Assembly bias and Redshift Space Distortions

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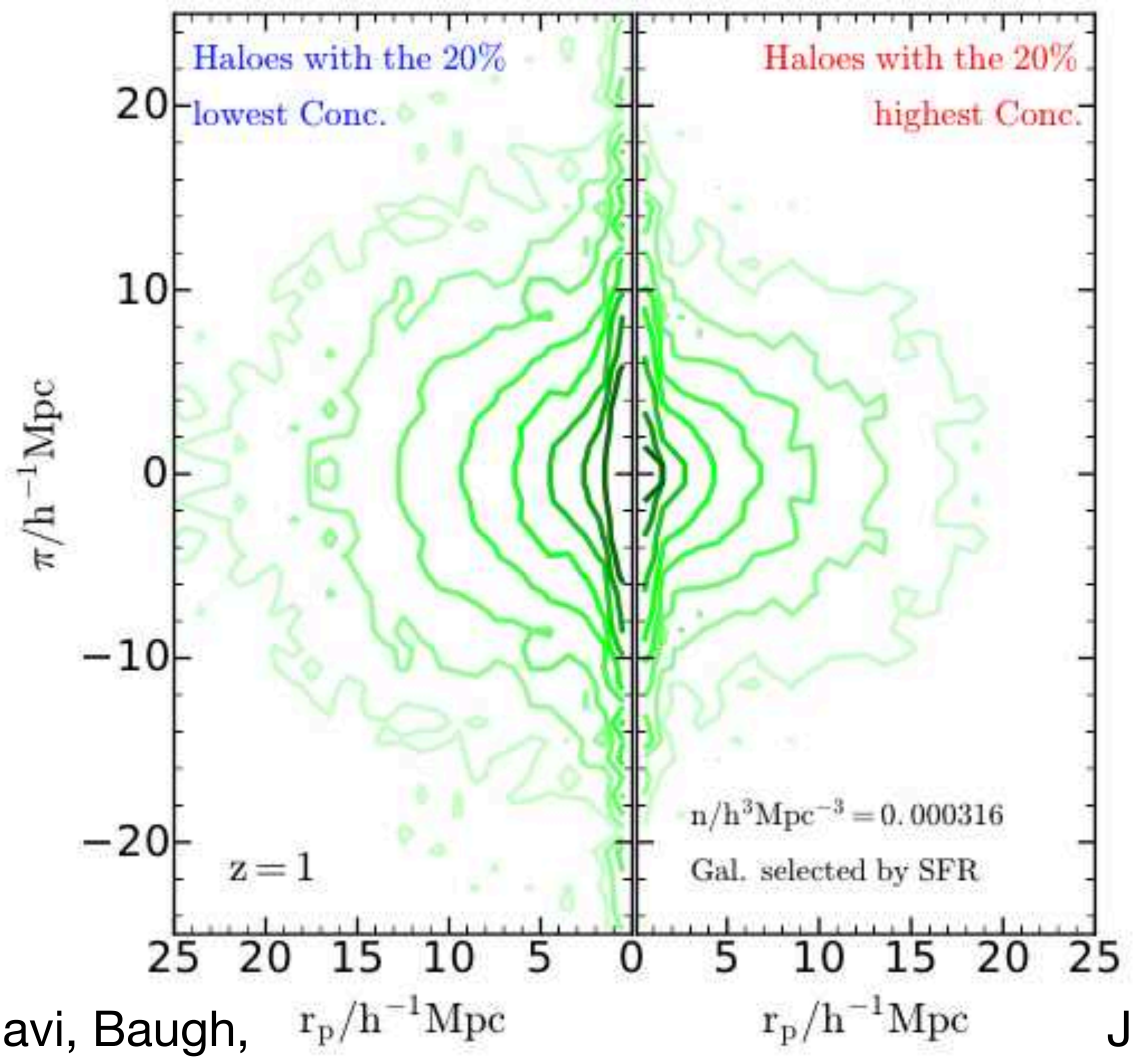
Mock Córdoba, April 2019



NP, Contreras, Zehavi, Baugh, Norberg arXiv:1809.06424.

Jimenez et al. in prep
Zehavi+18, Contreras+18

bias

/ˈbʌɪəs/

We use bias to denote the extent to which the overdensity field traced by a set of objects (denoted h) departs from the underlying overdensity field of the mass,

$$\delta_{\mathrm{h}}(1|0) = b(M_1, z_1)\delta$$

According to peak theory and spherical collapse (BBKS, Mo & White 1996), this depends on the linear amplitude of the overdensity peak.

$$\xi^{\mathrm{L}}_{\mathrm{hm}}(R_0, M_1, z_1) = \frac{(\nu_1^2 - 1)^2}{\delta_1^2}\Delta_0^2$$

where 1 is for the initial conditions, 0 for the present day, and $\boxed{\nu_1 \equiv \delta_1/\Delta_1}$

Notice that the relation between initial and final conditions is achieved via

$$M_1 = \frac{4\pi}{3}\bar{\rho}R_1^3.$$

, in the linear regime

Assembly bias of haloes

First reported back in 2004-2005 (Sheth & Tormen 2004, Gao+ 2005), where mass is not the only halo property that dictates the amplitude of clustering of haloes.

Not really surprising: why would halo mass encapsulate all the information on how many sigma away was the original overdensity from which a halo collapsed?

Additional parameters shown to be needed to achieve this:

Halo age
Halo concentration
Halo spin
Halo ellipticity
Environment

Assembly bias and velocities

➡ peculiar velocities respond to overdensity, therefore these should, in principle, be completely explained by this true bias factor

$$v(r) = -\frac{1}{3}\frac{H(z)}{(1+z)}\beta(z) r \Delta(r)$$

$$\Delta(r) := \frac{1}{V}\int_V \delta(r) dV = \frac{3}{r^3}\int_0^r \delta(r') r'^2 dr', \qquad \delta_{\rm h}(1|0) = b(M_1, z_1)\delta$$

