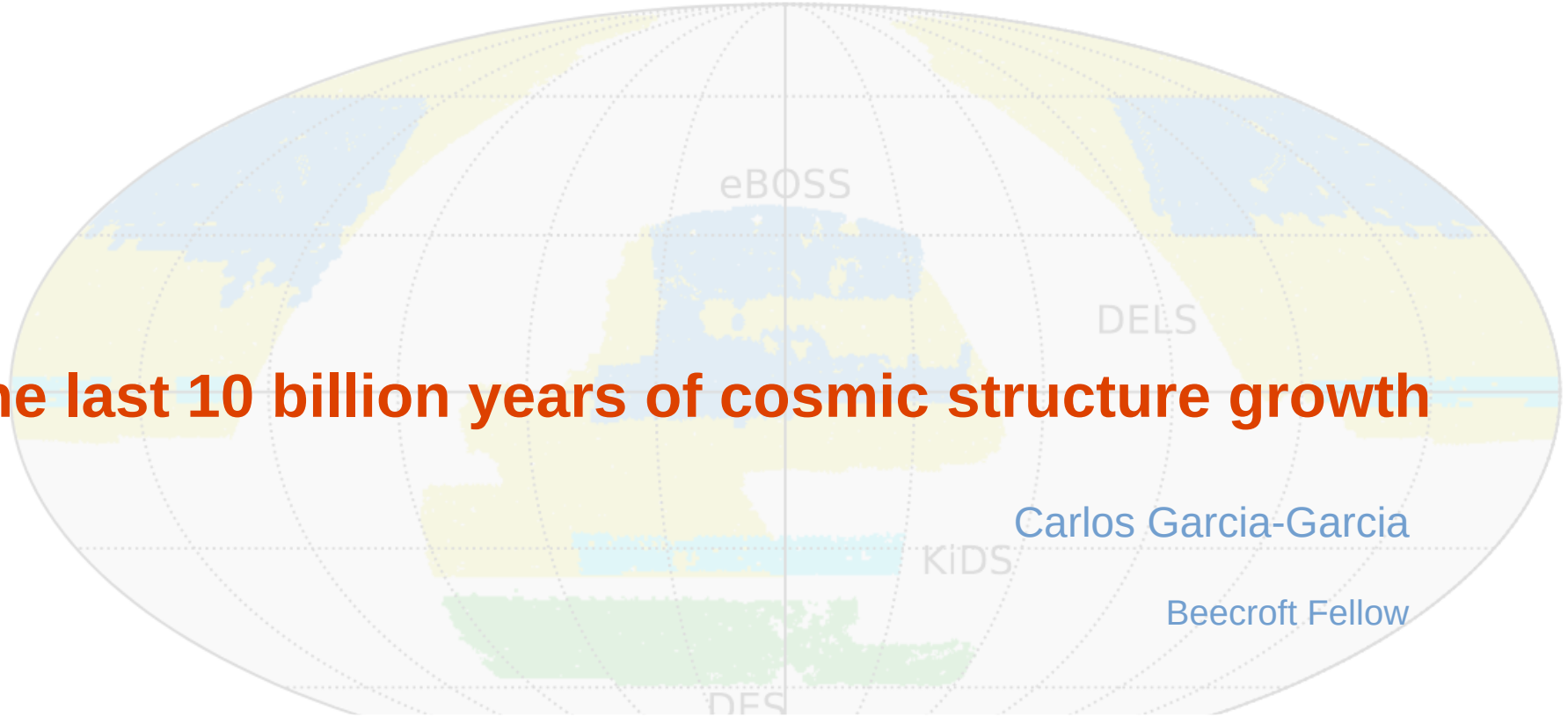


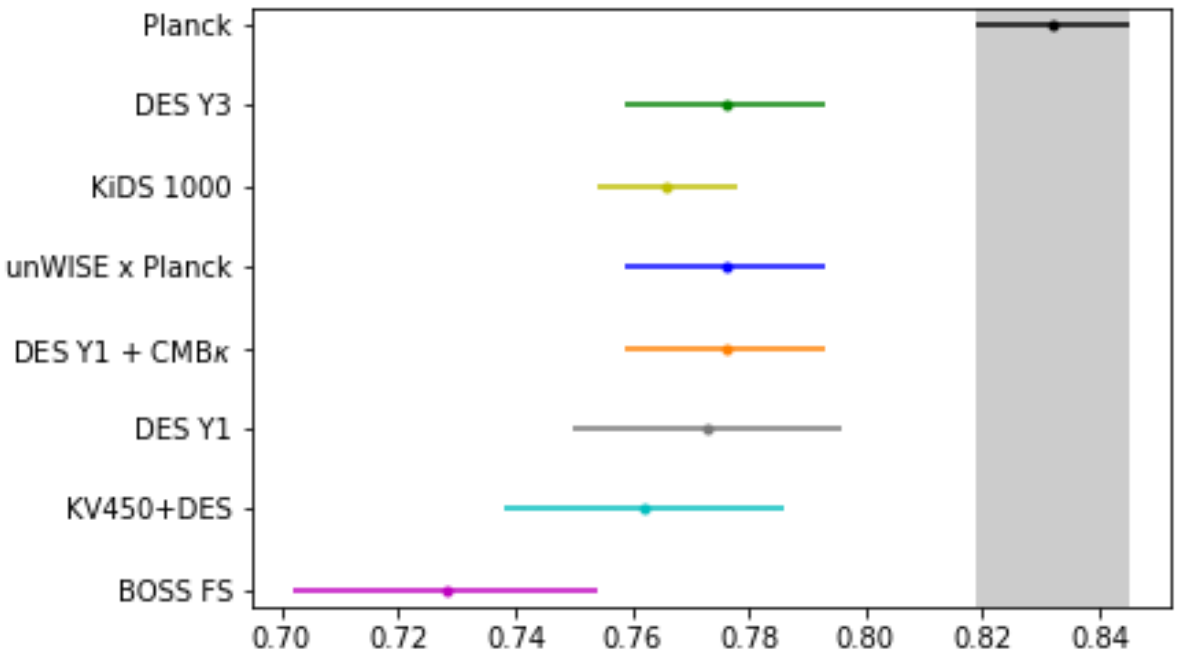
The last 10 billion years of cosmic structure growth

Carlos Garcia-Garcia

Beecroft Fellow

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

The S_8 tension



$$S_8 \equiv \sigma_8 \sqrt{\Omega_m / 0.3}$$

σ_8 ~ amplitude perturbations

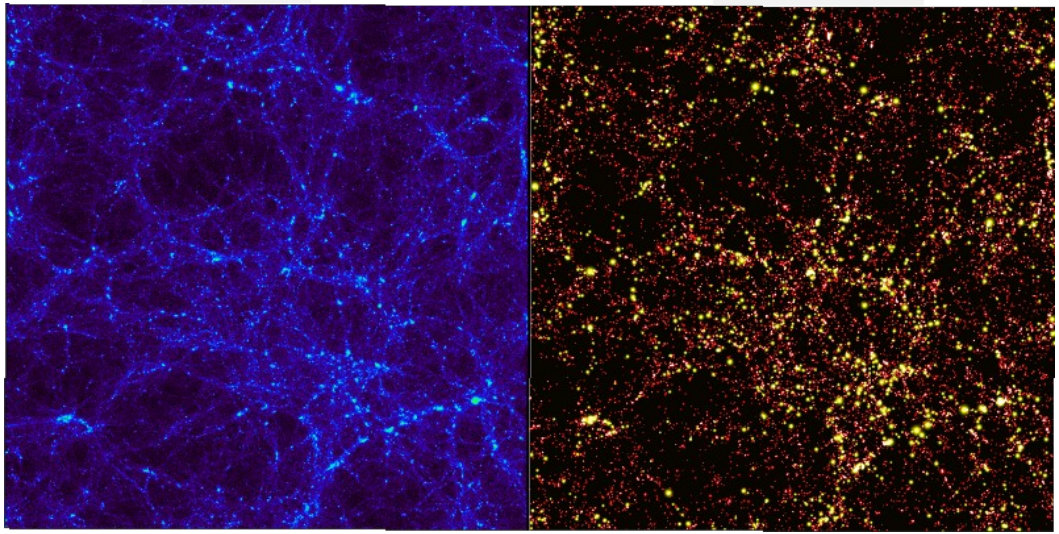
Troster et al. 2020
Abbott et al. 2017
Abbott et al. 2018
Joudaki et al. 2019

