Mass Calibration of Dark Matter Halos

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INTRODUCTION

Galaxy clusters are key to understanding cosmology and the nature of dark matter. Current observational constraints are primarily hindered by the uncertainty in measuring their masses. Weak Lensing (WL) offers a method to measure the mass of galaxy clusters. The WL signal is directly sensitive to the entire mass of the cluster, including both its baryonic (ordinary) and dark matter components, making WL-based mass measurements the most robust among the various techniques discussed in the literature.

KEYNOTES: PROJECT OUTLINE

Goal: Fit halo mass and concentration while incorporating systematic effects into simulations.

Motivation: Measuring the mass of galaxy clusters helps to understand our Universe, dark matter, and the overall matter distribution in our Universe.

Approach: Use traditional calibration methods such as MCMC to fit mass, concentration, and parameters of the systematic effects. We will do this mainly using simulations (Mini Uchuu and Cardinal simulations).

Gaps: Systematic effects are a major source of uncertainty in mass calibration, but are usually not accounted for in simulations.

COMPONENTS OF THE UNIVERSE TODAY

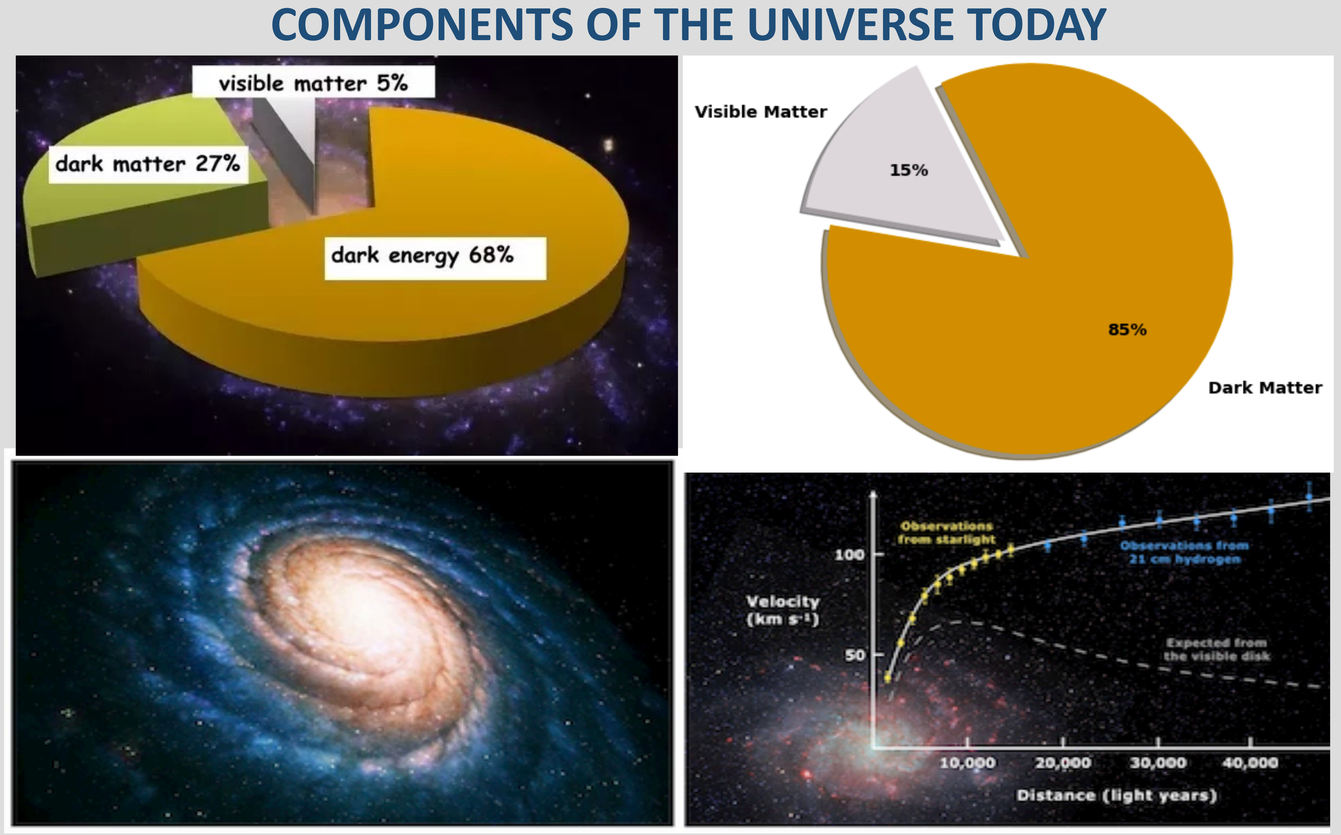


Image credit: Astro-Matter, Getty, Wikipedia

GRAVITATIONAL LENSING

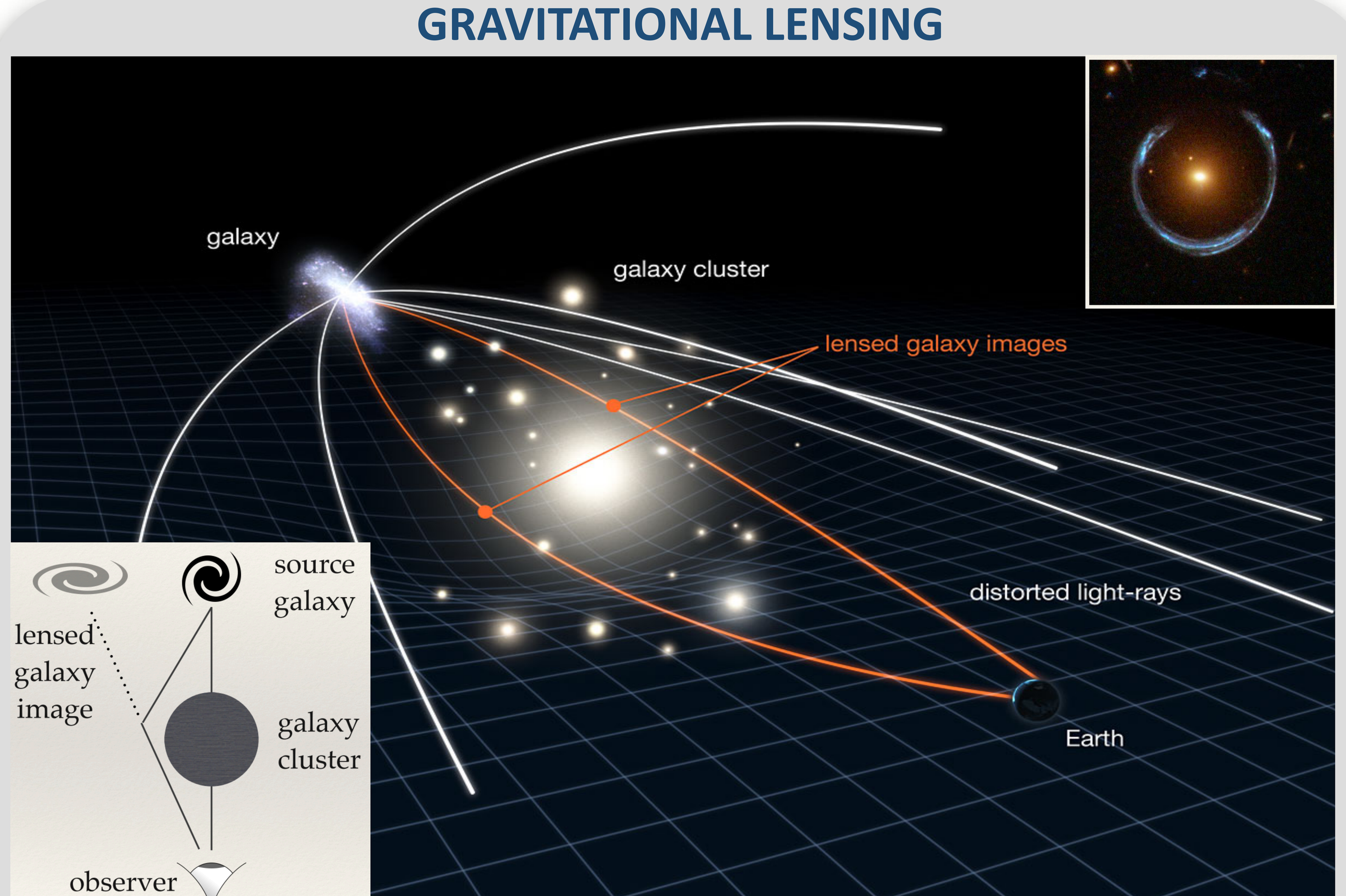


Image credit: NASA, ESA, HST

DISTORTED GALACTIC SHAPE

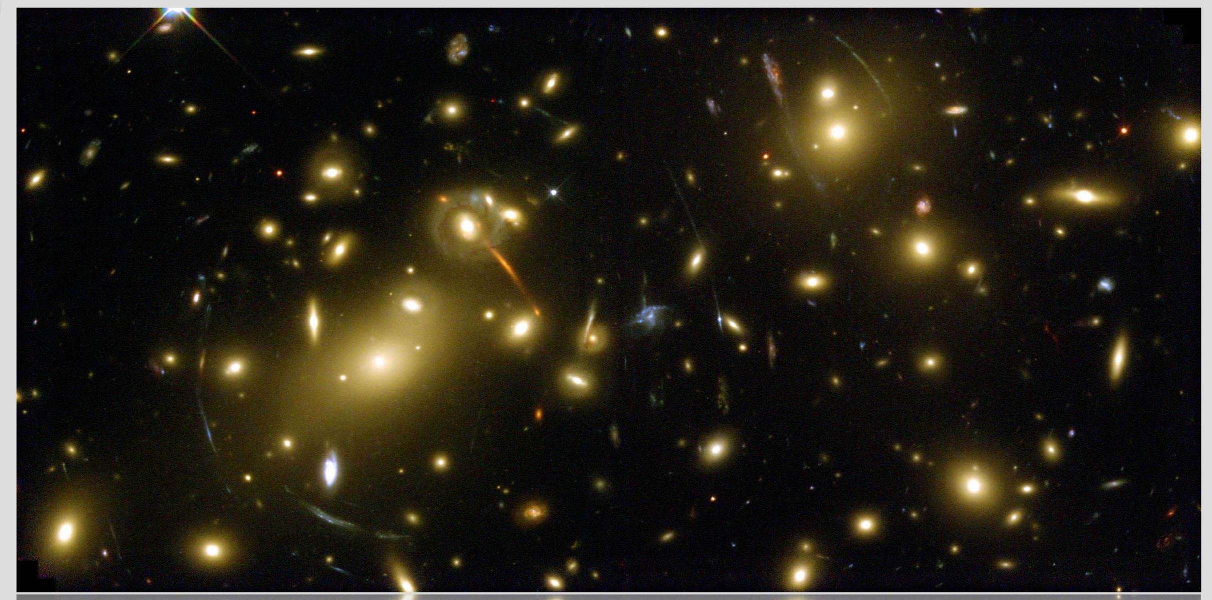
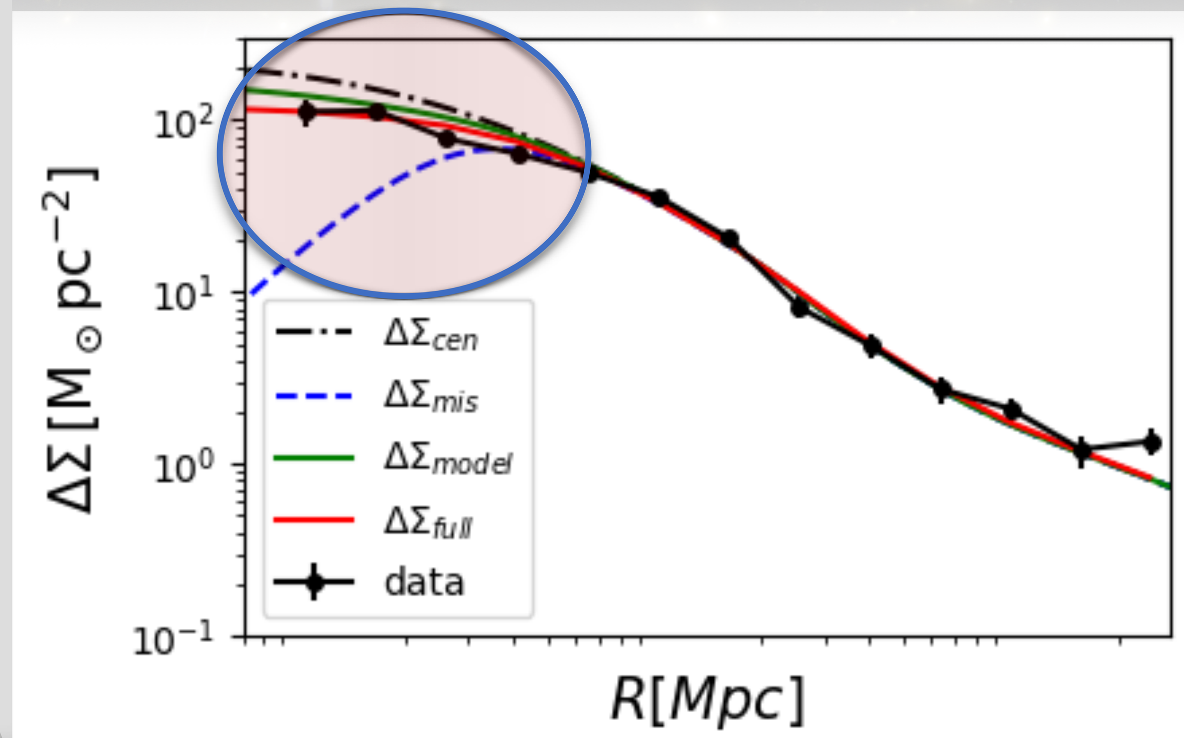


