Faint X-ray sources in the Nuclear Stellar Disk using deep Chandra observations

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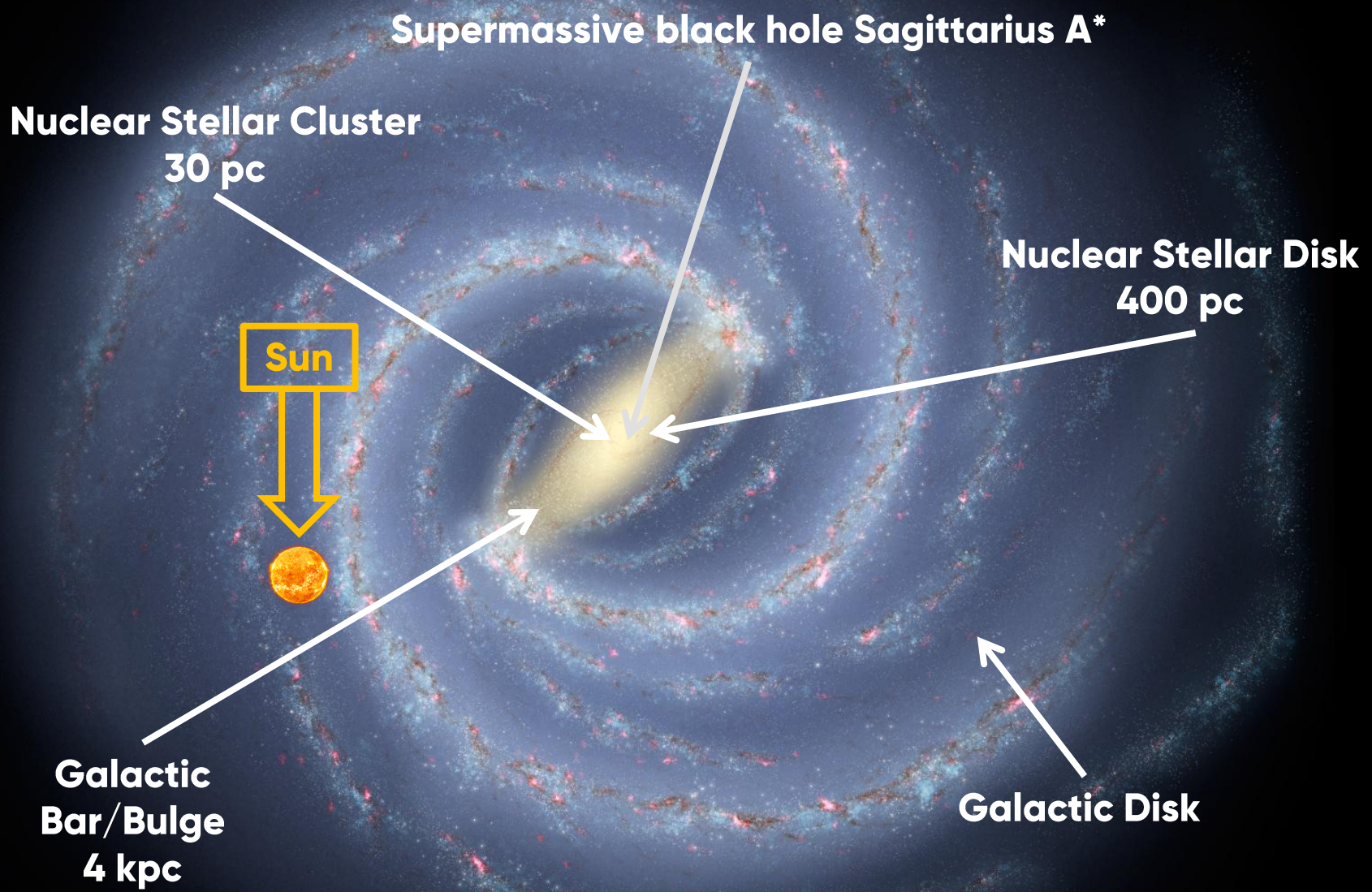
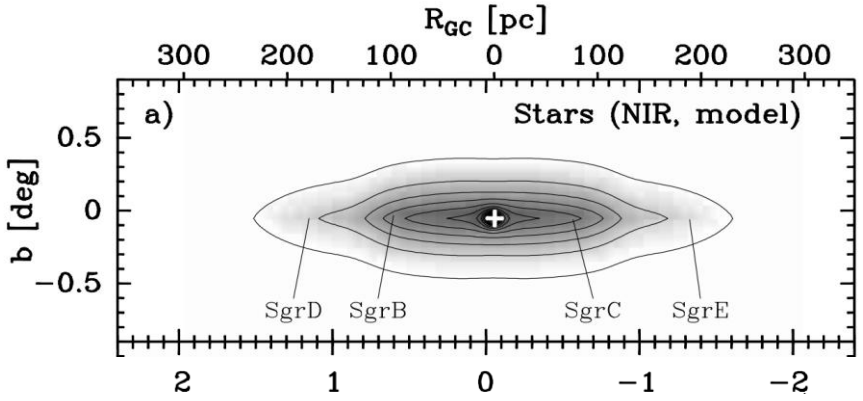
Introduction

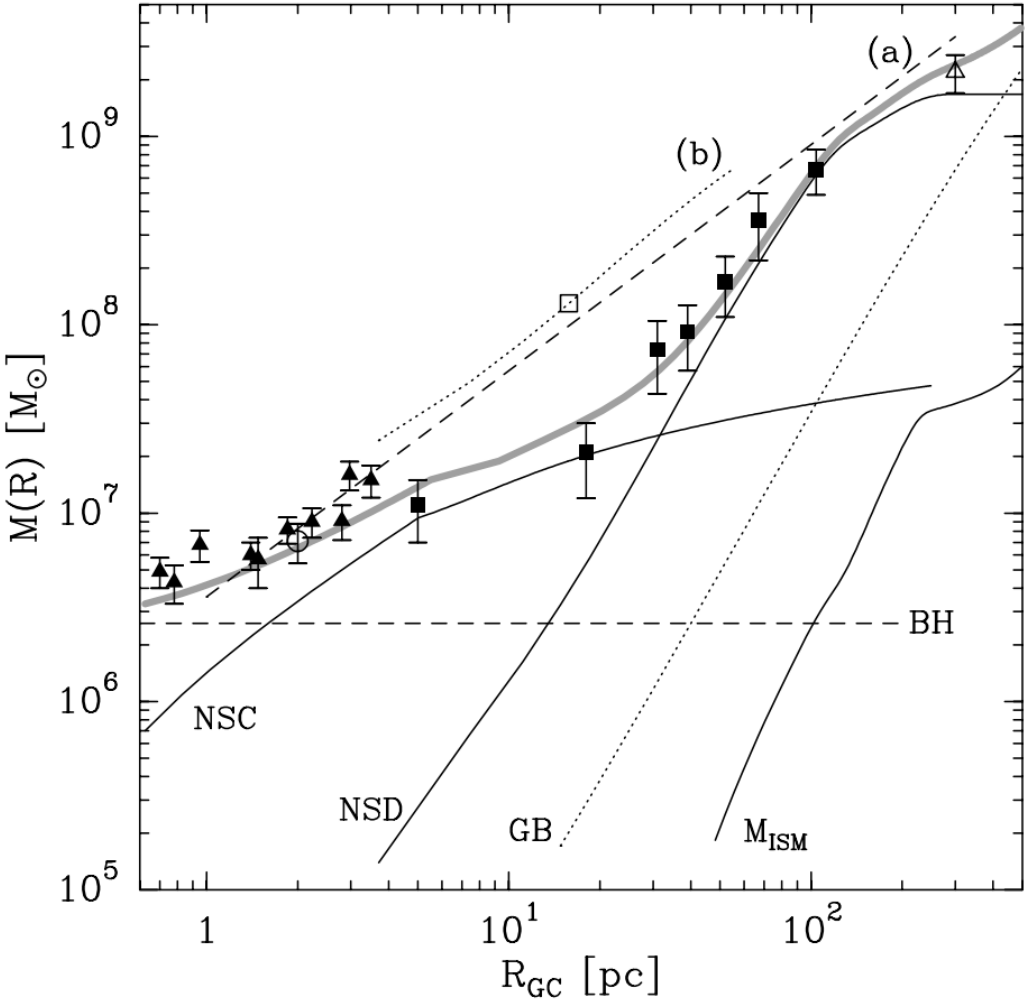


Nuclear Stellar Disk

- The structure was first described by Launhardt et al. (2002)
- The mass of the NSD was estimated at $1.4 \times 10^9\ M_\odot$.
- The NSD radius was approximately 230 pc.