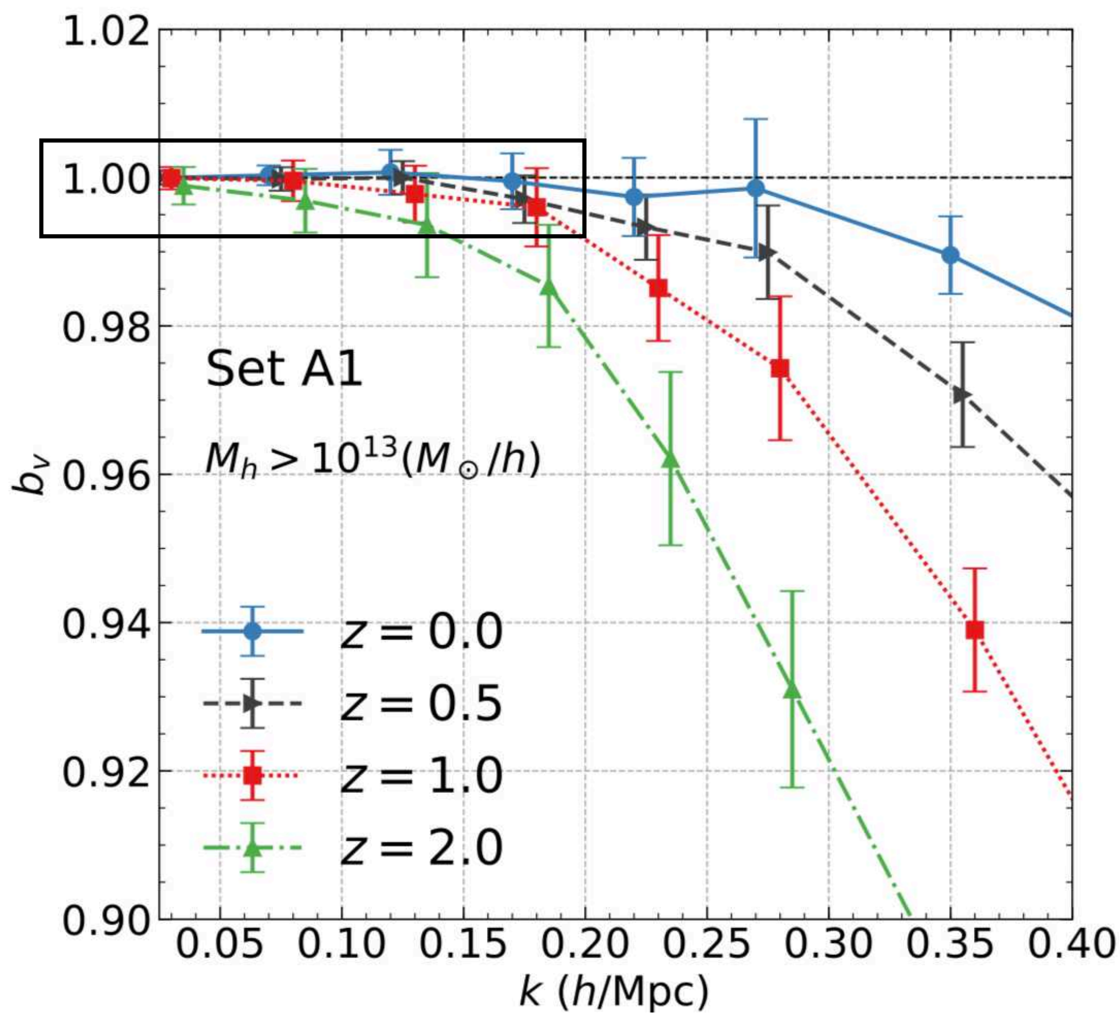
➡ in which case all cosmology information obtained from velocities should be free of systematics due to assembly bias.

➡ Except if there is non linear bias (as in Esteban's results)

➡ Or conditions on the environment or some other variable.

Velocity bias

- There is evidence of velocity bias but to a small degree (Chen+17).
- Haloes of any mass move with same average peculiar velocities as the density field in general.



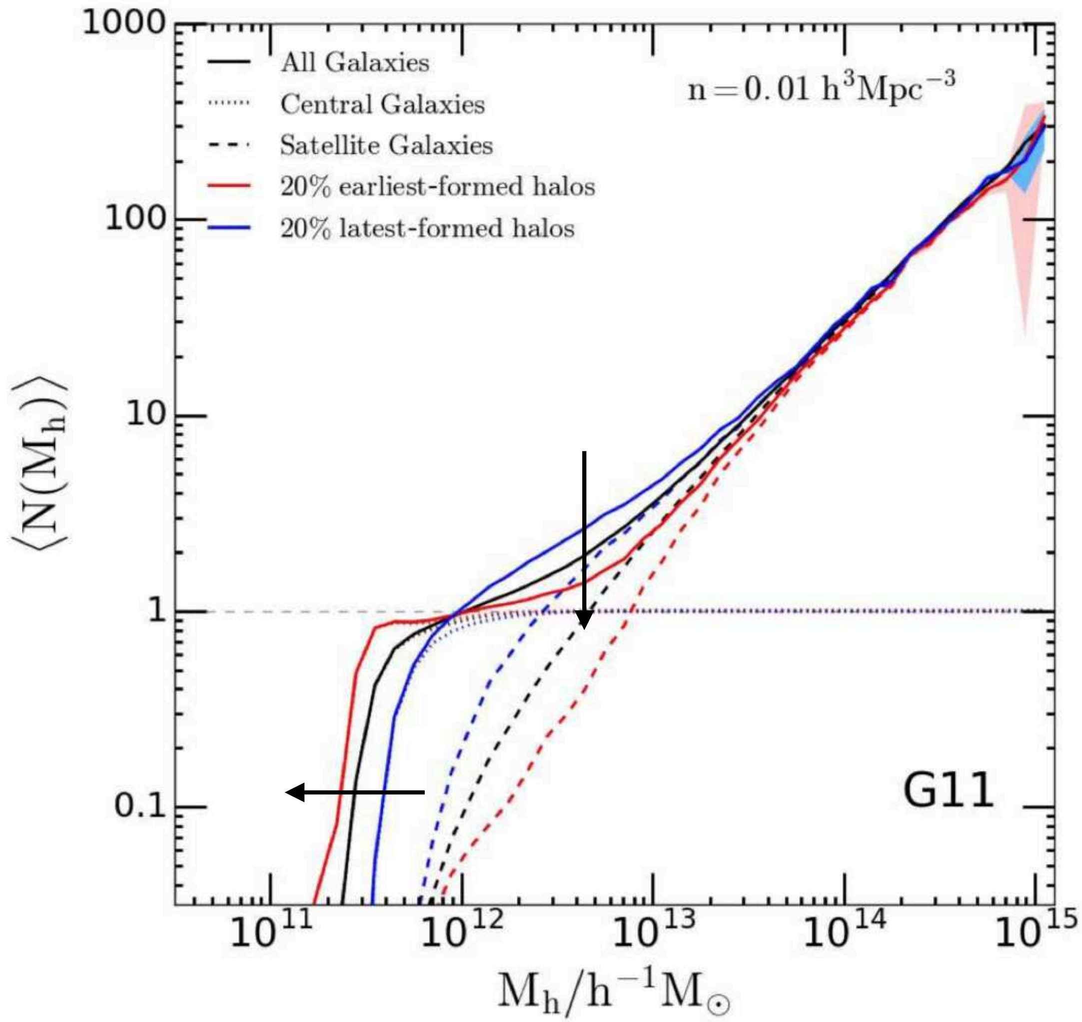
No systematics >1% should be found with assembly bias

