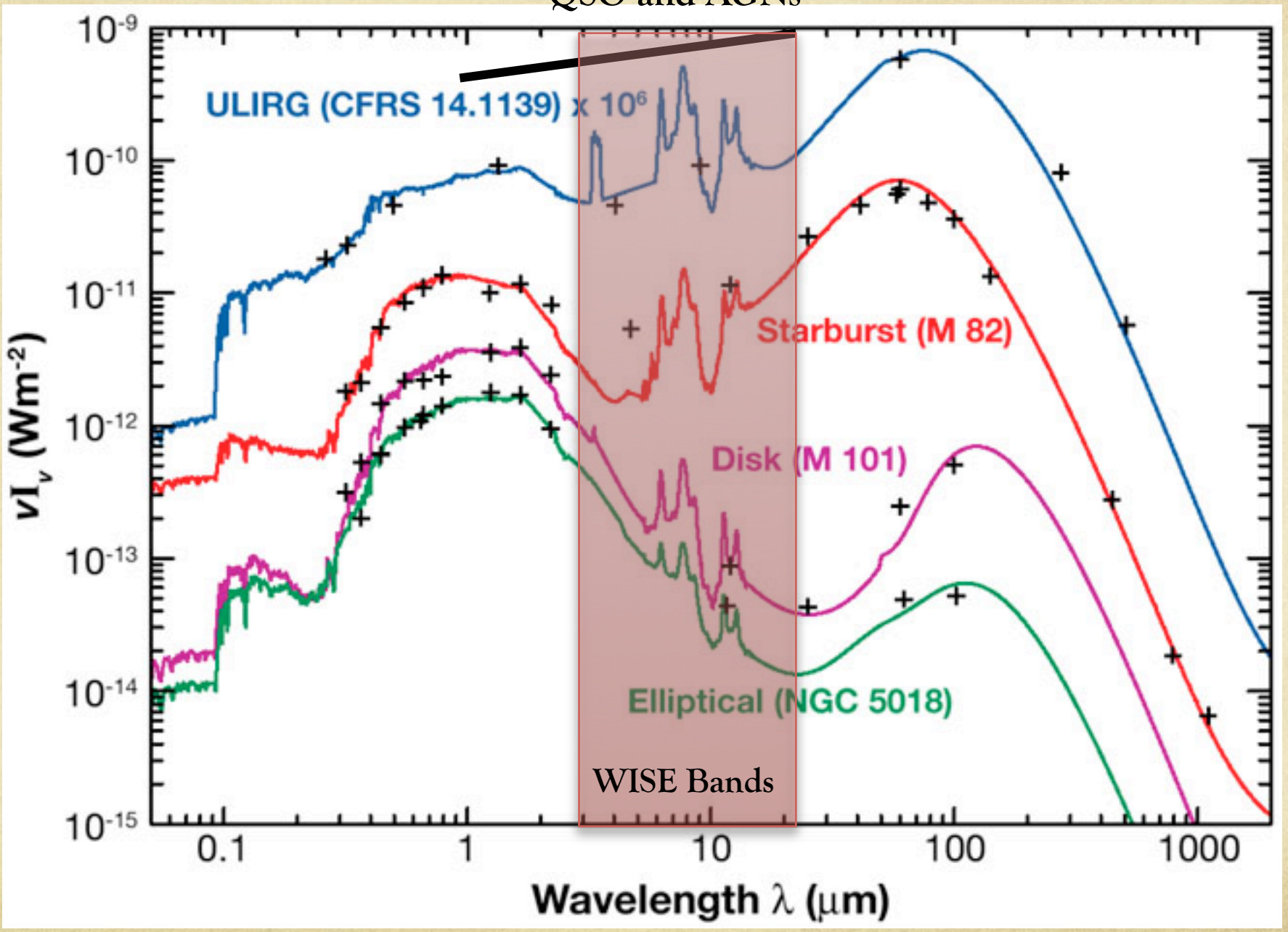
Large scale clustering of WISE AGNs

Lin Yan (WISE archive scientist, IPAC/Caltech)

QSO and AGNs


ULIRG (CFRS 14.1139) x 10⁶
Starburst (M 82)
Disk (M 101)
Elliptical (NGC 5018)
WISE Bands
νI_ν (Wm⁻²)
Wavelength λ (μm)
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁻¹⁴
10⁻¹⁵
0.1
1
10
100
1000

One of many great things WISE can do:

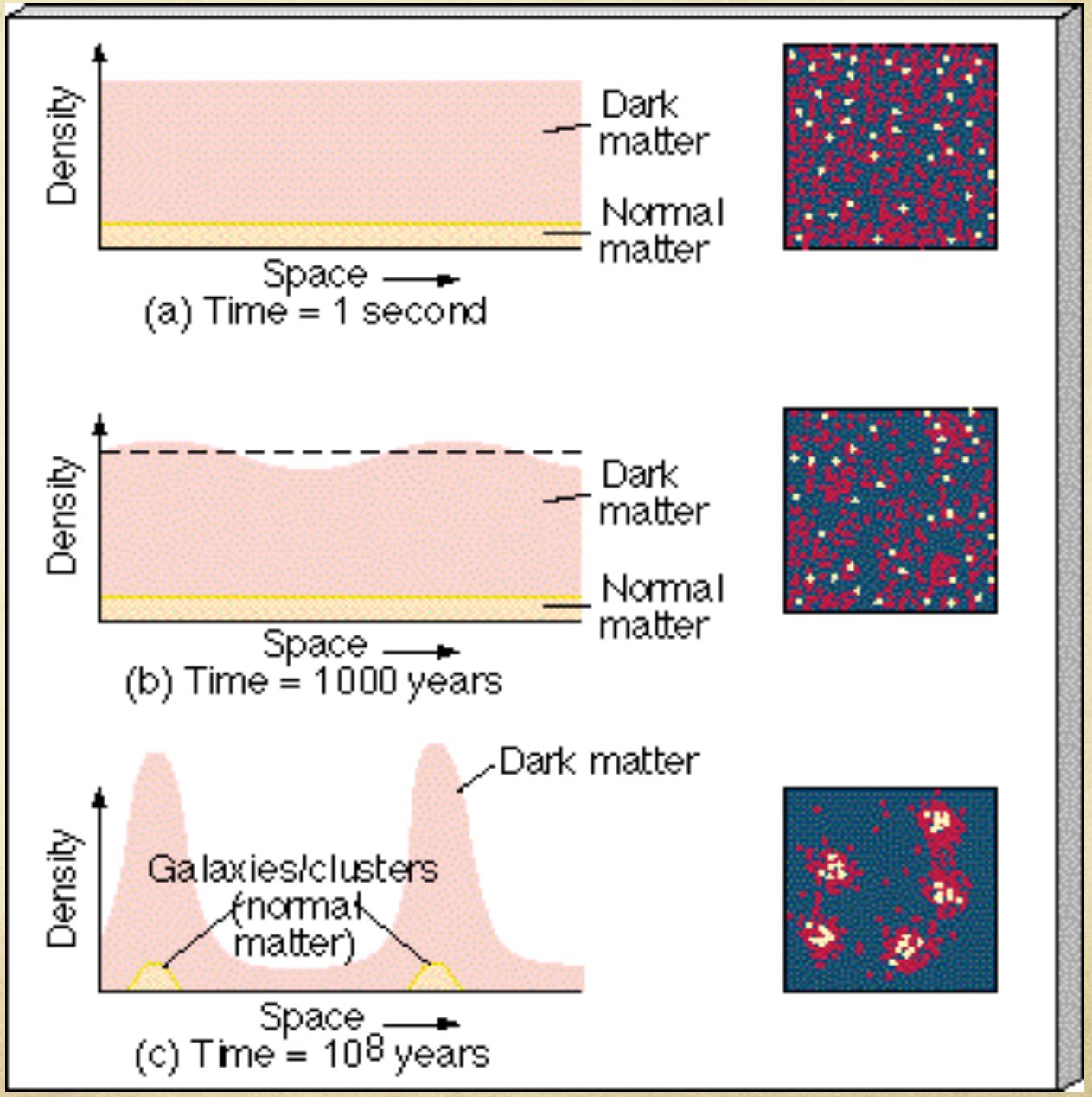
--- selection of **AGNs**, particularly infrared luminous, dust **obscured AGNs**.

1) Large scale clustering of WISE selected AGNs: obscured and unobscured --- *What did we learn about their dark matter halos?*

2) Far-IR spectroscopy of WISE IR bright SDSS QSOs --- *what we learnt about their warm neutral ISM?*

Donoso (Argentina), Yan (IPAC), Stern (JPL), Assef(Chile) ApJ 2014. Y.H. Zhao (IPAC & China) & Yan (IPAC) 2015, in prep

Galaxies form at the sites of dark matter density peaks



Large scale structures → M(halo) → constraint galaxy/QSO formation models

$\xi_{obj}(r)$ -- spatial correlation function – describes the probability of finding two objects within the same volume

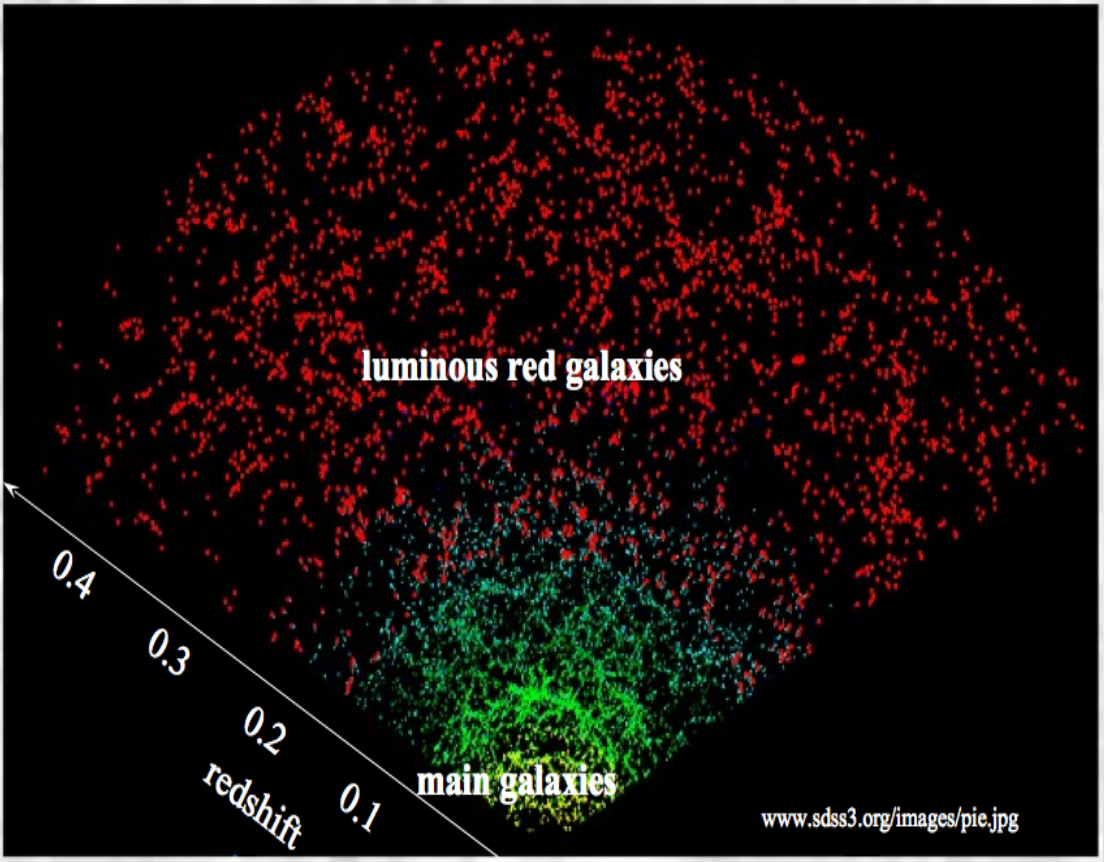


Image credit: Sloan Digital Sky Survey

$$\xi_{obj}(r)=b_{obj}^{2}\xi_{DM}(r)$$

Large scale bias b → M(dark halo)

