The history of structure growth from current LSS and CMB data

Carlos García-García

(2105.12108)

Jaime Ruiz-Zapatero, David Alonso, Emilio Bellini, Pedro G. Ferreira, Eva-Maria Mueller, Andrina Nicola, Pilar Ruiz-Lapuente

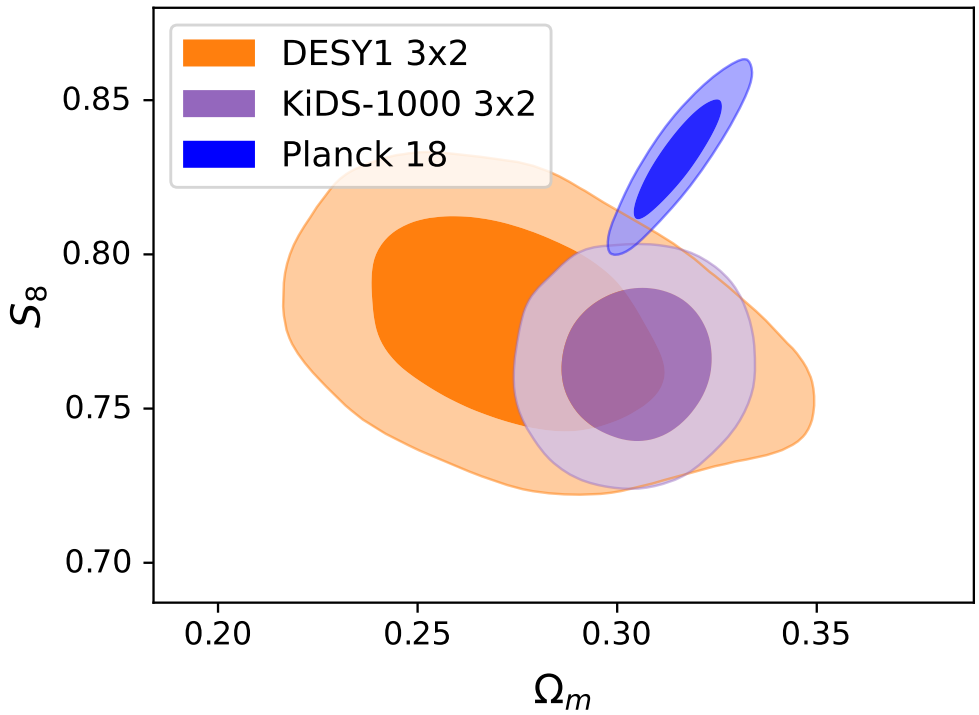
Cosmology From Home, 2021

KiDS, DES and the S_8 tension

	KiDS-1000	DES-Y3	Planck-18
$S_8 = \sigma_8 \sqrt{\frac{\Omega_m}{0.3}}$	$0.766^{+0.020}_{-0.014}$	0.776 ± 0.017	0.832 ± 0.013
Tension	$\sim 3\sigma$	$\sim 2\sigma$	–

Heymans+21; Abbott+17; Abbott+21; Planck coll.+18

- Measure of the granularity of the Universe
- σ_8 = variance of the perturbations at $8\,\mathrm{h}^{-1}\mathrm{Mpc}$
- $\sigma_8 \sim$ amplitude of the perturbations



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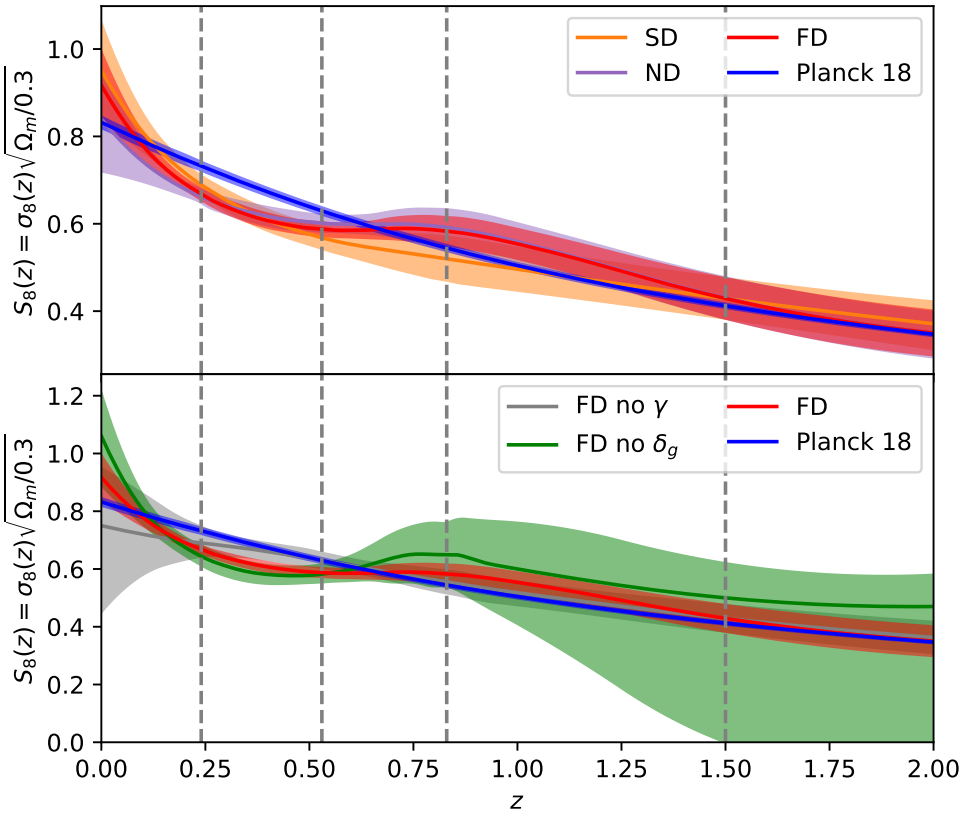
Freeing the growth evolution



