Universiteit Leiden
Leiden Observatory

Protoclusters traced by high-redshift massive galaxies

Cristina García Vergara

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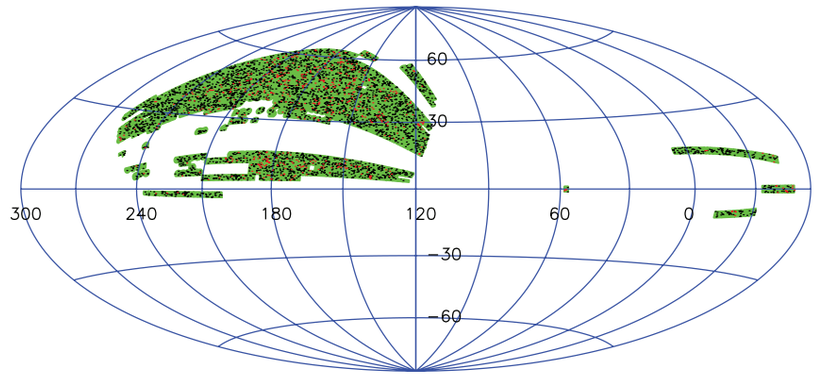
Garching, July 19, 2017

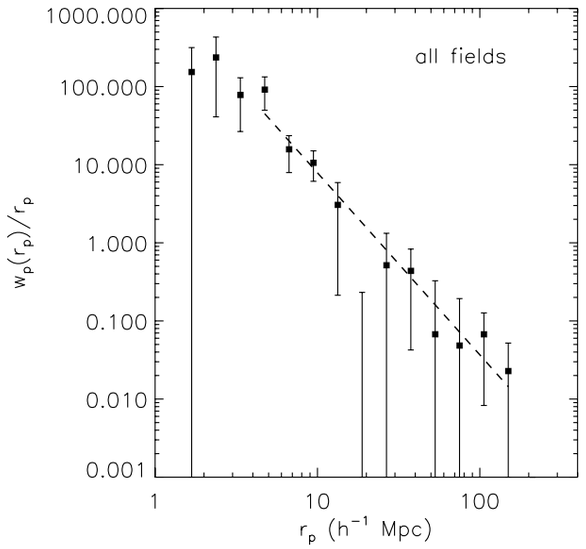
General theoretical prediction: Massive galaxies should trace massive dark matter halos in the early Universe

How could we test it observationally?