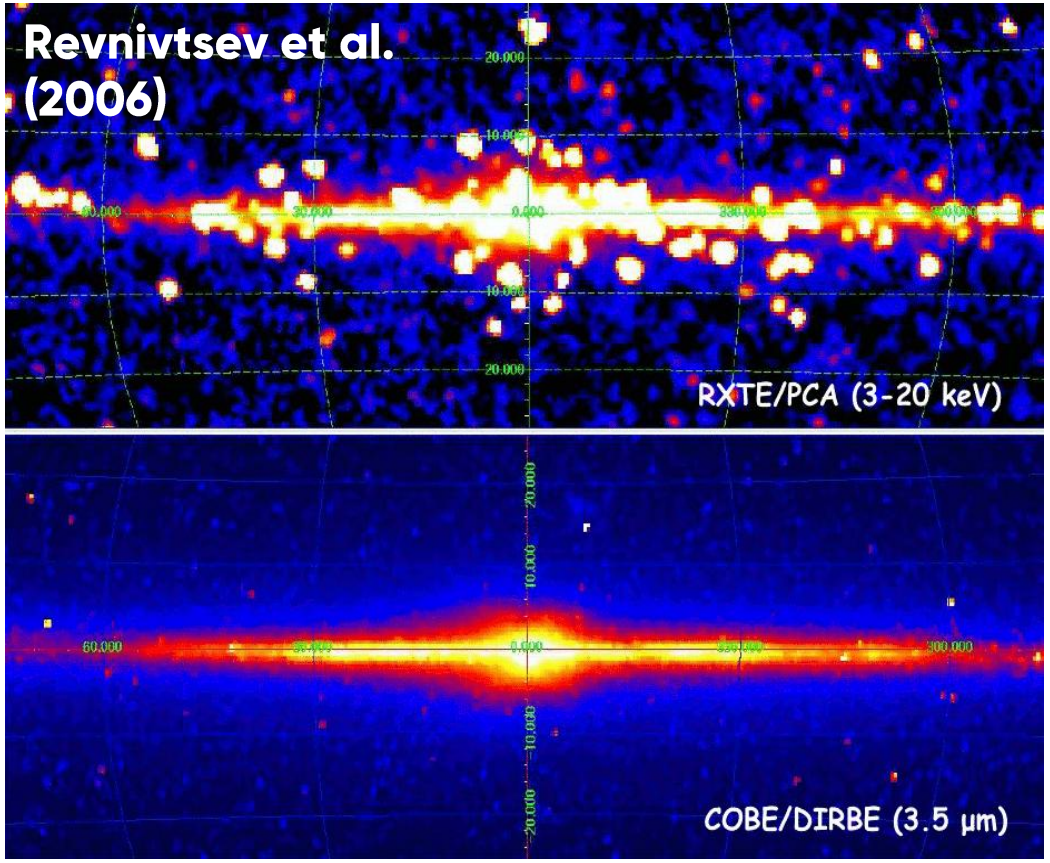


Model surface brightness map

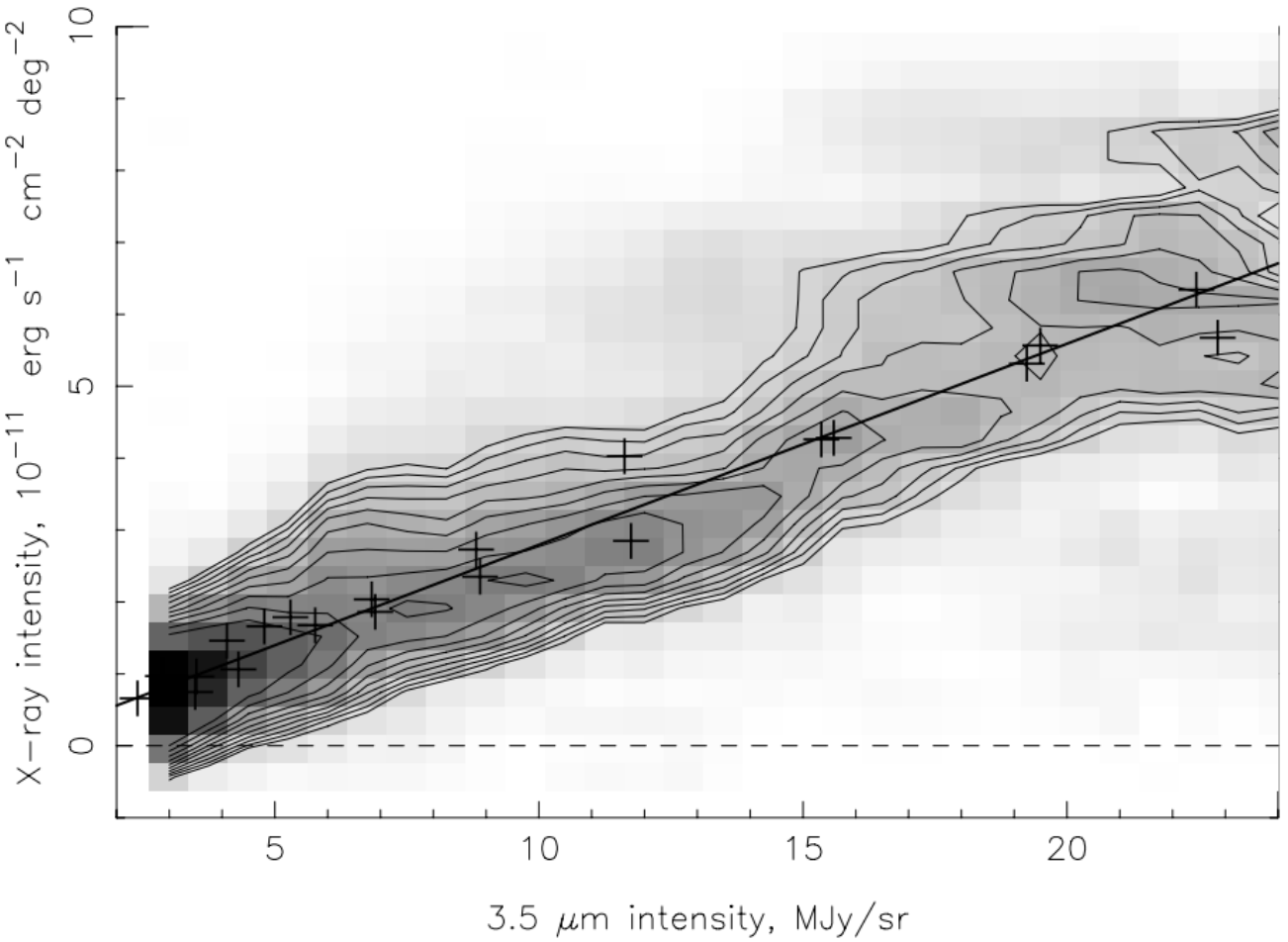


Radial profile of cumulative mass

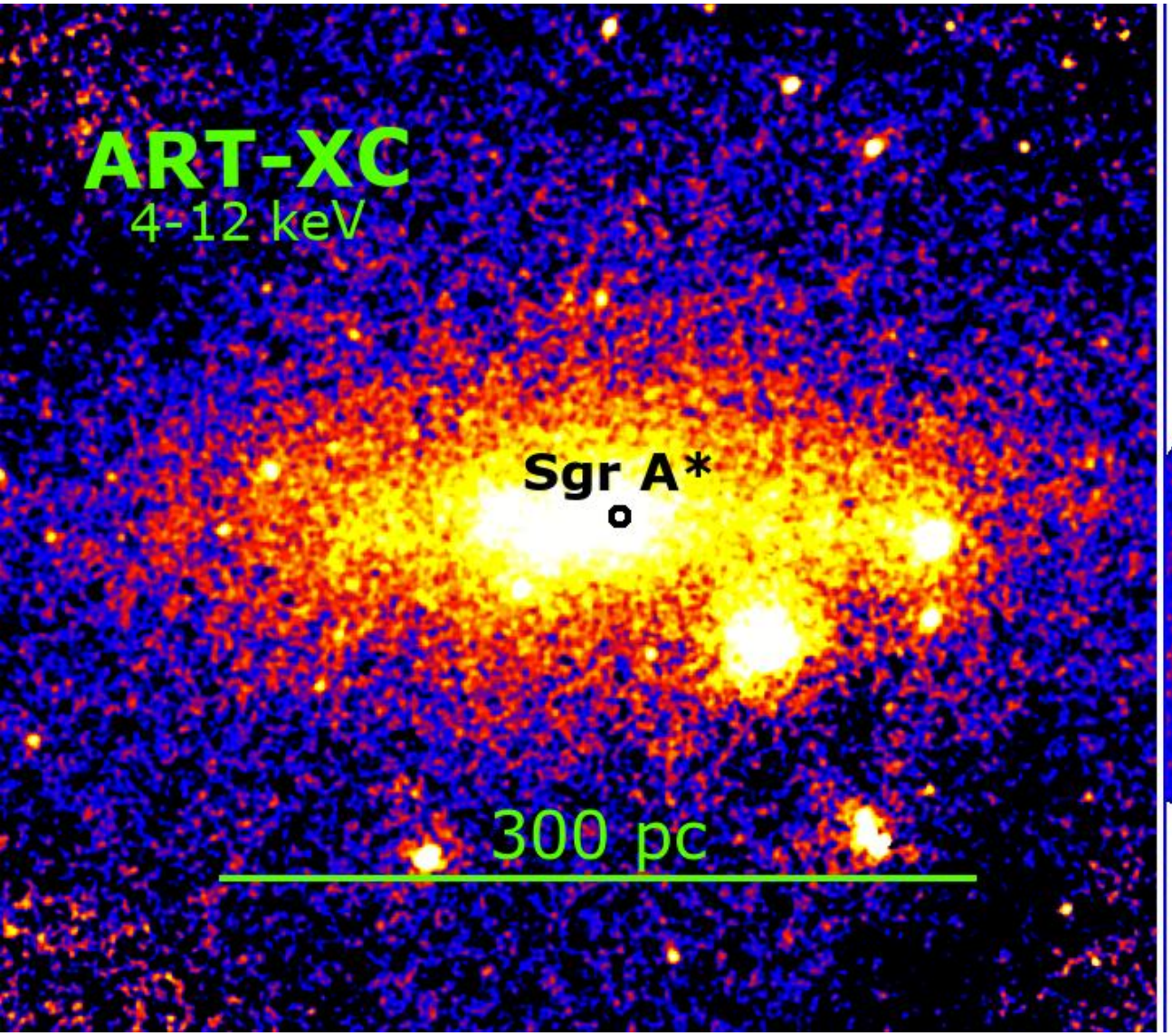
Galactic Ridge X-Ray Emission

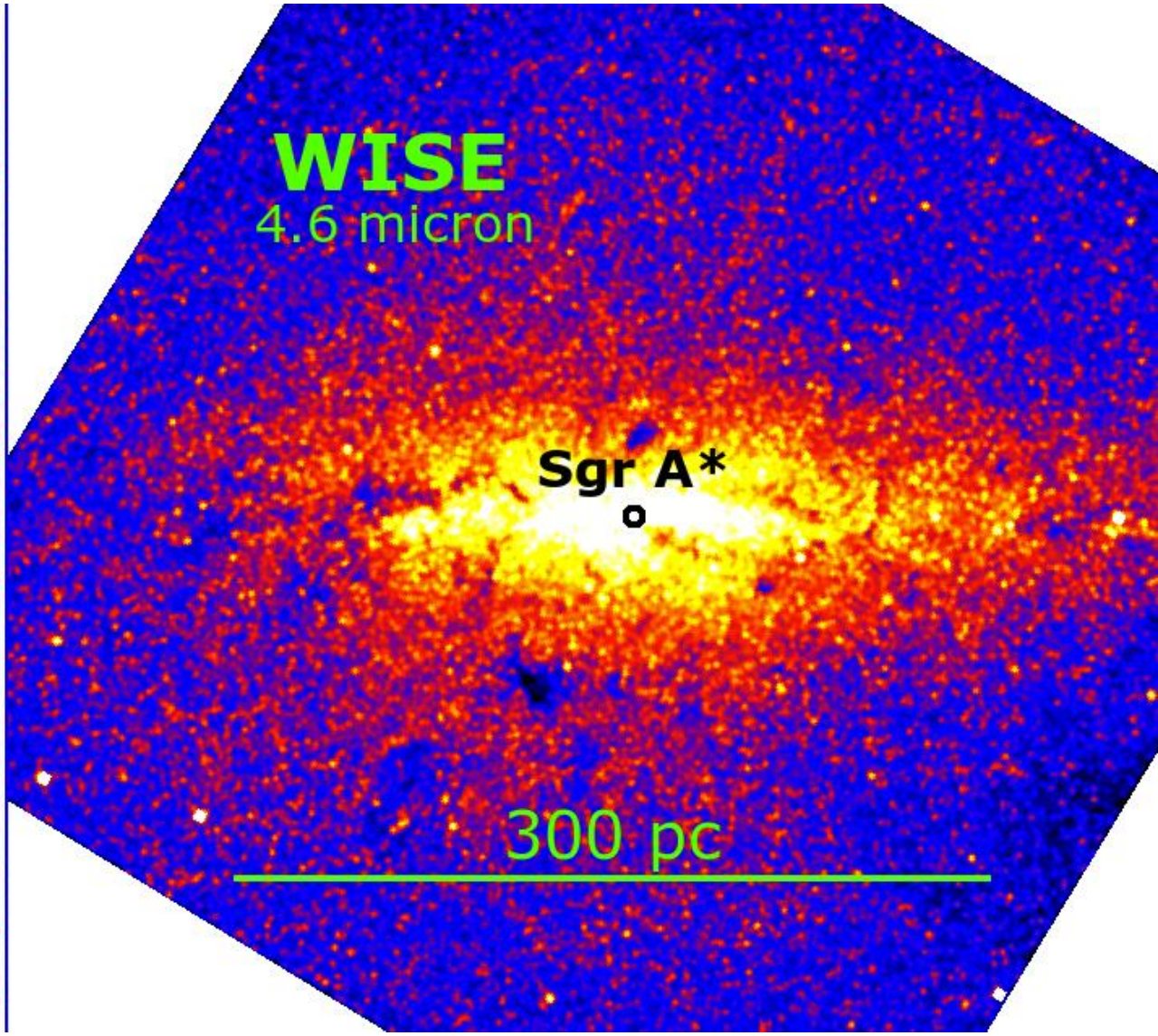


Comparison of X-ray and infrared radiation from the Galactic plane
M. Revnivtsev et al. (2006)