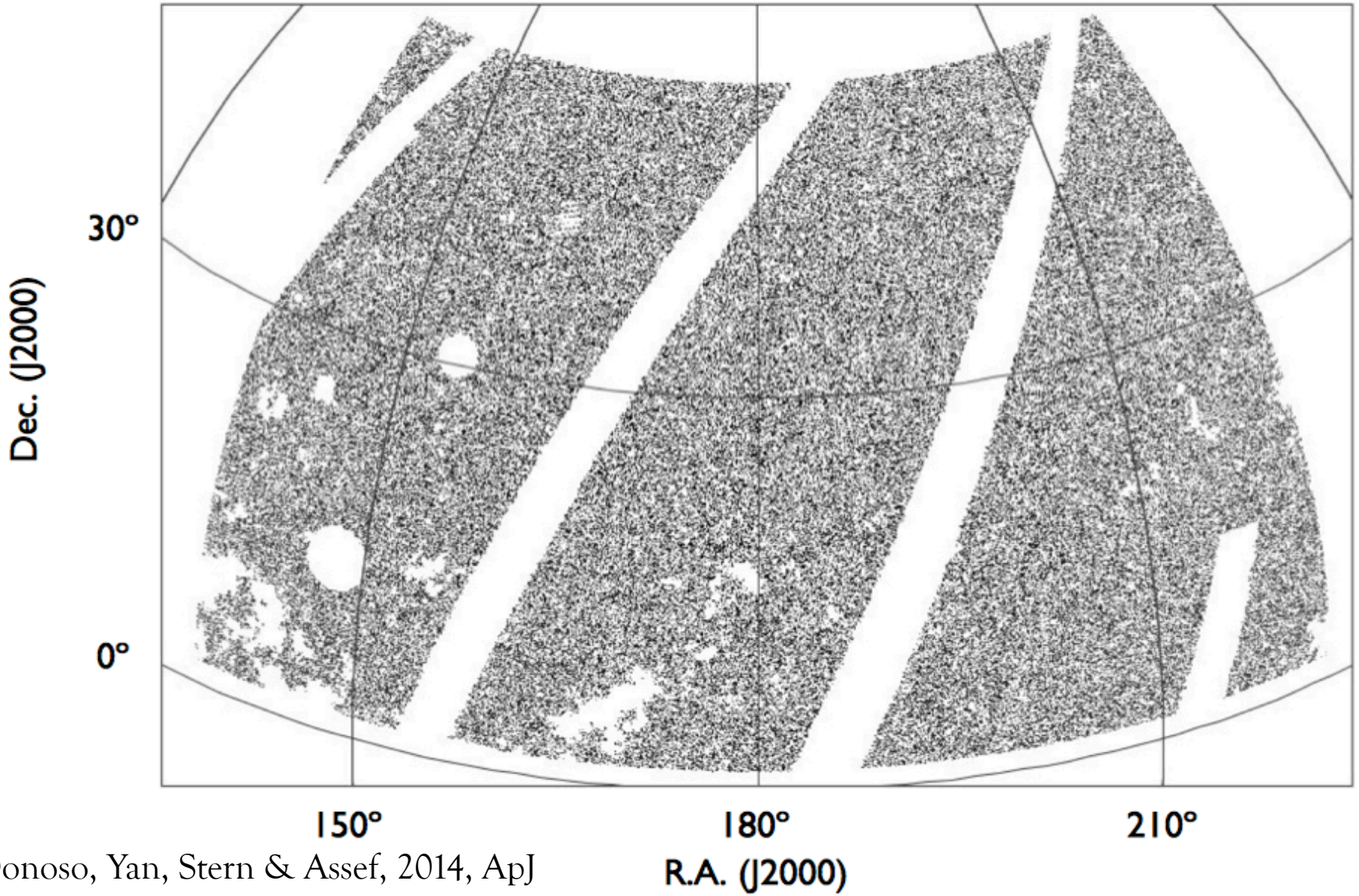
What do we know about AGN clustering (SDSS, 2dF etc)?

- Unobscured QSO shows that M(halo) ~ $3x10^{12}$, constant over z~0 – 5. Many papers from SDSS and 2dF

- Poorly known: clustering property of obscured AGN. A few conflicting results from small samples from Hickox et al. 2011, Wylezalek 2013, Gilli 2009

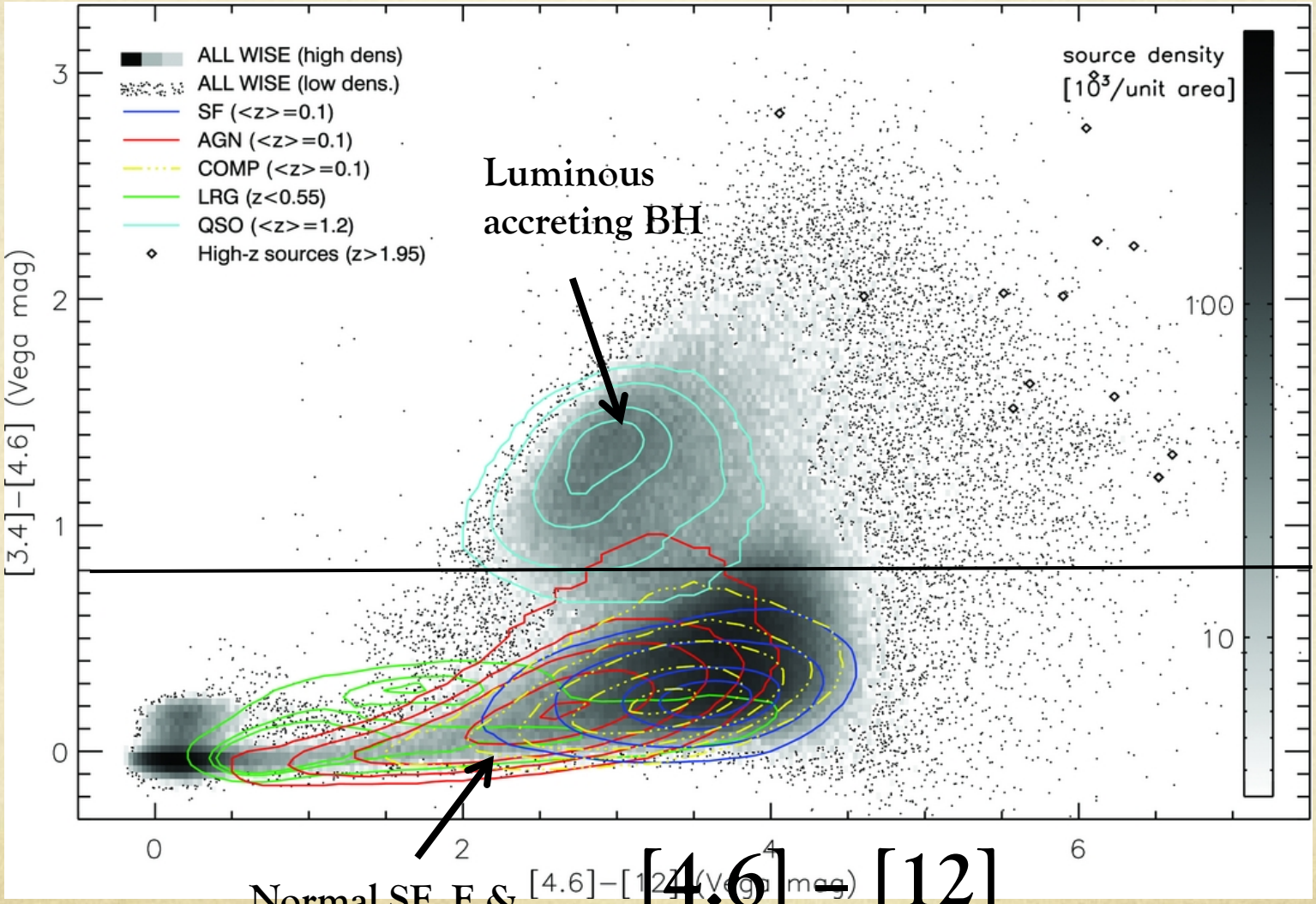
Angular Clustering of WISE-Selected AGN (in SDSS)

- angular clustering of 176,467 WISE-selected AGN over 3363 deg^2



Donoso, Yan, Stern & Assef, 2014, ApJ

Our AGN selection criteria: (1) [3.4] - [4.6]> 0.8, (2) [4.6]<15.05; (3) r – [4.6]>6 (red); r – [4.6]<6 (blue)



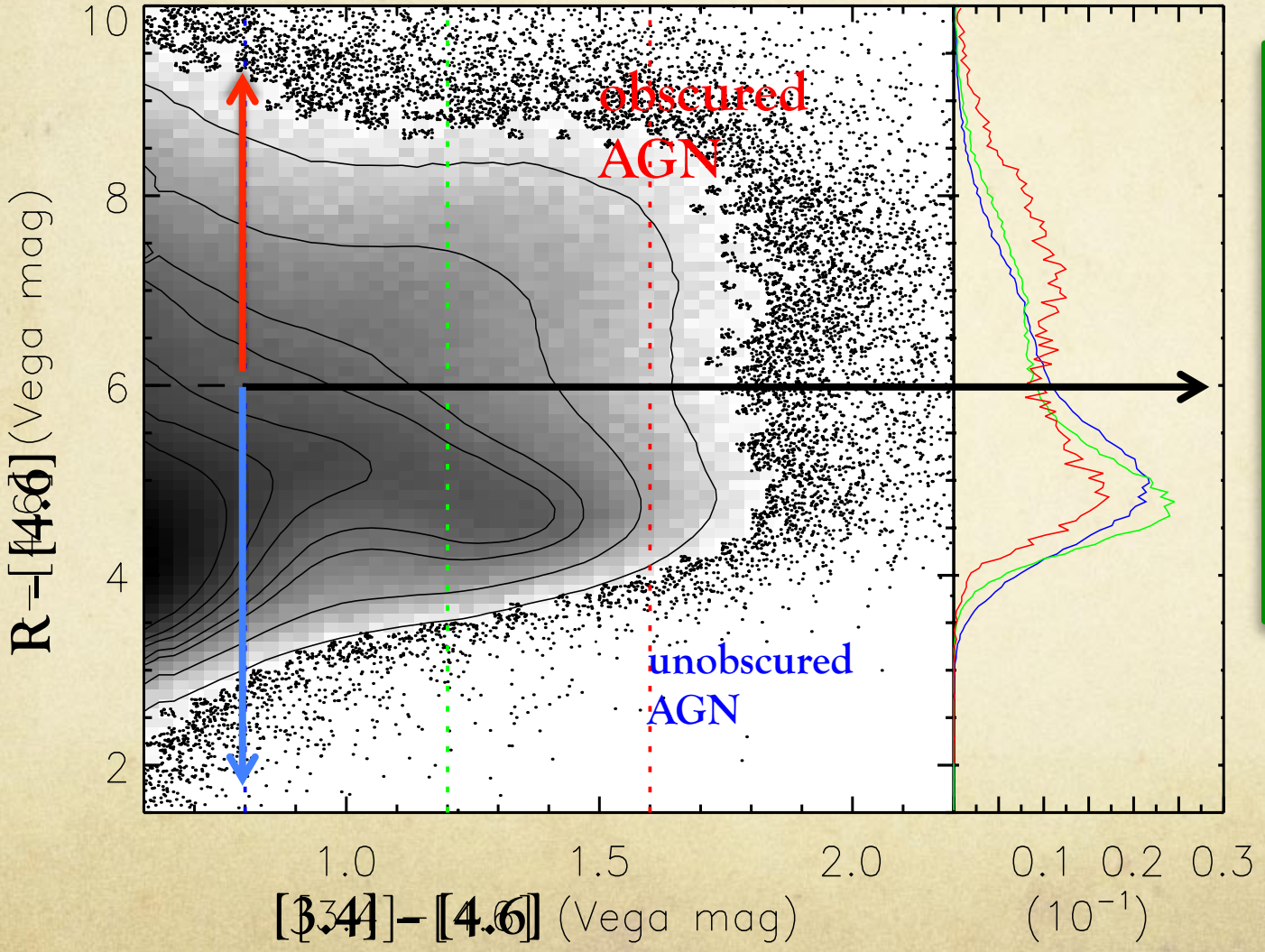
[3.4] – [4.6]