1. By measuring the clustering of massive galaxies



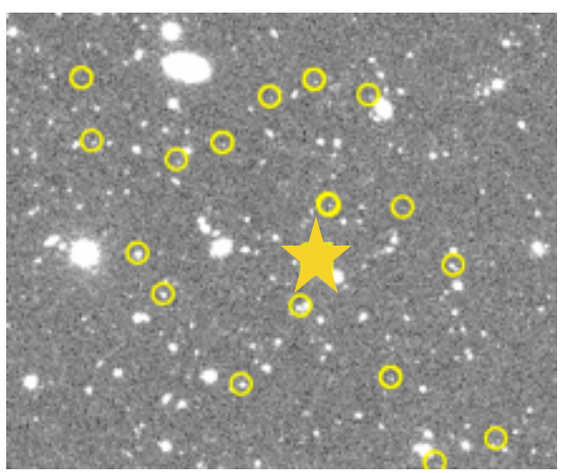
Massive galaxy survey



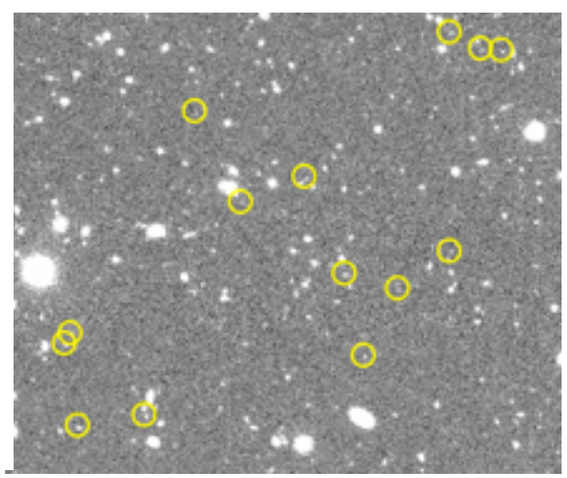
A large survey is needed

Shen et al. 2007

2. By detecting overdensities of galaxies around individual massive galaxies.



Massive galaxy field



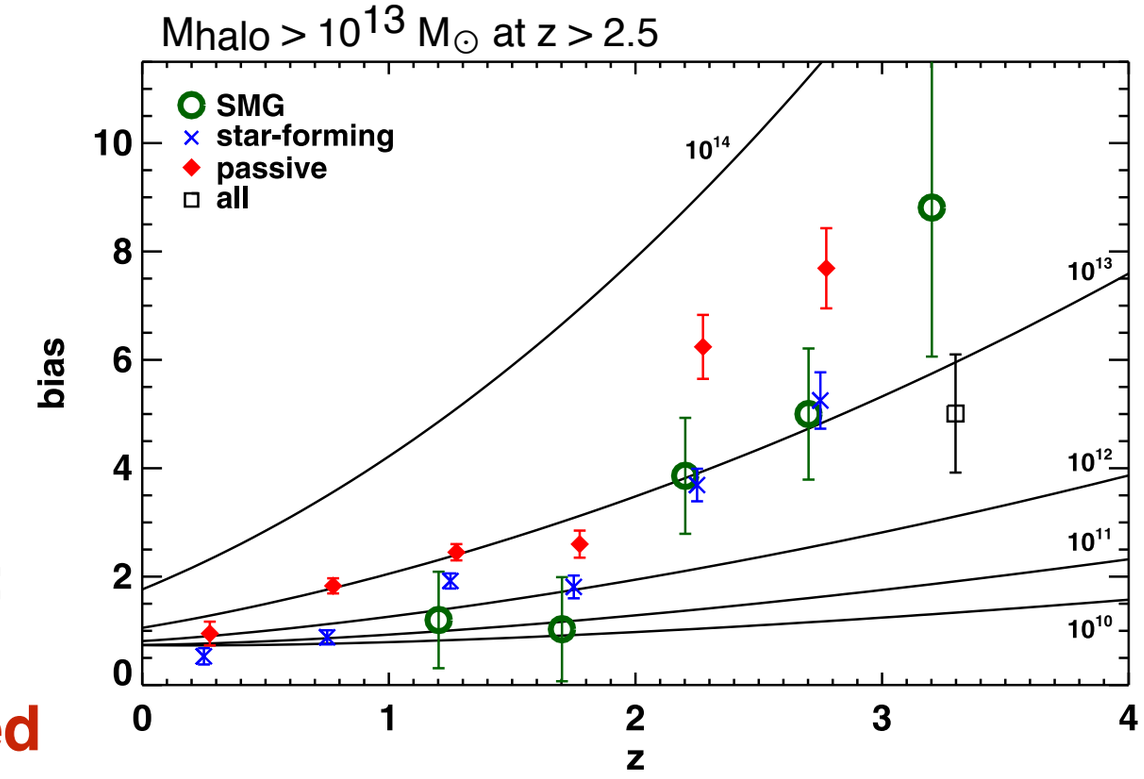
Blank field

$$\delta = \rho_{\mathrm{qso}} / \rho_{\mathrm{blank}}$$

A representative sample is needed

Massive galaxies as tracers of protoclusters: State of Art:

Wilkinson et al. 2017



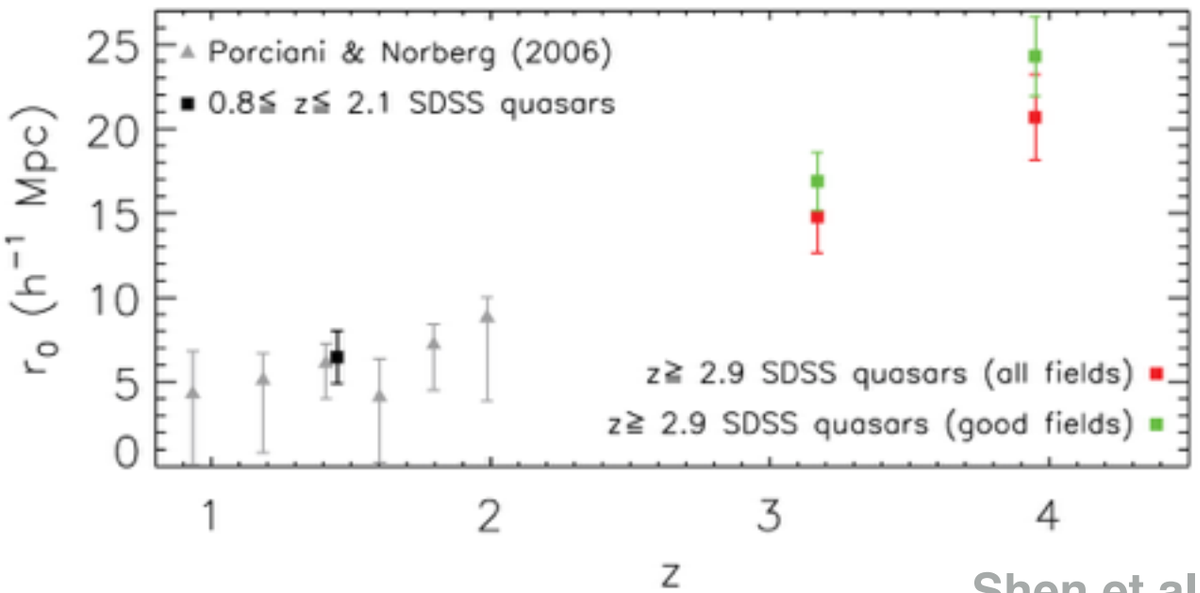
SMGs

SMG Clustering:
"Preliminar" moderate clustering measured

Overdensities around SMGs:
Few studies, but several examples of SMGs associated with overdensities

