BAO mock measurement of three dimensional correlation function for photometric surveys

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Outline

1. Introduction

- Galaxy observation methods
- Baryon Acoustic Oscillation
- Motivation

2. Setup & Method

- Simulation data we use
- 3D two-point correlation function for galaxies

3. Result

- In that case the magnitude of the photo-z error associated with data is known
- In the other case (**Not** known)
- Theoretical prediction for skewed non-Gaussian photo-z distribution

4. Summary

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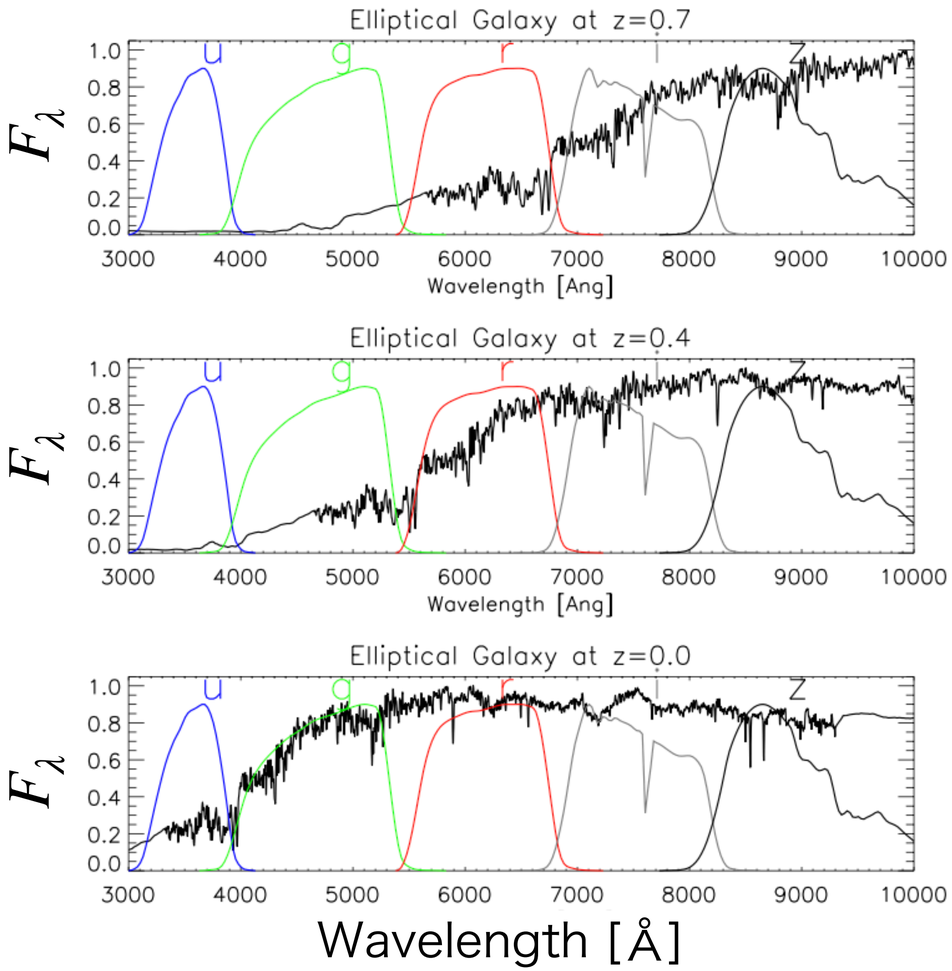
Two main observational methods

Spectroscopic & Photometric

- Photon flux is broken down by wavelength to make Spectral Energy Distribution.

	area	number density	redshift accuracy
spec	△	×	○
photo	○	○	△



Redshift accuracy of photometric is worse than one of spectroscopic.

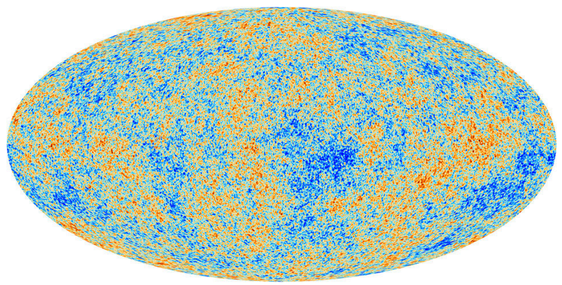
Padmanabhan et al. 2007 Fig.1

What is BAO?

Baryon Acoustic Oscillation (BAO)

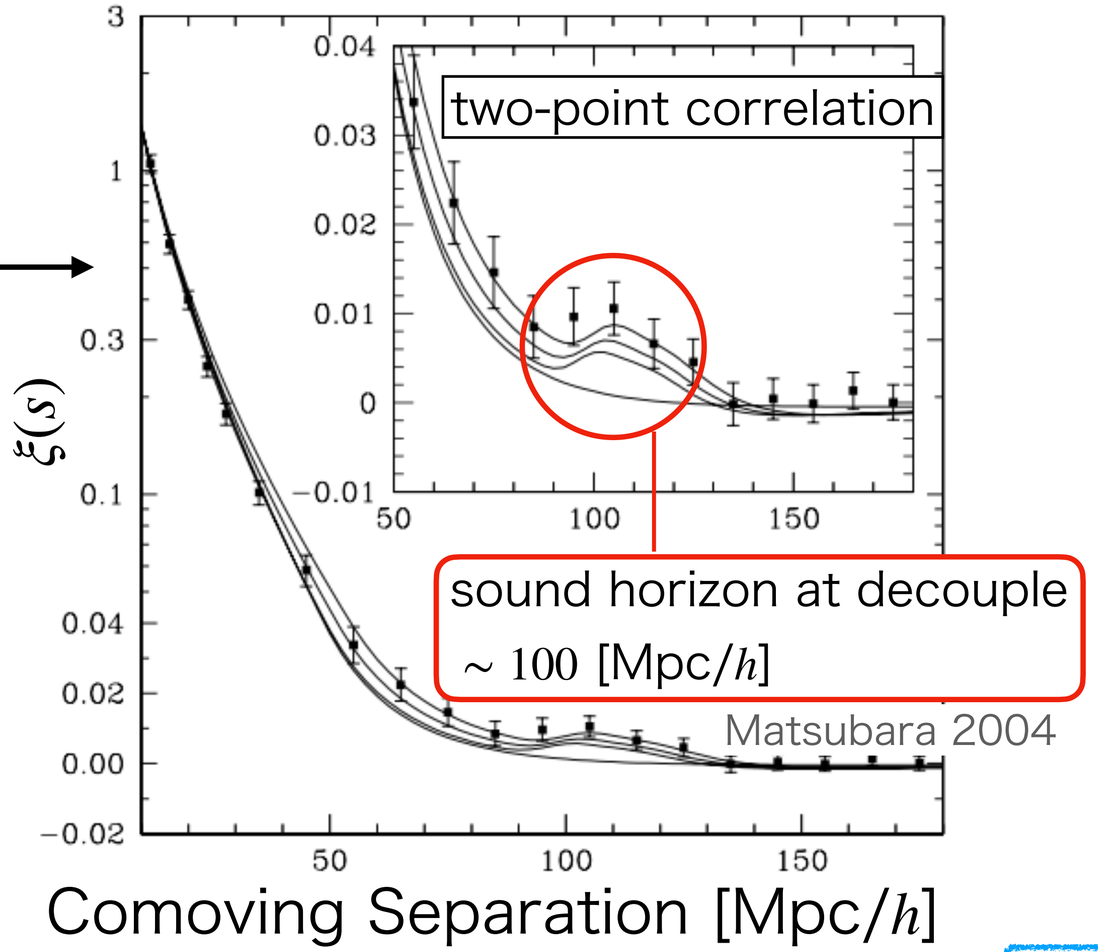
- Baryon & Photon mixed fluids transmit information as a sound wave.
- decoupled at $z \sim 1{,}100$

