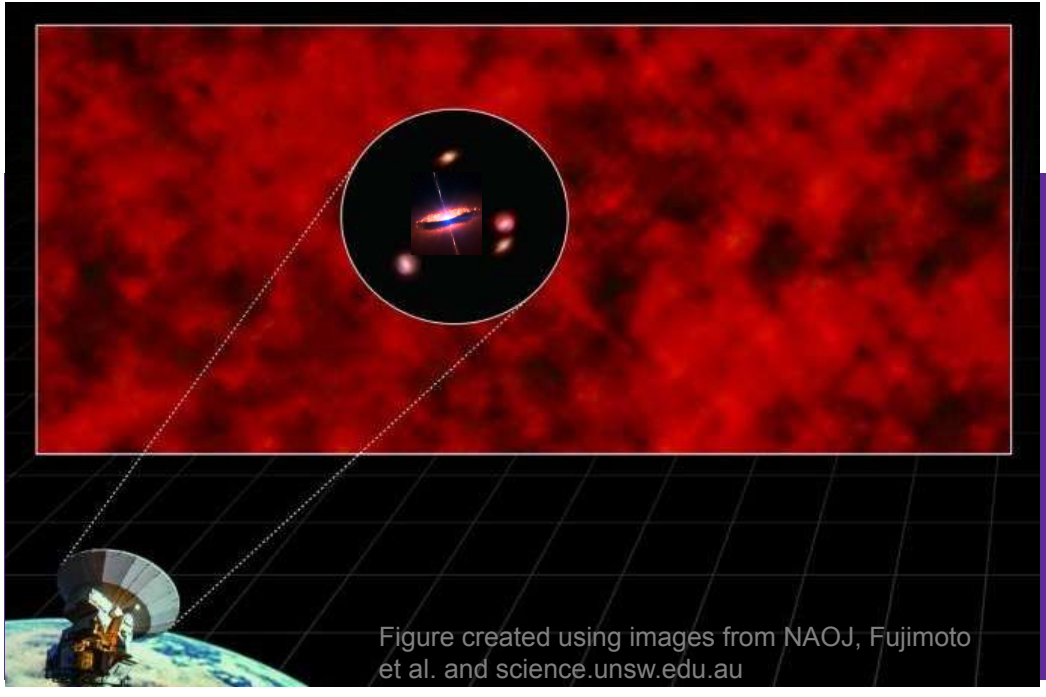
Downsizing of Star Formation: Weighing Dark Matter Haloes Hosting Dusty Star-Forming Galaxies



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Collaborators: Toby Marriage[1], Devin Crichton[2], Rachel Mandelbaum[3],

The ACT Collaboration

[1]Johns Hopkins University
[2]University of KwaZulu–Natal
[3]Carnegie Mellon University

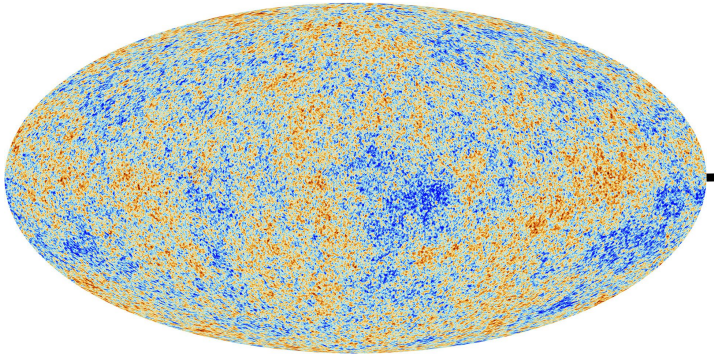
- Goal: Investigate the redshift evolution of physical properties of Dusty Star Forming Galaxies (DSFGs) responsible for the Cosmic Infrared Background (CIB)

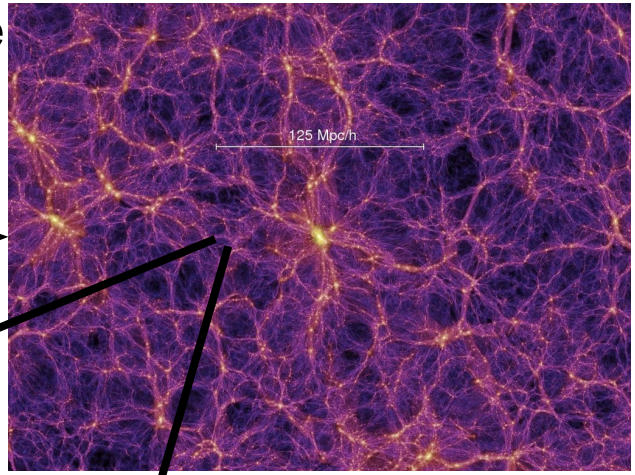
- Physical properties of interest:
  - Dark matter halo mass
  - IR Luminosity

  → Star formation rate

Hubble image of LIRG (DSFG) MCG-03-04-014

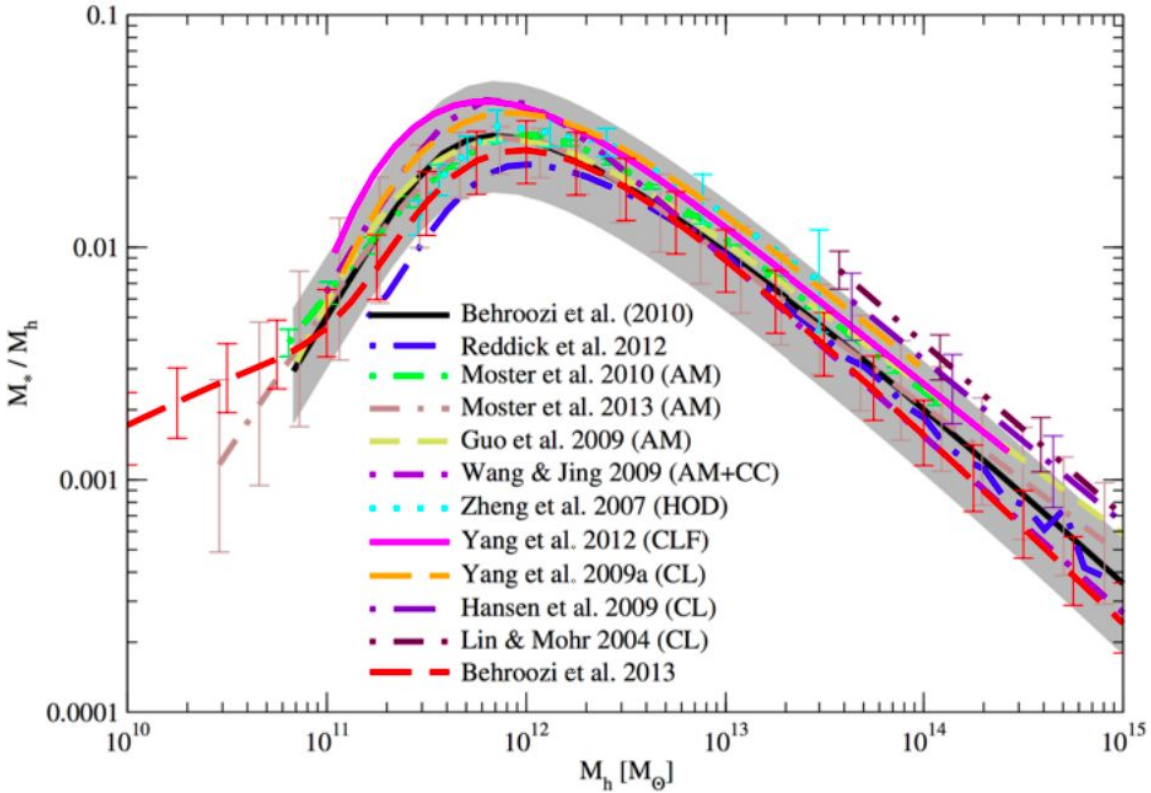
Dark matter physics → Evolution to large scale structure



