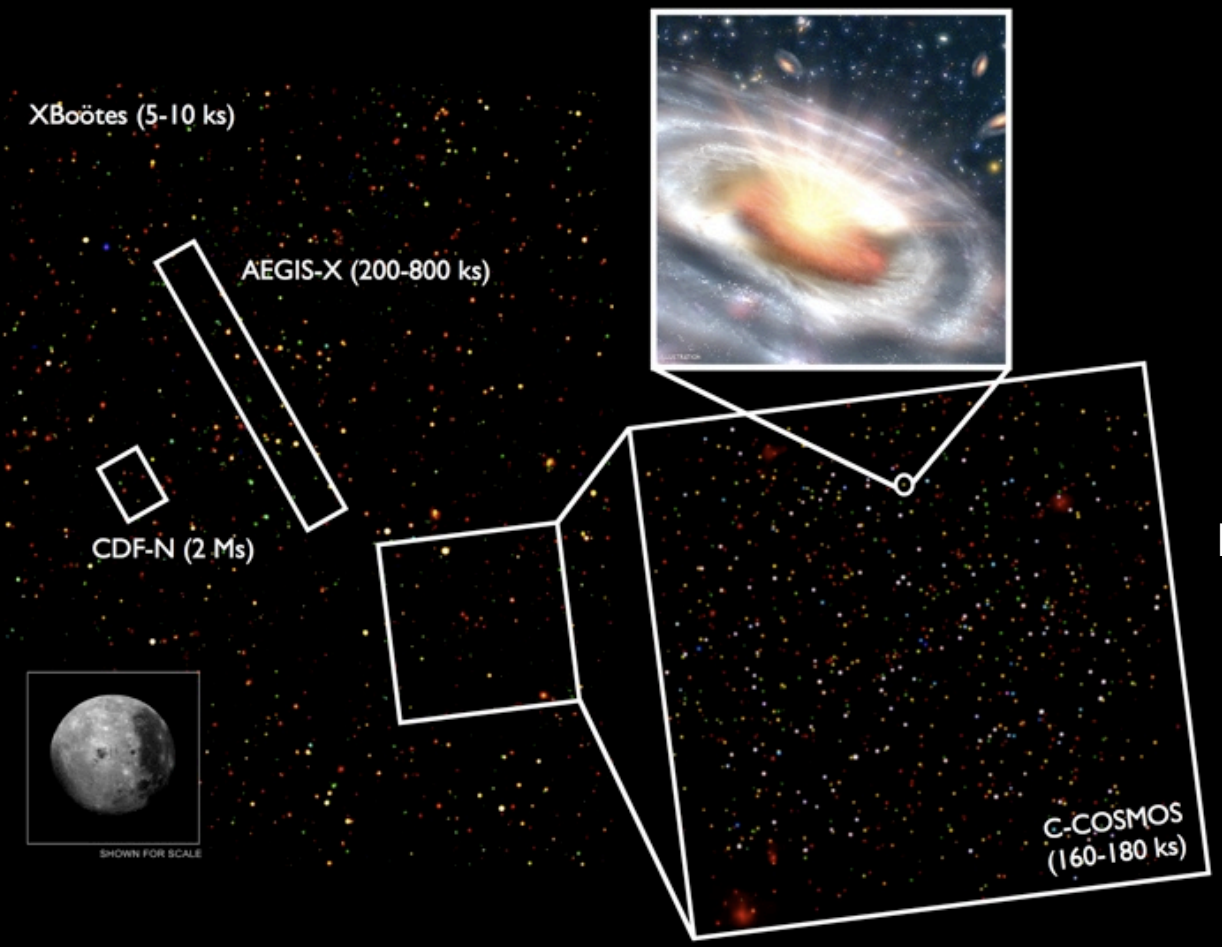
Black holes in the cosmic web: host galaxies and large-scale environments of AGN



Ryan C. Hickox

Durham University

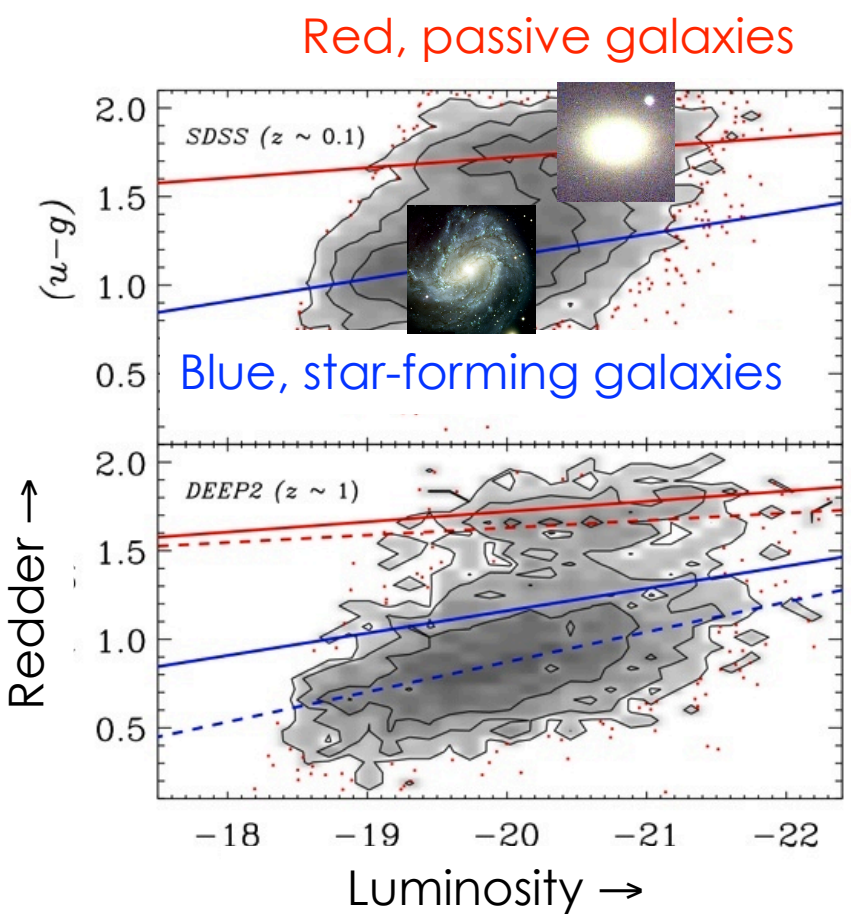
Birmingham-Nottingham Extragalactic Workshop

27 September 2010

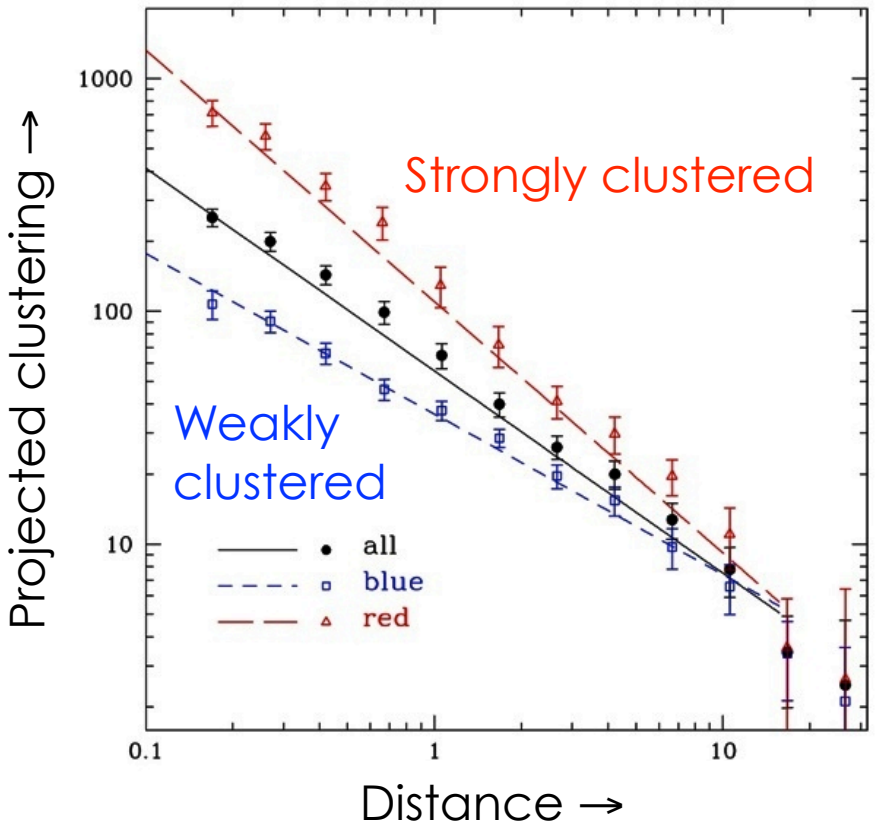
On the menu:

PART 1: Host galaxies and environments of different classes of AGN

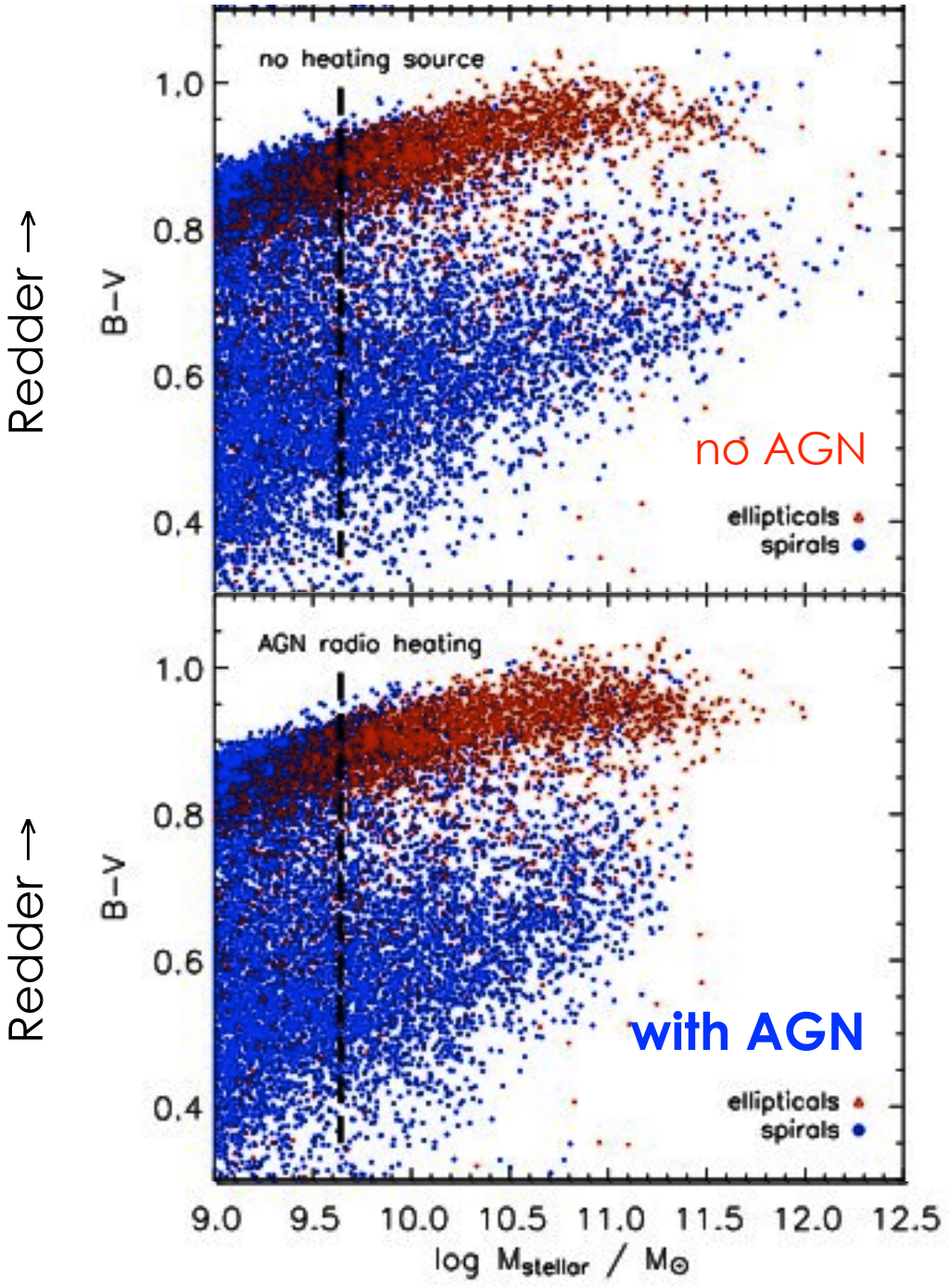
PART 2: Where and when does AGN feedback occur?

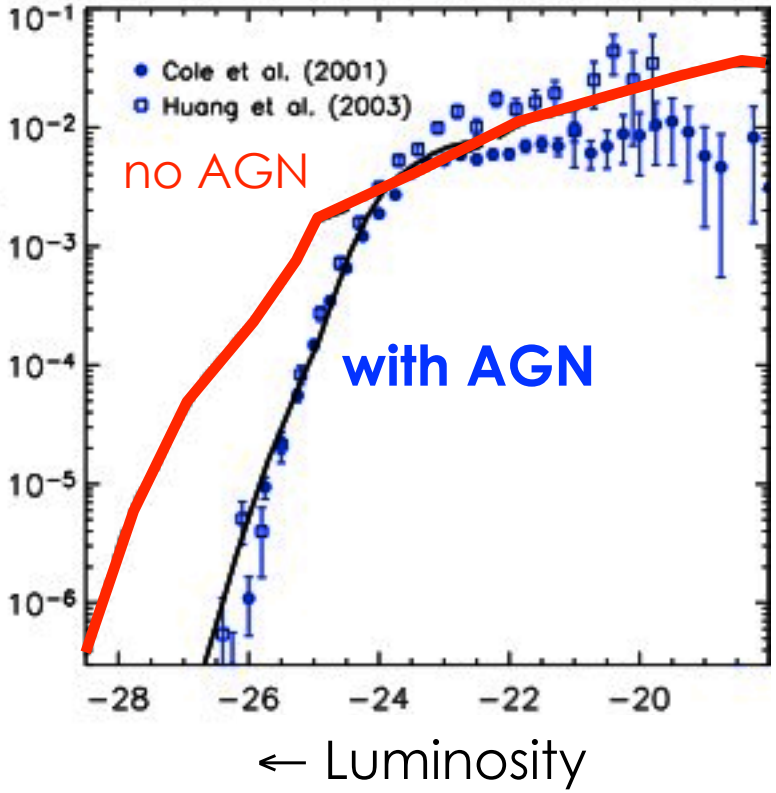


Blanton (2006)



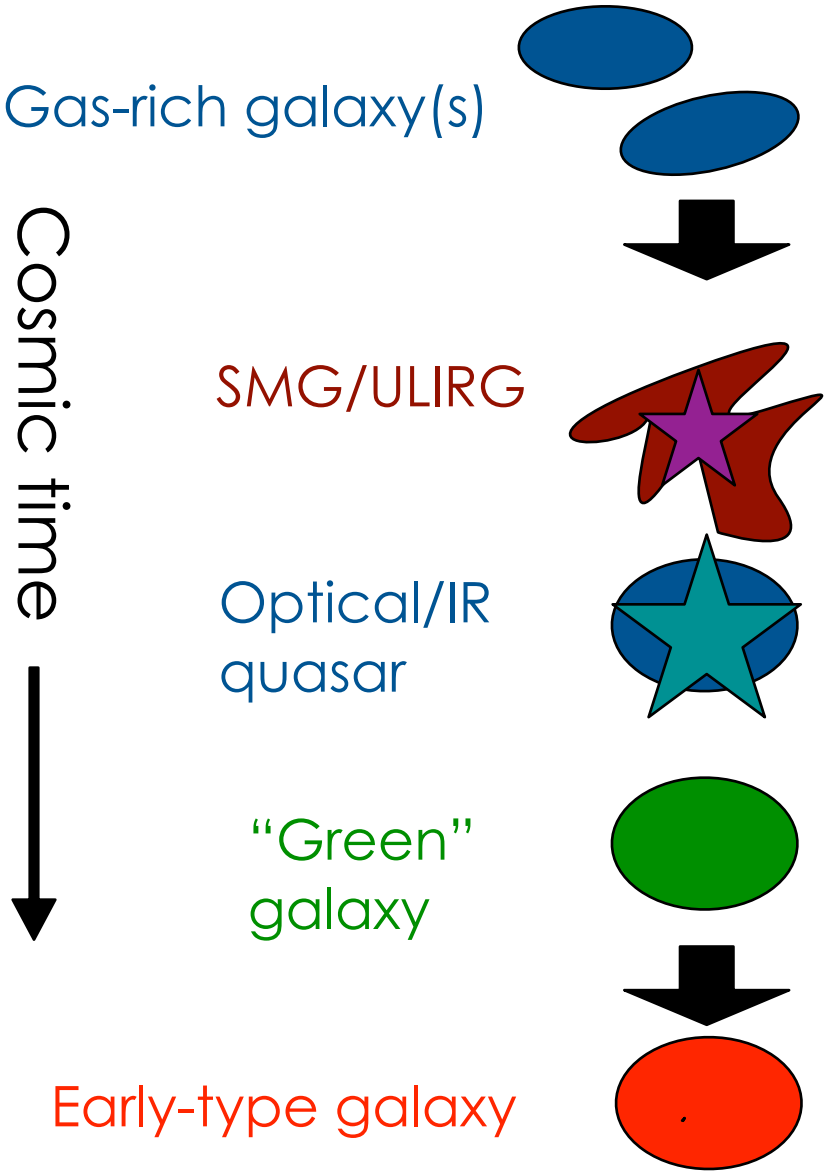
Zehavi et al. (2005)





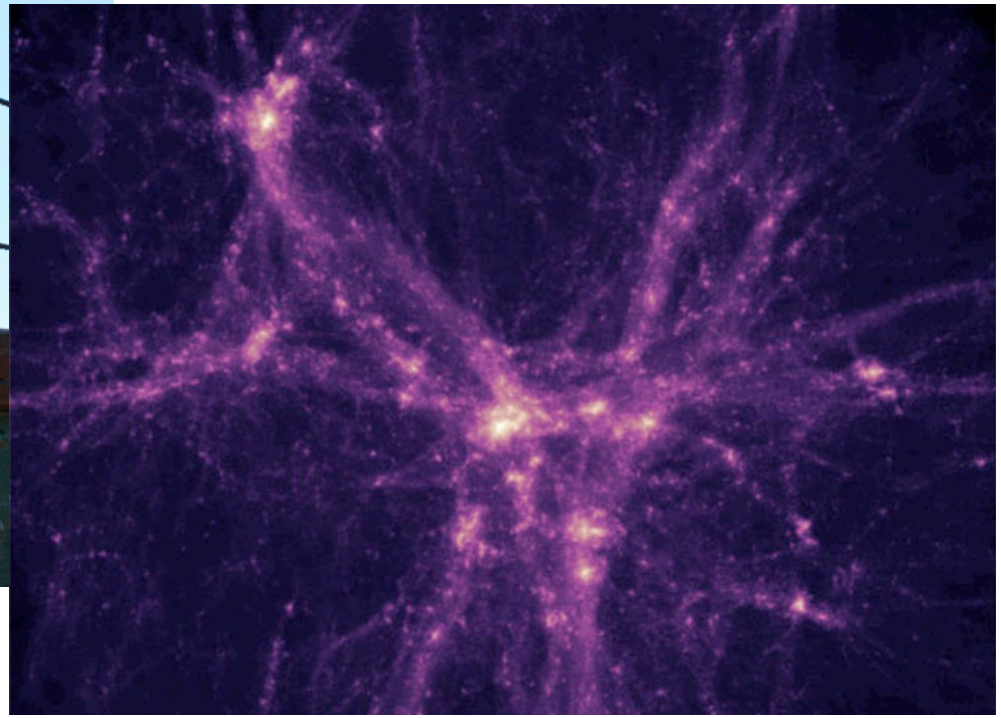
Croton et al. (2006), also Bower et al. (2006, 2008), etc. etc.

