宇宙論パラメータ推定への重力レンズバイスペクトルの影響

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DES, HSC, LSST, Euclid,...

- DES(Dark Energy Survey) 2012-
  - 4m, FOV 2.2deg^2, Ωs=5000 deg^2, ng=10 arcmin^-2, 4 filters
- HSC(Hyper Suprime-Cam) 2013-
  - 8.2m,FOV 1.5deg^2, , Ωs=1500 deg^2,ng=30 arcmin^-2, 5filters
- LSST(Large Synoptic Survey Telescope) 2020-
  - 8.4 m, FOV 9.6 deg^2, Ωs=20000 deg^2,ng=50 arcmin^-2, 6filters
- Euclid 20??-
  - 1.2m,FOV 0.7deg^2, Ωs=15000 deg^2,ng=30 arcmin^-2, 4>filters

We expect a statistical error is reduced compared to past and ongoing surveys.

Why weak lensing?

- It can construct mass maps without using tracers(e.g., galaxies), i.e., no bias
- It is the best way to constrain dark energy(have potential) (Albrecht et al.2006, Joudaki et al.2009)

BAO

Cluster

Super novae

Weak Lensing

MODEL	$[\sigma(w_a)\times\sigma(w_p)]^{-1}$
Stage II (CL-II+SN-II+WL-II)	53.82
BAO-IIIp-o	1.06
BAO-IIIp-p	0.55
BAO-IIIs-o	8.04
BAO-IIIs-p	6.97
BAO-IVLST-o	7.78
BAO-IVLST-p	4.58
BAO-IVSKA-o	55.15
BAO-IVSKA-p	21.53
BAO-IVS-o	42.19
BAO-IVS-p	19.84
CL-II	1.76
CL-IIIp-o	35.21
CL-IIIp-p	6.11
CL-IVS-o	38.72
CL-IVS-p	6.23
SN-II	7.68
SN-IIIp-o	13.91
SN-IIIp-p	6.31
SN-IIIs	12.39
SN-IVLST-o	22.19
SN-IVLST-p	7.93
SN-IVS-o	27.01
SN-IVS-p	19.10
WL-II	4.89
WL-IIIp-o	42.96
WL-IIIp-p	19.55
WL-IVLST-o	453.60
WL-IVLST-p	32.04
WL-IVSKA-o	645.76
WL-IVSKA-p	39.84
WL-IVS-o	310.10
WL-IVS-p	131.72