Photon



ESA and the Planck Collaboration

Baryon



Eisenstein et al. 2005 Fig.2

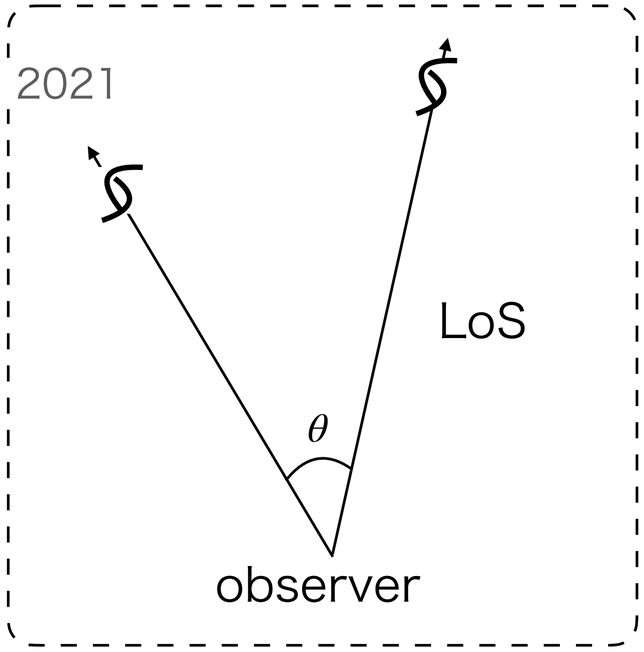
correlation function insensitive to LoS

different analysis methods

	area	density	redshift
spec	△	×	○
photo	○	○	△

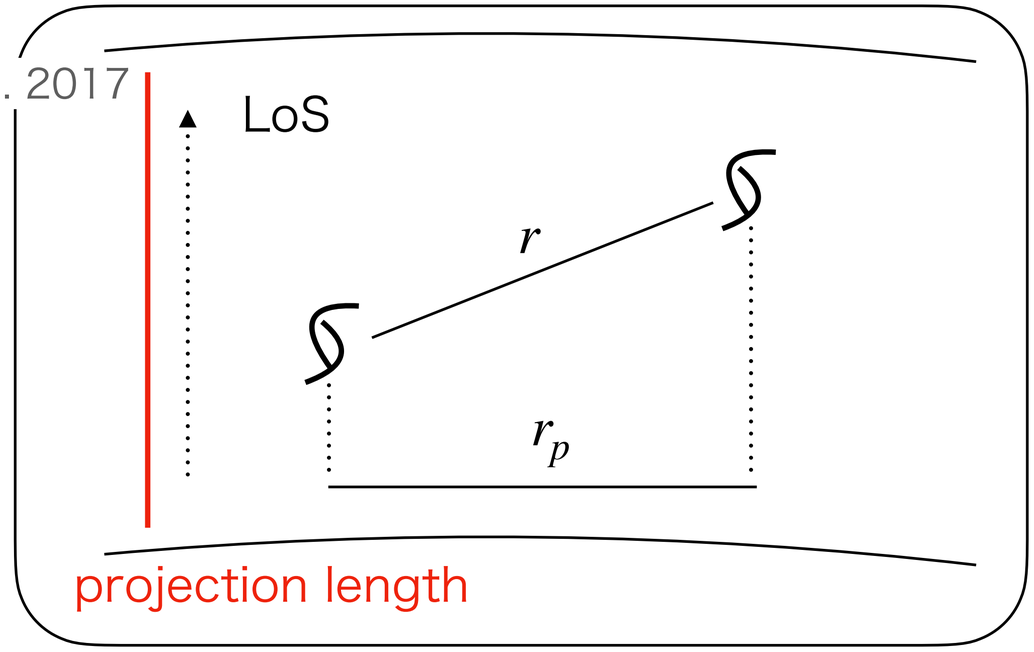
measure against angular or perpendicular to the LoS

ex. Abbott et al. 2021



angular correlation

ex. Ross et al. 2017



projected correlation

Goal：Verify acceptable photo-z uncertainty

The goal of this study

We aim to show the level of photo-z error

associated with photometric observations.

- It may improve statistical accuracy because of 3D box.
- It's possible to constrain the Hubble para. by LoS information.

In this presentation..

- We measure BAO using mocks of photometric observation with Line of Sight information to show the level of photo-z error.

- We check the effect if the photo-z distribution is not Gaussian but skewed non-Gaussian.

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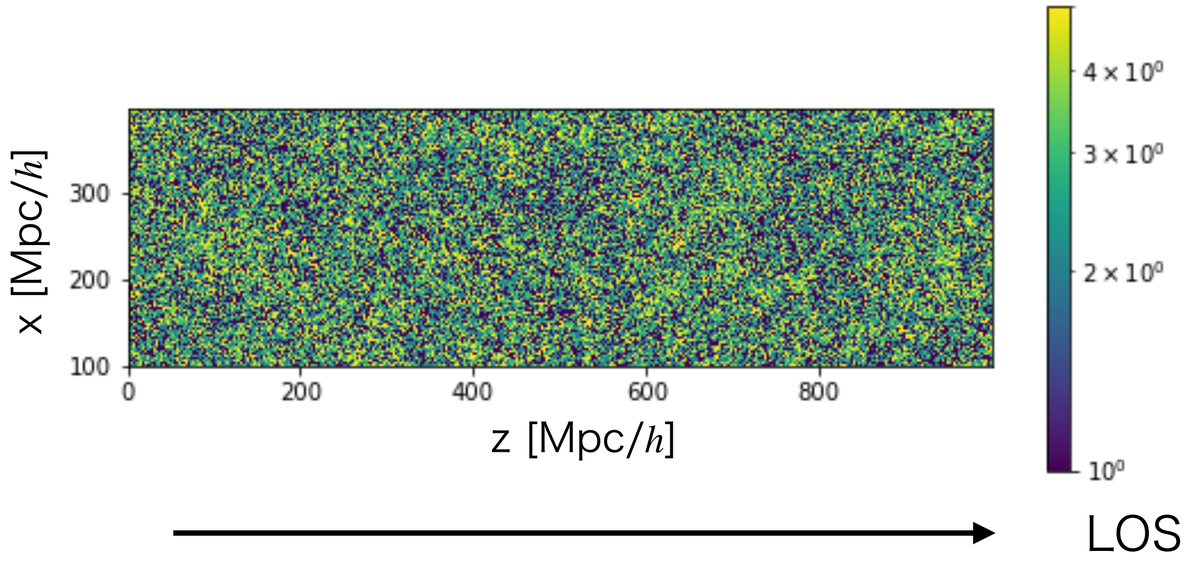
Simulation data we use

The property of mock

- Real space
- Box：1 [Gpc/h]^3 × 112 realizations
- Redshift $z = 0.251,\ 0.617,\ 1.03$
- Stellar Mass Limit：$10^{11}\ M_\odot$

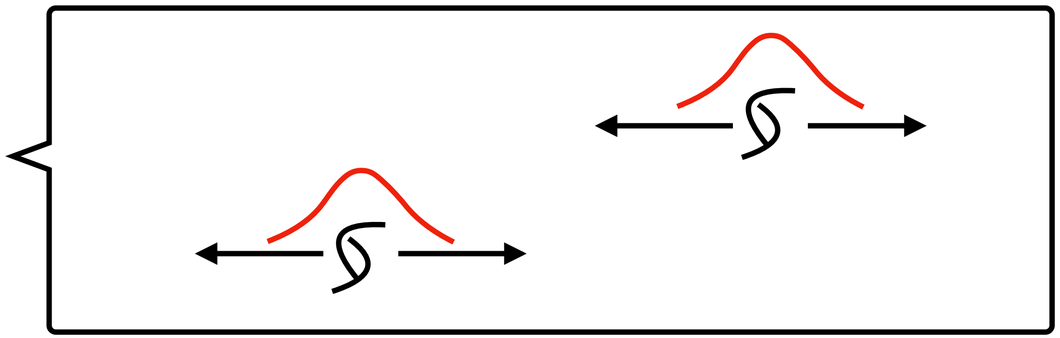
Nishimichi T. et al. 2019
Sunayama T. et al. 2020
Ishikawa S. et al. 2021

The density distribution of mock galaxies



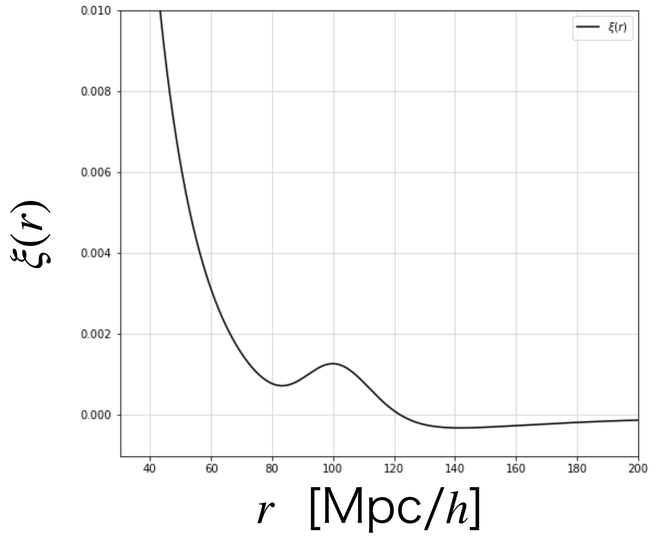
Gaussian which has the STD of $0.01 \times x(z)(1+z)$ [Mpc/h]

$x(z)$：comoving distance



fitting model

3D two-point correlation function for galaxies



$$\xi^{\mathrm{fit}}(r) = B^2 \xi_{\mathrm{m}}^{\mathrm{temp}}(\alpha r) + \frac{a_1}{r^2} + \frac{a_2}{r} + a_3$$

galaxy bias　broadband terms

ex. Padmanabhan et al. 2012

fitting parameter

$a_1,\ a_2,\ a_3,\ B,\ \Sigma_a,\ \alpha$

the parameter to capture BAO peak

There isn't degeneracy with other parameters.

In this case, we regard what α capture BAO peak when $\alpha = 1$.

$$\alpha = \frac{l_{\mathrm{obs}}}{l_{\mathrm{fid}}} = \frac{[D_A(z)/r_s]_{\mathrm{obs}}}{[D_A(z)/r_s]_{\mathrm{fid}}},$$

We incorporate the photo-z distribution.