Data combinations and footprint

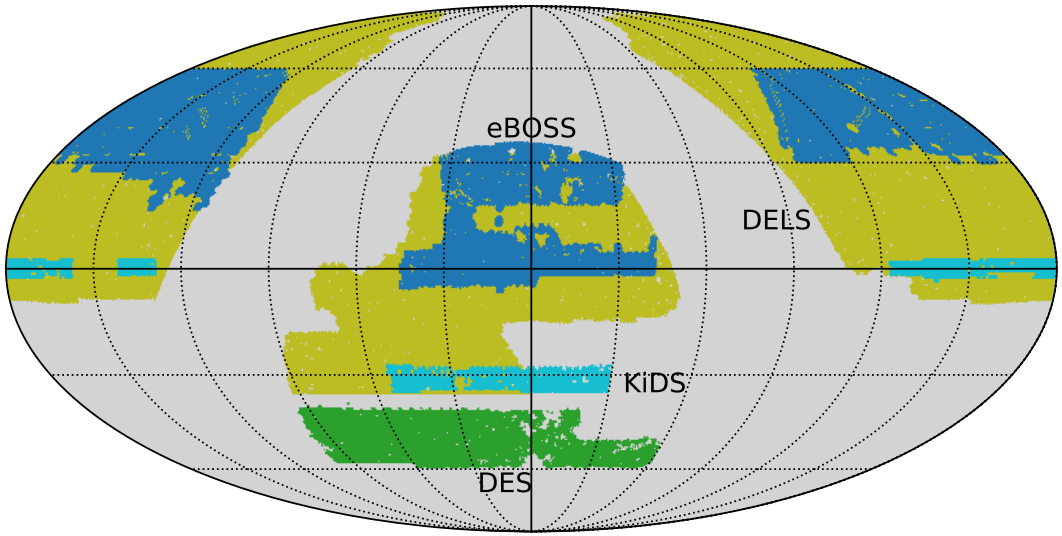
Full Dataset (FD)

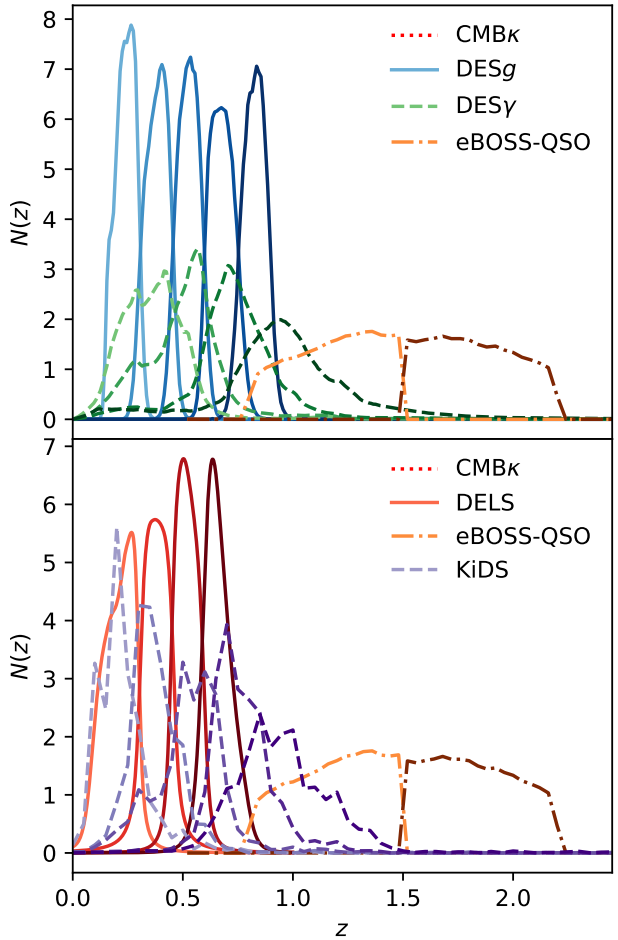
North Dataset (ND)

- DELS galaxy clustering
- KiDS-1000 weak lensing
- eBOSS-QSO's clustering
- Planck18 CMB lensing

South Dataset (SD)

- DESY1 galaxy clustering
- DESY1 weak lensing
- eBOSS-QSO's clustering
- Planck18 CMB lensing