Image credit: NASA, ESA

HOW SYSTEMATICS AFFECT DATA (DES Y1 DATA)



GOVERNING EQUATIONS

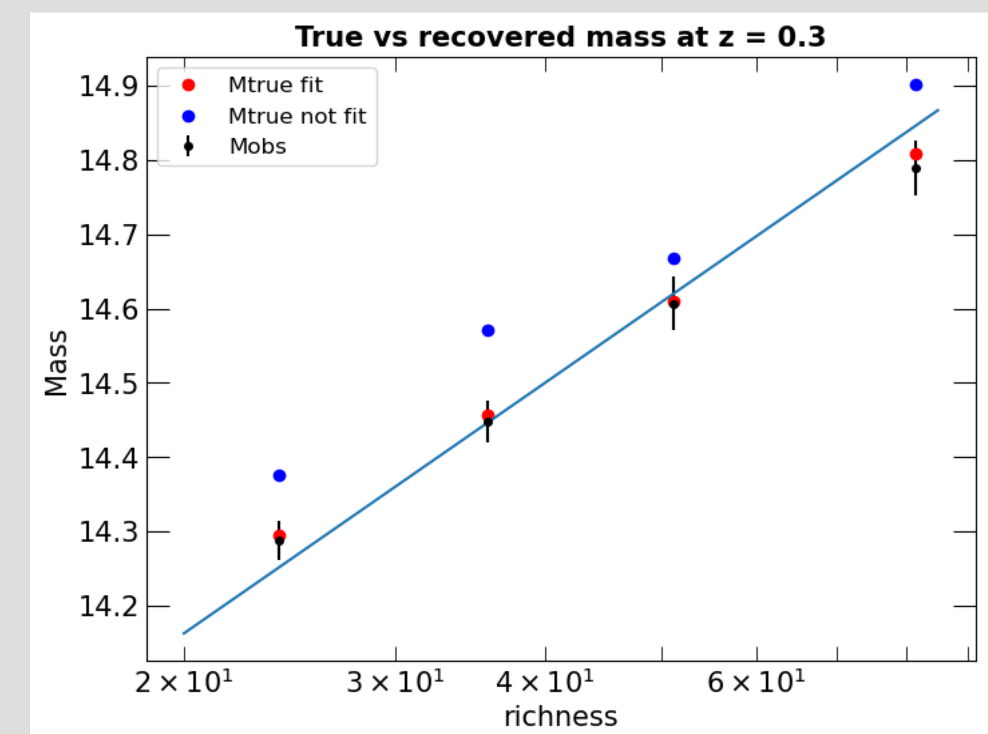
$$\Delta\Sigma_{full}(R) = \frac{A_m \mathcal{G}(R)}{\mathcal{B}(R)} \Delta\Sigma_{model}$$

$$\Delta\Sigma_{model} = \left(1 - f_{mis}\right) \Delta\Sigma_{cen} + f_{mis} \Delta\Sigma_{mis}$$

