Evaluating baryonic effects in HSC Y3 cosmic shear data with a dark matter-only model

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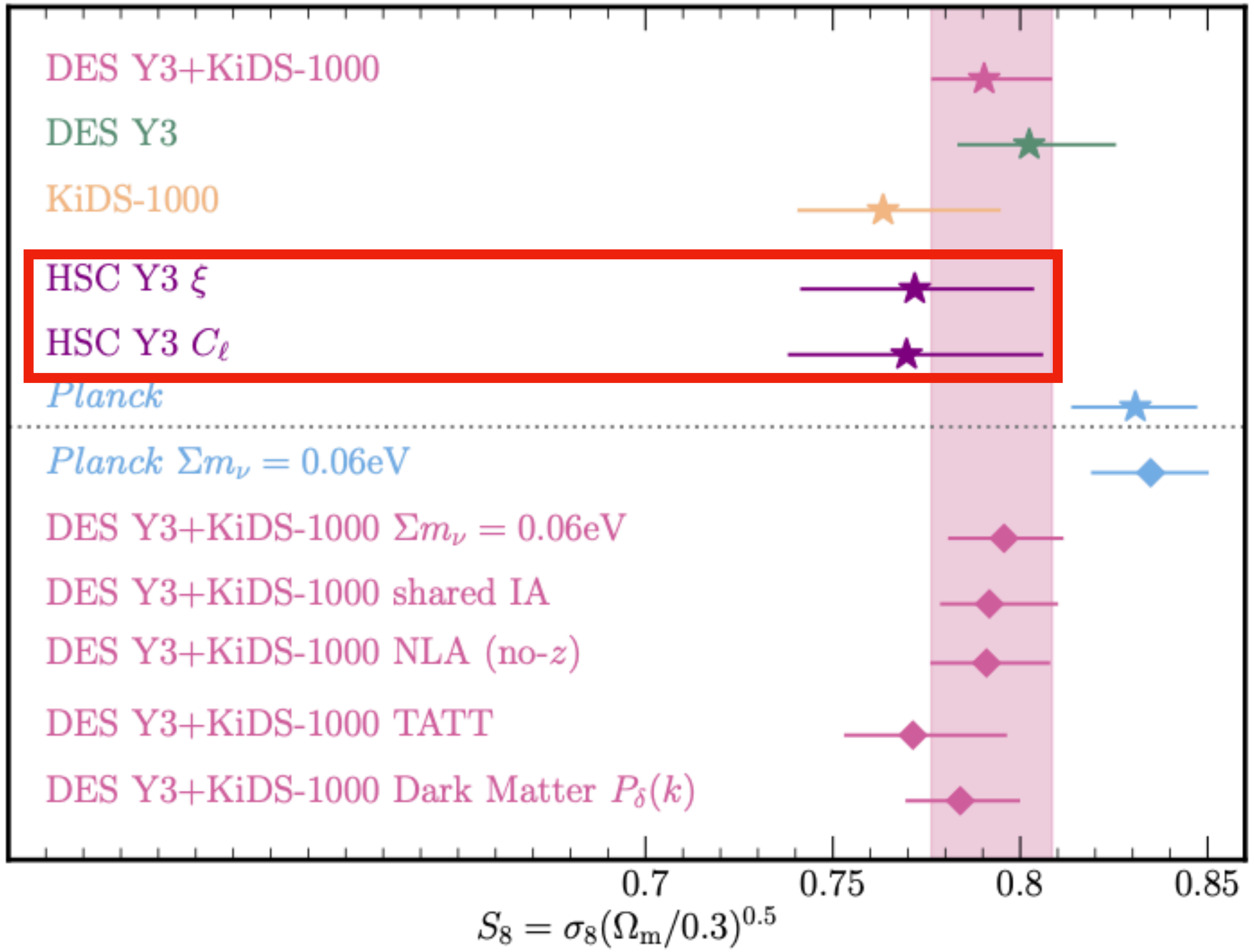
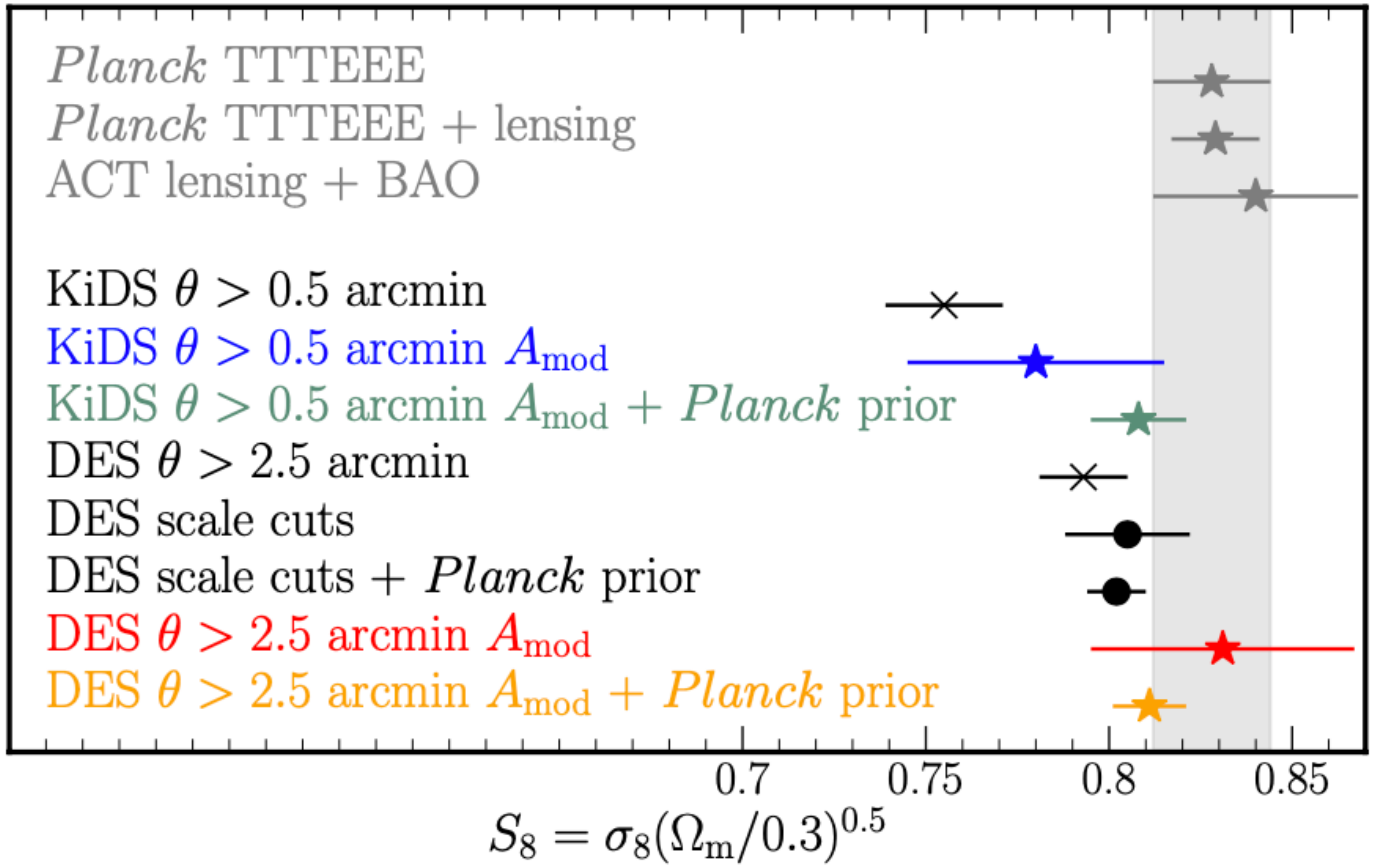
S_8 tension and small-scale suppression