If it is just bias

Figure from Chen+17

Galaxy assembly bias

- Use the Millennium database to study populations of SAM galaxies from the Guo+11 model run on the Millennium Simulation.
- Galaxies live in haloes, but the galaxy population in haloes can also depend on more than just the halo mass.
- For example: if the halo is old, it can have more time to merge satellites with centrals and have less galaxies above a certain stellar mass threshold.
- If haloes have different numbers of galaxies, the galaxy clustering changes because there are different weights applied to the bias of haloes



Zehavi, Contreras, NP+18

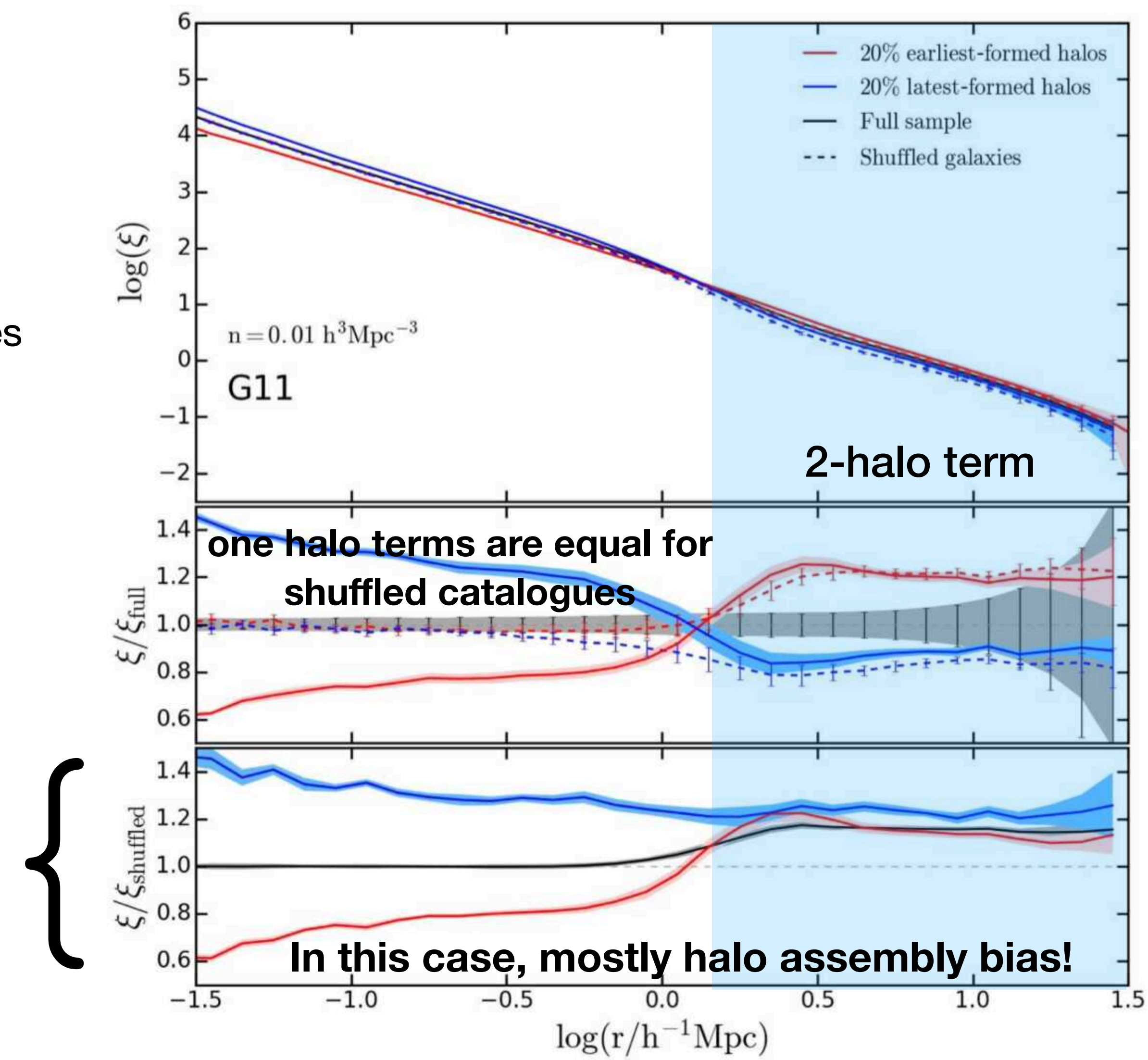
Shuffling: separate occupancy variation from halo assembly bias

- For this study we need to take into account velocities when shuffling around sets of galaxies in haloes.
- Move galaxies with positions and velocities relative to the central galaxies instead of just the satellite positions.
- Removes occupancy variation
- This also removes any dependence of intra-halo velocities on properties other than halo mass.

NP, Contreras, Zehavi, Baugh, Norberg arXiv:1809.06424.

Galaxy assembly bias

- One can remove this variation of galaxy population with secondary halo property shuffling the galaxies in haloes.
- Send all galaxies in one halo to another one chosen at random.
- Then repeat for all haloes!



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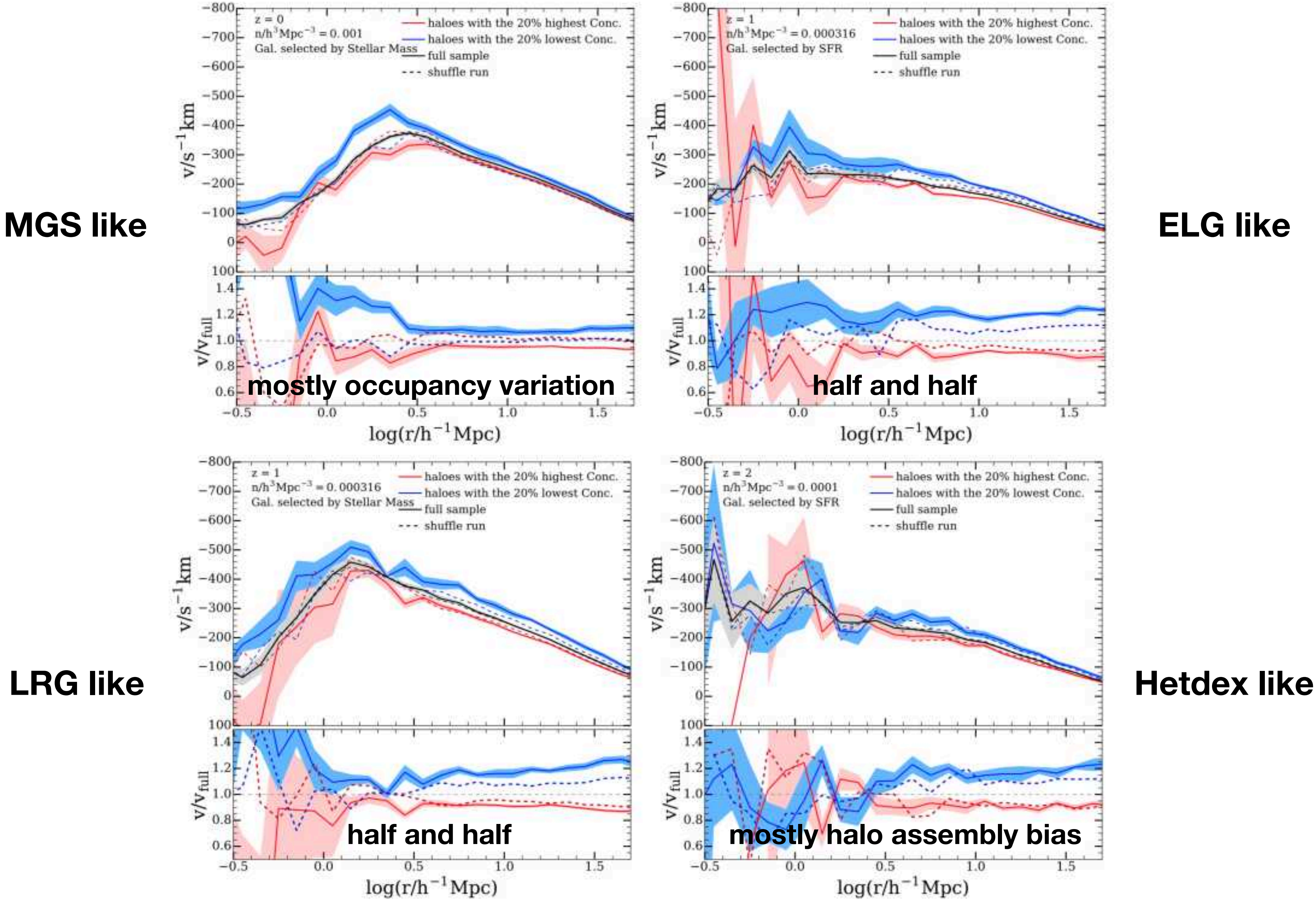
Pairwise velocities