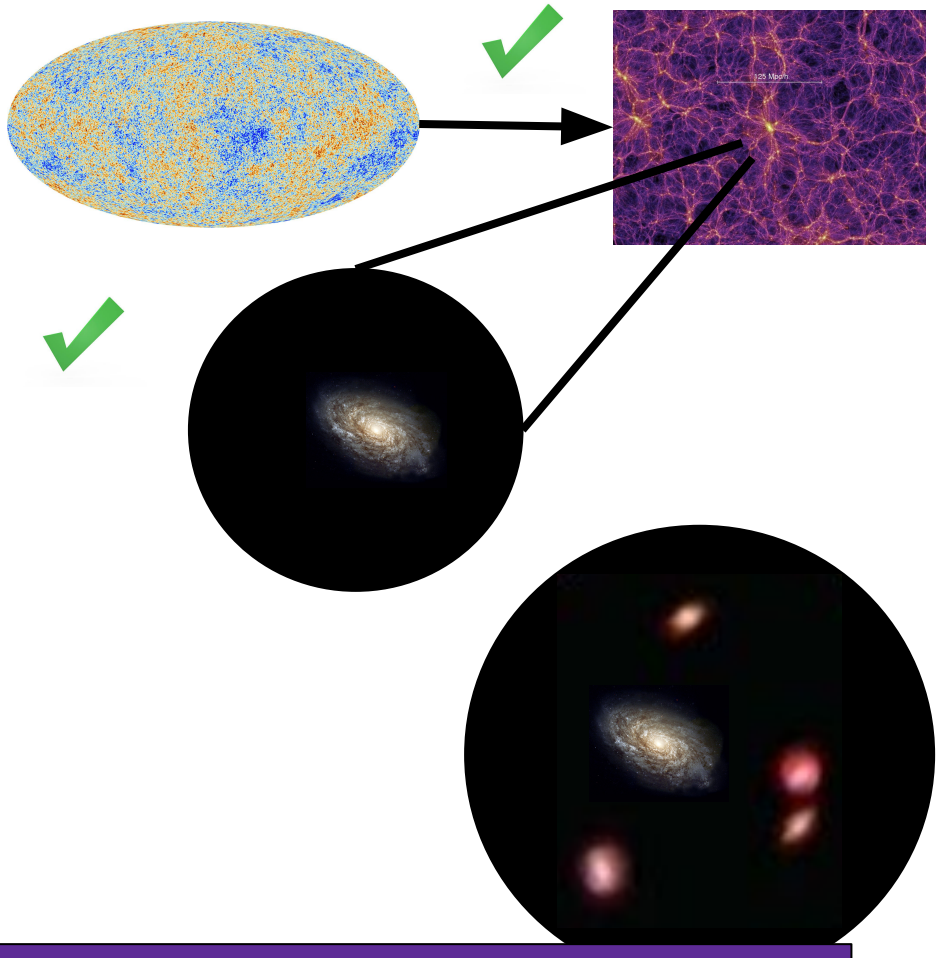


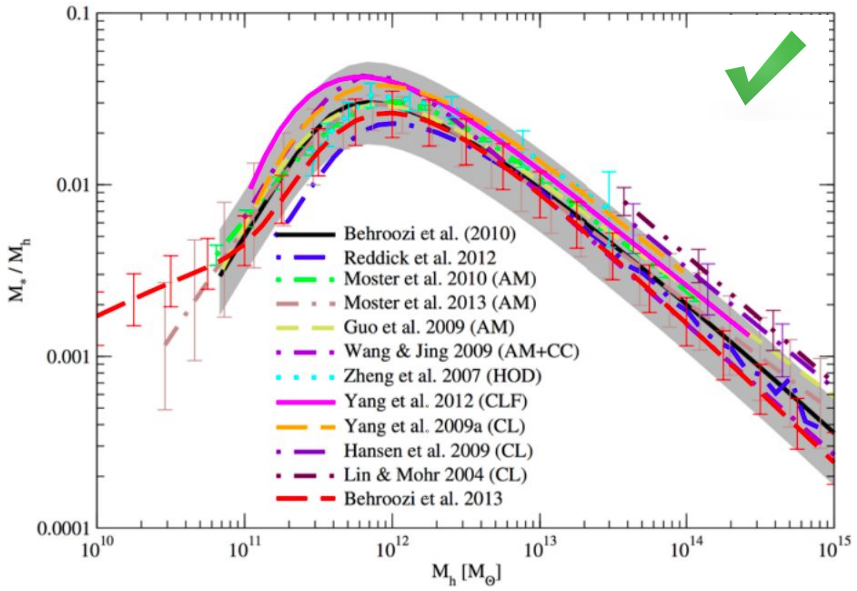
Dark matter collapses into halos
→ Galaxies form and evolve inside

Dark matter halo mass is correlated with galaxy properties.
→ e.g. Stellar mass, stellar growth rate



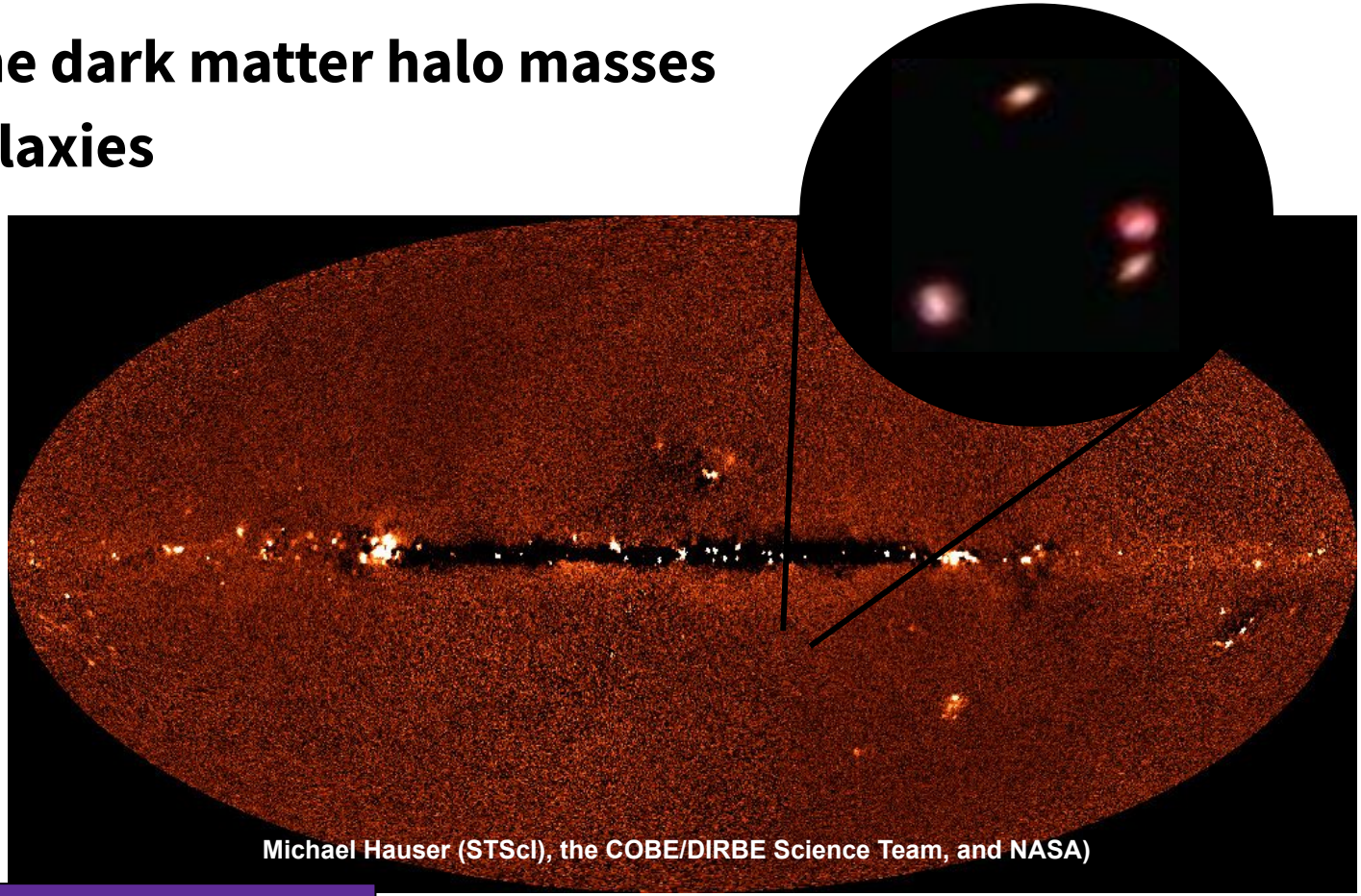
Behroozi et al. 2013



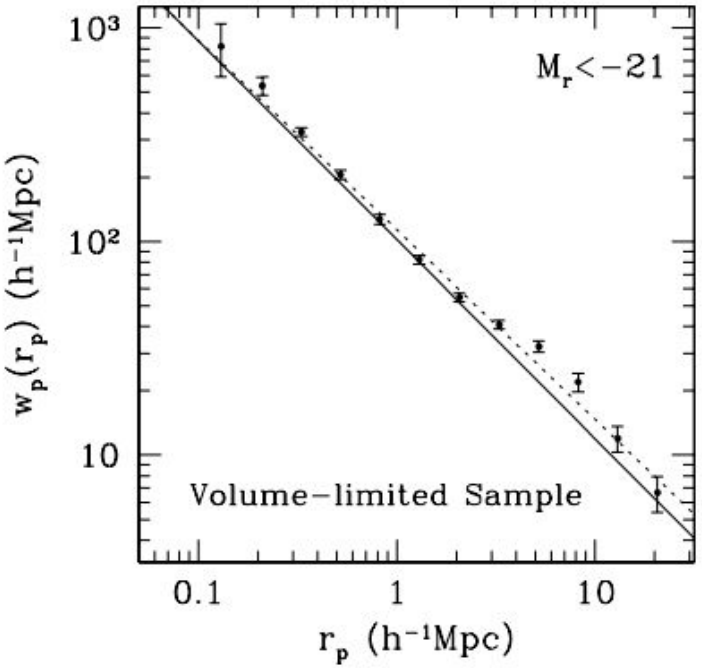


How exactly do galaxies populate dark matter halos?