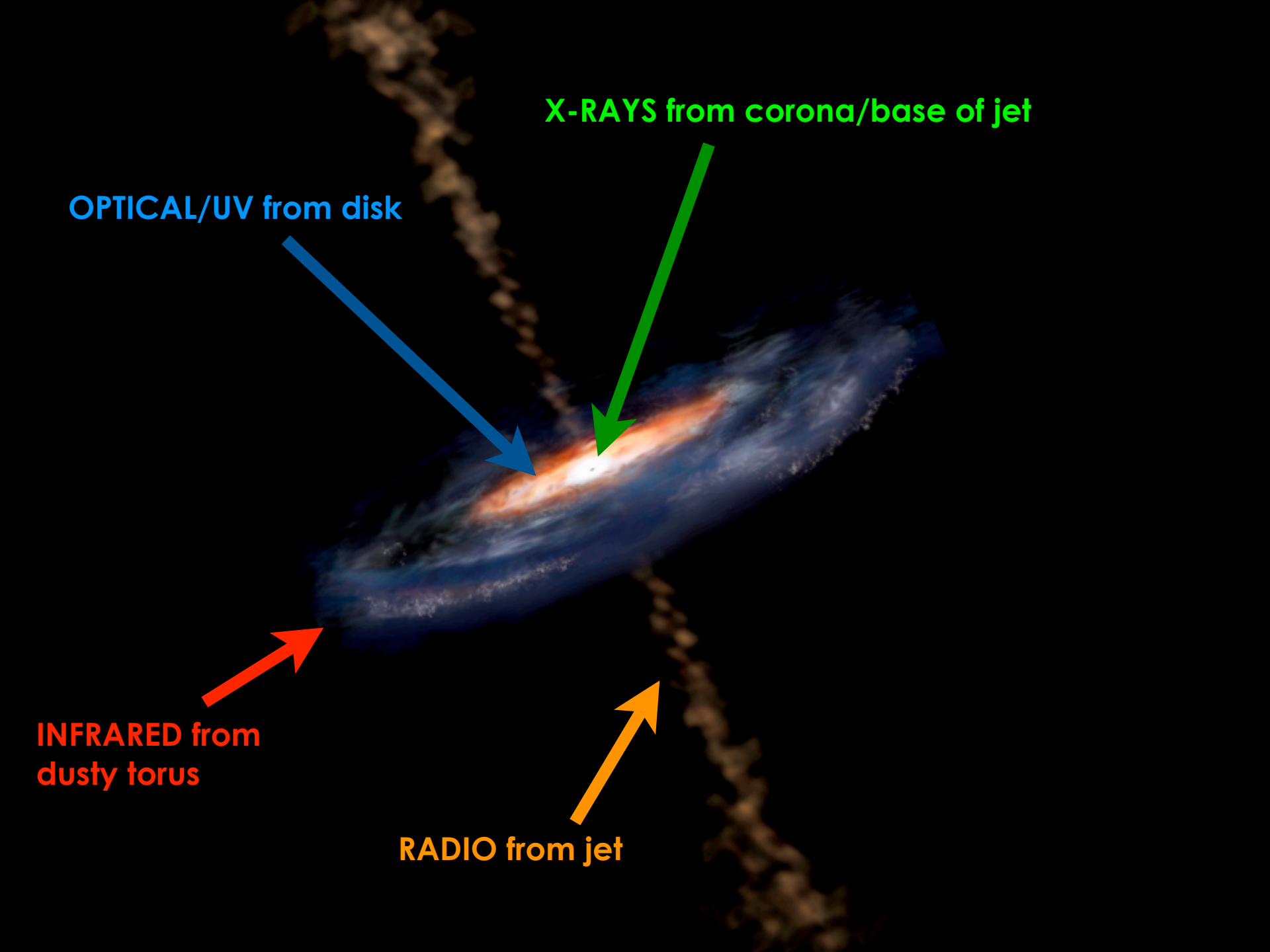
Cartoon of massive galaxy evolution

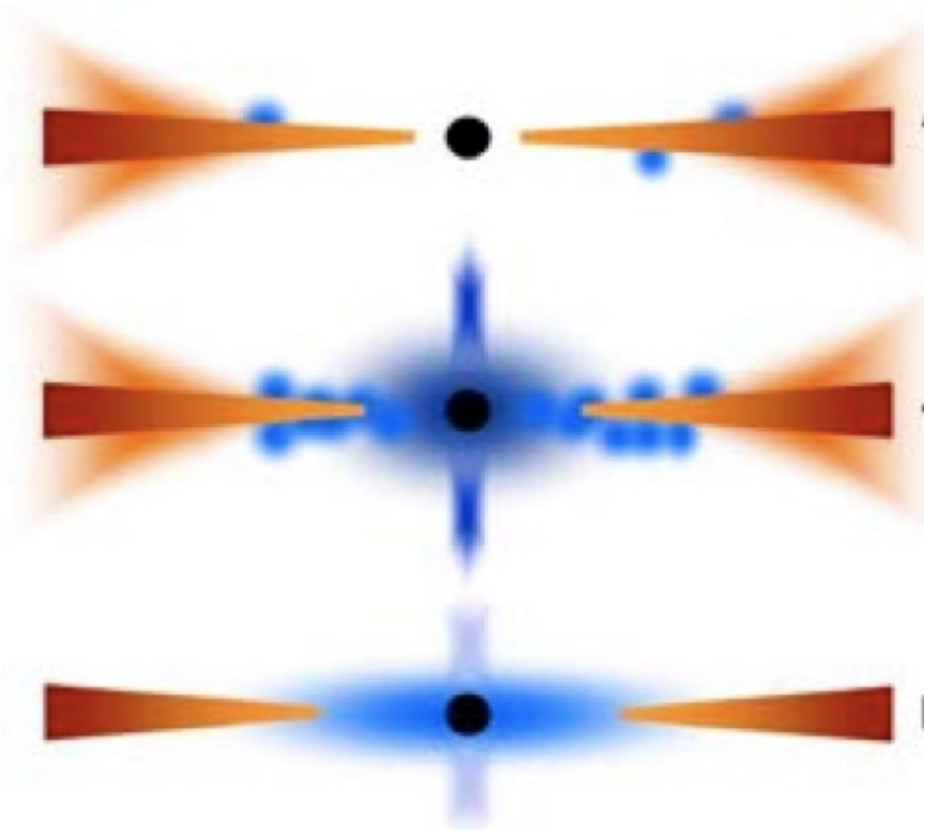


a la Sanders et al. (1988)

Where are the AGN?



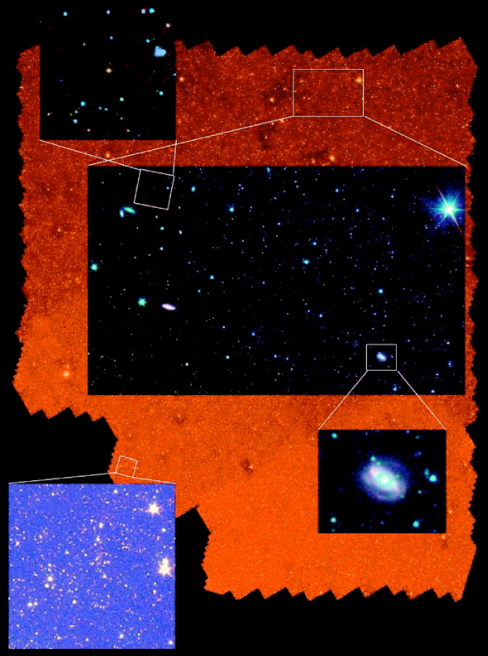

X-RAYS from corona/base of jet
OPTICAL/UV from disk
INFRARED from dusty torus
RADIO from jet

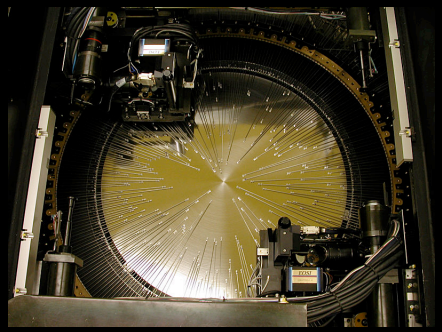


Done, Gierlinski & Kubota (2007)

Observational selection effects can severely bias some selection techniques toward particular Eddington ratios (e.g., Hopkins, Hickox, et al. 2009)

The 9 deg^2 Boötes survey





Chandra (CfA)
C. Jones
W. Forman
S. Murray
A. Kenter
R. Narayan

Optical photometry (NOAO/etc.)
B. Januzzi
A. Dey
K. Brand
M. Brown
and the NDWFS Team

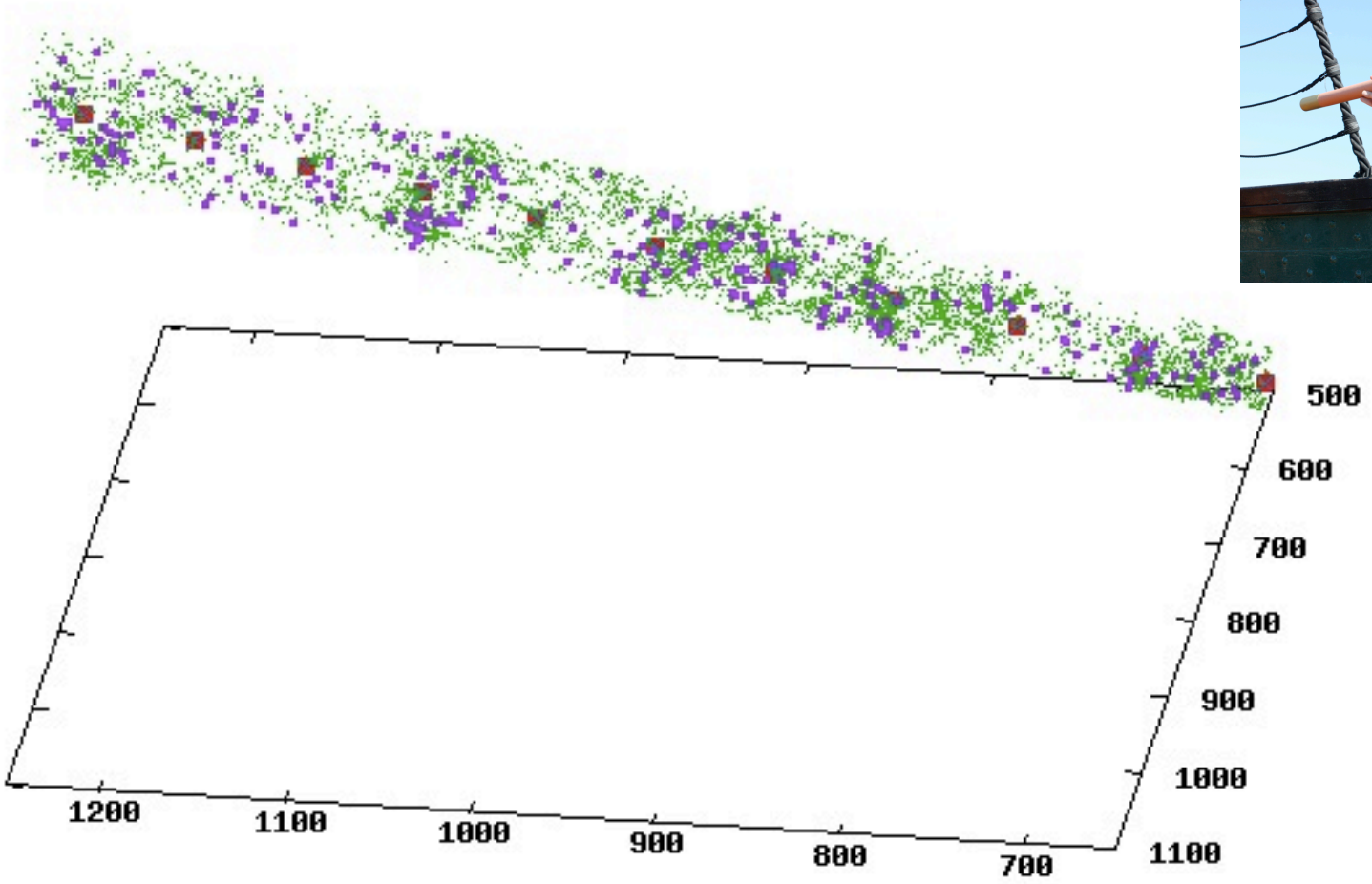
Spitzer IRAC (JPL/Caltech/CfA)
P. Eisenhardt
M. Brodwin
V. Gorjian
D. Stern
M. Pahre
and the IRAC Shallow Survey Team

Optical spectroscopy (OSU/Arizona/CfA)
K. Kochanek
D. Eisenstein
R. Cool
N. Caldwell
and the AGES Team

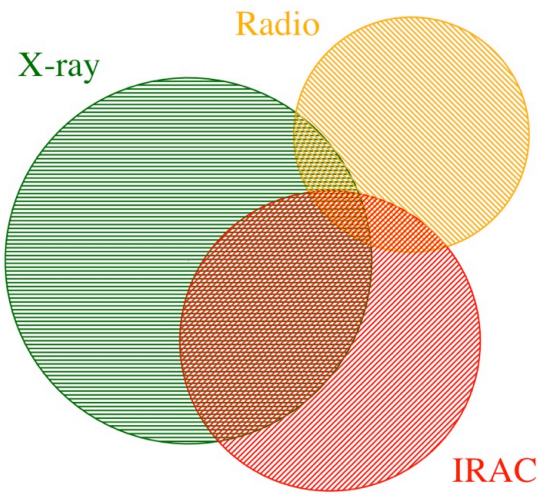

0
0.5
1
2
4
10
Redshift

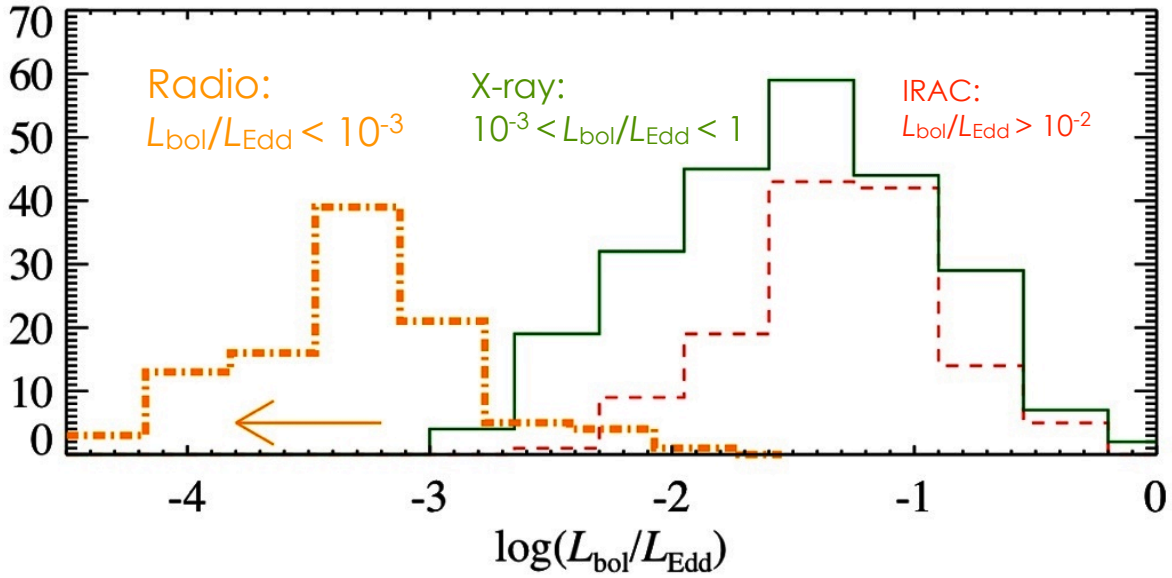
galaxies

X-ray AGN



Boötes AGN sample





~6000 galaxies and 600 AGN with AGES redshifts at $0.25 < z < 0.8$

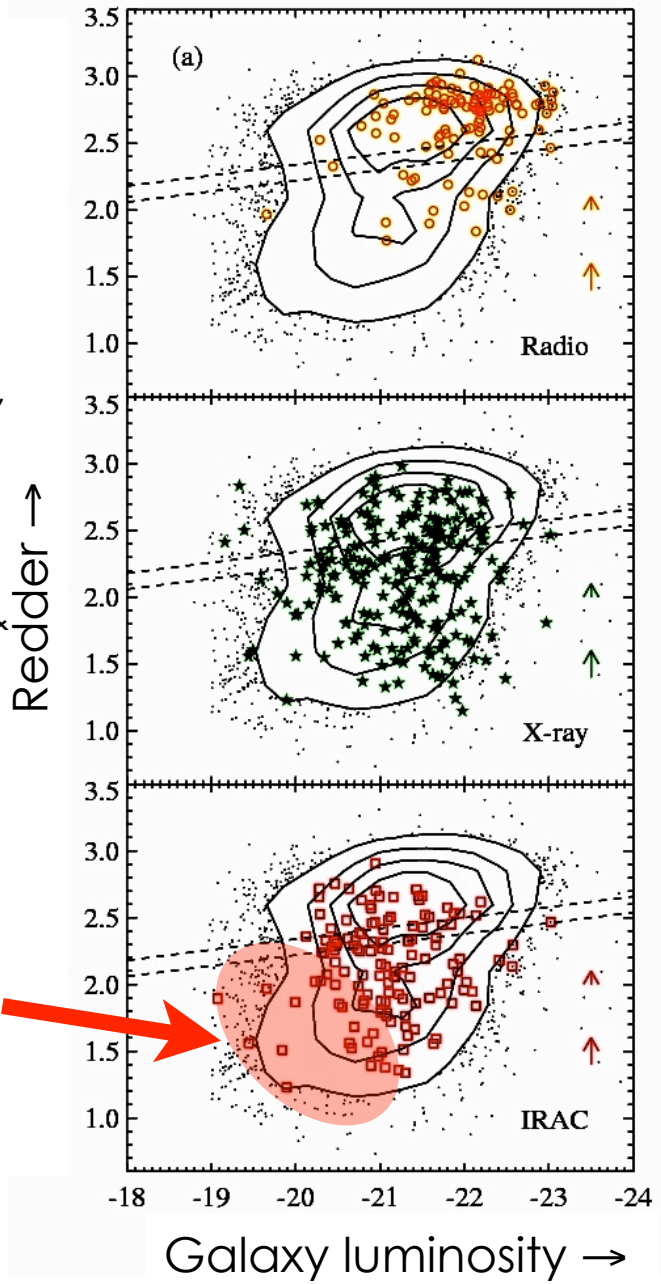
What types of galaxies host AGN?

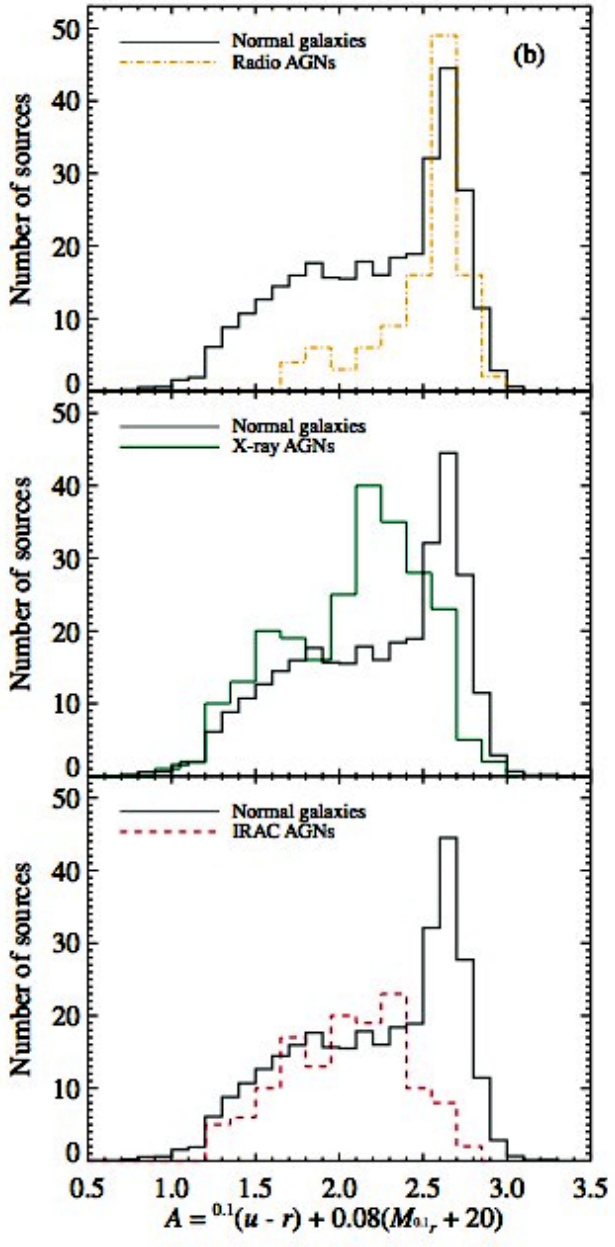
Hickox et al. (2009)

Similar results seen in other surveys for **X-ray AGN** (e.g., Nandra et al. 2007, Silverman et al. 2007, Alonso-Hererro et al. 2008, Georgakakis et al. 2008, Schawinski et al. 2009, even to z~3) as well as radio (Smolcic et al. 2009) and optical (Kauffmann & Heckman 2009)

weak AGN found through mid-IR spectra (Goulding et al. 2009)

many Compton-thick (Goulding et al. 2010)





AGN host morphologies

X-ray AGN, Georgakakis et al. (2009)

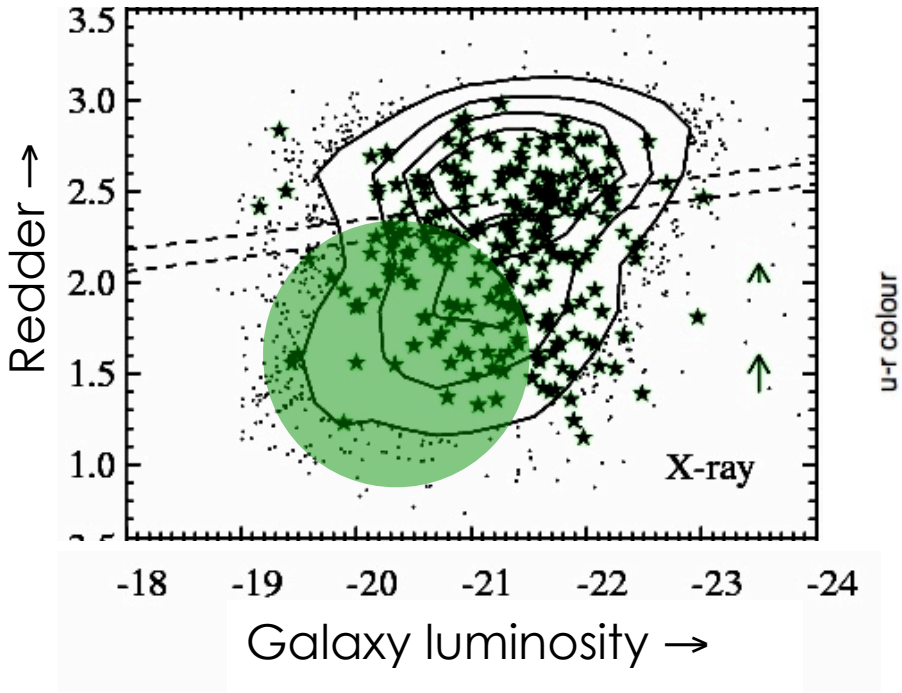
Radio AGN are almost all in bulge-dominated galaxies

