Towards robust LSS cosmology:
how to mitigate uncertainties in small-scale nonlinearities

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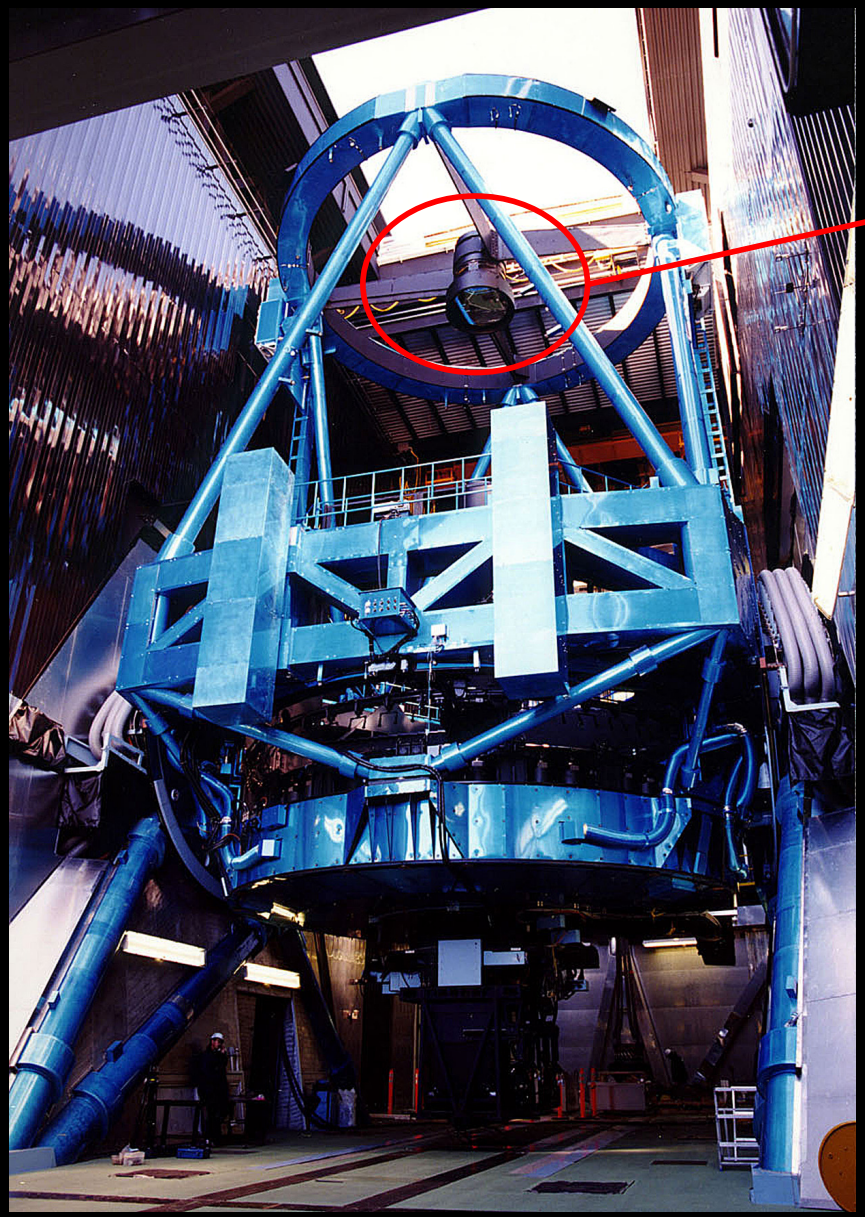
東京大学 THE UNIVERSITY OF TOKYO

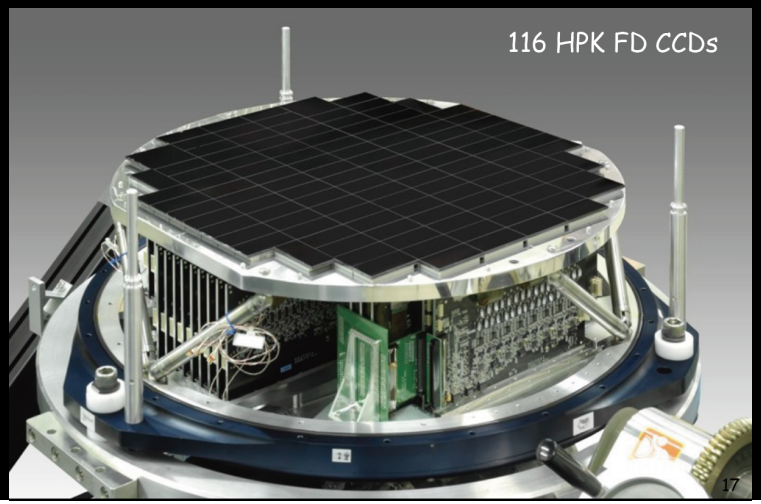
wpi

PTchat @ YITP, April 2019

Hyper Suprime-Cam

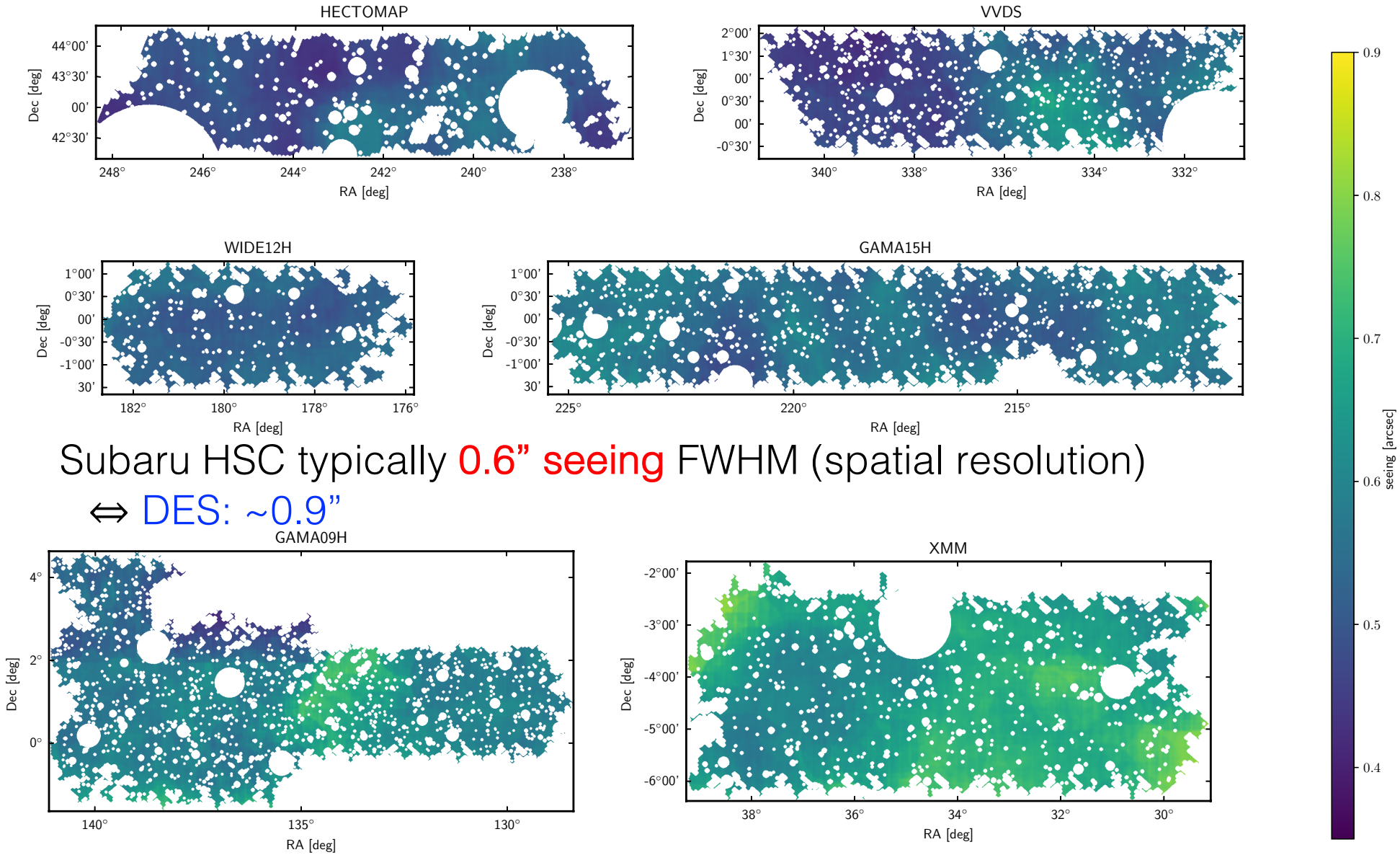


- largest camera
- 3m high
- weigh 3 ton
- 104 CCDs (~0.9G pixels)



Subaru HSC = superb image quality

6 fields (~140 sq. deg. in total): HSC-Y1 data

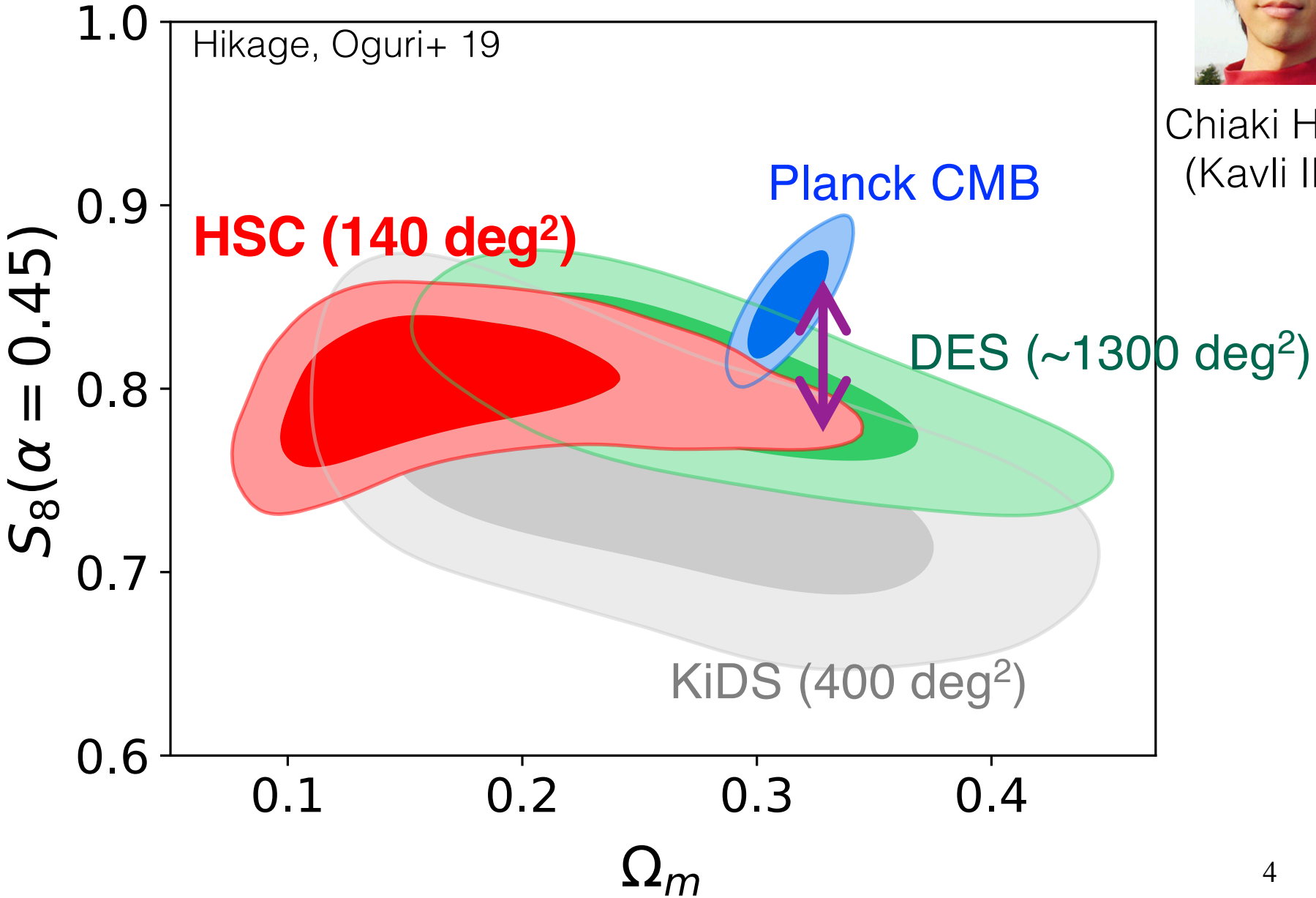


Subaru HSC typically 0.6” seeing FWHM (spatial resolution)