Data analysis: projected data in Fourier space

$$C_\ell^{a_\alpha b_\beta} = \int \mathrm{d}\chi \frac{q_{a_\alpha}(\chi) q_{b_\beta}(\chi)}{\chi^2} P_{\rm NL}\left(\frac{\ell + 1/2}{\chi}, z(\chi)\right)$$

Galaxy clustering, δ_g

- Linear galaxy bias
- Magnification bias (QSO's)

Weak lensing, γ

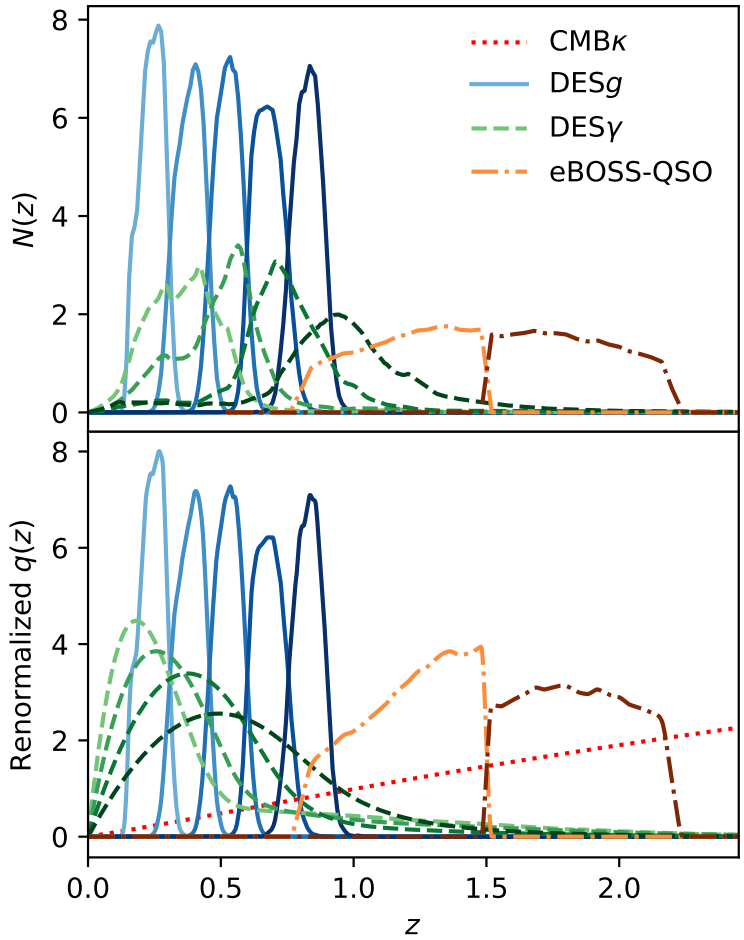
- Multiplicative bias
- Intrinsic Alignments

$$q_{\gamma^i} \to (1 + m^i) q_{\gamma^i} - IA(z)$$

Photo-z uncertainty

- Redshift bin mean free

$$N(z) = N(z + \Delta_z)$$



Computed with the `Core Cosmology Library`

Data analysis: from maps to C_ℓ

Data analyzed with the same pipeline:

- `NaMaster` as base code (Alonso+18)
- Catalogs $\rightarrow$ maps $\rightarrow$ Nx2pt C_ℓ:
  - For shear we follow (Nicola,CGG+20)
- Gaussian covariances for the Nx2pt C_ℓ:
  - Analytically as in (CGG+19; Nicola,CGG+20)
- 1275 data points

Parameter space sampling:

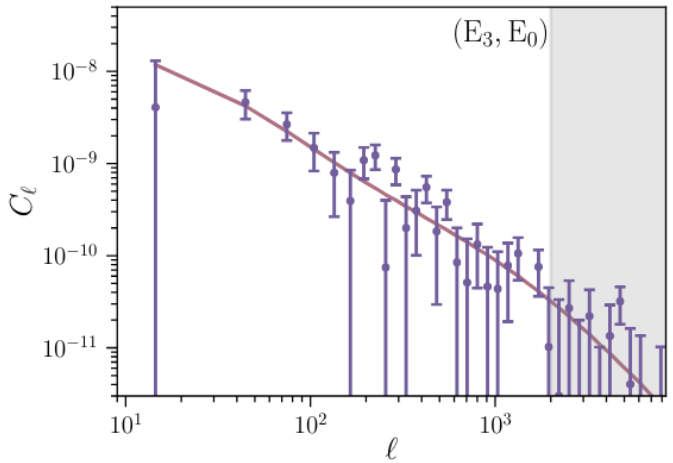
- Gaussian likelihood in MontePython:

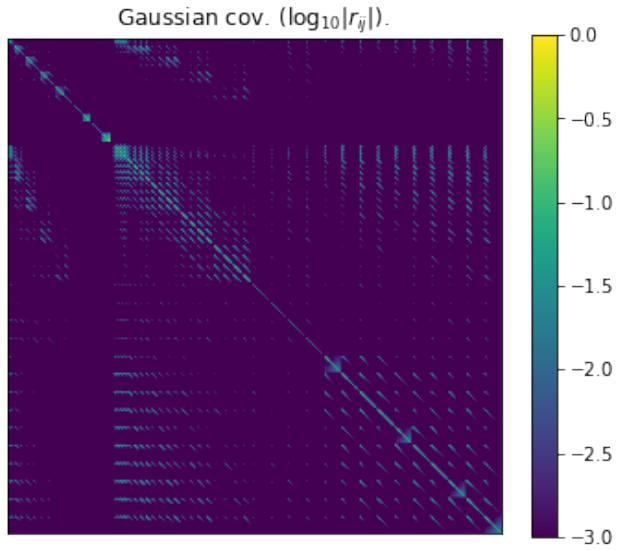
$$-2\log(\text{Likelihood}) = (C_\ell - C_\ell^{\text{data}})^T \text{Cov}^{-1} (C_\ell - C_\ell^{\text{data}})$$

- Conservative scale cuts

  Check (Hadzhiyska,CGG+21) for a study with a better galaxy bias:

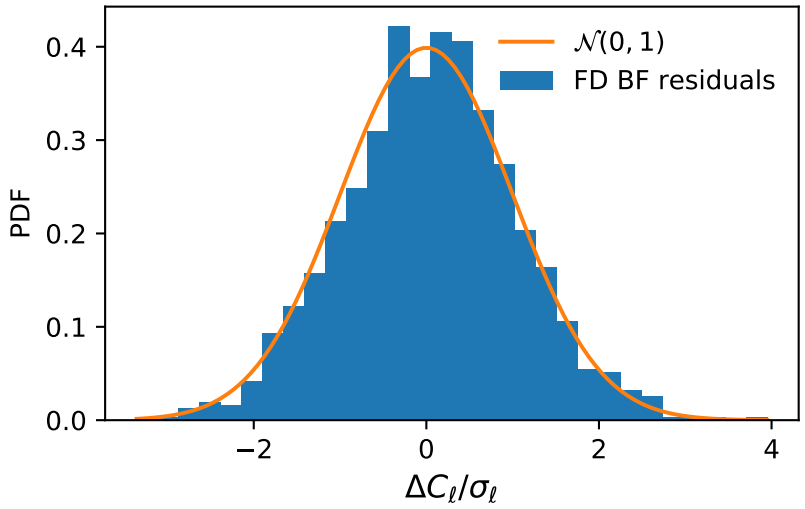
  $k_{\text{max}} = 0.6\,\text{Mpc}^{-1}$ and 30% better errors on Ω_m

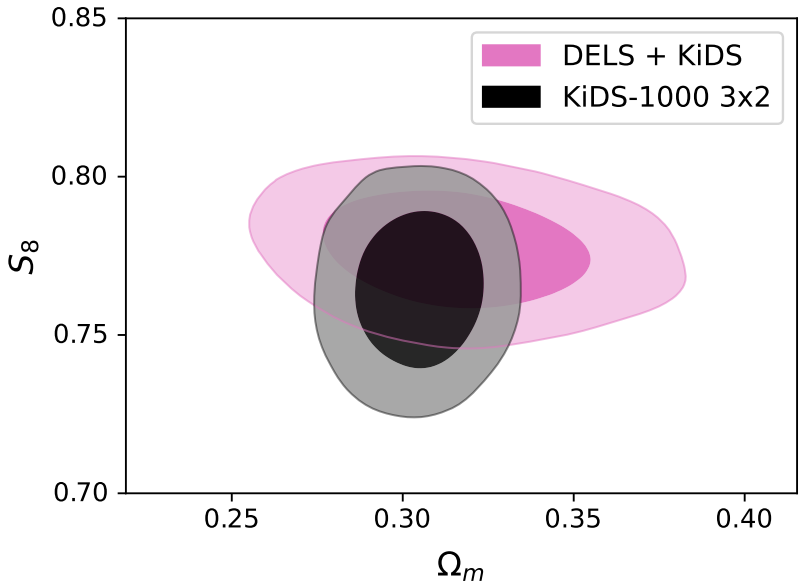


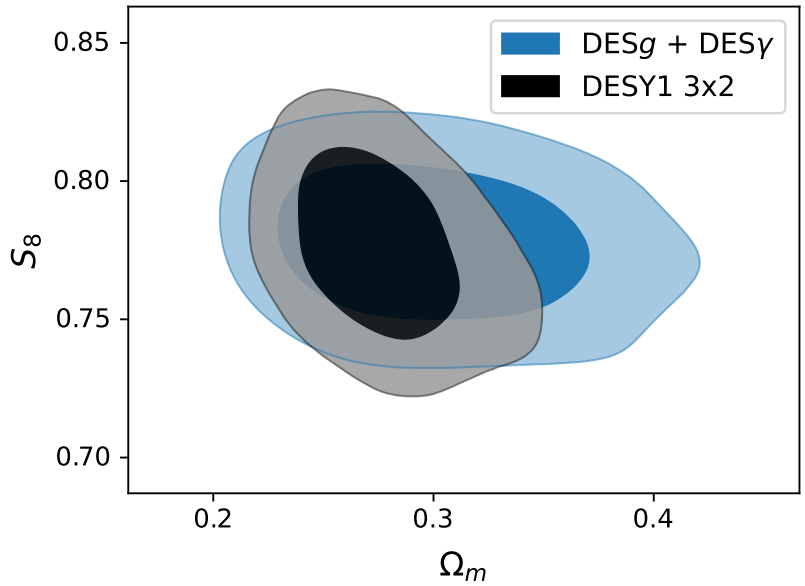


Validation

- Null-tests passed
- Compatible with official results
- Residuals $\sim$ Gaussian
- Good fits: $p \in [0.1, 0.9]$
- ΛCDM fits the data well