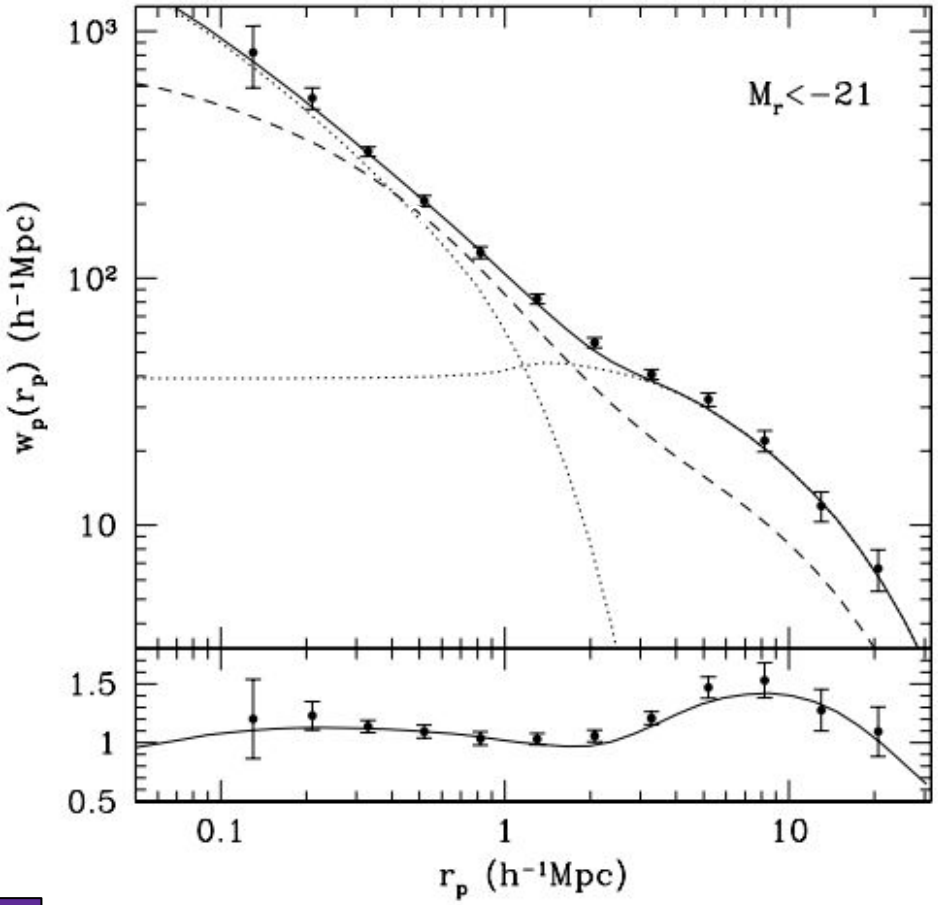
- **Linking the bulk of star formation in the universe to the dark matter halo masses of the host galaxies**

