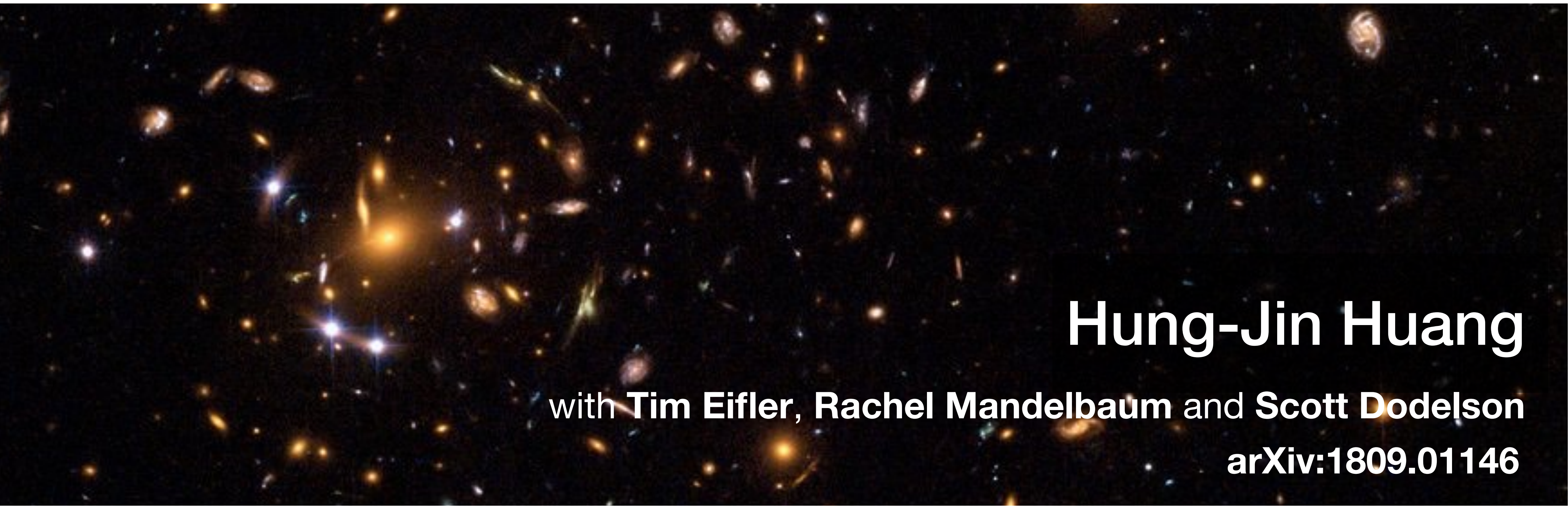
Modeling uncertainties of baryon in cosmic shear



Hung-Jin Huang

with **Tim Eifler**, **Rachel Mandelbaum** and **Scott Dodelson**

arXiv:1809.01146

BCCP accurate lensing workshop

January 15, 2019

Carnegie Mellon University
McWilliams Center for Cosmology

We rely on **gravity-only** simulations to interpret survey observables.

Convergence of P(k,z | cosmology) in DMO sims

DMO Power spectrum library

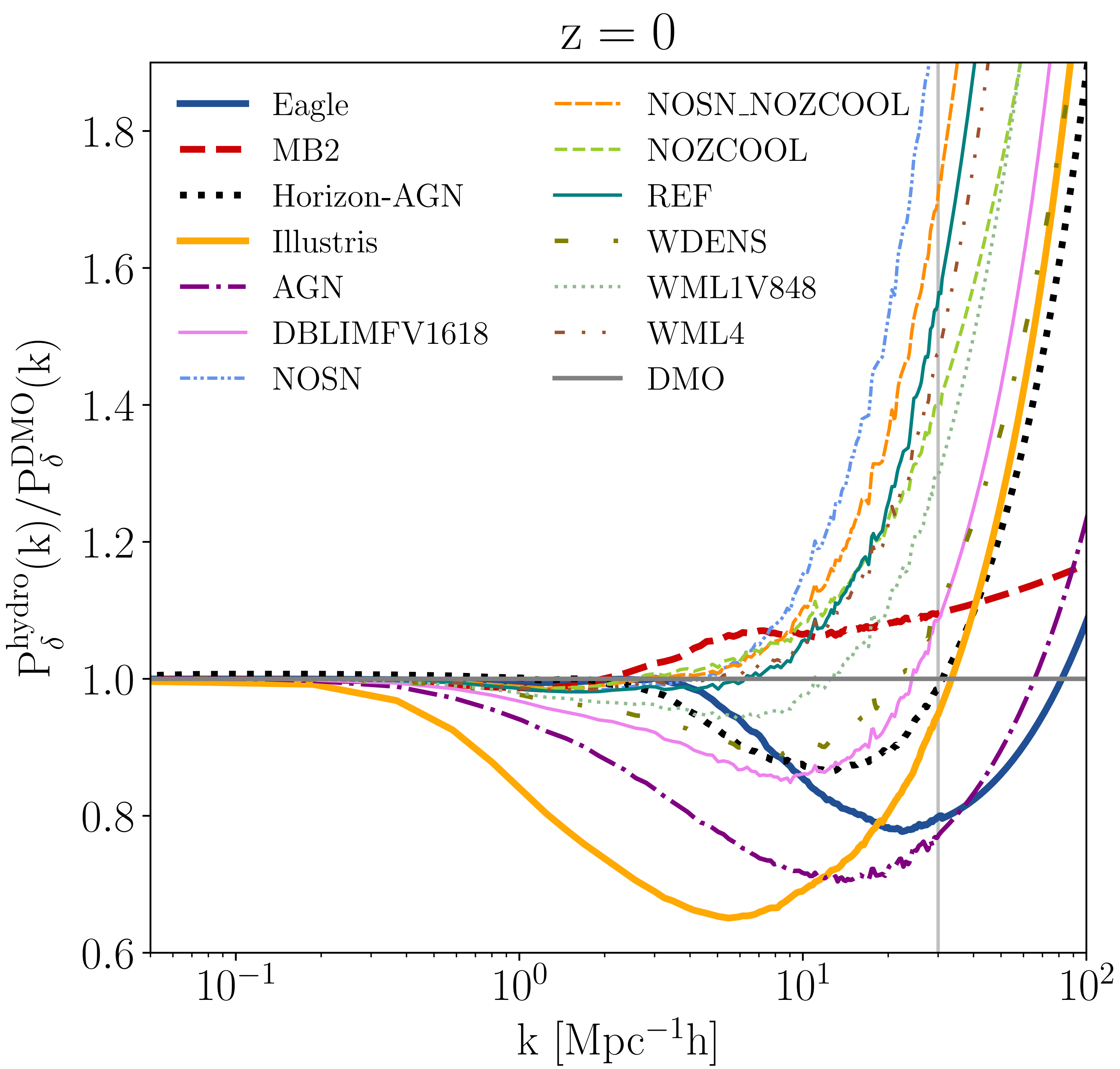
		k [h Mpc^{-1}]: 1 (L = 2π/k: 6 Mpc)	3 (2 Mpc)	10 (0.6 Mpc)
Halofit	(Takahashi+12)	~ 5%	~ 10%	~ 10%
HMcode	(Mead+15)	~ 5%	~ 5%	~ 5%
Emulator: COYOTE Universe	(Heitmann+10)	~ 1%	~ 5%	~ 5%
Emulator: Aemulus Project	(DeRose+18)	~ 1%	~ 1%	
Emulator: MIRA-TITAN Universe	(Heitmann+16)	~ 1%	~ 1%	

Uncertainties due to baryonic physics ~ 10-30%

The the accuracy of P(k) need to reach ~ **1% level** to **k~10 h Mpc^{-1}** in the era of LSST.

Impact of baryonic effects on P(k)

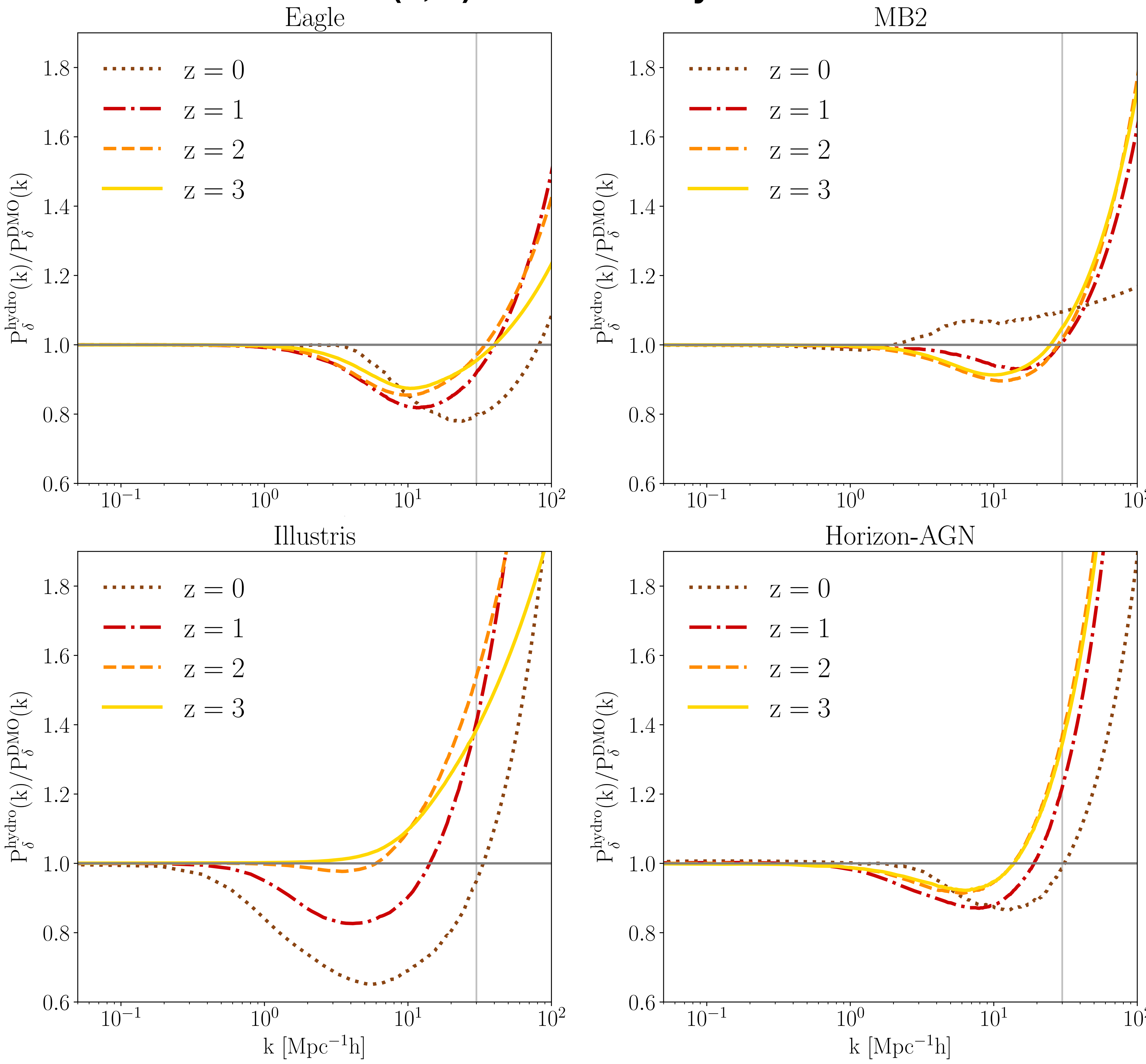
— Hydrodynamical simulations are far from converging…



60 Mpc 6 Mpc 0.6 Mpc 60 kpc L = 2π/k

The the accuracy of P(k) need to reach ~ **1% level** to **k~10 h Mpc^{-1}** in the era of LSST.

