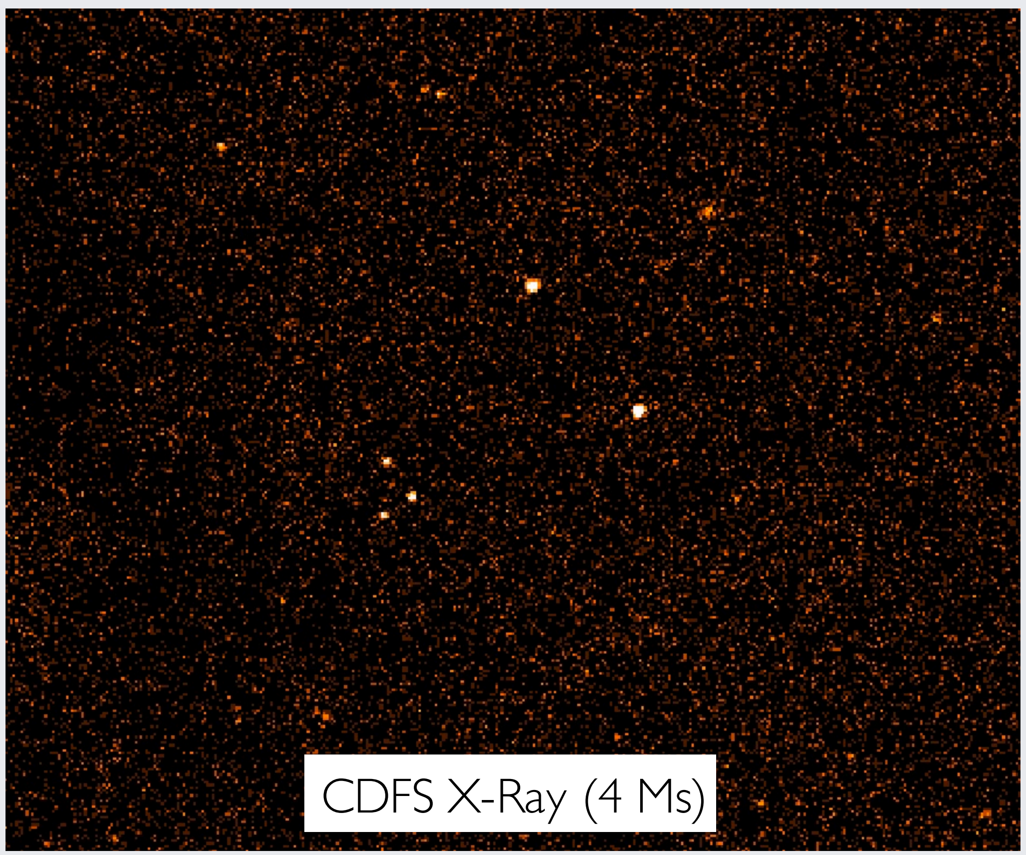
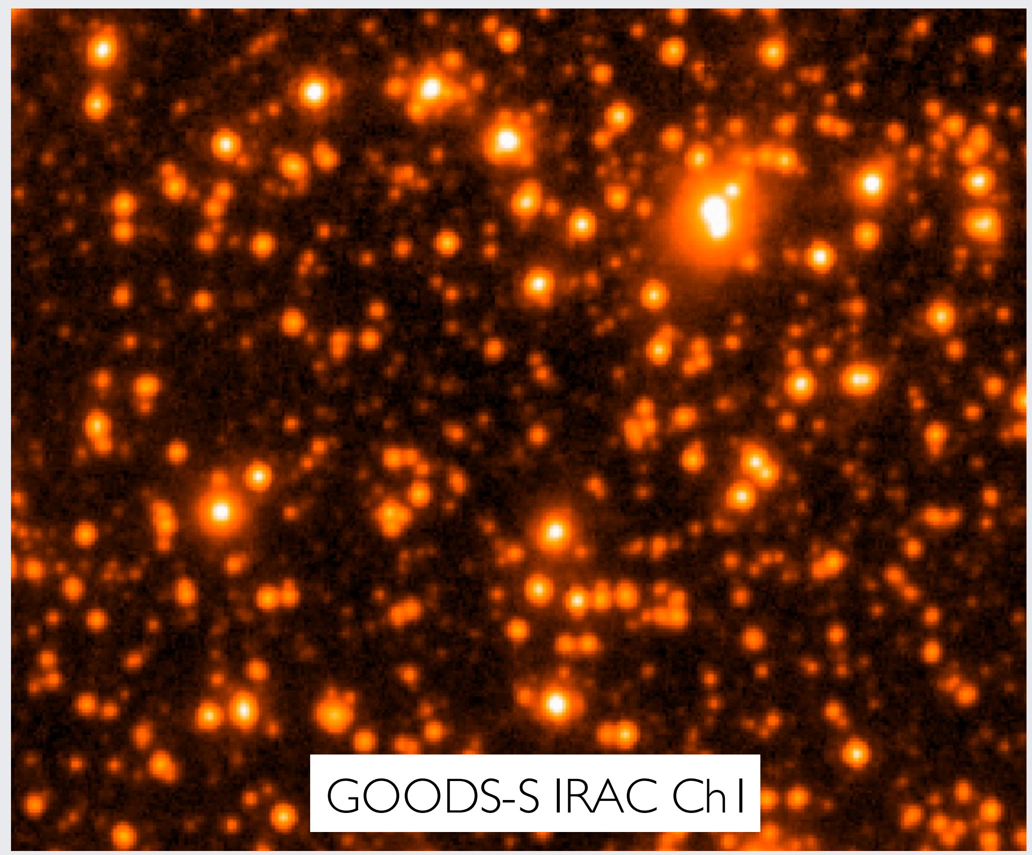
IDENTIFYING LUMINOUS AGN IN DEEP SURVEYS: REVISED IRAC SELECTION CRITERIA

Jennifer Donley
Giacconi Fellow, STScI

Anton Koekemoer, Marcella Brusa, Peter Capak, Carrie Cardamone, Francesca Civano, Olivier Ilbert, Chris Impey, Jeyhan Kartaltepe, Takamitsu Miyaji, Mara Salvato, Dave Sanders, John Trump, Gianni Zamorani

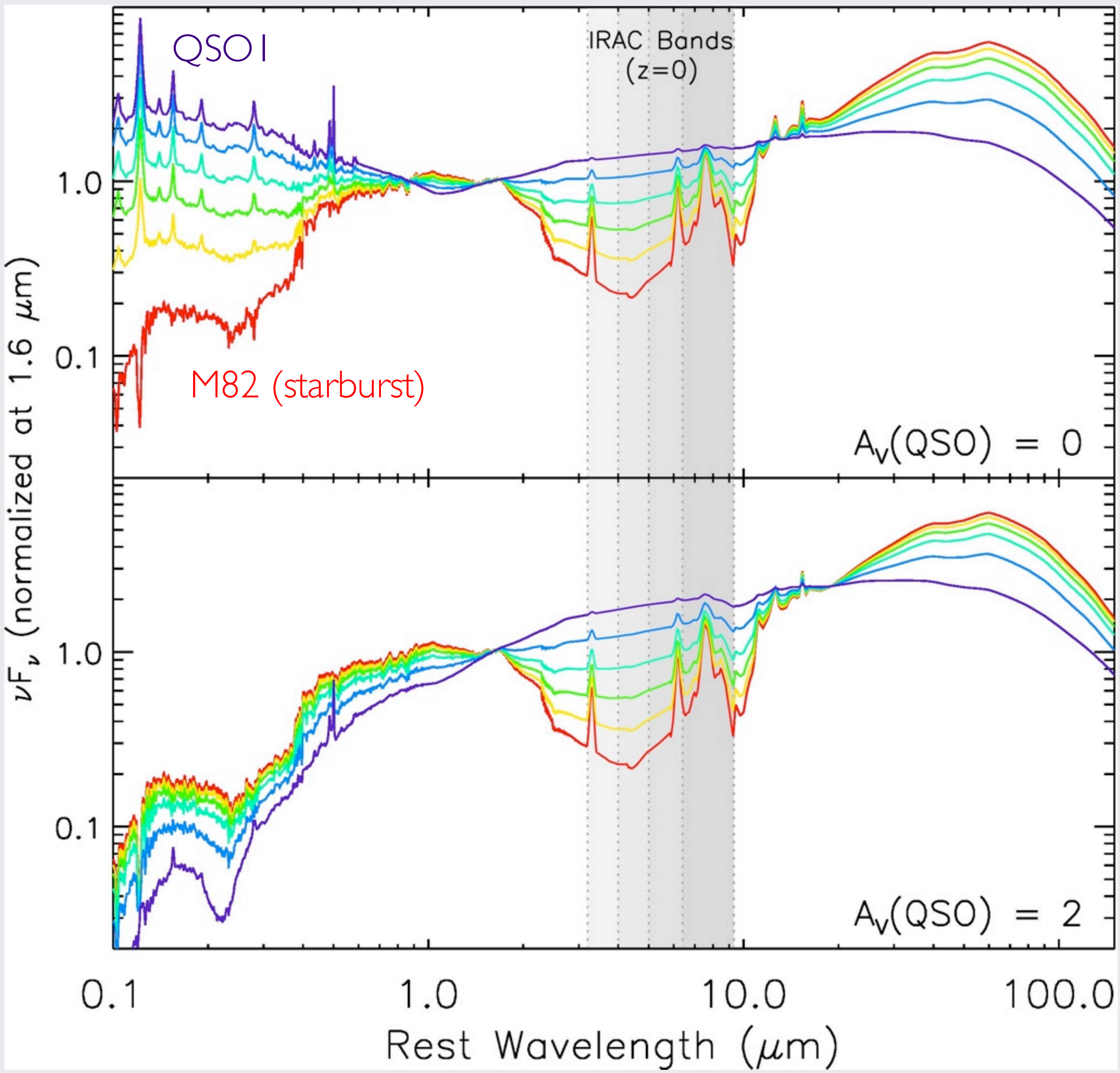




MIR Selection of AGN

(Donley et al. 2011, ApJ, submitted)

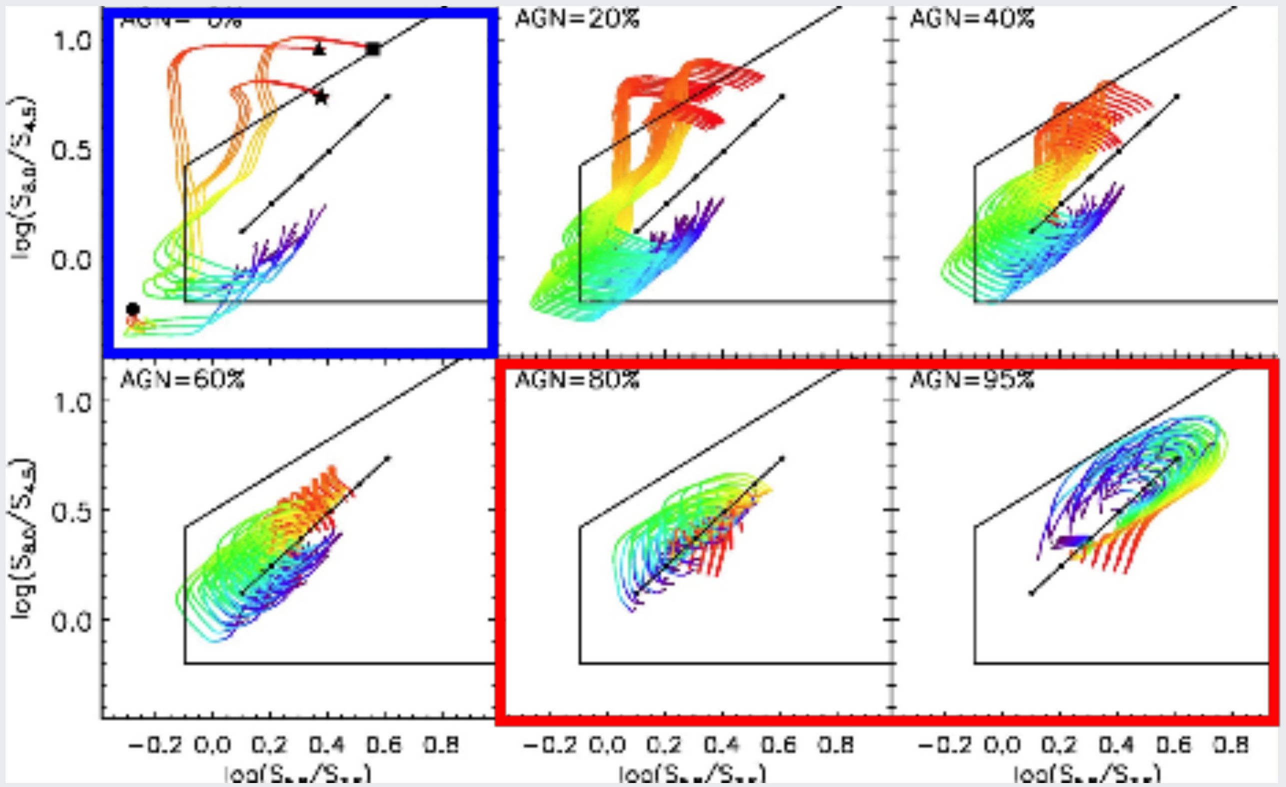
QSO1 + M82: AGN fractions of 0% - 100%, in steps of 20%