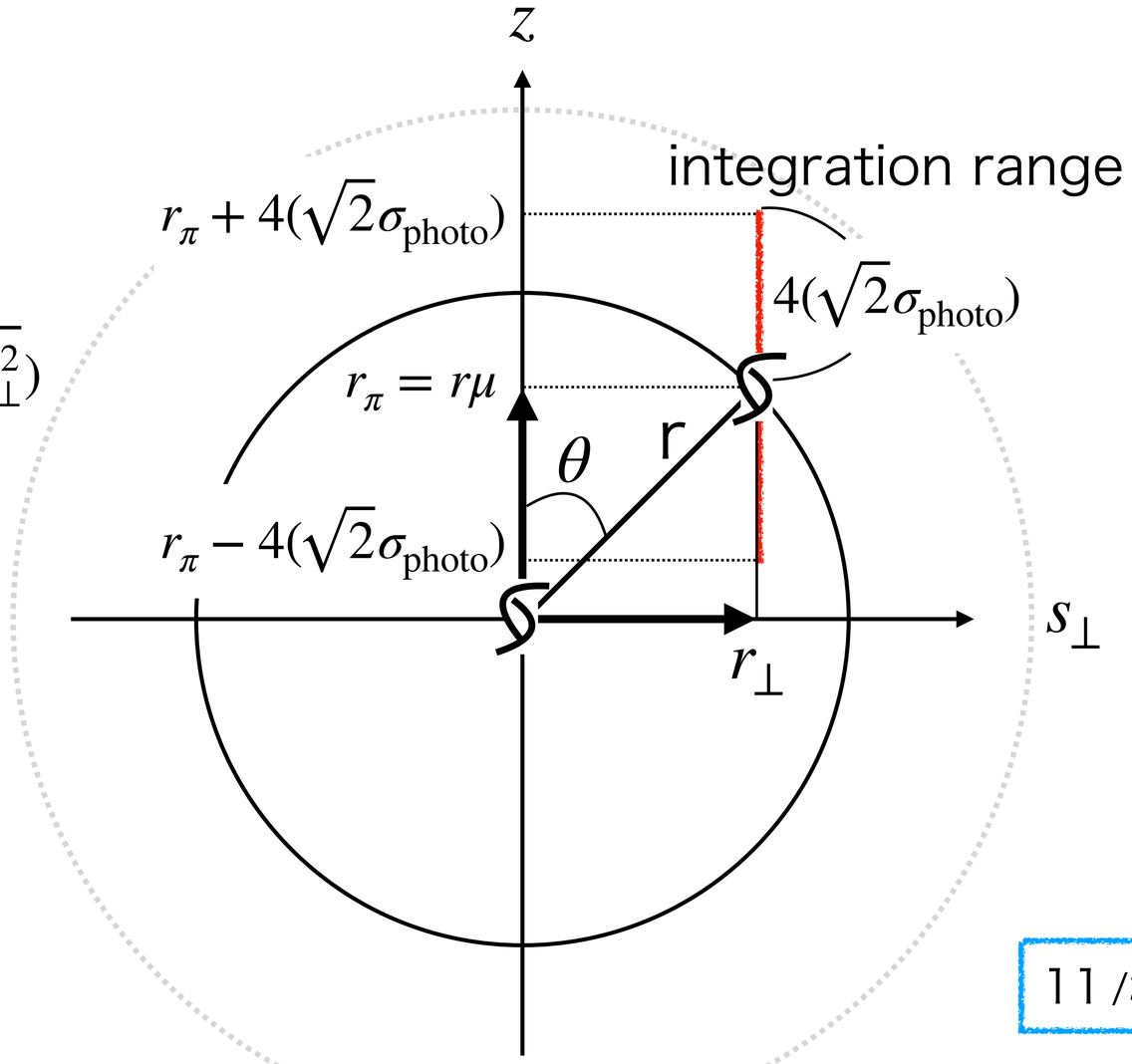
template model with photo-z effect

- $\xi_{\rm m}^{\rm temp}(r) = \int_{-1}^{1} d\mu \xi^{\rm int}(r,\mu)$ ← $\mu = \cos\theta$
  - $\xi^{\rm int}(r,\mu) = \int_{r\mu-4(\sqrt{2}\sigma_{\rm photo})}^{r\mu+4(\sqrt{2}\sigma_{\rm photo})} dr_\pi G(r_\pi, \sigma_{\rm photo})\ \xi_m(\sqrt{r_\pi^2 + r_\perp^2})$
  - $\xi_m(r) = \int dk\ \frac{k^2}{2\pi^2} P_m^{NL}(k) j_0(kr)$

$P_m^{NL}(k) = [P_{lin}(k) - P_{smooth}(k)]e^{-k^2\Sigma_{nl}^2/2} + P_{smooth(k)}$ [Mpc/h]

$\Sigma_{nl} = \Sigma_a\ D(z)/D(0)$ [Mpc/h]

Eisenstein et al. 2007



Fitting procedure: least chi square fit

- chi square

$$\chi^2 = \sum_{ij} \left(\xi_{\rm data}(r) - \xi_{\rm fit}(r)\right)_i {\rm Cov}_{ij}^{-1} \left(\xi_{\rm data}(r) - \xi_{\rm fit}(r)\right)_j^{\tau}$$

$${\rm Cov}(r_1, r_2) = \frac{1}{N_{\rm mock} - 1} \sum_i \left(\left[\xi_i(r_1) - \bar{\xi}(r_1)\right] \left[\xi_i(r_2) - \bar{\xi}(r_2)\right] \right)$$

- estimator

$$\xi(r) = \frac{DD(r) - 2DR(r) + RR(r)}{RR(r)}$$

Landy & Szalay 1993

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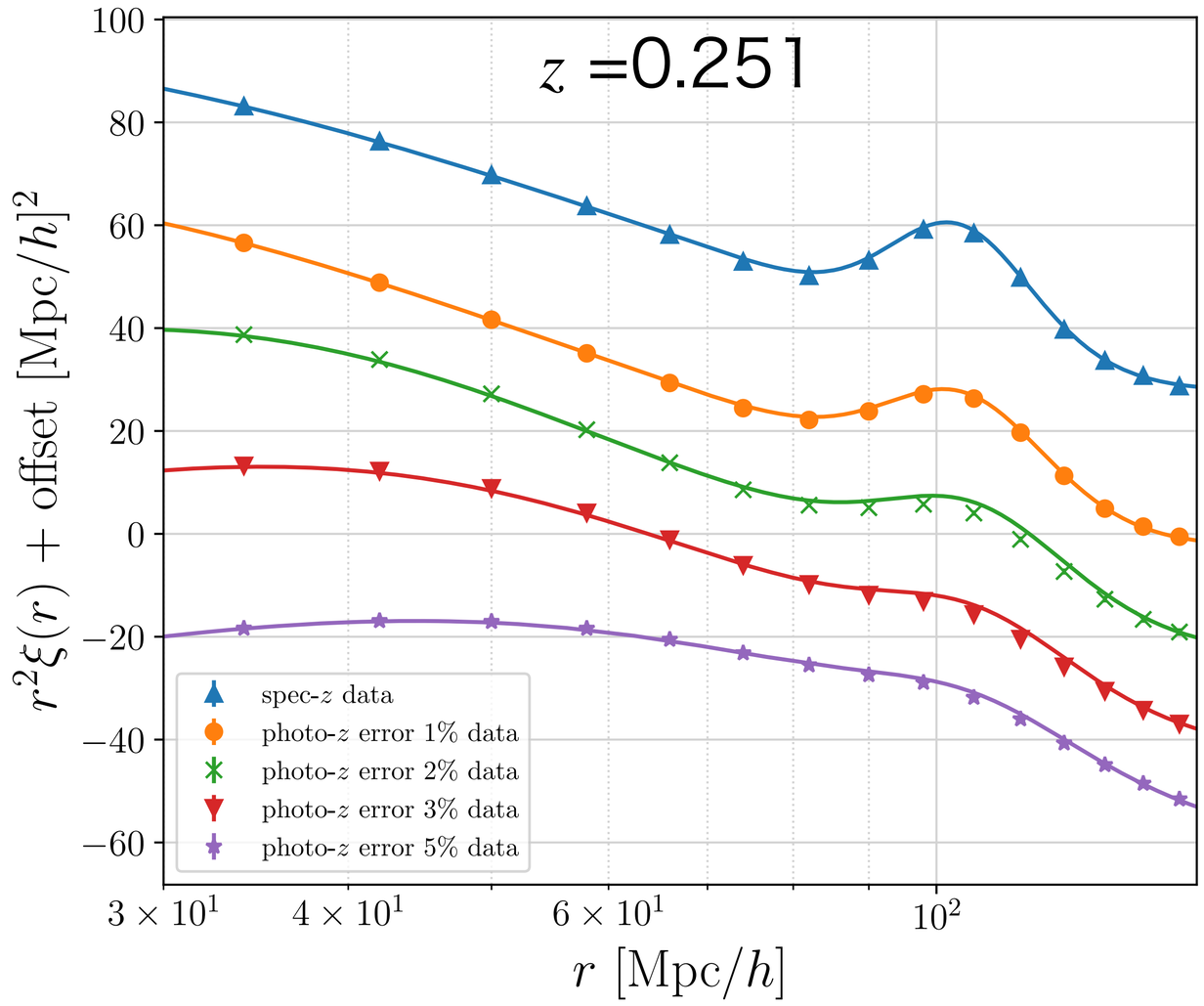
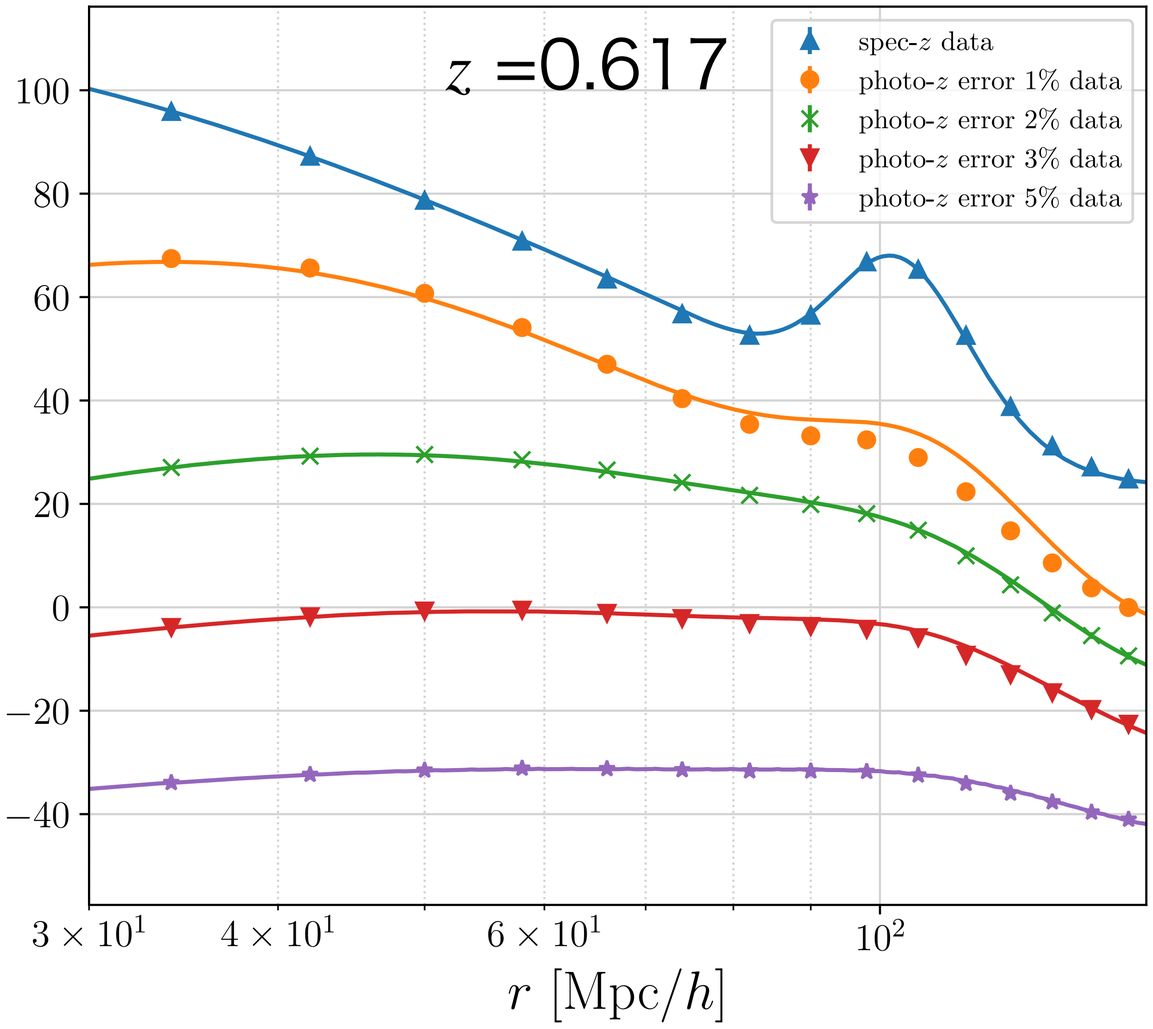
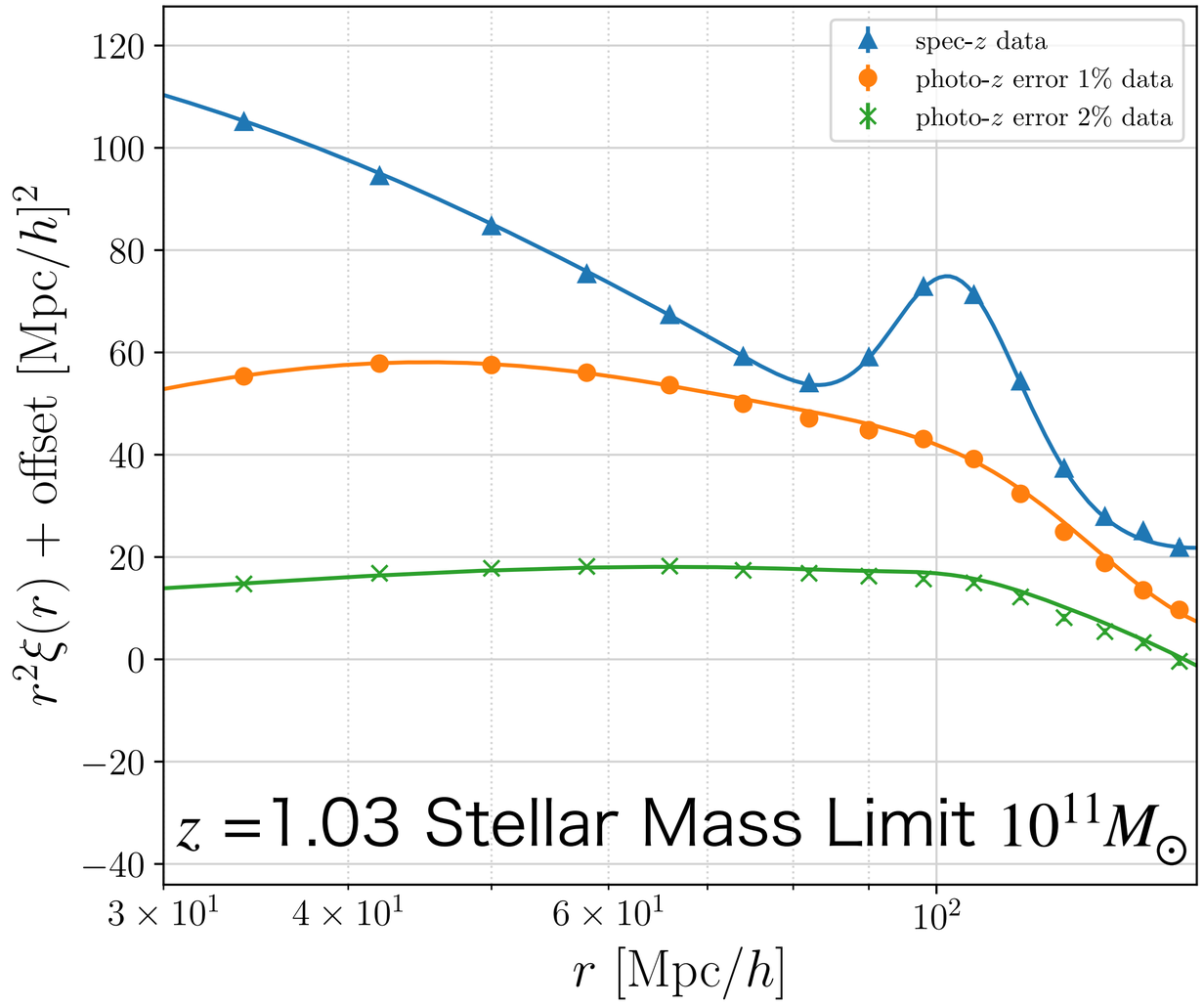
fitting result when photo-z error is known