Tracers of matter

Galaxy clustering:

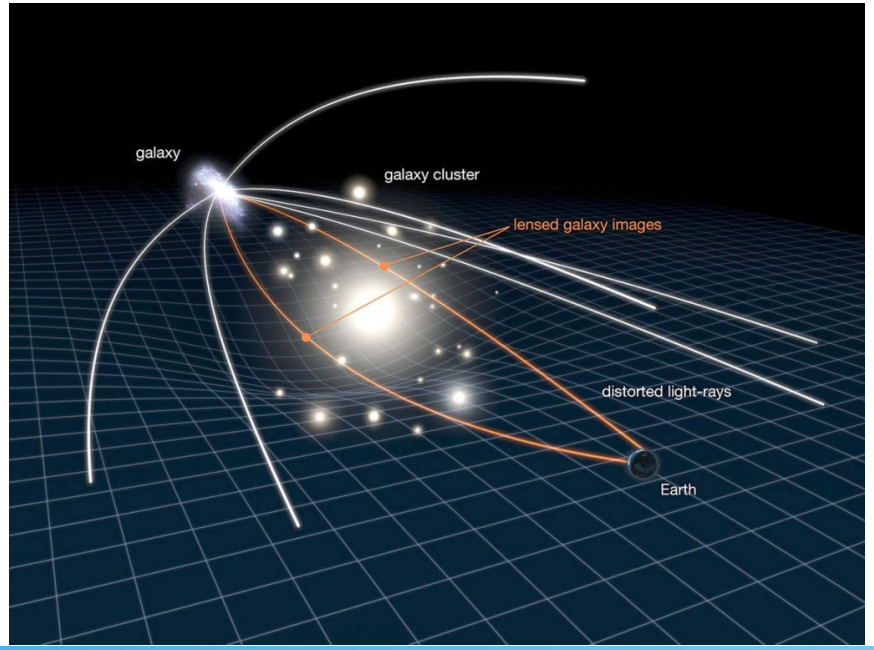
- $\delta_g = f[\delta_M] \sim b_g\, \delta_M$
- Local

Matter **Galaxies**



Weak lensing:

- $e_i \sim \gamma_i \sim \delta_M$
- Integrated



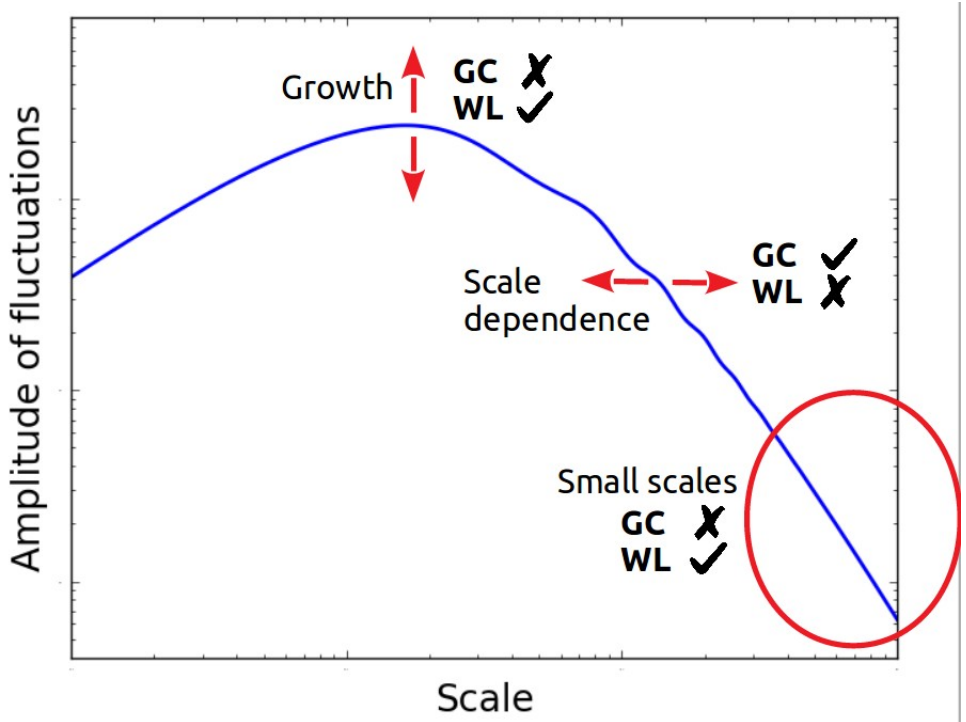
Galaxy clustering and weak lensing

Galaxy clustering:

- $\delta_g = f[\delta_M] \sim b_g \, \delta_M$
- Local

Weak lensing:

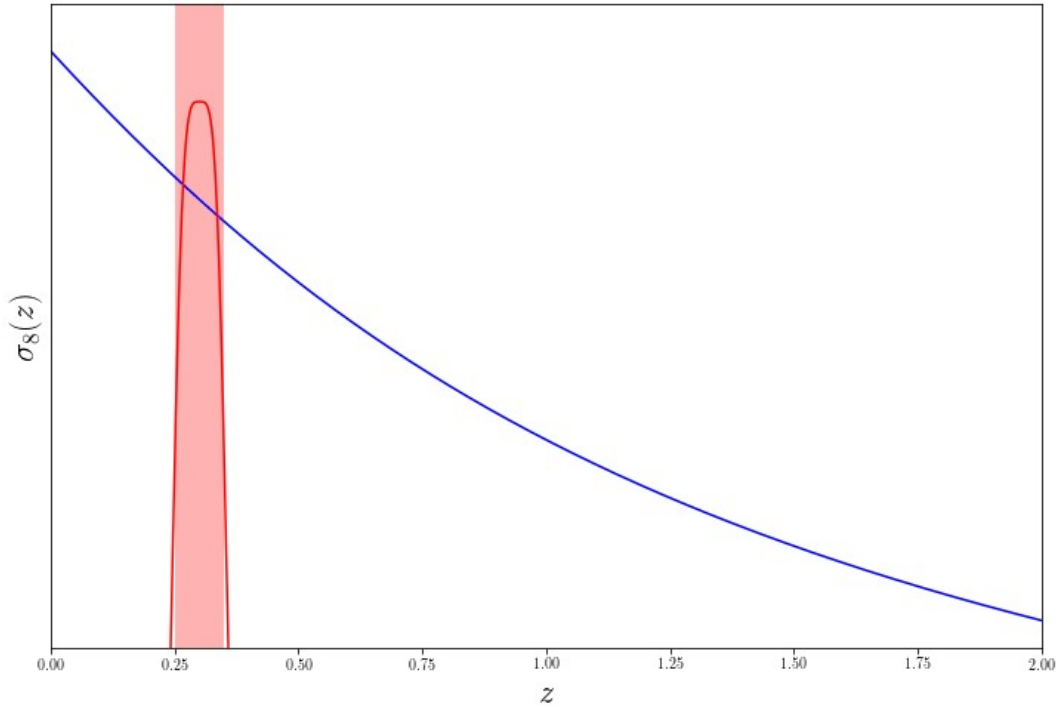
- $e_i \sim \gamma_i \sim \delta_M$
- Integrated