⇔ DES: ~0.9”

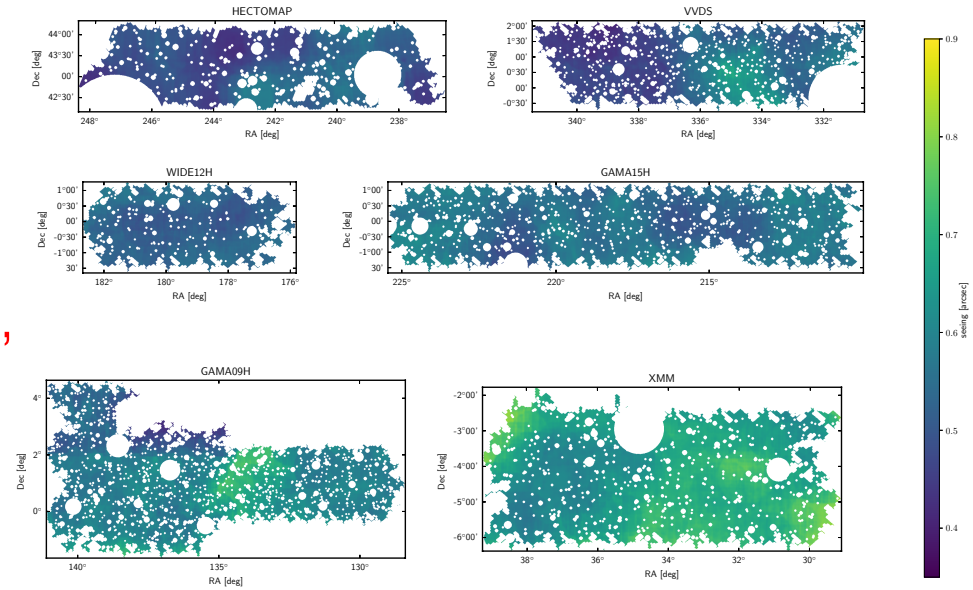
HSC-Y1 cosmic shear cosmology

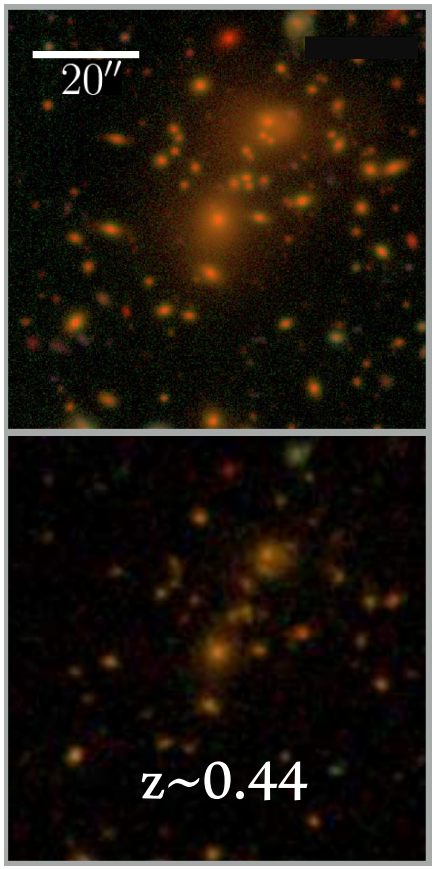
Chiaki Hikage
(Kavli IPMU)



HSC-SDSS joint probe cosmology

- HSC (140 sq. deg.): backgrd gals, g-g lensing
- SDSS (~10000 sq. deg.): spec-z gals (3D distribution) + RSD

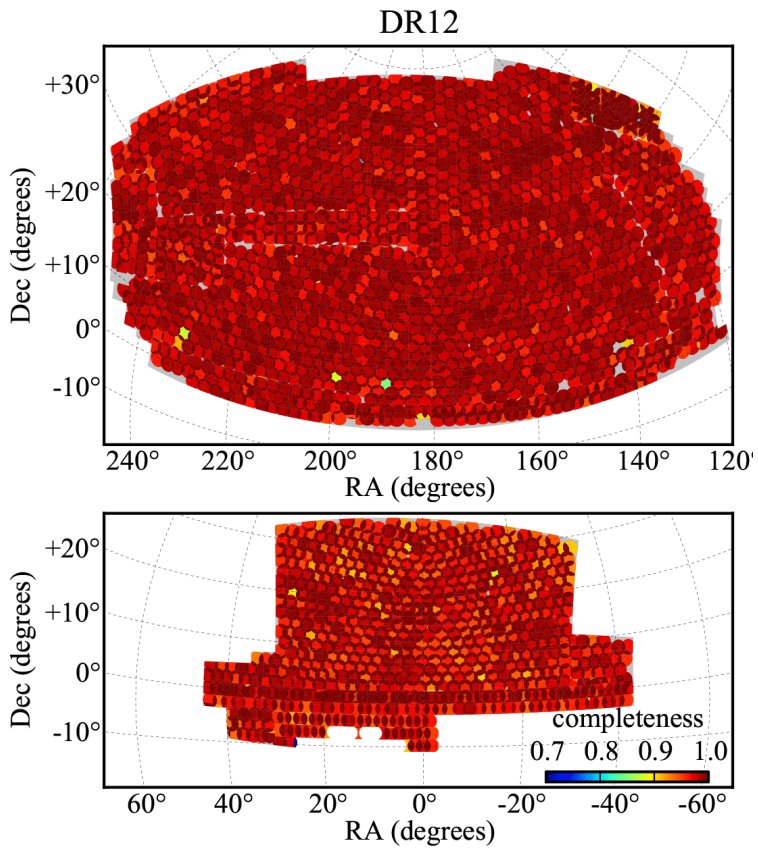




Subaru HSC (8.2m)

SDSS (2.5m)

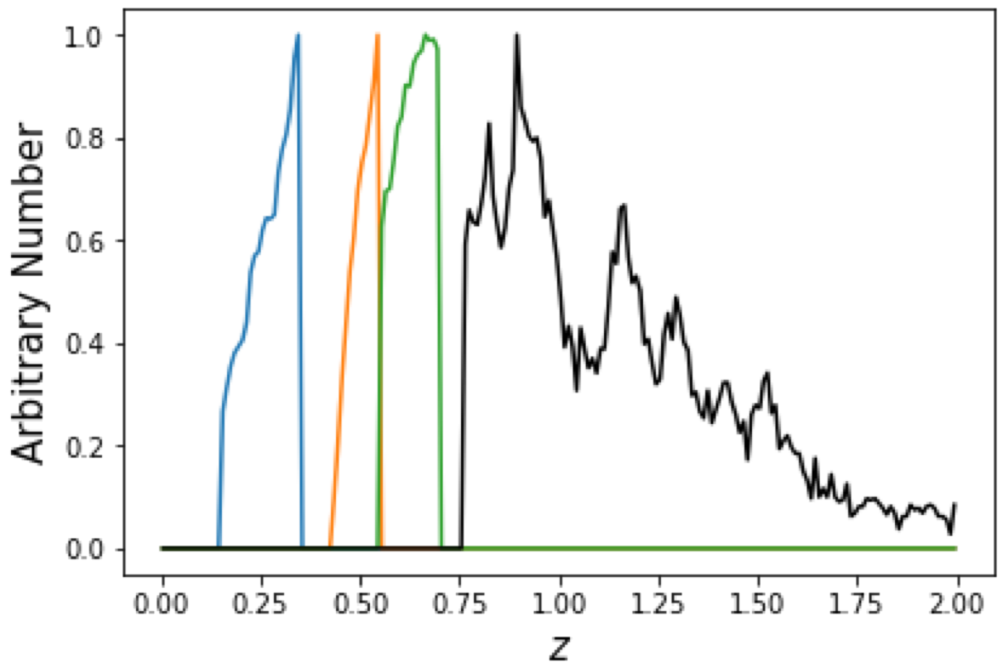
Huang et al. 18

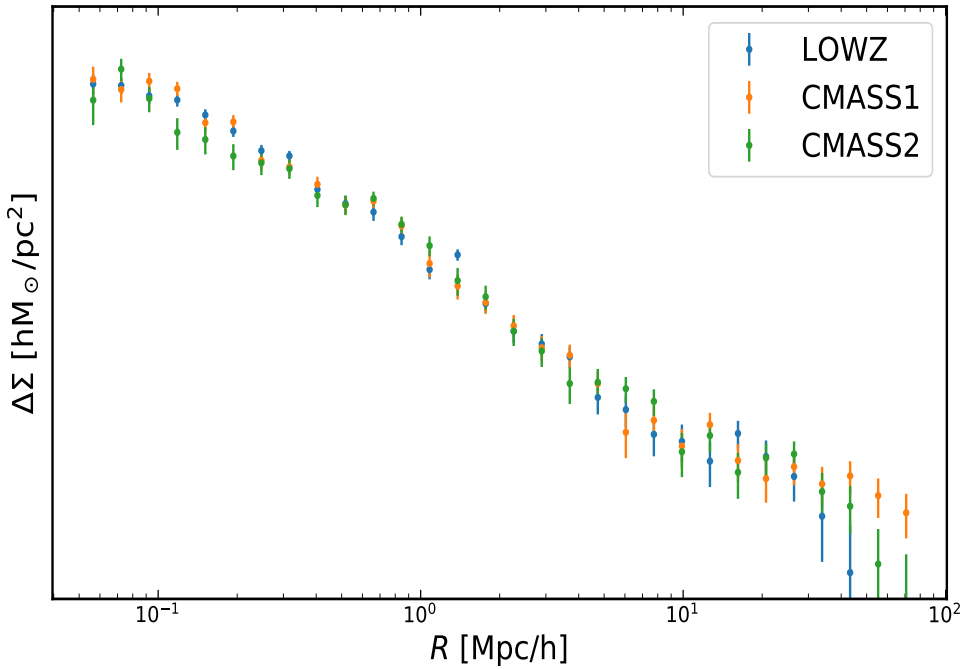


HSC-SDSS joint probe cosmology

Hironao Miyatake
(Nagoya/IPMU)

- Use a single population of source HSC galaxies for 3 lens samples of SDSS galaxies at 3 z-bins → this allows us to calibrate photo-z uncertainties (Oguri & Takada 11)
- S/N~50 in total for g-g lensing
- We are performing the blind analysis