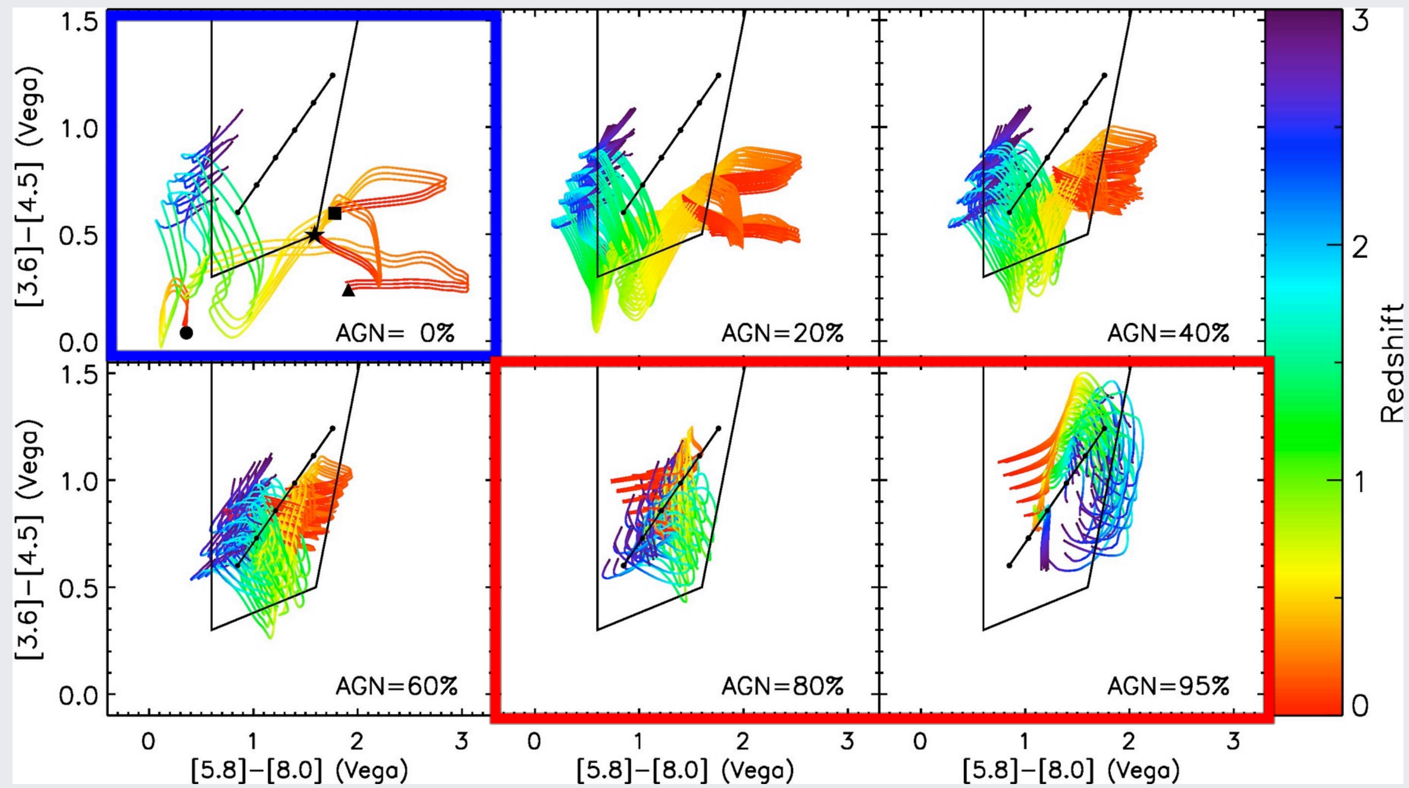
- AGN-heated dust emits down to one micron (T_{sub} = 1000-1500K)
- Superposition of blackbodies = power-law thermal continuum
- IR emission of luminous AGN fills in the dip in its host galaxy's SED.
- The strength of this feature depends on the relative luminosities of the AGN and the host galaxy
- Power-law continuum should be visible in both unobscured AND obscured AGN

Current AGN Selection Wedges

Lacy+ 04 Color Space



Stern+ 05 Color Space

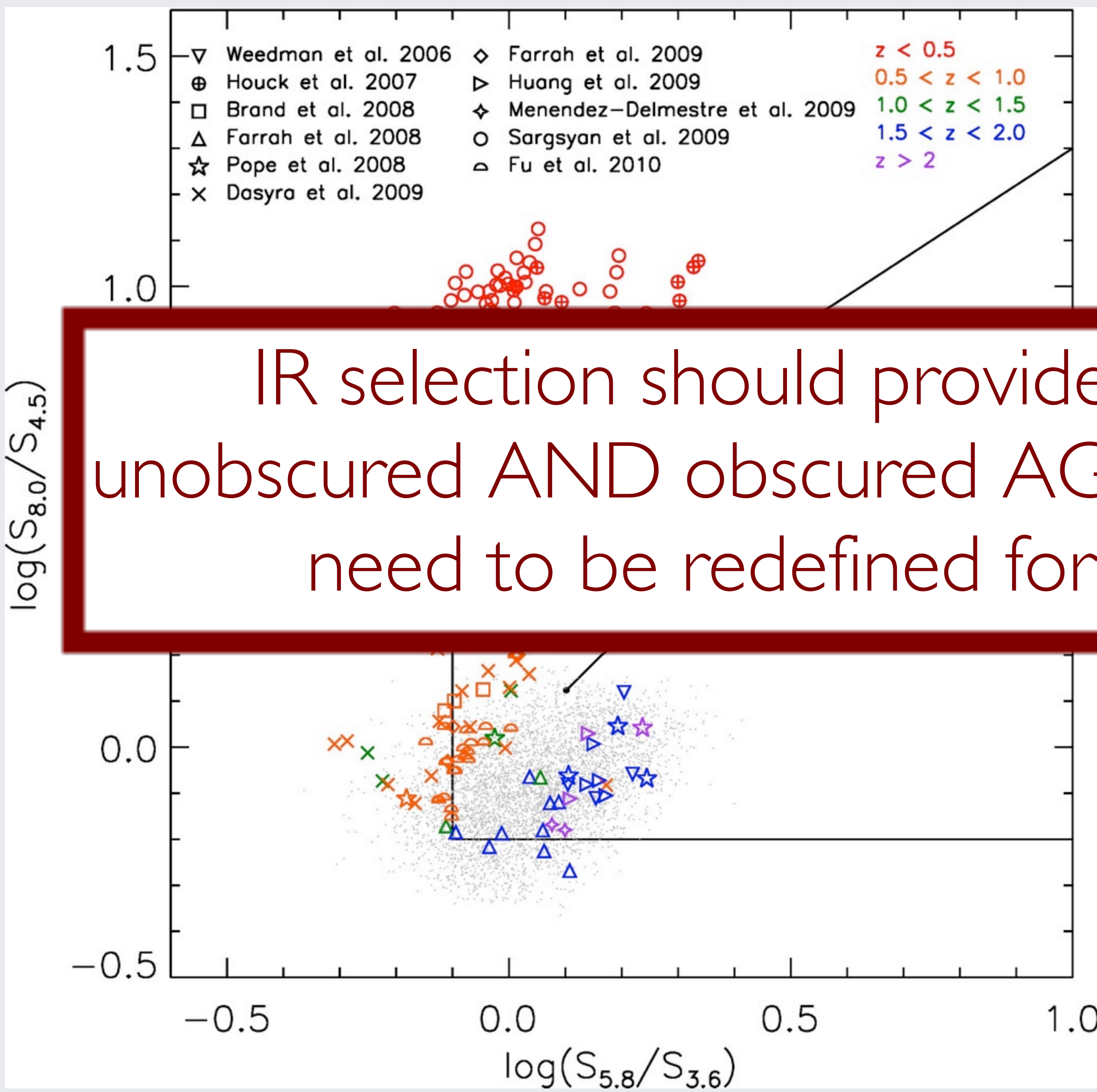


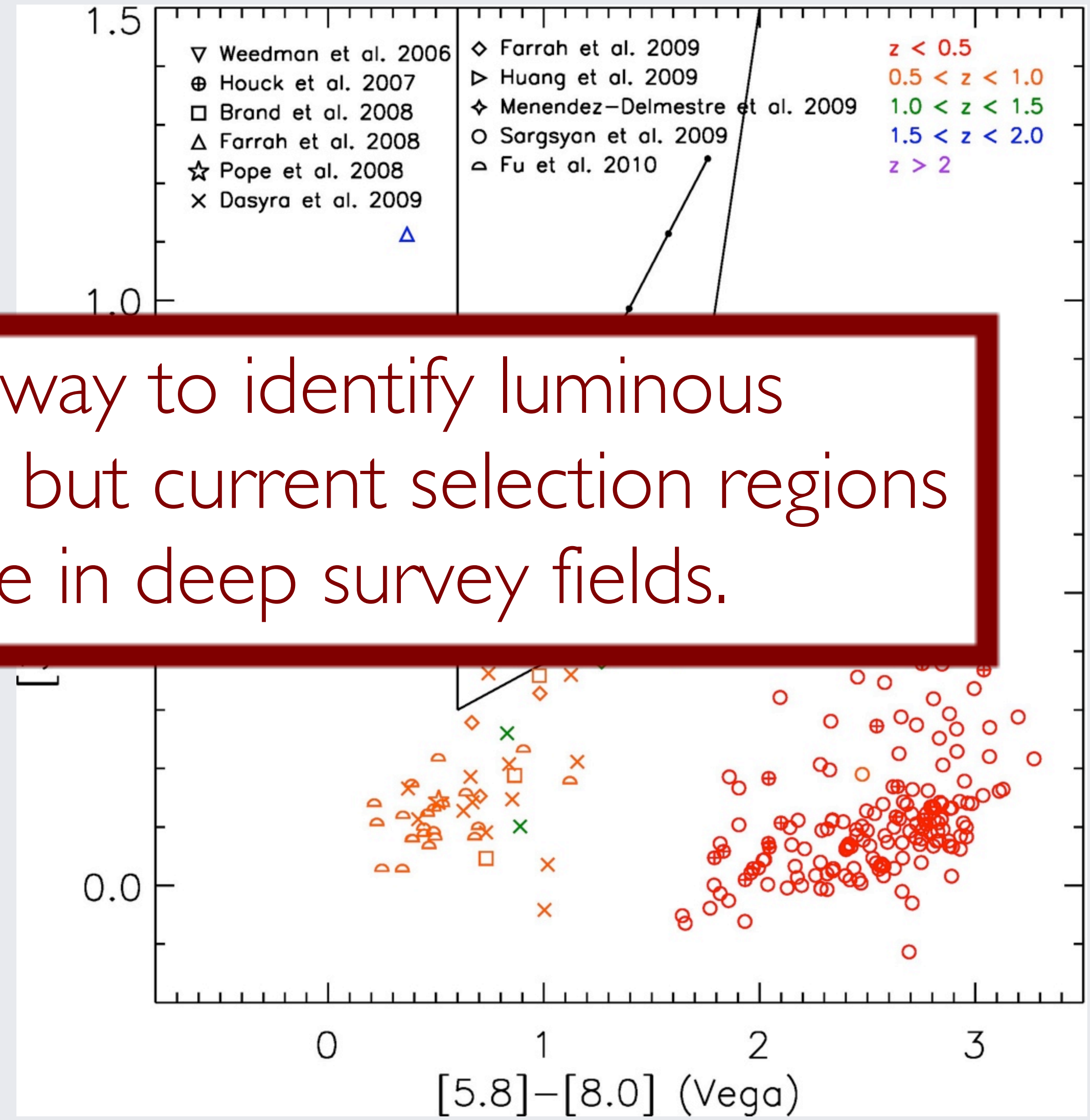
- Luminous AGN occupy a well defined region in color space, and fall largely within the Lacy+ 04/05 and Stern+ 05 regions

- Star-forming templates also fall in the selection wedges, which were originally defined in shallow surveys (SFLS, NDWFS) to which additional flux cuts in R-band (R<21.5), 8um (f>1 mJy), or 24um (F>5 mJy) excluded all but the brightest sources.

Star-forming Contamination?

Many "pure starbursts" observed with IRS fall in the AGN selection regions, as do the Huang+ 09 z=1.5-3 IRAC selected star-forming galaxies





IR selection should provide a way to identify luminous unobscured AND obscured AGN, but current selection regions need to be redefined for use in deep survey fields.

Redefining the AGN Selection Region

- COSMOS: deep and wide (2 sq. deg) coverage = large samples of luminous AGN
  - IRAC: 1200s over 2 sq. deg (5σ = 0.9, 1.7, 11.3, 14.6 uJy), >26,000 IRAC sources meet these cuts
  - Chandra: 150ks over 0.5 sq. deg, 80ks over additional 0.4 sq. deg.
  - XMM: 40ks XMM coverage over full 2 sq. deg, roughly equal numbers of Seyferts ($L_x < 44$) and QSOs ($L_x > 44$)
    - 1062 XMM sources meet the 5σ IRAC cuts
    - 62% have spectroscopic redshifts, remaining 38% have AGN-specific photometric redshifts from Salvato+ 09

