宇宙大規模構造の物質分布のバイスペクトル

Ryuichi Takahashi（Hirosaki U）

title：N体数値シミュレーションによる
全天重カレンズマップの作成

category B+

	max # of cores	memory
bulk	320	3TB
large	3440	33TB

data storage 100TB in work directory

Full-sky Weak Lensing Mock Catalogs for the Subaru HSC survey

constructed using CfCA XC30 & 50

with Hamana, T. , Shirasaki, M.（NAOJ）, Namikawa, T.（Stanford U）, Nishimichi, T.（IPMU）, Osato, K.（U Tokyo） & Shiroyama, K. （Hirosaki U）

simulation data sets are publicly available
（http://cosmo.phys.hirosaki-u.ac.jp/takahasi/allsky_raytracing）

（RT+ ApJ 2017）

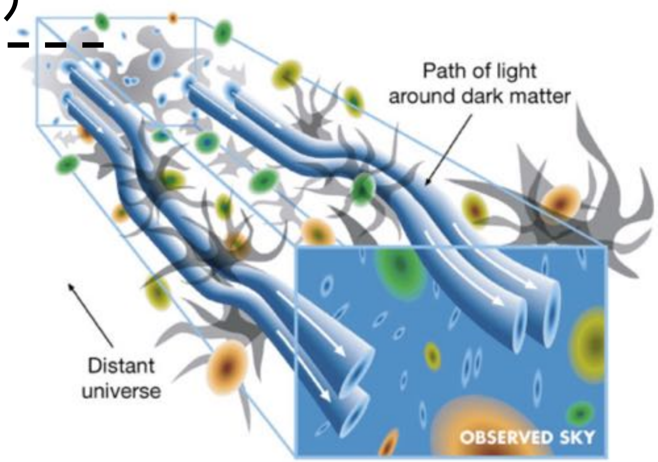
Introduction

・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.

Introduction

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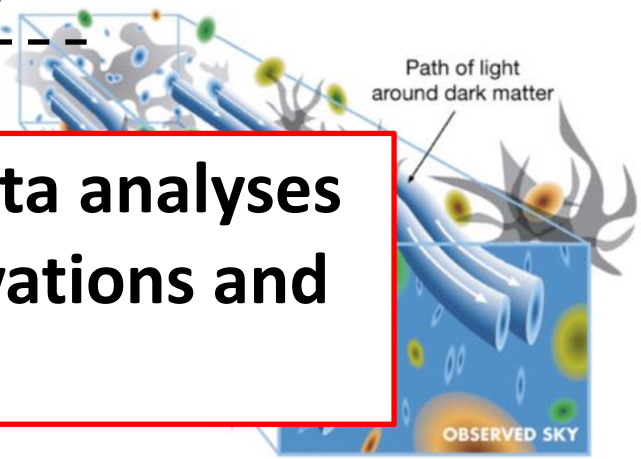
Full-sky mock catalogs needed for data analyses of weak-lensing surveys, CMB observations and their cross correlations.



