Revealing the heavily obscured AGN population with radio selection

Aim: to find ALL the AGN

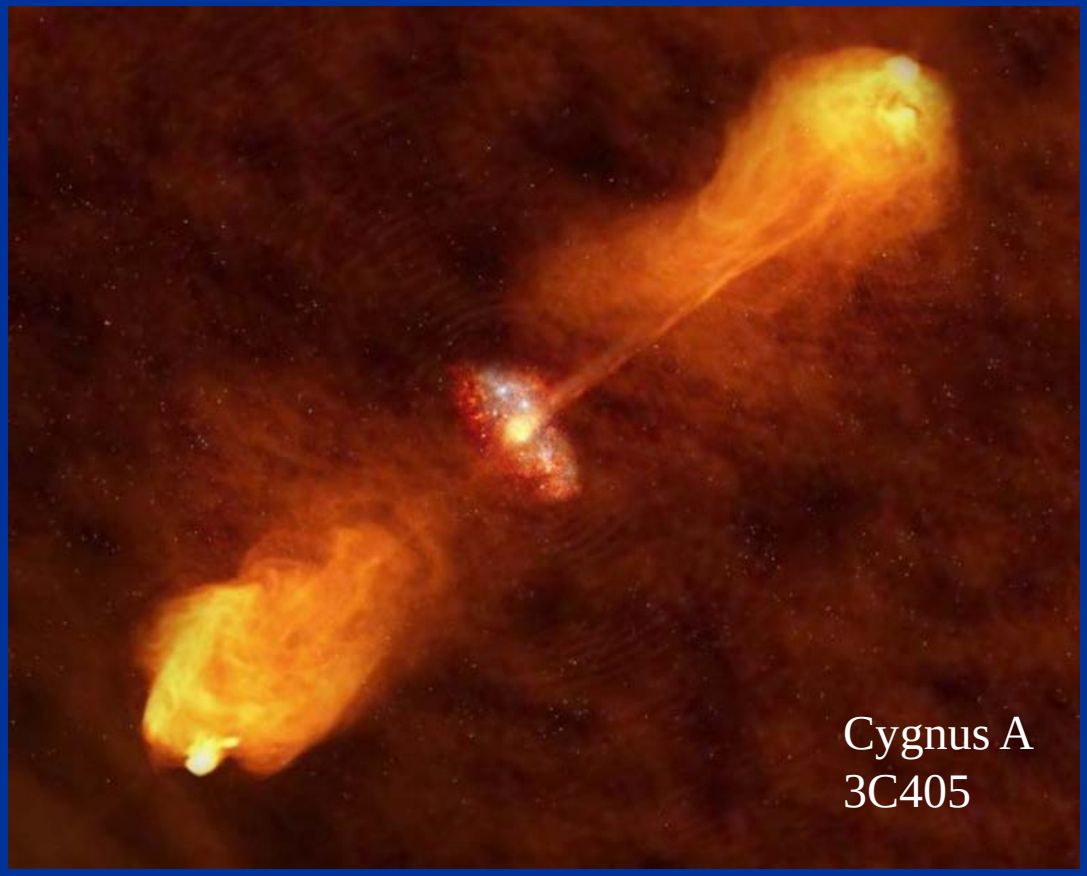
Wilkes, *Kuraszkiewicz, Atanas,*

Haas, Barthel*, Willner, Leipski, Worrall*
Birkinshaw, Podigachowski, Antonucci,

U.T. Cobley & all

Powerful, FRII Radio Galaxies

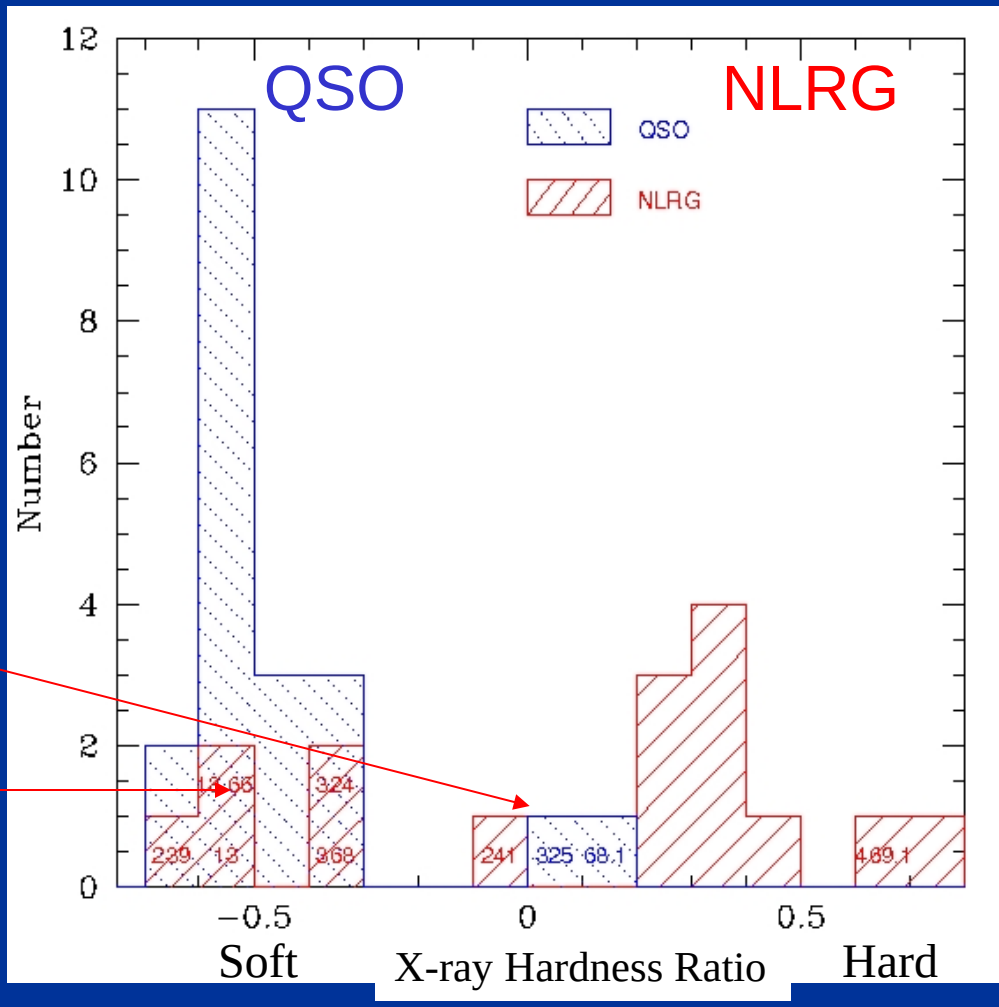
- 3CRR, z~1-2, low-frequency radio-selected
- High L/L_{Edd}, log $L \sim 10^{45\text{-}46}$ $ergs^{-1}$
- ***Orientation is dominant variable***



Chandra: X-ray Hardness Ratio

(Wilkes et al. 2013)

- **Simple Unification:**
  - QSO – face-on: bright + soft (Γ~1.9)
  - NLRG – edge-on: faint + hard
- **Exceptions**:
  - 2 QSOs + 1 NLRG: intermediate
  - 5 soft NLRG
- **Lower z~0.5-1 (+L)**
  - NLRGs: full range of HR

