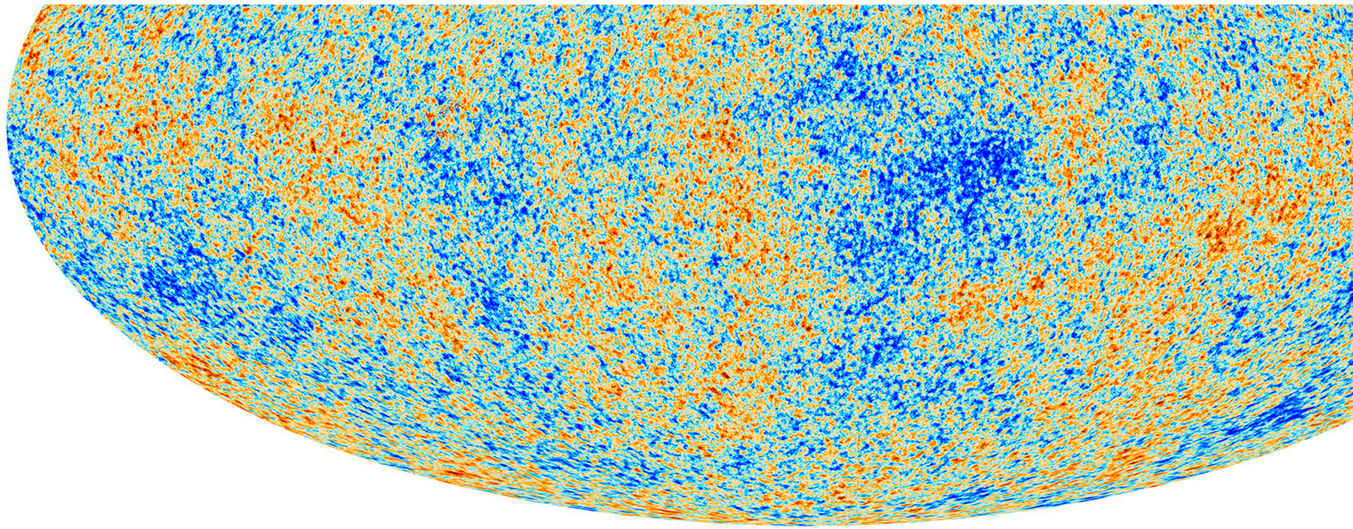
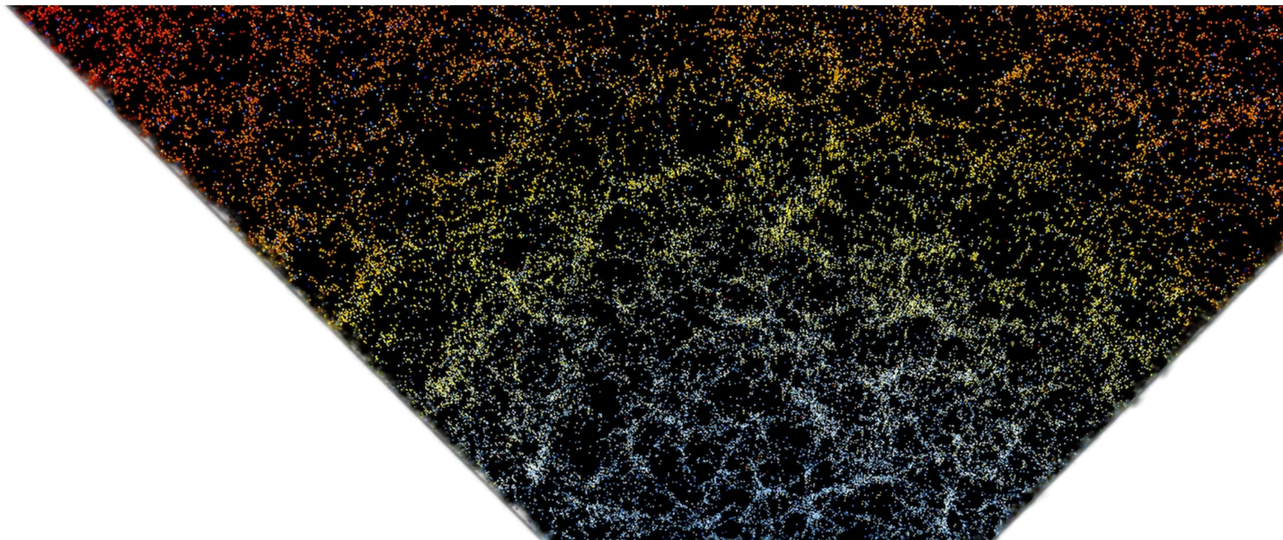


Forecasts on S_8 using tomographic cross-correlations with LSST and *Planck*

Chandra Shekhar Saraf
Korea Astronomy and Space Science Institute

In collaboration with David Parkinson (KASI)