X-ray AGN are primarily in bulge-dominated galaxies,

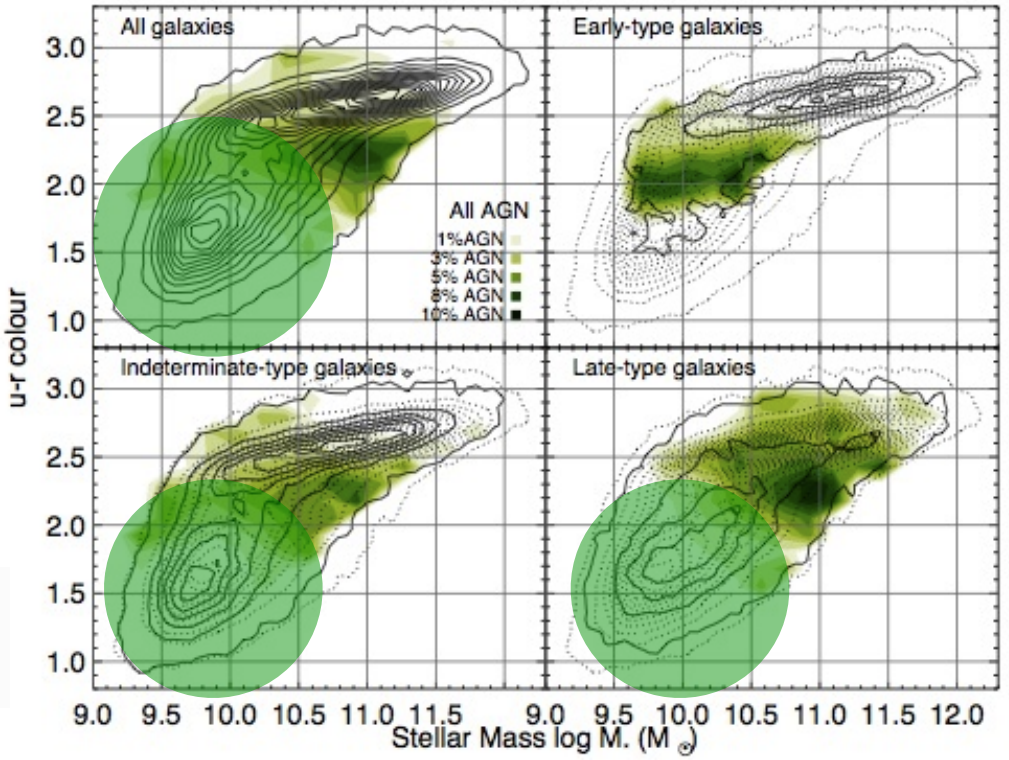
IR AGN are more likely to be in disks

(e.g., Georgakakis et al. 2009, Griffith & Stern 2010)

A cautionary note



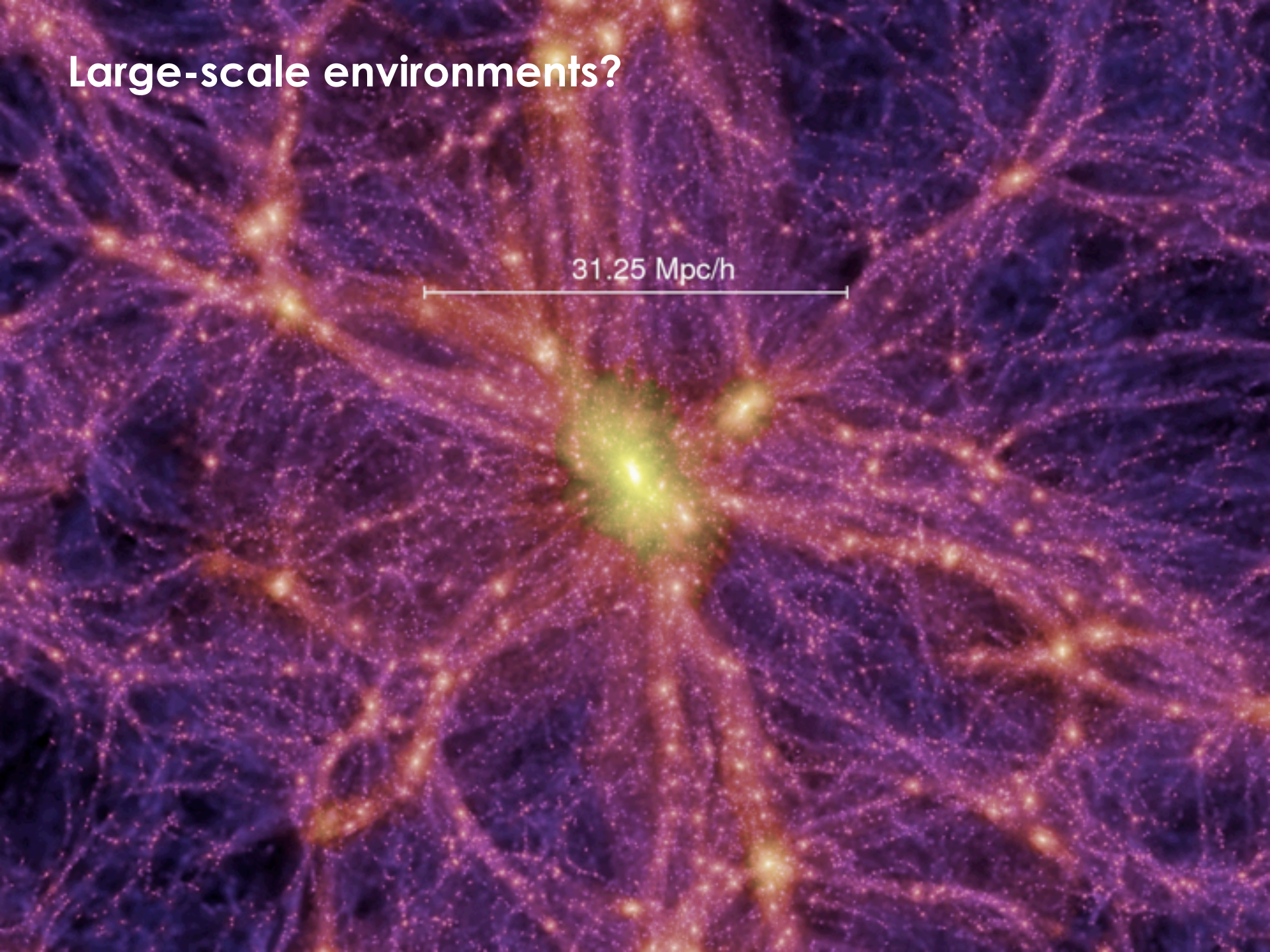
Hickox et al. (2009) [X-ray]



Schawinski et al. (2010) [optical]

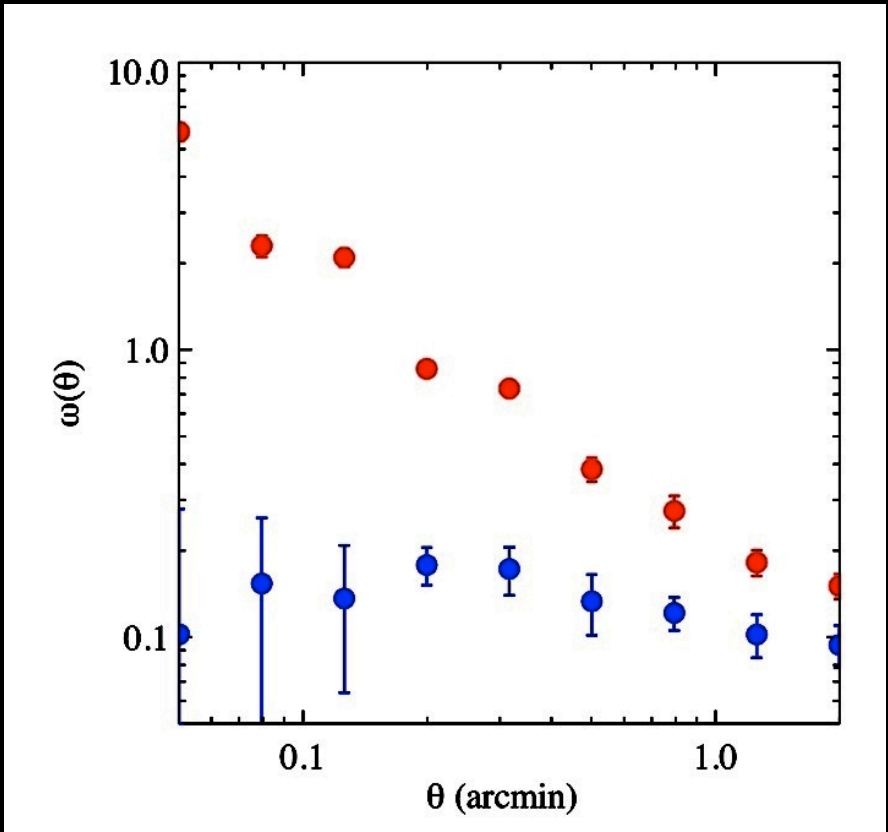
A paucity of AGN in low-mass blue cloud is likely be due to **selection effects** (small black holes, larger host galaxy contamination)

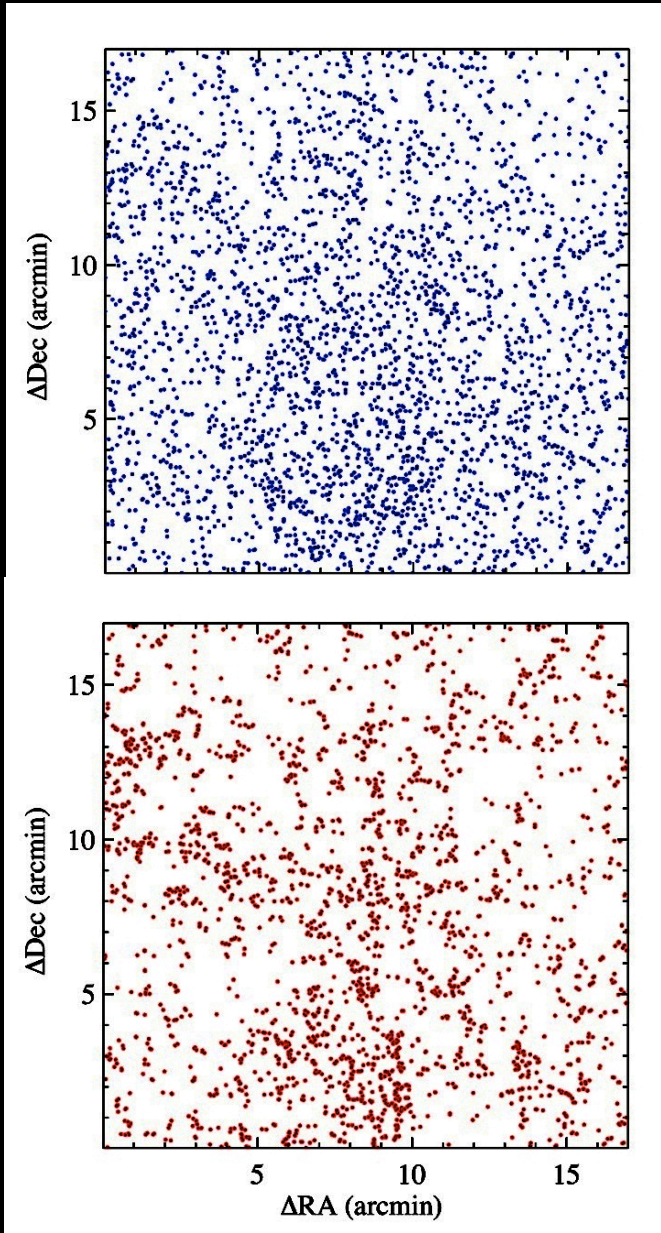
Large-scale environments?



Angular two-point correlation

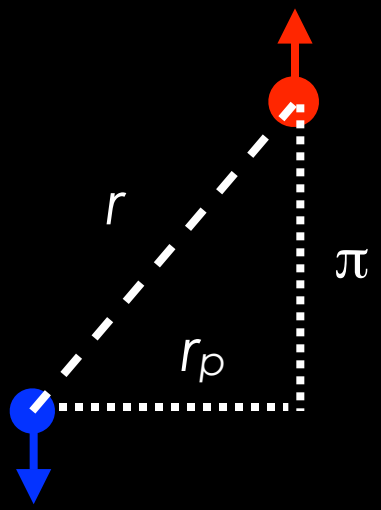
$\omega(\theta)$: $dP = n\,[1 + \omega(\theta)]\,d\Omega$





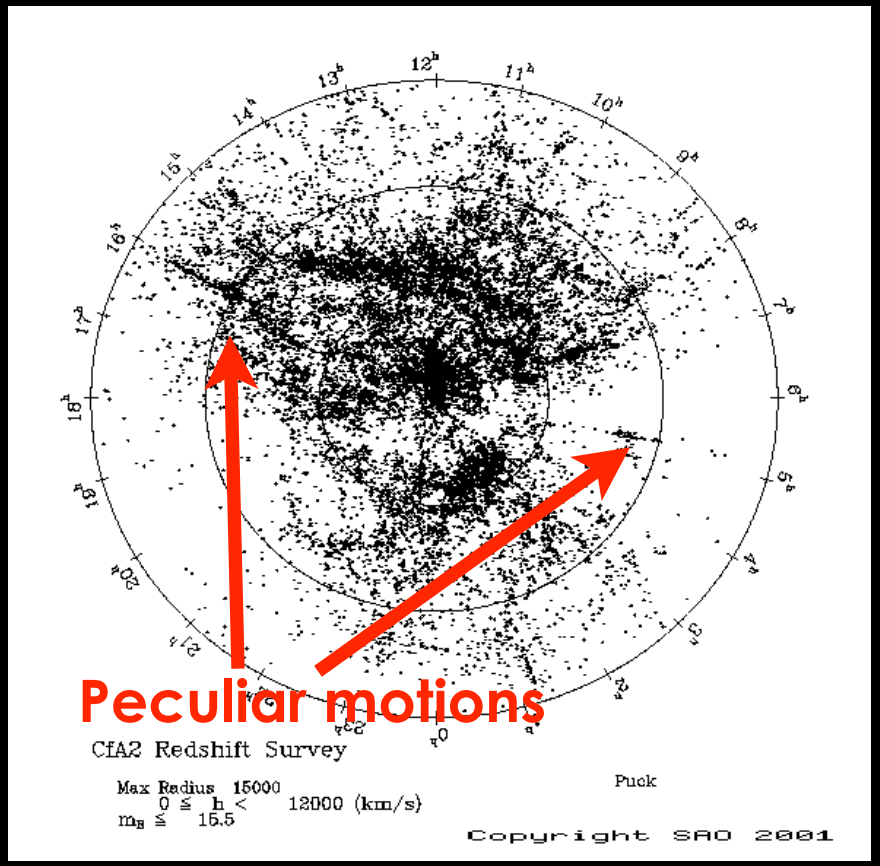
3-D spatial correlation

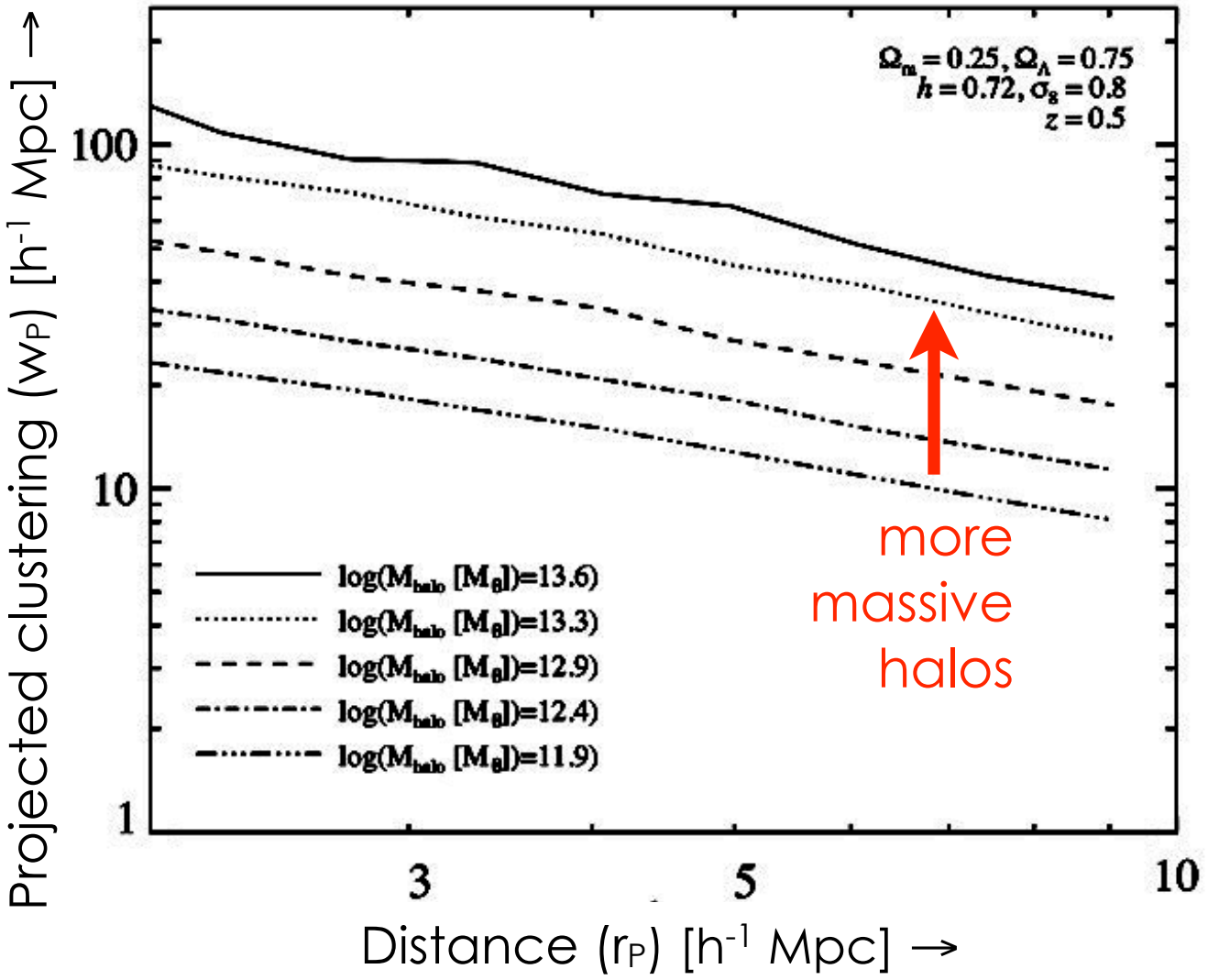
$\xi(r)$: $dP = n\,[1 + \xi(r)]\,dV$



Projected correlation

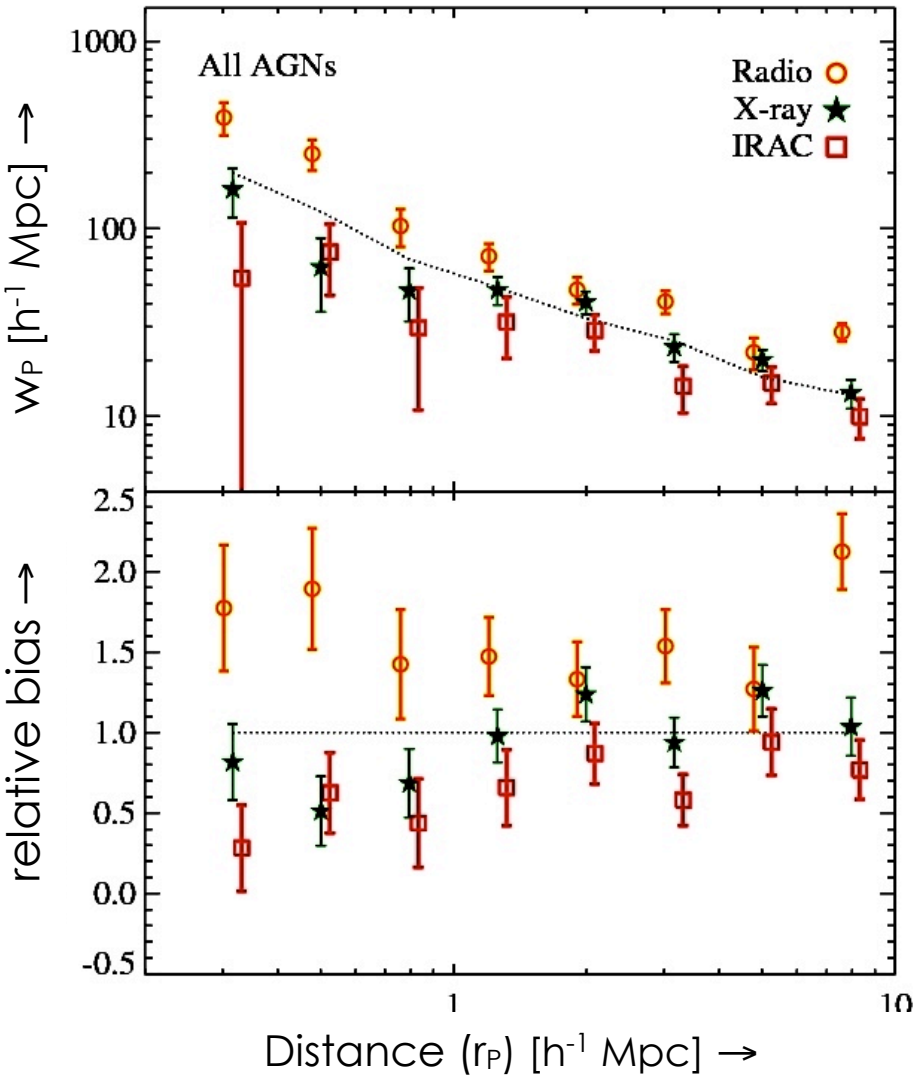
$$w_p(r_p) = 2 \int \xi(r_p, \pi)\, d\pi$$





Model: Padmanabhan et al. (2008)

clustering → halo mass!



