PRIMUS+AEGIS: The Clustering of X-ray, Radio, and IR-selected AGN

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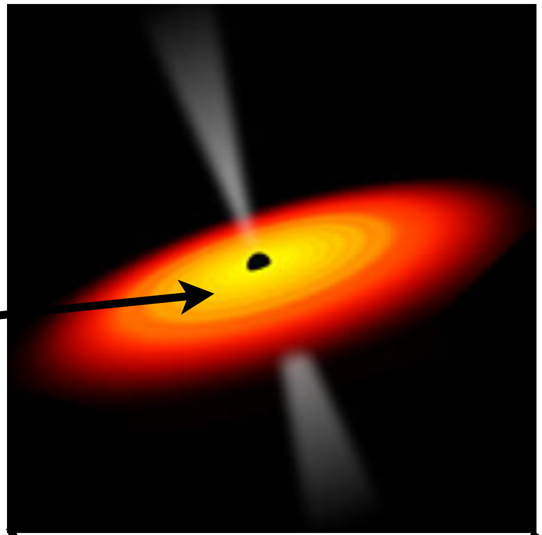
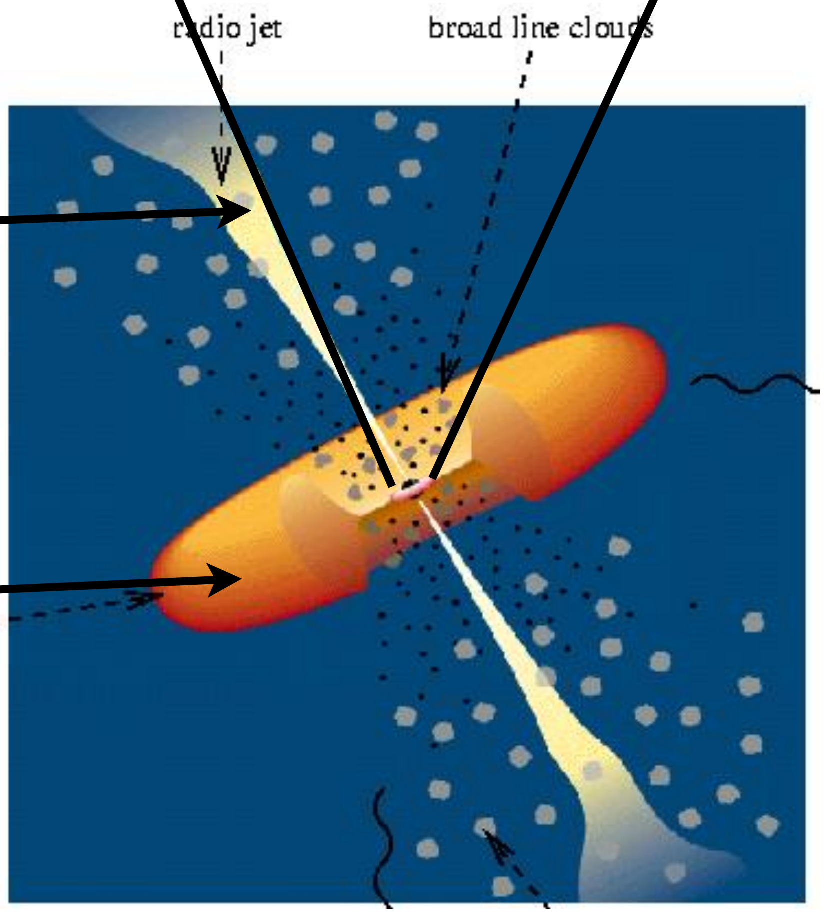
Outline

- X-ray AGN, radio AGN and IR AGN selection techniques
- Data: The PRIMUS and DEEP2 / AEGIS surveys
- Clustering results for X-ray AGN, radio AGN, and IR AGN
  - Comparison of clustering bias
  - Dependance on luminosity and specific accretion rate
  - Comparison with matched galaxy samples
  - IR AGN: obscured vs unobscured.

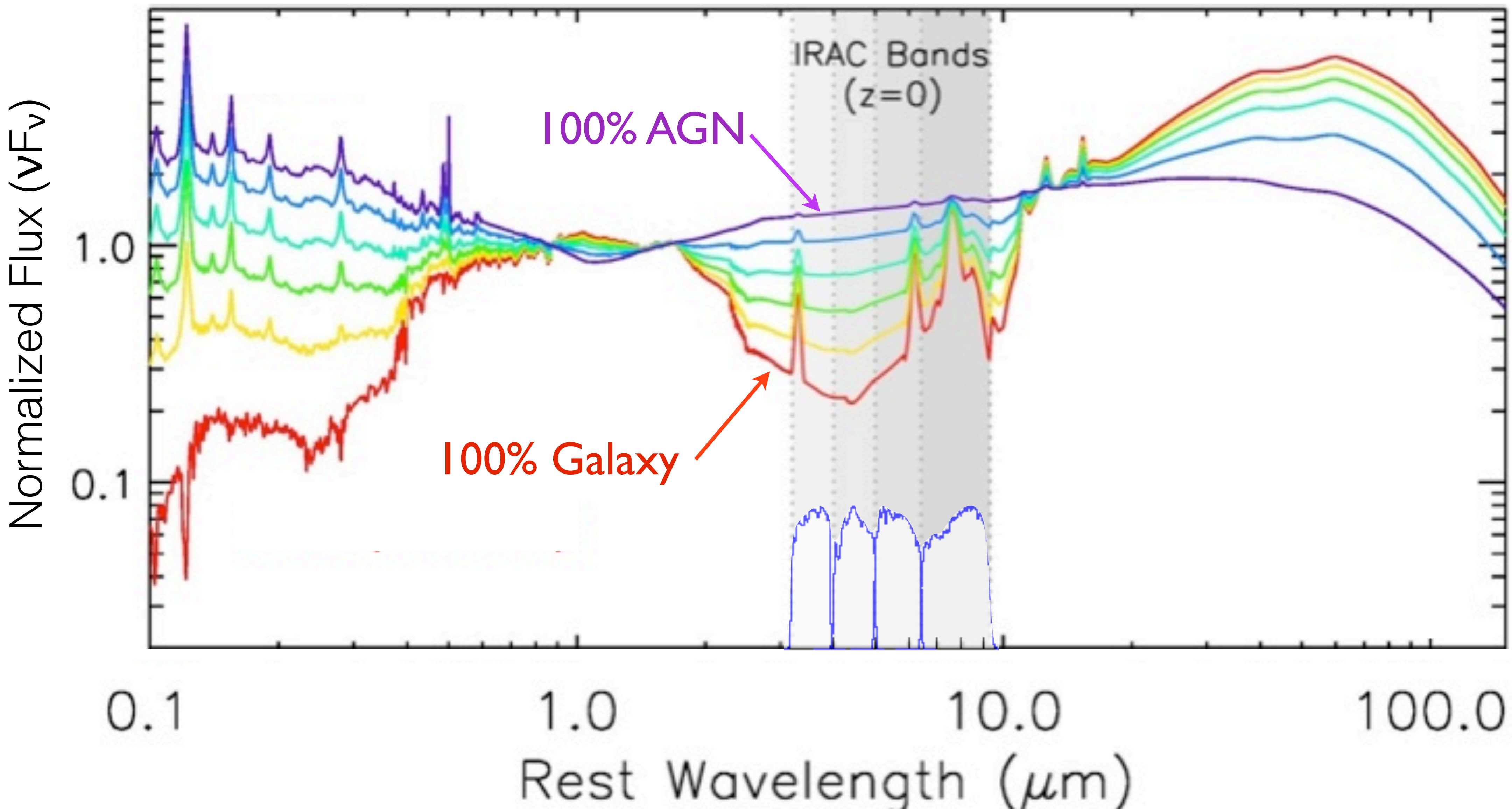
Observing AGN

- Three components:
  - Accretion disk (opt., UV, **X-ray**)
    - Highly luminous extragalactic X-ray sources are AGN
  - Jets (**Radio**)
    - Synchrotron emission
  - Dust (**MIR**)
    - Reprocesses photons into IR
    - Specific IR colors



