Testing the standard structure growth with HSC-Y3 cosmic shear data and CMB data: Implications for S_8 tension

Based on RT+25d (PRD 112(8):083556), RT+ in prep.

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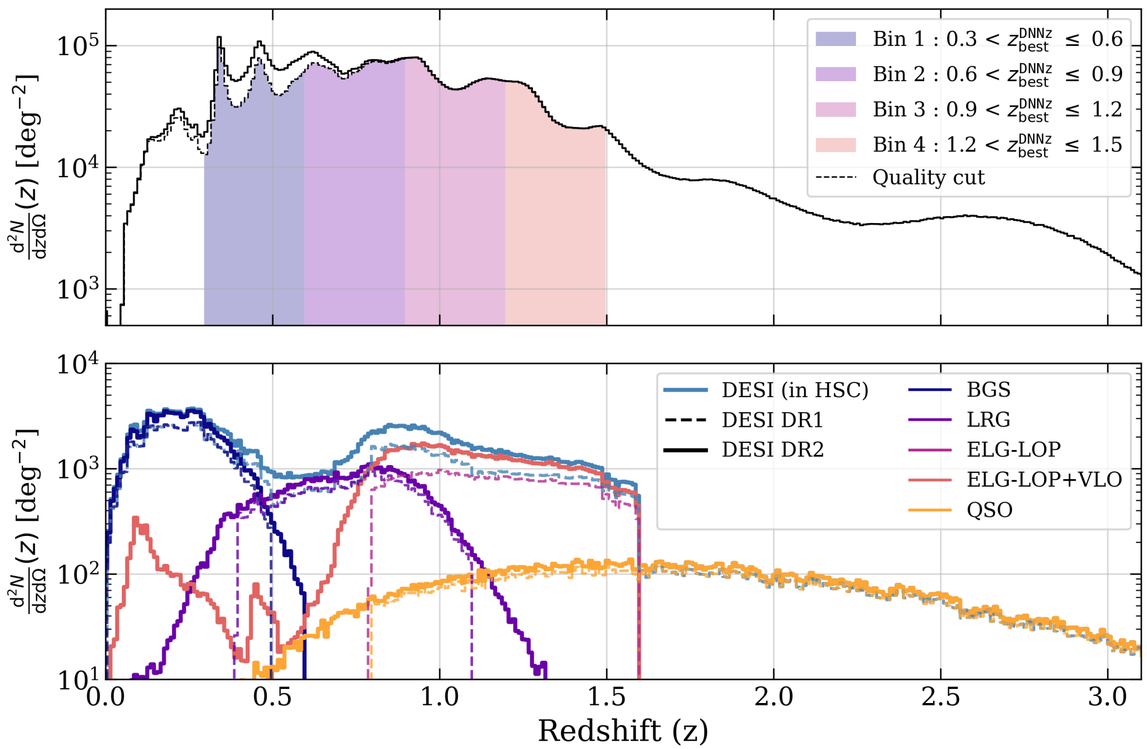
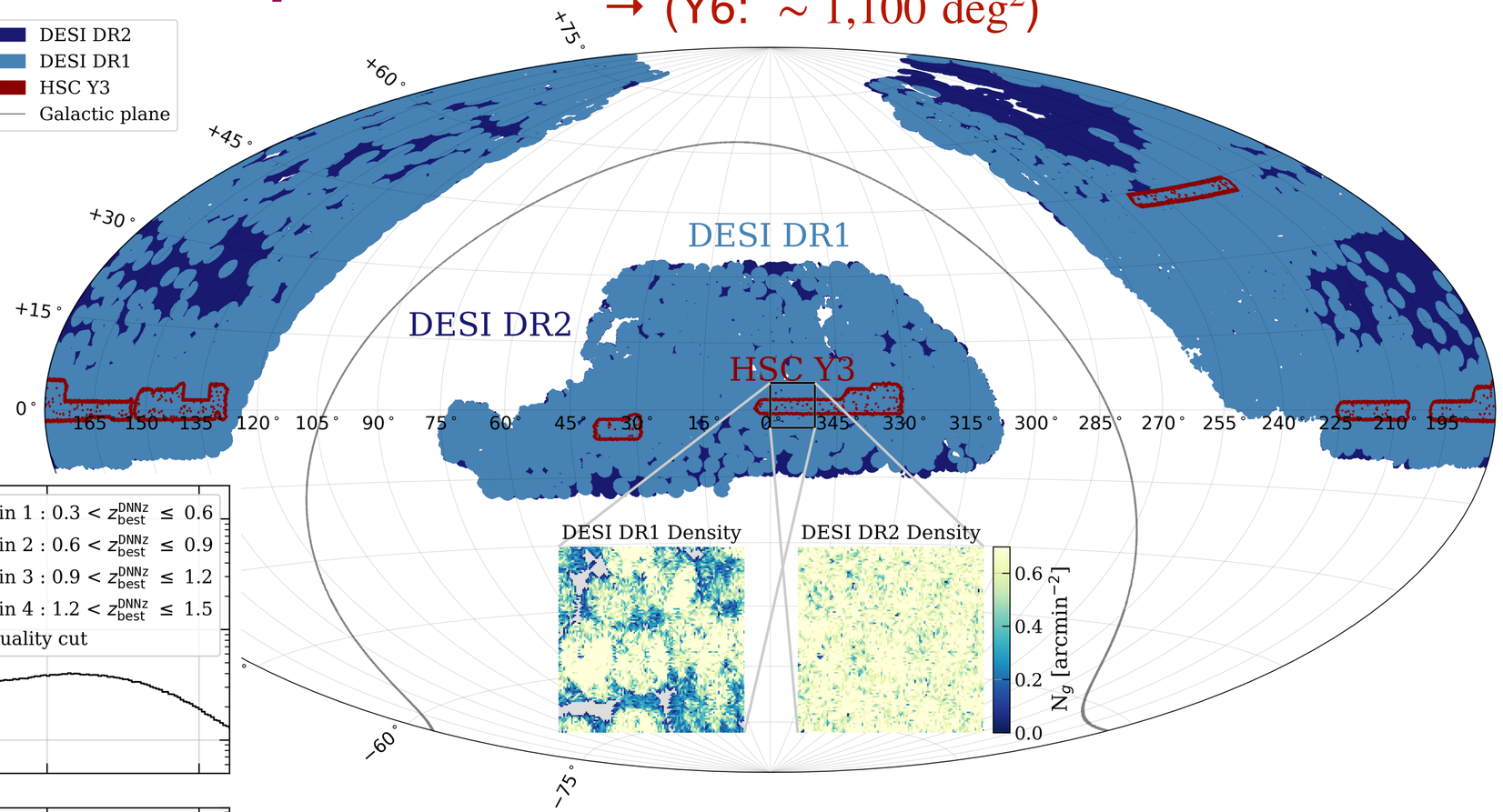
CD3

HSC & DESI: full overlap!

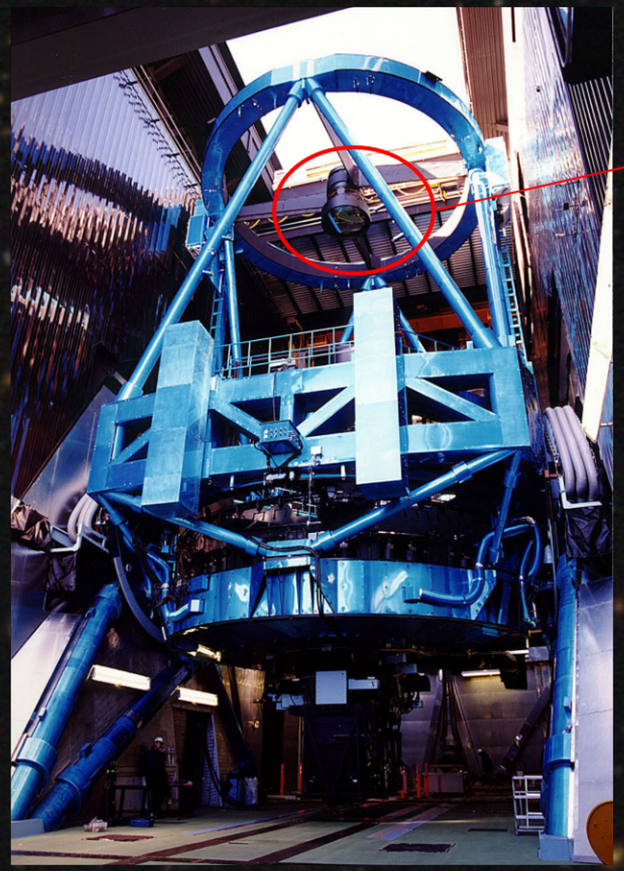
HSC-Y3: ~ 416 deg^2
→ (Y6: ~ 1,100 deg^2)