The redshift evolution on P(k, z) can be really different…



Strategies of modeling baryonic uncertainties

discard data	modeling discrepancy (hydro vs DMO)	halo model	fast correction on DMO sims
safe scale cut peak clipping (Simpson+12, Giblin+18)	Ratio $P_{hydro}(k)/P_{dmo}(k)$ (Harnois-Deraps+15, Chisari+18)	**HMcode** halo profile parameters (Mead+15, Copeland+17)	gradient-based method (Dai+18)

PCA method

(Eifler+15, Huang+18)

PC mode exclusion

weighted difference $w\,(\xi_{\pm,\,hydro} - \xi_{\pm,\,dmo})$

central stellar profile

gas profile

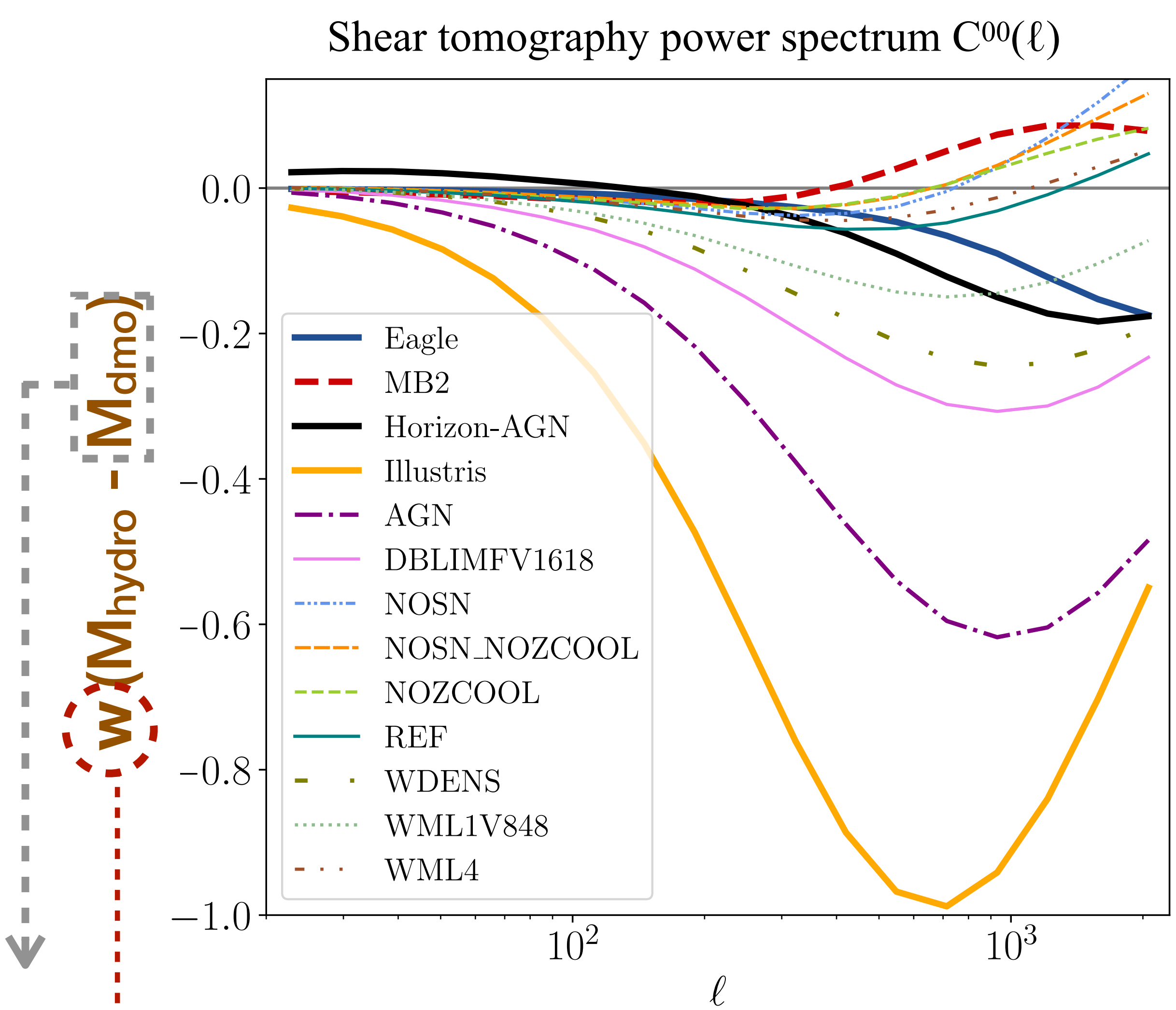
redistribution of DM particles

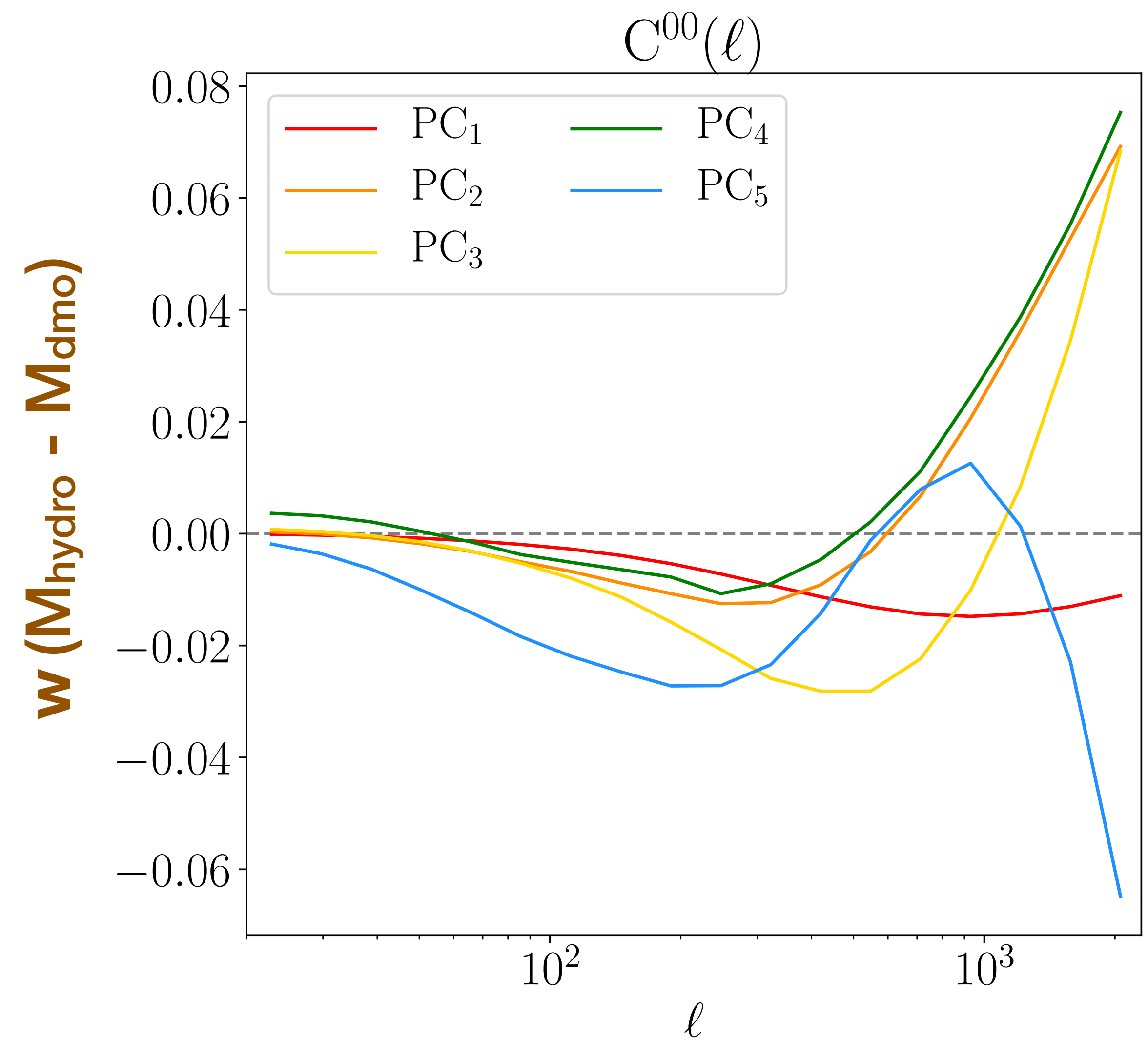
$$\rho_{\rm dmb}(r) = \rho_{\rm gas}(r) + \rho_{\rm cga}(r) + \rho_{\rm clm}(r) + \rho_{\rm 2h}(r)$$

(Mohammed+14, Schneider+18)

PC decomposition to model baryonic effects

(arXiv:1809.01146)





