# Evidence for Galaxy Assembly Bias in BOSS CMASS redshift-space 2PCF

Sihan Yuan, Boryana Hadzhiyska, Sownak Bose, Daniel Eisenstein, and Hong Guo

[arxiv:2010.04182]

### The lensing tension



Current galaxy-galaxy lensing predictions are 20-40% higher than observation.

Systematics? Modeling? Cosmology?

#### The galaxy-halo connection model



• The halo occupation distribution model (HOD).

 $P(N_g|M)$ , Parameters:  $[M_{cut}, M_1, \sigma, \alpha, \kappa]$ 

- Links galaxy occupation solely to halo mass.
- Assembly bias: secondary dependencies other than mass?

Yuan et. al. 2018

# **Extended HOD (GRAND-HOD)**

- Vanilla parameters.
- Generalized parameters:
  - Assembly bias based on concentration.
  - Satellite radial distribution parameters.
  - Velocity bias parameters for centrals and satellites.

 $\rightarrow [M_{\text{cut}}, M_1, \sigma, \alpha, \kappa]$ 

 $\rightarrow [A]$ 

 $\rightarrow [s, s_p]$ 

 $\rightarrow [\alpha_c, s_v, s_r]$ 

Yuan et. al. 2020

#### The lensing tension

Slide Credit: Johannes Lange



Clustering+Lensing mismatch cannot be explained by galaxy assembly bias.

#### The environmental assembly bias



Yuan et. al. 2020b Bose et al. 2018

#### **Environment definition**



# **Extended HOD with double assembly biases**

- Vanilla parameters.
- Generalized parameters:
  - Assembly bias based on concentration and environment.
  - Satellite radial distribution parameters.
  - Velocity bias parameters for centrals and satellites.

$$\rightarrow [M_{\text{cut}}, M_1, \sigma, \alpha, \kappa]$$



 $\rightarrow [s, s_p]$ 

 $\rightarrow [\alpha_c, s_v, s_r]$ 

# Fitting the BOSS redshift-space 2PCF

- Data:
  - $\circ$  BOSS CMASS galaxies within 0.46 < z < 0.61 (DR12).
  - Fiber-collision corrected.
- Algorithm:
  - Evolutionary global optimization routine (CMAES).





(wikipedia)

# Fitting the BOSS redshift-space 2PCF

- We get a good fit:  $\Box^2 = 50$  (d.o.f = 37).
- Preference for both assembly biases:
  - Include A:  $\Delta$ BIC = 21.
  - Include Ae:  $\Delta$ BIC = 17.
  - Combined:  $\Delta$ BIC = 36.





## The lensing prediction



# A path towards resolving the lensing tension?



Average halo mass per galaxy:

- No assembly bias: 4.1e13 Msun,
- Include A: 3.6e13 Msun,
- Include Ae: 3.7e13 Msun,
- Include both: 3.3e13 Msun.

The LOS structure of the 2PCF is pushing galaxies into lower mass halos.

# What is exactly driving these assembly biases?

Concentration-based assembly bias **A**:

Environment-based assembly bias **Ae**:



### A positive detection of Ae



• A consistent detection of Ae across all fits:

- Ae might depend on cosmology (need more testing).
- What is it tracing? Splashback?

# Inflating the 2PCF bin size



**Tophat Environment** 



Tophat, but inflated bins

#### Splashback can explain Ae

- Splashback would explain the scale preference.
- Splashback would explain a positive Ae.
- Splashback would explain the drop in average halo mass.
- We need to test this....



Credit: Benedikt Diemer

Credit: Johannes Lange

#### A negative detection of A



The concentration-based assembly bias is degenerate with sigma\_8.

#### **Other recent studies**



Amodeo et al. 2020

#### **Other recent studies**



Zu Ying 2020

## **Summary**

- We achieve a good fit on the redshift-space 2PCF with an extended HOD including two assembly bias terms.
- The inclusion of both assembly bias terms are strongly favored.
- The redshift-space 2PCF prefers to assign galaxies to lower mass halos, resulting in a lensing prediction consistent with observation.
- The environmental assembly bias shows a consistent positive detection, seems to trace some underlying processes, possibly splashback.