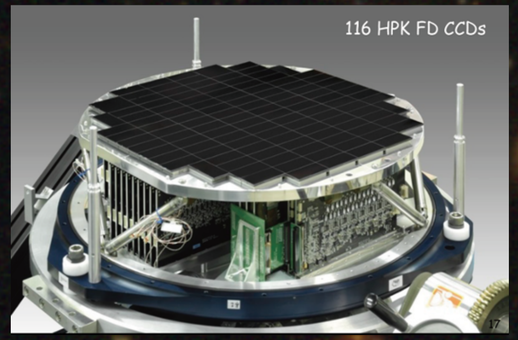




Choppin de Janvry+25a

Subaru Hyper Suprime-Cam (HSC)



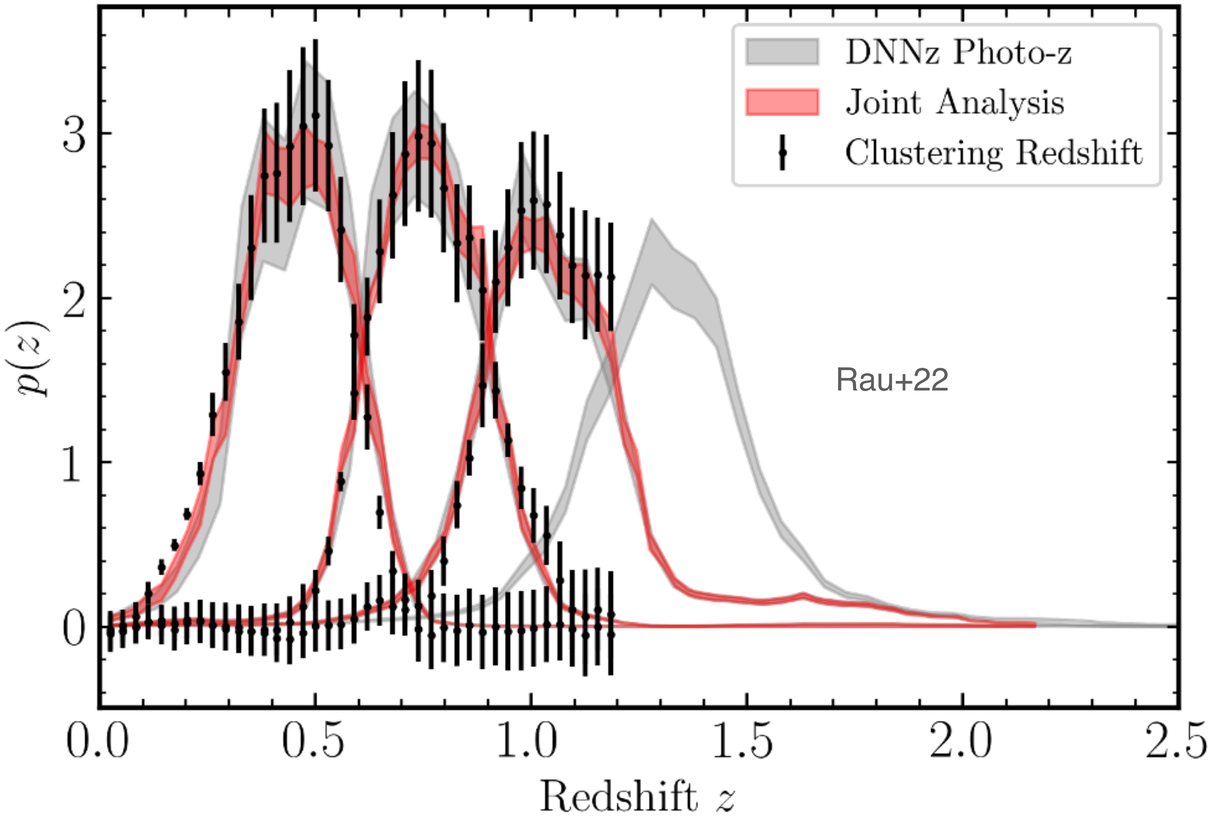


- WL information on small scales $\underset{\sim}{\propto} n_{\rm eff}/\sigma_\gamma^2$
- 8m primary mirror
  → can observe distant, faint galaxies
  → measure many (~25M) galaxy shapes
  → high number density: $n_{\rm eff} \sim 15\ {\rm arcmin}^{-2}$
  c.f. DESY6: $n_{\rm eff} \sim 8.3\ {\rm arcmin}^{-2}$,
  KiDS-Legacy: $n_{\rm eff} \sim 8.8\ {\rm arcmin}^{-2}$

  Upcoming surveys (LSST, Roman, Euclid) will have few times denser galaxy sample than HSC

Redshift distribution inference before DESI (Rau+22)

- Photo-z's of individual HSC galaxies from the 5-band (grizy) photometry
- Grey: photo-z likelihood (DNNz) with cosmic variance errors
  (4 tomographic redshift bins)
- Points with errorbars: "clustering redshift", obtained via cross-correlation between HSC source galaxies and CAMIRA-LRGs
- Red: joint posterior of the two



$$\xi_{\pm}^{ij}(\theta) = \int \frac{\ell \mathrm{d}\ell}{2\pi} J_{0/4}(\theta\ell) \int_0^{\chi_H} \mathrm{d}\chi \frac{q_i(\chi) q_j(\chi)}{\chi^2} P_{\mathrm{m}}\left(k = \frac{\ell + 1/2}{\chi}\right)$$

$$q_i(\chi) = \frac{3}{2}\Omega_{\mathrm{m}} H_0^2 \frac{\chi}{a(\chi)} \int_{\chi}^{\chi_H} \mathrm{d}\chi' \; p_i(\chi'(z)) \frac{\chi' - \chi}{\chi'}$$

