A non-linear solution to the S_8 tension II: Analysis of DES Year 3 cosmic shear

Calvin Preston[1,2⋆], Alexandra Amon [1,2†], George Efstathiou [1,2‡]

On the ArXiv: https://arxiv.org/abs/2305.09827

Motivation - The S_8 tension

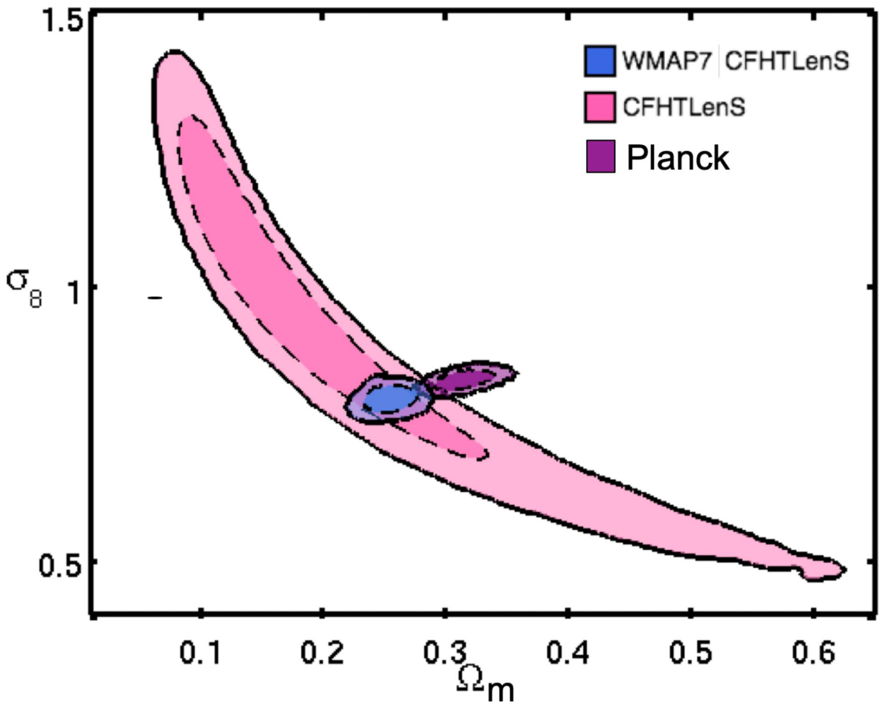

Figure from Catherine Heymans, 2013
~9 million galaxies

$$S_8 = \sigma_8 \sqrt{\frac{\Omega_m}{0.3}}$$

A persistent trend of low-significance, but seemingly consistently low-lensing measurements from ***independent analyses*** becoming known as the S_8 tension

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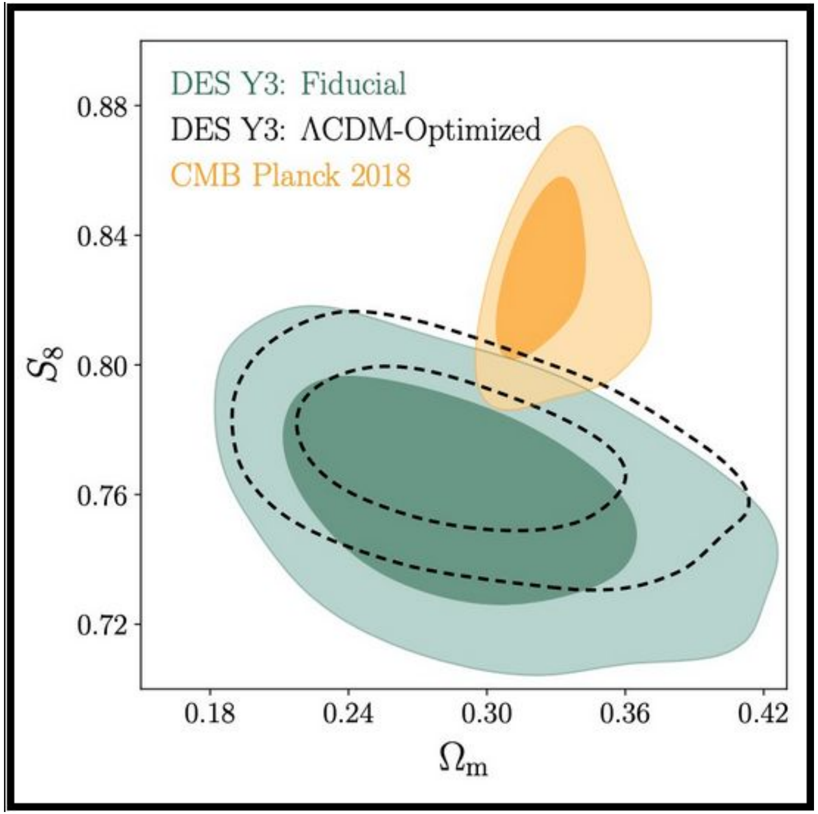

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A persistent trend of low-significance, but seemingly consistently low-lensing measurements from ***independent analyses*** becoming known as the S_8 tension

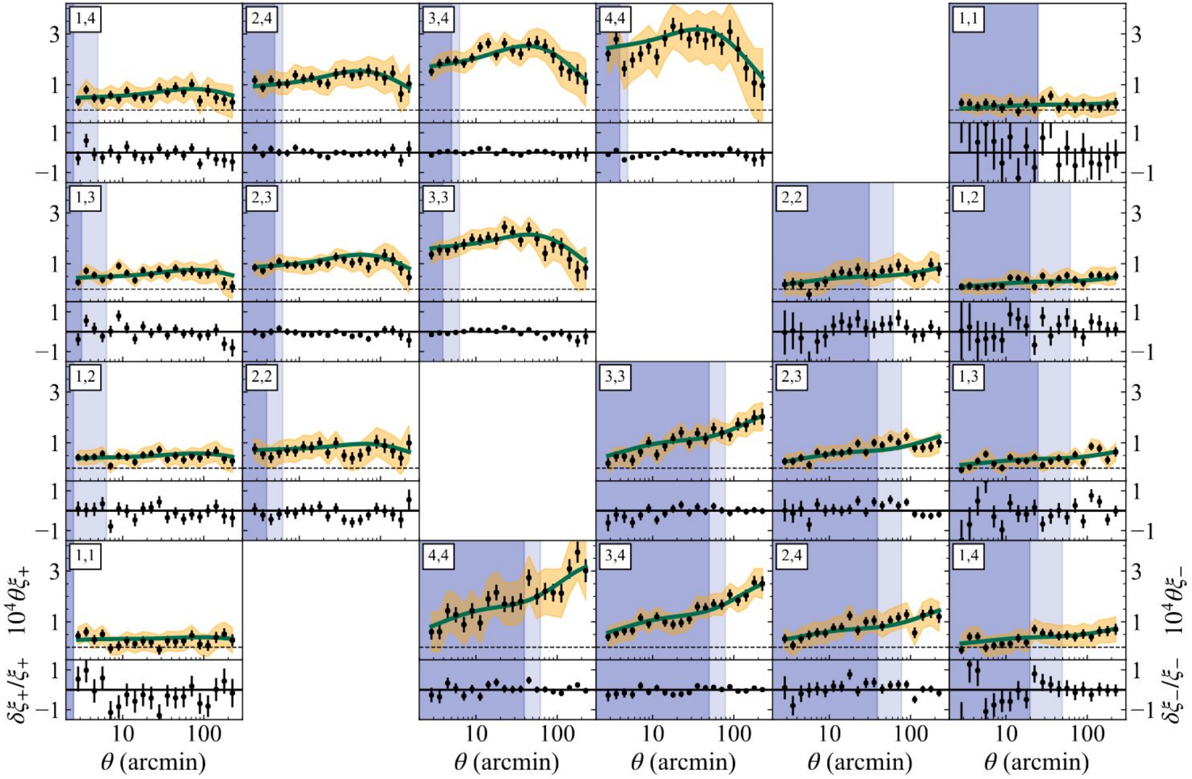
But these analyses are not on equal footing…

