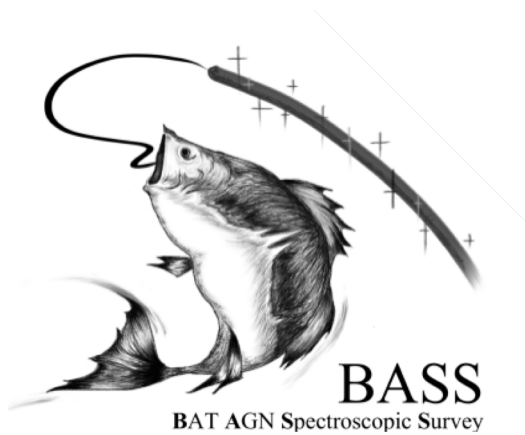


Clustering of hard X-ray selected AGN



Merry Powell
Yale University



With: Meg Urry, Nico Cappelluti, Justin Johnson, BASS Team, AHA Team

Clustering → environments

Halo mass



Field galaxies



Galaxy groups



Galaxy clusters



Large-scale clustering strength



What drives AGN clustering?

Selection Effects

- Host galaxy properties
- Incompleteness
- Survey volume

vs.

AGN parameters?

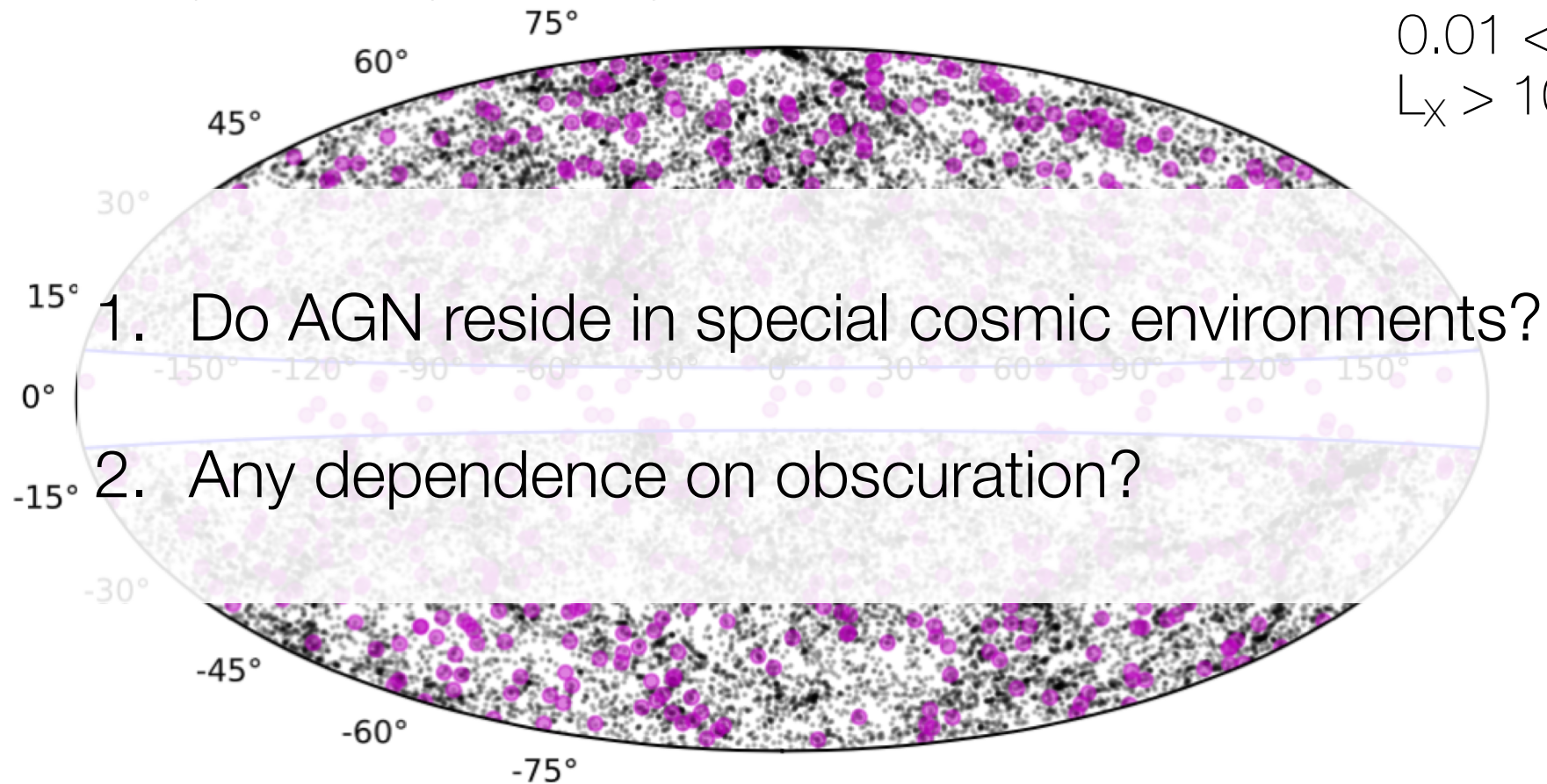
- Obscuration
- Accretion rate
- Black hole mass

AGN clustering at $z=0$

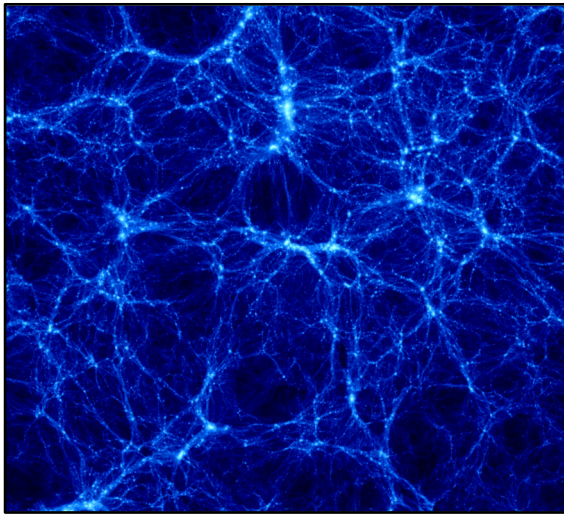
Swift/**BAT** **AGN** **S**pectroscopic **S**urvey