Model vector in observable space

Constructing PC modes

$$w\,(M_{hydro} - M_{dmo}) = \Sigma\, Q_i\, PC_i$$

$C = L\,L^t$
covariance driven weighting factor L^{-1}

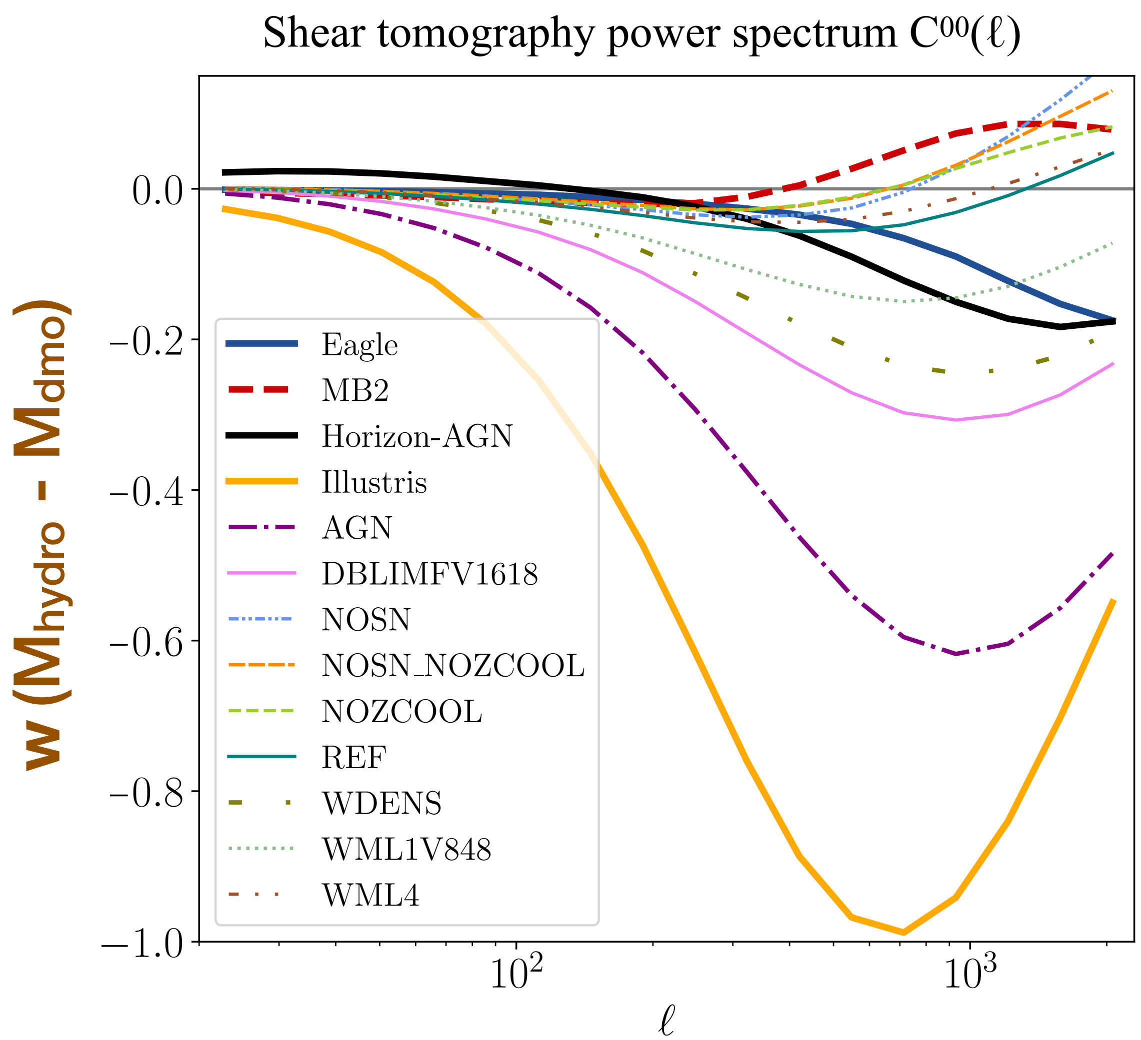
baryonic model generator

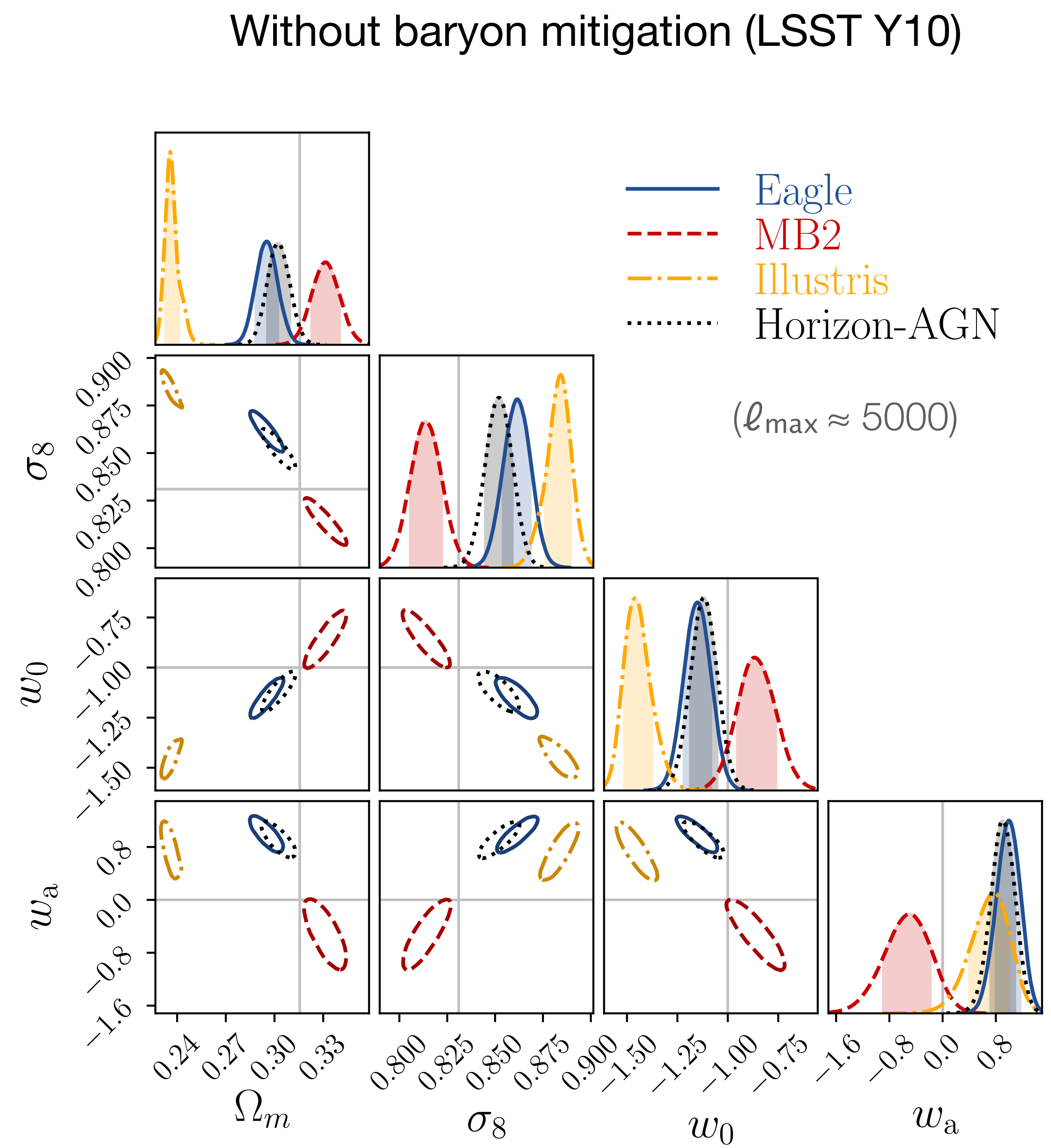
$$M_{baryon}\,(p_{co},\, Q_i) = M_{dmo}\,(p_{co}) + w^{-1}\,\Sigma\, Q_i\, PC_i$$

(Eifler+15, Huang+18)

Performance of PCA for LSST Y10

(arXiv:1809.01146)





Training: $w\,(M_{OWSL} - M_{dmo}) = \sum_{i=1}^{9} Q_i\, PC_i$

Testing: $w\,(D_{MB2} - M_{dmo}) = \sum Q_i\, PC_i$

Eagle

Illustris

Horizon-AGN

$$M_{baryon}\,(p_{co}, Q_i) = M_{dmo}\,(p_{co}) + w^{-1} \sum Q_i\, PC_i$$

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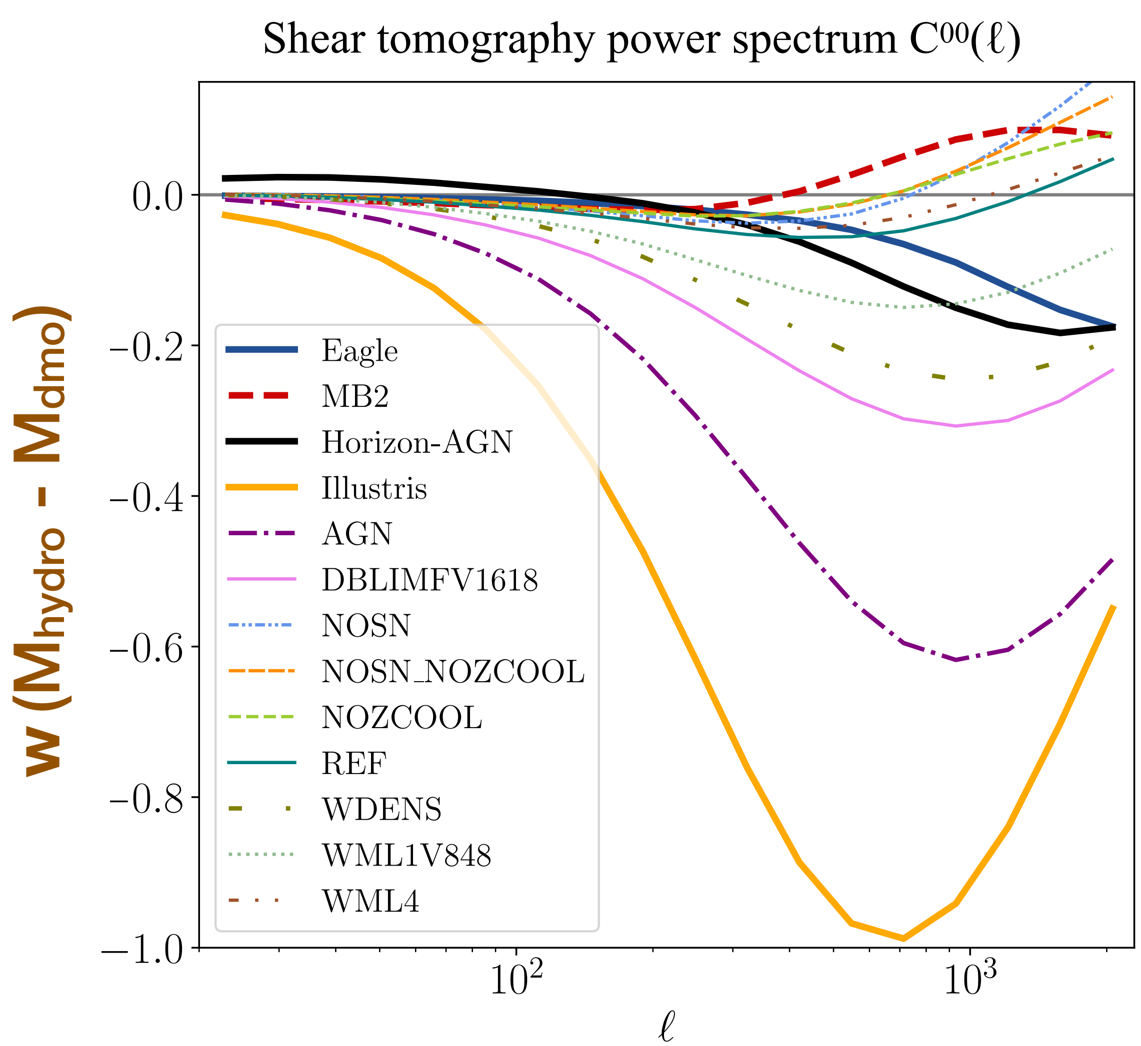
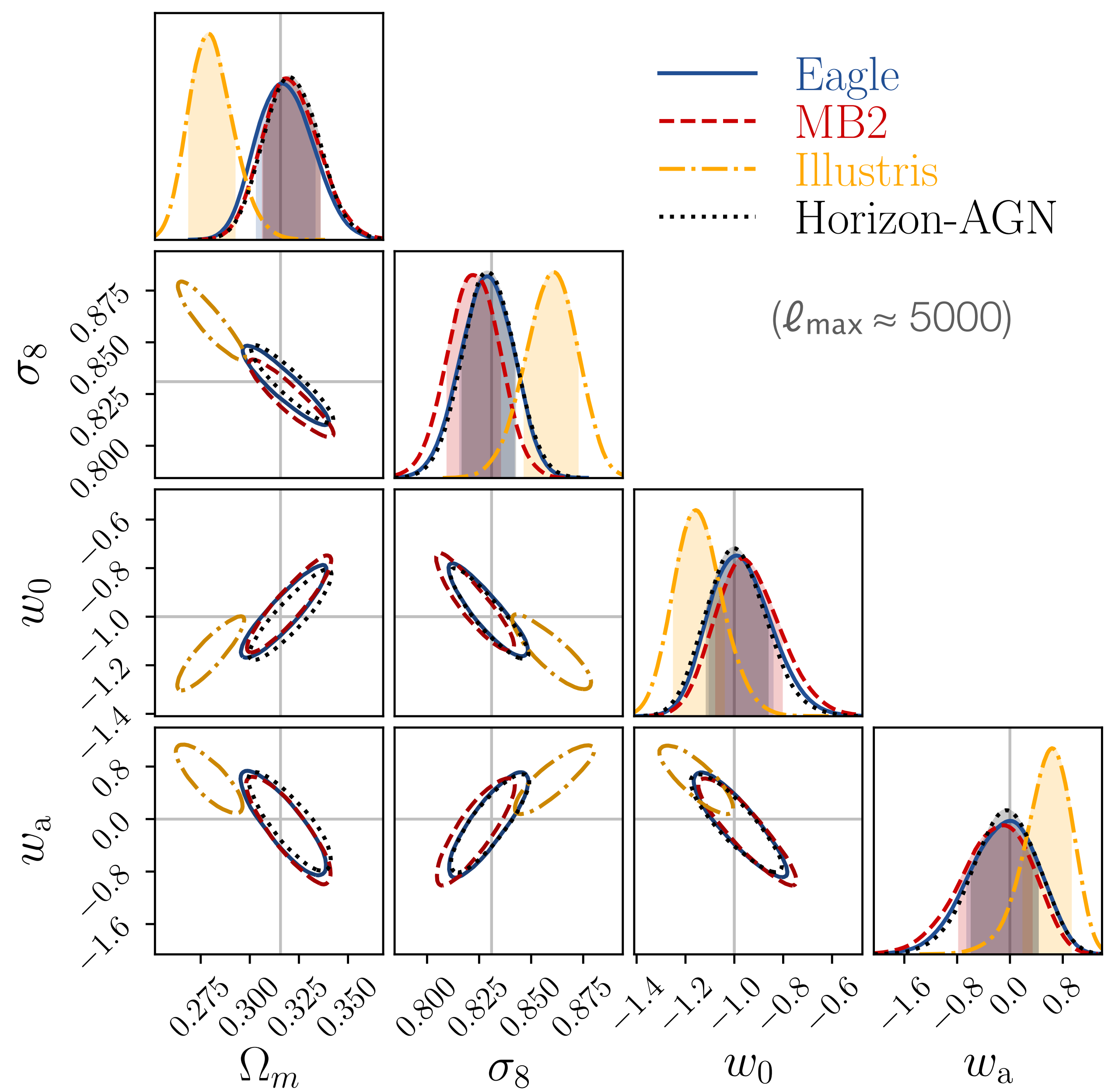