However, work done by KiDS+DES see the same result analysing data in the ***same pipeline***

Having made several decisions about the modelling choices made, the S_8 tension persists when analysing KiDS + DES. HSC see the same tension too…

Figure from KiDS+DES: https://arxiv.org/abs/2305.17173

The DES Y3 $\xi_\pm$ measurements are well fit on all scales - ***even where they are not included in the analysis***



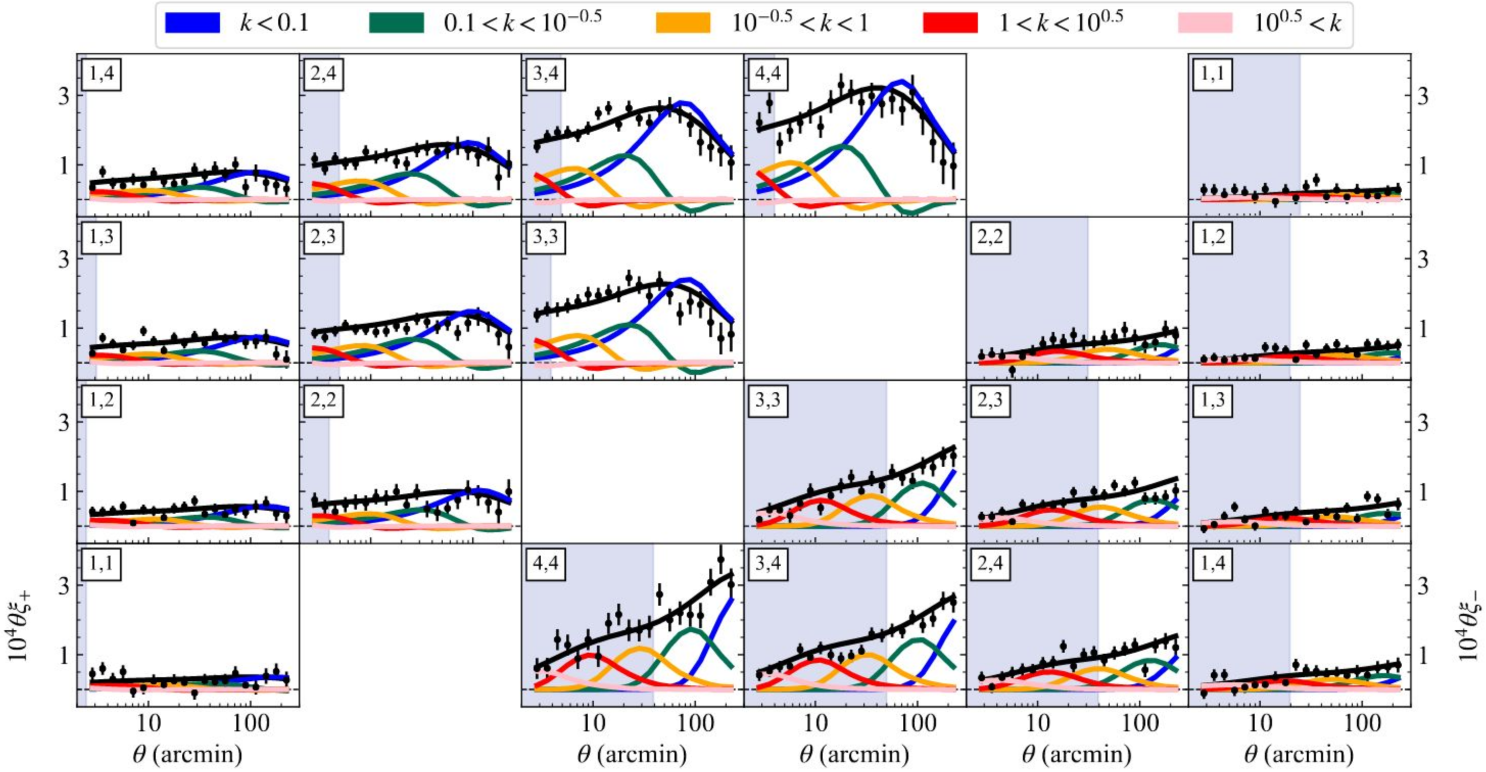
Only uses scales that are unshaded

But fits the shaded region well, even when they're not modelled

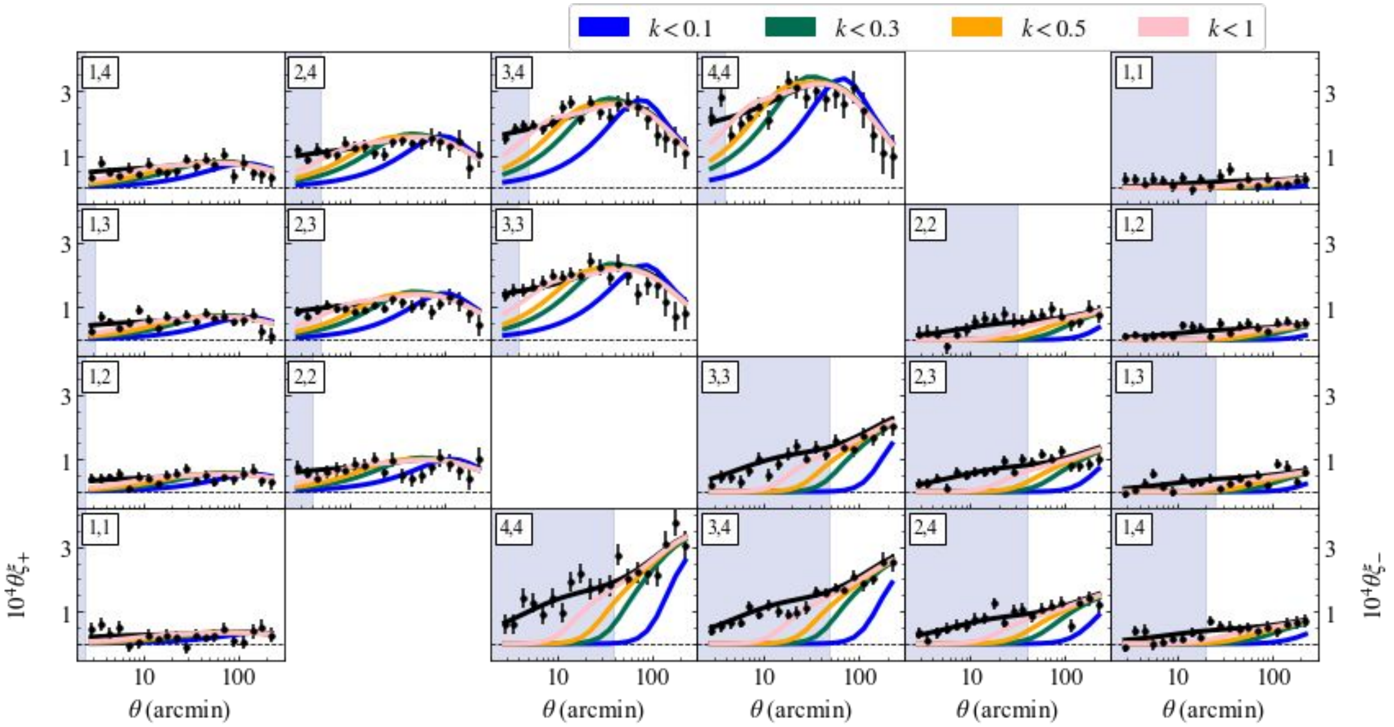
There exists a degeneracy with low S_8 and non-linear modelling

Credit: DES Y3 Cosmic shear (https://arxiv.org/pdf/2105.13543.pdf)

Measurements of angular scales ***mix*** wavenumbers - these mix and add together $\xi_\pm$ to give the overall best fit



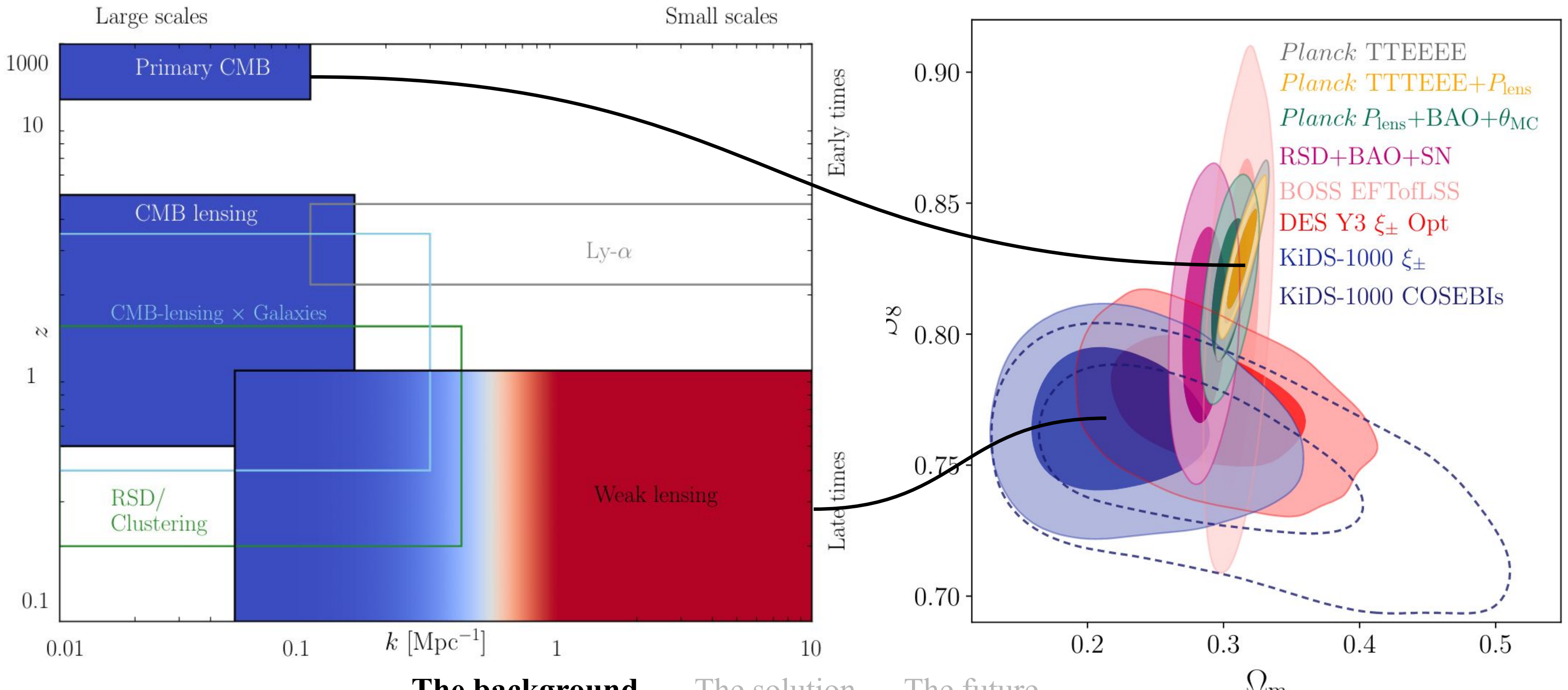
k scales leak into wide ranges of θ - cosmic shear is a way off from a **linear-only** analysis



Best fit data-vectors made only from k scales given in the legend

Almost no information from the largest scales in ξ_-

The extent of each probe in space and time is important to bear in mind in the context of this tension…



The hypothesis - *Planck's* ΛCDM cosmology is correct on linear scales, and the non-linear scales are poorly understood and modelled incorrectly

Amon & Efstathiou (2022) - https://arxiv.org/pdf/2206.11794.pdf first investigated a solution by modulating the non-linear matter power spectrum

$$P_{\mathrm{m}}(k,z) = P_{\mathrm{m}}^{\mathrm{L}}(k,z) + A_{\mathrm{mod}}[P_{\mathrm{m}}^{\mathrm{NL}}(k,z) - P_{\mathrm{m}}^{\mathrm{L}}(k,z)]$$

As we extend into the non-linear regime, we expect to see the suppression of power tend towards the value of A_{mod}