Power-law Selection: A Starting Point

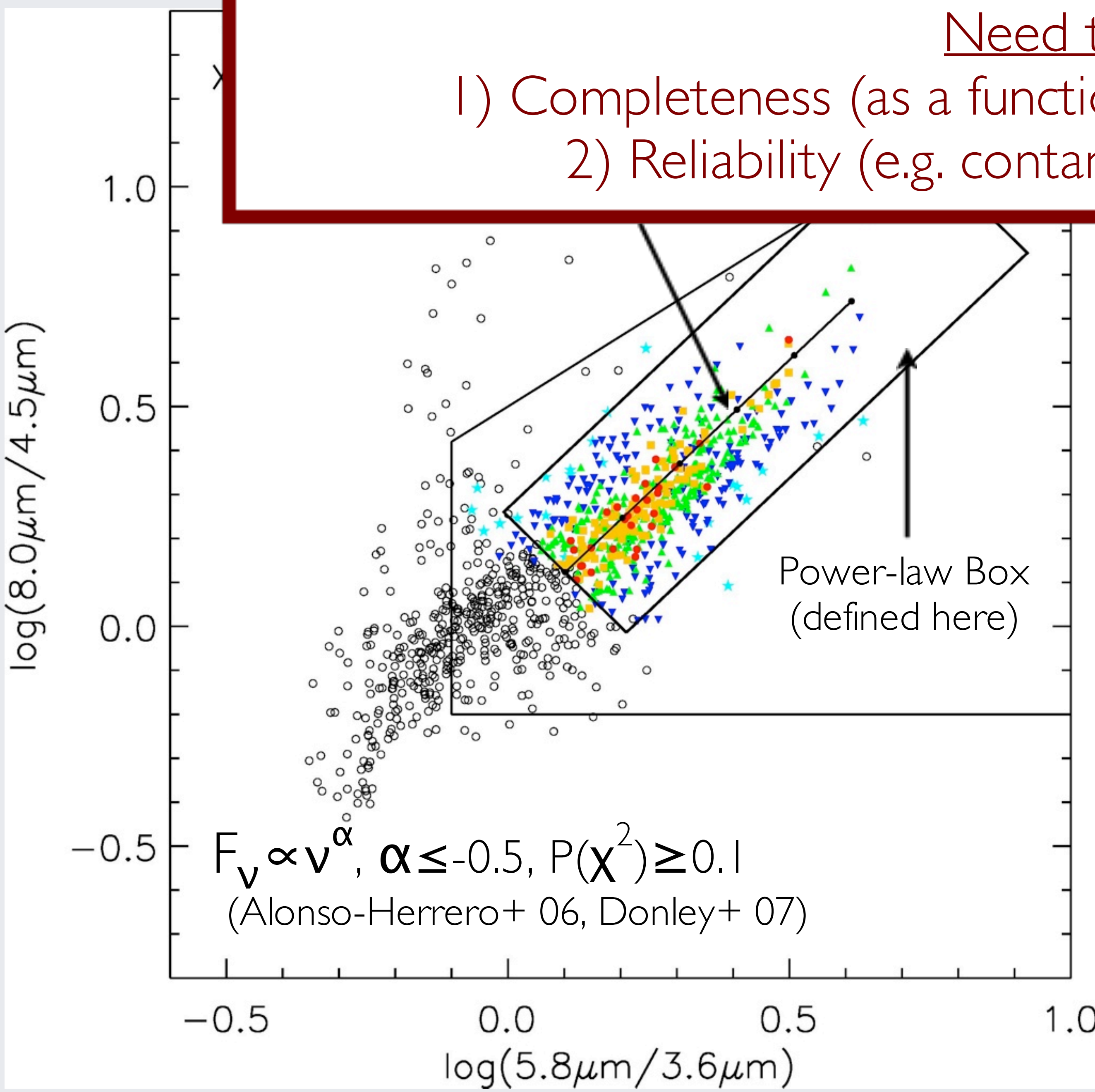
Provides ... ily on
both IRA ... ion.

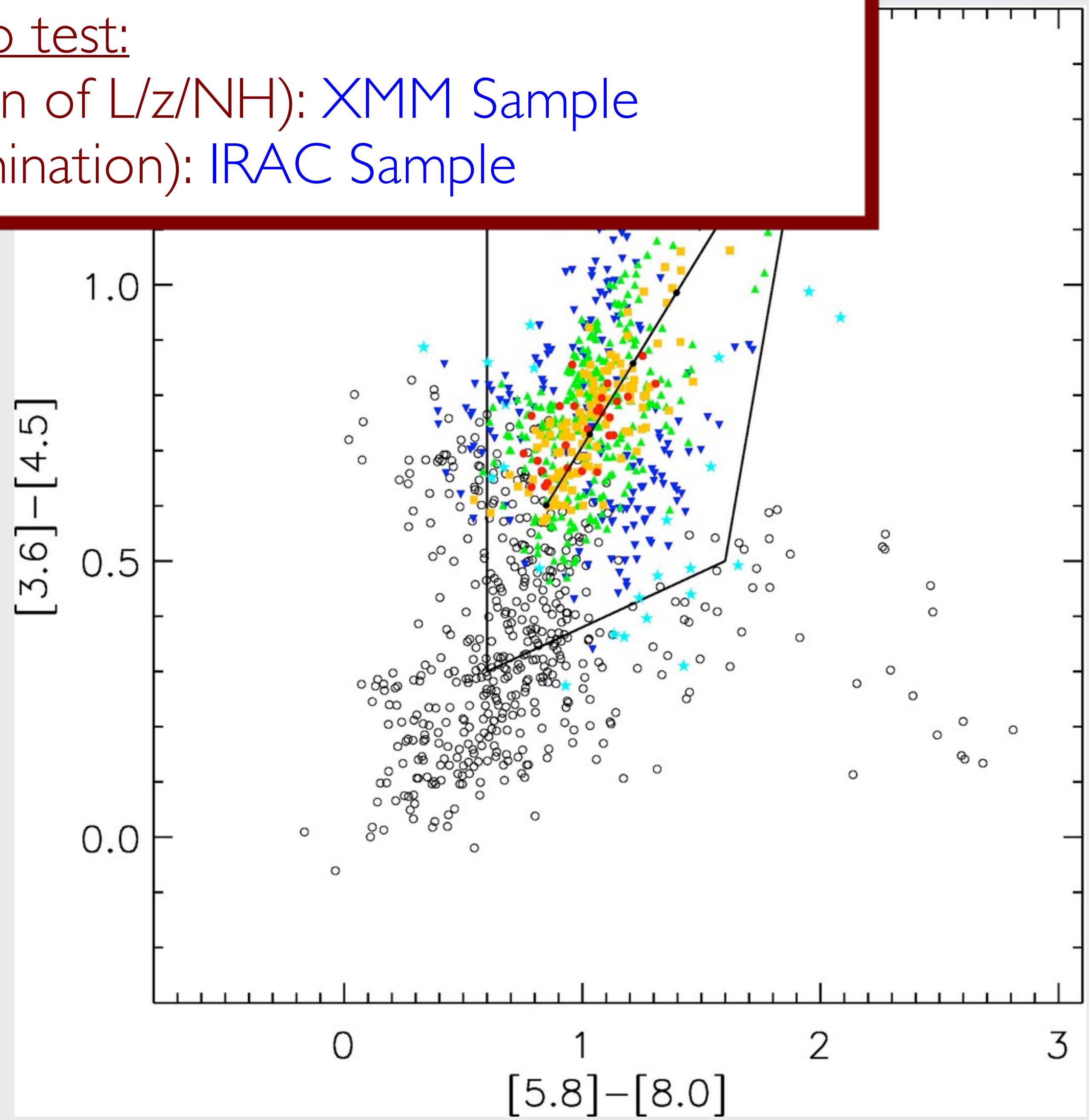
We take the power-law box as our starting point for a refined IRAC selection region, and focus on Lacy+ 04 color space.

Need to test:

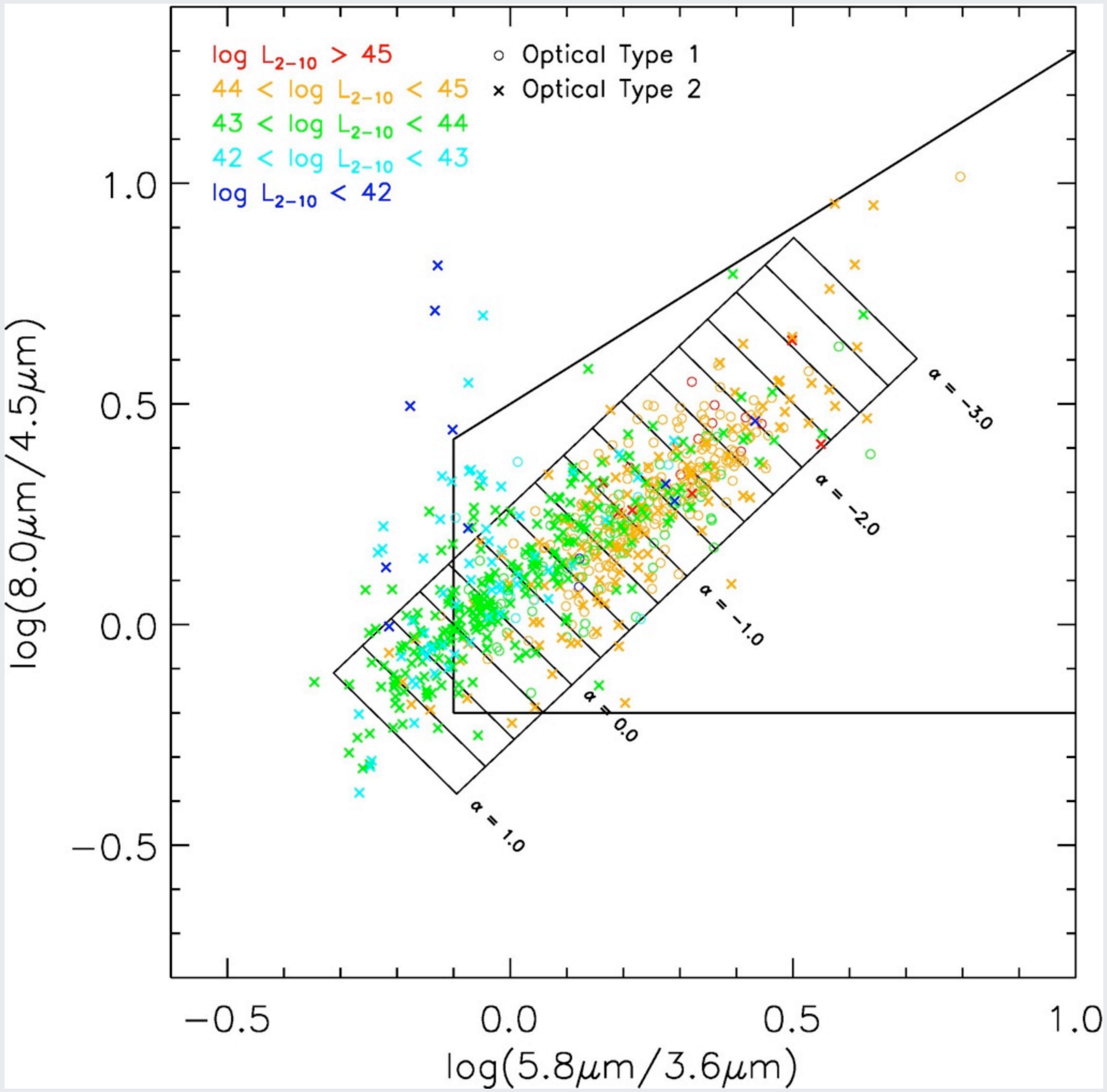
1) Completeness (as a function of L/z/NH): XMM Sample

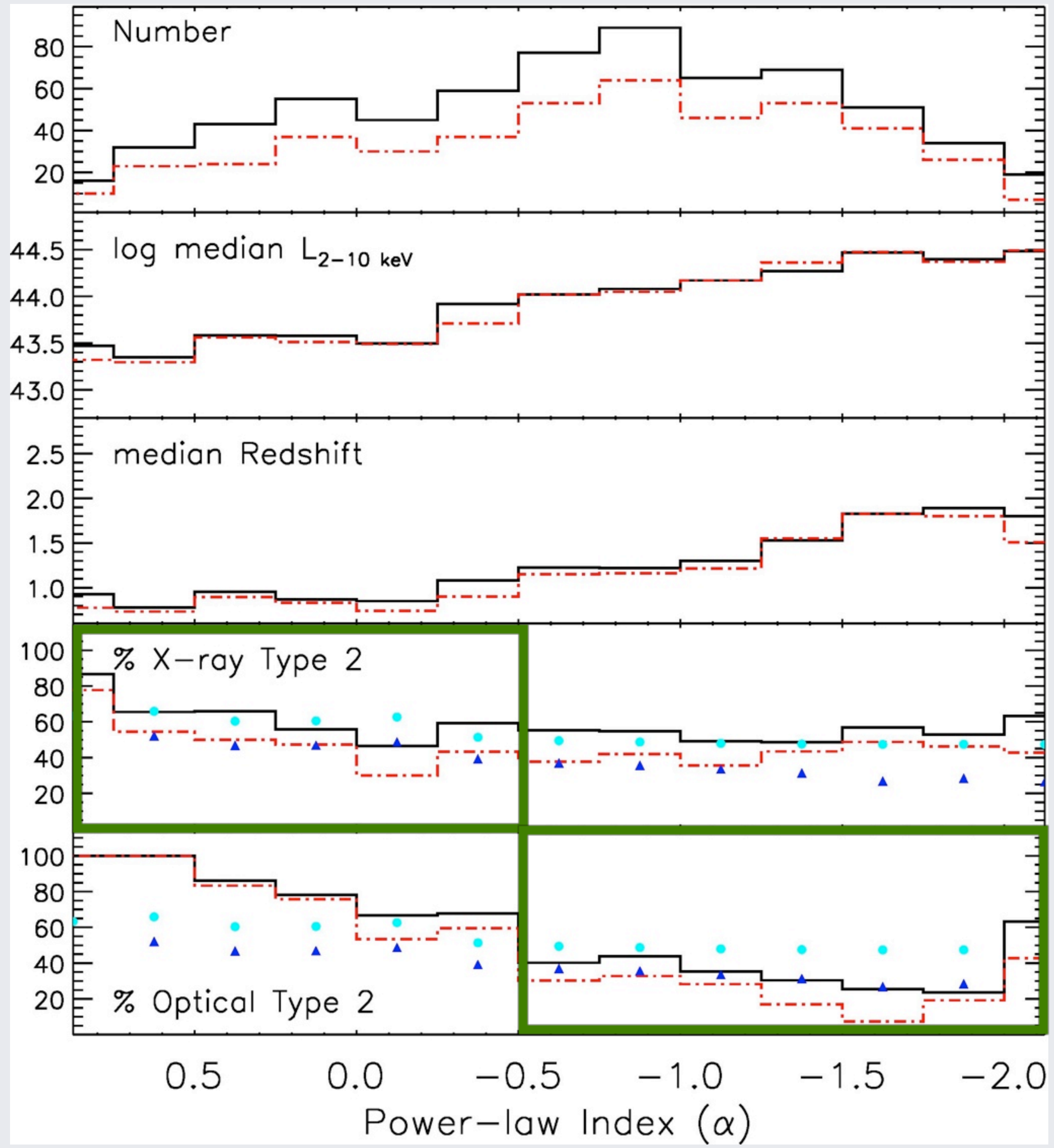
2) Reliability (e.g. contamination): IRAC Sample