Hickox et al. (2009)

Halo masses:

Radio: ~ 3 x 10^{13} h^{-1} $M_\odot$

X-ray: ~ 10^{13} h^{-1} $M_\odot$

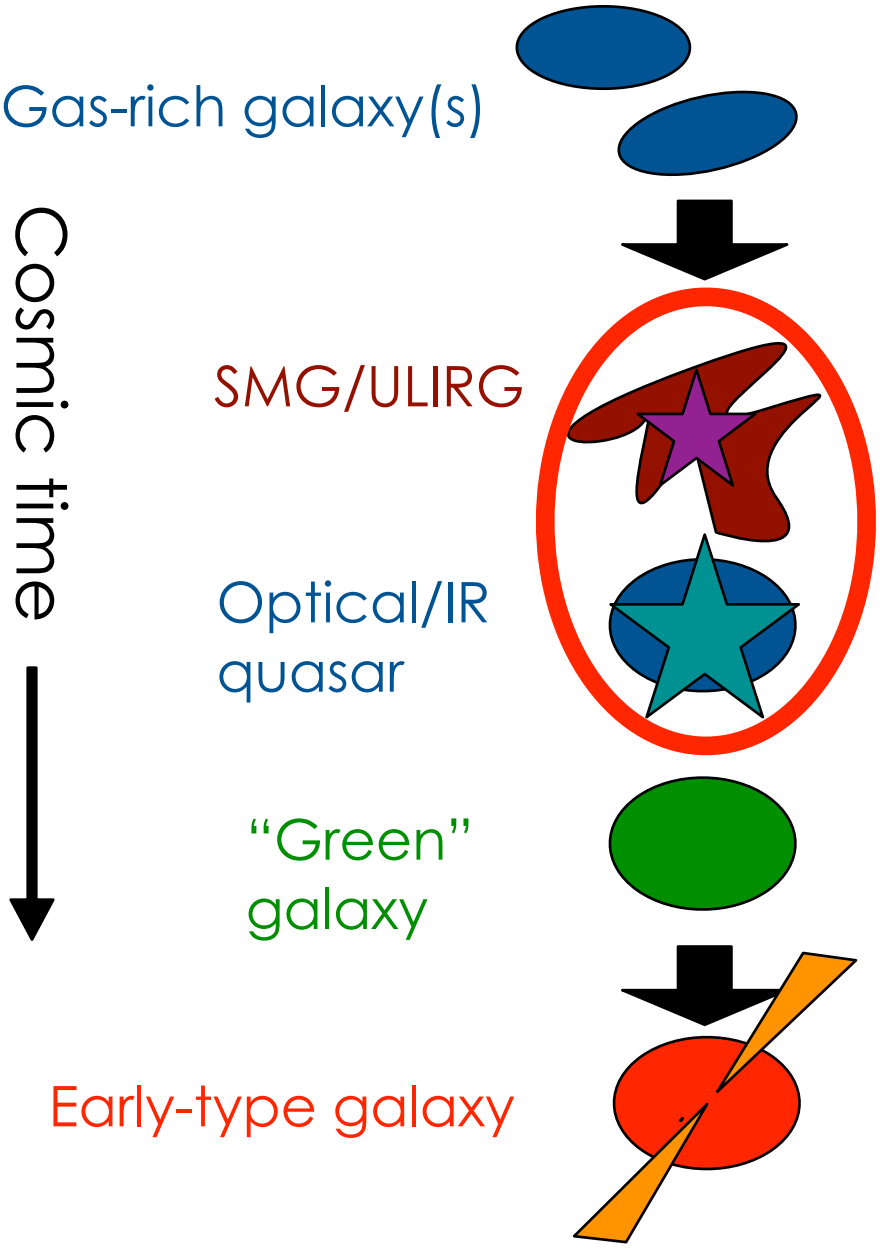
similar to matched galaxy samples

IRAC: < 10^{12} h^{-1} $M_\odot$

smaller than *matched galaxy samples*

see also Li et al. (2006), Coil et al. (2009), Wake et al. (2008), Mandelbaum et al. (2008)

Cartoon of massive galaxy evolution

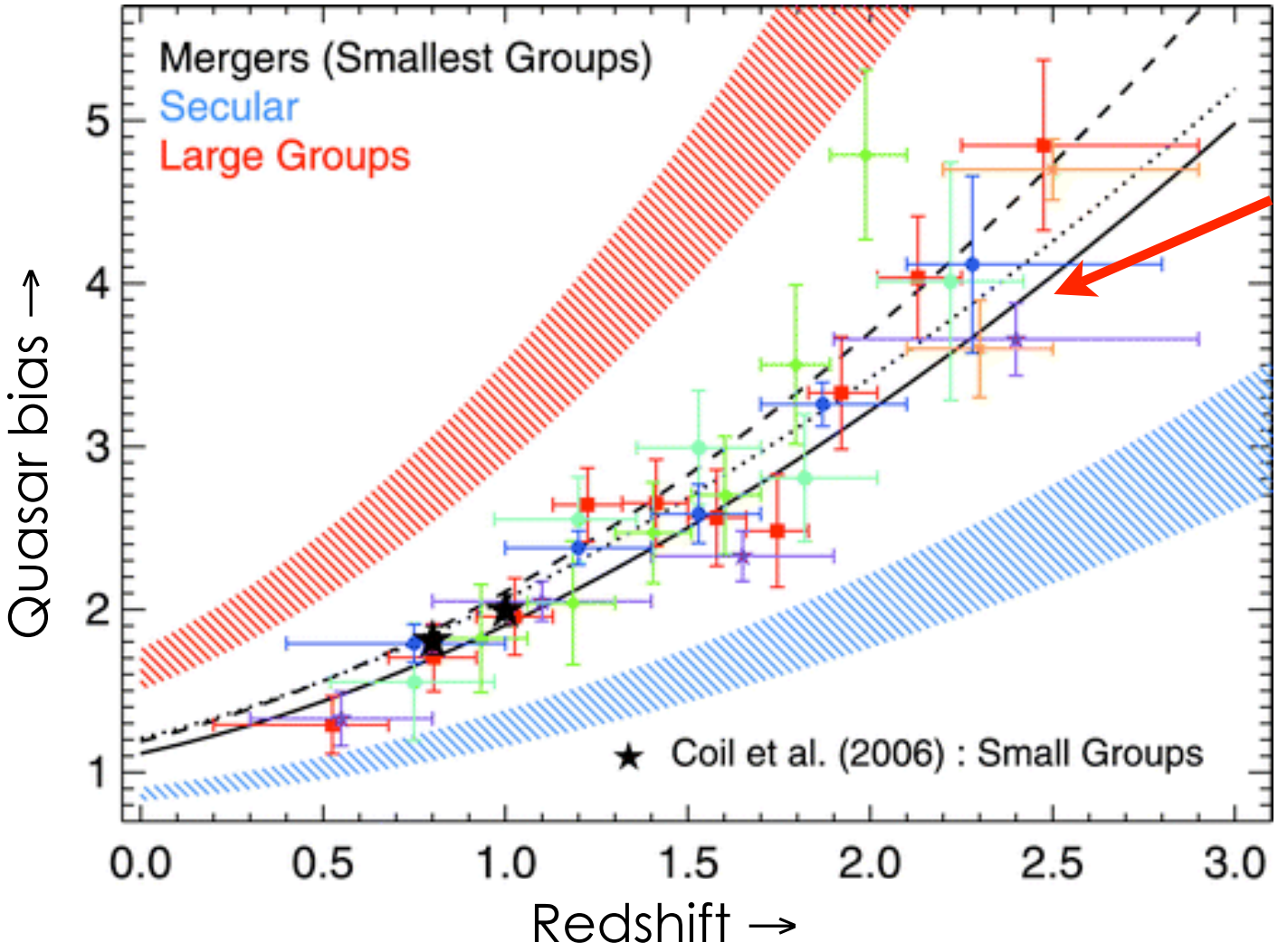


$M_{halo} \sim 10^{12} - 10^{13} M_{\odot}$

"small group" scale -- where **mergers** are most likely?

(e.g., Croom et al. 2005, Coil et al. 2007, Myers et al. 2007, Shen et al. 2008, Ross et al 2009, many others)

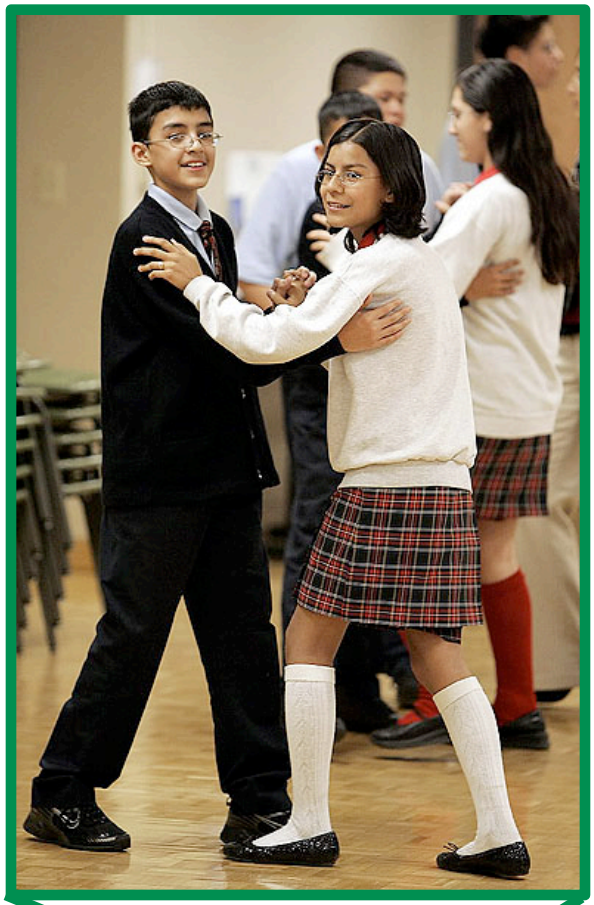
Optical quasars: large-scale clustering

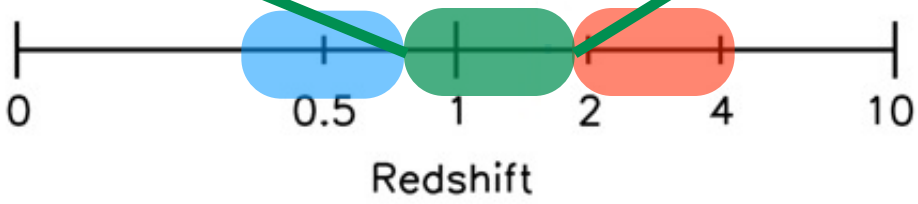


constant M_{halo}

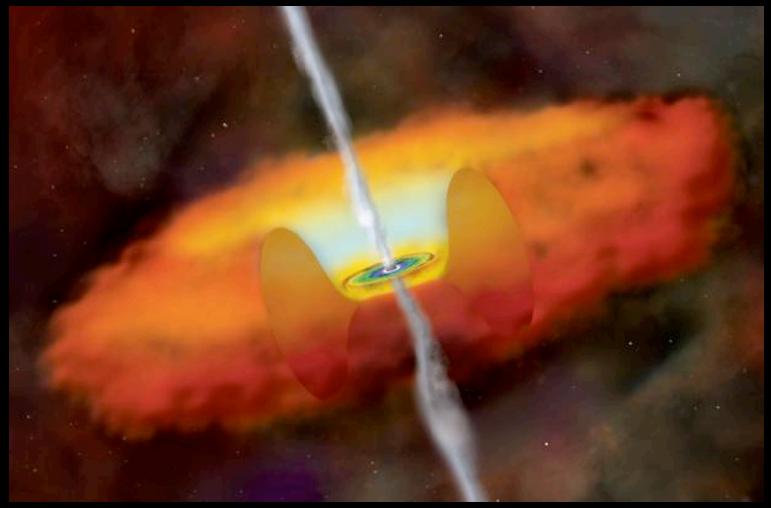
~ 3 x 10^{12} h^{-1} $M_{\odot}$

Hopkins et al. (2008)




0
0.5
1
2
4
10
Redshift

Unobscured (QSO1)



Obscured (QSO2)

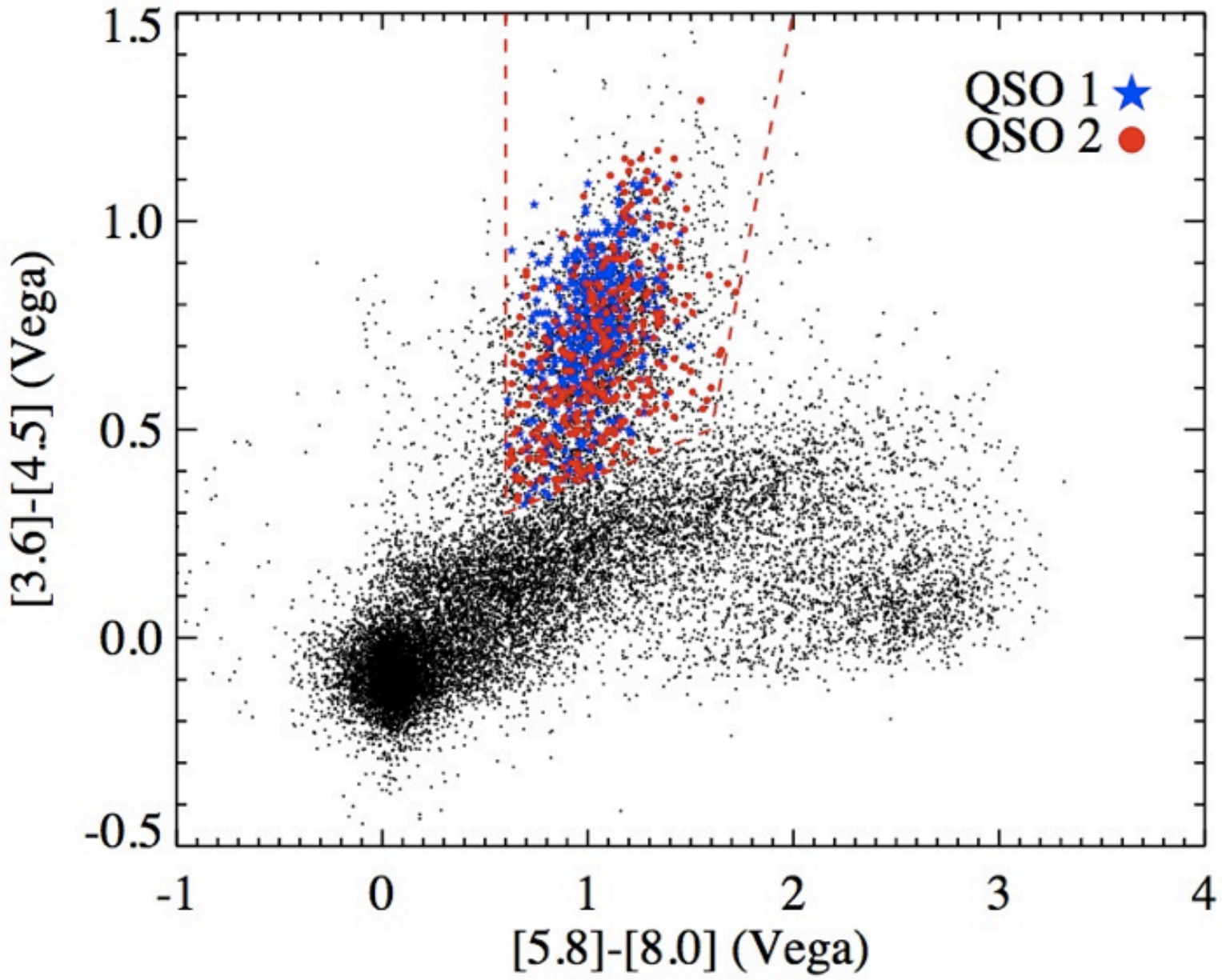
?

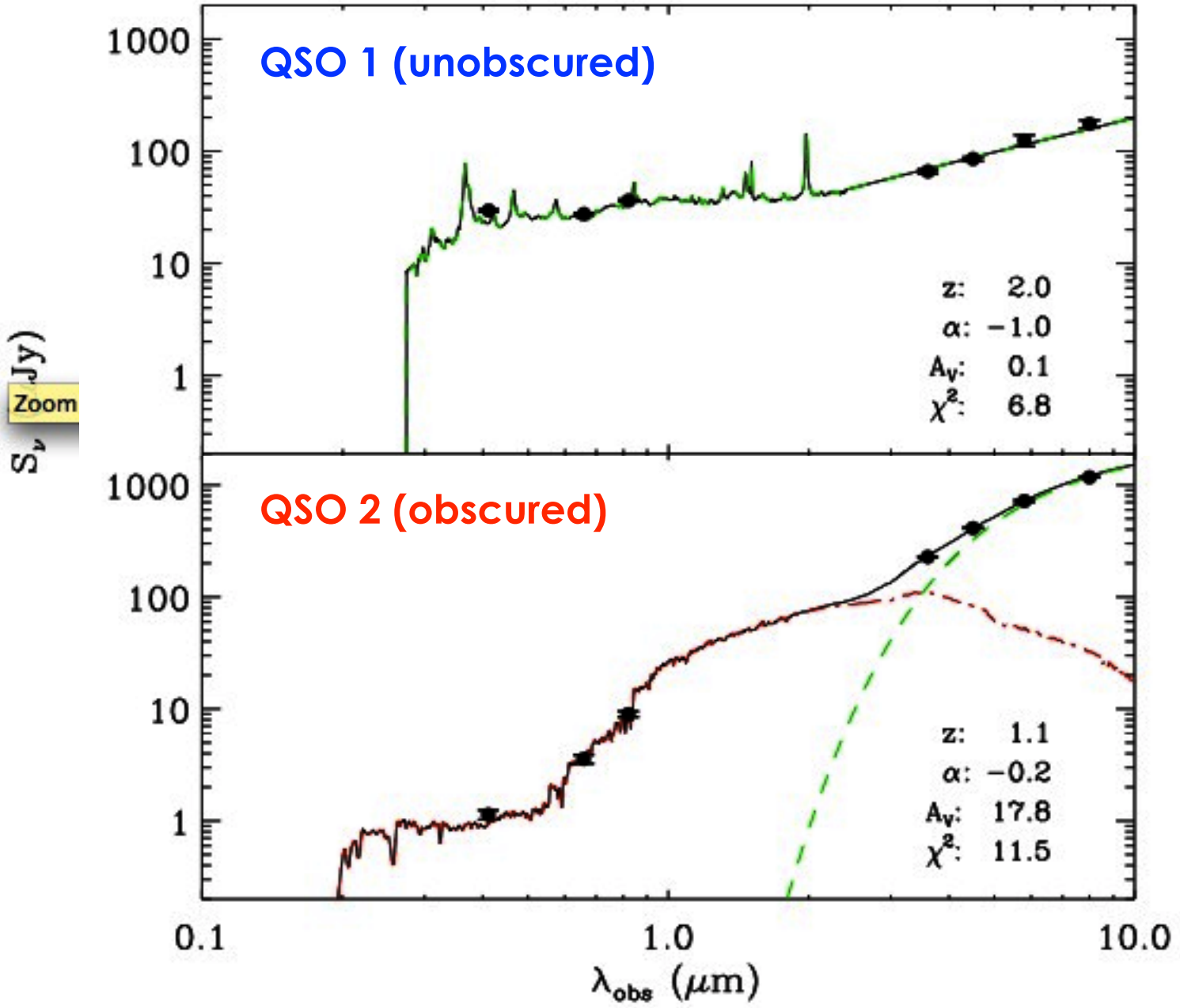
Can find large populations of obscured quasars with *Spitzer*!