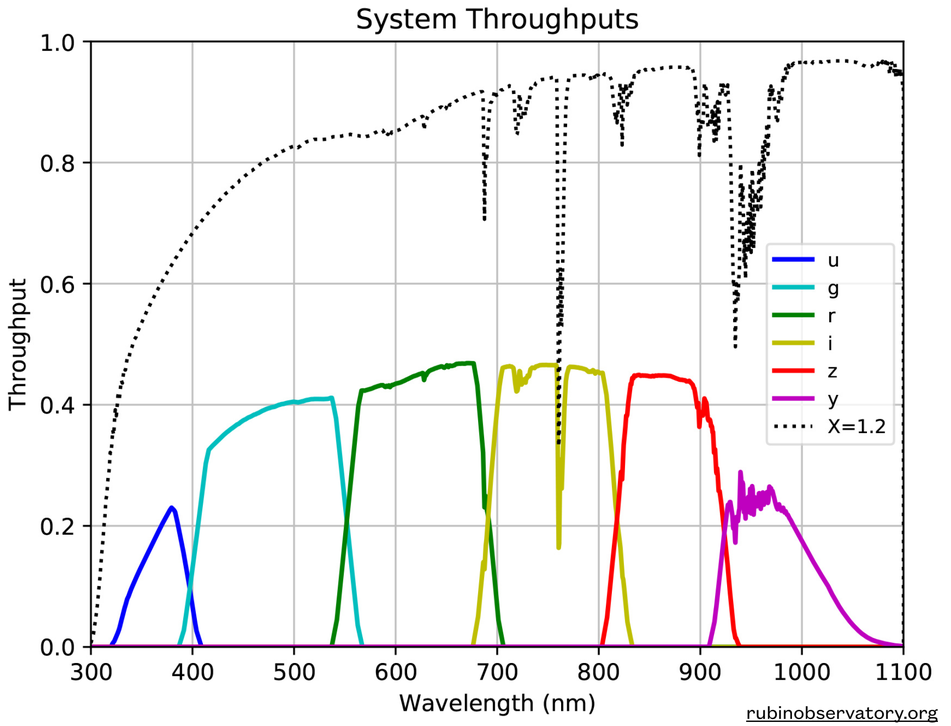


September 18, 2024

CASTLE 2024, Tagliolo Monferrato, Italy

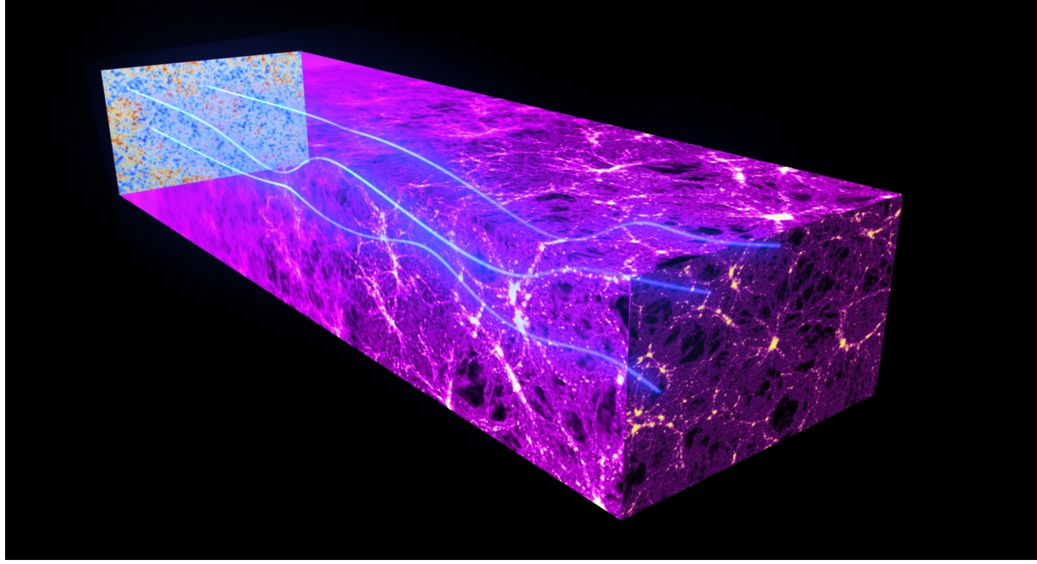
Vera C. Rubin LSST survey

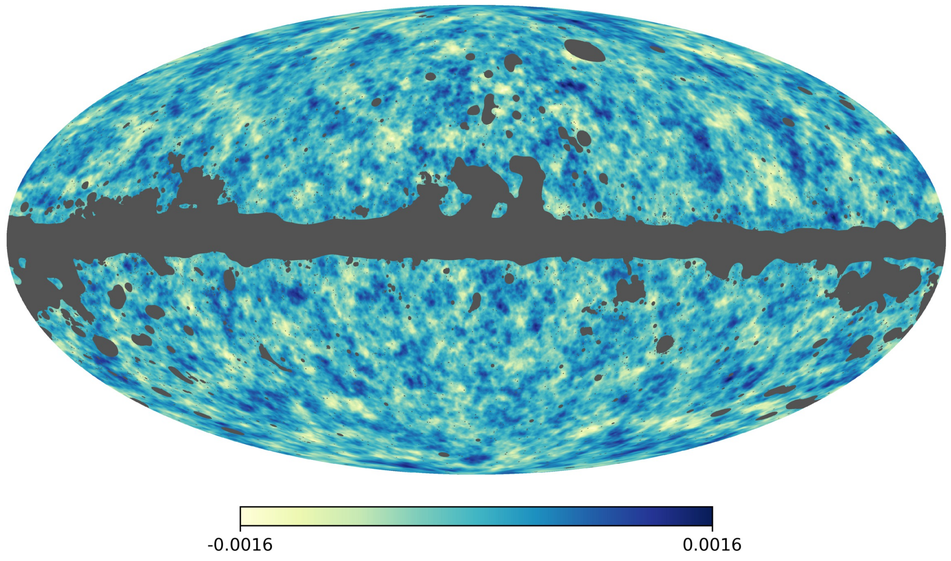
- Legacy Survey of Space and Time (LSST)
- Observatory located at Cerro Pachon, Chile
- 8.4 m primary mirror with $9.6\,\mathrm{deg}^2$ field of view
- Six photometric filters u, g, r, i, z, y covering $\sim 20{,}000\,\mathrm{deg}^2$
- Total survey time: 10 years
- First light expected in January 2025