[4.6] – [12]

Yan et al. 2013 ApJ

Angular Clustering of WISE-selected AGN (in SDSS)

- separate type-1 AGN (unobscured) from type-2 AGN (obscured) using r-W2 color
- note more contamination of red sources into blue selection than vice-versa



Selection Criteria:

- [3.4]-[4.6]>0.8
- [4.6] < 15.05
- =(SNR>10)
- r-[4.6]>6

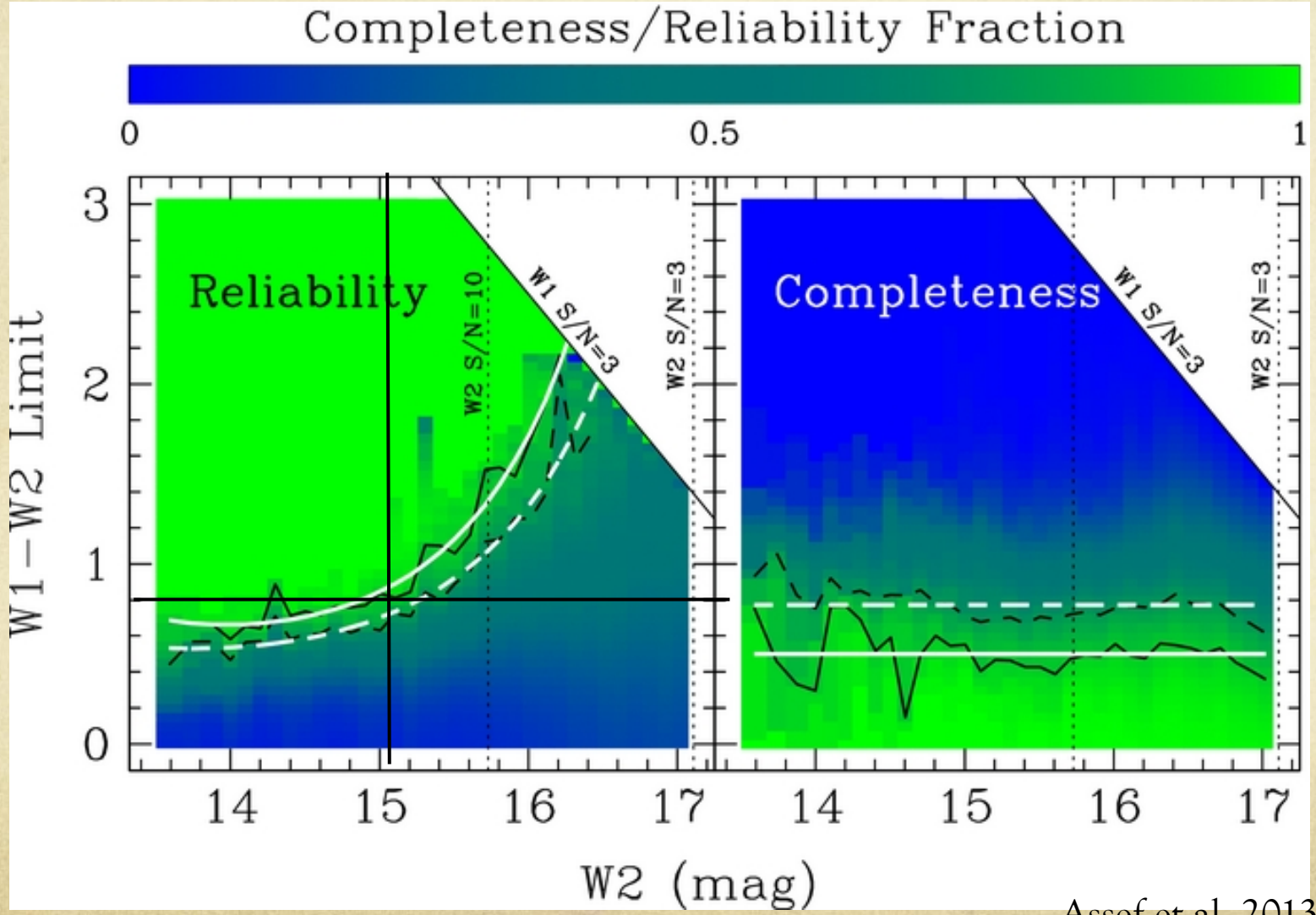
===>

60,000 obscured

11,600 unobscured

Donoso, Yan, Stern & Assef, 2014, ApJ,

Mid-IR color selection for AGN: How complete and reliable?



[3.4]-[4.6]>0.8
[4.6]<15.05

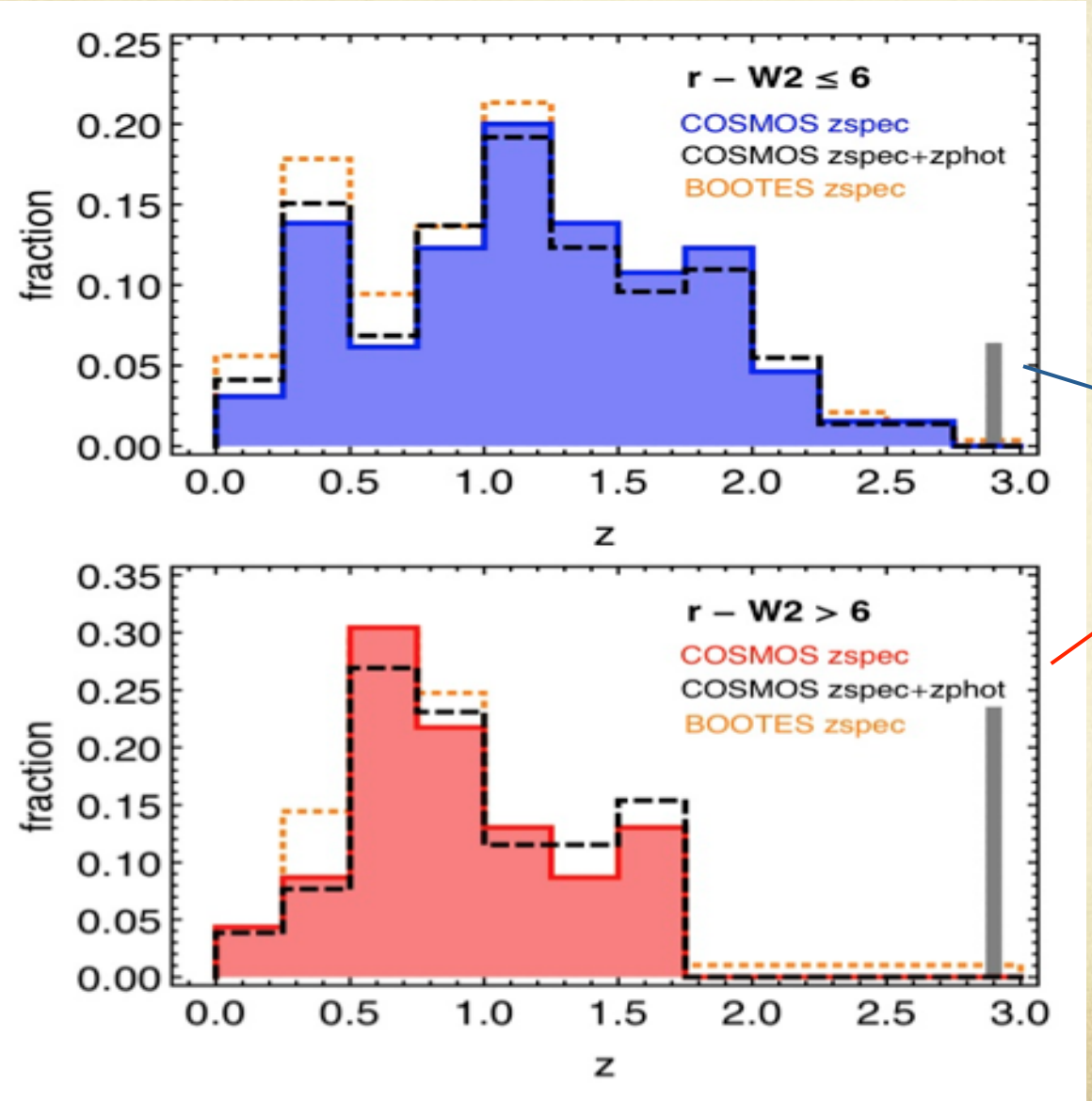
➔

95% reliability
80% completeness

Assef et al. 2013, ApJ

Angular Clustering of WISE-selected AGN (in SDSS)

- Redshift distribution of unobscured (blue) and obscured (red) WISE-selected AGN