$0.01 < z < 0.1$
 $L_x > 10^{42.5}$ erg/s

- BASS
- 2MASS



Galaxy (AGN) - halo connection

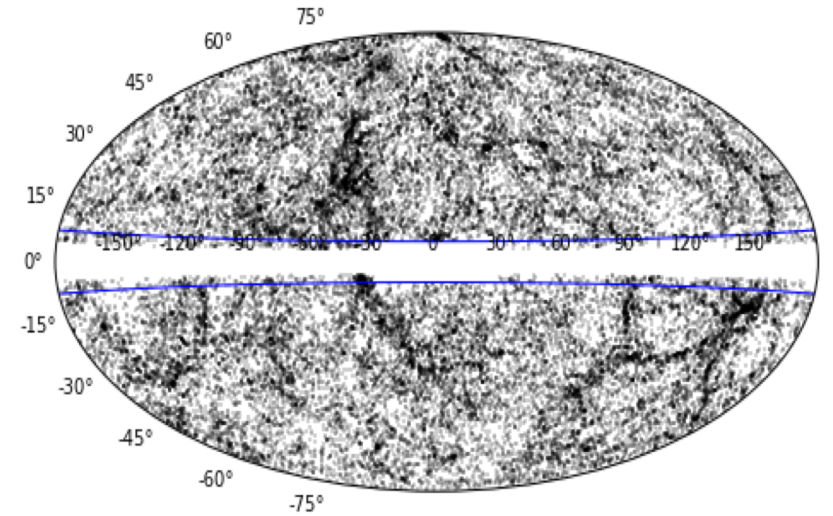


Dark matter

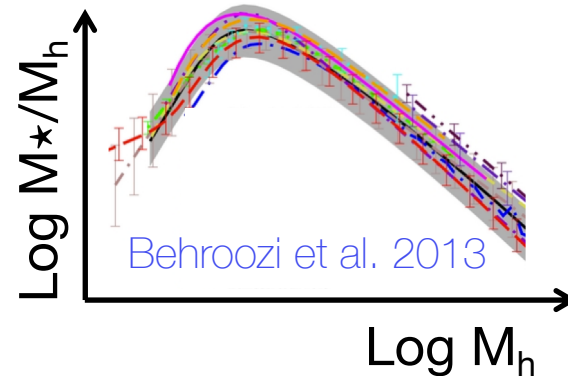
+

Empirical
Halo Model

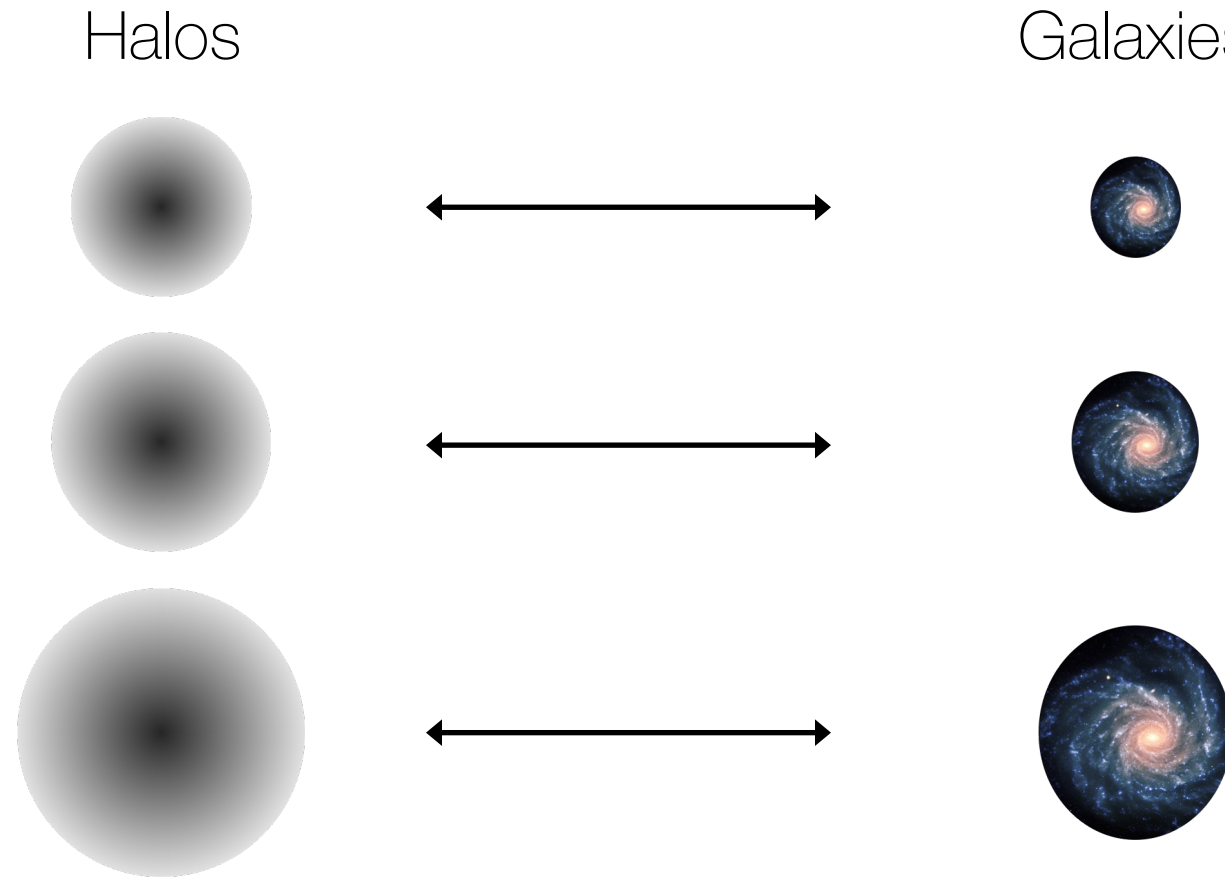
=



Galaxy distributions



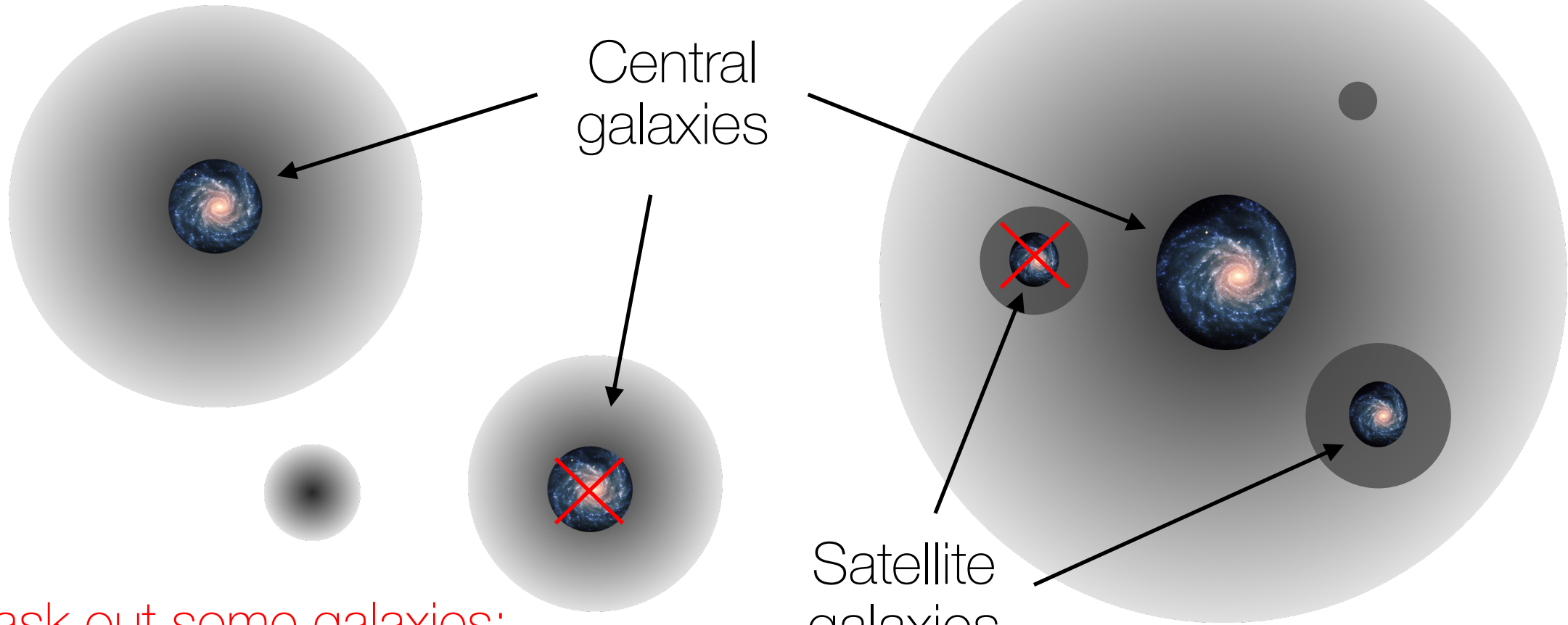
Subhalo Abundance Matching model



$$n_{\text{subhalos}}(>M_{\text{subhalo}}) = n_{\text{gal}}(>M_{\star})$$

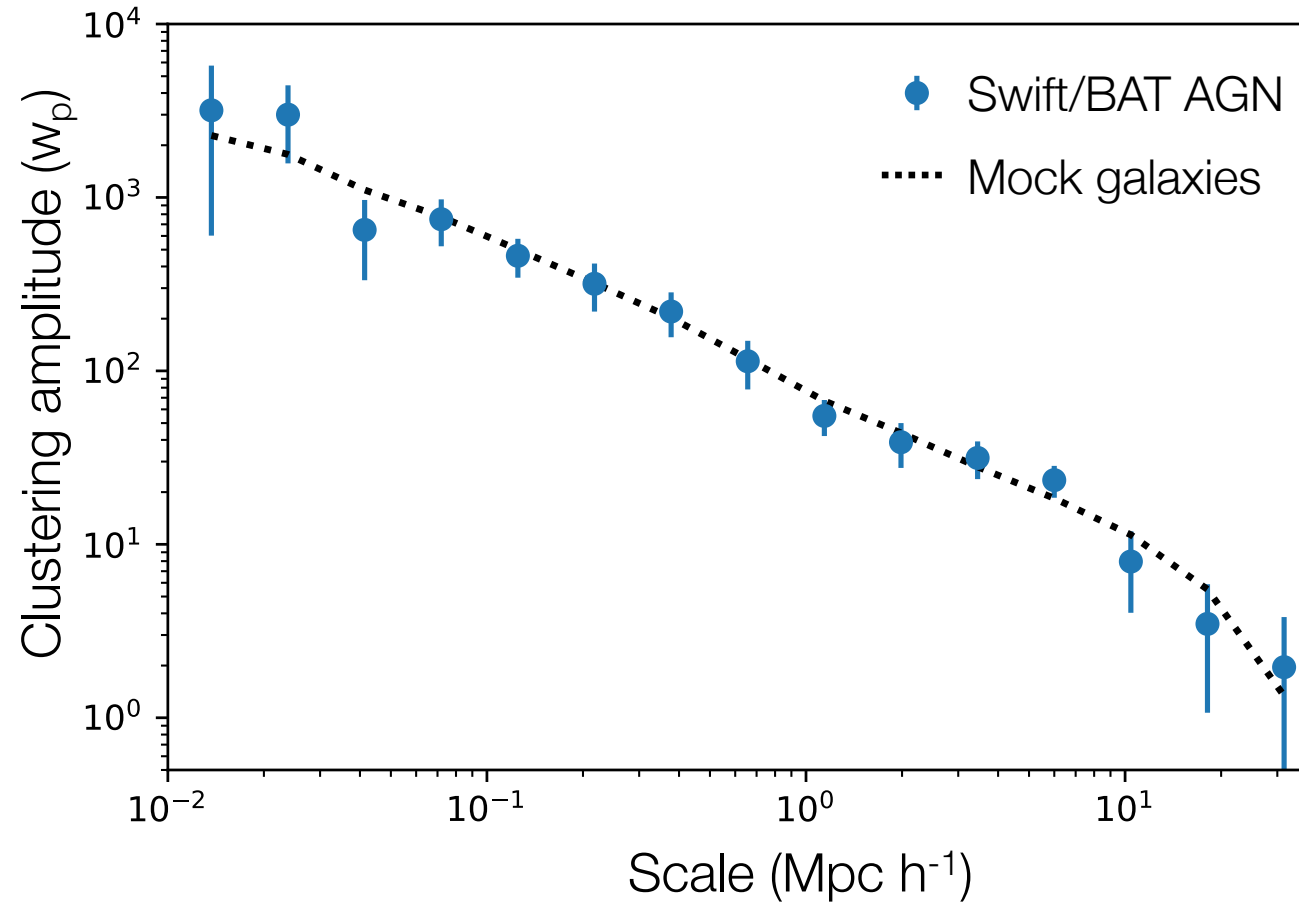