source galaxies' redshift distribution

Redshift distribution before DESI: Uninformative priors

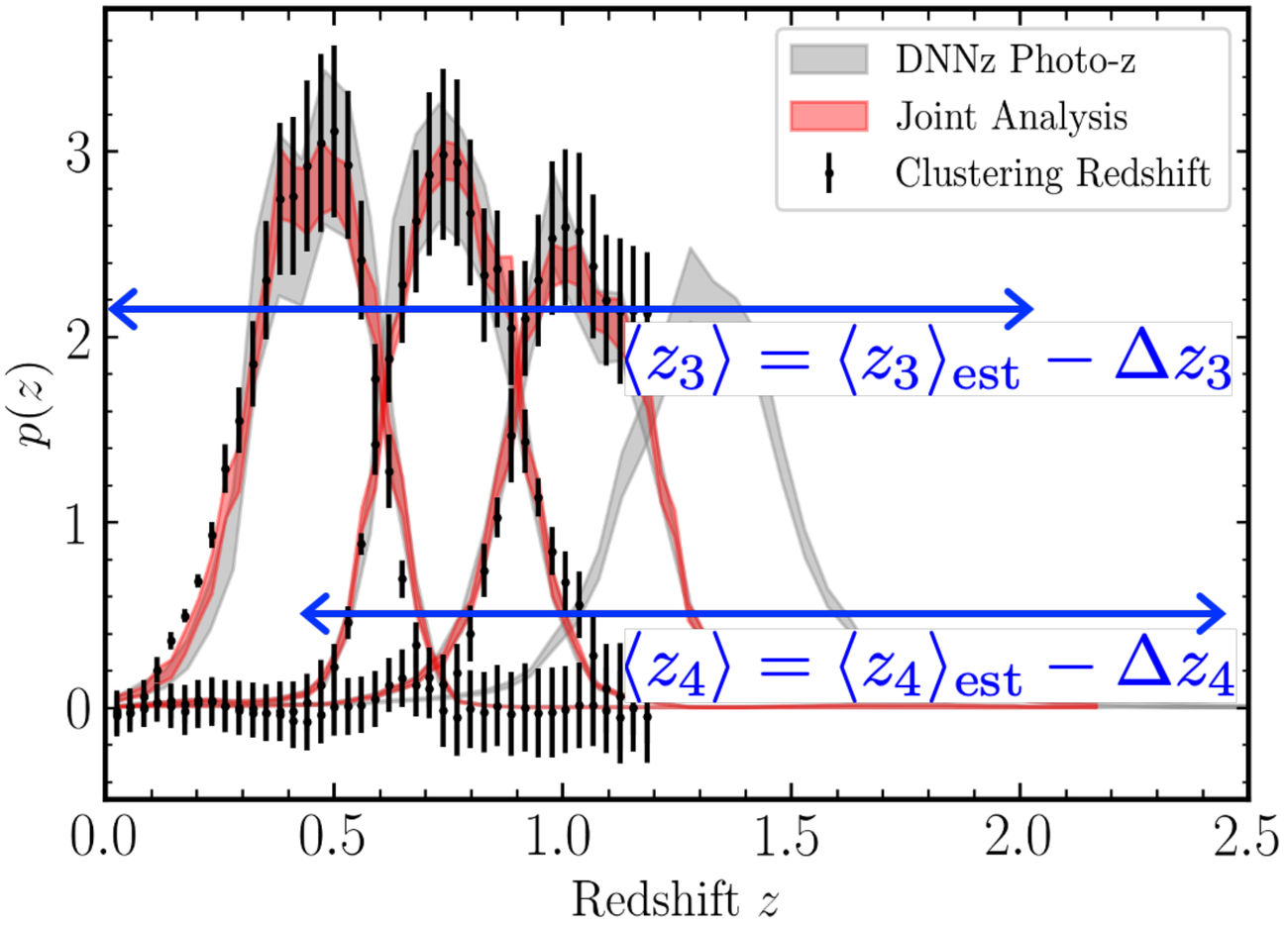
- Residual error is modeled by shift of mean redshift Δz_i

- Source galaxies with $z > 1.2$ are not calibrated by CAMIRA-LRG samples.

- Y3 analysis allows the mean redshift of the 3rd and 4th tomographic bin to be shifted by $\Delta z_{3,4} = \pm 1.0$

Photo-z systematics (Section IV C)	
Δz_1	$\mathcal{N}(0, 0.024)$
Δz_2	$\mathcal{N}(0, 0.022)$
Δz_3	$\mathcal{U}(-1, 1)$
Δz_4	$\mathcal{U}(-1, 1)$

- If cosmology & $\Delta z_{1,2}$ are well known, we can constrain $\Delta z_{3,4}$
  → self-calibration (Oguri & Takada 2011)

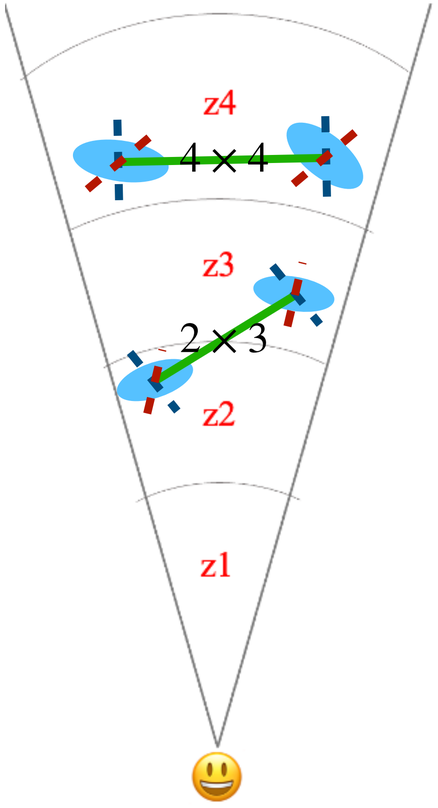


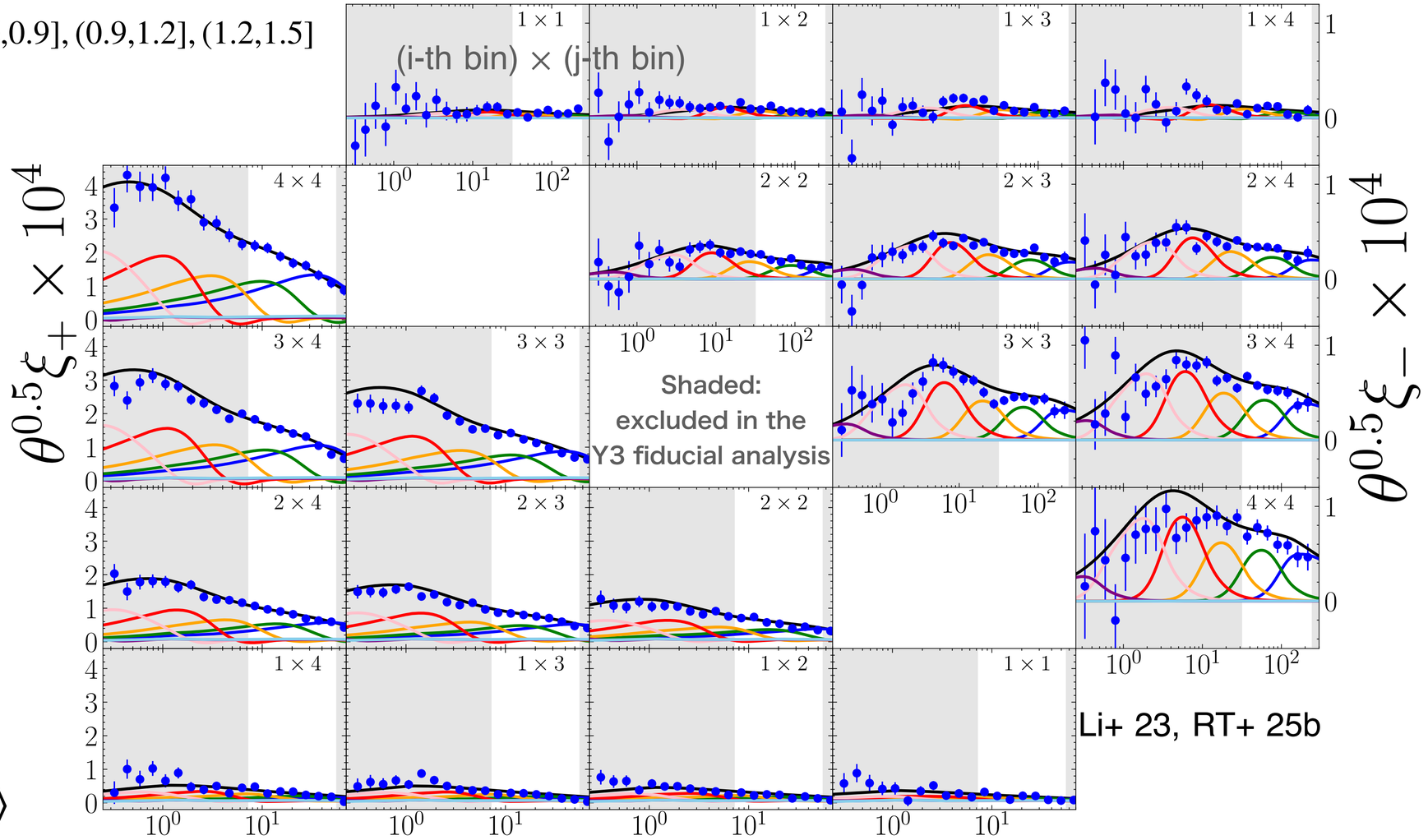
Rau+22

Cosmic Shear tomography

$k < 10^{-2}$ $10^{-2} < k < 0.1$ $0.1 < k < 10^{-0.5}$ $10^{-0.5} < k < 1$ $1 < k < 10^{0.5}$ $10^{0.5} < k < 20$ $20 < k$

