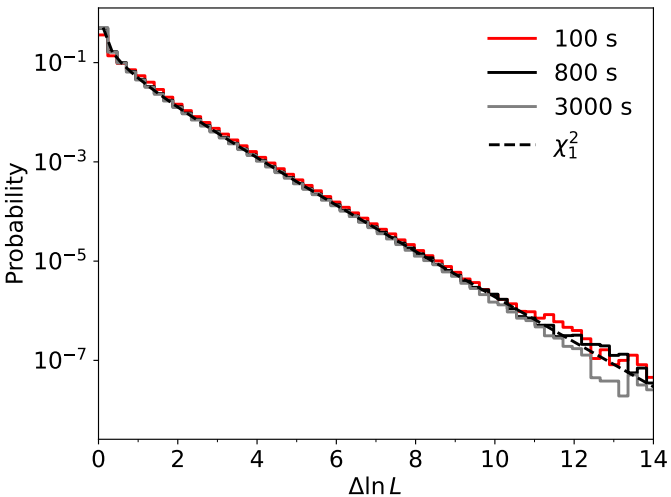
Designed source detection algorithm provides coherent estimate on the amount of false detentions.



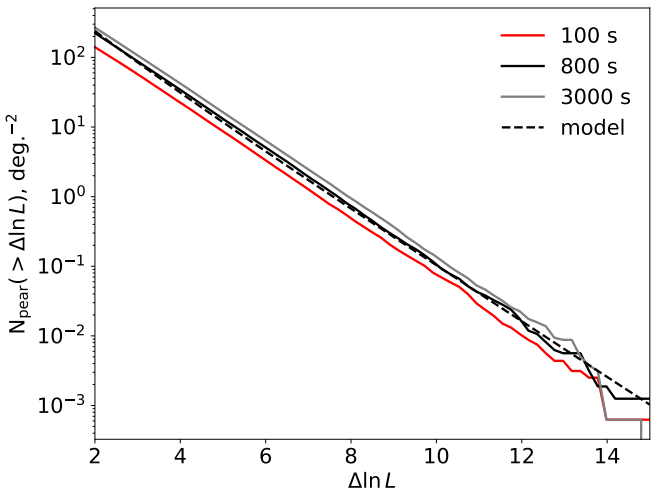
If computation resolution is better then the PSF scale then no sources will be overlooked.

Source detection algorithm

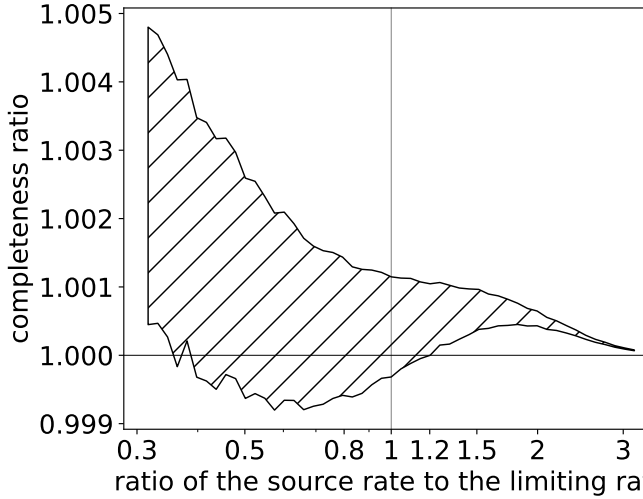
distribution of $\Delta \ln L$ in all point



distribution of $\Delta \ln L$ amplitudes in the local peaks



completness in comparison to simple model likelihood ratio criterion



Designed source detection algorithm provides coherent estimate on the amount of false detentions and almost optimal detection power. The likelihood ratio algorithms solves the problem off nonuniform exposure and background, there is no need to exclude parking or avoid edegs of the scan.