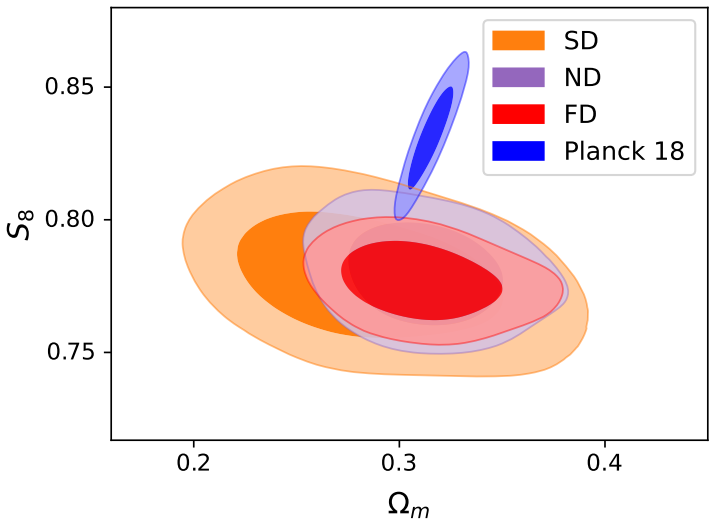


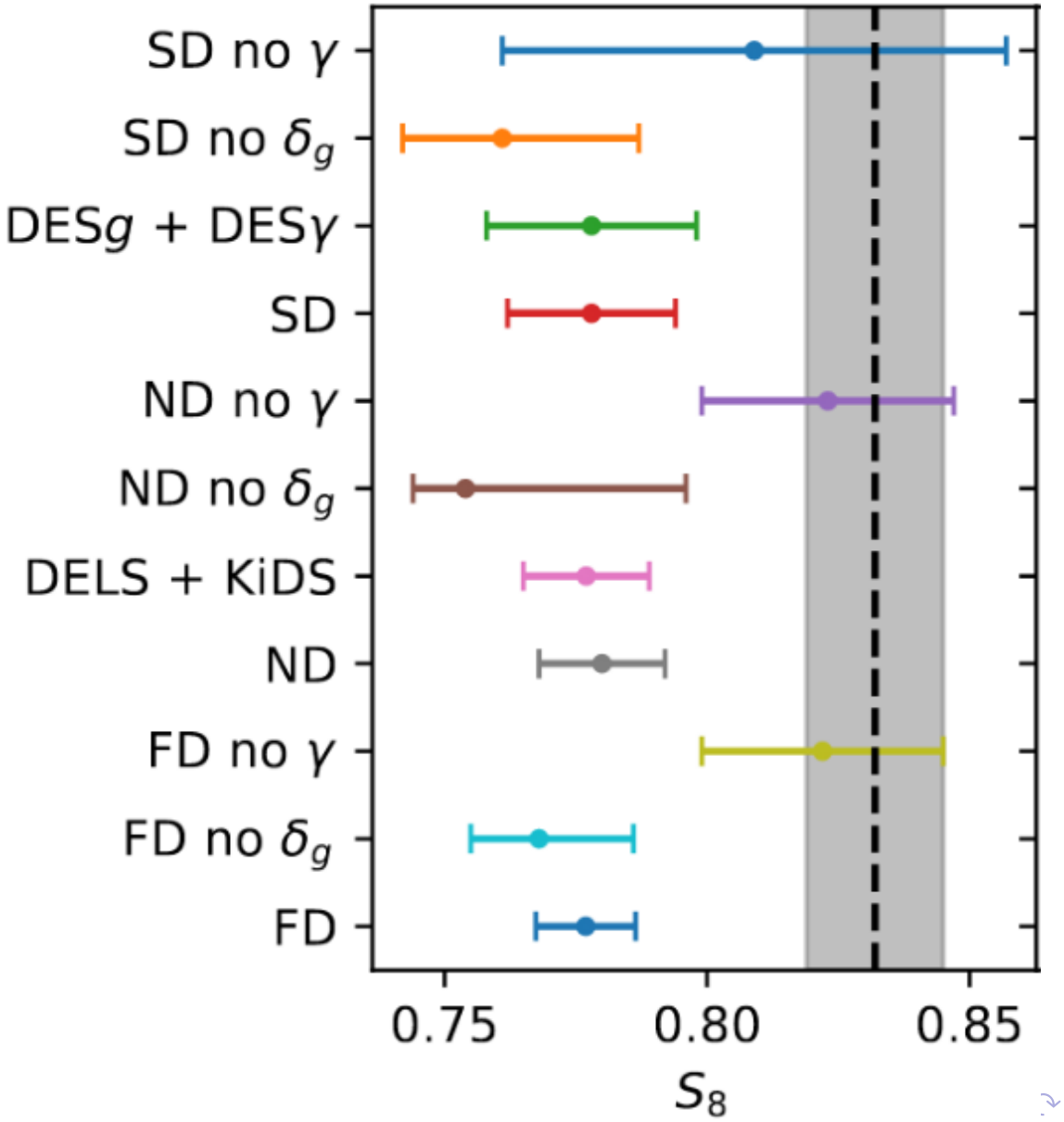
ΛCDM

- SD and ND agree
- γ drives the tension
- Combining all data shrinks errors by $\sqrt{2}$:

$$S_8 = 0.7769 \pm 0.0095$$

