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Blinding Techniques for LSS Surveys

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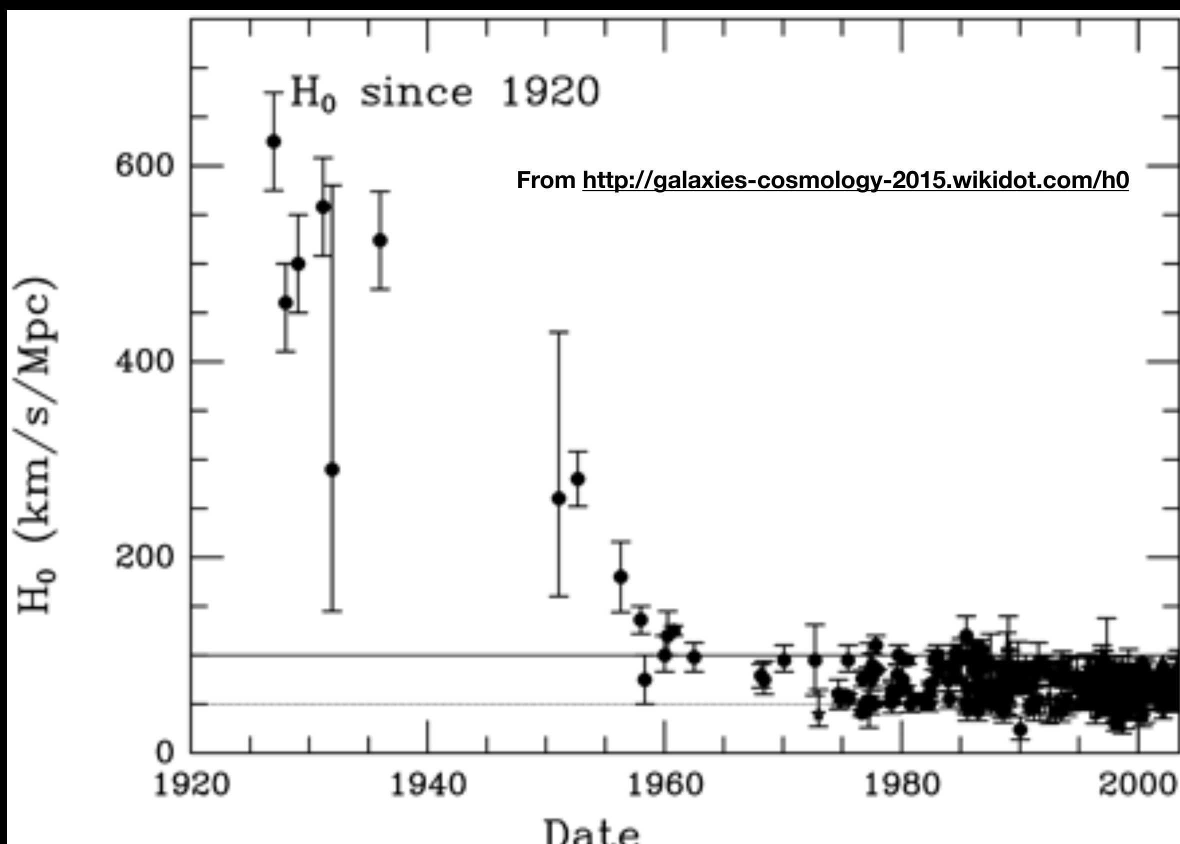
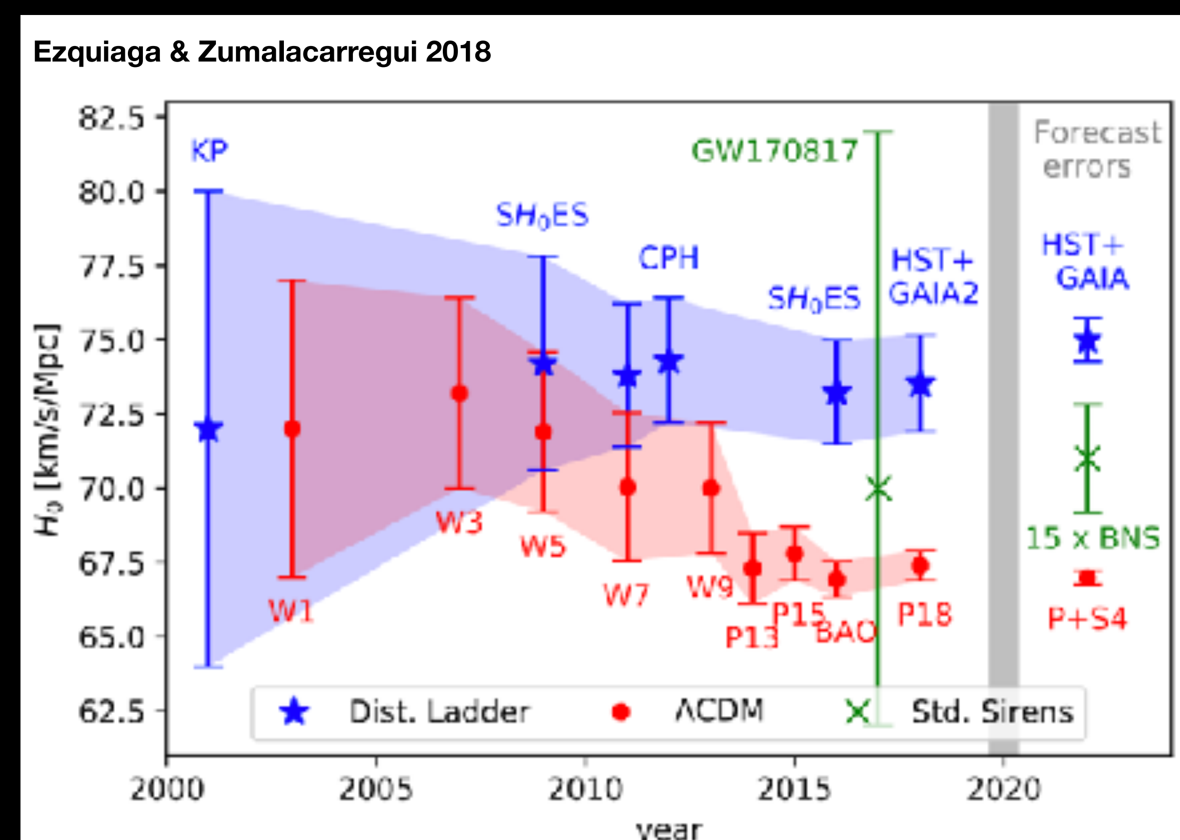
Blinding? In Cosmology?

… Where's the point ???

Bandwagon Effect

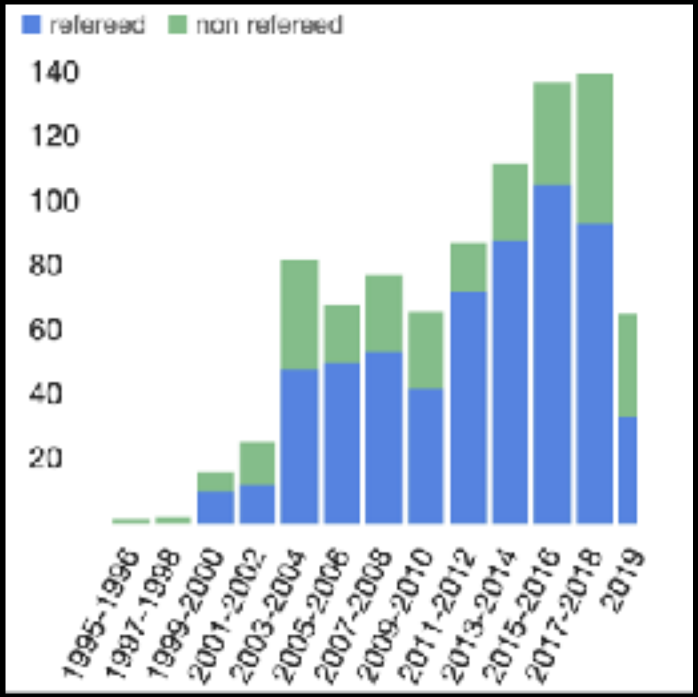


> “The question of when to stop the search for sources of error is then very important. One psychologically plausible end point is when the result ‘seems’ right”
>
> *–Allan Franklin, The Neglect of Experiment*

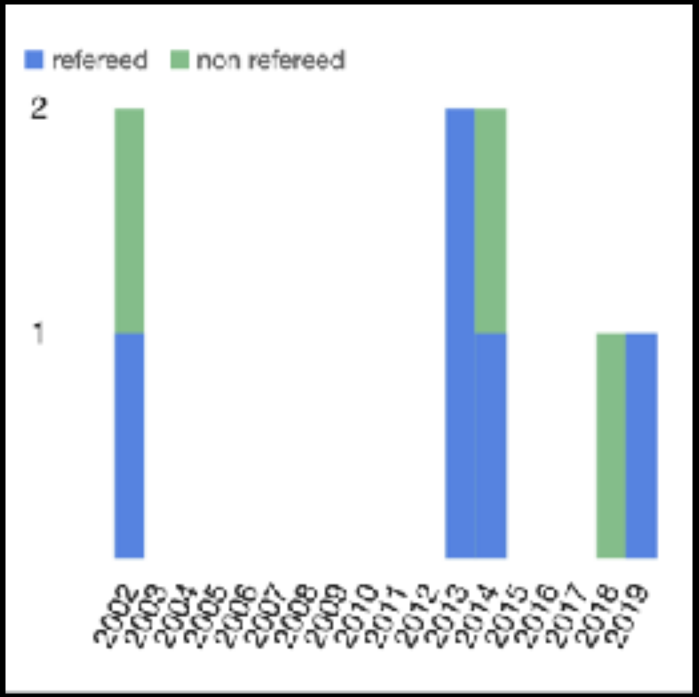


> “Although each experiment was honestly made, they were, except for the first, conducted in light of previous results.”
>
> *–Allan Franklin, The Neglect of Experiment*

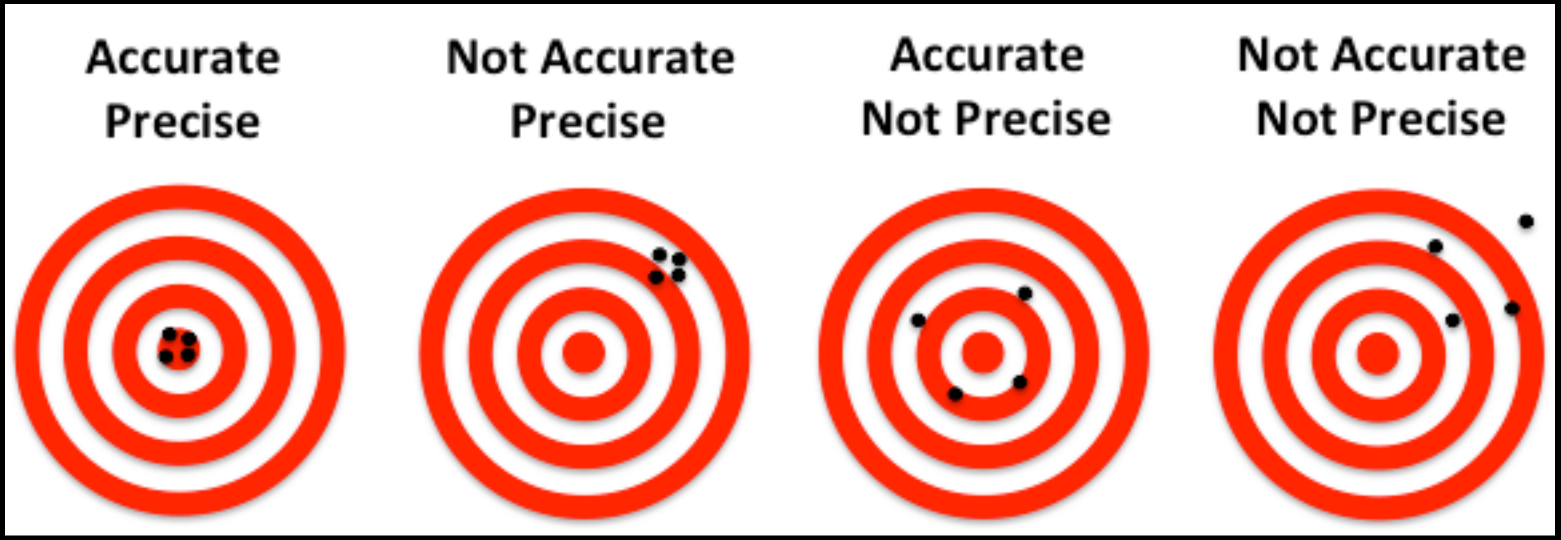
Precision vs Accuracy



“Era of Precision Cosmology”



“Era of Accurate Cosmology”



Does blinding help us to enter a new era in cosmology?