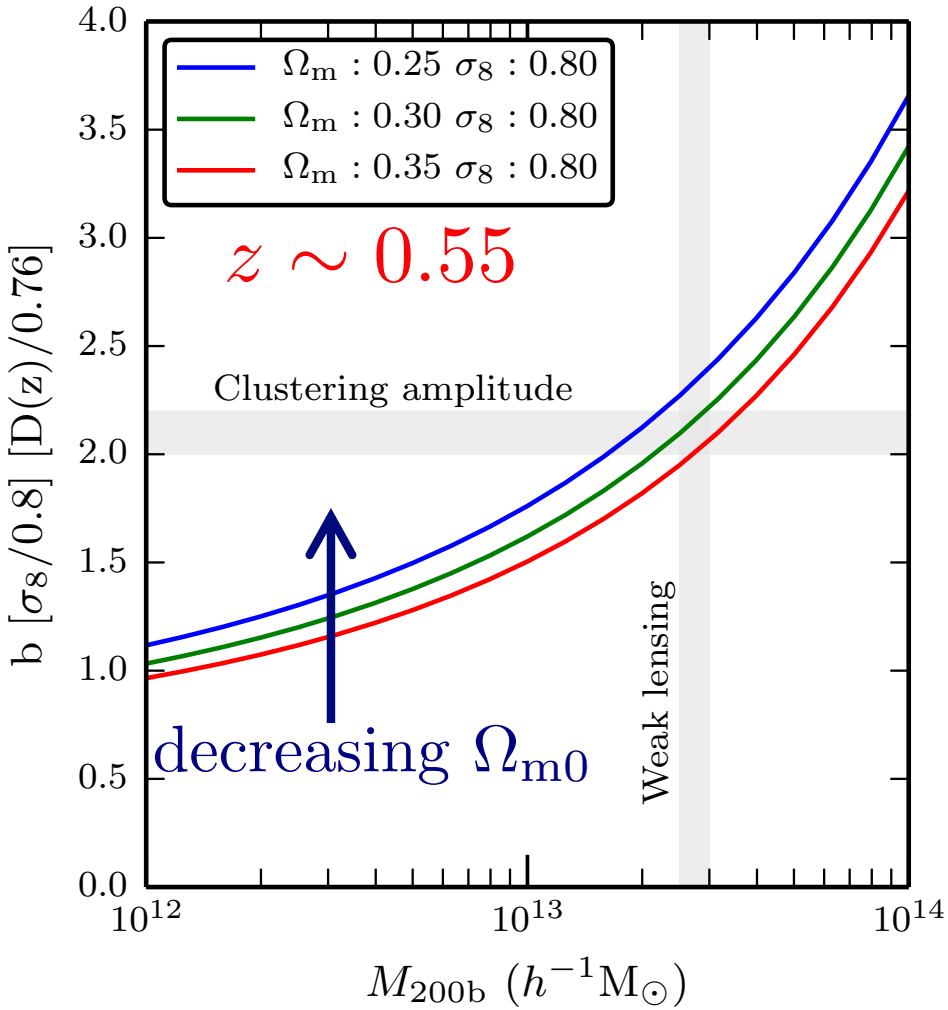


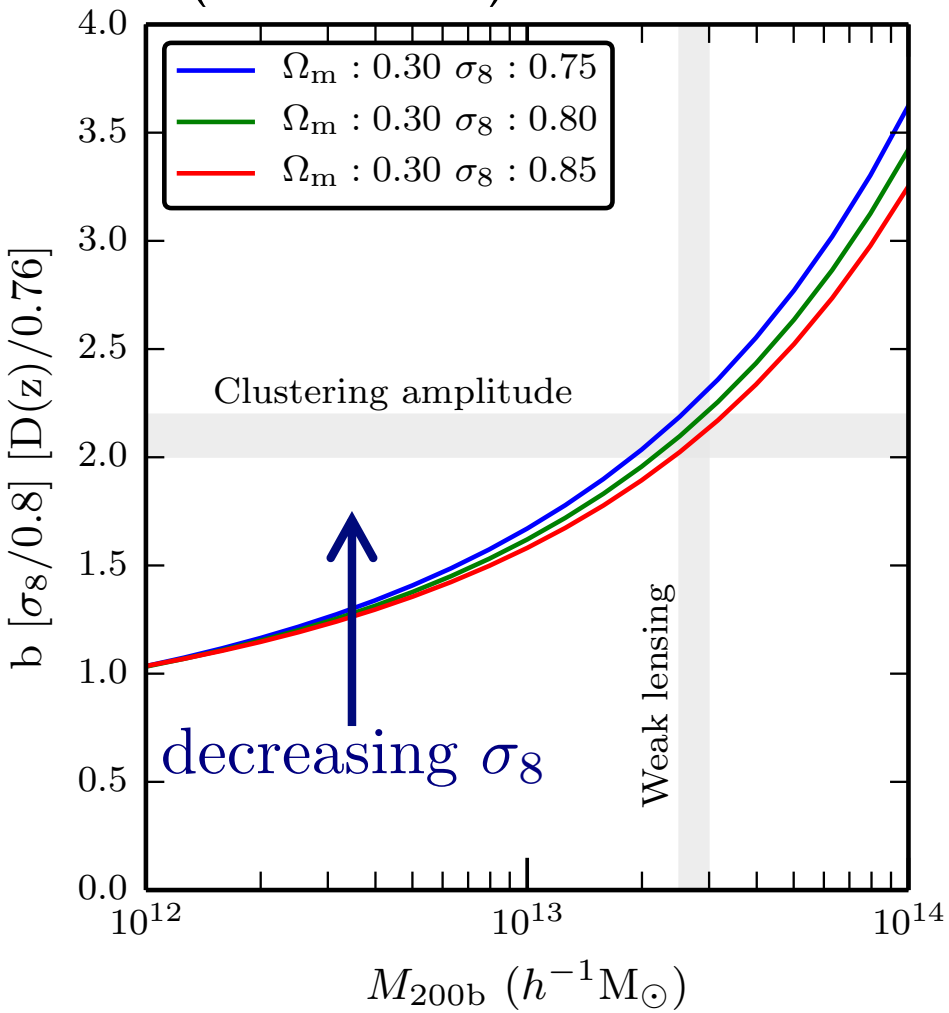
Lensing + Clustering complementarity

Surhud More (IUCAA/IPMU)

Hironao Miyatake (Nagoya)

IF $\xi_{\rm gm} \sim b\sigma_8^2, \xi_{\rm gg} \sim b^2\sigma_8^2, b \sim b(M)$





More, Miyatake, Mandelbaum, MT+15

How to extract cosmology against galaxy bias?

- Linear theory or PT: DES approach (see Elisabeth's talk)
  - Pros: robust, simple theory
  - Cons: has to be restricted to large scales

$$P_{\rm gm}(k) \simeq bP_{\rm mm}^{\rm NL}(k), \quad P_{\rm gg}(k) \simeq b^2 P_{\rm mm}^{\rm NL}(k)$$

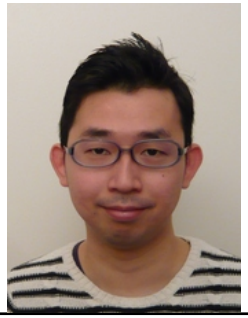
- Method filtering out the small-scale information (SDSS; Mandelbaum et al. 2013)
  - Pros: robust against small-scale NL's
  - Cons: conservative

$$\Upsilon_{\rm gm}(R) = \Delta\Sigma(R) - \frac{R_0^2}{R^2}\Delta\Sigma(R_0)$$

- Halo Emulator approach (HSC; Miyatake+ in prep.)
  - Pros: could use the small-scale information
  - Cons: need to introduce a sufficient number of paras to model 1-halo term uncertainties, assembly bias ….

Dark Quest & Dark Emulator

Nishimichi, MT, Takahashi et al.



Takahiro Nishiichi
(IPMU→YITP)

R. Takahashi (B03)

M. Shirasaki
(NAOJ: solicited)

H. Miyatake
(Nagoya: solicited)

Y. Kobayashi
(IPMU: D2)

M. Oguri (B02)

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DARK QUEST. I. FAST AND ACCURATE EMULATION OF HALO CLUSTERING STATISTICS AND ITS APPLICATION TO GALAXY CLUSTERING

Takahiro Nishimichi[1], Masahiro Takada[1], Ryuichi Takahashi[2], Ken Osato[3], Masato Shirasaki[4], Taira Oogi[1], Hironao Miyatake[5,6,1], Masamune Oguri[3,7,1], Ryoma Murata[1,3], Yosuke Kobayashi[1,3], and, Naoki Yoshida[3,7,1]

Draft version November 26, 2018

ABSTRACT

We perform an ensemble of cosmological N-body simulations with 2048^3 particles for 101 cosmological models within a flat wCDM cosmology framework, which are sampled based on a maximin-distance Sliced Latin Hypercube Design. By using the outputs of N-body simulations and the halo catalogs extracted at multiple redshifts in the range of $z = [0, 1.48]$, we develop an emulator, Dark Emulator, which enables fast and accurate computations of halo clustering quantities, the halo mass function, halo-matter cross-correlation, and halo auto-correlation as a function of halo masses, redshift, separations and cosmological models, based on the Principal Component Analysis and the Gaussian Process Regression for the large-dimensional input and output data vector. We use a validation set of N-body simulations for cosmological models, which are not used in training the emulator, to assess the performance of the emulator. We show that, for typical halos hosting CMASS galaxies in the Sloan Digital Sky Survey, the -matter cross correlation, relevant for galaxy-galaxy weak lensing, with an accurac alo auto-c for galaxy clustering correlation, with an accuracy bett l demonst of the emulator. For instance, the emulator outputs can s of halo m such as the mass-concentration relation and splashbac gy and re We also show that the emulator outputs can be combin iption of h tion such as the halo occupation distribution at the equ g the moc accurate predictions of galaxy clustering statistics su eak lensin correlation function for any model within the wCDM me of a fe

Keywords: large-scale structure of the universe — nun hine learni

1. INTRODUCTION

Cosmic large-scale structures are promising avenues to fun damental questions in cosmology. Various wide-area imaging

ellite syste the in the relation between distributions

Dark Quest

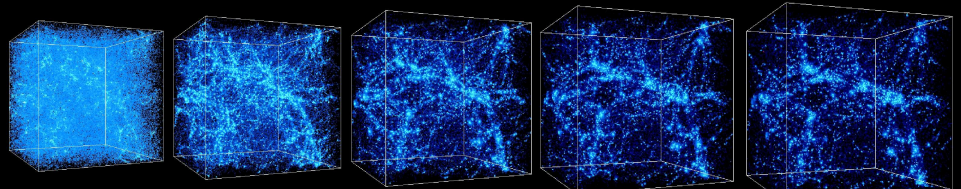
Nishimichi et al.

- Towards an accurate modeling of nonlinear structure formation

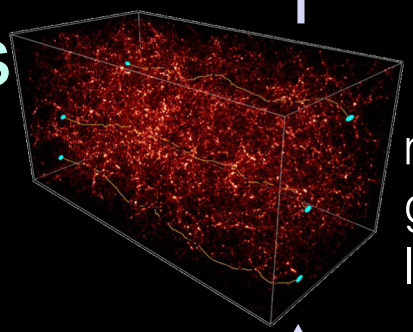
specify wCDM model

$$p_\alpha = \{\omega_{\rm c}, \omega_{\rm b}, \Omega_{\rm de}, \ln(10^{10}A_s), n_s, w_{\rm de}\}$$

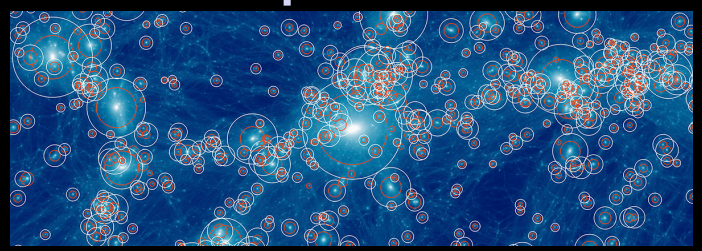
~a few days



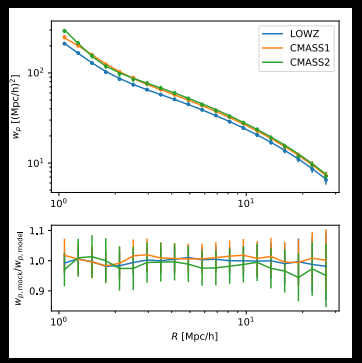
run N-body sim.



make a mock of galaxy survey (gals, lensing fields, …)



post processing (identify halos ~ place where galaxies form)