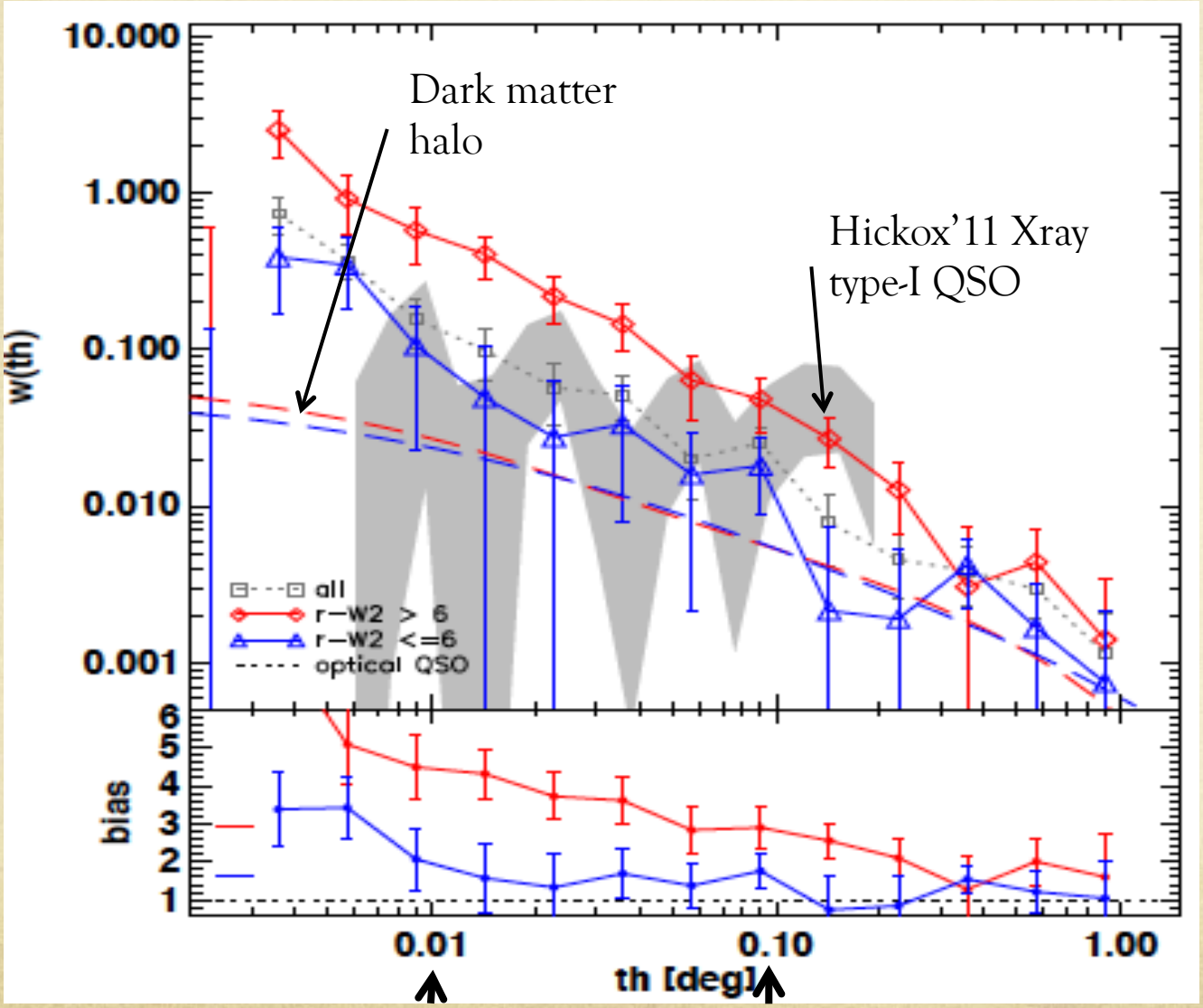


Use spec-z and photo-z from COSMOS and Bootes

Uncertainty in redshift distribution ➔ most uncertainty in bias at 20% level

Angular Clustering of WISE-selected AGN (in SDSS)

- angular correlation function $w(\theta)$ of blue & red WISE-selected AGN



Blue AGN:

- b = 1.6±0.6
- log(M)=12.4+0.57-1.0
- <z>=0.9

Red AGN:

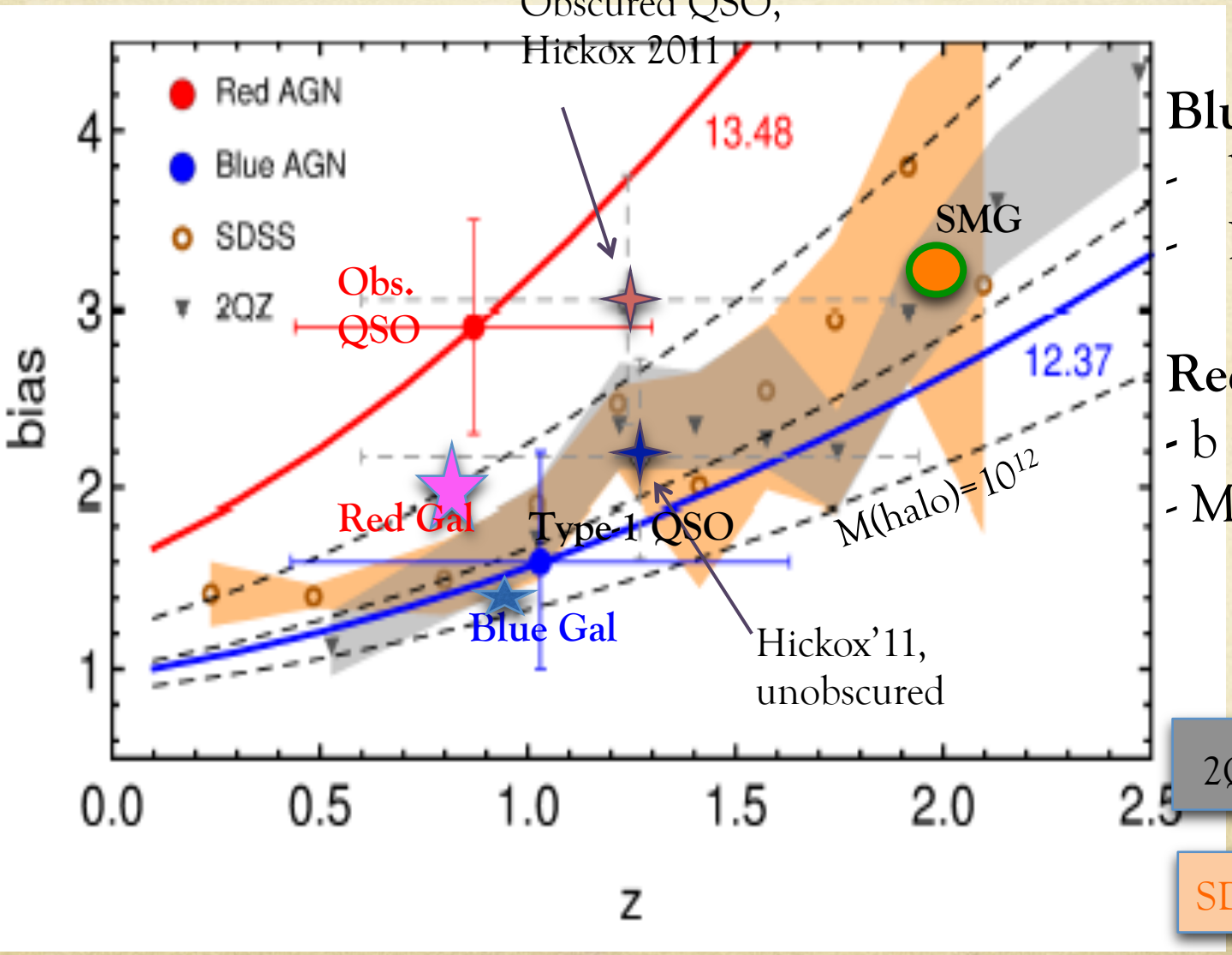
- b = 2.9 ± 0.6
- log(M)~13.5+0.54-0.3
- <z>=1.1

Donoso, Yan,
Stern & Assef, 2014, ApJ,

Myer et al'07, SDSS QSO
Hickox'11, type-1 QSO

Results: Bias vs. z with constant Halo masses

- Red AGN seem to reside in more massive haloes than that of blue AGN



Blue AGN:

- b = 1.6 ± 0.6
- M ~ $10^{12.4}$ M(sun)

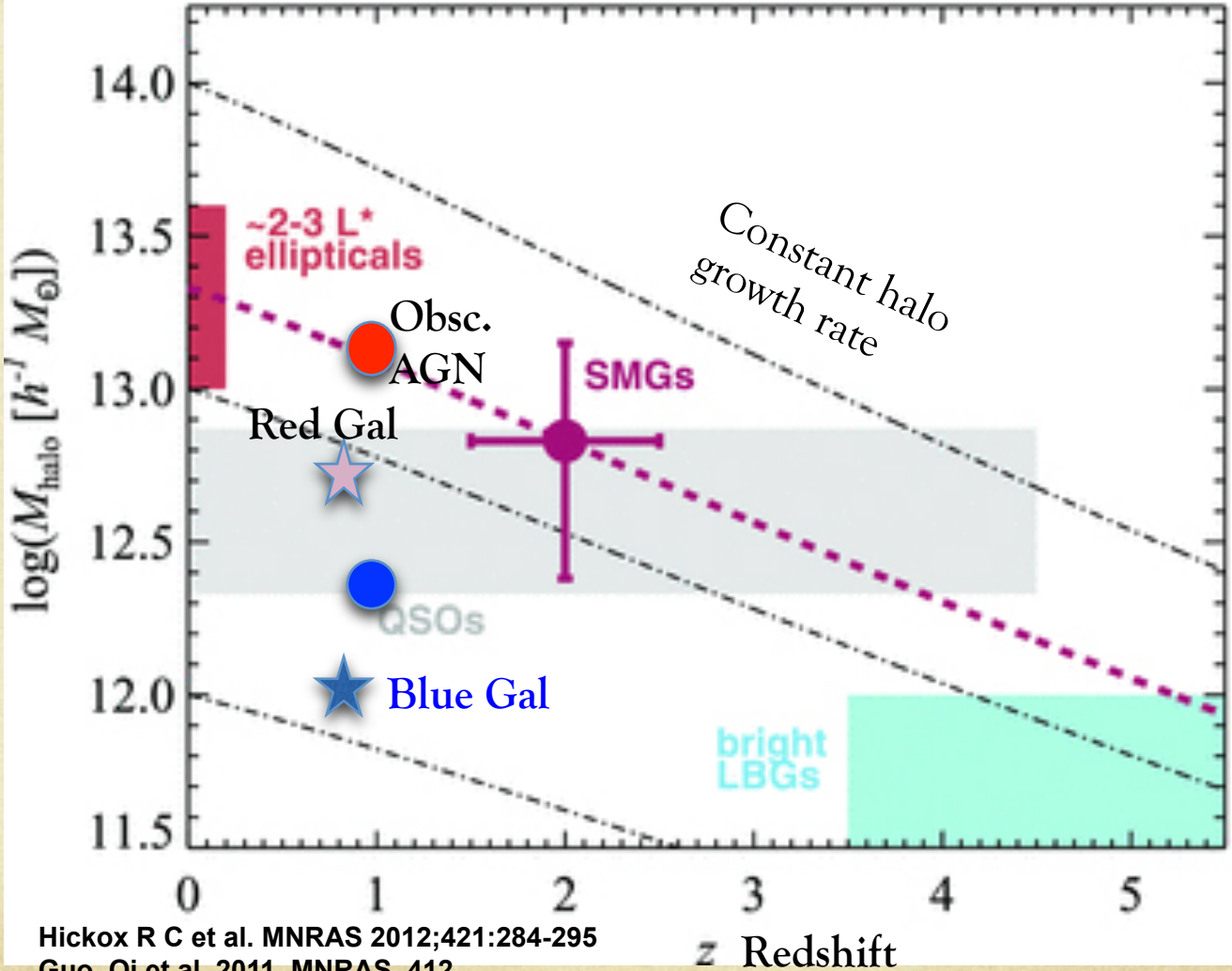
Red AGN:

- b = 2.9 ± 0.6
- M ~ $10^{13.5}$ M(sun)