DES and KiDS collaboration 2023



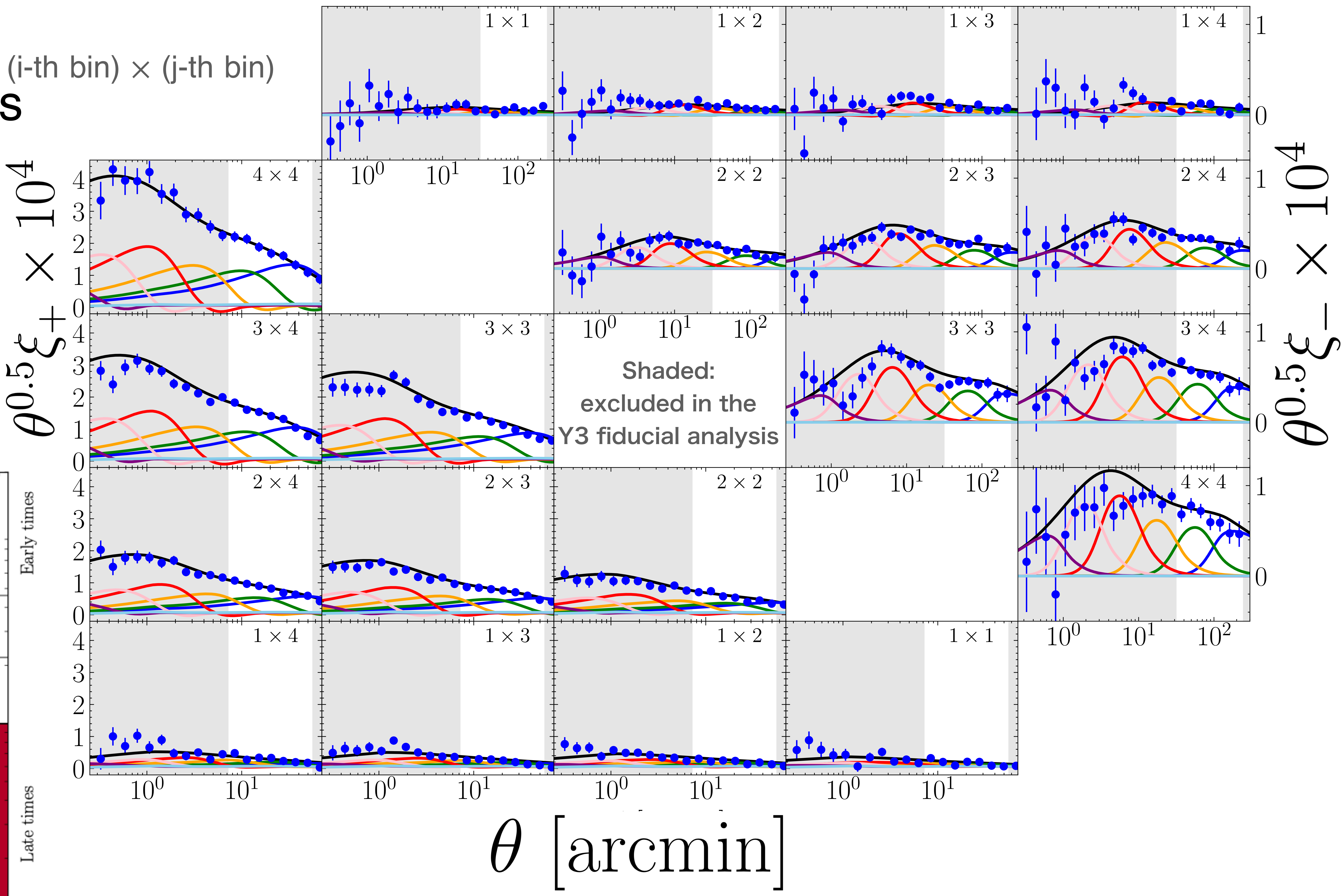
Preston, Amon & Efstathiou 2023

Extreme baryonic feedback might solve S8 tention:
How large the suppression really is?

