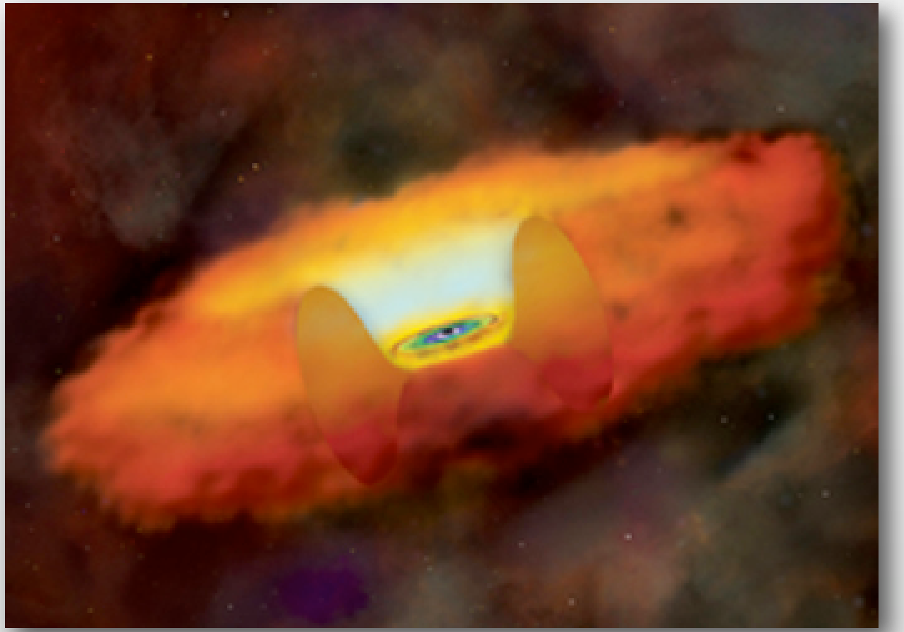
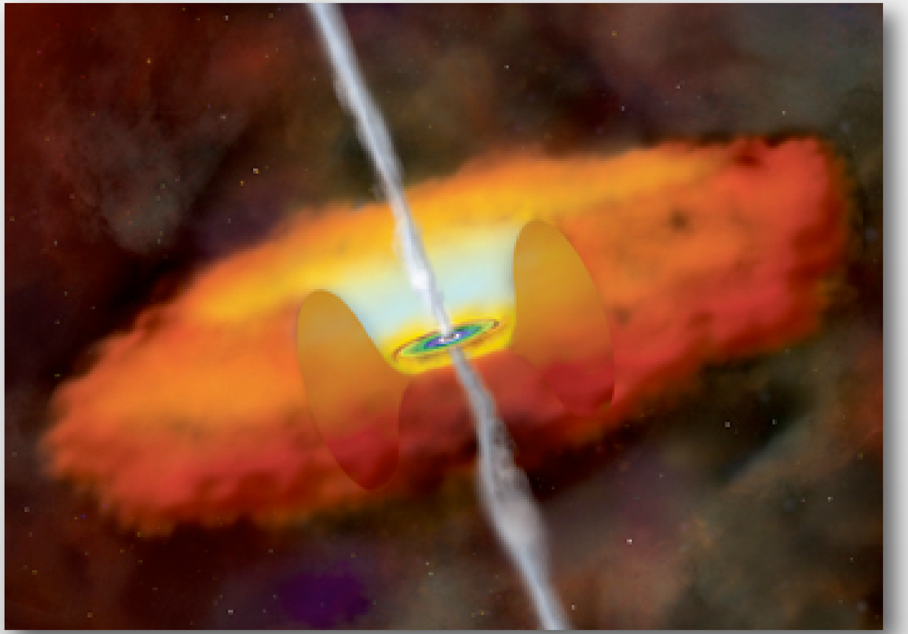
X-ray Properties of *Spitzer*-Selected AGN