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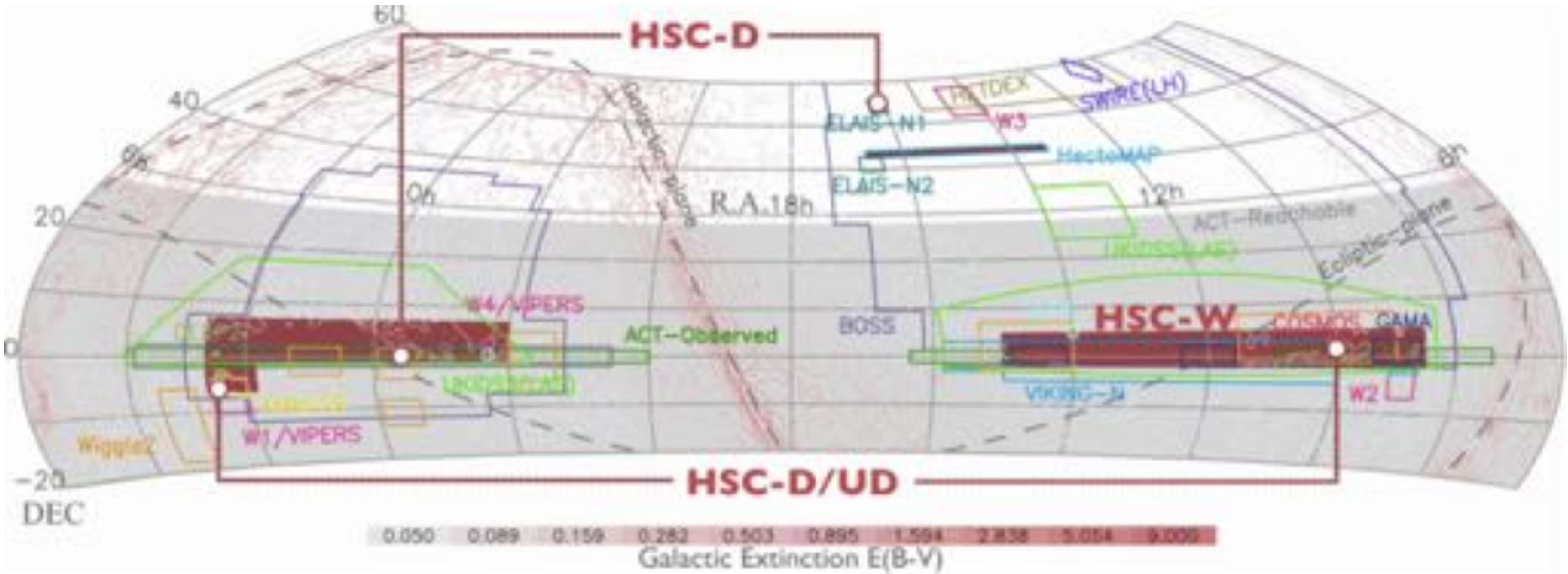
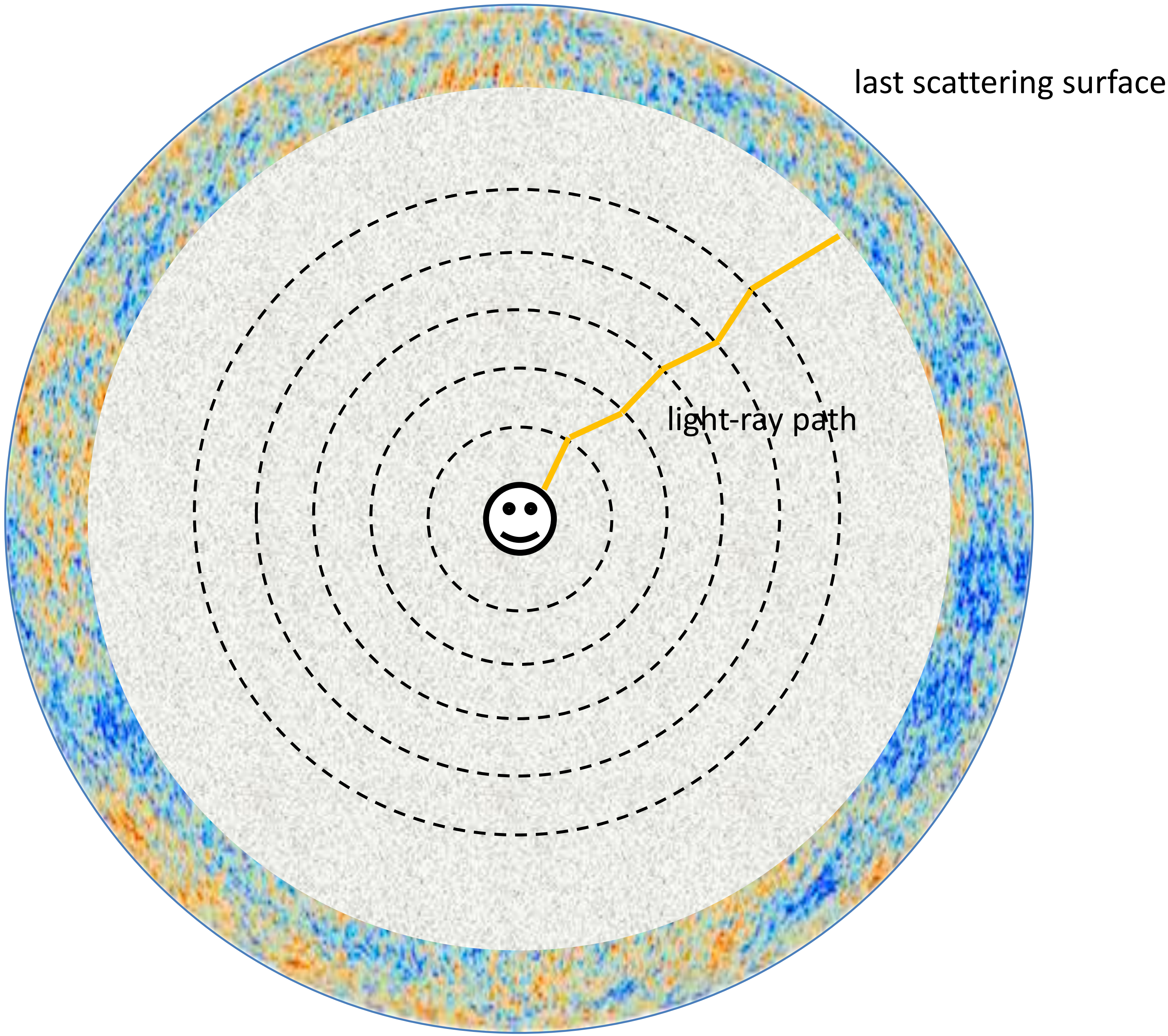
HSC survey fields