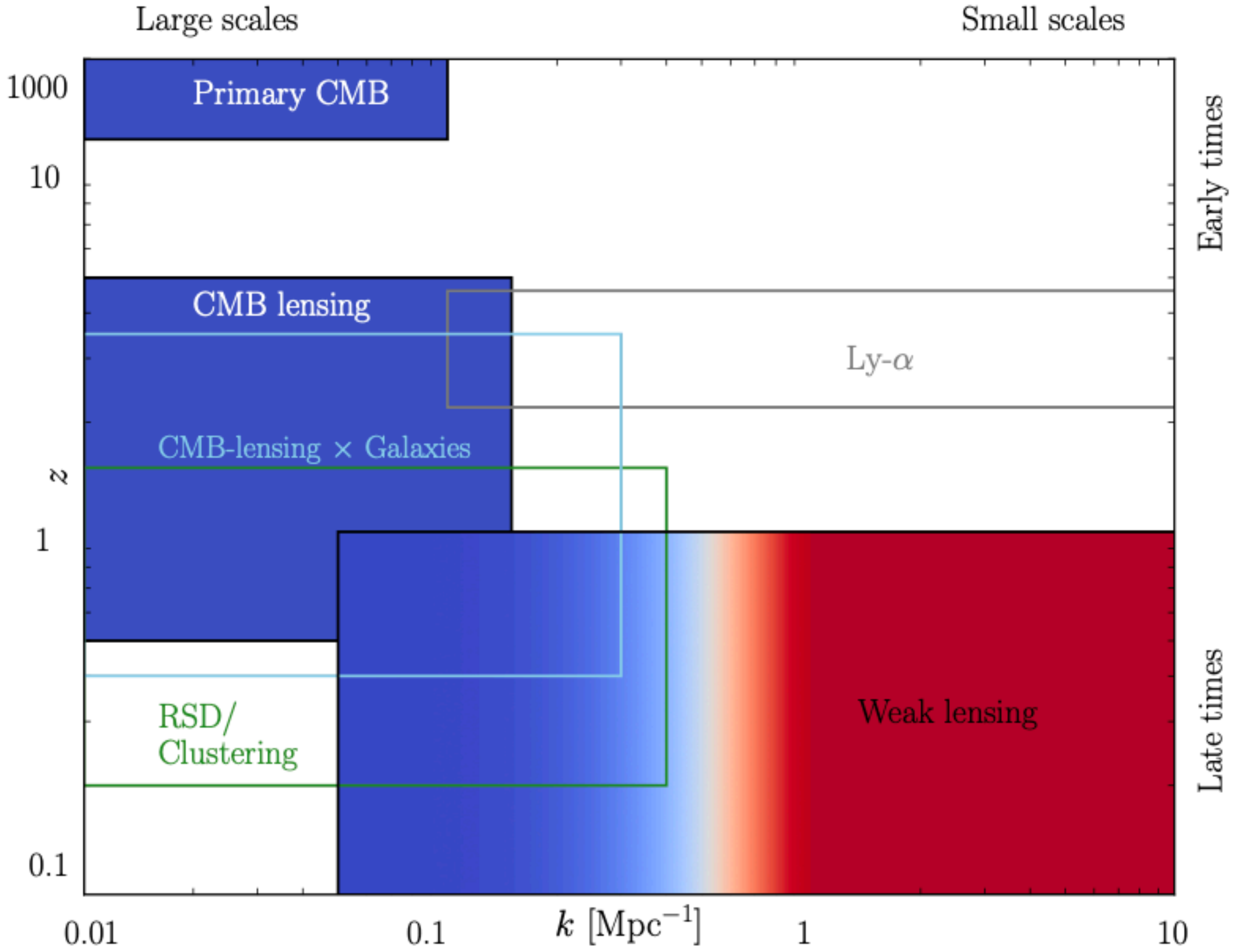
Cosmic Shear 2 Point Correlation Functions

$k < 10^{-2}$ | $10^{-2} < k < 0.1$ | $0.1 < k < 10^{-0.5}$ | $10^{-0.5} < k < 1$ | $1 < k < 10^{0.5}$ | $10^{0.5} < k < 10$ | $10 < k$

4 tomographic redshift bins
$z \sim 0.3 - 1.5$



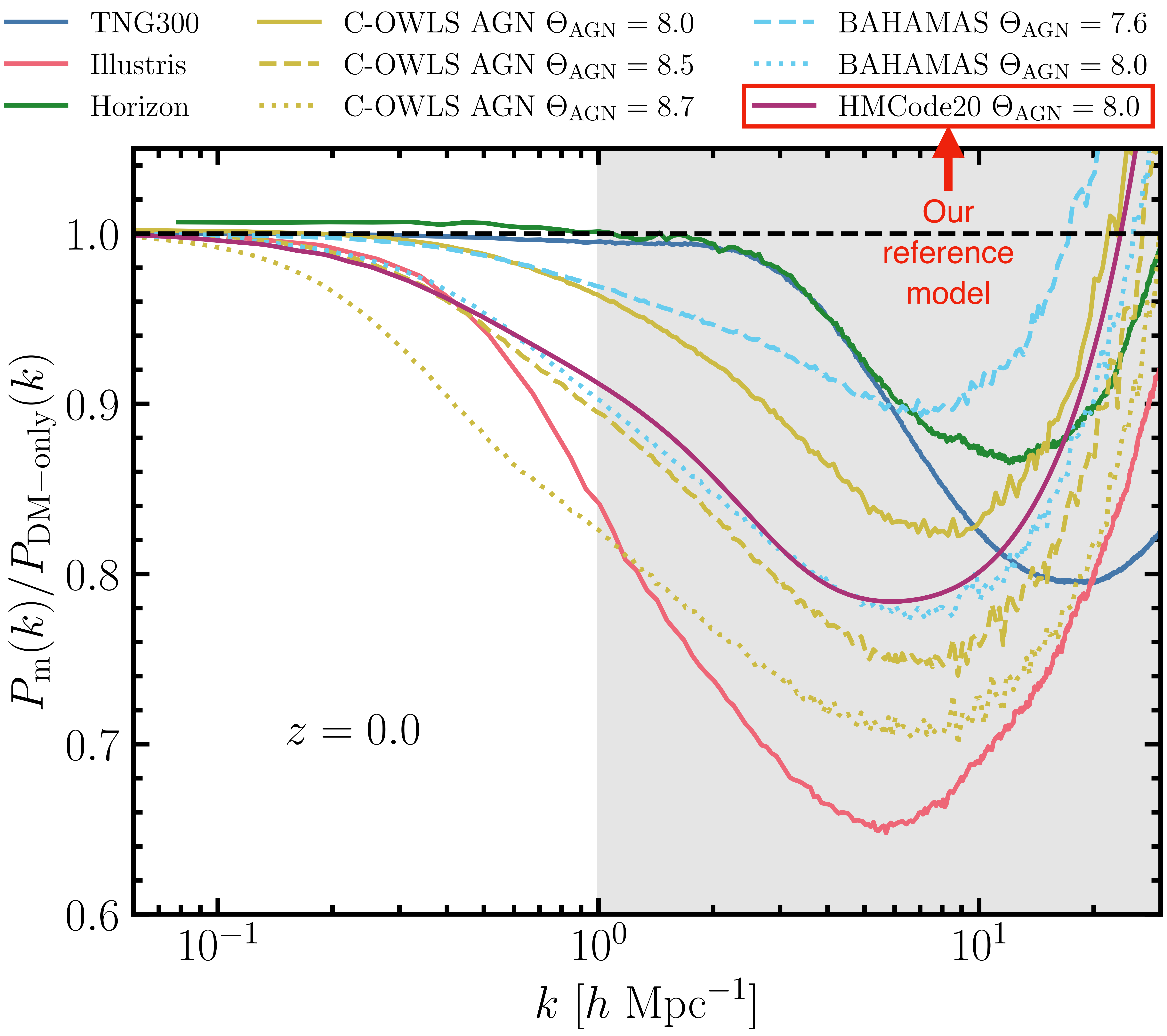
Preston, Amon & Efstathiou 2023



Baryonic effects

- Baryonic effects (e.g. AGN/SN feedback) suppress the matter clustering
  $\Theta_{\rm AGN} \equiv \log_{10}\left(T_{\rm AGN}/K\right)$