Hikage et al 2019

3x2pt as tomography

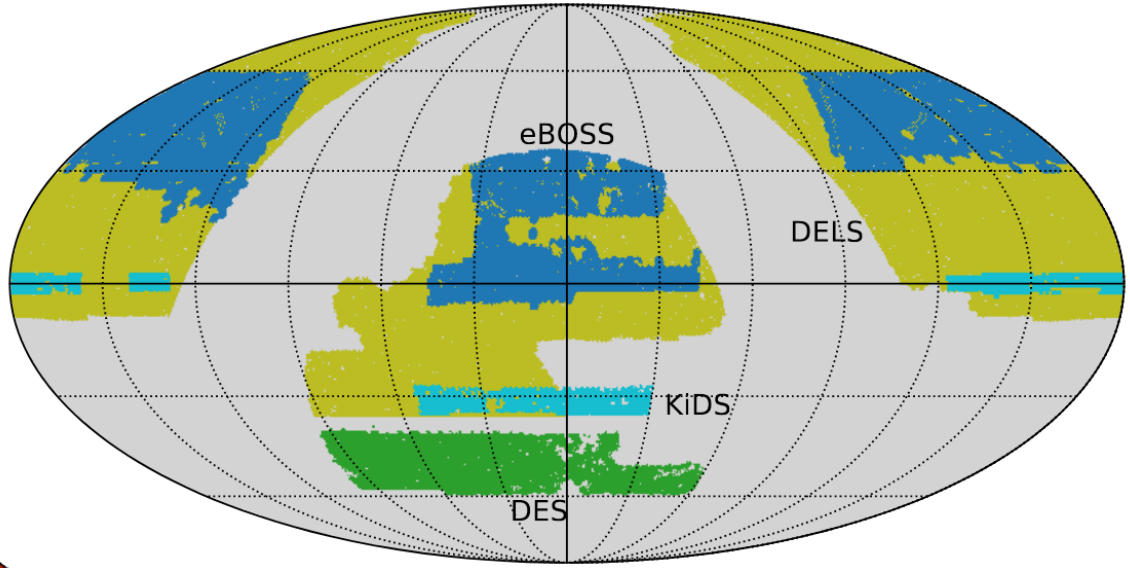
$$C_\ell^{\gamma\gamma} \propto \sigma_8^2 \qquad C_\ell^{g\gamma} \propto \sigma_8^2 b_g \qquad C_\ell^{gg} \propto \sigma_8^2 b_g^2$$

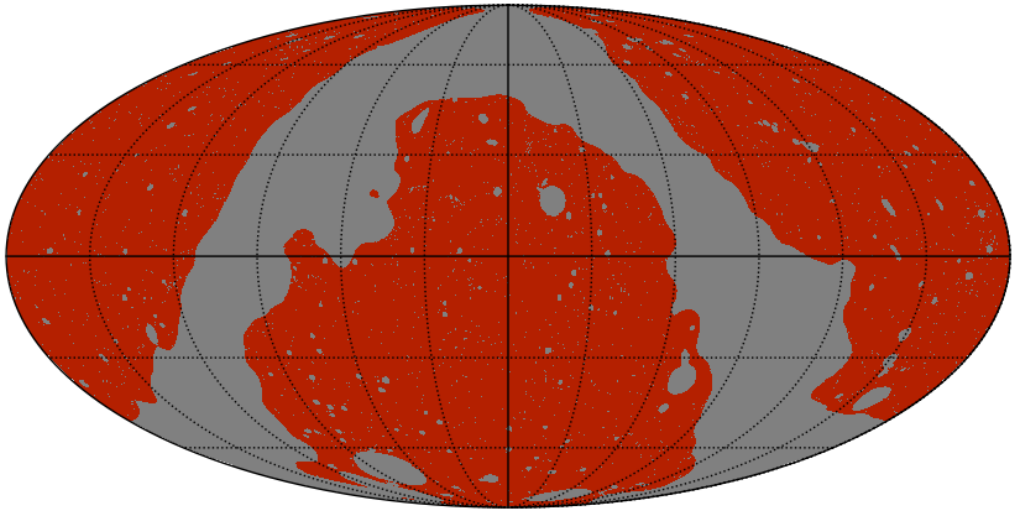


The data

Weak lensing:
- DES Y1
- KiDS-1000

Galaxy clustering:
- DES Y1 (redMaGiC)
- DESI Legacy Survey (DELS)
- eBOSS QSO





CMB lensing:
- Planck 2018 convergence map

Troxel et al. 2017; Elvin-Poole et al. 2017
Asgari et al. 2017; Hang et al. 2020
Neveux et al. 2020; Planck Coll. et al. 2018