After marginalizing over **3** PC modes



($\ell_{max} \approx 5000$)

Training: $w\,(M_{OWSL} - M_{dmo}) = \sum_{i=1}^{9} Q_i\, PC_i$

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Illustris

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- PCA method can capture baryonic feature within **few** combination of PC modes.

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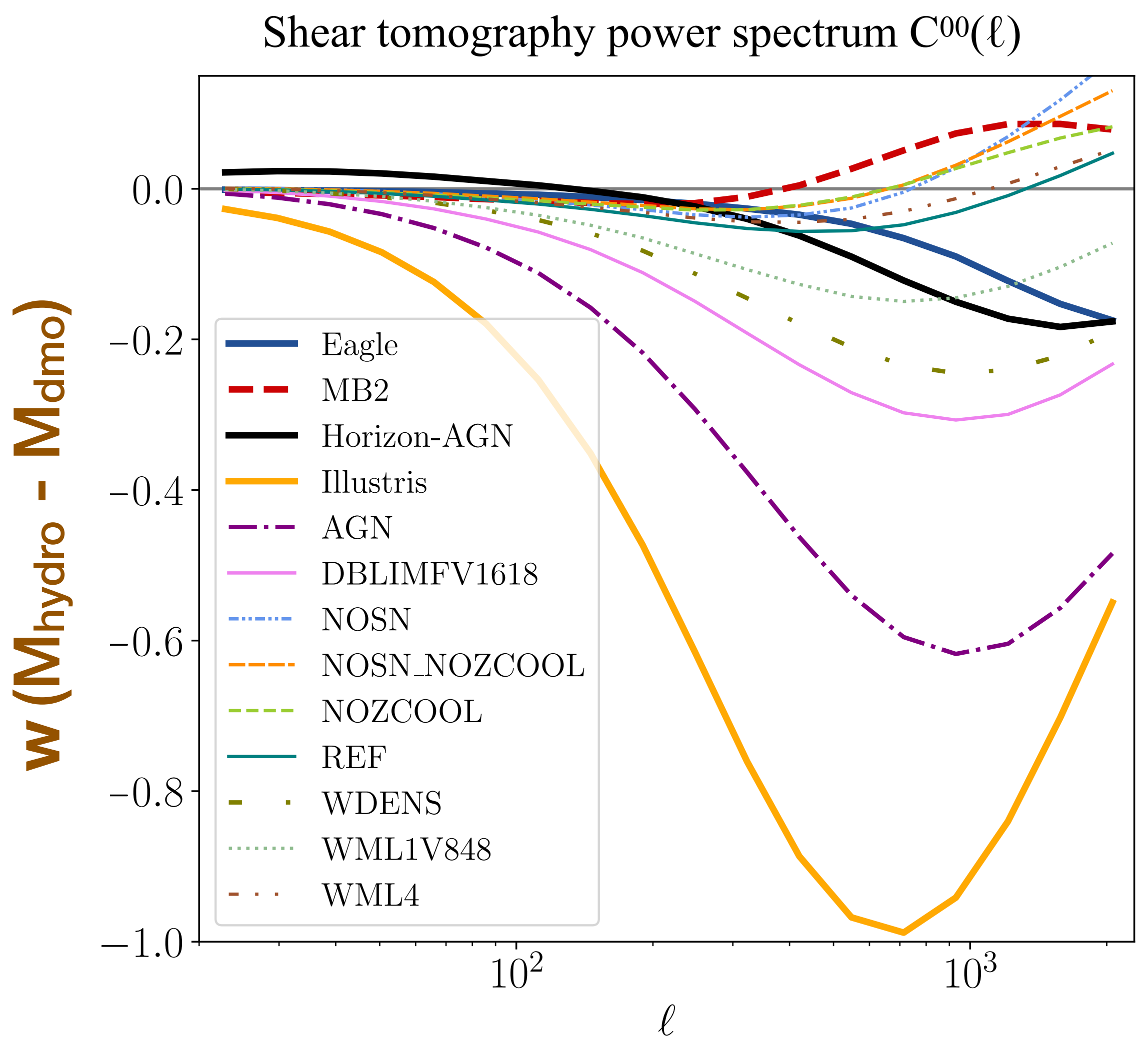
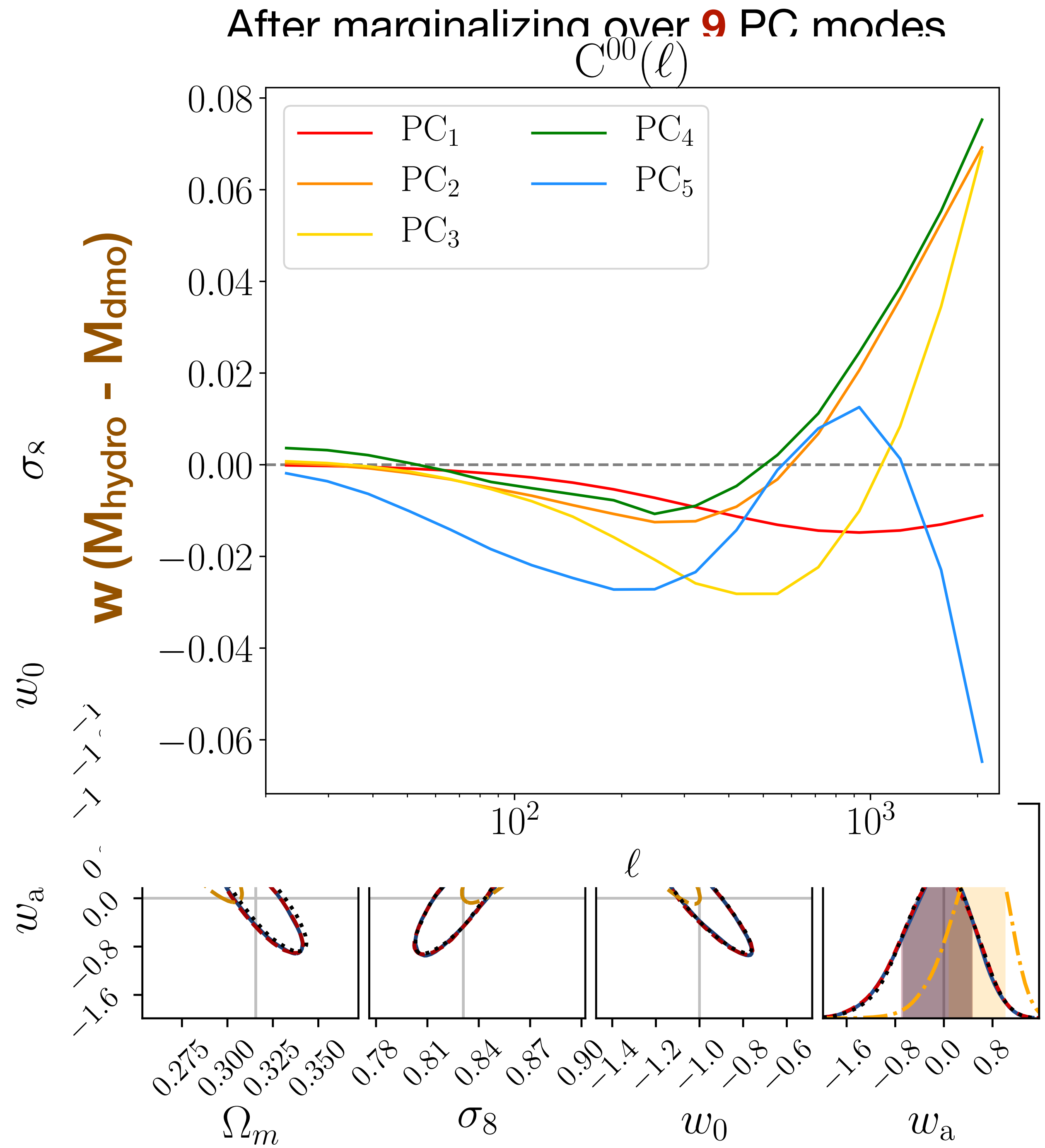


After marginalizing over **9** PC modes



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Eagle
Illustris
Horizon-AGN

- PCA method can capture baryonic feature within **few** combination of PC modes.
- The **posterior contours converge**, even after marginalizing over **all** available PC modes.