- Baryonic feedback model based on the hydro sims:
  HMcode (Mead+16,20)
  PCA (e.g. Xu+23)
  Baryon Correction Model (BCM; e.g. Arico+20,23)



Model uncertainties of cosmic shear

$$\xi^{ij}_{+/-}(\theta) = \frac{1}{2\pi} \int d\ell\, \ell J_{0/4}(\theta\ell) \left(C^{E;ij}(\ell) \pm C^{B;ij}(\ell)\right)$$

$$C^{E;ij} = C^{E;ij}_{\mathrm{GG}} + C^{E;ij}_{\mathrm{II}} + C^{E;ij}_{\mathrm{GI}}$$

$P_{\mathrm{m}}(k)$

N-body: $\sim 5\,\%$ uncertainty

Baryonic effects: $\sim 20\,\%$ uncertainty

Intrinsic Alignment: few $\times 10\,\%$ uncertainty

(no significant detection so far)

- In Y3 analysis, we marginalized the possible baryonic/IA contamination to get unbiased constraints on cosmological parameters
- Large baryonic feedback beyond HSCY3 prior can occur in our universe?

Minimal assumption: DM-only (DMO) model

$$\xi^{ij}_{+/-}(\theta) = \frac{1}{2\pi}\int d\ell\,\ell J_{0/4}(\theta\ell)\left(C^{E;ij}(\ell) \pm C^{B;ij}(\ell)\right)$$

$$C^{E;ij} = C^{E;ij}_{\rm GG} + C^{E;ij}_{\rm II} + C^{E;ij}_{\rm GI}$$

~~Intrinsic Alignment: few $\times 10\,\%$ uncertainty~~

(no significant detection so far)

$P_{\rm m}(k)$

N-body: $\sim 5\,\%$ uncertainty

~~Baryonic effects: $\sim 20\,\%$ uncertainty~~

(Both induce suppression)

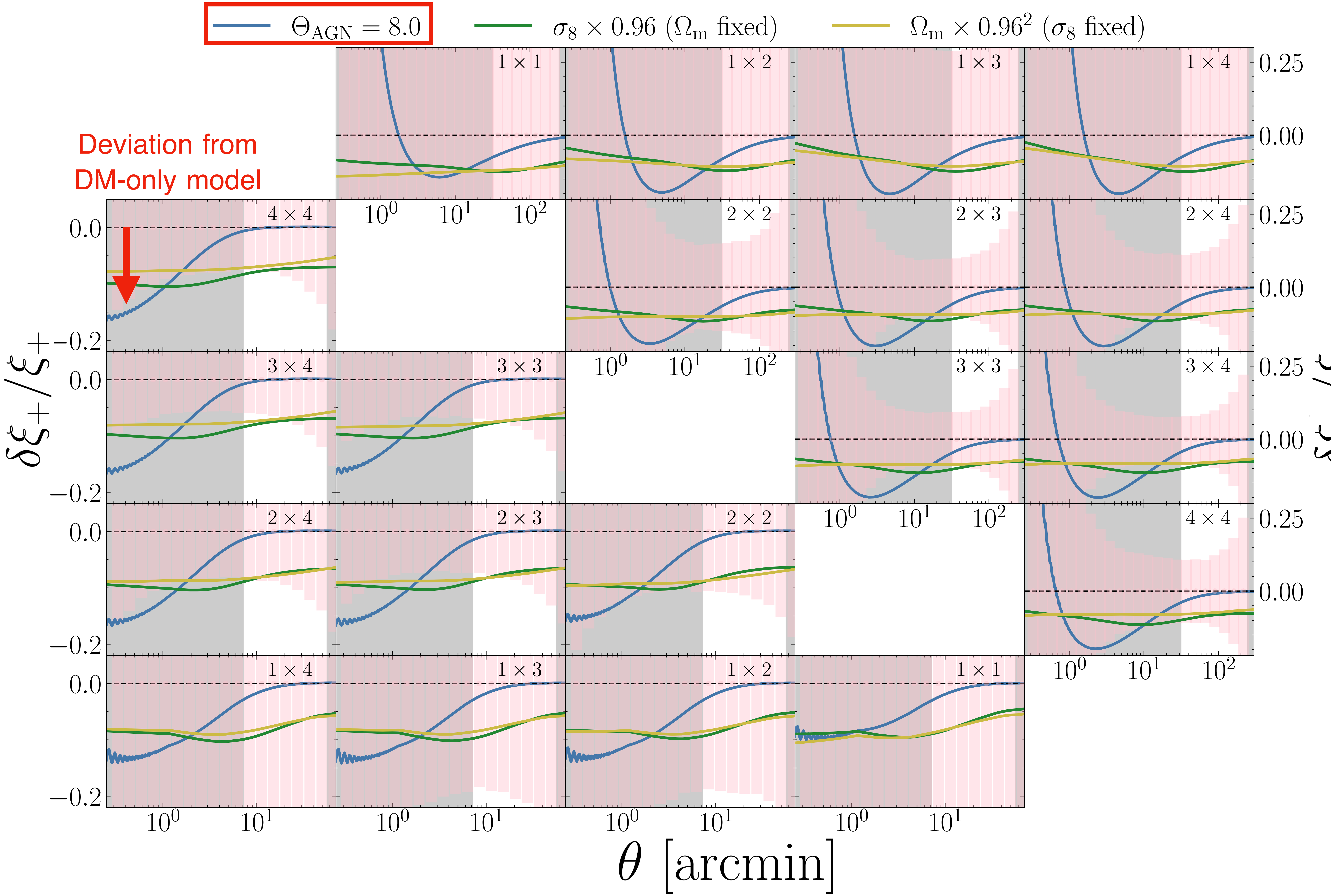
$$S_8^{\rm DMO} = 0.XX^{+0.0X}_{-0.0X} - \text{sys}$$

Minimum model uncertainty, but possible bias (even worse, the model may fail to fit the data)

Robust evaluation of baryonic effects with DM-only model

$S_8^{\rm DMO} = 0.XX^{+0.0X}_{-0.0X}$ $-$ $\mathrm{sys}(\theta_{\rm min})$ $\theta_{+\rm min}: 7'.1$ (Y3cut), $\theta_{+\rm min}: 2'.9$, $\theta_{+\rm min}: 1'.2$, $\theta_{+\rm min}: 0'.28$