$\rightarrow M_{\star}(M_{\text{subhalos}})$

Forward modeling: Populating a halo catalog



Mask out some galaxies:
Match stellar mass distributions

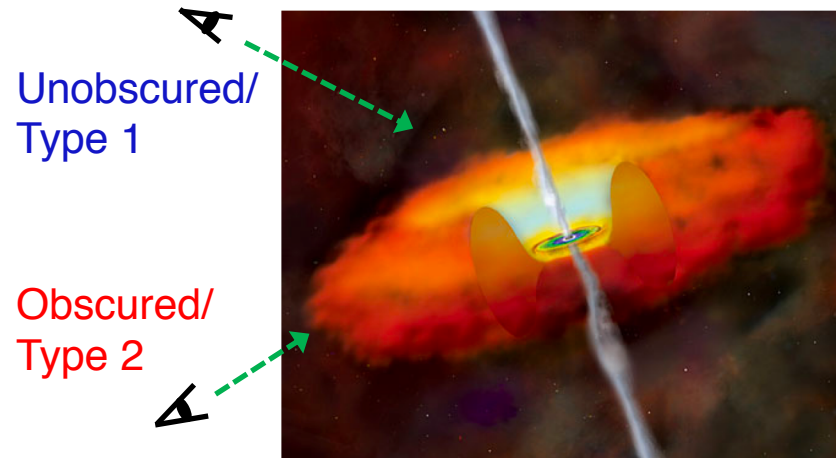
$z=0$: AGN cluster like inactive galaxies



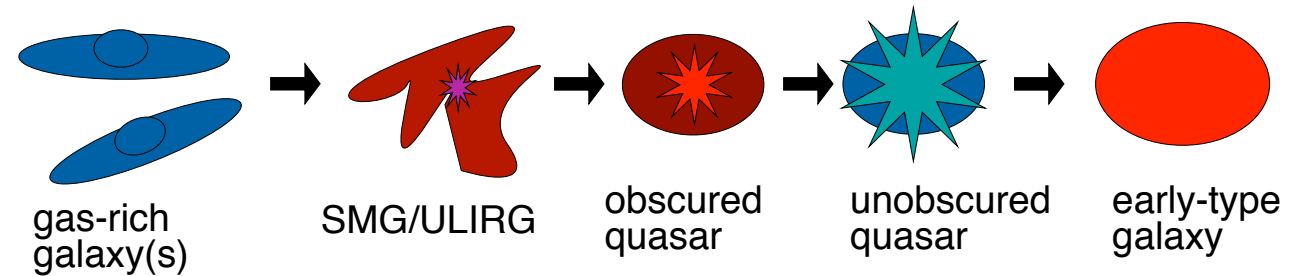
Consistent with galaxies of the same stellar mass
No special environments for AGN activation

Dependence on Obscuration

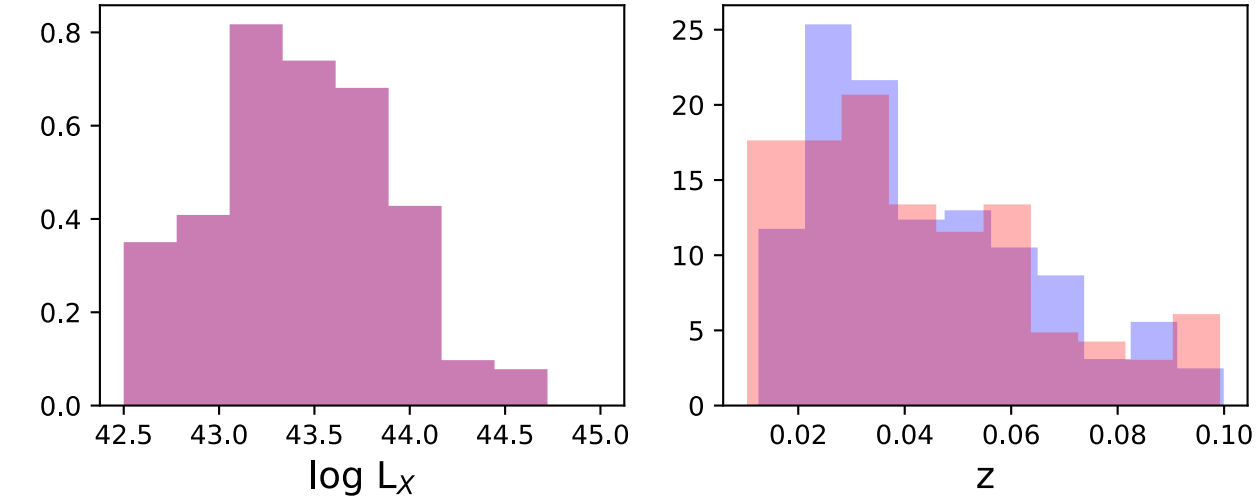
- Unified model?