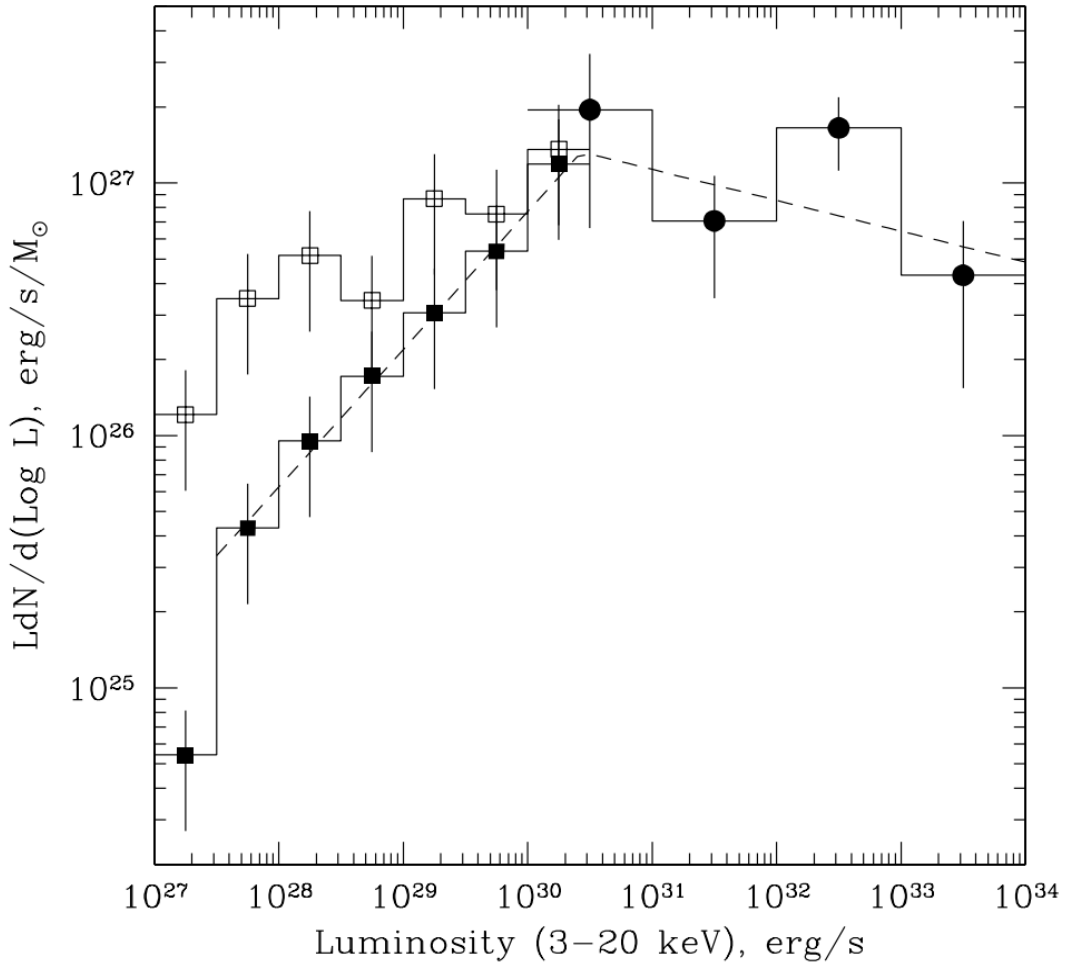


X-Ray Emission of the NSD





Luminosity Function of faint X-Ray Sources



S. Sazonov et al. (2006)

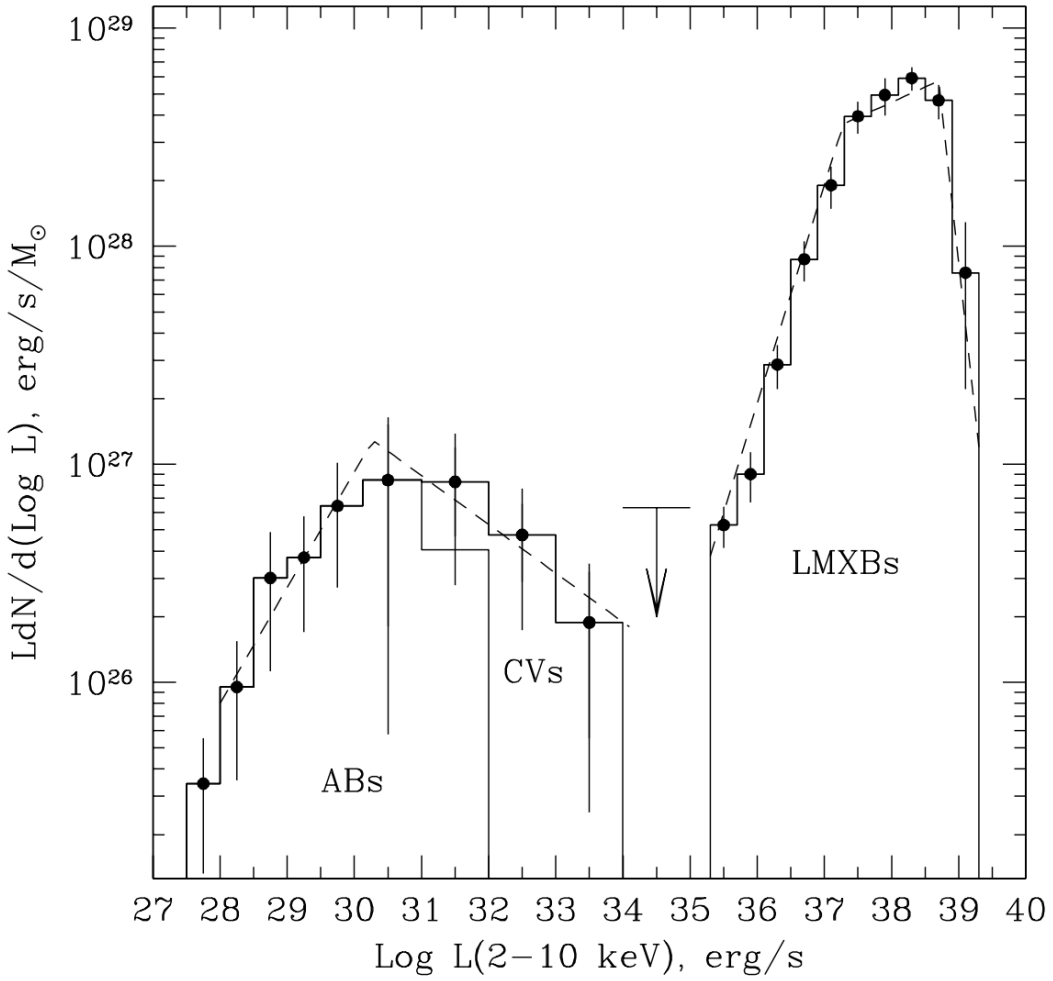
● – CVs by RXTE (25 – 3300 pc)
■ – ABs by ROSAT (6 – 50 pc)

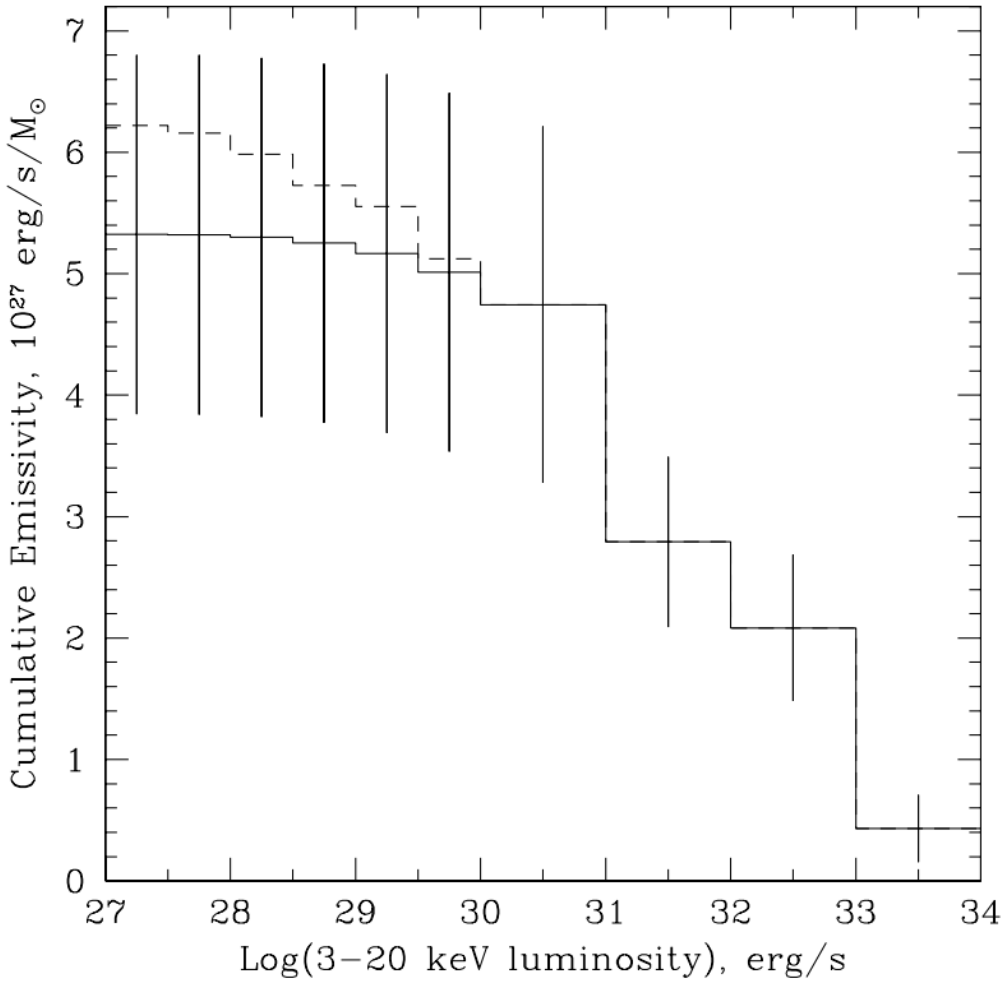
$$\frac{dN}{d\log L_h} = K \begin{cases} (L_b/L_h)^{\alpha_1}, & L_h < L_b \\ (L_b/L_h)^{\alpha_2}, & L_h > L_b, \end{cases}$$

with $K \approx 4.9 \times 10^{-4}\ M_\odot^{-1}$, $L_b \approx 2.7 \times 10^{30}$ erg s^{-1}, $\alpha_1 \approx 0.45$, and $\alpha_2 \approx 1.12$.

Luminosity Function of faint X-Ray Sources

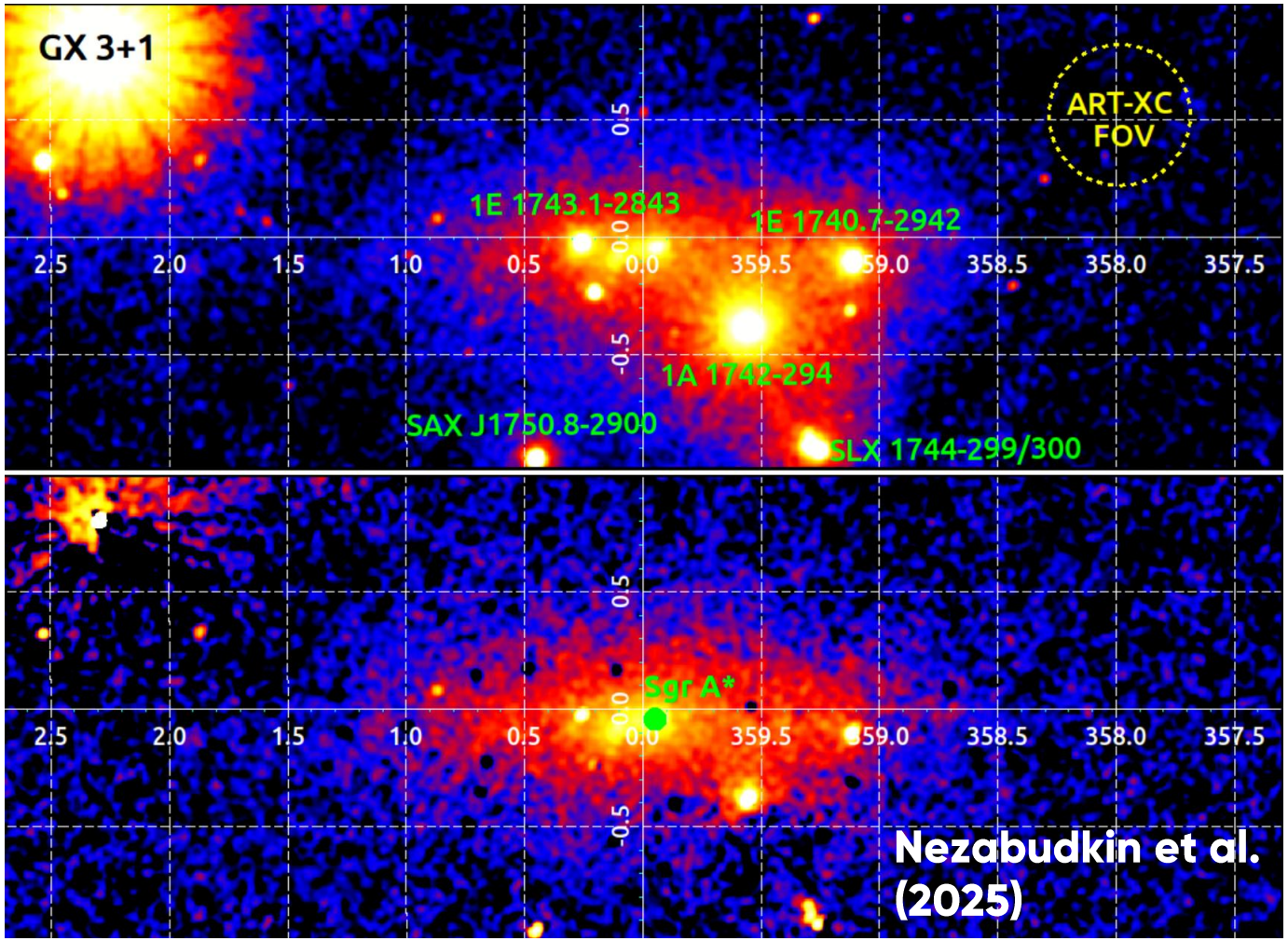
S. Sazonov et al. (2006)