- Try to fit the data with N-body based DM-only model for $P_{\rm m}(k)$ (Dark Emulator2; developed by Tanaka-san & Nishimichi-san in Kyoto)
- Can evaluate the baryonic effects without suffering from modeling uncertainty of baryonic effects



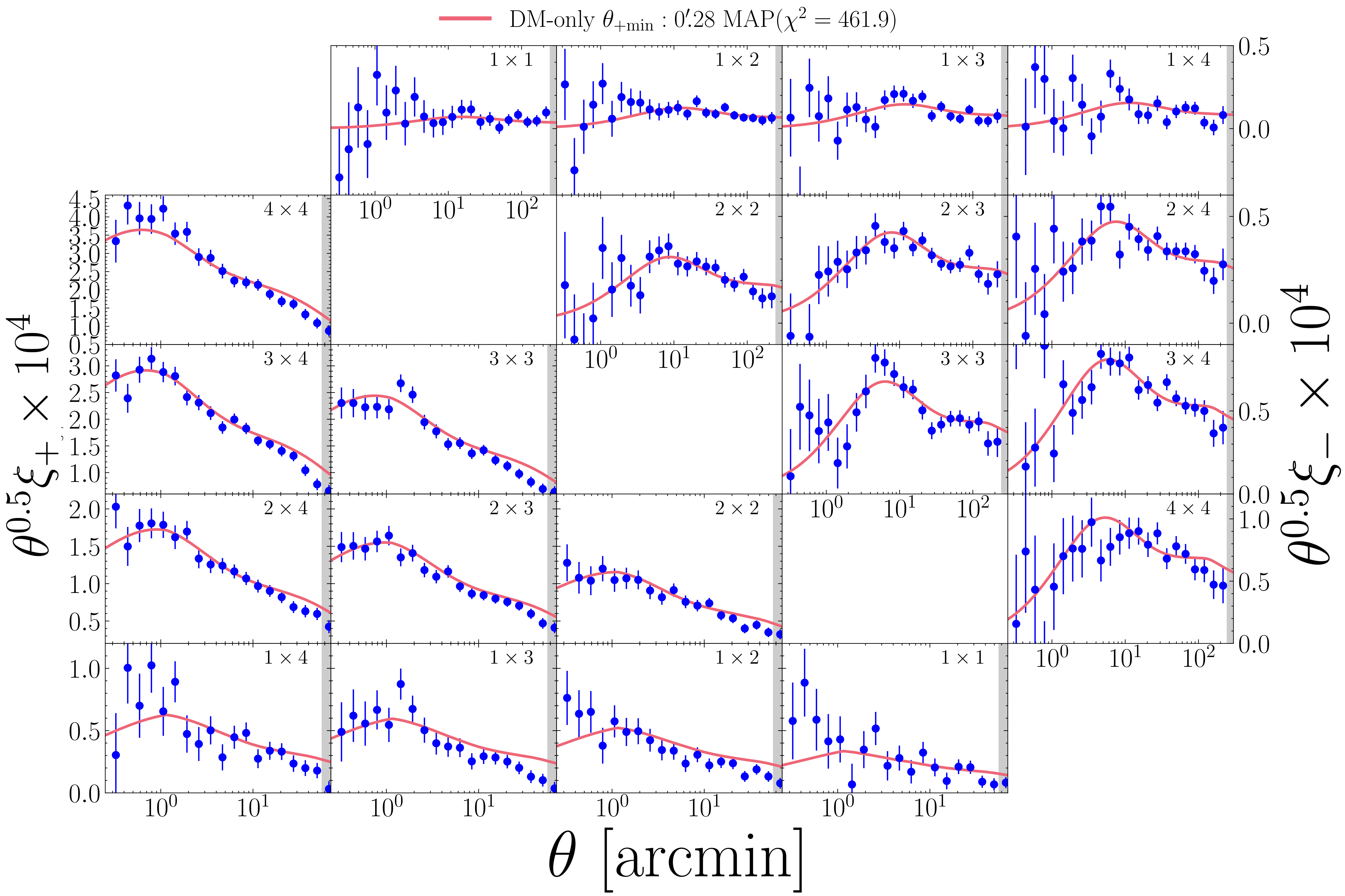
Goodness-of-fit

- p-value
  $p = 0.18$ for Y3 scale cuts
  $(\theta_{+\min} : 7'.1)$

  $p = 0.06$ for the smallest scale cuts $(\theta_{+\min} : 0'.28)$

Thanks to the high number density of HSC sources, we can use small scales down to 0.28 arcmin

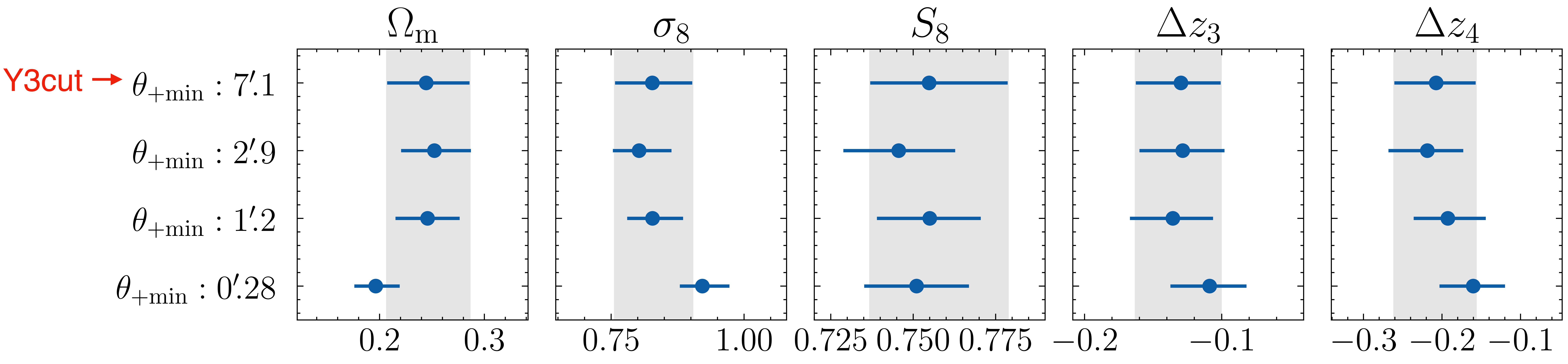
The DM-only model can fit the data!



S_8 constraints

$$S_8^{\rm DMO} = 0.XX^{+0.0X}_{-0.0X} - \text{sys}(\theta_{\rm min})\ ?$$

Note: used informative prior on $\Delta z_{3,4}$ for Y3 scale-cuts



- Confirm that shifts of $S_8 : \Delta S_8 \equiv S_8(\theta_{+\rm min}) - S_8^{\rm Y3cut}$ is statistically consistent with DM-only model using 50 noisy mock data vectors.