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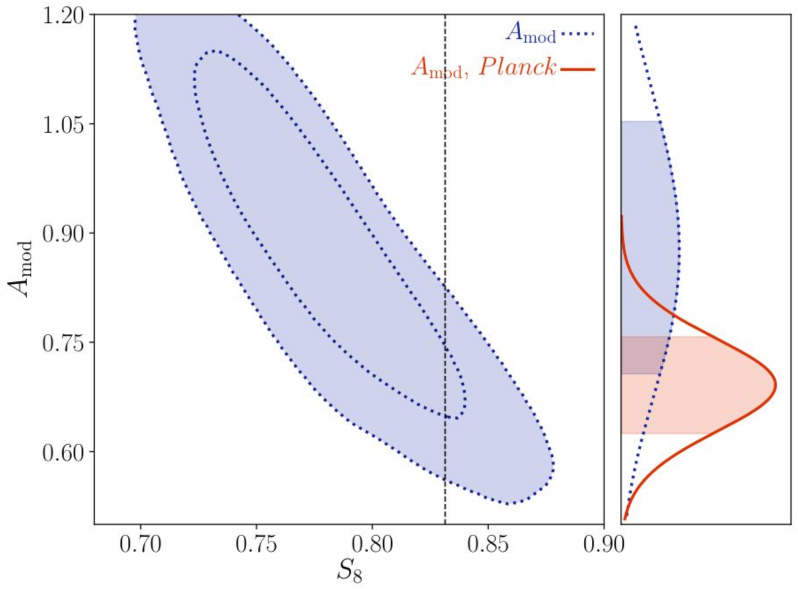
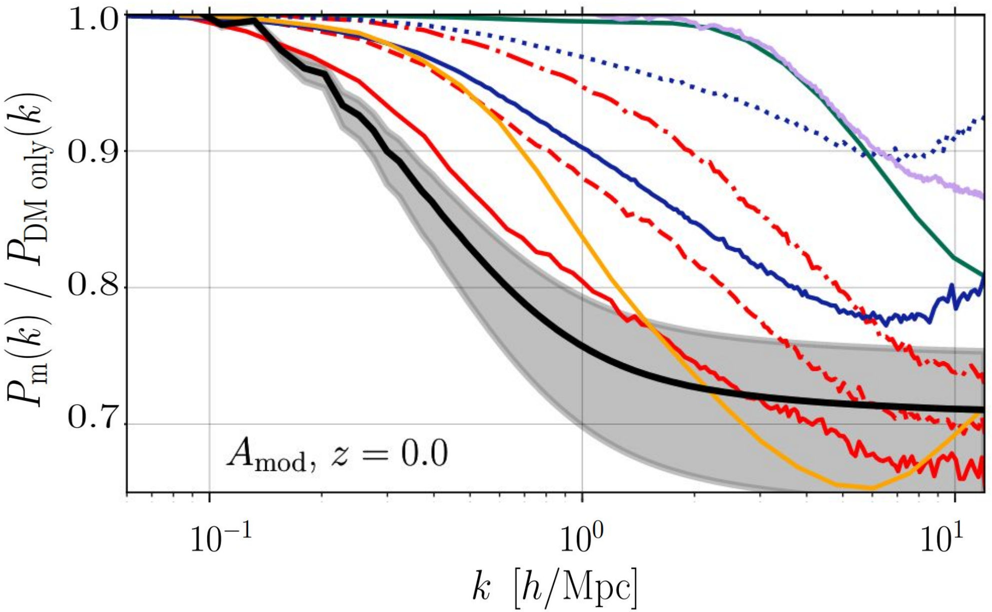




Analysis choices for this paper - Trying to keep things *simple*

IA model - 1 parameter NLA (no redshift dependence) - Fixed

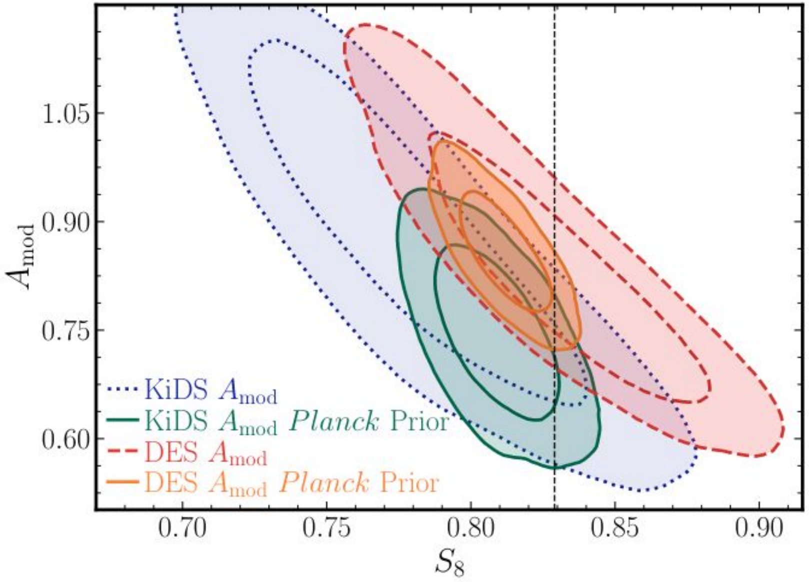
Shear and redshift calibration - Fixed

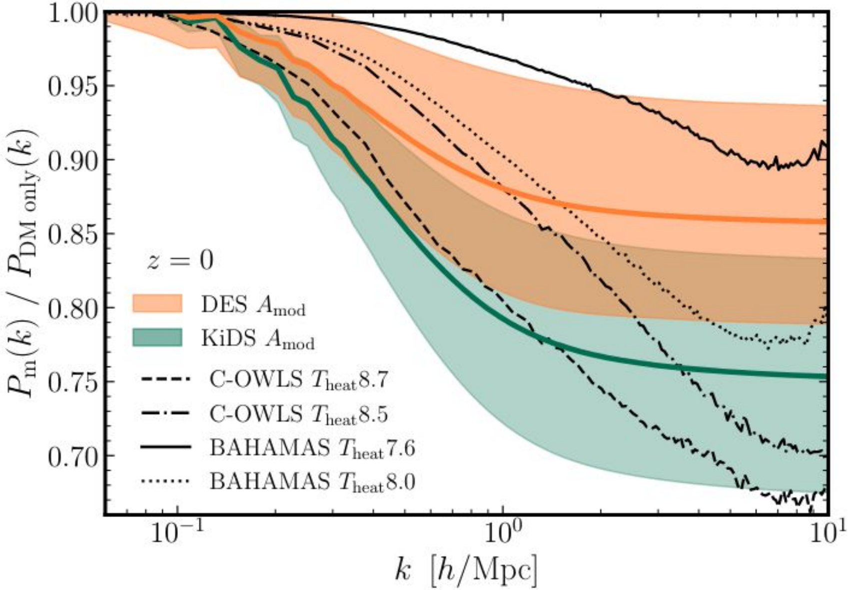
(Having checked throughout that free nuisance parameters don't affect our results)