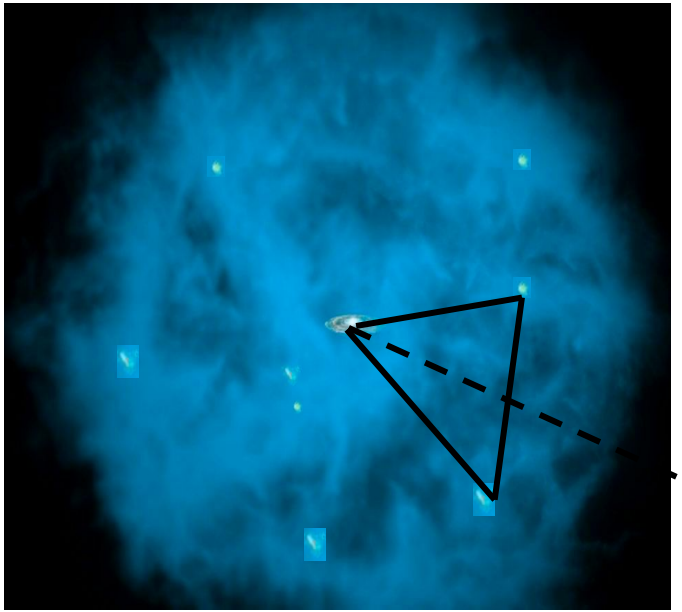


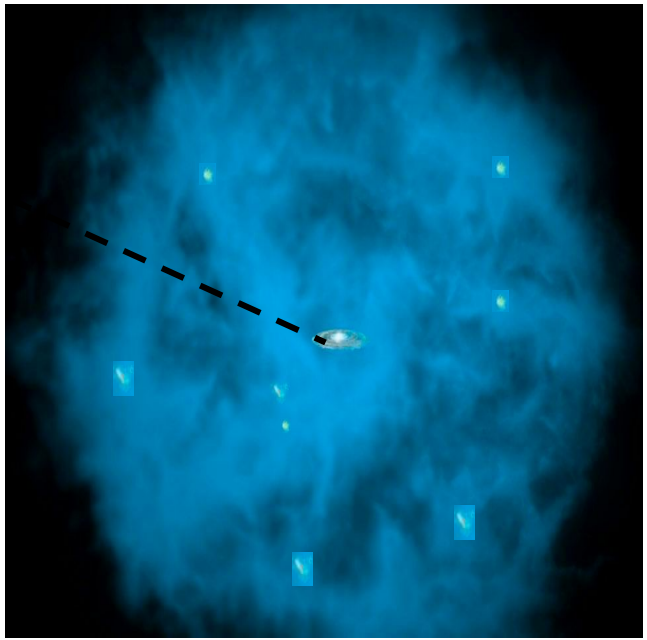
- Halo Occupation Distribution Model

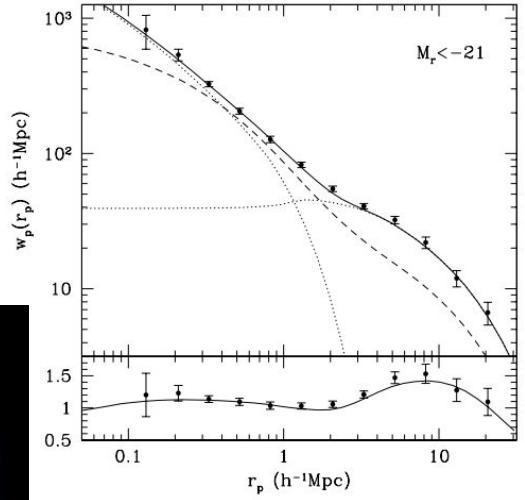


Zehavi et al. 2004





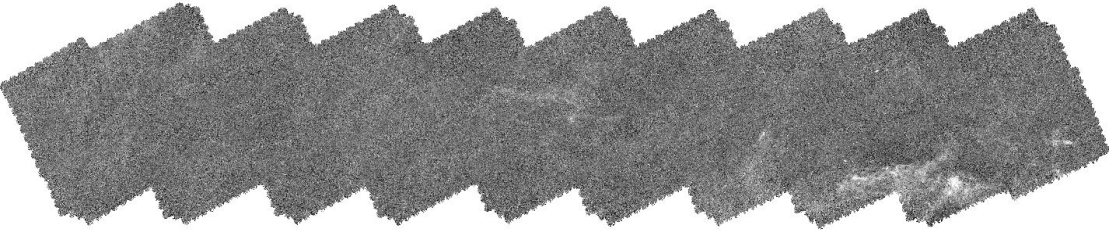




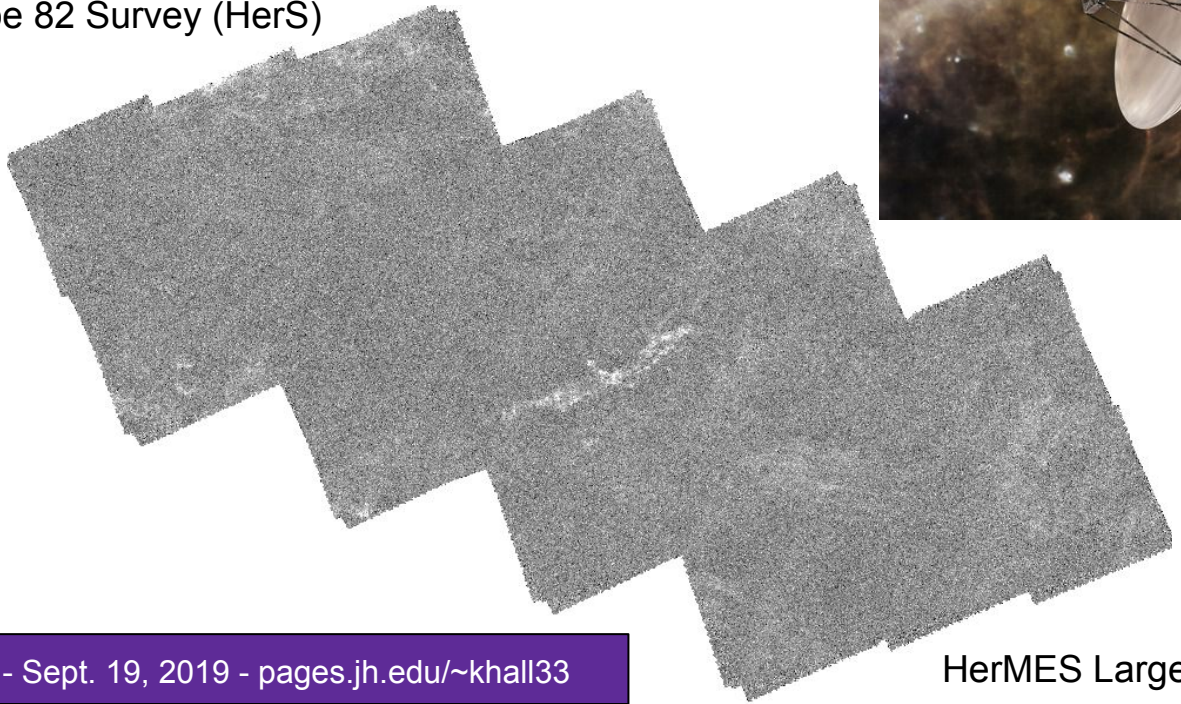
Zehavi et al. 2004

$$\langle N(M) \rangle = \langle N_{cen}(M) \rangle + \langle N_{sat}(M) \rangle$$