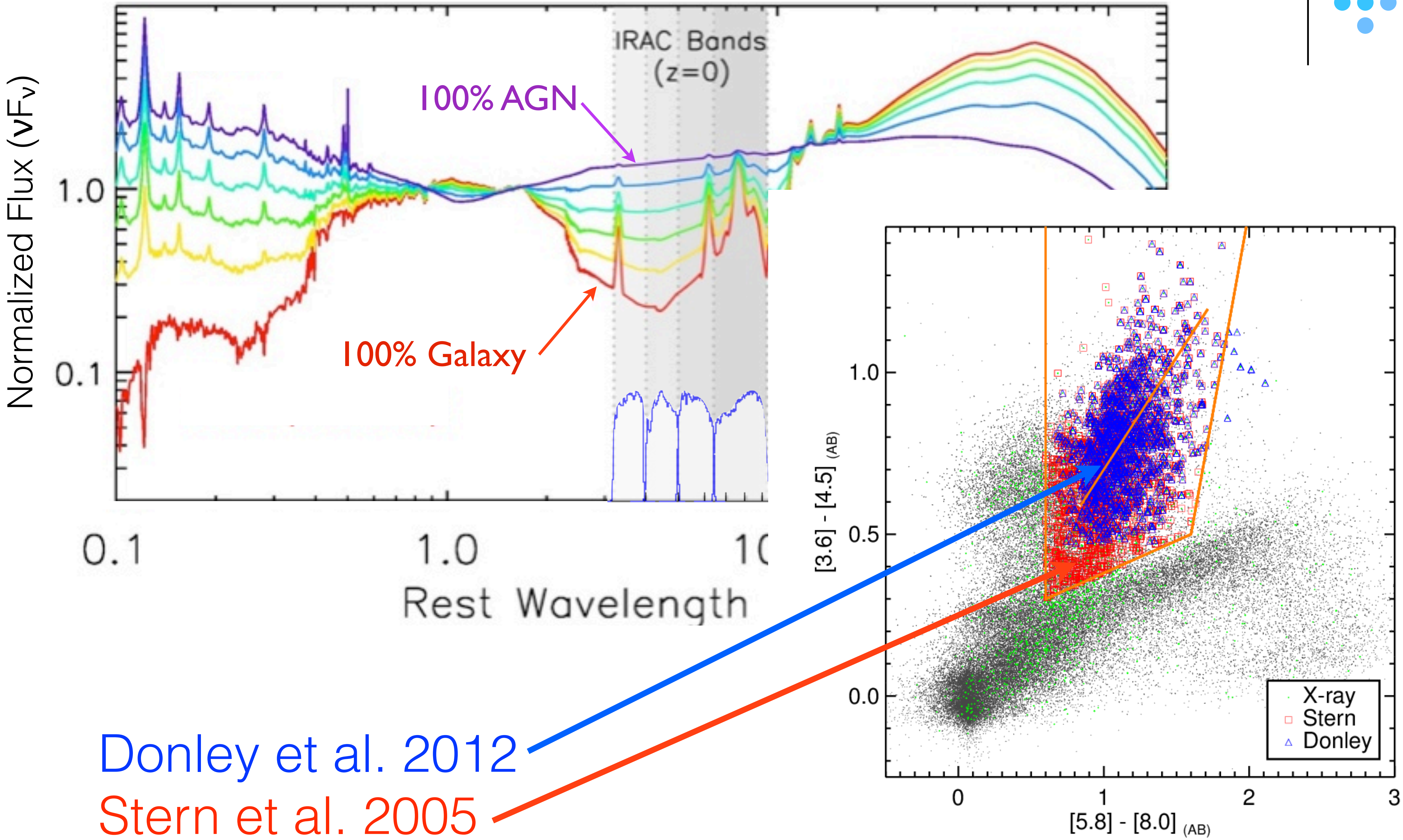


IR AGN SED



(Donley+12)

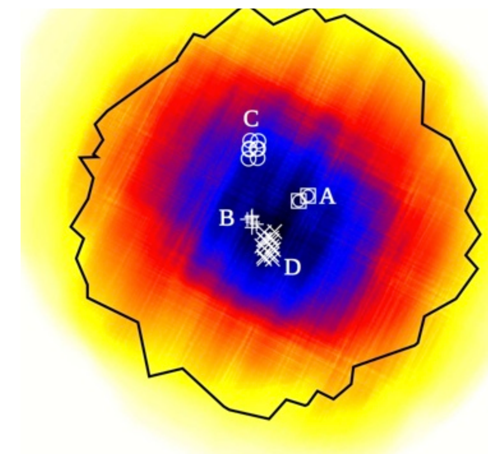
IR AGN SED



(Mendez+13)

X-ray AGN and IR-AGN

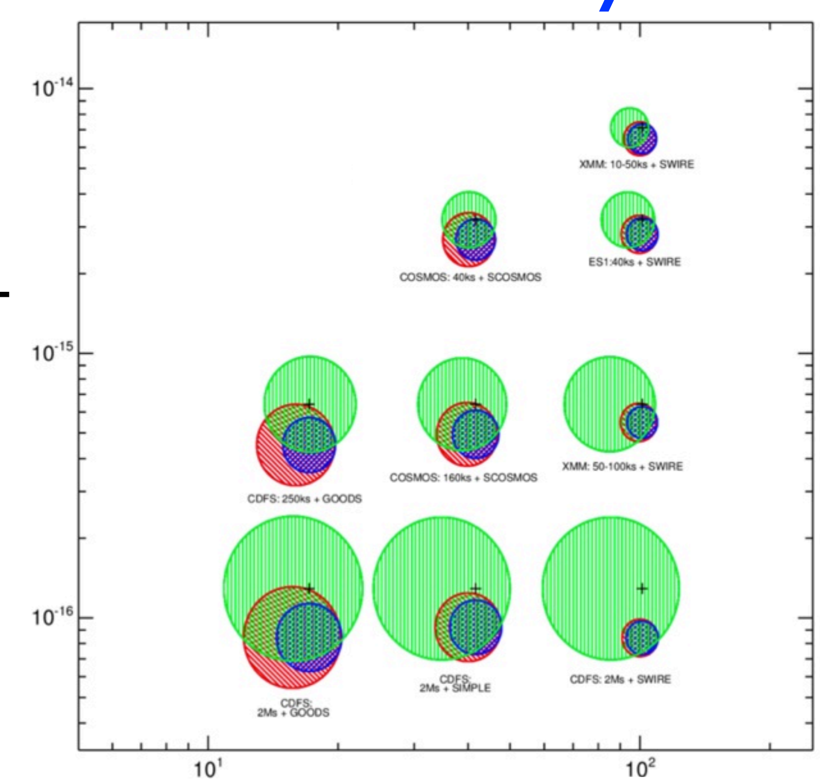
- Compare X-ray and IR selection techniques as a function of survey depth.
- Overlap between IR and X-ray is large with selection weights
- Deep X-ray identify majority (90%) of IR-AGN.
- IR identify more luminous AGN that dominate the galaxy light.
- See Mendez+2013 for details.



(Ranalli+13)