Outline

Part 1: BAO in the CMB

Part 2: Blinding BAO

- Alcock Paczyinski (AP) Effect
- Main Idea
- Test on Mocks
- Results

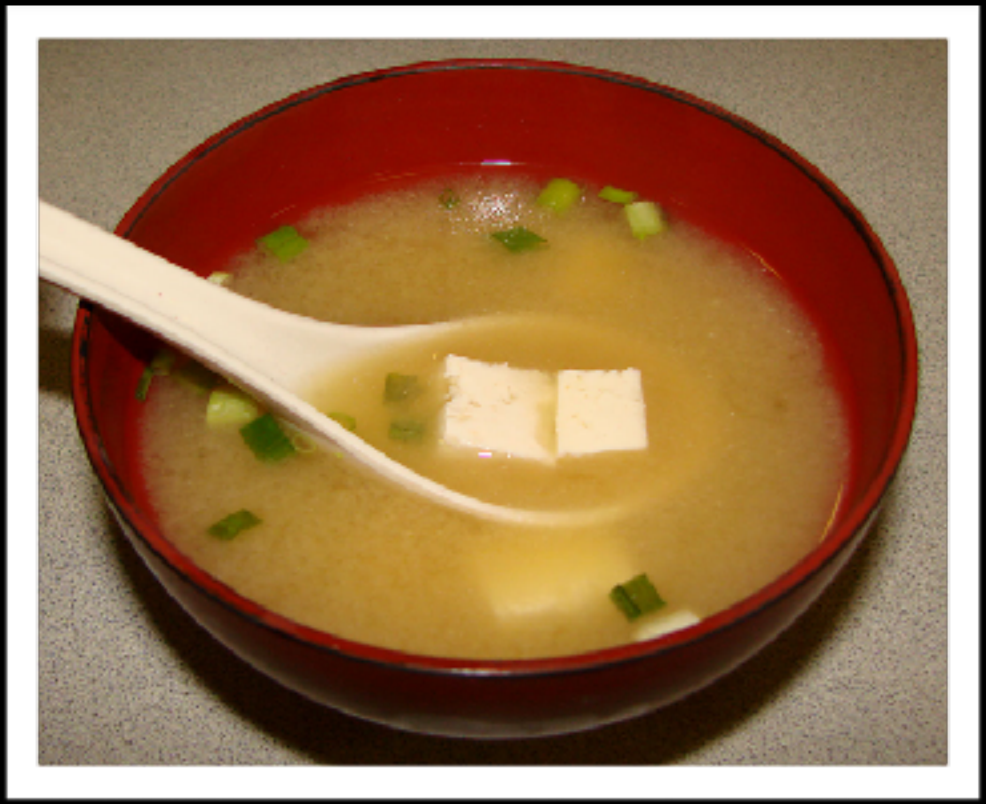
Part 3: Blinding RSD

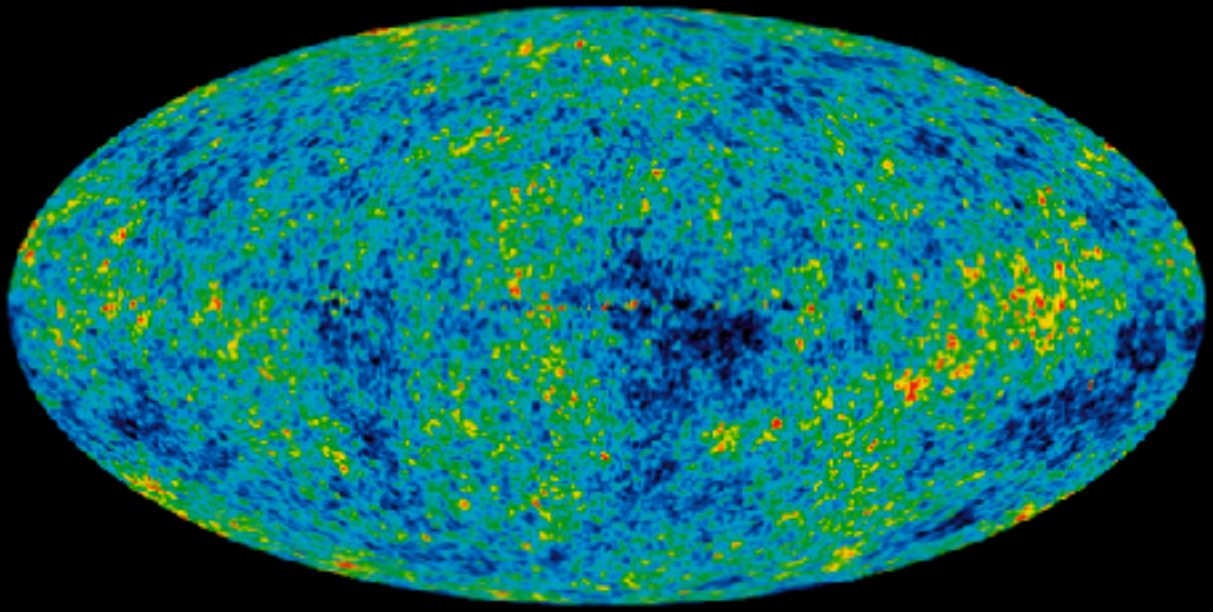
- Redshift Space Distortions (RSD)
- Reconstruction
- Main idea
- Outlook

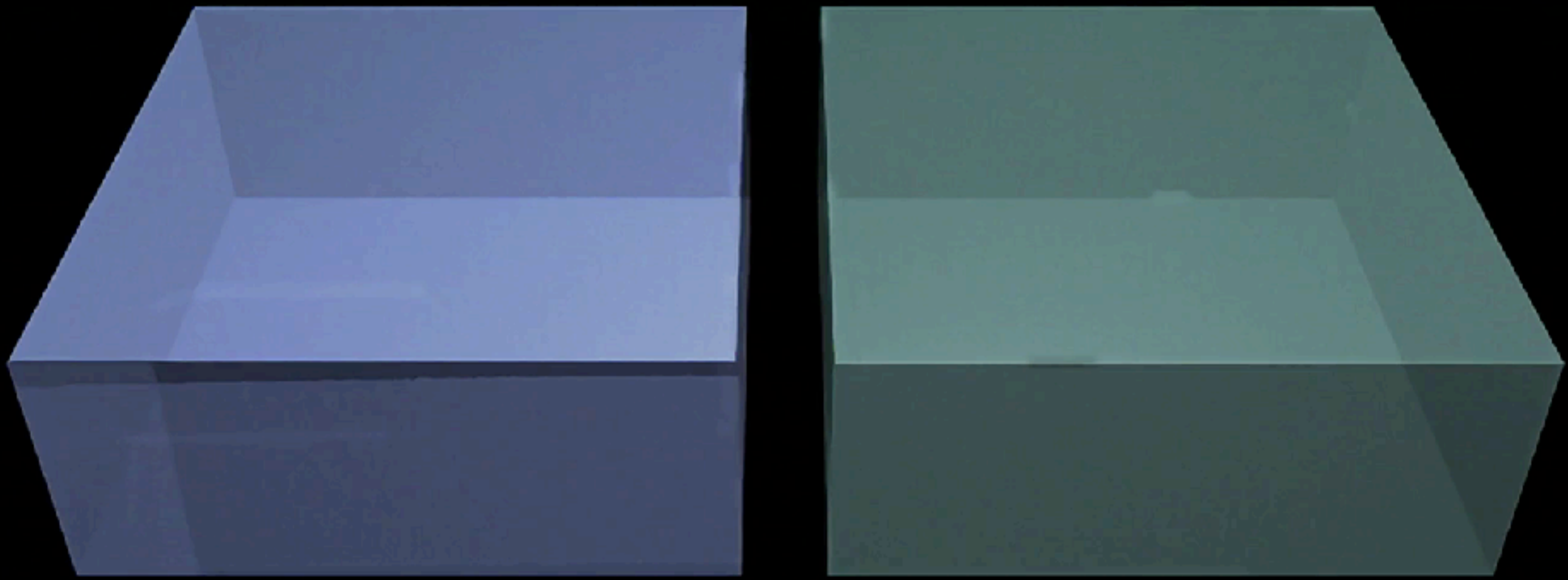
Part 1: BAO in the CMB

"The early universe was like a Miso-soup"

–Eiichiro Komatsu







credits: Eiichiro Komatsu

Baryon Acoustic Oscillations (BAO)

Early Universe:
Tightly coupled
baryon-photon-fluid

Initial perturbations propagate as sound waves until the end of radiation drag. Sound horizon:

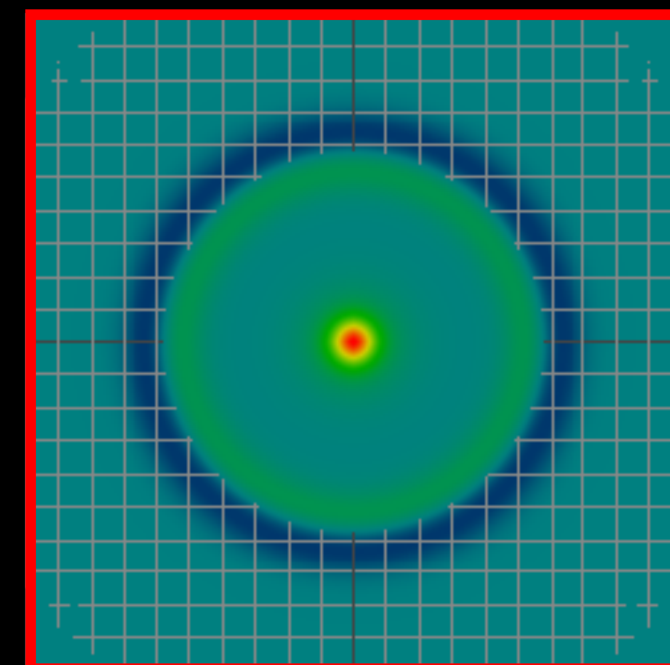
$$r_s = \int_{z_d}^{z_{ini}} \frac{c_s dz}{H(z, \Omega)}$$

Animations obtained with CLASS RealSpaceInterface for

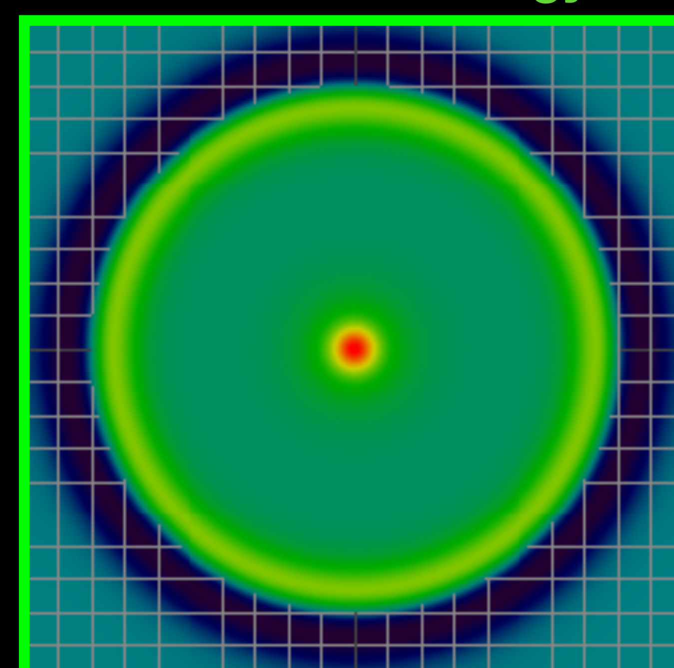
$$z_{ini} = 10^{13} \longrightarrow z_{dec} = 1089$$