XMM Sample: Trends in Luminosity/Type



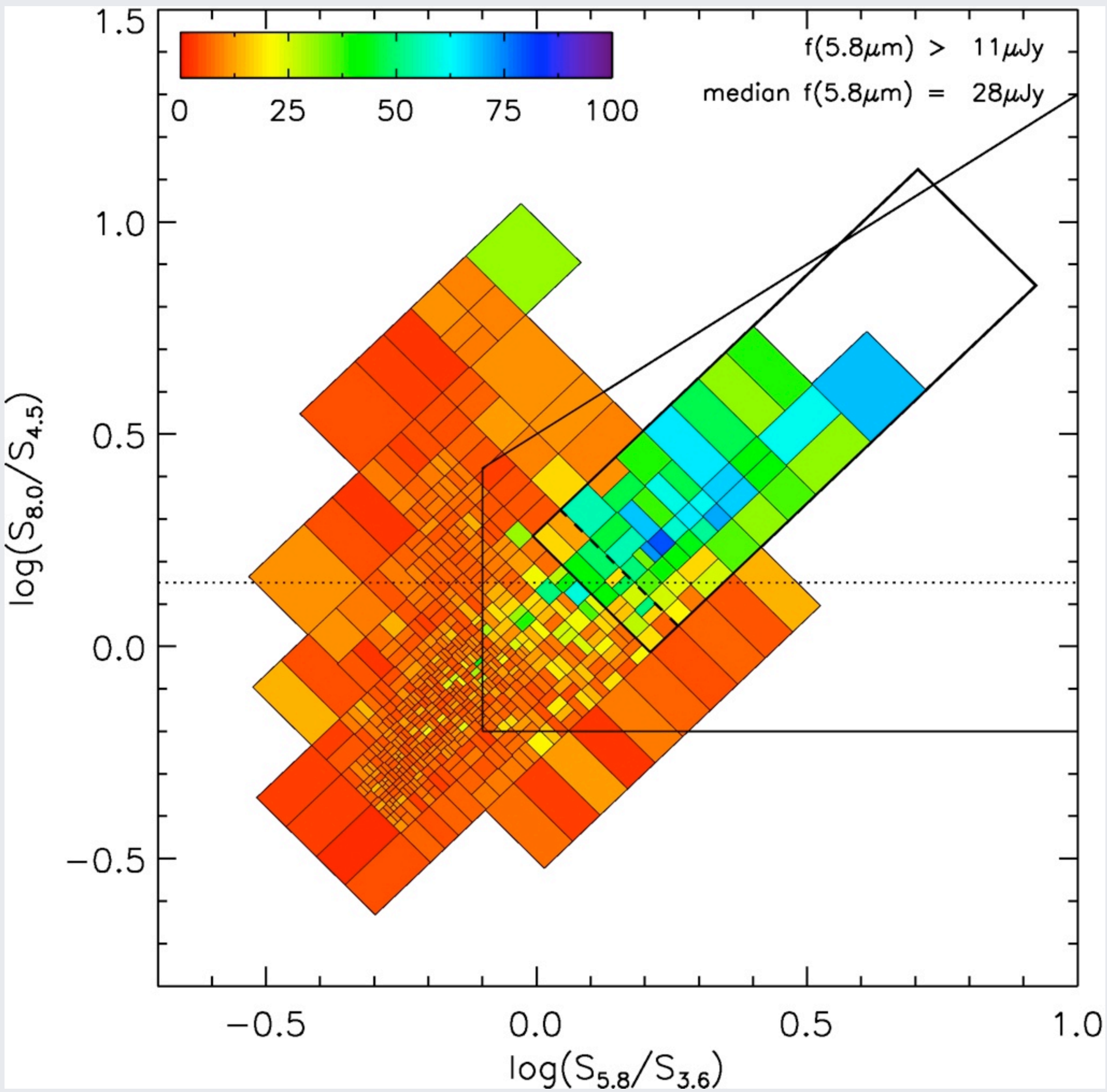


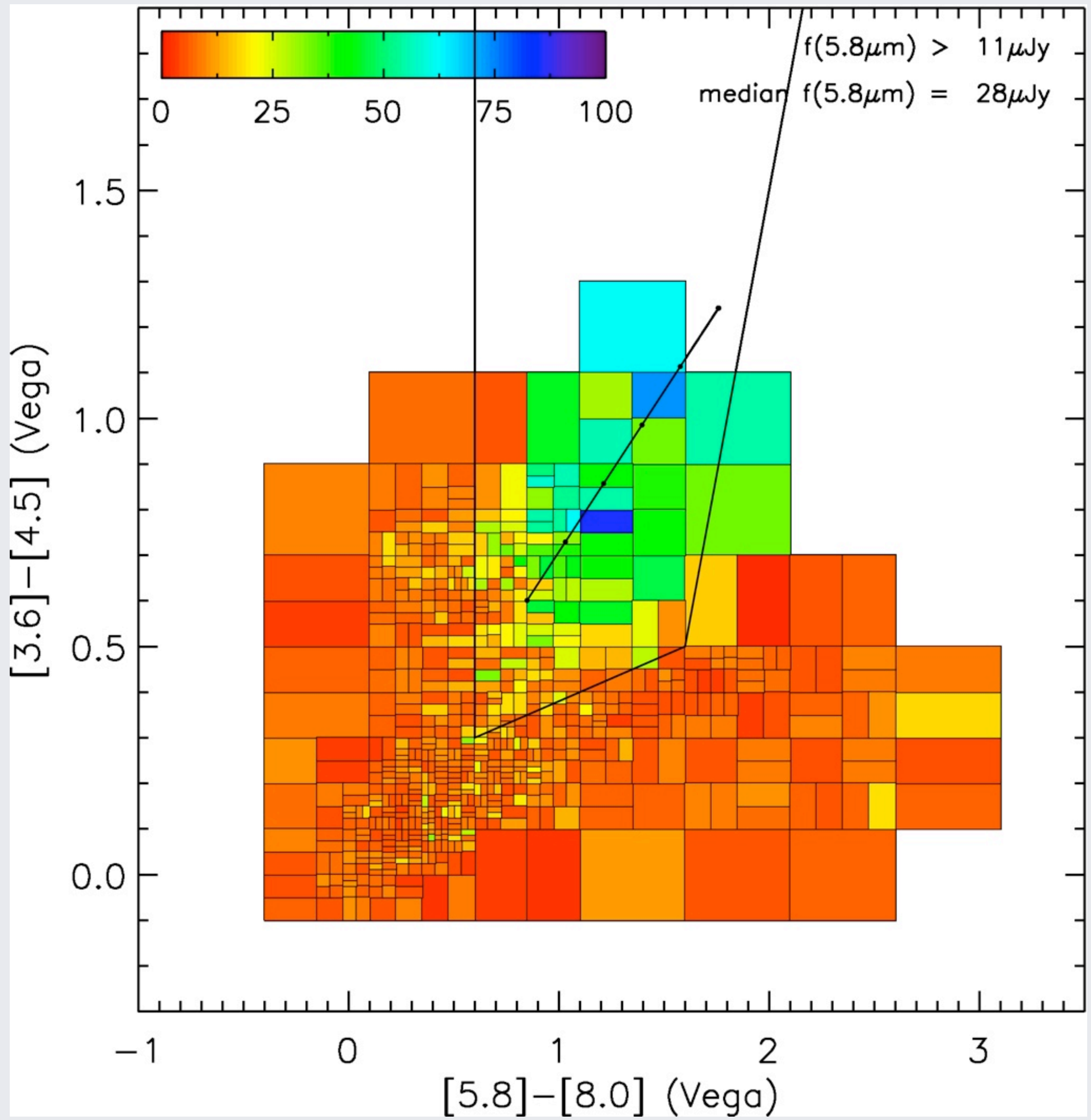
IRAC selection will be most complete to high-L (and thus high-z) AGN, as expected. Trends with obscuration are harder to constrain.

IRAC Sample: Reliability

XMM Sources comprise only 4% of the IRAC sample

Colors = X-ray Detection Fraction (for sources with T_X>50ks):

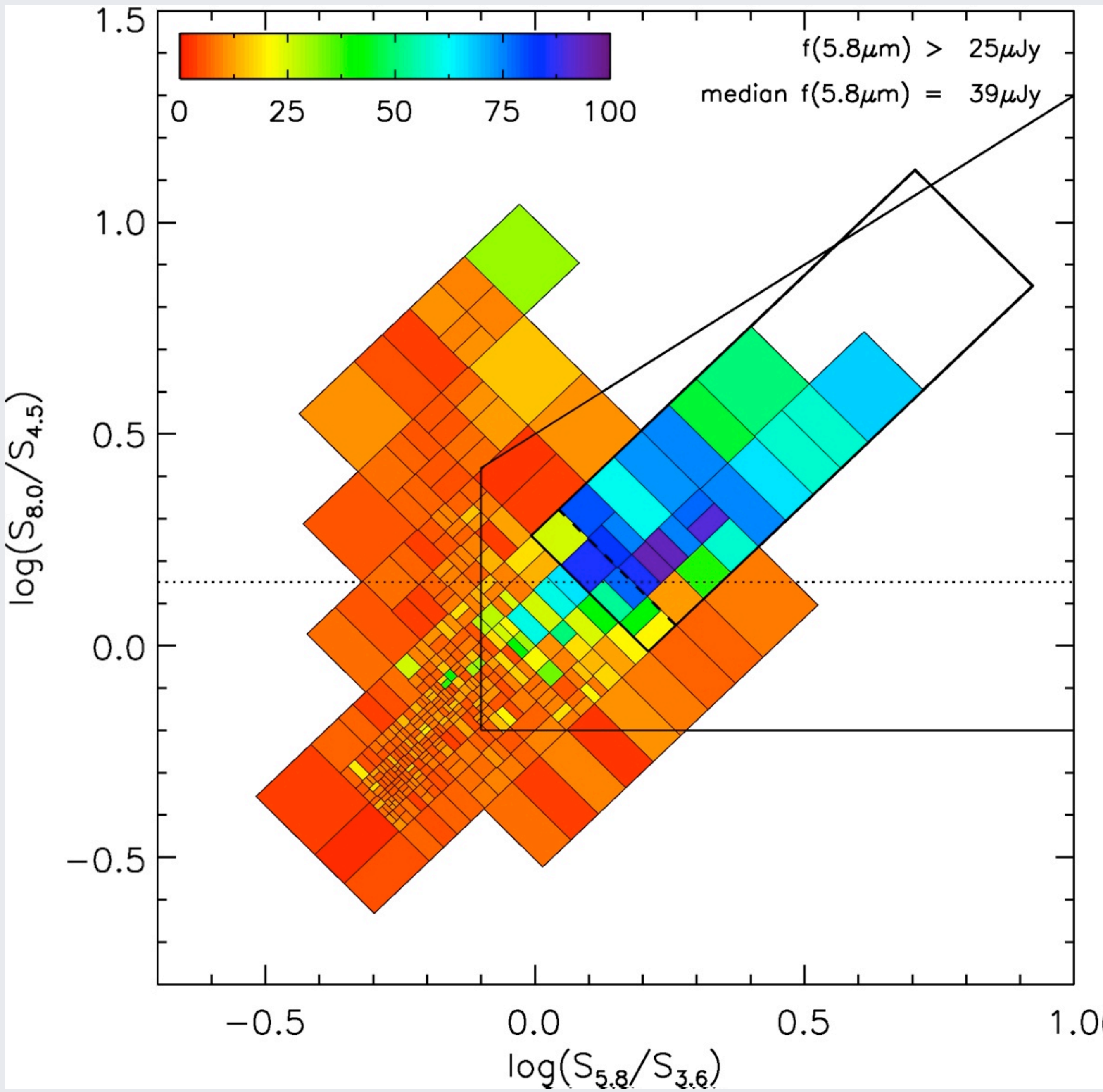


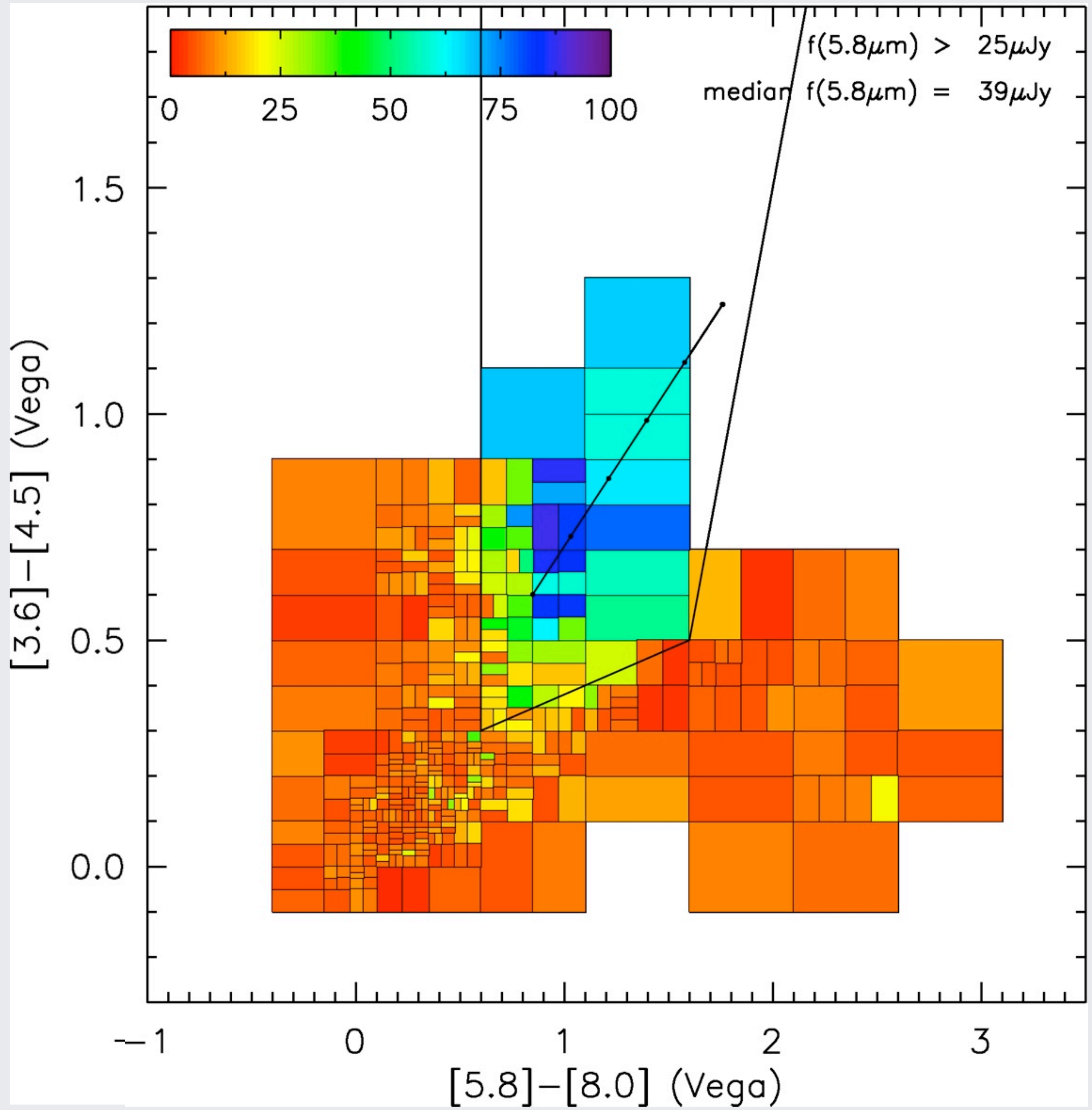


IRAC Sample: Reliability

XMM Sources comprise only 4% of the IRAC sample

Colors = X-ray Detection Fraction (for sources with T_X>50ks):