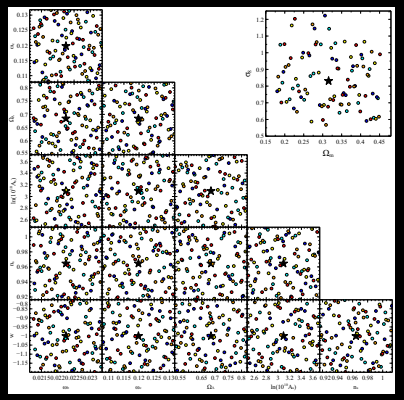
a measurement from the mock

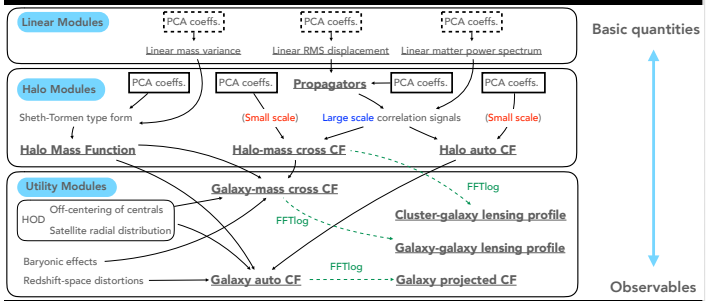
Dark Emulator

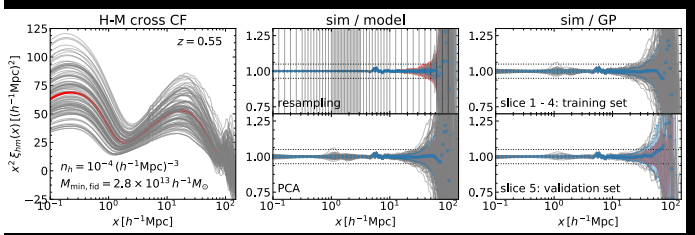
Nishimichi et al. +18

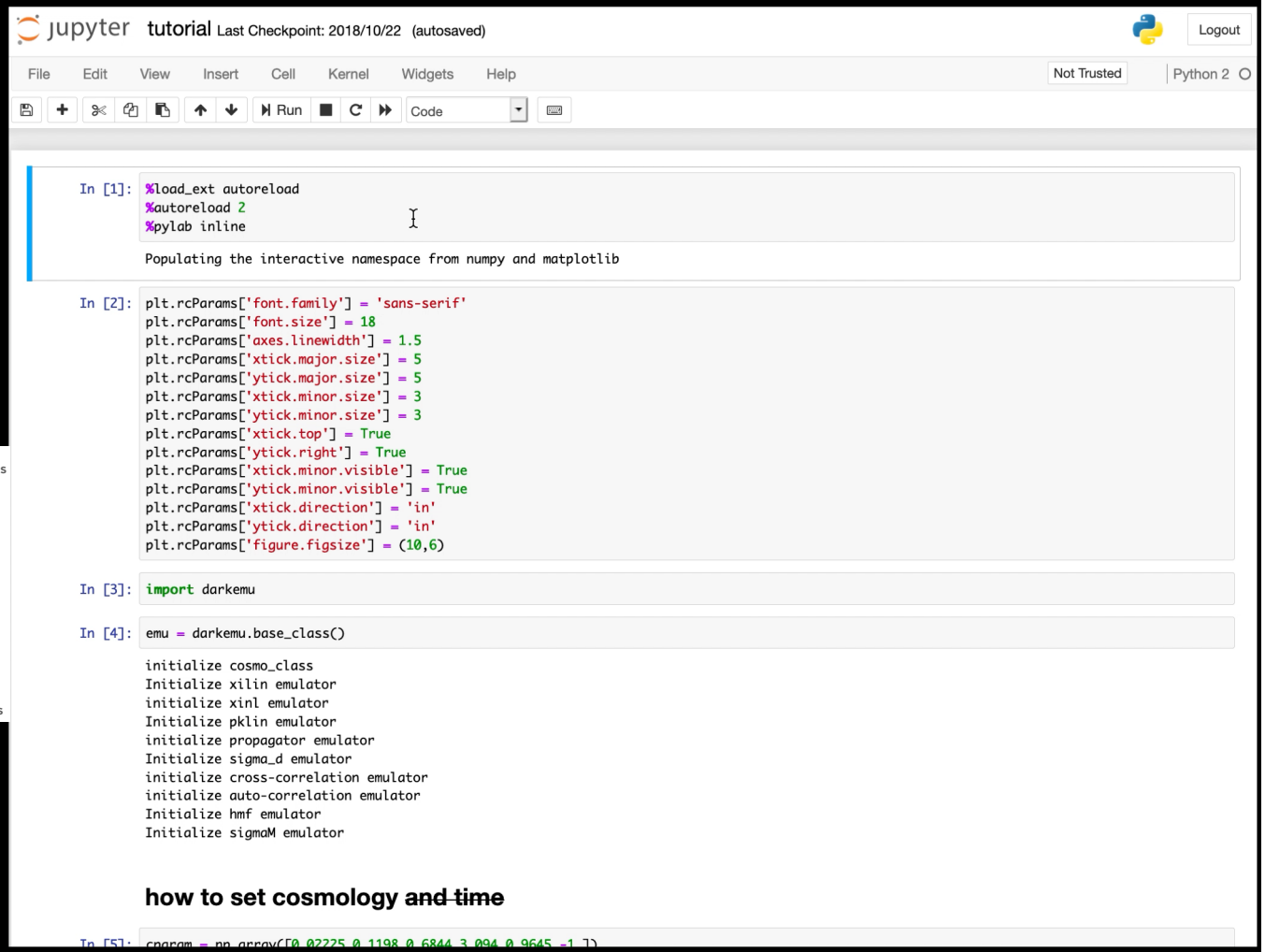
- Stored all data (~200TB)
- Gauss process & ML
- Make an “emulator” from the tabulated data

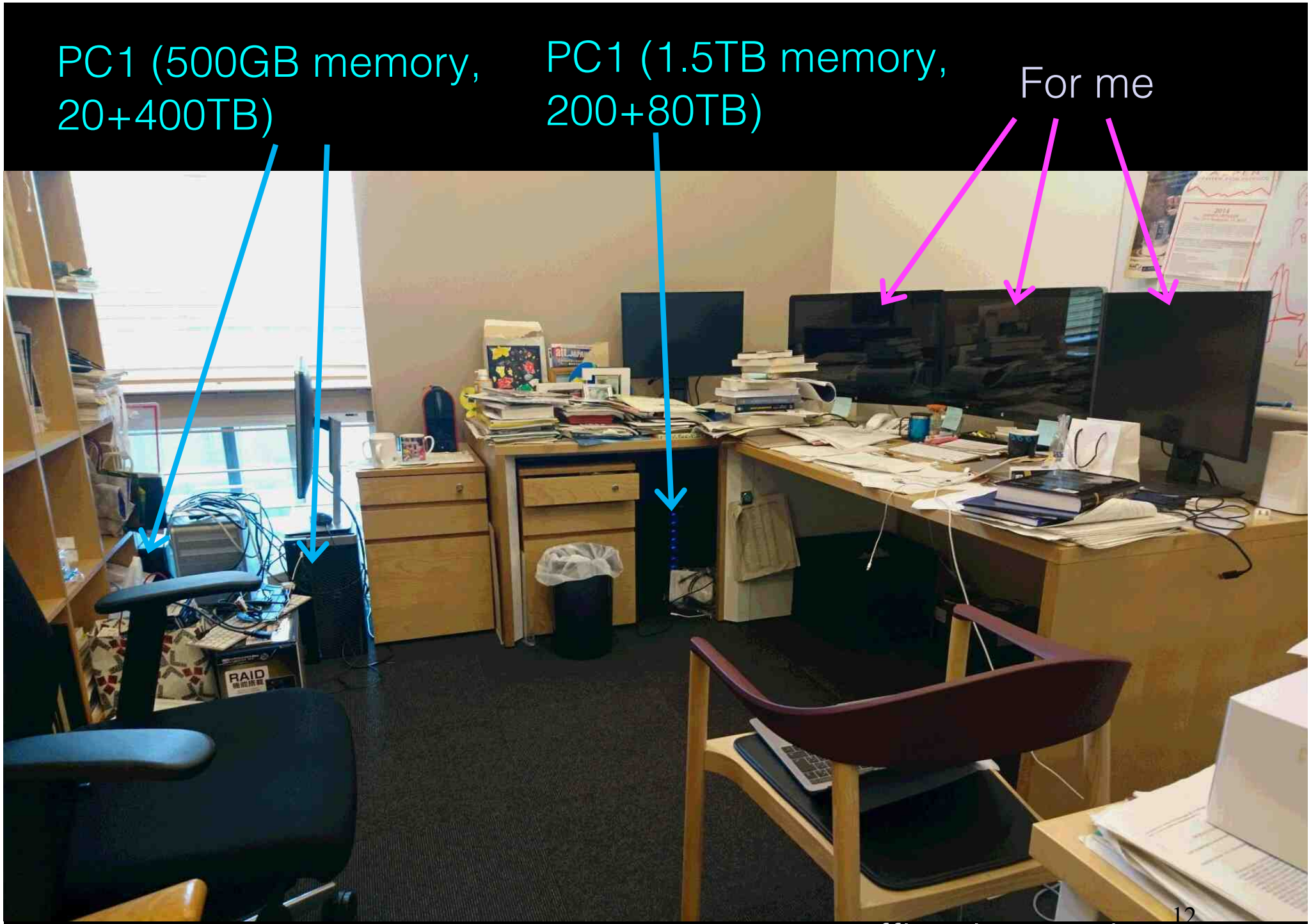
Allow a fast computation of galaxy clustering observables (<1sec)