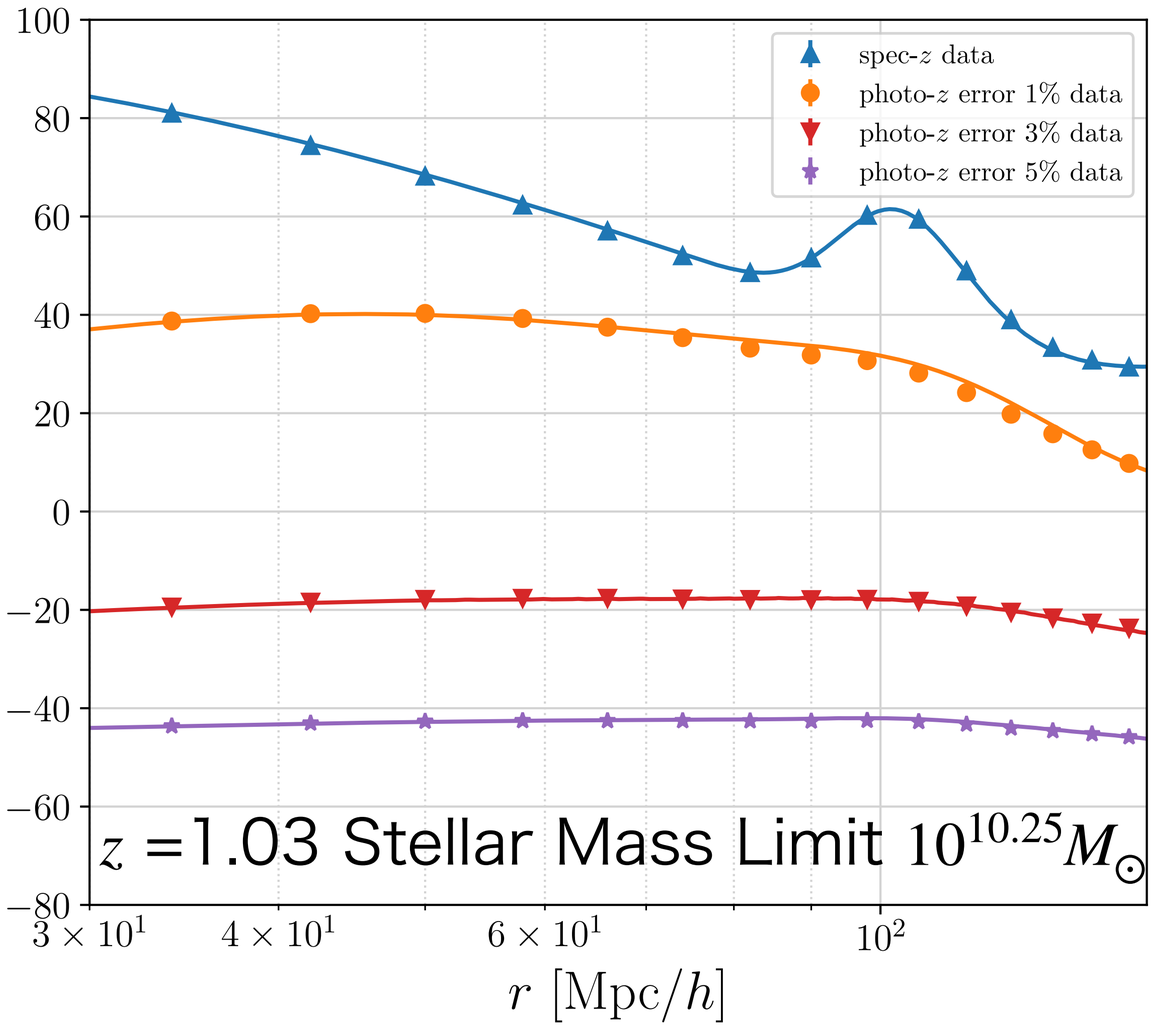




For ease of viewing, the amplitude is rescaled appropriately.