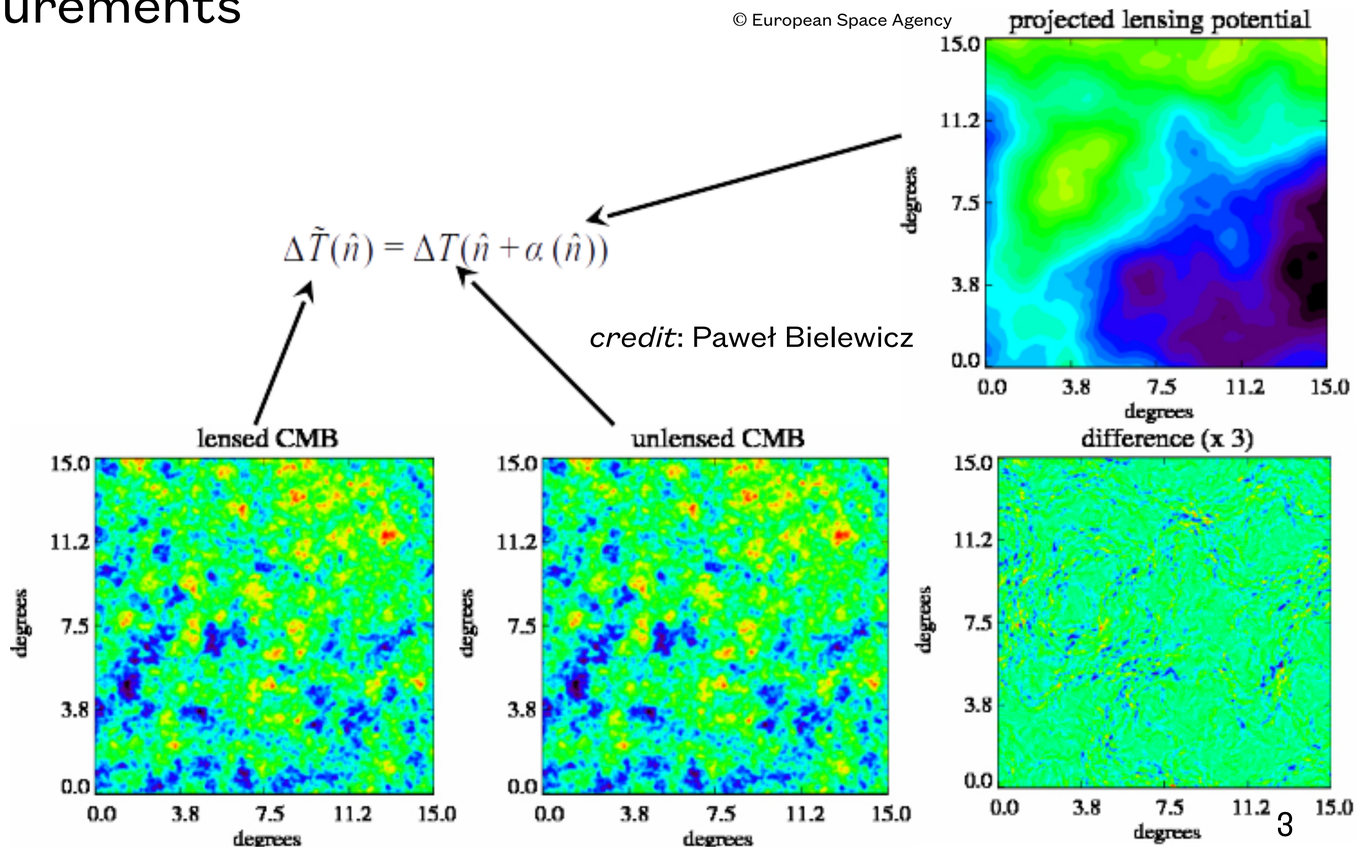
CMB Weak Lensing

- Deflection of CMB photons by large scale structure ($\sim 3'$)
- Correlated deflection angles over sky
- Changes the statistical properties of CMB anisotropies
- Reconstruct lensing potential from CMB measurements
- Excellent tracer of dark matter distribution





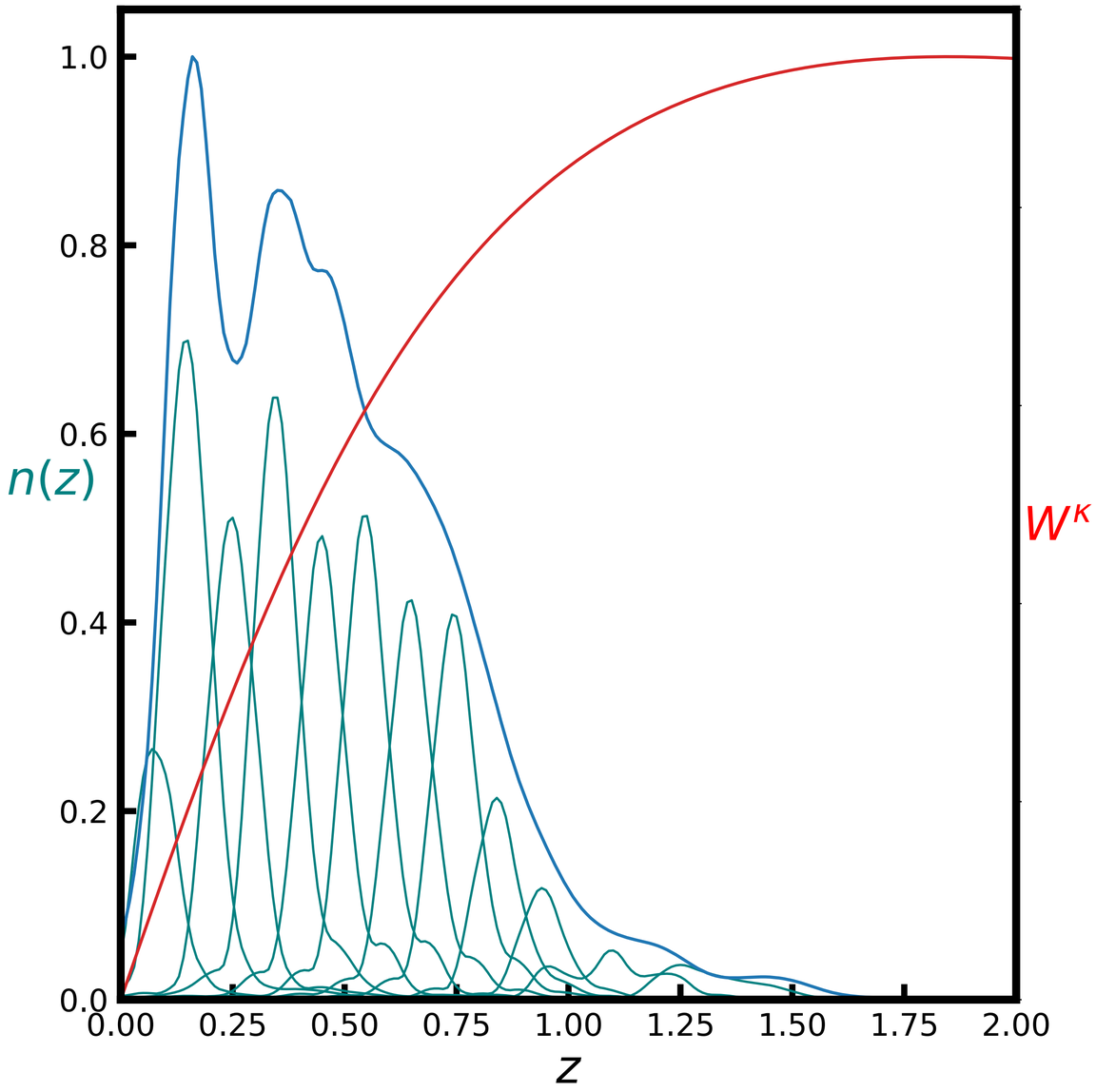
Planck Collaboration, 2020



credit: Paweł Bielewicz

Tomographic cross-correlation

- CMB lensing contains integrated information
- Cross-correlation with objects of known redshift
- Time evolution of cosmological parameters.
- Constrain cosmological models.



Simulation setup

Simulation setup

- Redshift Assessment Infrastructure Layers (RAIL)
- Redshifts and six band mags from Buzzard simulations (DeRose et al. 2019)
- Add errors on photometric magnitudes consistent with Y1

