X-ray bright AGN in local dwarf galaxies: insights from eROSITA

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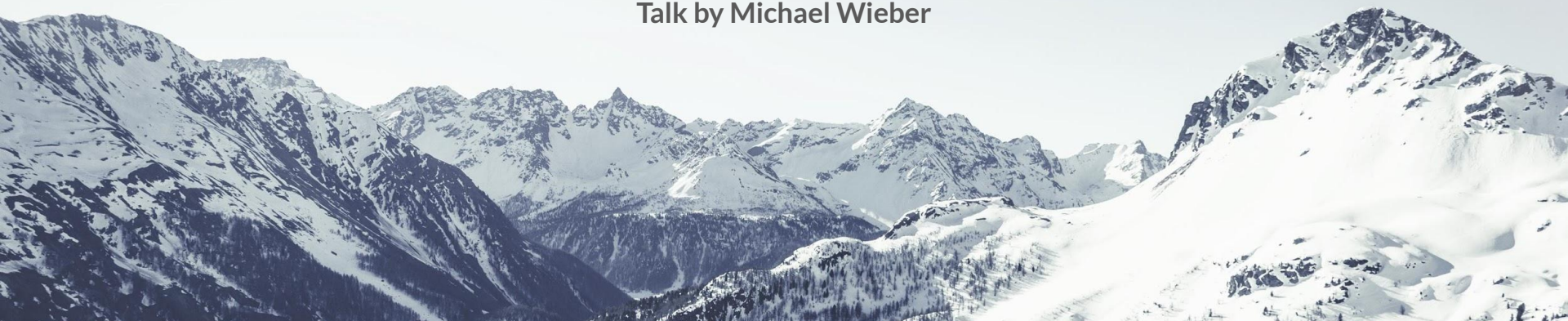

Outline

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Background & Purpose

Supermassive Black Holes

- Supermassive Black Holes (SMBHs) in virtually every massive galaxy
- Unknown seeding mechanisms for SMBHs (Direct Collapse, popIII stars)
- SMBHs recently have been found in high-redshift dwarf-like galaxies

Purpose: investigate the seeding and growth mechanisms of the first black holes by comparison to local dwarf galaxy AGN

Observational Methods

Methods to survey Active Galactic Nuclei (AGN)

- Optical spectroscopy……(Biased)
- Optical, UV, IR variability ……(Low Contrast)
- Radio emission……..(Expensive)
- X-ray observations ……(Shallow and low-resolution)