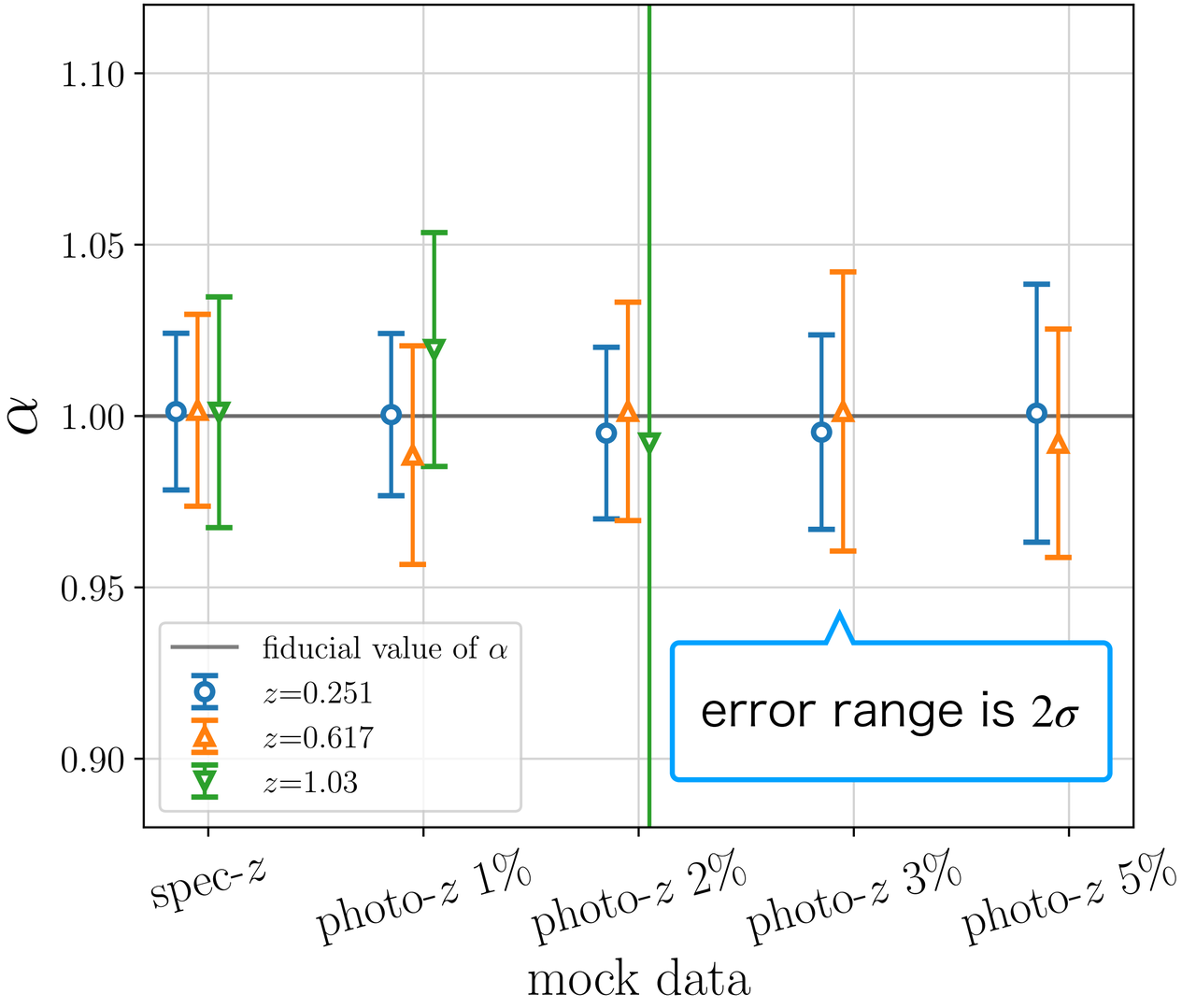
fitting result when photo-z error is known

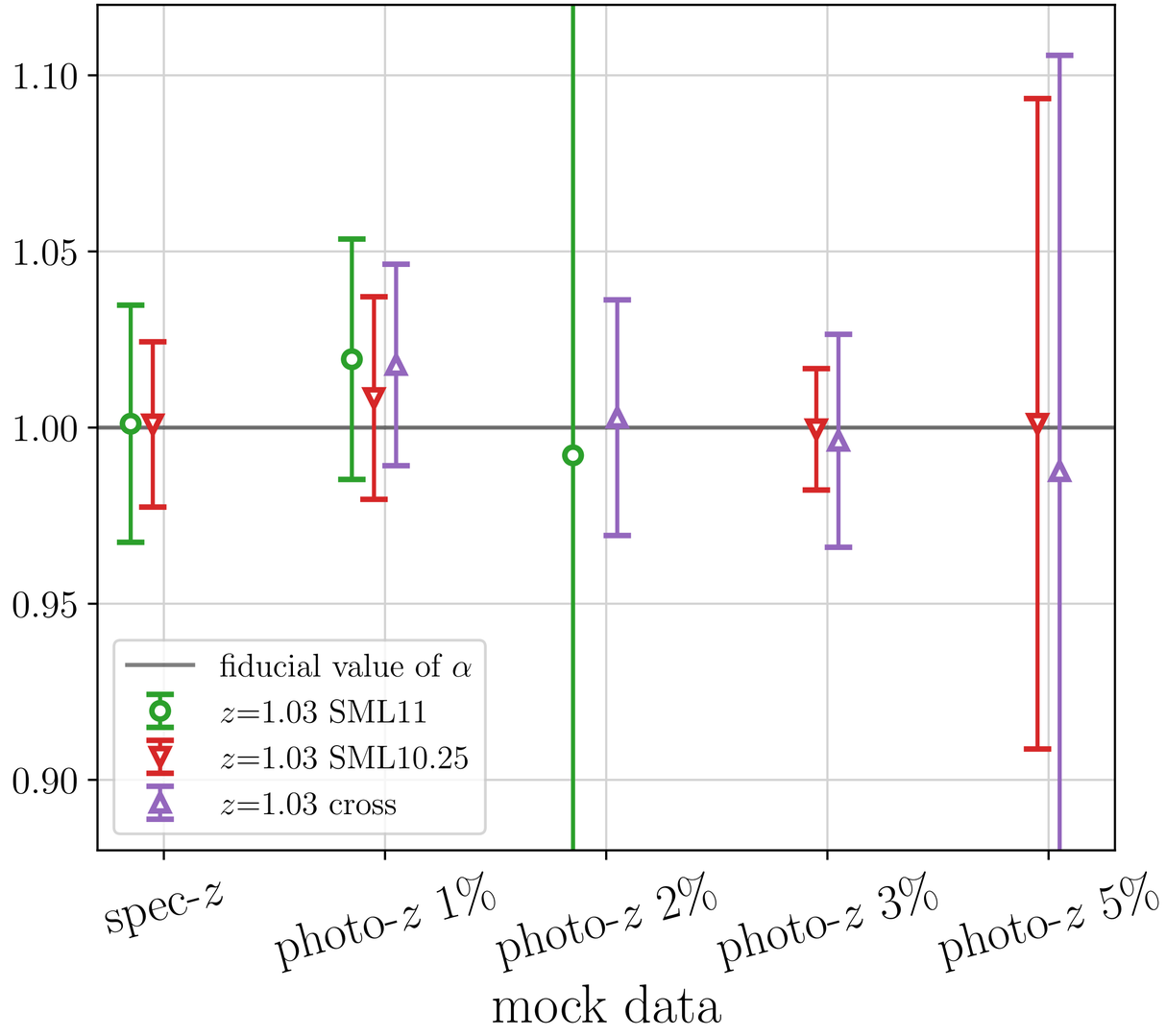




For ease of viewing, the amplitude is rescaled appropriately.