Simulation setup

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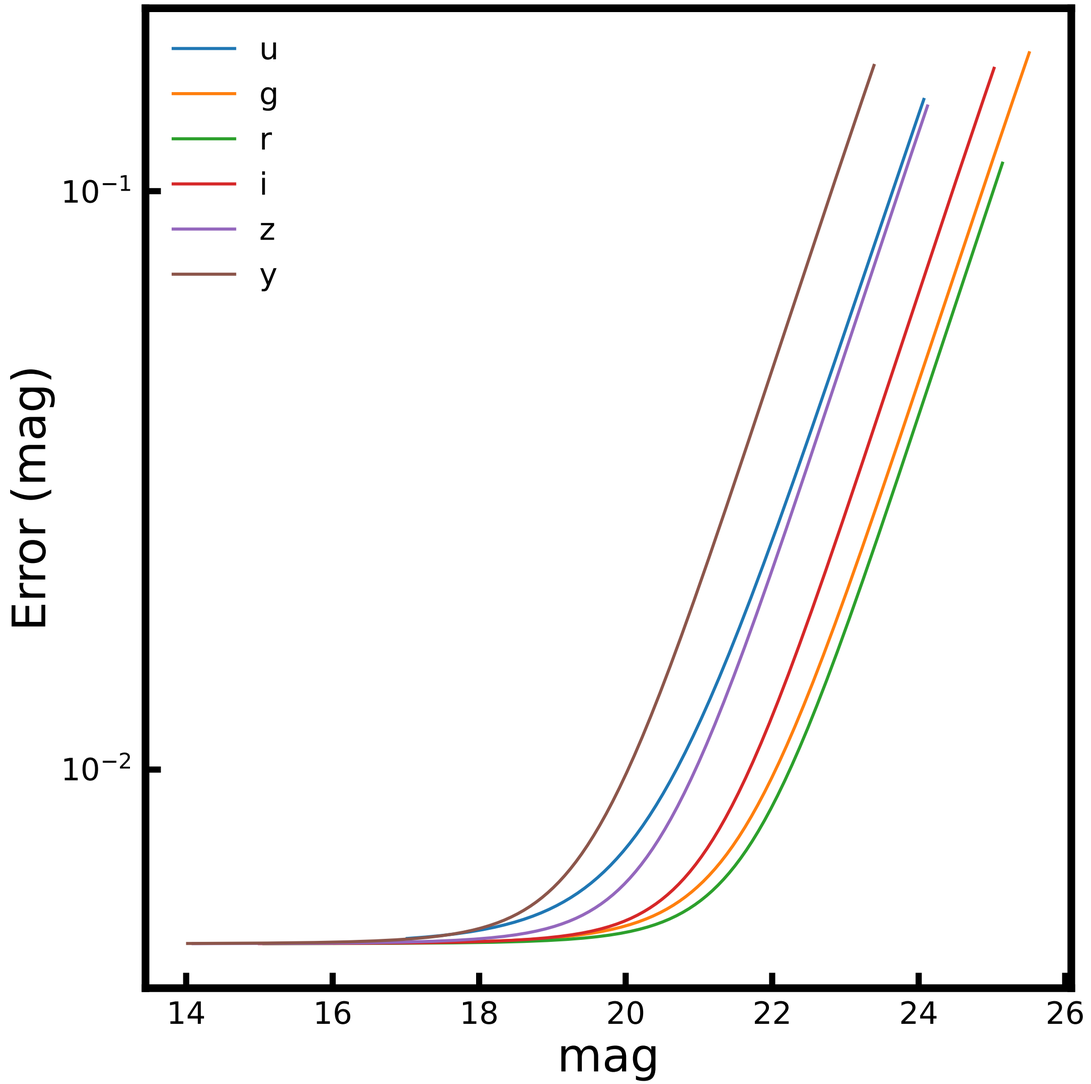
- Add errors on photometric magnitudes consistent with Y1
- 5σ depths

$u : 24.07, g : 25.60, r : 25.81, i : 25.13, z : 24.13, y : 23.39$



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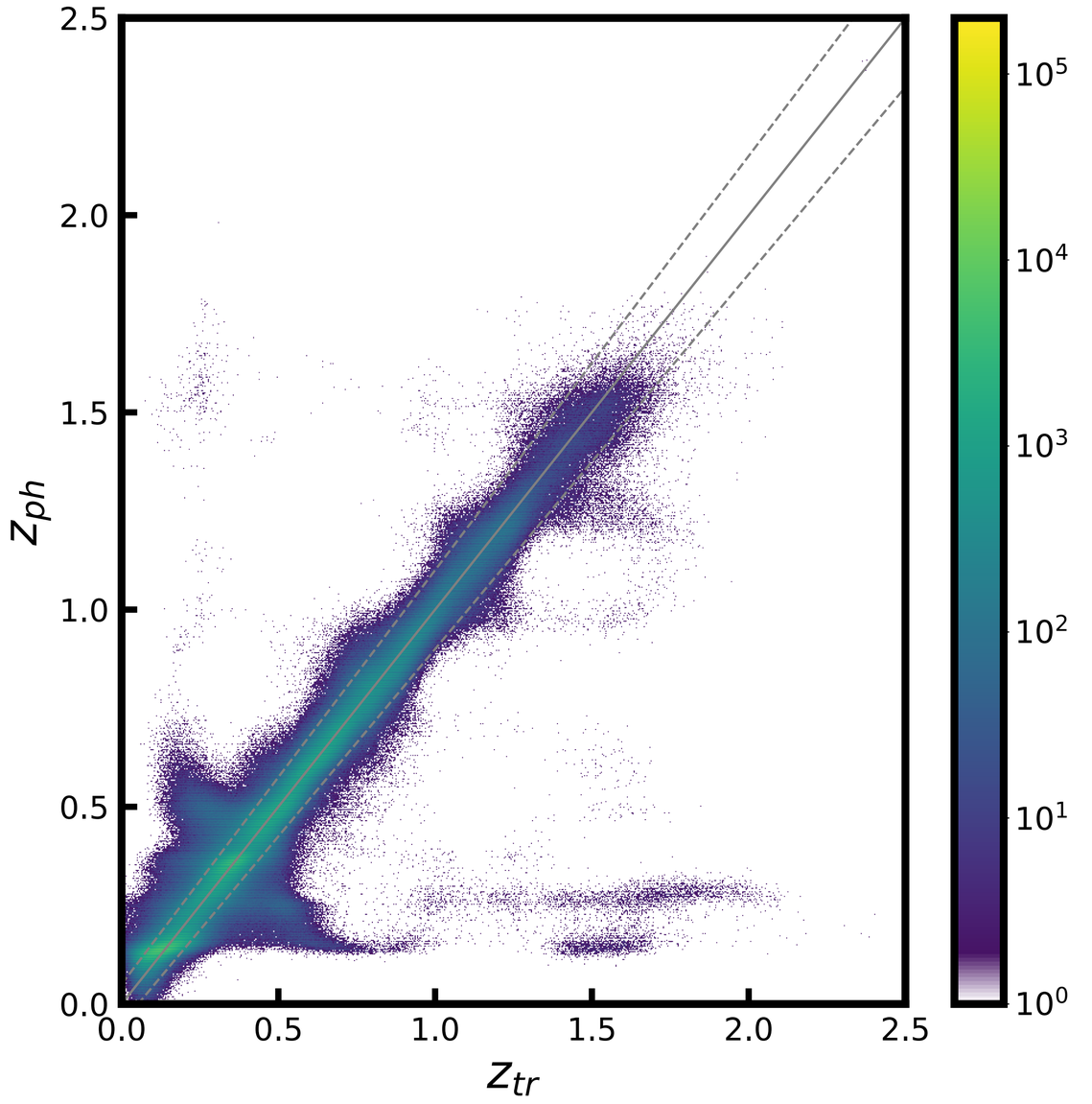