Herschel Space Observatory SPIRE Maps



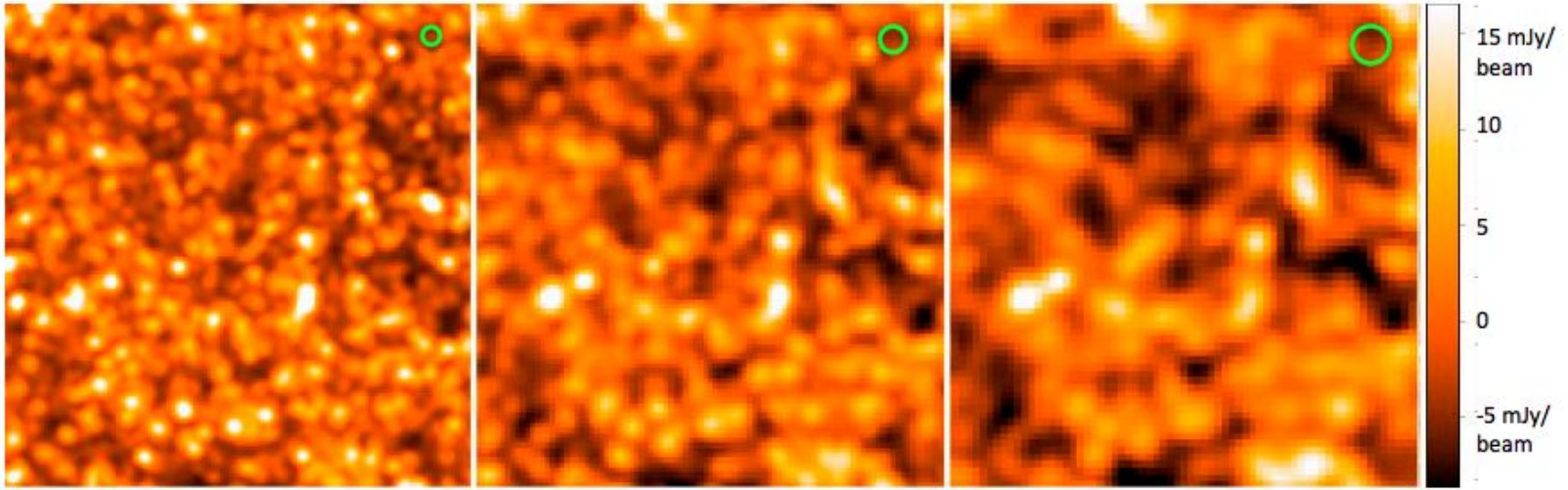
Herschel Stripe 82 Survey (HerS)



HerMES Large Mode Survey (HeLMS)

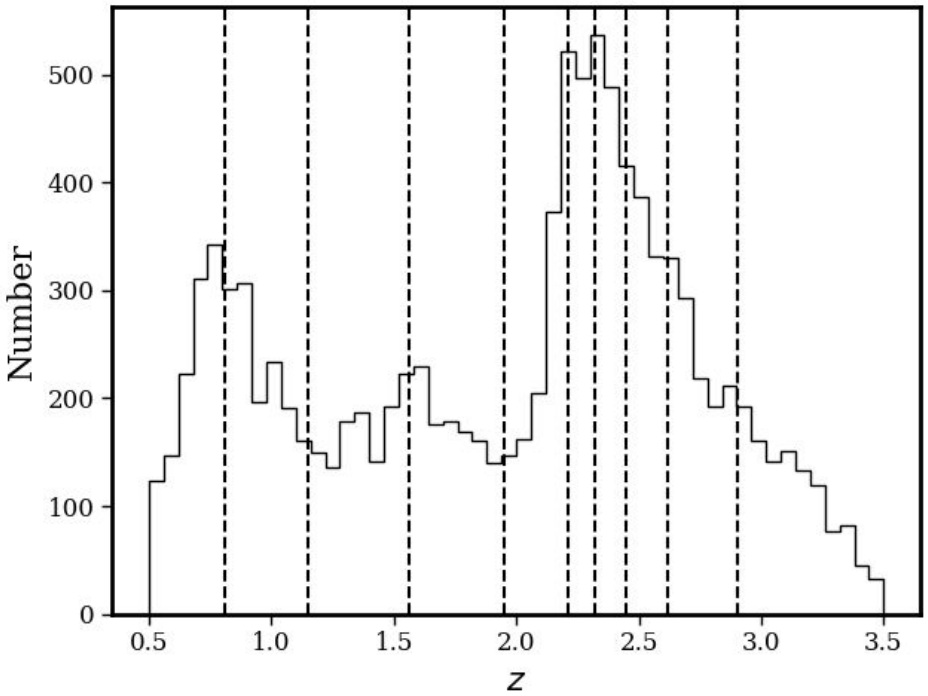
Herschel Space Observatory SPIRE Maps

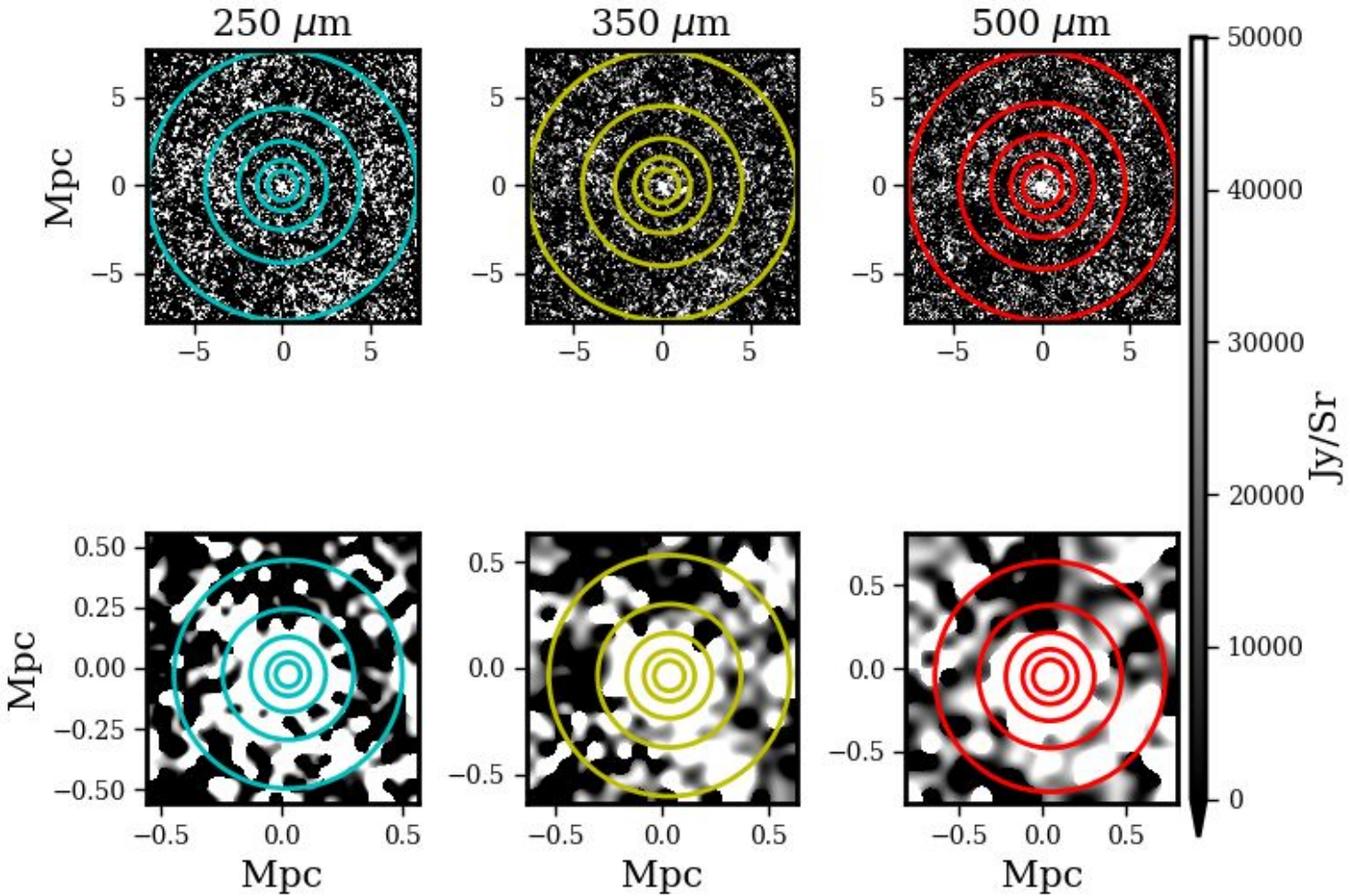
SPIRE beam sizes at 250, 350, and 500 μm are 18”, 25”, 36”, respectively
→ confusion limited