4 tomographic redshift bins: $z \sim (0.3,0.6], (0.6,0.9], (0.9,1.2], (1.2,1.5]$





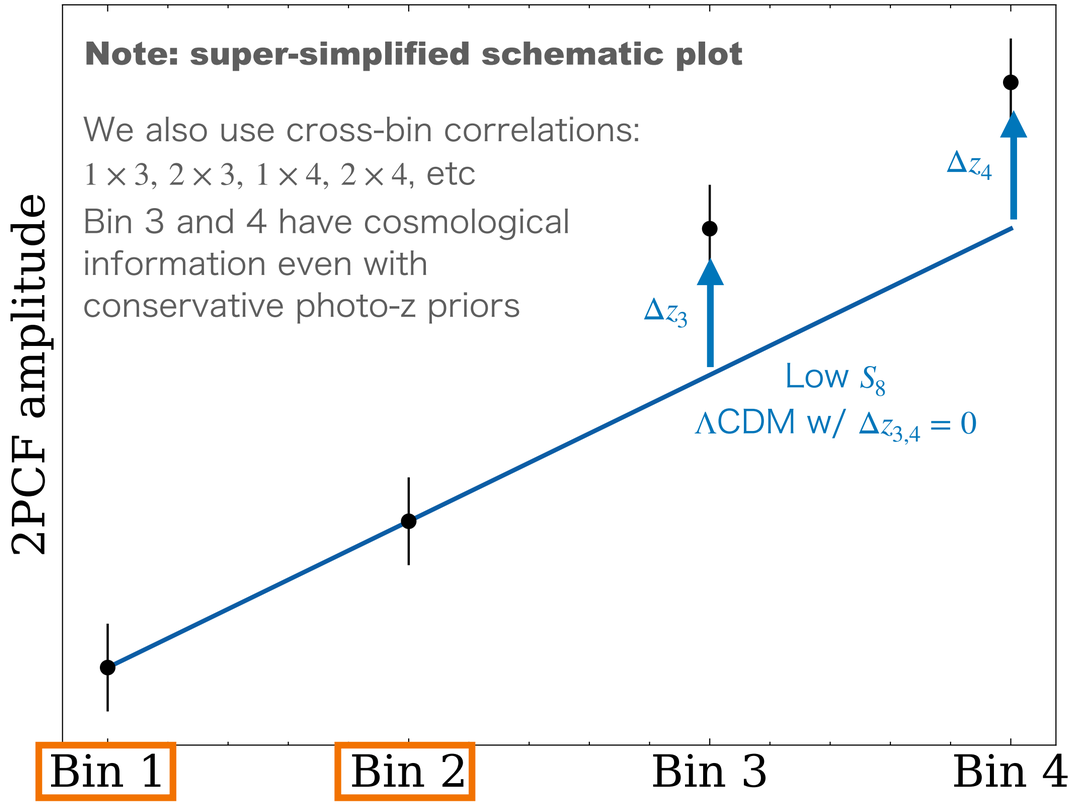
Li+ 23, RT+ 25b

$$\xi_{+/-}(\theta) = \langle \gamma_t(\mathbf{0})\gamma_t(\theta)\rangle \pm \langle \gamma_\times(\mathbf{0})\gamma_\times(\theta)\rangle$$

$$= \int \frac{\ell \mathrm{d}\ell}{2\pi} J_{0/4}(\theta\ell) \int_0^{\chi_H} \mathrm{d}\chi \frac{q_i(\chi) q_j(\chi)}{\chi^2} P_\mathrm{m}\left(k = \frac{\ell + 1/2}{\chi}\right)$$