~50% SMGs associated with overdensities (Smolcic et al. 2017)

Mhalo > 3x10^{12} M$_\odot$ at z > 3.0



Shen et al. 2007

QSOs

QSO Clustering:
Strong Clustering measured at z>3

Overdensities around QSOs:
Detection of overdensities has been elusive

Bañados et al. (2013), Willot et al. (2005), Kim et al. (2009), Simpson et al. (2014), Stiaveli et al. (2005), Zheng et al. (2006), Kim et al. (2009), Utsumi et al. (2010), Morselli et al. (2014)

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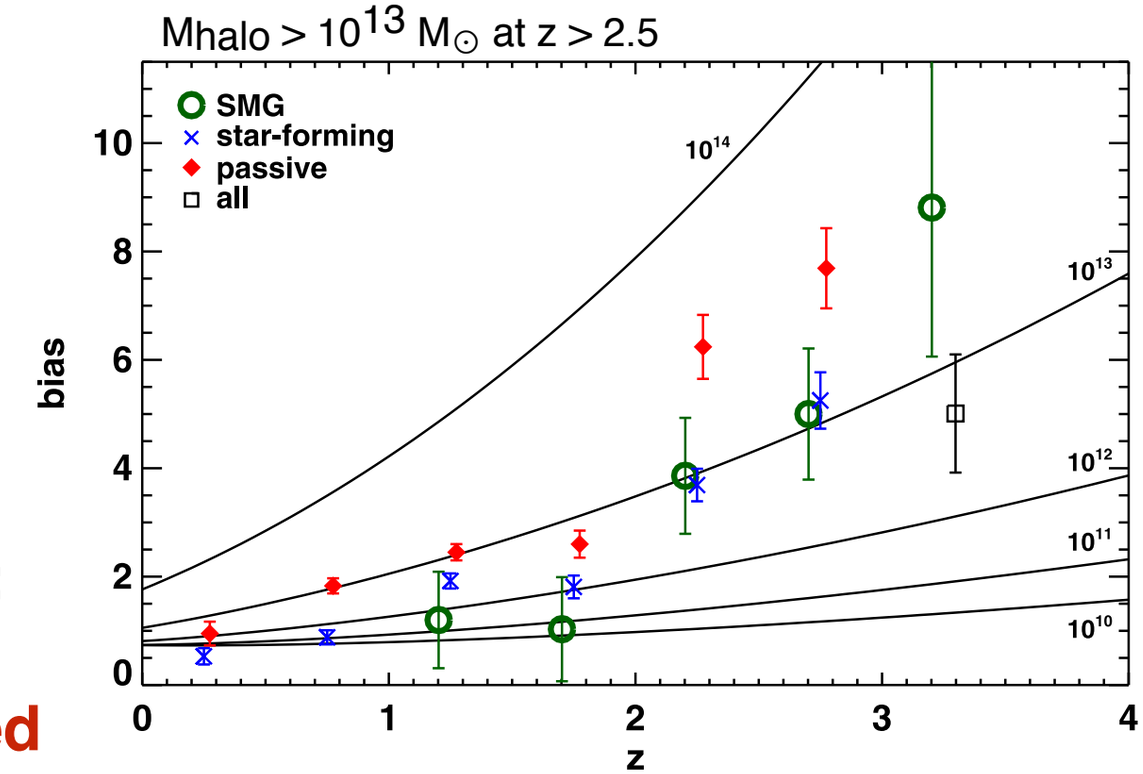