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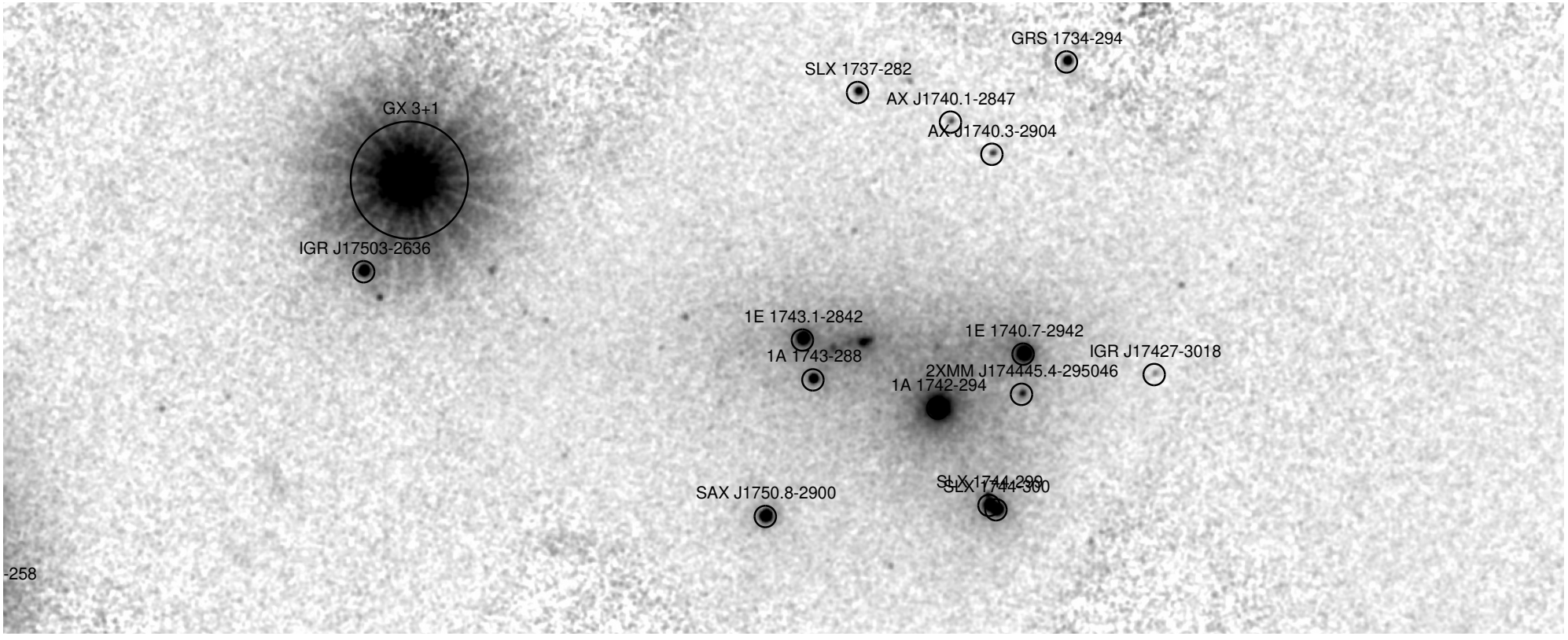
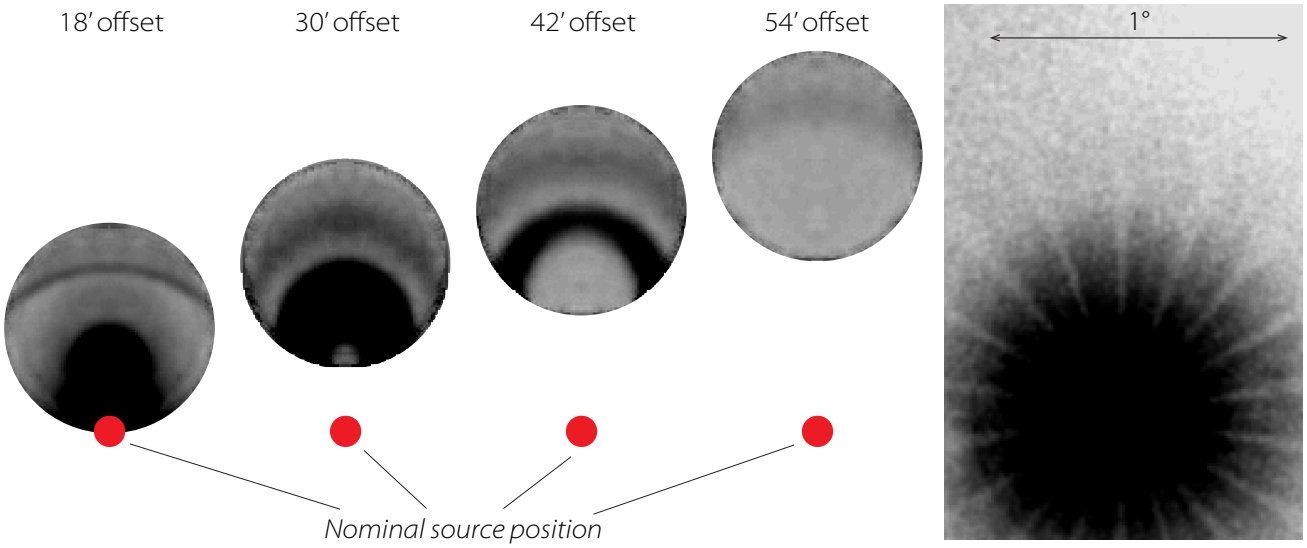
Illumination from bright sources



