Full-sky Weak Lensing Mock Catalogs

B03

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prepared mainly for the HSC survey, publicly available soon

（RT et al. in preparation）

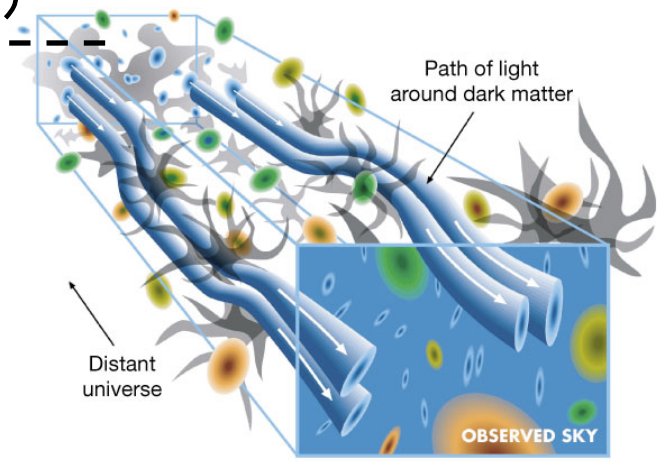
Introduction

- **Weak Lensing Galaxy Surveys**

distortion of background galaxy shapes

→ probe foreground matter distribution

	project	survey area（deg^2）
completed	CHFTLenS	150
ongoing	Subaru HSC	1400
	KiDS	1500
	DES	4000
planned	LSST	20000



（Wittman+ 2000）

- **CMB lensing**

Weak lensing also deforms the CMB temperature and polarization maps.

The lensing signals were already detected by WMAP and Planck.

The lensing B-mode acts as contamination for primordial gravitational waves.

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We need full-sky mock catalogs for data analyses of weak-lensing surveys, CMB observations and their cross correlations.

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Requirements for data analysis

- theoretical prediction ← perturbation theory, N-body simulation, etc.
- error estimation ← **mock catalogs**

Likelihood chi-squared analysis

observable　　theoretical prediction

$$\chi^2(\vec{p}) = \sum_{\mathrm{i}} \left[\frac{P_{\mathrm{obs}}(x_{\mathrm{i}};\vec{p}) - P_{\mathrm{theory}}(x_{\mathrm{i}};\vec{p})}{\Delta P(x_{\mathrm{i}})} \right]^2$$

standard deviation

$\vec{p}$: fitting parameters

x_{i} : data vector

We need a lot of mock catalogs to estimate variances of observables accurately.

● Summary of our mock catalogs

We ran multiple-lens raytracing through cosmological N-body simulation

Our weak-lensing mock catalogs contain

- convergence & shear maps up to z=5
- lensed CMB temperature & polarization maps
- halo catalog（halo positions, masses, virial radiuses, redshifts, etc.）

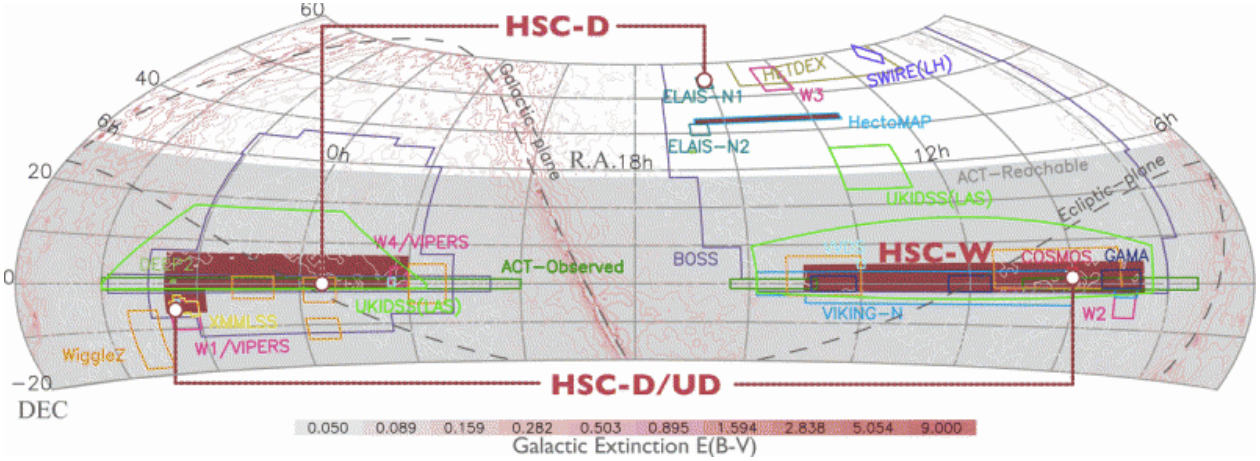
minimum halo mass ~10^13Msun（at z<1）

angular resolution ~0.5 arcmin

108 full-sky maps given in the Healpix pixelization and the FITS format

（Gorski+ 2005）

HSC survey fields



a single full-sky map → ~10-20 HSC survey regions

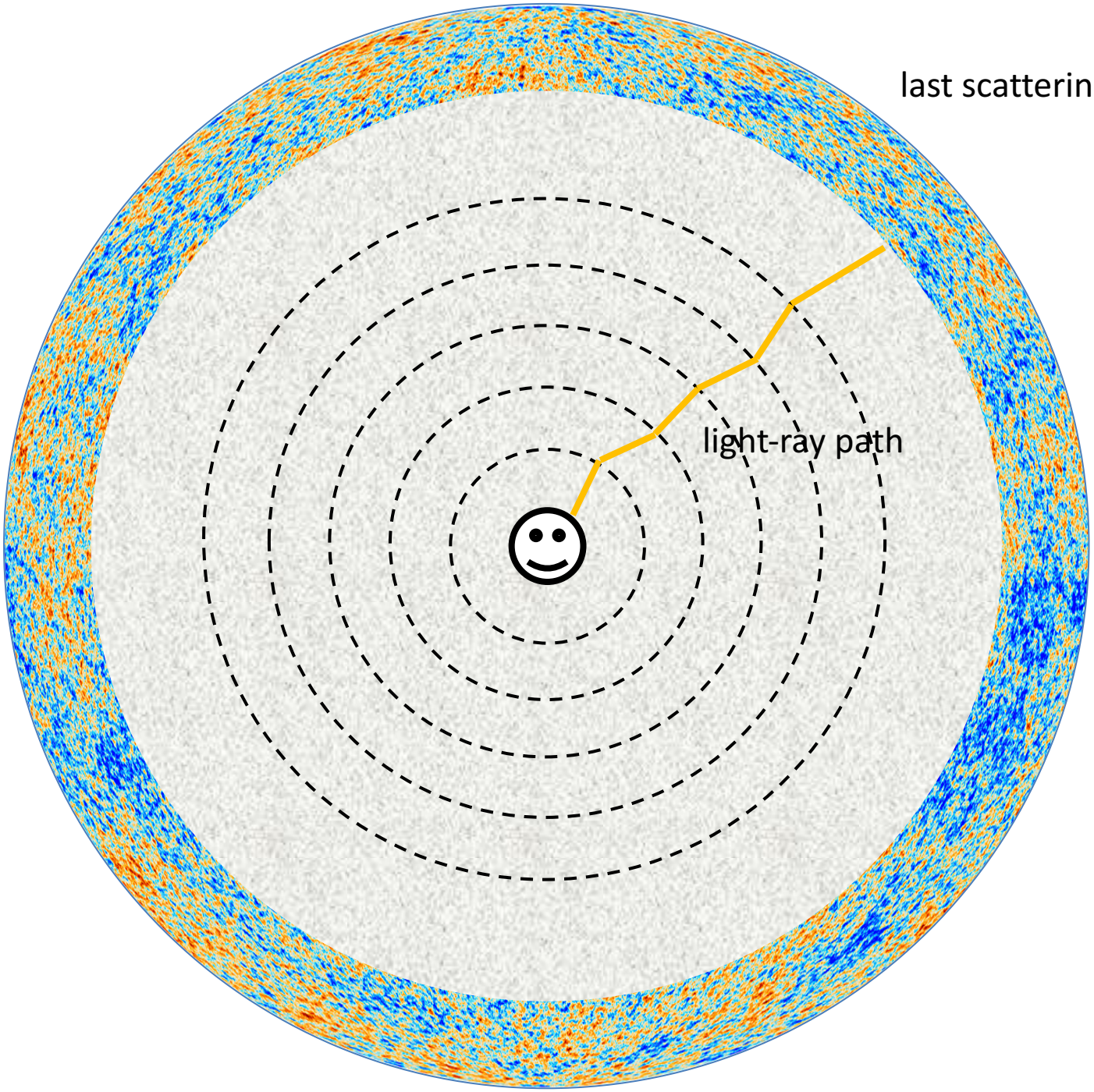
108 full-sky maps → ~1000-2000 HSC survey regions