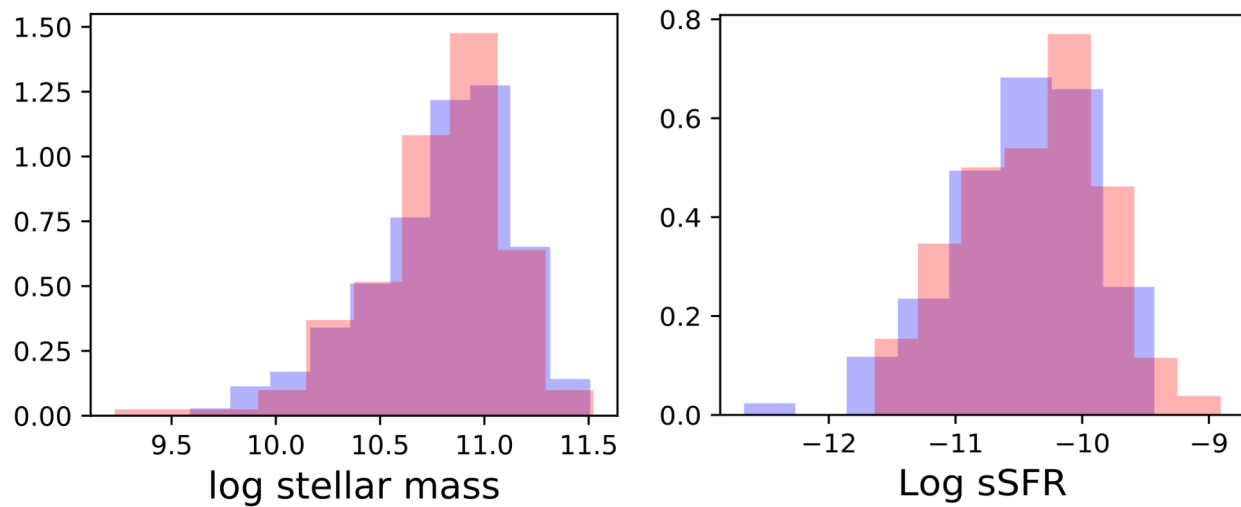
- Evolutionary phase of obscuration?



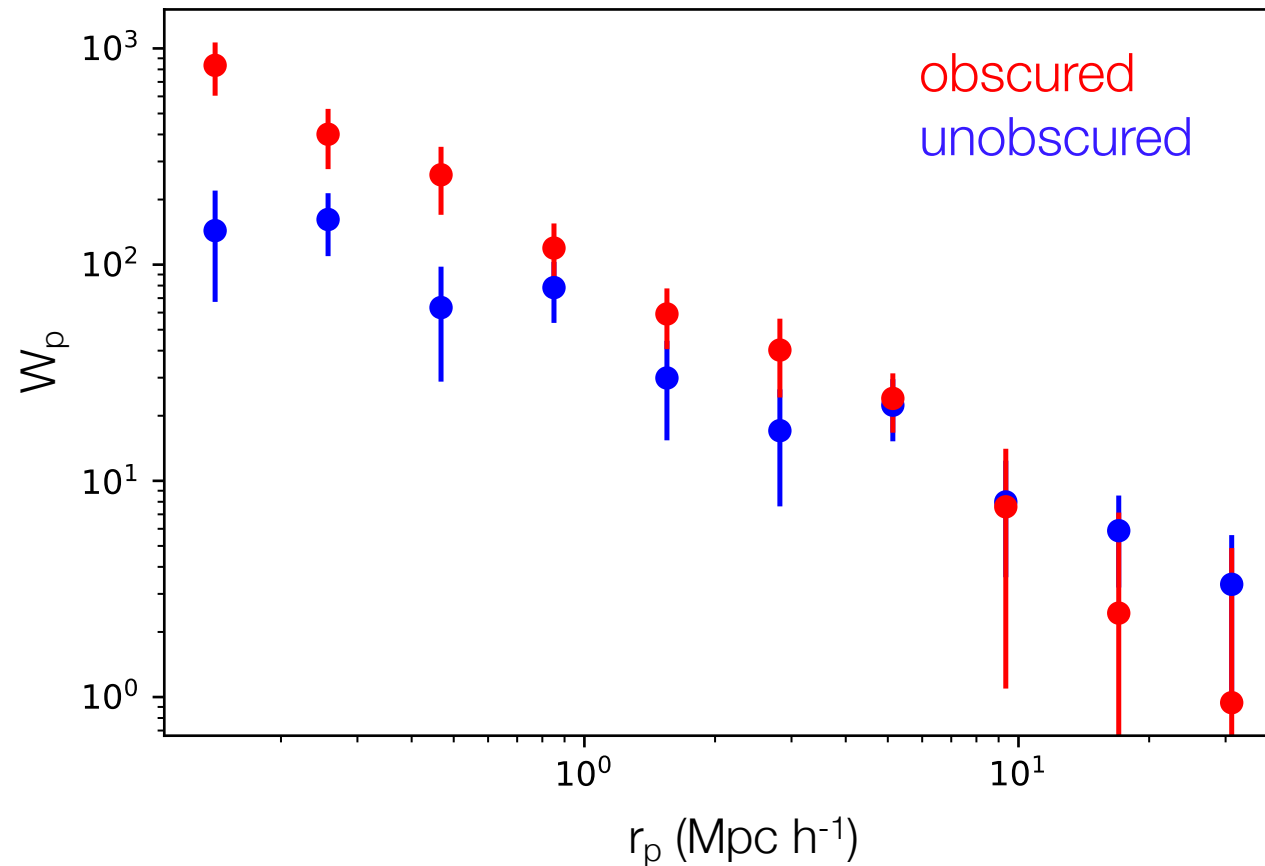
Dependence on Obscuration



■ $N_H \geq 10^{22} \text{ cm}^{-2}$ (obscured)
■ $N_H < 10^{22} \text{ cm}^{-2}$ (unobscured)