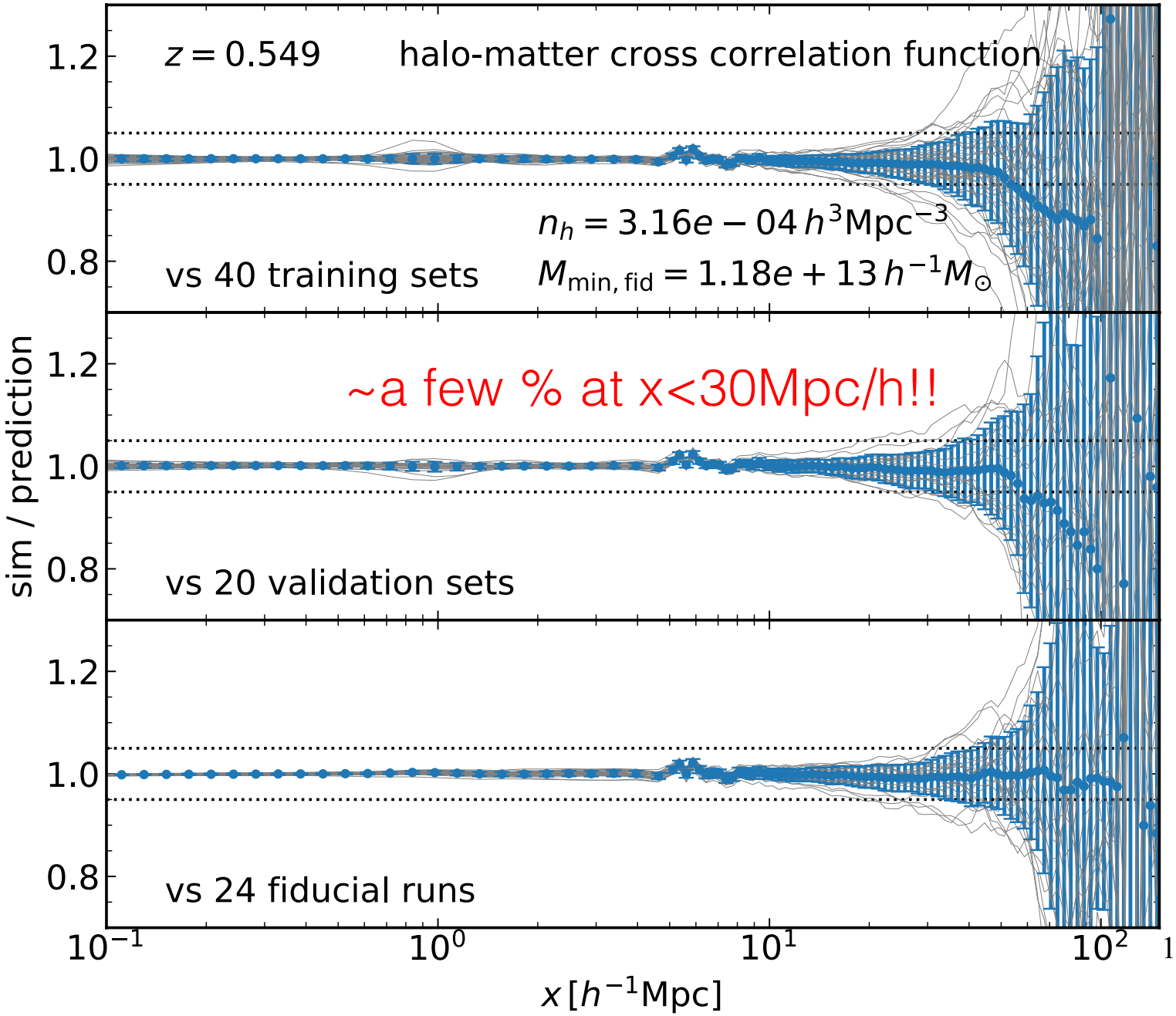


my office is very hot…

validation test

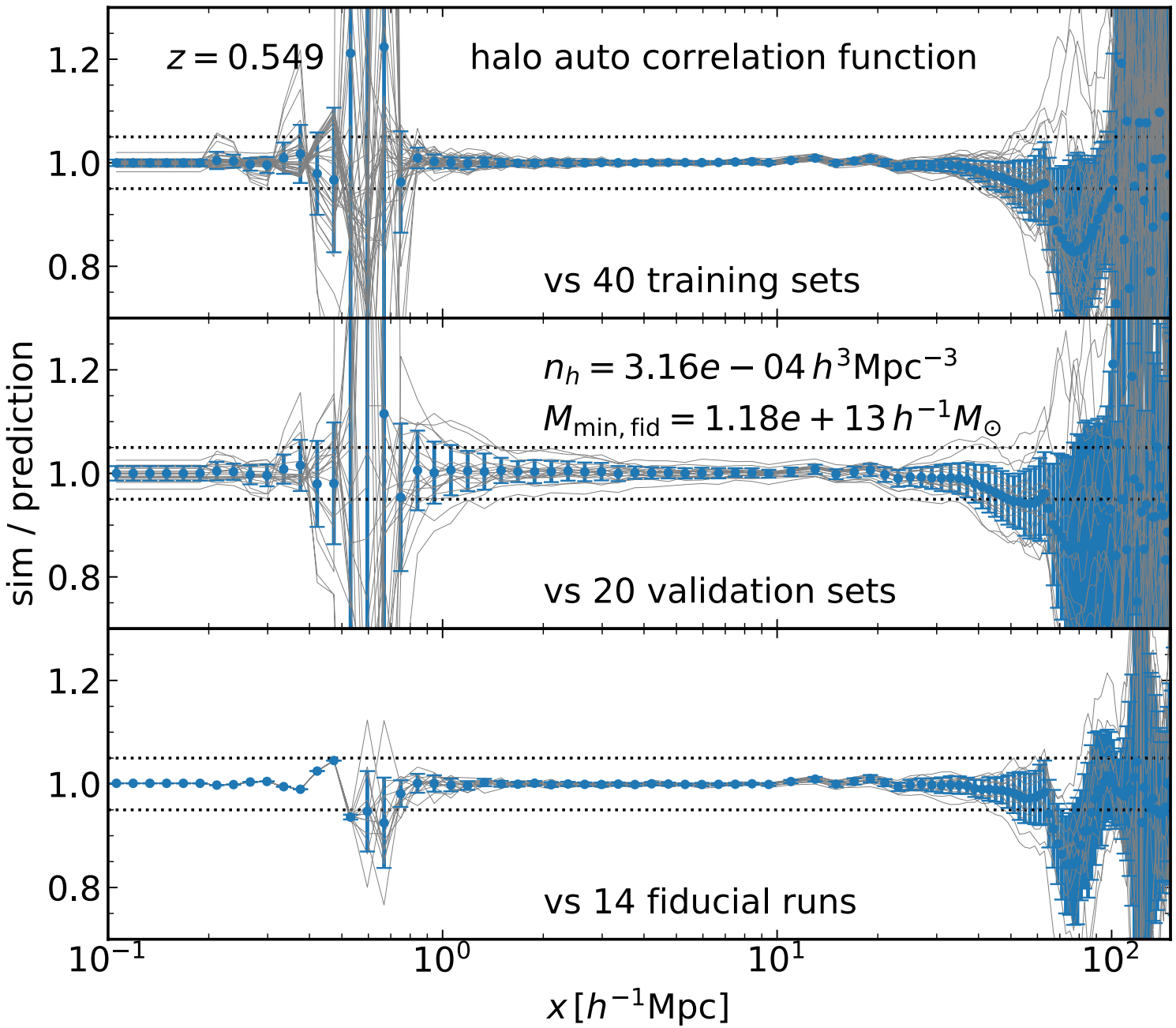
$\xi_{\rm hm}(r; M, z)$

Nishimichi+



validation test $\xi_{\rm hh}(r; M, M', z)$

Nishimichi+



Clustering observables form Halo Emulator

- The abundance of SDSS galaxies; we don't use for cosmology though (sensitive to masks, obs. systematics, …)

$$\bar{n}_{\rm g} = \sum_M \frac{{\rm d}n}{{\rm d}M} \left[\langle N\rangle_{\rm c}(M) + \langle N\rangle_{\rm s}(M)\right]$$

- g-g lensing

$$P_{\rm gm}(k) = \frac{1}{\bar{n}_{\rm g}} \sum_{\rm M} \frac{{\rm d}n}{{\rm d}M} \underbrace{\left[\langle N\rangle_{\rm c}\mathcal{H}_{\rm off}(k) + \langle N\rangle_{\rm s} u_{\rm s}(k)\right]}_{\text{nuisance}} \underbrace{P_{\rm hm}(k;M)}_{\text{emulator}}$$

$$\xrightarrow[\rm FFTlog]{} \Delta\Sigma(R)$$

- g-g clustering

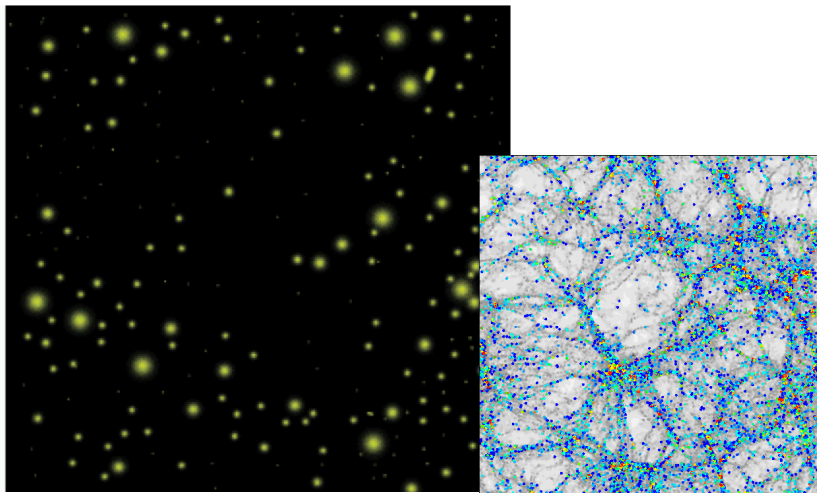
$$P_{\rm gg}(k) = P^{\rm 1h}_{\rm gg}(k) + \frac{1}{\bar{n}_{\rm g}^2} \sum_{M,M'} \left[\langle N\rangle_{\rm c}\mathcal{H}_{\rm off}(k)\langle N\rangle_{\rm s} u_{\rm s}(k)\right] \ldots P_{\rm hh}(k;M,M')$$

$$\xrightarrow[\rm FFTlog]{} w_{\rm gg}(R)$$

HSC cosmology challenges

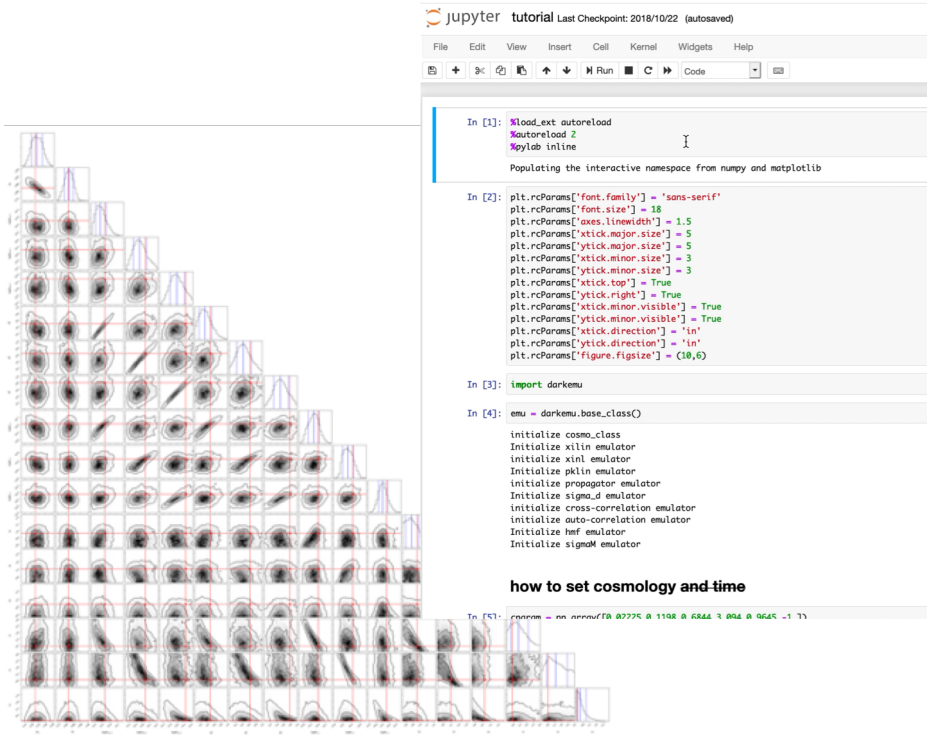
Yosuke Kobayashi
(Kavli IPMU)

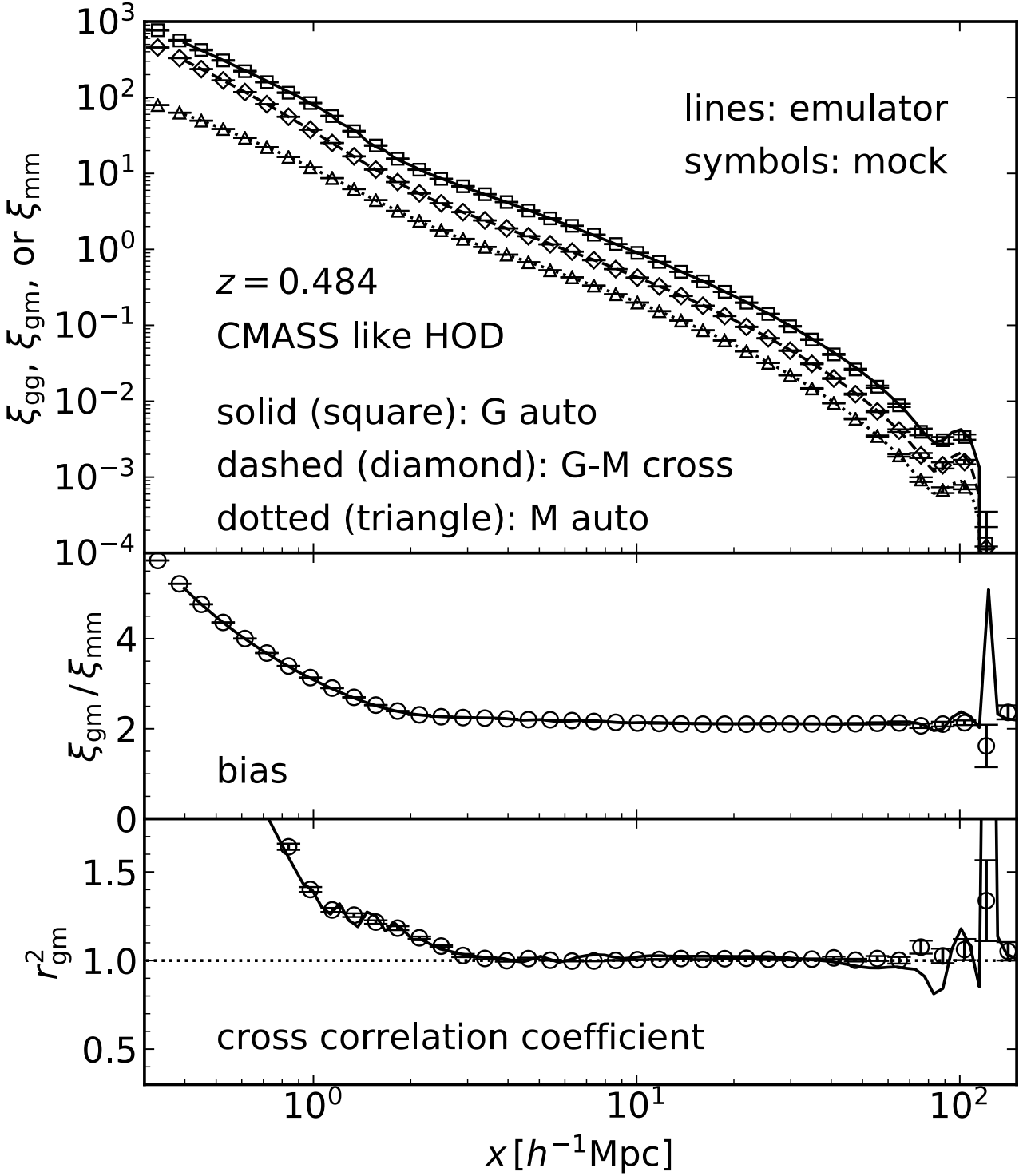
- Populating sim halos with galaxies using different gal recipes with many variants
  - Diff HOD paras
  - Sat gals distribution
  - Off-centering
  - Baryonic effects
  - Assembly bias