Jennifer Donley, University of Arizona



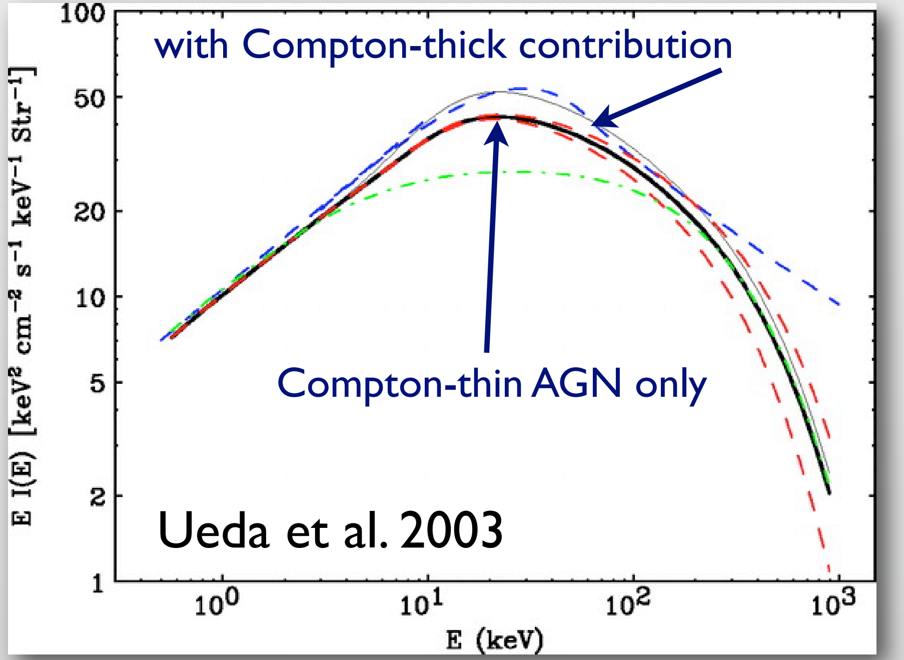


NASA/CXC/SAO

Collaborators: George Rieke, Pablo Pérez-González, Jane Rigby, Almudena Alonso-Herrero

Finding Obscured AGN with Spitzer

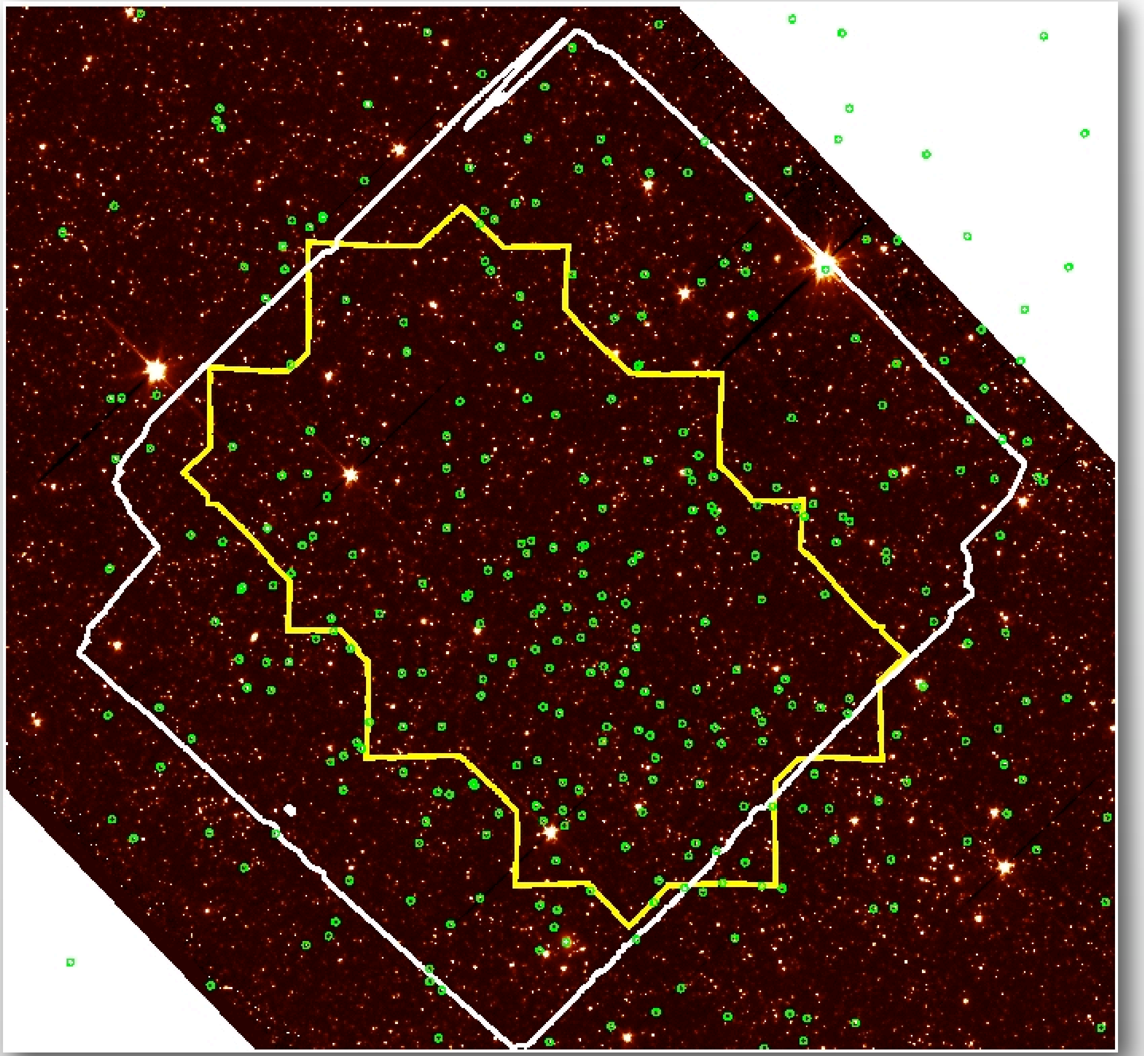
- Locally, Seyfert 2's outnumber Seyfert 1's by a factor of 4 and more than 1/2 of Seyfert 2's are Compton-thick ($N_H > 10^{24}$ cm^{-2}) (Maiolino & Rieke 1995, Risaliti et al. 1999)
- Population synthesis models of XRB predict large numbers of obscured AGN (3:1 to 4:1) in the distant universe (e.g. Comastri et al. 2001, Ueda et al. 2003, Gilli 2004, Treister et al. 2006, Tozzi et al. 2006)