The data

Shear:
- DES Y1
- KiDS-1000

Clustering:
- DES Y1 (redMaGiC)
- DESI Legacy Survey (DELS)
- eBOSS QSO

CMB lensing:
- Planck 2018 convergence map

Troxel et al. 2017
Elvin-Poole et al. 2017
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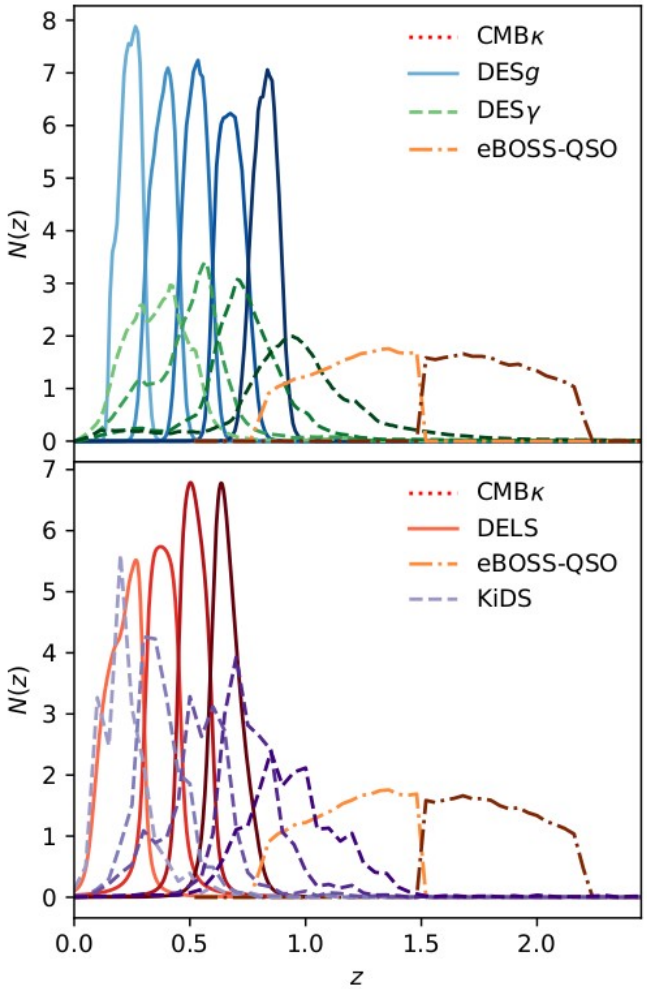
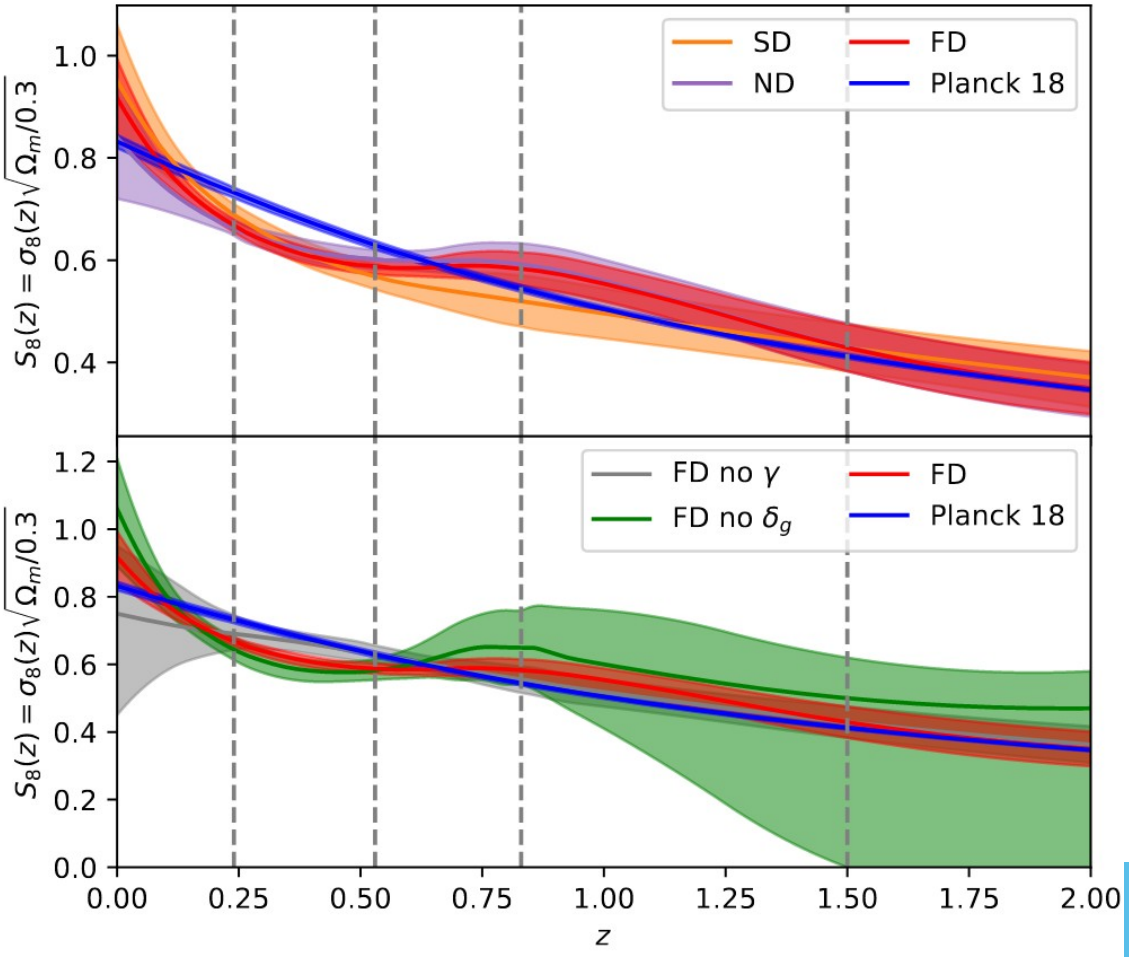


South Data (SD)

North Data (ND)

The reconstructed growth



SD = DESY1 + eBOSS QSO's + CMBκ

ND = KiDS-1000 + DESI Legacy survey + eBOSS QSO's + CMBκ

FD = SD + ND

$S_8(z)$ reconstruction:

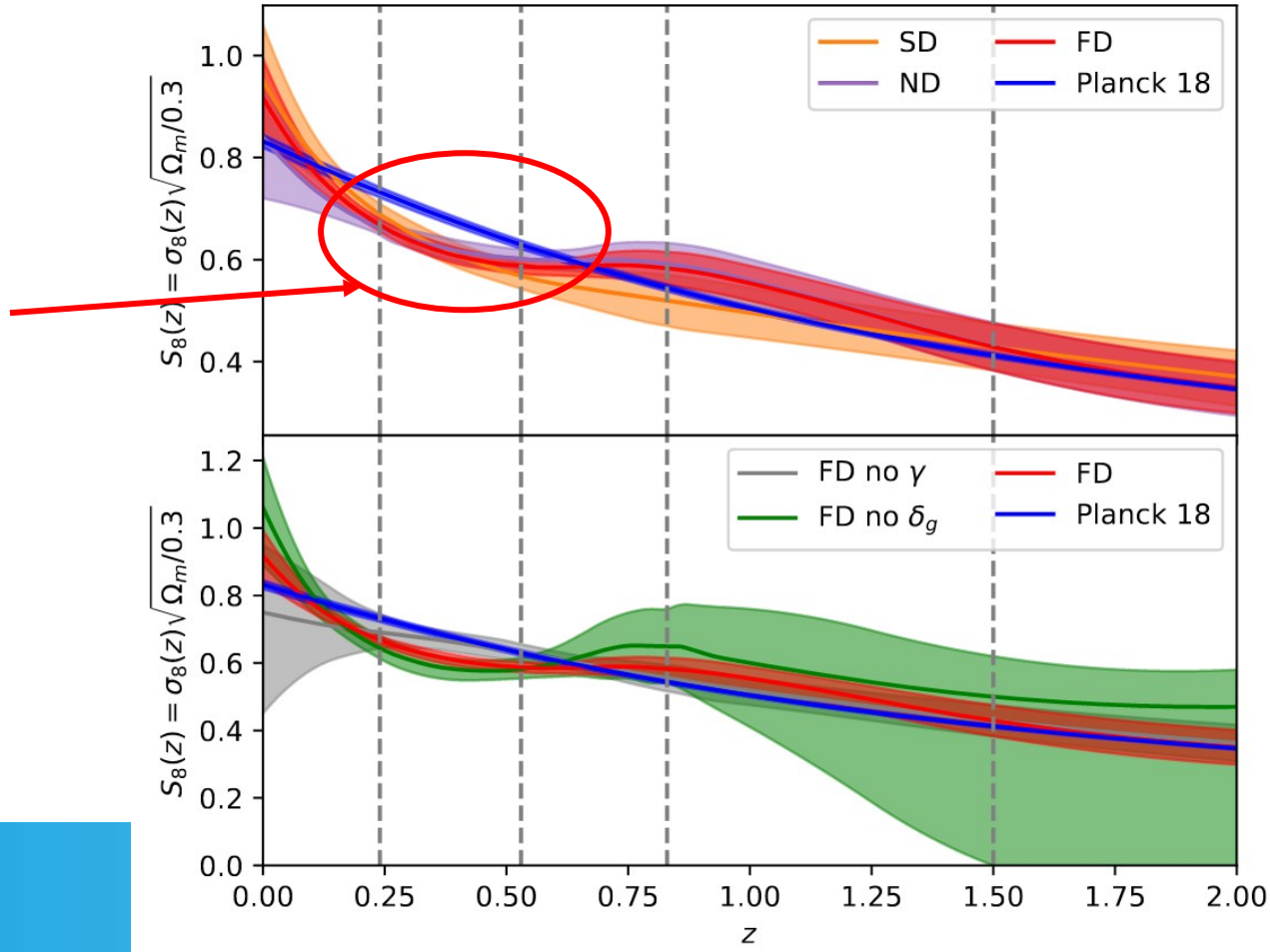
- ΛCDM background
- Free linear growth

Following ~DESY1 (scale cuts, systematics)