eROSITA

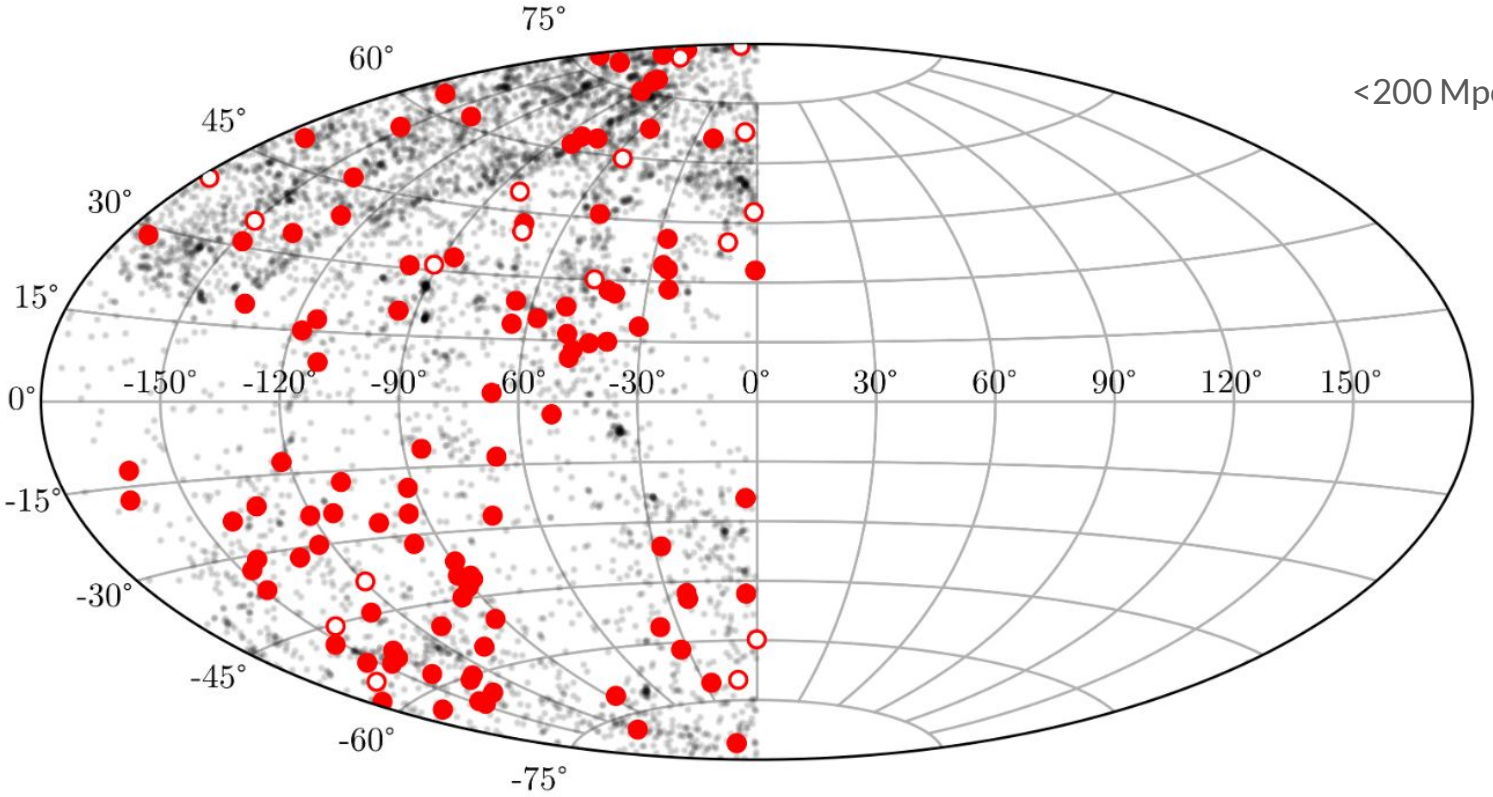
extended ROentgen Survey with an Imaging Telescope Array

Highest sensitivity X-ray all-sky survey to date

eROSITA All Sky Survey Data Release 1 (eRASS1) finds > 930,000 X-ray sources in western half of sky