Performance of PCA for LSST Y10

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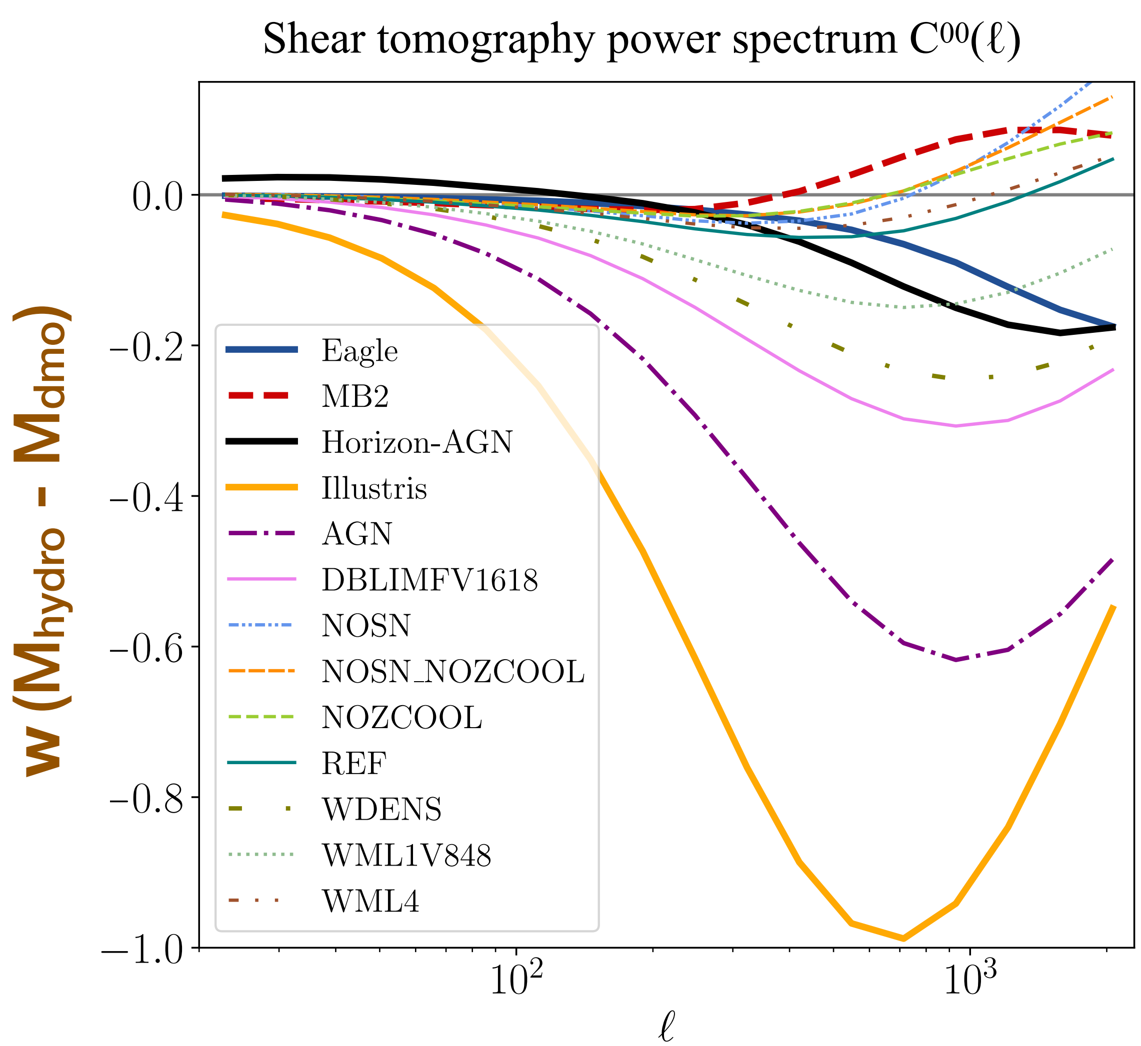

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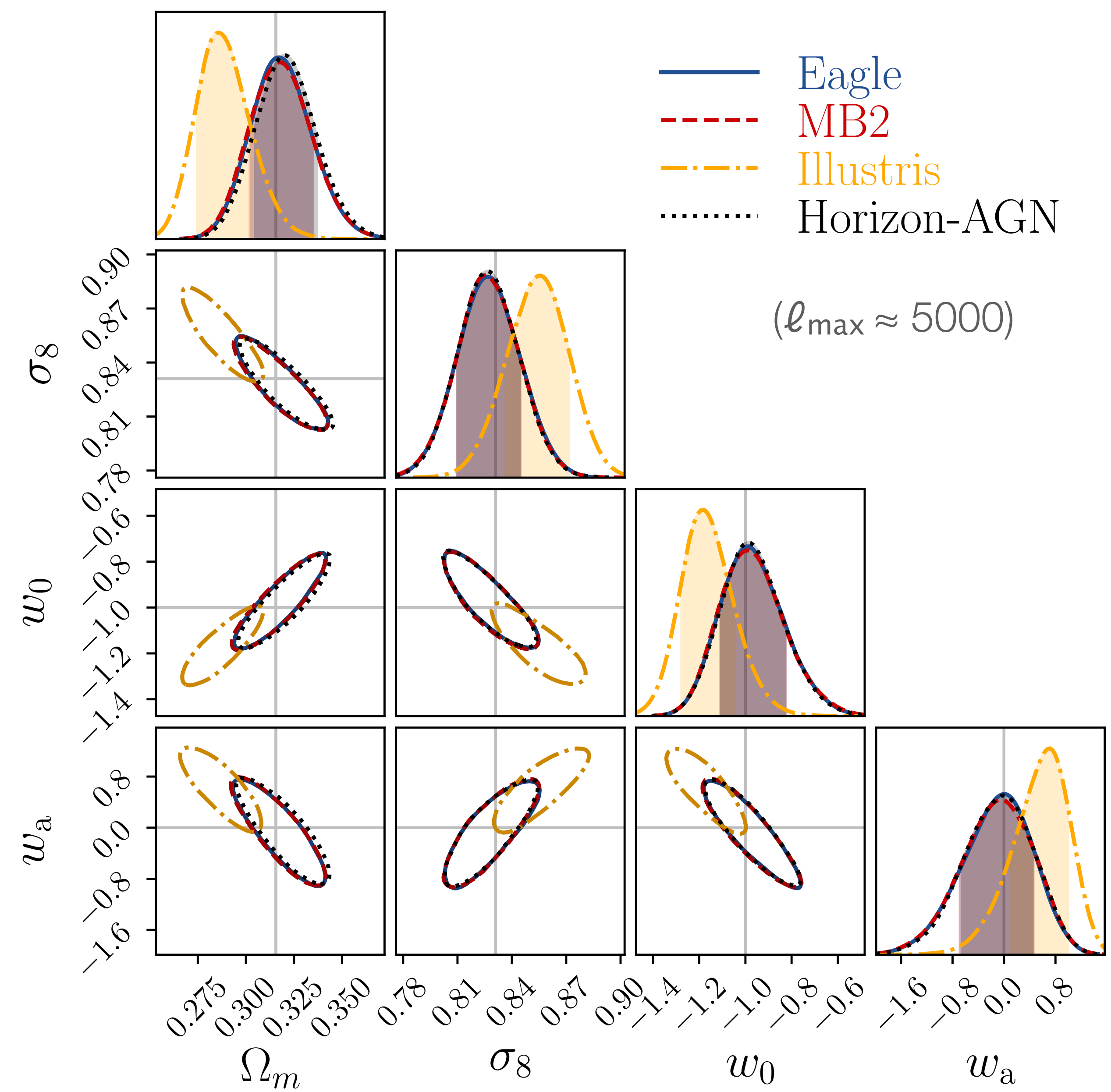

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Eagle
Illustris
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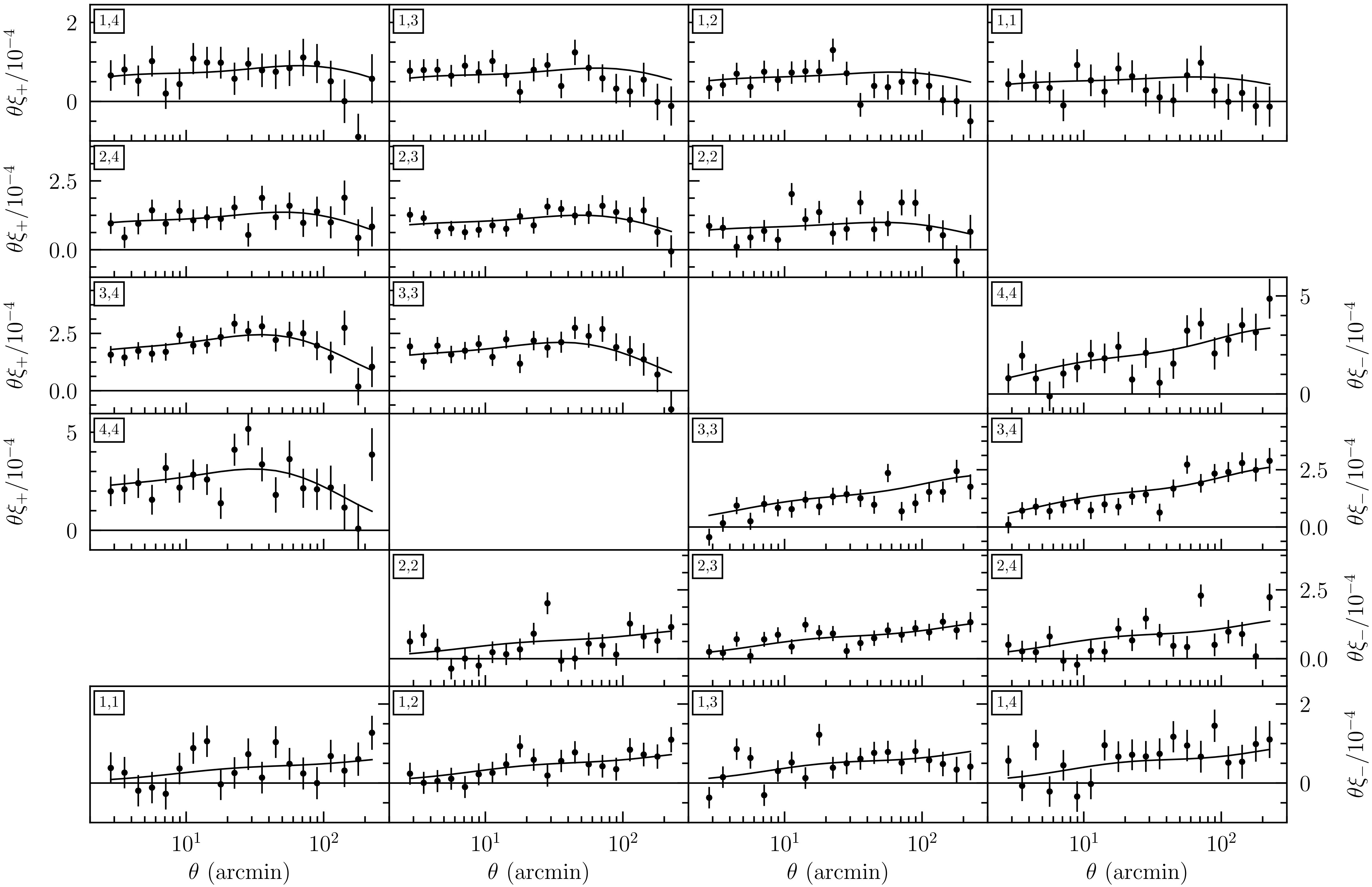
- PCA method can capture baryonic feature within **few** combination of PC modes.
- The **posterior contours converge**, even after marginalizing over **all** available PC modes.
- Distinct training simulations are needed to span the Illustris scenario (outlier).