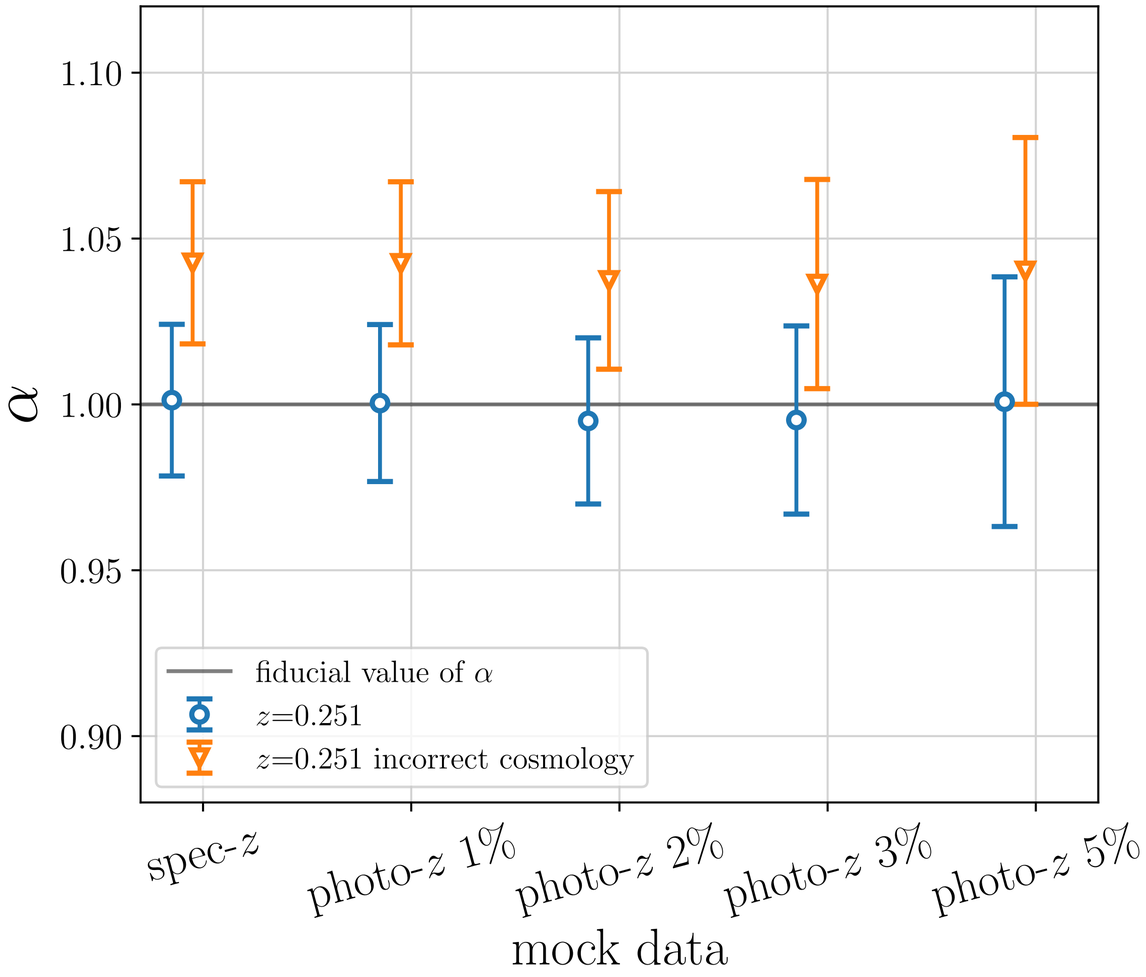
When photo-z error is known

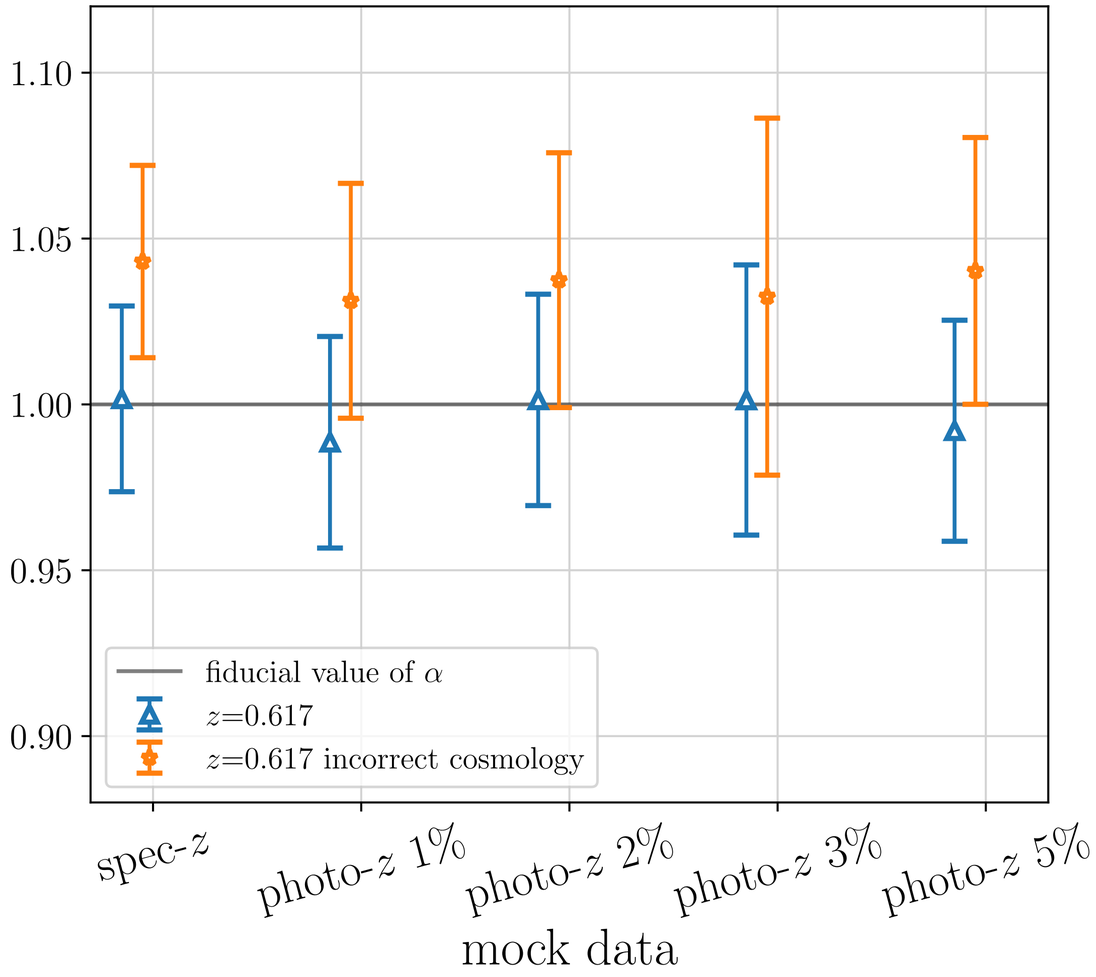




up to a photo-z error corresponding to about 50 Mpc/h

incorrect cosmology check





up to a photo-z error corresponding to about 50 Mpc/h

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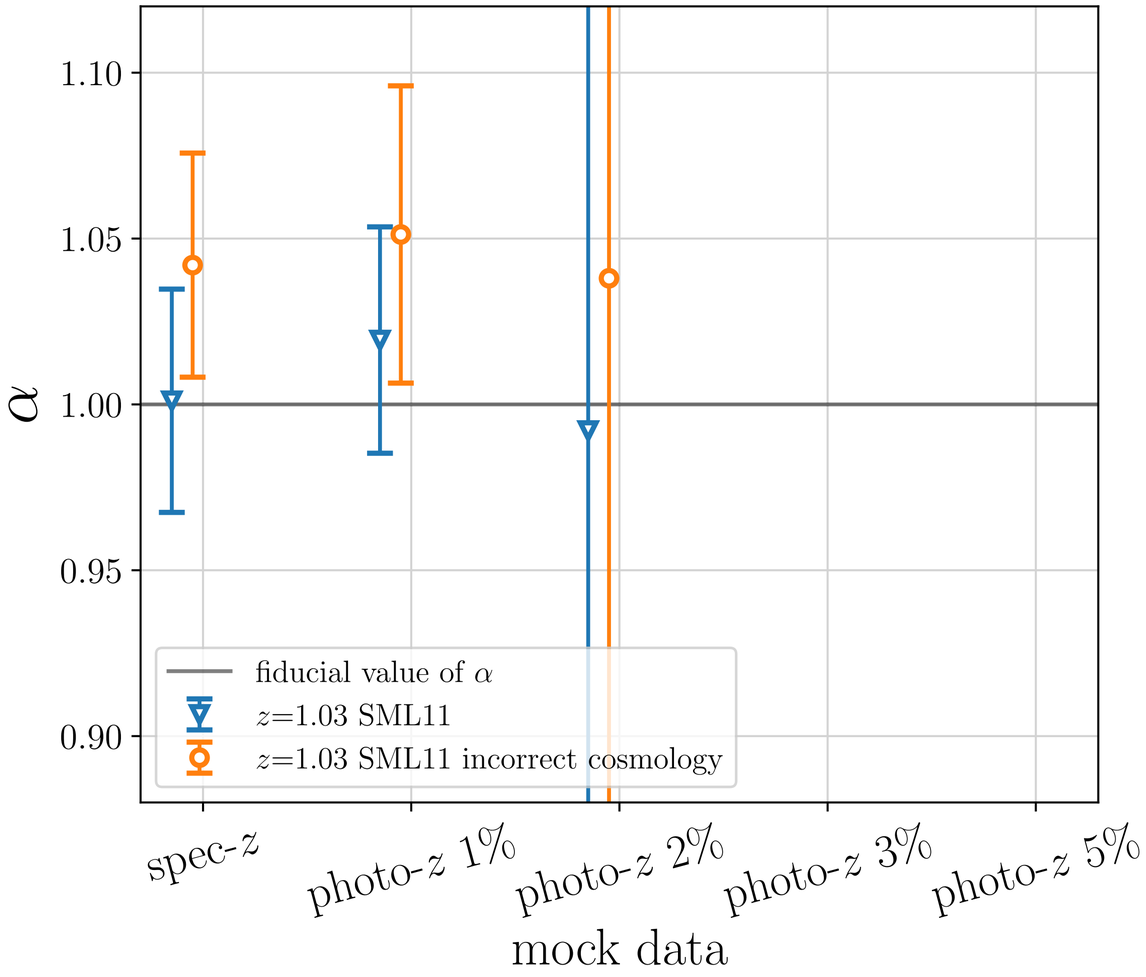
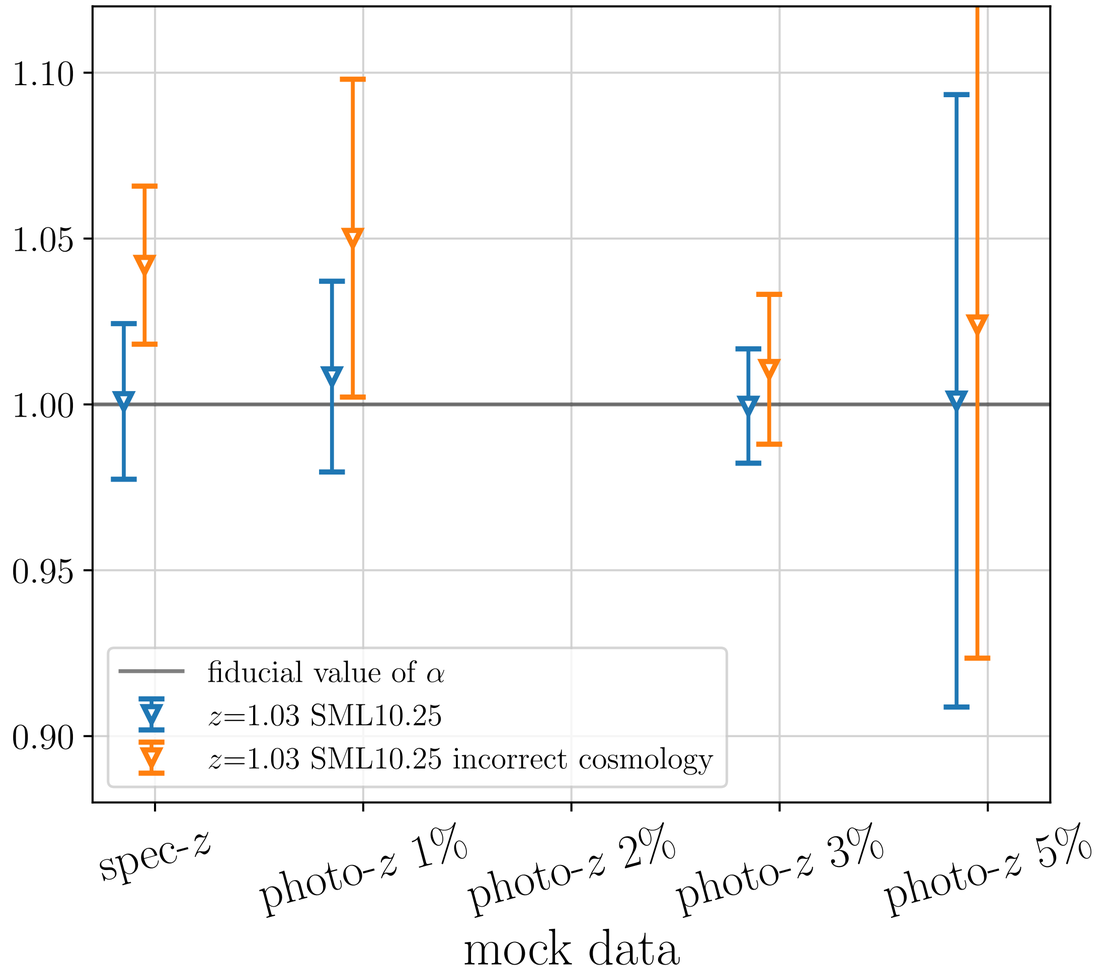