Data & Cleaning

Dwarf-X-ray Matches

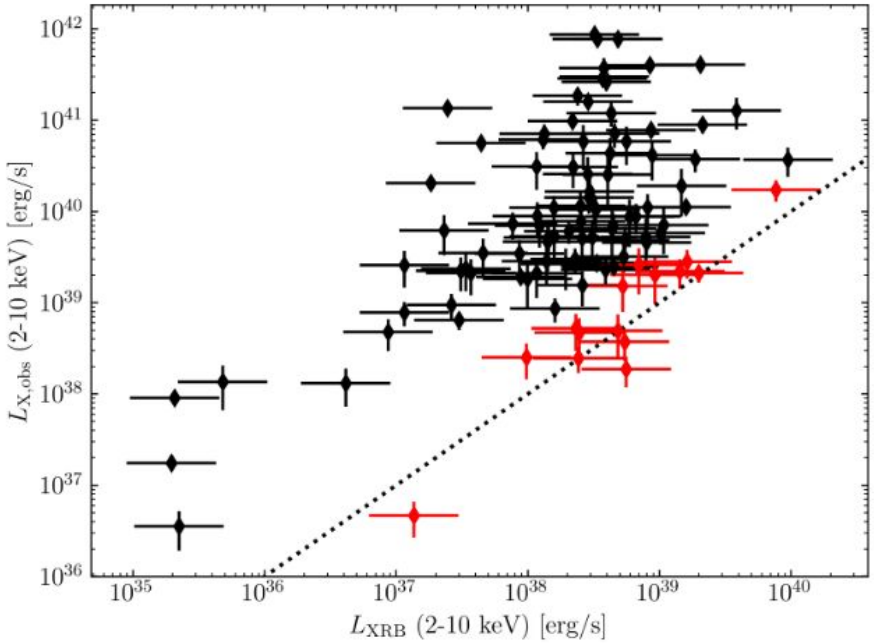


<200 Mpc

Unresolved X-ray Binaries

Low mass X-ray binaries (LMXBs) emission correlates with the stellar mass of galaxies

High mass X-ray binary (HMXB) emission correlates with the star forming rate (SFR) of a galaxy

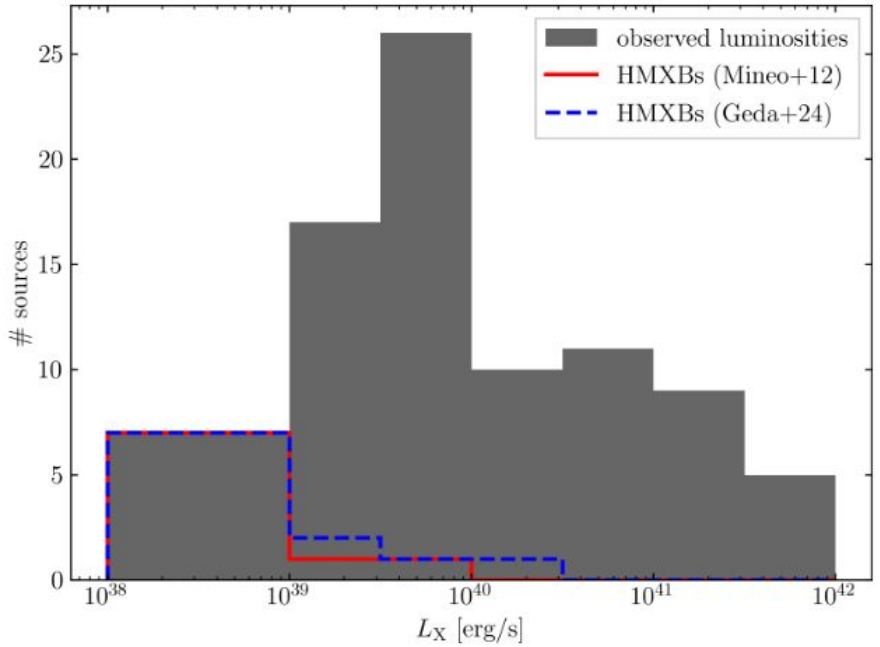


$$L_{2-10\,\mathrm{keV}}\,(\mathrm{erg/s}) = \alpha M_{\mathrm{gal}} + \beta \mathrm{SFR}$$

More X-ray Binaries

Removed all source with L < 10^39 erg/s

2 - 4 expected remaining HMXB contaminants



Crossmatching

XMM-Newton and Chandra telescopes

- 1 spurious detection
- 4 known ultraluminous X-ray sources (ULXs)