Higher Matter Density

rs ↓

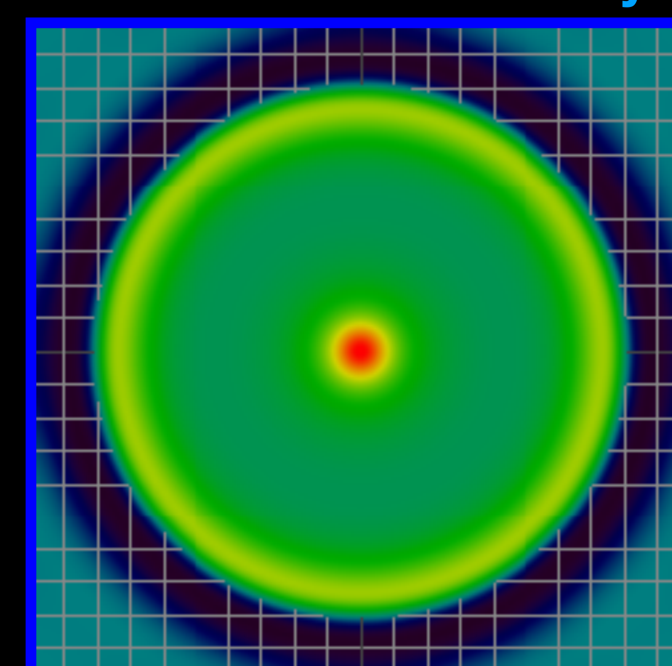


Planck Cosmology

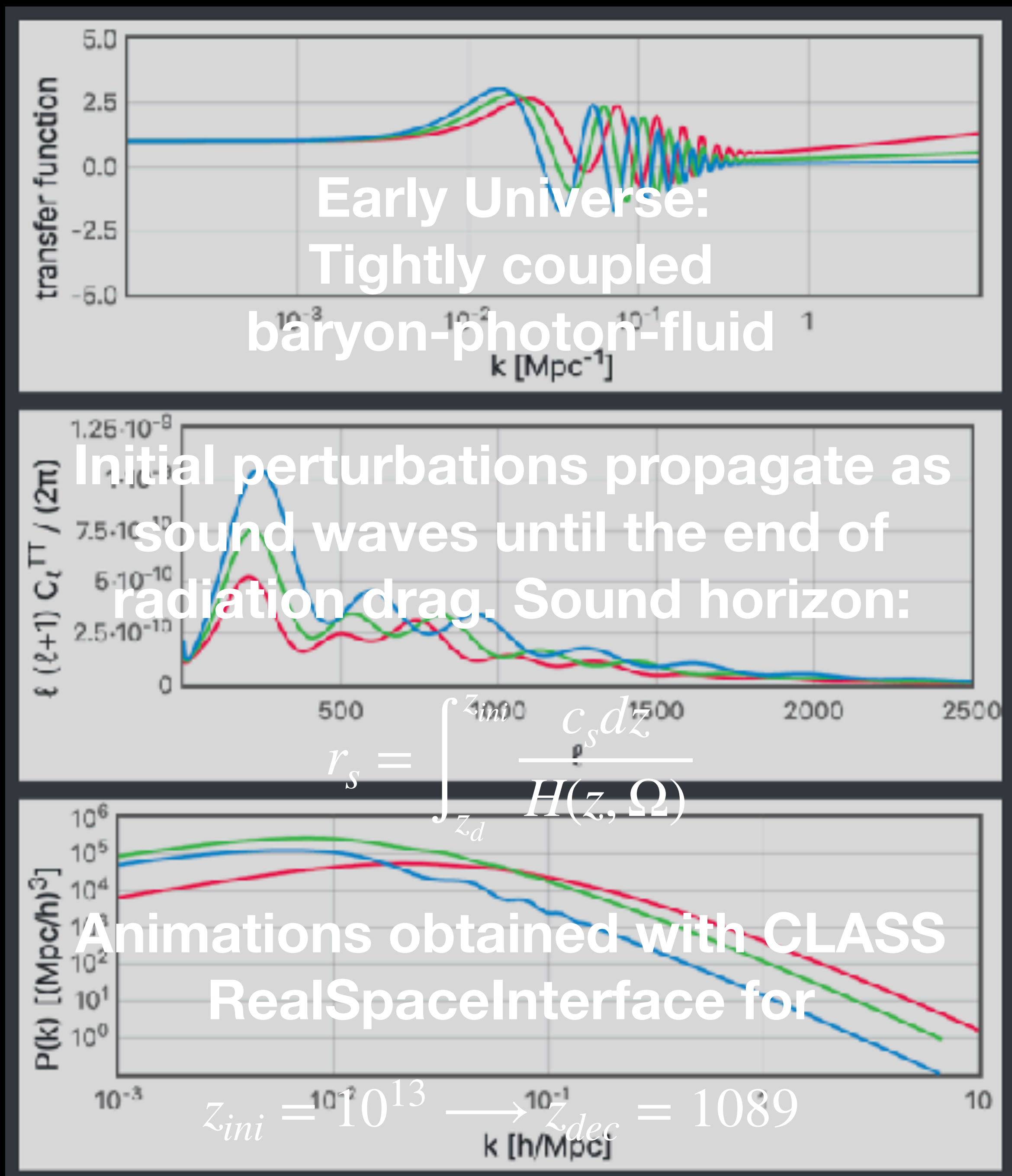


Lower Matter Density

rs ↑



BAO after Inflation



Early Universe: Tightly coupled baryon-photon-fluid

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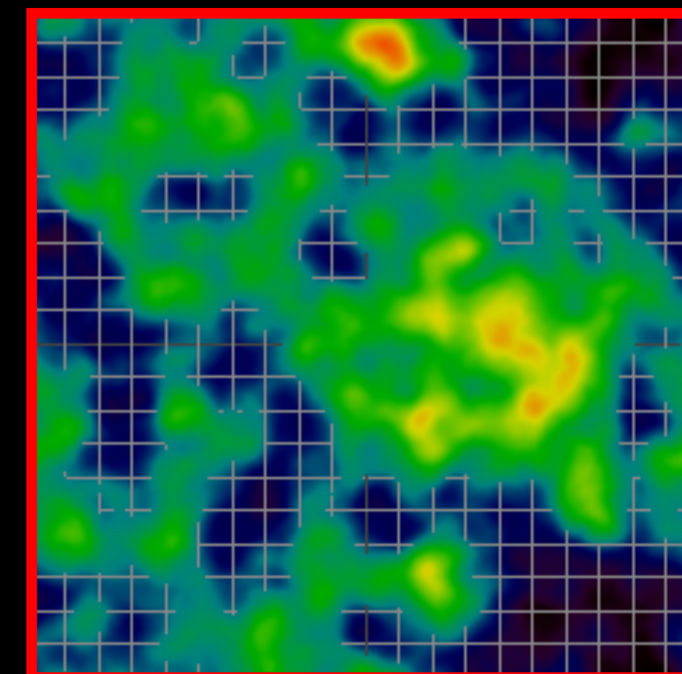

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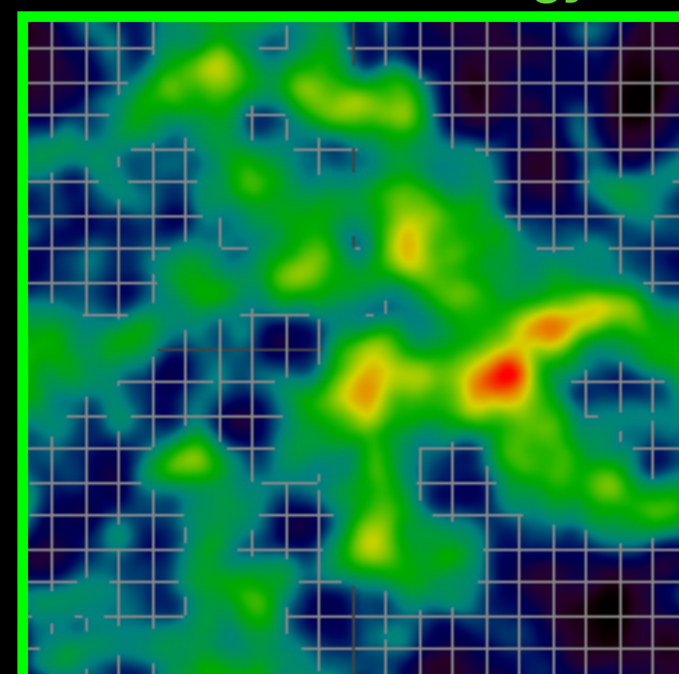
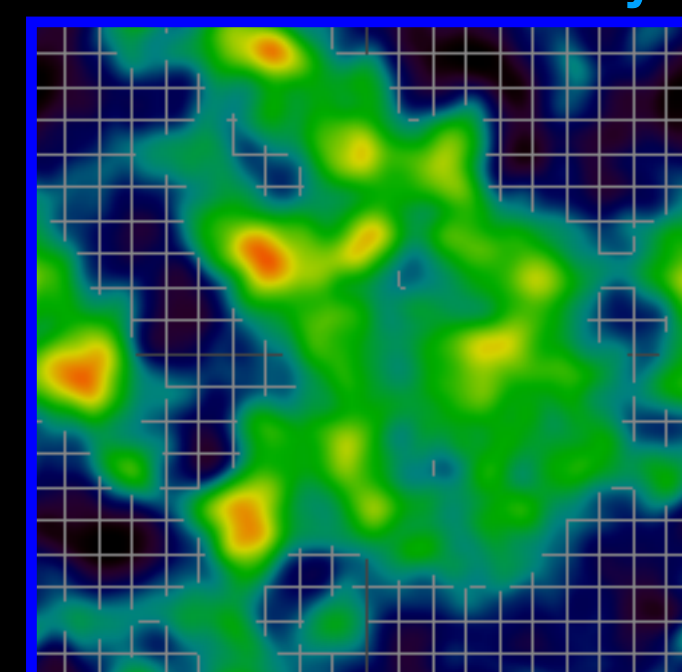
Planck Cosmology



Lower Matter Density



rs ↑

Back to the Miso soup…

Early Universe

Universe at decoupling

Late Universe

Part 2: Blinding BAO

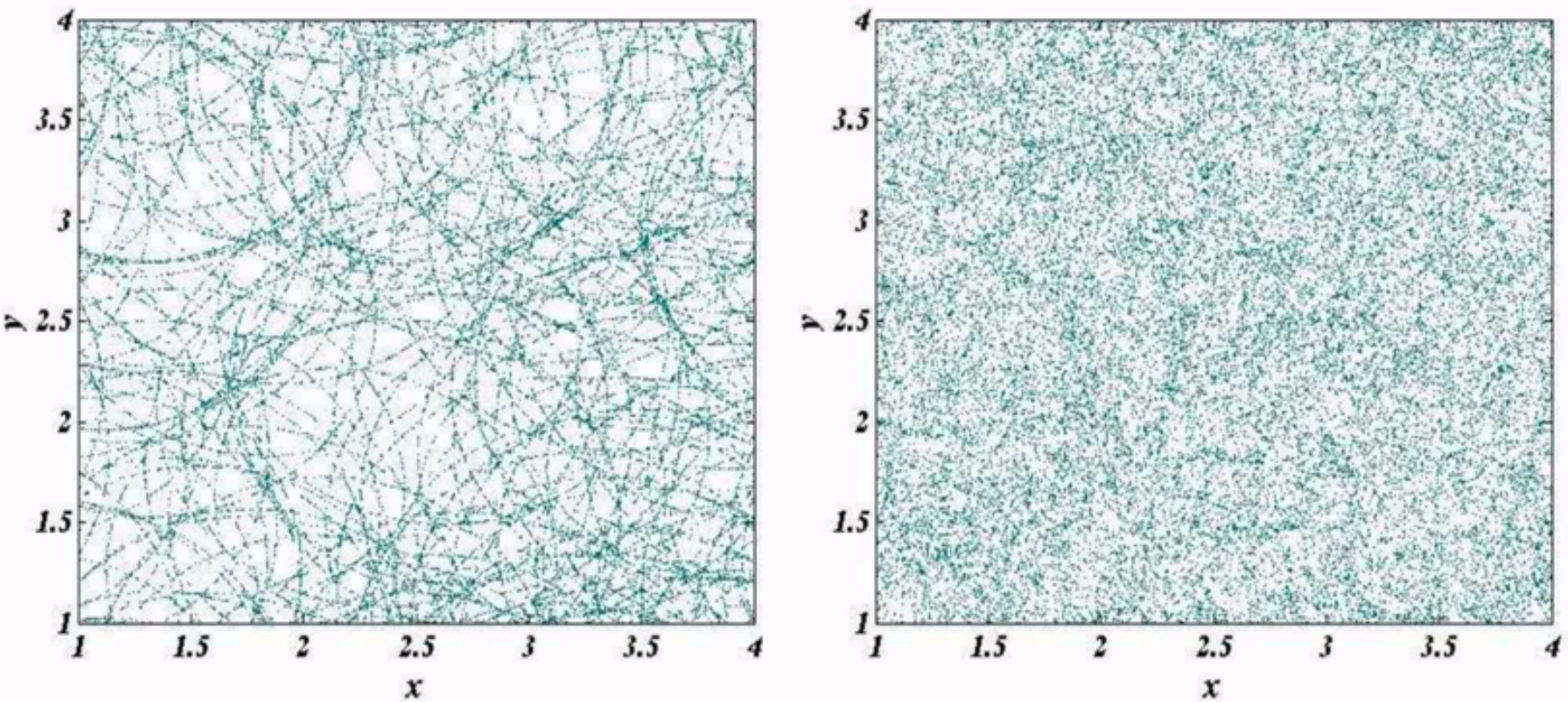


Fig. 1.5. Rings of power superposed. Schematic galaxy distribution formed by placing the galaxies on rings of the same characteristic radius L. The preferred radial scale is clearly visible in the left hand panel with many galaxies per ring. The right hand panel shows a more realistic scenario - with many rings and relatively few galaxies per ring, implying that the preferred scale can only be recovered statistically.