(e.g., Lacy et al. 2004, Stern et al. 2005, Rowan-Robinson et al. 2005, Martinez-Sansigre et al. 2006, 2008, Polletta et al. 2006, 2008, **Hickox et al. 2007**, Donley et al. 2007, 2008, Alexander et al. 2008)

IRAC quasar selection

Hickox et al. (2007)

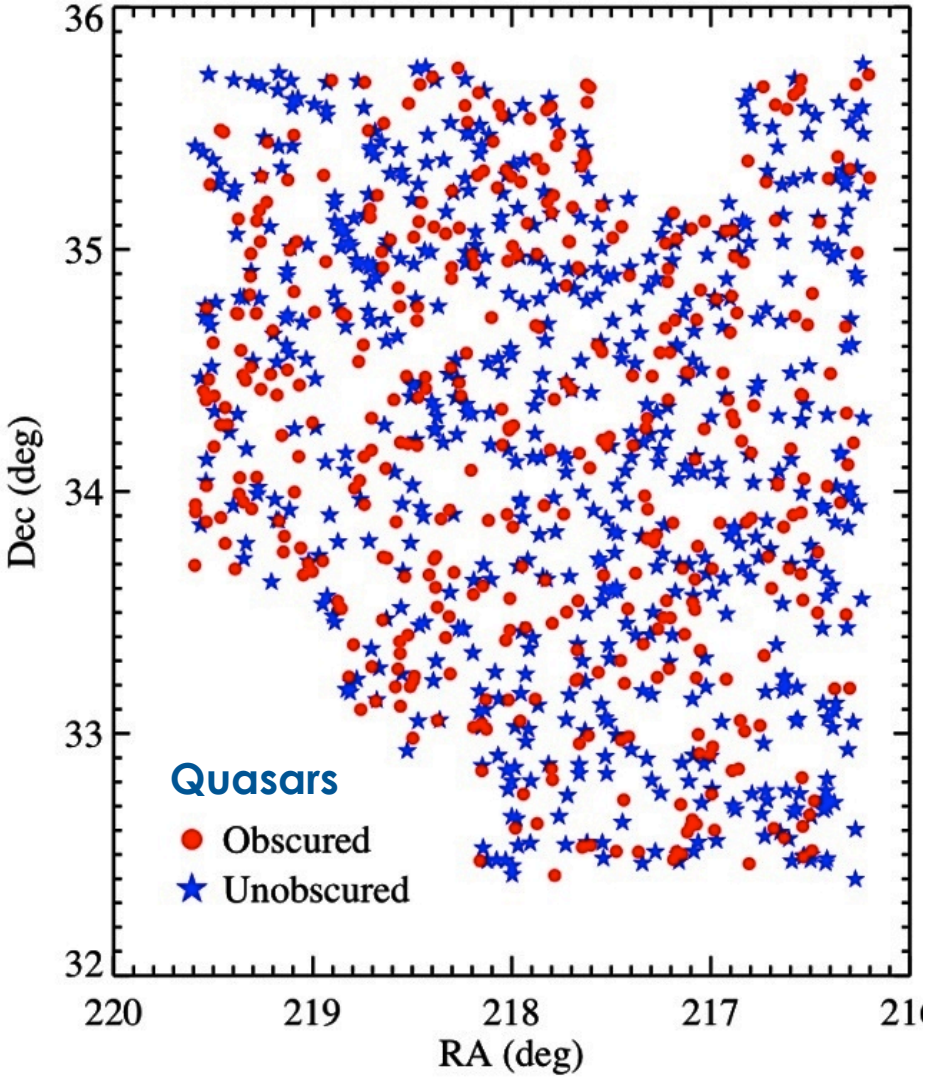




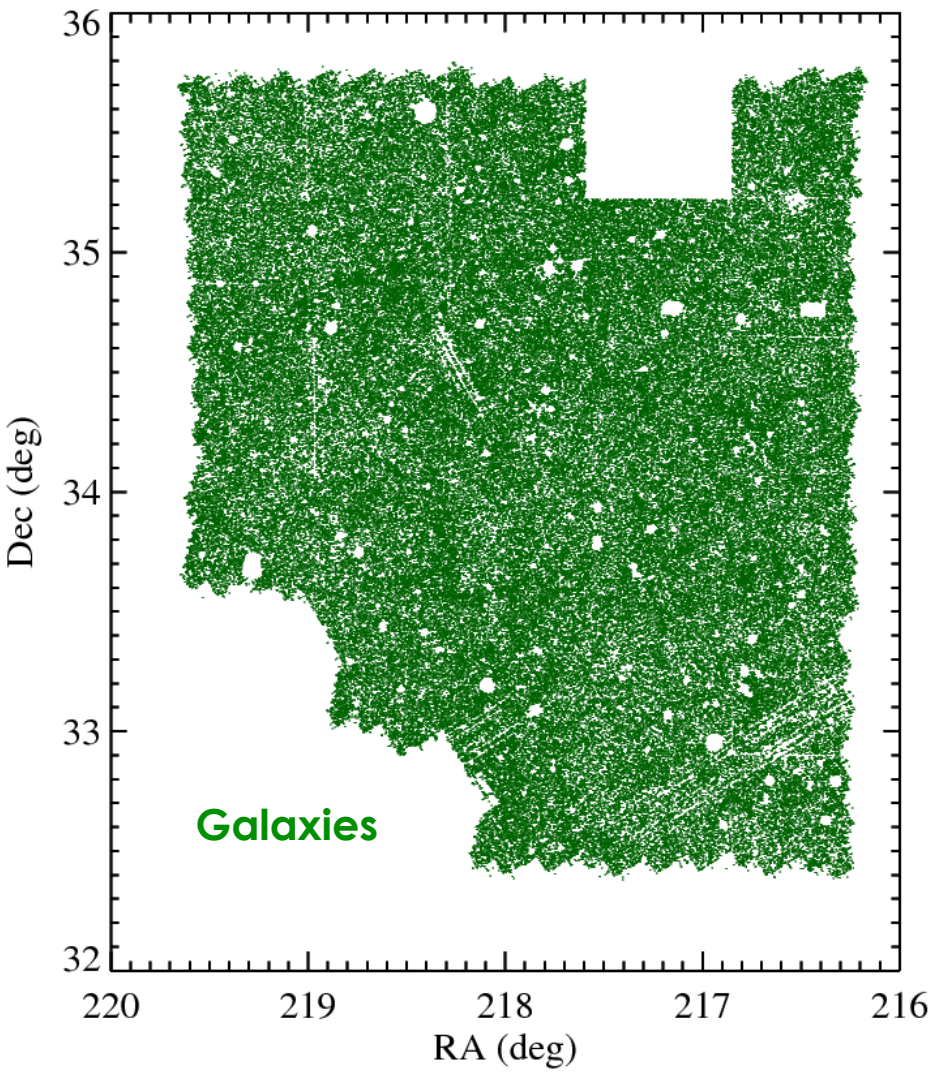
Hickox et al. (2007)

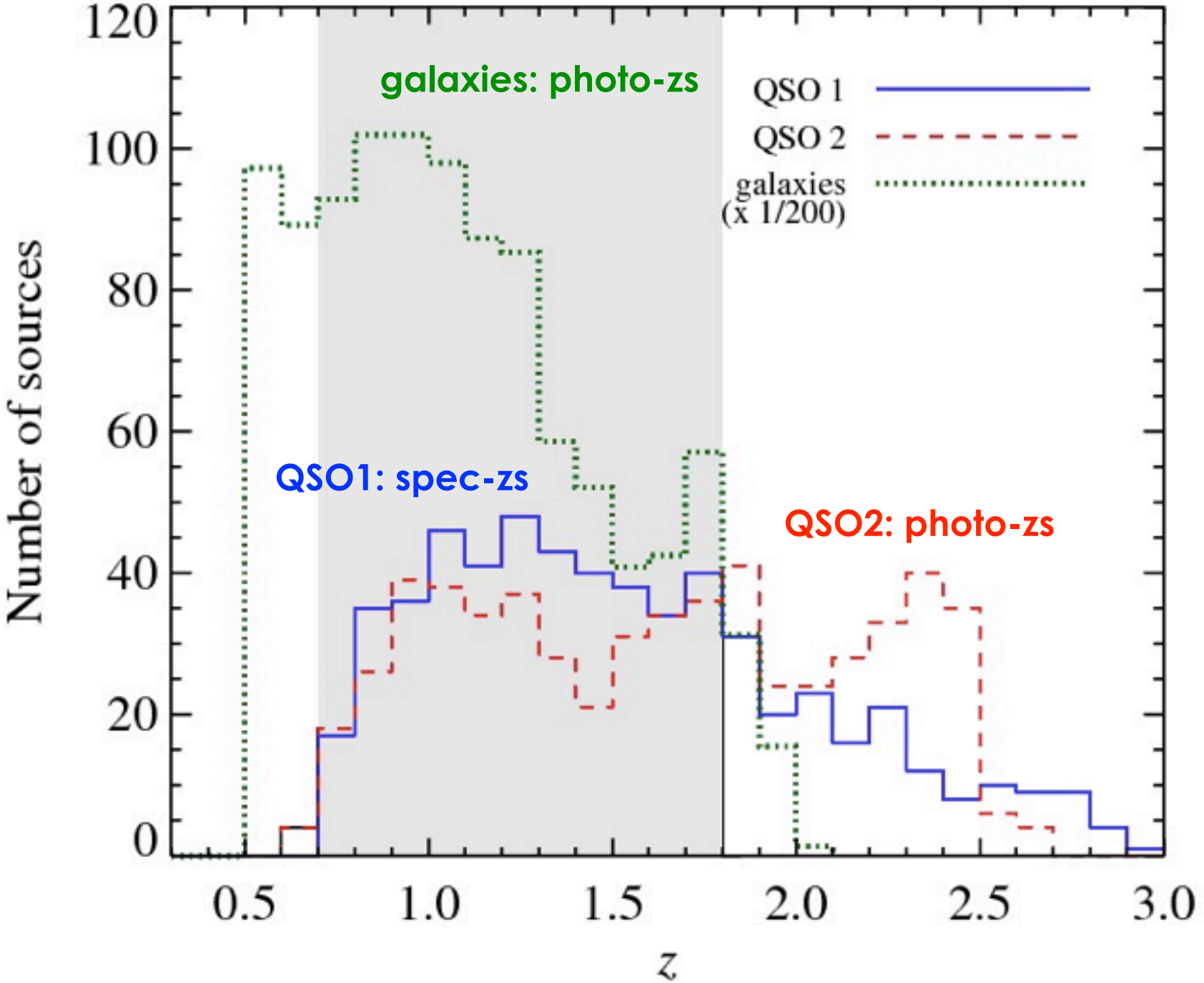
Infrared-selected quasars

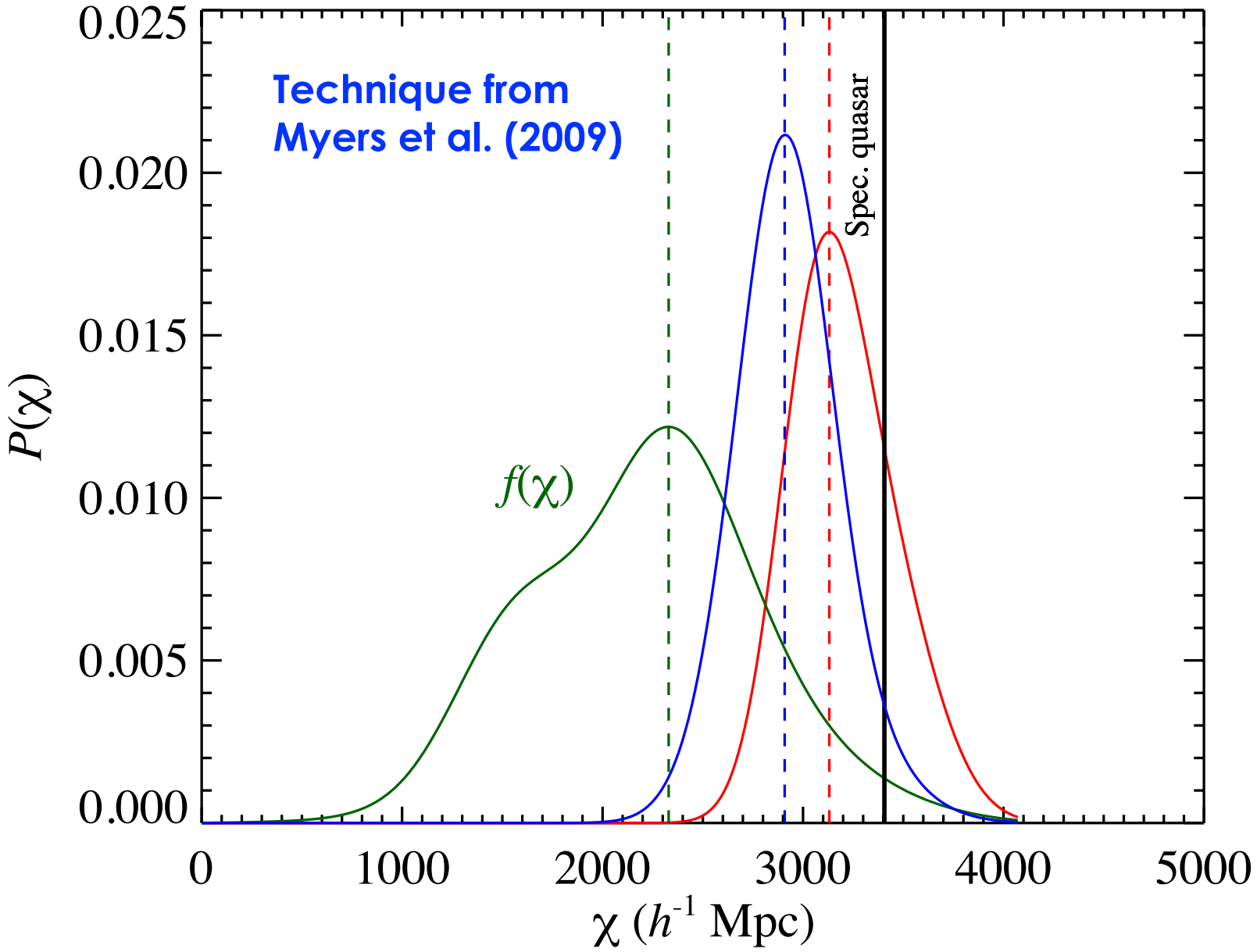
Hickox et al. (2007)

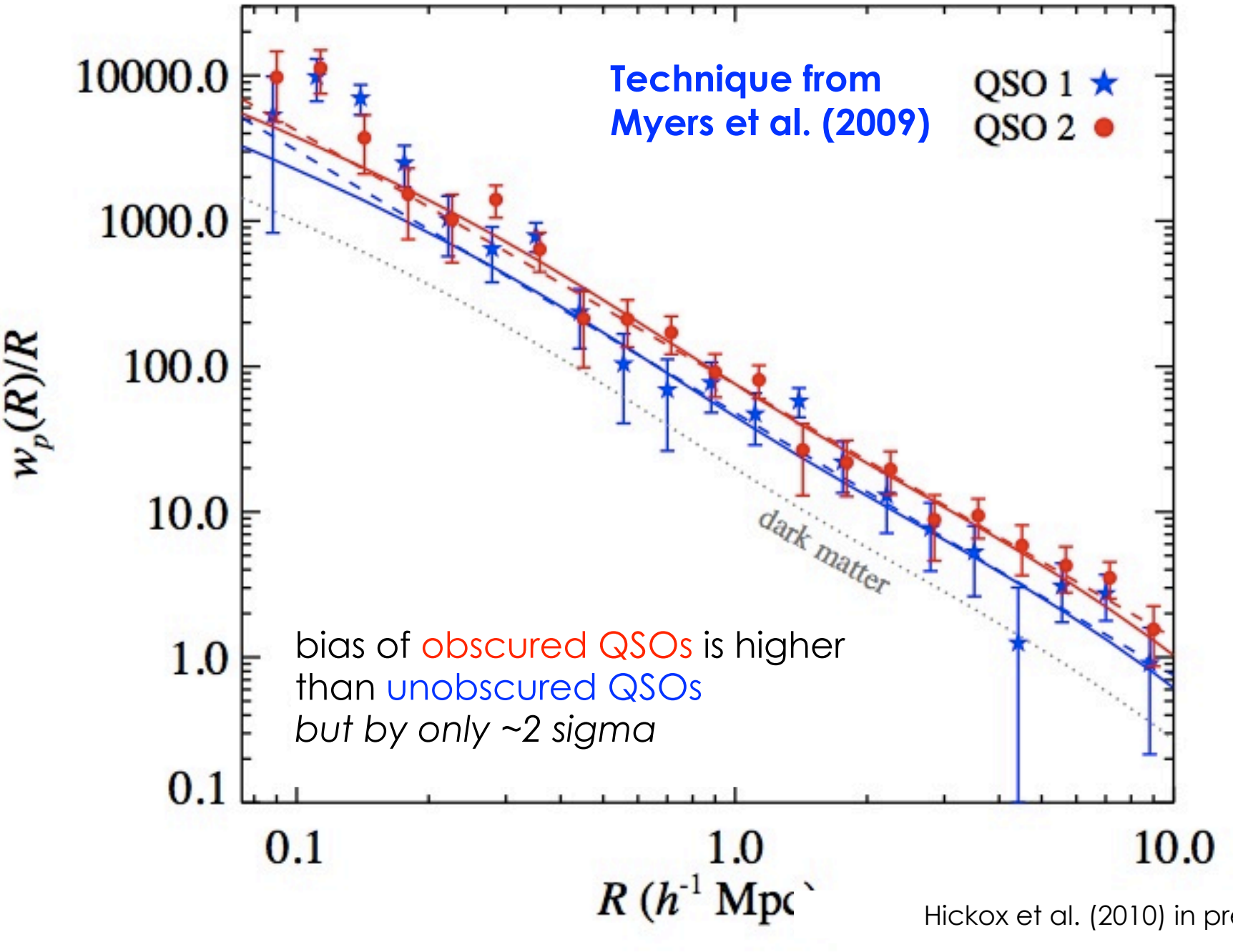


Brodwin et al. (2006)

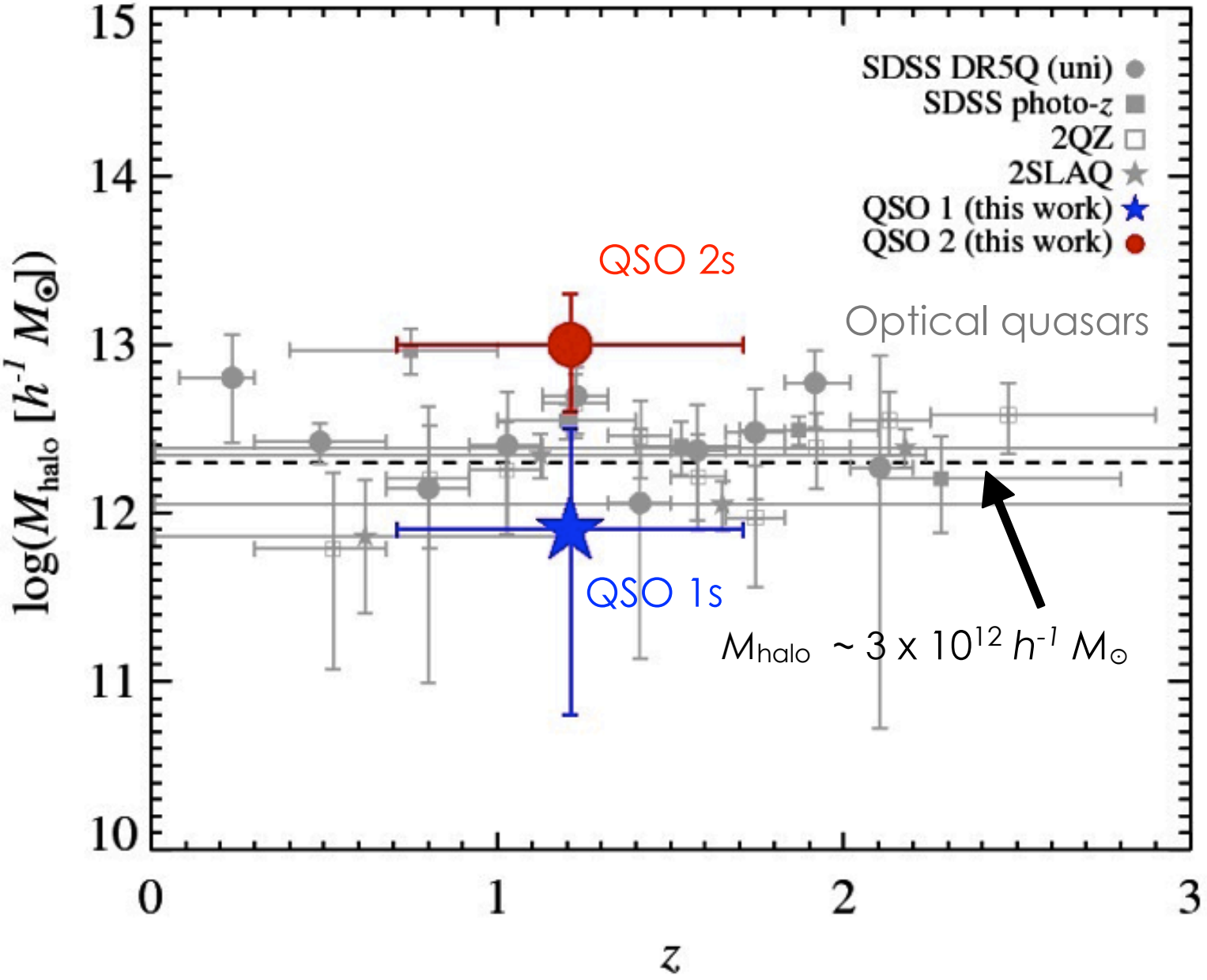


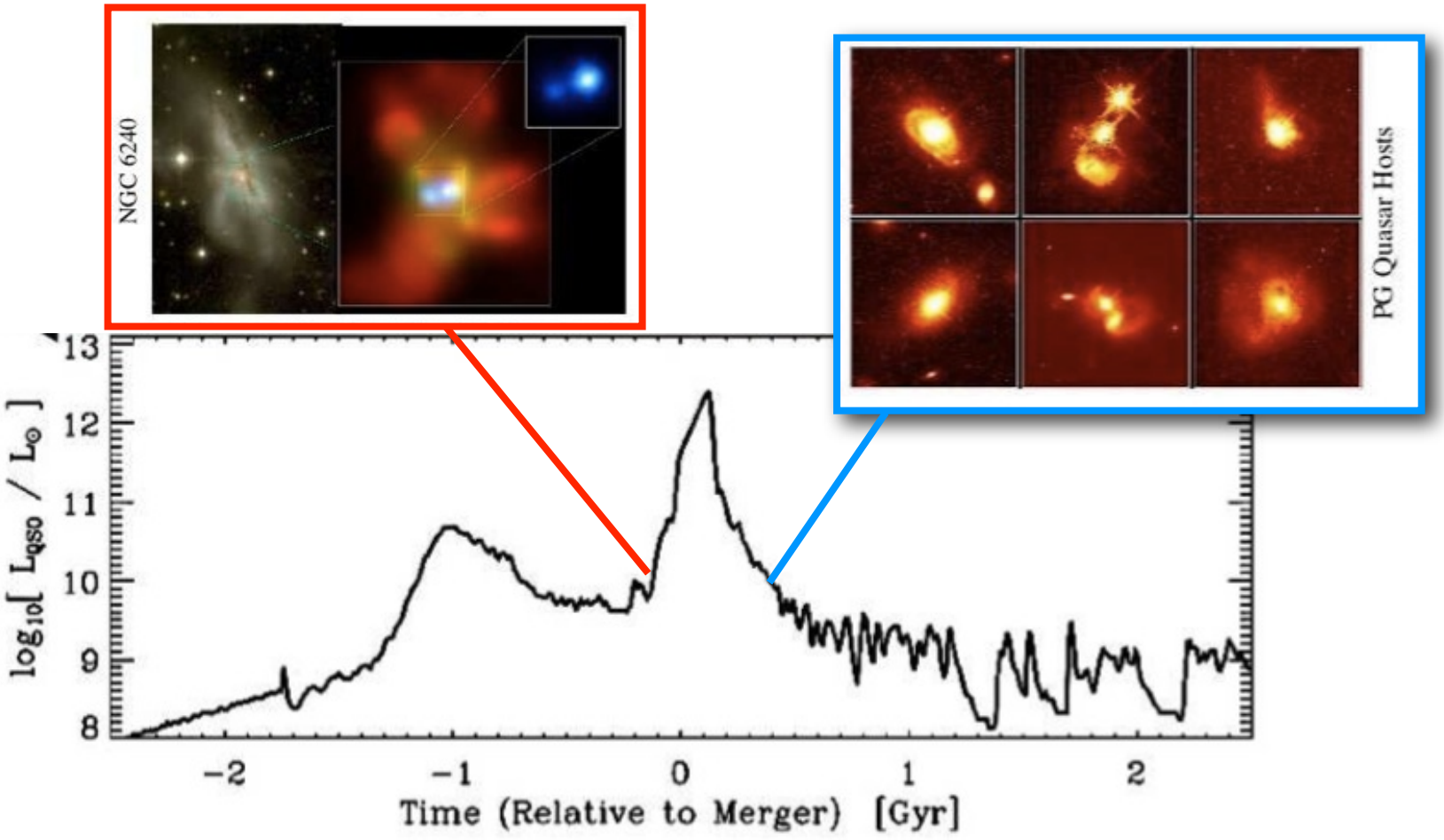

galaxies: photo-zs
QSO 1
QSO 2
galaxies
(x 1/200)
QSO1: spec-zs
QSO2: photo-zs
Number of sources
z
120
100
80
60
40
20
0
0.5
1.0
1.5
2.0
2.5
3.0