74 dwarf galaxies with an eROSITA-detected source

Results

X-ray Hardness Ratio

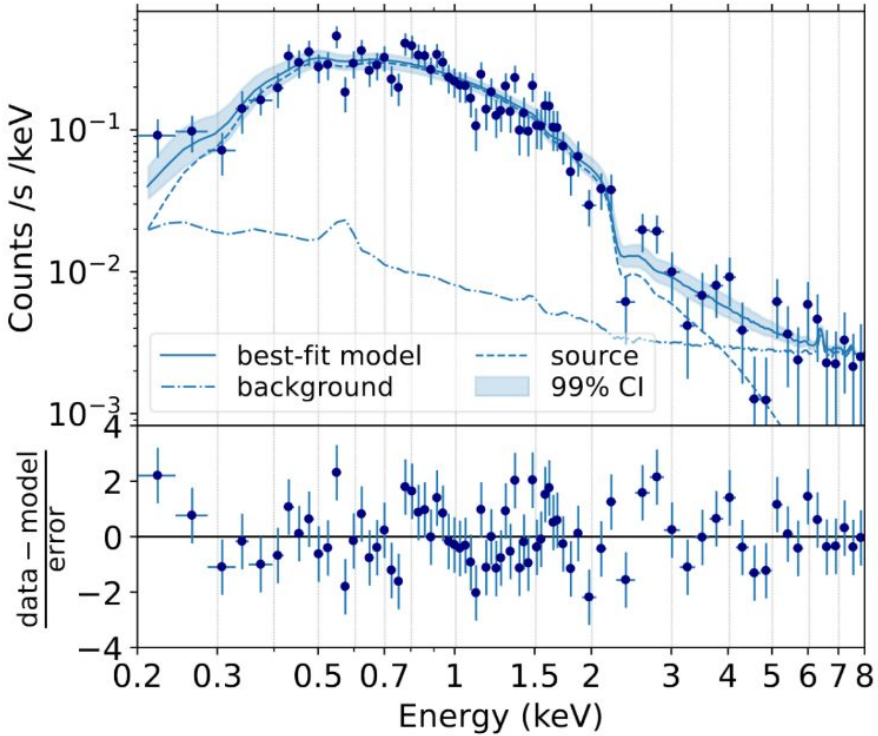
$$\mathrm{HR} = \mathrm{S/M}$$

S: number of counts measured in the “soft” band (0.5-1 keV)

H: number of counts measured in the “hard” band (1-2 keV)