Basset and Hlozek, 2009

Main idea: Mimick AP

Fiducial Cosmology

$$\mathbf{\Omega}^{\mathrm{fid}} = \{\Omega_{\mathrm{m}}, \Omega_{\mathrm{b}}, H_0, \sigma_8, n_s, w\}$$

Two options for catalog construction:

1. Invert to new blinded redshifts
2. Stick with blinded distances

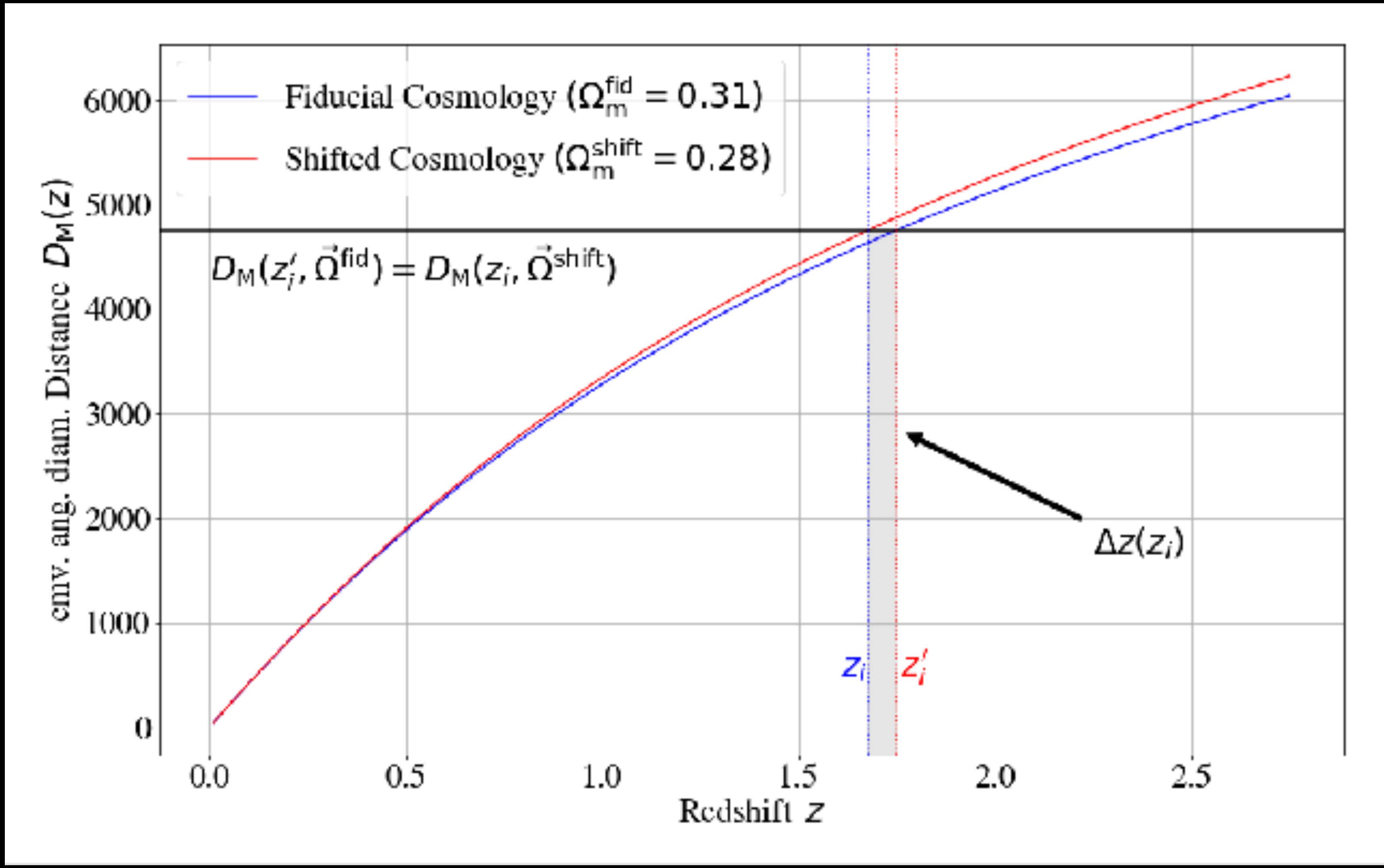
Shifted Cosmology

$$\mathbf{\Omega}^{\mathrm{shift}} = \mathbf{\Omega}^{\mathrm{fid}} + \mathbf{\Delta\Omega}$$

Transformation

$$z_i \xrightarrow{\mathbf{\Omega}^{\mathrm{shift}}} D_{\mathrm{M},i} \xrightarrow{\mathbf{\Omega}^{\mathrm{fid}}} z_i'$$

with $\quad z_i' = z_i + \Delta z$



Impact on BAO shift parameters

Fiducial:

$$\alpha_\perp = \frac{D_M\, r_d^{\rm fid}}{D_M^{\rm fid}\, r_d} \qquad \alpha_\parallel = \frac{H^{\rm fid}\, r_d^{\rm fid}}{H\, r_d}$$

Shifted:

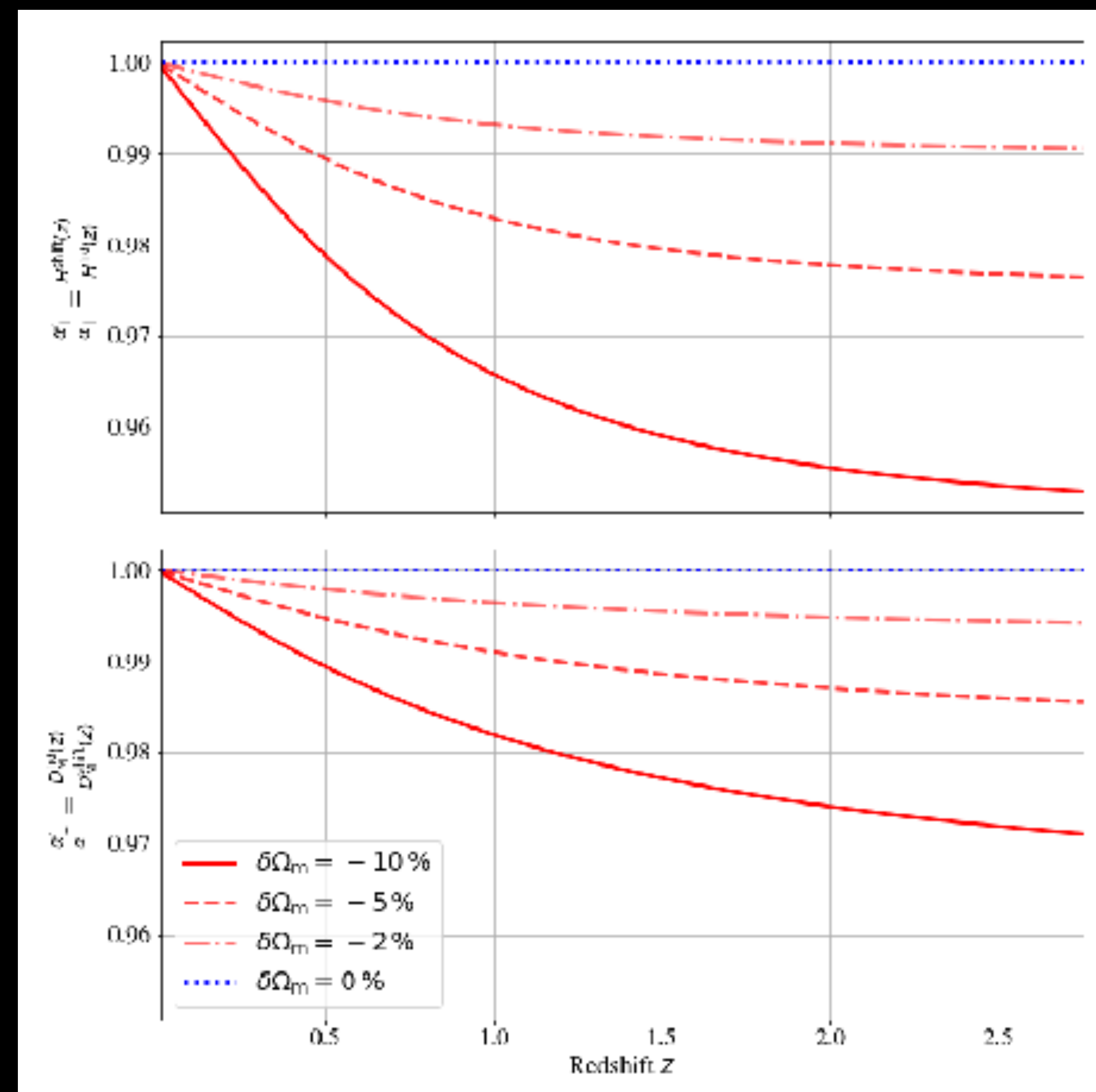
$$\alpha_\perp^{\rm shift} = \frac{D_M\, r_d^{\rm shift}}{D_M^{\rm shift}\, r_d} \qquad \alpha_\parallel^{\rm shift} = \frac{H^{\rm shift}\, r_d^{\rm shift}}{H\, r_d}$$

Blinded:

$$\alpha'_\perp = \frac{D_M r_d^{\rm fid}}{D_M^{\rm shift} r_d} \qquad \alpha'_\parallel = \frac{H^{\rm shift}\, r_d^{\rm fid}}{H\, r_d}$$

Ratio:

$$\frac{\alpha'_\perp}{\alpha_\perp} = \frac{D_M^{\rm fid}}{D_M^{\rm shift}} \qquad \frac{\alpha'_\parallel}{\alpha_\parallel} = \frac{H^{\rm shift}}{H^{\rm fid}}$$



Test on Mocks: Setup

- Patchy Mocks: 2048 realisations of CMASS and LOWZ for North and South each

- Original and fiducial cosmologies:

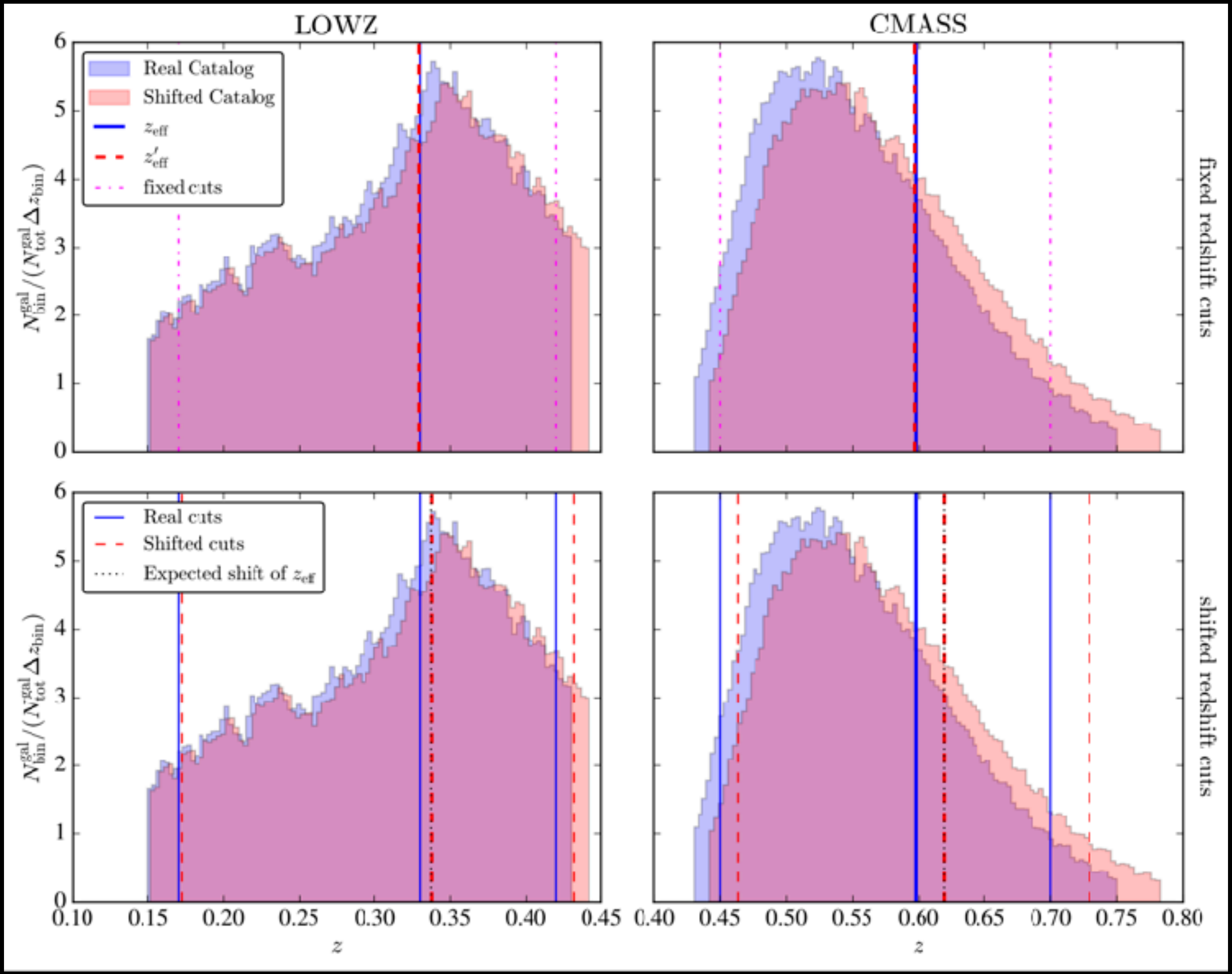
Parameters	Patchy	Fiducial
Ω	0.307115	0.31
w	-1.0	-1.0

- Blinded Cosmologies are obtained from varying the fiducial (Ω, w) by +/- 5%, 10%, 20% each