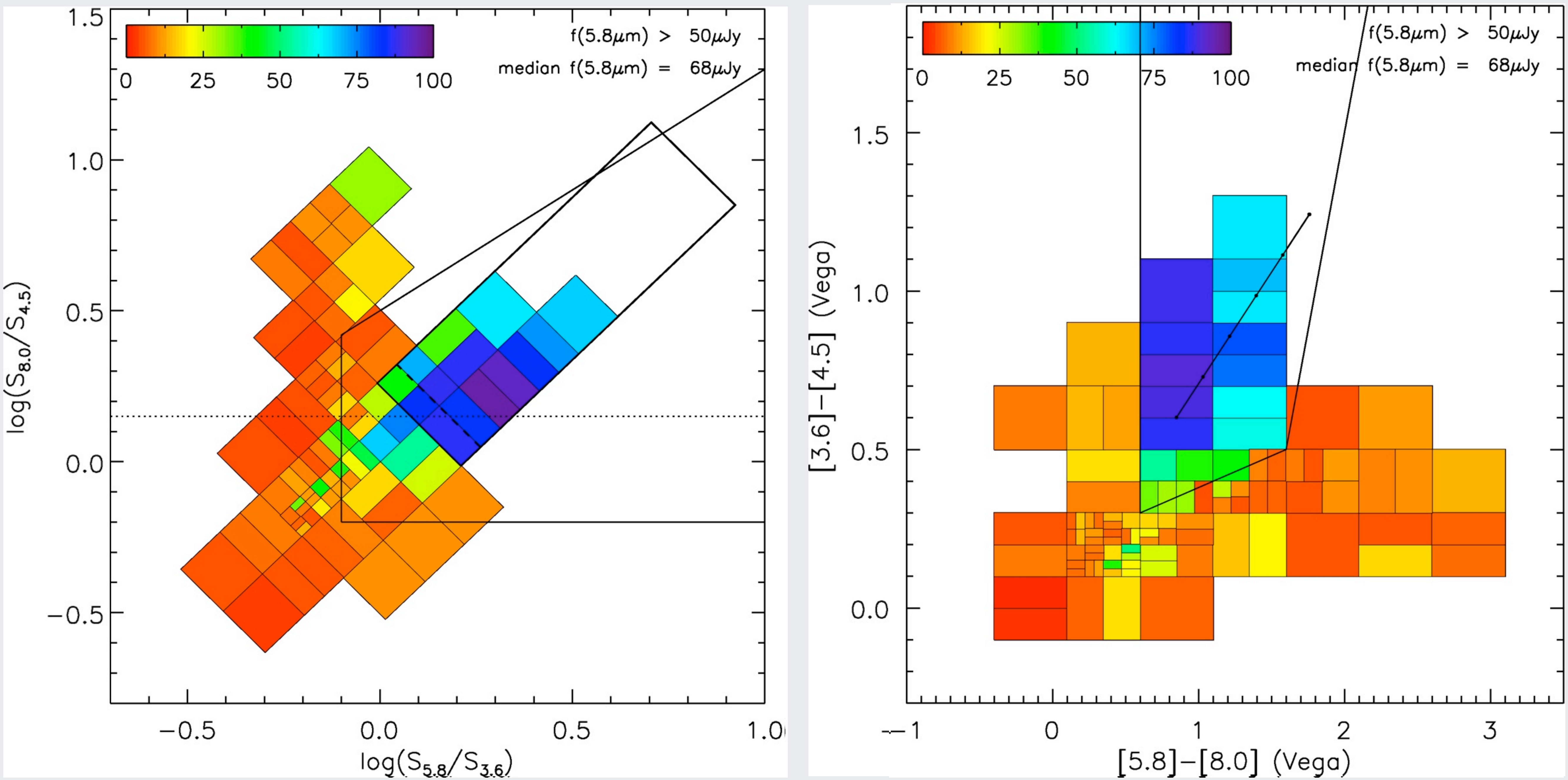




IRAC Sample: Reliability

XMM Sources comprise only 4% of the IRAC sample

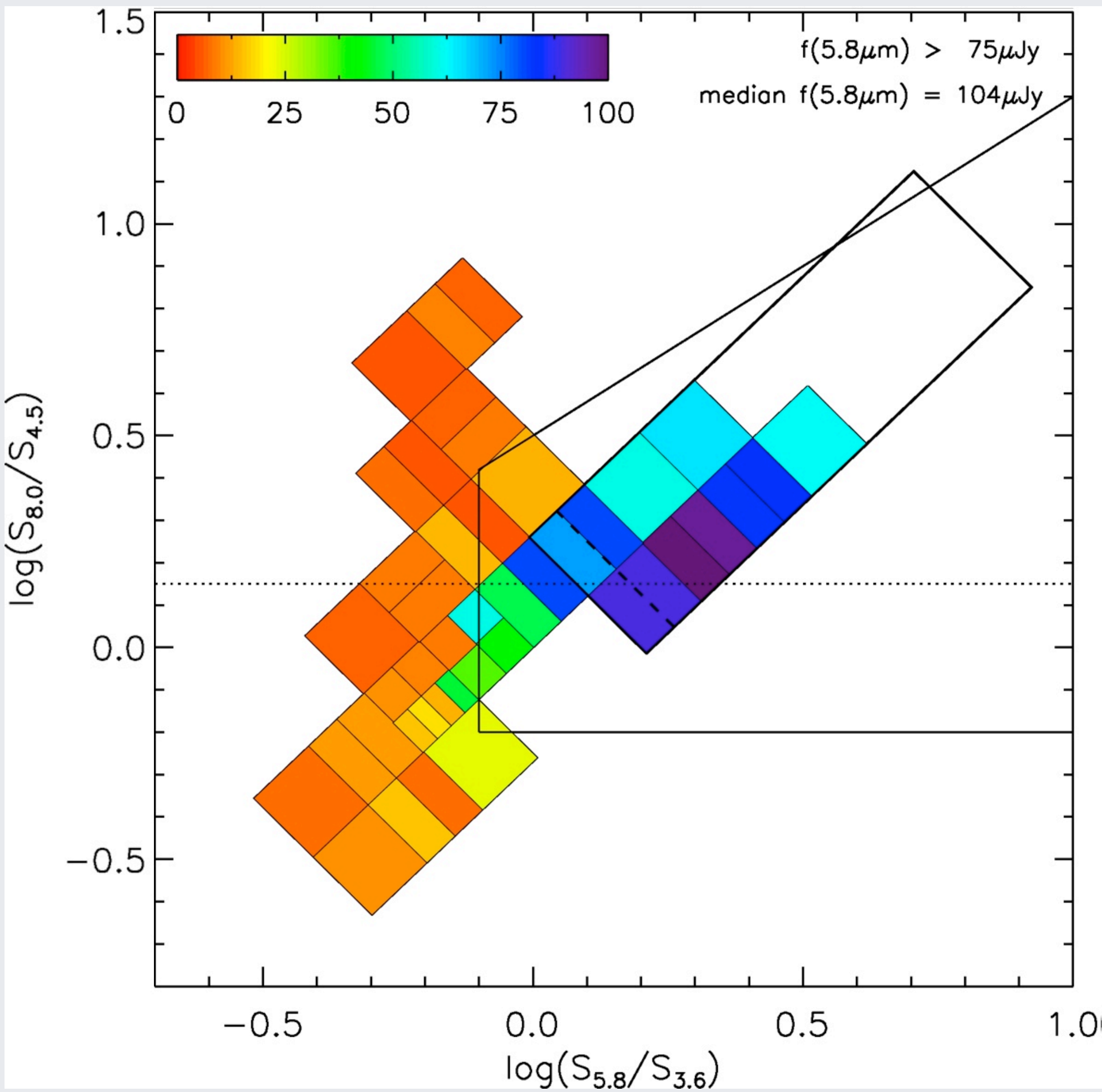
Colors = X-ray Detection Fraction (for sources with T_X>50ks):