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This talk

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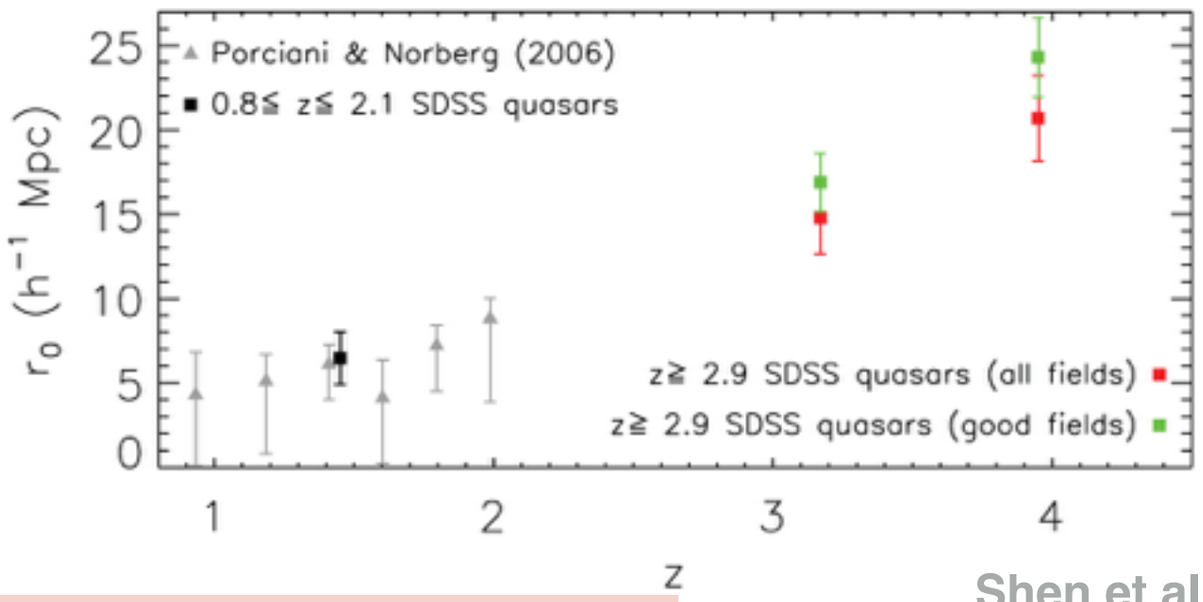