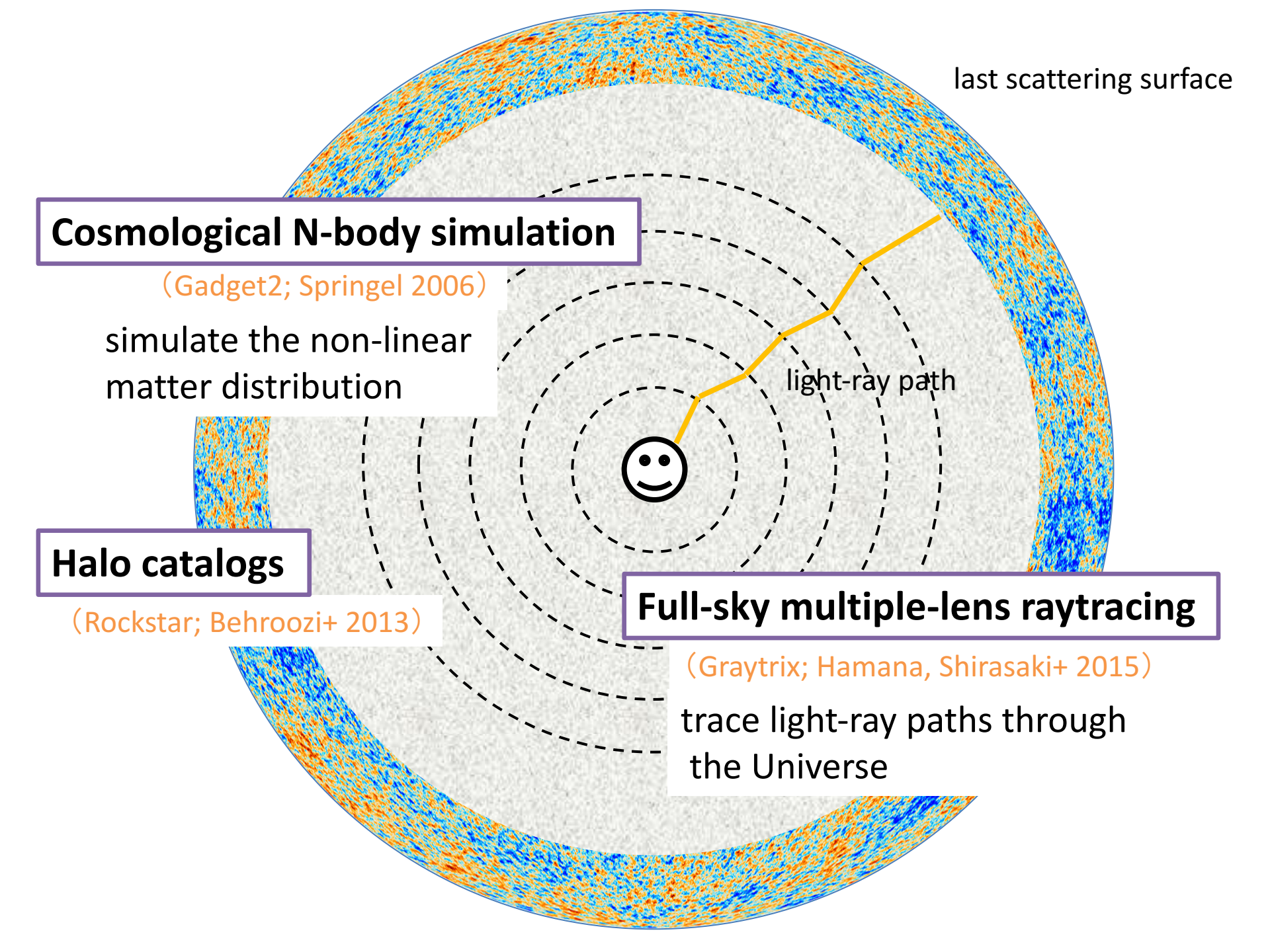
enough to calculate variances of observables accurately