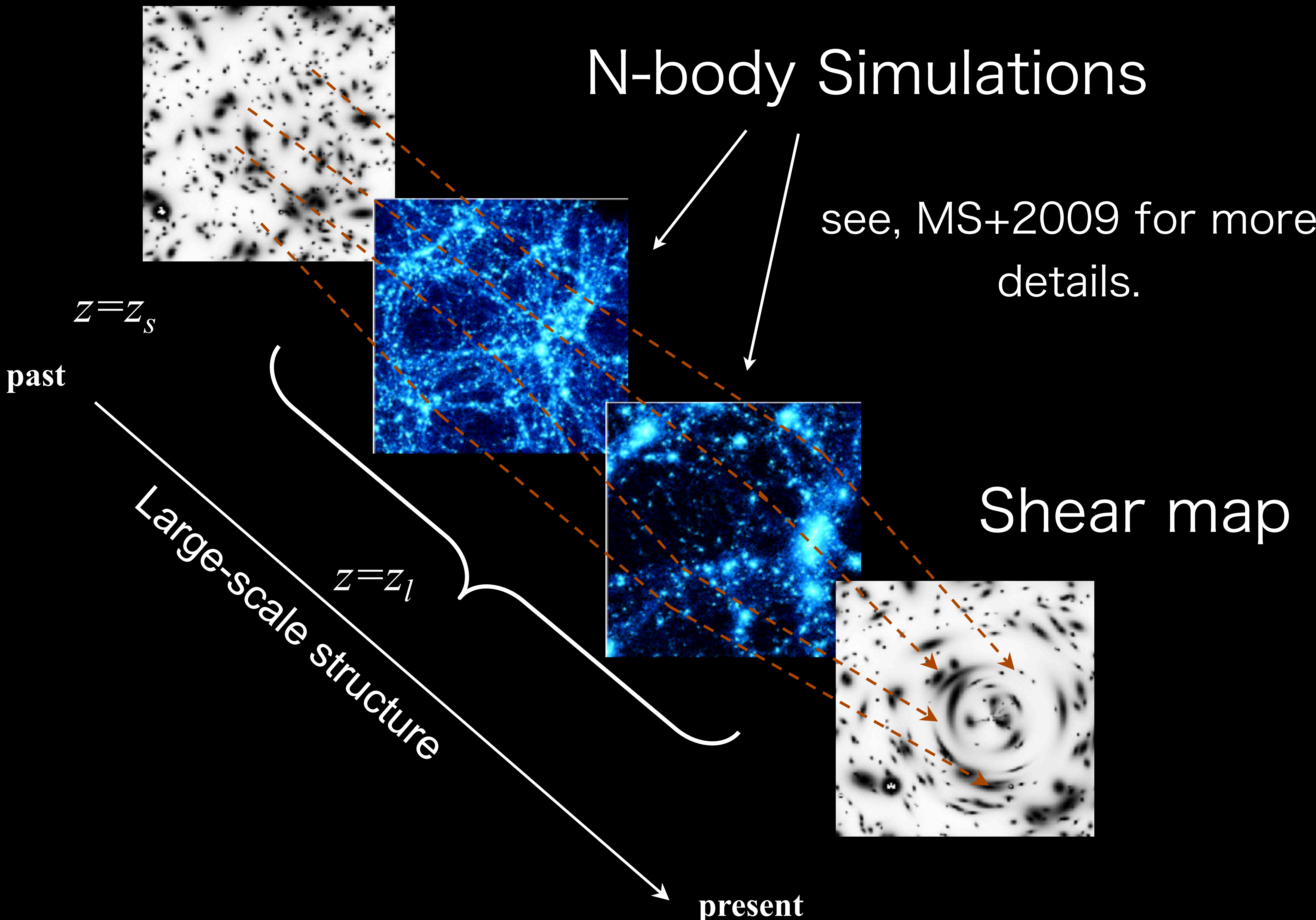
Motivation

- Unlike the CMB, the distribution of matter in the universe which determines the convergence field is highly non-Gaussian, reflecting the nonlinear processes that accompanied structure formation.
- Much of the cosmic information contained in the initial field is therefore unavailable to the standard power spectrum measurements.
- If we want to obtain full information, we have to go higher-order correlation such as bispectrum, so we will examine the impact of bispectrum on cosmological parameter estimation taking non-Gaussian covariance matrices into account.