MASS—RICHNESS SCALING RELATION

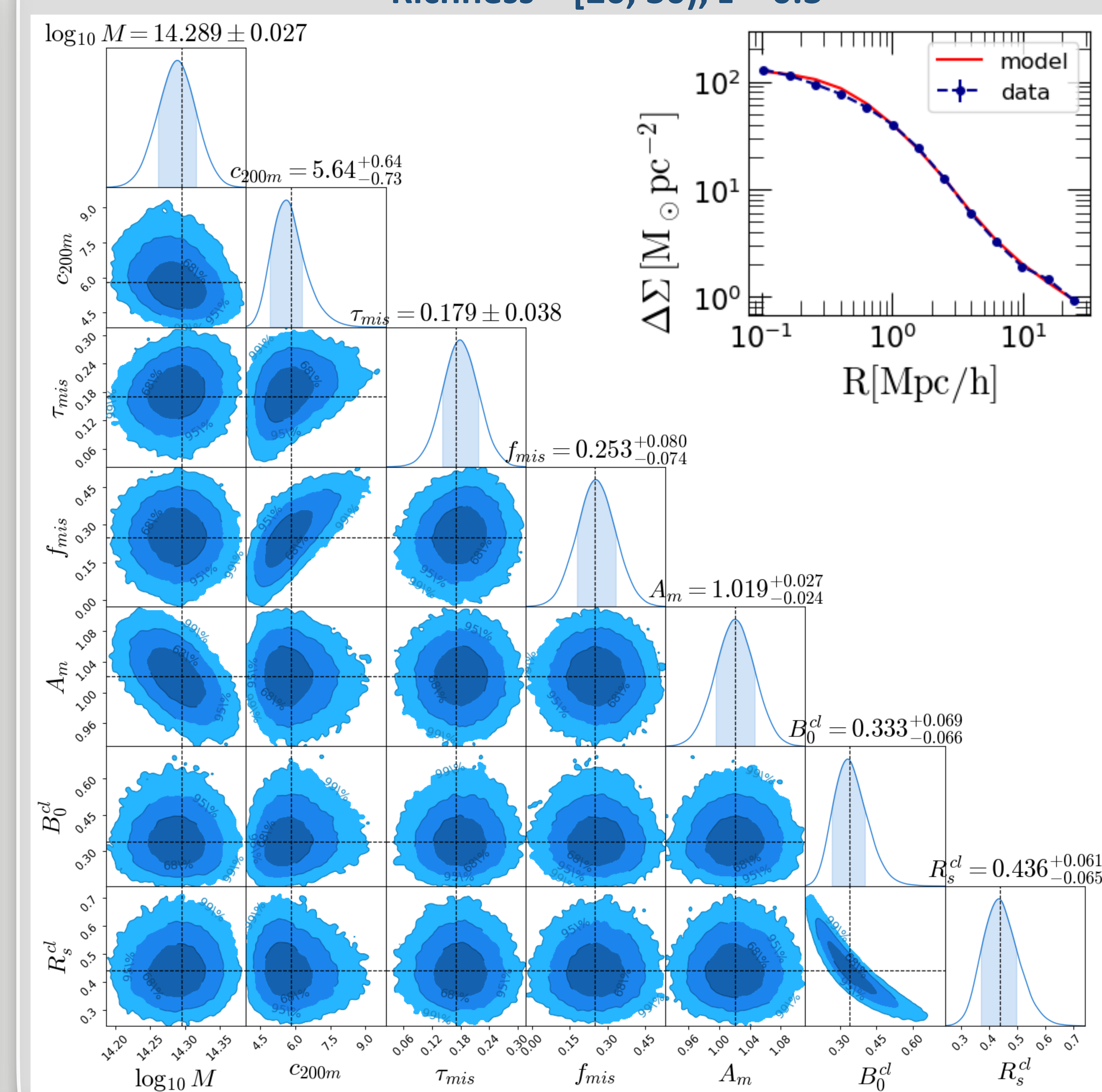
$$\langle M \,|\, \lambda, z \rangle = M_0 \left(\frac{\lambda}{\lambda_0}\right)^{F_\lambda} \left(\frac{1+z}{1+z_0}\right)^{G_z}$$