$$v(r) = \langle (\mathbf{v_i} - \mathbf{v_j}) \cdot (\mathbf{r_i} - \mathbf{r_j}) \rangle |_r$$

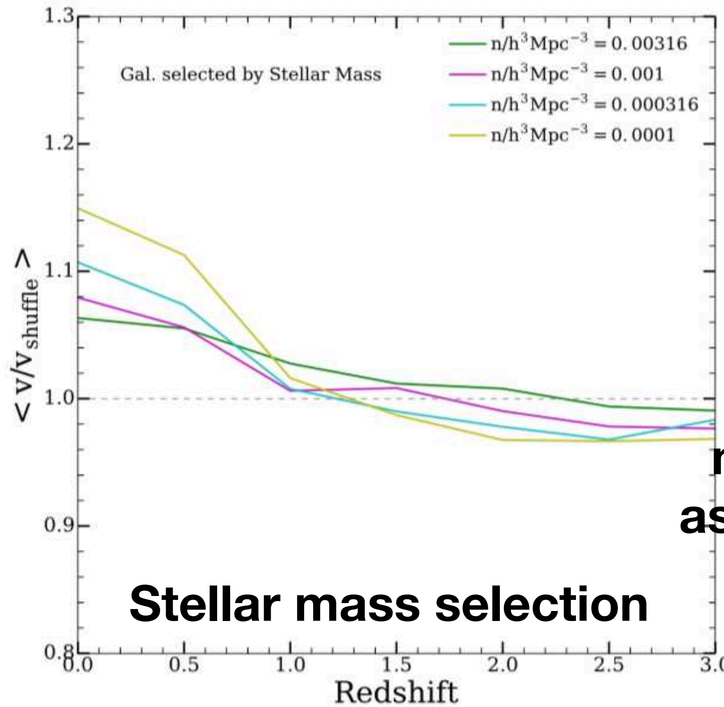


Average pairwise velocities

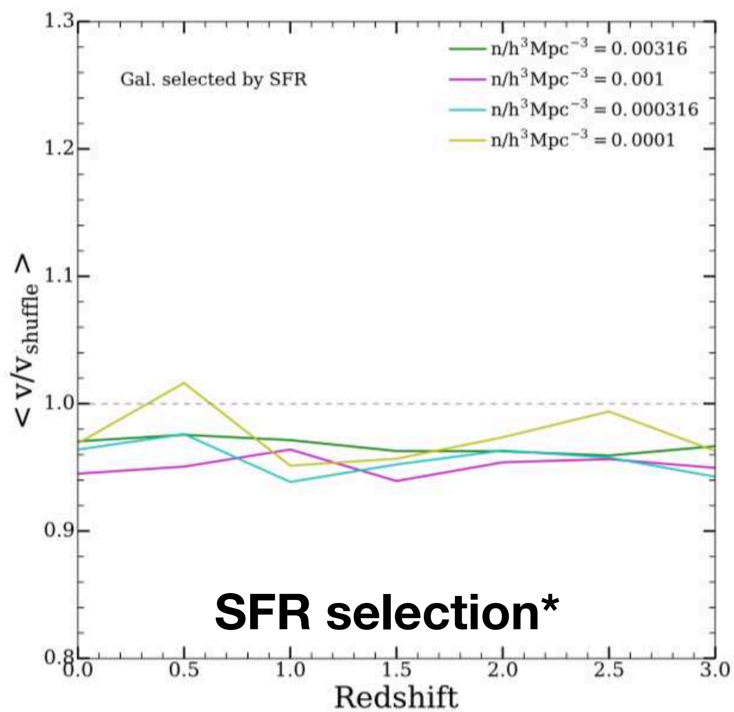
- Average 2-halo term velocities (over 10 to 35Mpc/h) and compare original vs. shuffled catalogues

- Stellar mass selection shows redshift dependence of variation in velocity correlations due to galaxy multiplicity and halo assembly bias: galaxy assembly bias.

- Star formation selection, ~emission line selection, shows b<1 due to weights.