- From the original and blinded realisations we measure

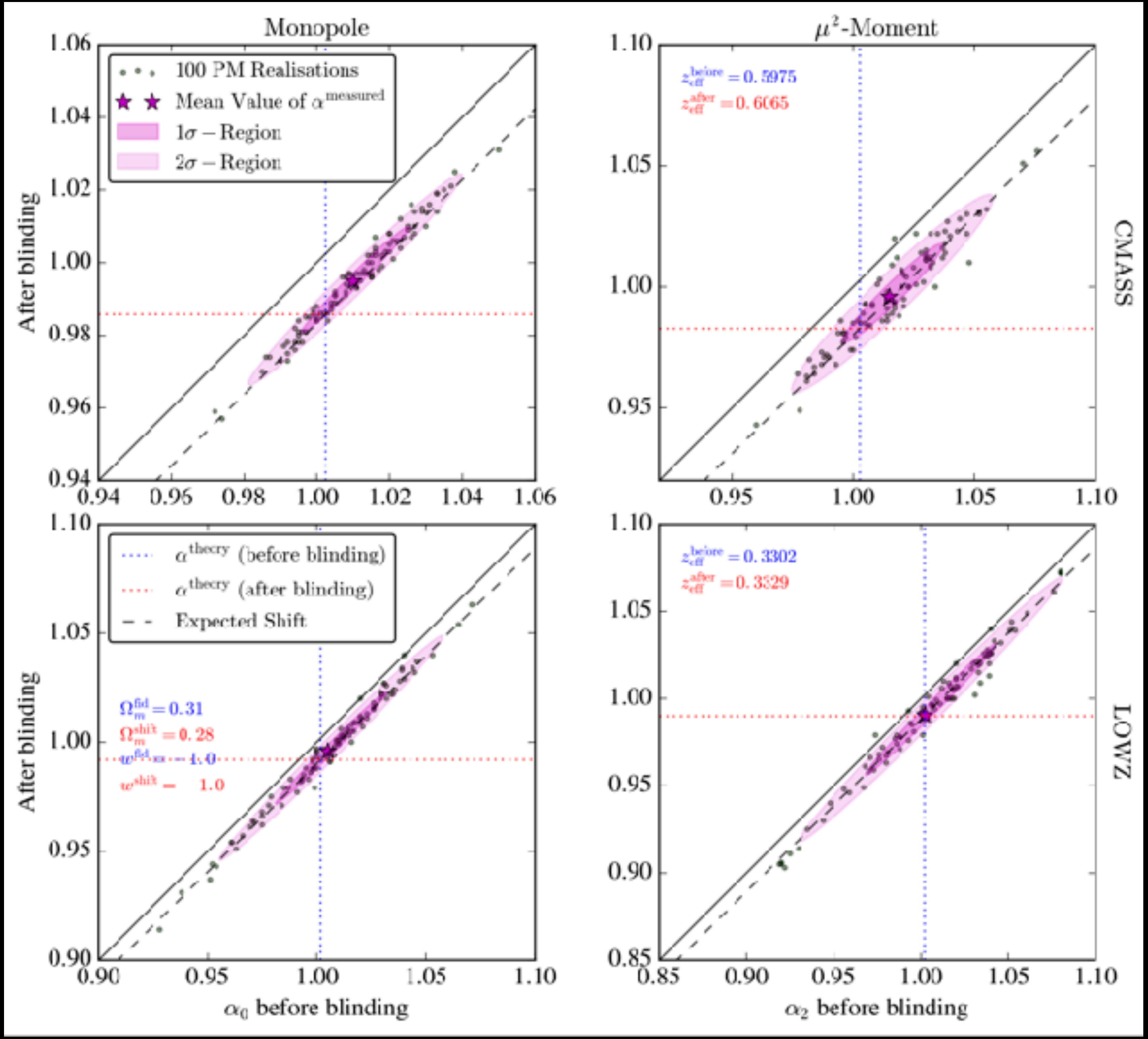
- $\alpha_0 = \alpha_\perp^{2/3}\alpha_\parallel^{1/3}$ $\alpha_2 = \alpha_\perp^{2/5}\alpha_\parallel^{3/5}$

Test on Mocks: The n(z) distribution



Results: Compare diff. Cut methods

Fixed Distance Cuts



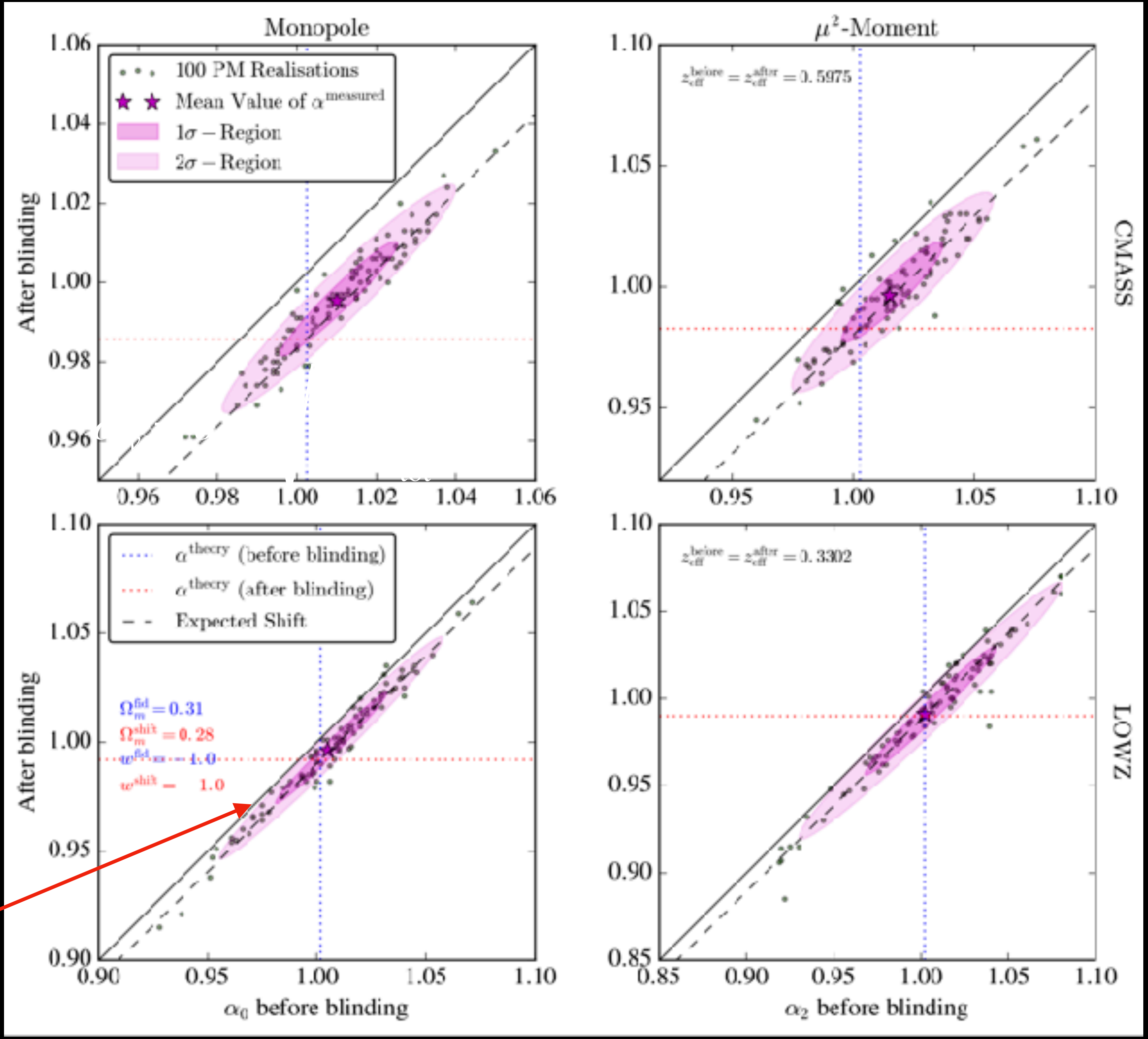
Results: Compare diff. Cut methods

Fixed Redshift Cuts

"Cosmic Variance" effect → Broadening

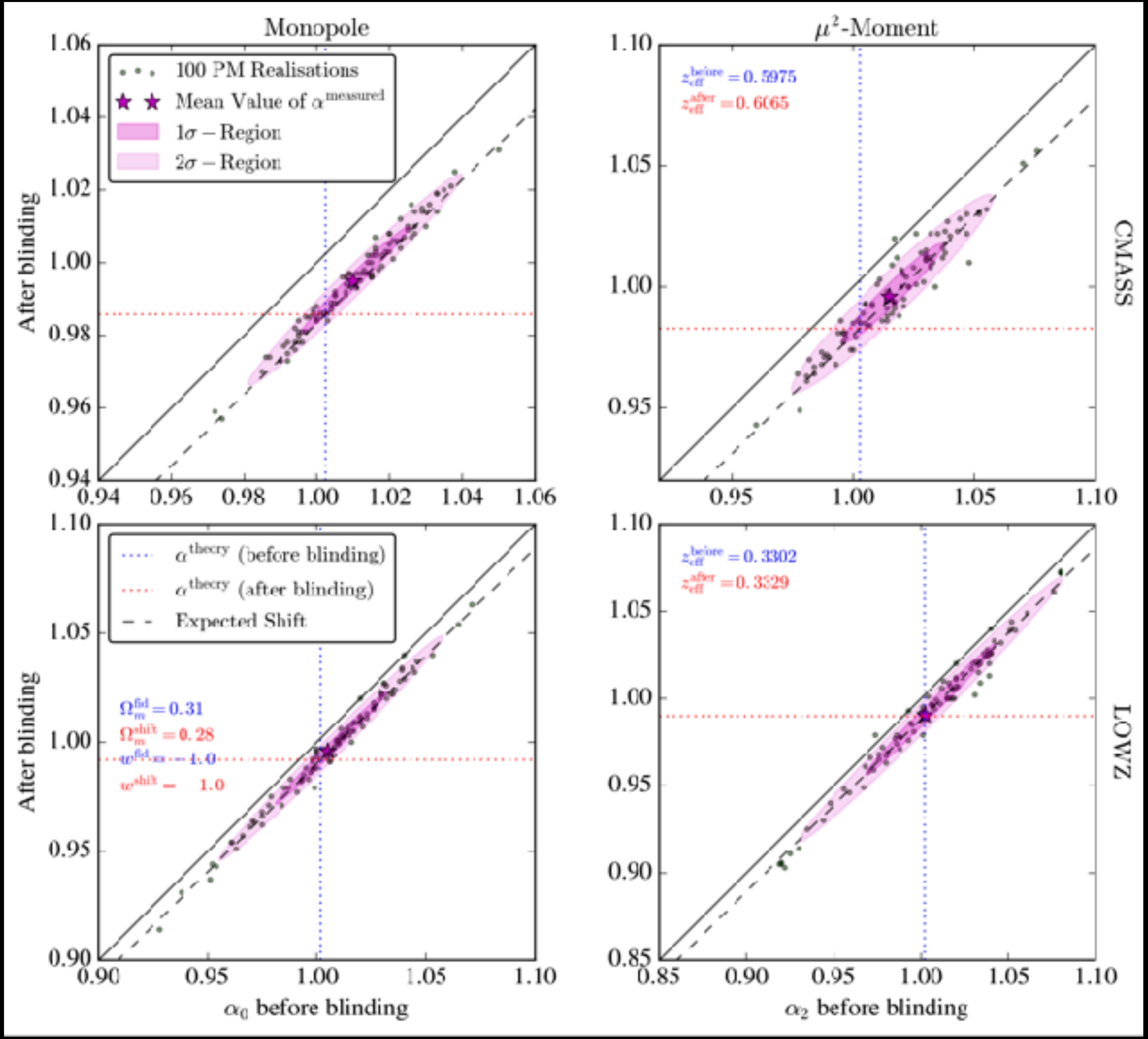
$$\sigma_{cv} = \sigma_{sv} \cdot \sqrt{\frac{N_{in} + N_{out}}{N_{tot}}}$$

$$\sigma_{cv}^{obs} = 0.0033$$
$$\sigma_{cv}^{theo} = 0.0036$$



Results: Compare diff. blinded Cosmologies

Varying only Ω

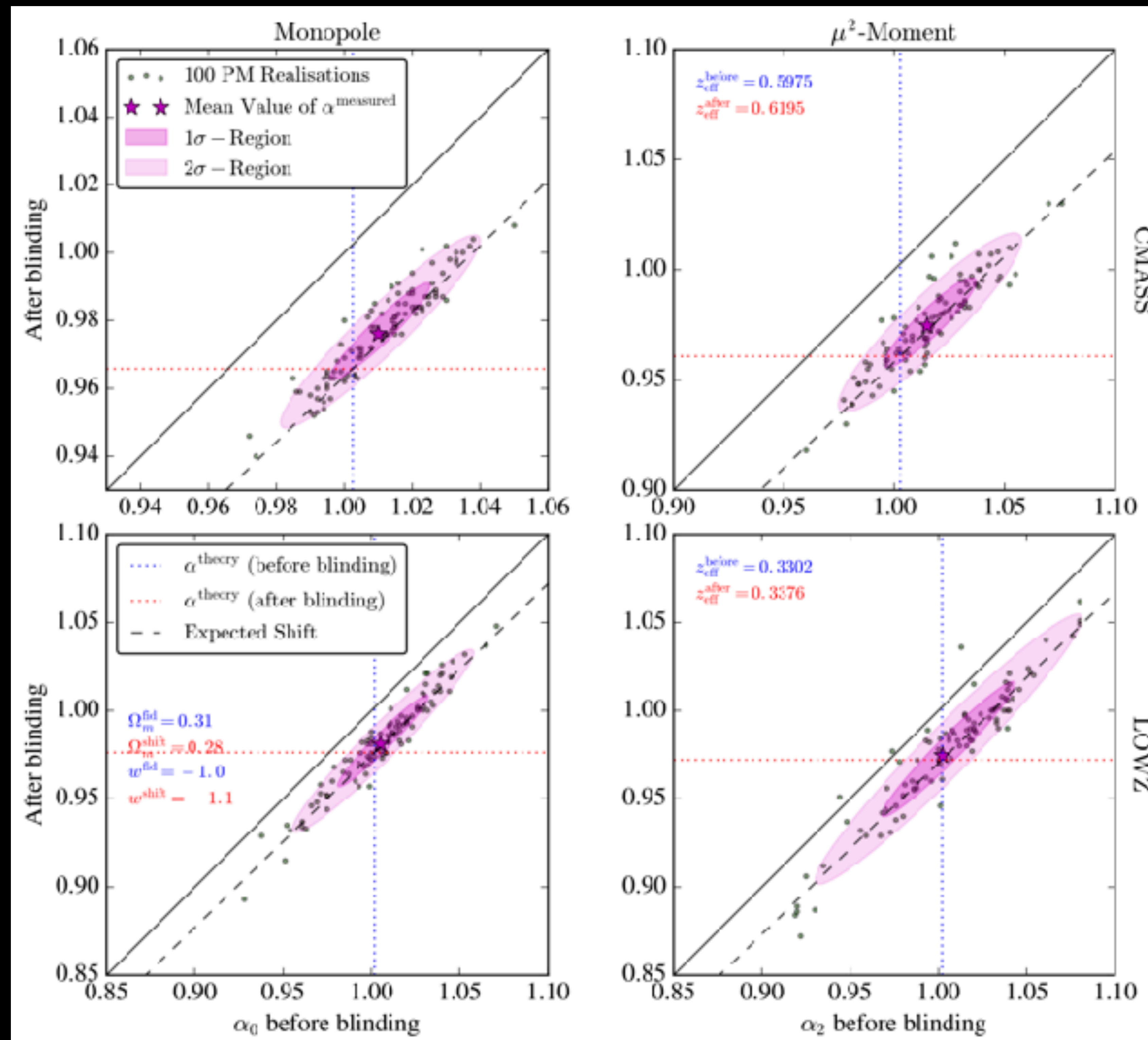


Results: Compare diff. blinded Cosmologies

Varying (Ω, w)