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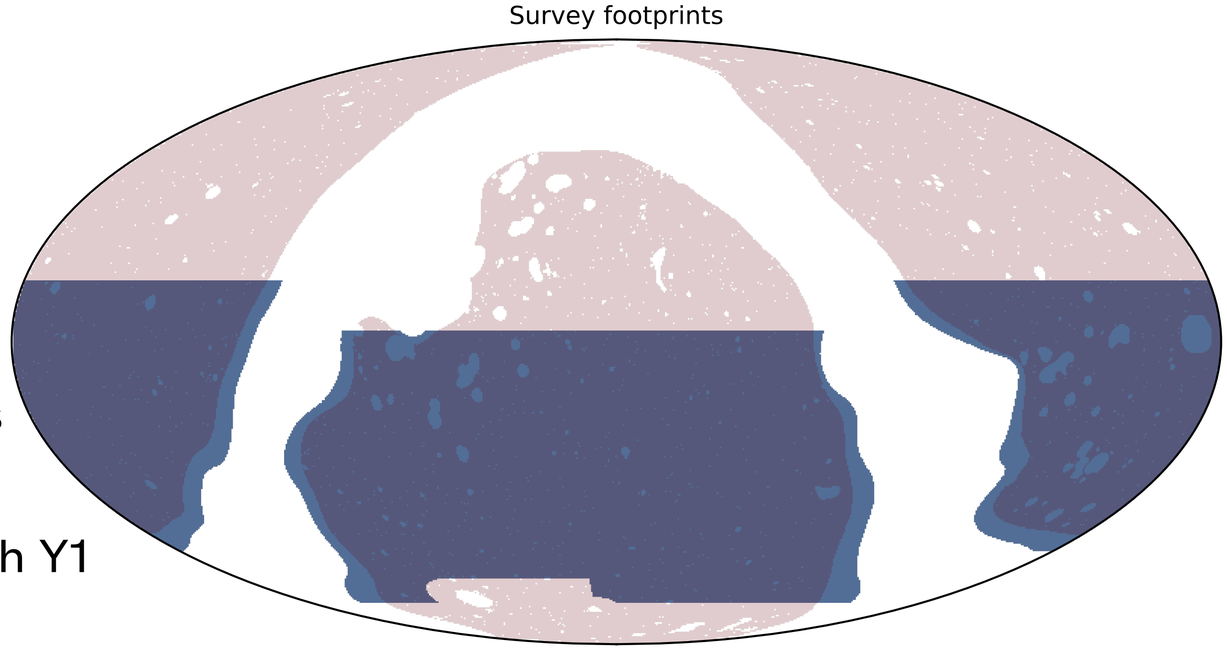

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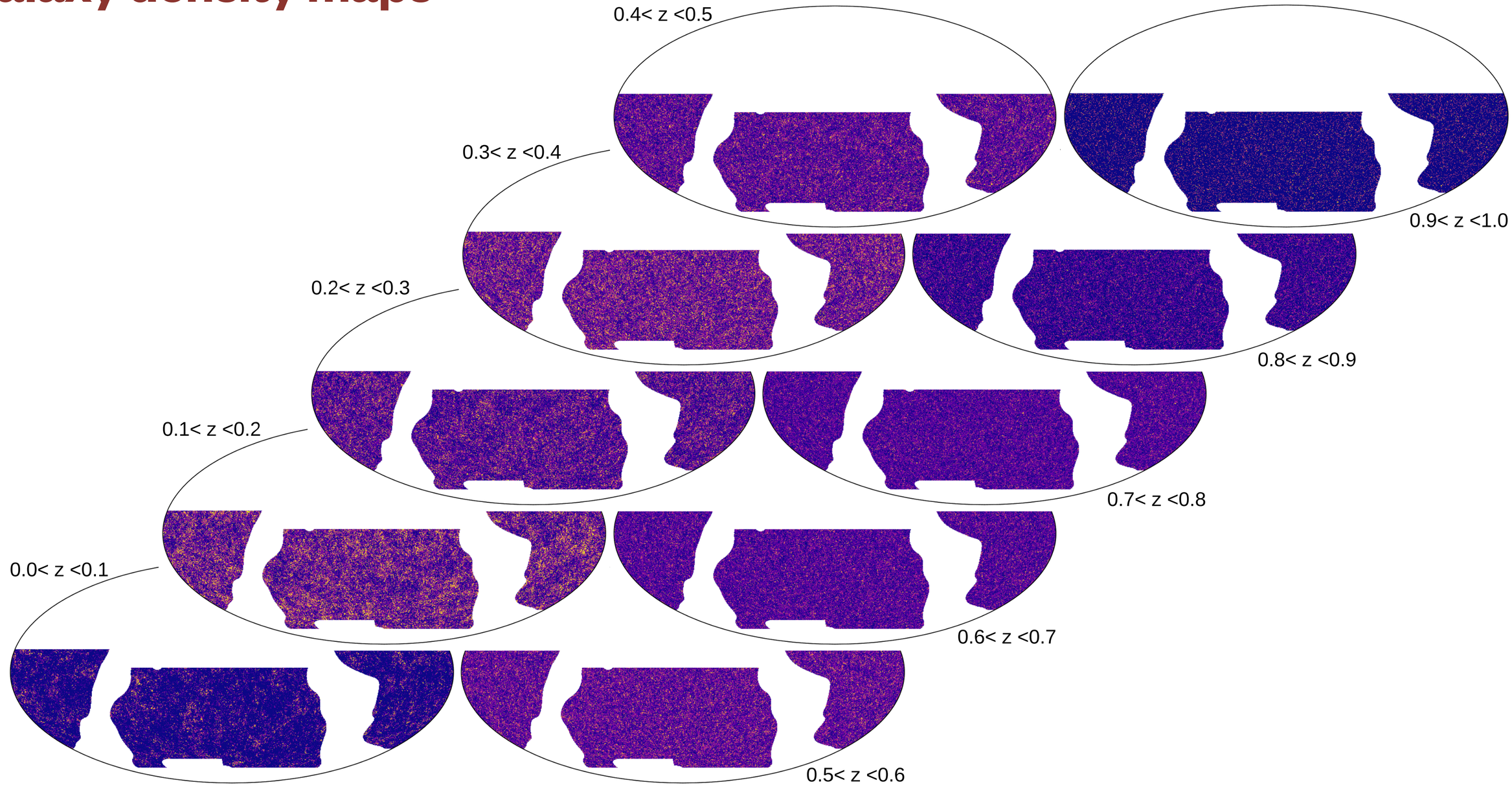
- Redshifts and six band mags from Buzzard simulations
- Add errors on photometric magnitudes consistent with Y1
- 5σ depths $u : 24.07, g : 25.60, r : 25.81, i : 25.13, z : 24.13, y : 23.39$
- Estimate photo-zs using FlexZBoost
- Add fiducial correlations using GLASS (Tessore et al. 2023)
- Compute angular power spectra based on photo-zs
- Estimate S_8 and galaxy bias