Technique from
Myers et al. (2009)
Spec. quasar
f(χ)
P(χ)
0.025
0.020
0.015
0.010
0.005
0.000
0
1000
2000
3000
4000
5000
χ (h^-1 Mpc)



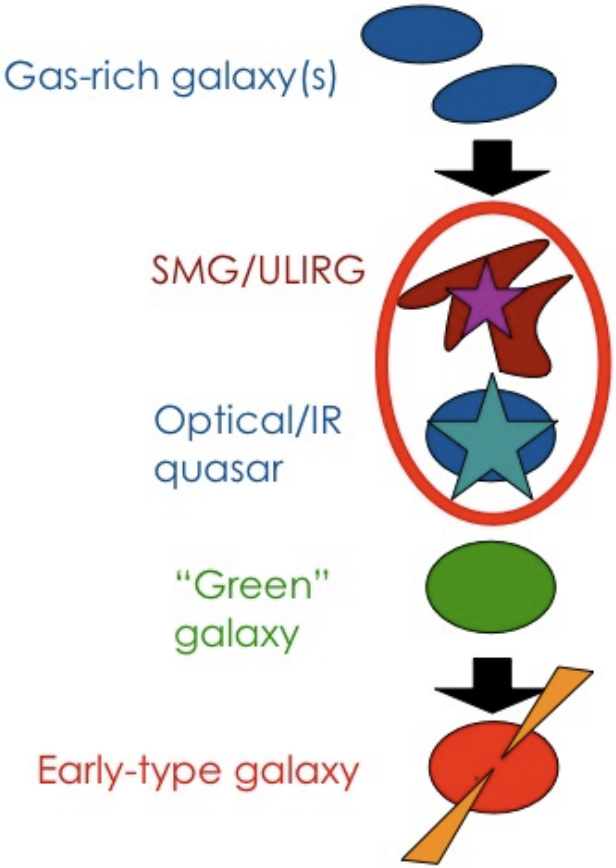
Hickox et al. (2010) in prep

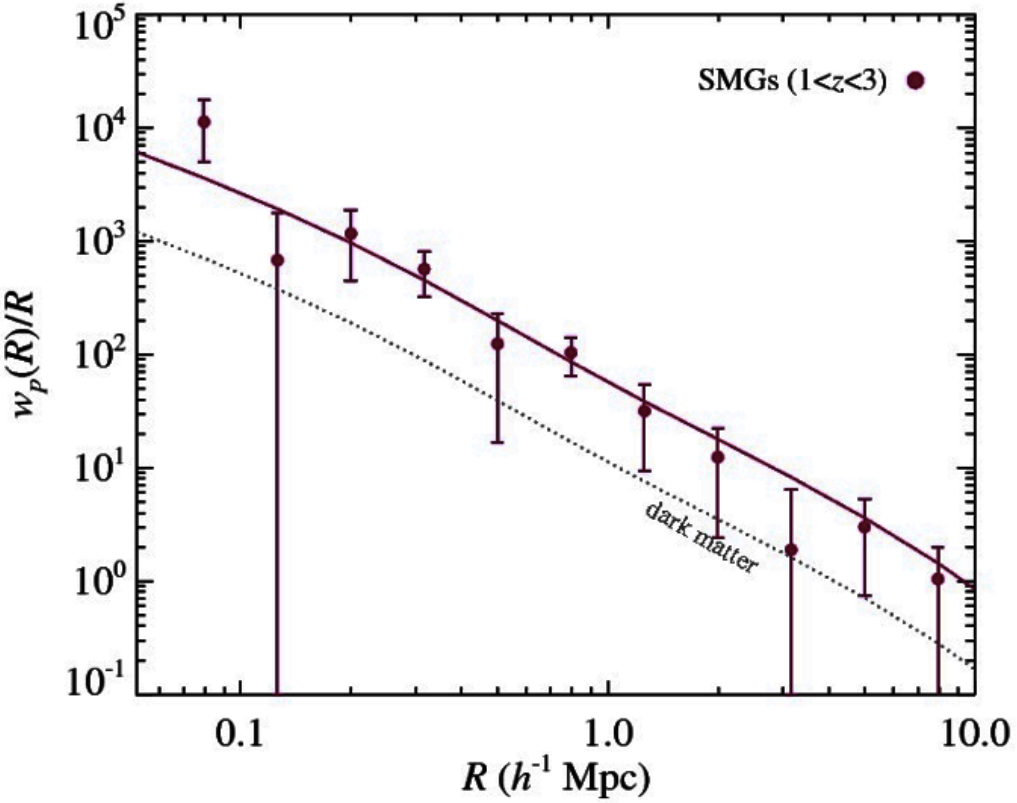

SDSS DR5Q (uni)
SDSS photo-z
2QZ
2SLAQ
QSO 1 (this work)
QSO 2 (this work)
QSO 2s
Optical quasars
QSO 1s
Mhalo ~ 3 x 10^12 h^-1 M⊙
log(Mhalo [h^-1 M⊙])
z
15
14
13
12
11
10
0
1
2
3



?

Hopkins et al. 2008

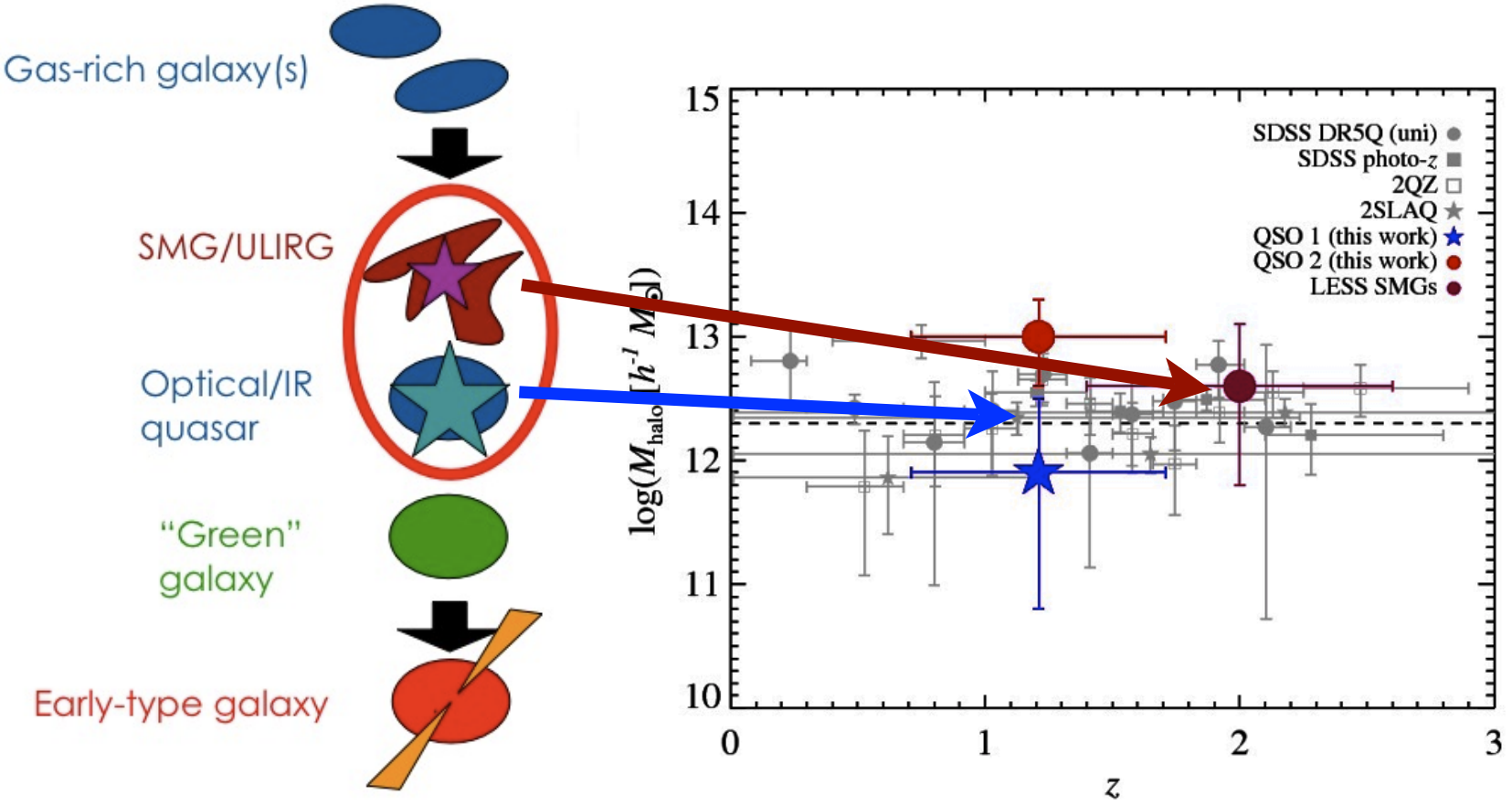




LESS submm galaxies

(Wardlow et al. 2010, Hickox et al. in prep

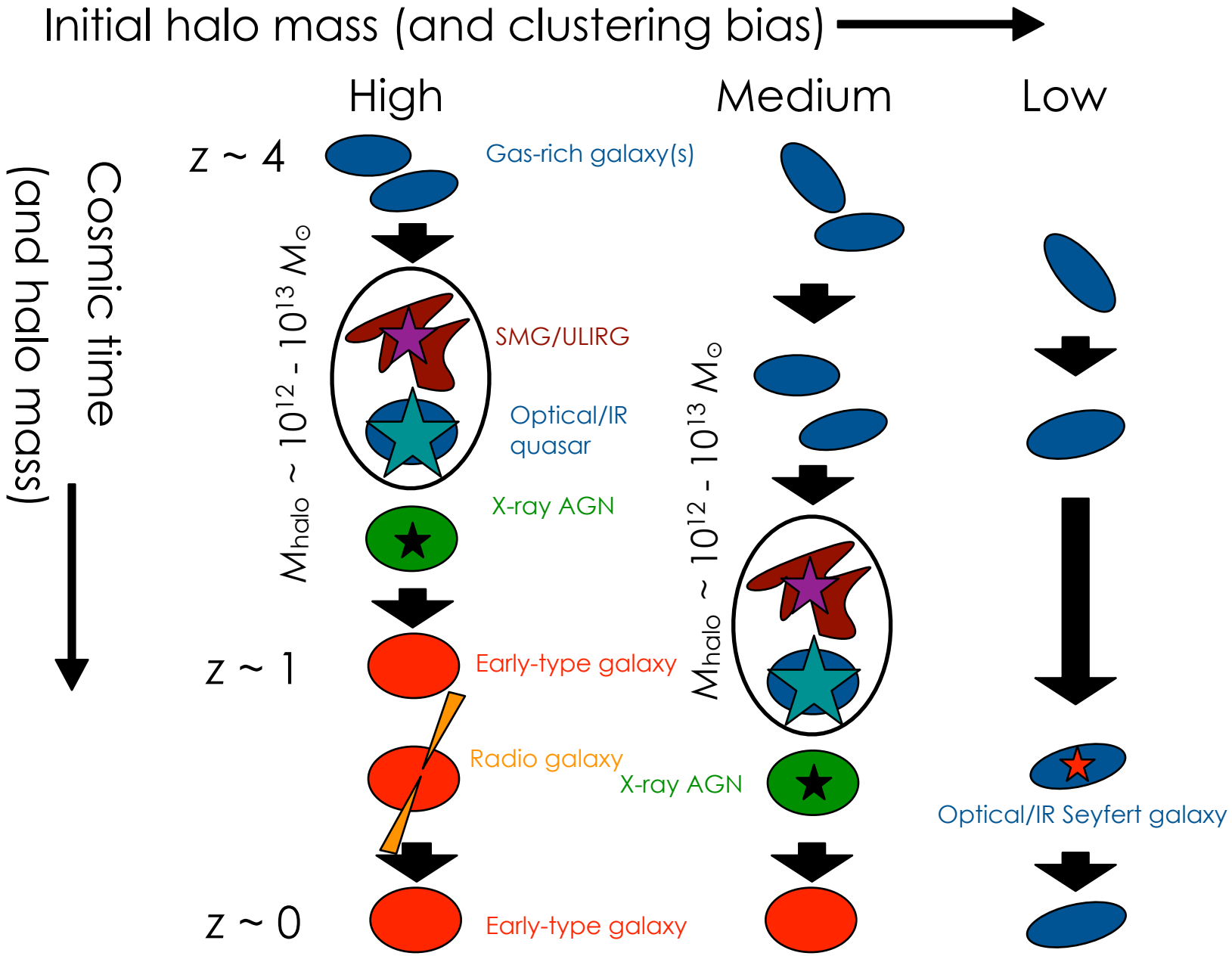
see also e.g., Weiss et al. 2009, Blain et al. 2004)

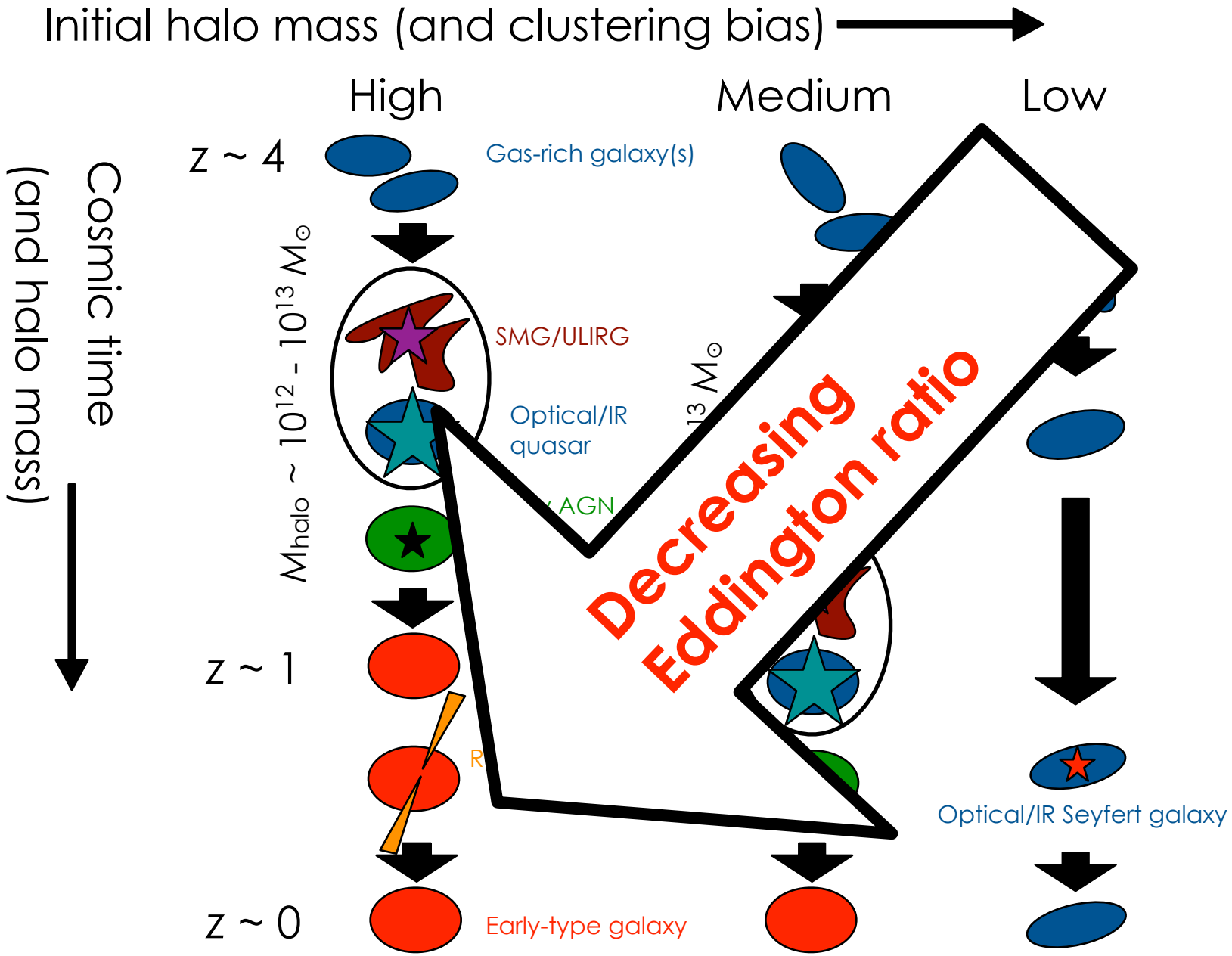


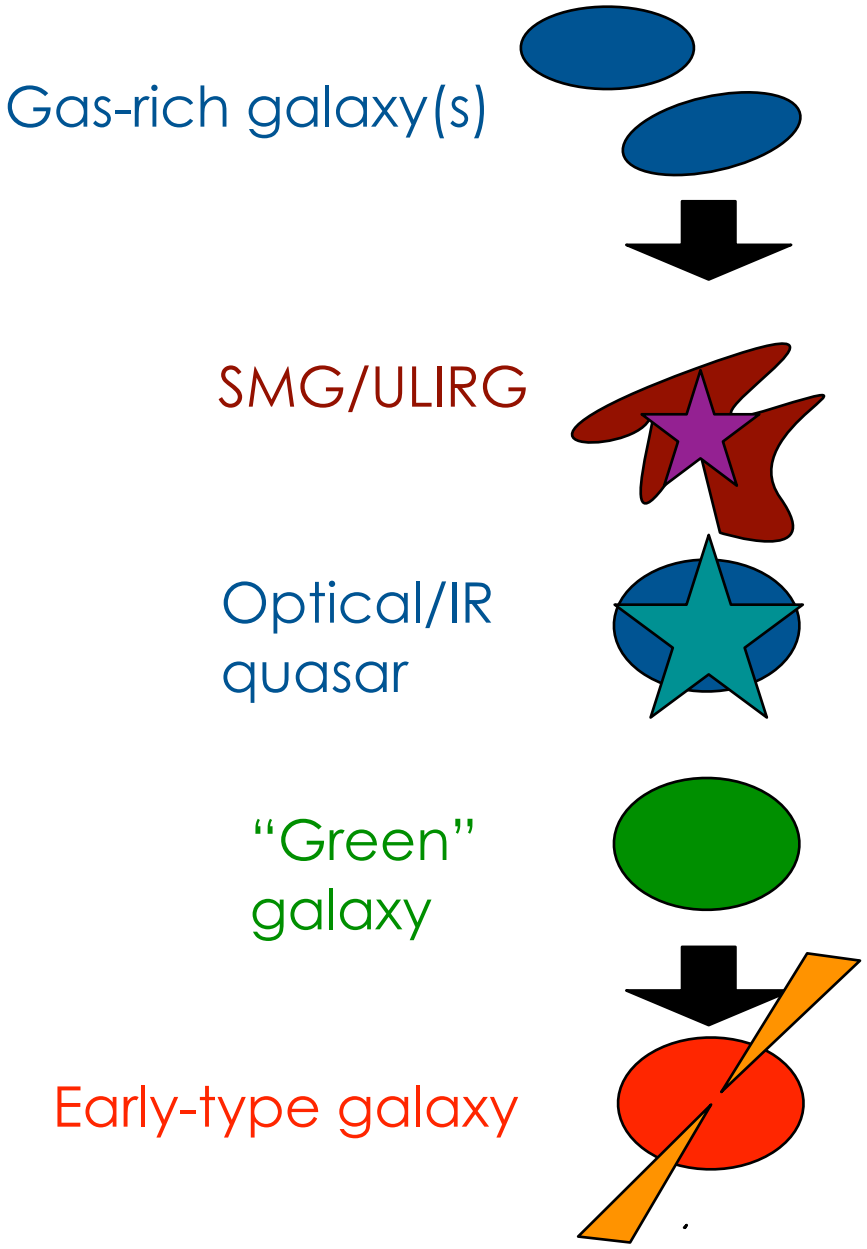
LESS submm galaxies

(Wardlow et al. 2010, Hickox et al. in prep

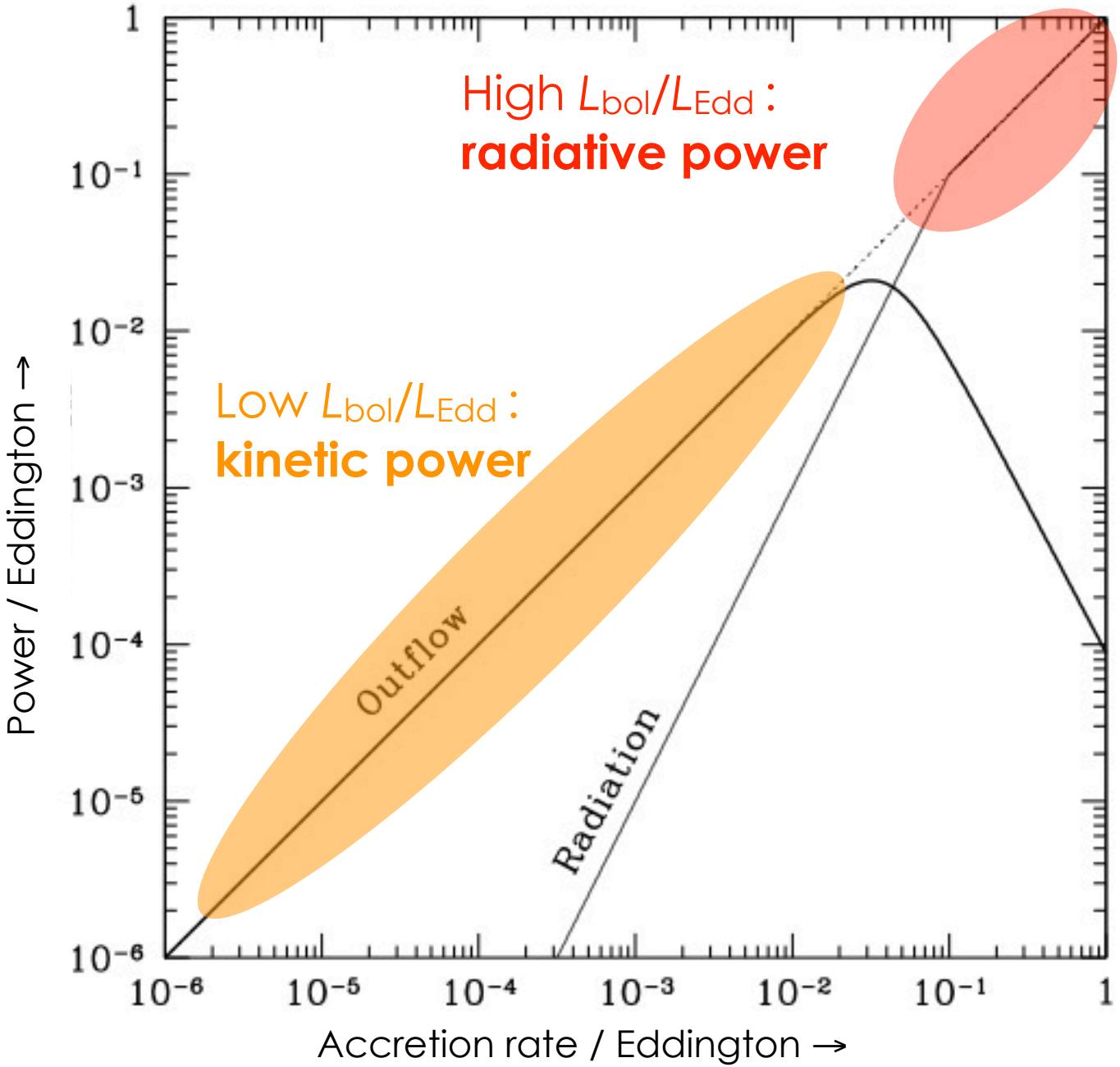
see also e.g., Weiss et al. 2009, Blain et al. 2004)