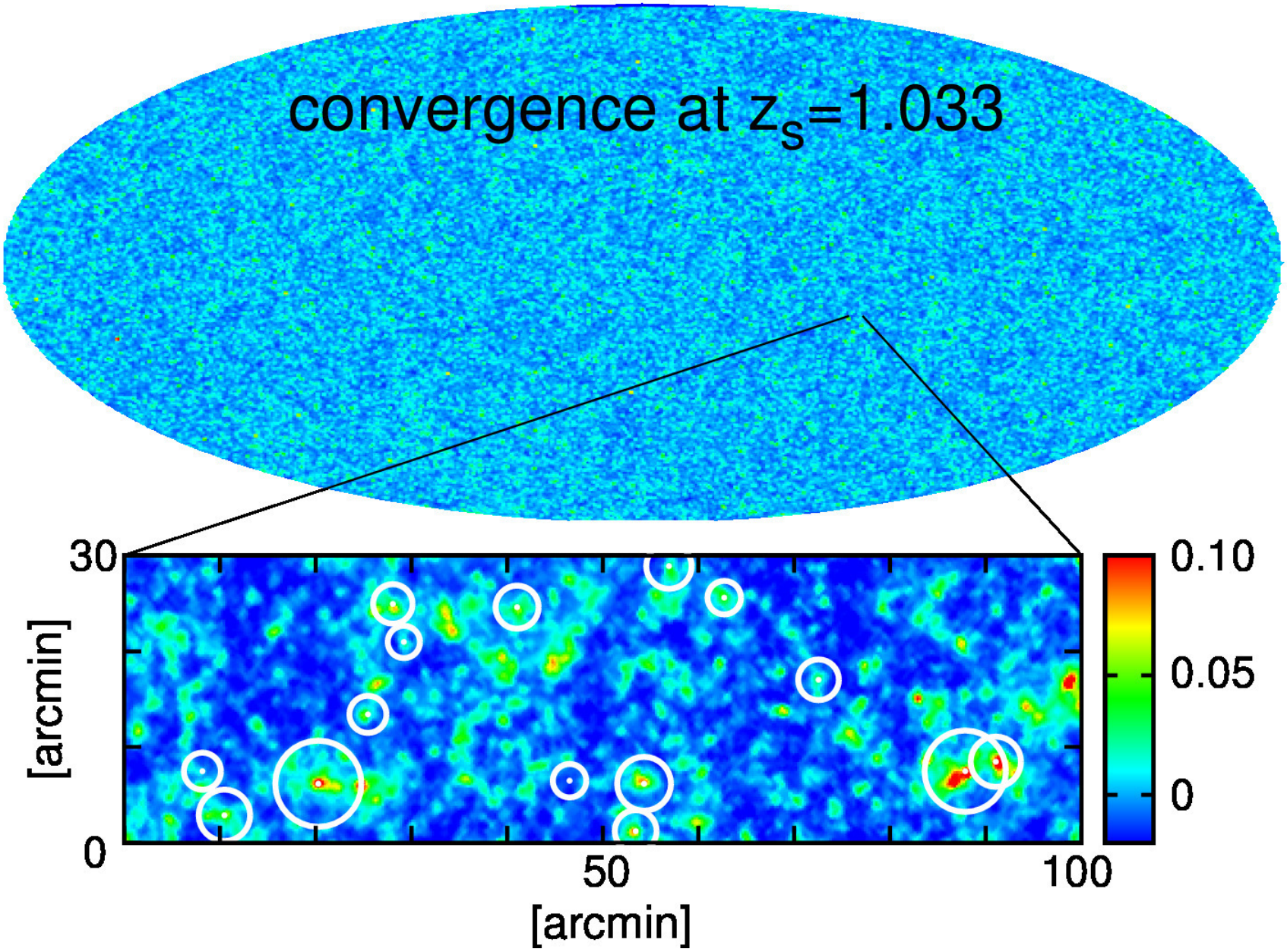
HSC Project 233（Shirasaki et al.）:

Mock catalogs of galaxy shapes and large-scale structure tracers for the first-year HSC cosmological analyses

They are making 1000 mock catalogs now.

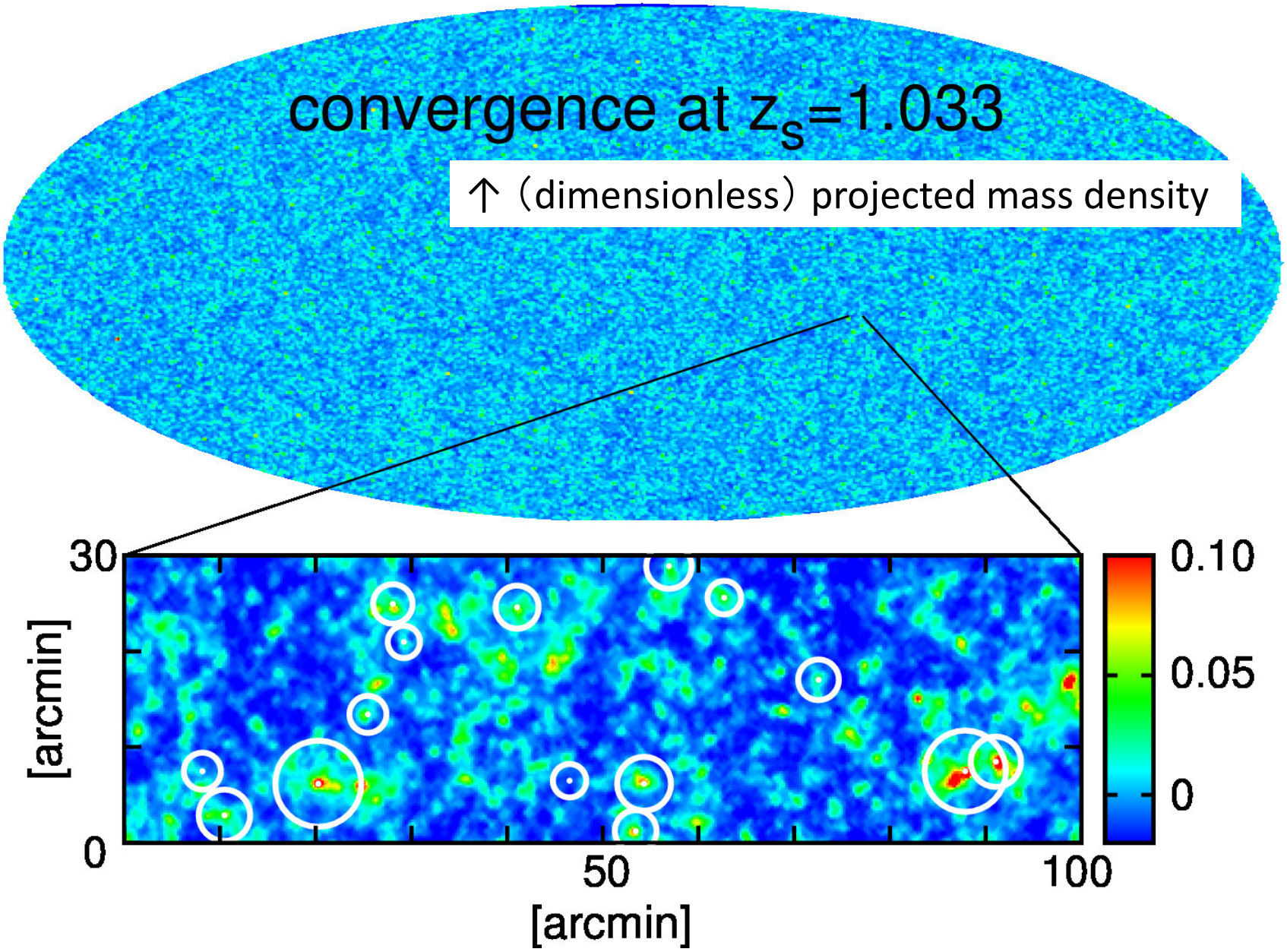

last scattering surface
light-ray path


last scattering surface
Cosmological N-body simulation
(Gadget2; Springel 2006)
simulate the non-linear matter distribution
light-ray path
Halo catalogs
(Rockstar; Behroozi+ 2013)
Full-sky multiple-lens raytracing
(Graytrix; Hamana, Shirasaki+ 2015)
trace light-ray paths through the Universe