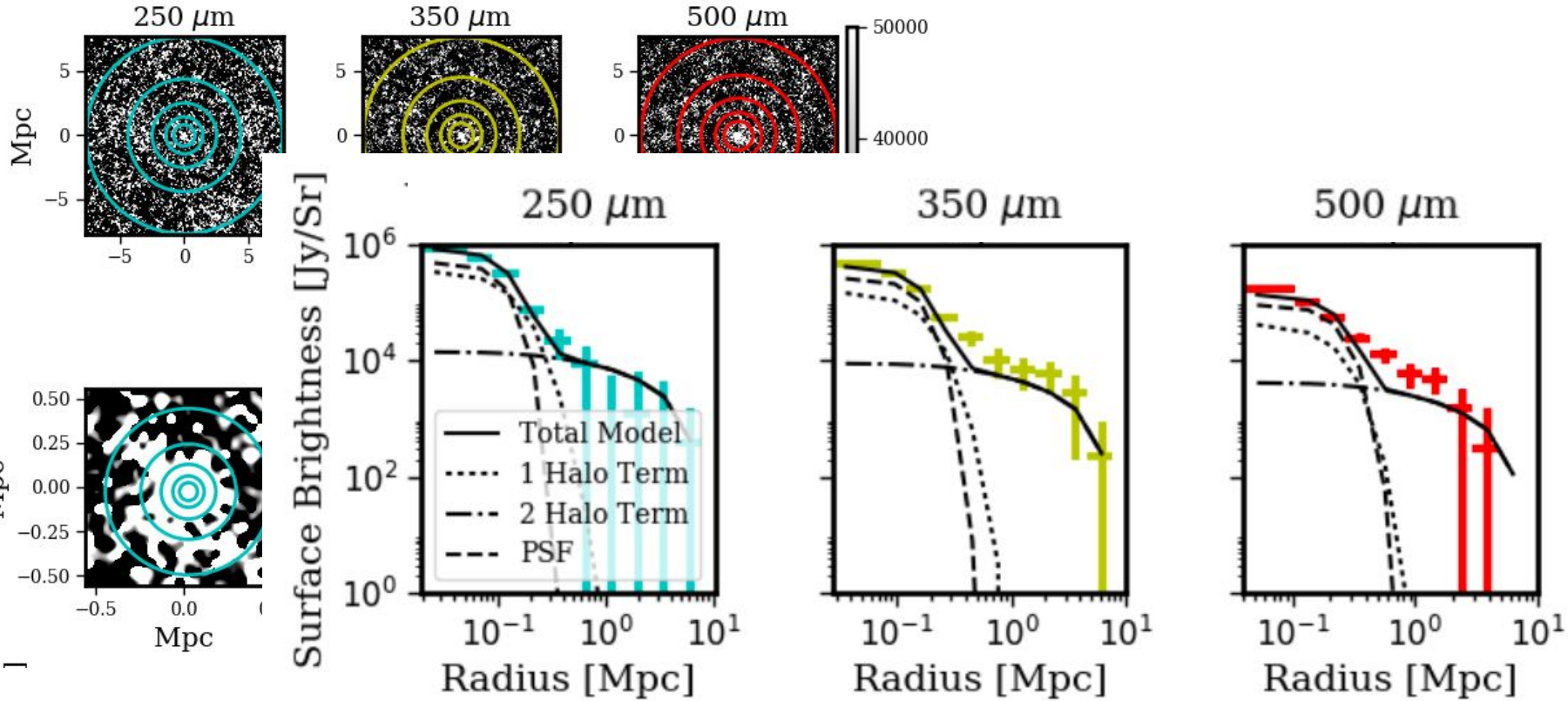
Nguyen et al. 2010

Cross-correlate SPIRE Maps & Quasar Catalog





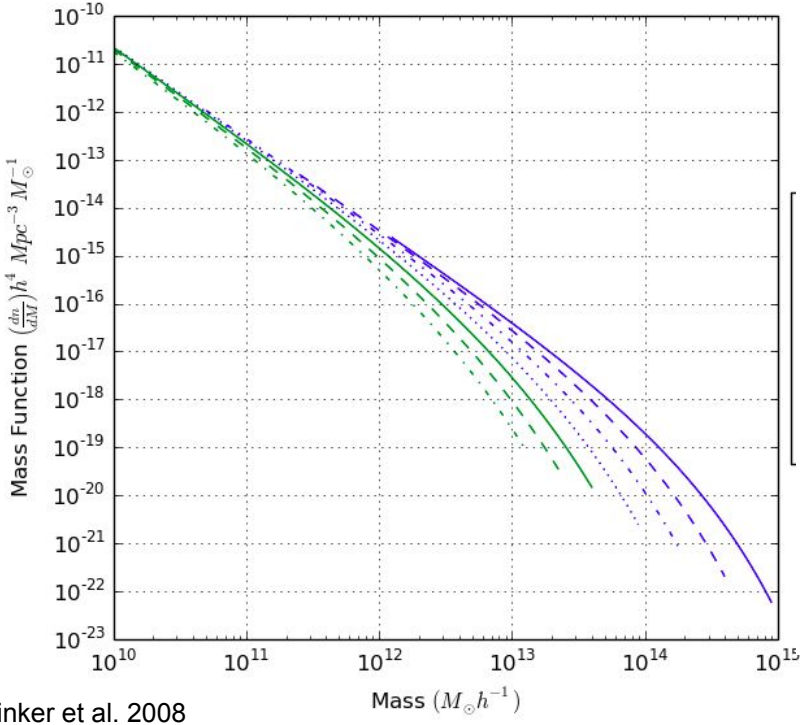
Hall et .al, 2018 MNRAS, 480, 149



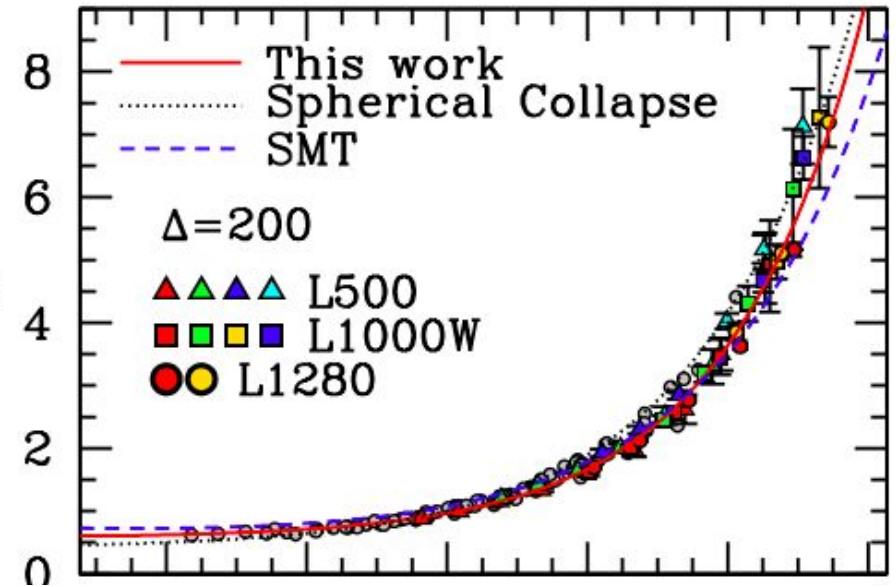
Hall et .al, 2018 MNRAS, 480, 149

A physically-motivated model: Dark matter

- Dark matter halo clustering is fixed



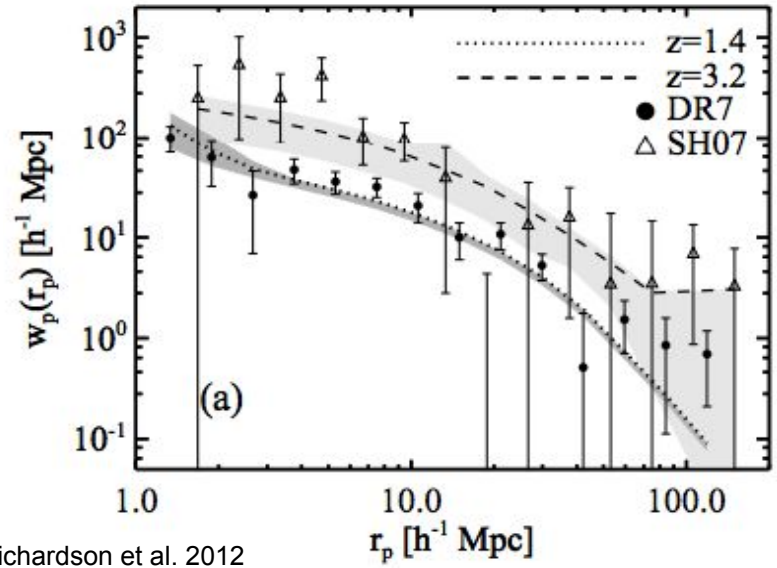
Tinker et al. 2008



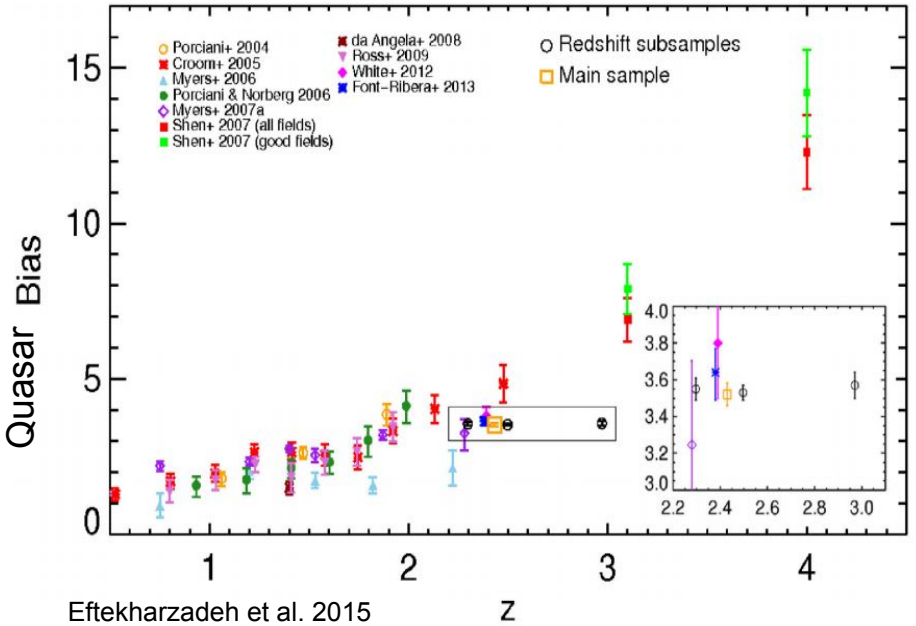
Tinker et al. 2010

A physically-motivated model: Dark matter

- Quasar HOD, bias from other studies



Richardson et al. 2012

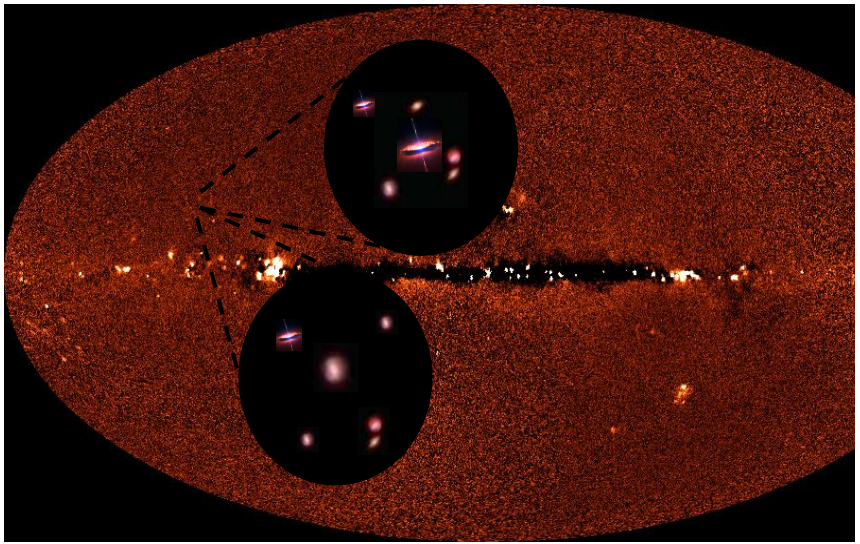


Eftekharzadeh et al. 2015

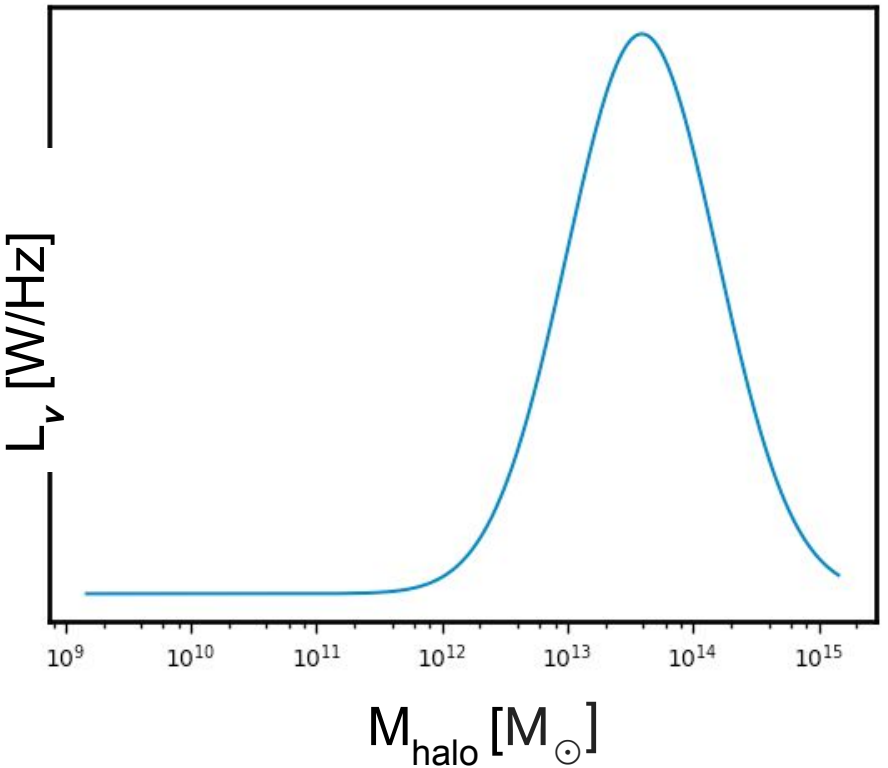
$$\langle N(M) \rangle = \langle N_{cen}(M) \rangle + \langle N_{sat}(M) \rangle$$