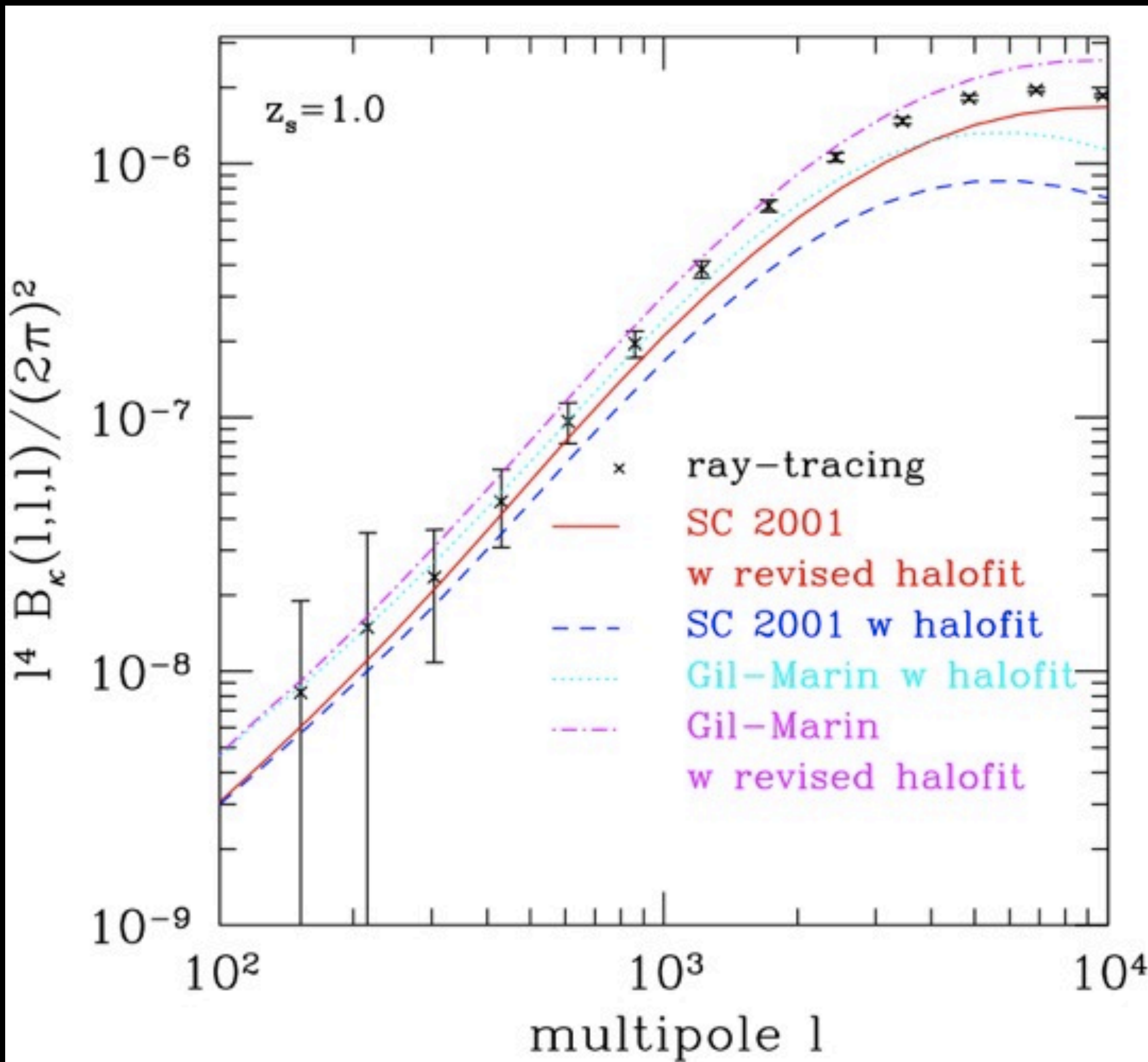
Method

- MCMC method is not important for weak lensing prediction, because likelihood function is close to Gaussian (Wolz+ 2012).
- Therefore, we use the Fisher matrix method to predict how future surveys are powerful.
- For the covariance matrix, we use non-Gaussian covariance matrix estimated from ray-tracing simulations to include nonlinear effects.
- We use 1000 shear field performed by Seo et al. 2012 at zs=0.6,1.0,1.5 to construct tomography surveys.