white circles : foreground massive halo（M>6e+13Msun） positions

its radius : the halo virial radius



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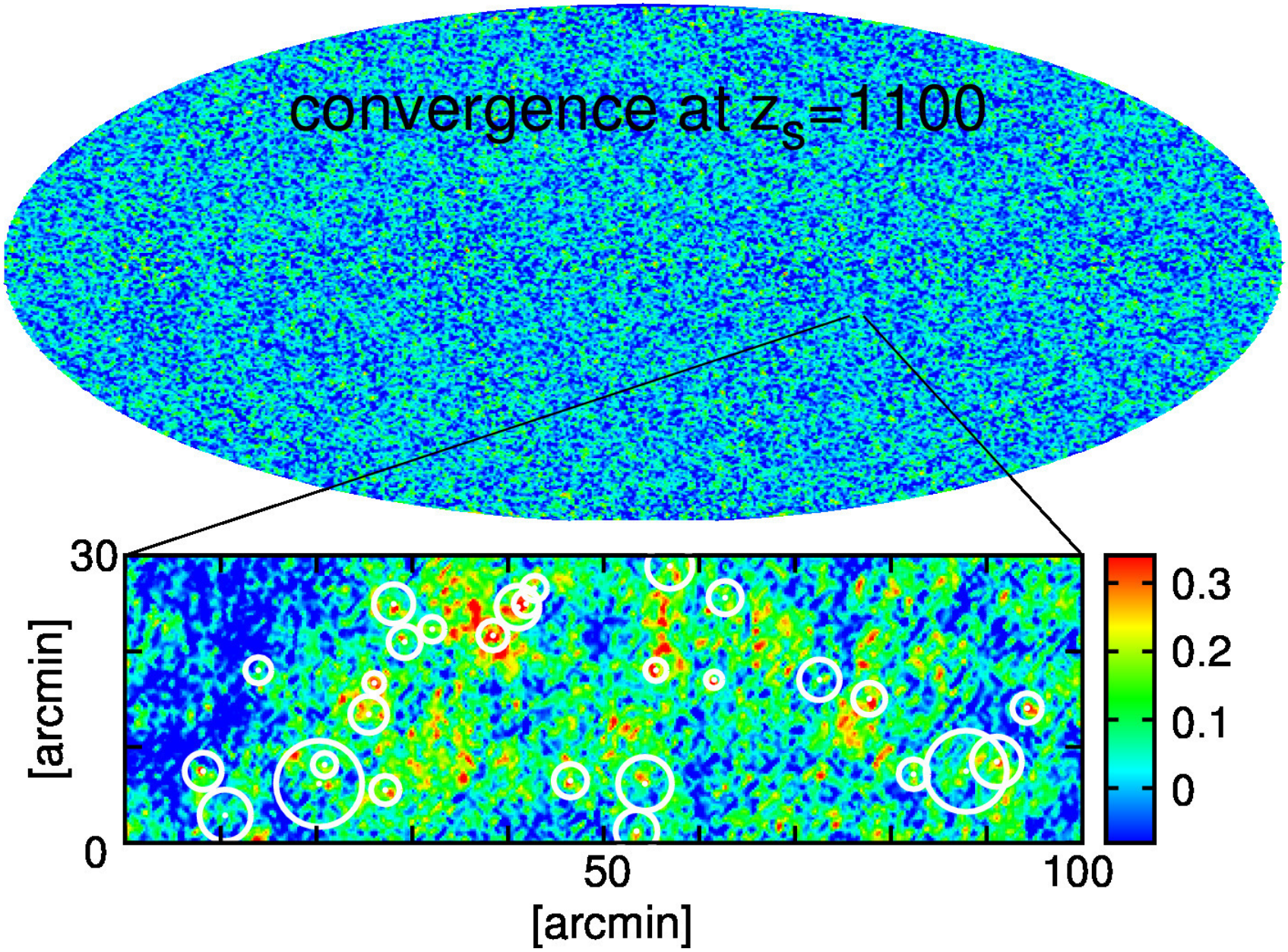

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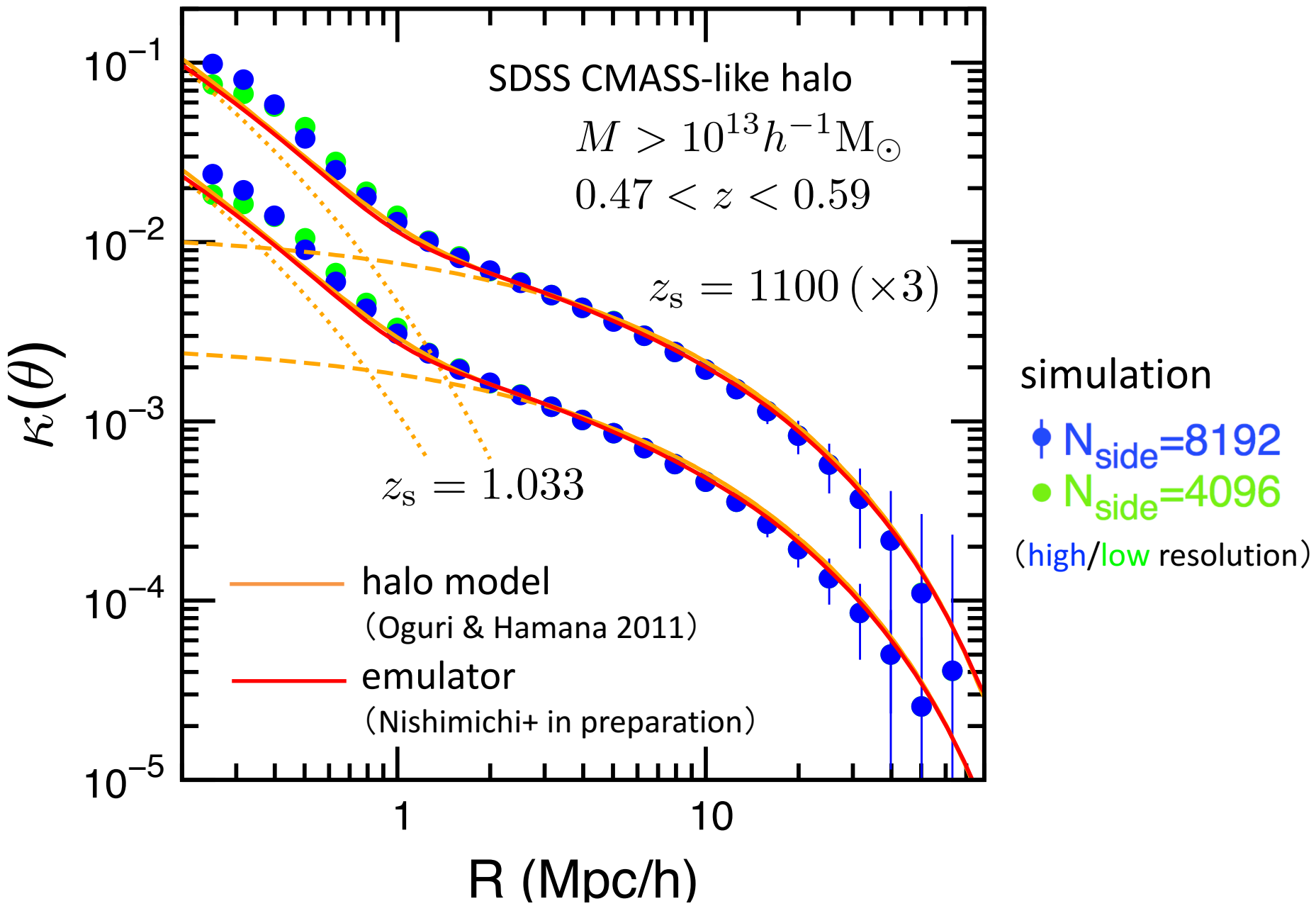
mean convergence profile of halos