2QZ QSO

SDSS QSO

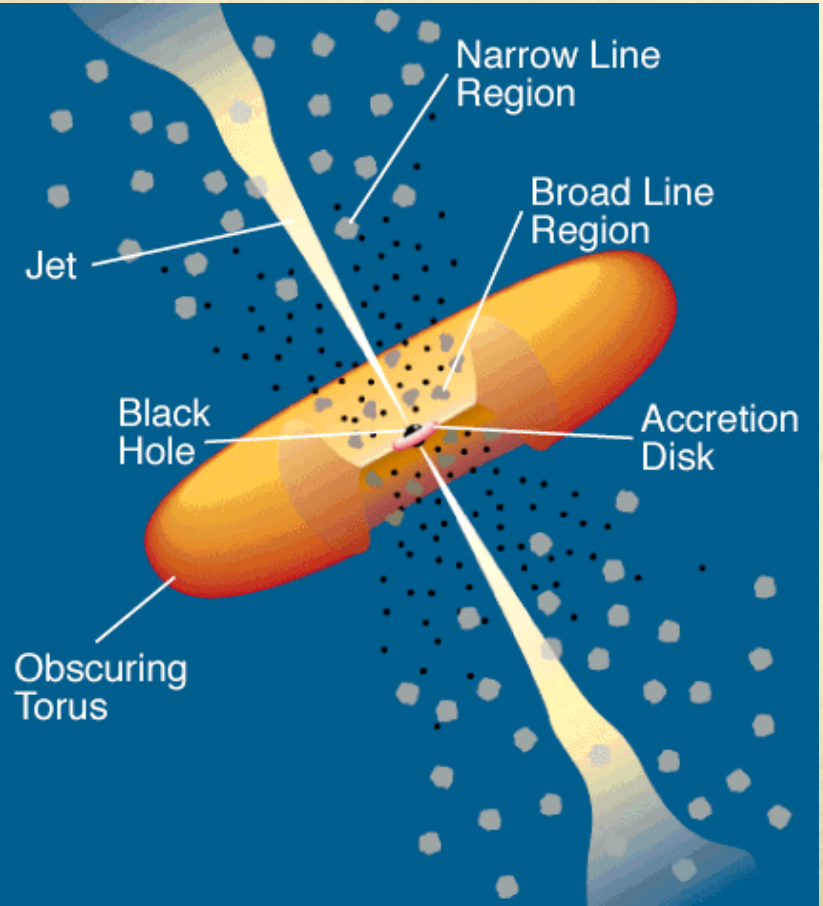
Broad schematic for the evolution of M(halo) vs. z, showing the approximate halo masses corresponding to likely progenitors and descendants. Lines indicate the median growth rates of haloes with redshift (Fakhouri et al. 2010).



Hickox R C et al. MNRAS 2012;421:284-295
Guo, Qi et al. 2011, MNRAS, 412
Donoso, Yan, stern, Assef, 2013, ApJ, submitted
Coil et al. 2008, ApJ, DEEP2 survey

Summary

- clustering analysis of WISE-selected AGN sample shows obscured quasars to reside in different (more massive) dark matter haloes than unobscured AGN ➡ hard to reconcile with the traditional orientation- driven, or torus "unified model of AGN"



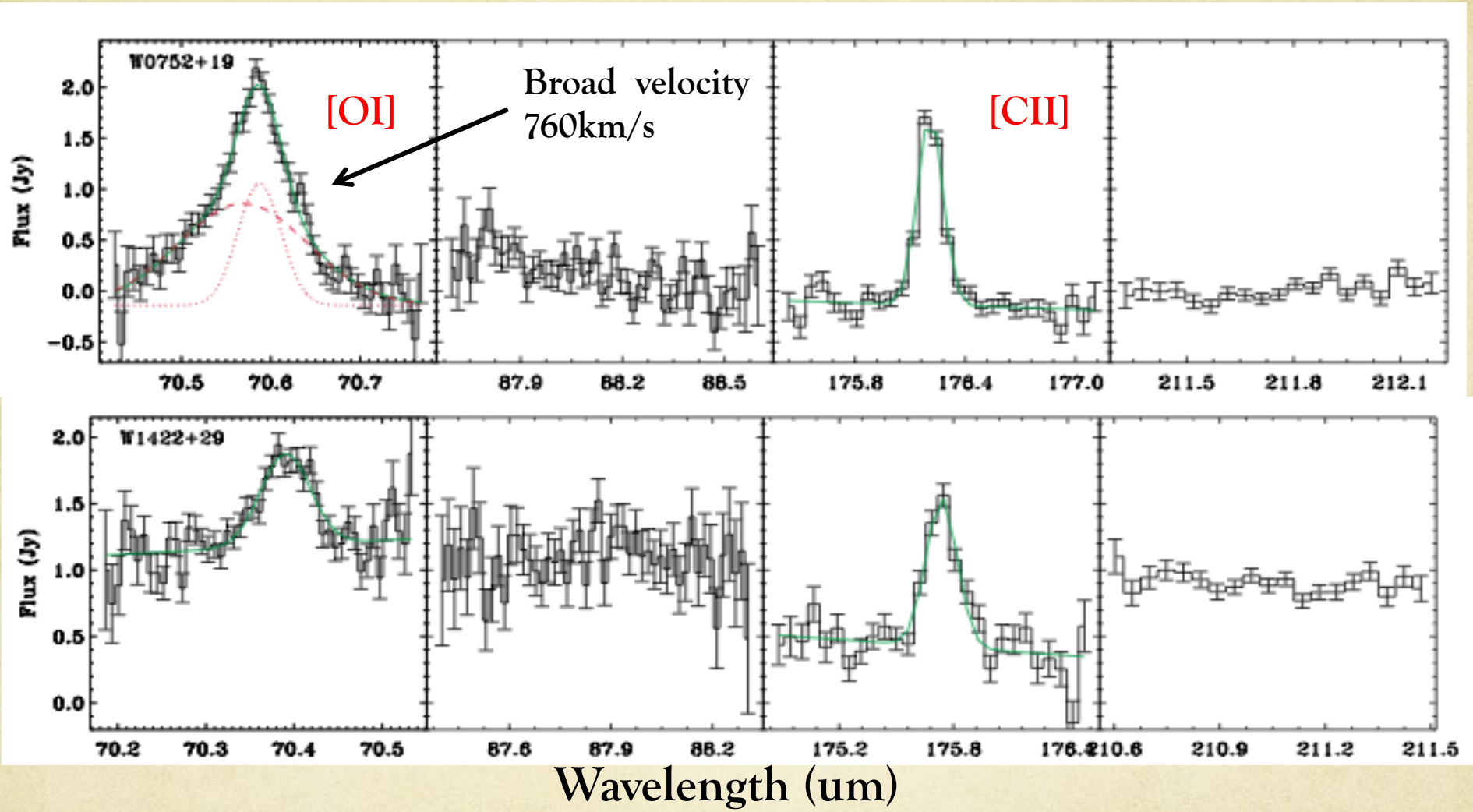
Detecting [OI]63um and [CII]158um emission lines in WISE QSOs

--- Properties of their warm neutral gas

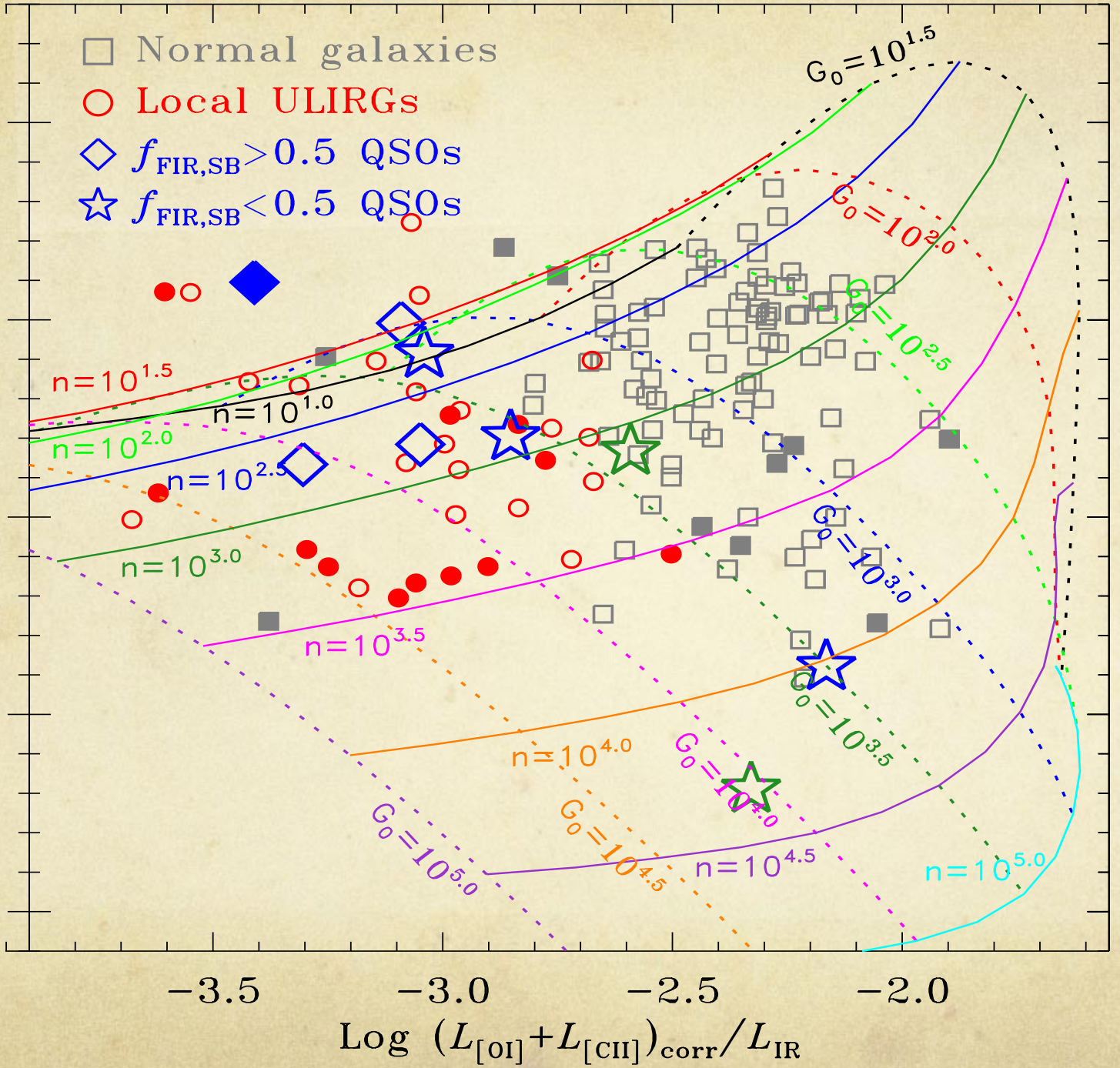
Basic program: Herschel PACS observations of 9 SDSS QSOs at z~0.1-0.3 with WISE 24um > 100mJy.

[OI]63um and [CII]158um lines are the dominant coolant for gas with T ~ a few 100K.