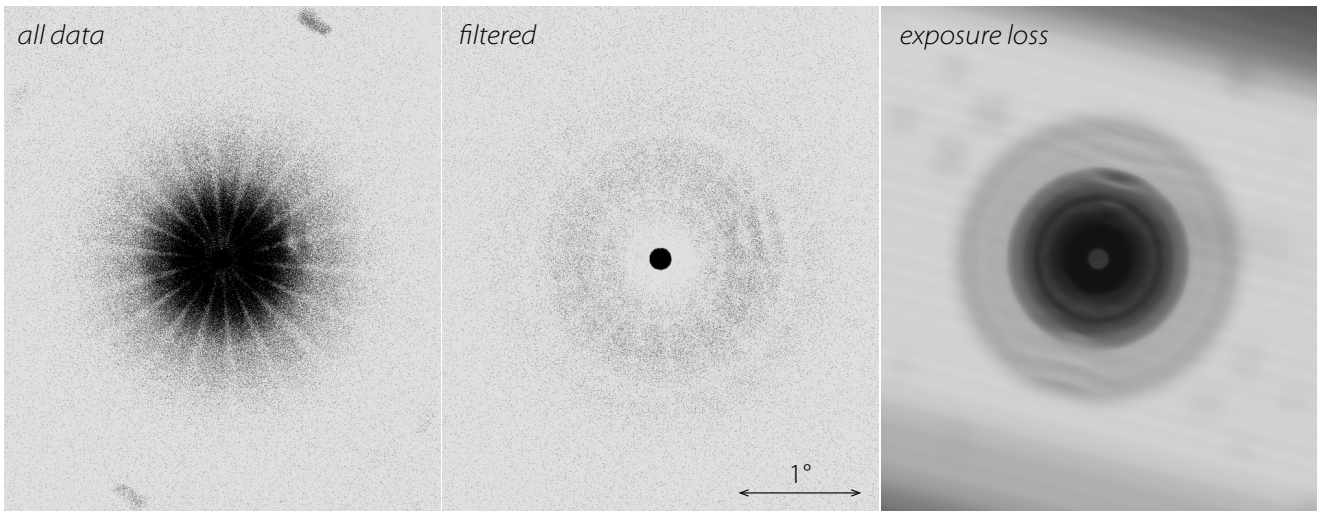
- GX 3+1
- GX 5-1
- 1E 1740.7-2942
- GX 354+0

An abundance of bright X-ray sources in the Galactic center reduces available for the analysis area by $\approx 10^{\circ}$