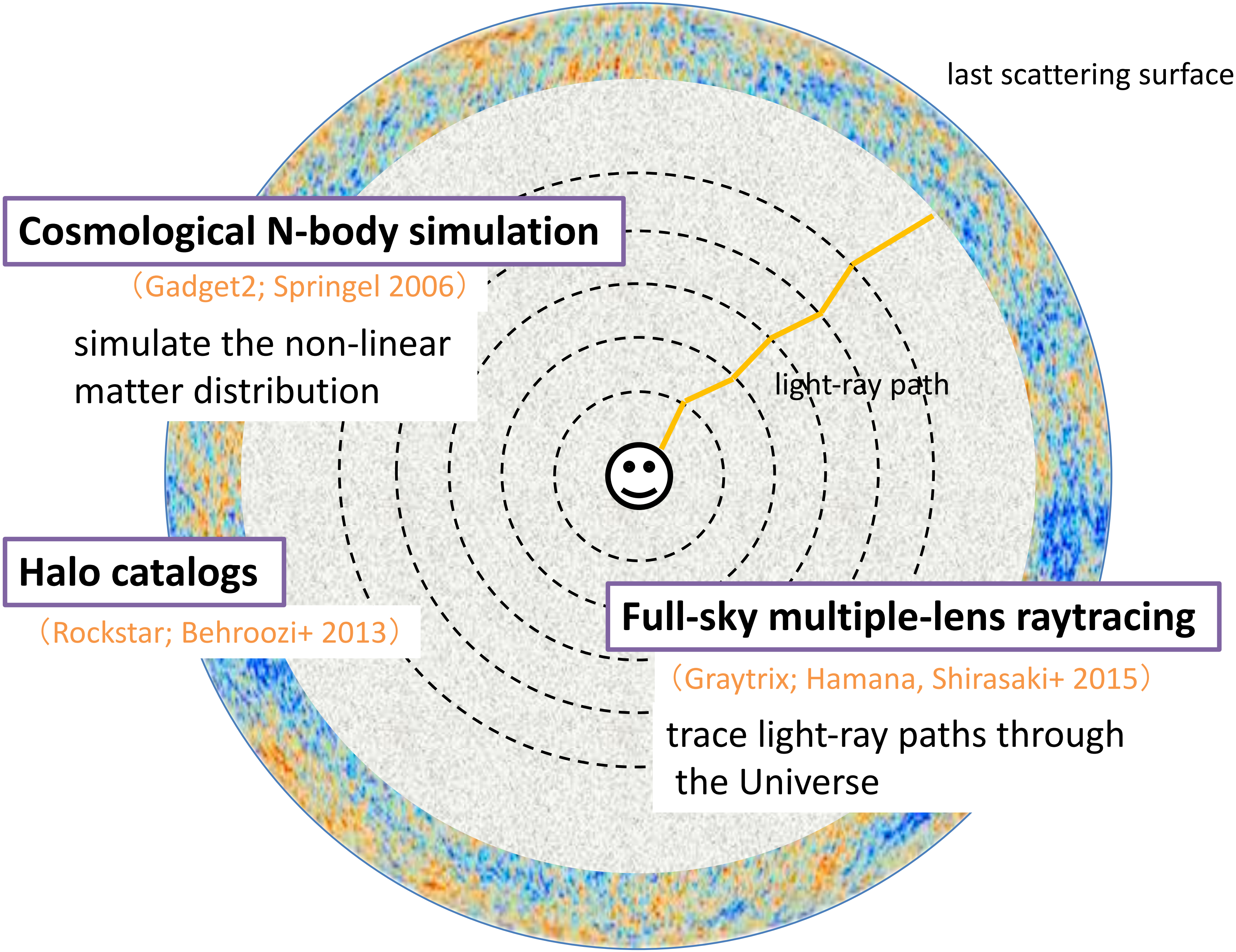


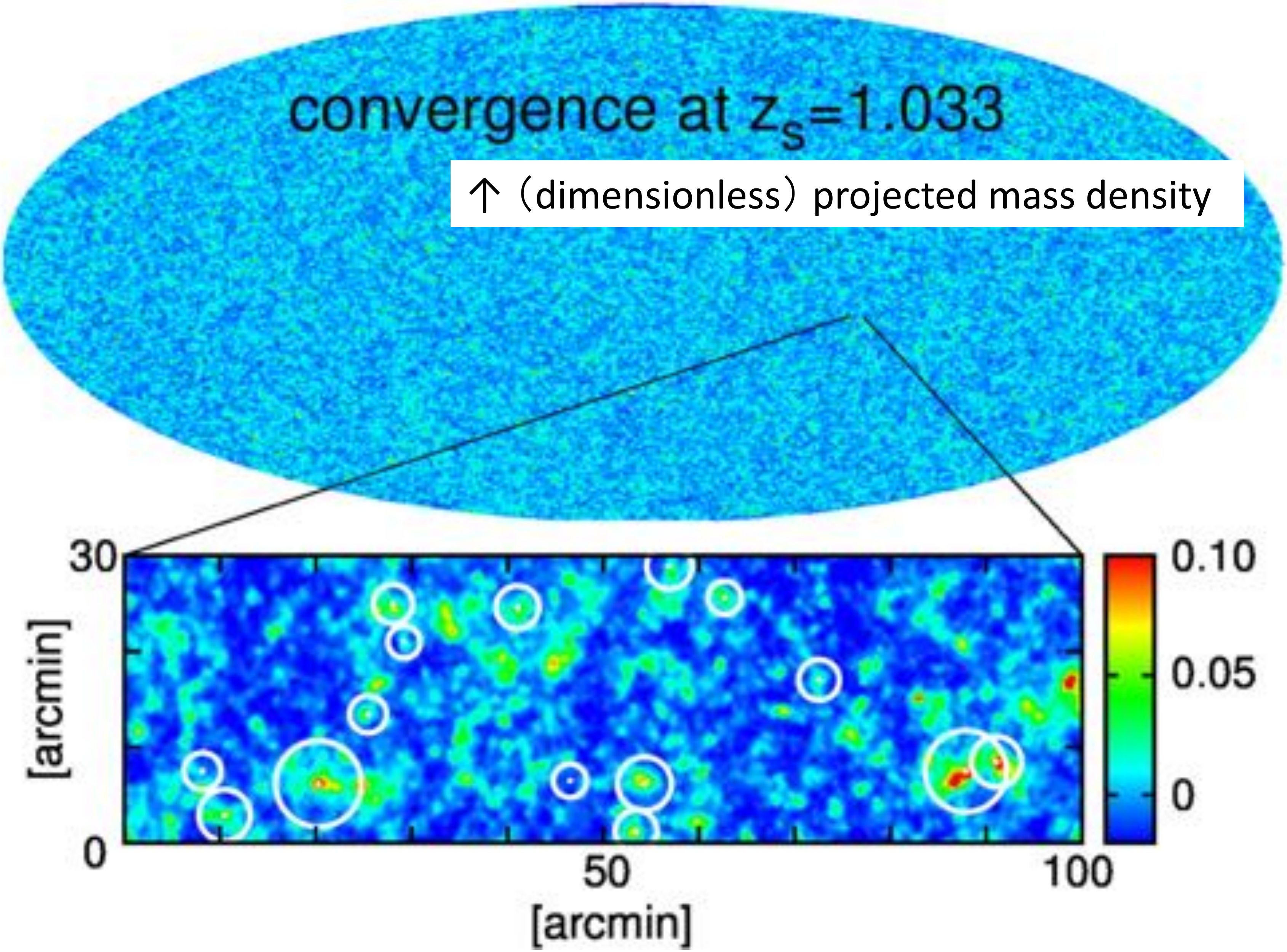
a single full-sky map → ~10-20 HSC survey regions