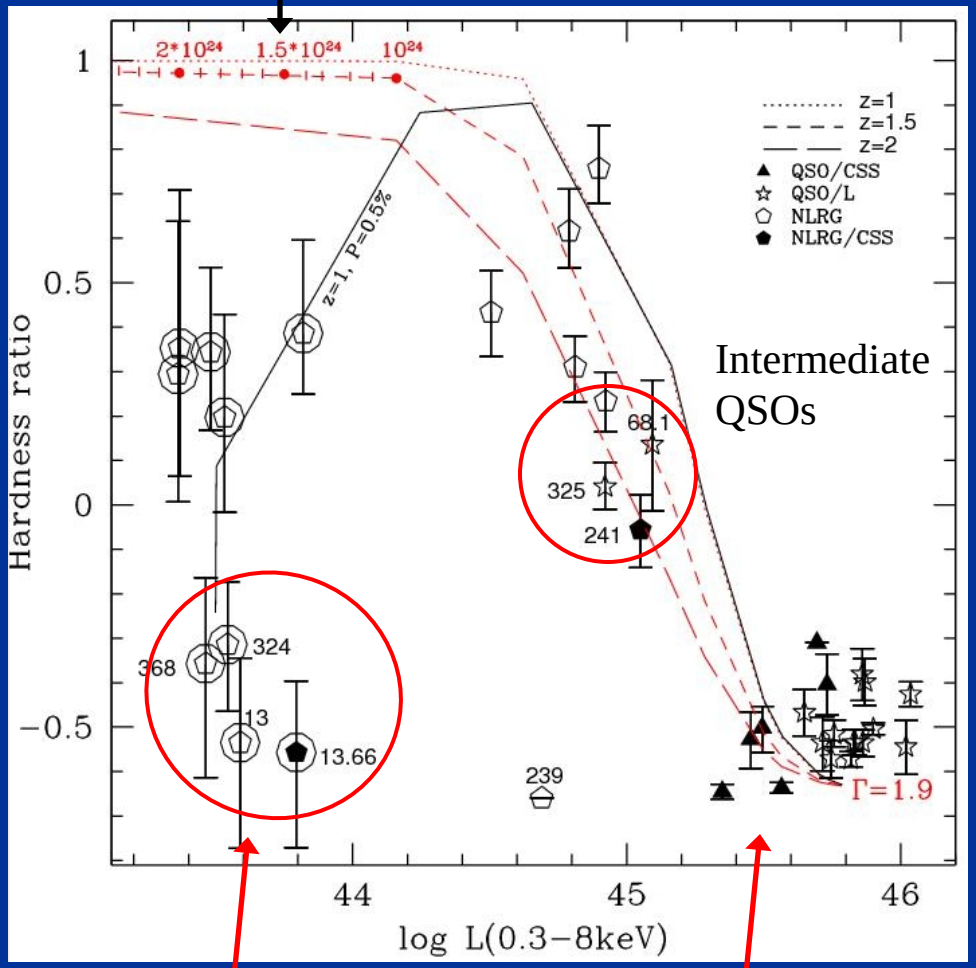


X-ray Luminosity is obscured

- HR hardens as L_X decreases
- Weakest sources include 2nd component: soft excess
- Possibilities:
  - Scattered nuclear light
  - Partial covering
  - Extended emission (NLR?)
  - Jet-related *(Hardcastle et al.)*

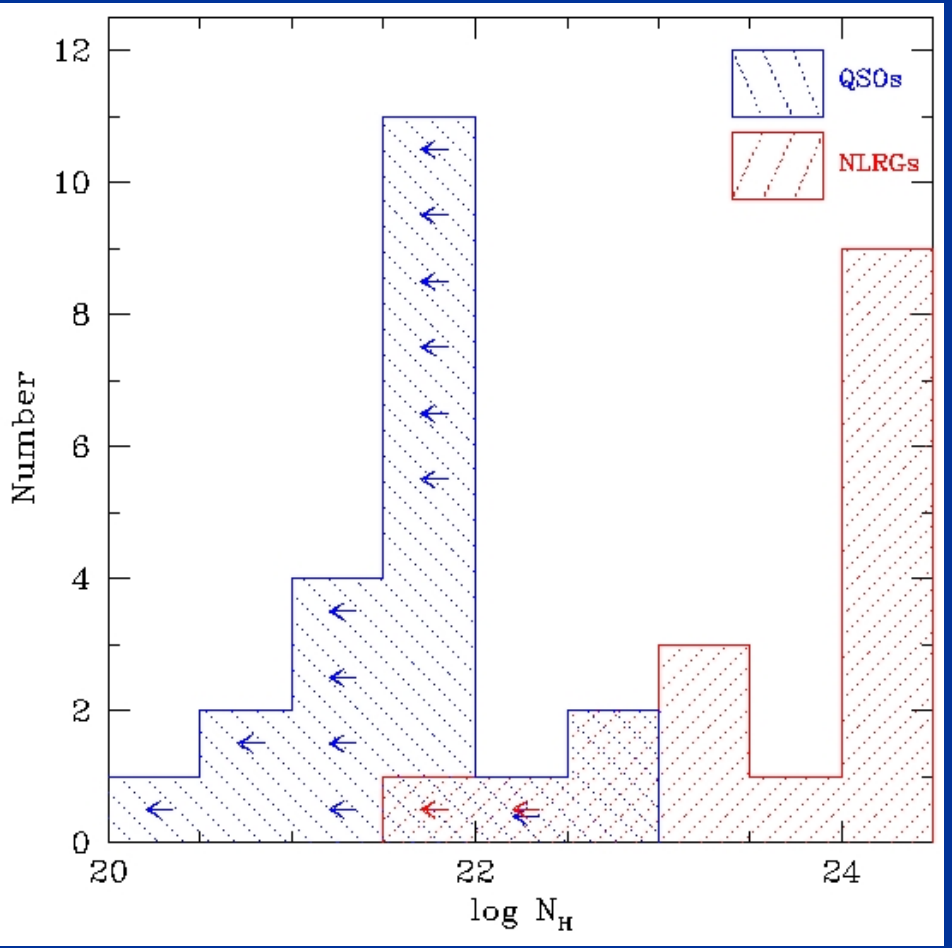
- Obscuration → decrease L_x
  - Hard to find + measure obscured sources
- HR ≠> N_H for low L_X