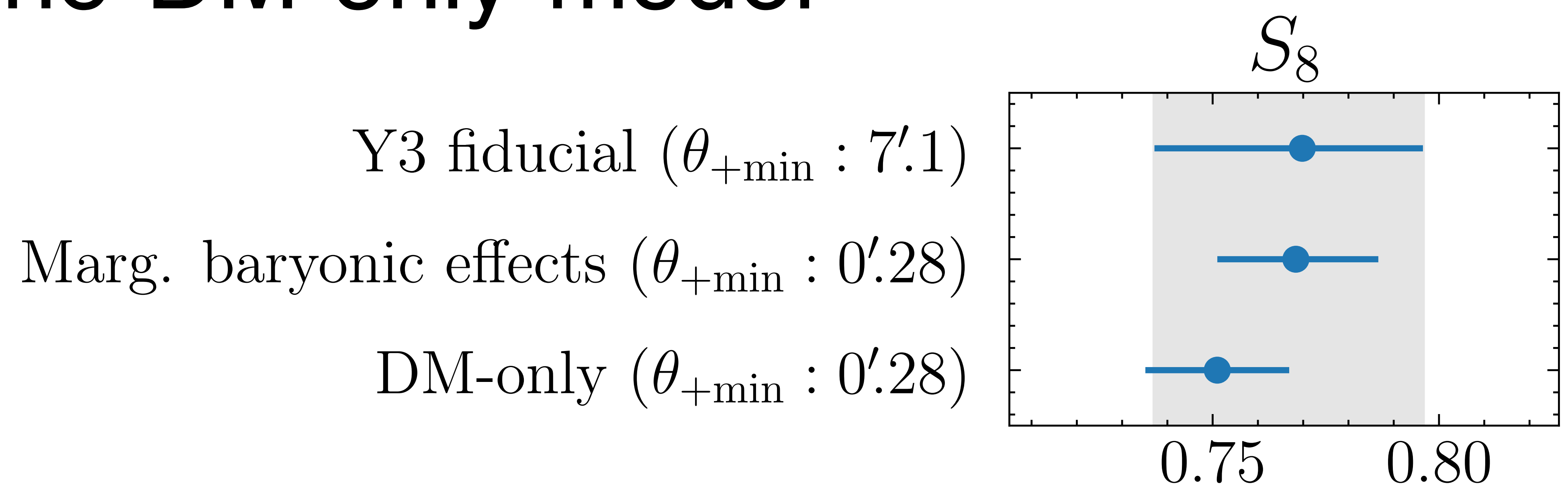
Quick summary of DM-only analysis

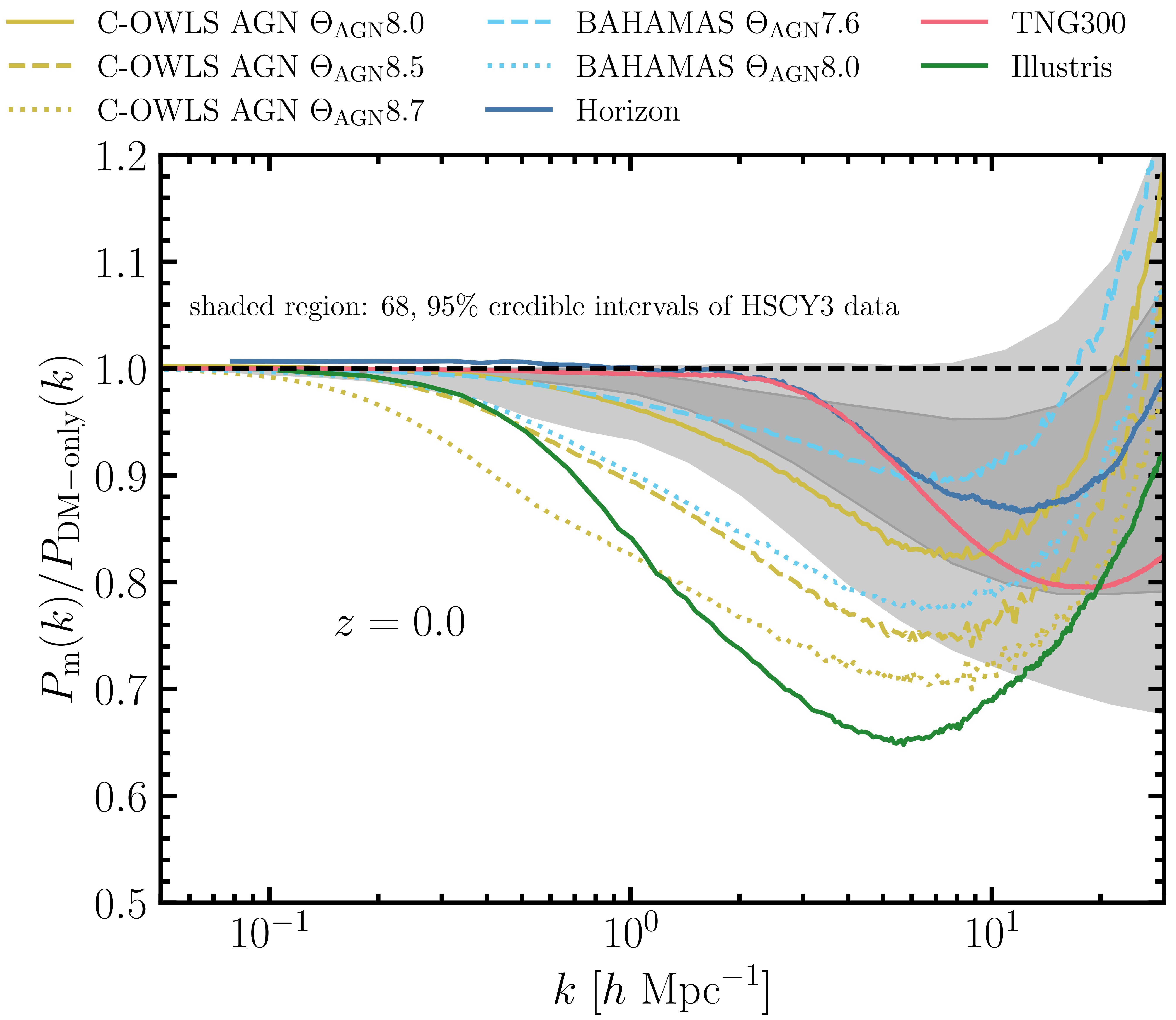
- DM-only analysis is a robust test of baryonic effects; no need to assume any particular model for baryonic effects
- DM-only model can fit the data down to small scale without bias of S8
- No significant feature of baryonic suppression: data is consistent with DM-only model (and weak baryonic feedback model)

How ``weak” baryonic feedback is?