Expected performance of PCA mitigation on DES Y1

DES Y1 cosmic shear

ξ+ scale cut : 4 ~ 6 arcmin

ξ- scale cut : 30~70 arcmin

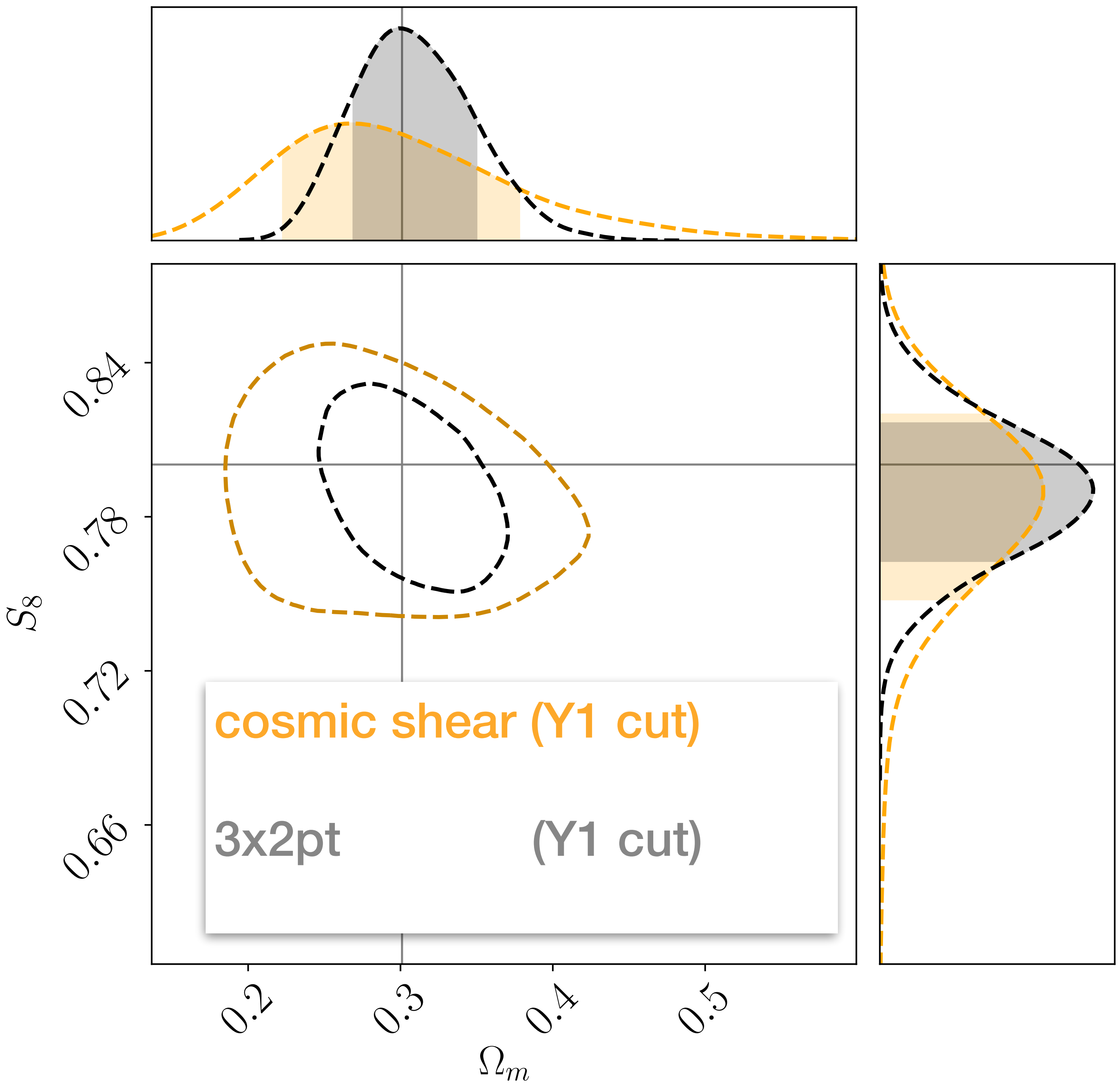


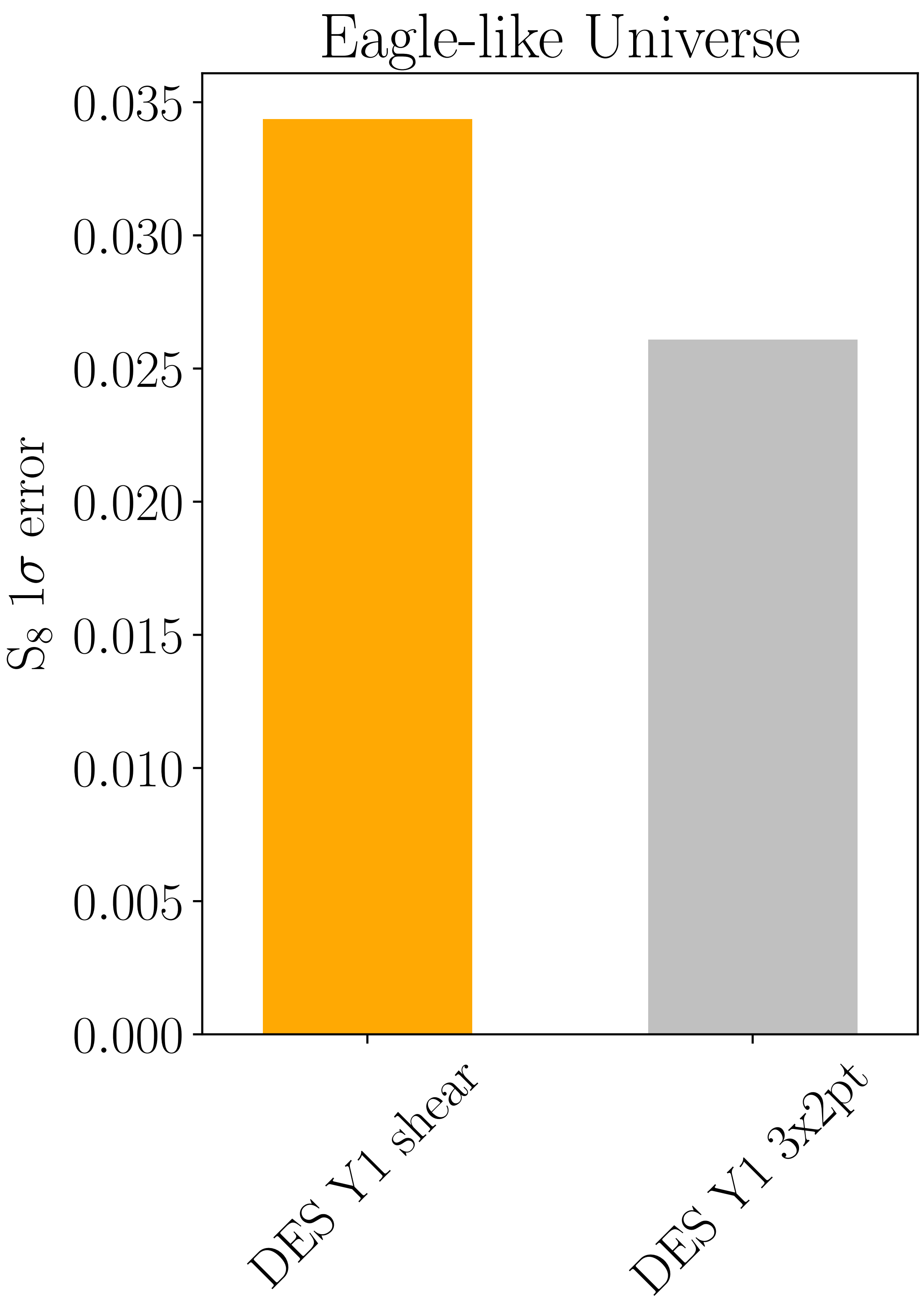
(Troxel+18)

Expected performance of PCA mitigation on DES Y1

Preliminary

Do we gain more information from small scale cosmic shear?





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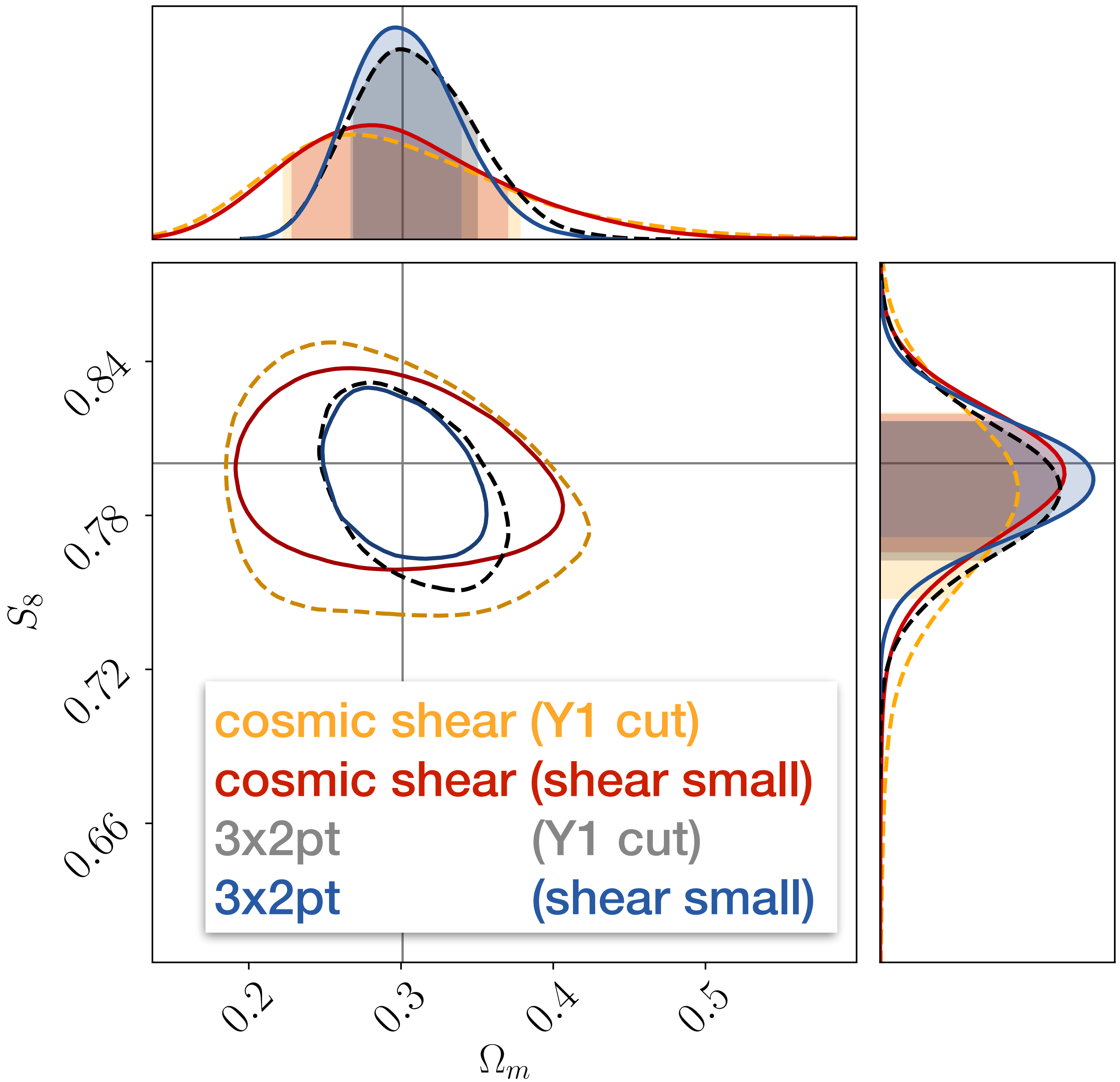
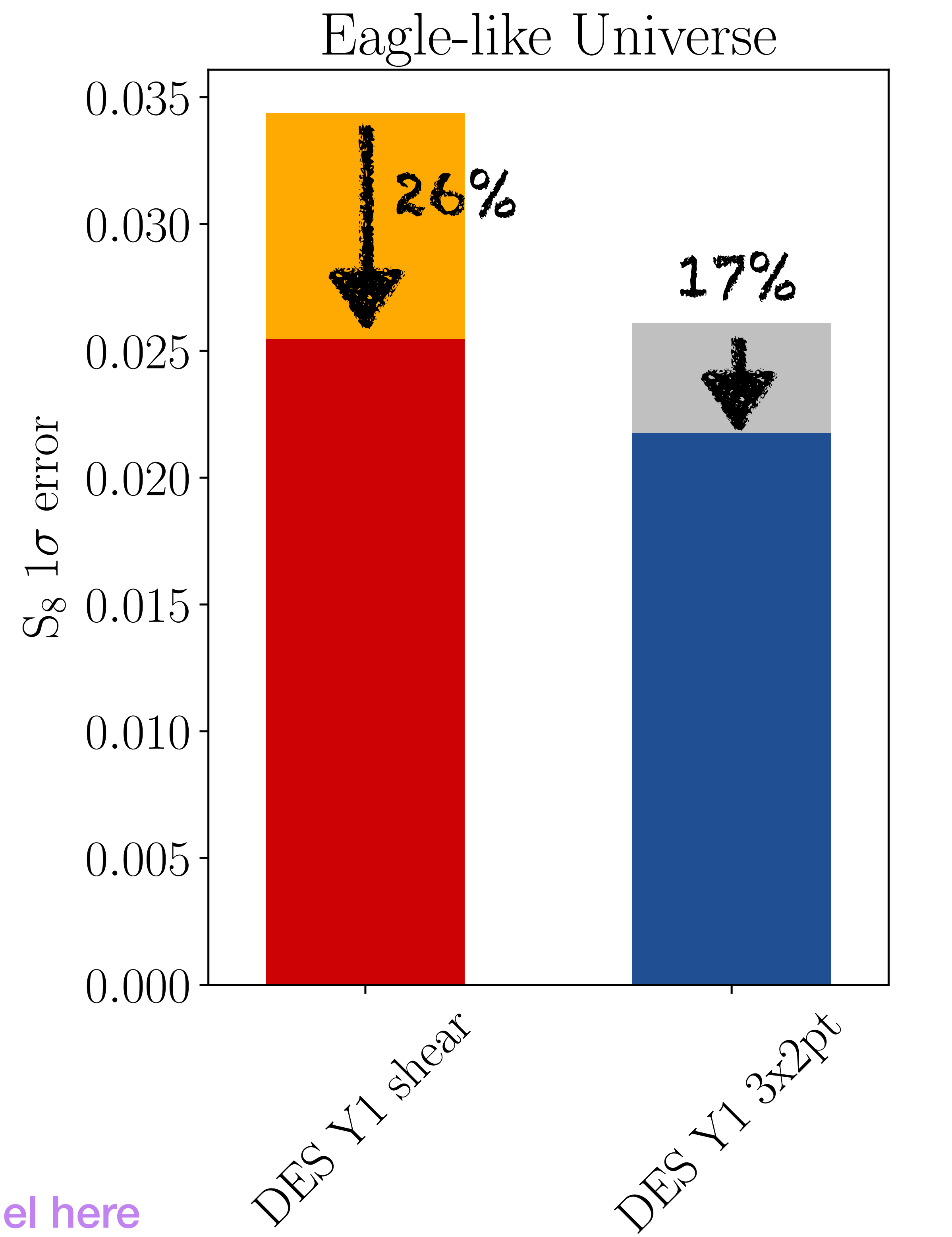