- 3.5σ tension with Planck





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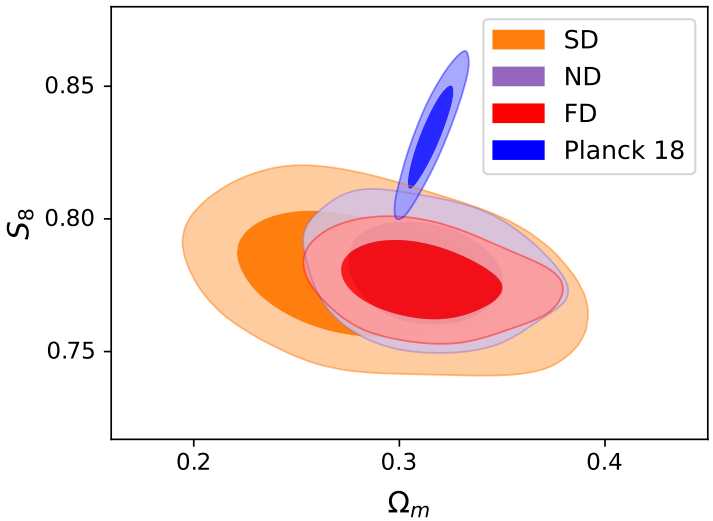
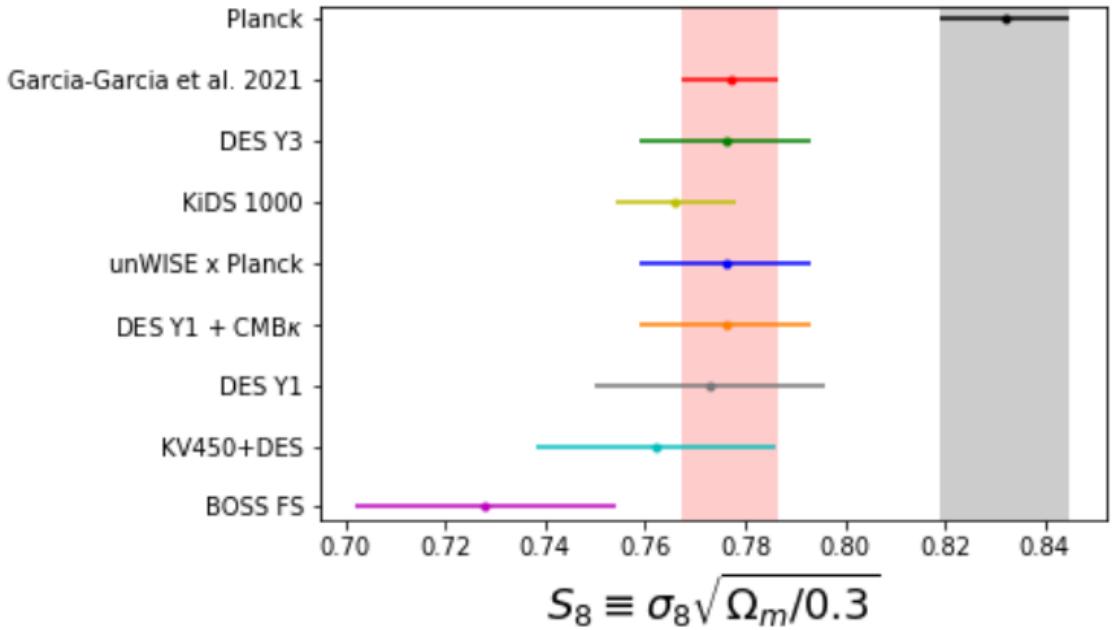


Best constraints at the moment!