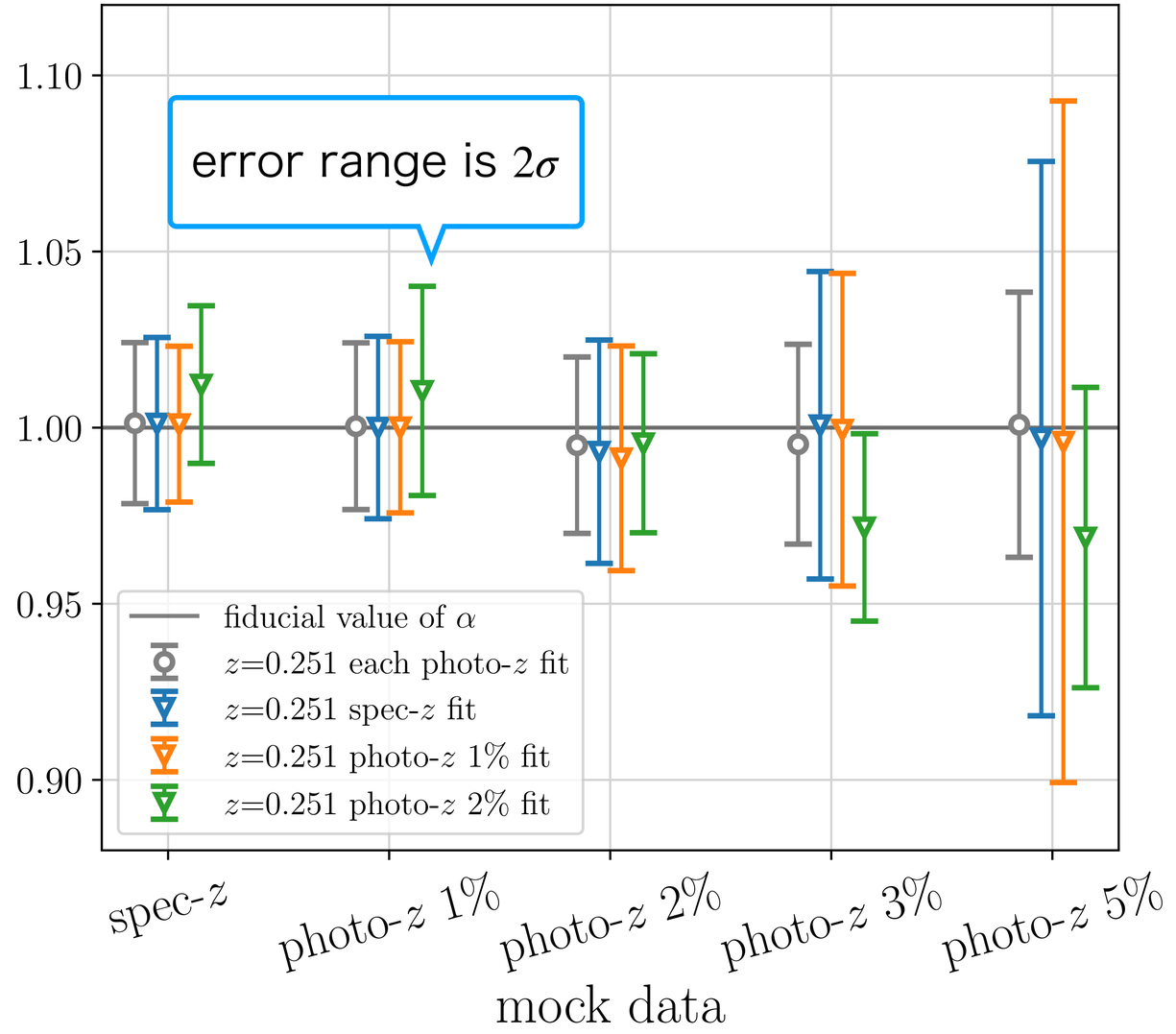
When photo-z error is unknown

α parameter distribution

At $z = 0.251$,

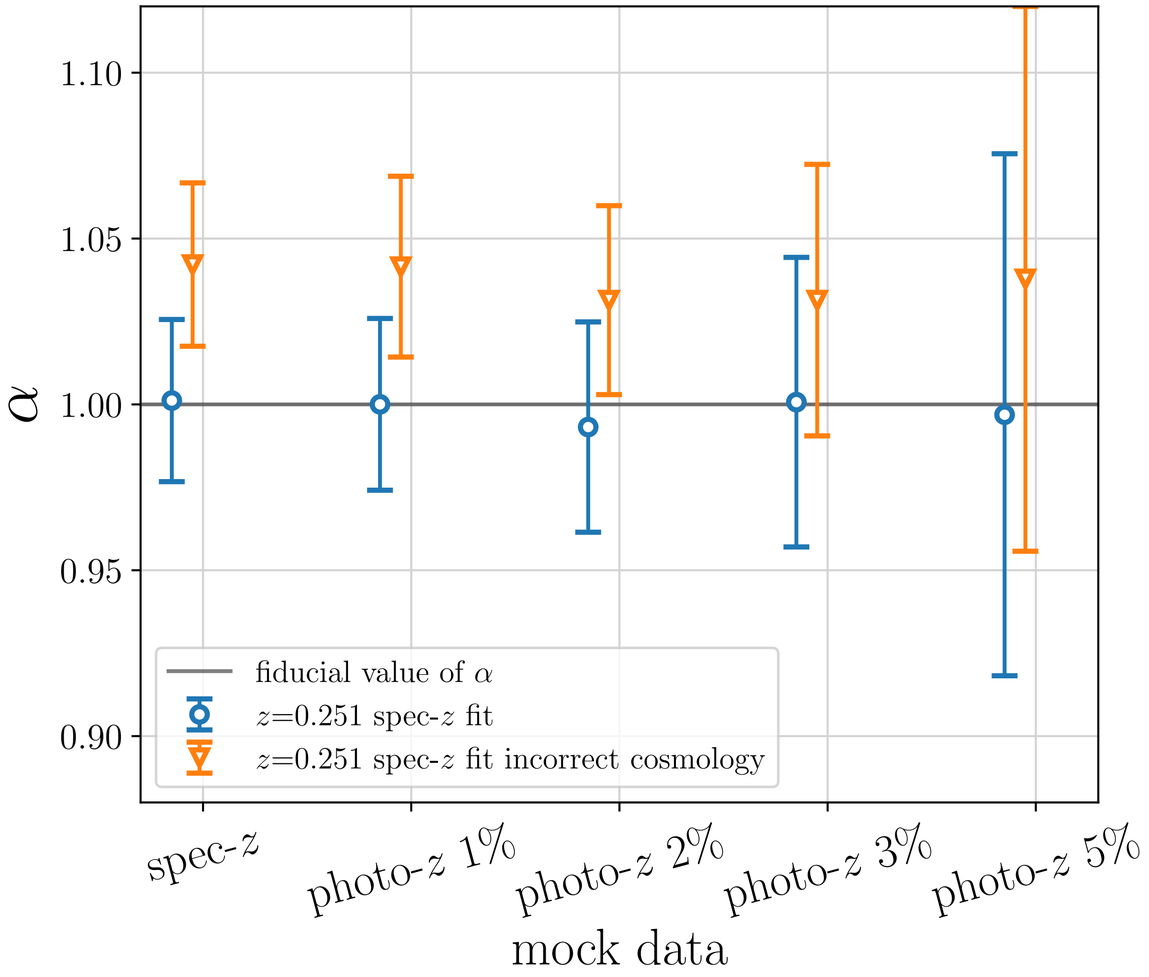
fitting with the spec-z or the photo-z 1% template will not bias the BAO location (although the statistical error will be larger).