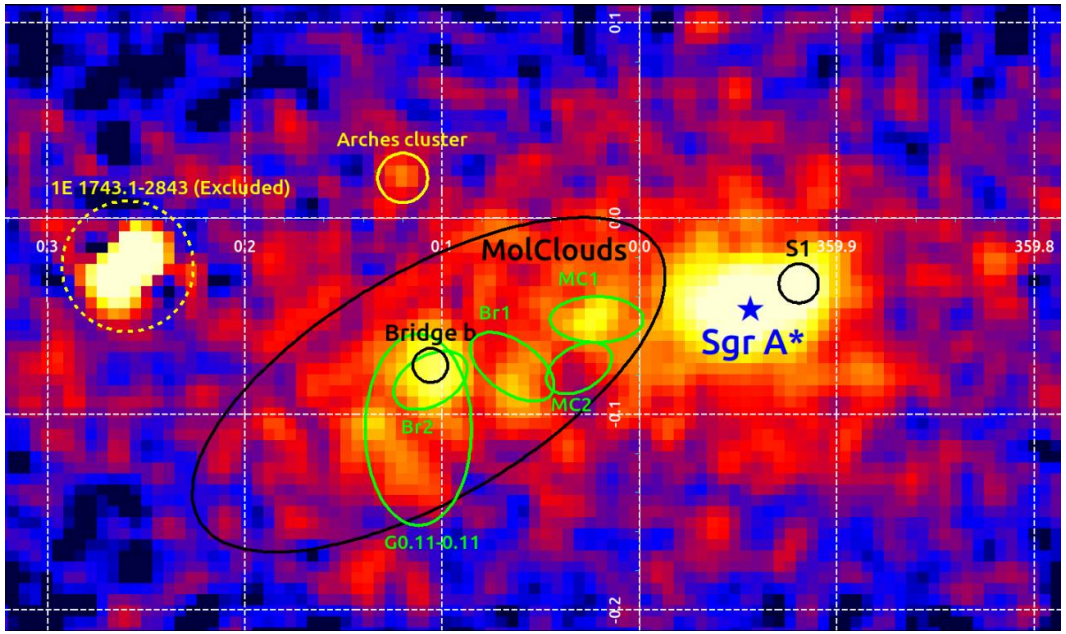


Integral X-ray emissivity of the Galactic Ridge = $(3.5 \pm 1.5) \times 10^{27}\ erg\ s^{-1} M_\odot^{-1}$!

X-Ray Emission of the NSD



- M. N. Pavlinsky ART-XC telescope
- ~1-month scanning during the 2019 calibration phase
- 4–12 keV energy range
- Mean exposure ~3 ks



X-Ray Emission of the NSD

NSD X-ray flux model (2D)

Discrete deprojection

NSD X-ray luminosity model (3D)

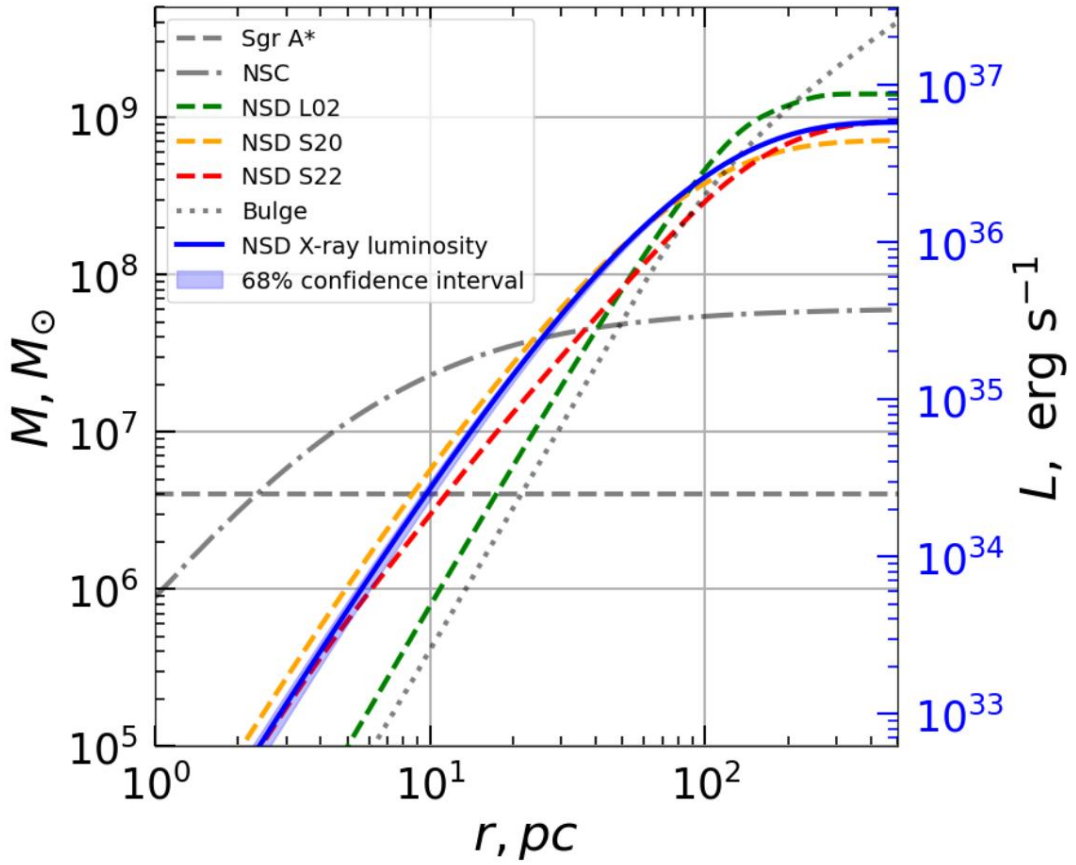
NSD: $\langle L/M \rangle = (5.58^{+0.54}_{-0.65}) \times 10^{27} erg\ s^{-1}\ M_{\odot}^{-1}$

Ridge: $\langle L/M \rangle = (1.69^{+0.15}_{-0.08}) \times 10^{27} erg\ s^{-1}\ M_{\odot}^{-1}$

Depends on the Galactic bar and disk models

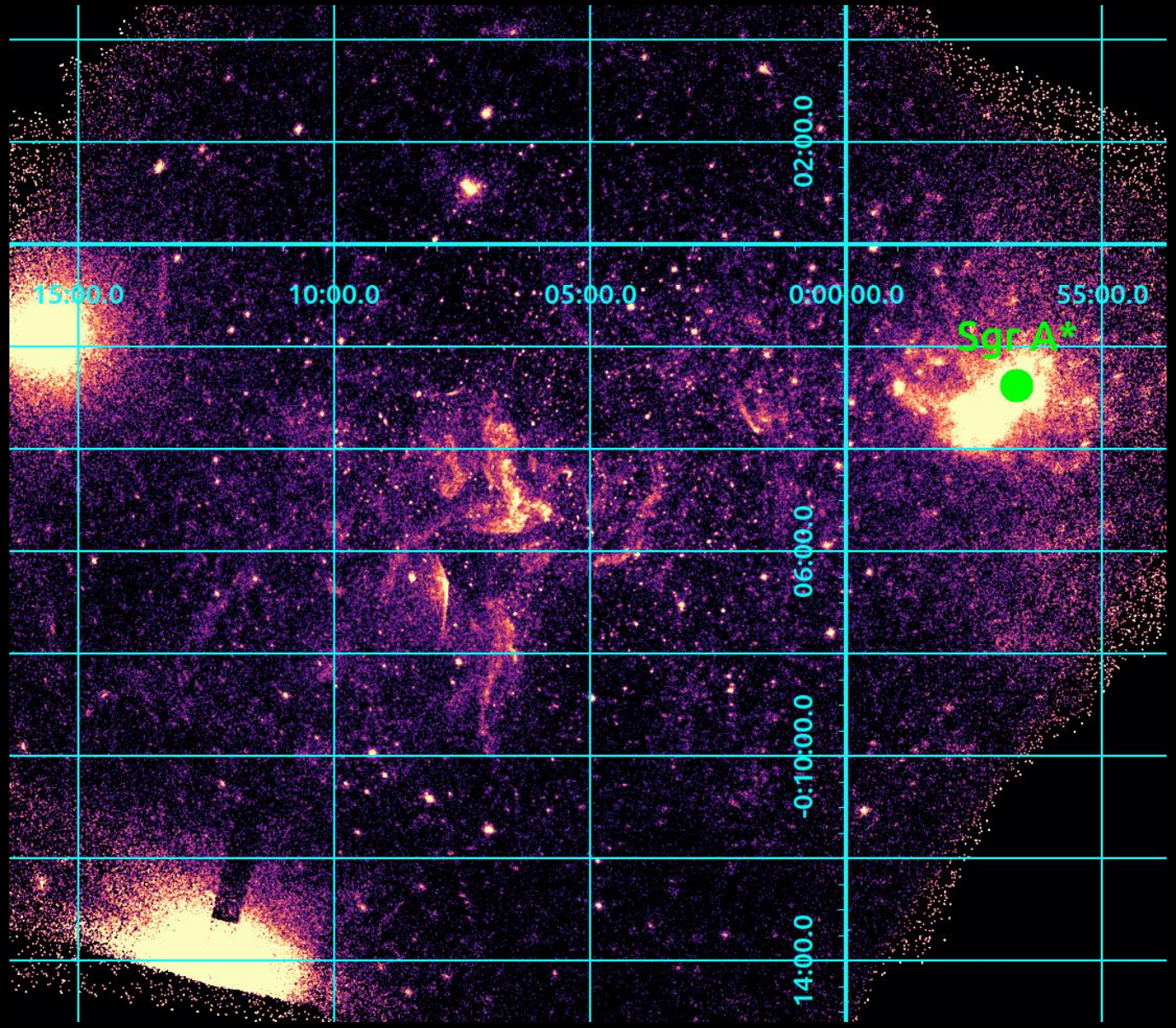
Resulting ratio is ~2–3 depending on the model

Total 6.7 keV line flux per unit mass in the NSD region is ~1.3–1.5 times higher than in the bar/disk (Anastasopoulou et al., 2023)



Nezabudkin et al. (2025)

Chandra Observations



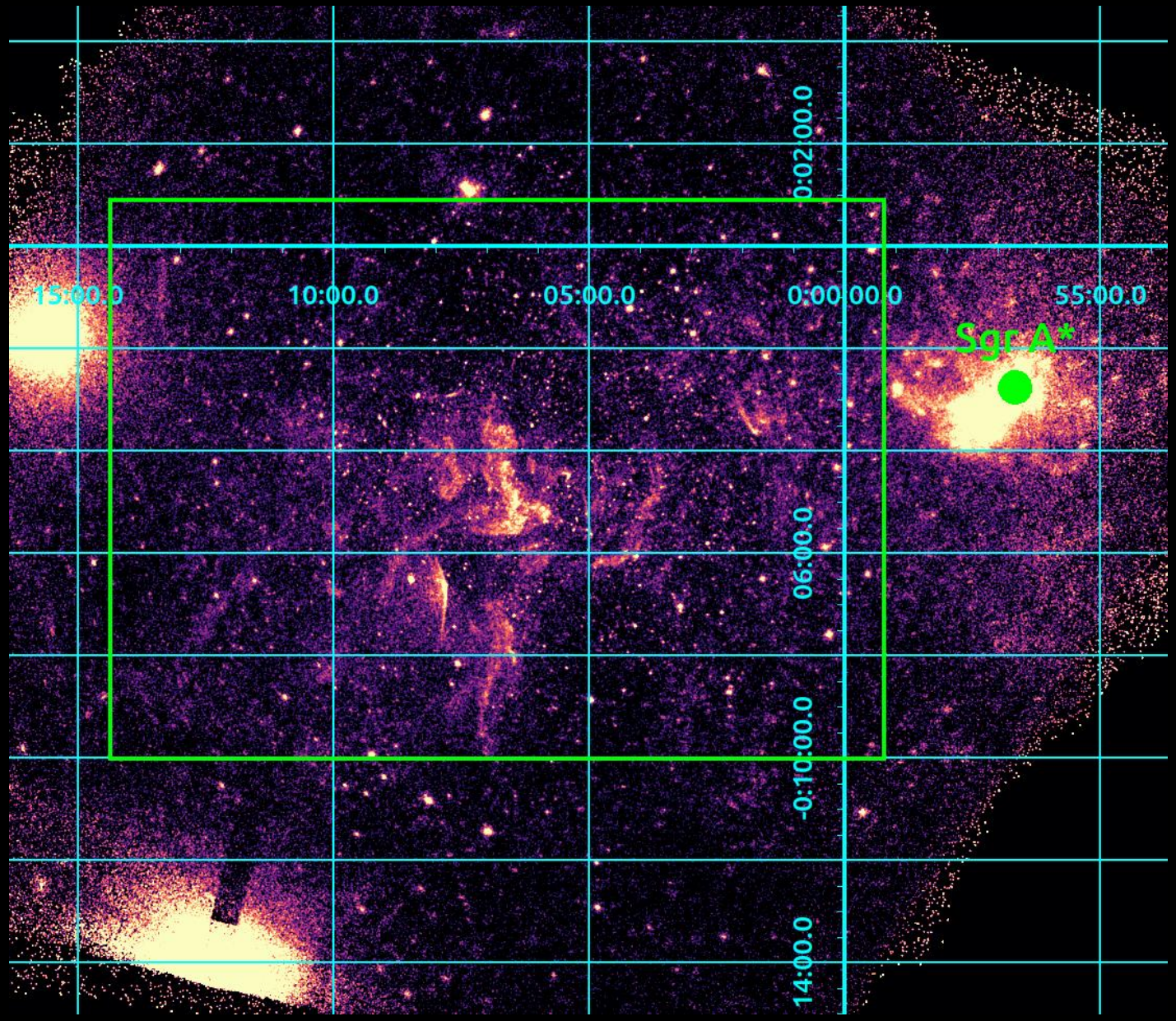
Target: CMZ region with molecular clouds