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

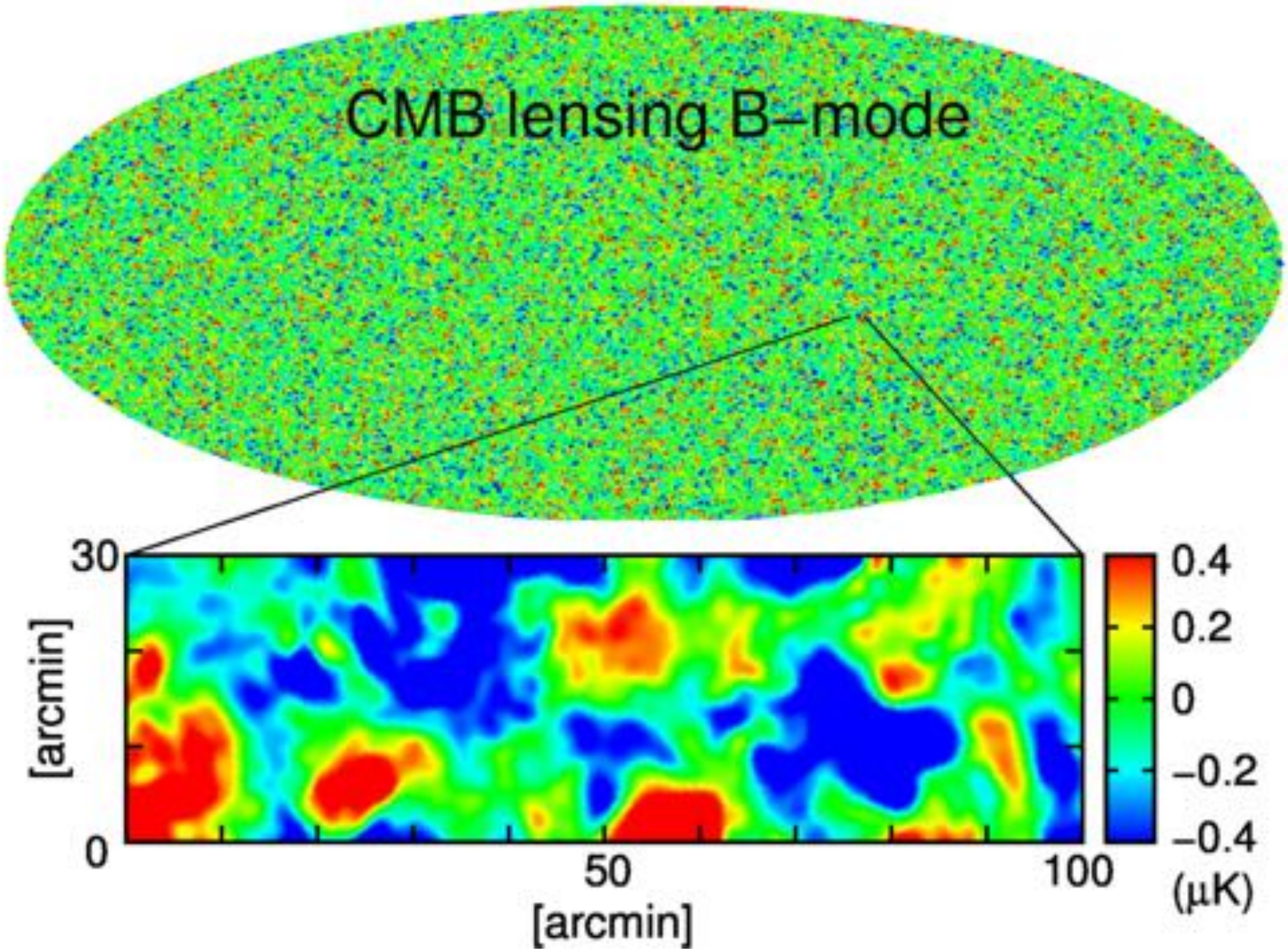
enough to calculate variances of observables accurately