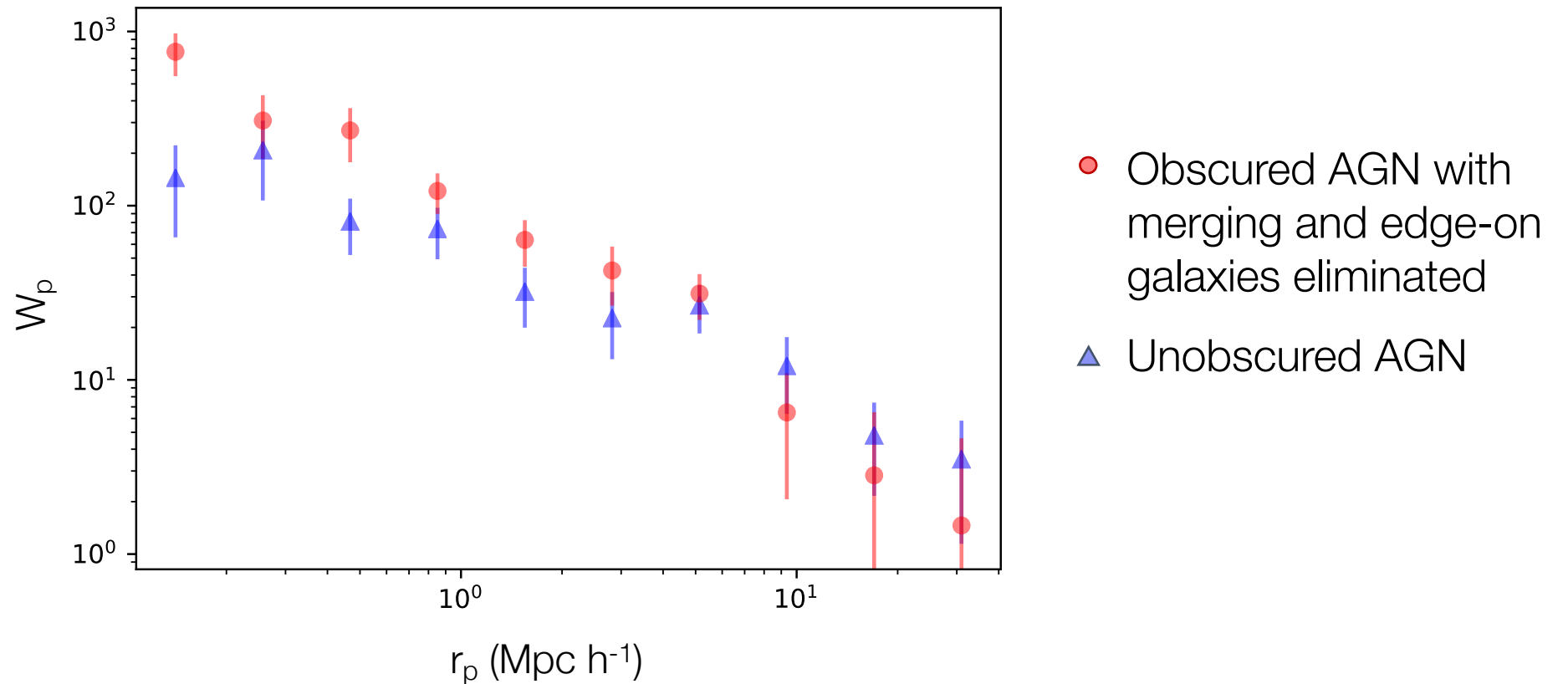


Obscured and Unobscured AGN cluster differently



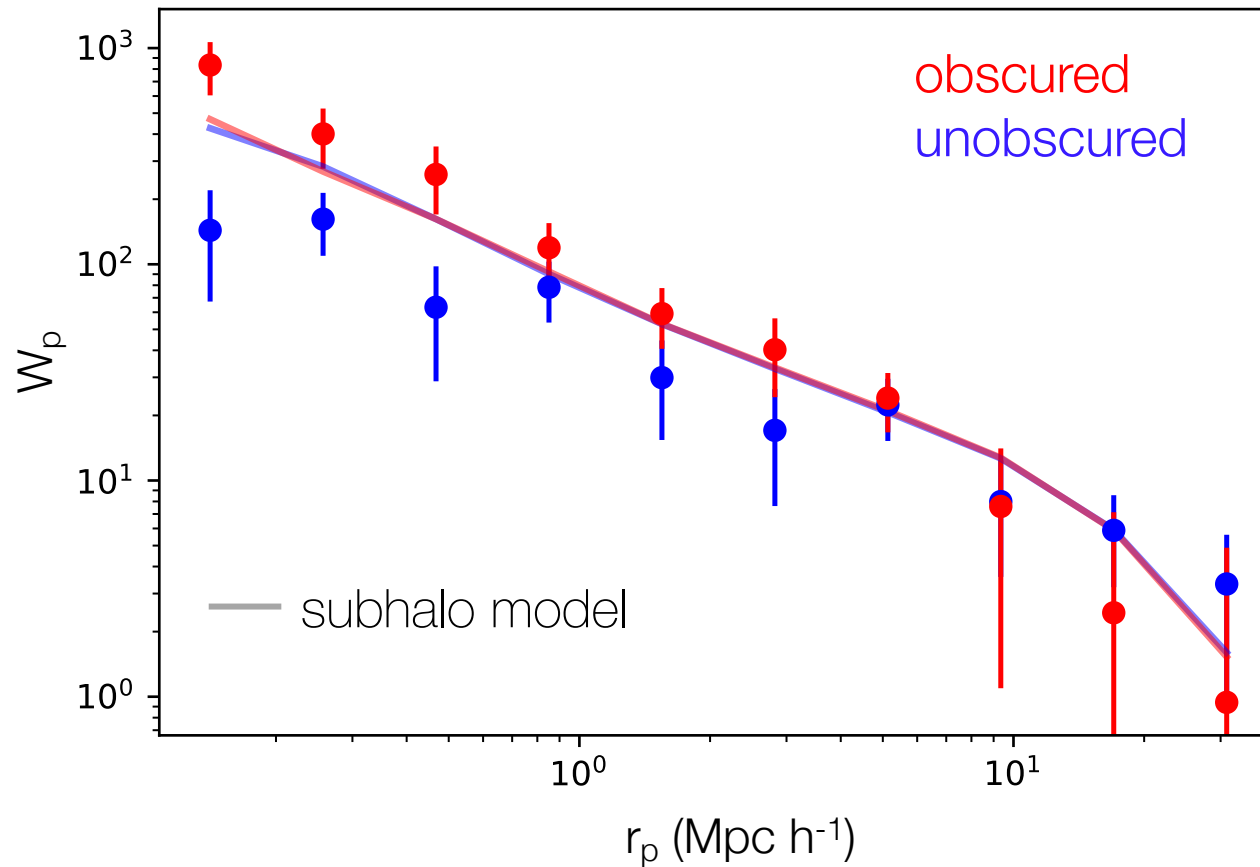
Obscured AGN \rightarrow denser environments

Host galaxy obscuration?



Taking out clear cases of mergers, galaxy interactions, and host galaxy obscuration in obscured AGN did not change clustering difference

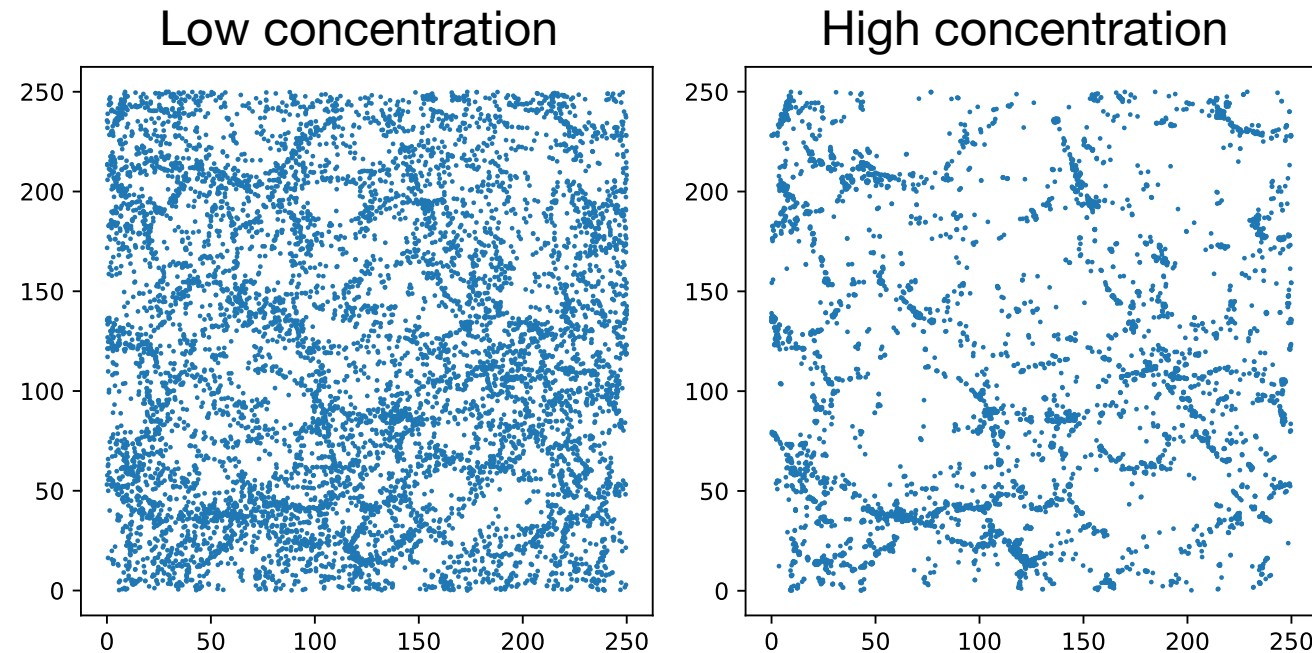
Obscured and Unobscured AGN cluster differently



Obscured AGN \rightarrow denser environments

Assembly bias?