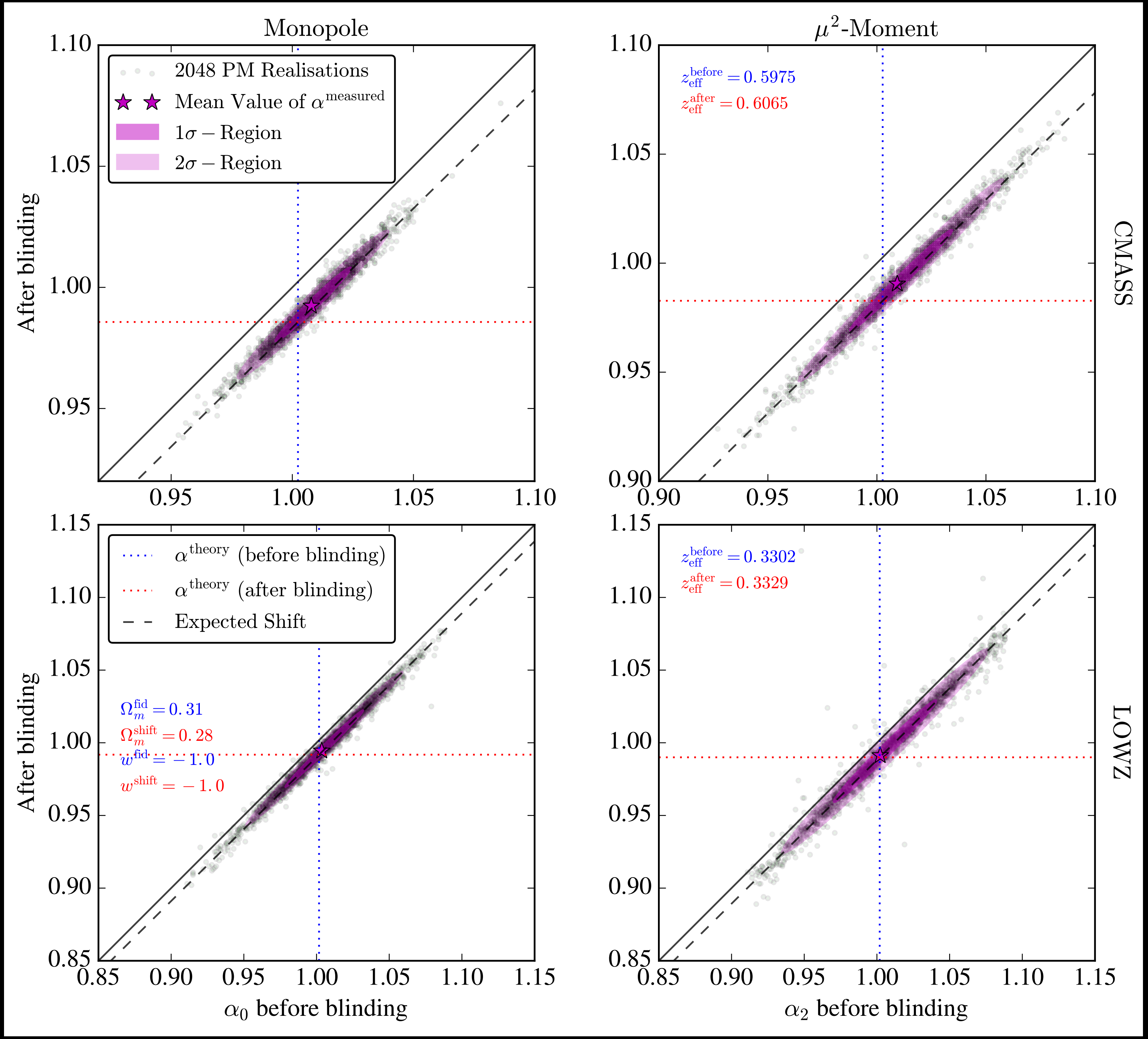
Broadening due to increased change in volume?

Can be parameterised by V or Veff?



Results: Compare diff. Covmats

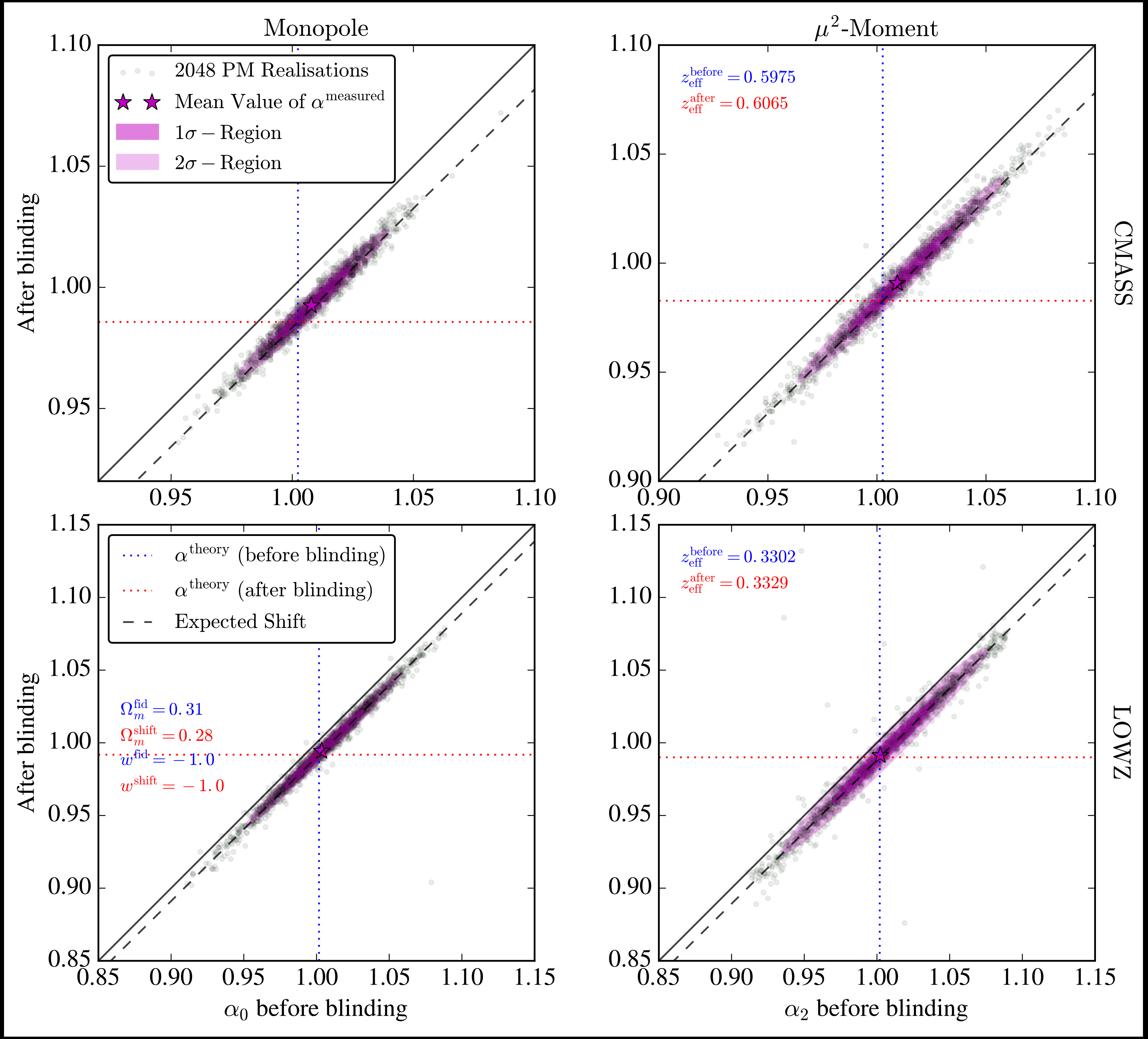
Using the corresponding covmats



Results: Compare diff. Covmats

Using the same covmats

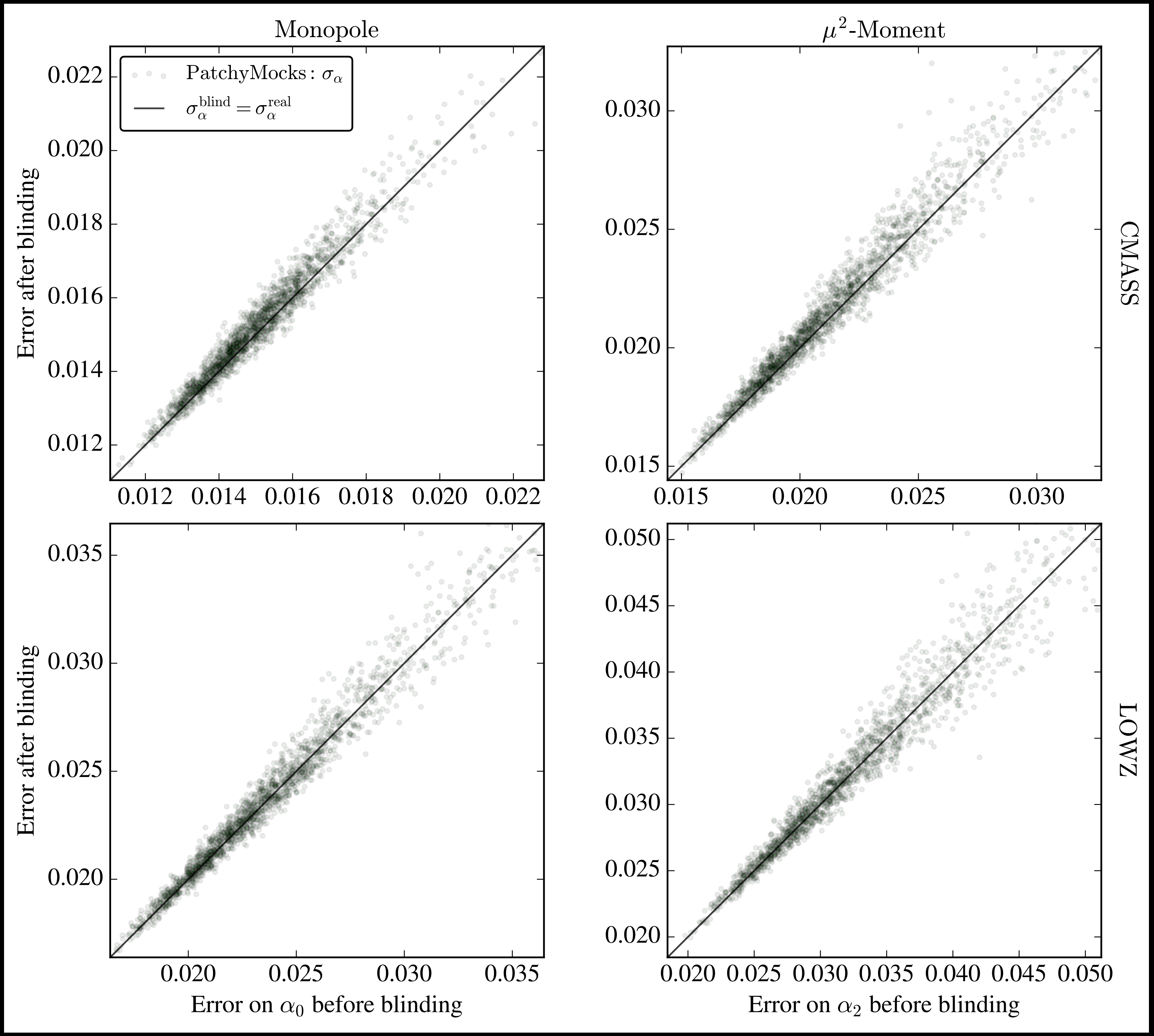
More outliers when using original mocks covmats for blinded mocks?