Hironao Miyatake

- MCMC parameter inference
  - Use the fiducial HOD/gal paras
  - Address whether to recover the underlying cosmo paras





Stochasticity in galaxy clustering

- Scale-dependent bias
- Stochasticity

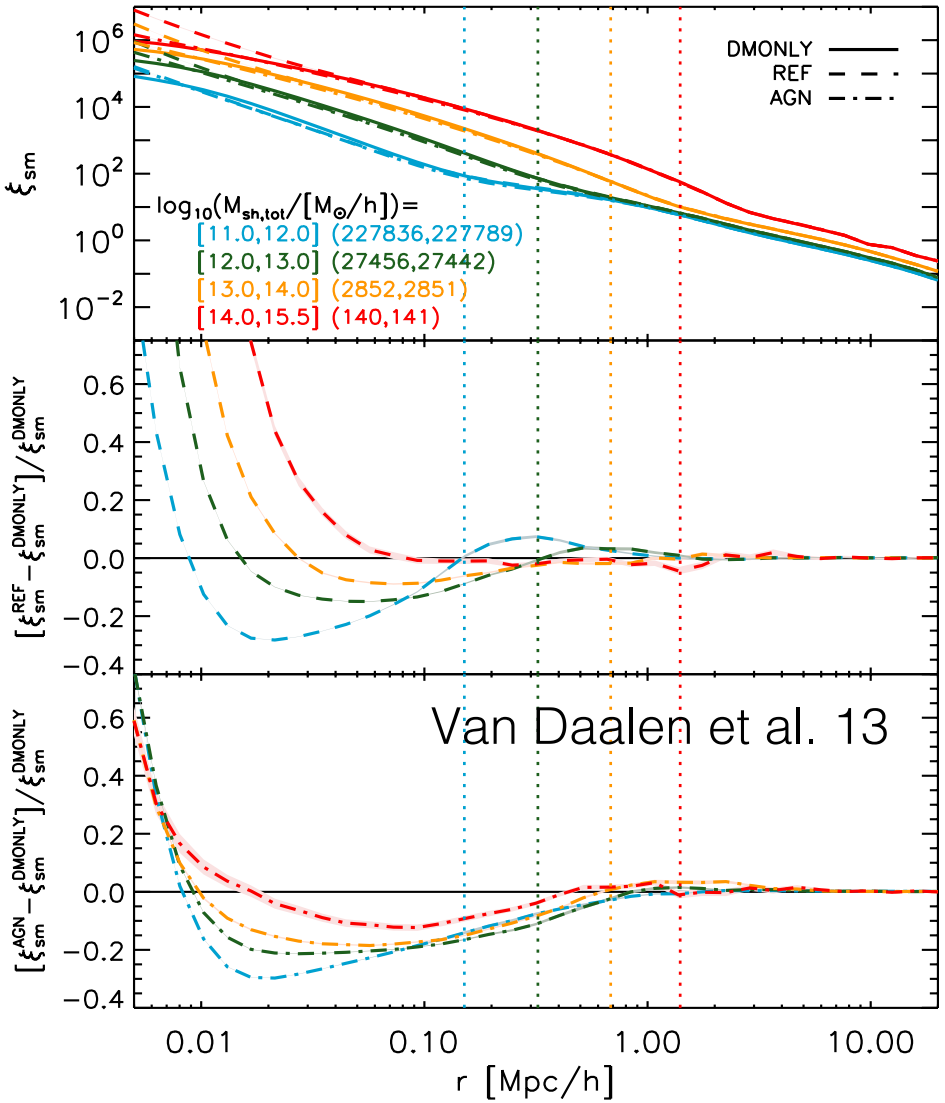
$$\langle N_g(N_g-1)\rangle \neq \langle N_g\rangle^2$$

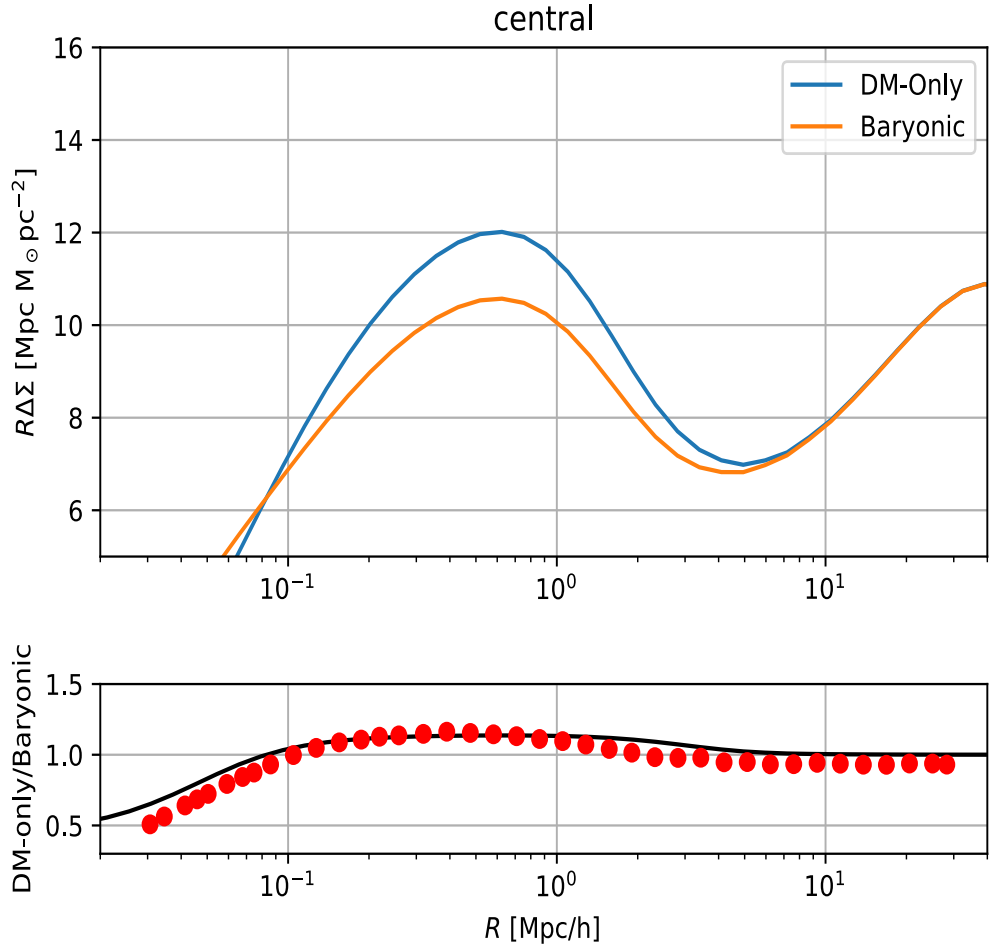
$$r(r) \equiv \frac{\xi_{gm}(r)}{\sqrt{\xi_{gg}(r)\xi_{mm}(r)}} \neq 1$$

Seljak 00
Scoccimarro + 01

conservation laws for baryonic effects

- (red) galaxy bias not changed: galaxies form from the same initial peaks
- mass conservation around each galaxy -- baryonic effects causes a redistribution of total matter around each galaxy





Schneider & Teyssier 15; Leautahud+17

Re

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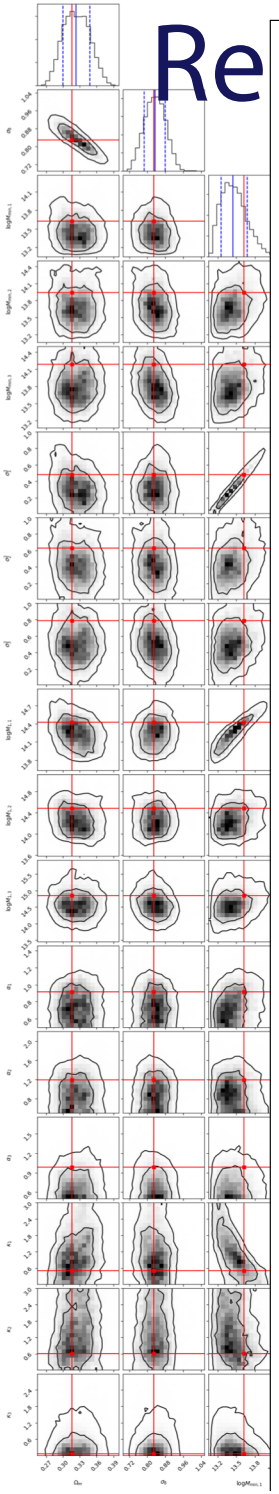