=1 implies mostly halo assembly bias



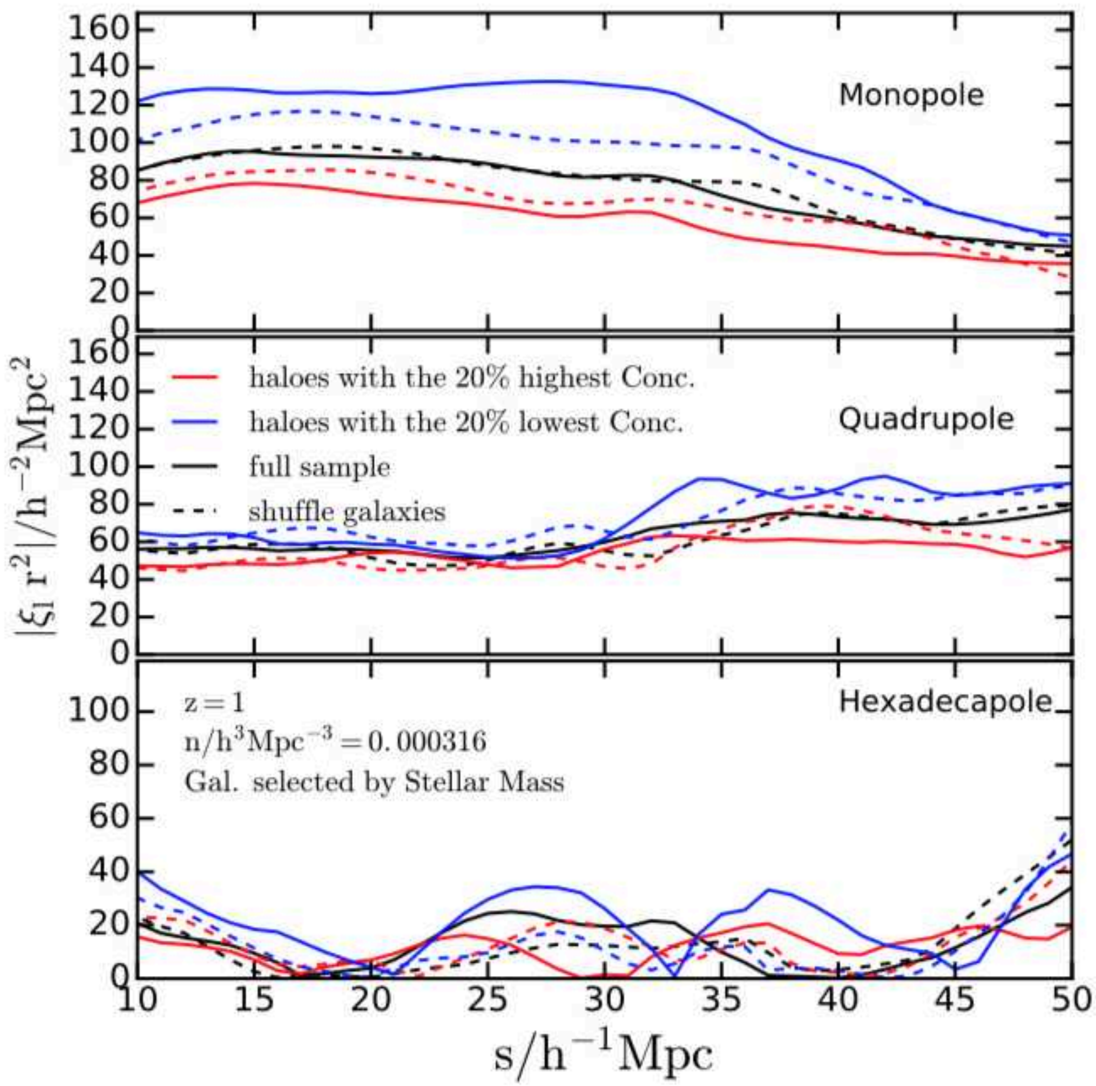
NP, Contreras, Zehavi, Baugh, Norberg arXiv:1809.06424.

Multipoles

$$\xi_l(s) = \frac{2l+1}{2}\int d\mu\xi(r_p,\pi)L_l(\mu)$$

$$s = \sqrt{r_p^2 + \pi^2} \qquad \mu = \pi/s,$$

- The amplitude of the monopole responds to the second parameter, in part to assembly bias, in part to occupational variation.
- Quadrupole also responds this way. This is mostly due to the velocity field.



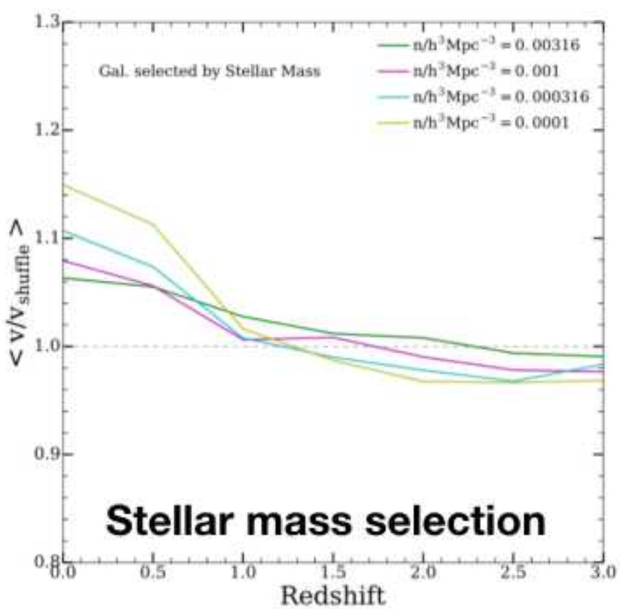
Stellar mass selection

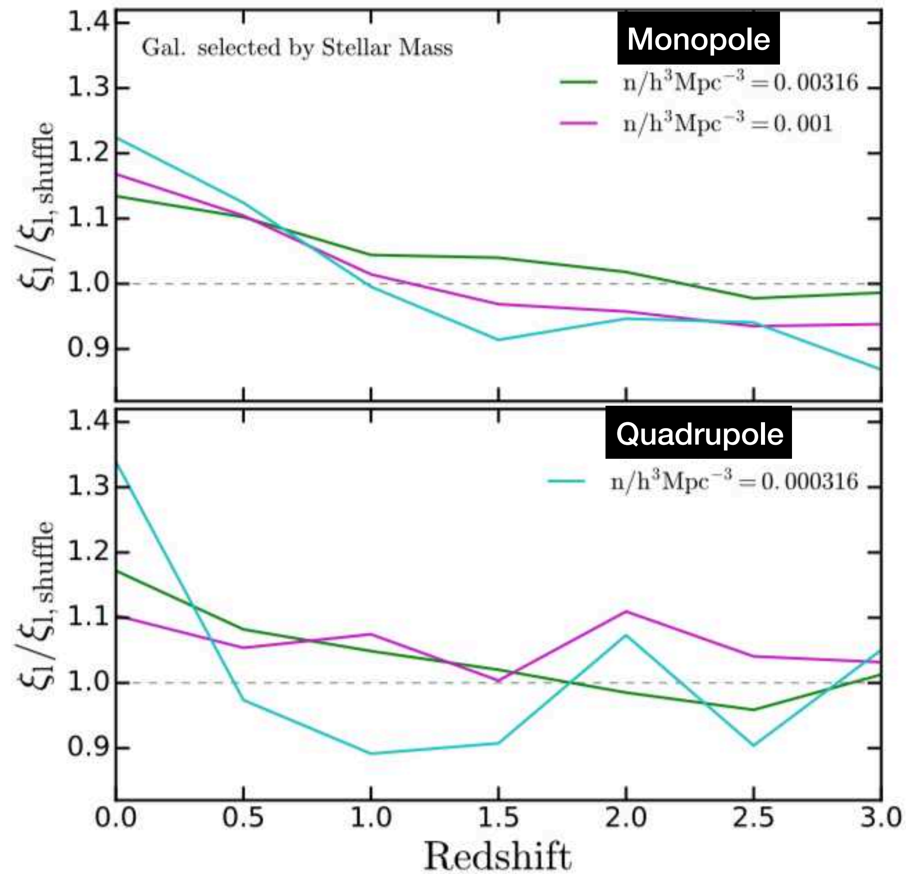
NP, Contreras, Zehavi, Baugh, Norberg arXiv:1809.06424.