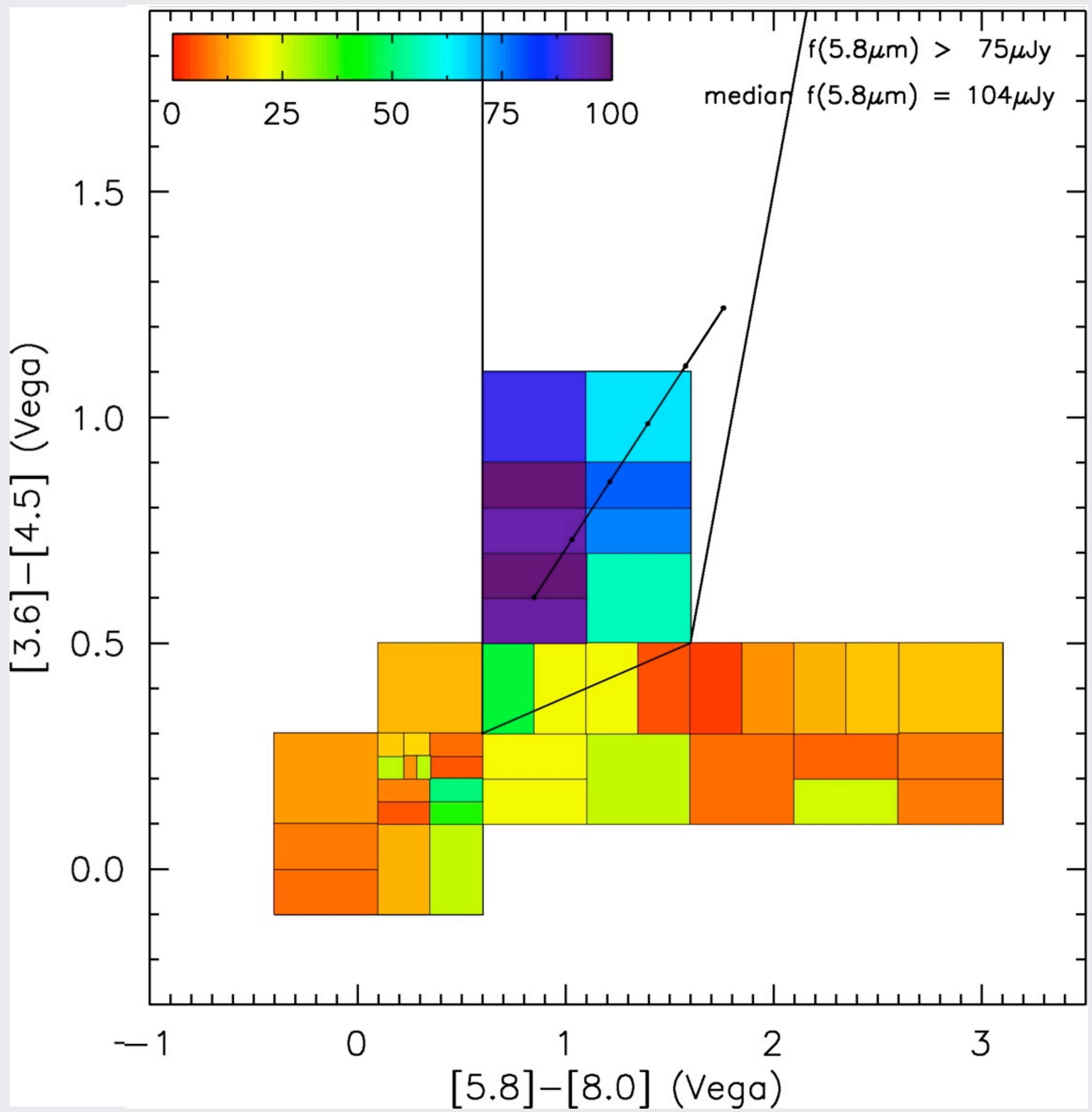


IRAC Sample: Reliability

XMM Sources comprise only 4% of the IRAC sample

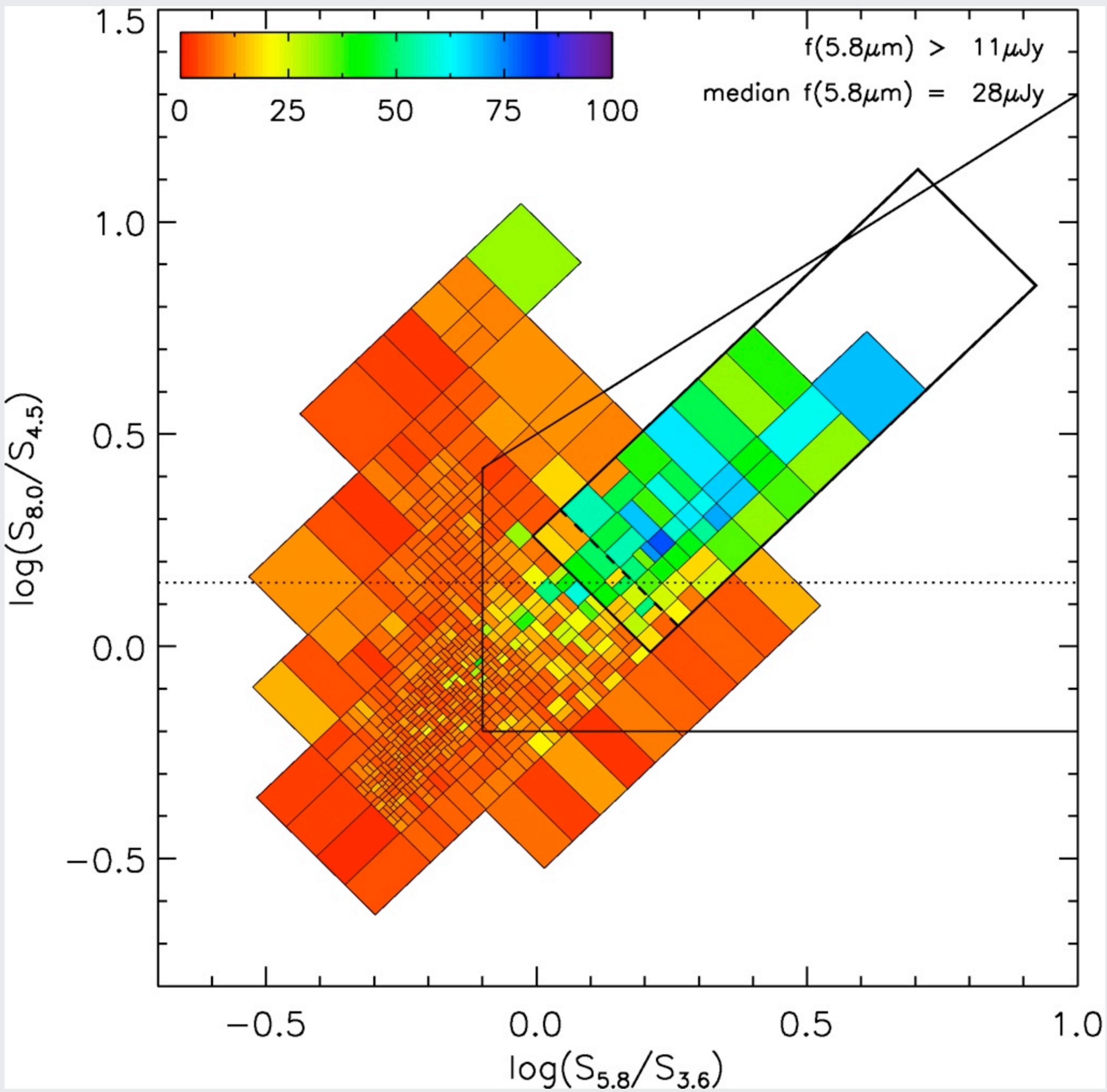
Colors = X-ray Detection Fraction (for sources with T_X>50ks):

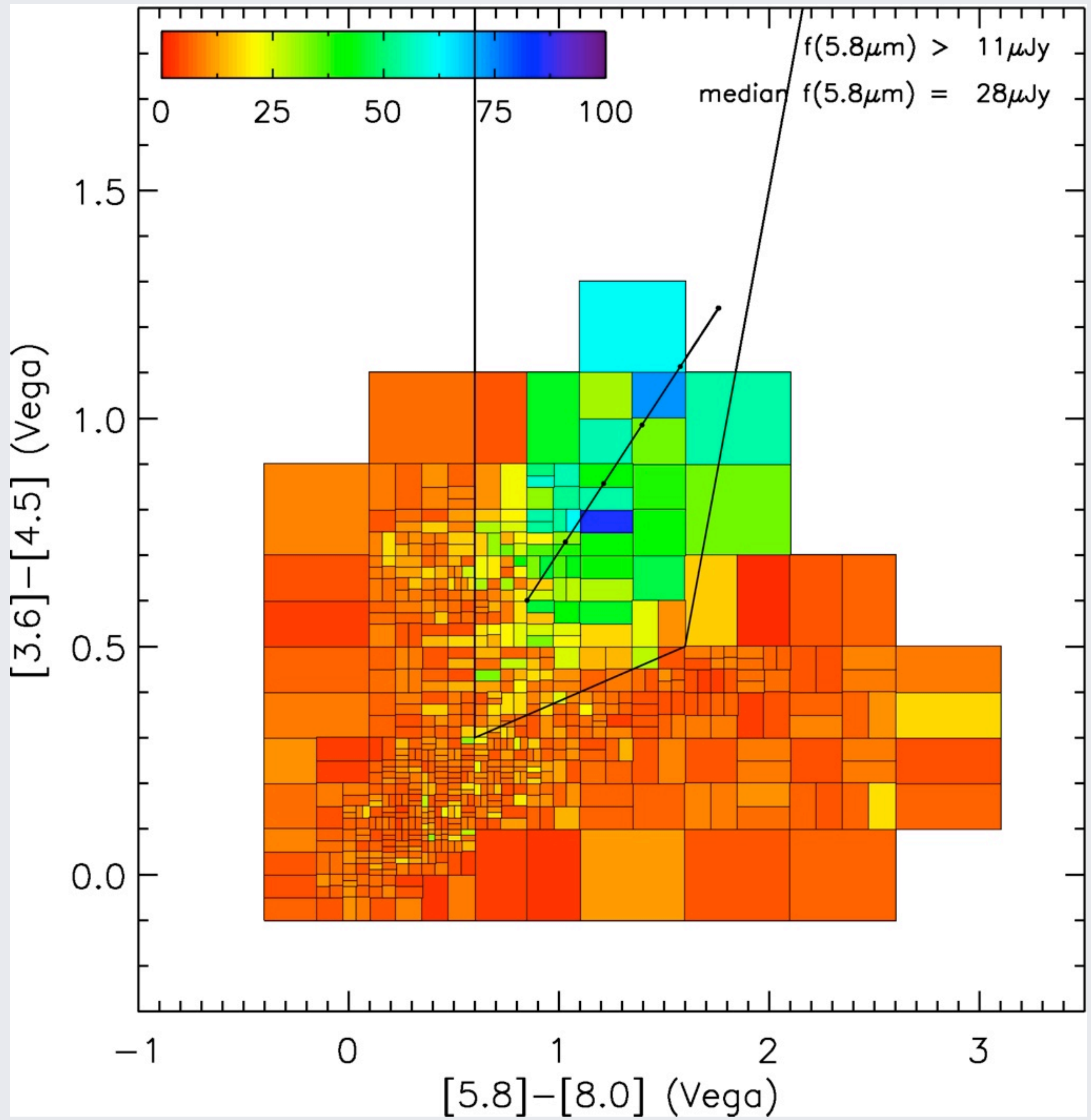




IRAC Sample: Reliability

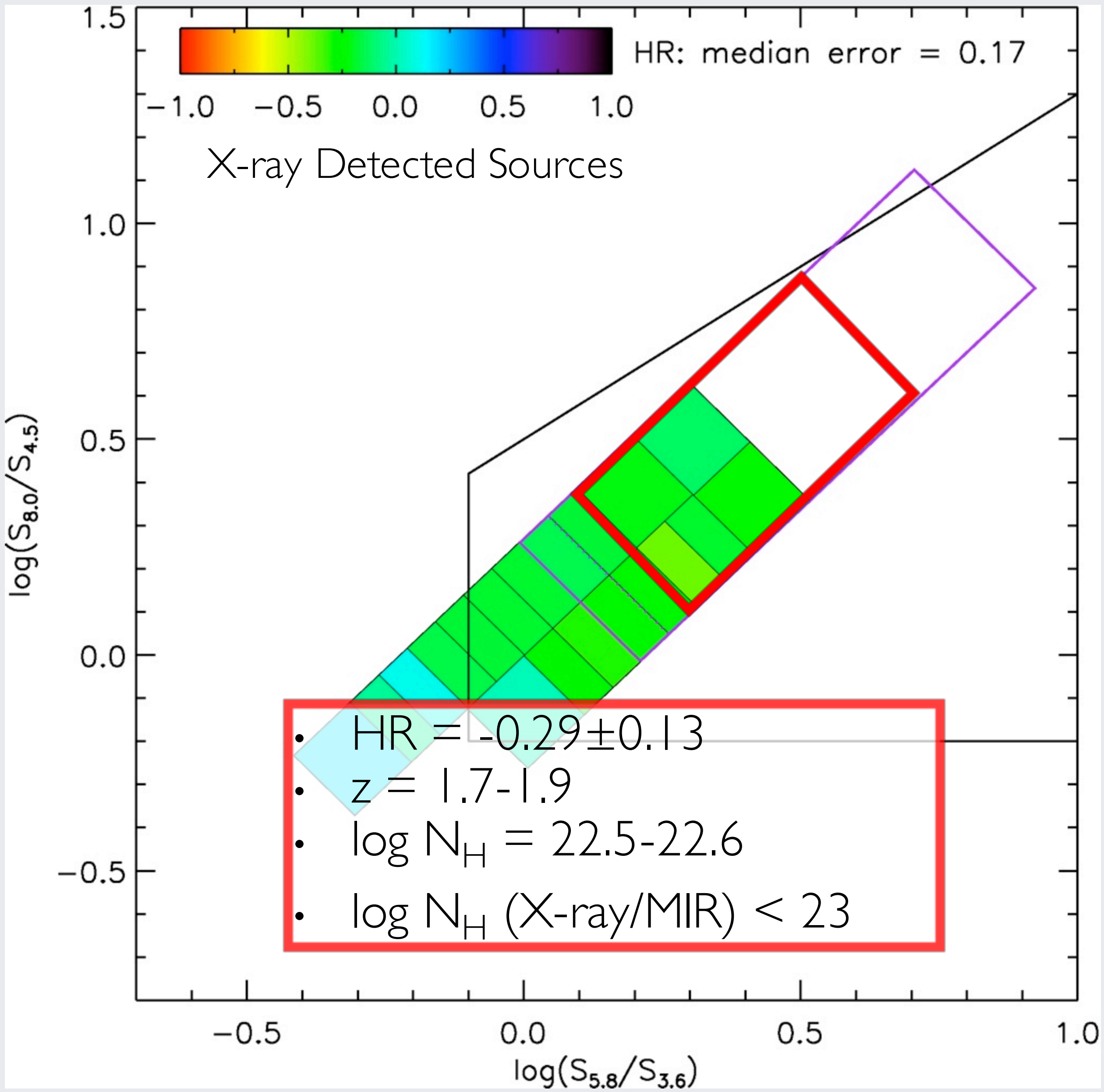
X-ray detection fraction is low in the same regions where we expect contamination from star-forming galaxies.