Cosmology choices - Free + *Planck Prior*

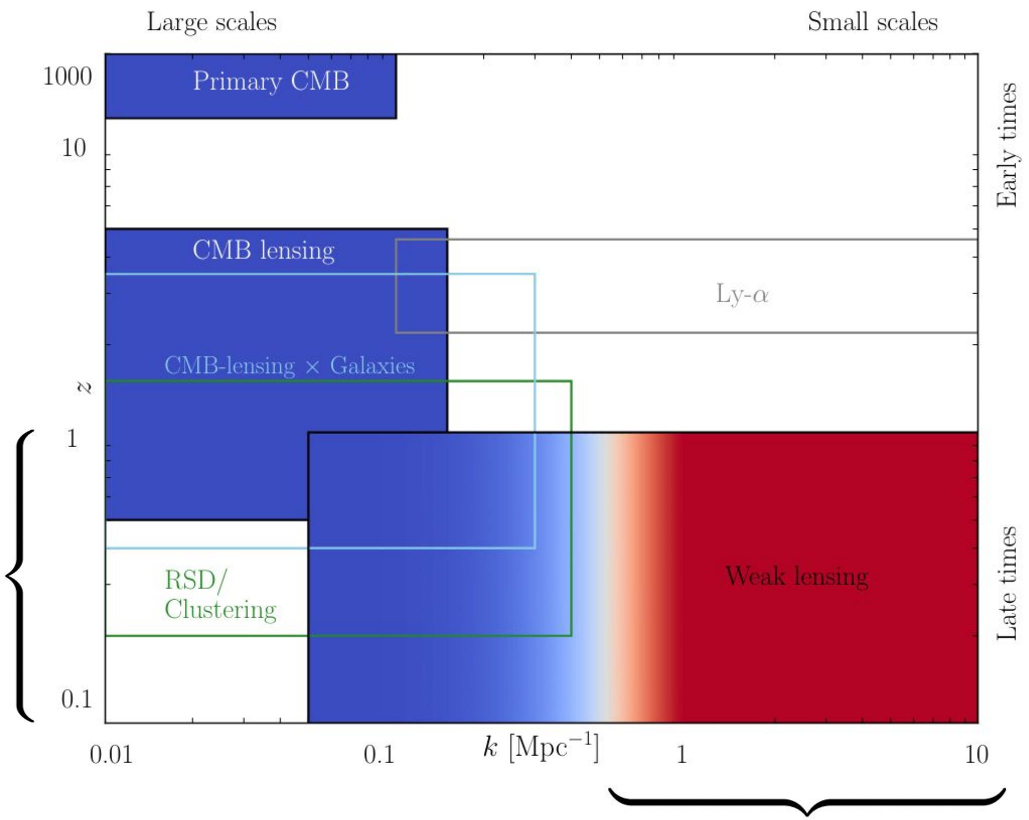
Planck prior fixes parameters well constrained parameters ($n_s, \Omega_m h^3$, but samples over Ω_m and S_8)

This paper first updates the results with DES Y3 data, and includes the uncertainties on *Planck* cosmological parameters





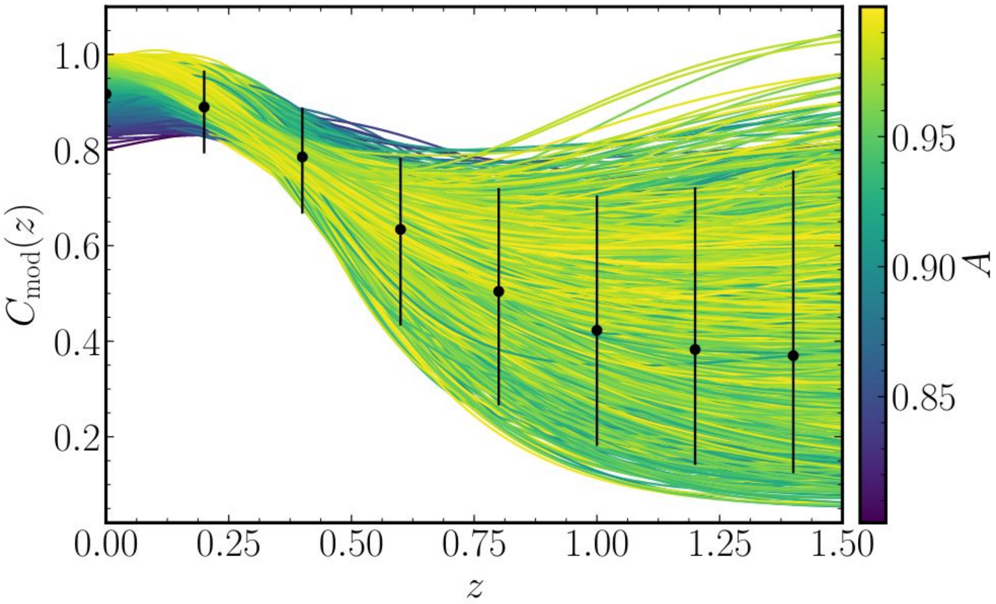
Can we do better than that?



We've motivated a solution on small scales, but can we isolate the exact scales and redshifts we need to this suppression to act on?

i.e. where is the real tension in these 2 dimensions?

The lensing data are not sensitive in a wide redshift range, only $z \approx 0.3$