X-ray
IR: Donley

Deeper X-ray

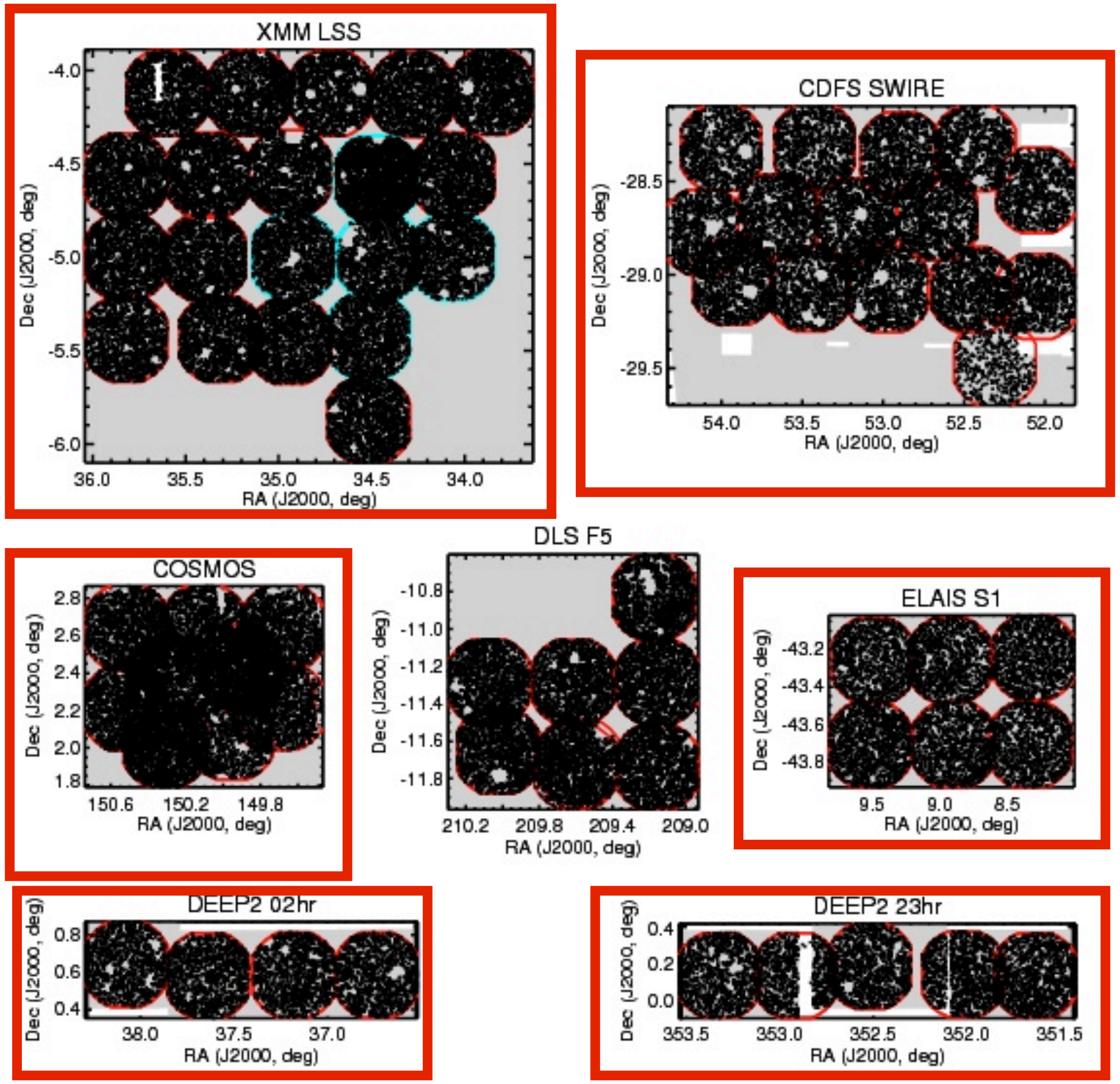


Deeper IR

(Mendez+13)

PRism MUlti-object Survey

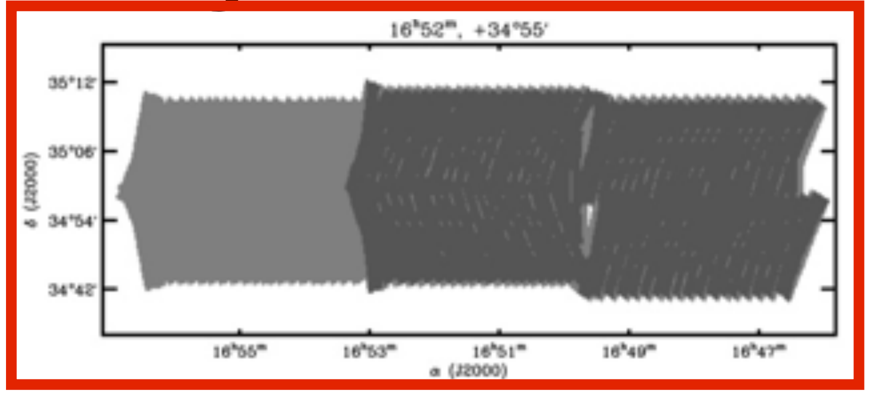
- 9 sq. deg. over 7 fields with mutli-wavelength data: radio, IR, optical, UV, and X-ray
- ~120,000 spec z's to z=1.2
- with Deep X-ray, radio, and IR
- Fields: CDFS, COSMOS, ES1, XMM-LSS DEEP2 02hr + 16hr

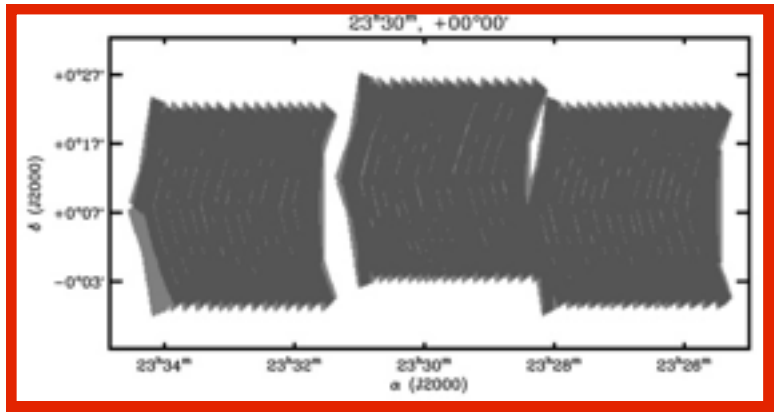


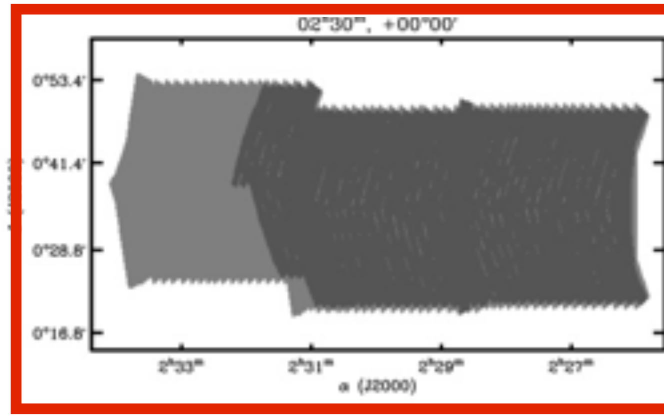
(Coil+11)

AEGIS / DEEP2 Surveys

- DEEP2 2hr, 16hr, and 23hr fields
  - Medium X-ray coverage
  - Shallow radio coverage
  - Partial IR coverage

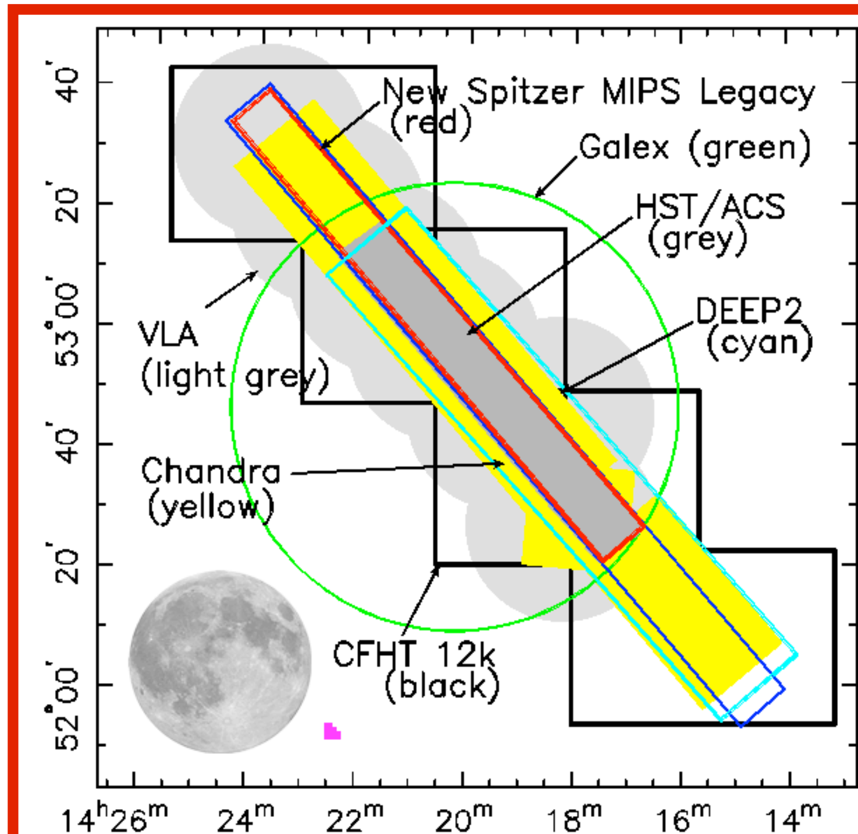






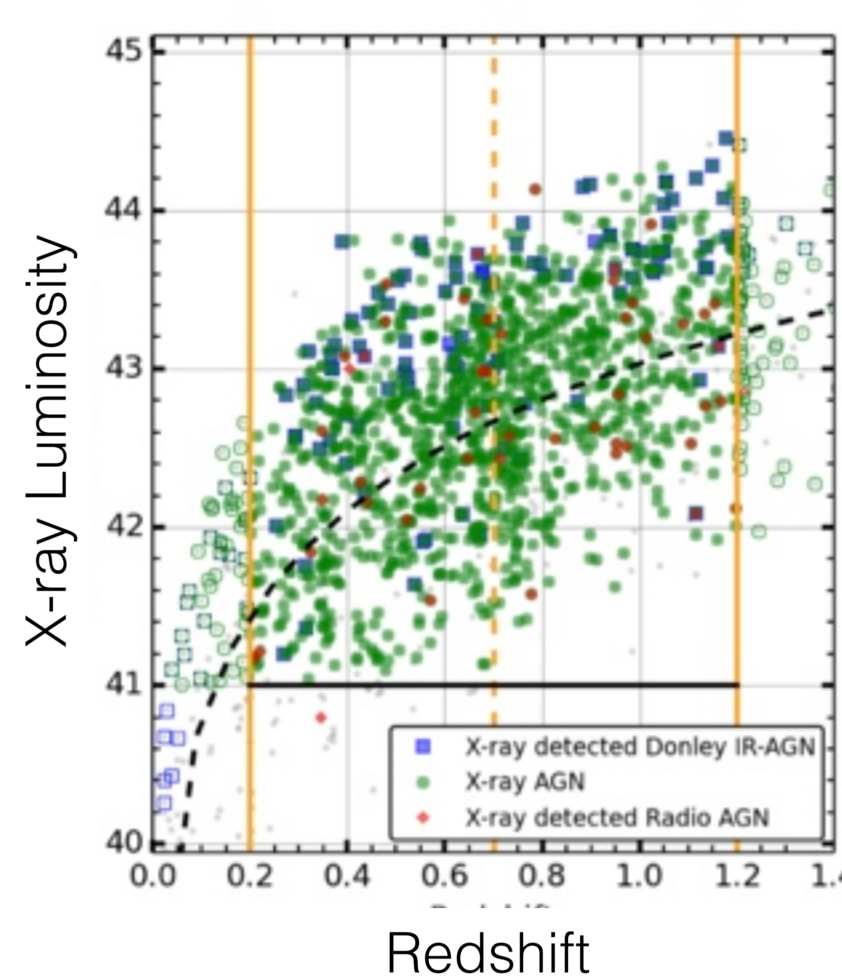
- Deep X-ray, radio, and IR in EGS field from AEGIS.

