



Forward modeling of galaxy cluster lensing

Heidi Wu

Assistant Professor

Southern Methodist University

Dallas, Texas

My story with CCAPP

- 2007, 2008: visited as a grad student (working with Eduardo Rozo)
- **2017-2020: CCAPP postdoc** (working with David Weinberg)
- 2020-2024: Boise State University (visited CCAPP 2022)
- 2024-present: Southern Methodist University (visited CCAPP 2025)
- Still collaborating with David, Eduardo, Andres Salcedo, Chun-Hao To, et al.



David Weinberg

CCAPP postdoc position

To: hywu@caltech.edu, Cc: Chris Hirata & 4 more

February 15, 2017 at 2:17 PM

[Details](#)

Dear Heidi,

Apologies for this message being rather out-of-the-blue and late, and we hope that it is not too late.

We're pleased to inform you that we have decided to offer you a position as a CCAPP Postdoctoral Researcher, for work on galaxy clustering, weak lensing, and WFIRST. It will probably take a few days to get a formal letter of offer out from the university, but we wanted to let you know of our decision as soon as possible so that you can begin to think about it. Please confirm receipt of this message by email, or by giving David a call at 614-292-6543.

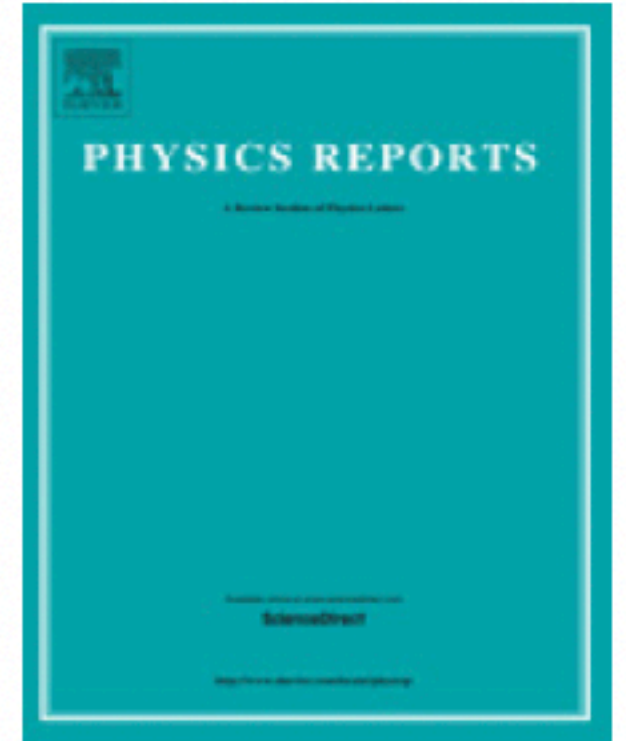
Michael Troxel (2016–2018)
Niall MacCrann (2016–2019)
Ami Choi (2016–2021)
Tuguldur Sukhbold (2016–2021)
Heidi Wu (2017–2020)
Johnny Greco (2018–2021)
Steven Prohira (2018–2022)
Jack Elvin-Poole (2018–2022)
Juri Smirnov (2019–2021)
Yi-Kuan Chiang (2019–2021)
Amy Sardone (2019–2023)
Fiorenzo Vincenzo (2019–2021)



Contents lists available at ScienceDirect

Physics Reports

journal homepage: www.elsevier.com/locate/physrep



Observational probes of cosmic acceleration



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Christopher Hirata^e, Adam G. Riess^f, Eduardo Rozo^g

^a Department of Astronomy, Ohio State University, Columbus, OH, United States

^b Center for Cosmology and Astro-Particle Physics, Ohio State University, Columbus, OH, United States

^c Steward Observatory, University of Arizona, Tucson, AZ, United States

^d Harvard College Observatory, Cambridge, MA, United States

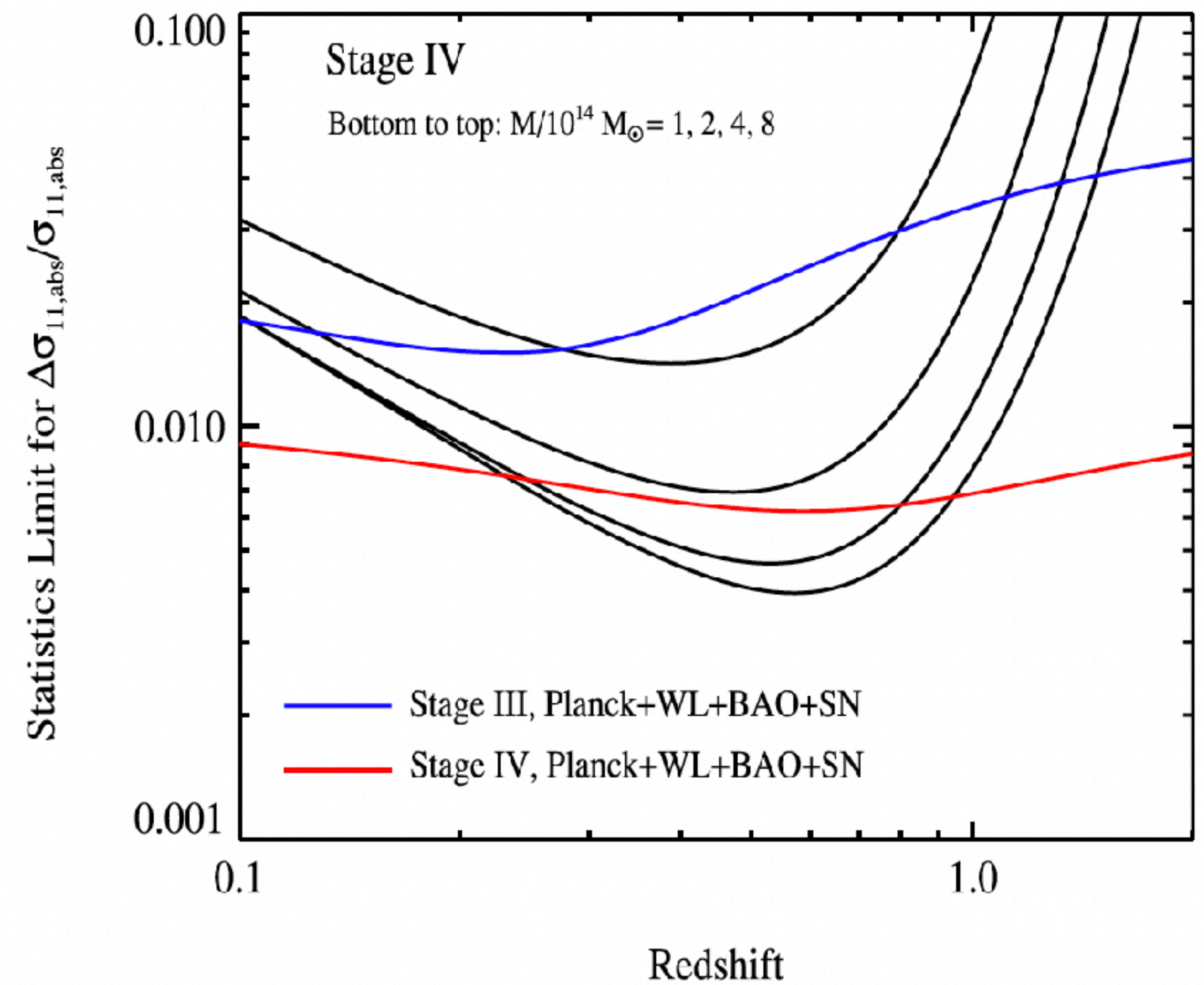
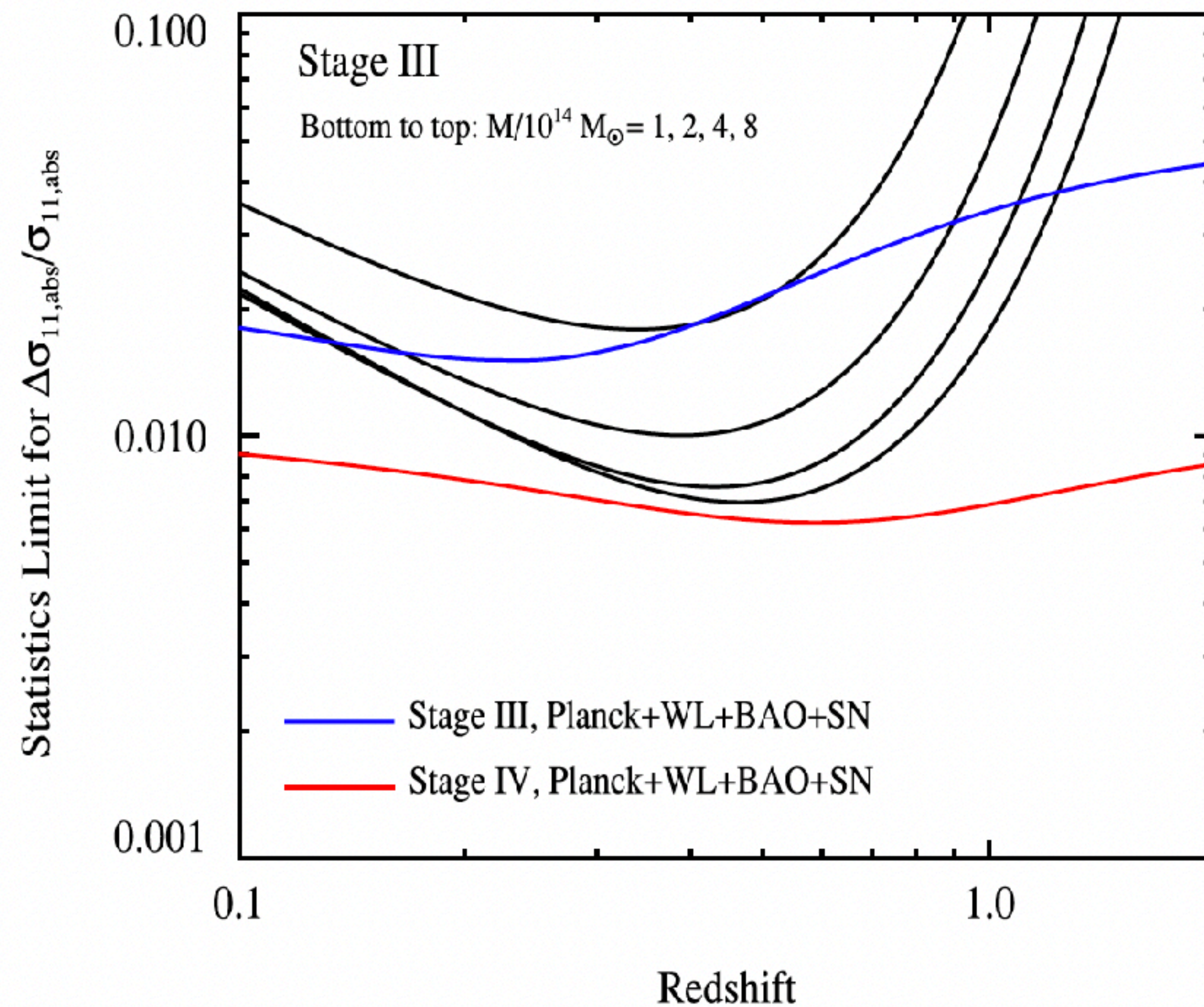
^e California Institute of Technology, Pasadena, CA, United States