Illumination from bright sources



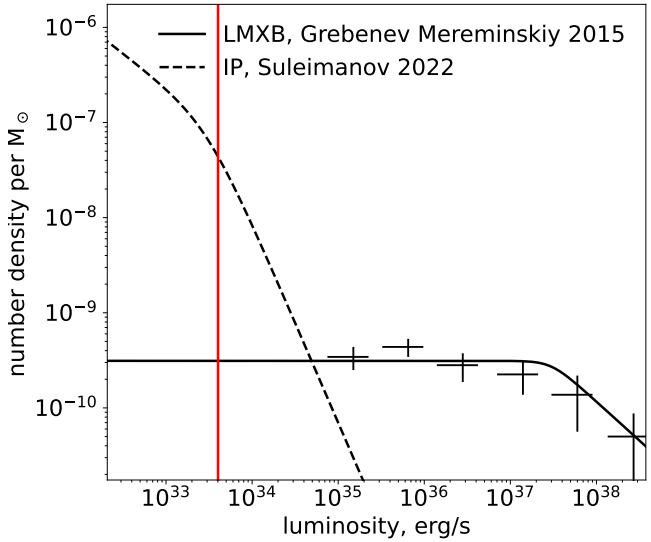
b) *Filtering of the Sco X-1 data*

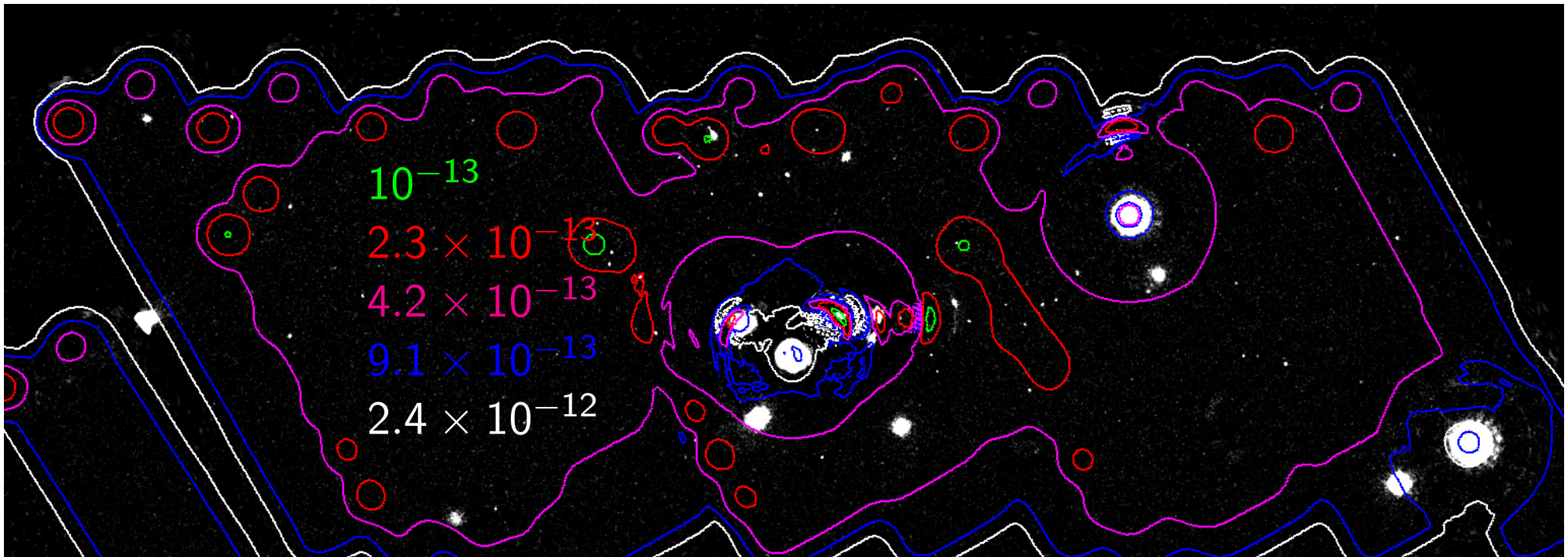


Illumination from the bright sources ($\sim$ 0.1Crab) significantly contaminates analysis with the multiple spurious detections. Its just few dozens regularly bright sources on the sky.

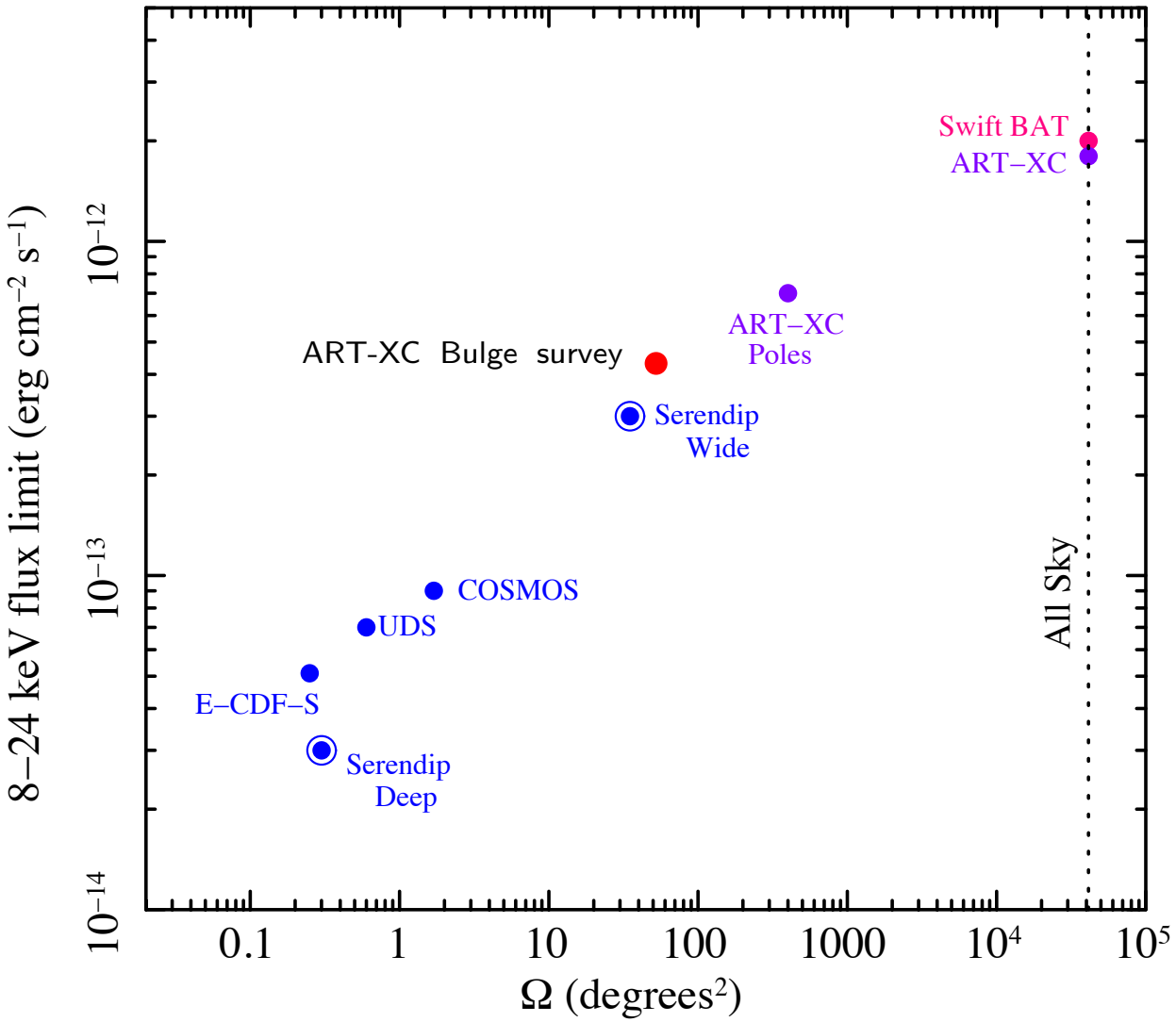
The sensitivity of the SRG/ART-XC Galactic center survey

The acquired in the SRG/ART-XC Galactic center survey sensitivity still allows to hide transient CVs and faint LMXBs outbursts under the sensitivity of the Chandra, XMM-Newton and Swift/XRT surveys. The number of new sources, suggests, that we do not overlook them on a small b.