Method: Basic concept of ray-tracing simulations



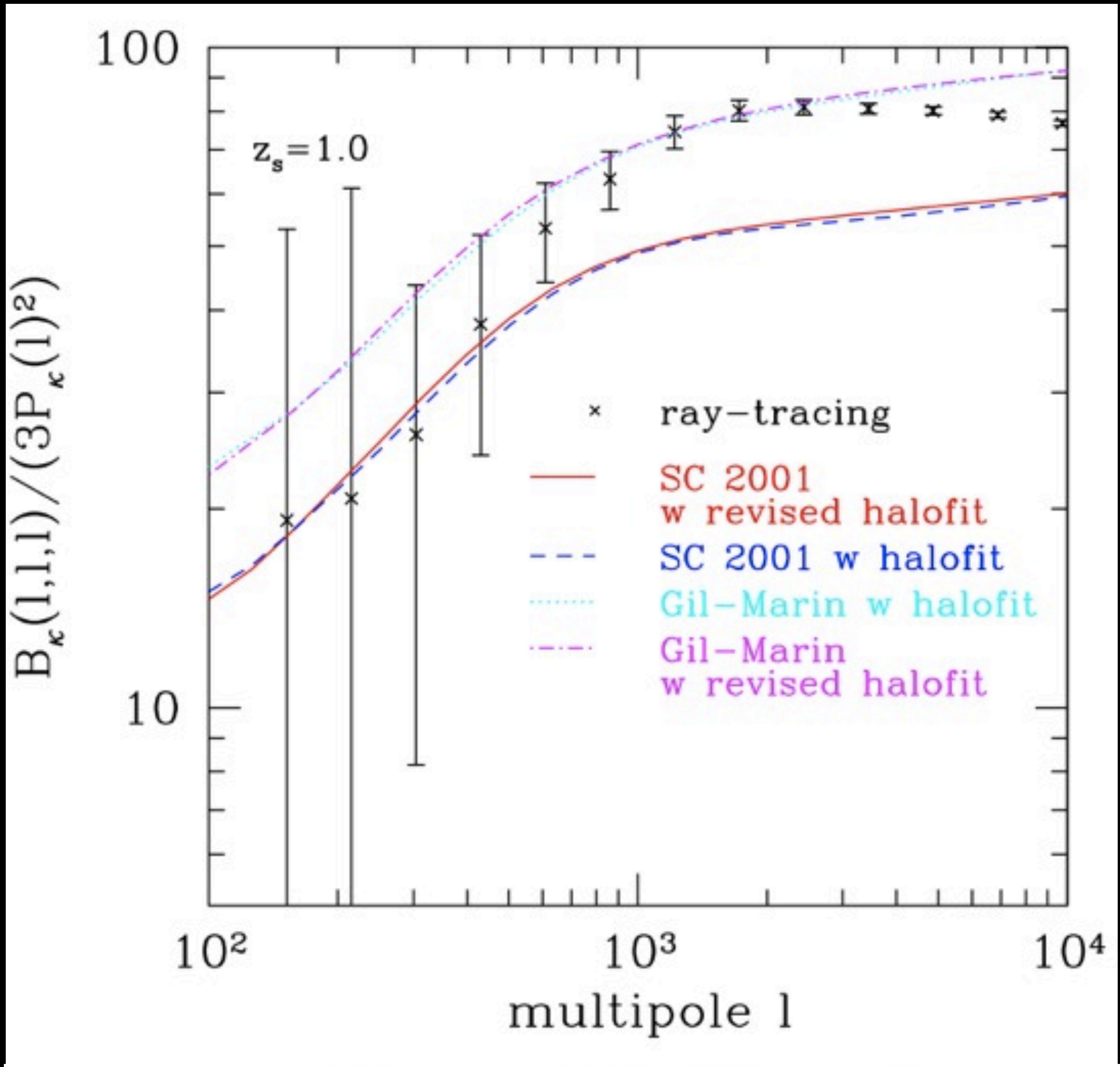
The convergence bispectrum at zs=1.0



- Gil-Marin+ fitting formula shows better agreement with simulations
- Revised halofit(Takahashi+ in prep) gives larger amplitude

$$B_\kappa(l_1, l_2, l_3) = \int_0^{\chi_s} d\chi \, \frac{W(\chi)^3}{f_K(\chi)^4} B_\delta(k_1, k_2, k_3; z),$$