^f Department of Physics and Astronomy, Johns Hopkins University, Baltimore, MD, United States

^g Kavli Institute for Cosmological Physics, University of Chicago, Chicago, IL, United States

Fig 30 in Weinberg et al. (2013), cluster forecasts by Eduardo Rozo

D.H. Weinberg et al. / Physics Reports 530 (2013) 87–255





Covariance matrices for galaxy cluster weak lensing: from virial regime to uncorrelated large-scale structure

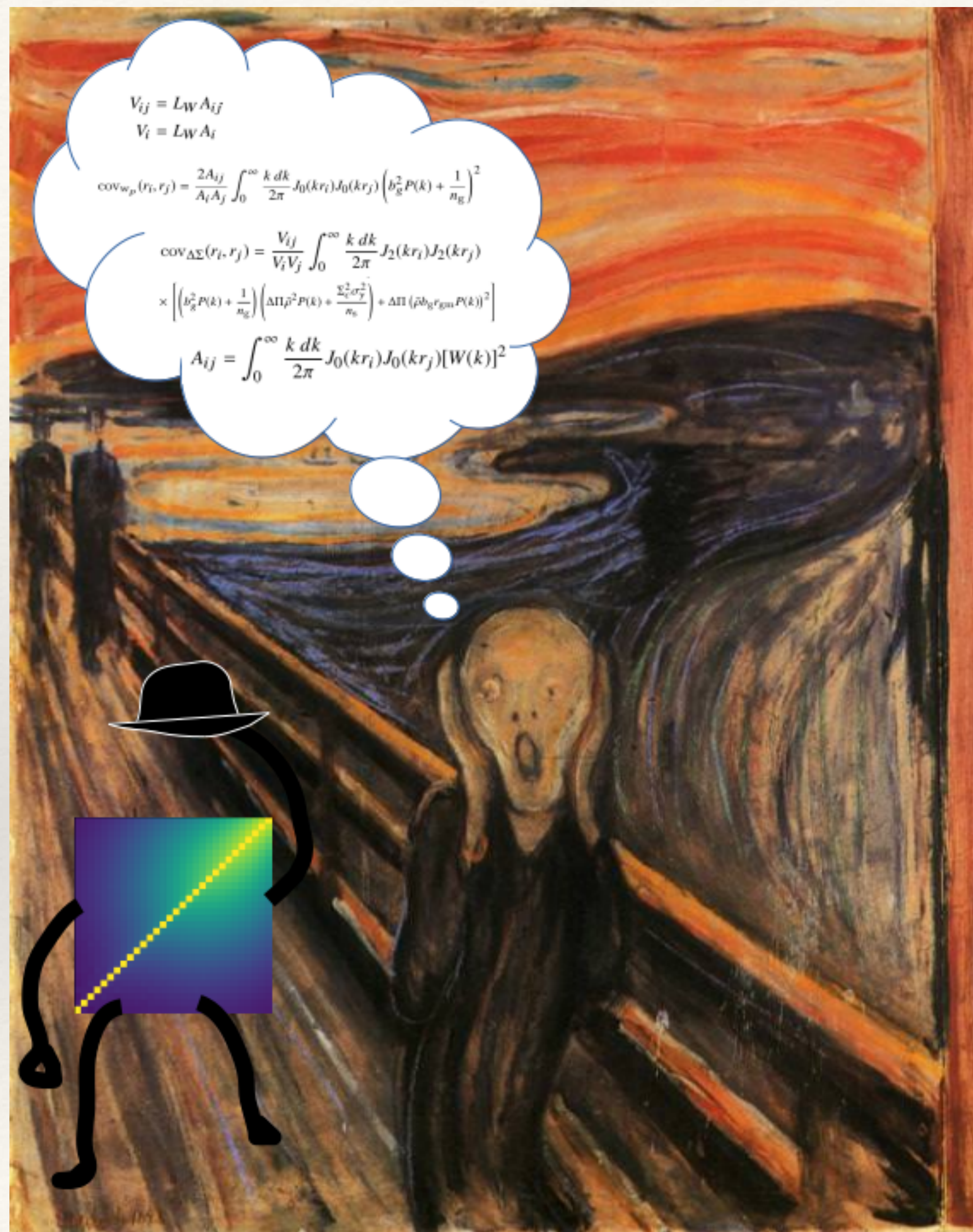
Hao-Yi Wu¹,¹★ David H. Weinberg,¹ Andrés N. Salcedo¹, Benjamin D. Wibking¹
and Ying Zu²

¹Department of Physics, Department of Astronomy, and Center for Cosmology and Astro-Particle Physics, The Ohio State University, Columbus, OH 43210, USA

²Department of Astronomy, School of Physics and Astronomy, Shanghai Jiao Tong University, Minhang, Shanghai 200240, China

$$\text{Cov}^{\text{Gauss}} \left[\gamma_t(\theta_1), \gamma_t(\theta_2) \right] = \frac{1}{4\pi f_{\text{sky}}} \int \frac{\ell d\ell}{2\pi} \hat{J}_2(\ell\theta_1) \hat{J}_2(\ell\theta_2) \\ \times \left[\left(C_{\ell}^{\text{hh}} + \frac{1}{n_{\text{h}}^{(2\text{D})}} \right) \left(C_{\ell}^{\text{KK}} + \frac{\sigma_{\gamma}^2}{n_{\text{s}}^{(2\text{D})}} \right) + (C_{\ell}^{\text{hK}})^2 \right].$$





From Andrés Salcedo



Mungo was in our meetings!