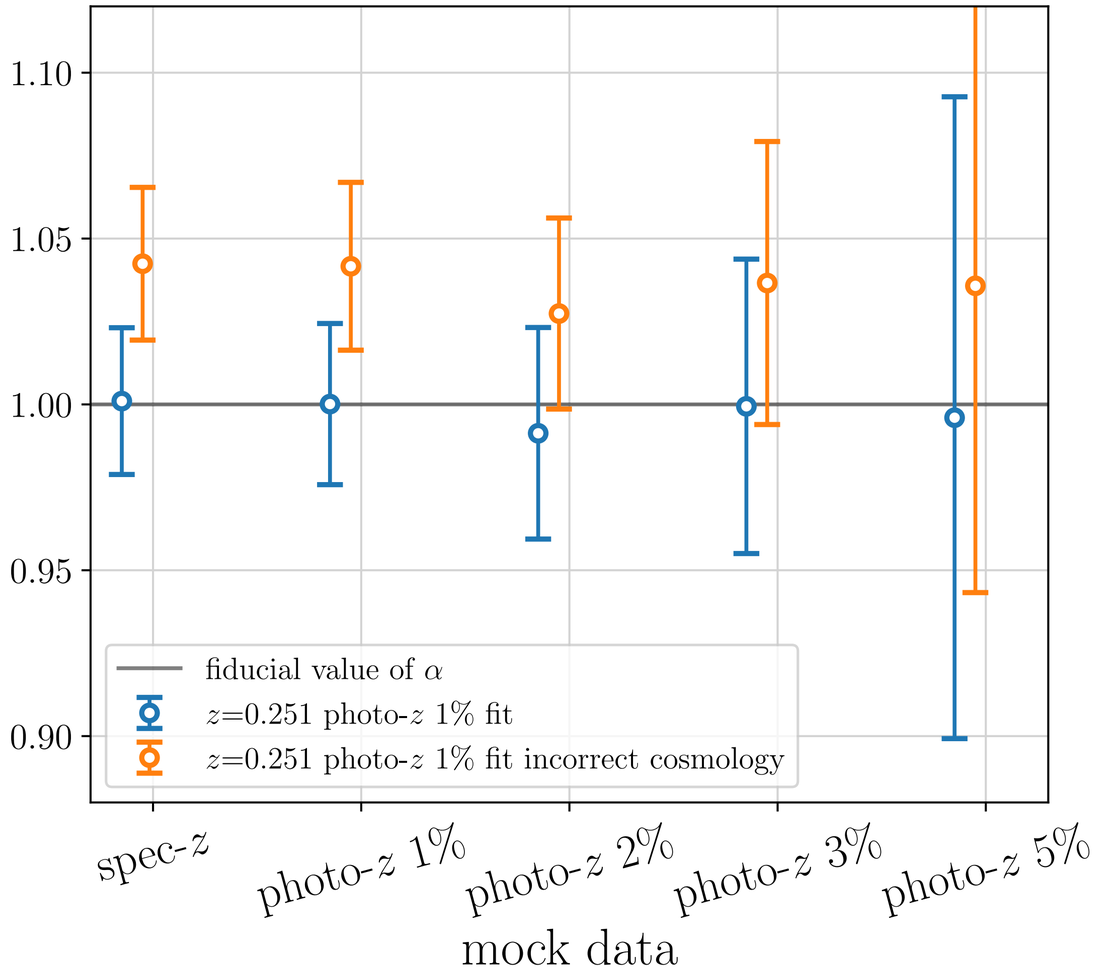
When we fit photo-z 3% data using photo-z 2% template, the result was biased.



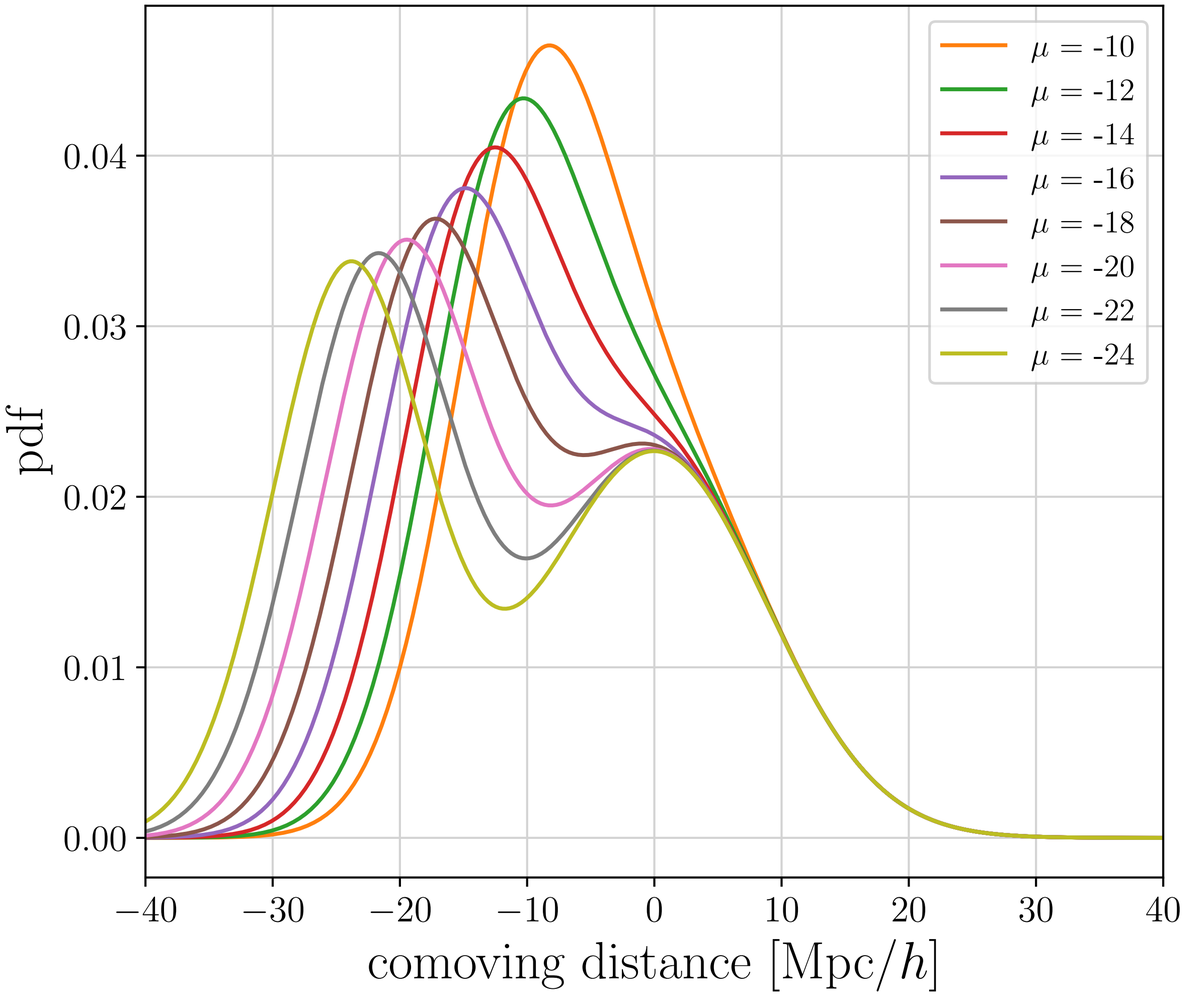
up to a photo-z error corresponding to about 15 Mpc/h

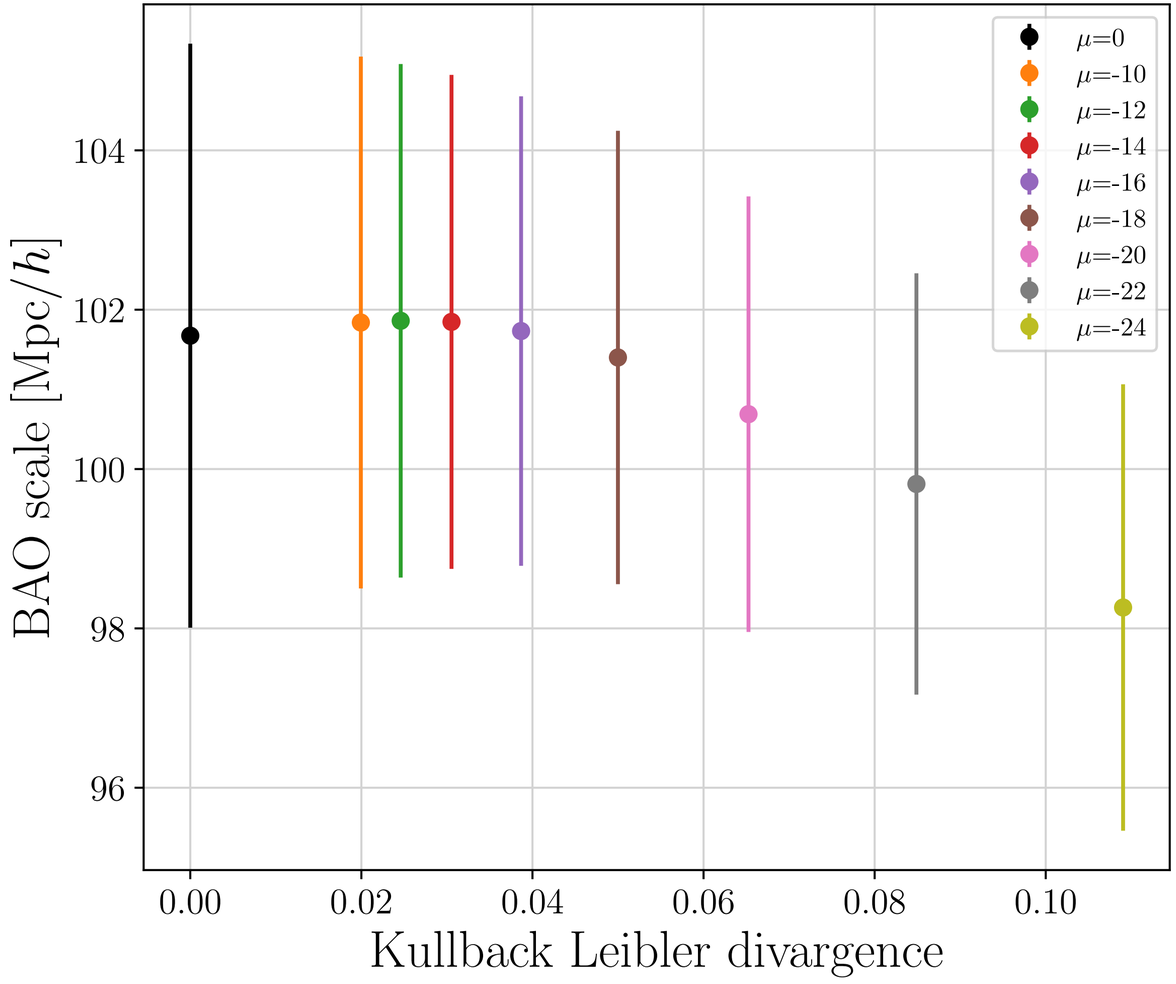
incorrect cosmology check





nonGaussian photo-z data w/ Gaussian fit





Summary & Future work

Summary

- In the case that photo-z error is known, we could measure BAO until it becomes 50 Mpc/h.
- In the case that photo-z error is **unknown**, we could measure BAO until it becomes 15 Mpc/h using spec-z or photo-z 1% template.
- Even if the photo-z distribution is skewed non-Gaussian, skewness does not affect the BAO measurement.

Future work

- Fitting parameterization of photo-z error σ_{photo}
- Comparison to MCMC