- Halo clustering also depends on **halo formation epoch/concentration**
 - Old halos cluster more strongly than young halos

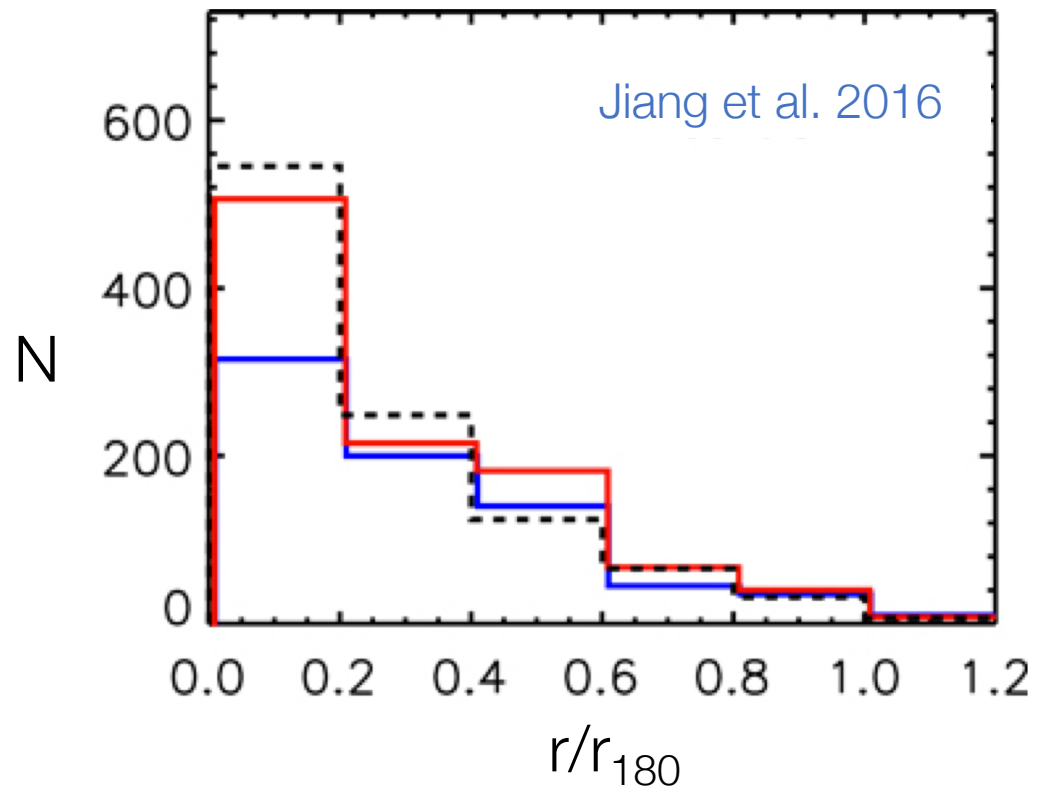


Bolshoi-Planck
Simulation
(Riebe et al. 2013)

- different host halo concentrations → different clustering

Hint for assembly bias

- Evidence that SDSS Type 1 AGN have fewer close pairs (Jiang et al. 2016, Villarroel & Korn 2014)



Assembly bias?

Obscured AGN



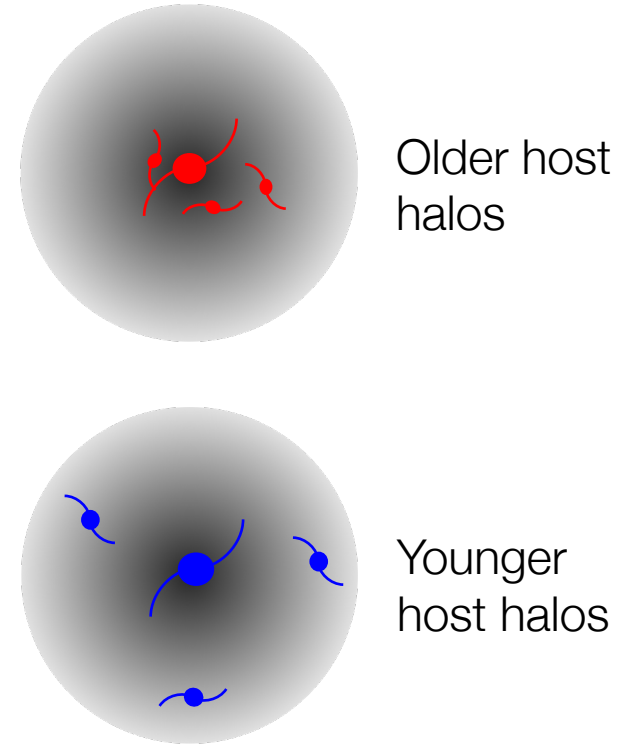
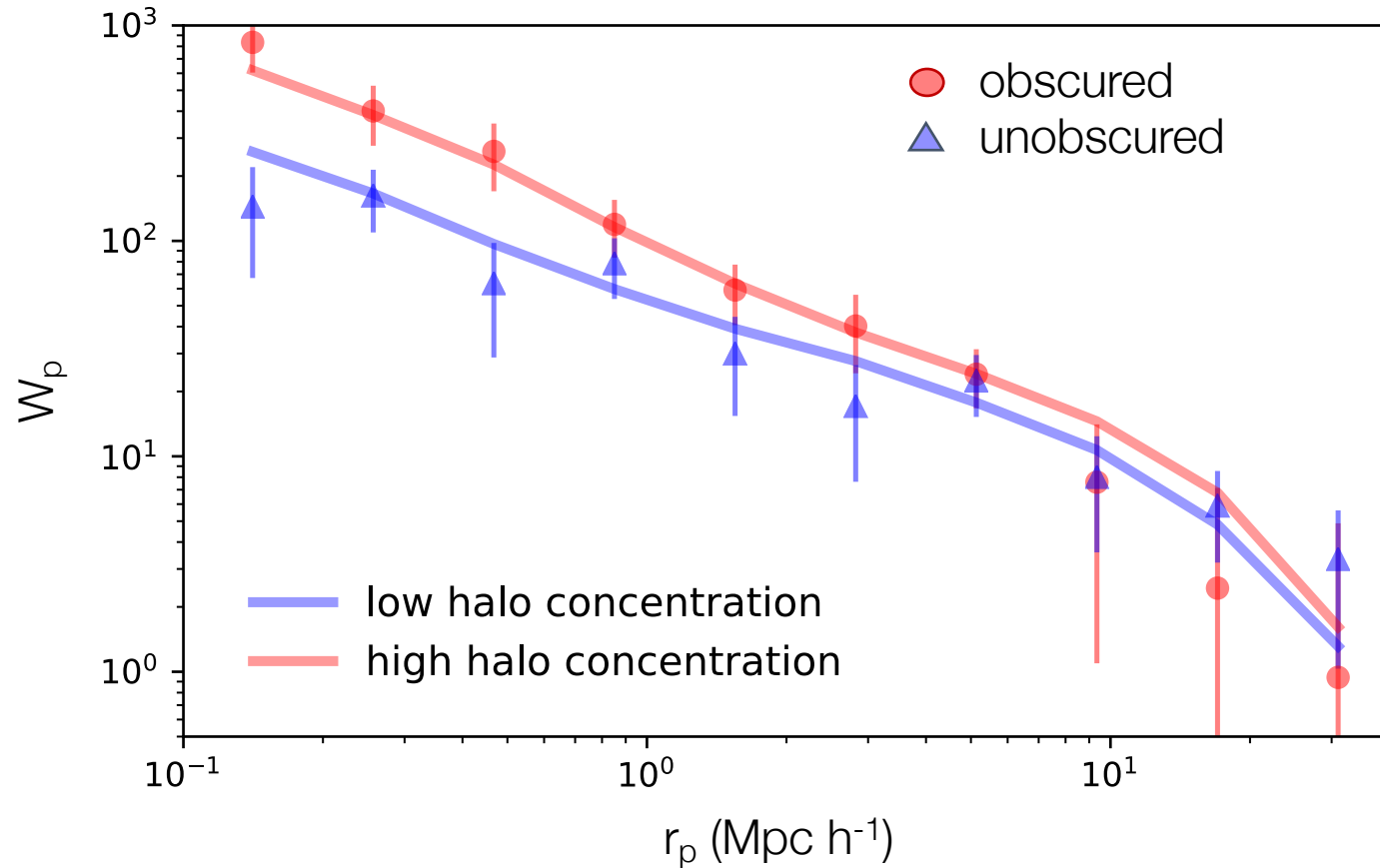
Minimum host halo
concentration