Results: Compare errors on alphas

Using the same covmats

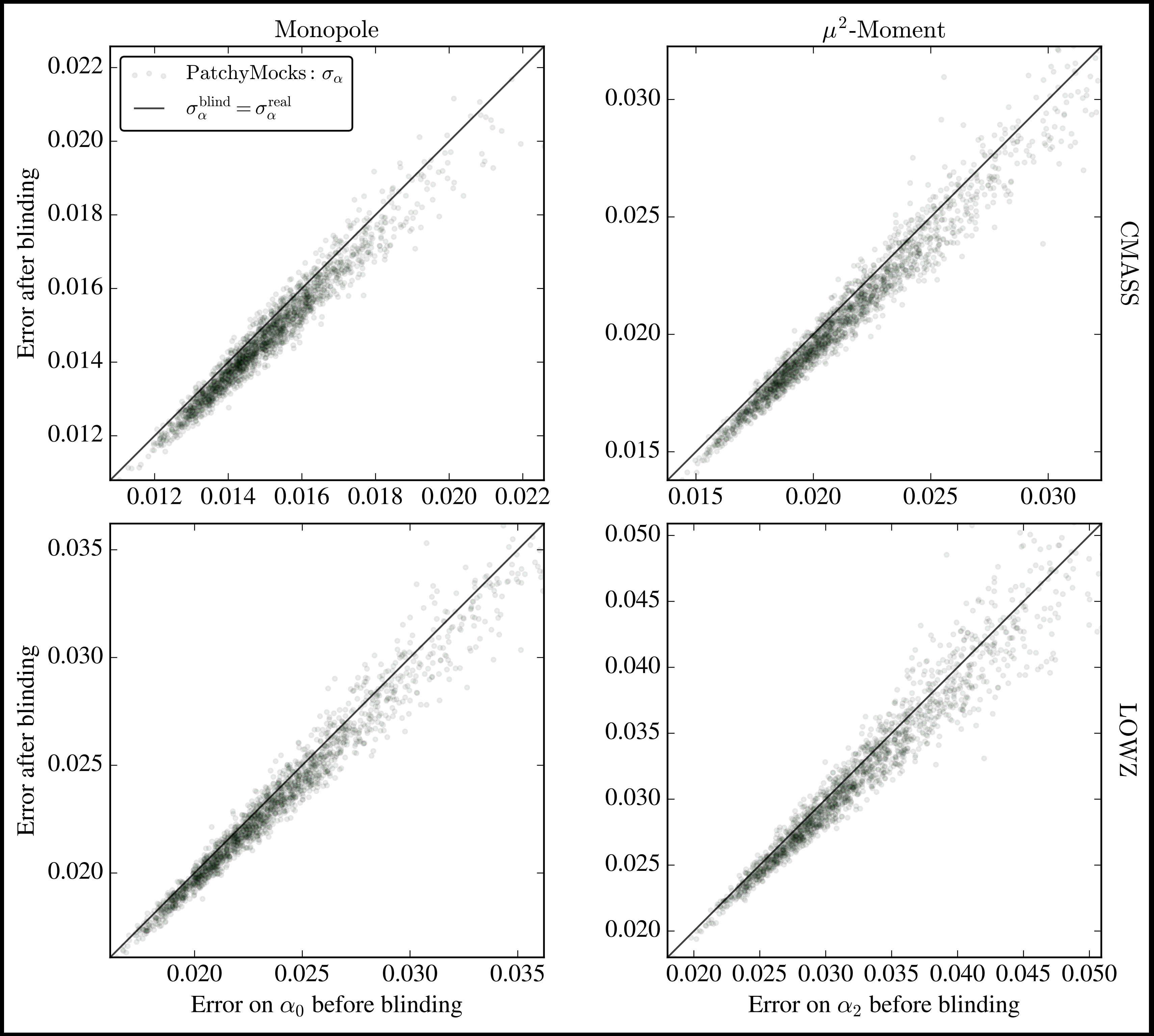
Almost perfect aligned



Results: Compare errors on alphas

Using the corresponding covmats

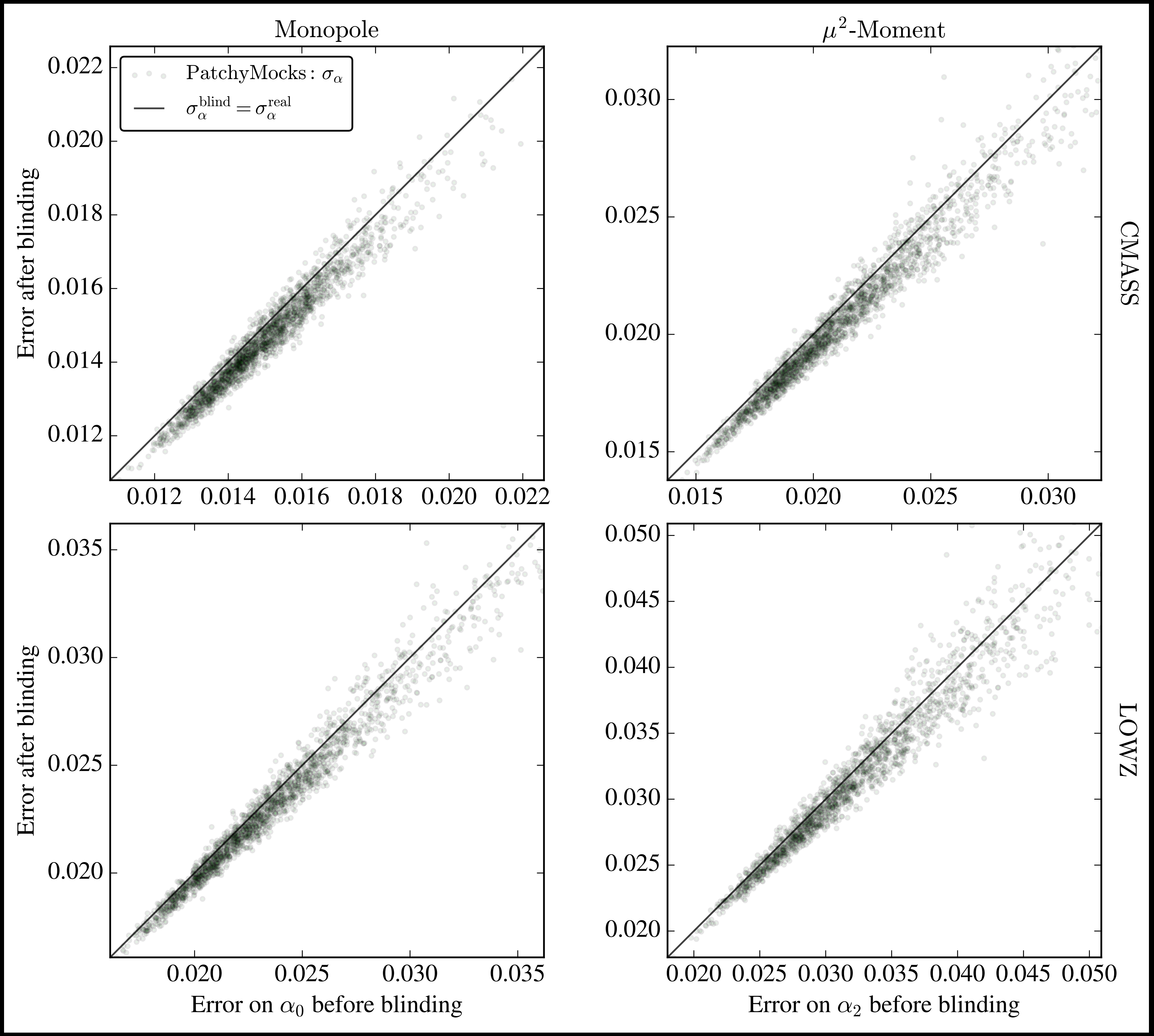
Small tilt



Results: Compare errors on alphas

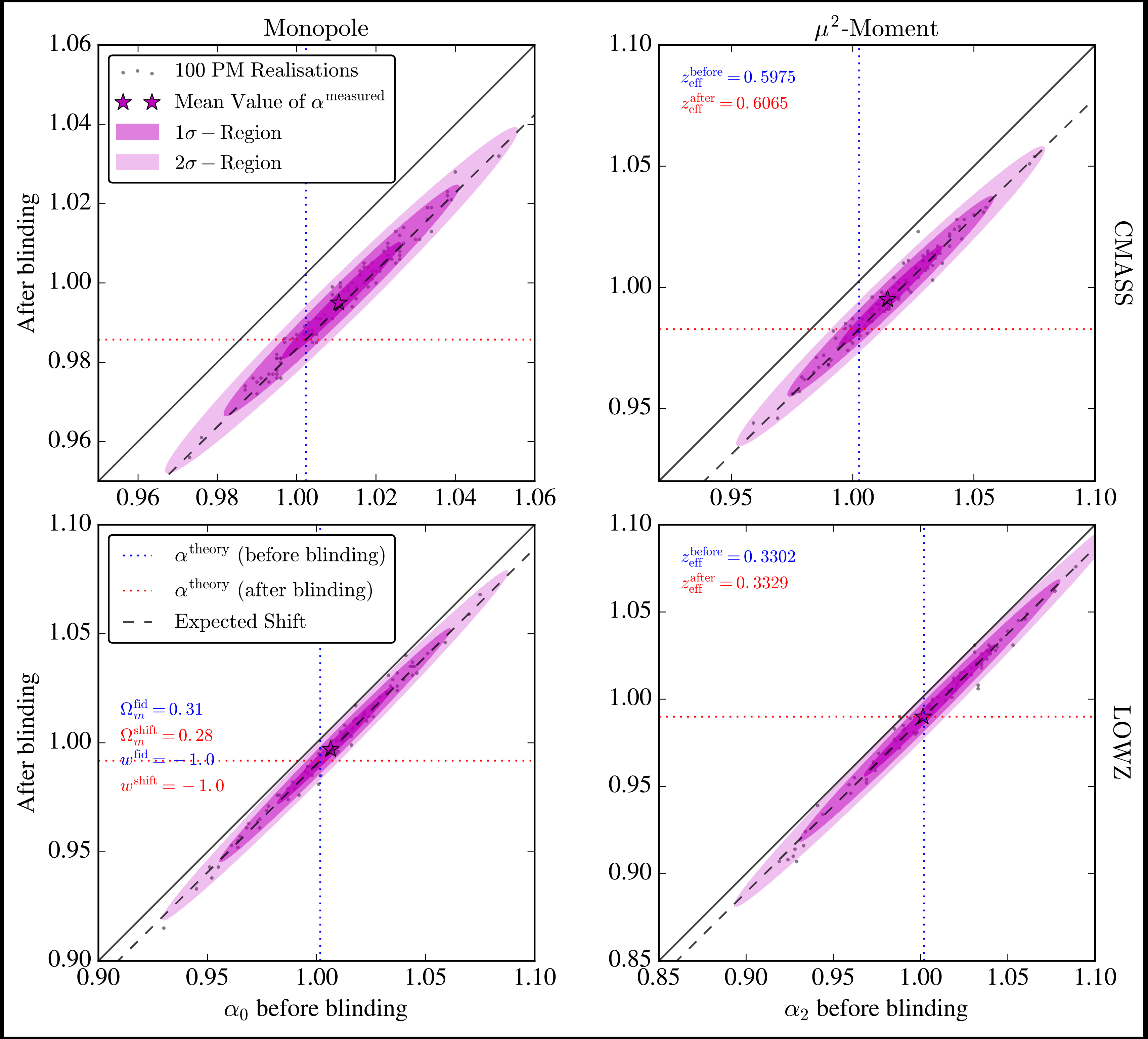
Varying also w

Bigger tilt



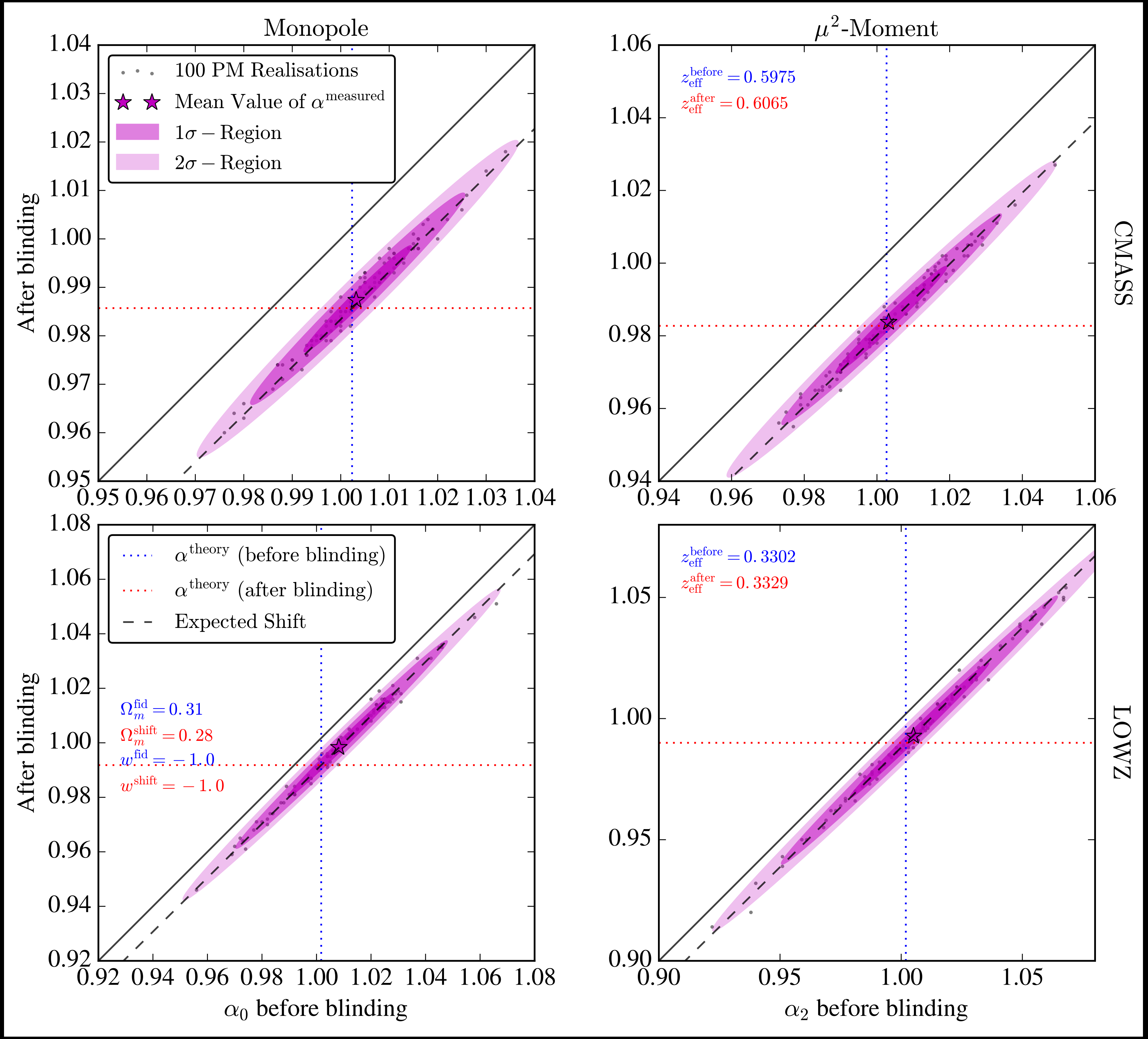
Results: Compare pre/post reconstruction