Results:



[CII] collisional excitation critical density ~ 3000 cm^-3,
[OI] critical density ~ 5x10^5 /cm^3



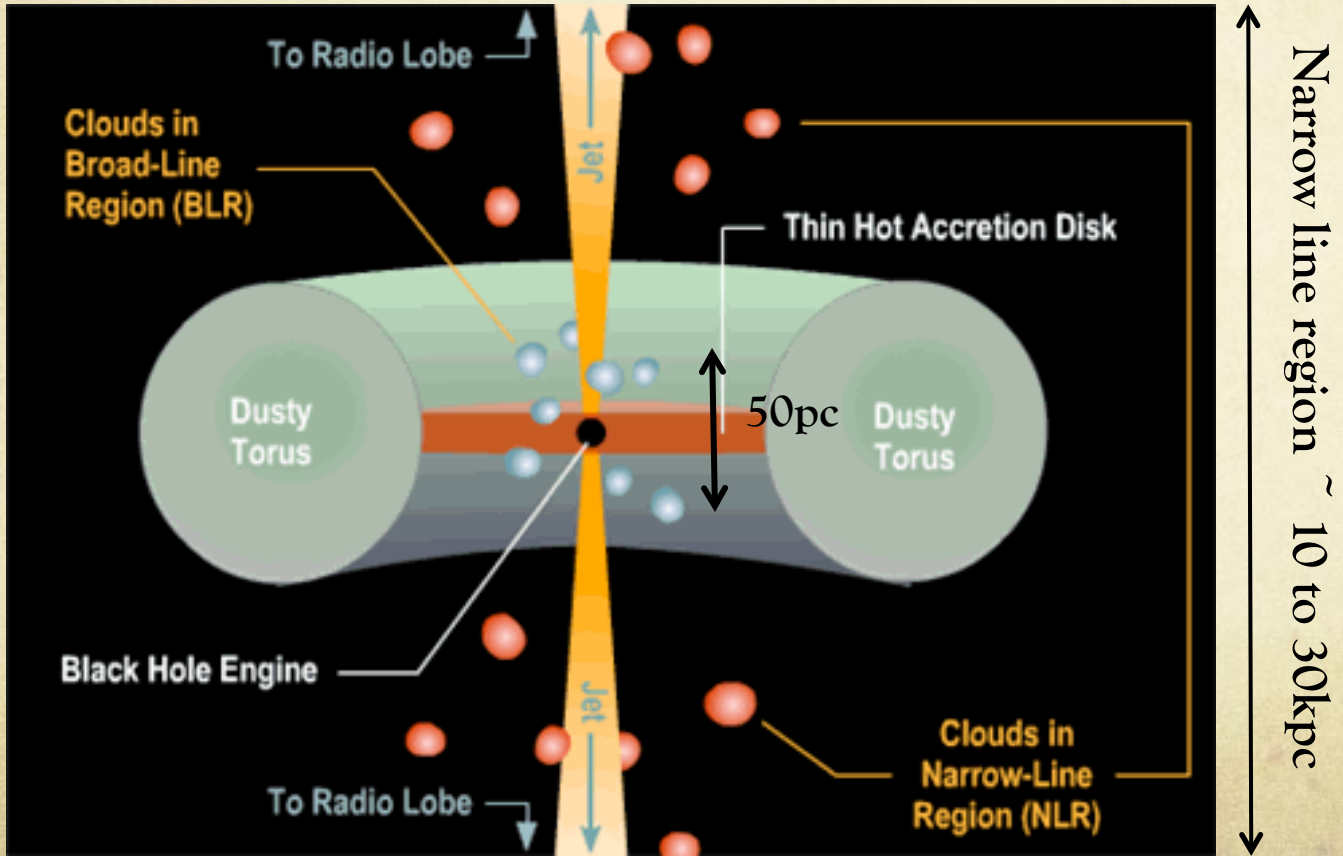
Moderate density:
n ~ 50 – 1000
(n = 10000),
Lower than ULIRGs

Radiation Field G0:

1000 – 10000
Similar to ULIRGs

Questions:

- Where is this neutral ISM?
- Are they outflow? Disk rotation? Shock?

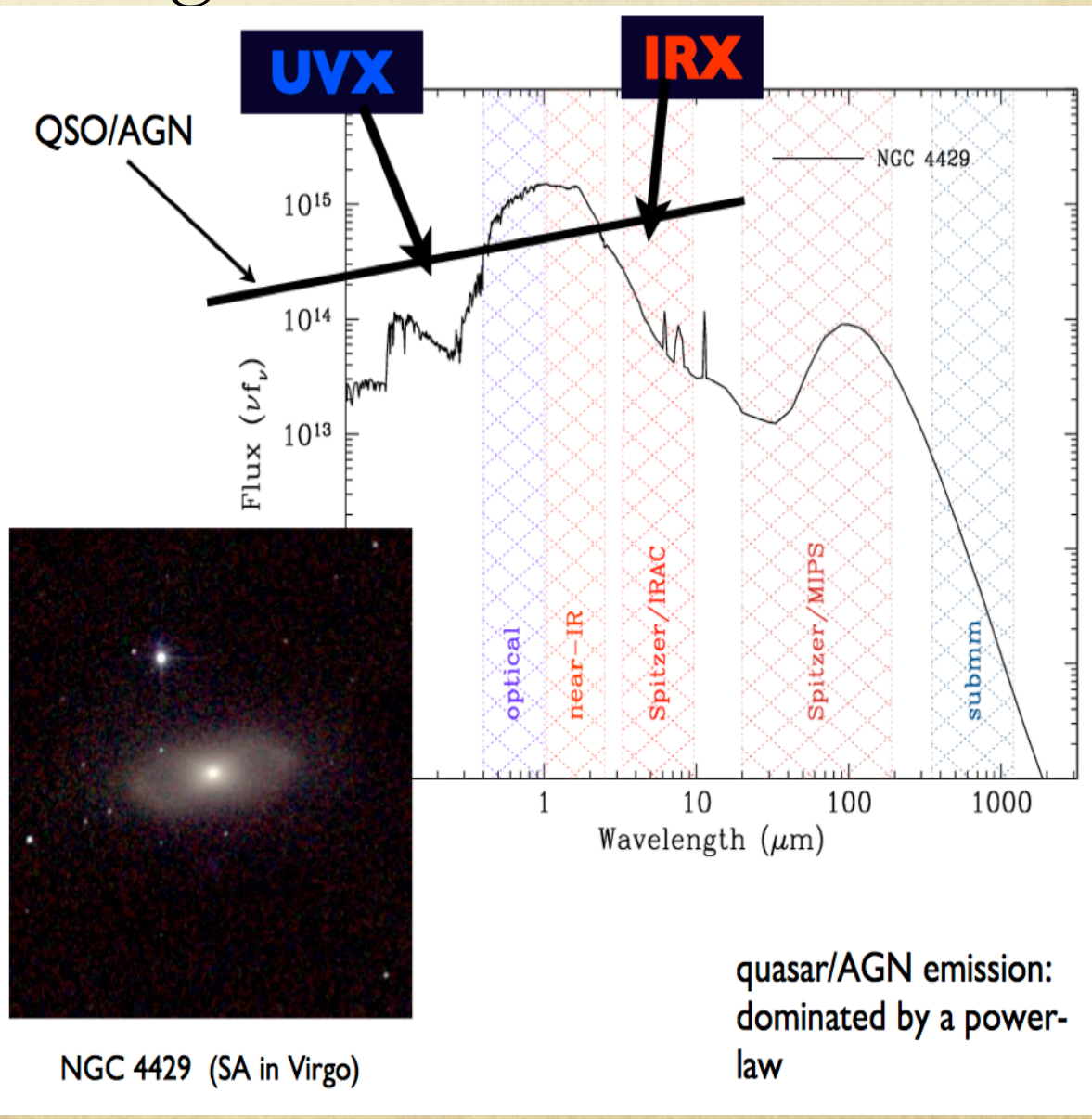


Narrow line region ~ 10 to 30kpc

More analyses are in progress.

Unique advantages of WISE Data

- Efficient selection of bright AGNs using 3.4 & 4.6um color
- Whole sky → Large area & Large statistics



Large Scale Clustering of WISE selected AGN: obscured vs. un-obscured:

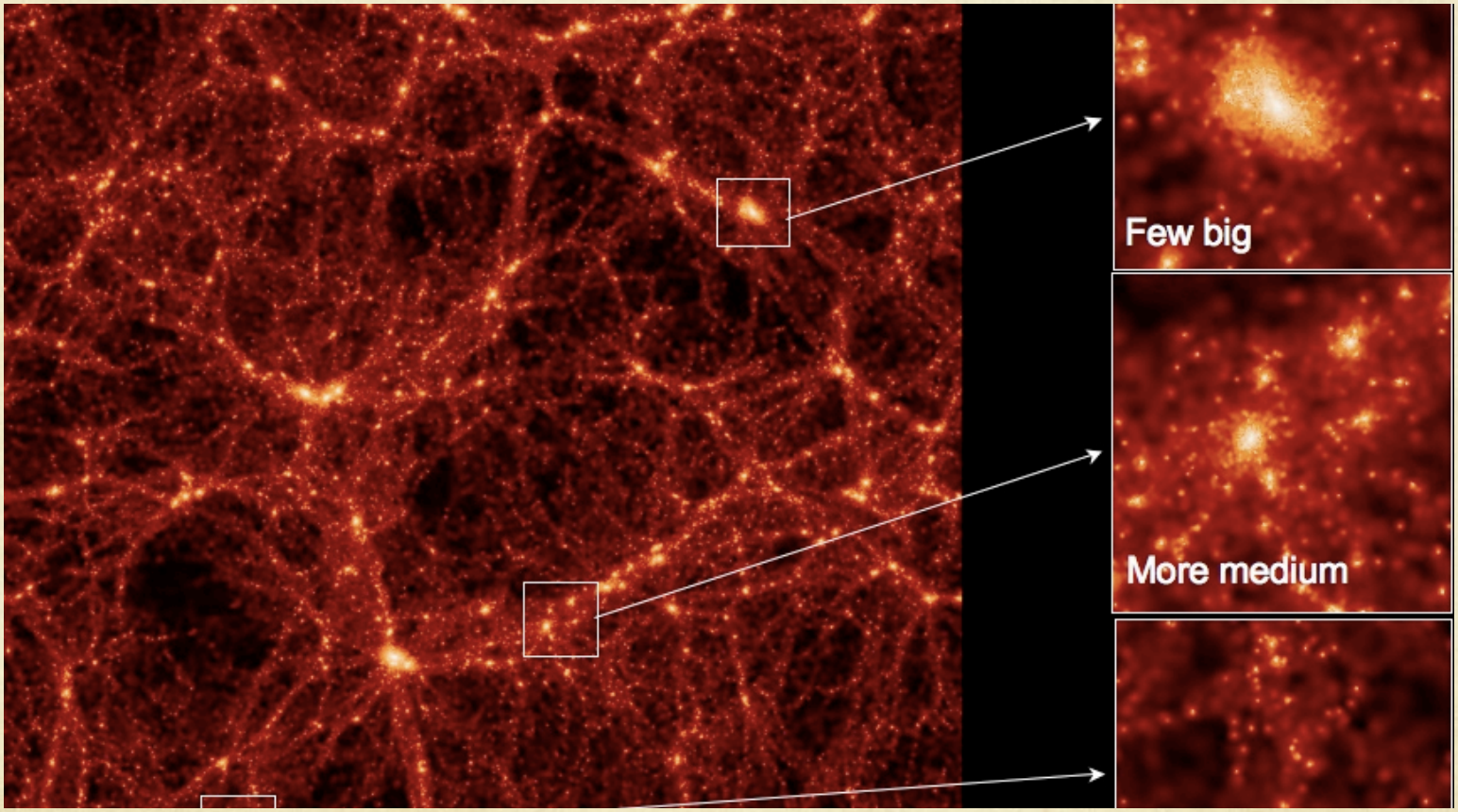
what did we learn about their dark matter halos?