Unobscured AGN

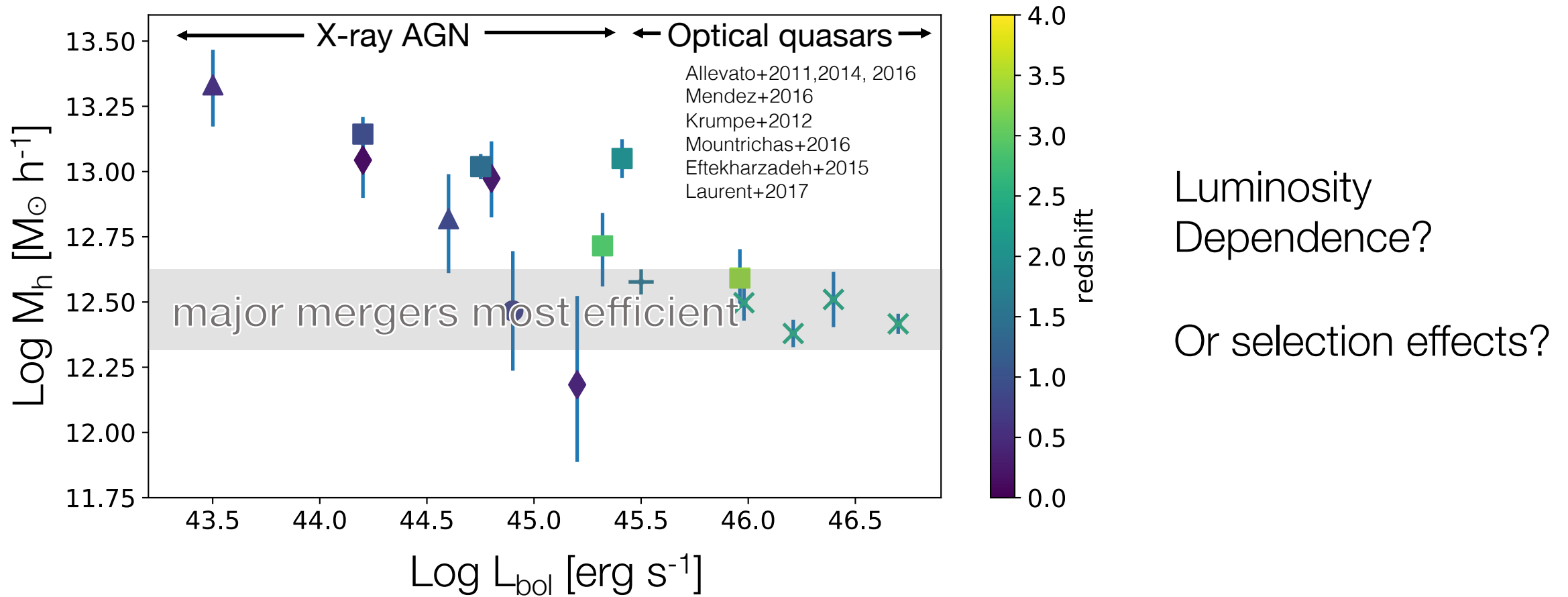


Maximum host halo
concentration

Assembly bias?