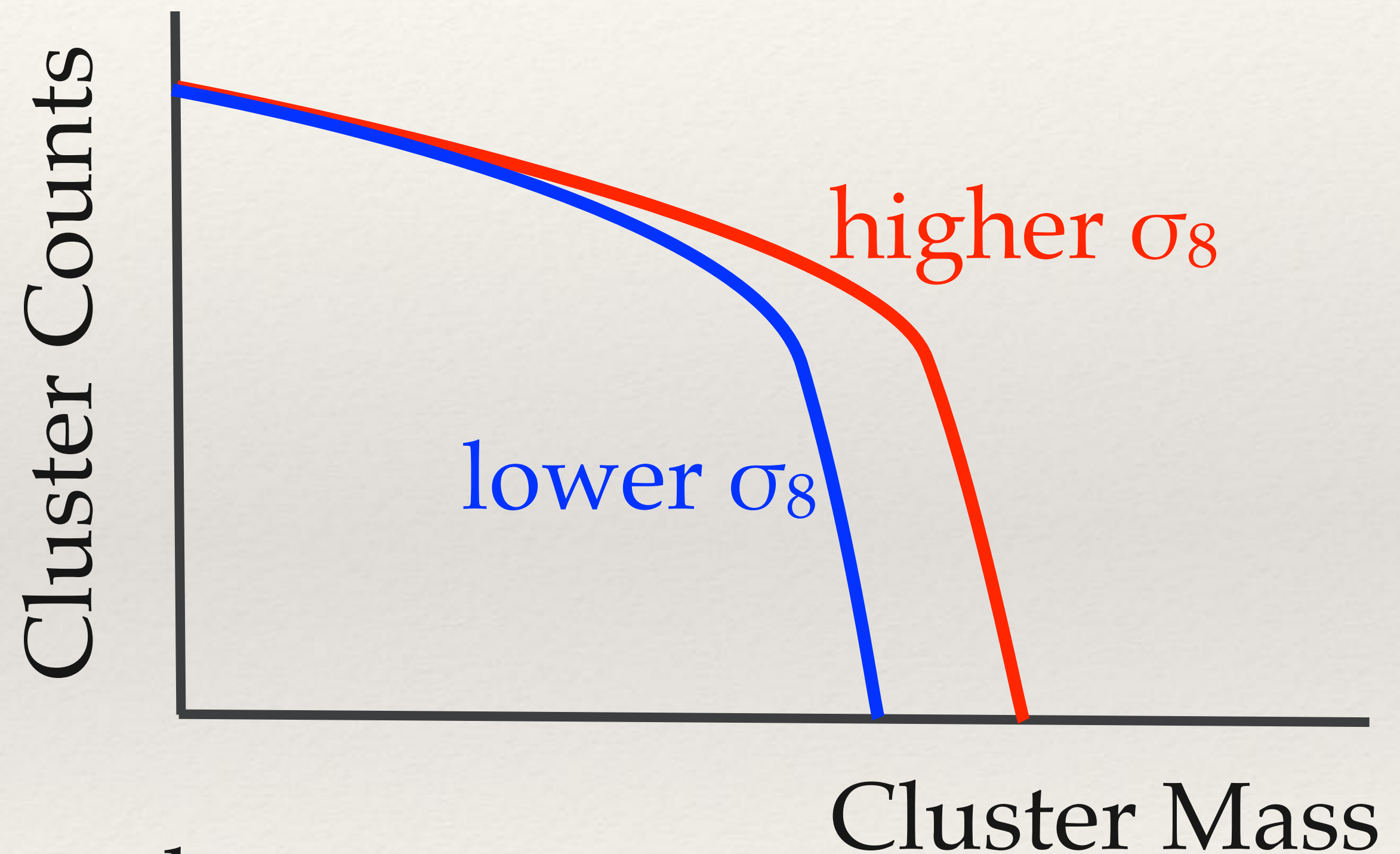
Working on Dark Energy Survey



Cosmology with cluster counts and lensing



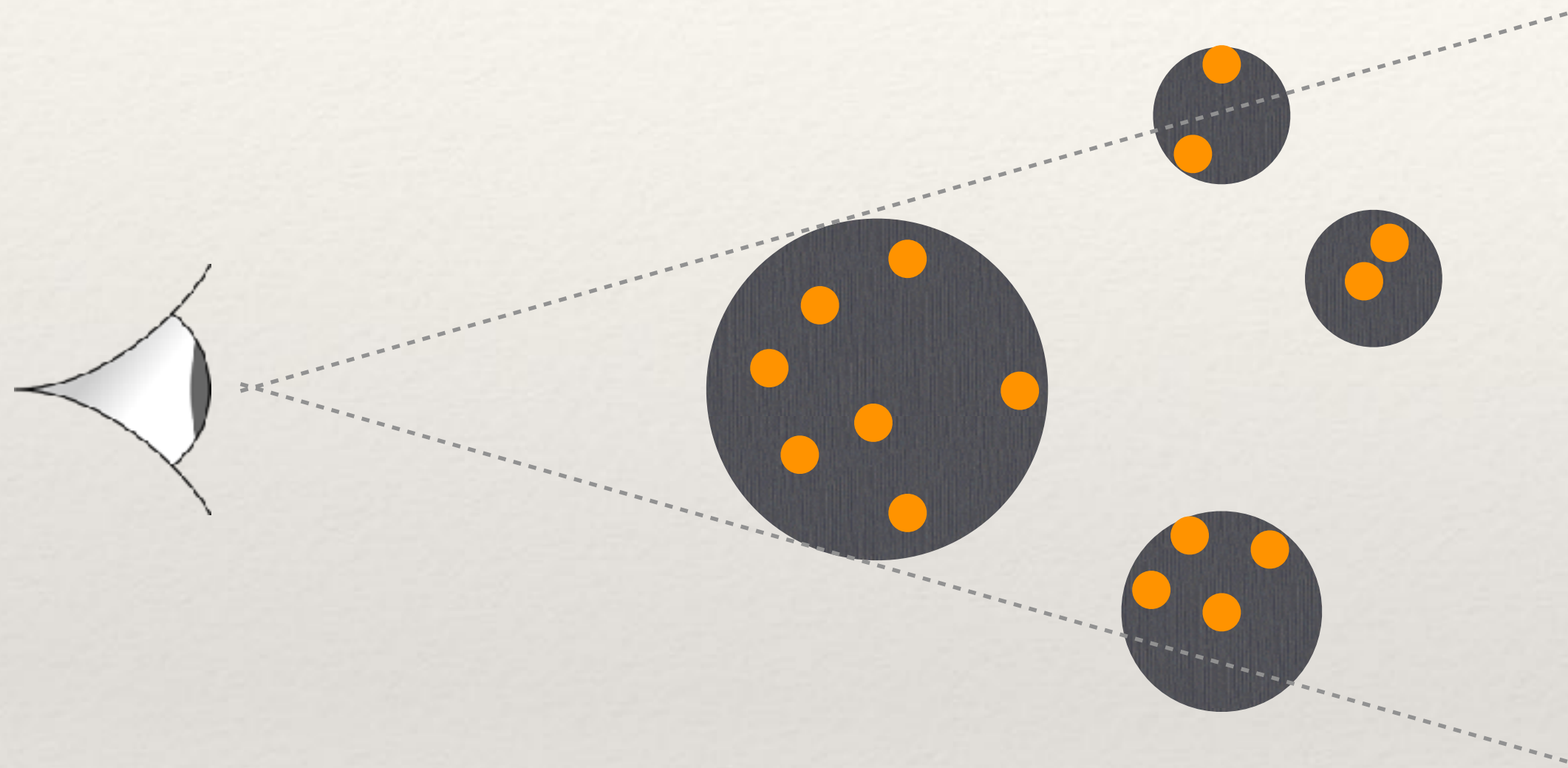
Higher $\sigma_8 \rightarrow$ larger density contrast



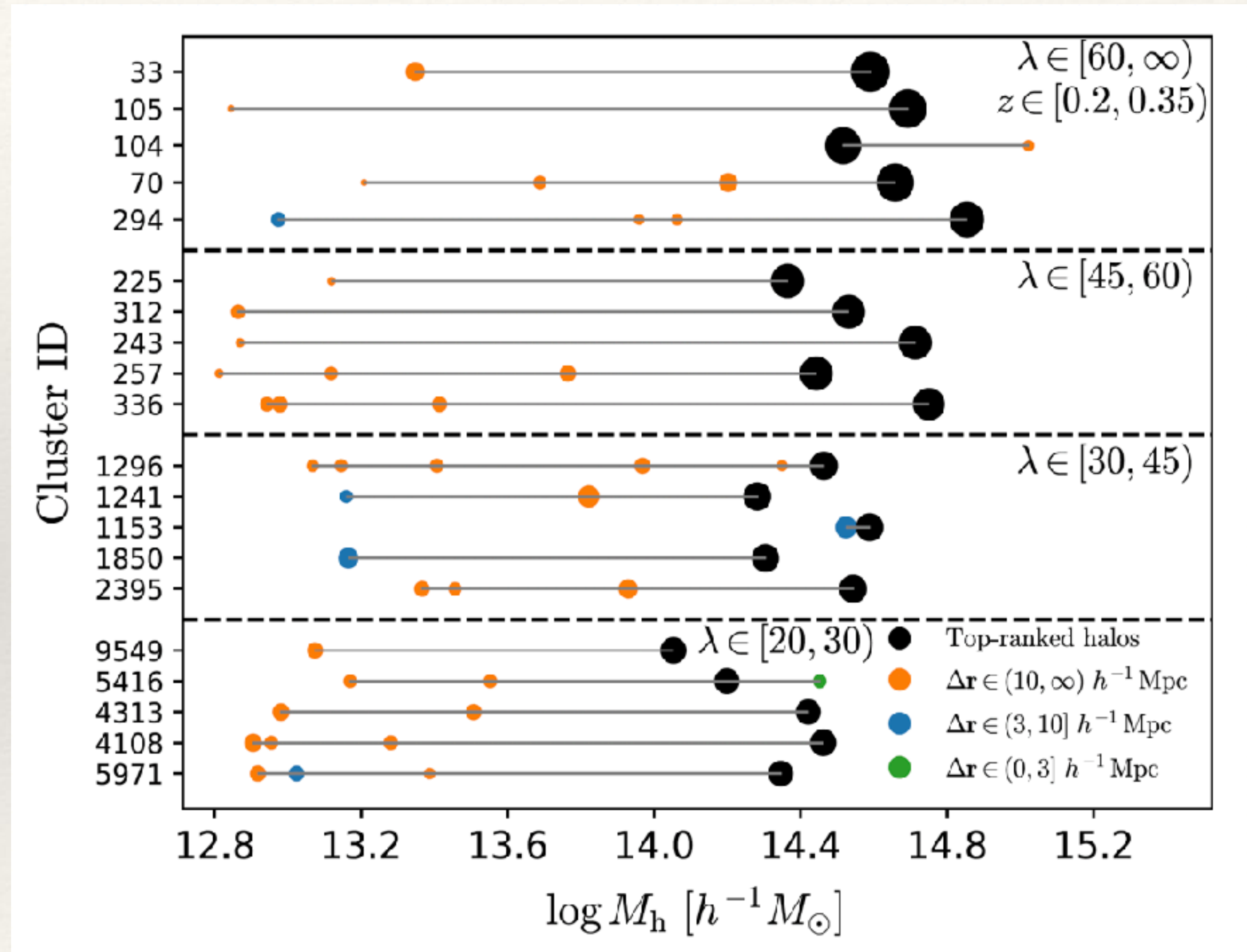
Richness: number of galaxies in a cluster