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



primordial B-mode is zero

Covariances for cosmic shear and galaxy-galaxy lensing in the response approach

（RT, Takada, Nishimichi+ 2019, MNRAS）

auto-correlation function of convergence field $\xi_{\kappa\kappa}(\theta)$

cross-correlation function of halo-convergence field $\xi_{\mathrm{h}\kappa}(\theta)$

modeling the covariances accurately

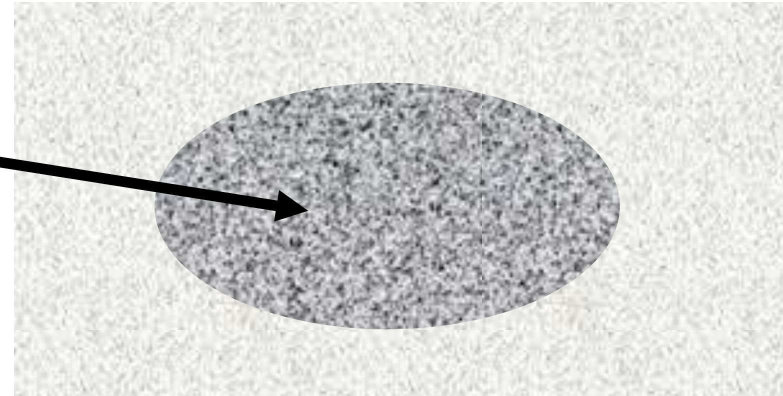
$$\mathrm{Cov}(\theta,\theta') = \langle (\xi(\theta) - \langle \xi(\theta) \rangle)(\xi(\theta') - \langle \xi(\theta') \rangle) \rangle$$

measured the covariances for various survey areas（54, 215, 860 deg^2）
& compared them with theoretical prediction

Super-sample covariance (SSC) (Takada & Hu 2013)

mean density contrast
in a survey region

$$\delta_{\rm b}$$



In a high (low) $\delta_{\rm b}$ region

density fluctuations grows faster (slower) and more (less) halos form

$$\xi(r;\delta_{\rm b}) \simeq \xi(r)\left(1+\frac{\partial\xi(r)}{\partial\delta_{\rm b}}\delta_{\rm b}\right)$$

additional variance

$$(\Delta\xi(r))^2 \simeq \xi(r)^2\left(\frac{\partial\ln\xi(r)}{\partial\delta_{\rm b}}\right)^2\sigma_{\rm b}^2$$

with $\sigma_{\rm b}^2 = \langle|\delta_{\rm b}|^2\rangle$

We study the SSC for projected matter and halo density fields.