<u>Predicted X-ray incompleteness:</u> (Treister et al. 2005):

- 25% at $N_H = 10^{23}$ cm^{-2} (obscured but Compton-thin)
- >75% at $N_H > 10^{24}$ cm^{-2} (Compton-thick)

Data: Chandra Deep Field-North



- IRAC 3.6-8.0 μm - 500s *
- MIPS 24 μm- 1400s *
- 2Ms Chandra (Alexander et al. 2003)
- 1.4 GHz (Richards 2000)
- GOODS optical (Giavalisco et al. 2004)
- Ground-based optical/ NIR (Capak et al. 2004)

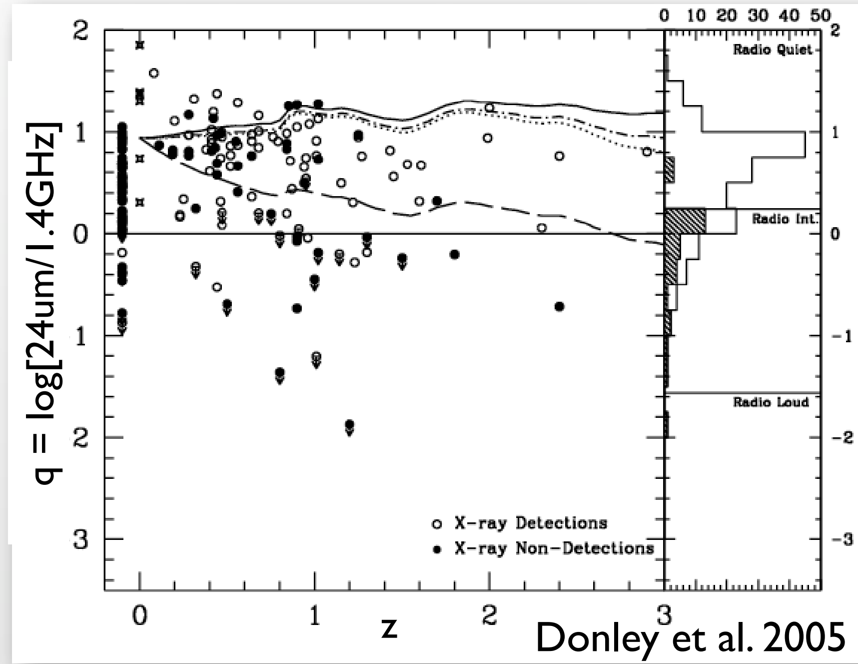
* MIPS GTO data, to maximize sky coverage

- Using this data, how can we detect obscured AGN?

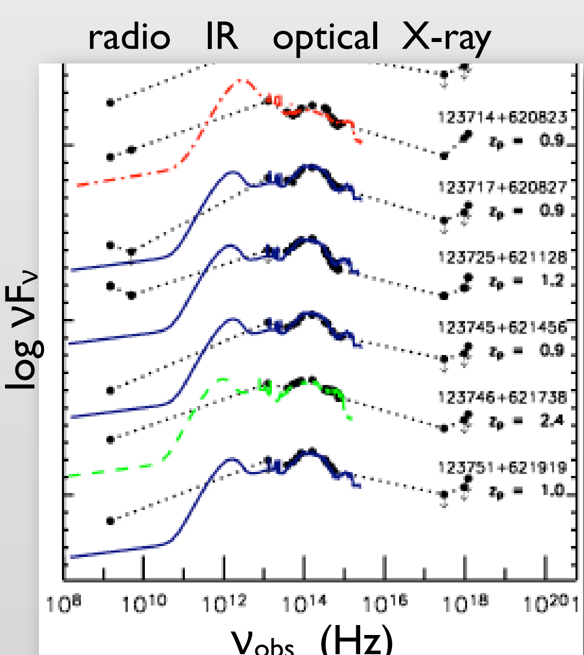
I. Radio-Infrared Selection

1. <u>Radio/Infrared Selection</u> (Donley et al. 2005, Martínez-Sansigre et al. 2005)