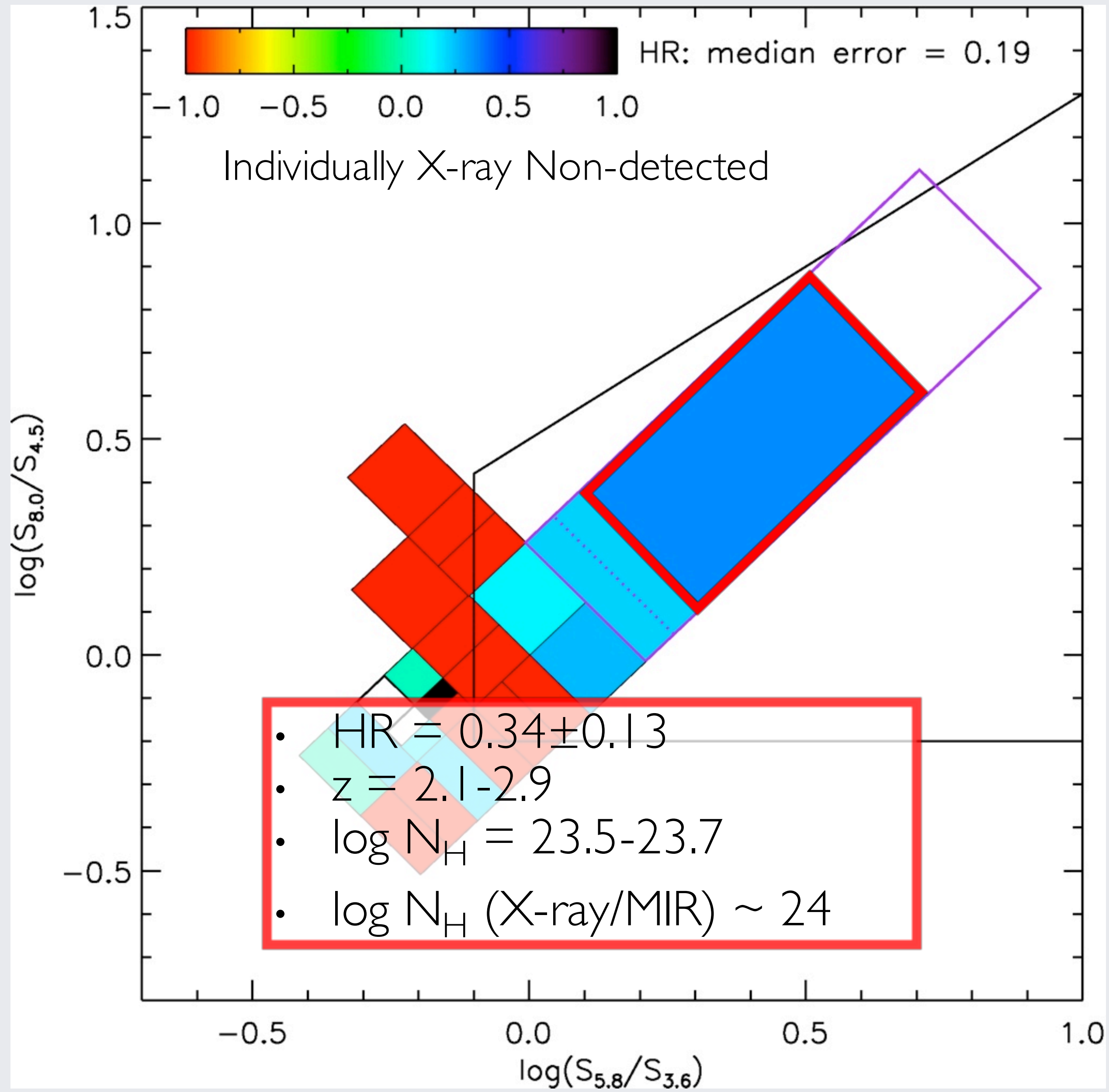




IRAC Sample: Reliability

X-ray Stacking: Average Properties of X-ray Detected (and non-detected) Samples

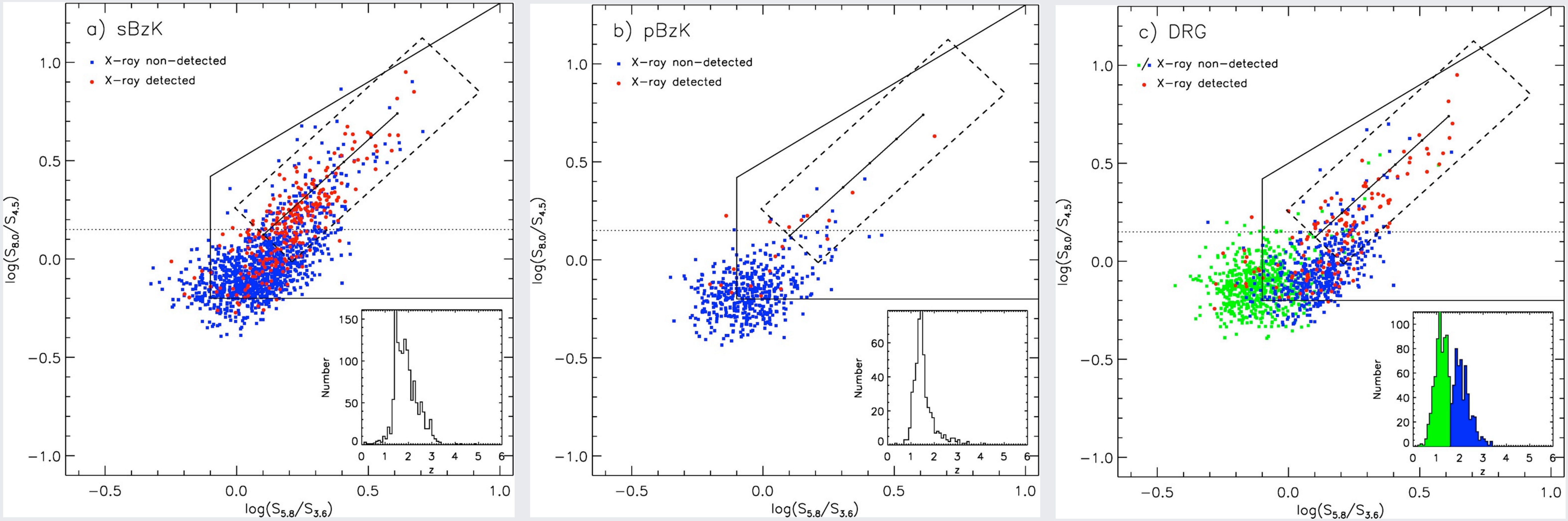




X-ray undetected sources = high-z, luminous, heavily obscured AGN

IRAC Sample: Contamination from high-z galaxies?

At high-z, IRAC bands sample blue side of stellar bump



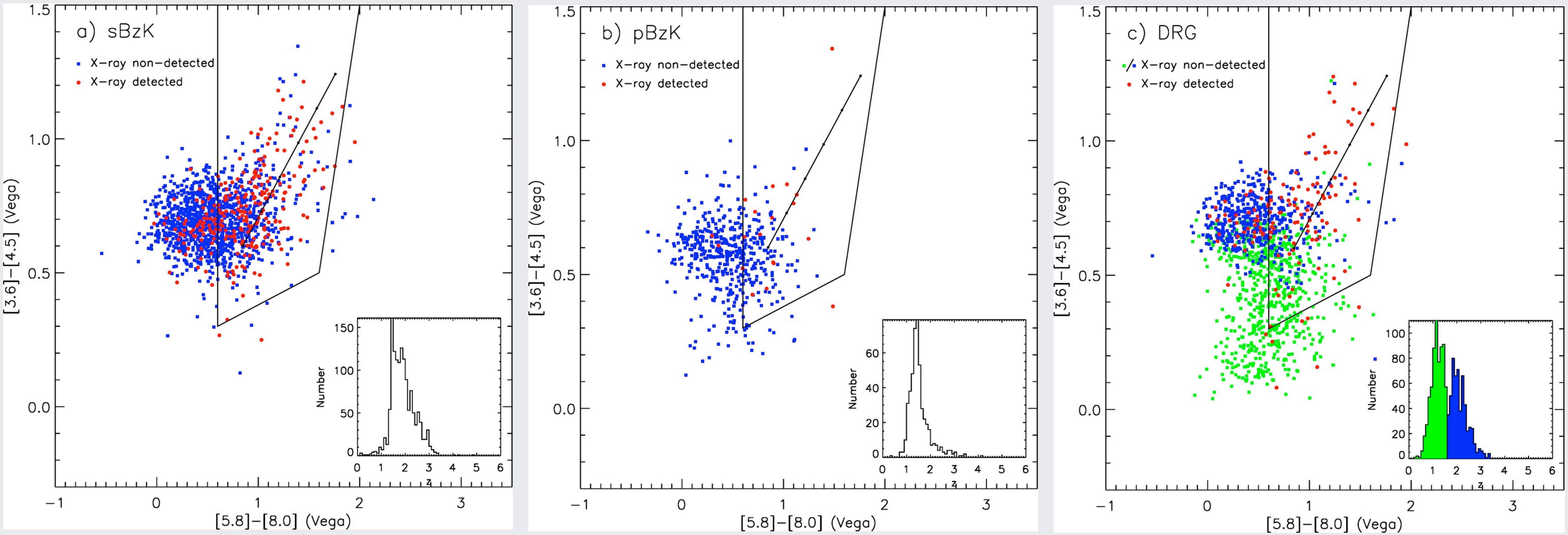
Two populations of BzK and DRG sources:

1) Low X-ray detection fraction (blue/green) star-forming cloud

2) High X-ray detection fraction extension along the power-law locus (AGN)

➡ Can be separated by a cut in 8.0/4.5 color

IRAC Sample: Contamination from high-z galaxies?



Two populations of BzK and DRG sources:

1) Low X-ray detection fraction star-forming cloud

2) High X-ray detection fraction extension along power-law locus (AGN)

➡ Cannot be cleanly separated in Stern+ color space

IRAC Sample: Contamination from high-z galaxies?

Only three spectroscopically-confirmed z>3 LBGs in COSMOS meet the IRAC cuts, so we turn to the GOODS field.

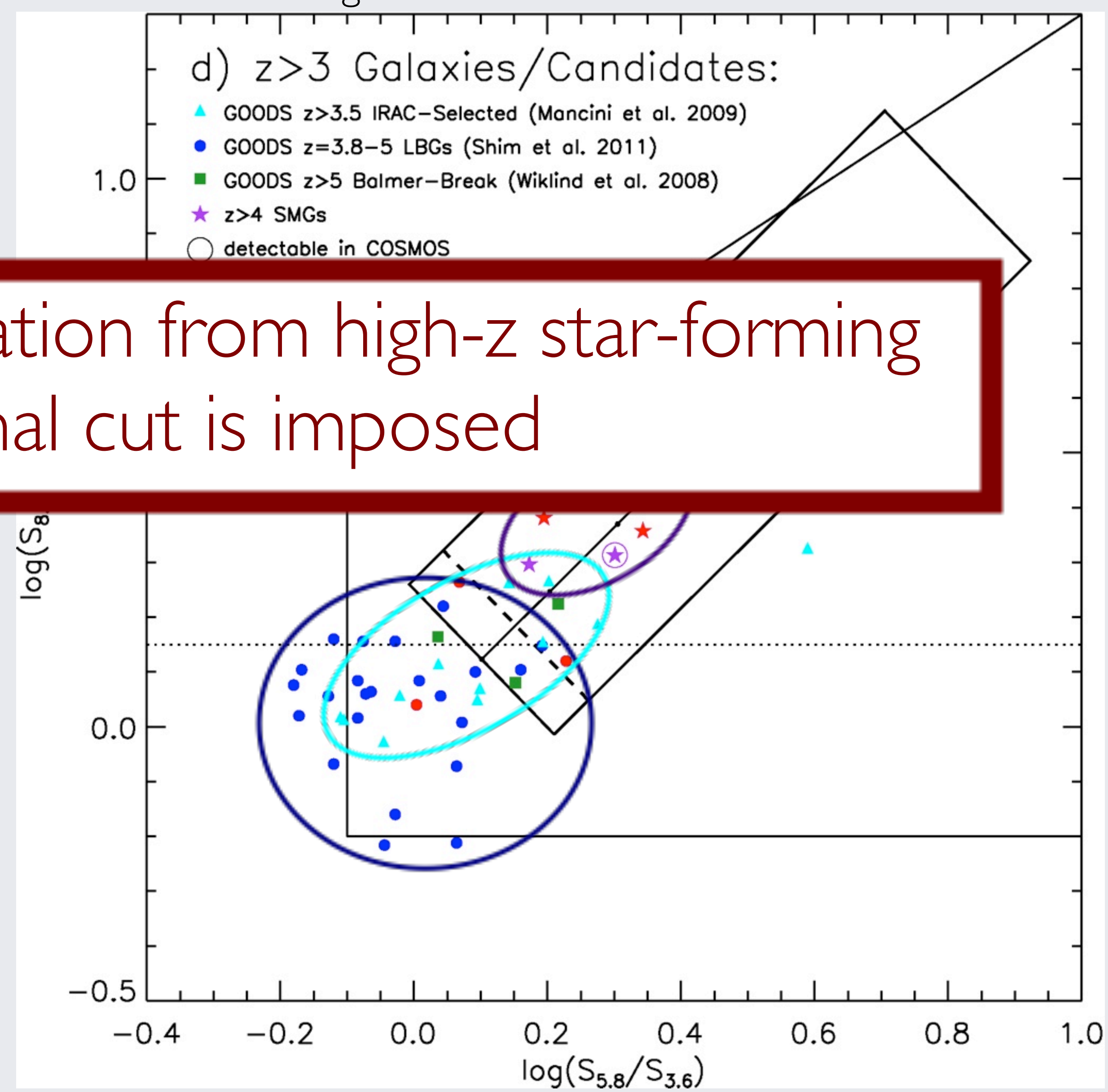
High-z Galaxies/Candidates:

- z=3.8-5 LBGs (spec. conf., Shim+11)

We expect little to no contamination from high-z star-forming galaxies after additional cut is imposed

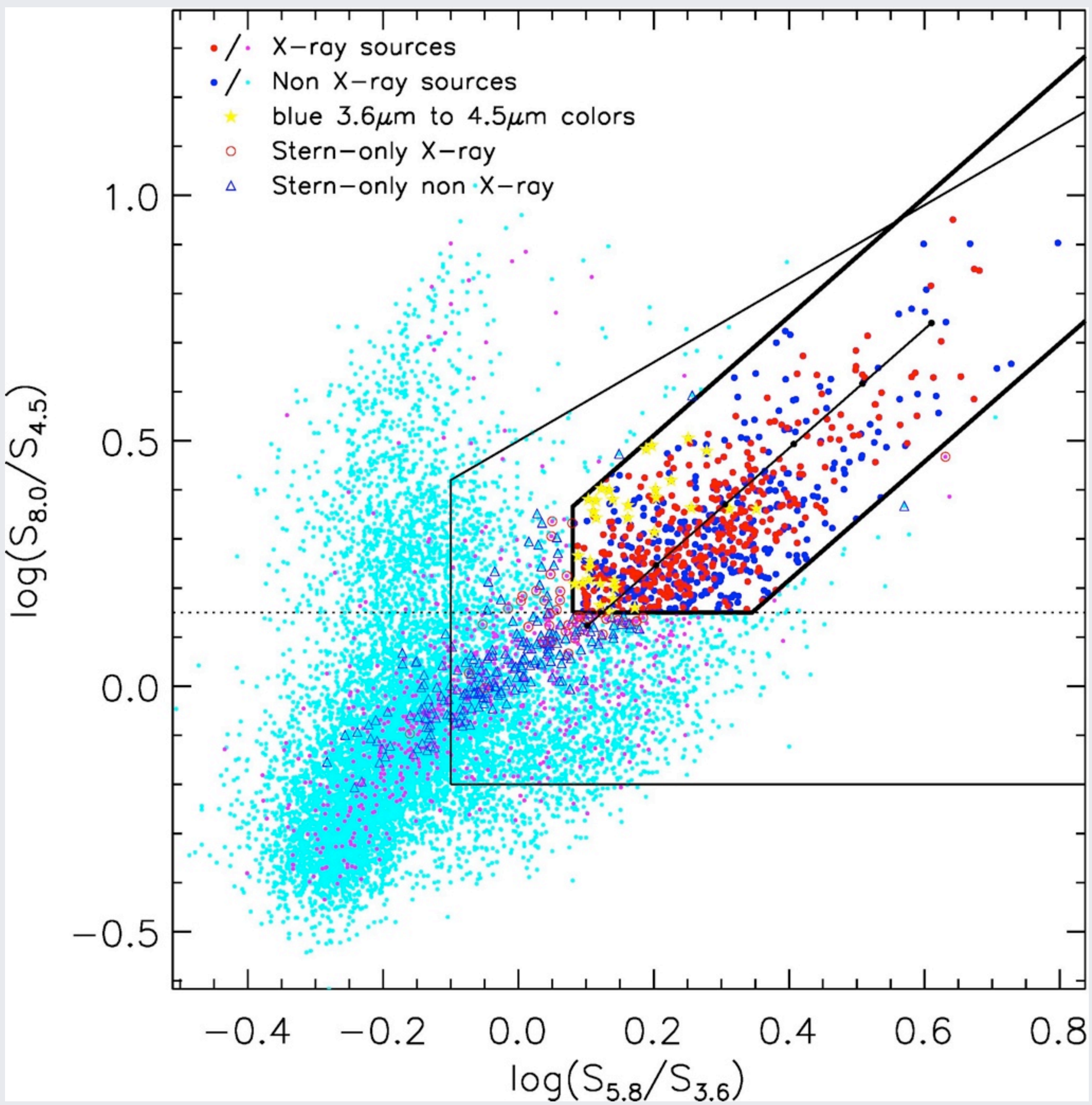
- z>3 evolved galaxy candidates (Mancini+ 09, Wiklind+ 08)
  - slightly redder, but none detectable in COSMOS
- z>4 SMGs
  - all in power-law box, but 3/6 are known AGN and the rest are bright 24um sources