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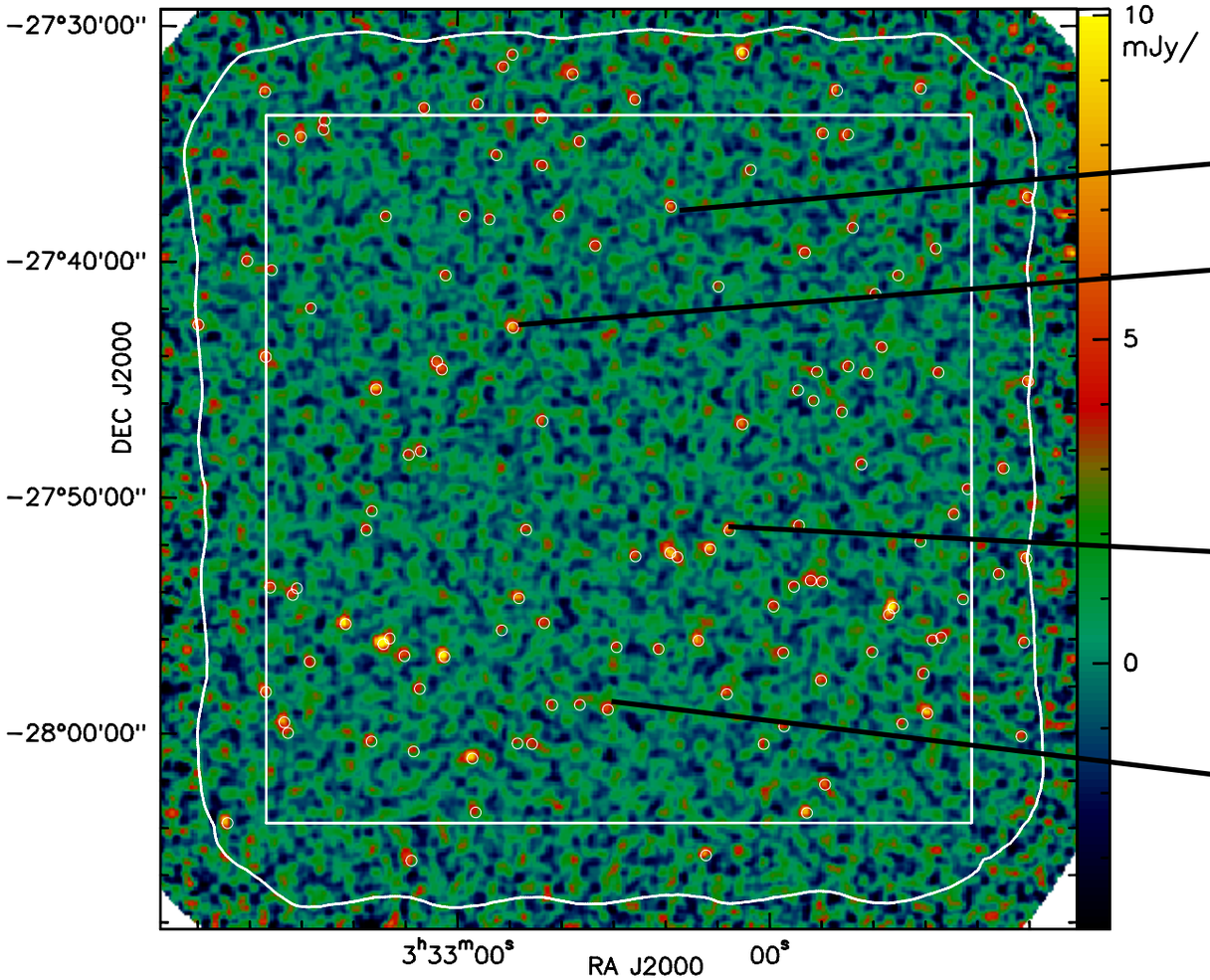
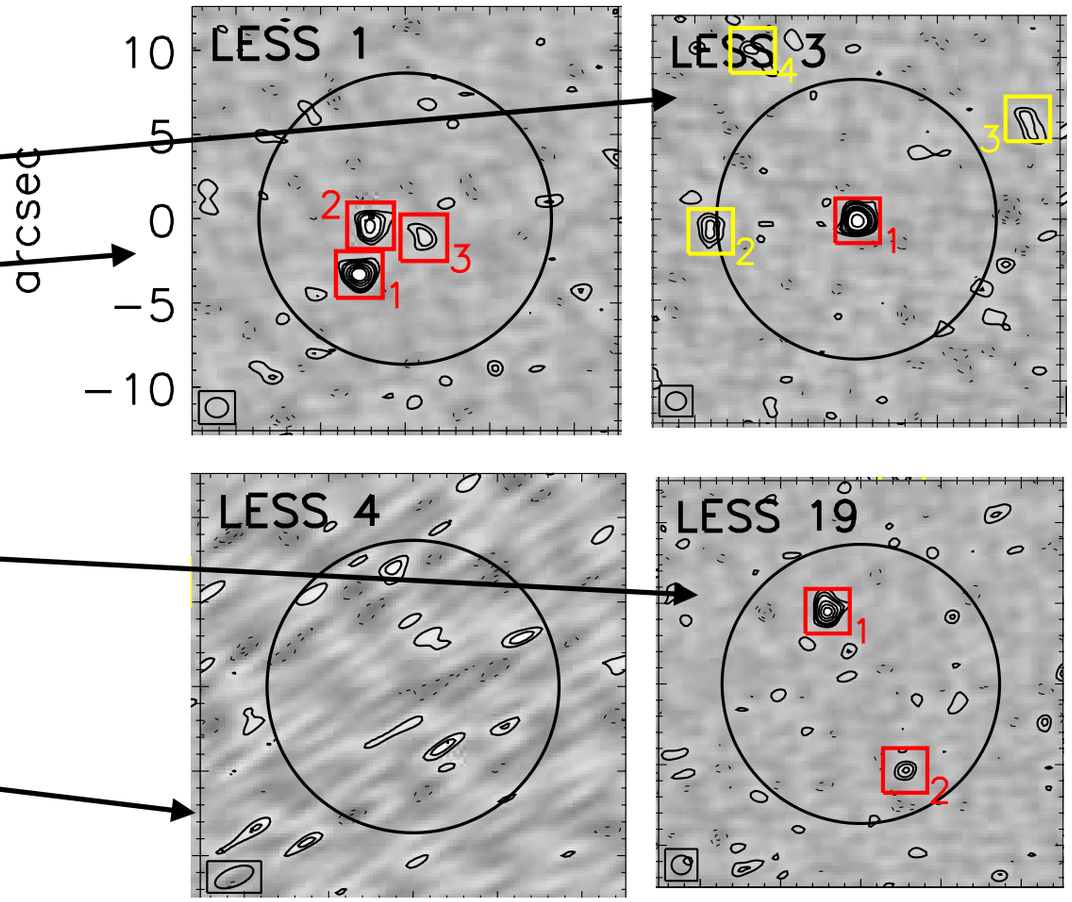
LESS (LABOCA ECDFS submillimeter survey)



- **Survey of 30'x30' at 870 micrometers**
- **Angular resolution ~15-20"**
- **126 SMGs detected at S/N >3.7**

ALESS (ALMA LESS)
Follow-up of 126 SMGs (26"x 26")



- **Angular resolution ~1-1.5"**
- **3 times deeper than LESS**
- **Several LESS sources composed by multiple faint sources**

Measuring the clustering of SMGs using ALMA data: critical to test if SMGs trace particularly massive structures.

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What we did?