- ✦ **Radio emission much greater than expected from radio/IR correlation** (e.g. Yun et al. 2001, Drake et al. 2003)



Donley et al. 2005

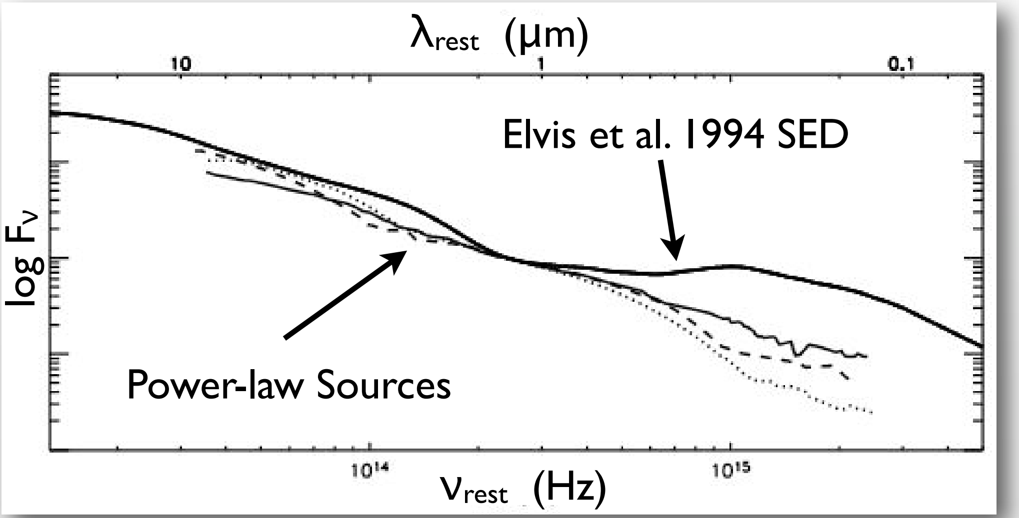


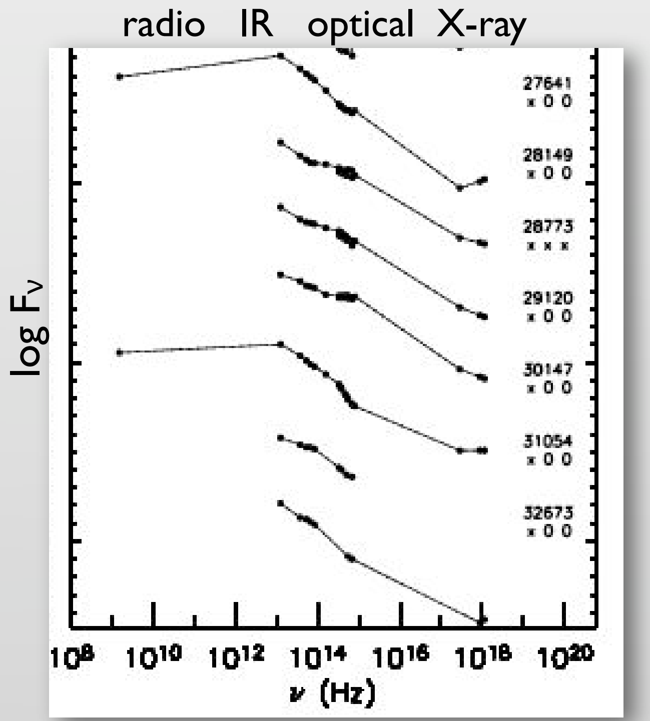
- ✦ 27 radio-excess AGN in the CDF-N
  - ✦ 40% (75%) are detected (weakly) in the X-ray
  - ✦ have Seyfert-like X-ray luminosities, and z~1
  - ✦ Almost all are consistent with being obscured, but not Compton-thick

2. MIR Power-law Selection

2. Power-law Selection (Alonso-Herrero et al. 2006, Donley et al. 2006)

- red power-law SEDs in the 4 IRAC bands (3.6-8 μm)
- $\alpha < -0.5$ ($f_\nu \propto \nu^\alpha$)
- X-ray exposure > 0.5 Ms





- 62 power-law galaxies in the CDF-N
  - only 30% have radio counterparts
  - lie at high redshift (mean z~2)
  - SEDs are AGN-dominated
    - ➡ very different from radio-excess sample
  - 55% (85%) are detected (weakly) in the X-ray