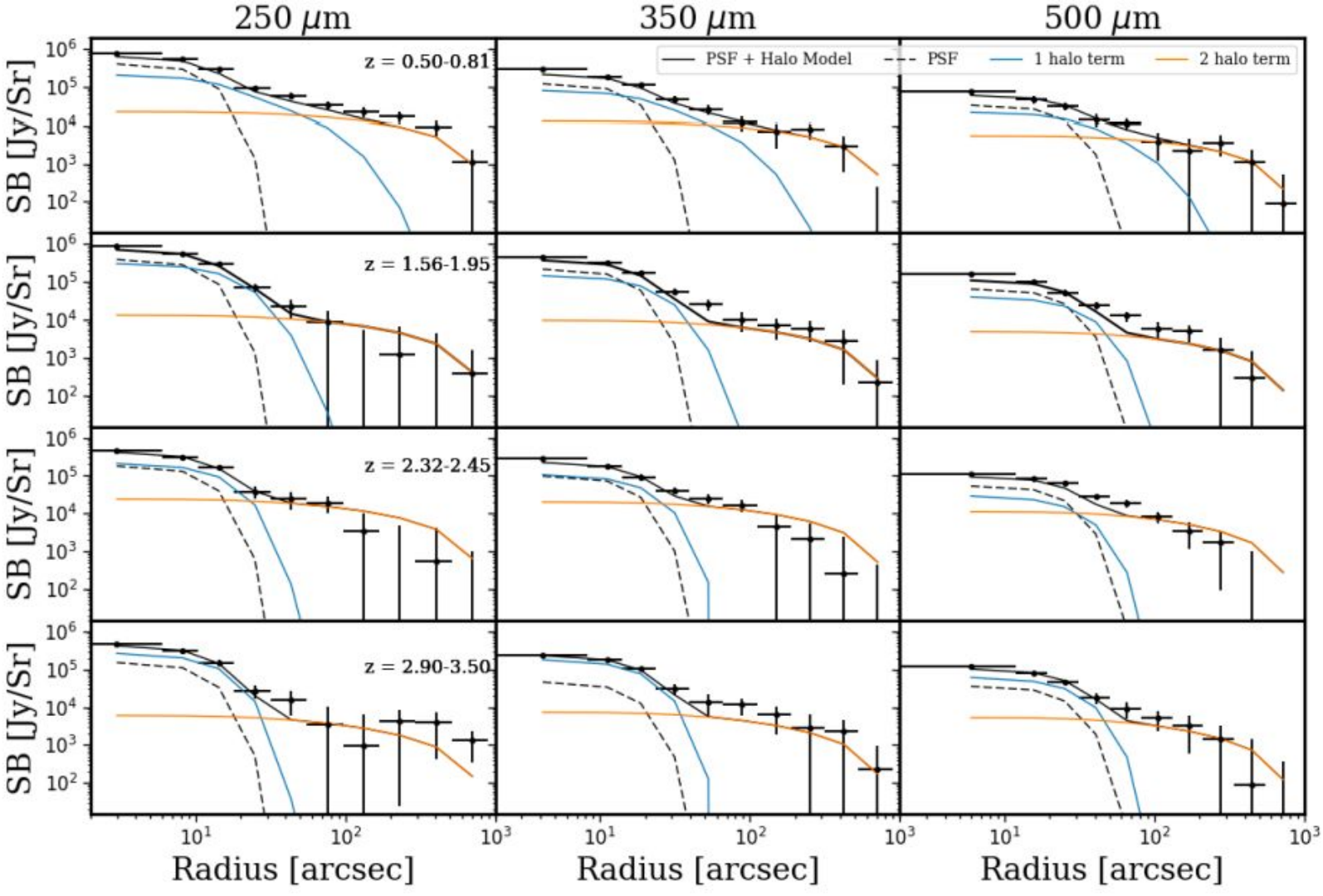
A physically-motivated model: Dark matter

Relate IR emission to the most efficient halo mass at hosting DSFGs, M_{eff}

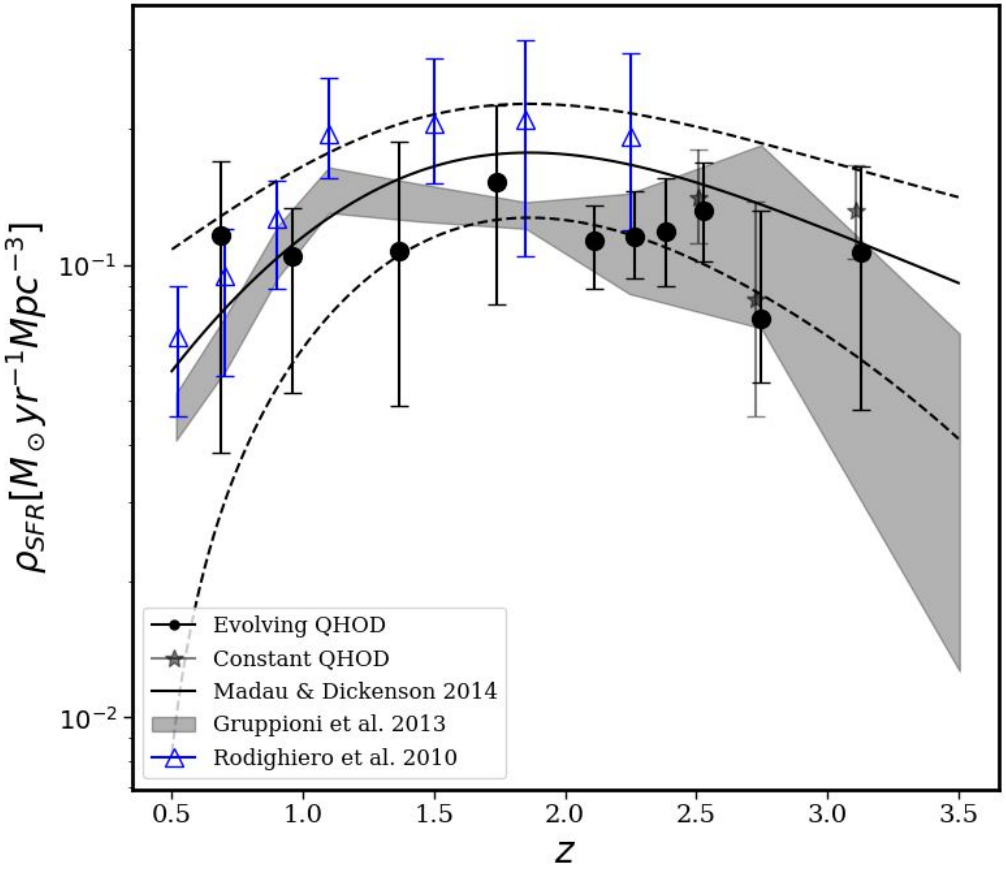


$\langle N(M) \rangle \rightarrow f(M) \propto N \times L_{\nu}(M)$




250 μm
350 μm
500 μm
PSF + Halo Model
PSF
1 halo term
2 halo term
z = 0.50-0.81
z = 1.56-1.95
z = 2.32-2.45
z = 2.90-3.50
SB [Jy/Sr]
Radius [arcsec]

Consistency with cosmic star formation rate density

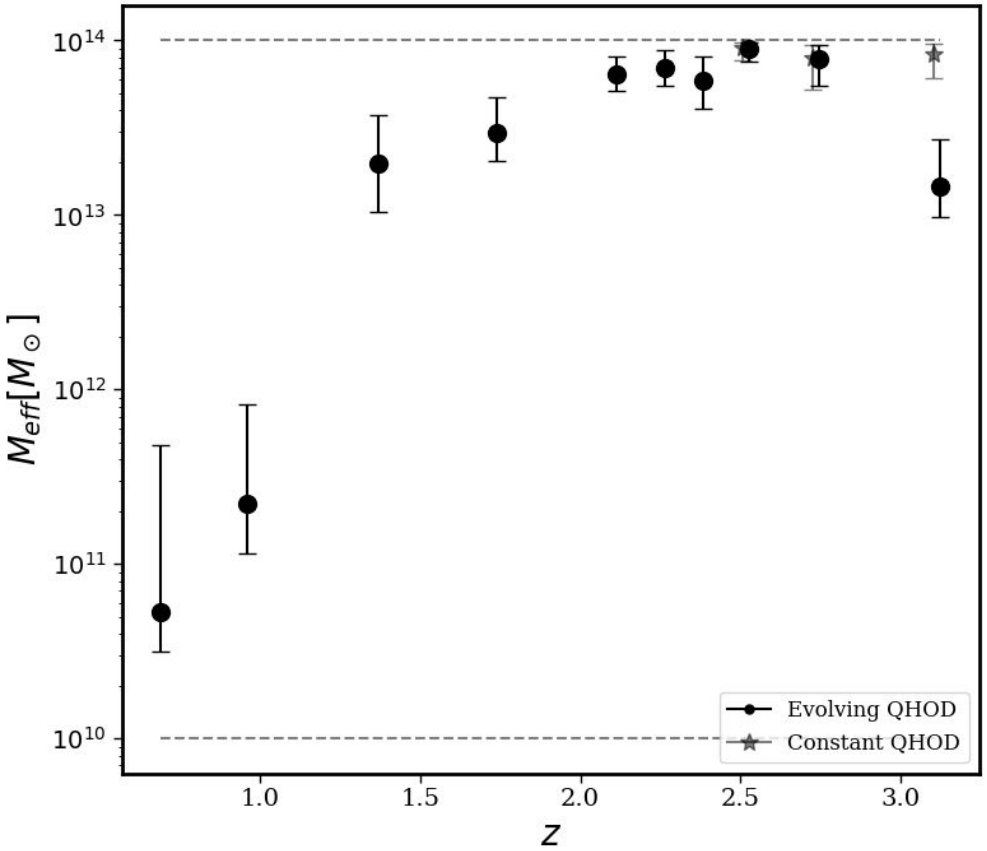


Hall et .al, 2018 MNRAS, 480, 149

Most efficient halo mass at hosting DSFGs

Downsizing:

[1]The mass of ‘star-forming galaxies’ declines with decreasing redshift
(Cowie et al. 1996; Bundy et al. 2006; Fontanot et al. 2009; Conroy & Wechsler 2009; Ishikawa et al. 2016, Wilkinson et al. 2017)