- Lower z: more complex



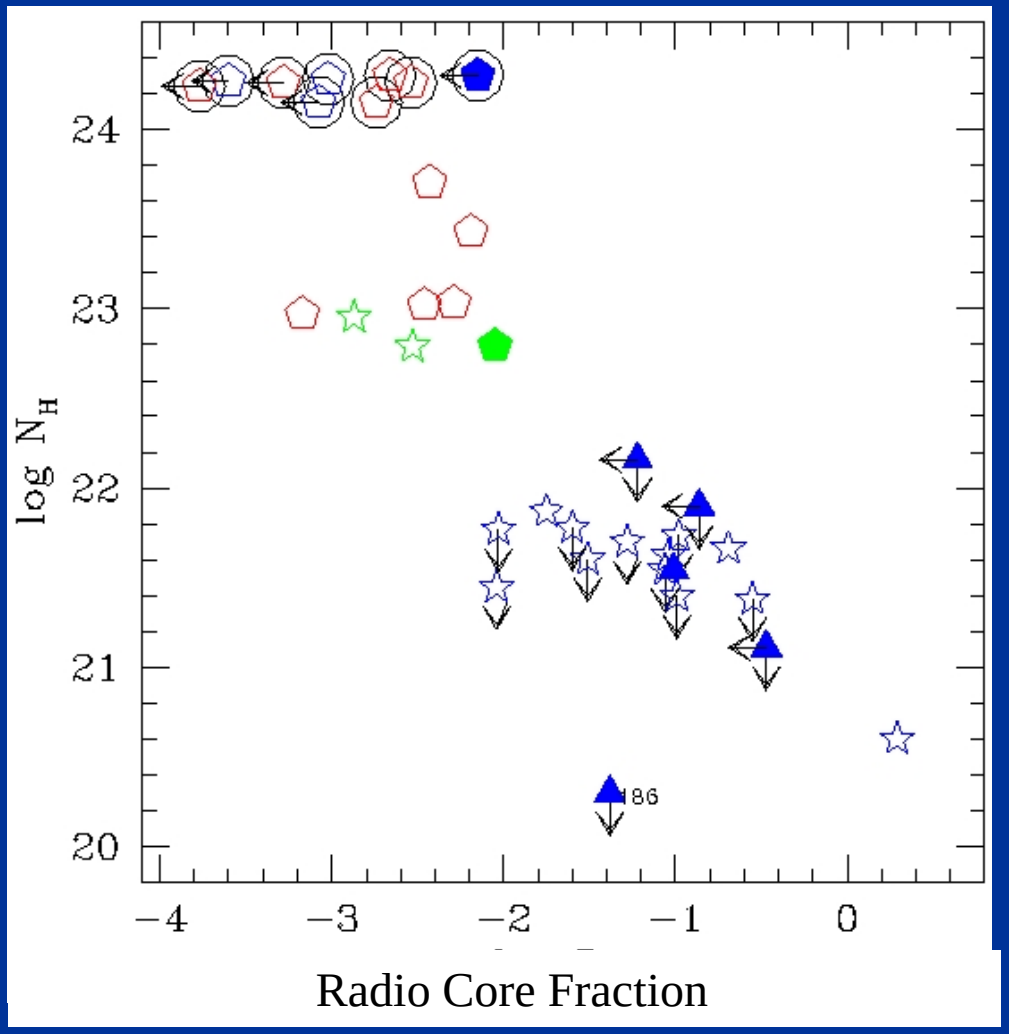
N_H Distribution

- NLRG N_H peaks at high values, $>10^{24}cm^{-2}$
- Consistent with z<1 3CRRs
  (Hardcastle et al 2009)
- CT fraction ~ 0.2
- Obscured fraction ~ 0.5, for $L \sim 10^{44\text{-}46}$ cgs RL AGN