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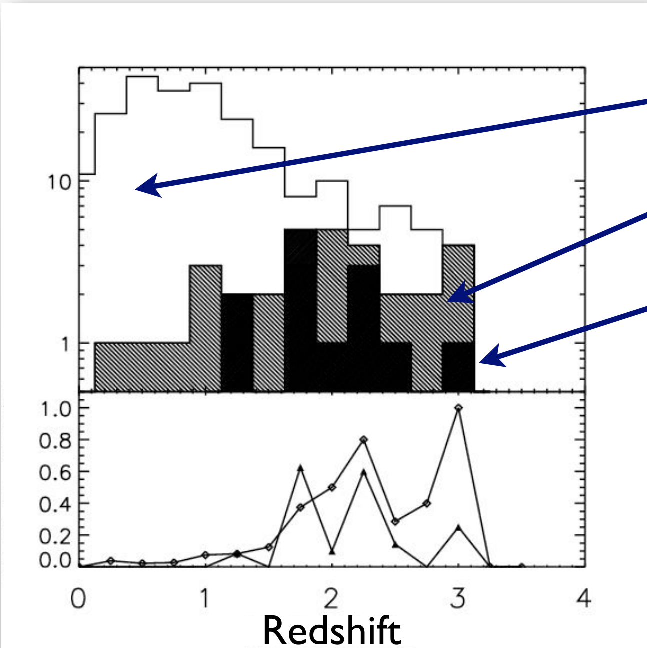
MIR Power-law Selection

1. What is the relation between the power-law sample and the X-ray selected AGN sample in the distant universe?

2. How obscured is this population?

3. How does power-law selection compare to IRAC color-color selection criteria in the deep fields?

MIR Power-law vs. X-ray Selection

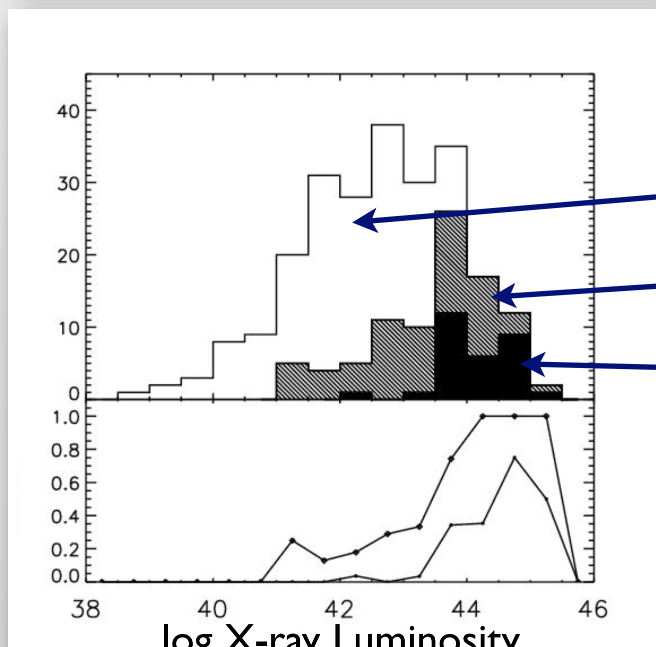


X-ray sources with IRAC counterparts

X-ray-detected power-laws

X-ray non-detected power-laws

Power-law galaxies make up a significant fraction of the high-z and high-luminosity X-ray sources