⚠ Assume non-linear IA model here

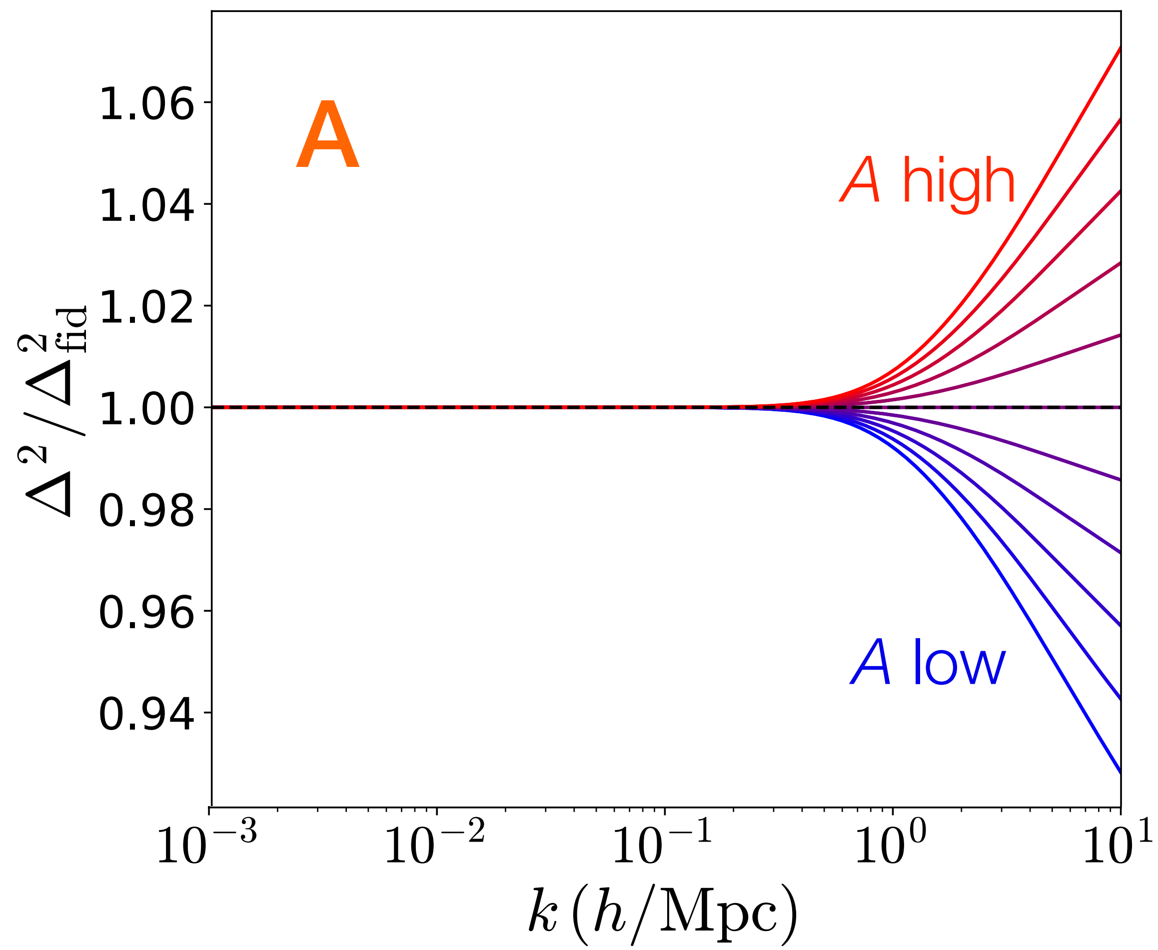
- ~ 20% improvement in S8, after marginalizing over 1st PC mode.