X-ray Absorption vs. Radio Core-Fraction

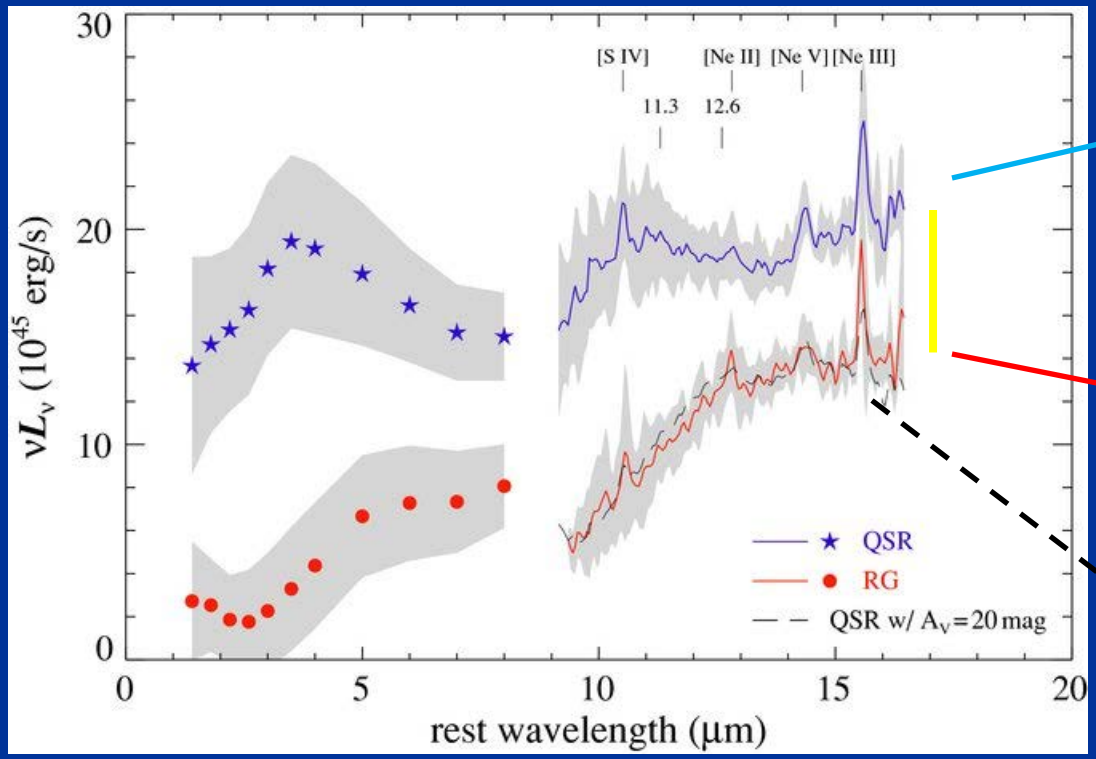
- Strongly correlated
- → Observed X-rays are consistent with orientation dependent obscuration of Unification Models



Spitzer Spectral Energy Distributions (SEDs)

[Normalized to Radio Luminosity]