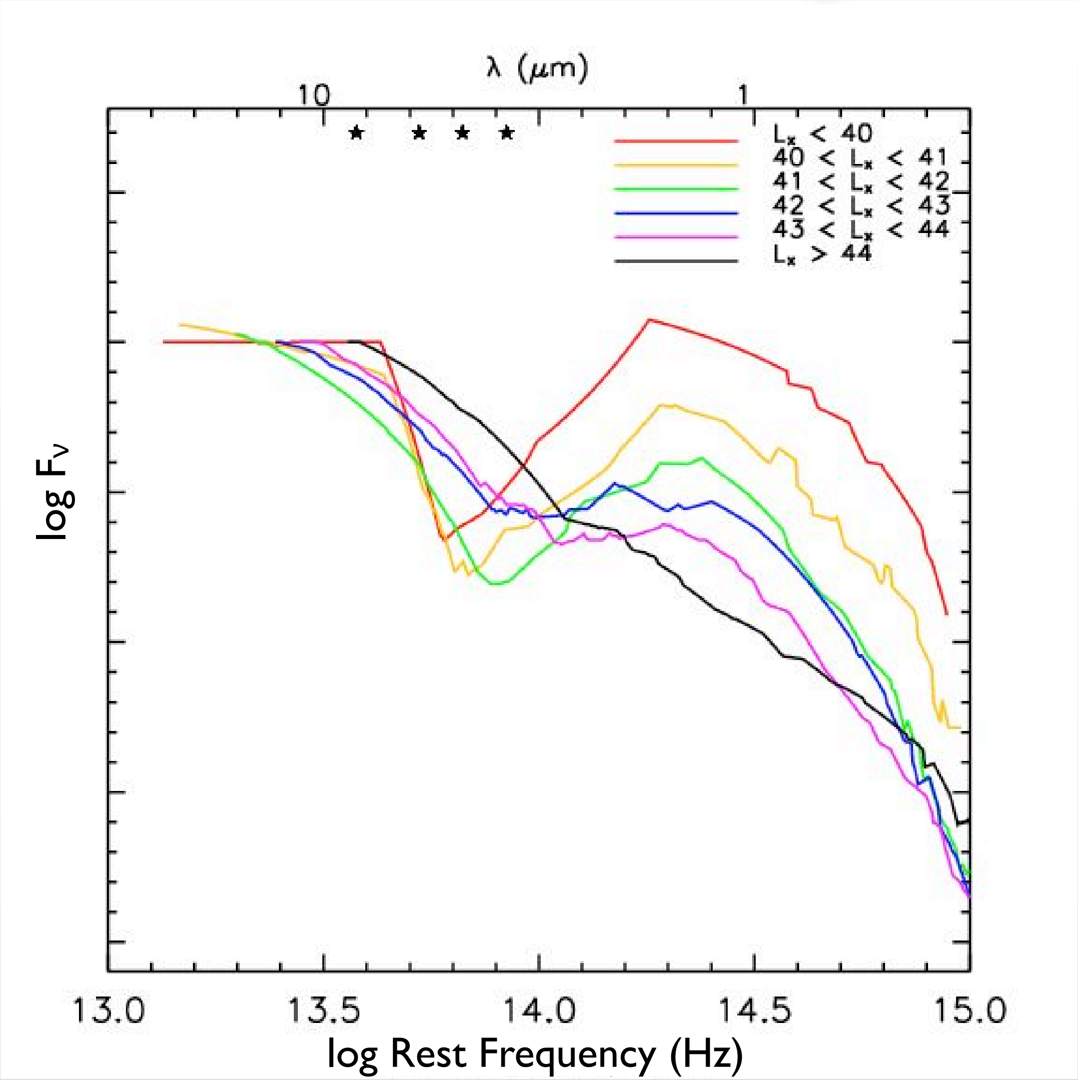


X-ray sources with IRAC counterparts

Color-selected sources

X-ray-detected power-laws

MIR Power-law vs. X-ray Selection



As X-ray luminosity increases, the strength of the stellar bump decreases

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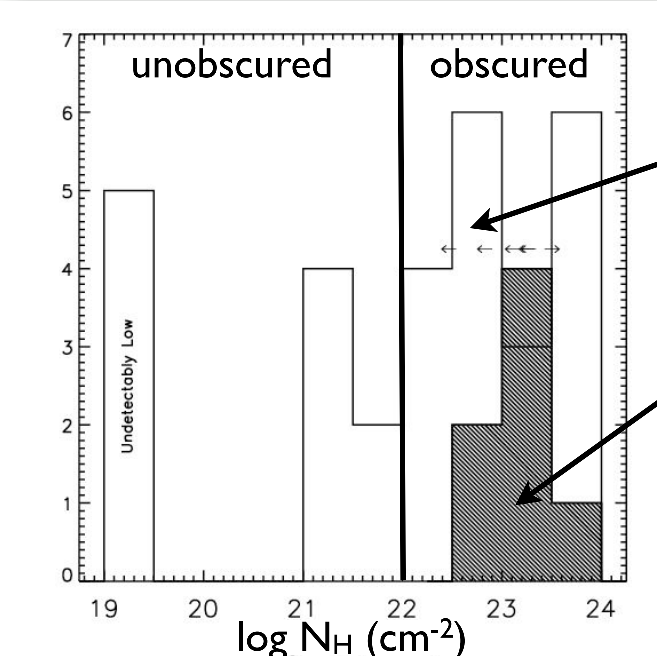
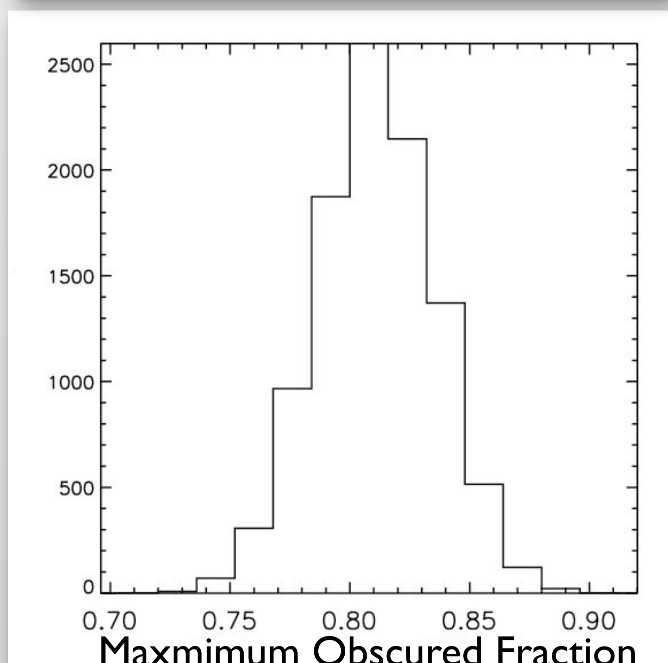
Obscuration



X-ray detected power-law galaxies: 65% (2:1) are obscured

Weakly-detected power-law galaxies: obscured, but not Compton-thick

X-ray non-detected power-law galaxies: all obscured?