The reduced bispectrum at zs=1.0

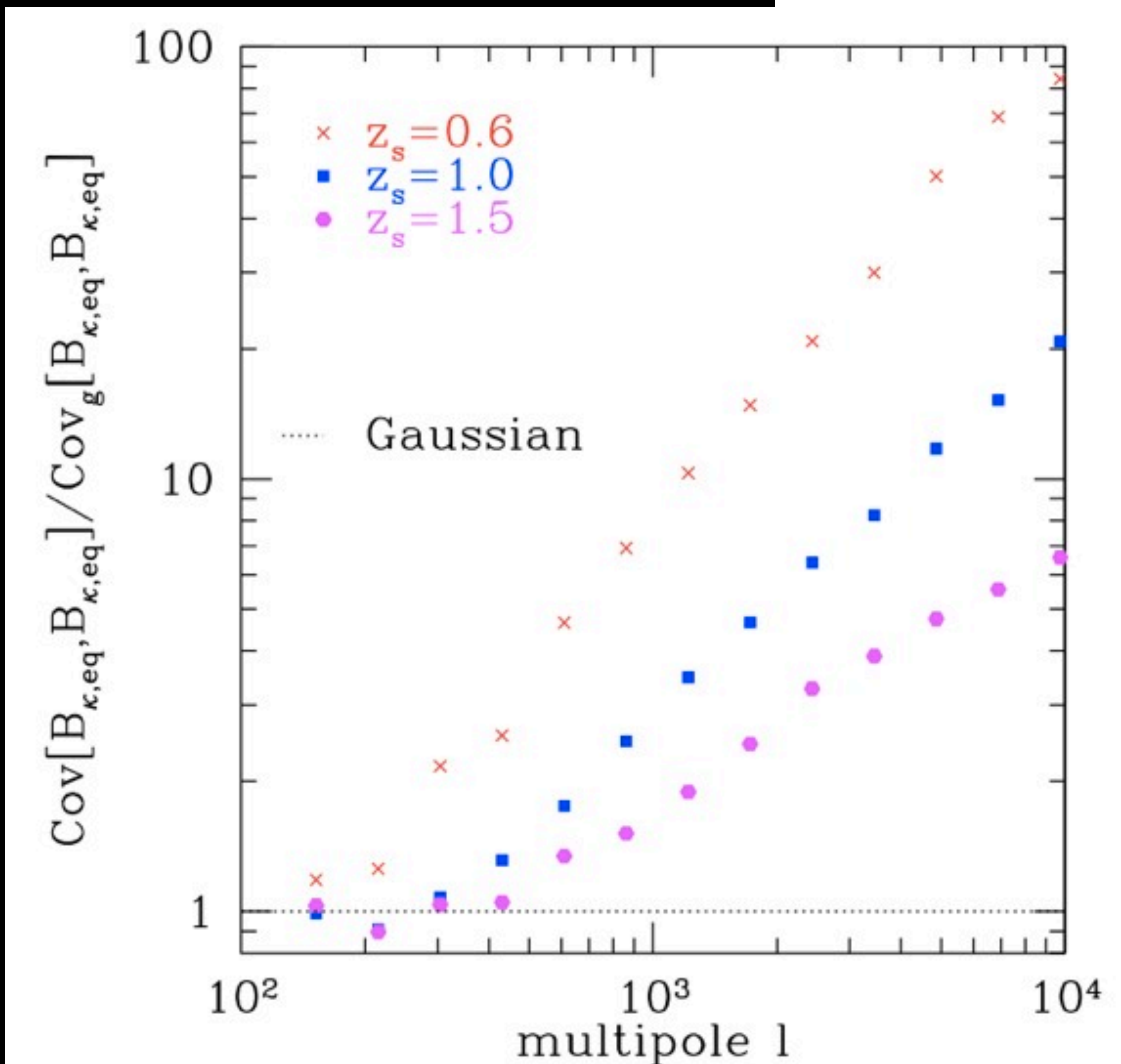


- Gil-Marin+ fitting formula shows better agreement with simulations

$$P_\kappa(l) = \int_0^{\chi_s} d\chi \, \frac{W(\chi)^2}{f_K(\chi)^2} P_\delta \left(k = \frac{l}{f_K(\chi)}; z \right)$$