Galaxy density maps



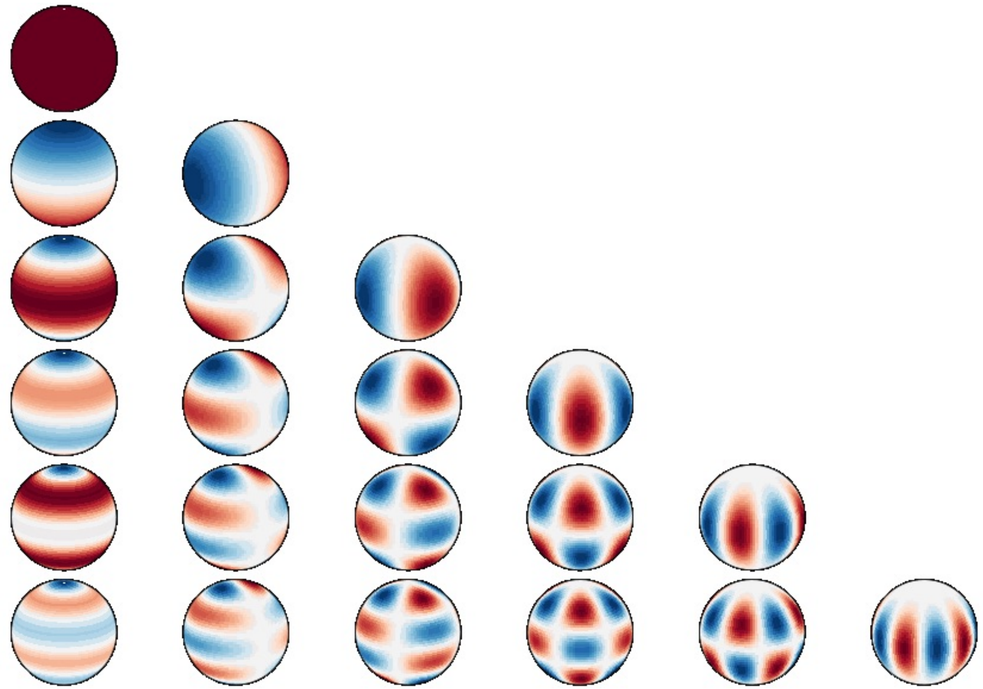
Angular Power Spectrum

Distribution of power as a function of angular scale

$$C_\ell^{XY} = \langle a_{\ell m}^X a_{\ell m}^{Y*} \rangle, \qquad \theta \propto \frac{1}{\ell}$$

Lensing Convergence: $\kappa(\hat{n}) = -\frac{1}{2}\nabla^2\phi(\hat{n})$

Galaxy over-density: $g(\hat{n}) = \frac{n_g(\hat{n}) - \overline{n_g}}{\overline{n_g}}$



Spherical Harmonics

Theoretical Power Spectrum

$$C_\ell^{XY} = \int_0^{\chi_*} d\chi \frac{W^X(\chi) W^Y(\chi)}{\chi^2} P\left(k = \frac{\ell + 1/2}{\chi}, z(\chi)\right)$$

Lensing Kernel: $W^\kappa(\chi) = \frac{3\Omega_{m,0}}{2c^2} H_0^2 (1+z)\chi \frac{\chi_* - \chi}{\chi_*}$