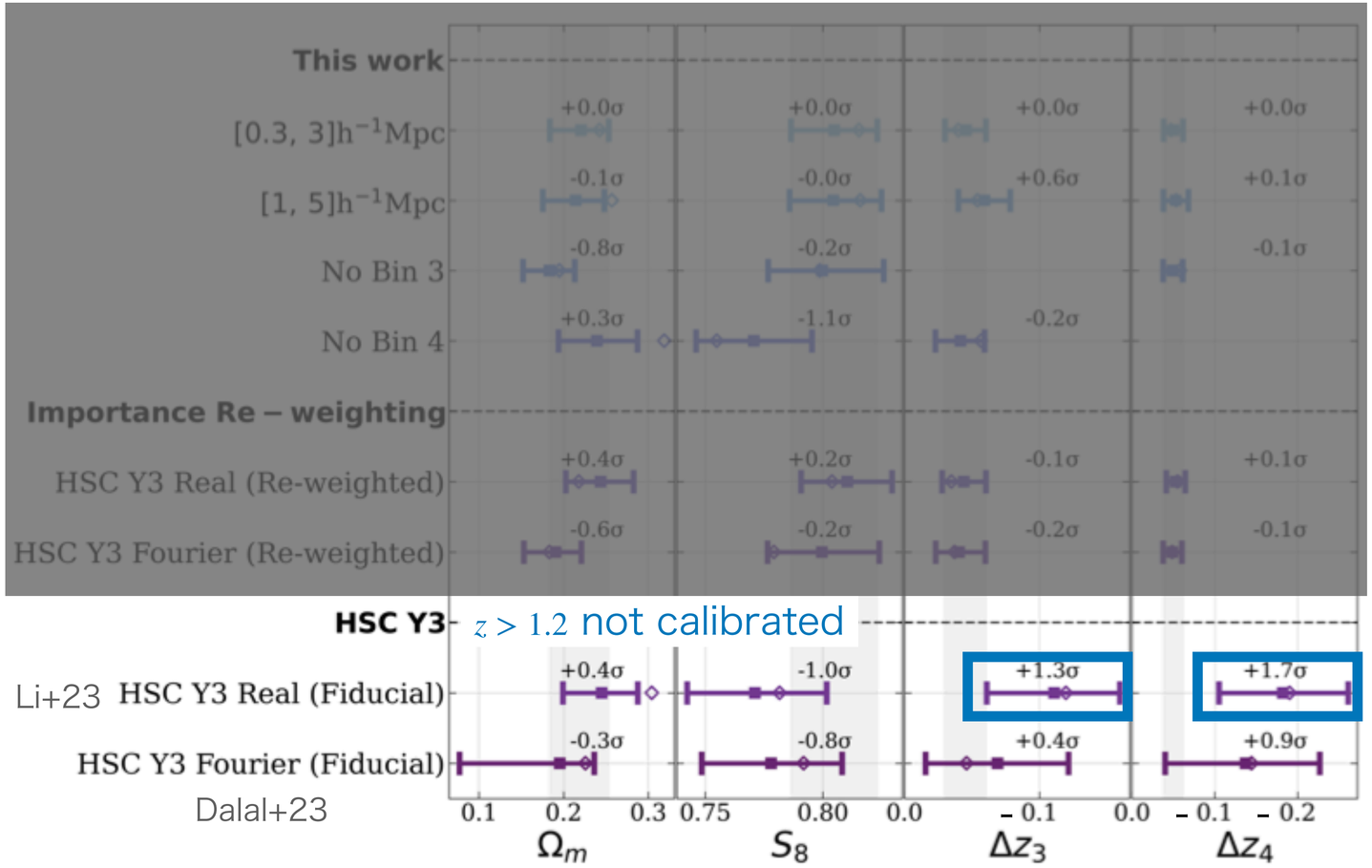
HSC-Y3 results before DESI

Self-calibration



Well-calibrated anchor

Choppin de Janvry+25b, RT edited

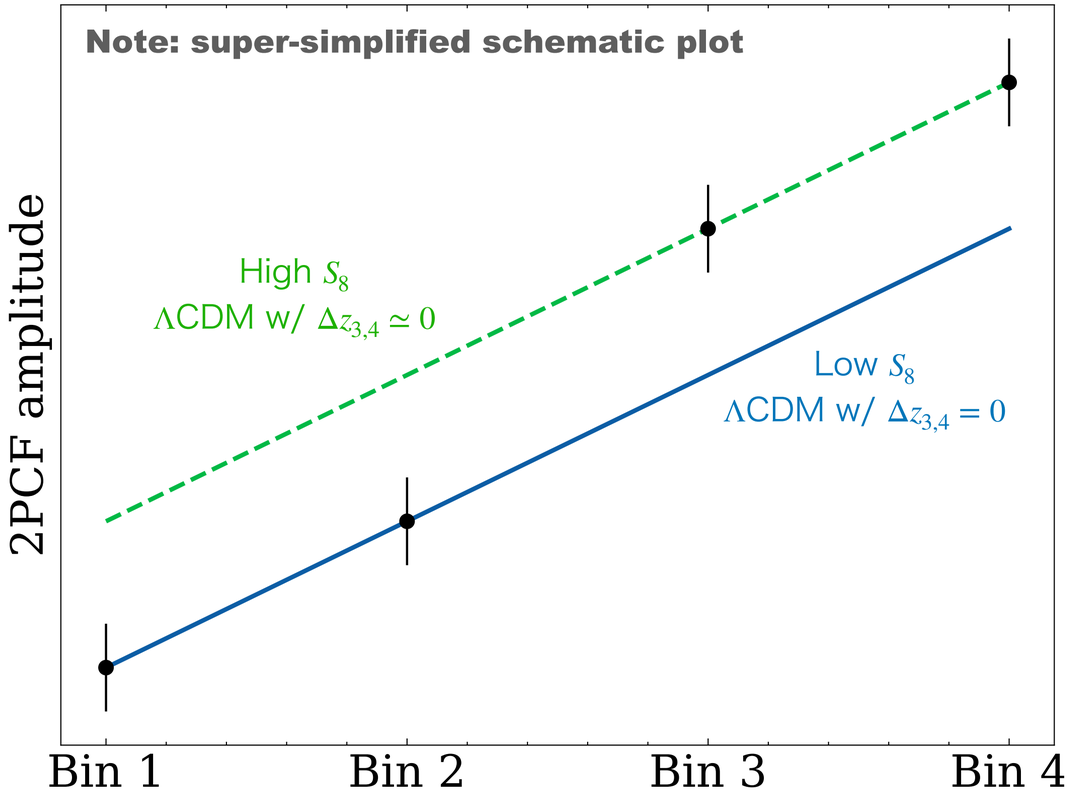


Similar shifts found in 3 x 2 pt (Zhang+25)

HSC-Y3 results w/ clustering redshift from DESI x HSC (Choppin de Janvry+25)

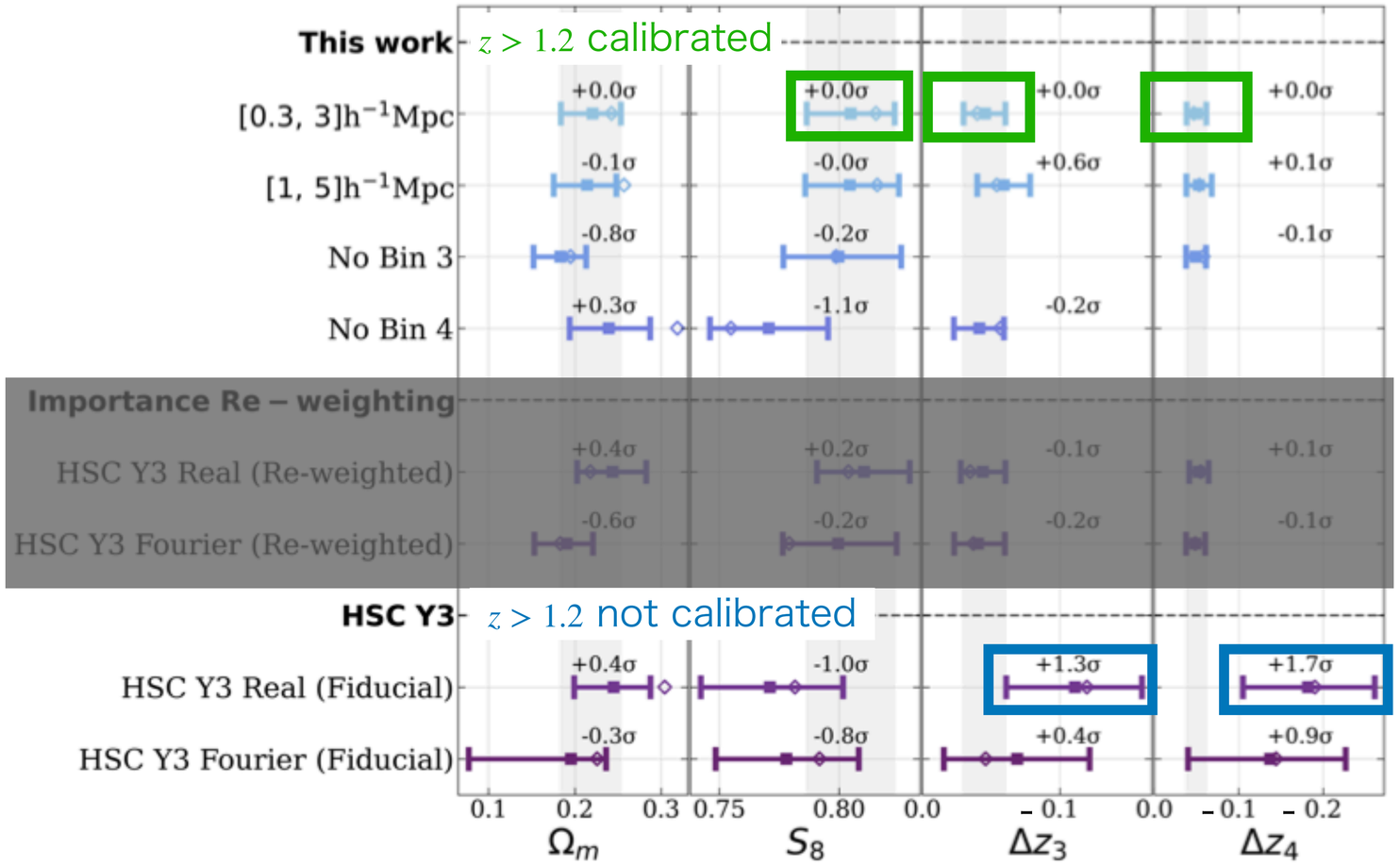
DESI clustering redshift

$(\Delta z_{3,4} \simeq 0)$



All bins are well-calibrated w/ DESI

Choppin de Janvry+25b, RT edited



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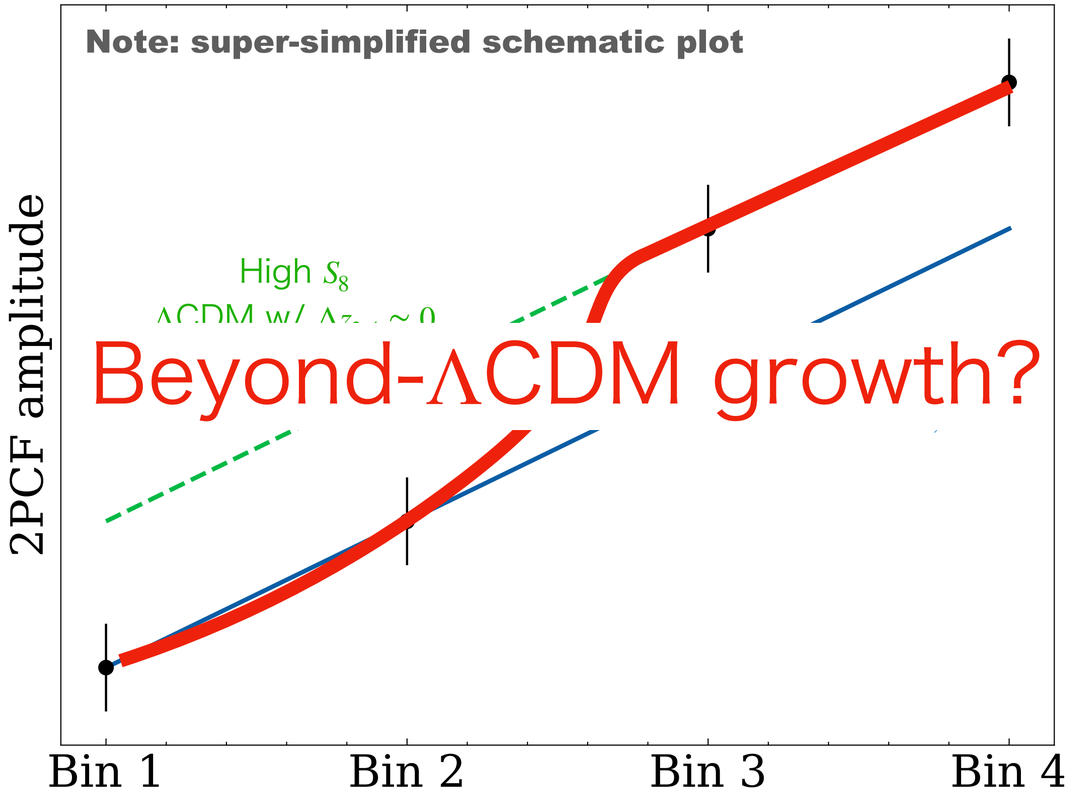