Radio Galaxies are obscured Quasars



Median Quasars

Radio Galaxies

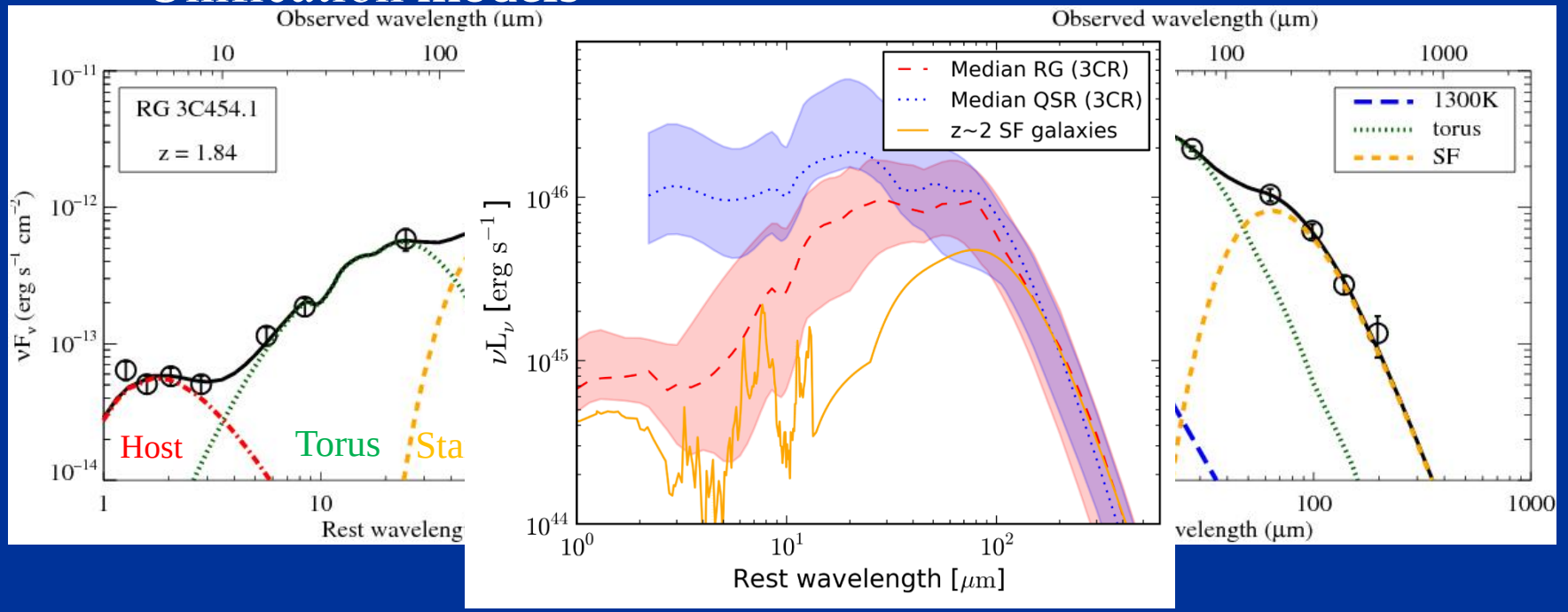
Quasar w/A_V~20

(Leipski et al. 2010)

Herschel Observations: IR SEDs

(Barthel GTO)

- 40% have high SFR
- FIR properties of quasars and RGs are similar
- MIR (<~40μm) colors of RGs are significantly redder
- → Unification models



See Poster: Monday's list

Unification Scenario

Orientation-dependent obscuration explains radio-X-ray SEDs of high-luminosity, high-redshift, low-frequency-selected radio sources

Rough Statistics:

- 19 (50%) QSO
- 3 (8%) intermediate
- 8 (21%) NLRGs
- 8 (21%) CT NLRGs

Results are inconsistent with a smooth torus

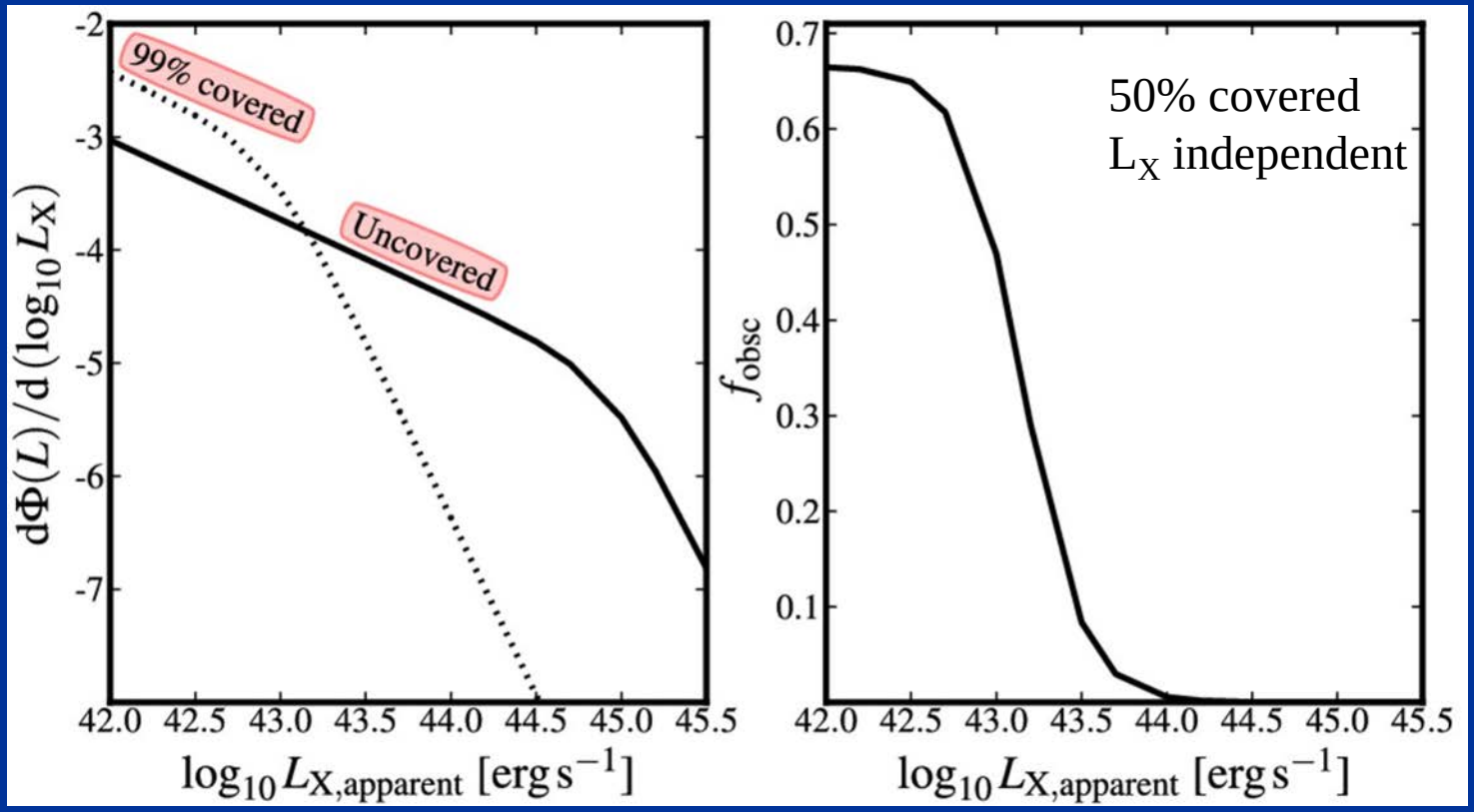
X-ray Active Galaxy Population

- Orientation alone → range of 100s in observed L_X
  - preferentially miss obscured sources of given L_X
  - fraction of obscured sources missed ~L, z

- For those we **do** find in X-ray surveys:
  - Without high S/N X-ray spectra → N_H and L_X underestimated
    - High L_X AGN → #s underestimated
    - Low L_X AGN → #s overestimated
  - Thus:
    - Luminosity Functions: ↑ as L_X ↓ (cosmic downsizing)
    - Obscured fractions: ↑ as L_X ↓, + as z ↑

Luminosity Function and obscured fraction

(Mayo & Lawrence 2013)



Change in LF if all are CT

Obscured fraction vs L_X

Obscured Active Galaxy Populations

- Current “state-of-the-art” results:
  - Obscured fraction ↑ as L ↓ and as z↑
  - Source #s ↑ as L ↓
- Mirror systematic effects inherent in X-ray survey data
- Critical Question for understanding the “TORUS”: “How can we be sure that the observed relations are not the result of selection effects?”