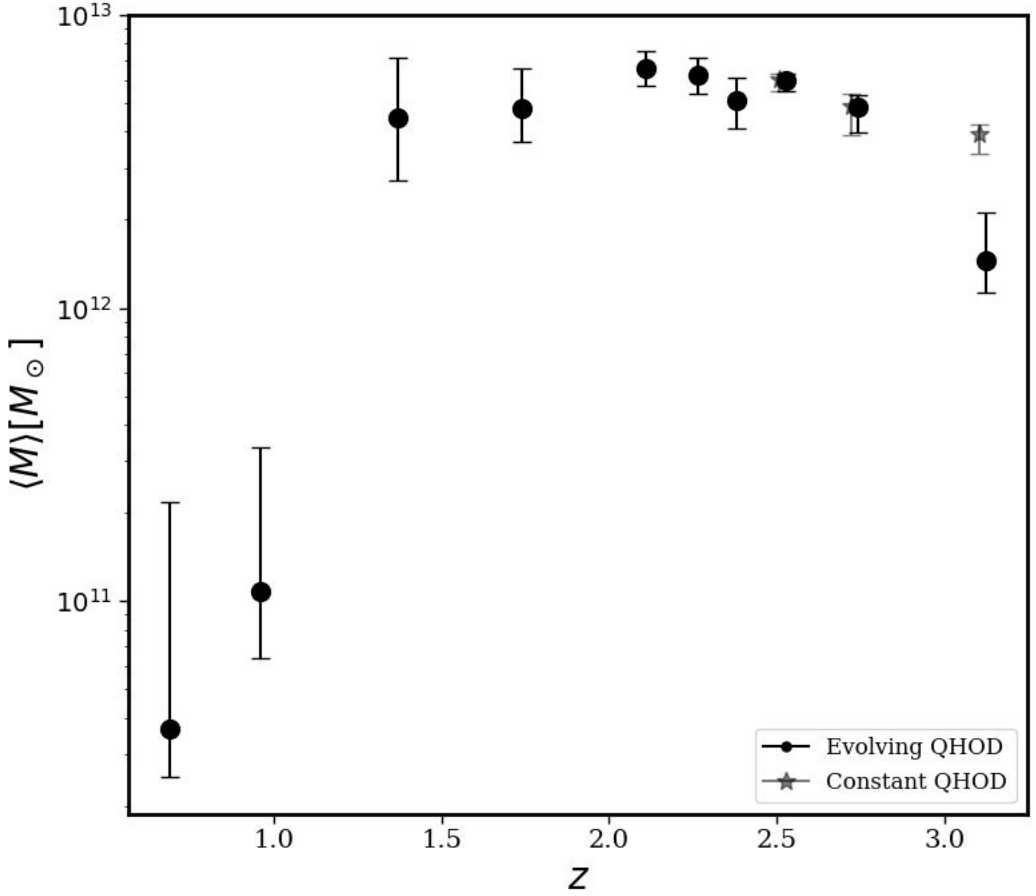


Hall et .al, 2018 MNRAS, 480, 149

Mean halo mass hosting DSFGs

Archaeological Downsizing:

[2]More massive halos host galaxies that assembled their stars earlier
(Behroozi et al. 2013; Tojeiro 2016; Cochrane et al. 2017)



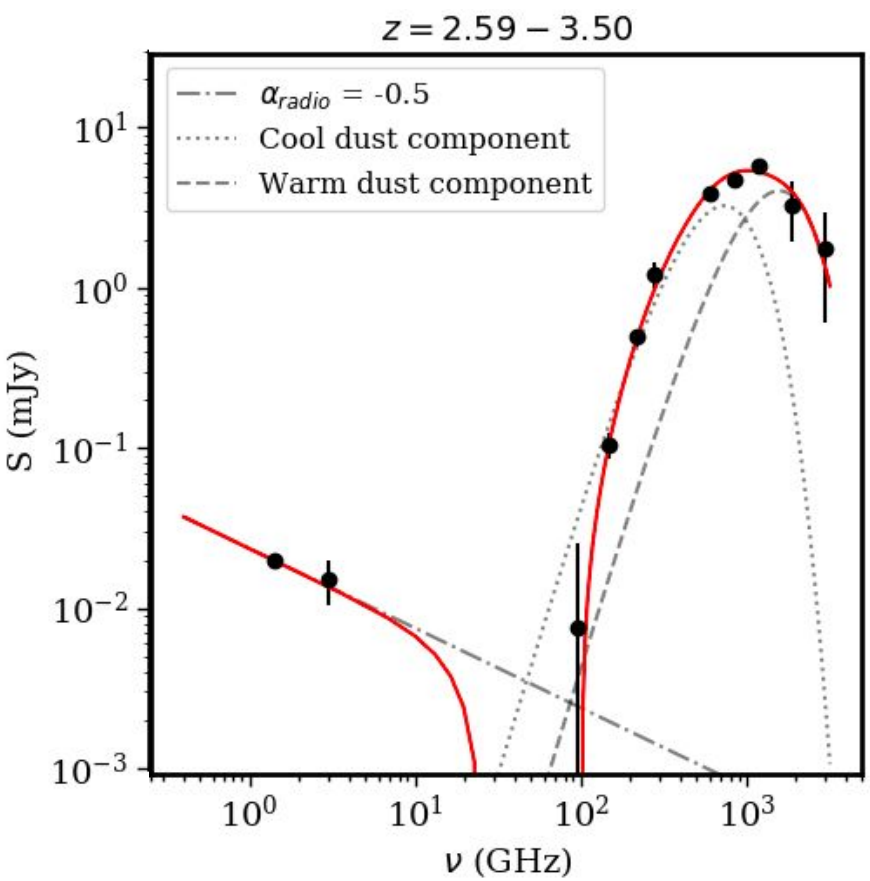
Hall et .al, 2018 MNRAS, 480, 149

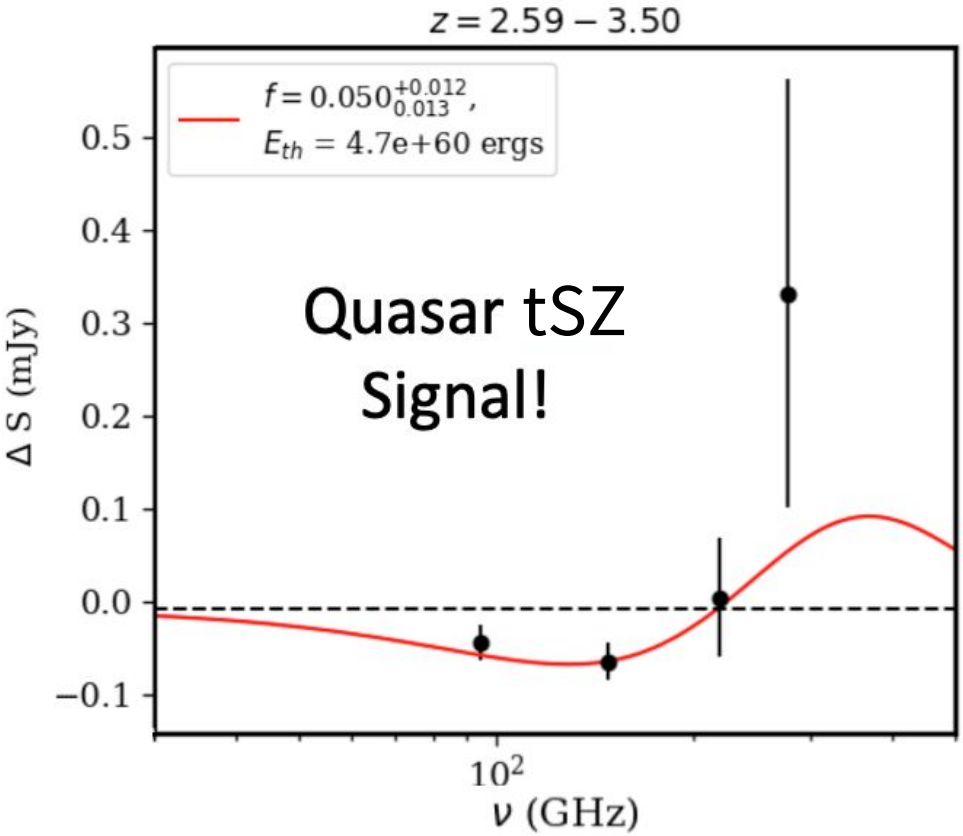
One more reason this study is important...

Quantifying the clustered infrared background = Quantifying a bias in other stacking analyses

- SEDs of quasars in the far-infrared, then the clustered background component needs to be understood/quantified

  ⇒ Other very exciting work by me and my research group and the ACT collaboration





Hall et al. 2019, submitted arXiv:1907.1131

See also: Crichton, Gralla, **Hall** et al. 2016

Summary: *Clustering of star forming galaxies around quasars*

- Halo masses of DSFGs as a function of z ⇒ Cosmic downsizing
  1) Most efficient halo mass at hosting DSFGs decreases from z~3 to z=0.5
  2) Mean halo mass of DSFGs indicates galaxies in today's most massive halos formed their stars at higher z
  3) $\rho_{SFR,\ DSFG}$ consistent with $\rho_{SFR,\ cosmic}$

- Cross-correlations are extremely useful for studying quasars, their clustered environments, and clustering in general