HR = 0.98 ~ Γ = 1.8

Agrees with earlier data for AGN

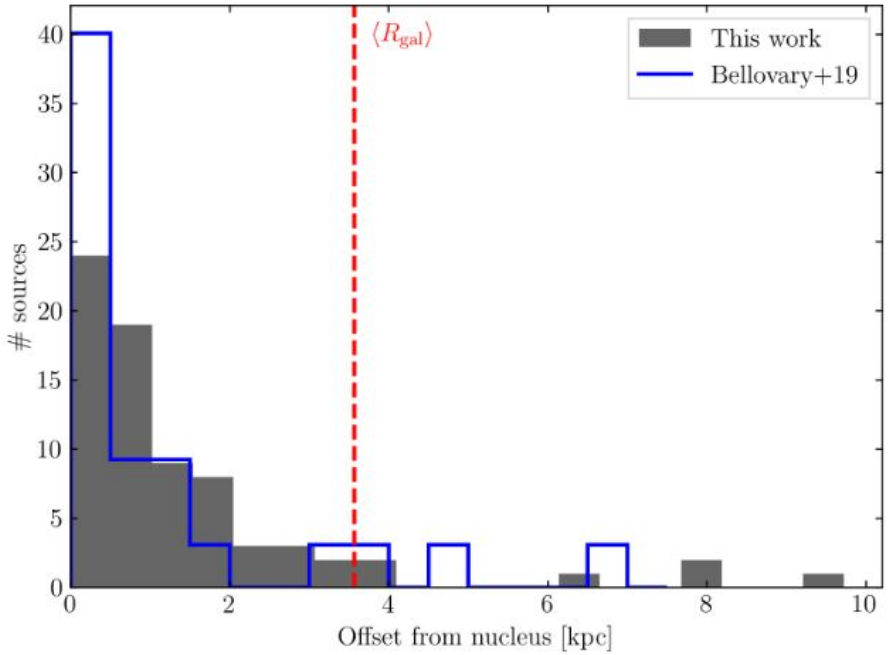


AGN Offset

Offset between galaxy centroid and X-ray source

Align with earlier work for dwarf galaxy AGN

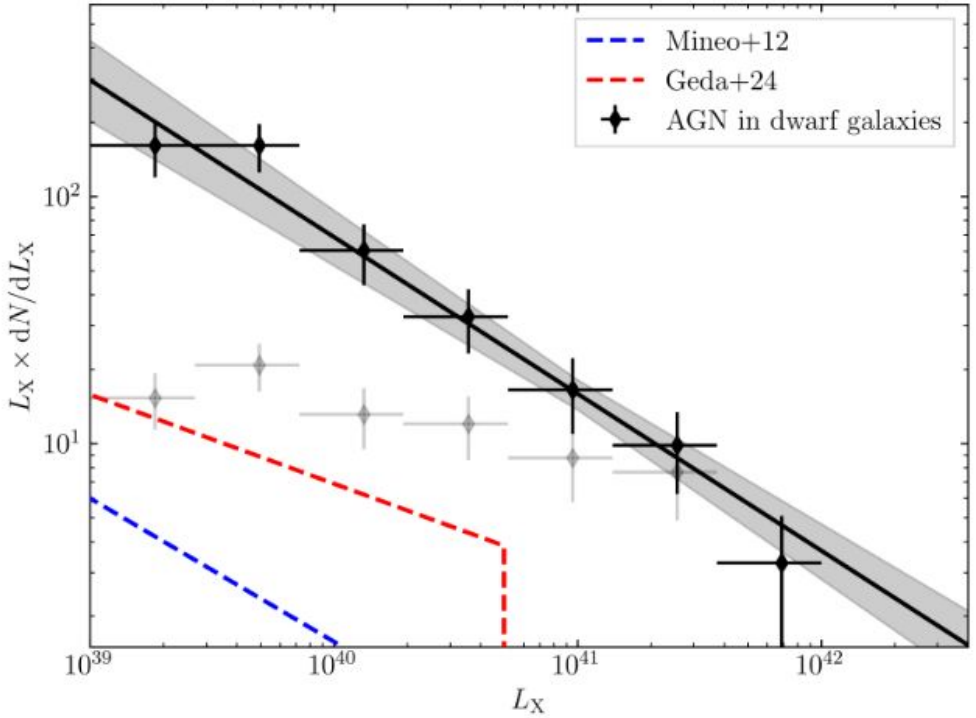
Low spatial resolution cannot accurately place X-ray sources