Lin Yan (Caltech/IPAC)

Emilio Donoso (Argentina), D. Stern (JPL), R. Assef (Chile)

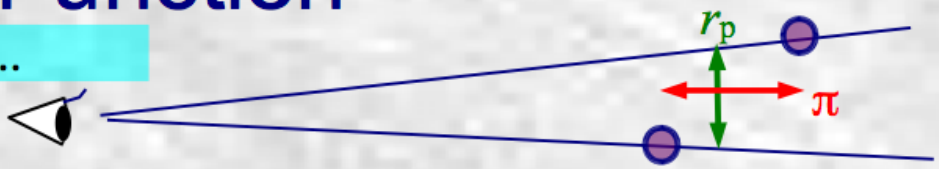
Donoso, Yan, Stern, Assef 2014 ApJ

Galaxies form at the sites of dark matter density peaks



Angular clustering:

Following a common recipe ...

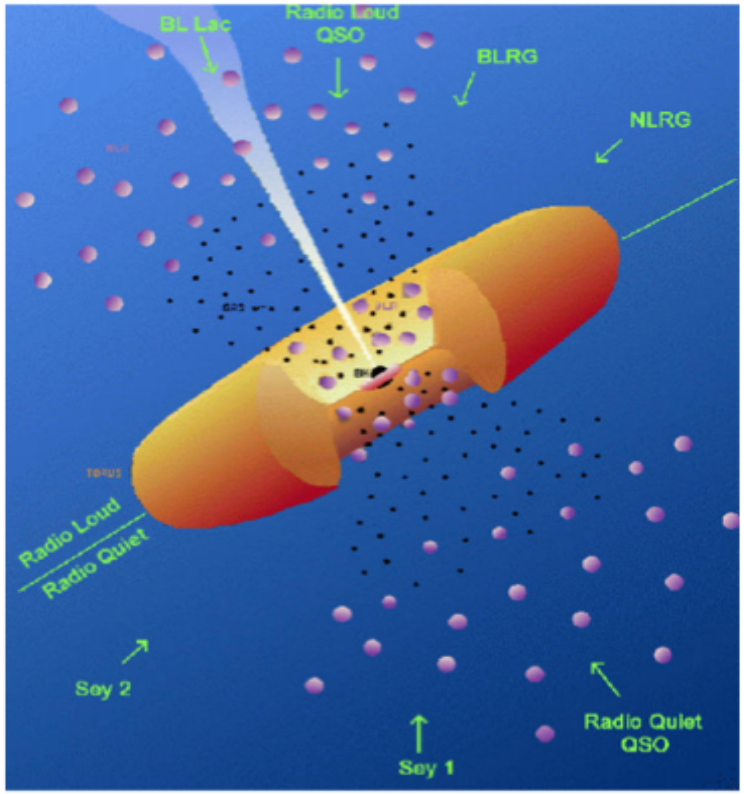


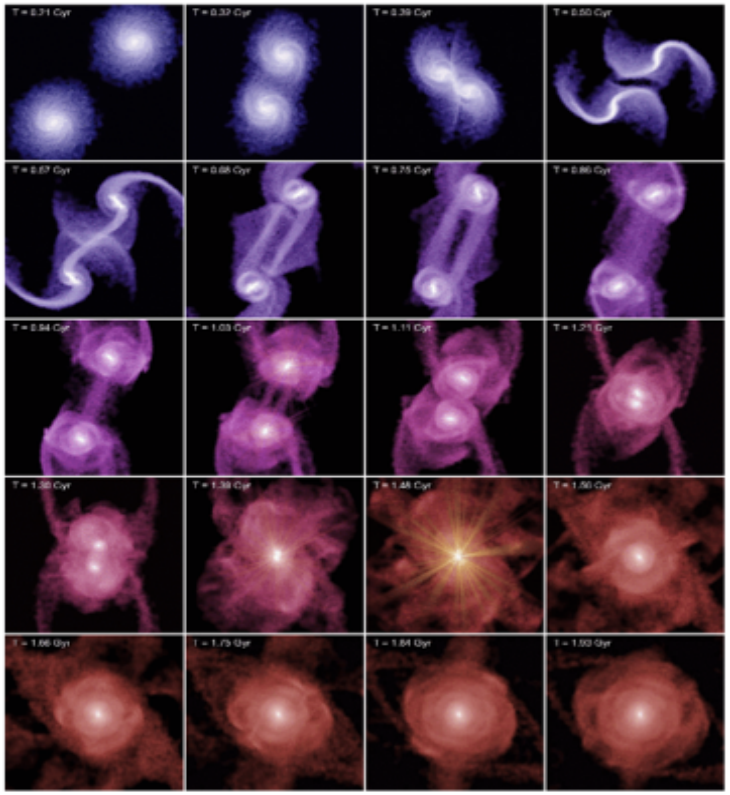
- Caluculate $\xi(r_p,\pi)$
  - r_p: projected-distance
  - π: line-of sight separation
    - (distances from redshift --> Redshift distortion.)
- Integrate over π —> the projected-distance correlation function.
  - Free from the "redshift distortion".

Projected Distance Line of sight separation

$$\int^{\pi_{max}}$$

Accreting Black Holes – obscured and unobscured





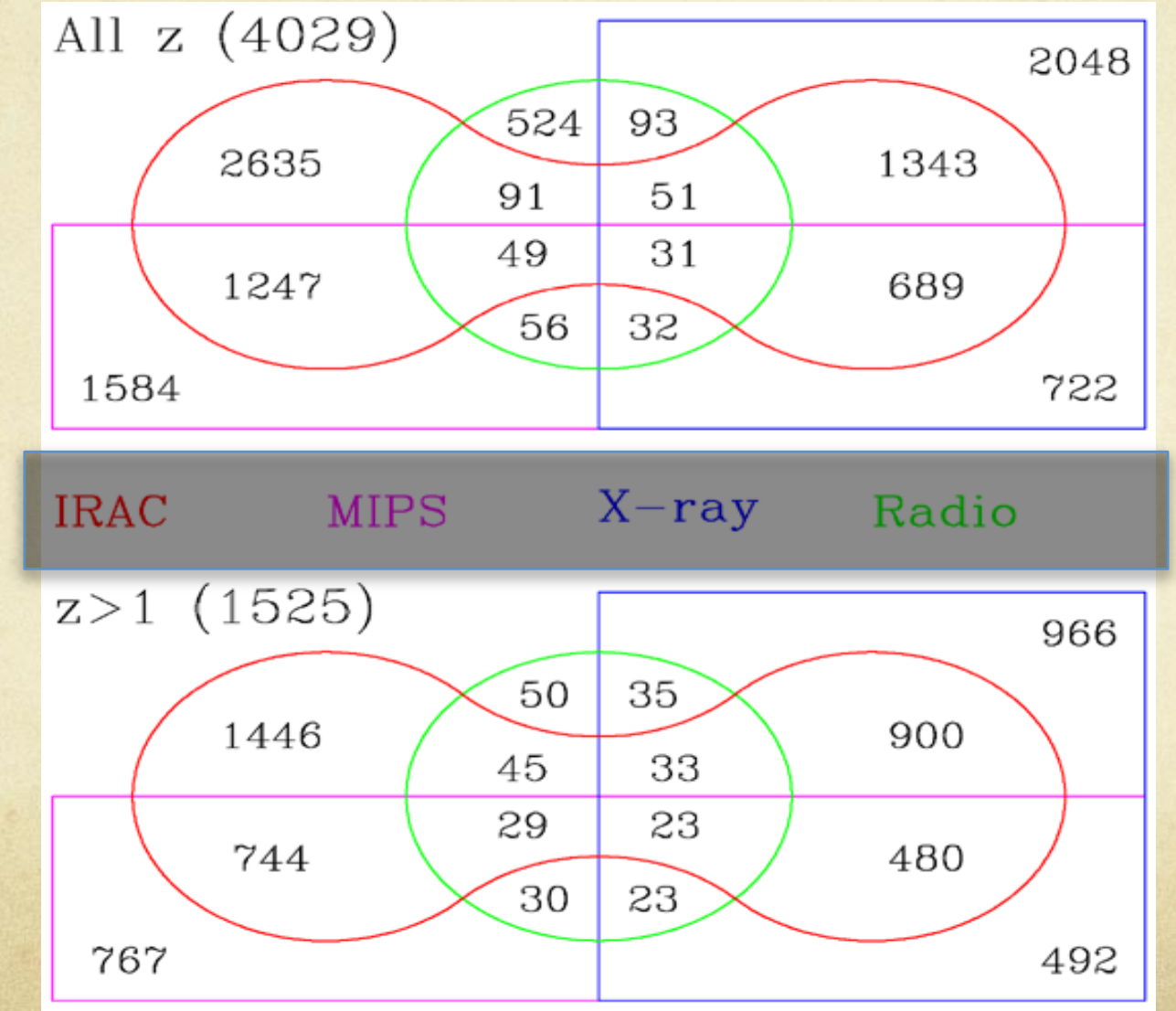
Orientation Models
obscuring torus

Urry & Padovani 1995, PASP, 107, 803

Dynamical Models
merger-induced obscuration

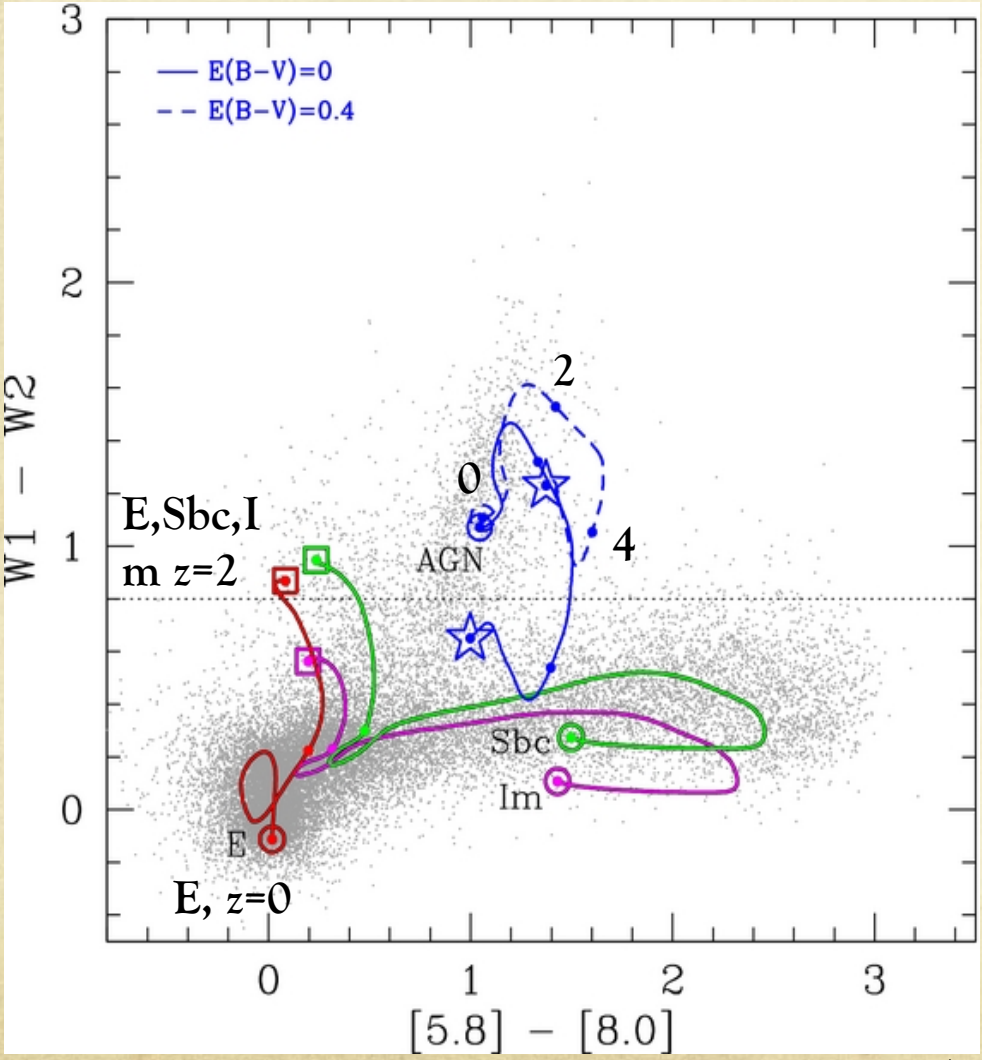
Hopkins et al. 2006, ApJS, 163,

Caveat: absolute complete identification of AGN



Bootes field with multiwavelength photometry and spectroscopy
Assef et al. 2010, ApJ