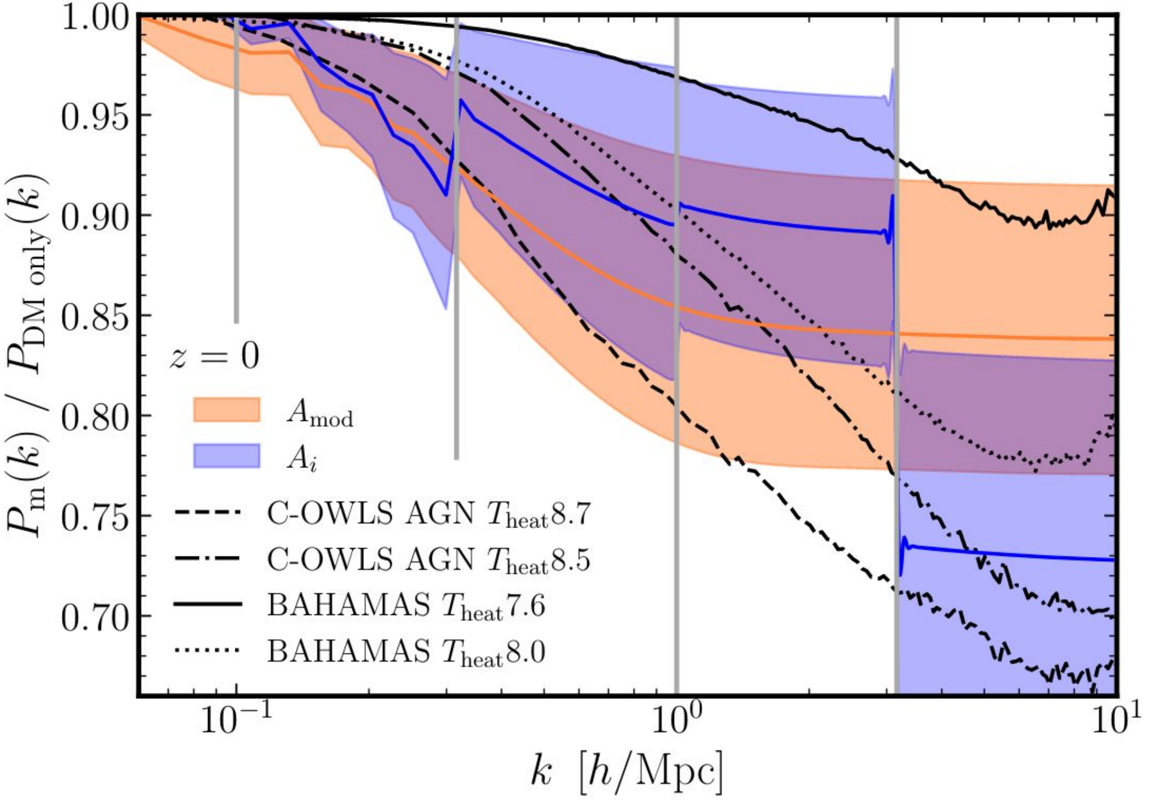


$$C_{\rm mod}(z) = A[1 - f_1(z)] + B[f_2(z)]$$

$$f_k(z) = \frac{(z/z_{\rm c_k})^{\alpha_k}}{1 + (z/z_{\rm c_k})^{\alpha_k}}, \quad k = 1, 2$$

Therefore, generally difficult to weigh in on the z dependence of S_8 with weak lensing data alone

But with a binning approach, we can ***start*** to say something about the scale-dependence of the required suppression



Using 5 bins in k, with an Amod for each bin

$$\left.\begin{array}{ll} A_1: & \log_{10} k \le -1, \\ A_2: & -1 < \log_{10} k \le 0.5, \\ A_3: & -0.5 < \log_{10} k \le 0, \\ A_4: & 0 < \log_{10} k \le 0.5, \\ A_5: & \log_{10} k > 0.5. \end{array}\right\}$$

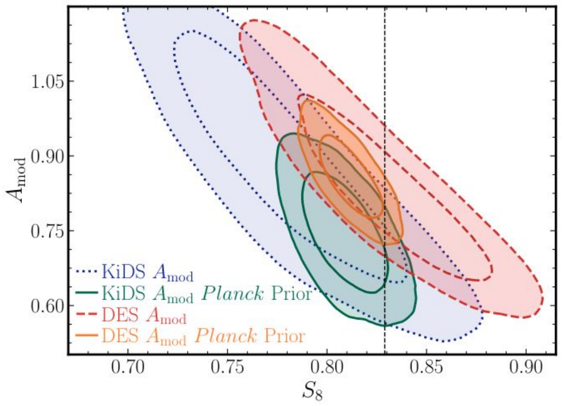
Summary so far

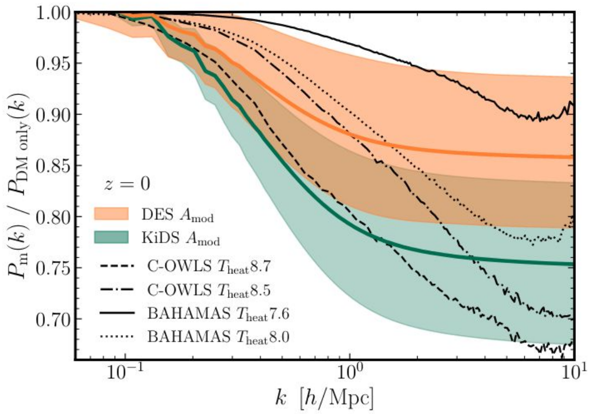
- The required suppression must extend into the mildly non-linear regime - $k \; 0.2h\mathrm{Mpc}^{-1}$
- The lensing data required is most sensitive to revealing the required suppression at and much less sensitive at higher $z \approx 0.3$
- The required suppression is less extreme than presented in Amon & Efstathiou 2022's analysis with KiDS data, but still generally more extreme than most hydrodynamical simulations

What could $A_{\rm mod}$ be physically?

Alternative dark matter models suppress the matter power spectrum. E.g. Rogers et al: https://arxiv.org/abs/2007.12705

Other work probing this with SZ effects (e.g. Tröster et al https://arxiv.org/abs/2109.04458). Work done here in Cambridge looking to use kSZ .





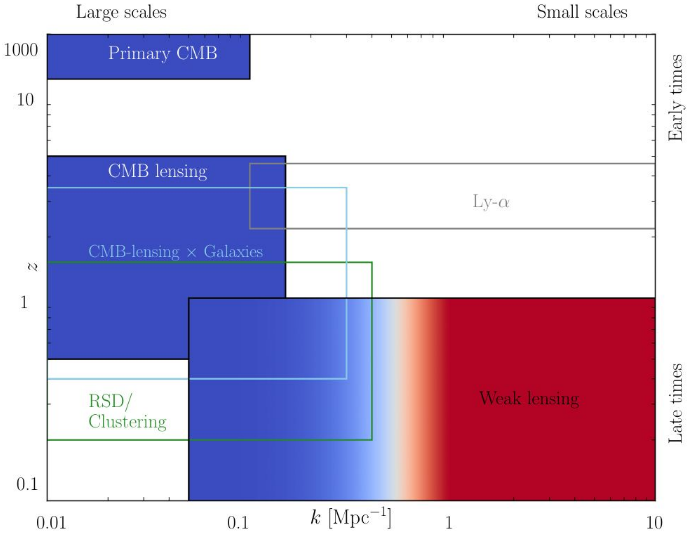
However, we need to see if this baryons or not, before we explore beyond CDM physics…

What does this mean for other probes?