The reconstructed growth

Results:

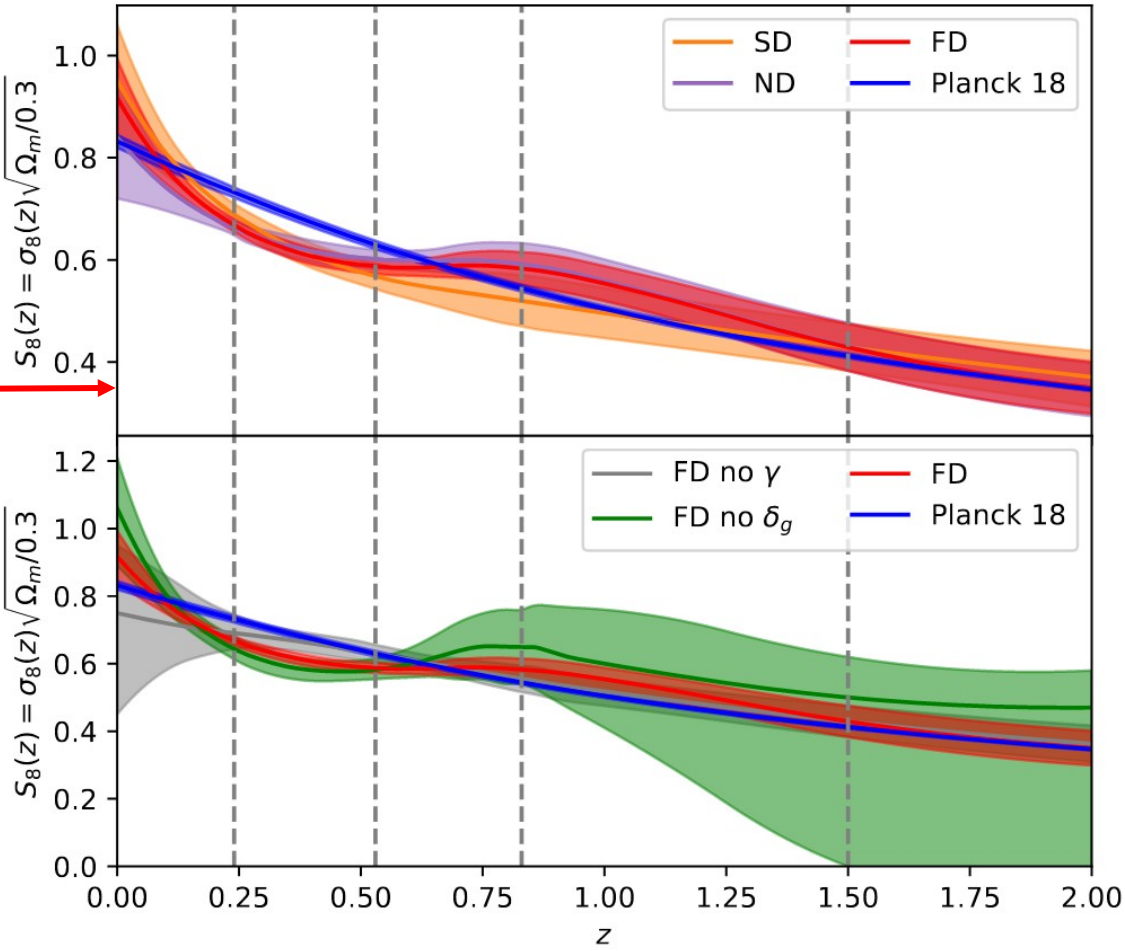
- Lower growth (~2σ) at 0.2<z<0.6



The reconstructed growth

Results:

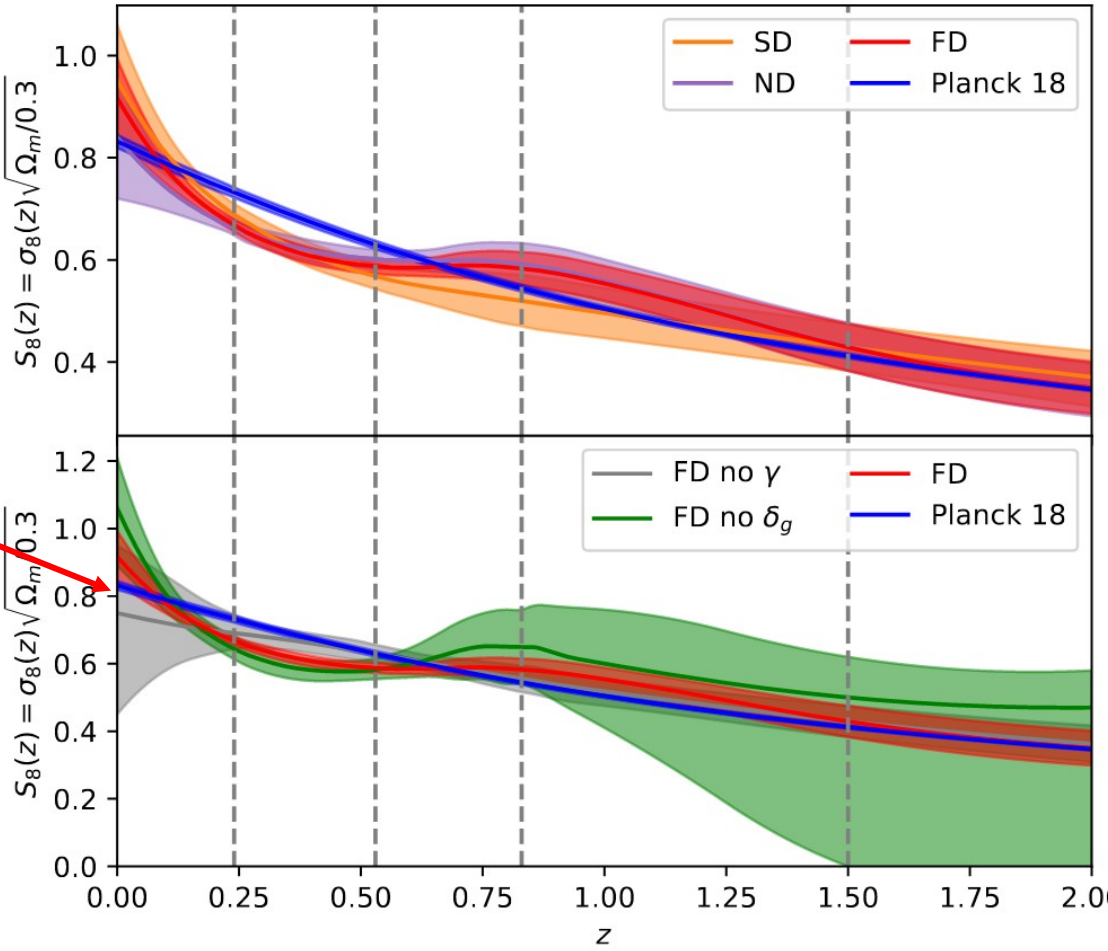
- Lower growth (~2σ) at 0.2<z<0.6
- North and South data recover compatible growth histories



The reconstructed growth

Results:

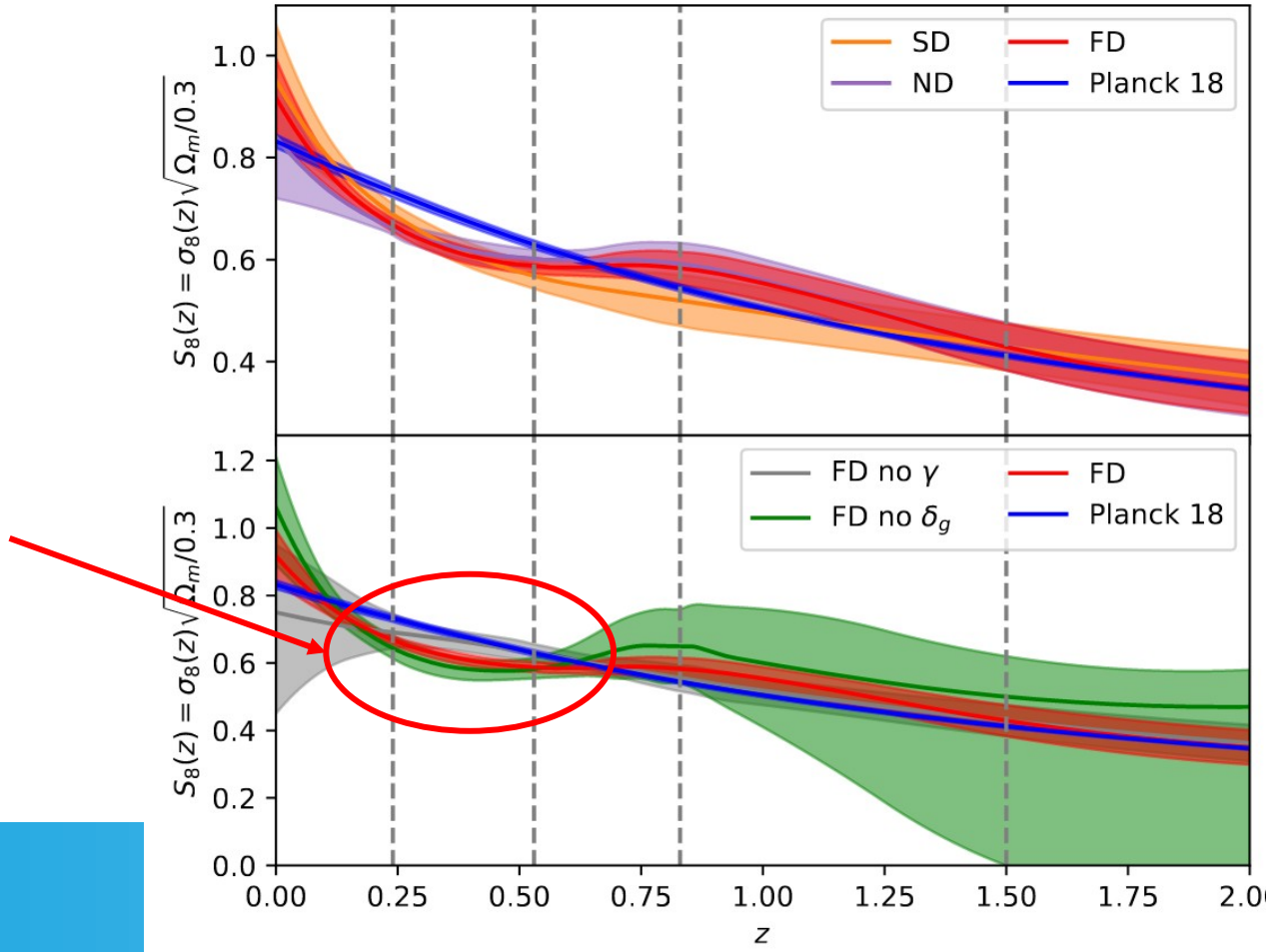
- Lower growth (~2σ) at 0.2<z<0.6
- North and South data recover compatible growth histories
- Tension driven by shear data



The reconstructed growth

Results:

- Lower growth (~2σ) at 0.2<z<0.6
- North and South data recover compatible growth histories
- Tension driven by shear data
- Clustering + CMBκ compatible with Planck (but also with shear).