FITTING EXTRA TERM FOR SLOPE CHANGE



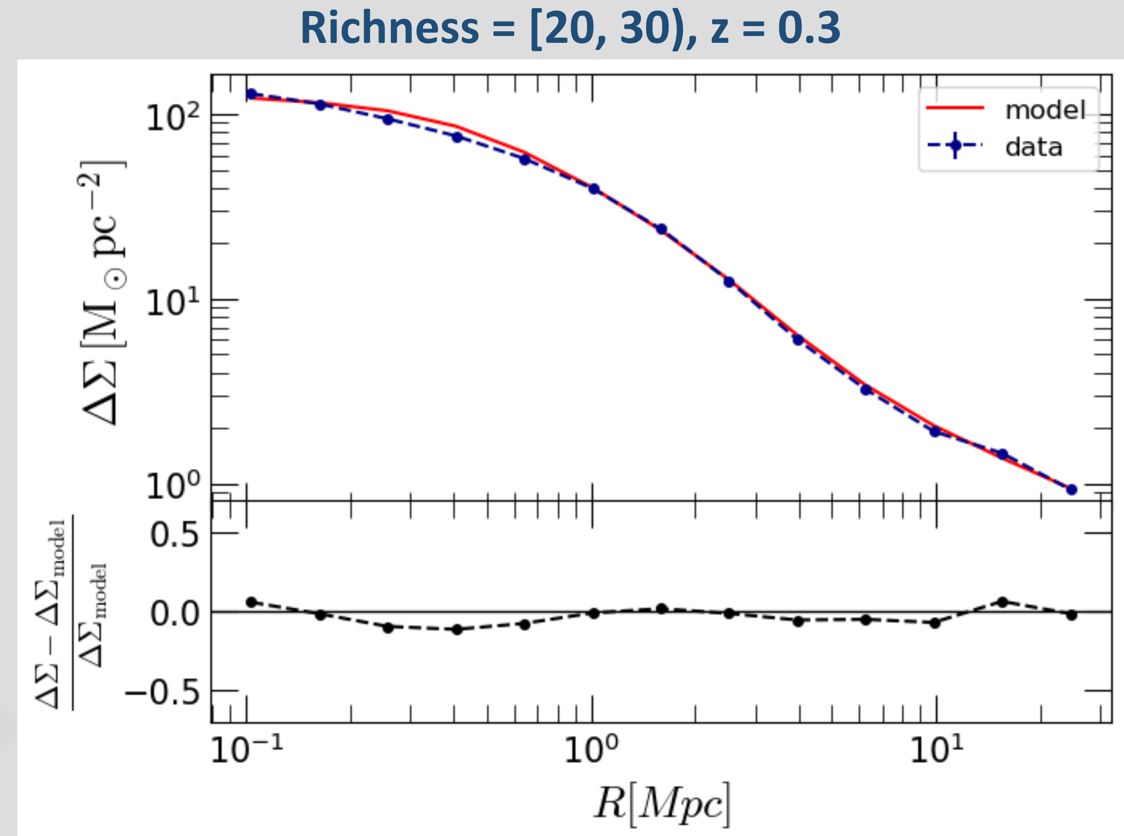
PARAMETER FITTING - MCMC RESULTS

Richness = [20, 30), z = 0.3

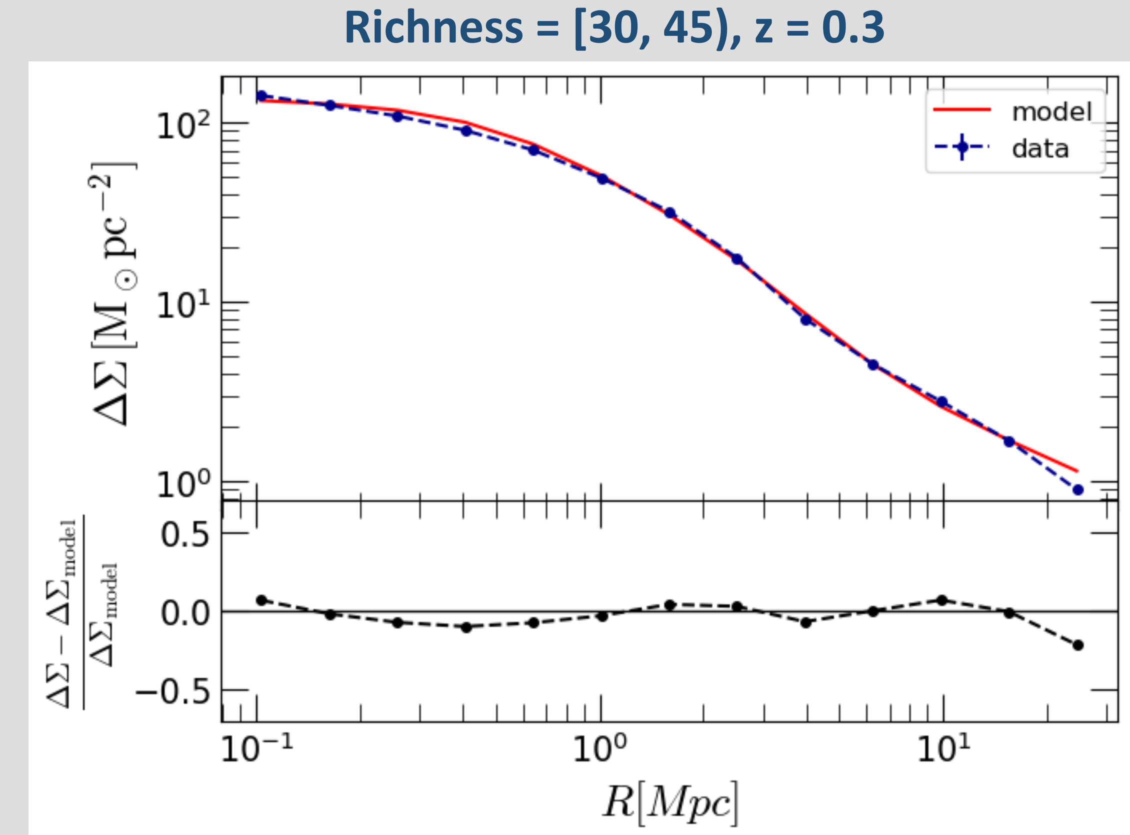


DATA VS MODEL (POSTERIOR MEANS)