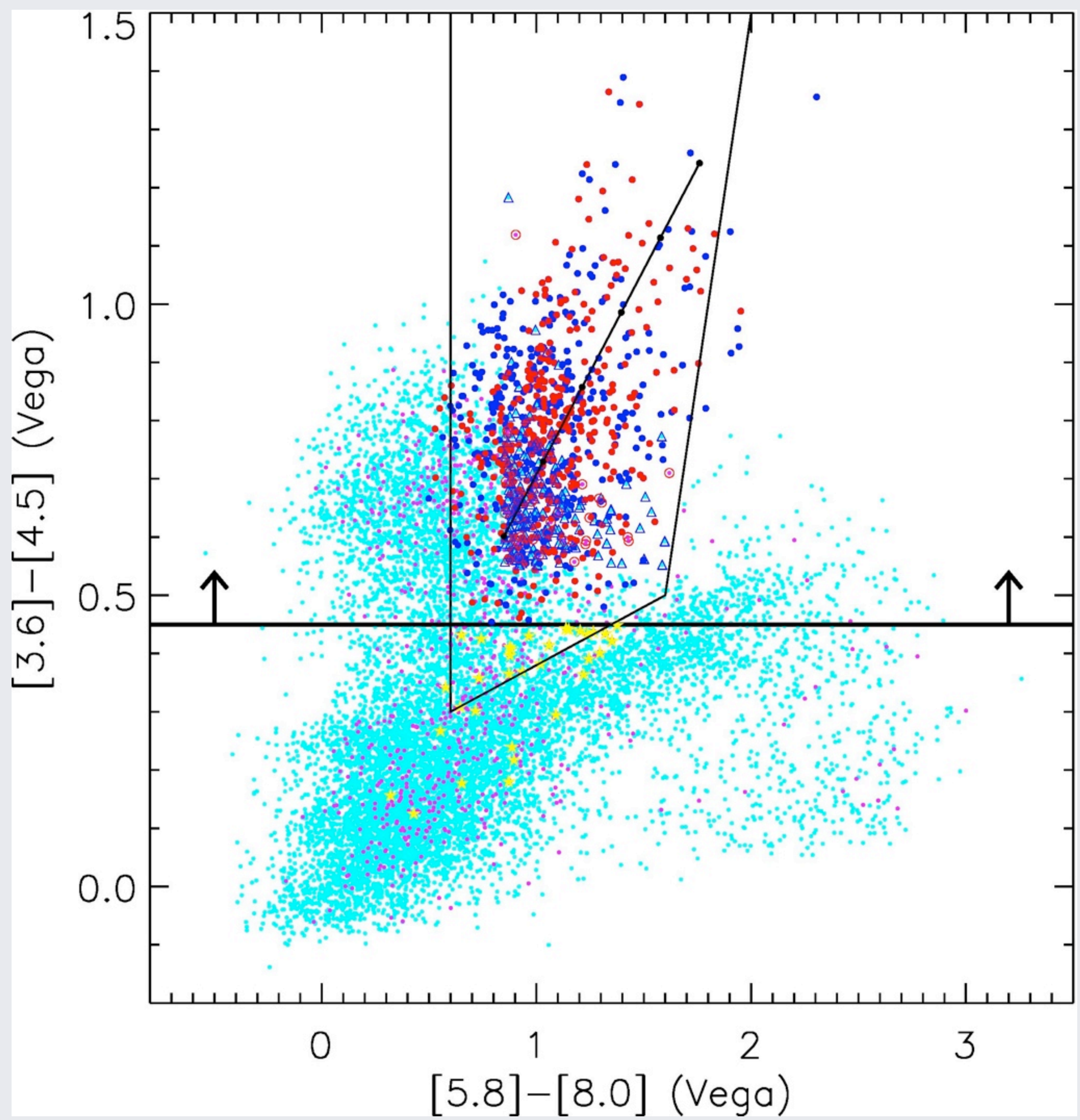
High-z Candidates in GOODS



Revised AGN Selection Criteria:

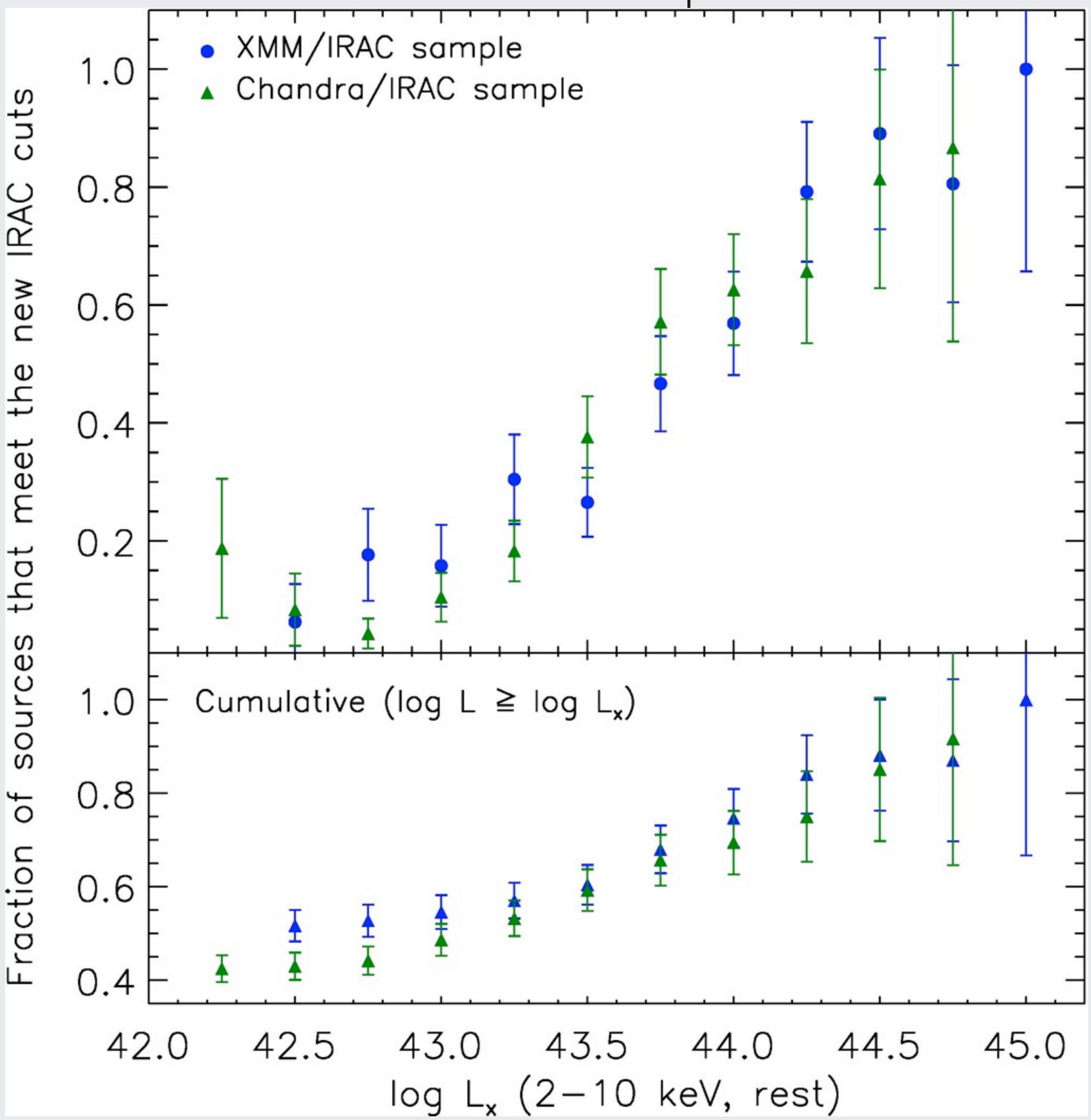
- Combines a revised wedge in Lacy+ color space with a cut in Stern+ color space
- 1611 IRAC sources meet our new selection cuts: only 37% are X-ray sources over full field, 50% are X-ray sources in deep Chandra field

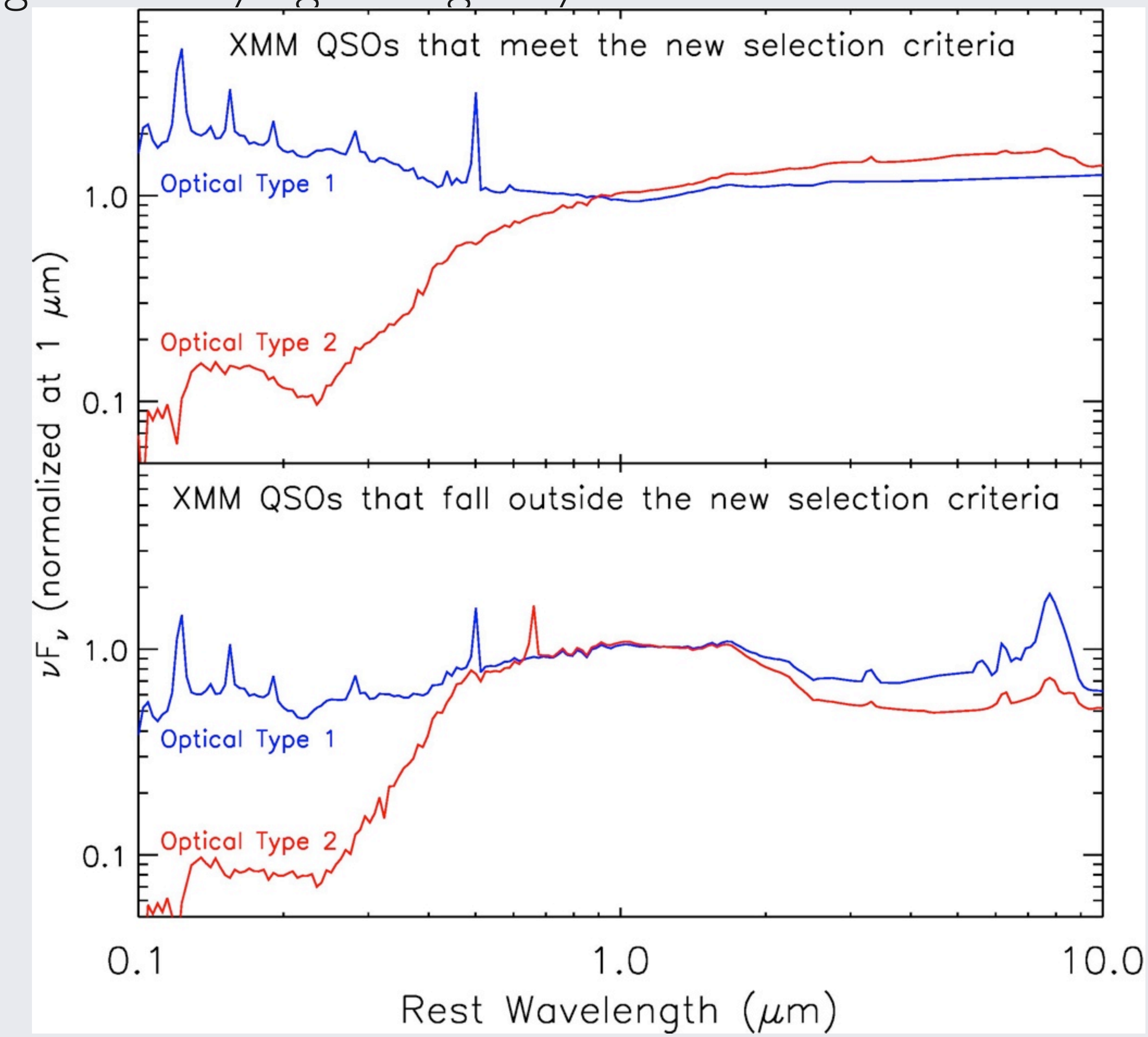




Revised AGN Selection Criteria:

- Cut recovers 75% of sources with QSO luminosities of L_x>44 and 75% of heavily obscured (potentially Compton-thick) DOGs, but only 30% of Type 2 radio galaxies.
- QSOs (Lx>44) missed by the cut tend to be slightly more obscured, and show a prominent 1.6 micron stellar bump indicative of a bright underlying host galaxy.





Summary: IR Selection of Luminous AGN

(Donley et al. 2011)

- IRAC selection is an efficient way to select **luminous** unobscured and obscured AGN, but current AGN selection regions are insufficient for use with deep IRAC surveys
- Using COSMOS, we redefine the IRAC AGN selection region to be maximally complete and reliable.
- We expect minimal contamination from high-redshift galaxies (LBG, BzK, DRG, SMG, etc.)
- Despite far smaller selection region, the new cuts recover >75% of QSO-luminosity AGN, 50% of which lack X-ray counterparts.

$$x = \log_{10}\left(\frac{f_{5.8\mu m}}{f_{3.6\mu m}}\right),\ y = \log_{10}\left(\frac{f_{8.0\mu m}}{f_{4.5\mu m}}\right),\ z = \log_{10}\left(\frac{f_{4.5\mu m}}{f_{3.6\mu m}}\right)$$

$$x \geq 0.08 \ \wedge \ y \geq 0.15 \ \wedge \ z \geq -0.03$$

$$\wedge \ y \geq (1.21 \times x) - 0.27 \ \wedge \ y \leq (1.21 \times x) + 0.27$$