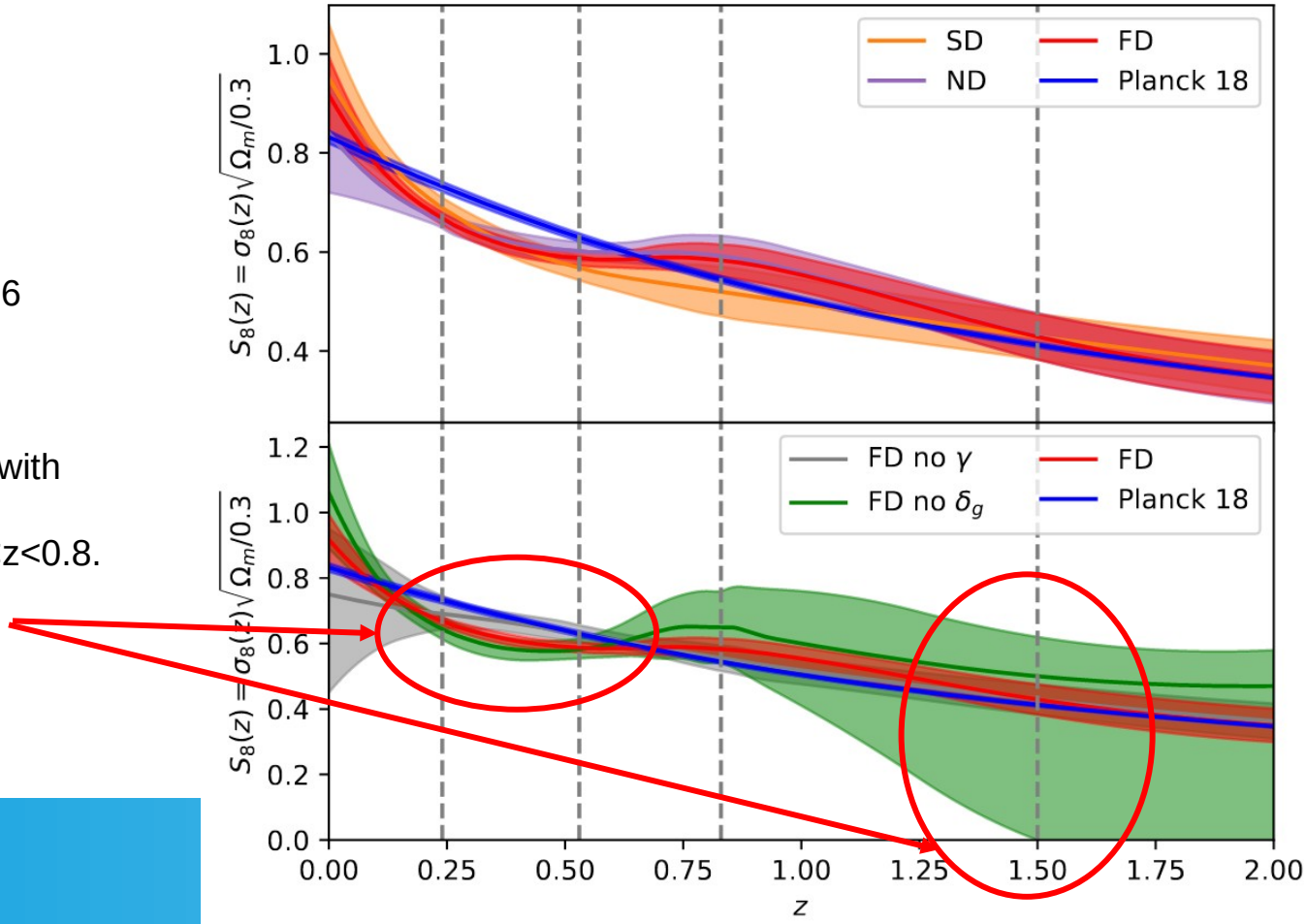


But see *Krolewski et al. 2021* & *White et al. 2021*

The reconstructed growth

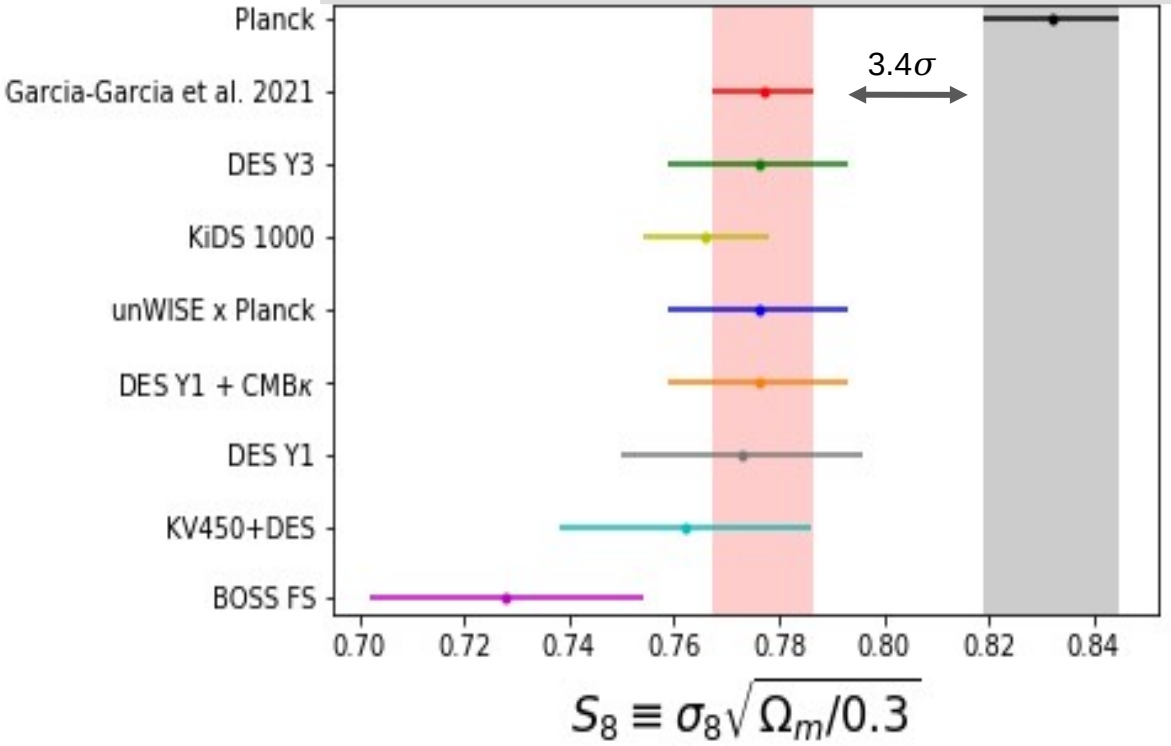
Results:

- Lower growth (~2σ) at 0.2<z<0.6
- North and South data recover compatible growth histories
- Tension driven by shear data
- Clustering + CMBκ compatible with Planck (but also with shear).
- Most constraining power at 0.2<z<0.8. QSOs vital for high-z growth.



ΛCDM

Best constraints at the moment



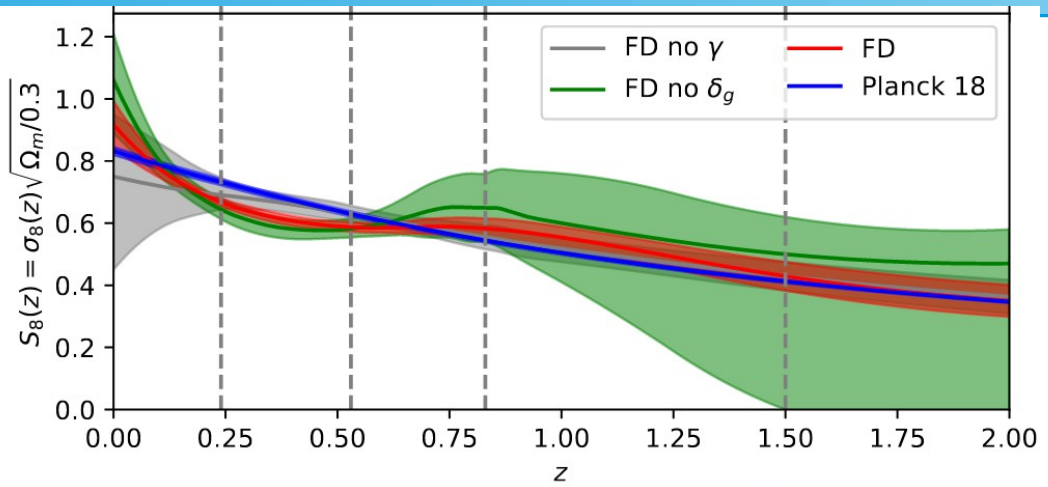
Large scale structure C_l repository

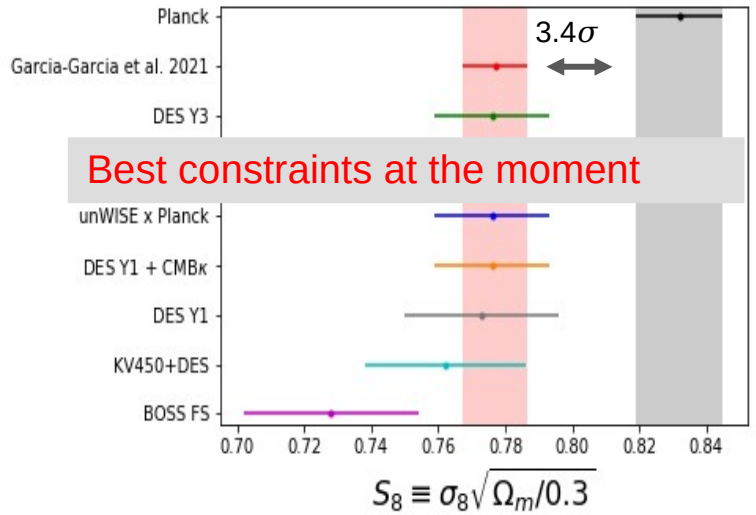
- **Galaxy clustering:**
  - DESY1
  - DESI Legacy Survey
  - BOSS & eBOSS-QSOs
  - WixSC
  - WISE
  - 2MPZ
  - NVSS
- **Weak lensing:**
  - DESY1
  - KiDS1000
  - KV450
  - HSC DR1
- **CMB lensing:**
  - Planck 2018
  - ACT
- **Cosmic Infrarred Background (CIB):**
  - Planck 2015
- **Thermal Sunyaev-Zeldovich (tSZ):**
  - Planck 2015
  - SPT
  - ACT
- **X-ray:**
  - ROSAT

Credits also to Jaime Ruiz Zapatero, David Alonso et al.