prerecon



Results: Compare pre/post reconstruction

postrecon



Time For Questions

Part 2: Blinding RSD

Reconstruction: Basics

- Lagrangian (1st order) Displacement Field:

$$\mathbf{x}(\mathbf{q}, t) = \mathbf{q} + \mathbf{\Psi}(\mathbf{q}, t)$$

$$\Big| \mathbf{\Psi} = \frac{1}{f}\mathbf{v}$$

- With growth rate:

$$f = \frac{d \ln D}{d \ln a} = (\Omega_m(z))^\gamma$$

$$\Big| \gamma = 0.55$$

- To 1st order PT , Eulerian density field is

$$\nabla \cdot \mathbf{\Psi}(\mathbf{q}, \mathbf{t}) = \delta(\mathbf{x}, t)$$

- Assuming linear bias we get in redshift space

$$\nabla \cdot \mathbf{\Psi} + \frac{f}{b} \nabla \cdot (\mathbf{\Psi} \cdot \hat{\mathbf{r}})\, \hat{\mathbf{r}} = -\frac{\delta_g}{b}$$

Reconstruction: Procedure

- Smooth density field, solve for displacement ψ, with input growth and bias (iterative procedure with FFTs, Burden et al. 2014)

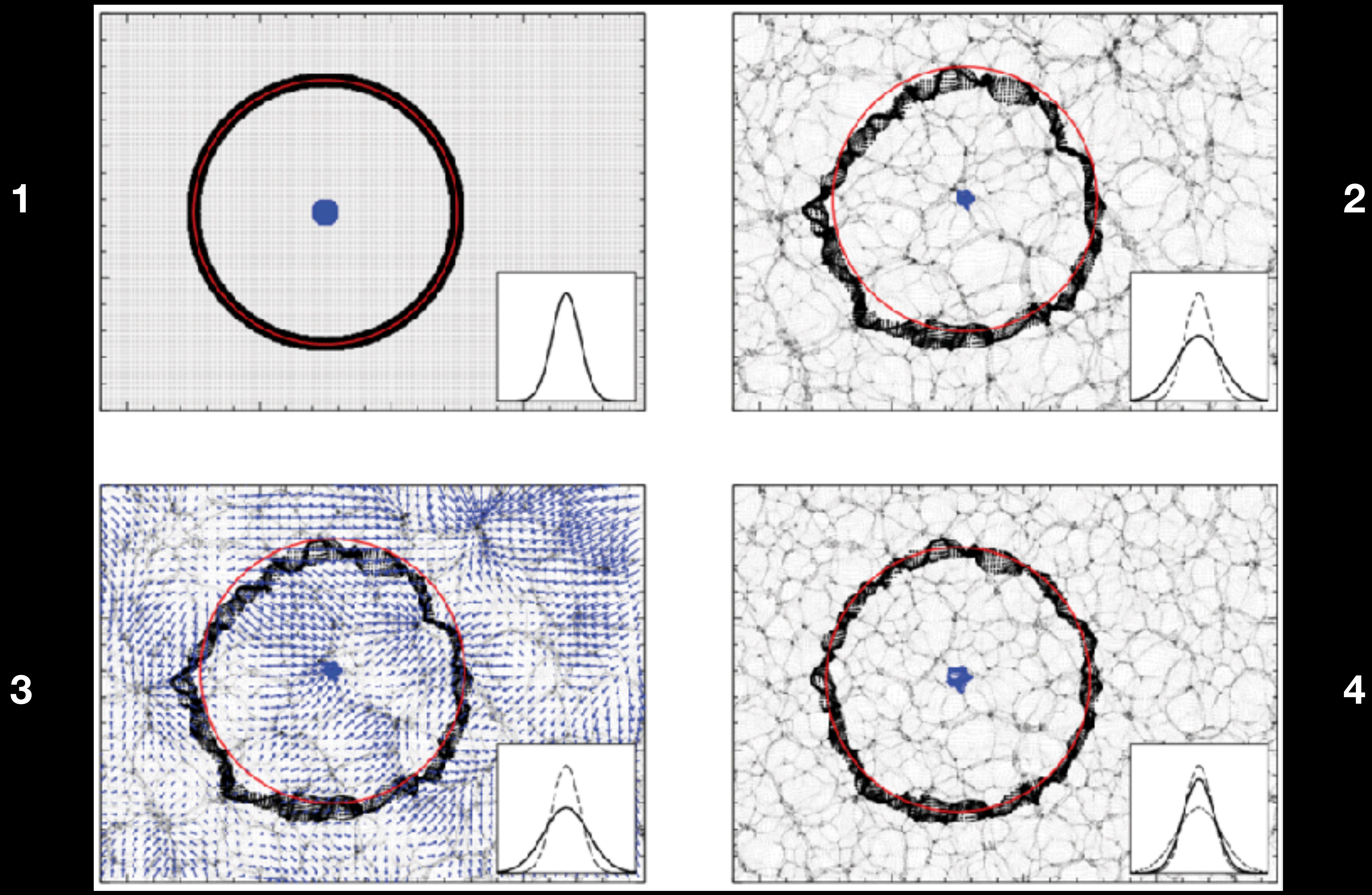
$$\nabla \cdot \mathbf{\Psi} + \frac{f}{b} \nabla \cdot (\mathbf{\Psi} \cdot \hat{\mathbf{r}})\, \hat{\mathbf{r}} = -\frac{\delta_g}{b}$$

- Shift catalog particles back by ψ+ψ(RSD) and get displaced density field (d)

$$\mathbf{x} \longrightarrow \mathbf{x} - \mathbf{\Psi} + f(\mathbf{\Psi} \cdot \hat{\mathbf{r}})\, \hat{r}$$

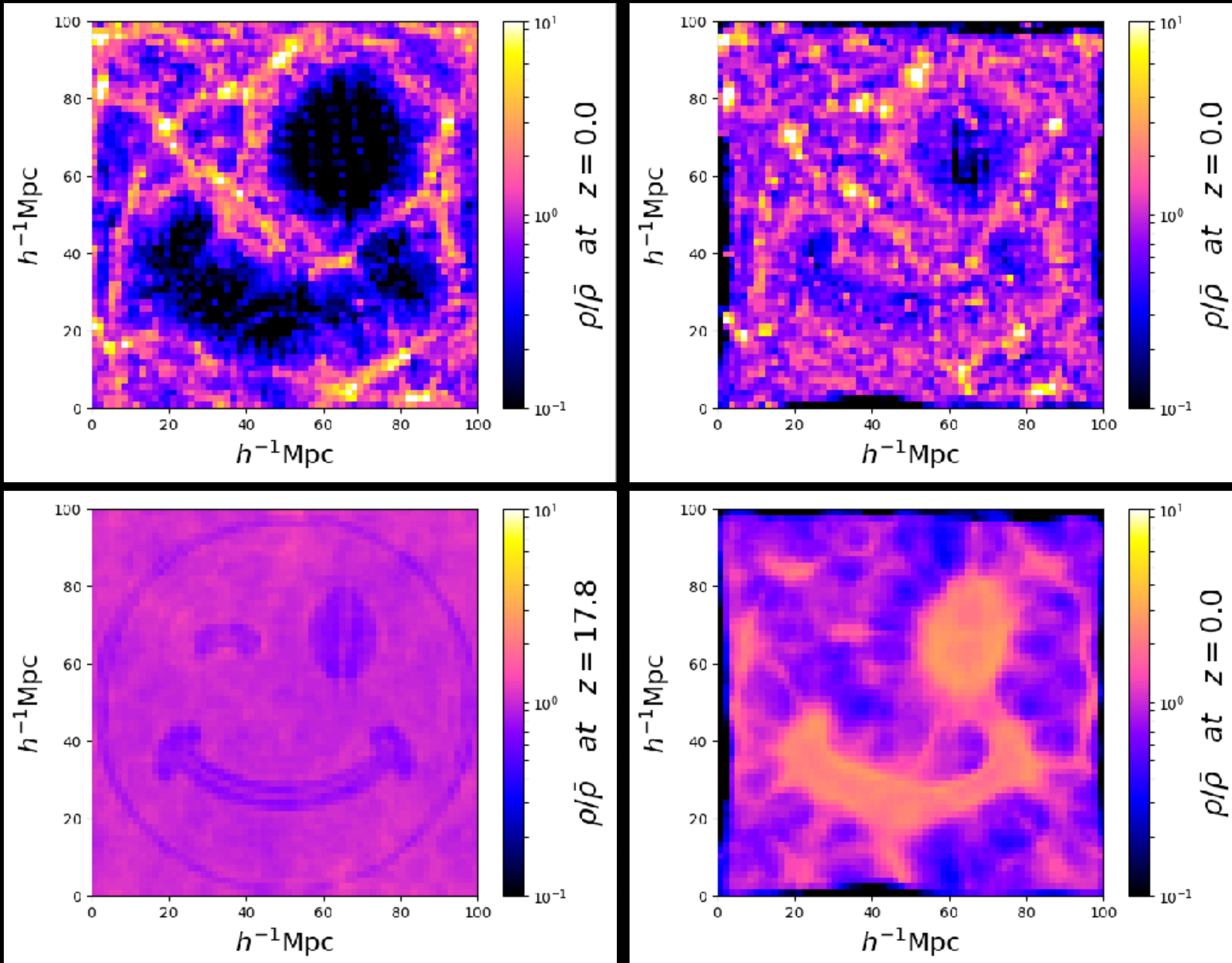
  - If evolution completely linear: $\delta_{\rm d} = 0$
- Shift random catalog by -ψ and get shifted randoms (s) field
  - If evolution completely linear: $\delta_{\rm s} = -\delta_{\rm lin}$
- Reconstructed overdensity field given by: $\delta_{\rm recon} = \delta_{\rm d} - \delta_{\rm s}$

Reconstruction: Picture



Reconstruction: Quiz

- Preparation:
  - Create weird initial conditions
  - Run Gadget2 locally
    (4 cores, 100 Mpc and 64 particles per dim., takes ~30 min
  - Perform reconstruction (with f=0, b=1) and shift field + randoms
- Rules: 4 rounds, try to guess ICs, while I show to you
  1. Gadget2 output at z=0
  2. Reconstructed field
  3. Reconstructed randoms
  4. Backwards movie



h^{-1}Mpc
$\rho/\bar{\rho}$ at $z = 0.0$
$\rho/\bar{\rho}$ at $z = 17.8$
10^{1}
10^{0}
10^{-1}
0
20
40
60
80
100

Main idea

- Option 1: As in Reconstruction, find displacement field ψ:

$$\nabla \cdot \mathbf{\Psi} + \frac{f}{b} \nabla \cdot (\mathbf{\Psi} \cdot \hat{\mathbf{r}})\, \hat{\mathbf{r}} = -\frac{\delta_g}{b}$$

- Instead of shifting galaxies back by the total displacement field ψ, use only the RSD part (along los) and add new f':

$$\mathbf{x} \longrightarrow \mathbf{x} + (f - f')\, (\mathbf{\Psi} \cdot \hat{\mathbf{r}})\, \hat{\mathbf{r}} \qquad \Big| \; f' = (\Omega_m(z))^{\gamma'}$$

- Option 2: Solve equation twice, using f and f'. Then shift by difference between the two RSD displacement fields

$$\mathbf{x} \longrightarrow \mathbf{x} - \mathbf{\Psi}_{\mathbf{RSD}} + \mathbf{\Psi}'_{\mathbf{RSD}} = \mathbf{x} - f\, (\mathbf{\Psi} \cdot \hat{\mathbf{r}})\, \hat{\mathbf{r}} - f'\, (\mathbf{\Psi}' \cdot \hat{\mathbf{r}})\, \hat{\mathbf{r}}$$

Outlook

- Test the previously mentioned 2 options on N-body simulations, which one does a better job in mimicking RSD?
- Perform BAO+RSD analysis on blinded mocks
- Combine Blinding schemes

Thank you for your attention