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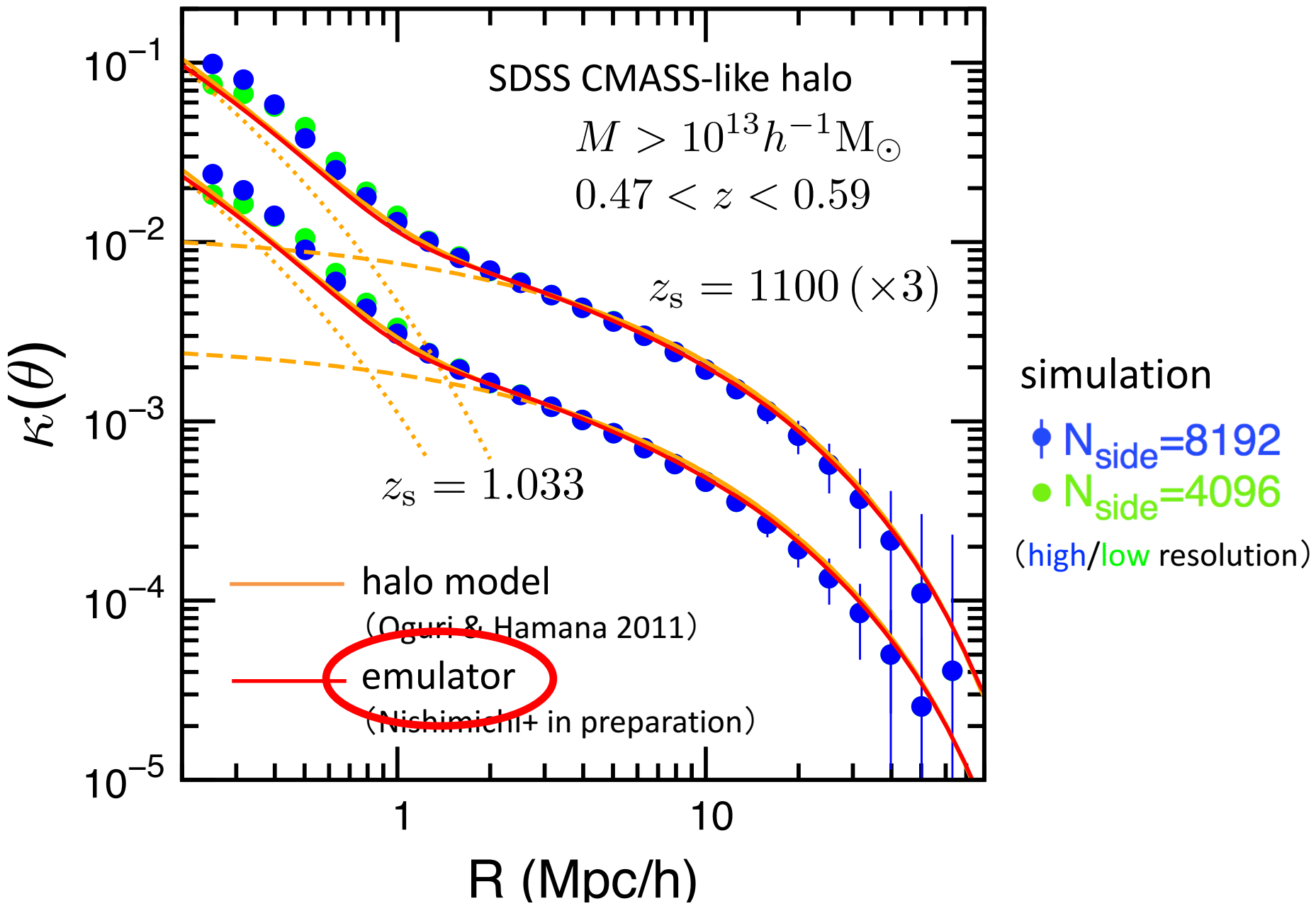


Cosmic Dark Emulator

developed by T. Nishimichi（IPMU）

M. Takada, N. Yoshida, T. Oogi（IPMU）, K. Osato, M. Oguri（U Tokyo）
M. Shirasaki, T. Hamana（NAOJ）, RT（Hirosaki U）

We ran cosmological N-body simulations to follow non-linear gravitational evolution.
The emulator code is calibrated with the simulations for 100 cosmological models.
It will be publicly available soon（Nishimichi+ in preparation）.

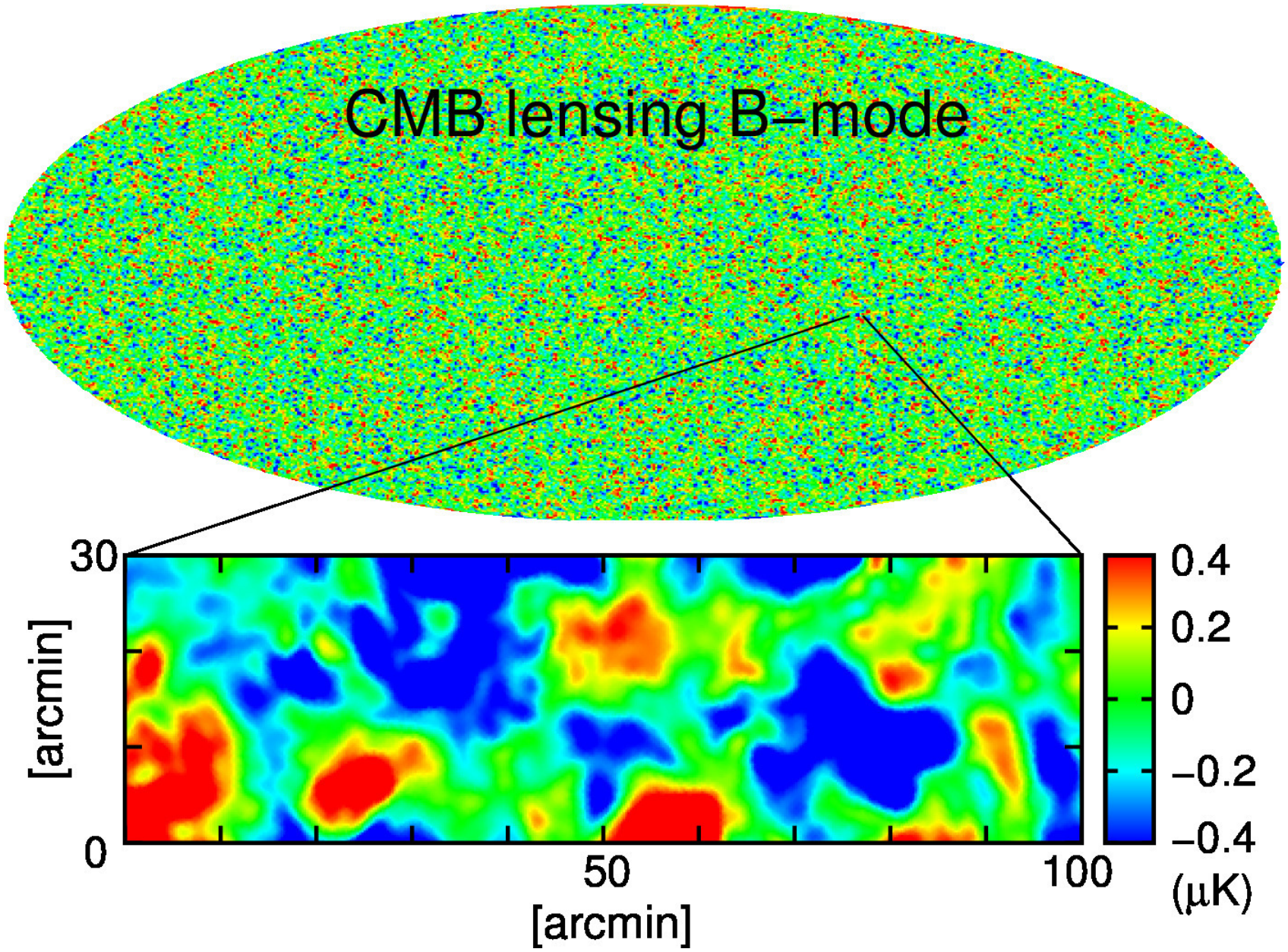
Emulator

input parameters

cosmological parameters
$(\Omega_{\rm b}, \Omega_{\rm cdm}, \Omega_\Lambda, h, A_{\rm s}, n_{\rm s})$
redshift
halo mass
etc.