Average multipoles

- Average 2-halo term monopole and quadrupole and compare original vs. shuffled catalogues

- Effectively comparable to dependence of velocities on occupancy variation

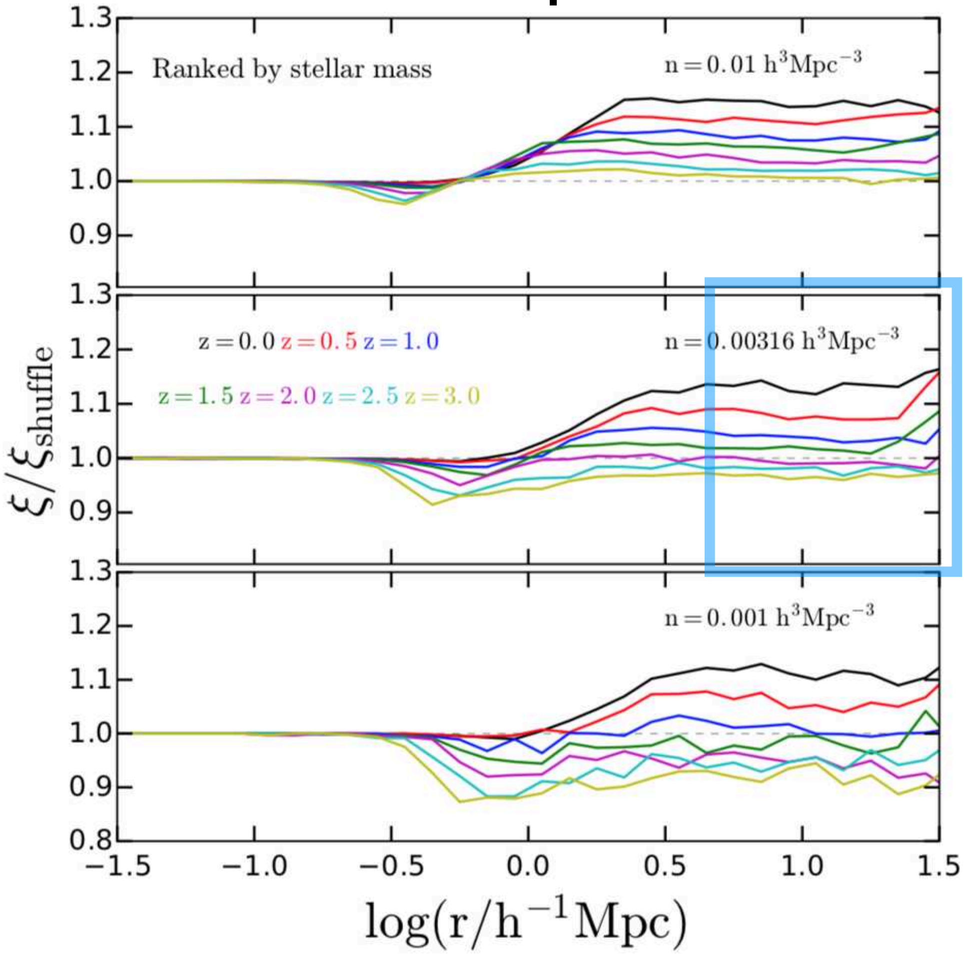




Stellar mass selection

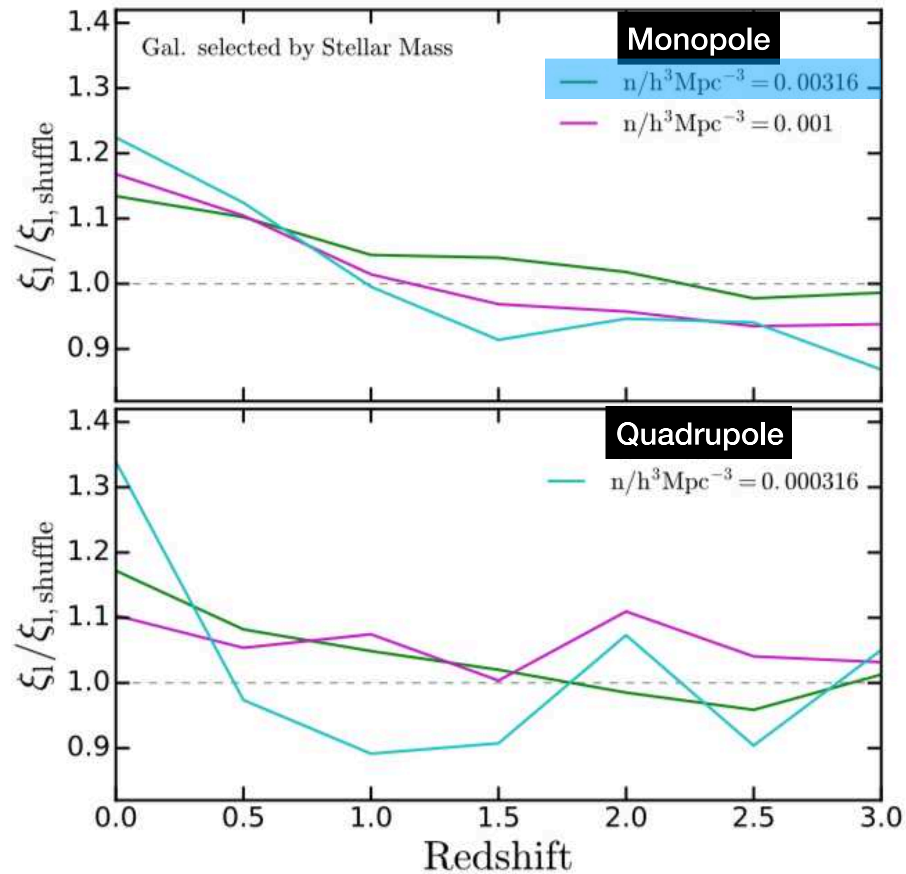
Average multipoles compared to real space correlations