Dataset: Chandra deep field

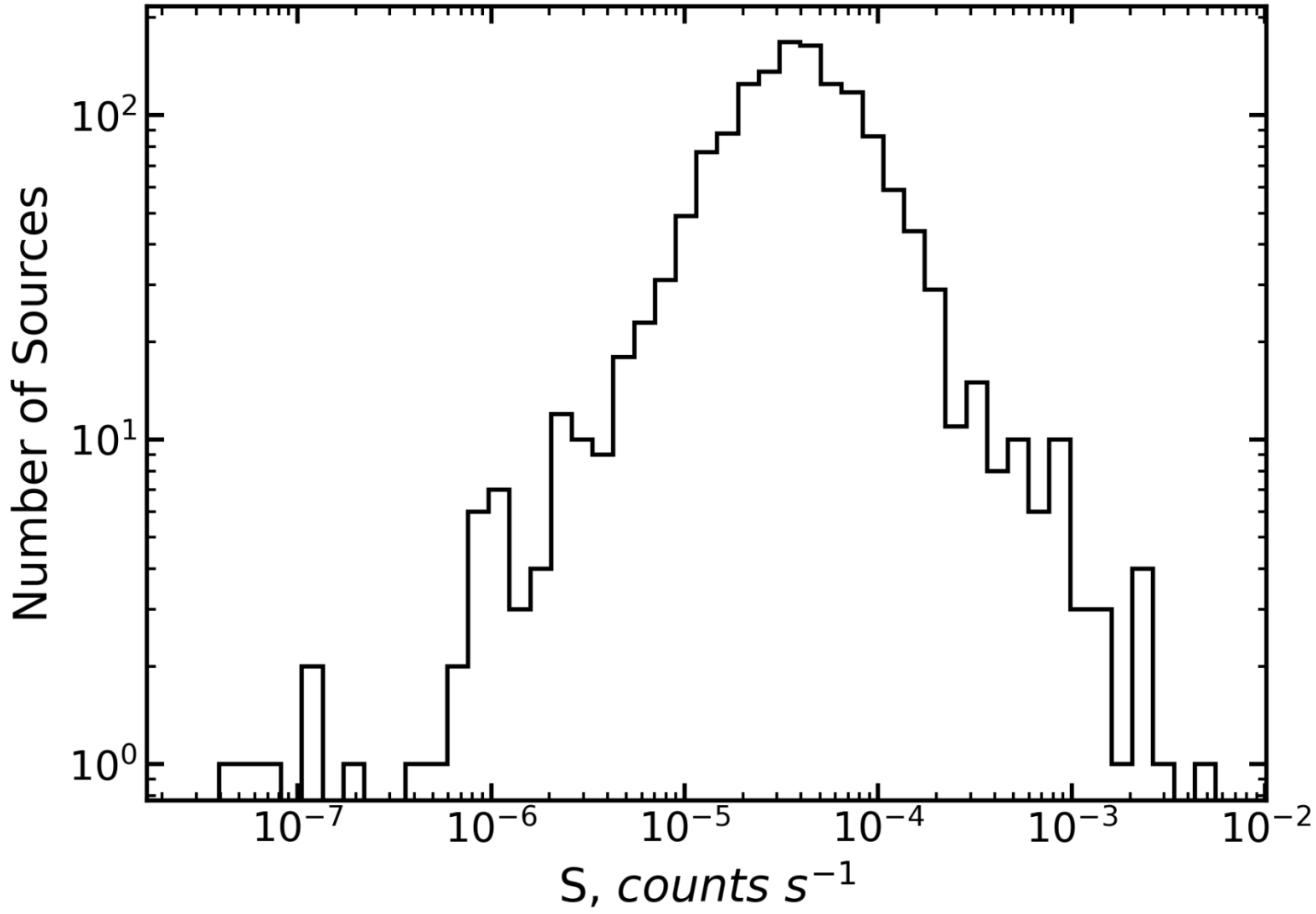
Energy range: 4–8 keV

Peak exposure: 800 ks

Investigated Area



Count Rate Distribution of X-Ray Sources



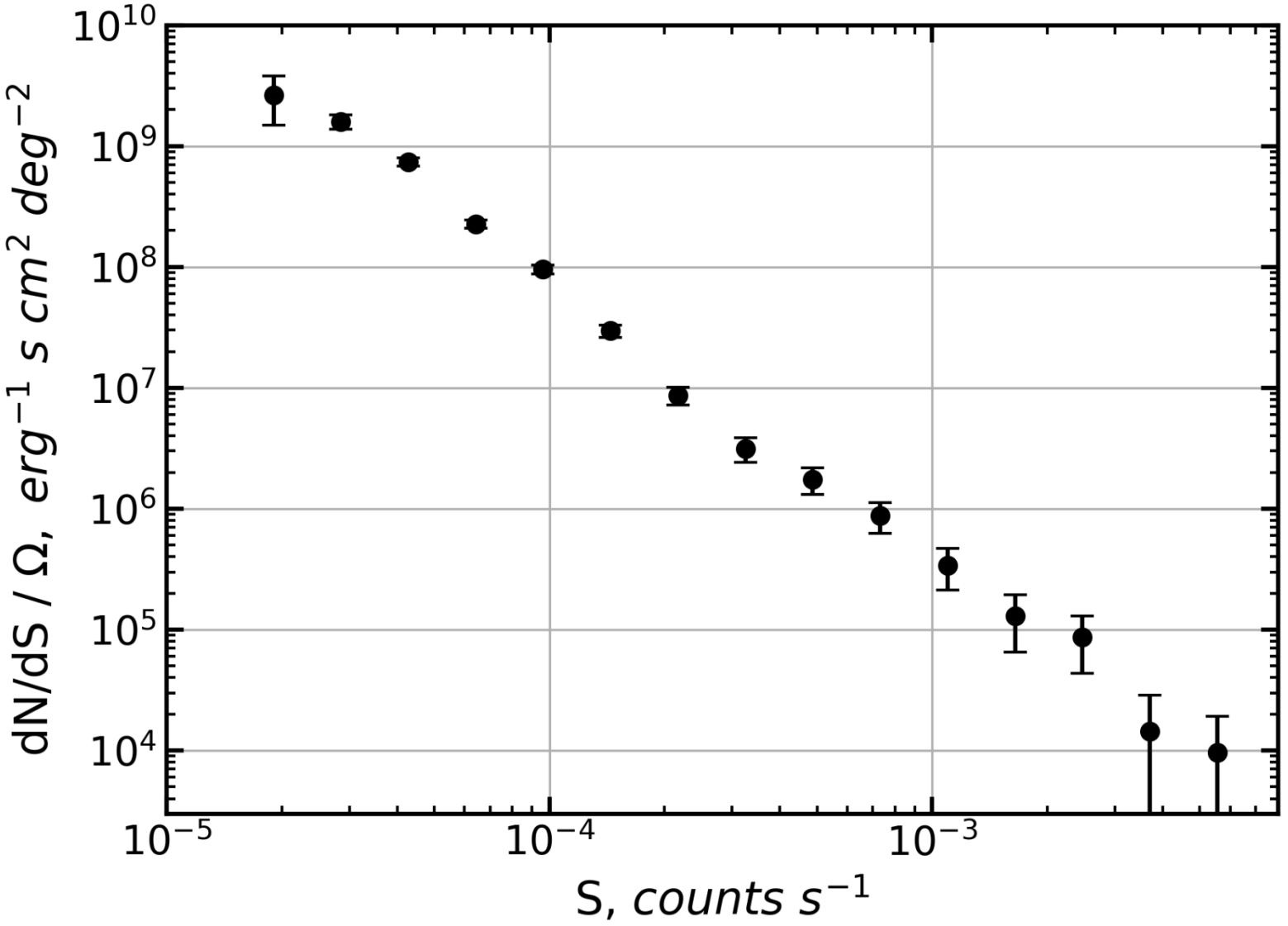
Total:

- 1725 sources (165 arcmin^2)

Source detection:

- wavdetect
- 1% false-source rate

dN/dS Distribution of Sources



Background map generation:

- wavelet decomposition

Detection threshold:

- 4σ

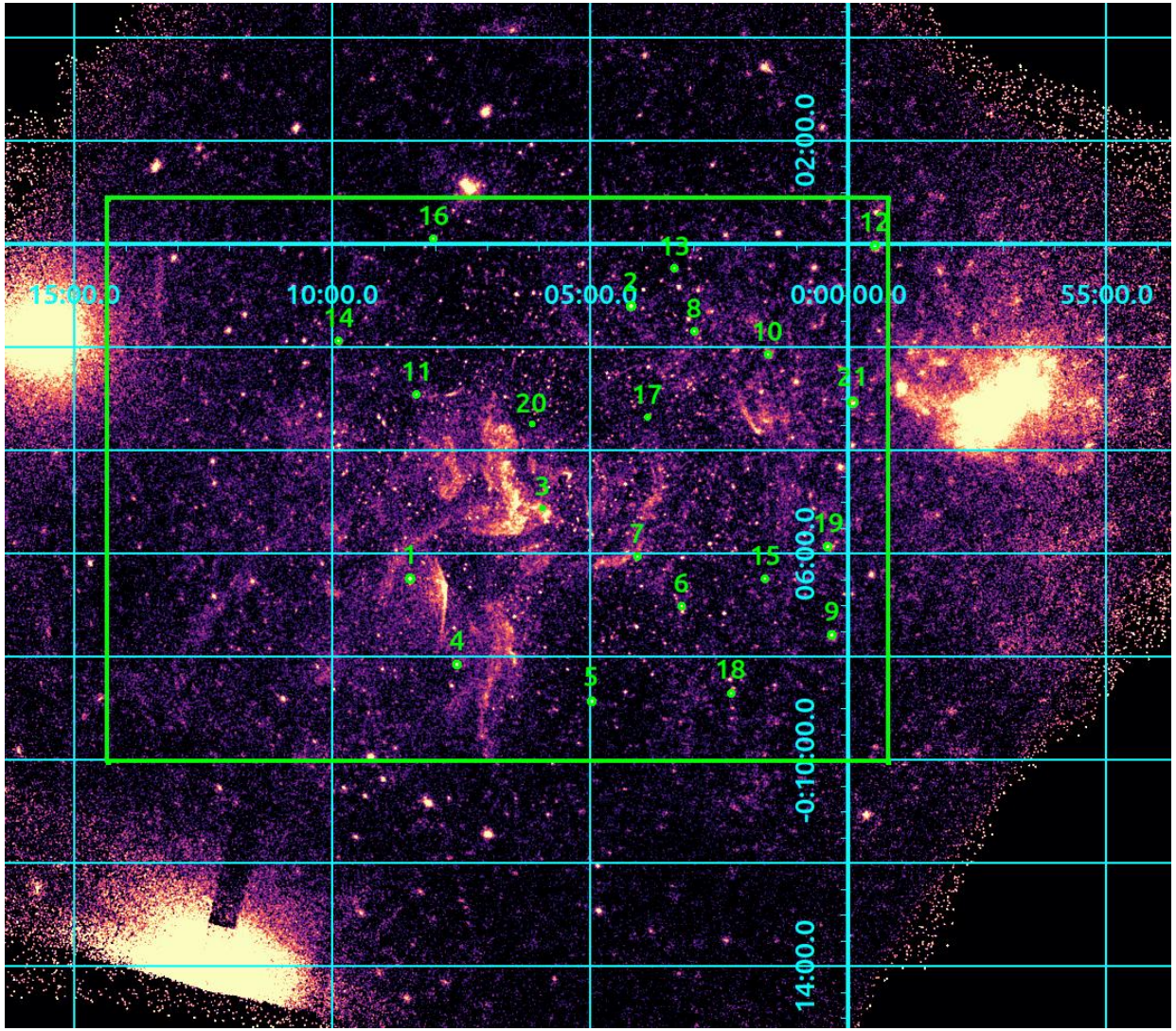
Flux measurement:

- aperture photometry

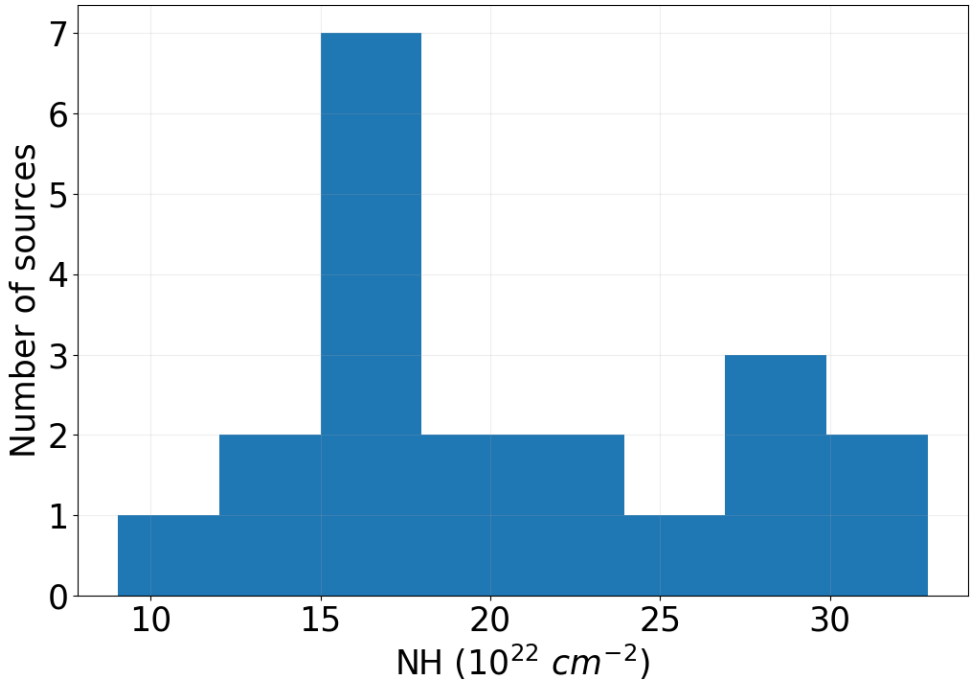
Effective area correction:

- based on the 4σ sensitivity map

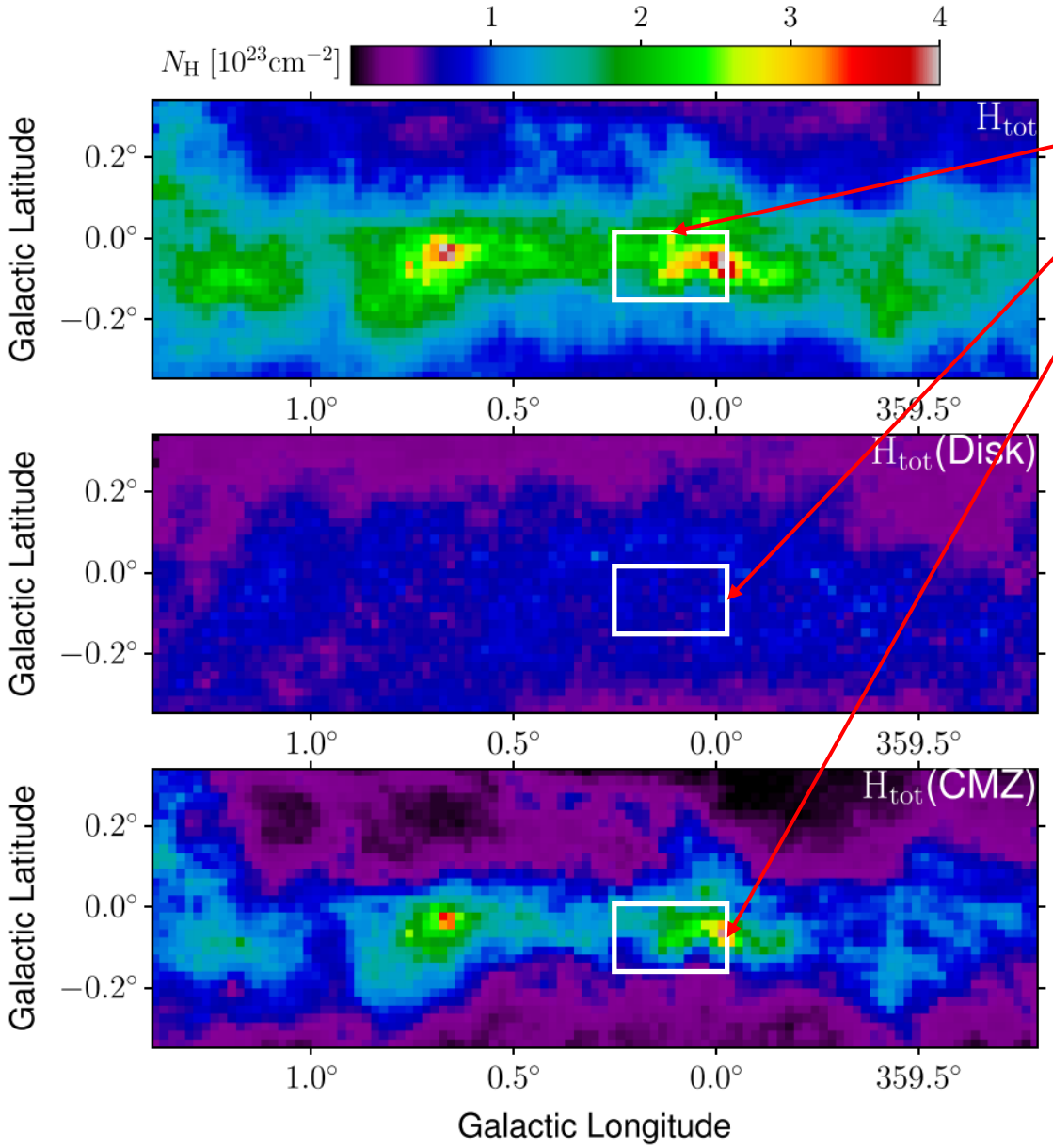
Spectral Properties



Model = **tbabs*(powerlaw + gauss1 + gauss2)**
gauss1: **6.67 keV** (Fe XXV)
gauss2: **2.46 keV** (S XV)



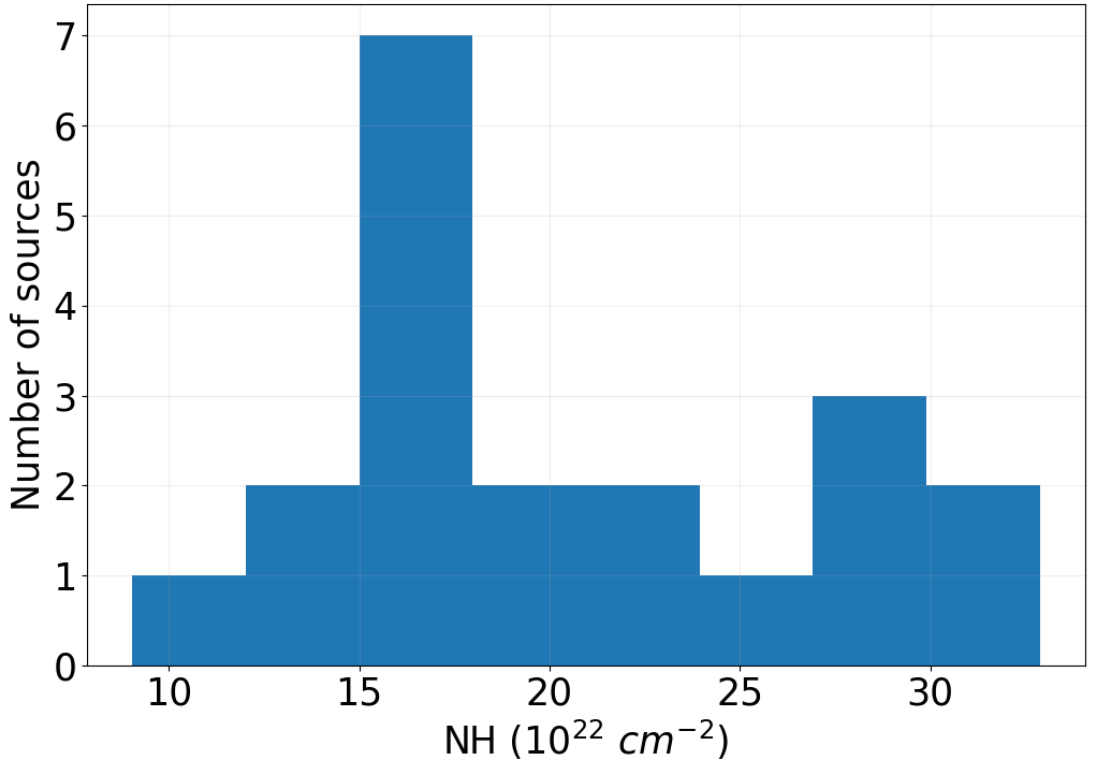
Spectral Properties



Ren et al. (2025)

Analyzed region

Current results



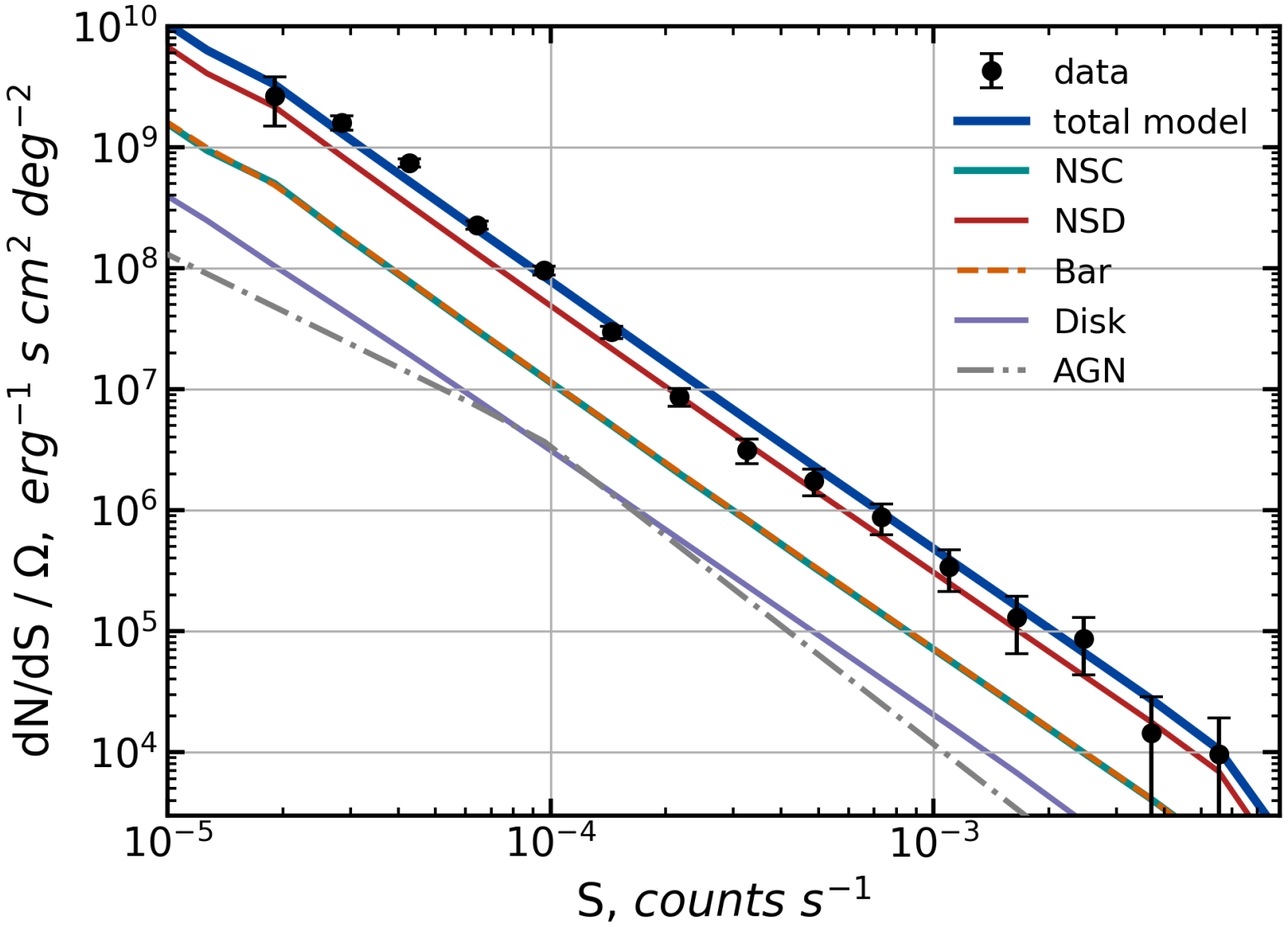
dN/dS Modeling

1. **Mass models:**
   - NSC – Chatzopoulos et al. (2015)
   - NSD – Sormani et al. (2022)
   - Bar/Bulge – Sormani et al. (2022)
   - Disk – Hunter et al. (2024)