WISE [3.4]-[4.6] color effective for selecting luminous AGN/QSO at z<3

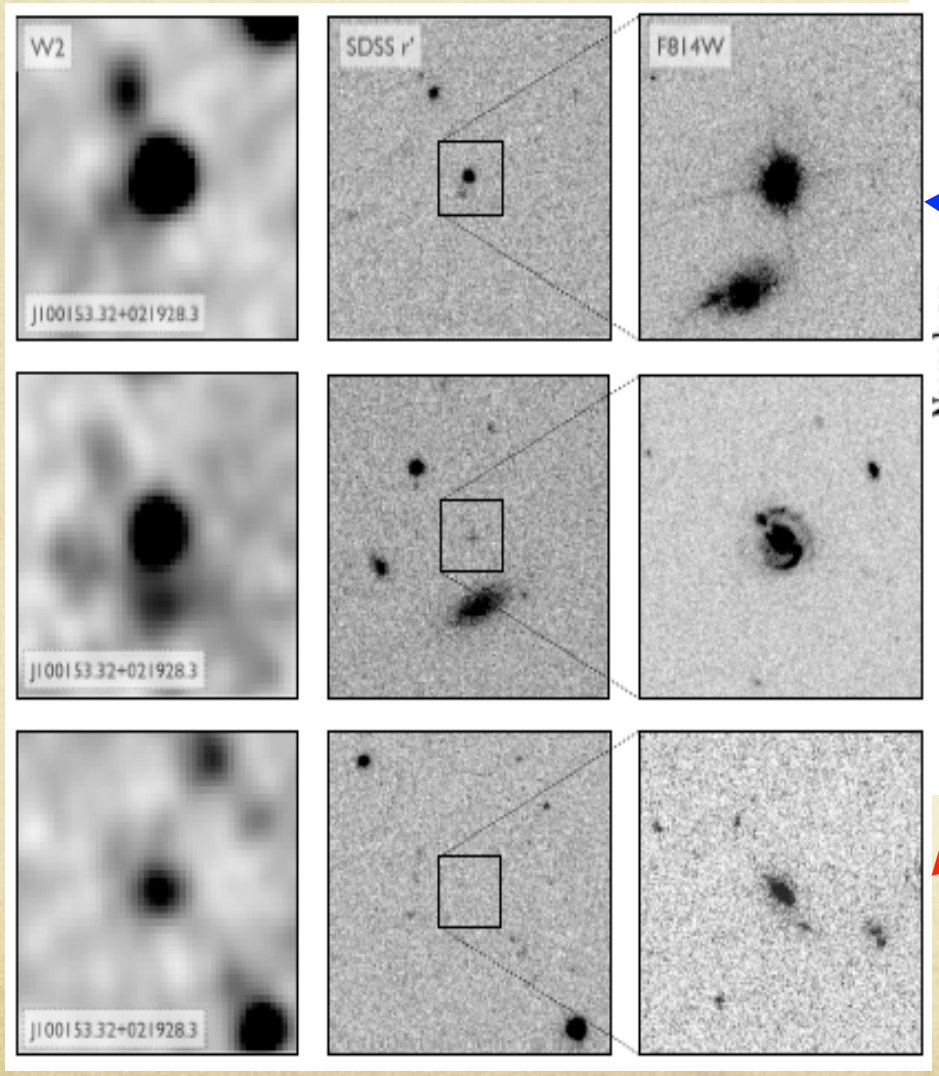


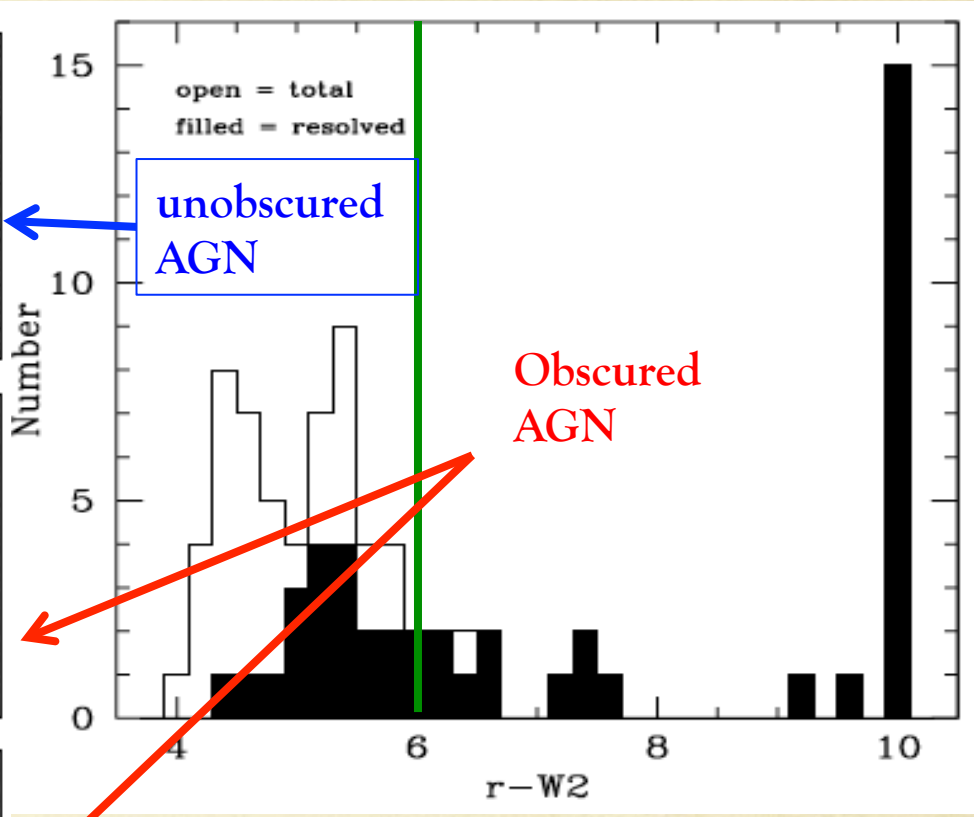
[3.4] – [4.6] > 0.8
Selects luminous AGNs with L(AGN)/L(host) >1 at z<3

Assef et al. 2013 ApJ

Host galaxies of WISE AGN

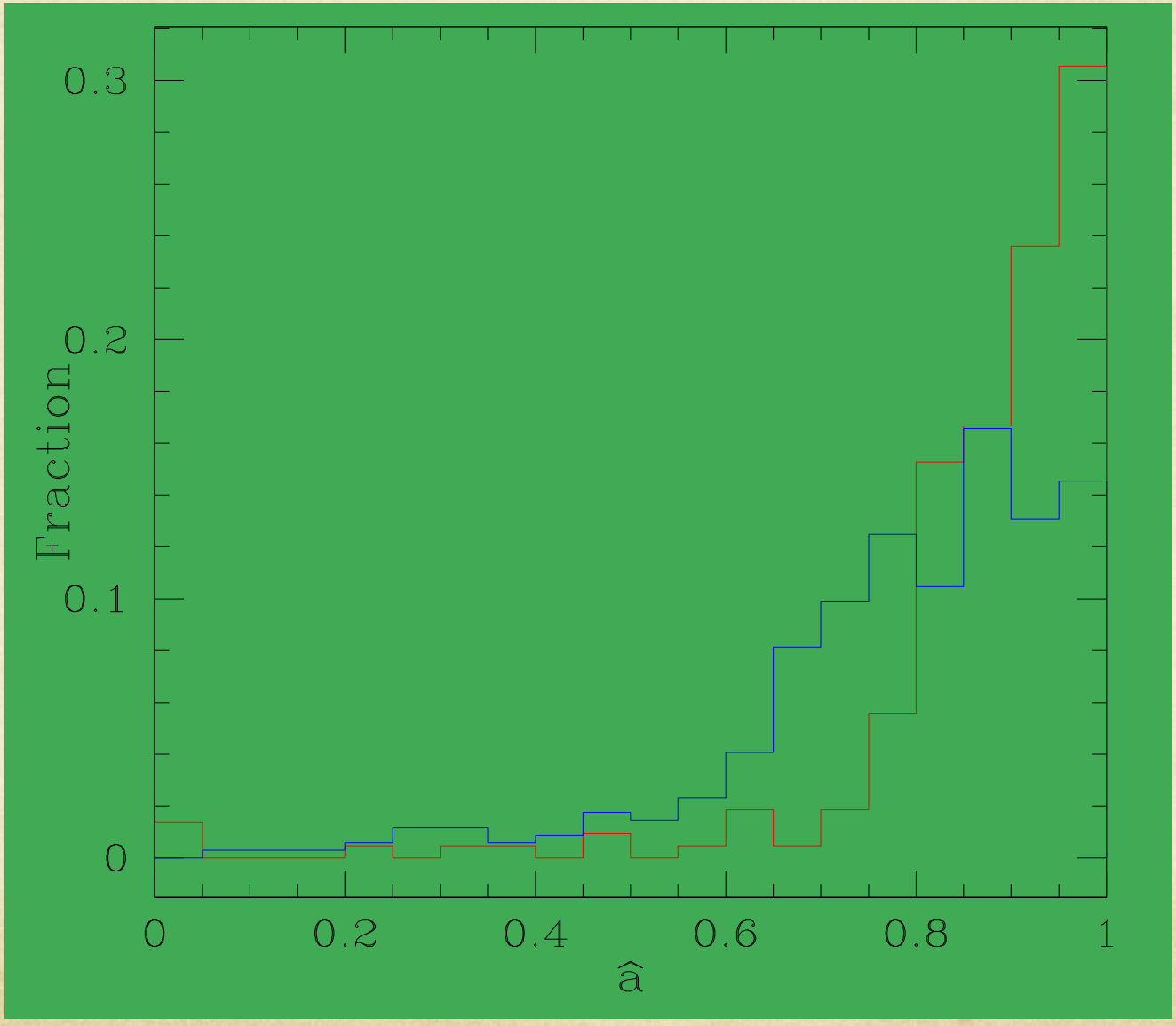
- HST morphologies of host galaxies in COSMOS field





COSMOS field: 65% red AGN have Sabc with large disks or interacting morphologies; 86% blue AGN unresolved point sources or compact ellipticals

Luminous AGN



L(AGN)/L(total) $\langle L(AGN) \rangle \sim 5 \times 10^{45}$ erg/s