- 25% better than P18



Reconstructing the growth

We put constraints on

$$S_8(z) = \sigma_8(z)\sqrt{\frac{\Omega_{\rm m}}{0.3}}$$

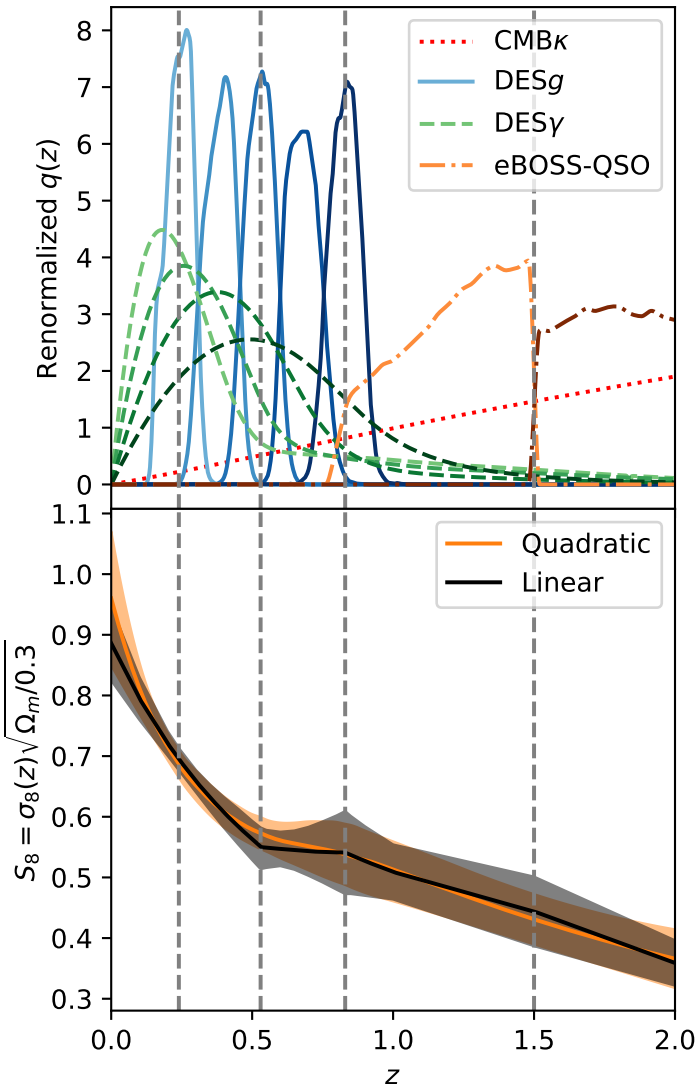
by decoupling the background and the perturbations:

- keeping a ΛCDM background
- modifying the perturbations s.t.