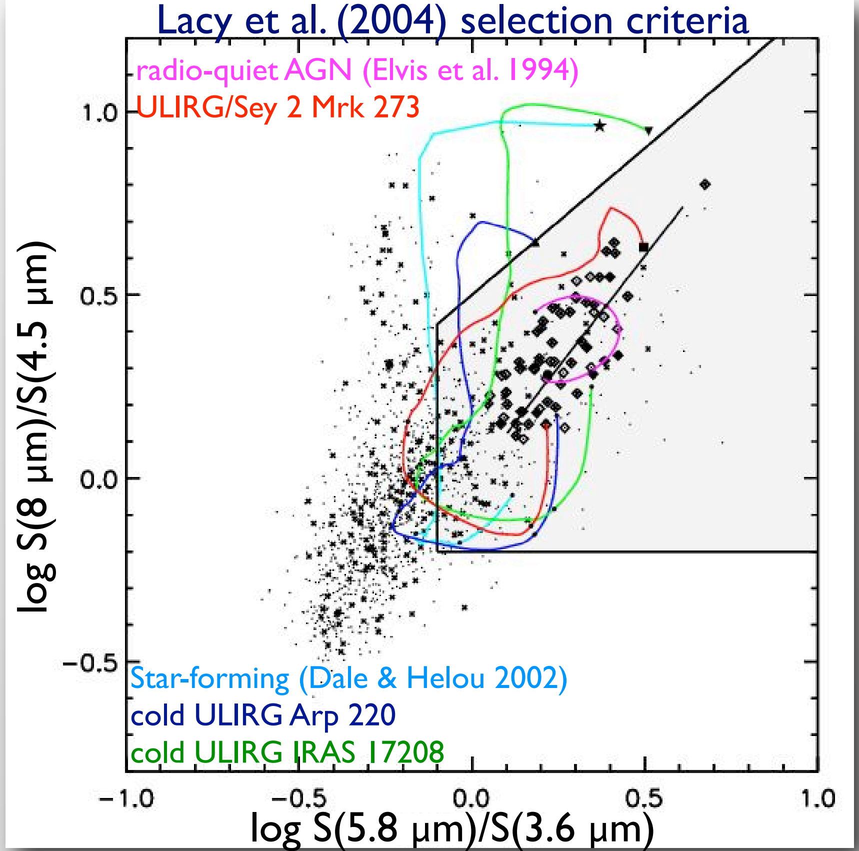


- ✦ Maximum obscured fraction of luminous AGN: 80% (4:1) (consistent with XRB)
- ✦ < 20-30% of the MIPS-detected obscured AGN have high S/N power-law IRAC continua (based on number count predictions of Treister et al. 2006)

Γ= 1.81 ± 0.20 (Tozzi et al. 2006)

Power-law vs. IRAC Color-Selection

- Power-law selection is similar to IRAC color-color selection
  (Ivison et al. 2004, Lacy et al. 2004, Stern et al. 2005, Hatziminaoglou et al. 2005)



	Power-law	Stern et al. 2005	Lacy et al. 2004
Number	62	216	393
Detected in X-rays	55%	38%	25%
Detected at 24µm	>92%	83%	72%
$L_{rad}>10^{24}$ W/Hz	88%	54%	49%
Quiescent opt/X-ray colors	≥3%	≥10%	≥15%

- Color-selected samples are more complete, but also suffer from more contamination by star-forming galaxies.