Initial halo mass (and clustering bias)
High
Medium
Low
Cosmic time (and halo mass)
z ~ 4
z ~ 1
z ~ 0
Gas-rich galaxy(s)
SMG/ULIRG
Optical/IR quasar
X-ray AGN
Early-type galaxy
Radio galaxy
X-ray AGN
Early-type galaxy
Optical/IR Seyfert galaxy
Mhalo ~ 10^12 - 10^13 M⊙
Mhalo ~ 10^12 - 10^13 M⊙

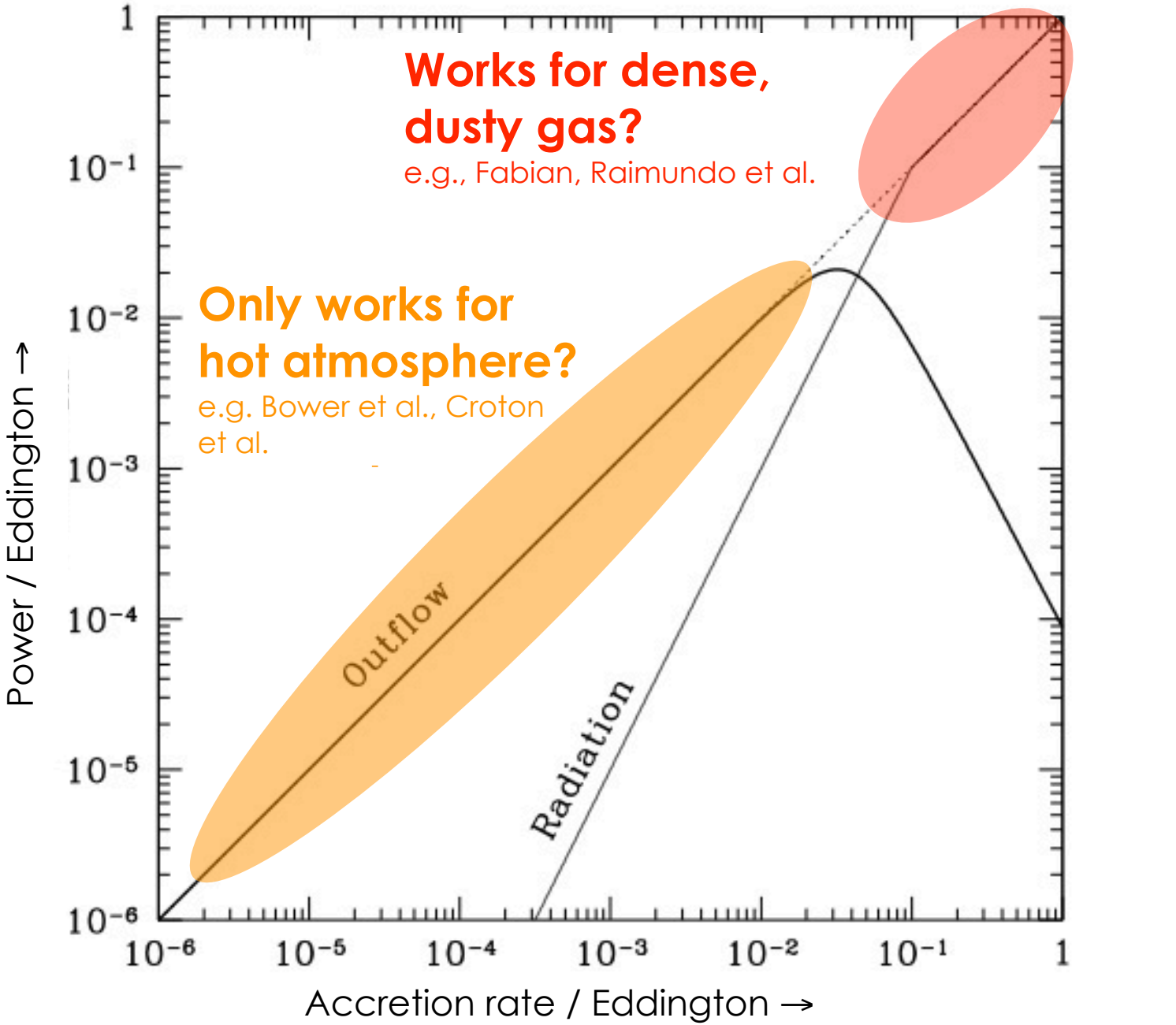

Initial halo mass (and clustering bias)
High
Medium
Low
Cosmic time (and halo mass)
z ~ 4
z ~ 1
z ~ 0
Gas-rich galaxy(s)
SMG/ULIRG
Optical/IR quasar
AGN
Decreasing Eddington ratio
Optical/IR Seyfert galaxy
Early-type galaxy
$M_{halo} \sim 10^{12}$ - 10^{13} $M_\odot$
^{13} $M_\odot$



Where is feedback at work?

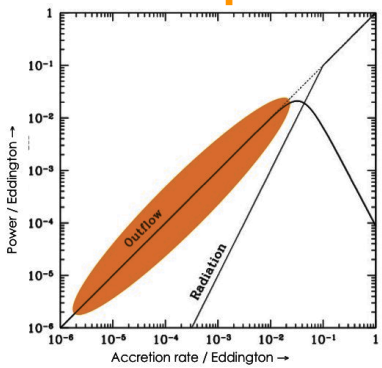


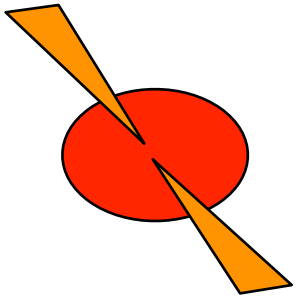
Churazov et al. (2005)

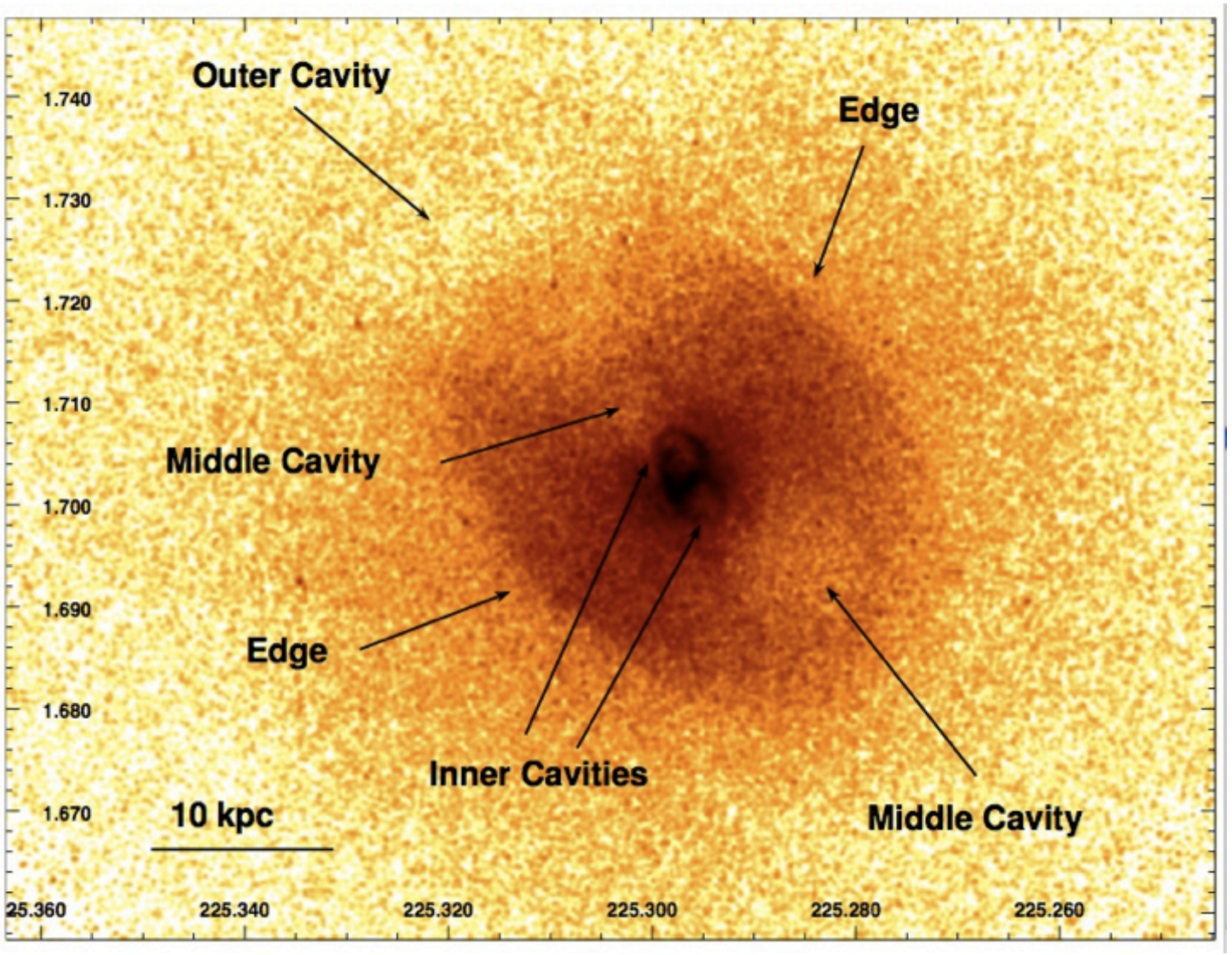


Churazov et al. (2005)

Kinetic power

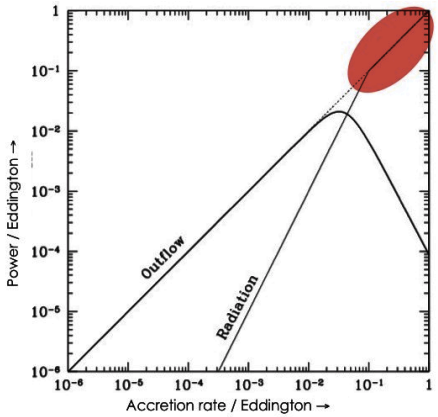


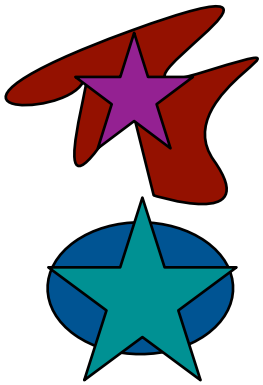




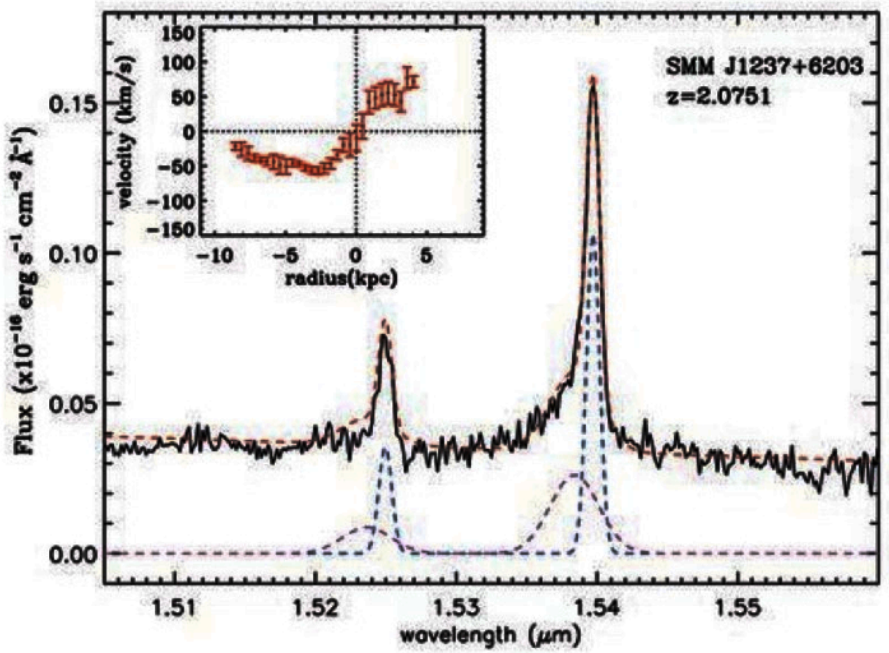
Group central galaxy NGC 5813 (Randall et al. 2010) see **many others** for similar examples

Radiative power



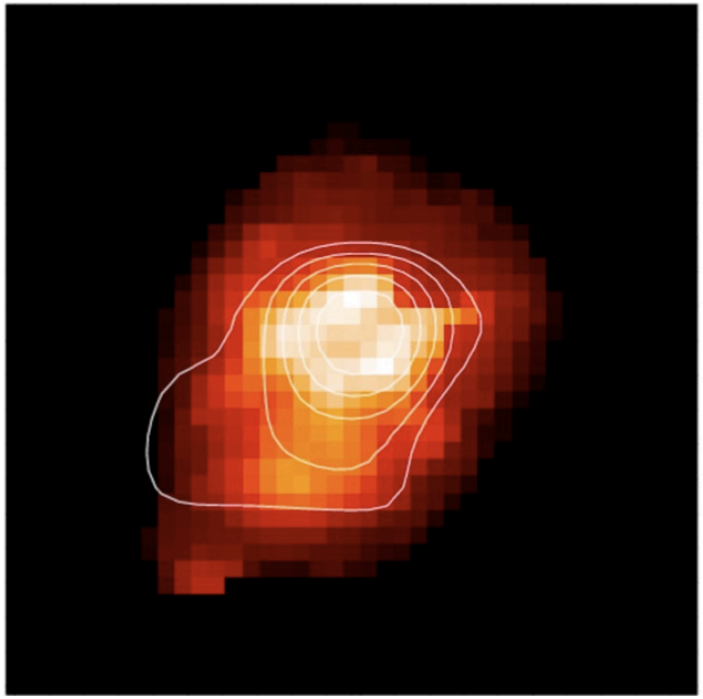


Collapsed IFU spectrum of z~2.07 SMG



Alexander et al. (2010)

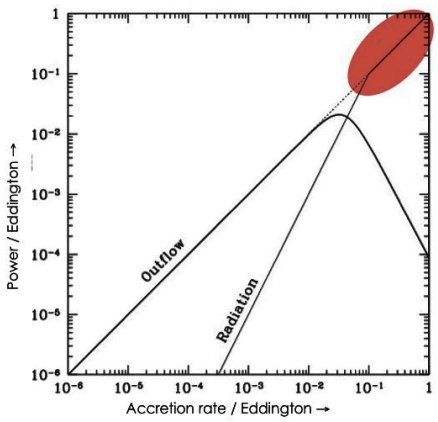
~4-8 kpc extent of broad [OIII gas]

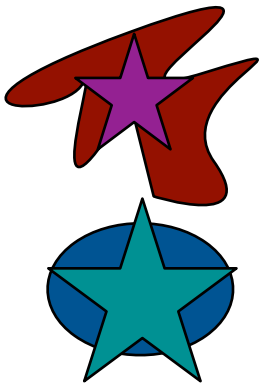


Broad (800 km/s) high-velocity (200-500 km/s) [OIII] gas

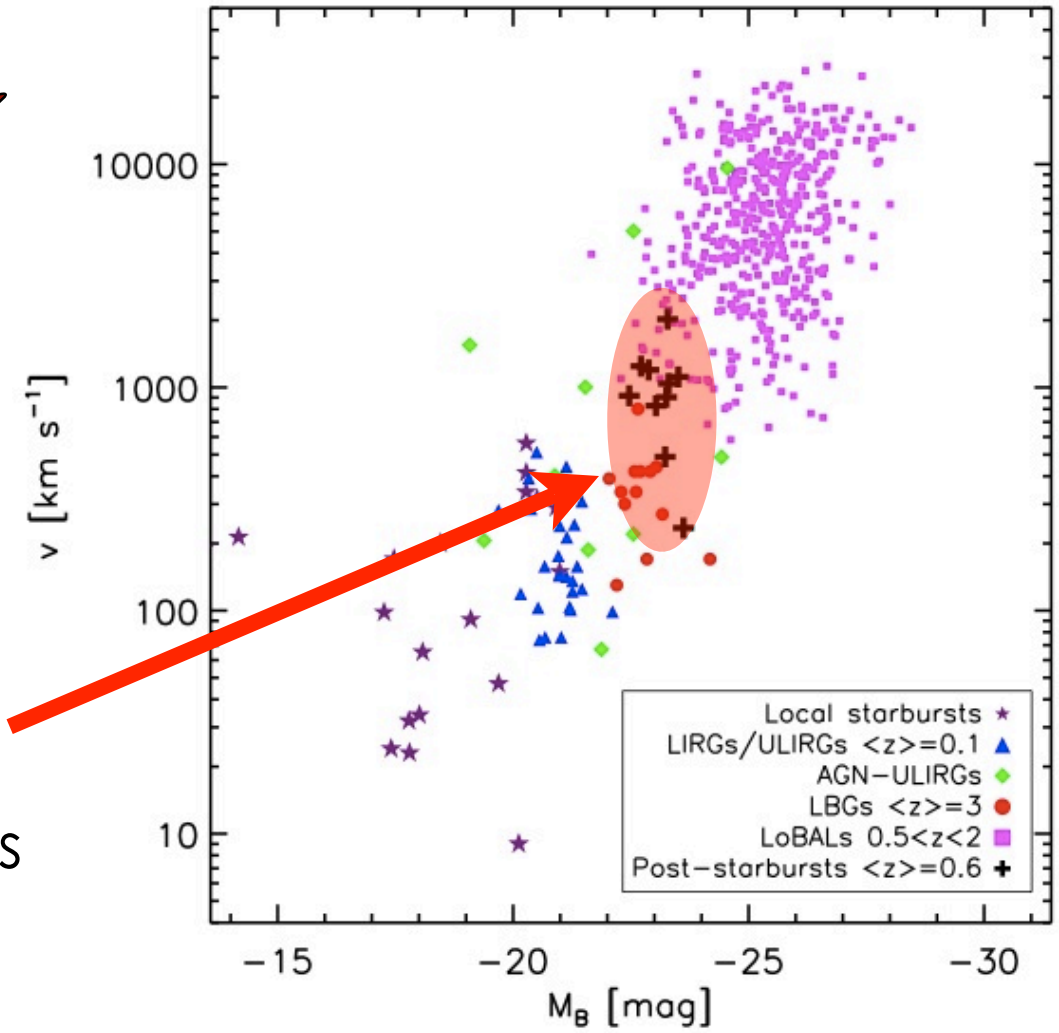
For radio-loud sources see Nesvadba et al., Siemignowska et al.