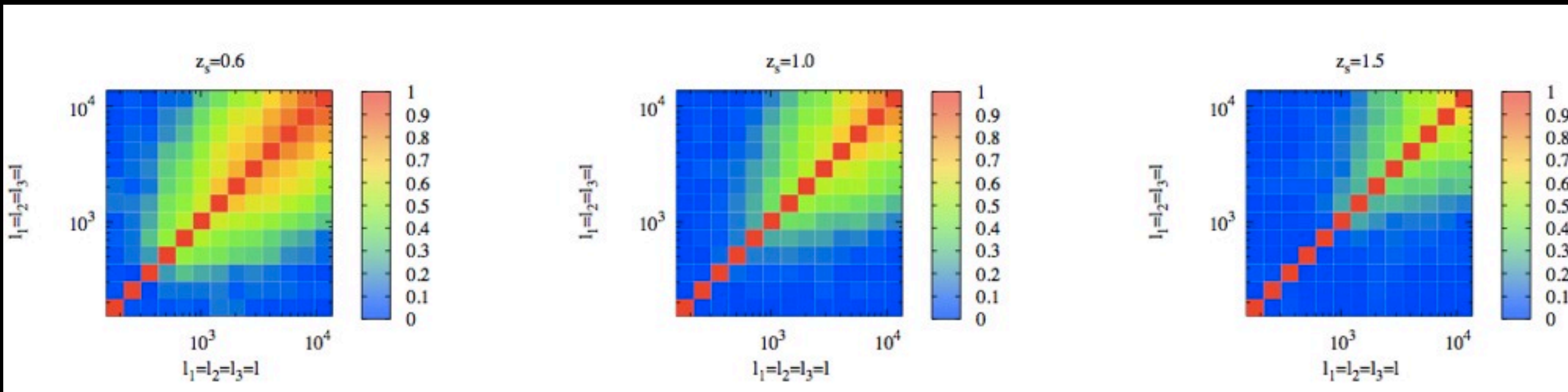
Diagonal components of the covariance for bispectrum

$$\mathrm{Cov}[B_\kappa(l_1,l_2,l_3),B_\kappa(l_4,l_5,l_6)] = \gamma P_\kappa(l_1)P_\kappa(l_2)P_\kappa(l_3) + T_{3\times 3} + T_{4\times 2} + T_6.$$



- Non-Gaussian errors start to be significant as goes to small scales
- They are greater for lower source redshifts due to the nonlinear evolution of matters