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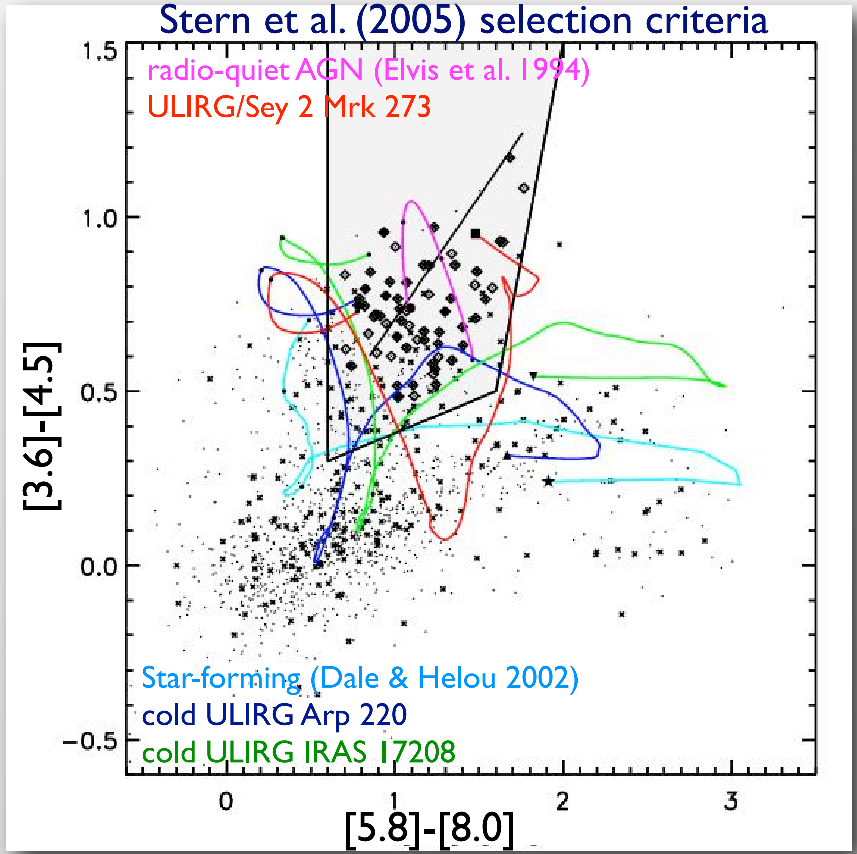

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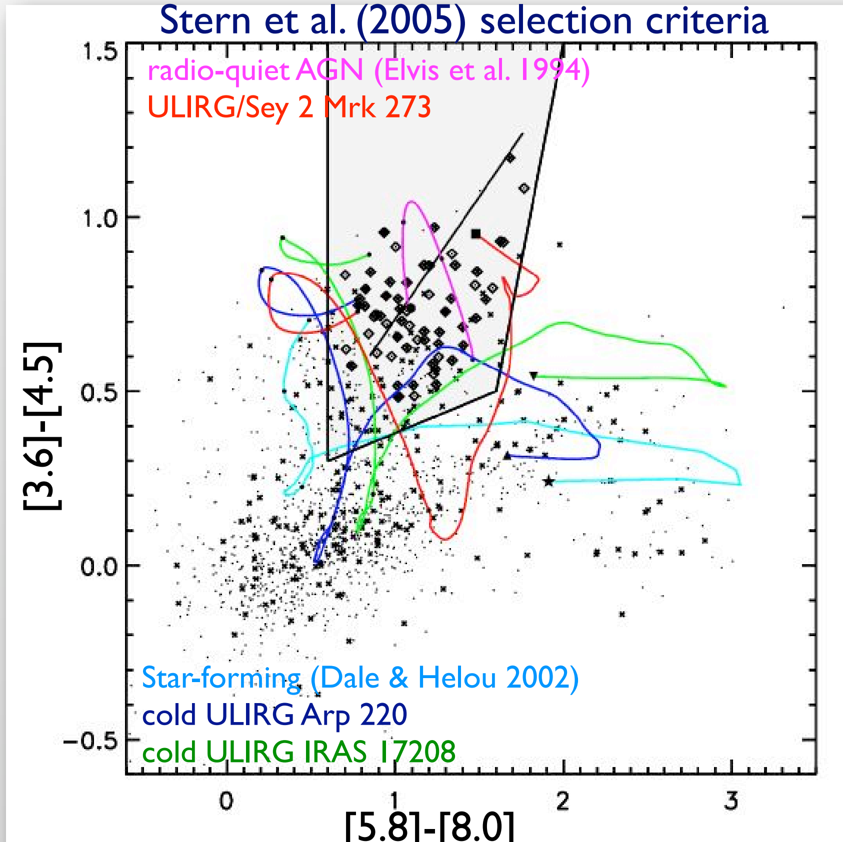

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- Combining IRAC color-selection with addition spectral diagnostics and selection criteria can give more complete and reliable samples.

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Summary

- Large numbers of obscured (and X-ray non-detected) AGN are predicted in the distant Universe
- We identified samples of such AGN with Spitzer using (1) radio-infrared selection and (2) IRAC MIR power-law selection
- Power-law sources:
    - only 55% are X-ray detected; 85% show signs of faint X-rays (similar to radio-excess sample, even though the two populations of AGN are distinct)
    - comprise a significant fraction of AGN at high z and high L_x
    - ≤ 80% (4:1) are obscured
    - make up ≤ 20-30% of MIPS-detected obscured AGN
    - similar to AGN selected via IRAC colors- smaller in number but also suffer from less contamination by galaxies