Radiative power



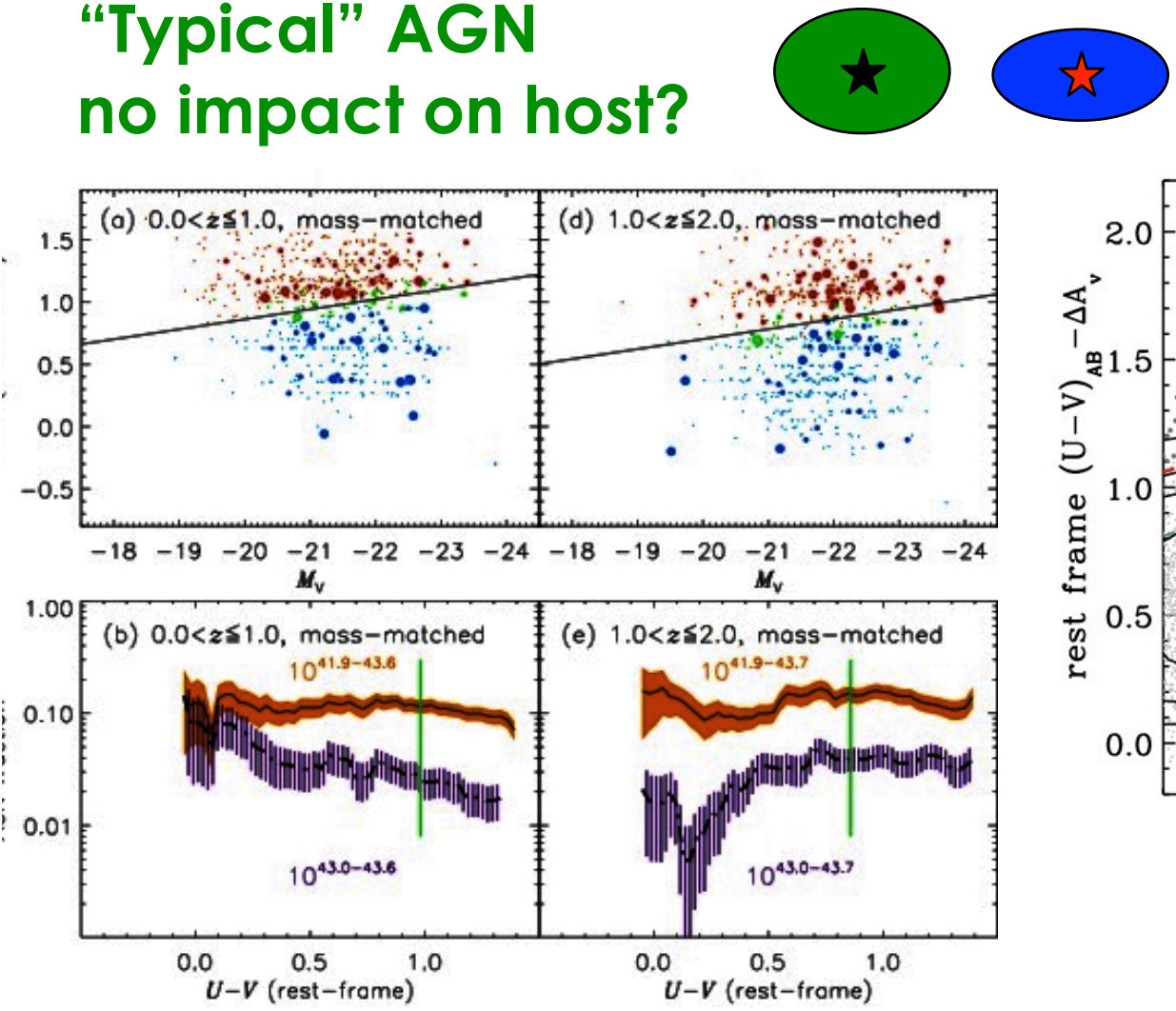


v ~ 1000 km/s winds from massive, young post-starburst galaxies

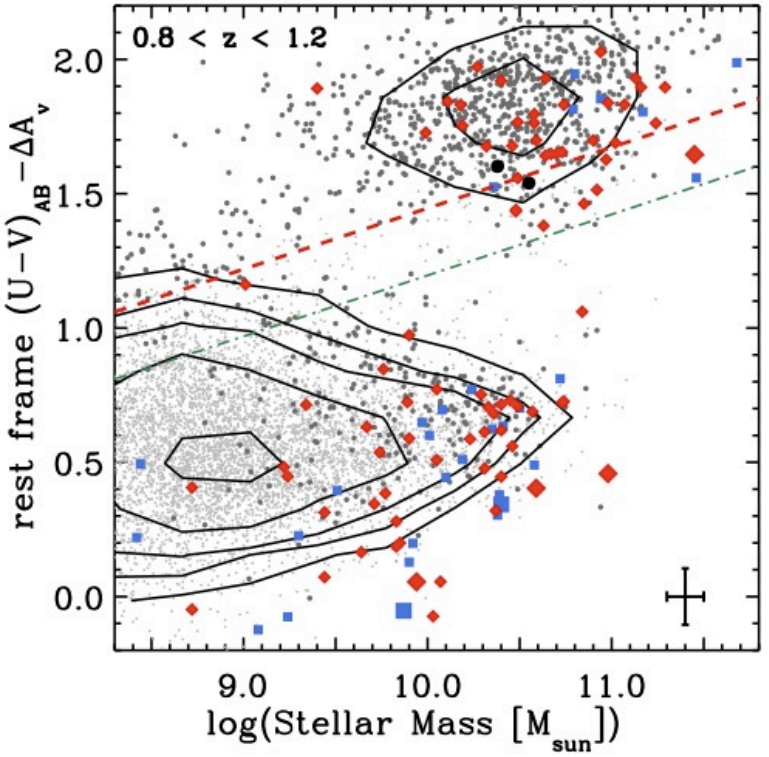


Tremonti et al. (2007) [optical]

"Typical" AGN
no impact on host?

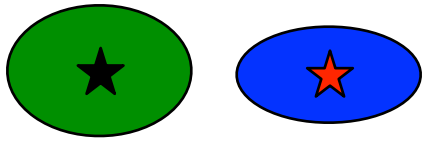


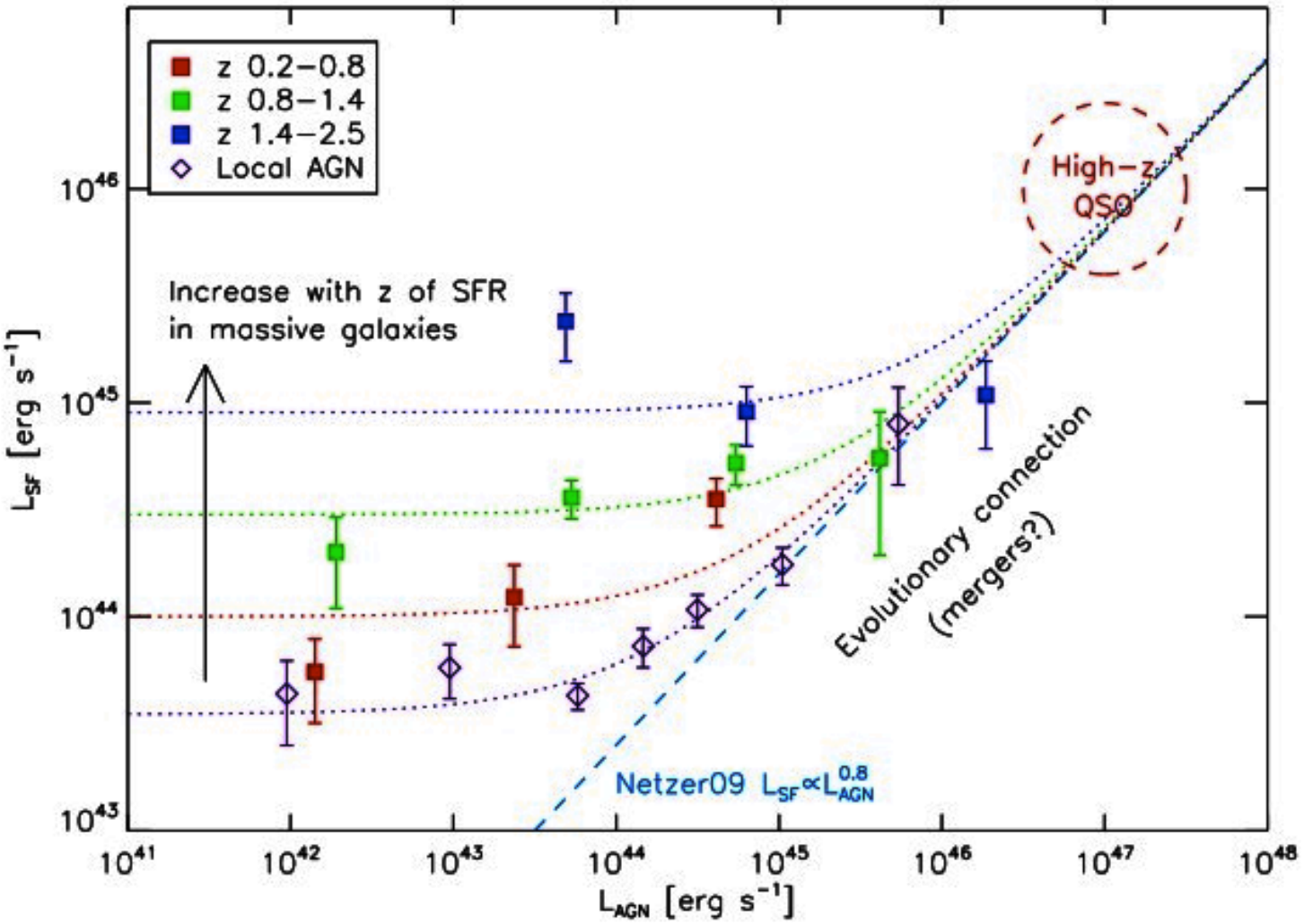
Xue et al. (2010) [X-ray]



Cardamone et al. (2010) [X-ray]

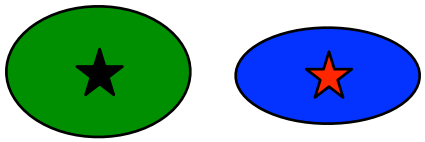
"Typical" AGN
no impact on host?

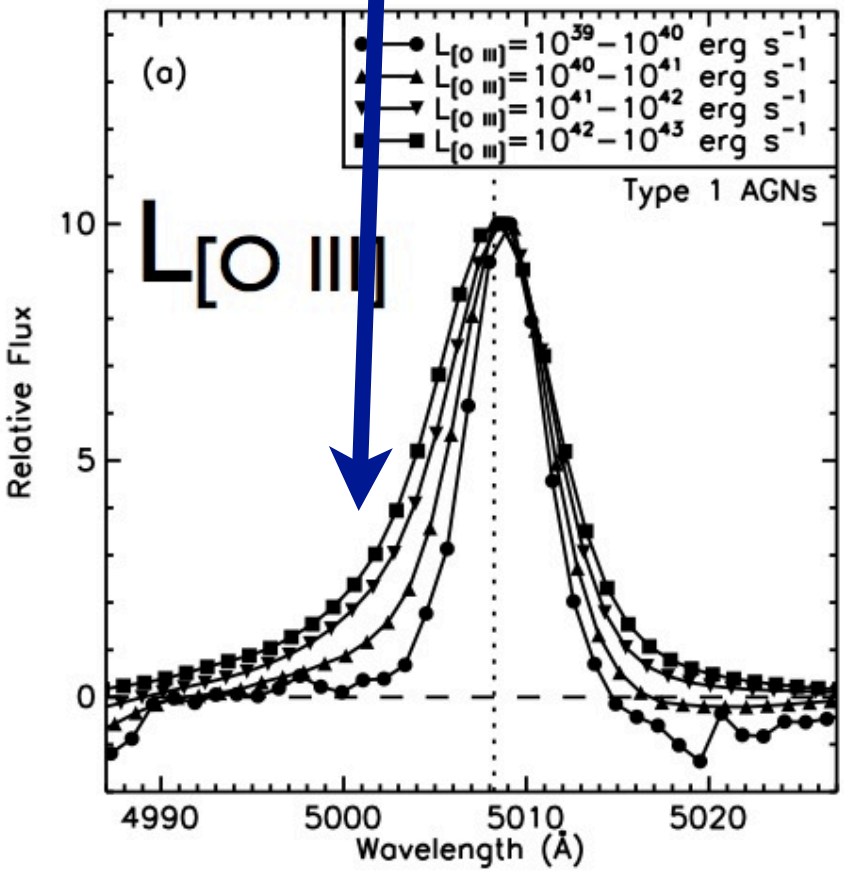




Shao et al. (2010) [X-ray], see also Mullaney et al. (2010), Laird et al., Silverman et al.

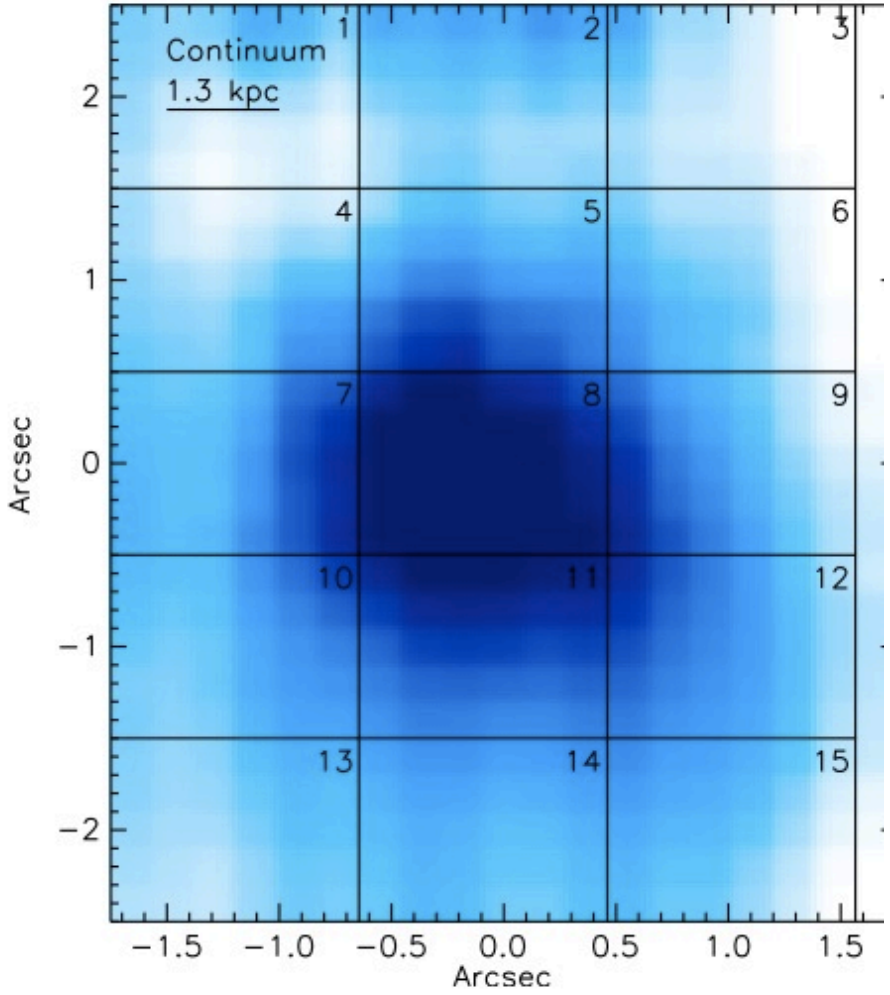
Ubiquitous outflows at low z?





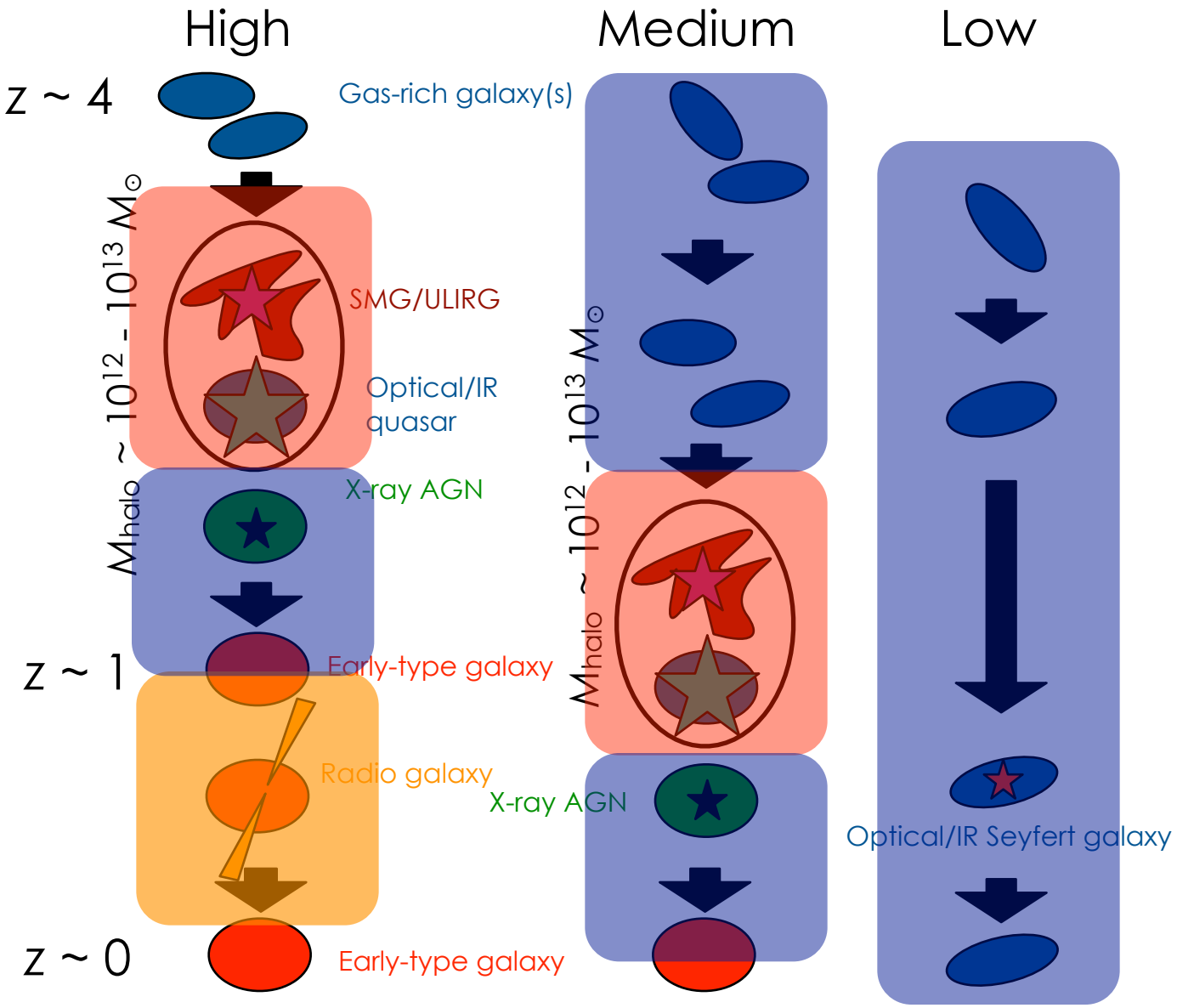
Mullaney et al. in prep [optical]

Black hole self-regulation?

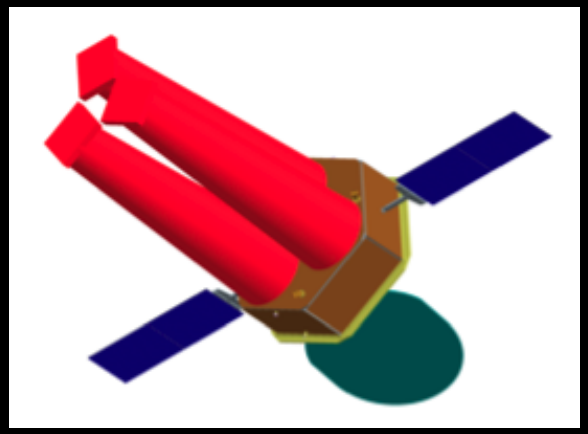


Radiative and **mechanical** feedback strongly affects host

Black hole **self-regulation?**

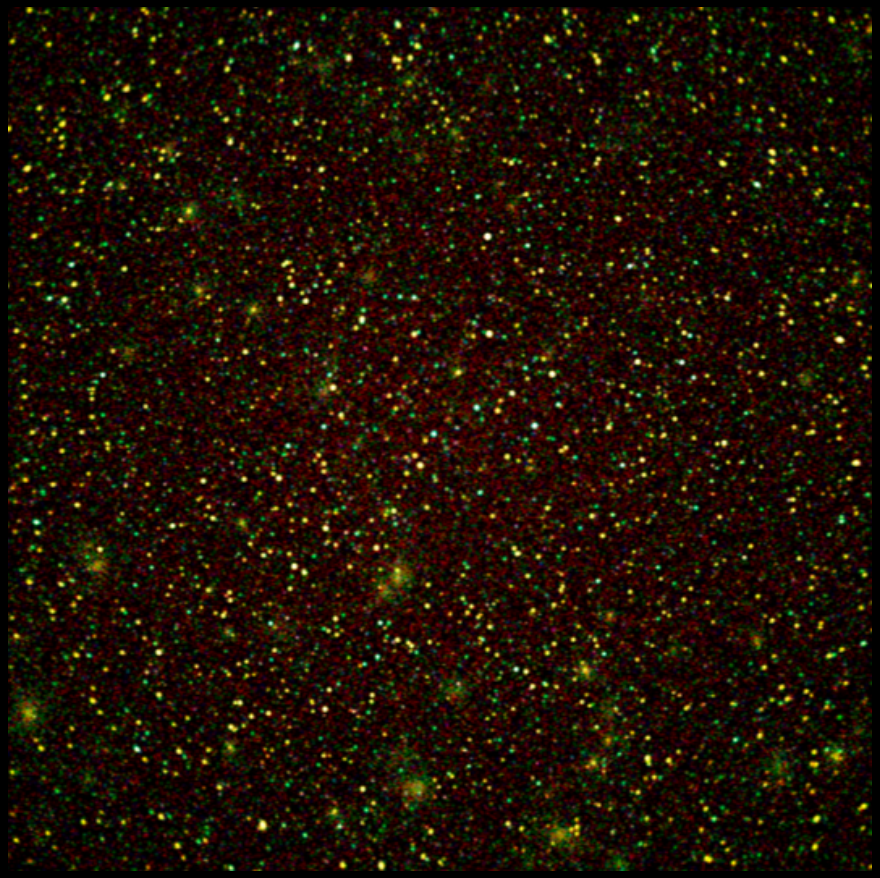


Wide-Field X-ray Telescope (WFXT)



Large-area survey mission (0.1-6 keV)

Will detect and characterize **tens of millions of AGN**. Similar studies for AGN evolution as SDSS has enabled for galaxies.



Simulated 1 deg^2 WFXT image

http://wfxt.pha.jhu.edu