Lensing: 2D mass density, used for mass calibration

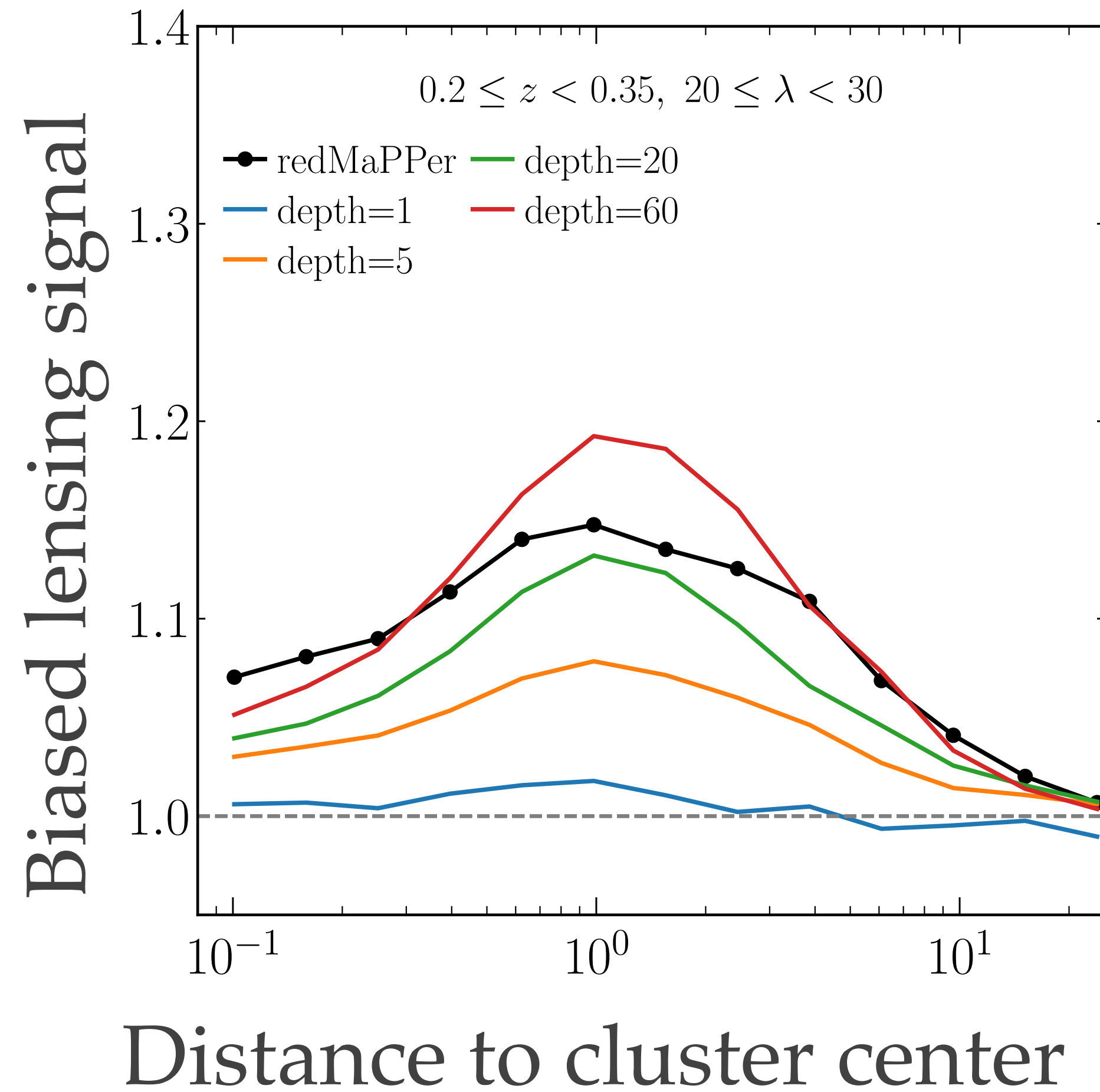
Projection effects due to distance uncertainties



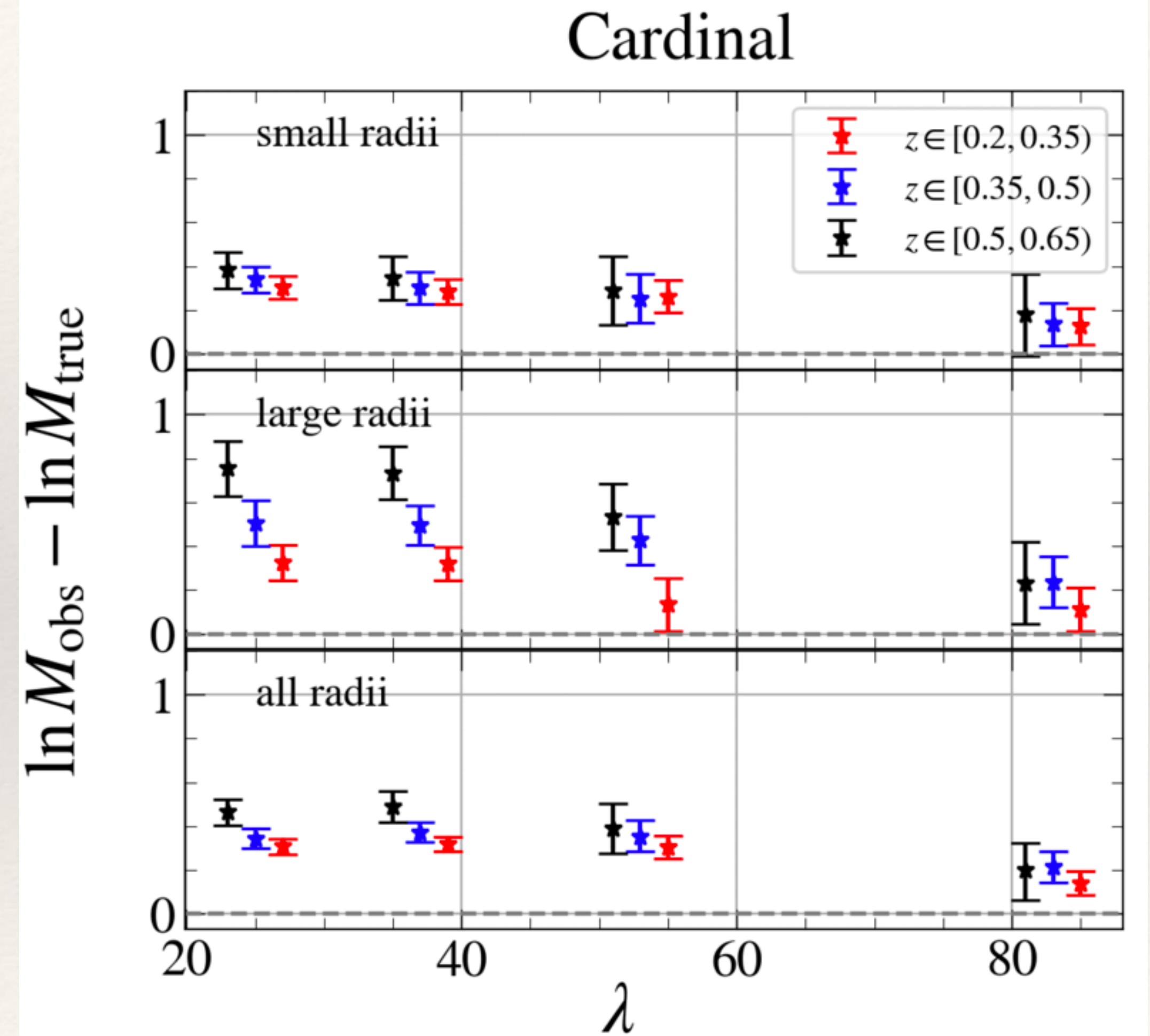
An observed cluster is contributed by multiple halos