ART-XC deep Bulge survey



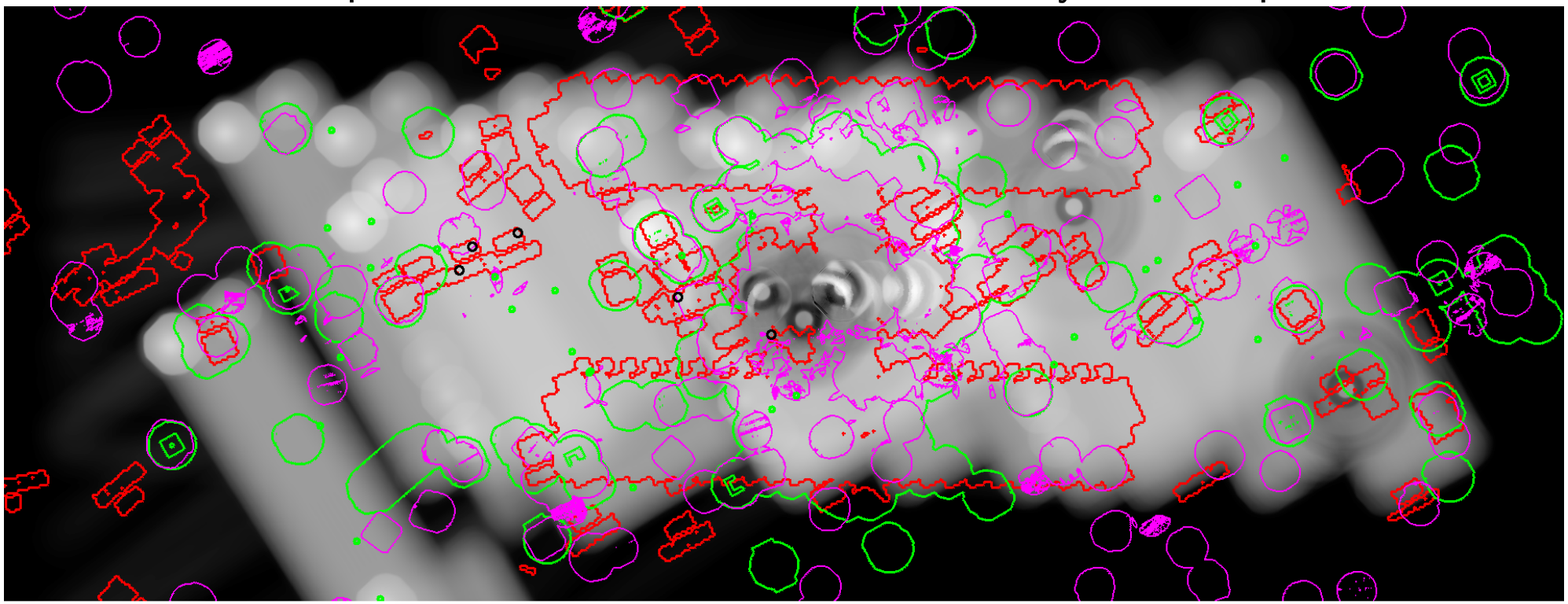
Intersection with soft deep surveys:

Chandra 19 sq.deg.
XMM Newton 26 sq.deg.
Swift 20 sq.deg.

Brandt & Yang 2022

Observations of the Galactic center in X-ray band

Overall area, in the intersection with other surveys is $\approx 30^\circ$. Since most of this survey, including serendipitous, are usually deeper the ART-XC GC survey,
it allows to probe our estimation of the sensitivity and completeness.