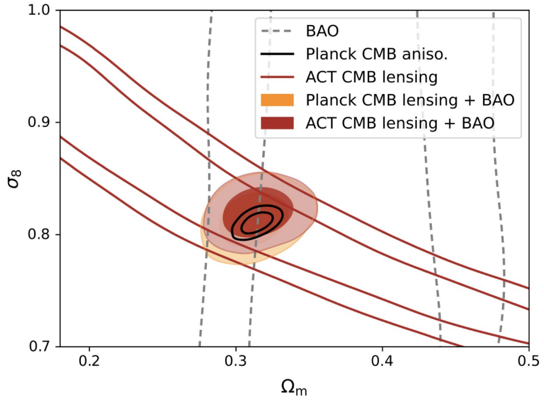
New ACT CMB lensing results are consistent with our solution

Cross correlations of galaxies with CMB should be consistent with Planck (unWISE with ACT etc)

DESI will prove decisive for this hypothesis.
RSD from linear scales should be consistent with *Planck*

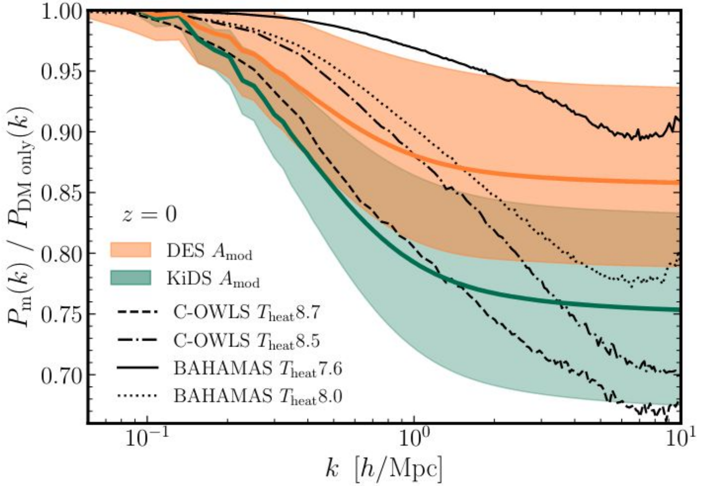


Madhavacheril + Adv ACT 2023



Looking ahead: Beyond the A_{mod} model

Restriction of functional form - No ‘uptick’ for largest k in suppression

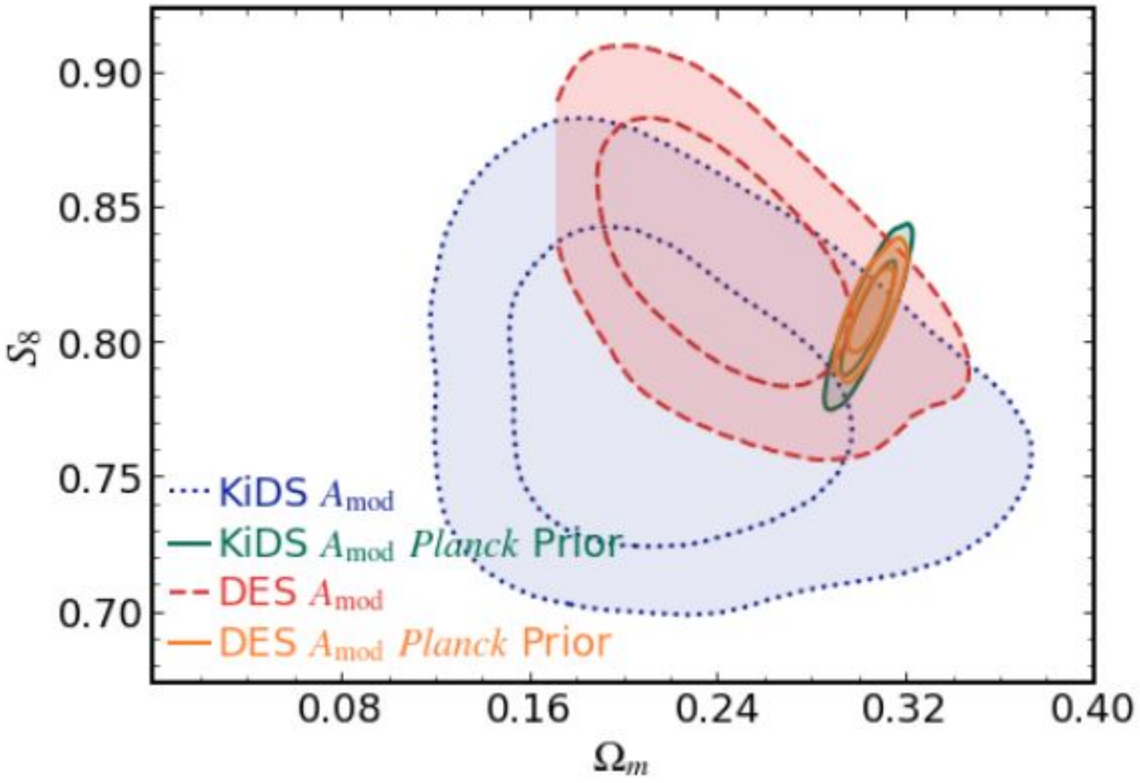


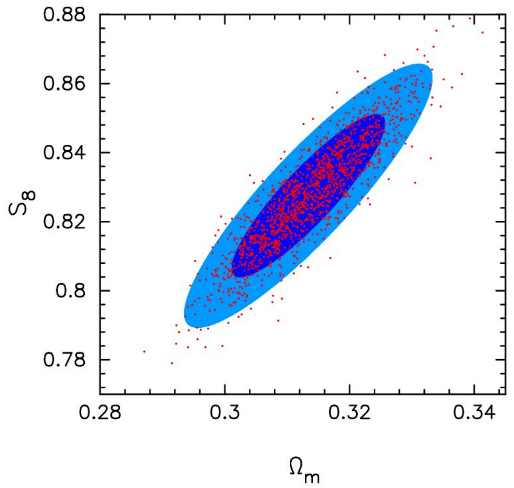
Ideally, we’d want to reconstruct the matter power spectrum from weak lensing statistics alone, but results of this work show we’re a long way off… But future surveys (Euclid and Rubin), should help solve this problem

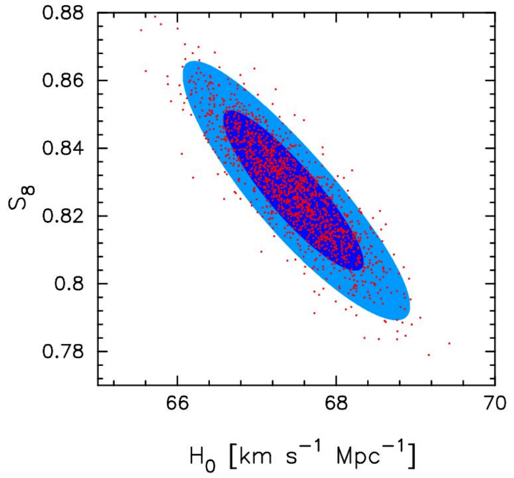
Thank you!
Any questions?