・Bispectrum of convergence reconstructed from CMB lensing

（Namikawa, Bose, Bouchet, RT, Taruya 2018, submitted to PRD）

convergence bispectrum reconstructed from CMB lensing

$$B(\ell_1, \ell_2, \ell_3) = \langle \kappa(\vec{\ell}_1)\kappa(\vec{\ell}_2)\kappa(\vec{\ell}_3) \rangle$$

$\vec{\ell}$: multipole

with $\vec{\ell}_1 + \vec{\ell}_2 + \vec{\ell}_3 = 0$

compared to theoretical fitting formulae

・Non-linear effects on CMB delensing

（Namikawa & RT 2019, appear in PRD）

effects of non-Gaussian density fluctuation on CMB lensing reconstruction

Related works using our mock

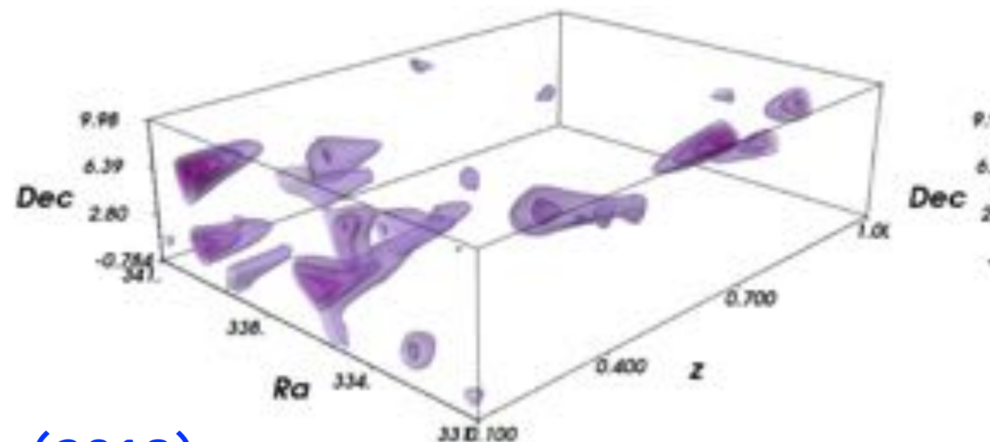
- **Mock shear catalog for Subaru HSC survey**

  dark matter mass distribution probed by weak lensing

  Oguri+ (2018), Miyazaki+ (2018), Mandelbaum+ (2018)

  constraints on mass-richness relation of redMaPPer clusters **Murata+ (2018)**

  cosmic shear **Hikage+ (2018)**



- **Shirasaki+ (2017), Shirasaki & Takada (2018)**

  estimating an accurate covariance matrix of galaxy-galaxy lensing

  constructing ~2000 mock catalogs

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

  a cross correlation between CMB map (POLARBEAR) and shear map (HSC)

Galaxy bispectrum

In 3D galaxy distribution, three-point correlation function (or bispectrum) contains useful additional information to two-point correlation function (or power spectrum)

$$B(k_1, k_2, k_3) \sim \langle \tilde{\delta}(\vec{k}_1)\tilde{\delta}(\vec{k}_2)\tilde{\delta}(\vec{k}_3) \rangle$$

$\tilde{\delta}(\vec{k})$: density fluctuation in Fourier space

with $\vec{k}_1 + \vec{k}_2 + \vec{k}_3 = 0$

bispectrum is exactly zero for Gaussian fluctuation, so it is sensitive to non-Gaussianity