Real space



from Contreras+18

Redshift space

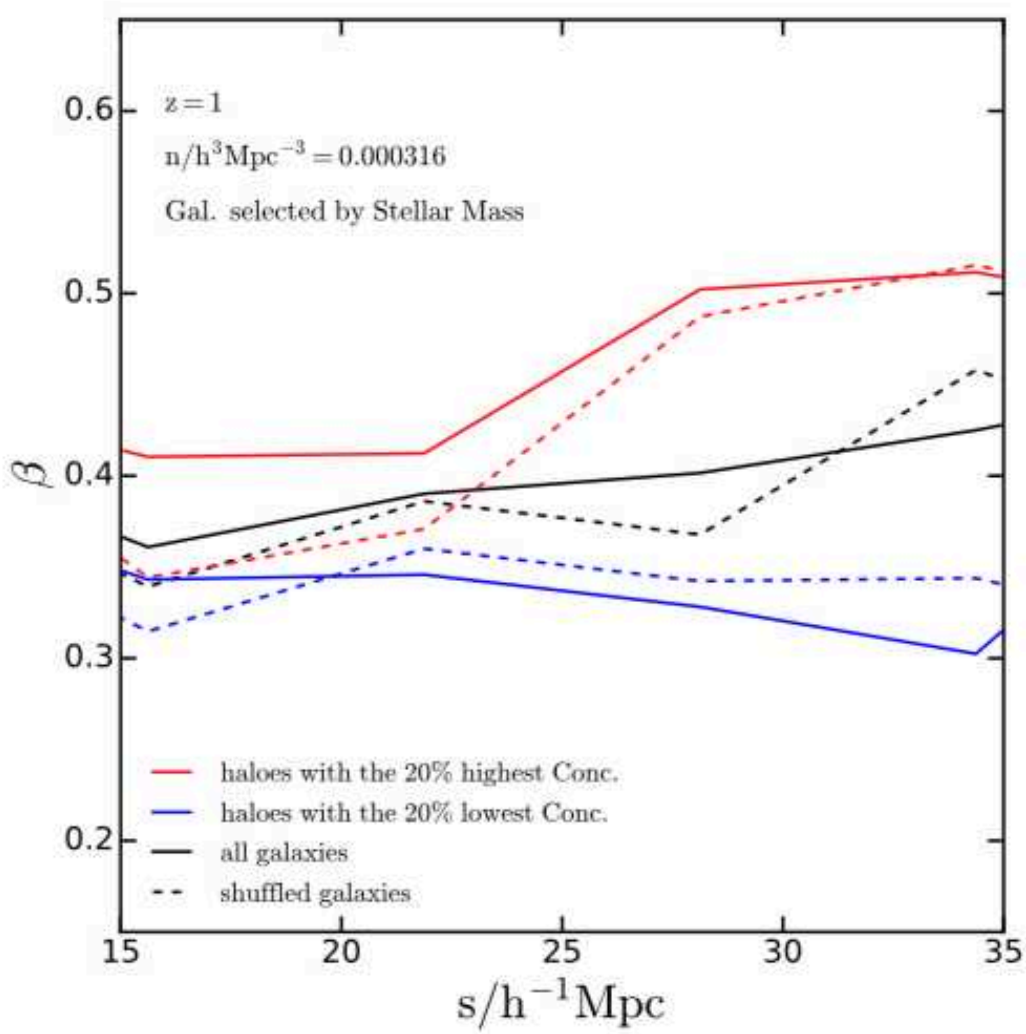


Stellar mass selection

- Velocities respond to mass as if assembly bias is just bias.

Resulting Beta parameters

- Dependence on concentration mirrors variation of bias.
- Results for shuffled samples (dashed) are similar to full samples, as was the case for pairwise velocities.
- Kevin McCarthy's talk (McCarthy, Zheng & Guo 19)



Stellar mass selection

NP, Contreras, Zehavi, Baugh, Norberg arXiv:1809.06424.

To what degree is the response to the second parameter in phase space the same as in configuration space?

- In linear theory the monopole of the redshift space correlation function and the real space correlation functions are related via

$$\xi_0(s) \equiv \left(1 + \frac{2}{3}\beta + \frac{1}{5}\beta^2\right) \xi(r),$$

- Beta encapsulates cosmological information; a stronger anisotropy in the line of sight indicates stronger velocities, i.e. a more developed growth of density perturbations, which in turn responds to the expansion history of the Universe.

$$\beta = \frac{f(\Omega)}{b_s}$$

- Is the bias factor the one indicated by the real space clustering? If so, it should be the same as the ratio of the real space correlation functions of the samples with different secondary parameters.

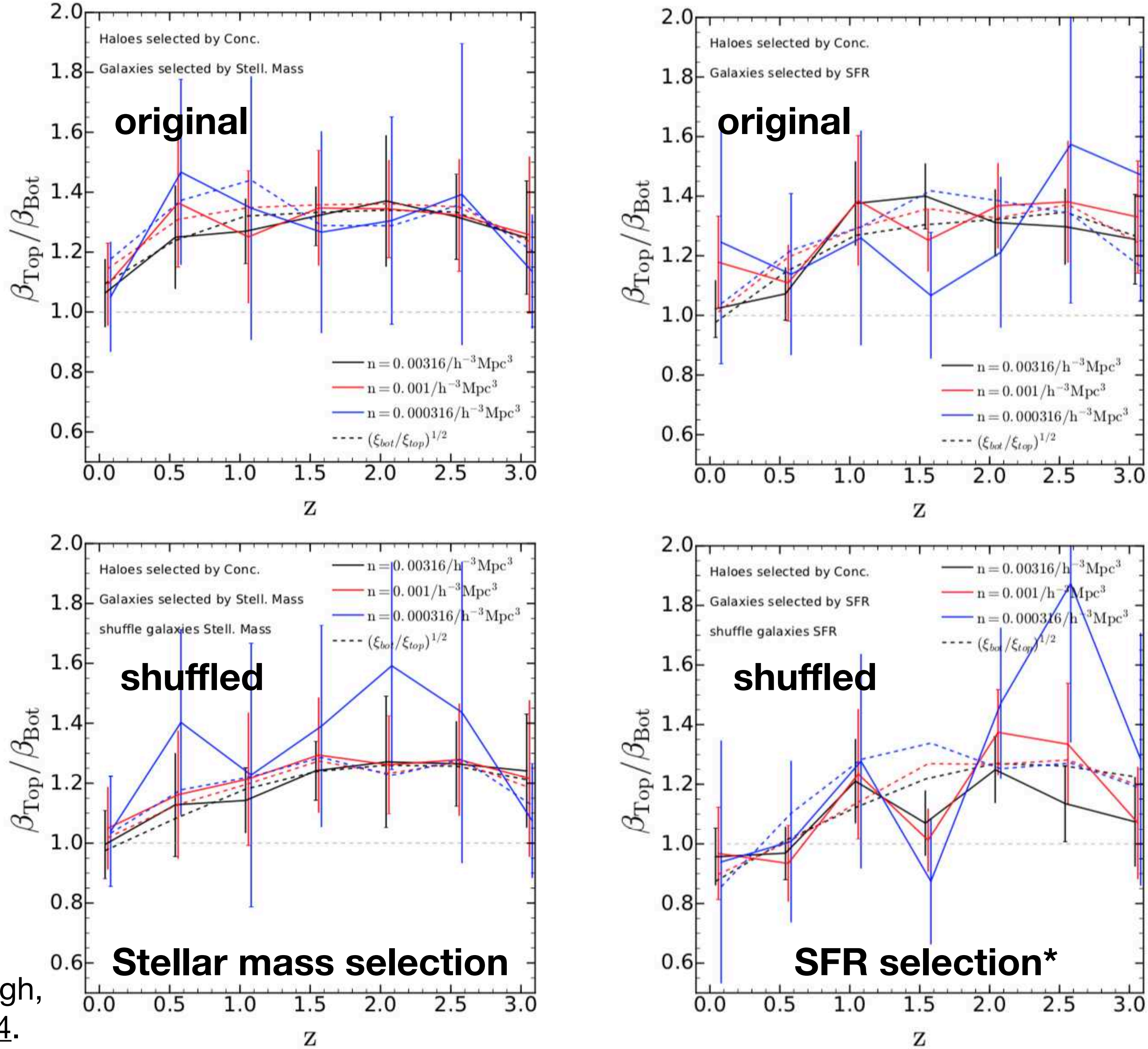
solid lines $\frac{\beta_1}{\beta_2} = \frac{b_2}{b_1} \overset{?}{=} \sqrt{\frac{\xi_2}{\xi_1}}$ **dotted lines**