Catalog of point sources

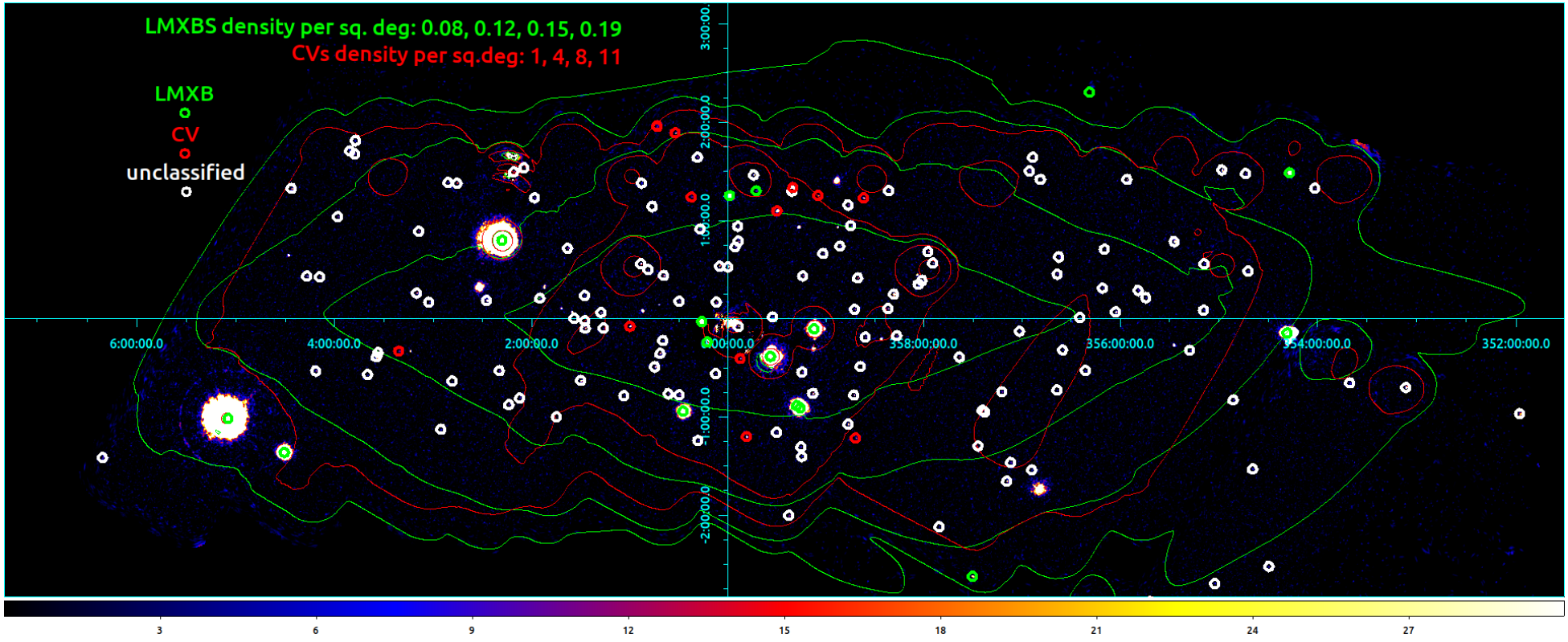
Overall count 172:

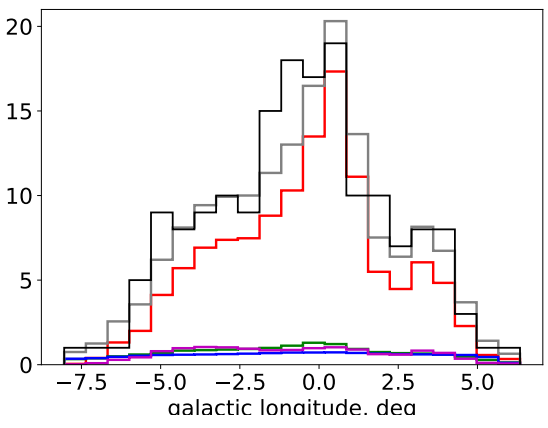
- 43 classified
- 7 hard (with detection only in 7–12 keV band)
- 11 fast transient (visible only during single scan)
- 121 unknown nature
- 99 with counterparts in the XMM-Newton & Chandra catalogues, 5 without companions.

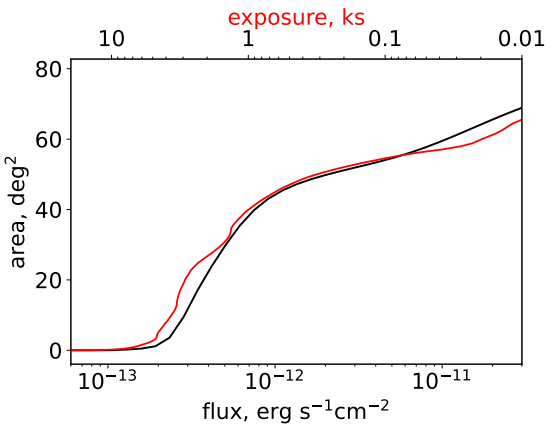
Table: Distribution of the sources with known classes:

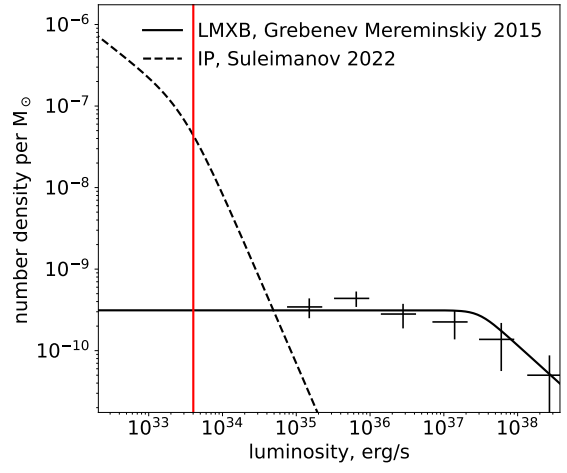
Type	Number
LMXB	17
CV	14
HMXB	8
CWB	1
SyXB	1
AGN	2