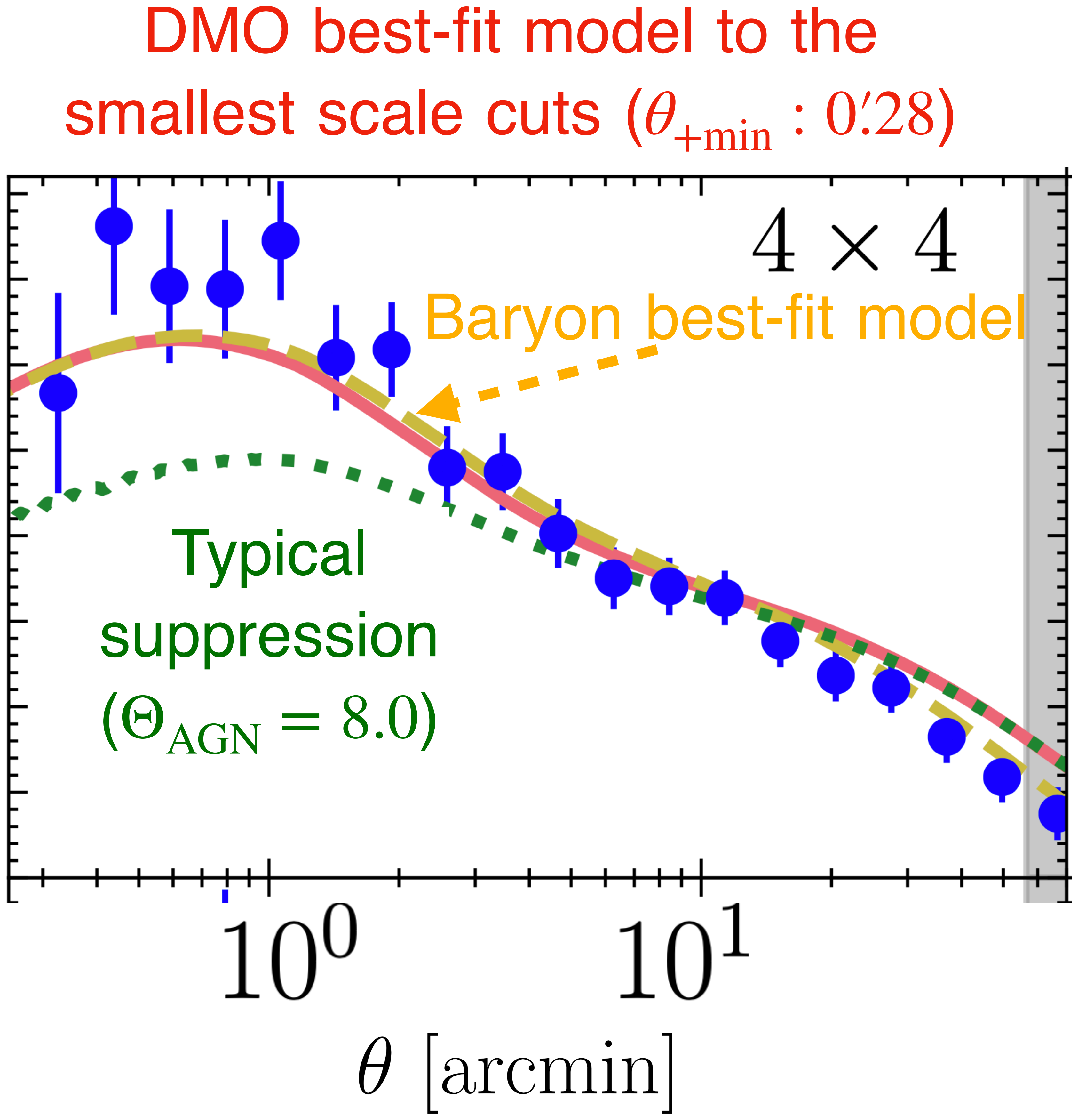
Constraints on Baryonic feedback

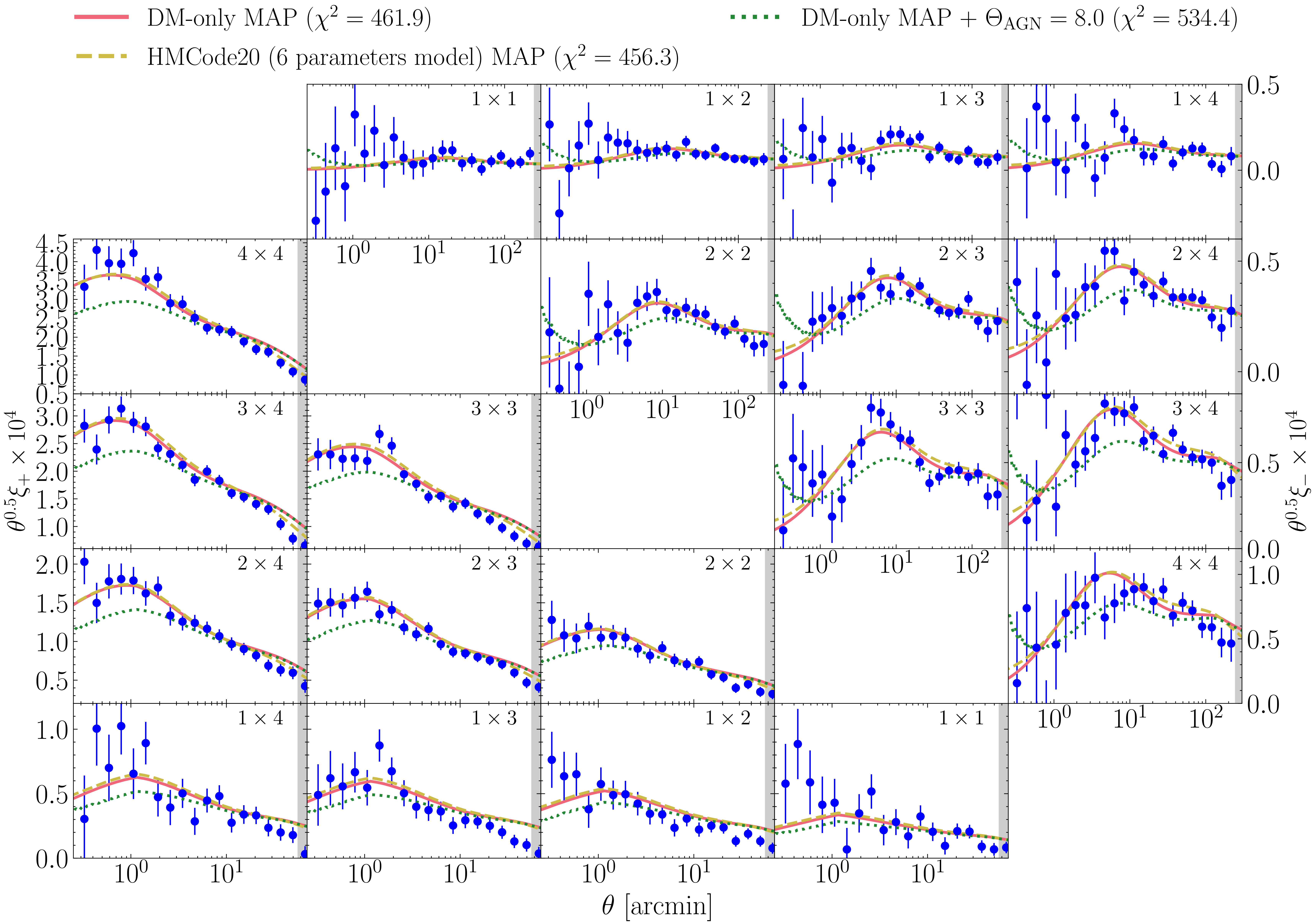
- Assume a specific model to constrain the baryonic feedback
- Flexible model of baryonic effects with 6 free parameters (HMCode2020)
- Data is consistent with DM-only model
- Exclude extreme feedback scenario
- Inclusion of baryonic effects alleviate the S_8 tension only slightly compared to the DM-only model