Beta ratios

Solid lines: ratios of beta values found using redshift space measurements.

Dotted: obtained from real space measurements

Colours: different space densities



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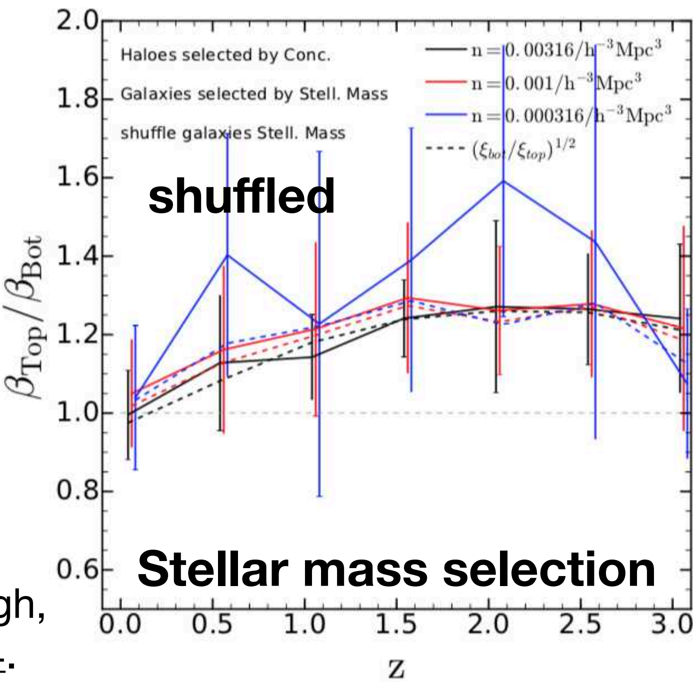
Beta ratios

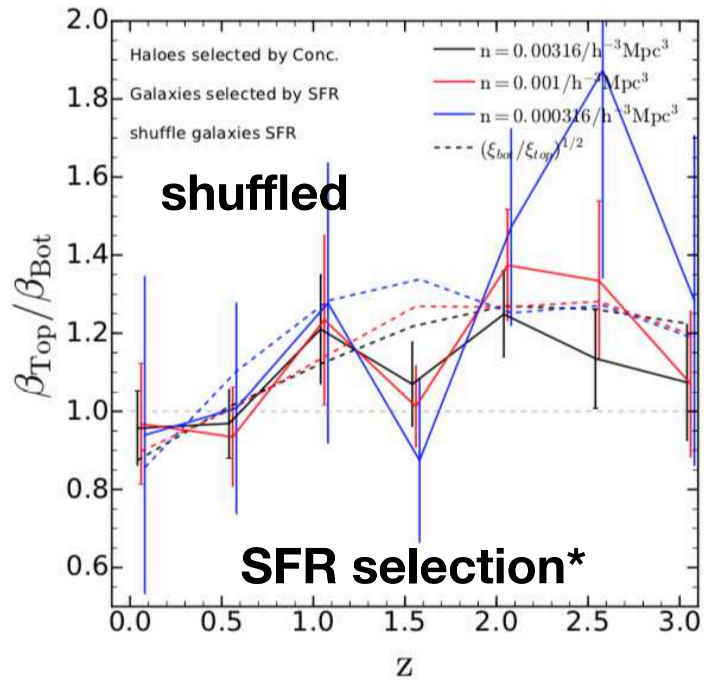
Dashed and solid lines consistent with one another points to velocity field responding to assembly bias as if it is just bias*

Solid lines: ratios of beta values found using redshift space measurements.

Dotted: obtained from real space measurements

Colours: different space densities





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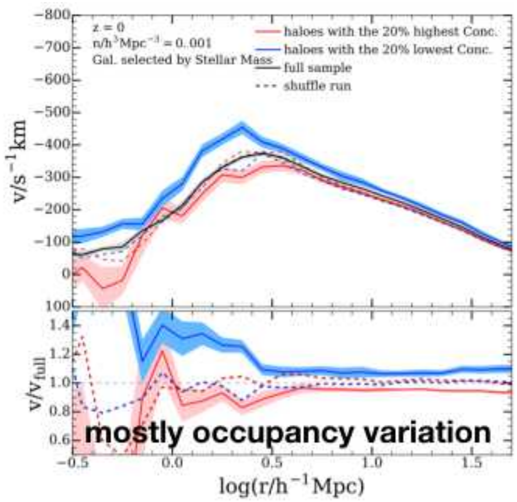
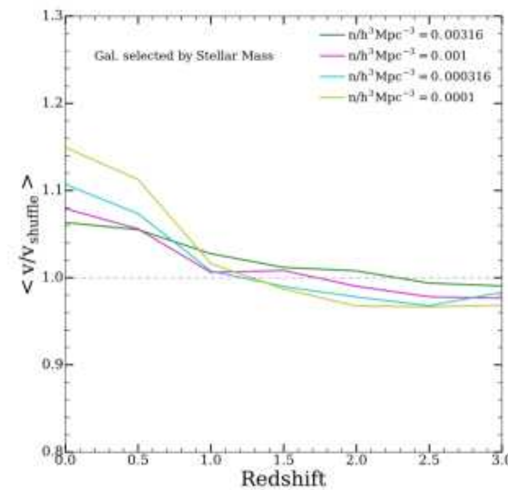
Conclusions



Shuffling can be used to identify whether halo assembly bias or occupancy variation contribute to GAB

assembly bias is just bias*

Cosmological constraints from redshift space distortions should be free of systematics due to assembly bias



Clustering and pairwise velocities respond equally to secondary halo param, e.g. Esteban's talk.

NP+19, Contreras+18, Zehavi+18

(*) to the level allowed by Millennium WMAP7, for Stellar mass of SFR selection