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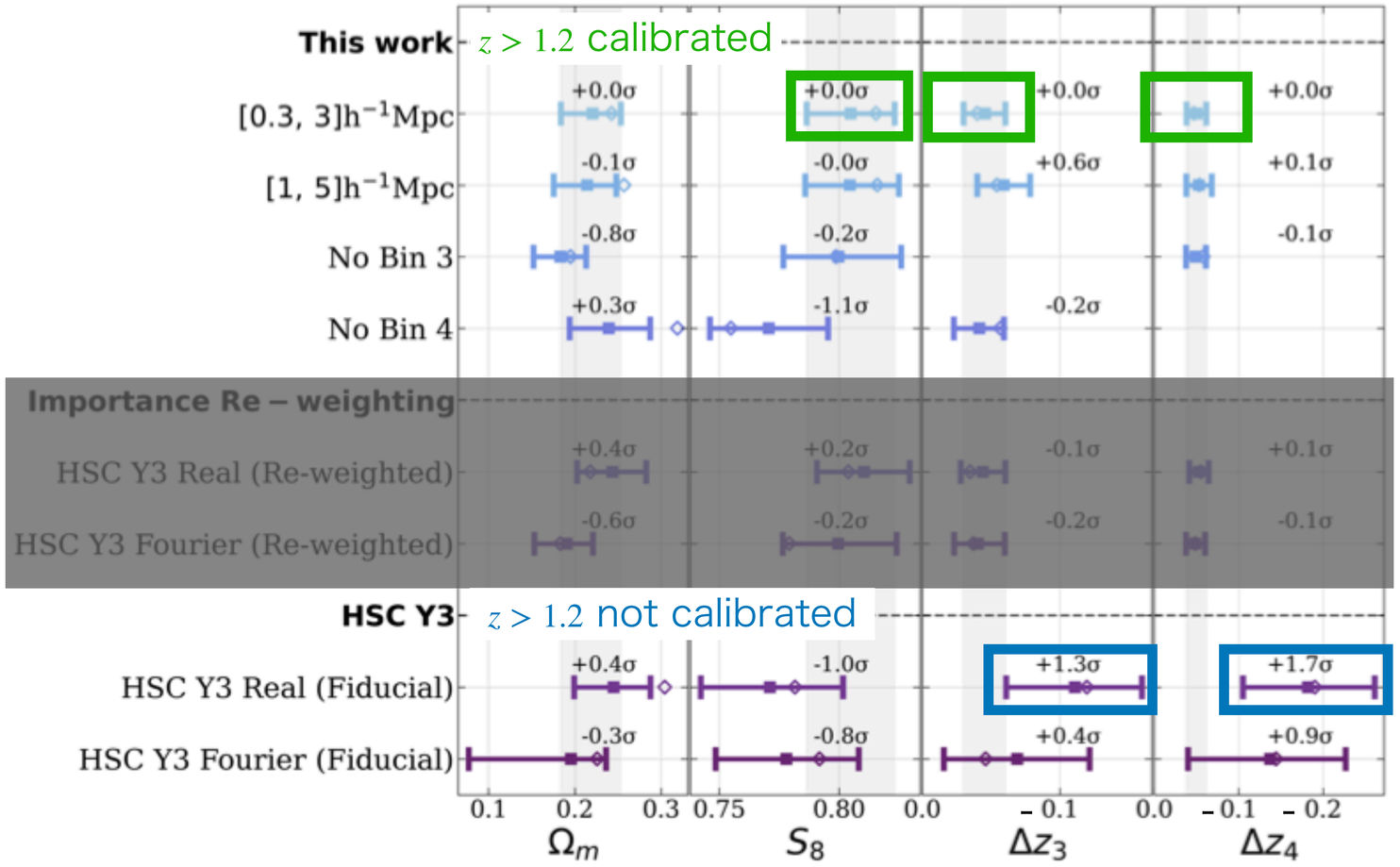
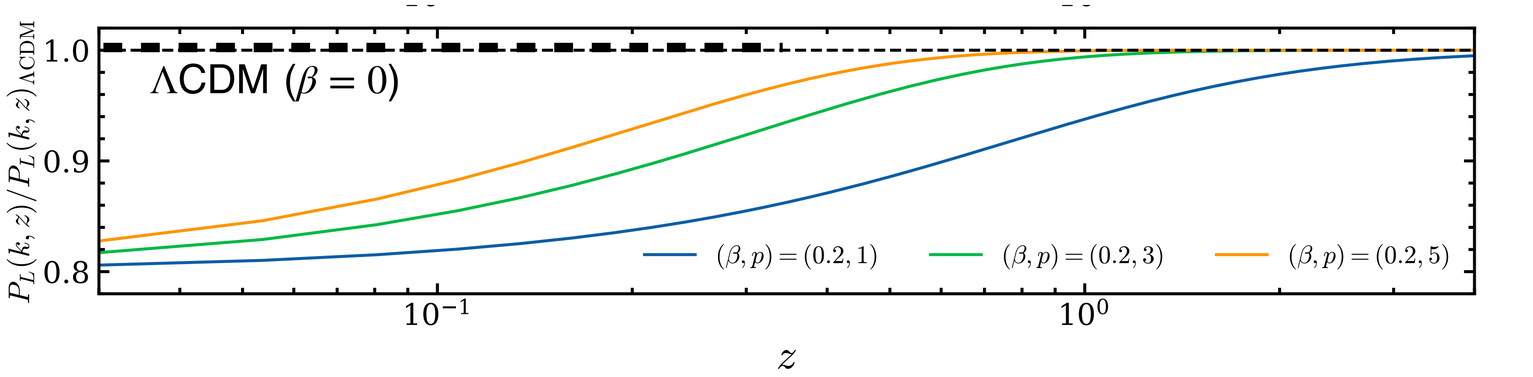


Late-time growth suppression

$$\alpha(z) \equiv \frac{P_L(k,z)}{P_L(k,z)_{\Lambda\mathrm{CDM}}} = 1 - \beta \left(\frac{\Omega_{\mathrm{DE}}(z)}{\Omega_{\mathrm{DE}}(z=0)} \right)^p$$



Present ← time (log scale)

- z-dependent view of S_8 tension: $S_8^{\mathrm{low}-z} < S_8^{\mathrm{high}-z}$, Late time growth is slower
- Re-scaling of the linear power spectrum $P_L(k) = \alpha(z) P_L(k)_{\Lambda\mathrm{CDM}}$ at the dark energy dominated era
  Dark Energy Tracking Growth (DETG) model (Lin+23)
- This work: Data-driven way to infer the deviation from ΛCDM structure growth ($\beta = 0$)
- More work is needed to build physical model on theory side