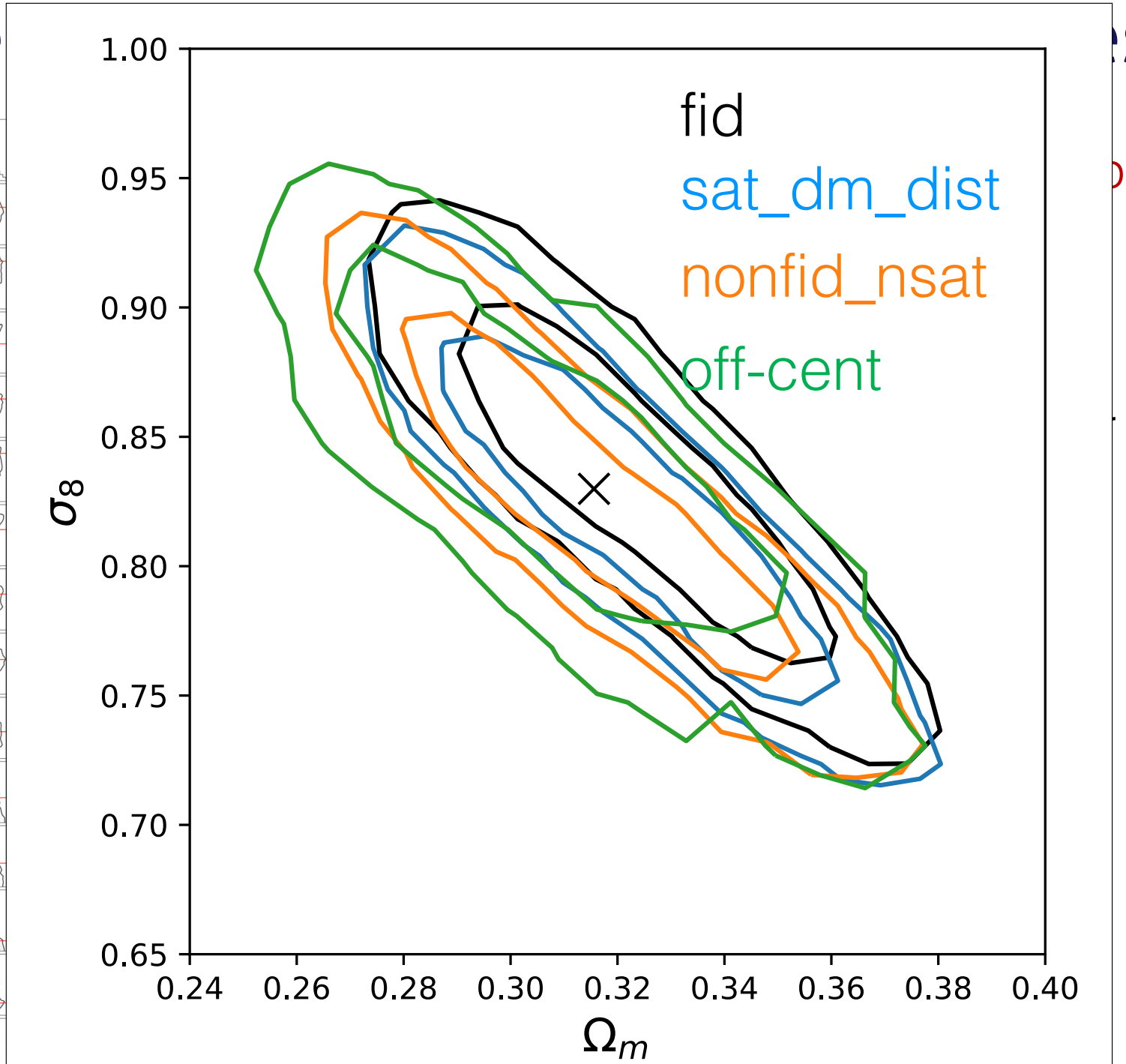
fid
sat_dm_dist
nonfid_nsat
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1.00
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0.75
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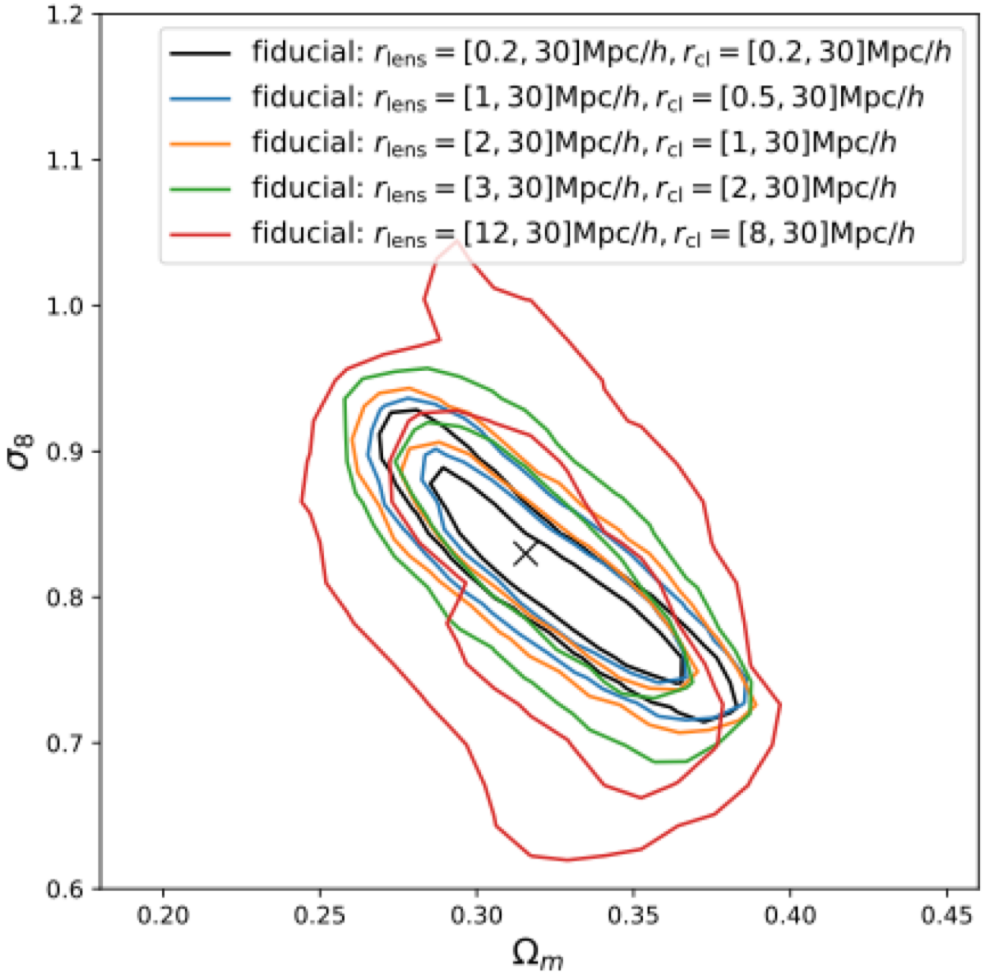
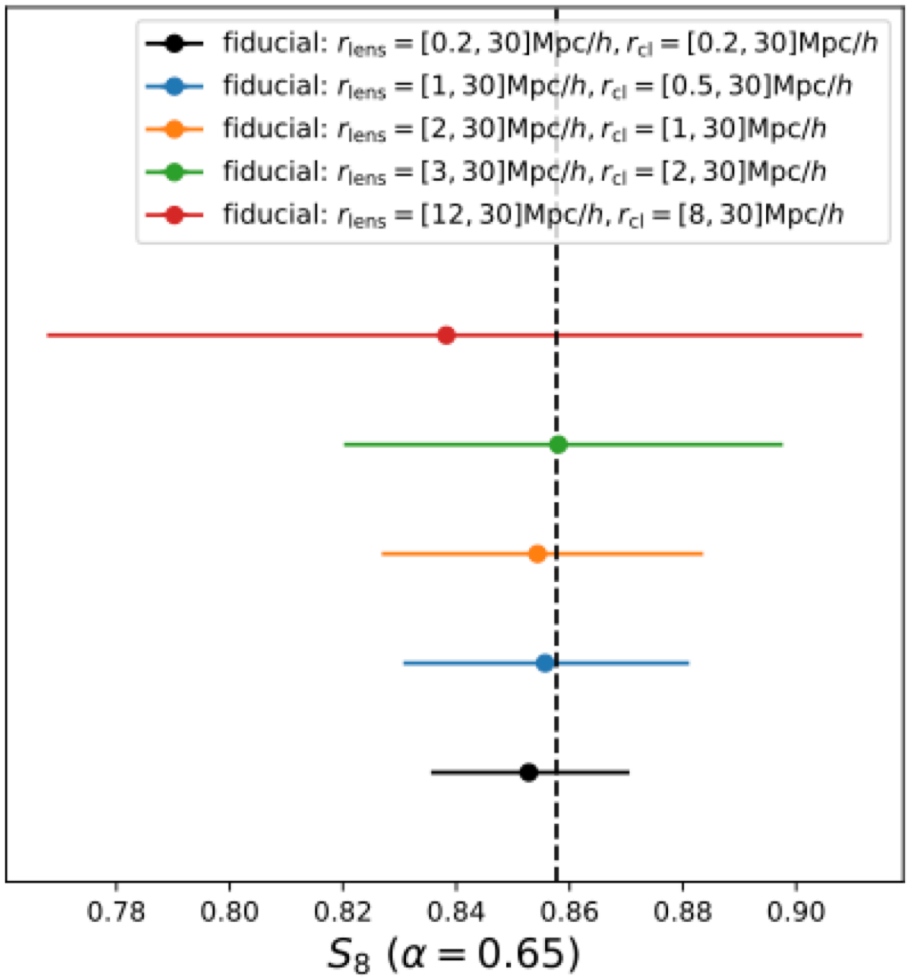
0.65
σ_8
0.24
0.26
0.28
0.30
0.32
0.34
0.36
0.38
0.40
Ω_m