- Total: ~50K spectroscopic redshifts.



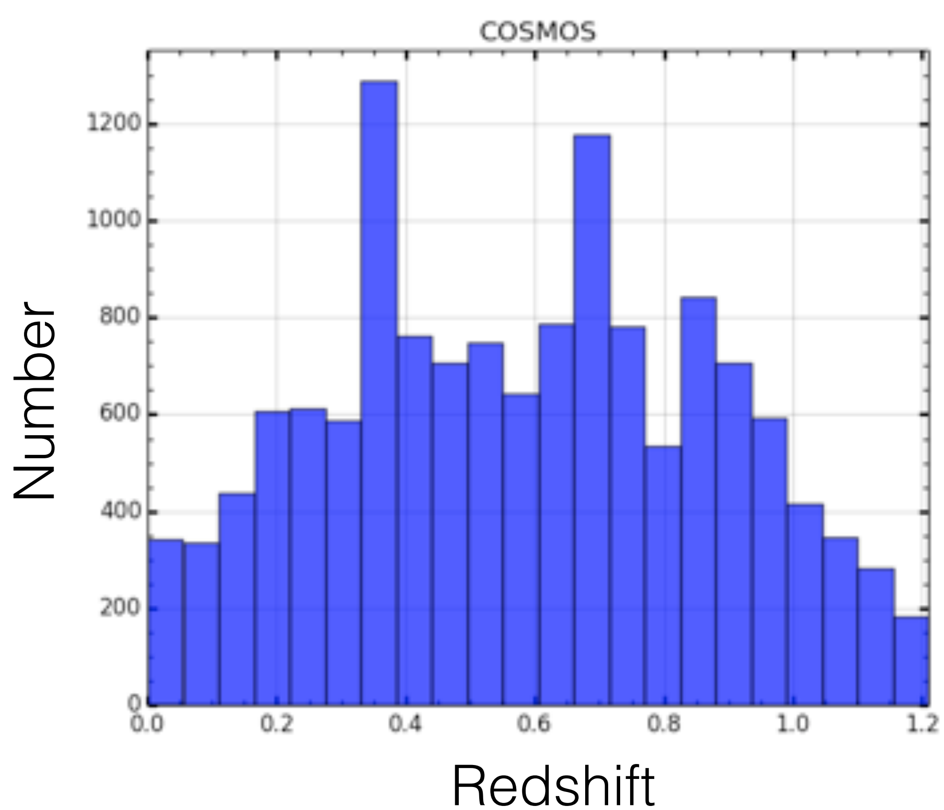
PRIMUS + AEGIS

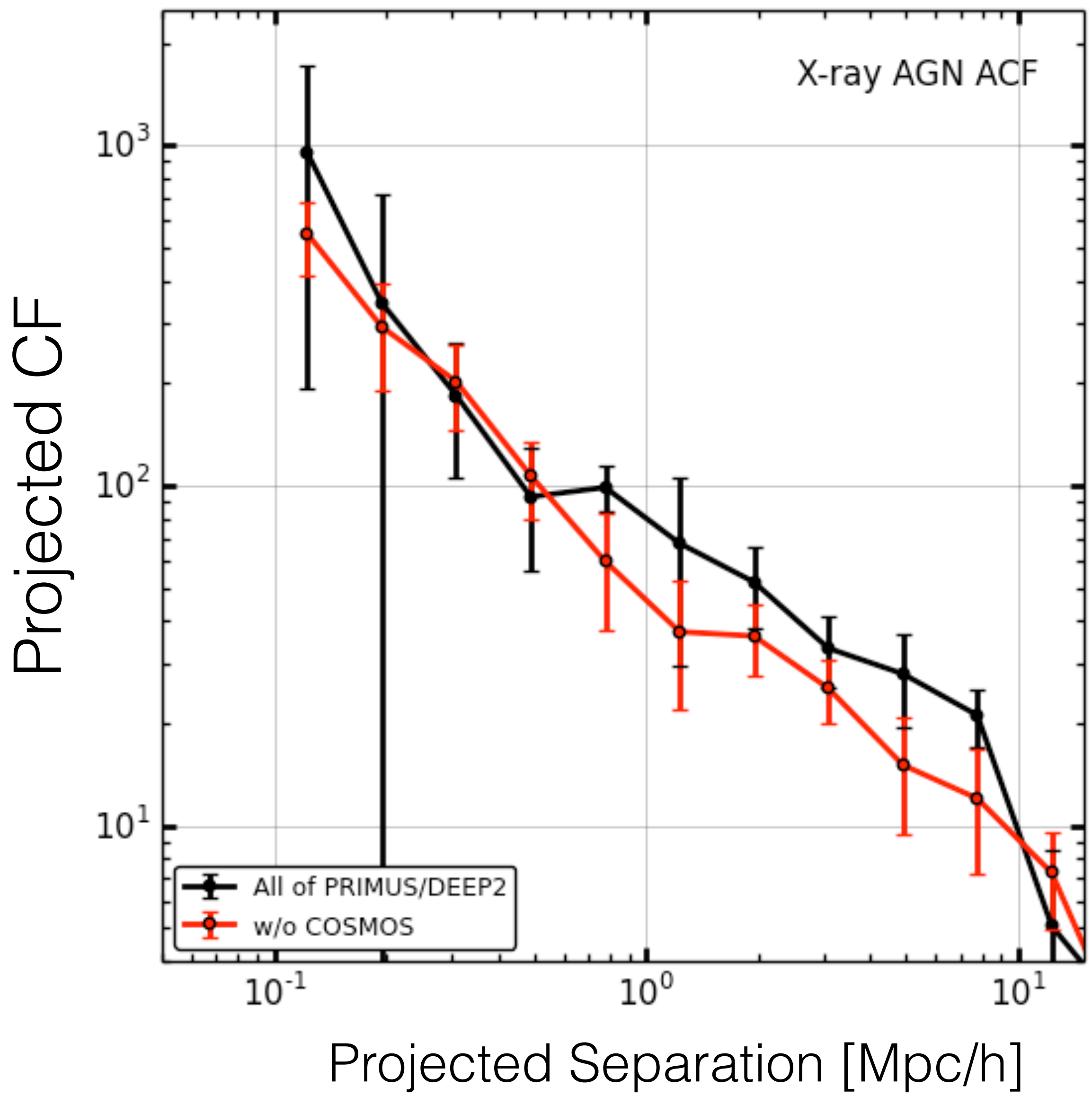
- Combination of multiple fields gives better estimate on clustering measurements accounting for cosmic variance.
- Probes larger parameter ranges than before (e.g. luminosity, specific accretion rate).
- Compare to matched galaxy samples.