Example of obtained sources population



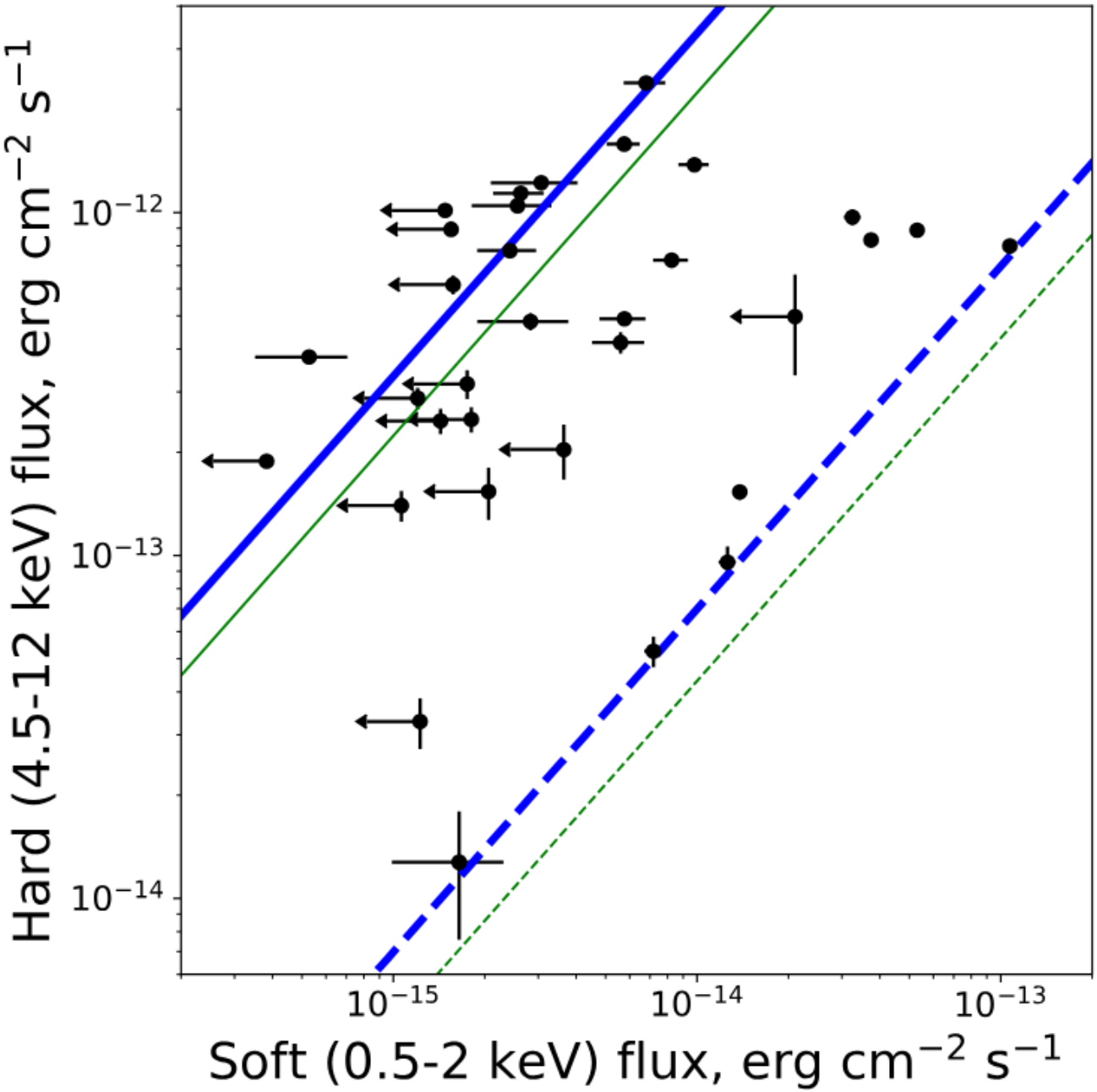






Semenat et.al. 2024 2024MNRAS.529..941S

Classification



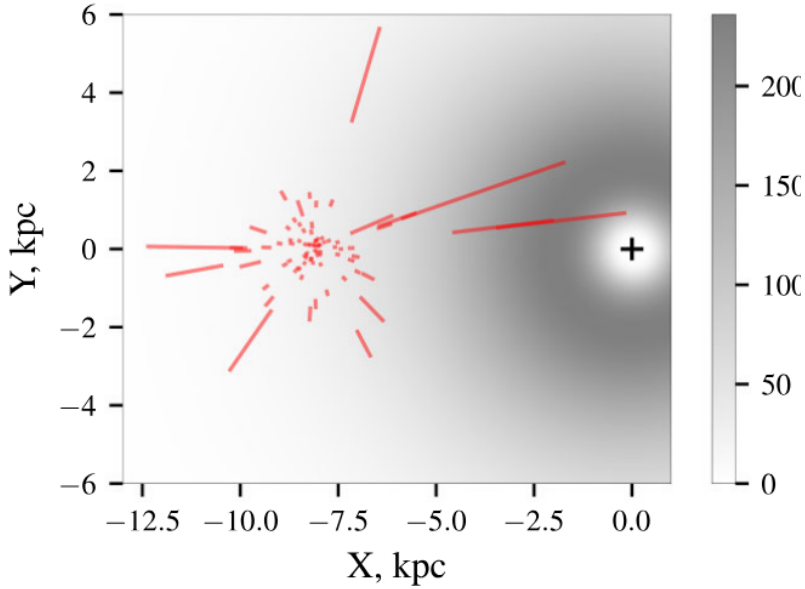
our naive classification efforts for 33 unclassified sources, seen by XMM-Newton:

* far away LMXBs
* dorming HMXBs
* bright CVs

Conclusions

* Galactic bulge and disk source catalogs is published and accesible at Vizier
* in these catalogues obscured sources are likely not overlooked
* moving deeper in fluxes in hard X-ray band may provide a prospect to reveal quiescent sources.
* we can expect some fraction of faint sources to belong to quiescent LMXBs.
* with the quasi uniform coverage along the galactic latitude one can accurately estimate characteristic distribution spatial scale.
* yet another probe on short lasting outbursts in X-ray sources.

The riddle of CVs



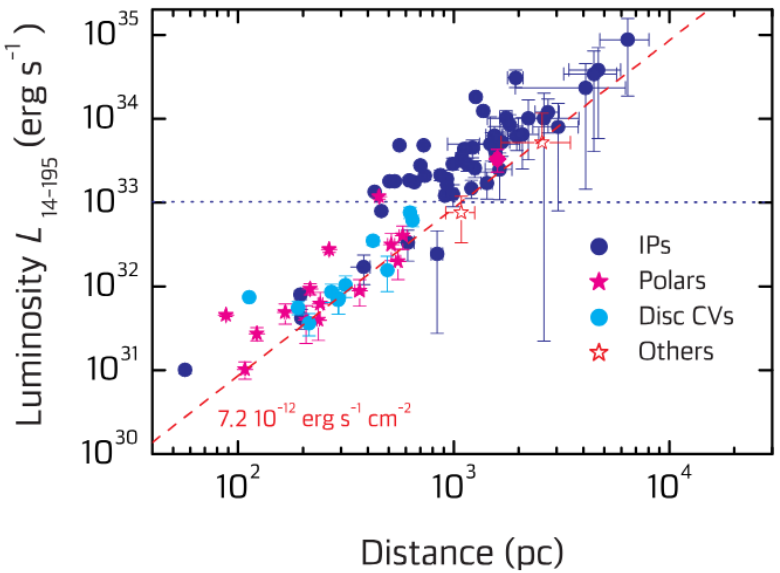


Table 4. Comparison of the total space, mass, and luminosity densities of CVs.