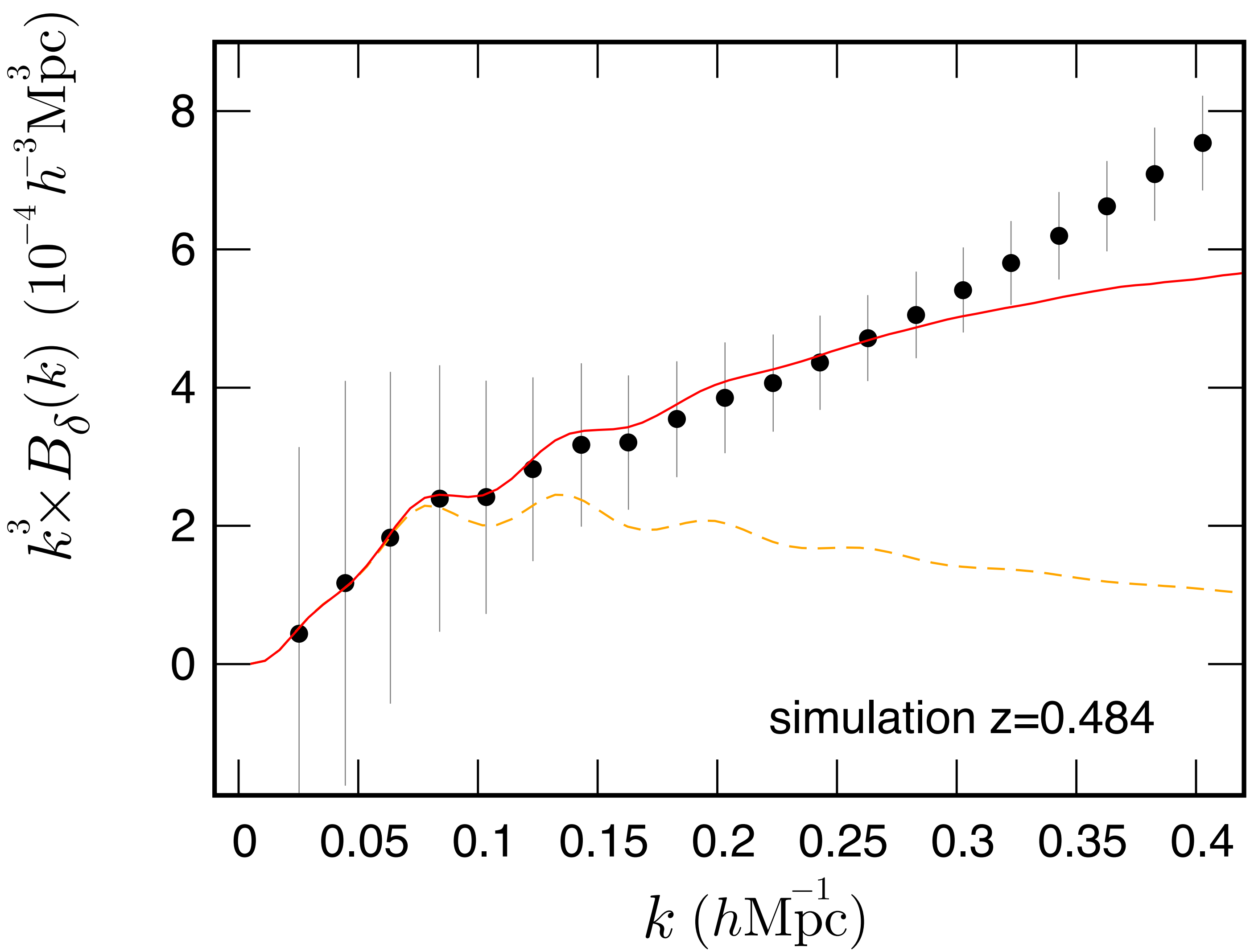
purpose of this study

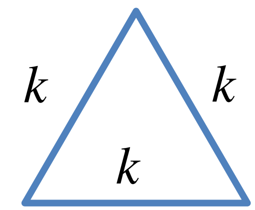
run a lot of N-body simulations (4000 realizations) to measure $B(k_1,k_2,k_3)$ covariance & compare it to theoretical predictions

with Taruya, Hashimoto (Kyoto U), Sugiyama, Takada (IPMU)

matter bispectrum in real space

mean of 4000 realizations





equilateral triangle

perturbation theory

one loop

(Taruya-san)

(Hashimoto+ 2017)

tree level

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)

(Nishimichi+ 2018, submitted to ApJ)

We ran cosmological N-body simulations to follow non-linear gravitational evolution.

The emulator code is calibrated with the simulations for 100 cosmological models.

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