Projection effect biases the lensing signal and mass

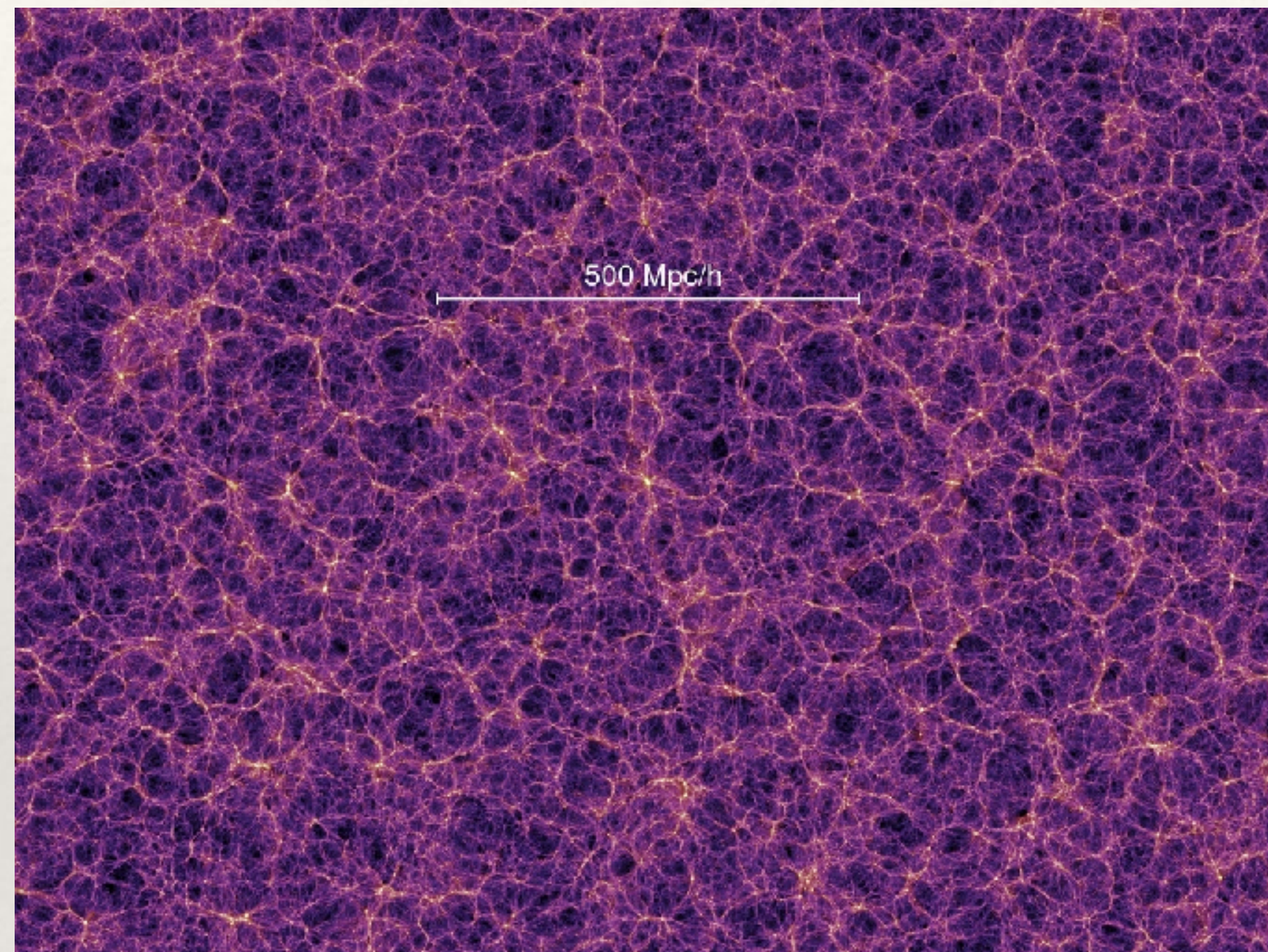


Wu et al. (2022)

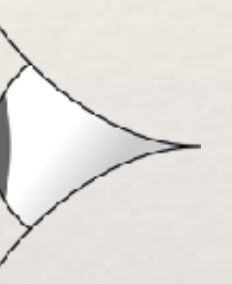
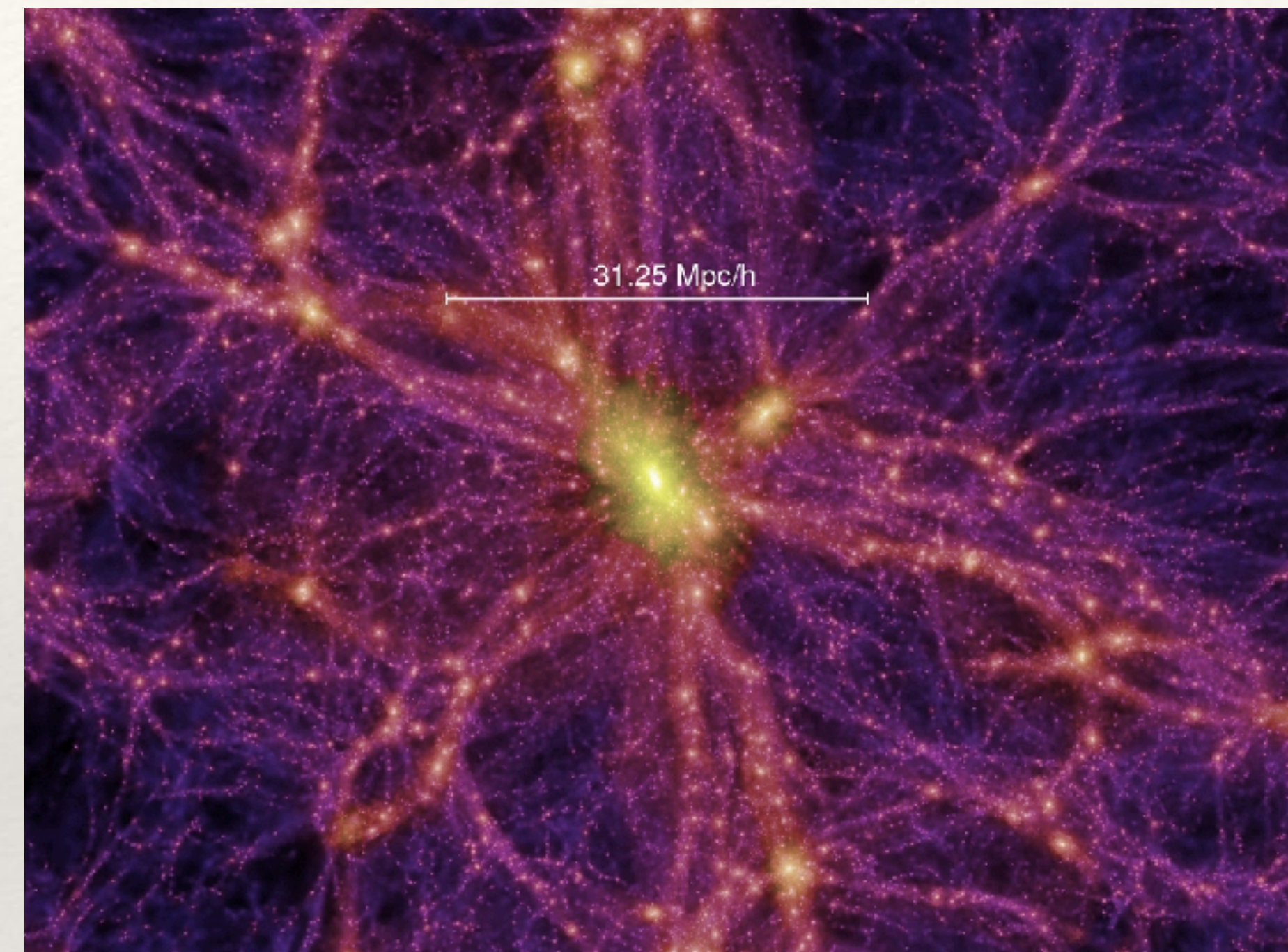
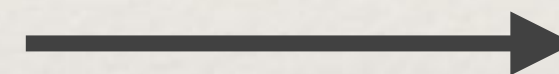


Nde et al. (2026, Boise grad student)