Galaxy Kernel: $W^g(\chi) = b(z)\frac{dN}{dz}$

stacking photo-z posteriors

$P(k, z) \equiv$ Matter power spectrum

$\chi \equiv$ comoving distance

$\chi_* \equiv$ comoving distance to last scattering

$z \equiv$ redshift

$\Omega_{m,0} \equiv$ present matter density parameter

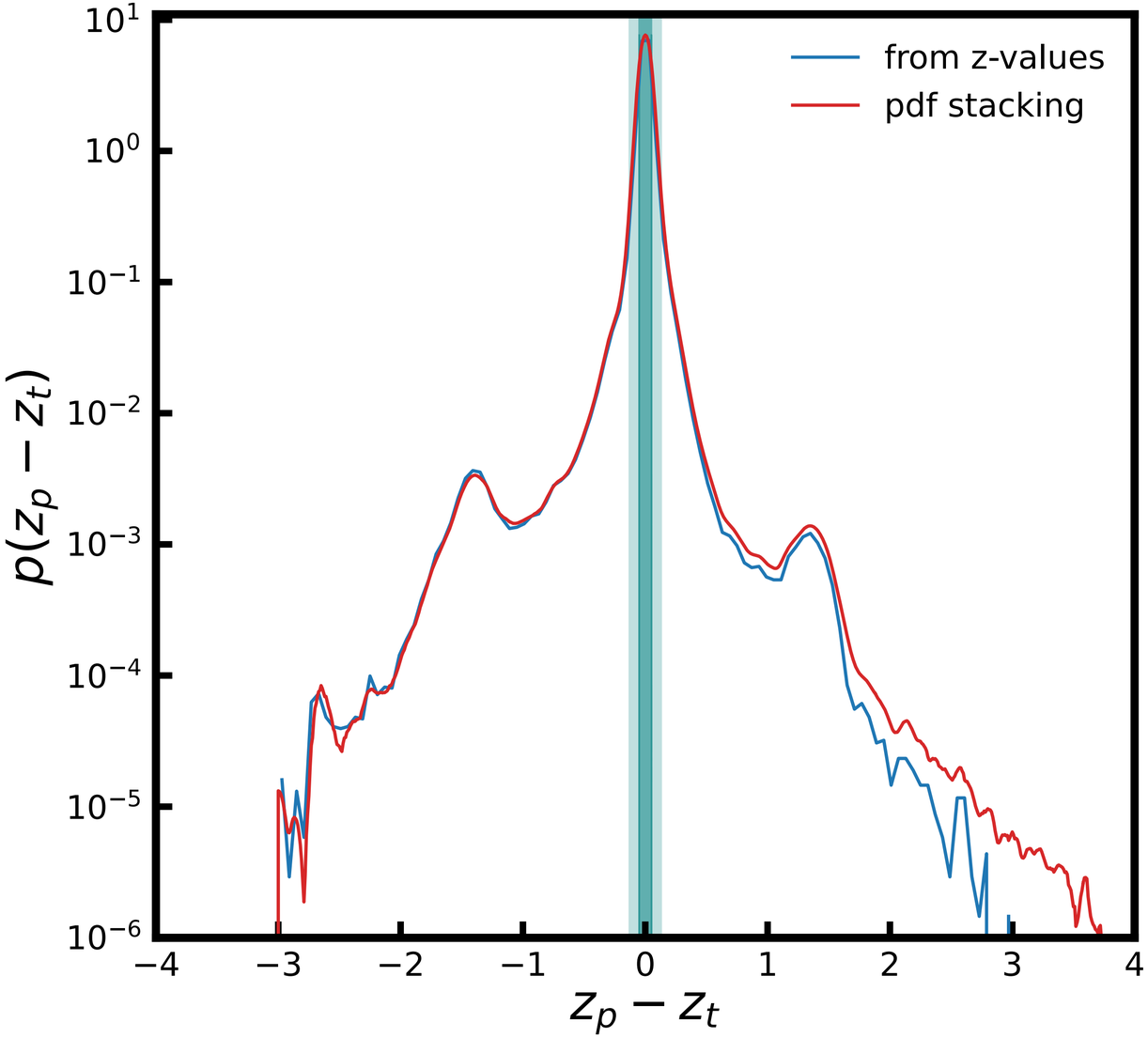
$H_0 \equiv$ Hubble constant