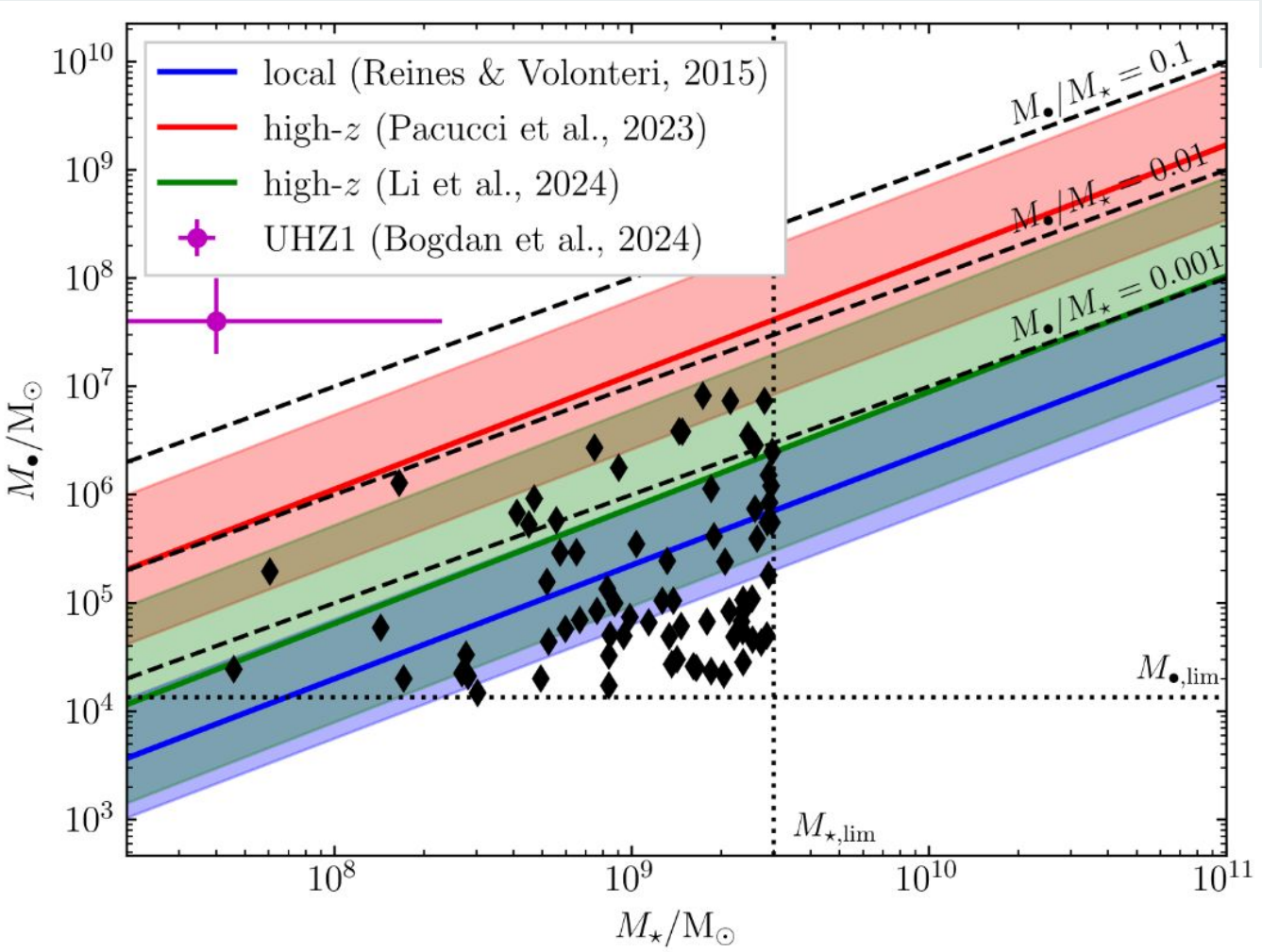


Luminosity Function

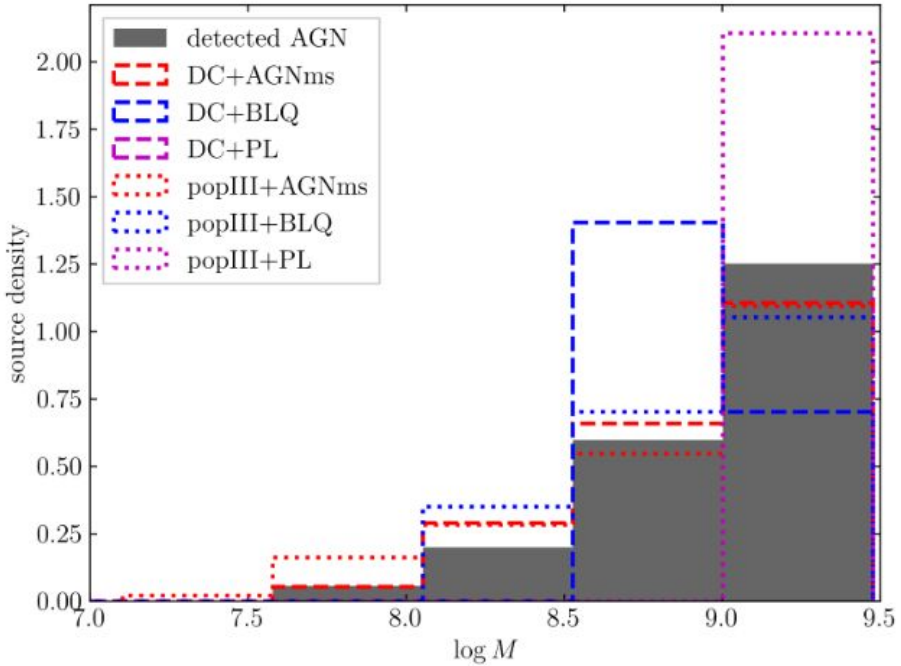
Distribution of X-ray sources per luminosity