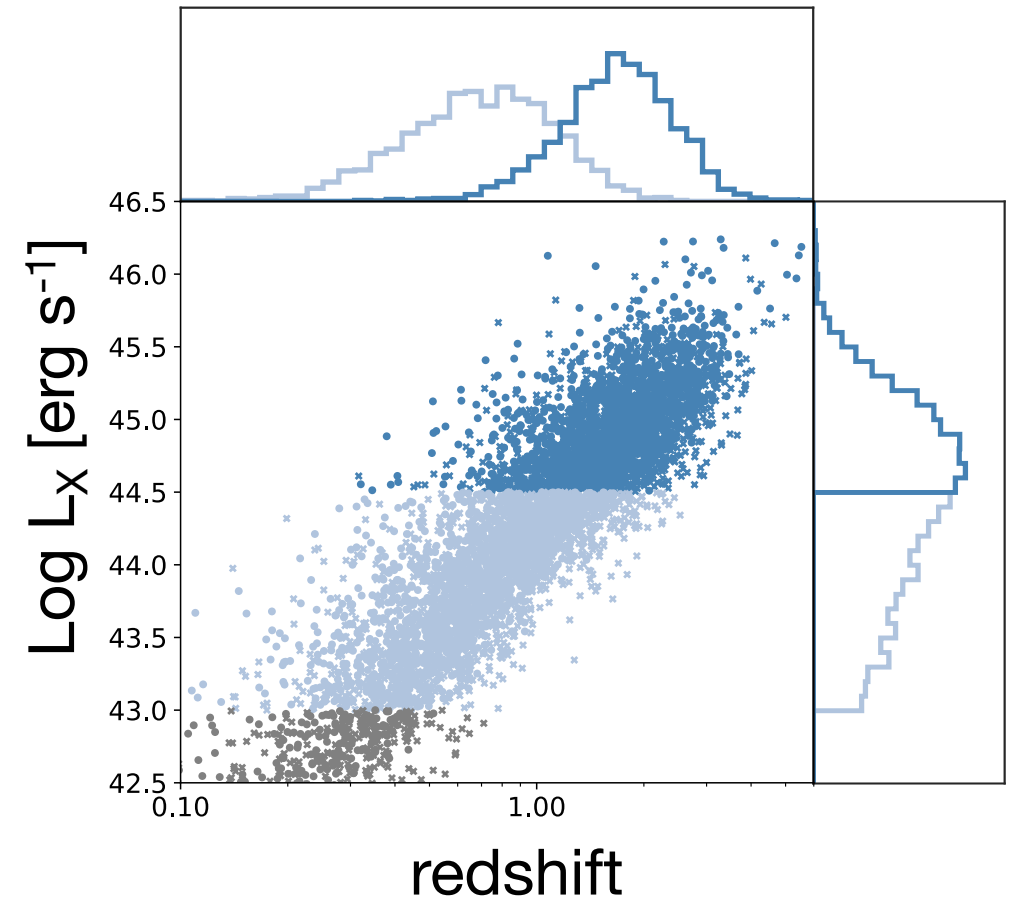
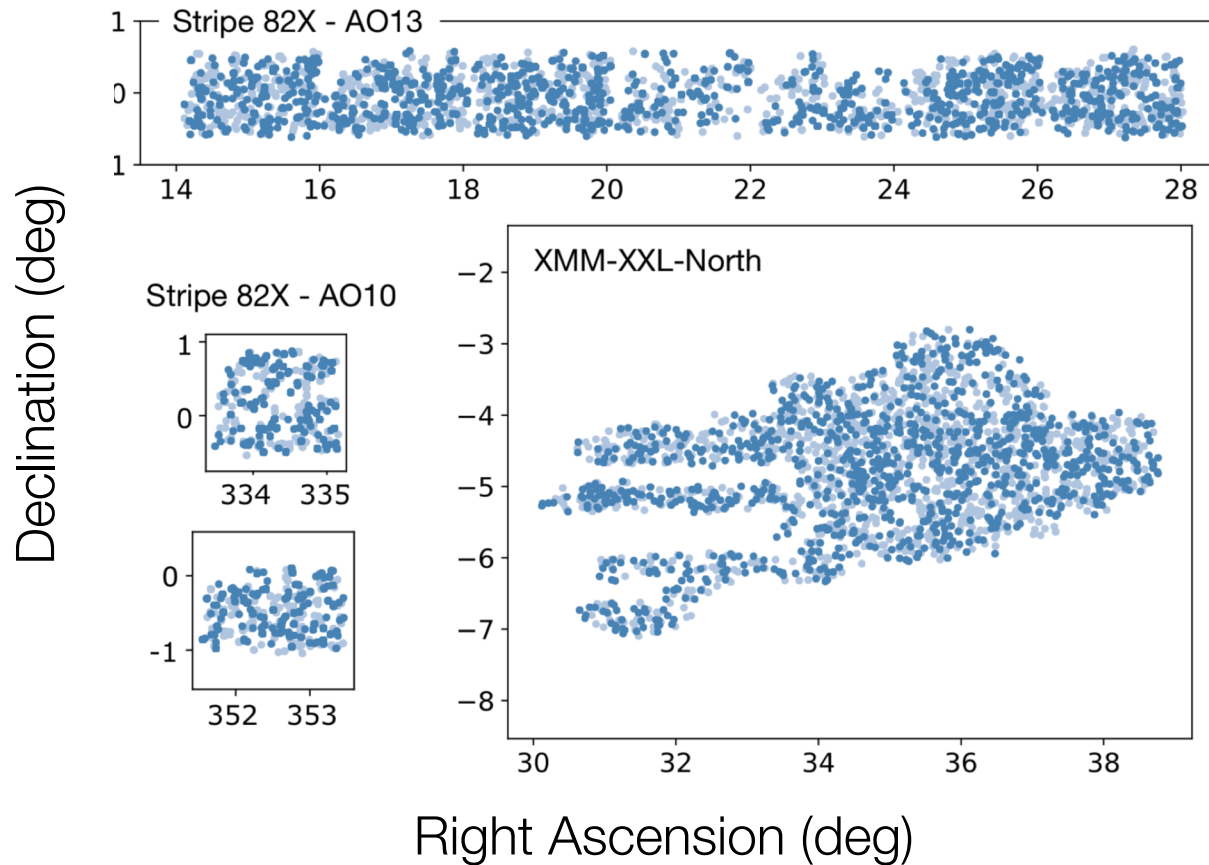


Dependence on redshift / luminosity

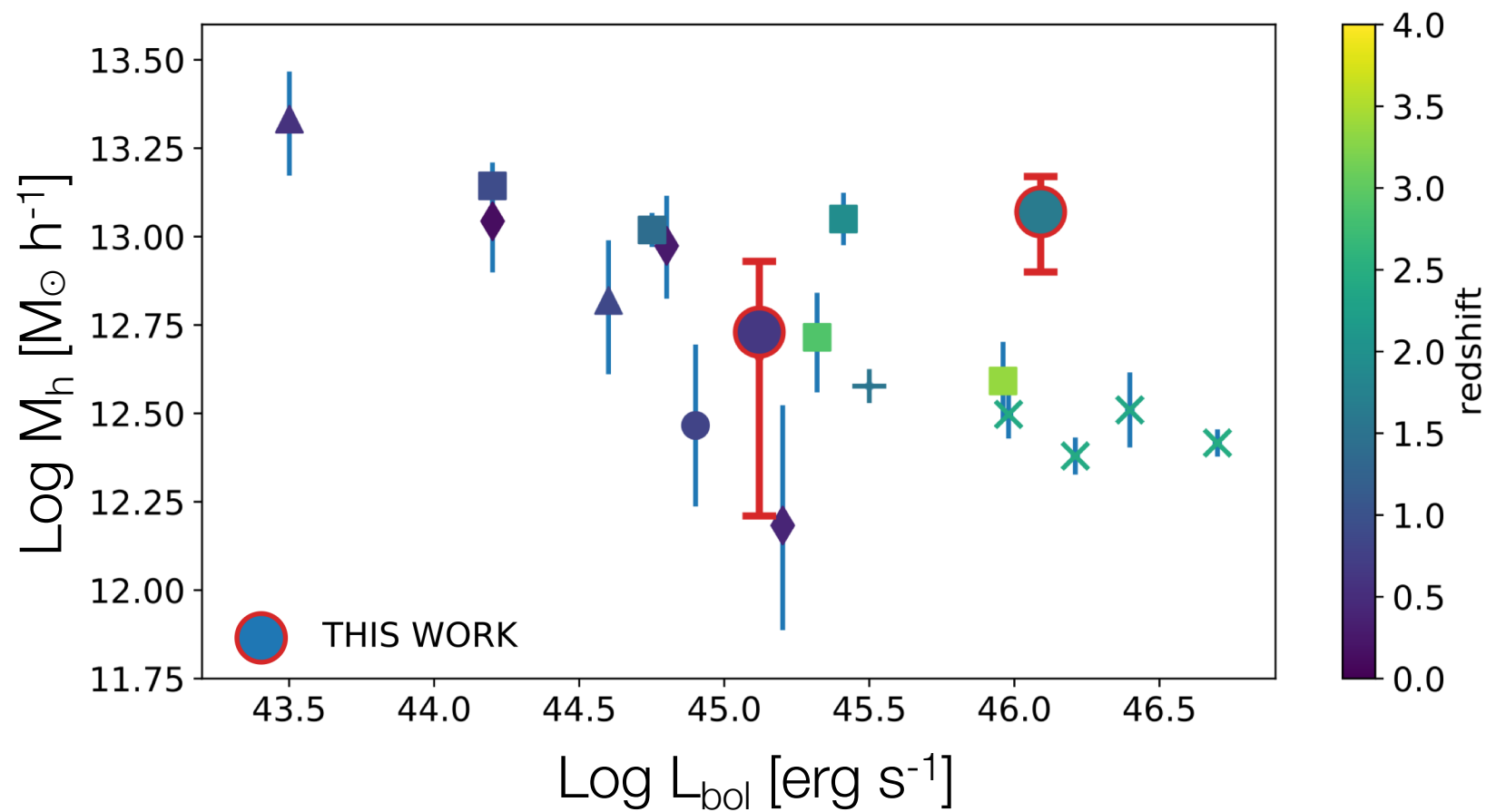


X-ray-luminous Quasars

Stripe 82X + XMM-XXL-north



X-ray-luminous Quasars



~~Luminosity
Dependence?~~

Or selection effects?

Summary

- **Local universe:**

- X-ray AGN cluster like inactive galaxies when controlling for stellar mass
- Obscured AGN live in denser environments than unobscured AGN, despite similar host galaxy properties

- **$z \sim 1-2$:**

- No evidence for luminosity-dependent clustering