Simulation-based forward modeling



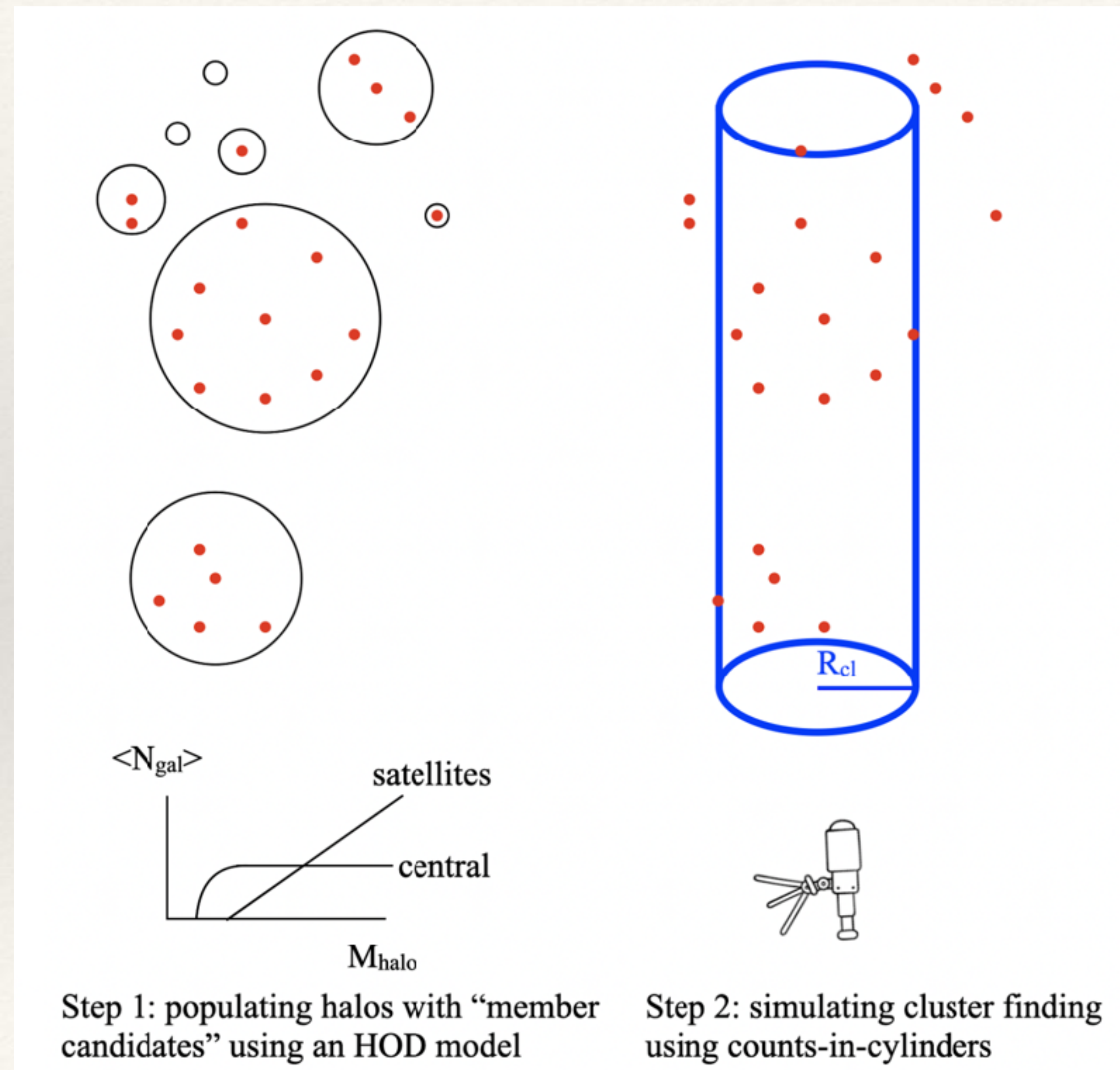
Zoom in
on a
cluster



We simulate many universes with different parameters and interpolate them (“emulator”).



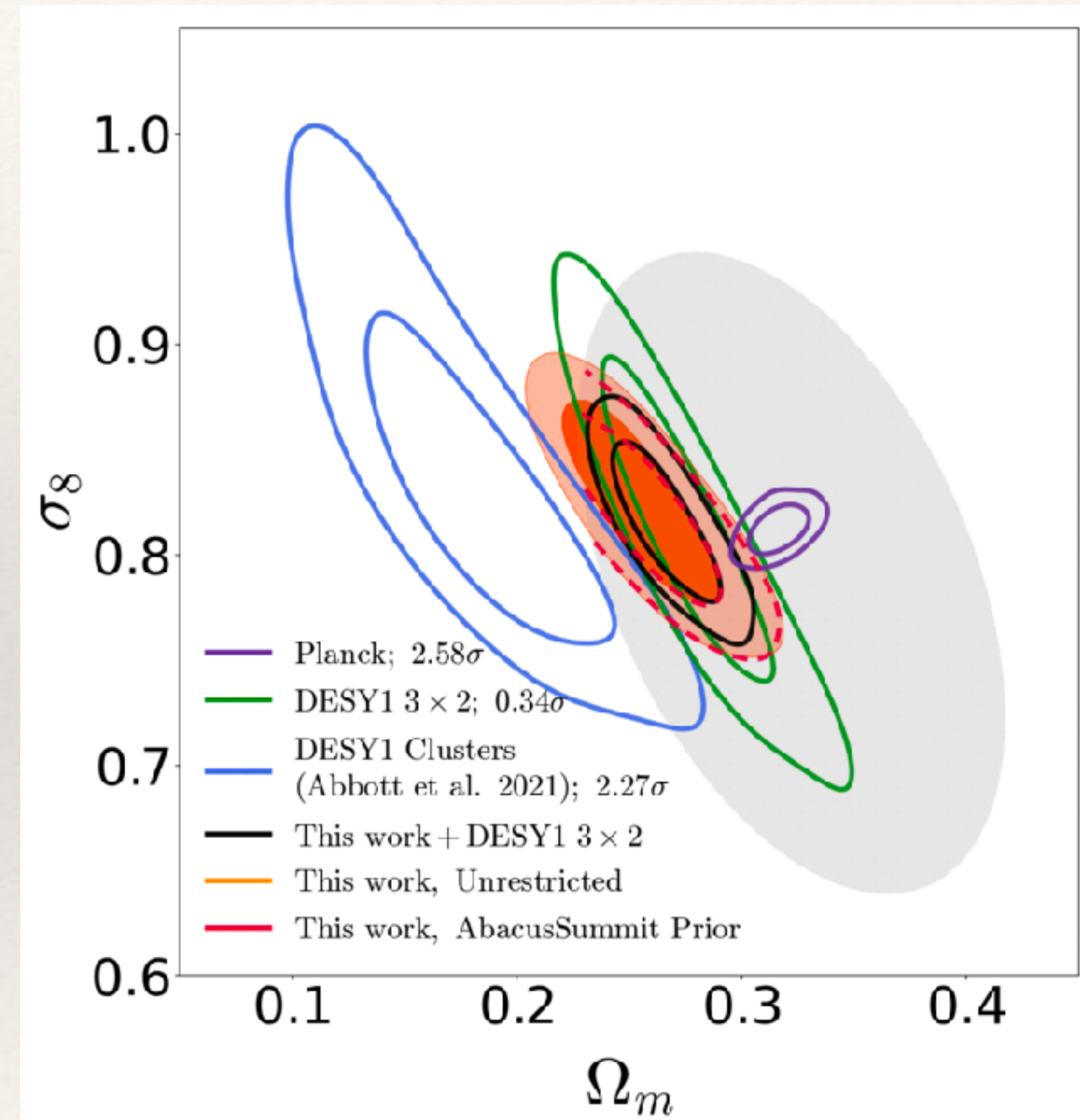
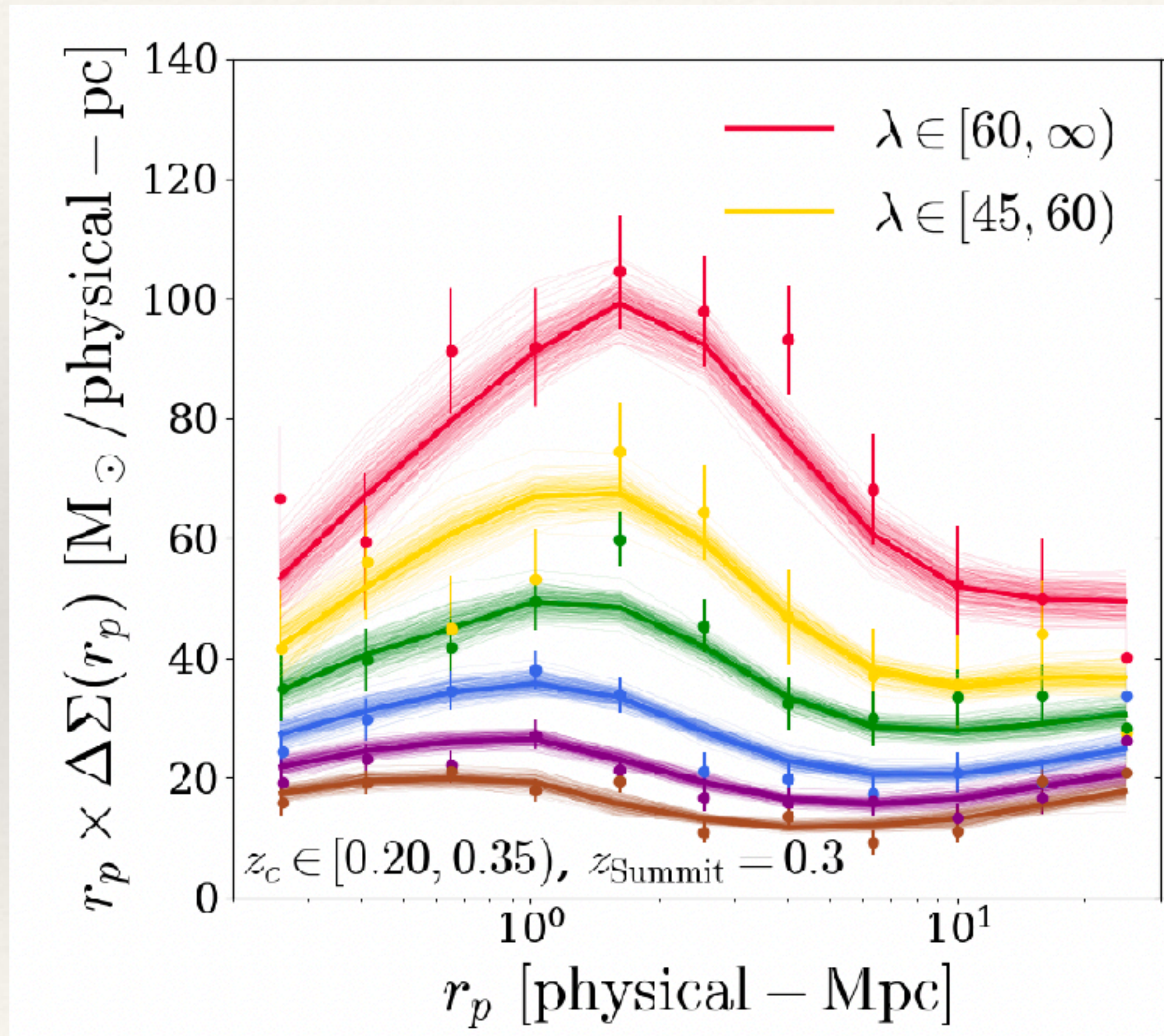
Forward-modeling optical clusters



- We put red galaxies in halos in N-body simulations using Halo Occupation Distribution (HOD)
- We simulate cluster finding using counts-in-cylinders.