2. **Luminosity function of CVs and ABs**

3. **Column density and spectral models**

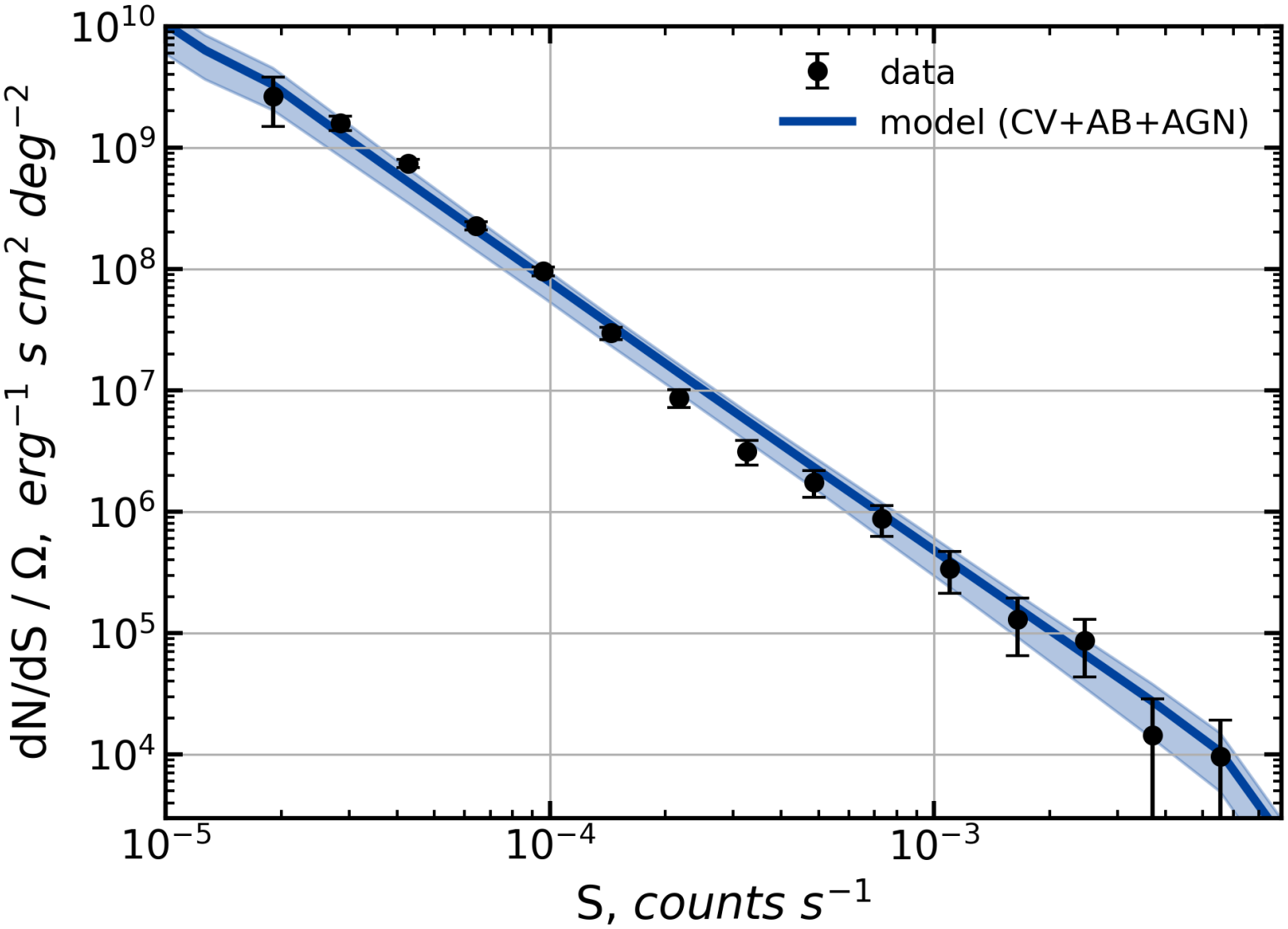
Results



Rates at $10^{-4} cnts/s$:

NSC – 14.5%
NSD – 62.5%
Bulge/Bar – 14.7%
Disk – 4.0%
AGN – 4.3%

Results


data
model (CV+AB+AGN)
dN/dS / Ω, erg^{-1} s cm^2 deg^{-2}
S, counts s^{-1}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{-5}
10^{-4}
10^{-3}

Comparison with the Norma Arm

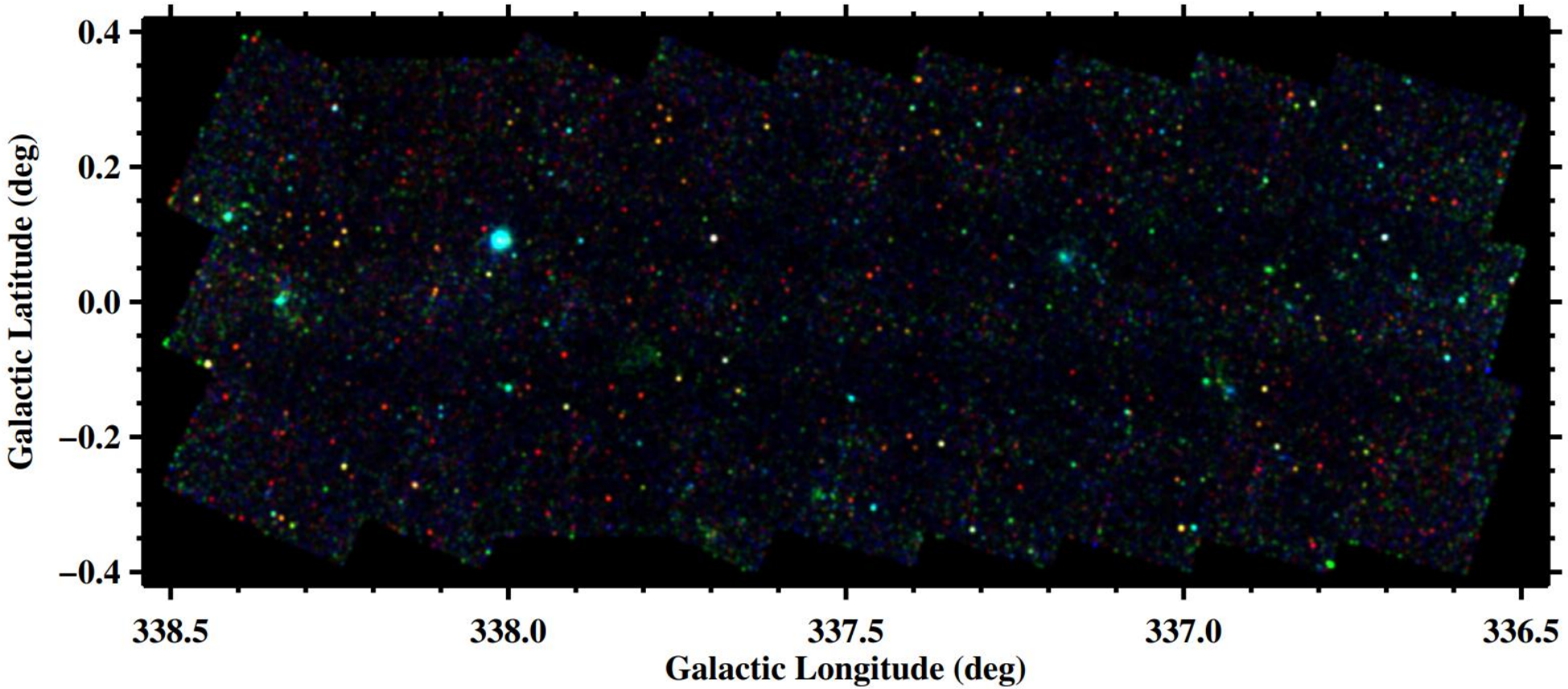
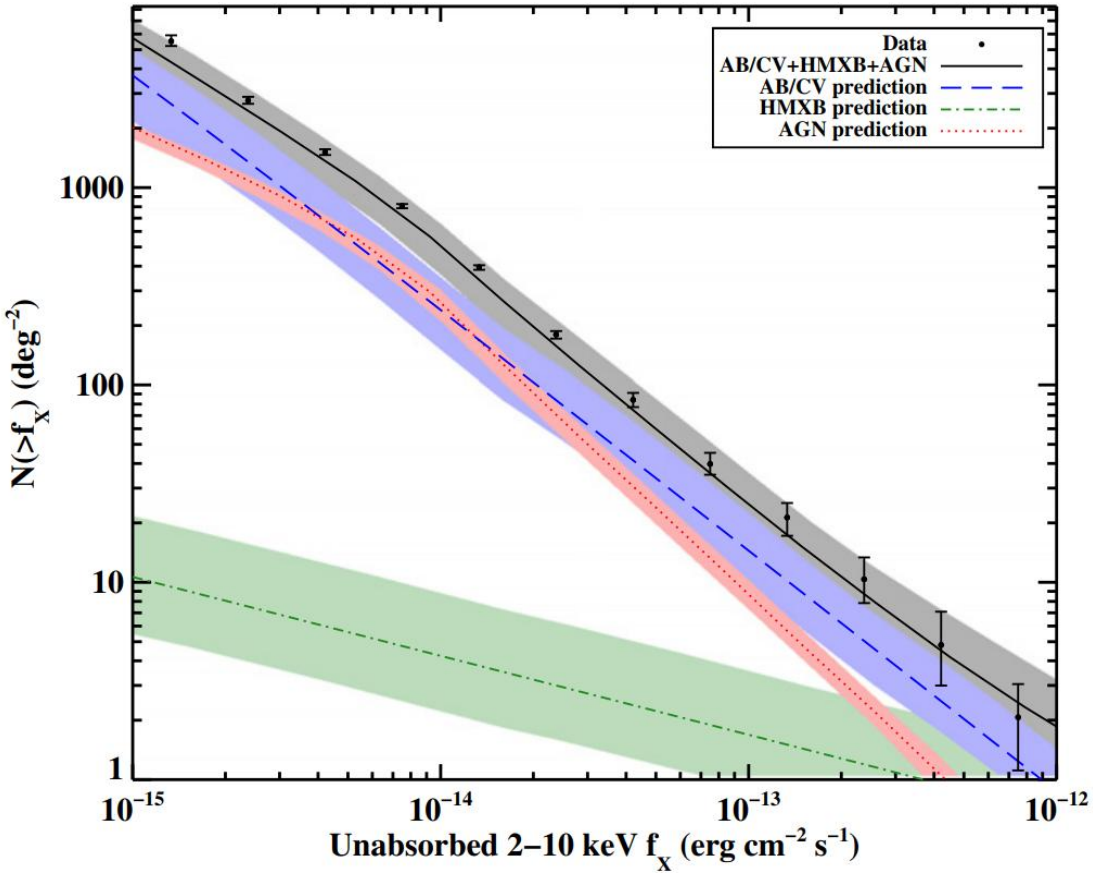