Distinct from ULX and HMXB objects

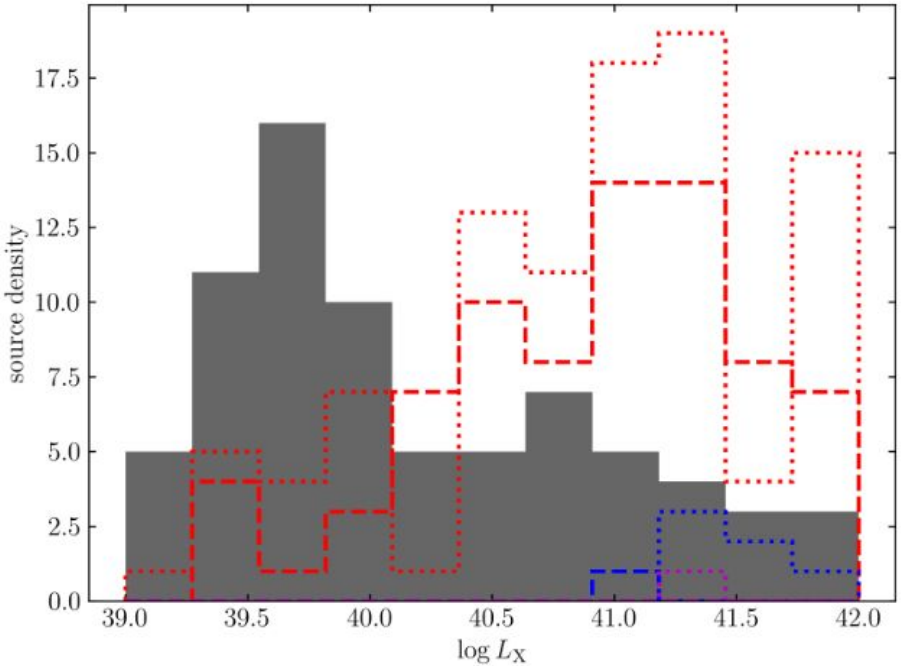



local (Reines & Volonteri, 2015)
high-z (Pacucci et al., 2023)
high-z (Li et al., 2024)
UHZ1 (Bogdan et al., 2024)
$M_\bullet/M_\star = 0.1$
$M_\bullet/M_\star = 0.01$
$M_\bullet/M_\star = 0.001$
$M_{\bullet,\mathrm{lim}}$
$M_{\star,\mathrm{lim}}$
$M_\bullet/M_\odot$
$M_\star/M_\odot$
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{8}
10^{9}
10^{10}
10^{11}

Models



AGNms: 10^(-3) * SFR



Preferred accretion mode is AGNms, inconclusive for seeding mechanism
More modeling efforts to reproduce luminosity distribution

Conclusions

Conclusion

- Matched 74 likely AGN-dwarf galaxy pairs in the western half of the sky with an expected contamination of 2 - 4 non-AGN objects
- Characterized observations with the X-ray hardness ratio, off-nuclear sources, luminosity function, and black hole to galaxy mass, all of which agree with AGN expectations
- Models show that AGN accretion seems to be tied to SFR, but ultimately more modeling must be done to determine seeding mechanisms and reproduce the luminosity distribution