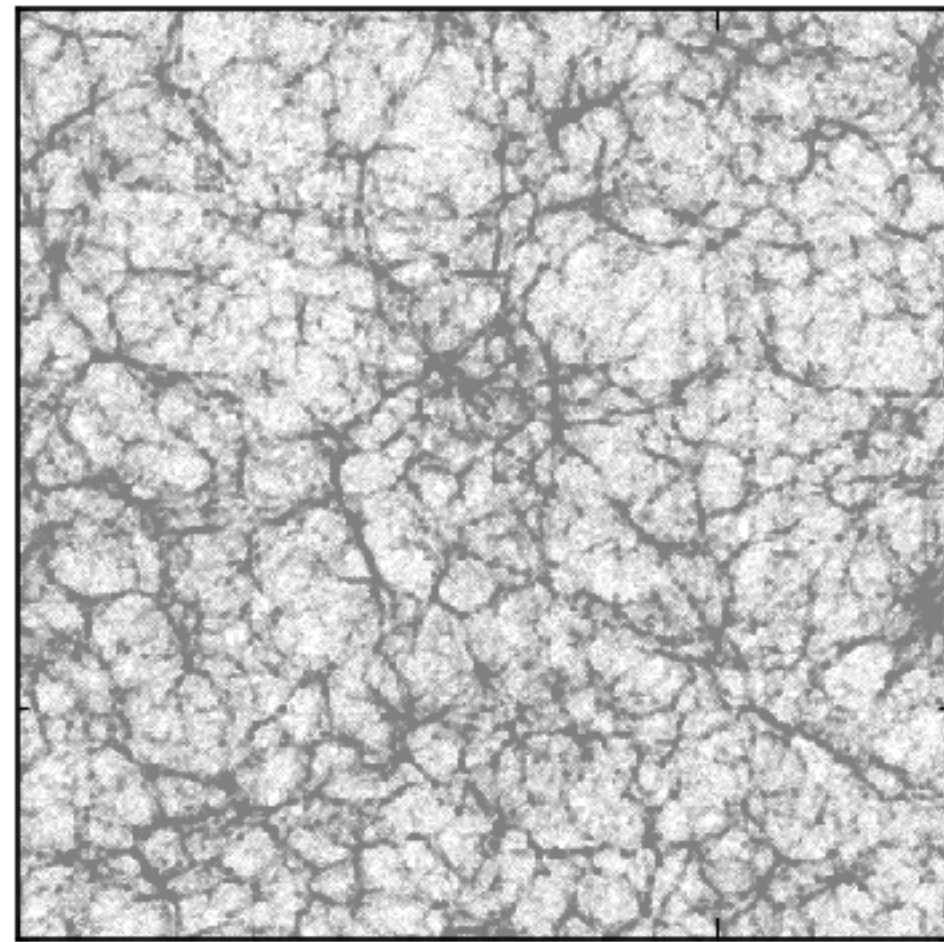
Salcedo et al. (2024, 2310.03944)