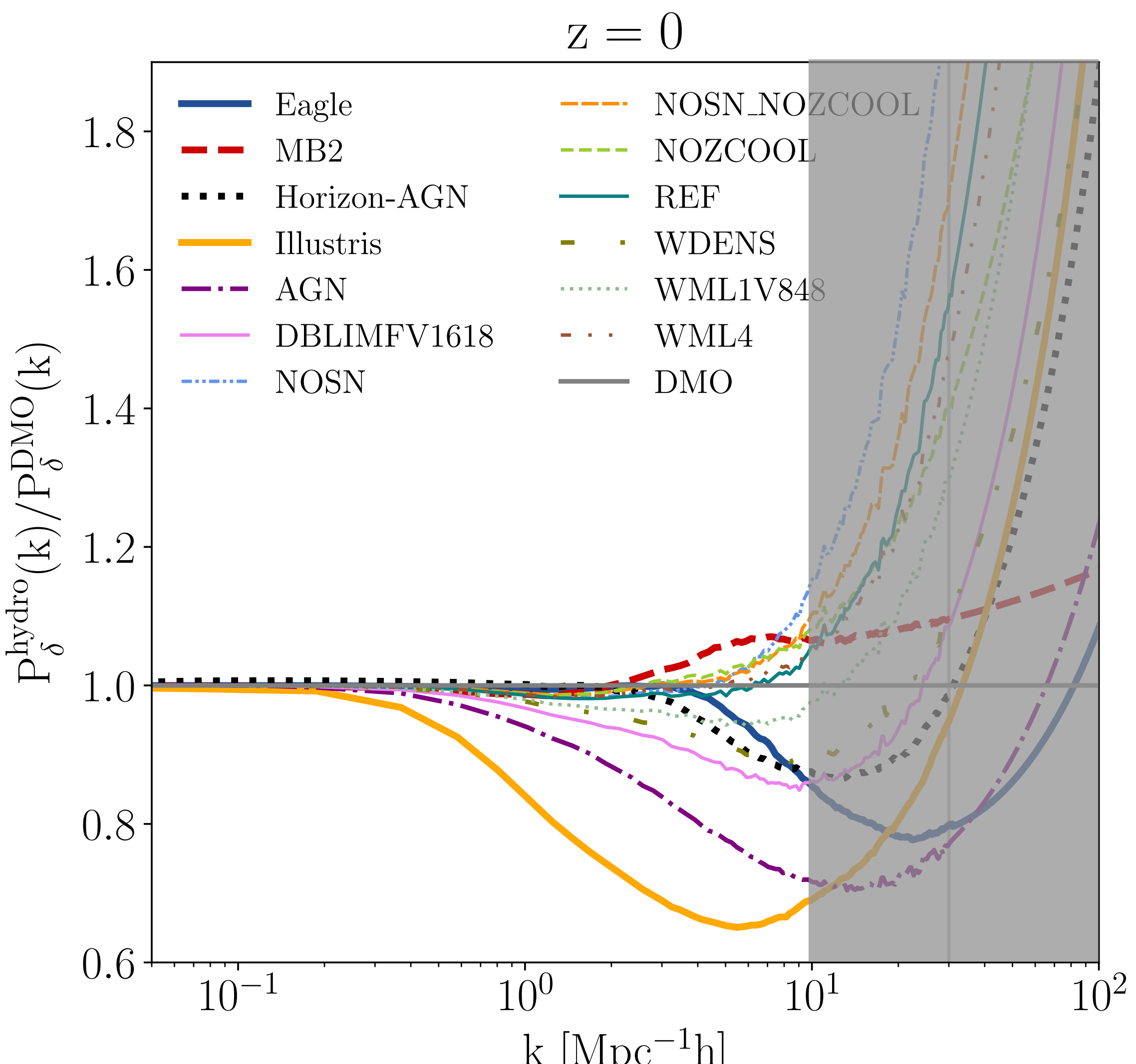
HMcode to model baryonic effects

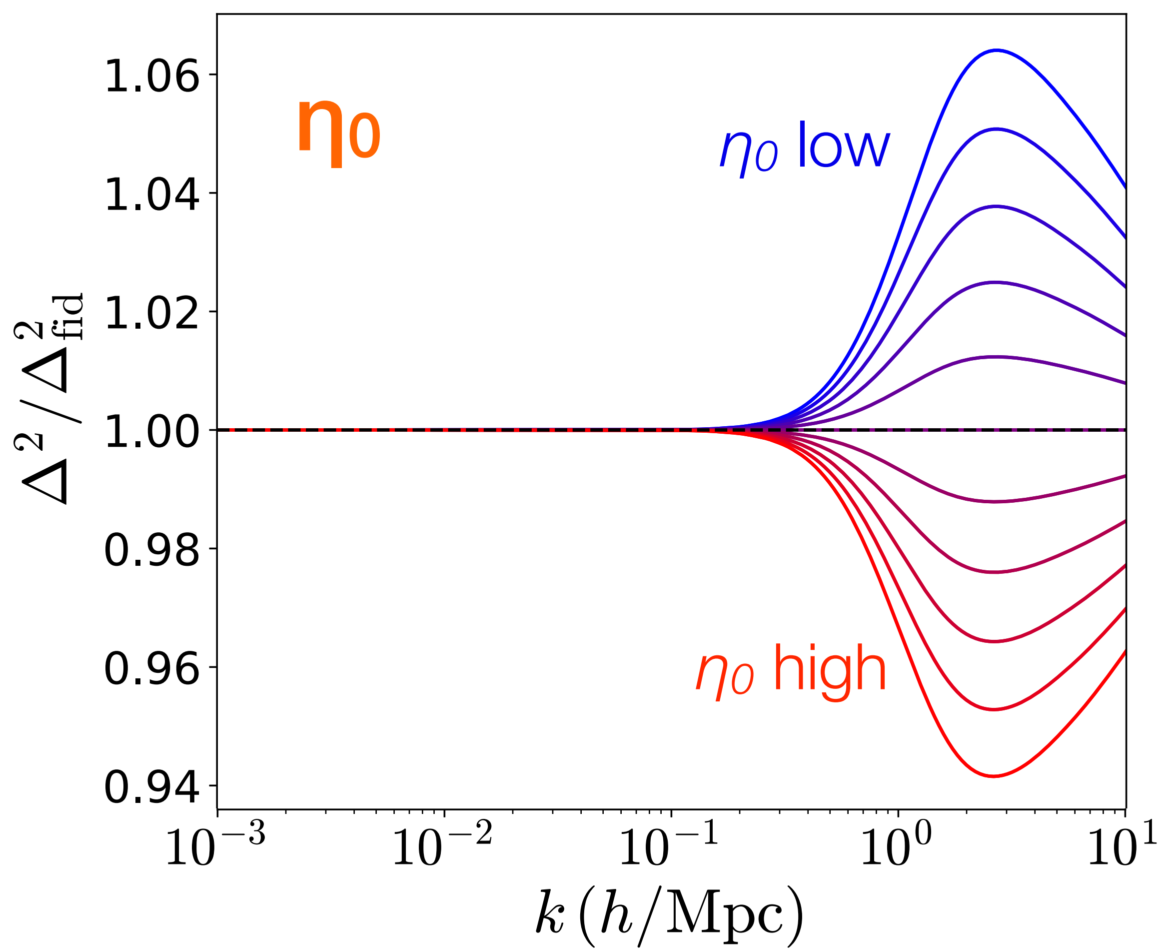
Halo structure parameters

A Amplitude of concentration-mass relation

η_0 Halo bloating factor (mass dependent feedback)

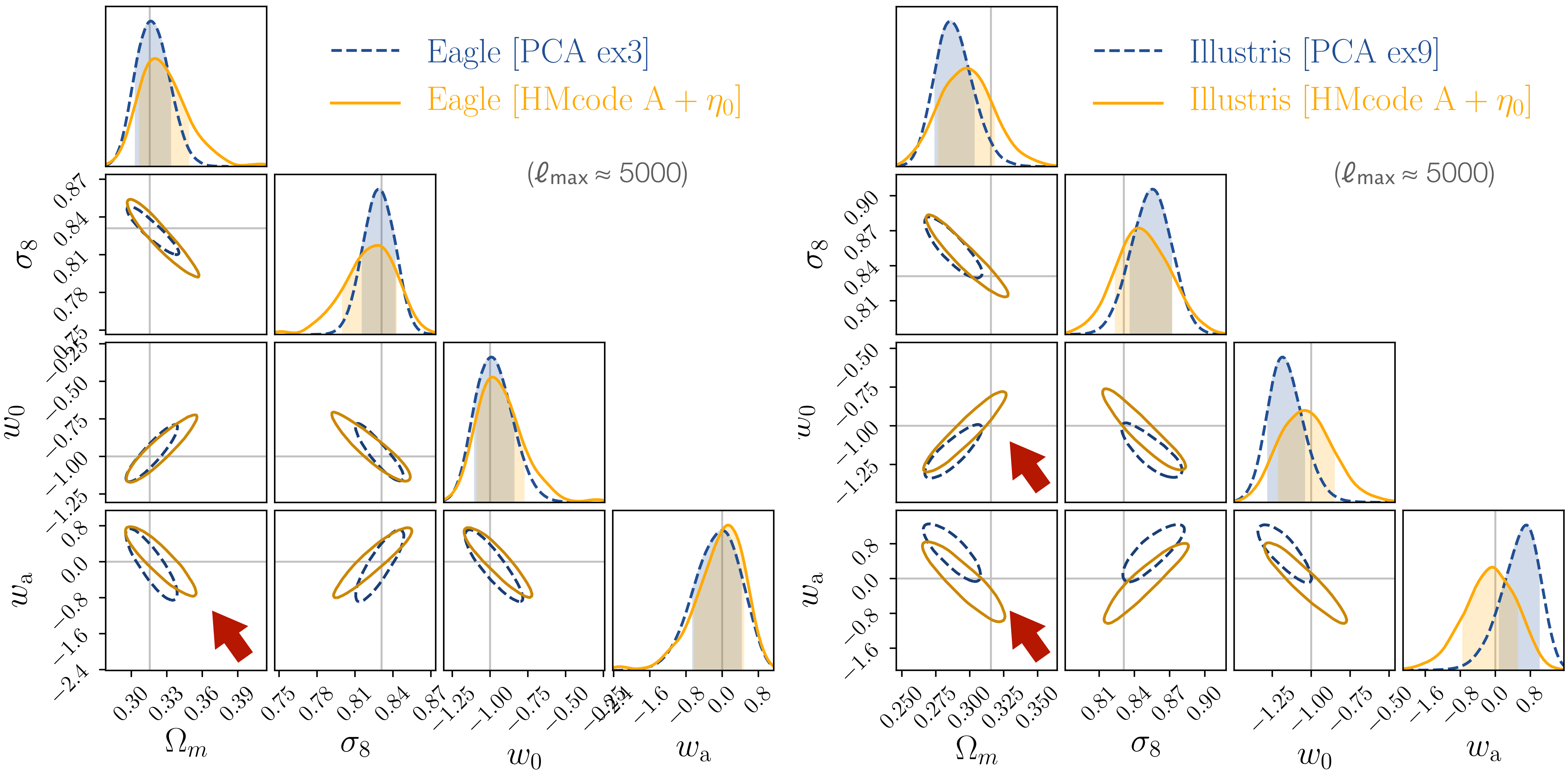






(Mead+15, Copeland+18)

Performance of HMcode for LSST Y10

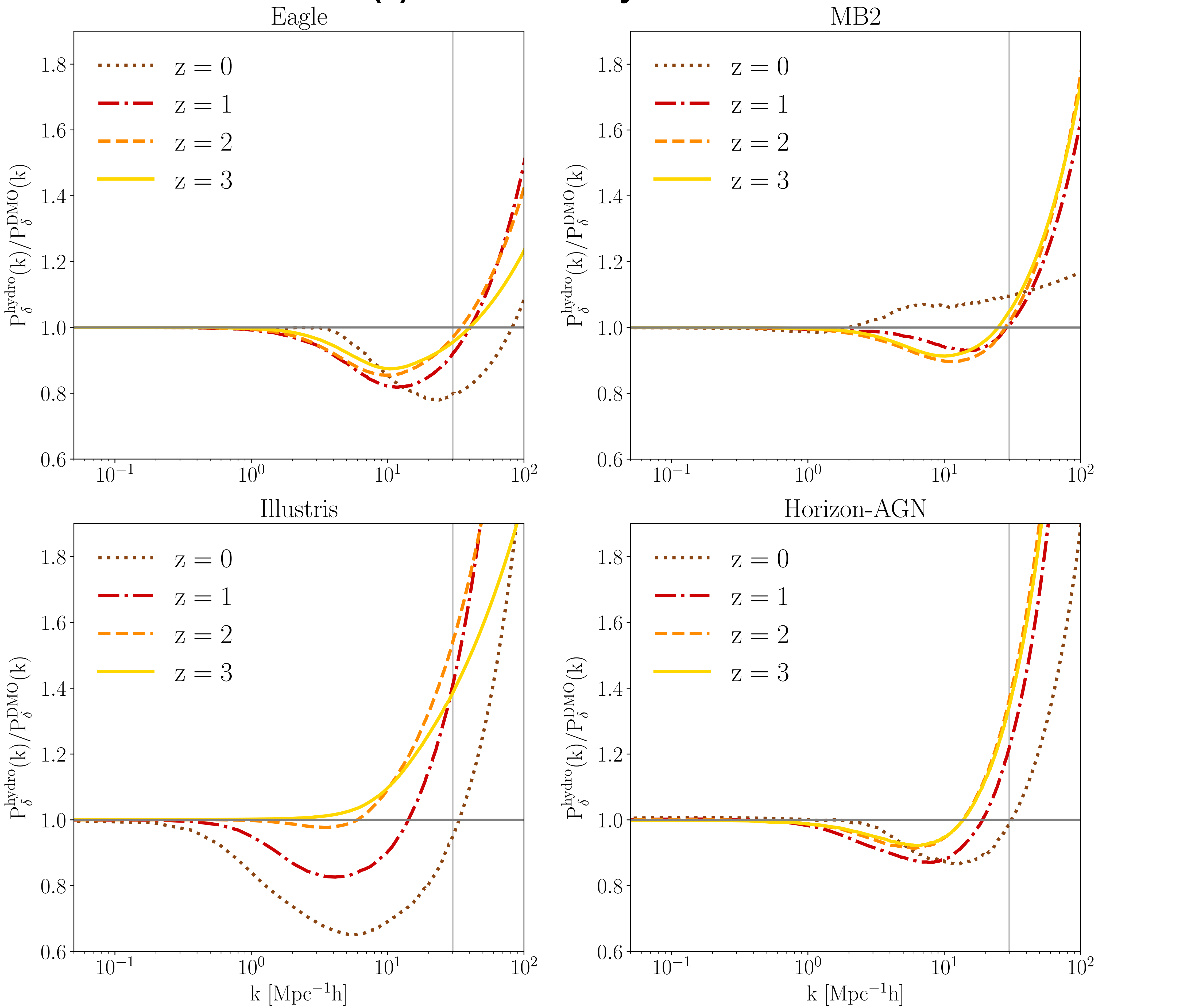


- HMcode works better for strong AGN feedback scenario like Illustris.
- Tension in 2D posterior constraints.

Summary

PCA	Halo Model / Fast correction on N-body sims
Compact and flexible PC modes (functional form)	Physically meaningful parametrization
Based on hydro sims	Link to observational quantities
Flexibility in both Scale and Redshift directions	[Current Model] Assume no strong redshift evolution on halo/gas profiles. Redshift evolution build in via evolution of halo mass function.

The redshift evolution on P(k) can be really different…



Summary

PCA

Halo Model

Fast correction on N-body sims

Compact and flexible PC modes (functional form)

Physically meaningful parametrization

Based on hydro sims

Link to observational quantities

Flexibility in both Scale and Redshift directions

[Current Model]
Assume no strong redshift evolution on halo/gas profiles.
Redshift evolution build in via evolution of halo mass function.

[Assumptions]
- Independence between baryon and cosmology.
- Input hydro sims are all under ΛCDM.

- Cosmology/Baryon separation via 1-halo & 2-halo terms
- go beyond ΛCDM

Emulator