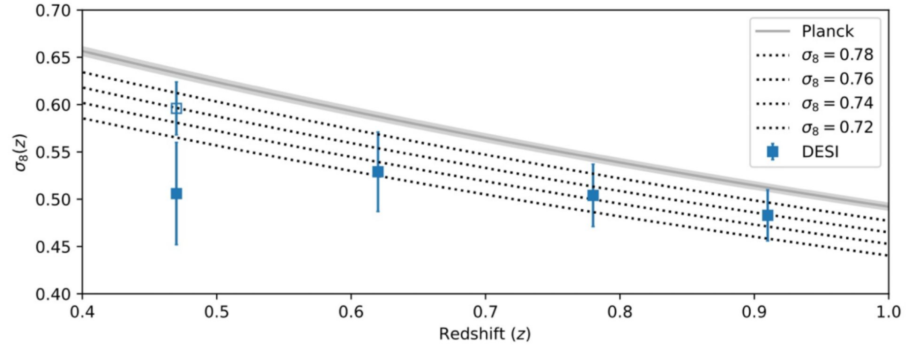
Additional slides

Planck prior

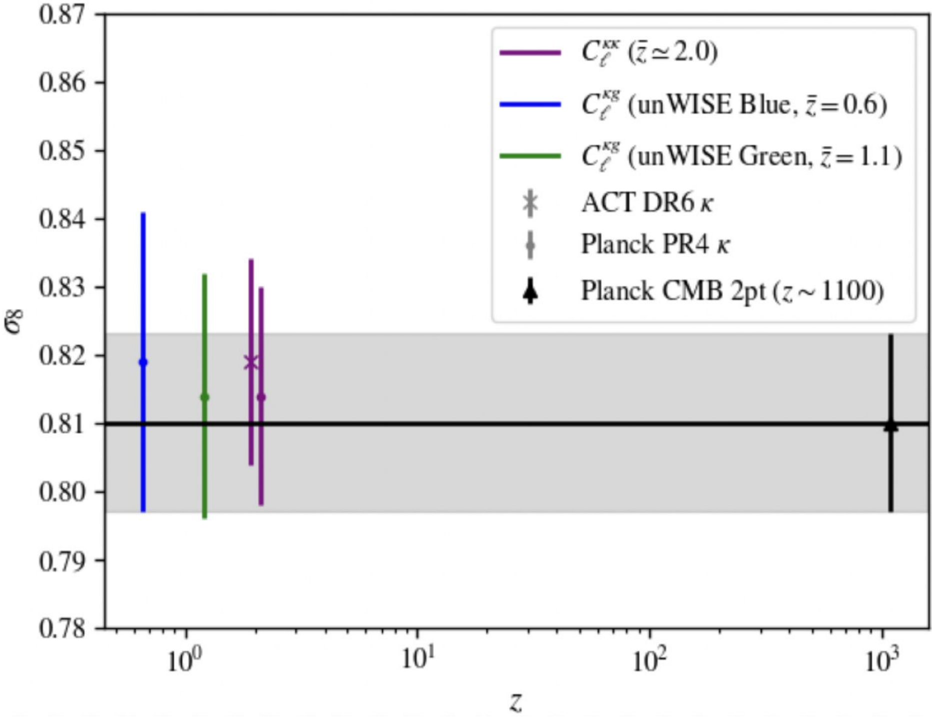




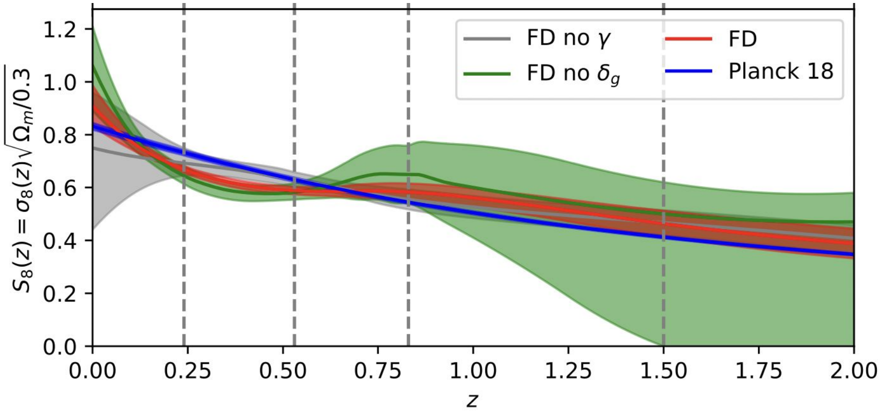




White et al

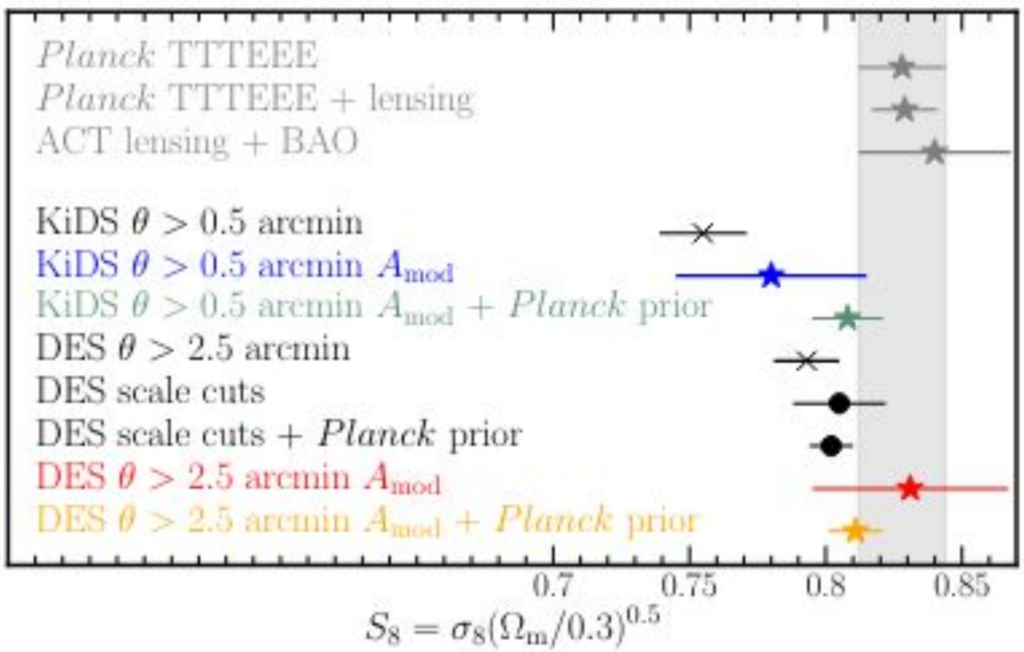


Plot from Simone Ferraro & Gerrit Warren from Japan conference



Garcia-Garcia + 2021

Compilation plot



Shows the effect of different modelling choices on the value of S_8

Consistency of fits between different models - $\hat{\chi}^2$ all essentially identical