The correlation coefficient matrices of the covariance matrix for bispectrum



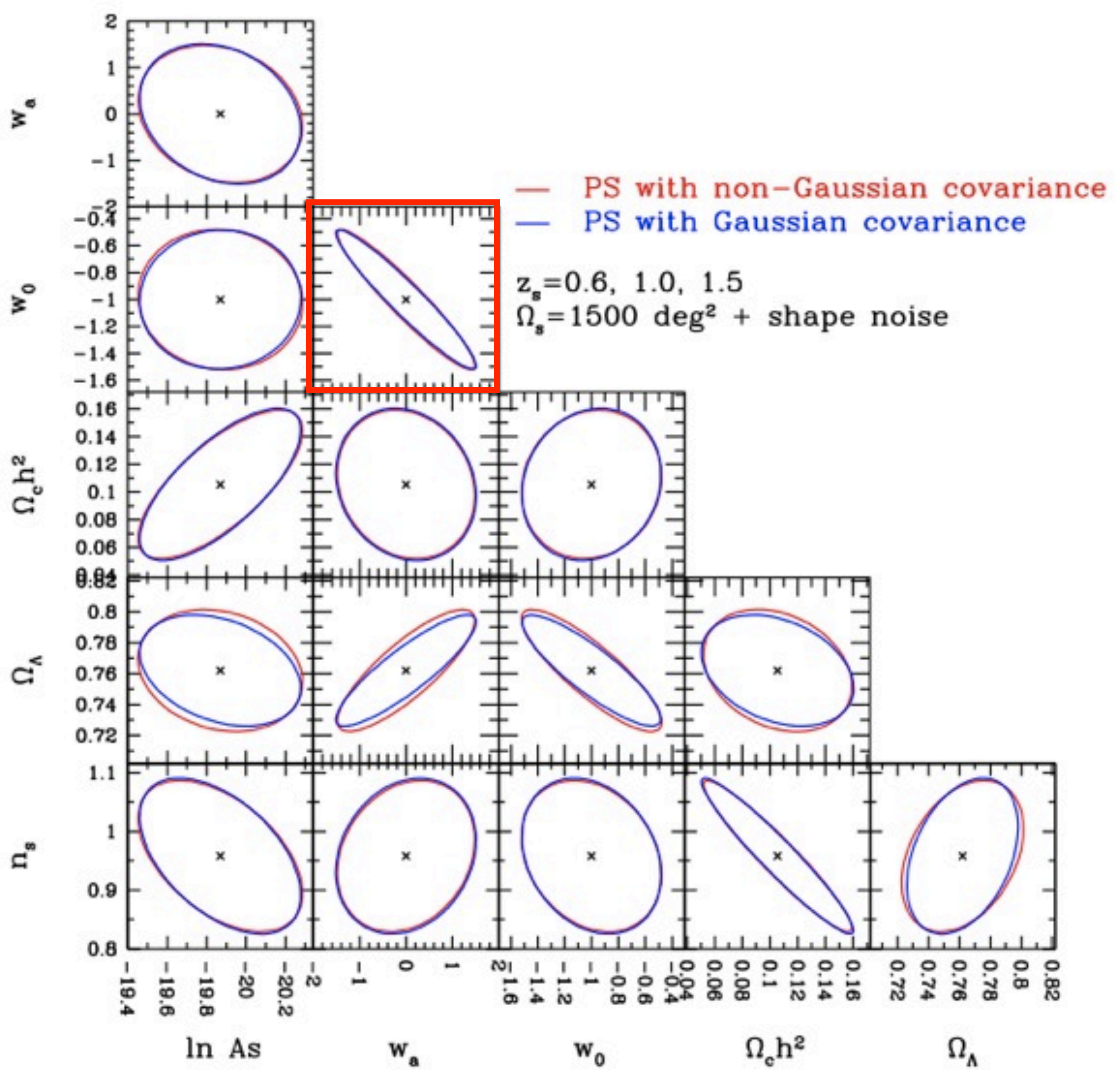
- Similar to the diagonal case, off-diagonal components of covariance matrices are larger for lower source redshifts, as expected.
- Correlation for bispectrum is weaker than power spectrum.

Fisher matrix forecast

- We want to propagate the errors on the convergence power and bispectrum into the projection of cosmological parameters using Fisher information matrix formalism.
- To do this, we varied each of the following parameters: As, ns, Ωch^2, Ωx, w0 by ±10% and wa by ±0.5.
- We assume HSC type surveys, i.e. Ω=1500deg^2