The COSMOS field

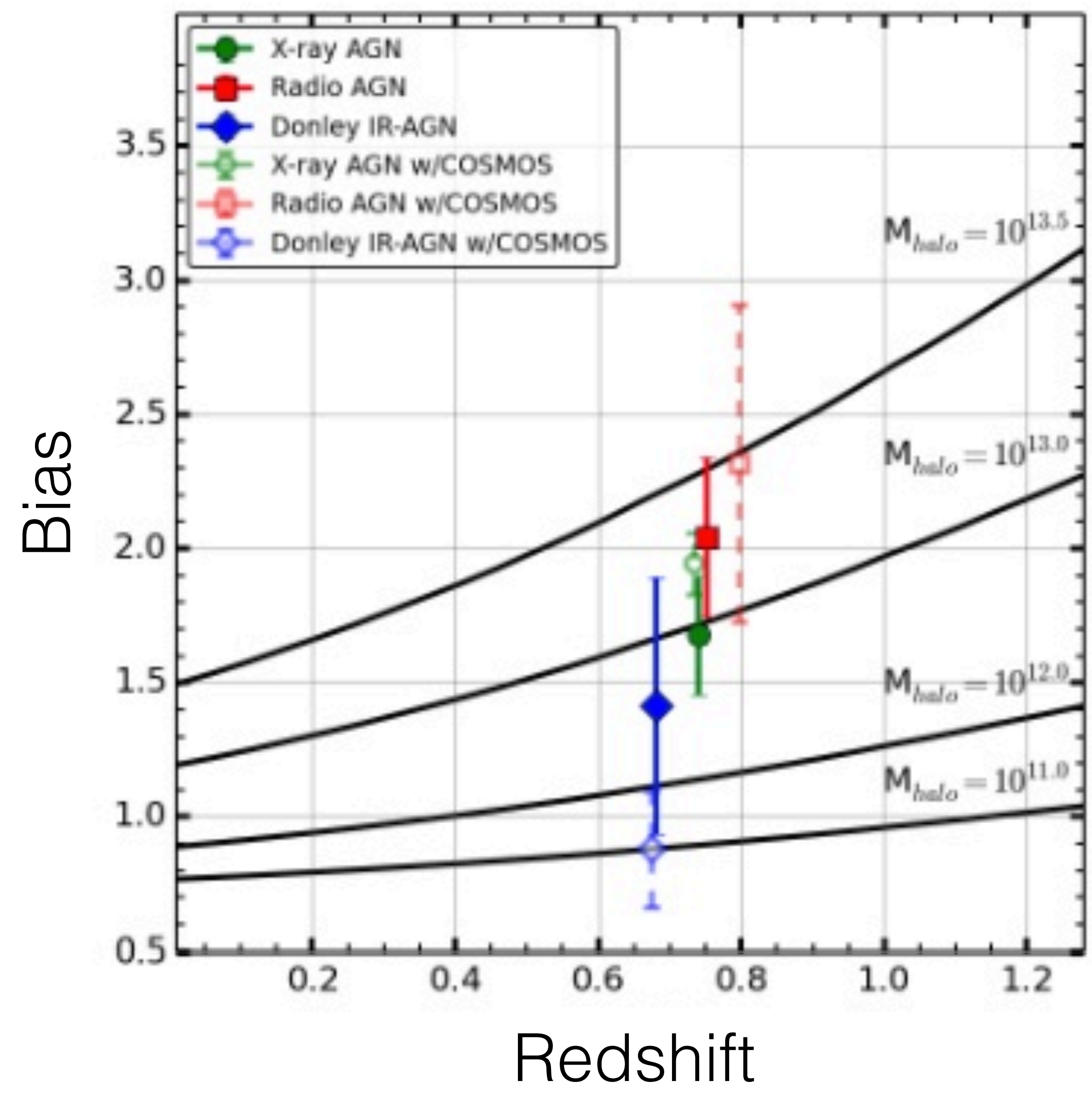
- Having multiple fields highlights the differences in each field.
- Differences in COSMOS:
  - Significant over-densities found at z=0.3 and z=0.7
  - We present results without COSMOS.





AGN Clustering Comparison

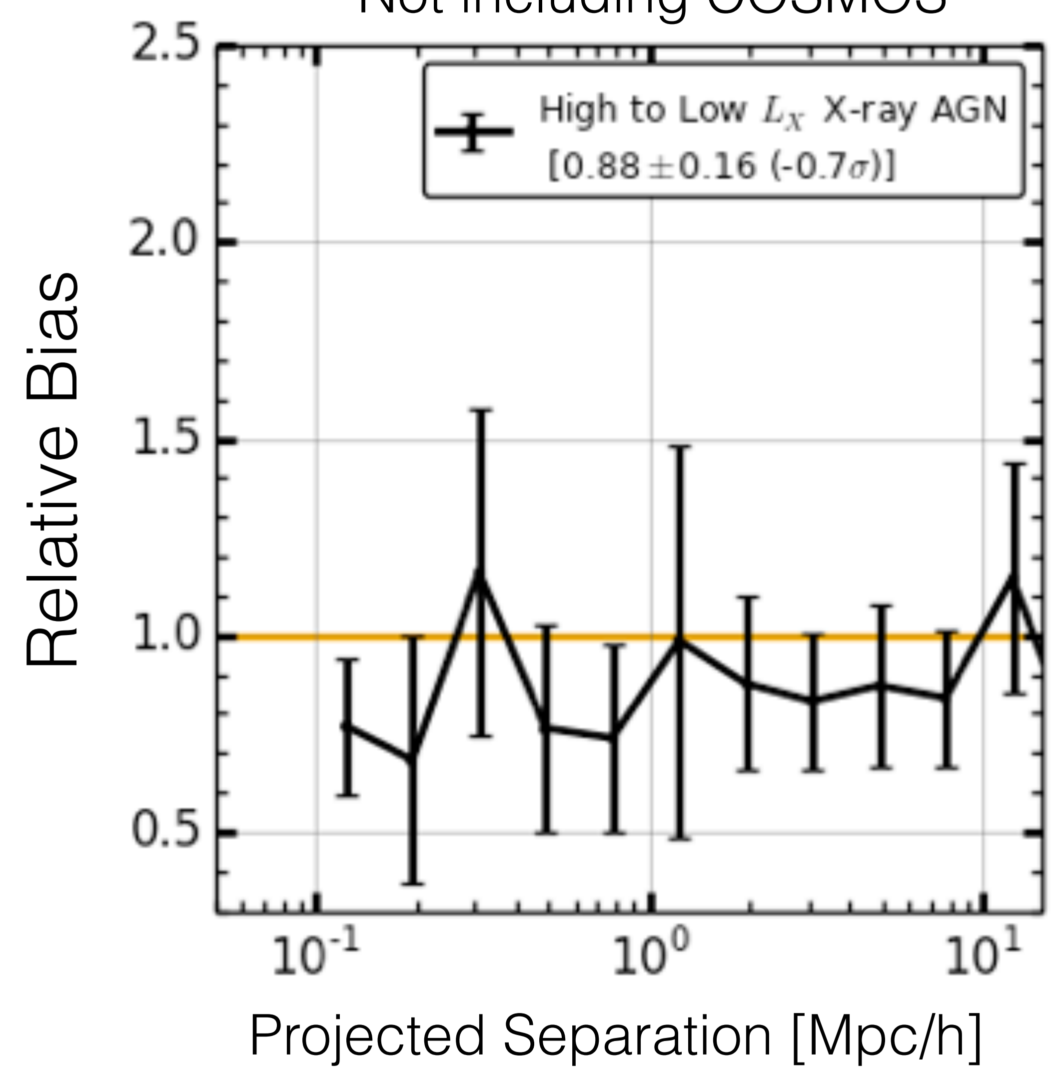
- Use the cross-correlation with galaxies to measure the auto correlation function of AGN
- We find that the bias parameter: IR < X-ray < radio
  - Similar to Hickox+09
- Can we explain these differences?



No Luminosity Dependance

- We find no significant (<1σ) bias dependance on X-ray luminosity.
- The IR-AGN that are X-ray detected are generally more luminous but no differences within X-ray population.
- Luminosity depends on both the accretion rate and mass of the black hole.

Not including COSMOS



Specific Accretion Rate

- Eddington Ratio: Bolometric luminosity relative to the Eddington limit:

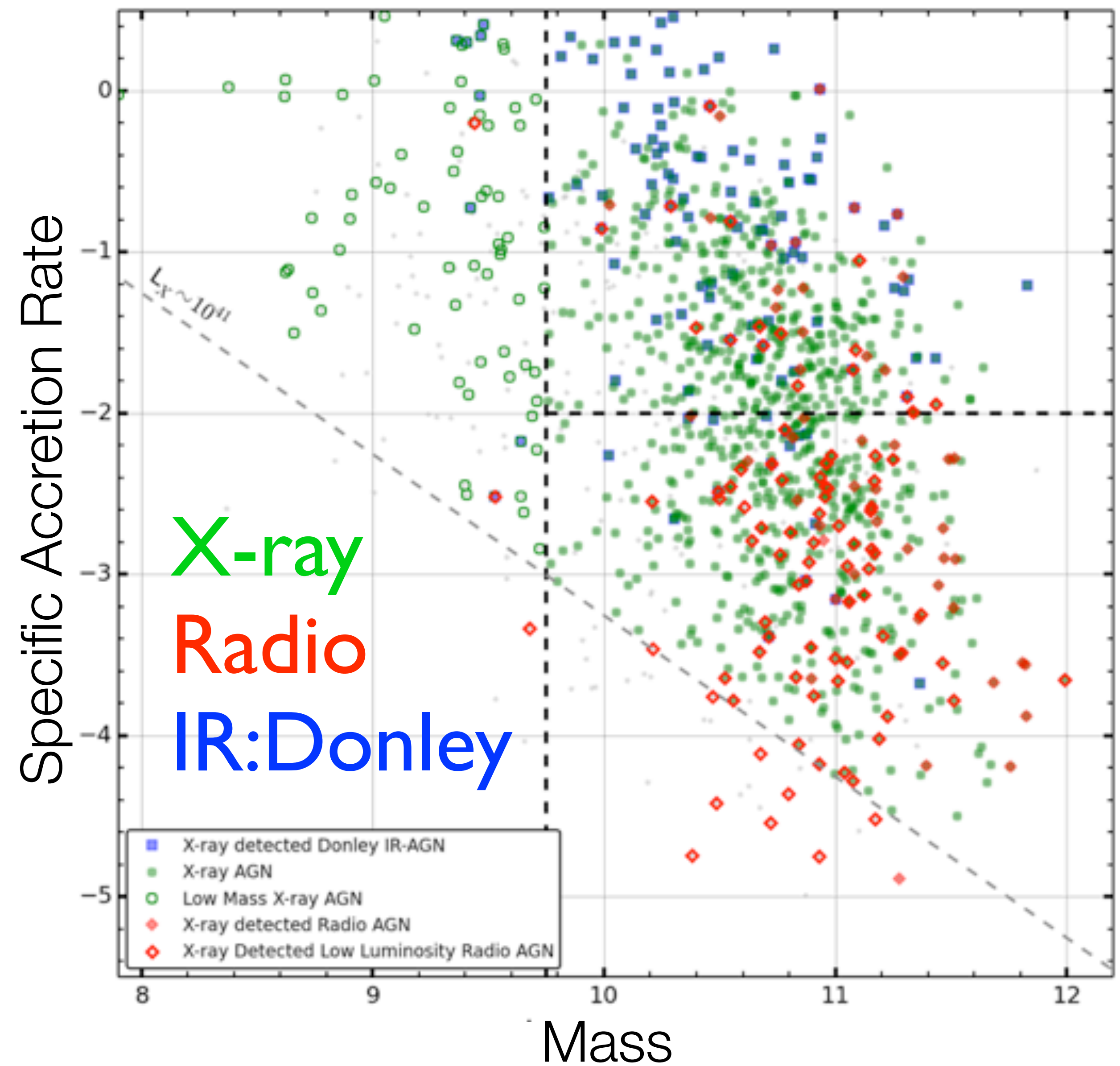
$$\eta = \frac{L_{acc}}{L_{edd}} = \frac{\sigma_T L_{acc}}{4\pi c m_p G M_{BH}}$$

- Specific Accretion Rate: Assumes a relationship between the black hole mass and mass of the galaxy

$$\lambda = \frac{L_{bol}}{L_{Edd}} = \frac{L_{bol}}{1.3 \times 10^{38} \text{ erg s}^{-1} \times 0.002 \frac{\mathcal{M}_*}{\mathcal{M}_\odot}}$$

Specific Accretion Rate

- Specific accretion rate ~ $L_{bolometric}$ / $M_{stellar}$
  - Proportional to Eddington Ratio
- X-ray samples identify a large range of specific accretion rates
- IR-AGN samples identify higher accretion rate AGN
- Radio samples identify lower specific accretion rate AGN



(Mendez+13)

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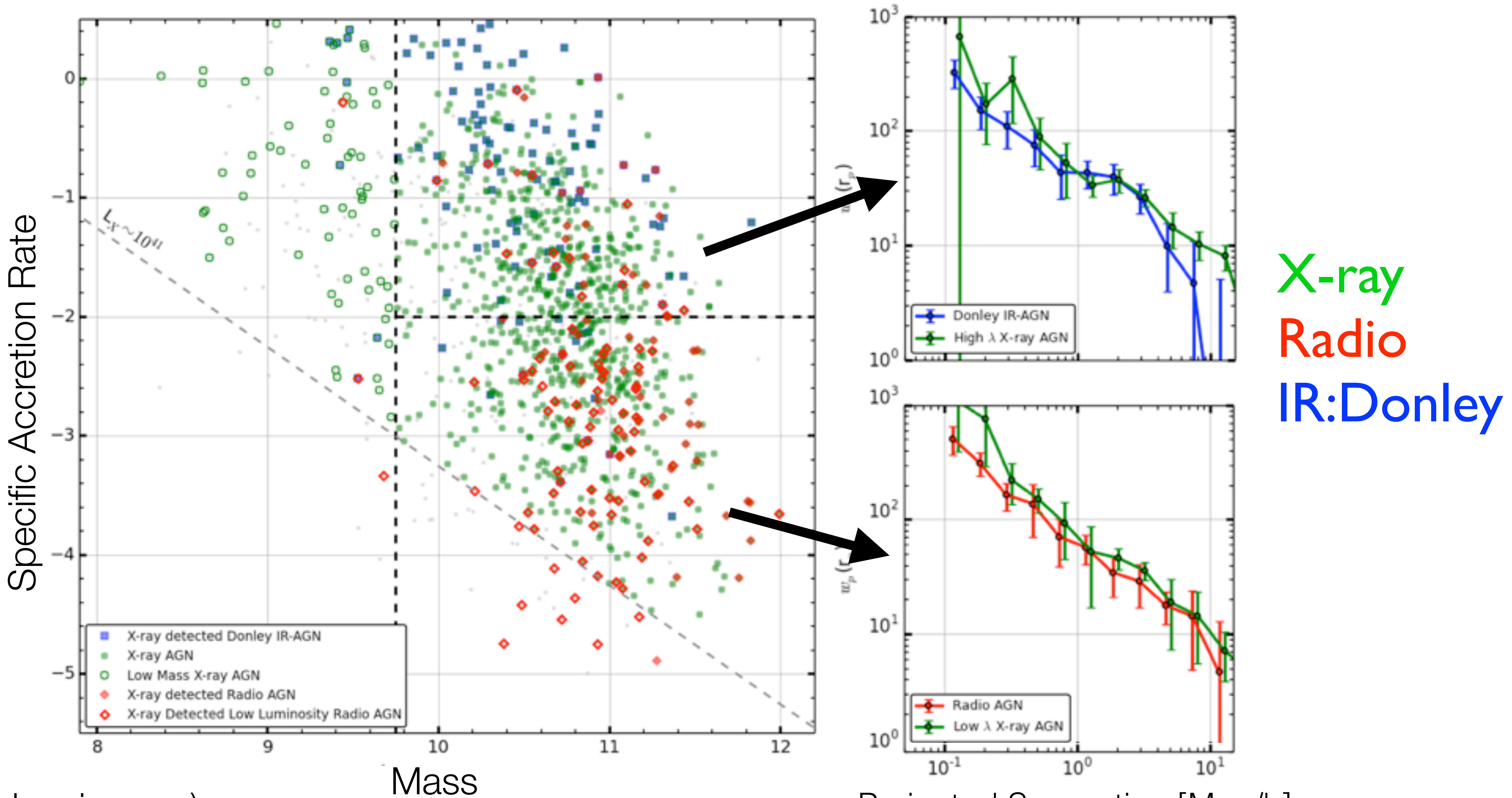
Specific Accretion Rate

- Clustering amplitude differences partially due to specific accretion rate differences.