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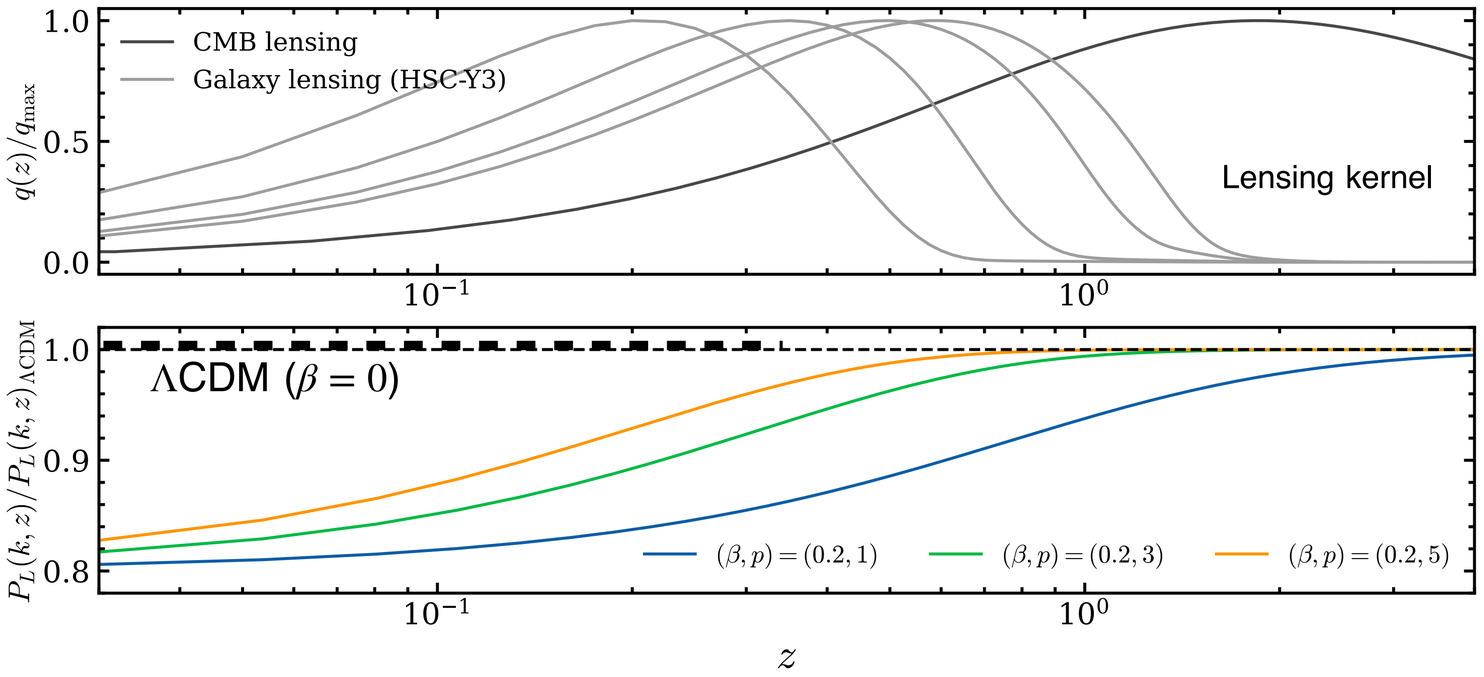

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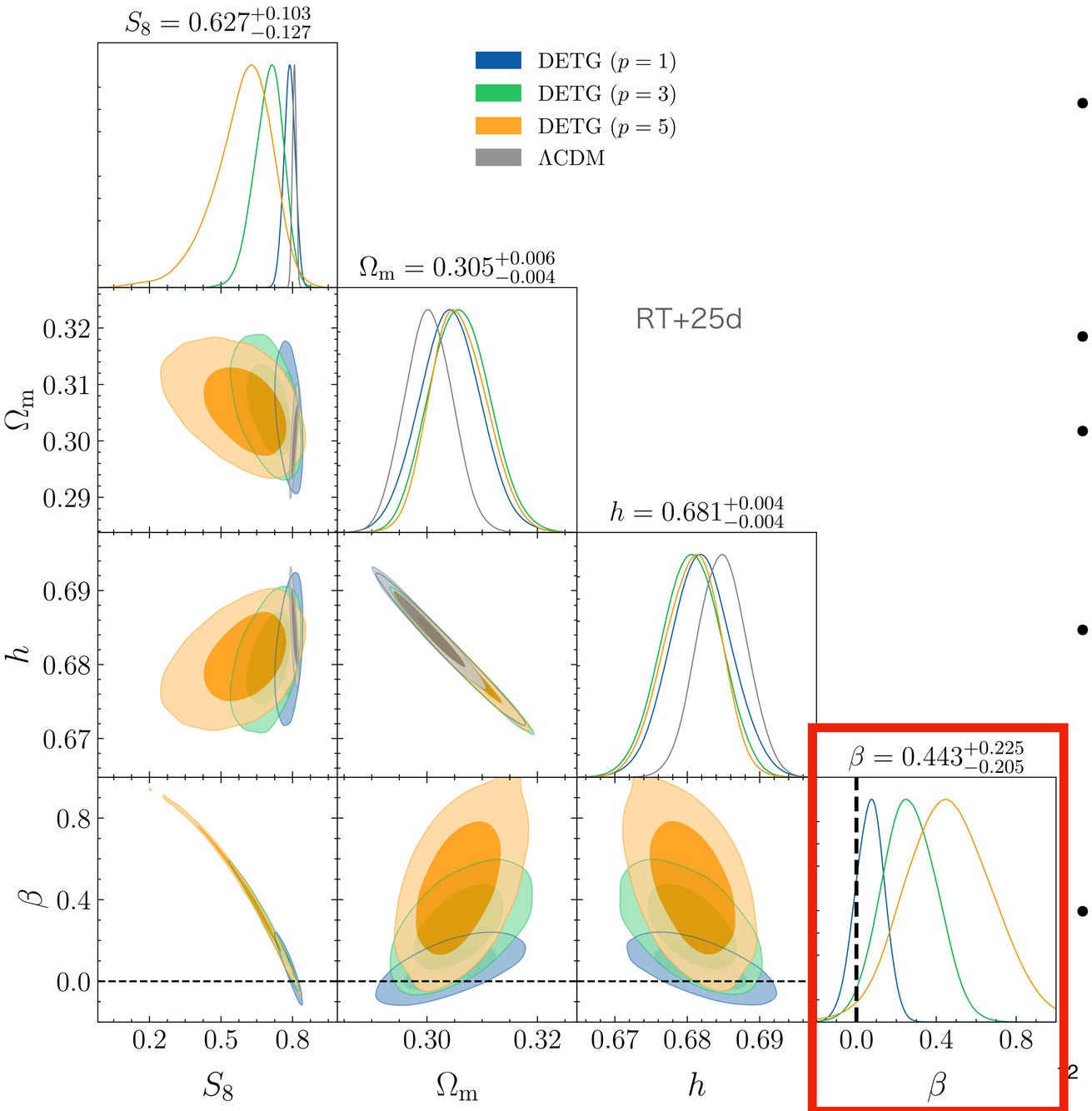
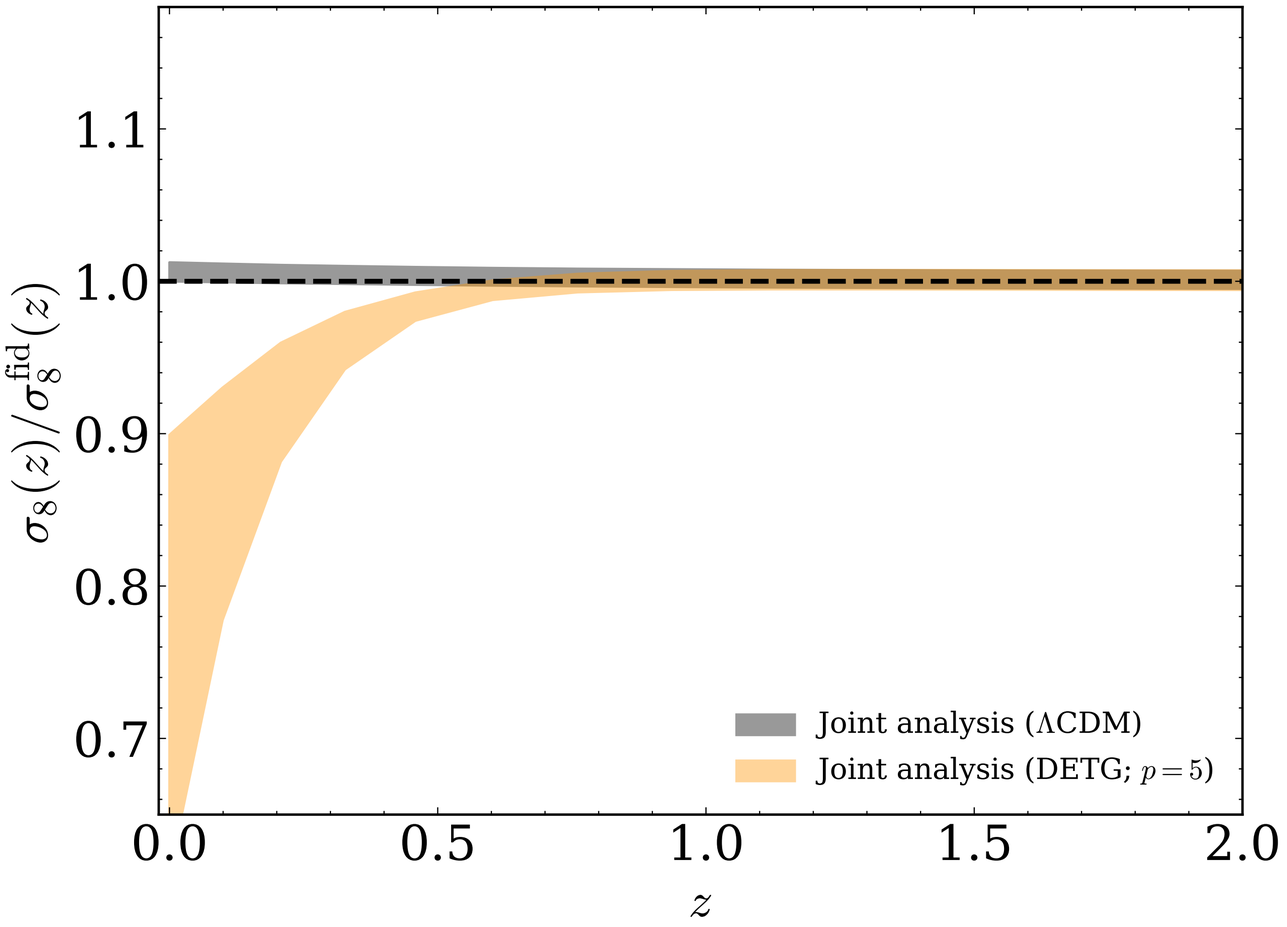
HSC-Y3 + CMB with suppressed growth model