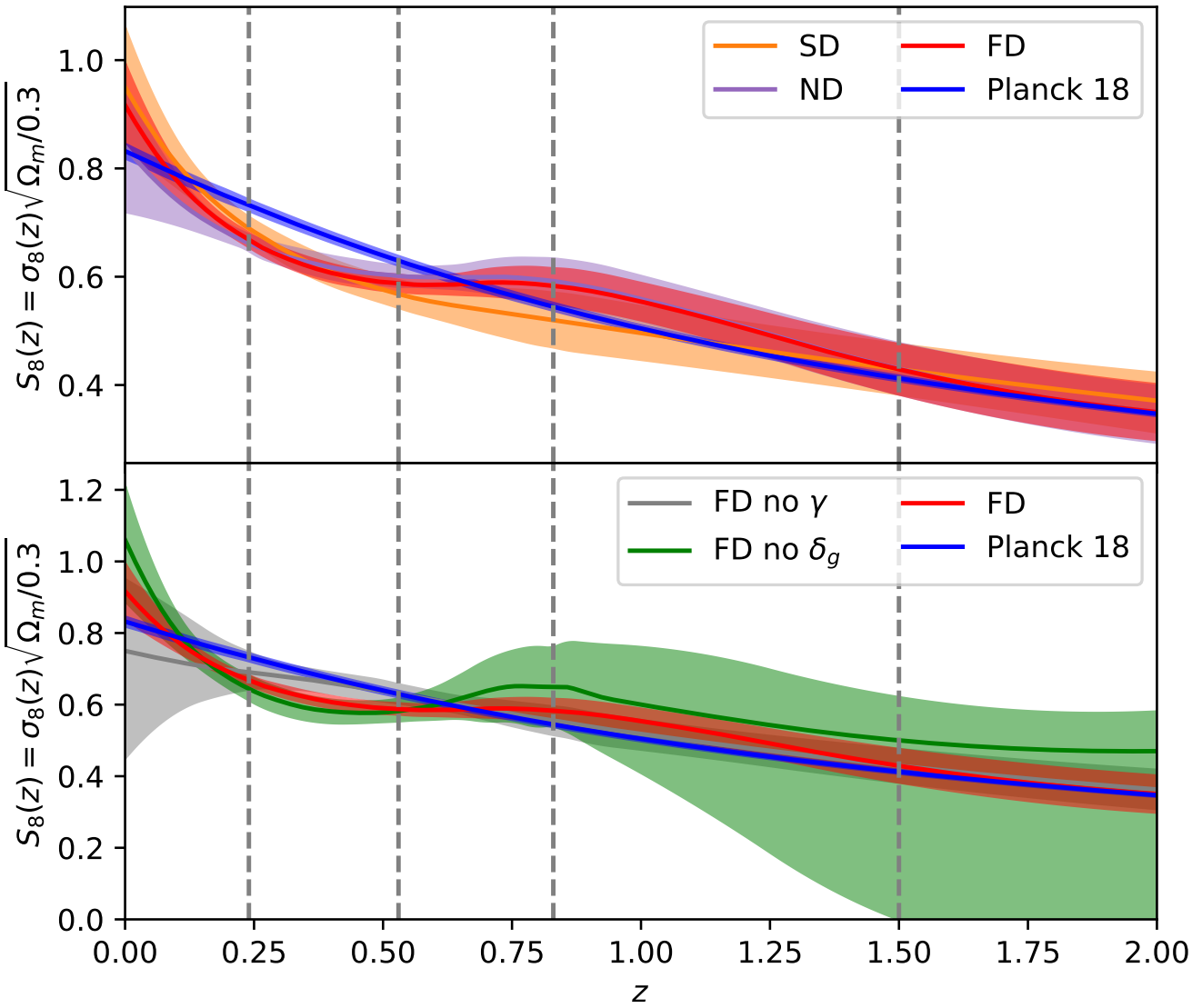
$$P_k(z) = D(z)^2 P_k^{\rm P18}(z=0)$$

with

$$D(z) = \text{quadratic\_spline}(\tilde{D}_z)$$



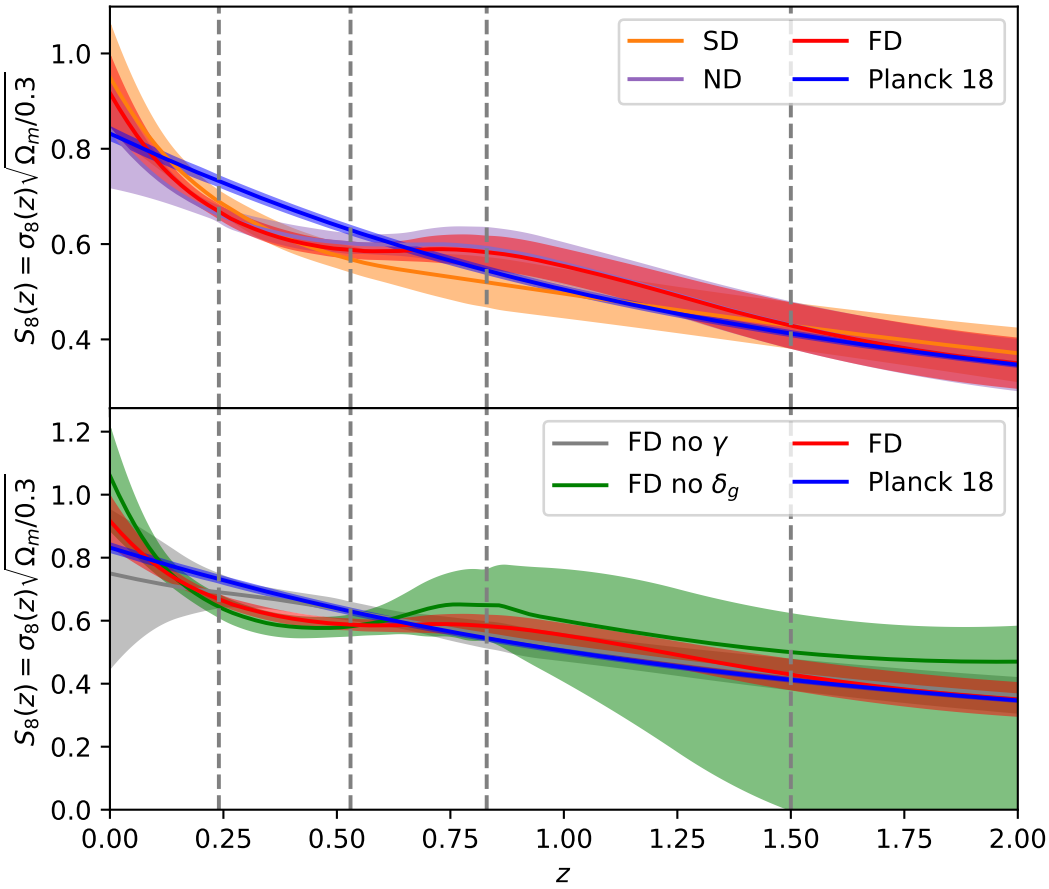
Results


SD
ND
FD
Planck 18
FD no γ
FD no δ_g
$S_8(z) = \sigma_8(z)\sqrt{\Omega_m/0.3}$
z

Future work

- Add more data:
  - $z \sim 0$: 2MPZ, tSZ
  - $z \sim 1$: unWISE

    (Krolewski+21)
- $S_8(z)$ with Gaussian Processes
- Improve systematics modelling:
  - Galaxy bias
  - Baryonic effects
  - Intrinsic alignments
- Add m_ν



Summary

- Combining current LSS data can reduce the errors on S_8 substantially
- LSS data inform about the evolution of the perturbations
- S_8 tension driven by the redshift range $0.2 \lesssim z \lesssim 0.5$, where current data have the best statistical power
- S_8 tension driven by shear
- **More in 2105.12108**