Result: power spectrum

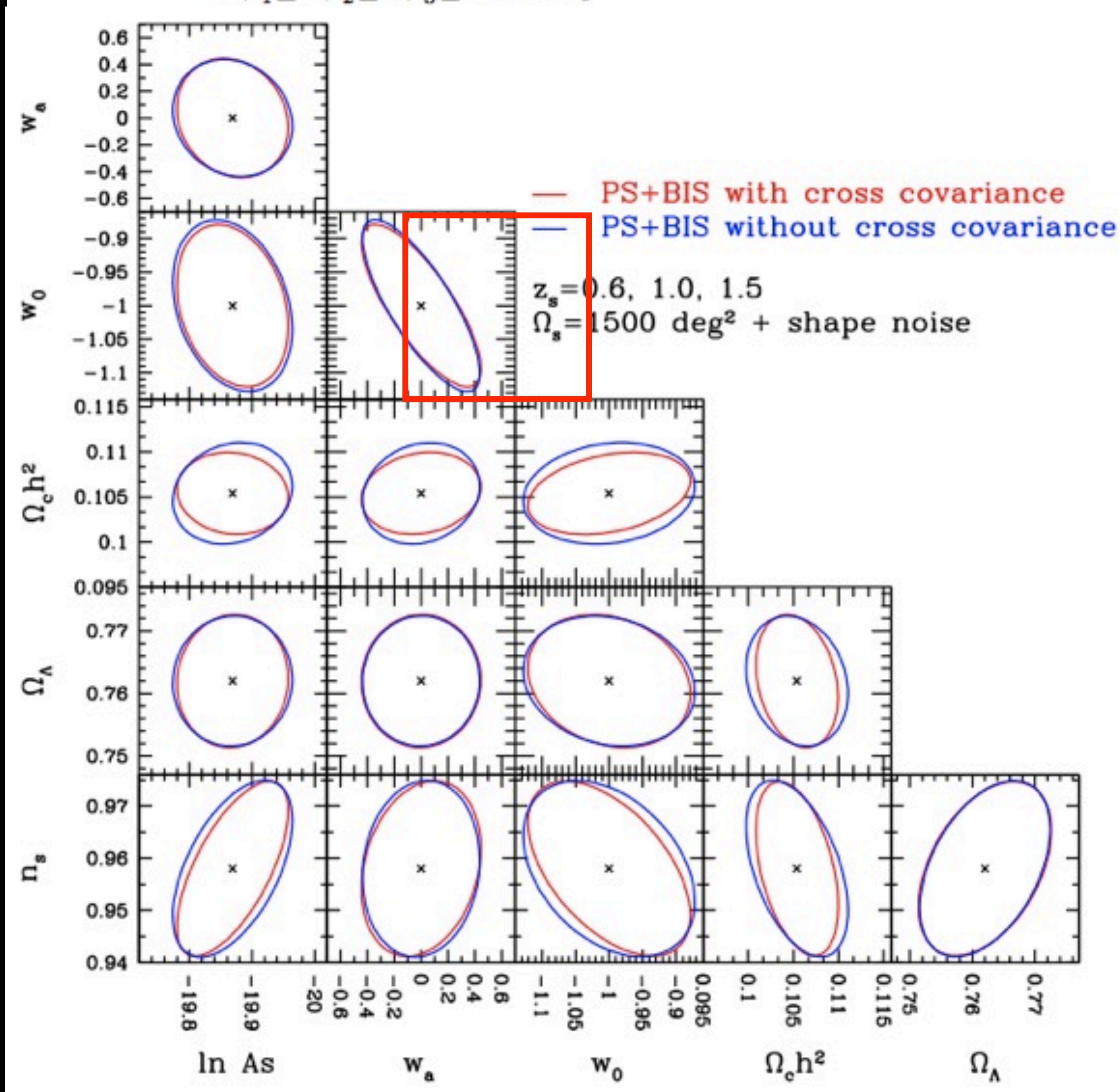
$$F^{\mathrm{WL,ps}}_{\alpha\beta} = \sum_{l,l' \le l_{\max}} \sum_{z_s, z_s'} \frac{\partial P_{\kappa,z_s}(l)}{\partial p_\alpha} \mathrm{Cov}^{-1}(l, z_s, l', z_s') \frac{\partial P_{\kappa,z_s'}(l')}{\partial p_\beta}$$



Non-Gaussian errors are not important when shape noise is ng=30arcmin^-2

Result: ps+bispectrum

$$F_{\alpha\beta}^{\mathrm{WL,bisp}} = \sum_{l_1,l_1'\le l_2,l_2'\le l_3,l_3'\le l_{\max}} \sum_{z_s,z_s'} \frac{\partial B_{\kappa,z_s}(l_1,l_2,l_3)}{\partial p_\alpha} \mathrm{Cov}^{-1}(l_1,l_2,l_3,z_s,l_1',l_2',l_3',z_s') \frac{\partial B_{\kappa,z_s'}(l_1',l_2',l_3')}{\partial p_\beta}$$



Bispectrum information is crucial to strongly constrain the cosmological parameters.

Cross-Covariance of power spectrum and bispectrum is not so important.

Conclusion

- We investigate improvement in precisions of dark energy parameters(Ωx, w0,wa) using Fisher matrix analysis based on full-nonlinear simulations.
- We carefully investigate how the approximation of Gaussianity is valid for computing the bispectrum covariance, by comparing the full covariance matrix.
- Weak lensing bispectrum is crucial when we constrain dark energy parameters from future wide-field weak lensing surveys.
- Weak lensing simulations are available. Please check http://www.a.phys.nagoya-u.ac.jp/~masanori/HSC/