Not including COSMOS



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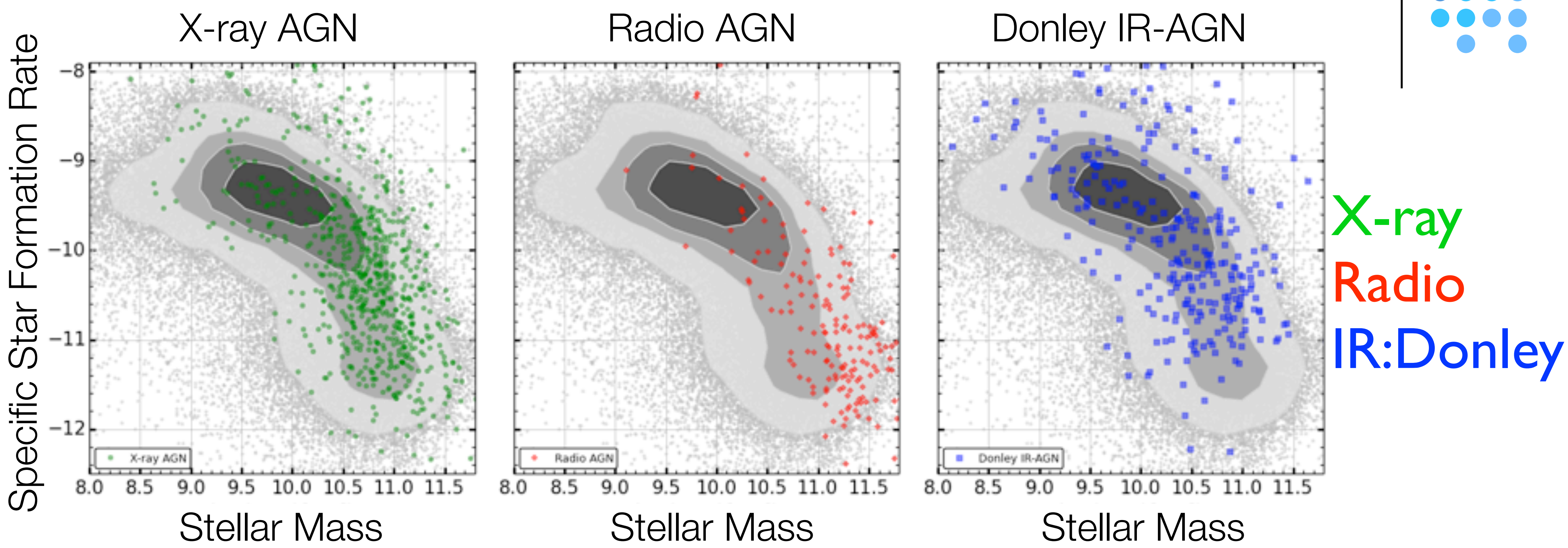
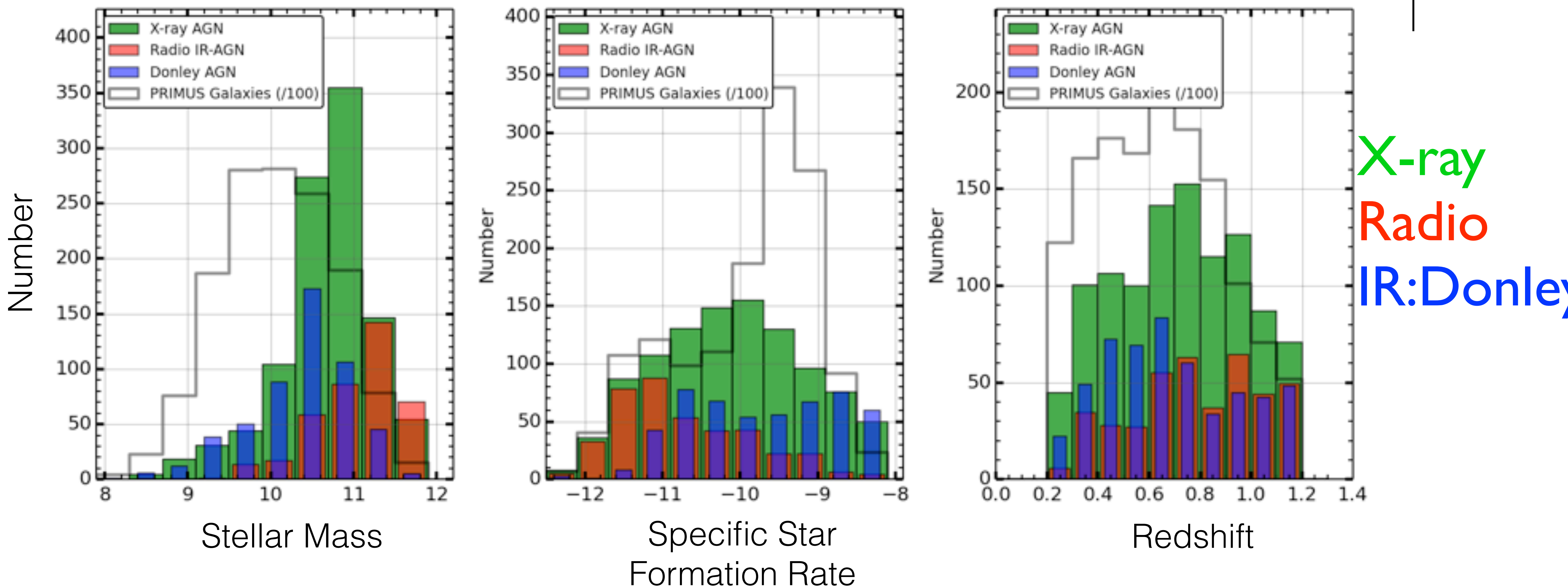
Host Properties



- AGN selected at different wavelength reside in different kinds of host galaxies
  - X-ray AGN are widely found in both SF and quiescent galaxies
  - More radio AGN in quiescent galaxies
  - Slightly more Donley IR-AGN in star forming galaxies
- Strong dependance on stellar mass -- more AGN are detected with higher stellar mass

(Mendez+13)

Matched Galaxy Samples



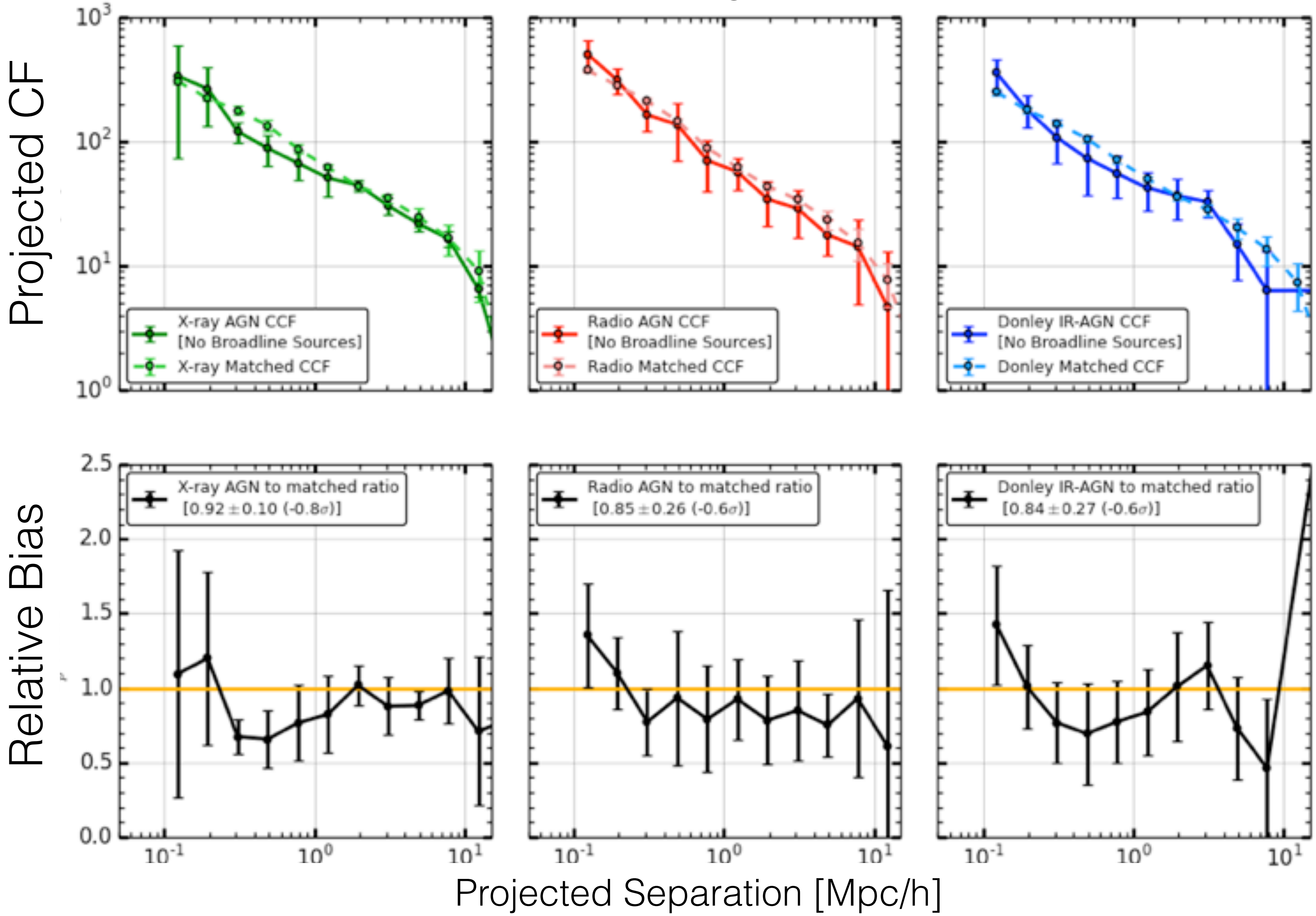
- Compare X-ray, radio and IR AGN against matched galaxy control samples.
  - These samples have the same stellar mass, SFR, and redshift distributions as each of the X-ray, radio, and IR AGN samples

(Mendez+in prep)

Matched Galaxy Samples

- No significant differences (<0.8σ) compared to matched galaxy control samples.