Work	ρ_N (10^{-7} pc^{-3})	ρ_L (10^{26} erg s^{-1} $M_\odot^{-1}$)	ρ_M (10^{-6} $M_\odot^{-1}$)
This work	$8.6^{+1.8}_{-1.0}$	$8.95^{+0.15}_{-0.1}$	$13.7^{+3.0}_{-1.6}$
Suleimanov, Doroshenko & Werner (2020)[a]	≈ 1.14	≈ 8	≈ 3
Pretorius & Mukai (2014)[b]	$1^{+1}_{-0.5}$		
Schwope (2018)[c]	$0.36^{+0.4}_{-0.13}$		
Revnivtsev et al. (2008)[d]	1.5 ± 0.6	13 ± 3	3.8 ± 1.5
Sazonov et al. (2006)[e]		24 ± 6	12 ± 3
Pretorius & Knigge (2012)[f]	40^{+60}_{-20}		
Pala et al. (2020)[g]	48^{+6}_{-8}		

[a] 34 brightest IPs from 105-month BAT Catalogue were used. [b] 15 IPs with $L_{14-195} > 10^{32}$ erg s^{-1} from 70-month BAT Catalogue were used. [c] For the same IPs as in Pretorius & Mukai (2014) but using Gaia DR2 distances and assuming the height scale 200 pc. [d] Used 17 sources, 16 IPs, and SS Cyg, observed with *INTEGRAL*. [e] Using *RXTE* data in 3–20 keV energy band. [f] 20 non-magnetic CVs were used. [g] 43 optically and UV-selected CVs, a volume-limited survey (< 150 pc).

Suleimanov et.al. 2022