- Primary CMB (Planck18 PR3 high-ell TTTEEE)
  + CMB lensing (ACT DR6)
  + Cosmic shear (HSC-Y3)
  + BAO (DESI Y1)
- Modified CAMB → consistently model all the probes
- p is fixed, β & 6 cosmo. params are varied
  Nuisance params for cosmic shear are fixed to the MAP values of cosmic shear-only analysis (Li+23)
- Among several fixed values of p, suppression starting at $z \sim 0.7$ ($p = 5$) is favored
  ($\Delta\chi^2 = 5.1$, Bayes factor $\ln\left(Z/Z_{\Lambda\rm CDM}\right) = 1.0$)
- $\sim 2\sigma$ hint of growth suppression ($\beta > 0$)

Evolution of clustering amplitude $\sigma_8(z)$



- $\sigma_8(z)$: clustering amplitude at redshift z
- Orange region: constraints from the joint analysis with DETG (suppressed growth) model

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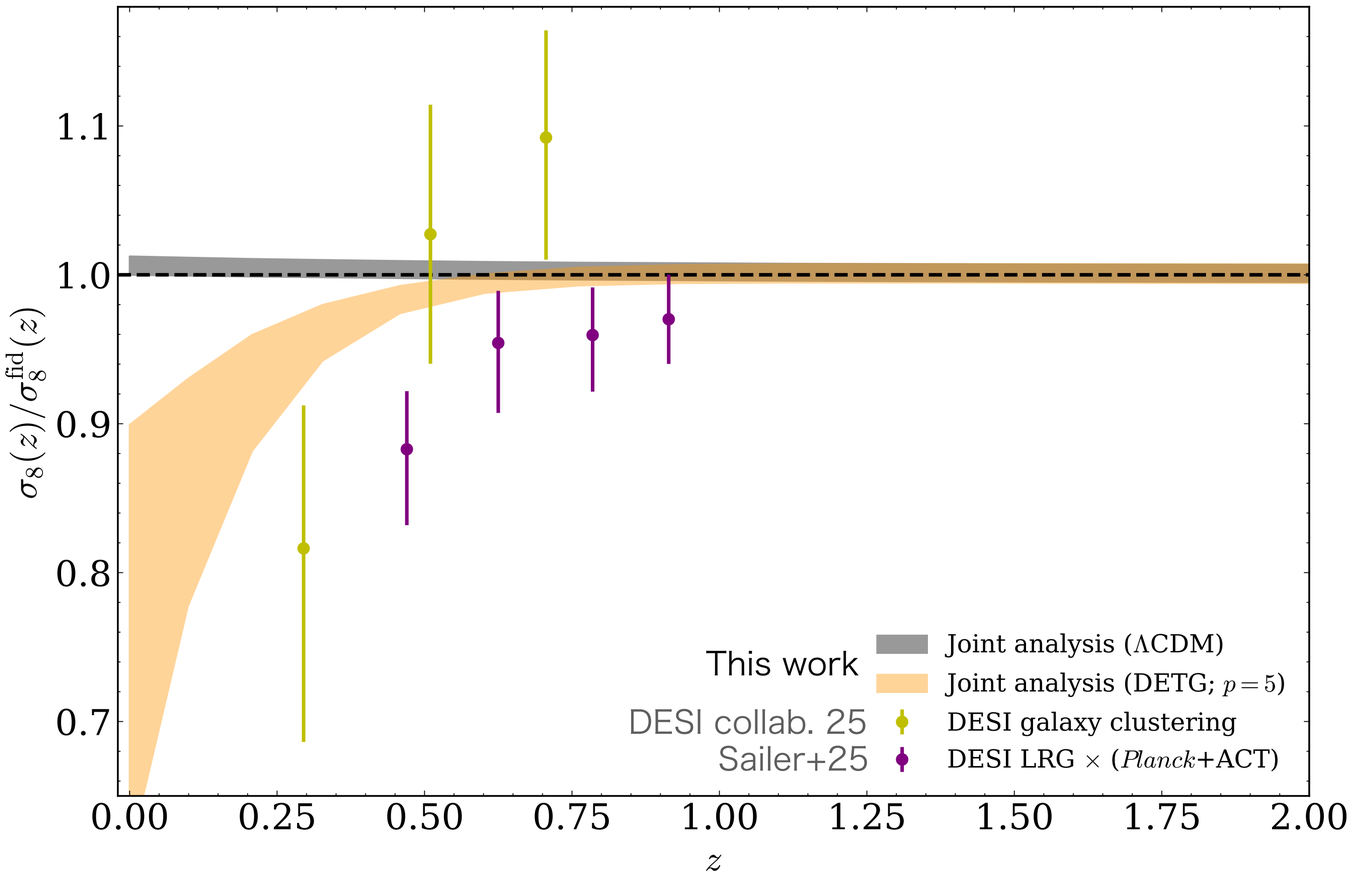

- $\sigma_8(z)$: clustering amplitude at redshift z
- Orange region: constraints from the joint analysis with DETG (suppressed growth) model
- Comparison w/ other measurements (DESI)
  - Galaxy clustering
  - Cross correlations of galaxy and CMB lensing

Summary: Testing the Standard Cosmological Model with CMB + HSC WL data

- Apparent shifts $\Delta z_{3,4}$ in HSC-Y3 self-calibration can be due to suppressed growth at low redshifts
- Tested the standard growth scenario ($\beta = 0$) with joint analyses of CMB (Planck primary CMB, ACT CMB lensing), cosmic shear (HSC), and BAO (DESI)

What we found

- Found $\sim 2\sigma$ hint for the late time growth suppression ($\beta > 0$)
- Growth suppression simultaneously explains
  - Bias in photo-z self-calibration
  - HSC-Y3 + CMB joint analysis
  - Other measurements (e.g., DESI LRGs x CMB lensing) at low redshifts

Future

- HSC-Y6 analysis will use DESI clustering redshift: all 4 bins will be well-calibrated
- Analysis with the high-precision data from upcoming surveys, joint analysis with galaxy x CMB lensing data
- Exploring / Building the physical model realizing the growth suppression