Not including COSMOS



X-ray
Radio
IR:Donley

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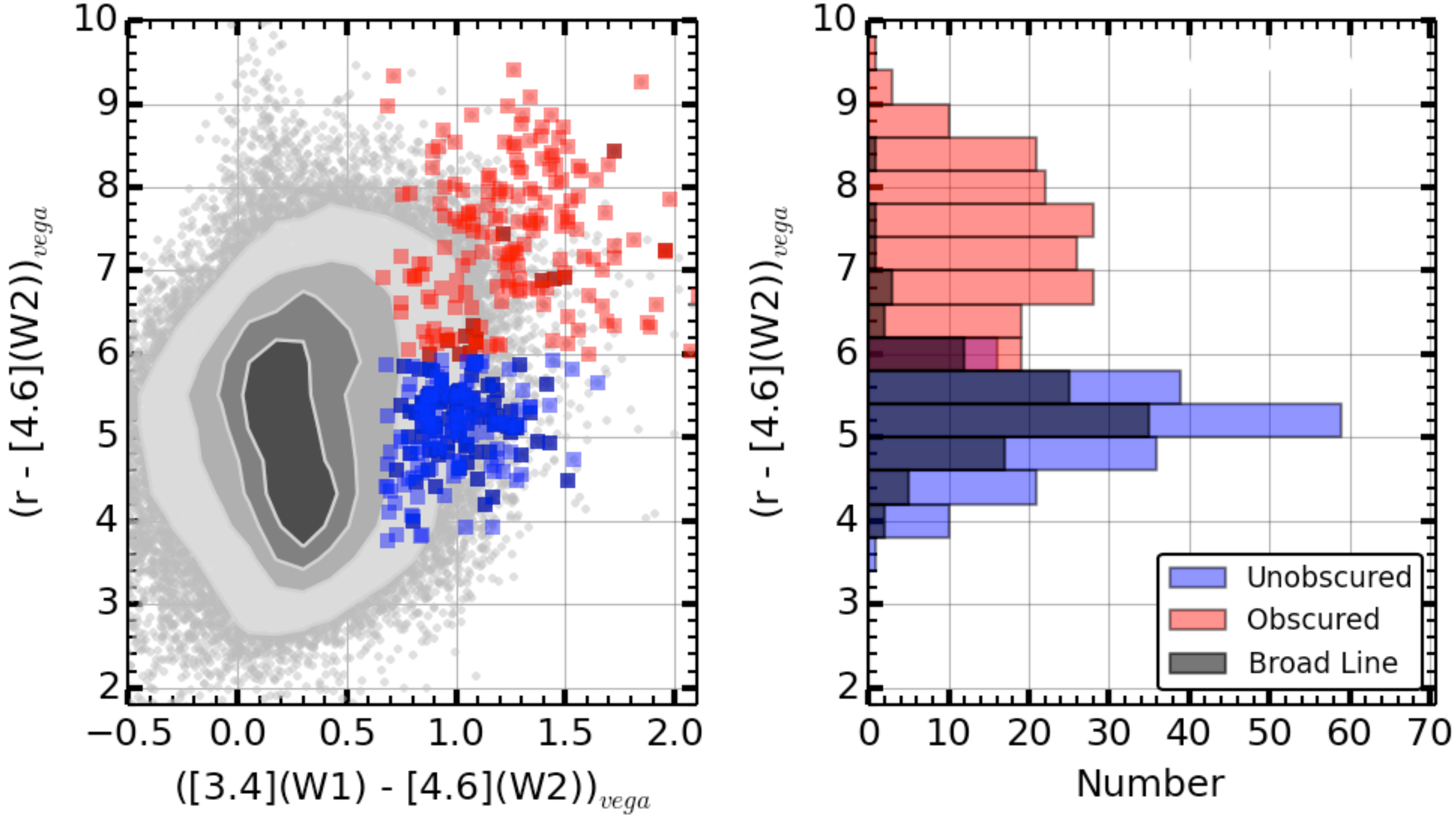
Dependance on Obscuration

- Hickox+11: Obscured are at least as clustered as unobscured
- Yan+12: Obscuration can be traced by optical-WISE color
- Donoso+13: Claim *Angular* clustering depends on obscuration
- DiPompeo+14: More robust *Angular* clustering measurement
  - Both: Obscured IR-AGN are more clustered than unobscured IR-AGN



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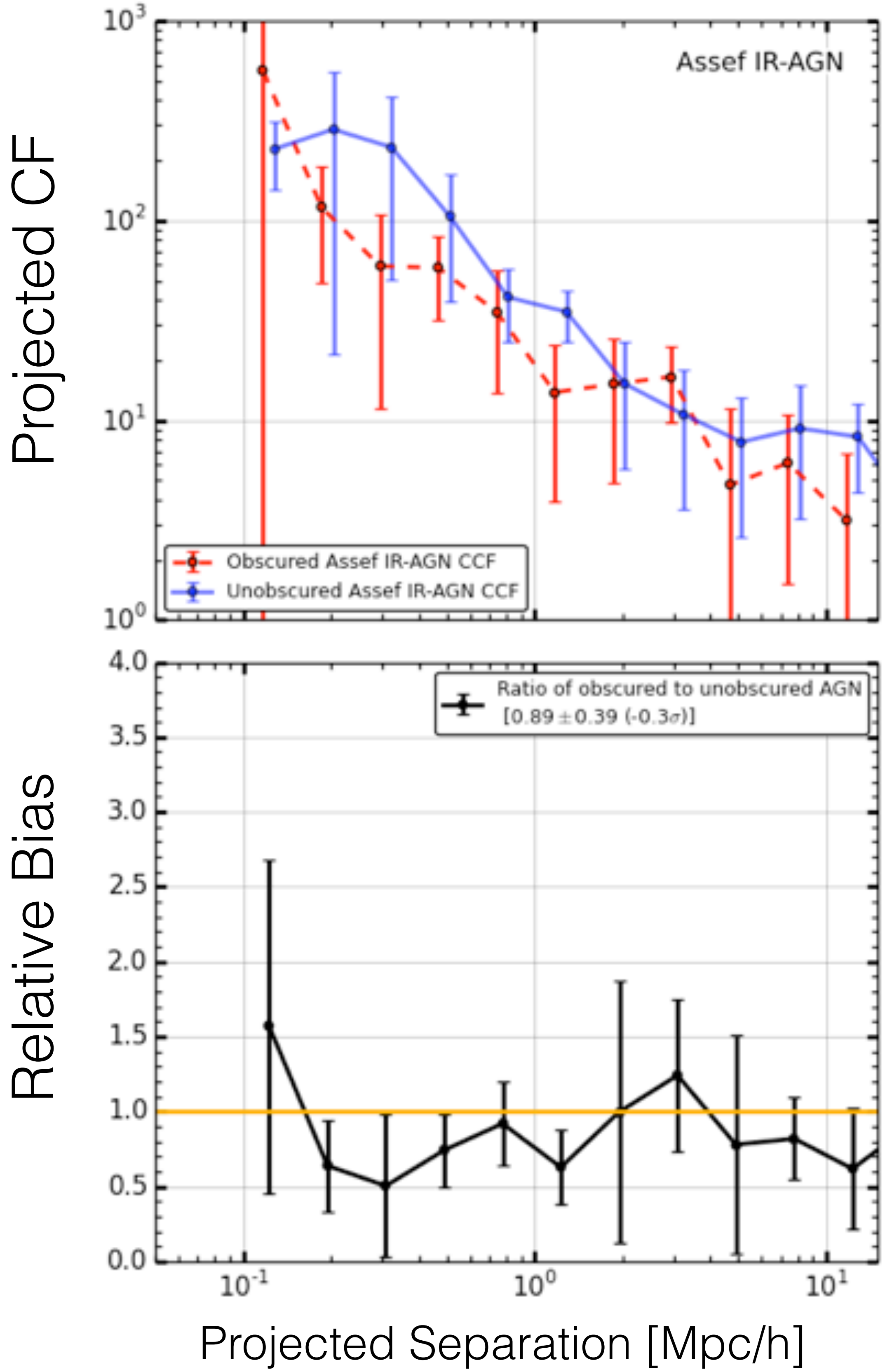
No Dependence on Obscuration

- We find <0.3σ difference in the relative bias of obscured to unobscured IR-AGN (selected using Assef+13) .
  - This accounts for the variation in the redshift distributions between the two samples.
  - No significant differences with Donley+12, Stern+12, or Mateos+13 selections.
  - No significant differences using IRAC vs WISE.



Take home points

- Very large and deep spectroscopic multi-wavelength sample
  - Covers multiple fields to constrain cosmic variance errors
  - Allows comparison of luminosity, specific accretion rates, and other parameters.

- No significant dependance of clustering on luminosity.

- Differences in clustering amplitude for X-ray, radio and IR can be explained by differences in specific accretion rates.

- No significant differences with respect to matched galaxy control samples
  - Accounts for differences in stellar mass, sSFR, and redshift of the AGN selection technique

- No significant differences in obscured or unobscured IR-AGN clustering amplitude

- **Suggests AGN are found in all kinds of galaxies, and that any differences seen are really due to differences in the host galaxies**