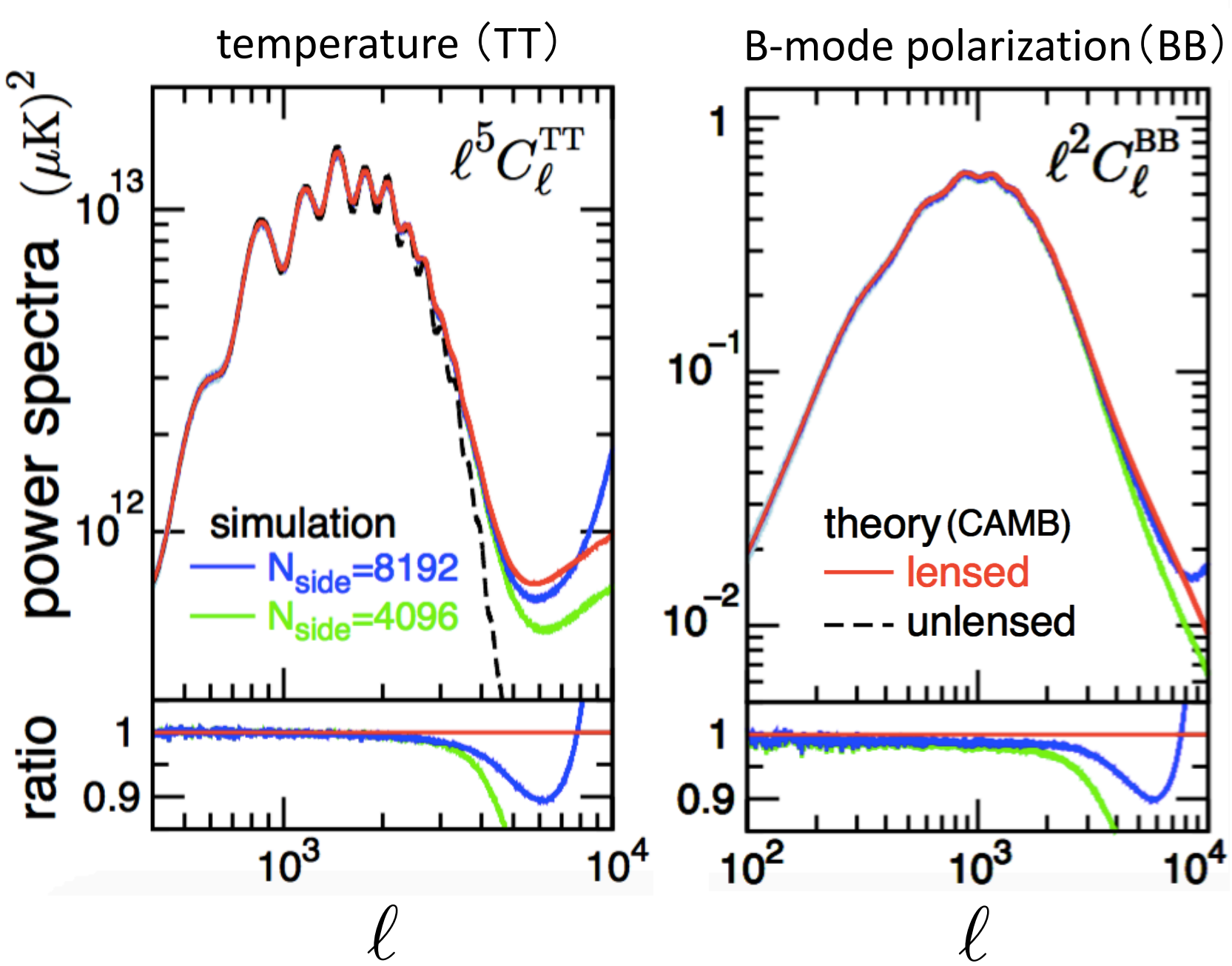
outputs（observables）

convergence/tangential shear profile of halos
halo mass function
halo power spectrum in real/redshift space