Summary

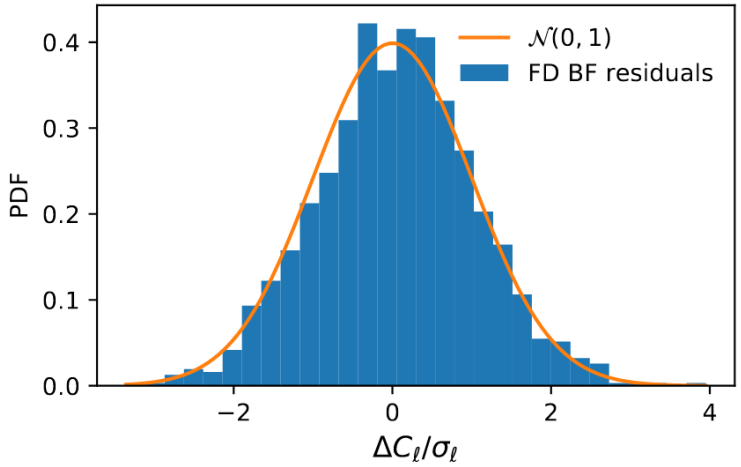
- Combination of 6 projected LSS surveys
- Reconstructed growth at z < 2
- Growth compatible with ΛCDM
- But in tension with Planck (~2σ)
- Constraining power at 0.2 < z < 0.7
- Future:
  - Better data at low-z (already exists) and high-z (LSST and DESI will help).
  - Beyond ΛCDM
  - Large scale structure C_l repository

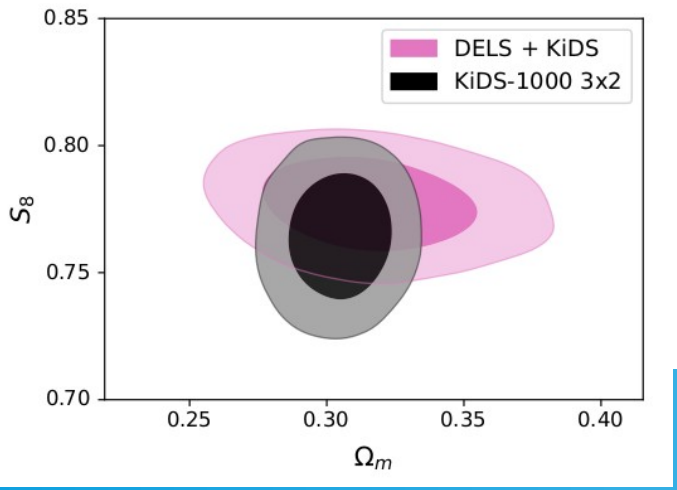


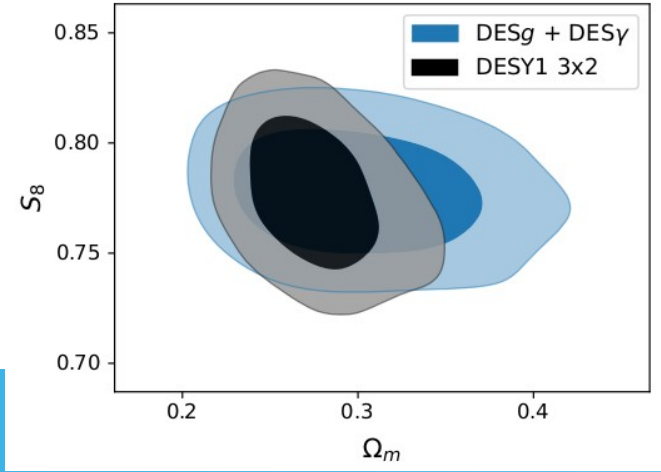


Validation

- B-modes compatible with 0
- Recover official results
- Residuals ~ Gaussian
- Good fits: 0.1 < p-value < 0.9



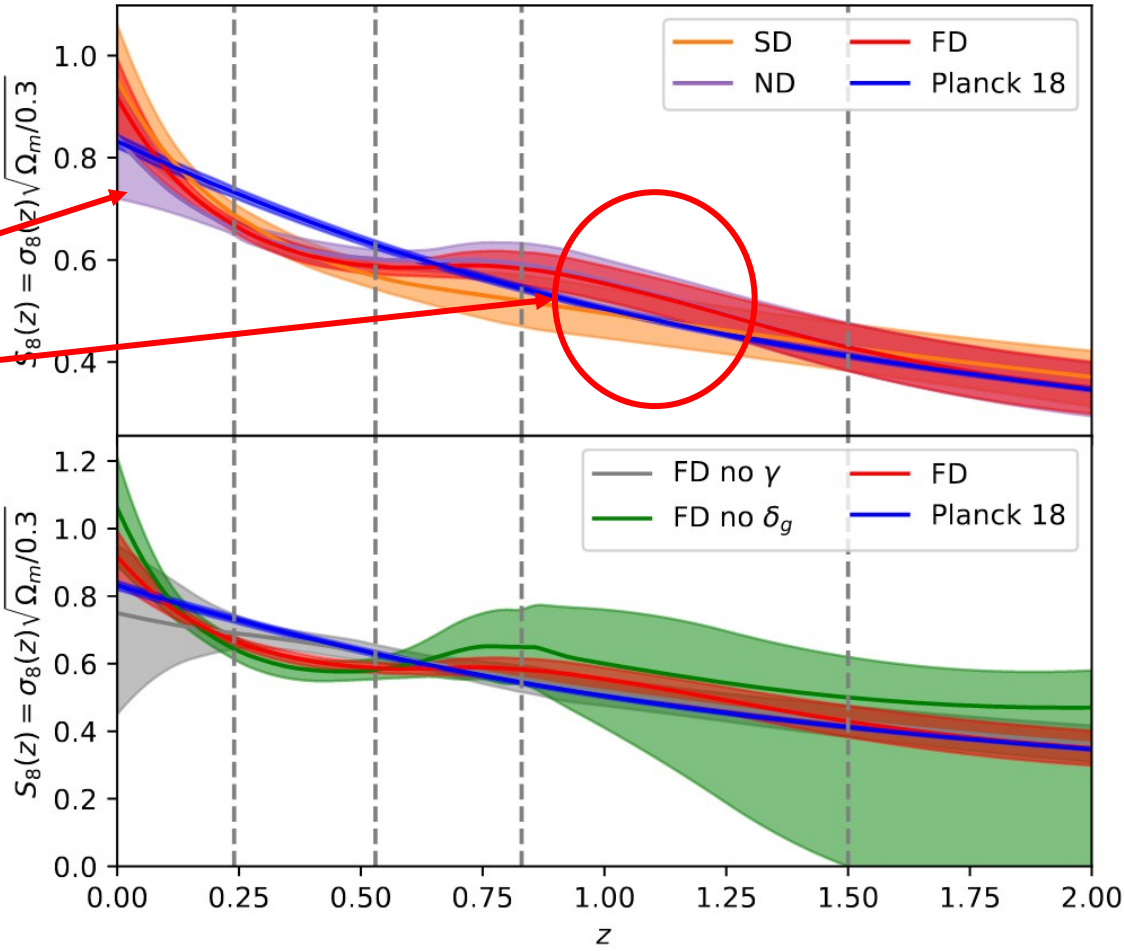




The reconstructed growth

Future work:

- Add more data:
  - z~0: 2MPZ, tSZ
  - z~1: unWISE
- $S_8(z)$ with Gaussian Processes
- Add massive neutrinos
- Improve systematics (e.g. Galaxy bias)



Beyond ΛCDM

- Modify the linear perturbations eqs.:
  - Growth equation: $\mu(z)$
  - Lensing: $\Sigma(z)$
- Preliminary:
  - Tension translated to $\mu - \Sigma$