each

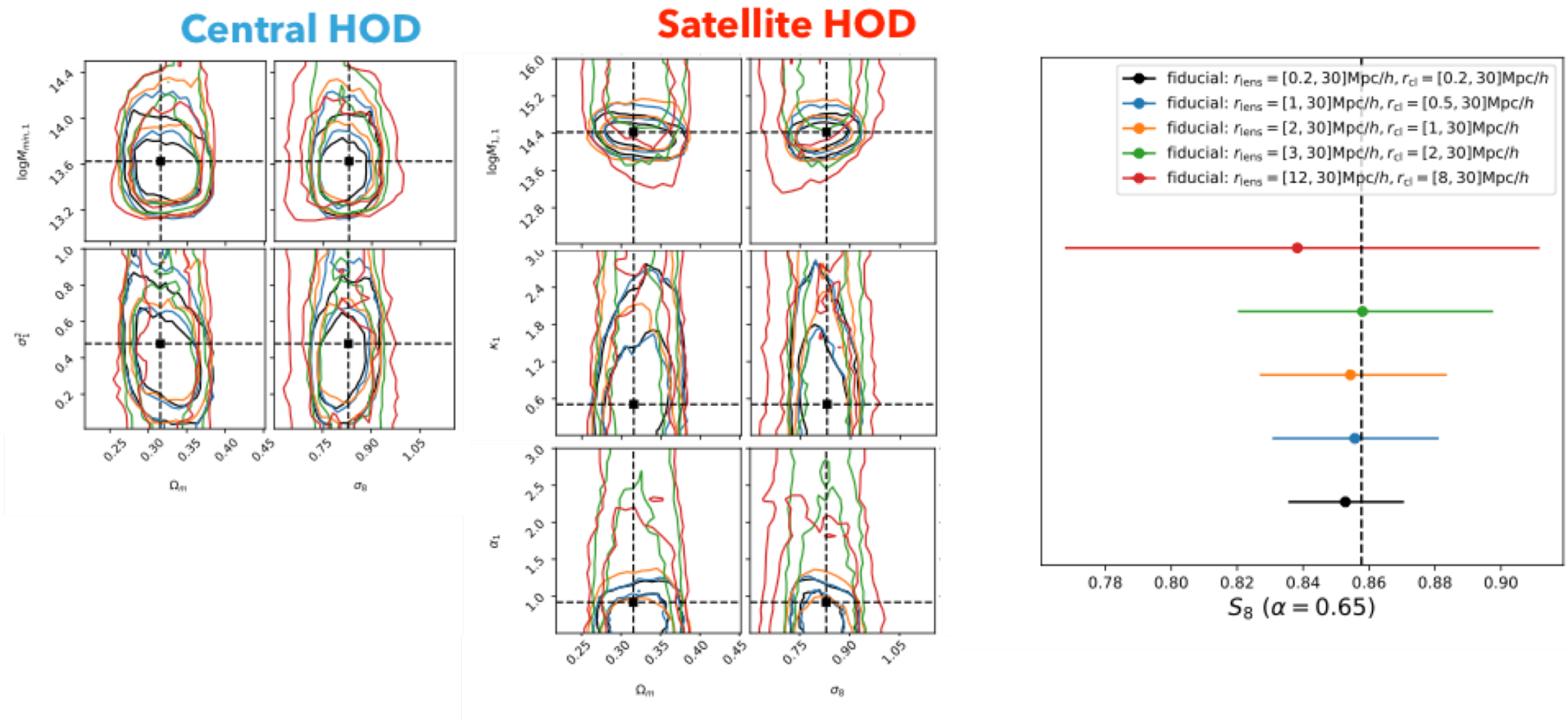
Used HSC+BOSS mocks for covariance

We expect ~3% accuracy in S8





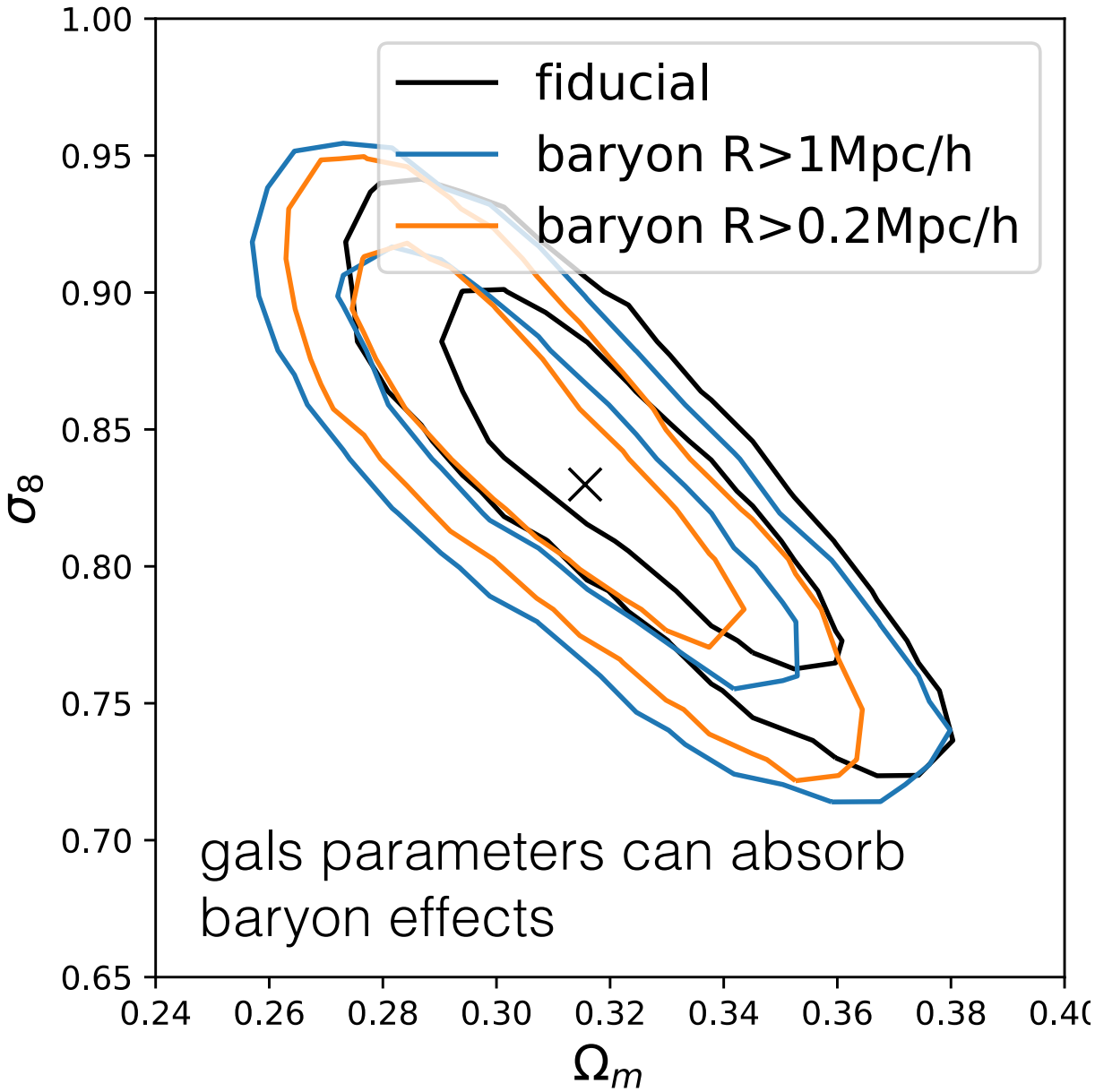
Miyatake, Kobayashi+

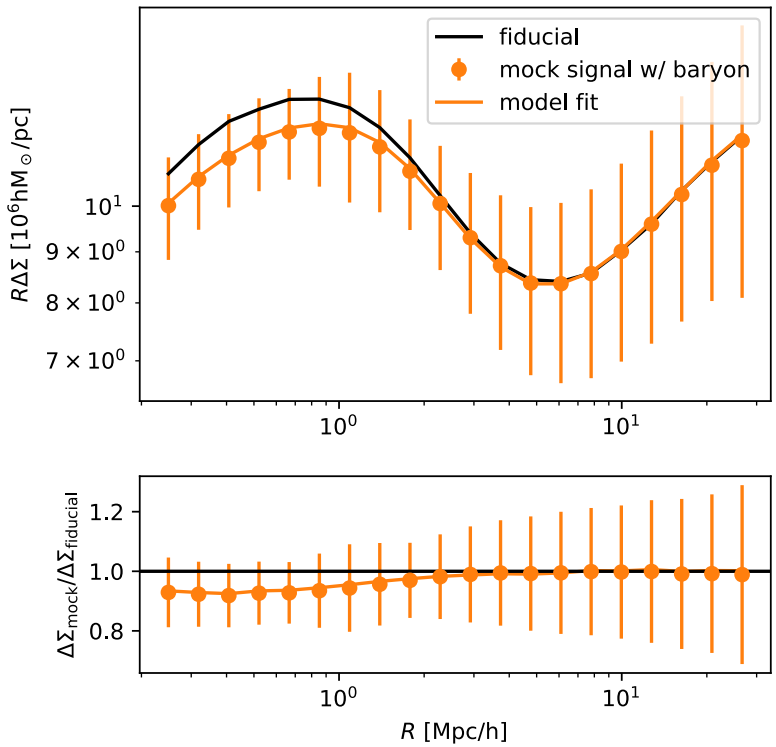


galaxy parameters are nuisance
we don't care any bias in galaxy parameters

Miyatake, Kobayashi+

Against baryon effects …





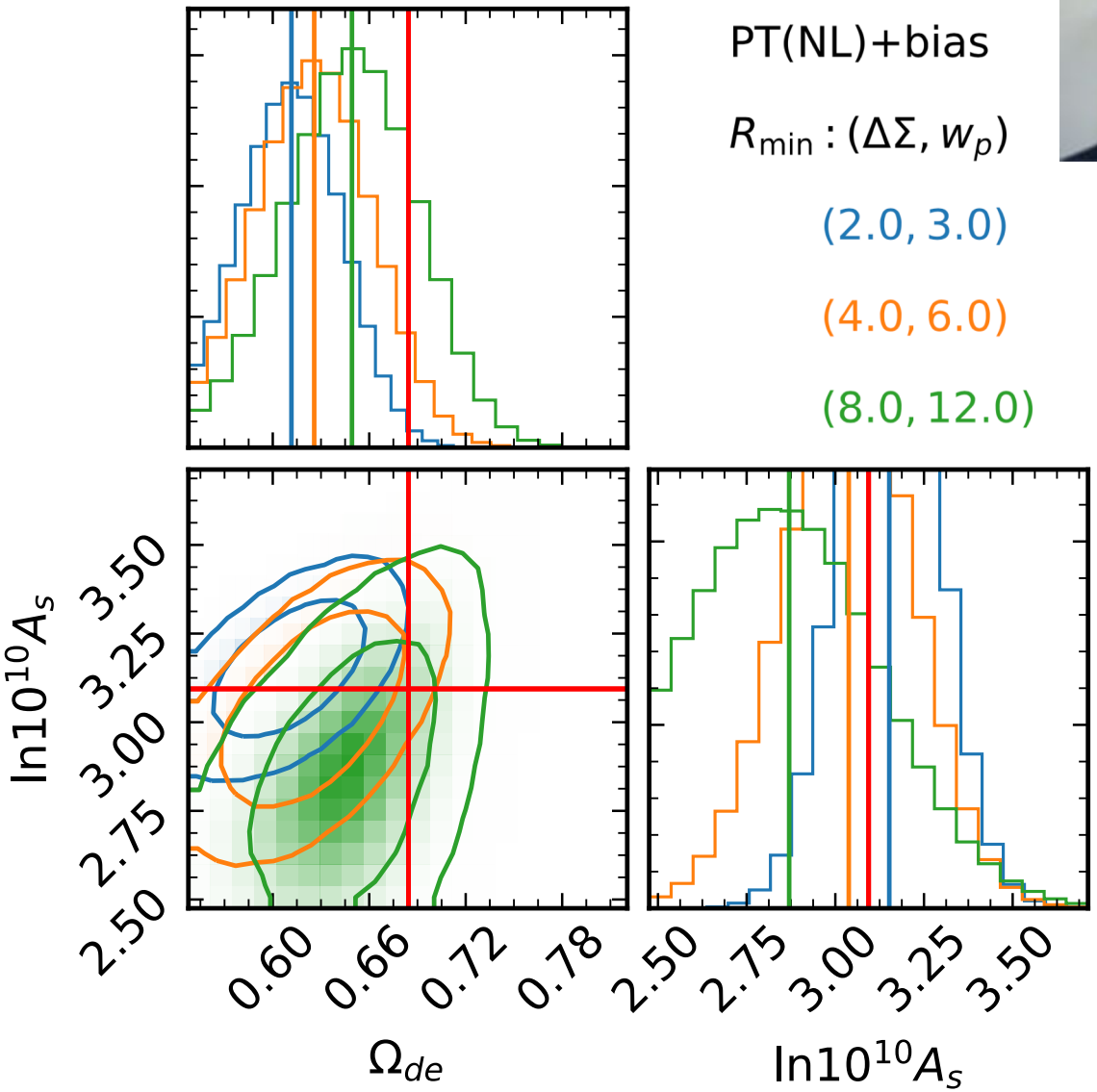
Miyatake, Kobayashi+

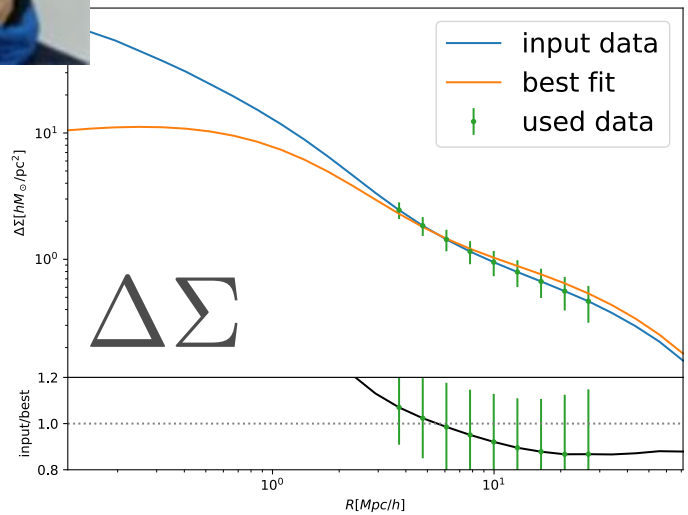
Mocks very useful! testing/validation of PT-based approach

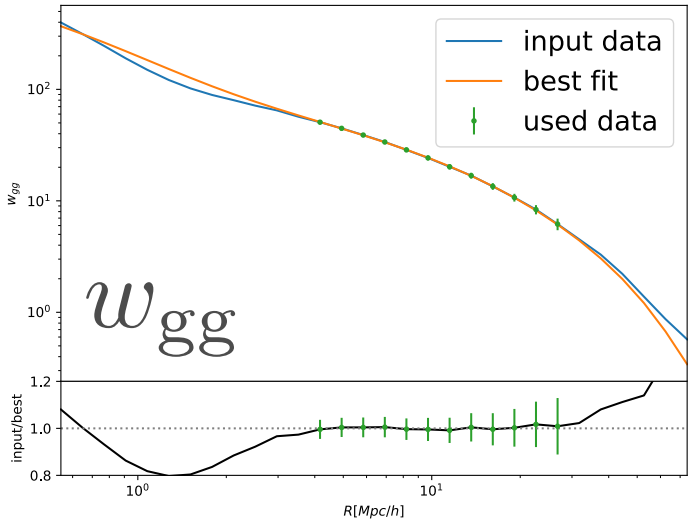
$$P_{\rm gm}(k) = b_1 P_{\rm mm}^{\rm NL}(k) + b_2 A^{\rm PT}(k)$$

$$P_{\rm gm}(k) = (b_1)^2 P_{\rm mm}^{\rm NL}(k) + 2 b_1 b_2 A^{\rm PT}(k) + \frac{b_2}{2} B^{\rm PT}(k)$$

See Sunao's poster







summary

- Galaxy bias so annoying (except for Nick's linear bias!)
- The community NEEDS a good, practical method (valuable data there)
  - Give us a good method
  - **Linear theory**: are you satisfied? Loose a lot of small-small info
  - **PT**: looks great, but useful?
  - **Halo-model approach** (our HSC approach): are you convinced?
- Want to impose conservation laws
  - Mass/momentum conservation laws
  - Small-scale stochasticity backreaction, P(k)~k^4 (Peebles 1980)