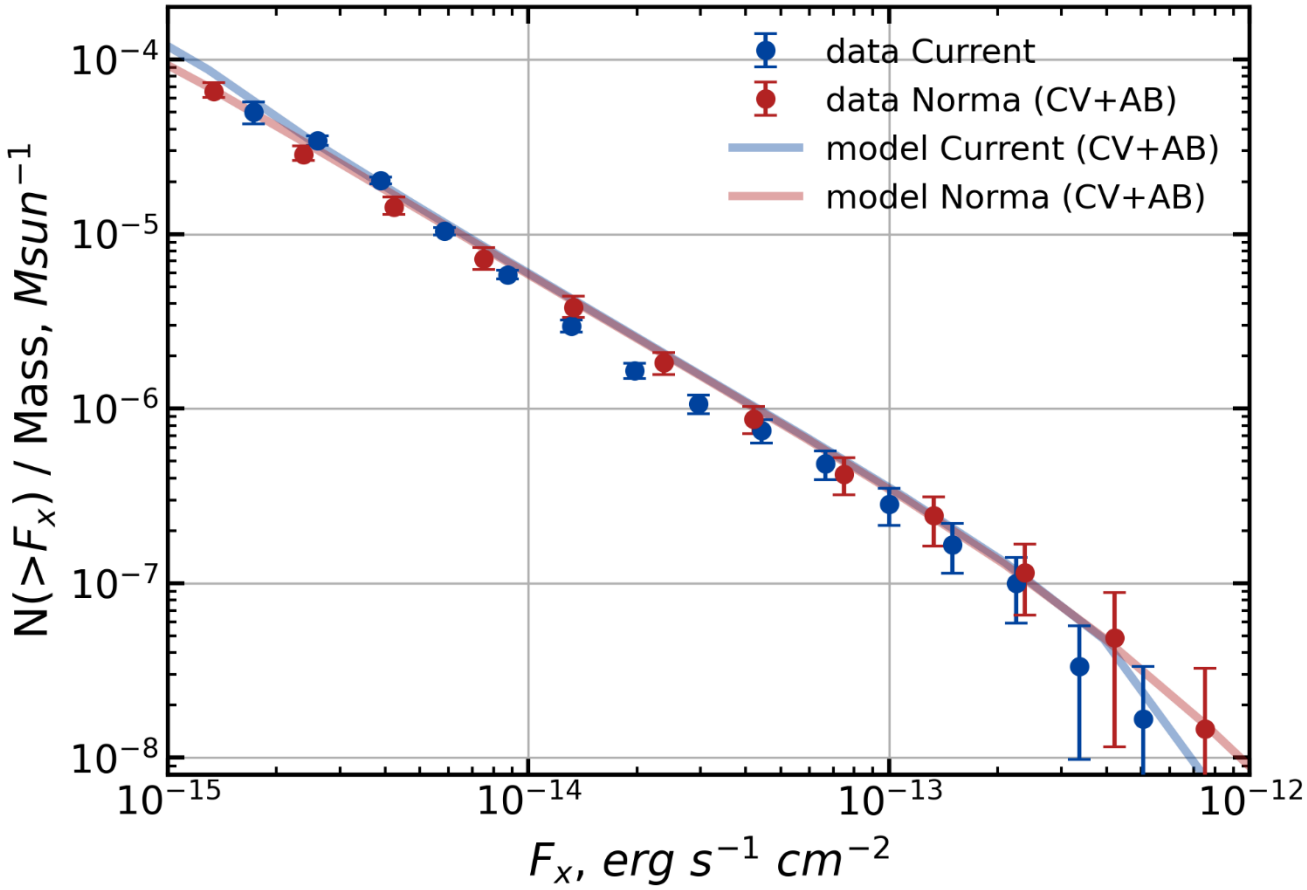
Figure 1. Three-color image of the Norma survey area. Red is 0.5–2 keV, green is 2–4.5 keV, and blue is 4.5–10 keV. Each energy band was smoothed using `aconvolve`. Some artifacts are present at the chip edges.

Fornasini et al. (2014)

Comparison with the Norma Arm



Fornasini et al. (2014)

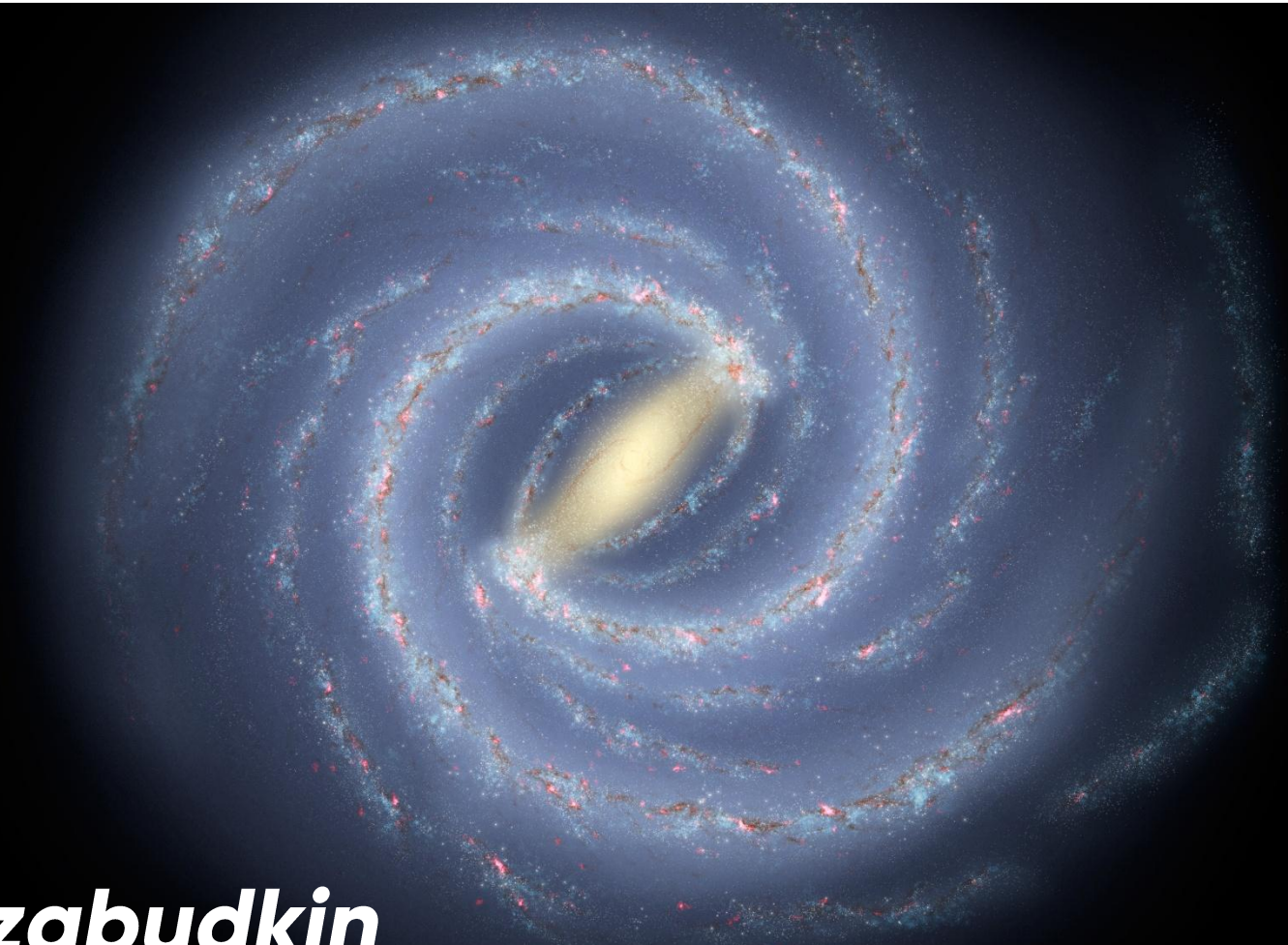


X-ray emission at fluxes > 10^{-15} $erg\ s^{-1}\ cm^{-2}$ is consistent across the NSD, Solar neighborhood, and Norma arm!

Conclusions

- **Differential source dN/dS distribution for the Galactic Center (NSD region) obtained**
- **CMZ absorption independently derived from spectral analysis of a source sample (median $N_H = 1.66 \times 10^{23}\ cm^{-2}$)**
- **Faint X-ray source population in the Galactic Center is consistent with the solar neighborhood and Norma arm above $10^{-15}\ erg\ s^{-1}\ cm^{-2}$ (2–10 keV)**

Thank you for your attention!



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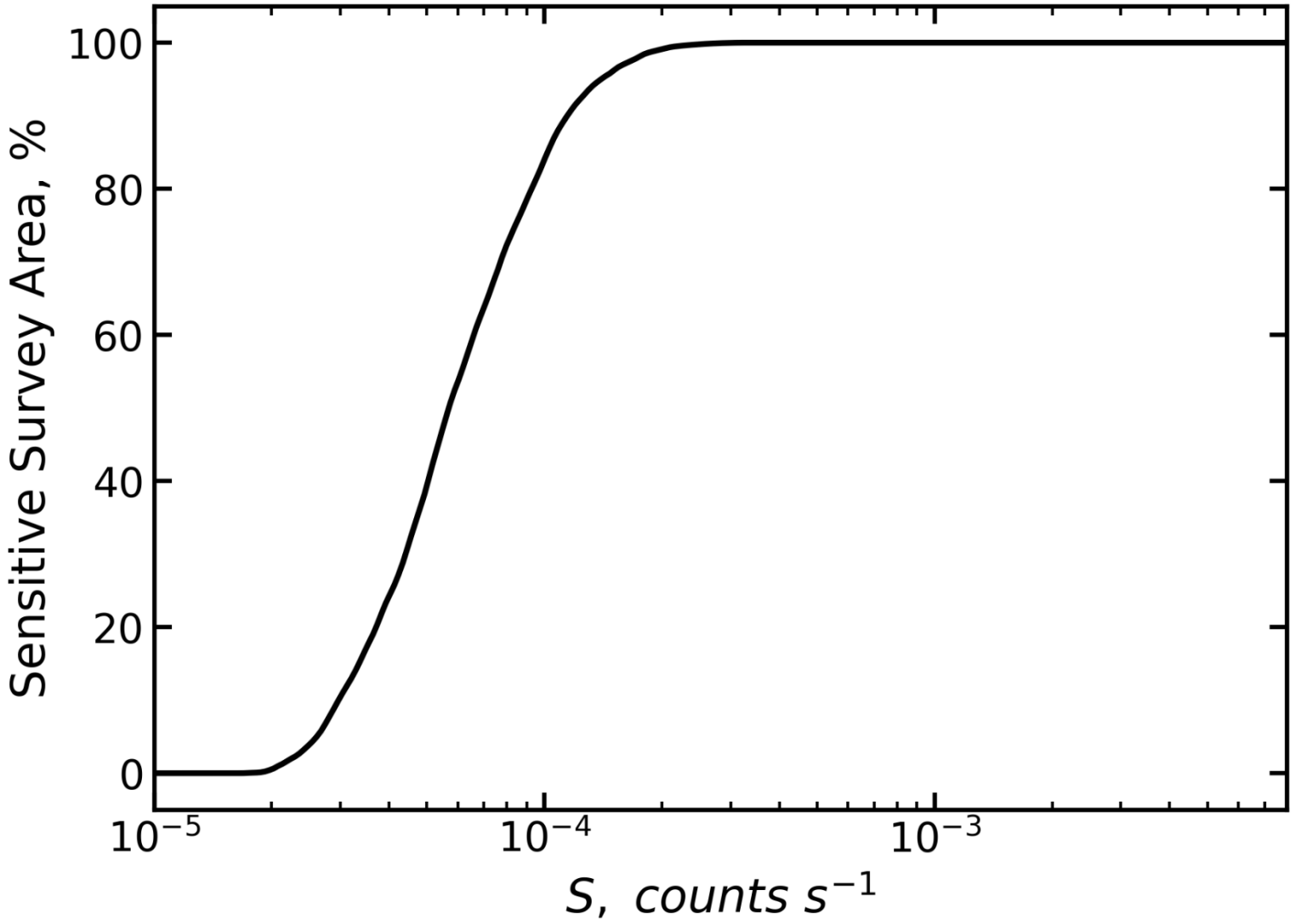
Additional slides

Normalized Sky Coverage



Example Spectrum of the Brightest Source