primordial B-mode is zero

Power spectra of lensed CMB



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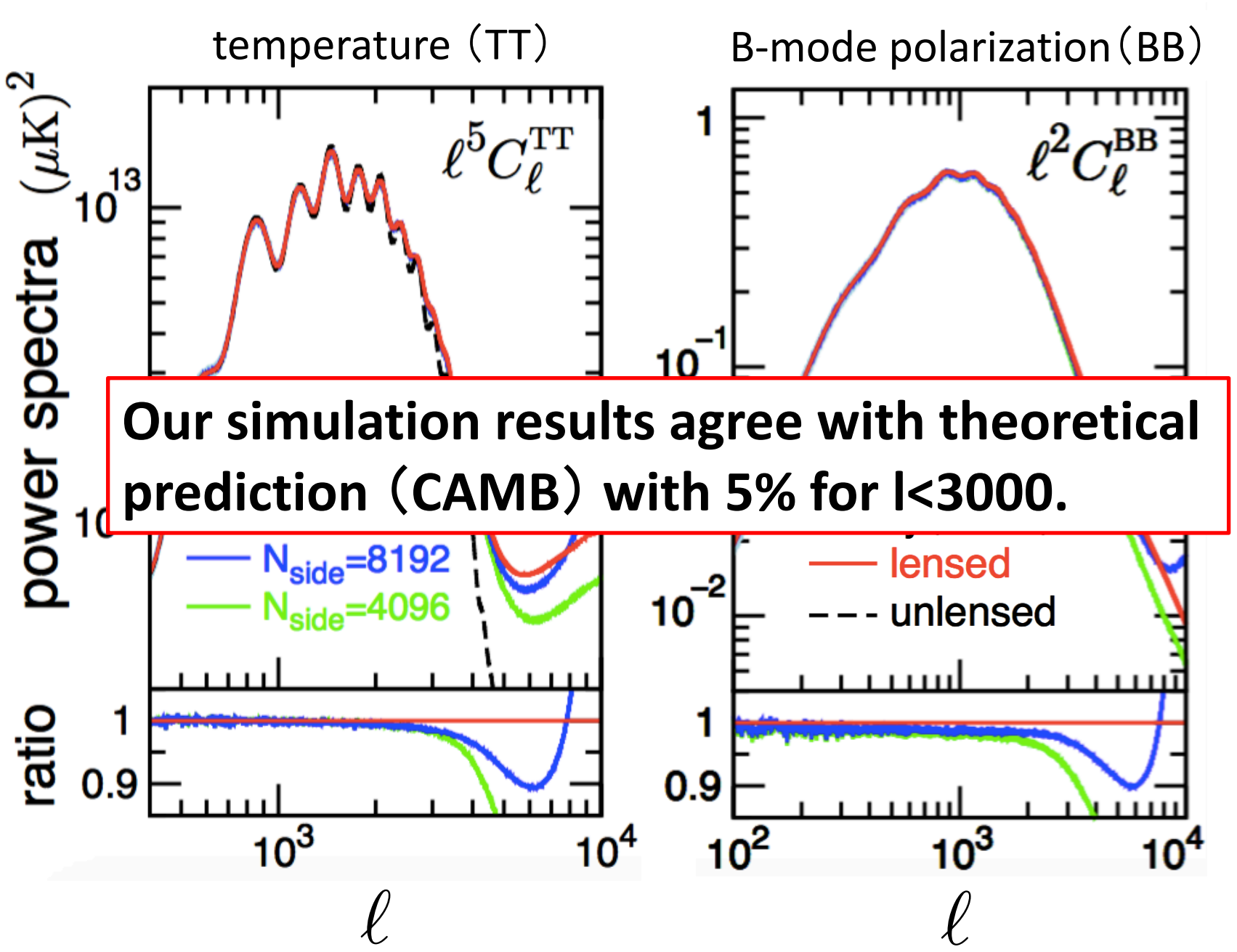
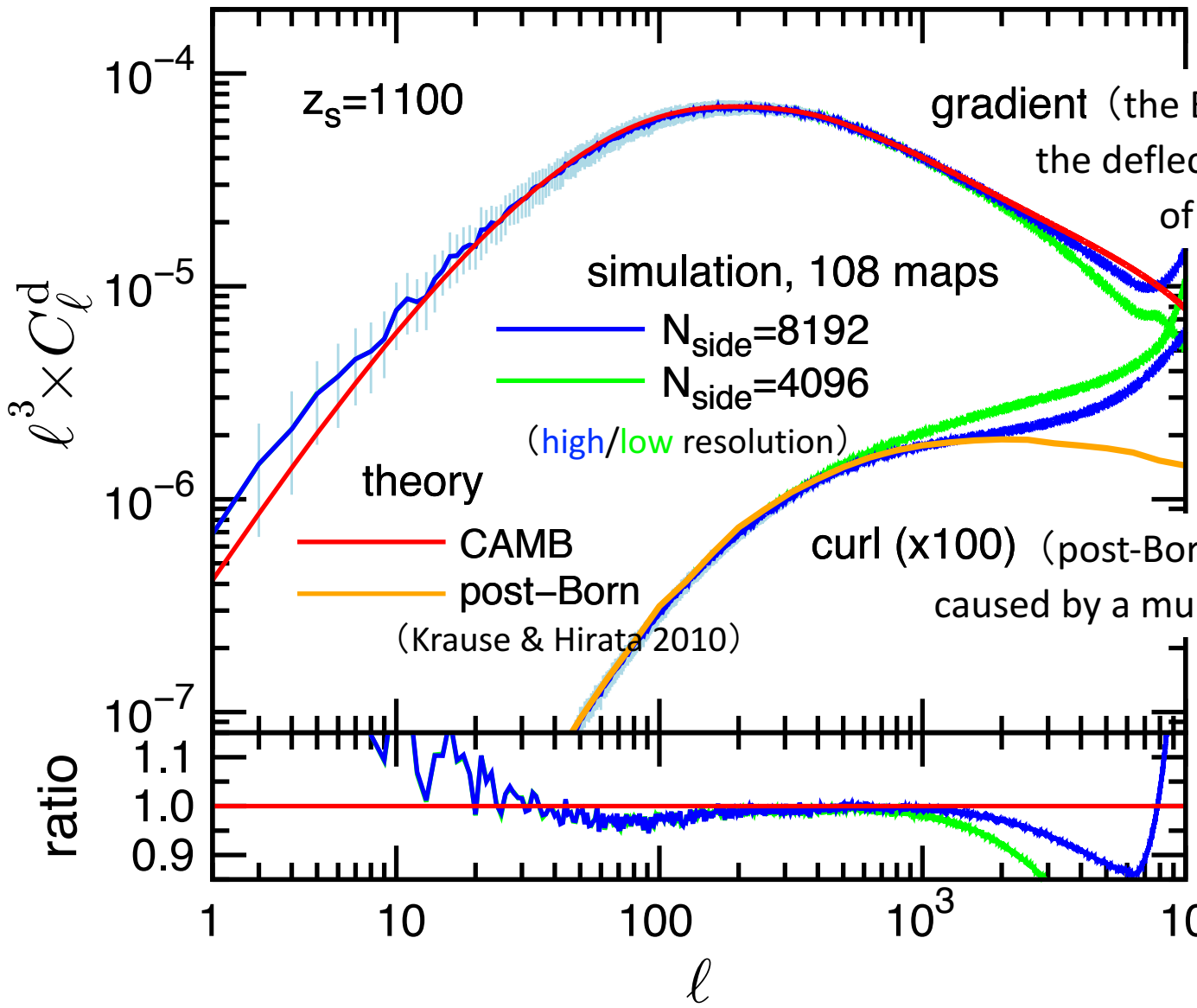


Our simulation results agree with theoretical prediction（CAMB）with 5% for l<3000.

Angular power spectrum of deflection angle

Our simulation includes the post-Born corrections to CMB lensing.



Related works using our mock

- **Shirasaki+（2016），arXiv:1607.08679, submitted to MNRAS**

  estimated an accurate covariance matrix of galaxy-galaxy lensing
  for SDSS LRG, CMASS, and redMaPPer cluster samples
  and then compared it to the jack-knife covariance