Re-analyzing DES clusters

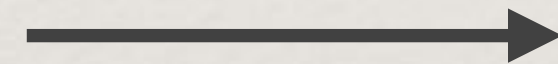


Unifying cluster and galaxy analyses

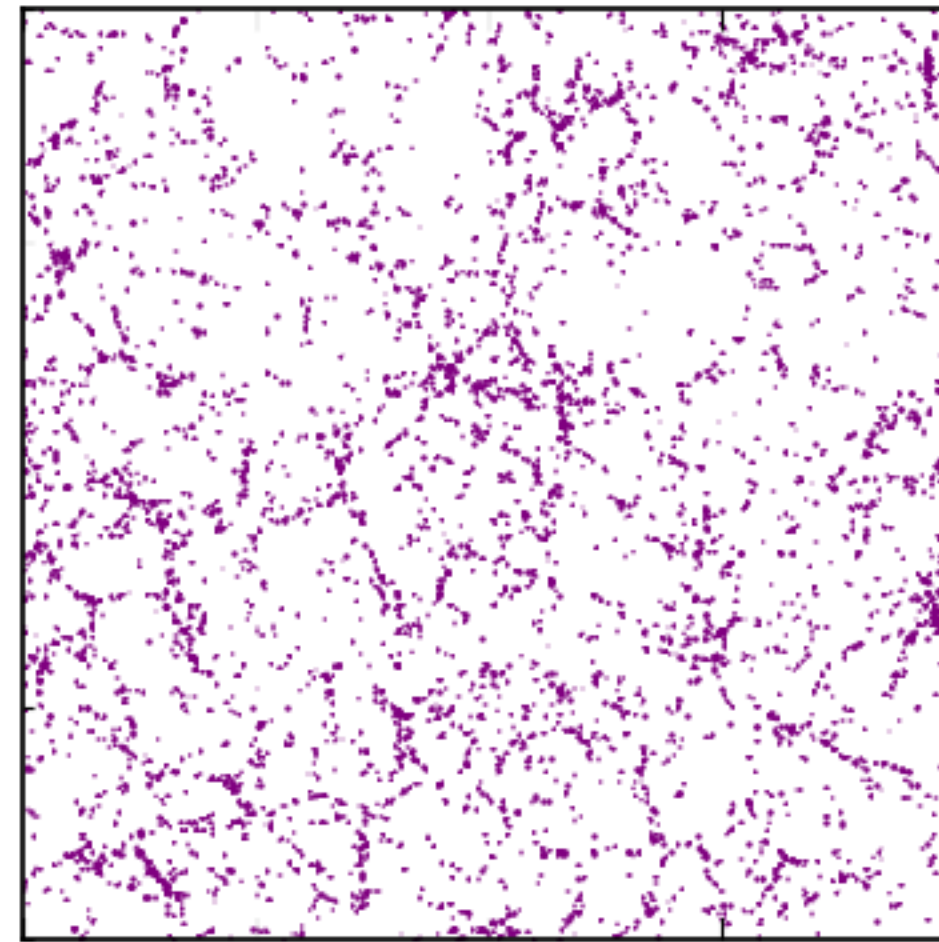
Dark Matter



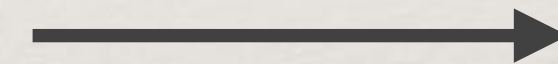
Galaxy-halo
connection



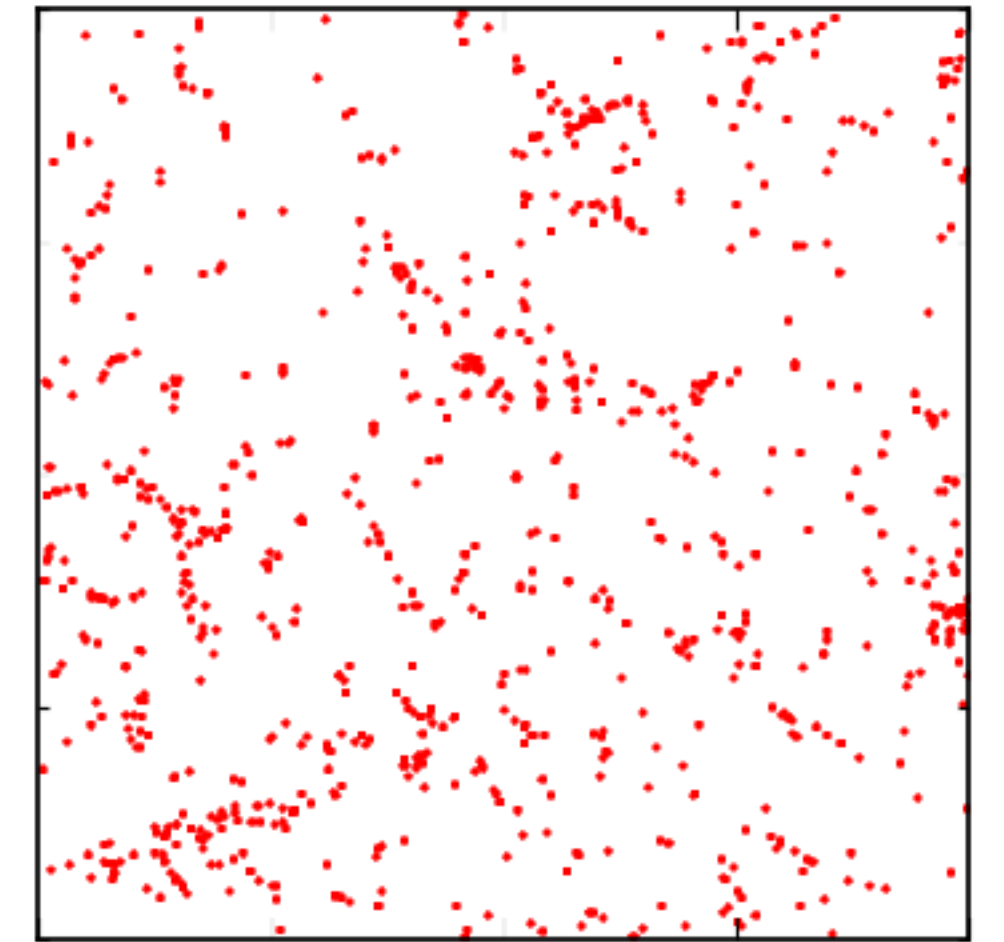
Galaxies



Cluster
finding

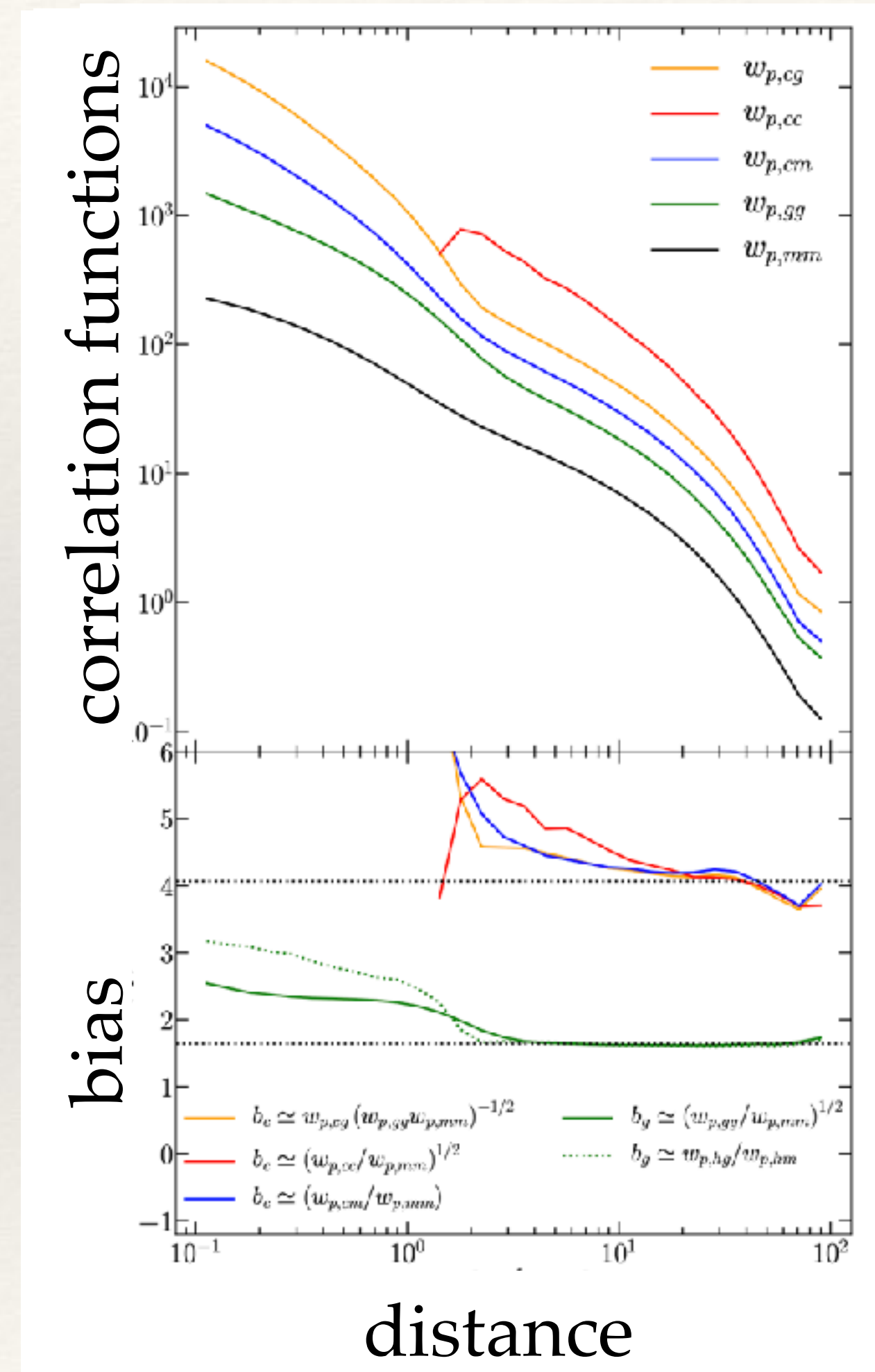
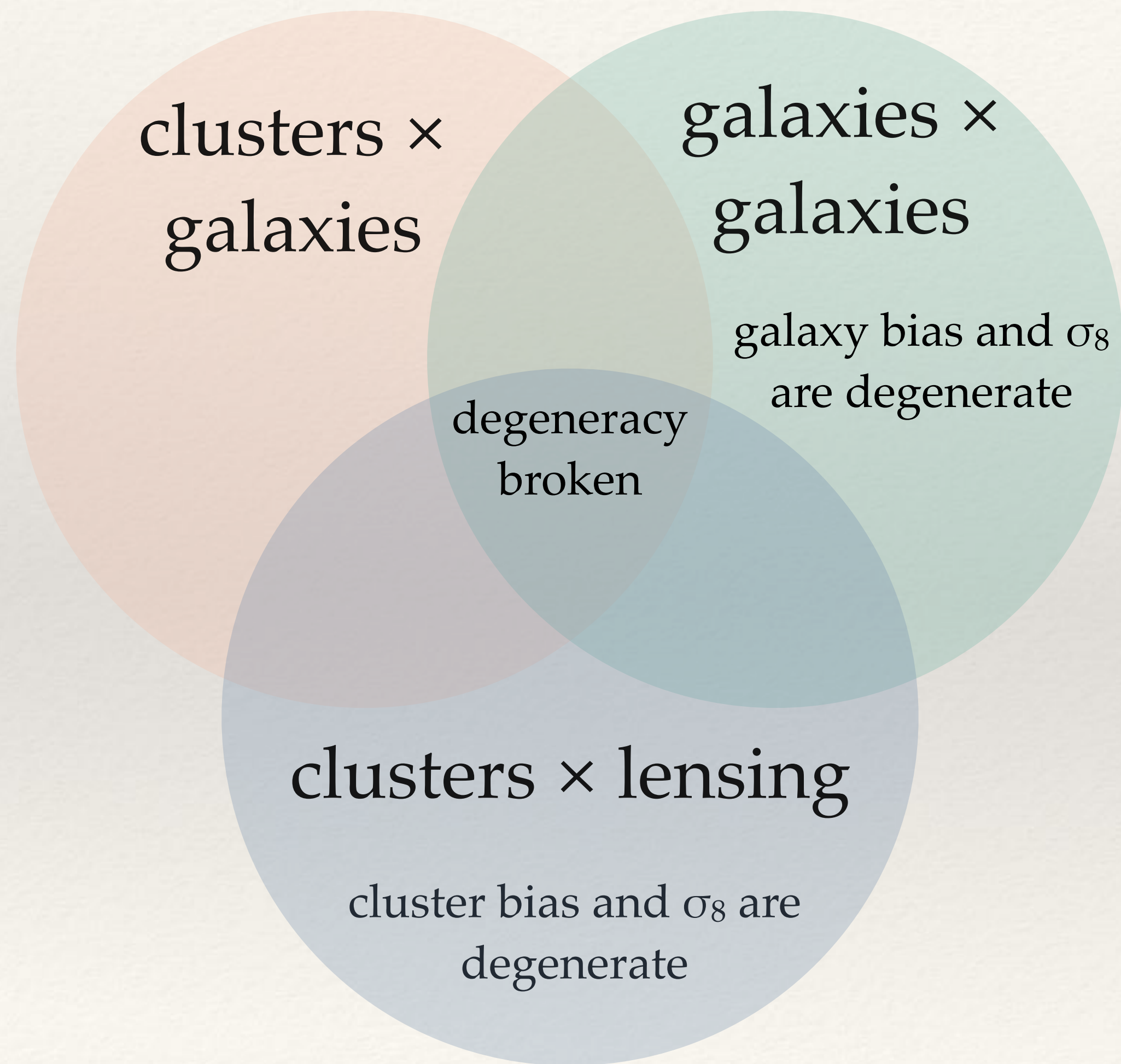


Clusters



For a given cosmology, we can simulate observed clusters, galaxies, and gravitational lensing self-consistently.

Cross-correlation between clusters, galaxies, and lensing



No mass
calibration is
needed!

What CCAPP has given me

- A second chance
- Opportunity to work on Dark Energy Survey
- Skills needed for a faculty job (giving talks, mentoring undergrads, teaching, organizing seminars)
- Role models and aspirations of effective mentoring

2019 SciAccess conference



2019 Hocking Hills



2021 Huntsville, TX



Mischief + music



2023 Arizona workshop