We measured the “unbiased” SMG clustering using ALMA data (i.e with the exact positions) for 35 SMGs at 1< z <3

We also have spectroscopic redshifts

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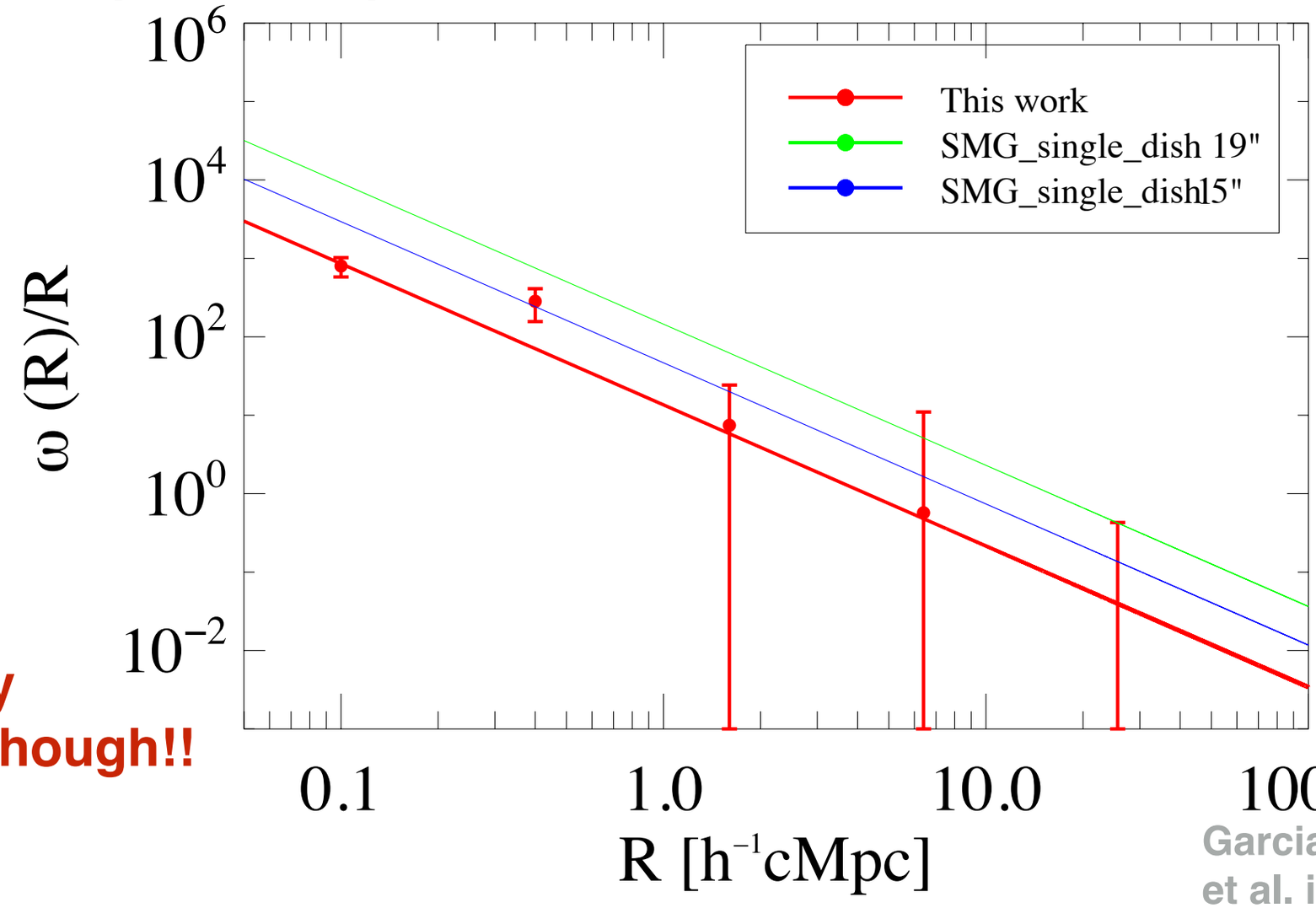

r0 = 2.1±1.3 Mpc/h

SMGs are not as strongly clustered as previously though!! (at least up to z~3)

Garcia-Vergara et al. in prep.