No suppression feature seen in even smallest scales

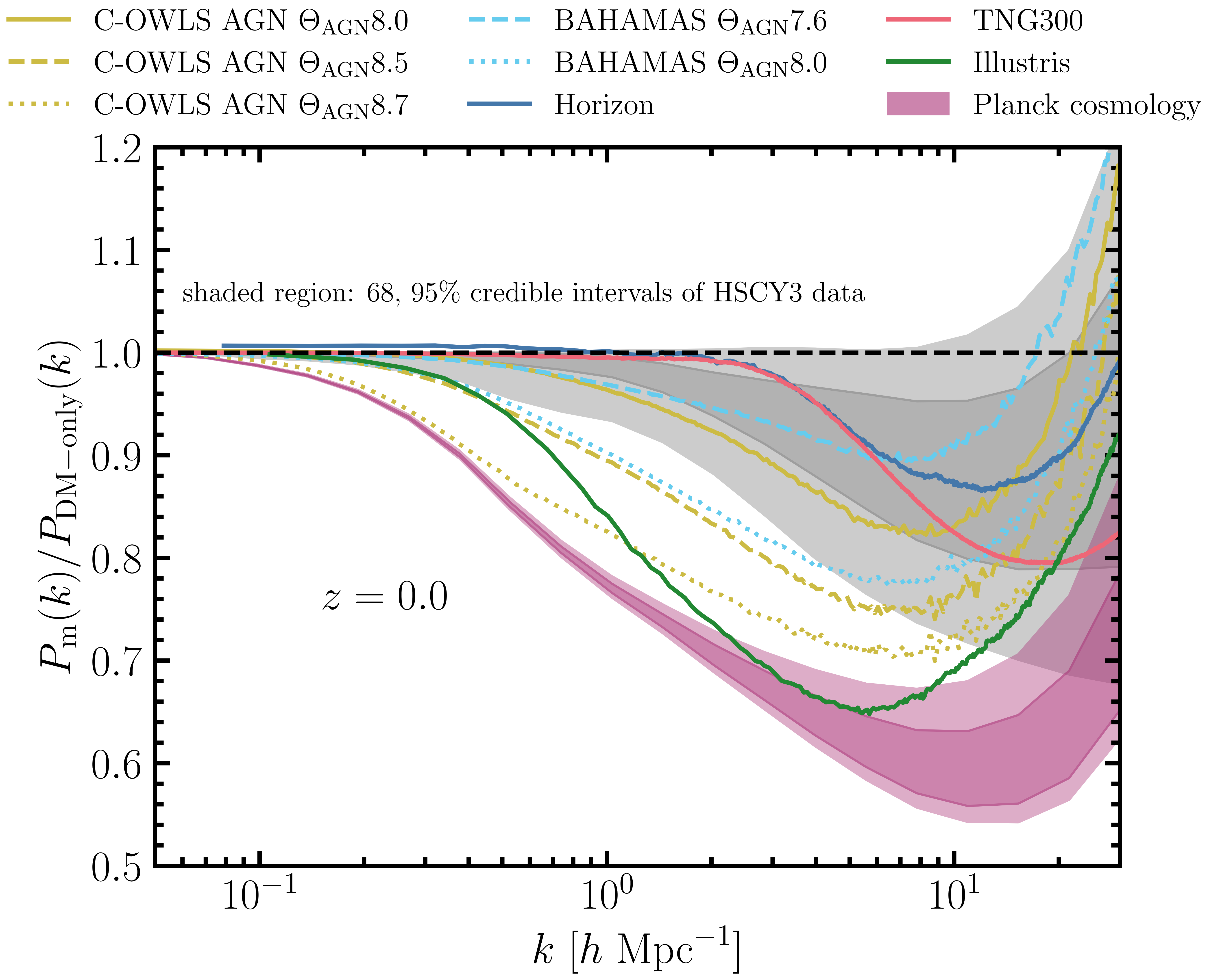




(unrealistically) extreme feedback needed to solve S_8 tension

- Assume Planck cosmology
- Allow ``extreme" feedback that is not realized in any hydro simulations
- The baryon feedback required to reconcile the tension is too strong compared to the existing hydro simulations and the HSC cosmic shear data

Baryonic effects can't solely solve the S_8 tension



Summary

Feel free to contact me via email (ryo.terasawa@ipmu.jp) for questions and discussion.

- Baryon feedbacks leads to suppression in the cosmic shear signal at small angular scales and is difficult to accurately model
- We assessed whether the DM-only model can fit the HSC-Y3 cosmic shear data even down to very small angular scales that are sensitive to the baryonic suppression effects.
- The HSC-Y3 cosmic shear data does not show any clear signature of the baryonic effect; the DM-only model can explain the data down to very small scales (~ 0.3 arcmin: $k \sim 20\ h\mathrm{Mpc}^{-1}$).
- We conclude that the S8 result from the HSC-Y3 data is robust, not affected by the unknown baryonic effect; it confirms the S8 tension between HSC WL and CMB.