- **Murata+ in preparation**

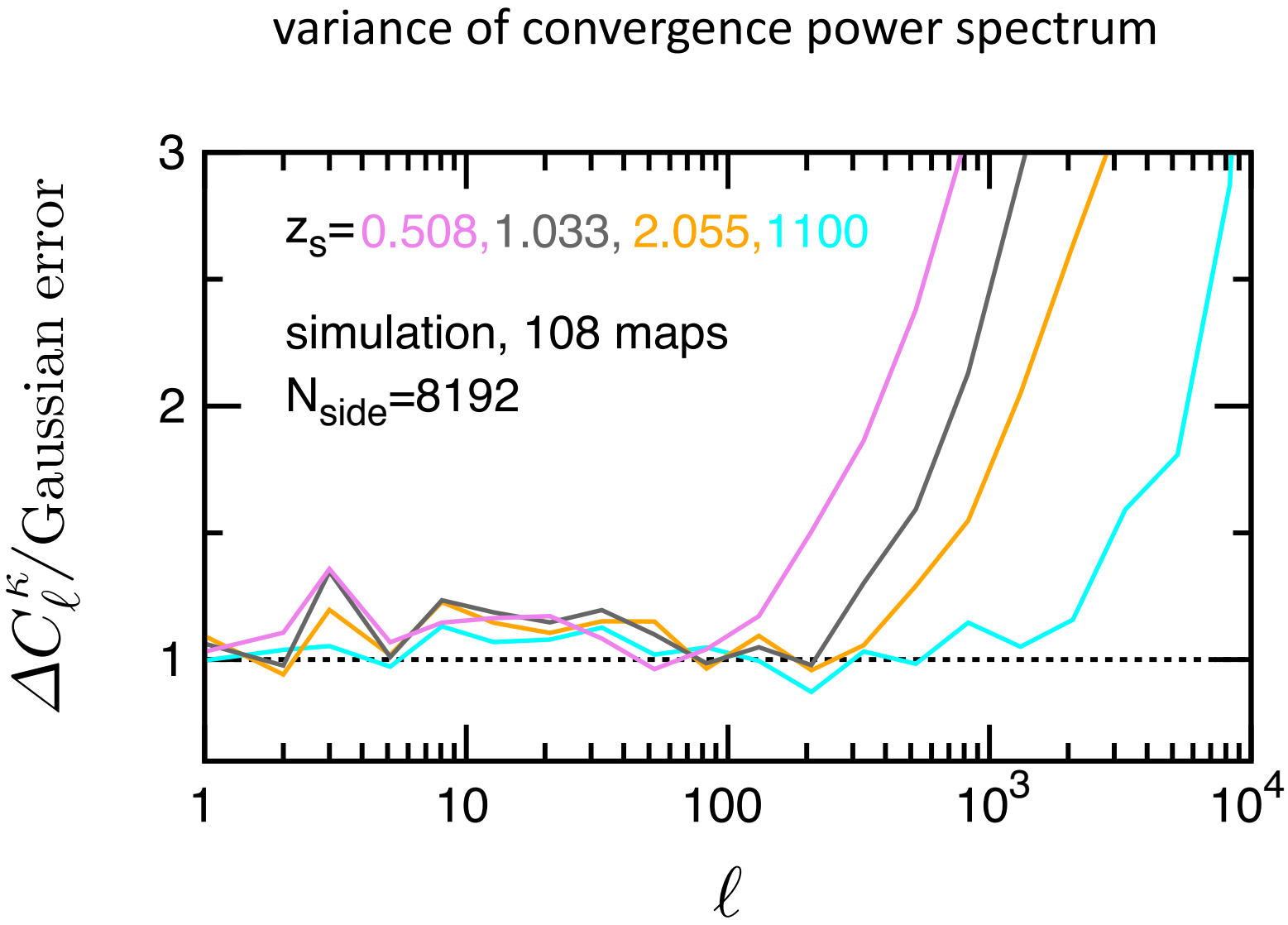
  measure a covariance matrix of the tangential shear profile of the
  redMaPPer clusters and give a constraint on the mass-richness relation
  using SDSS data

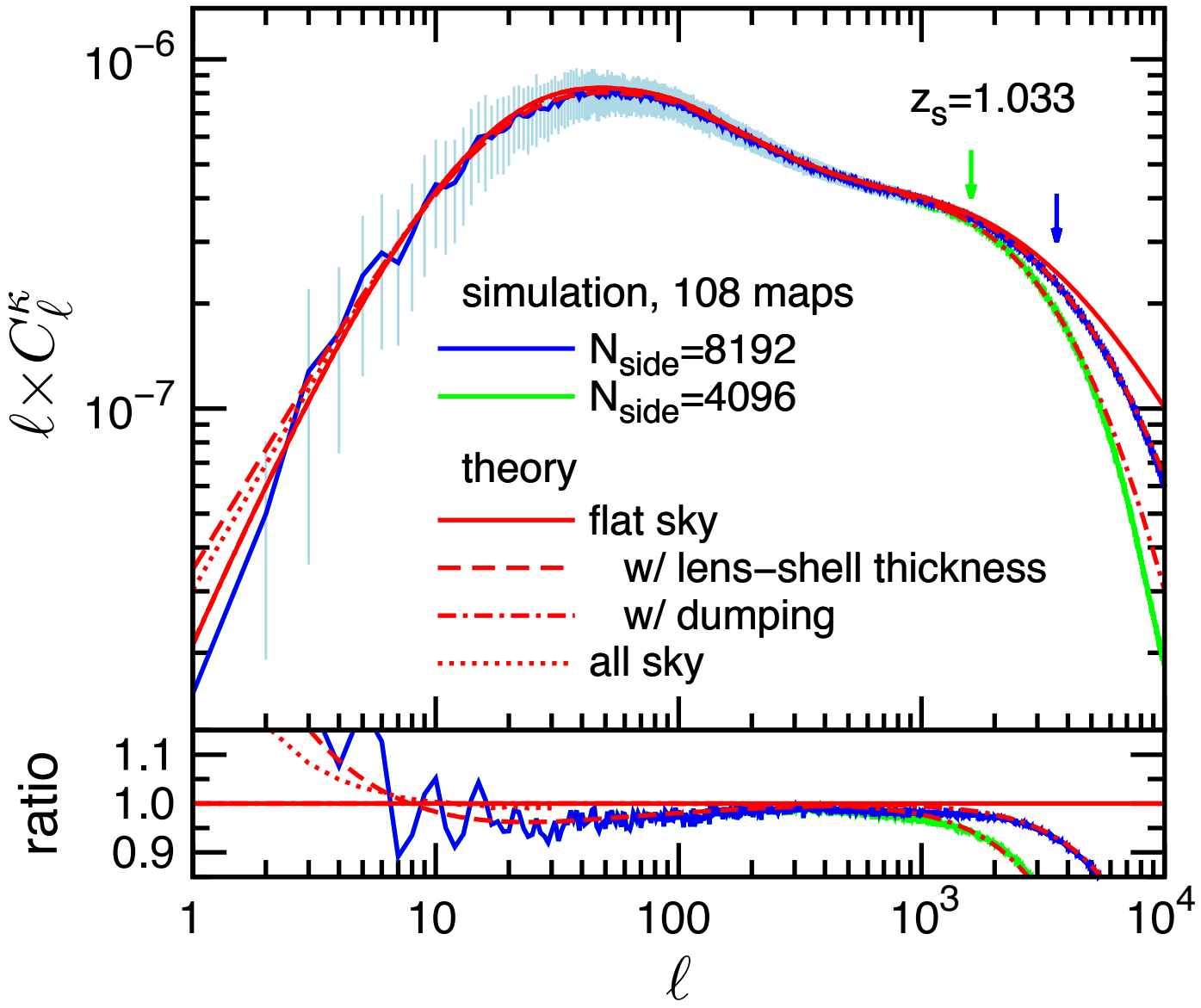
- **Namikawa, Chinone, Oguri, Kusaka, … in progress**

  mock catalog for a cross correlation analysis between POLARBEAR and HSC

Summary

- We prepared 108 full-sky weak lensing maps for galaxy imaging surveys and CMB observations.
- Our catalog will be publicly available soon.
  The maps are based on the Healpix pixelization and given in the FITS format.
- Angular power spectra of cosmic shear and lensed CMB agree with theoretical predictions within 5% up to $l<3000$ (or angular resolution > 0.5arcmin).
- The source planes are dumped at every 150Mpc/h（corresponding to $\Delta z=0.05$）, therefore you can make a realistic shear map for an arbitrary source distribution.
- Our lensed CMB maps include the post-Born corrections.
- Our mock catalog would be quite useful to estimate variances of observables for WL measurements, CMB observations and their cross correlations.


variance of convergence power spectrum
ΔC_ℓ^κ/Gaussian error
z_s= 0.508, 1.033, 2.055, 1100
simulation, 108 maps
N_{side}=8192
3
2
1
1
10
100
10^3
10^4
ℓ


10^{-6}
10^{-7}
$\ell \times C_\ell^\kappa$
z_s=1.033
simulation, 108 maps
N_{side}=8192
N_{side}=4096
theory
flat sky
w/ lens–shell thickness
w/ dumping
all sky
ratio
1.1
1.0
0.9
1
10
100
10^3
10^4
ℓ