Studying the environments of 23 QSOs at z~4: QSO-galaxy cross-correlation function

- Six QSOs imaging to search for Lyman Break Galaxies (LBGs)
- 17 QSOs imaging to search for Lyman Alpha Emitters (LAEs)

More than only detect overdensities, we measure the QSO-galaxy cross-correlation function

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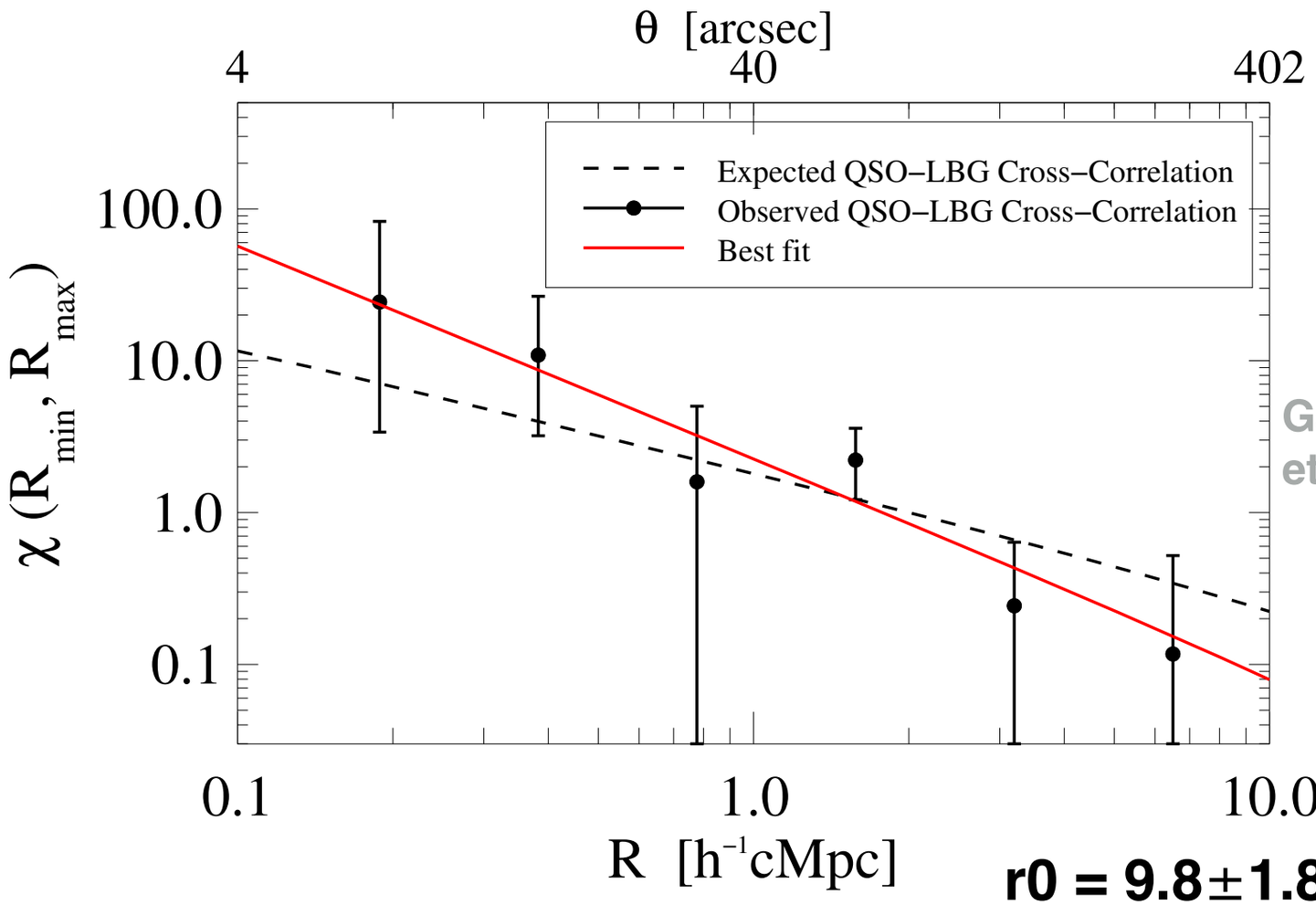
QSO-LBGs:

$$\chi = \frac{\langle QG \rangle}{\langle QR \rangle} - 1$$

⟨QG⟩: Observed number of LBGs in QSO fields.

⟨QR⟩: Expected number of LBGs in blank fields for a randomly distributed population



Garcia-Vergara et al., submitted

r0 = 9.8±1.8 Mpc/h

- **Overall overdensity of 1.5**
- **LBG are strongly clustered around QSOs at z~4**