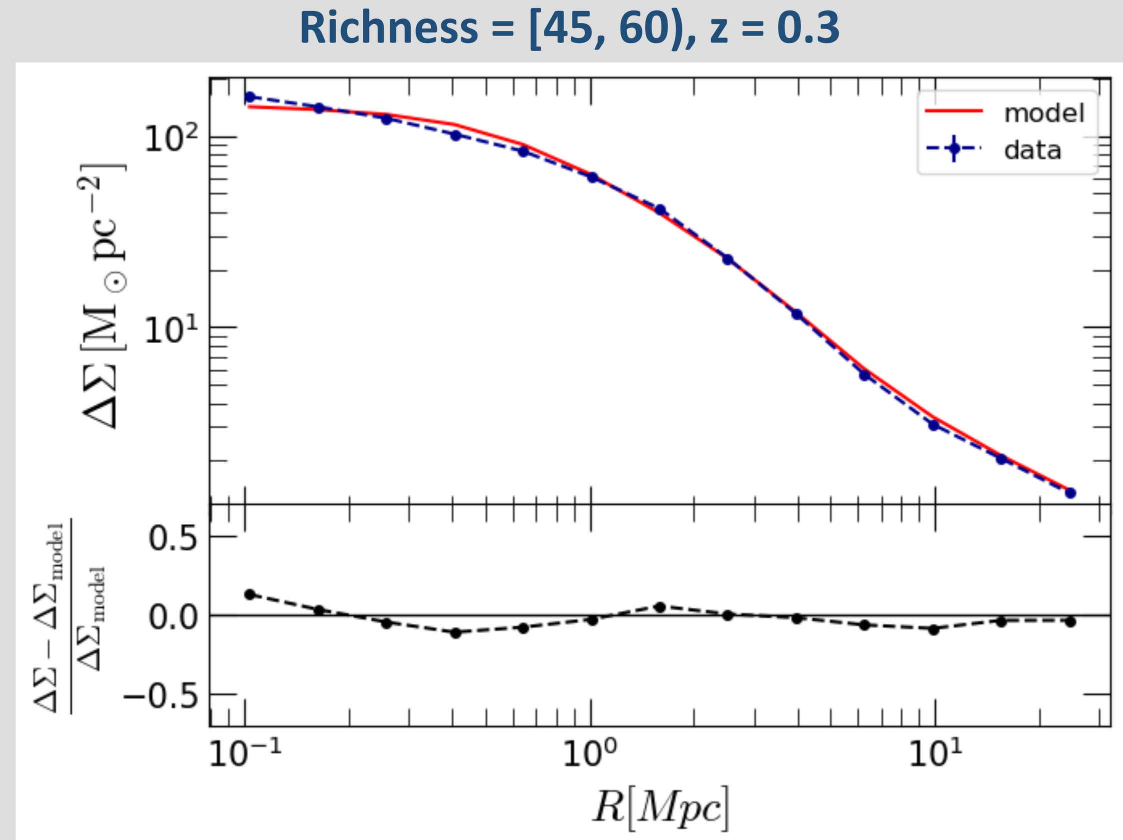
Richness = [20, 30), z = 0.3



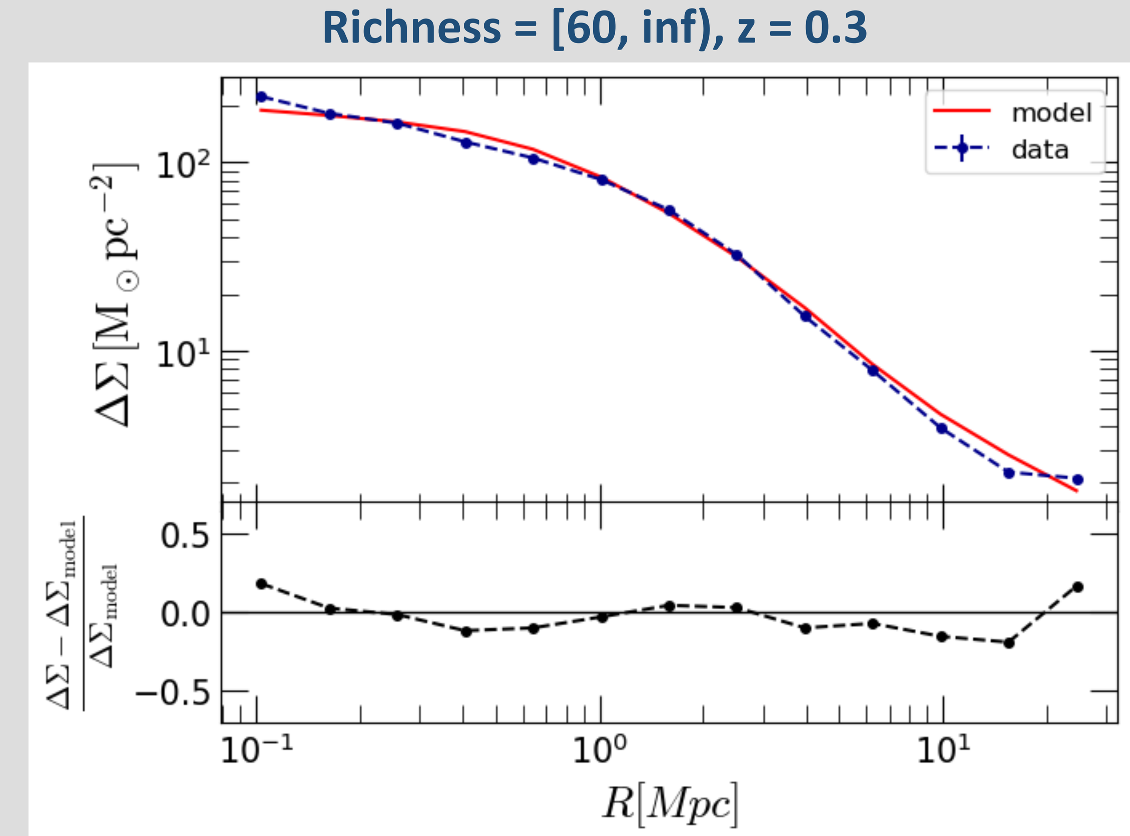
Richness = [30, 45), z = 0.3



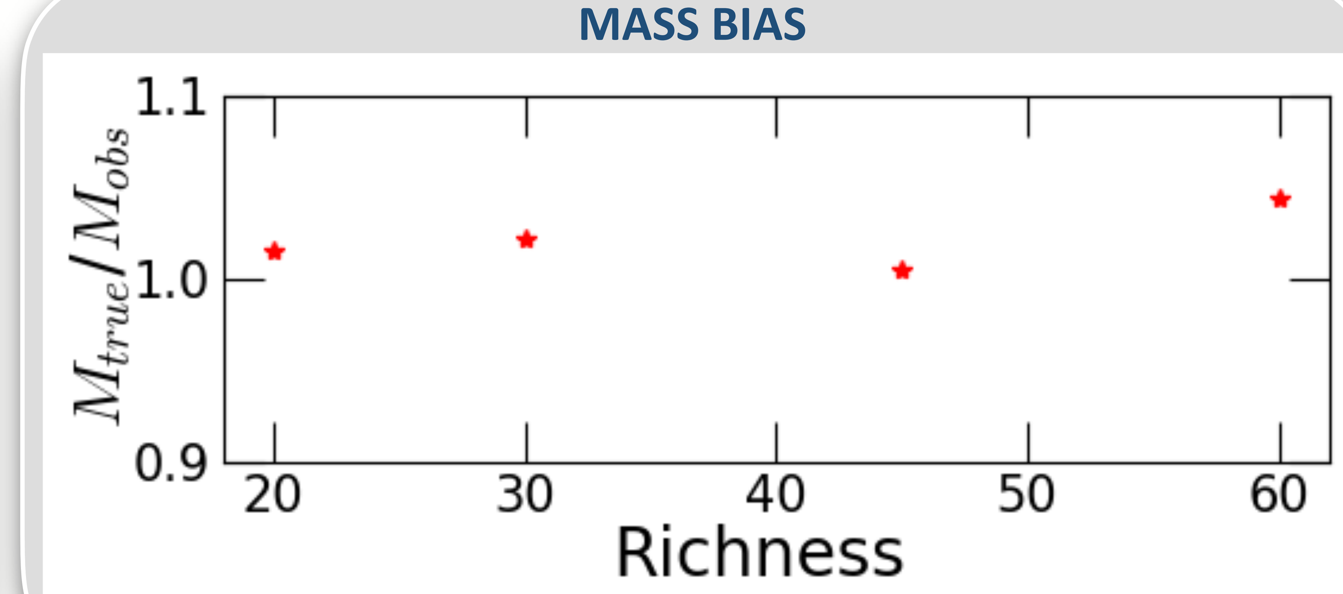
Richness = [45, 60), z = 0.3



Richness = [60, inf), z = 0.3



MASS BIAS



CONCLUSION

We fit the mass of galaxy clusters while incorporating systematic effects into simulations, addressing a common shortfall in cosmological simulations. Our method helps to make inferences with simulated data that is directly comparable to observations. Our approach not only narrows the gap between theoretical simulations and real-world astronomical surveys but also advances the analytical framework necessary for analyzing the most recent data release of the Dark Energy Survey (DES). We show that we can get tight constraints on observational parameters from the DES Year 1 data release. In the future, we will also quantify uncertainties in density profile predictions.

ACKNOWLEDGEMENTS

This work is supported by DOE Grant DE-SC0021916 and NASA grant 15-WFIRST15-0008. The authors would like to thank Boise State University — Borah computing cluster (DOI: 10.18122/oit/3/boisestate) and the National Energy Research Scientific Computing Center (NERSC) for providing computational resources for this study. We acknowledge the DES for making their data release 1 available to help us in this analysis.

Scan the QR code to access the model code on GitHub

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Grants: Department of Energy (DOE) Grant DE-SC0021916; NASA Grant WFIRST15-0008. PI: Heidi Wu