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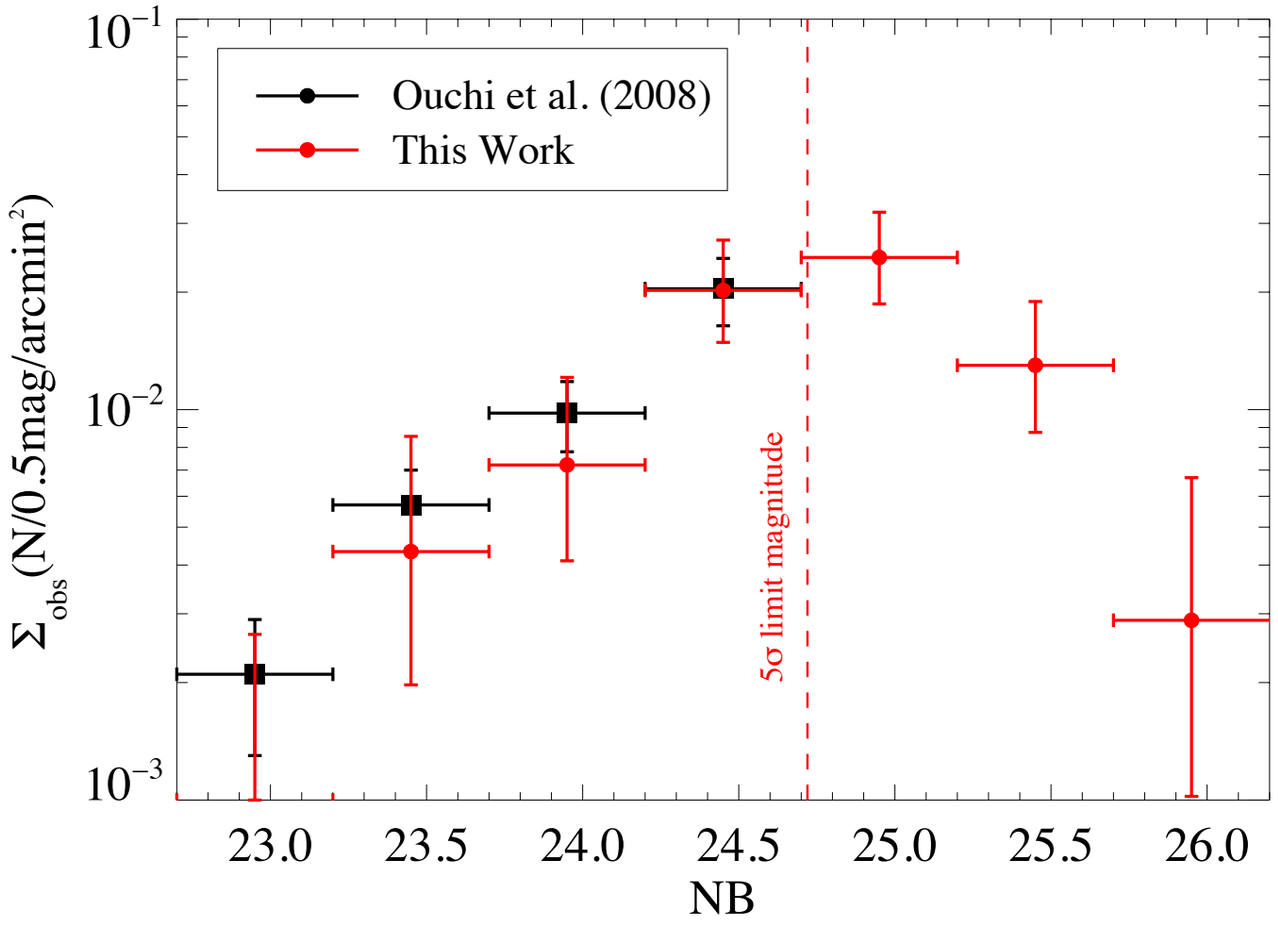
QSO-LAEs:



Garcia-Vergara et al., submitted.

- **LAEs number density is consistent with blank fields**
- **LAE are weakly clustered around QSOs at z~4**

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…then what is going on??

- Overdensity on larger scales? (Morselli et al. 2014, Utsumi et al. 2010, Uchiyama et al. 2017)
- Galaxies could be highly dusty and then invisible at optical wavelengths

(Priddey et al. 2008, Miller et al. 2016)

(QSO companions detected with ALMA at z~6: Trakhtenbrot et al. 2017, Decarli et al. 2017)

Definitely from only optical wavelengths we are not able to explain the non detection of overdensities in QSO fields, we need to move to longer wavelengths, which is a pending but promising possibility

Conclusions

QSO clustering measurements suggest that QSO trace overdense regions in the early universe (z > 3) however the detection of such overdensities in optical wavelengths has been elusive.

Some high-z QSO environments studies suggest overdensity of dusty galaxies in their close vicinity, but a systematic search of dusty galaxies in their environments is a pending task.

Current SMG clustering measurements suggest that SMGs trace overdense region at z>1. We detect that such measurements are overestimated because are based in single dish telescope data.

Using precise ALMA +spectroscopic data, we measured a weak SMG clustering at 1 < z < 3 implying that SMGs doesn't reside in specially massive locations. This could be different at higher-z. It is needed larger samples to measure clustering more accurately.

It is still pending to prove SMGs environments by looking for galaxies in both optical and radio wavelengths

Studies of structure formation need to be done from a combined optical+radio approach