$c \equiv$ speed of light

$\frac{dN}{dz} \equiv$ redshift distribution of galaxies

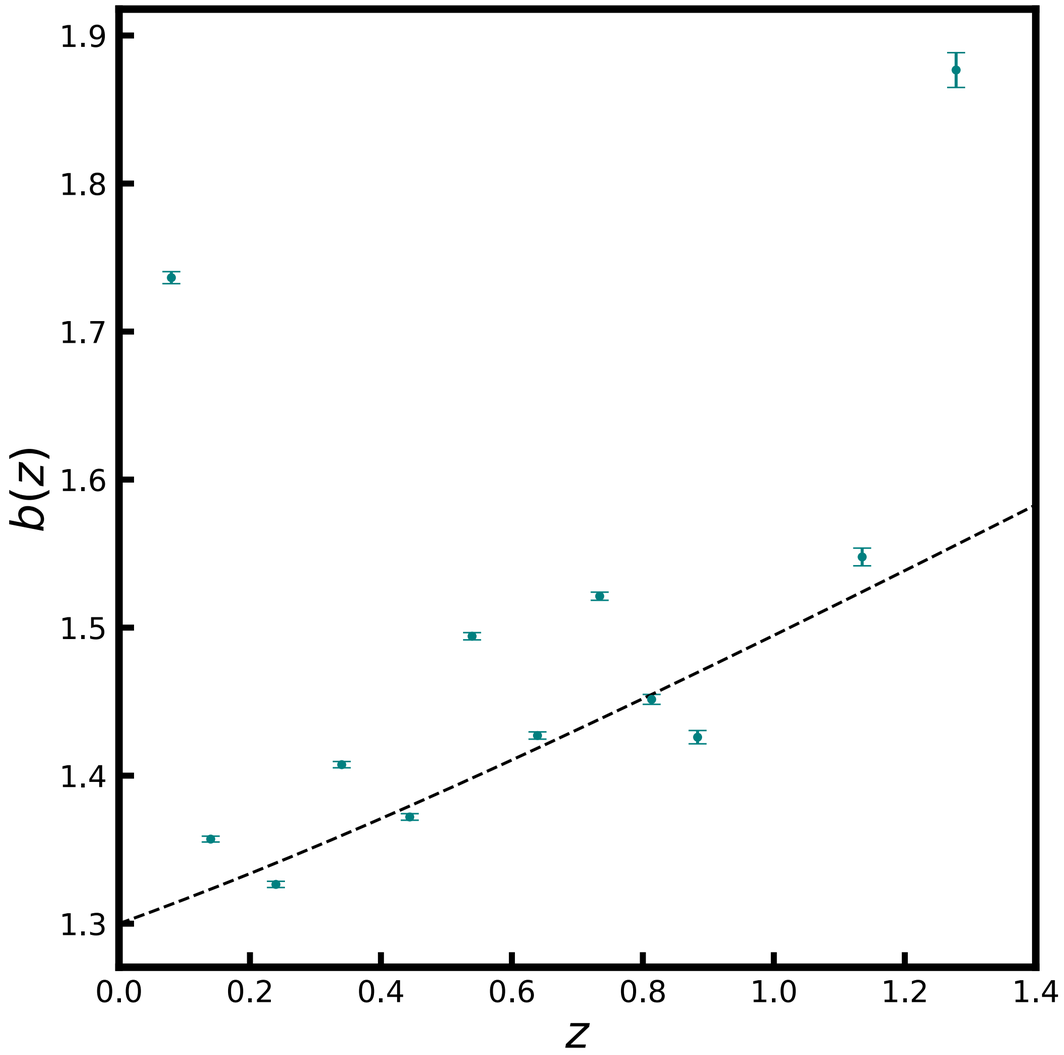
$b(z) \equiv$ galaxy bias

Redshift error distribution

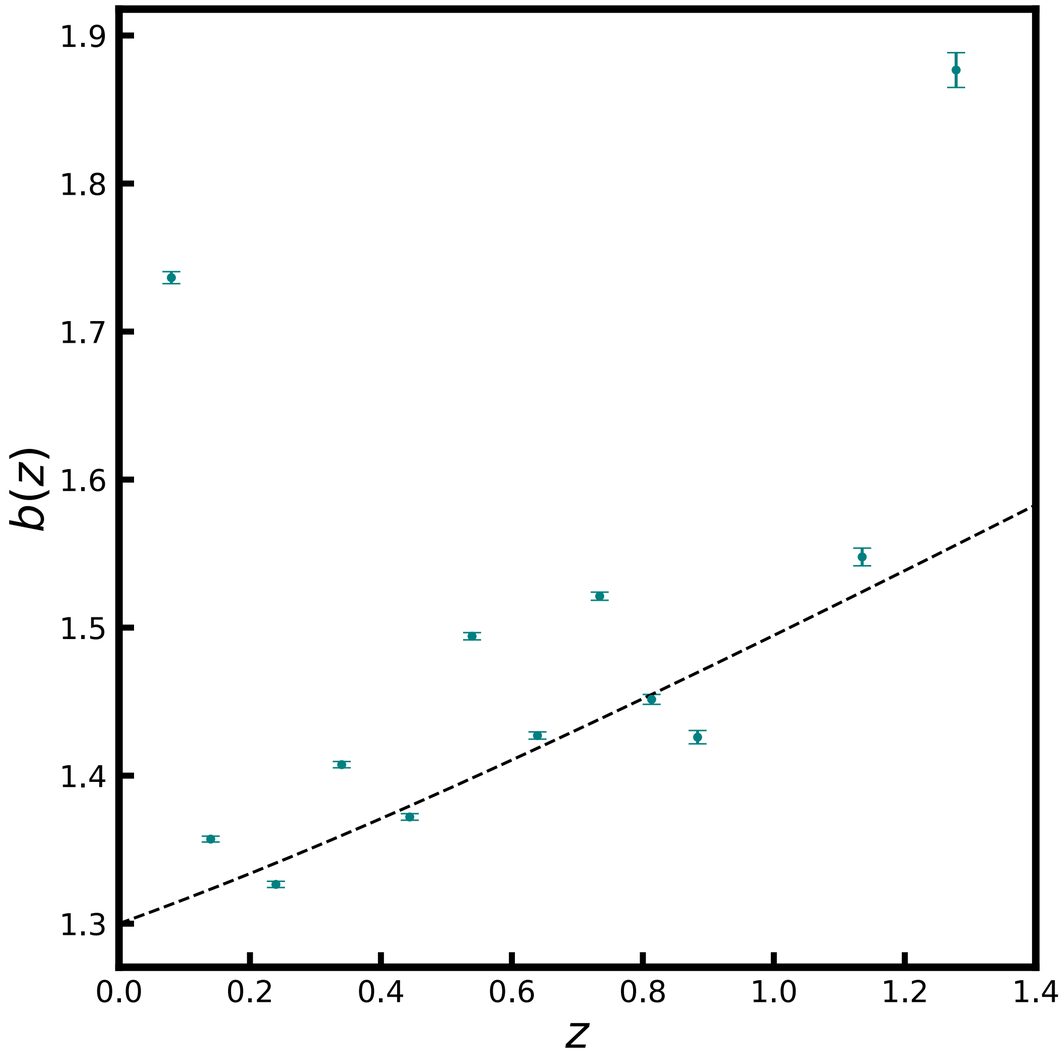


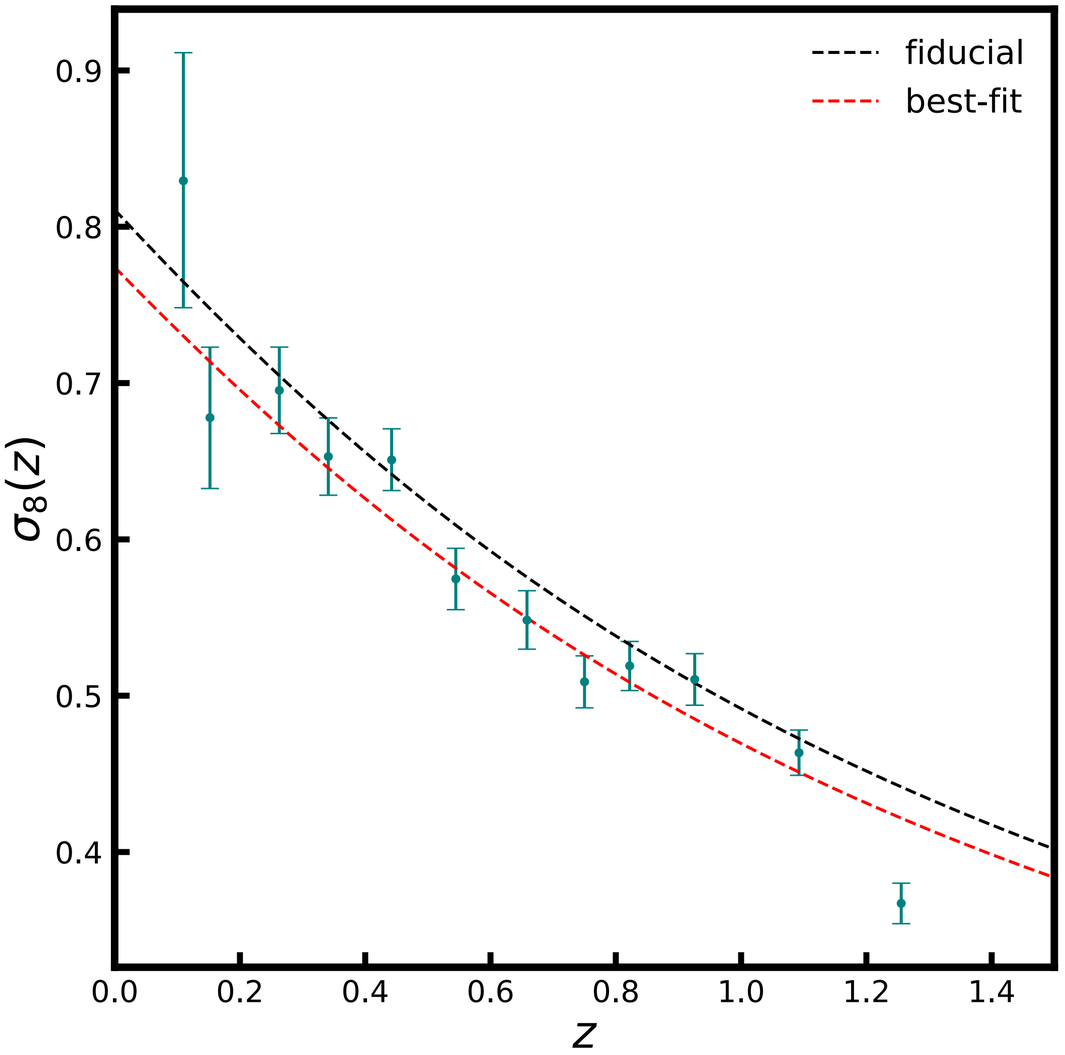
Results

Galaxy bias



Galaxy bias and σ_8

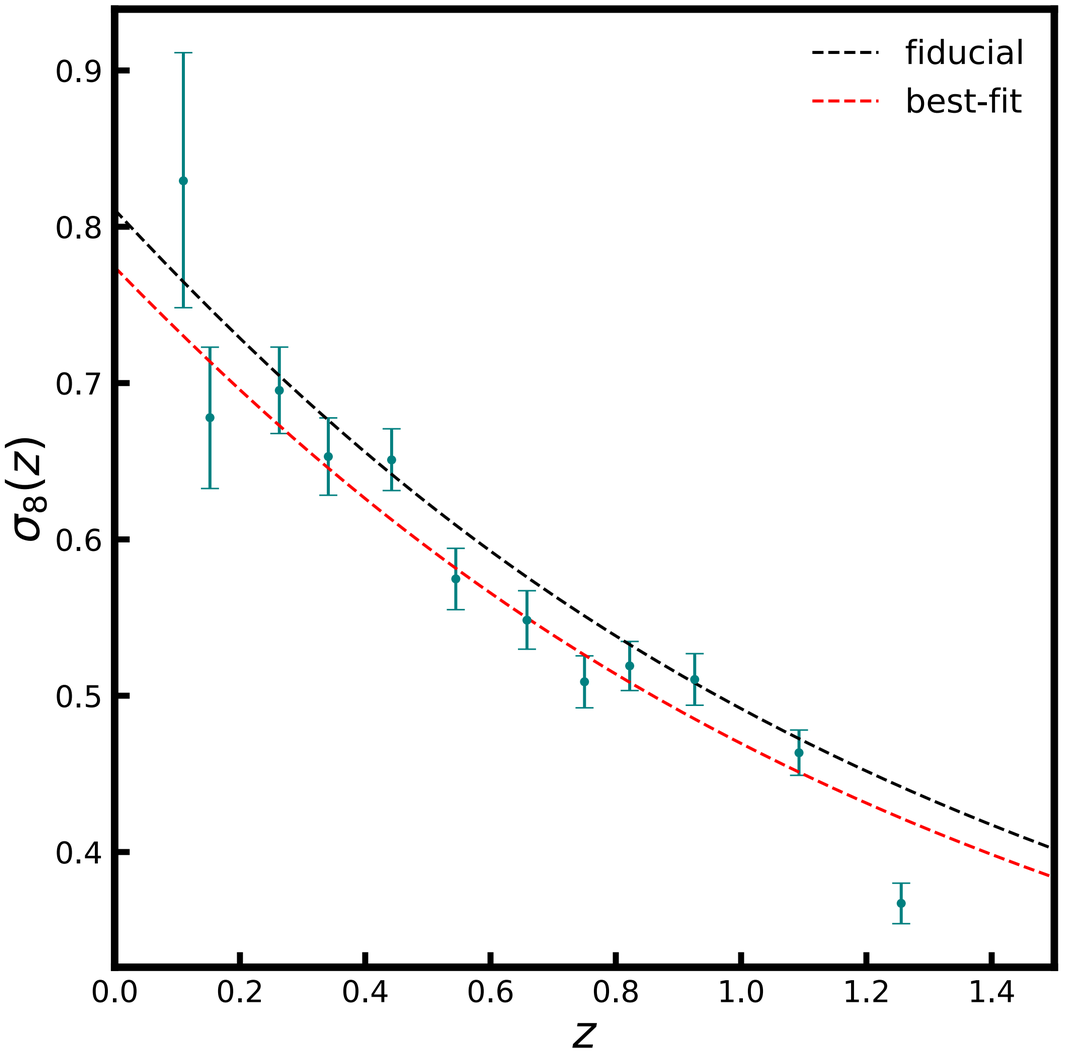




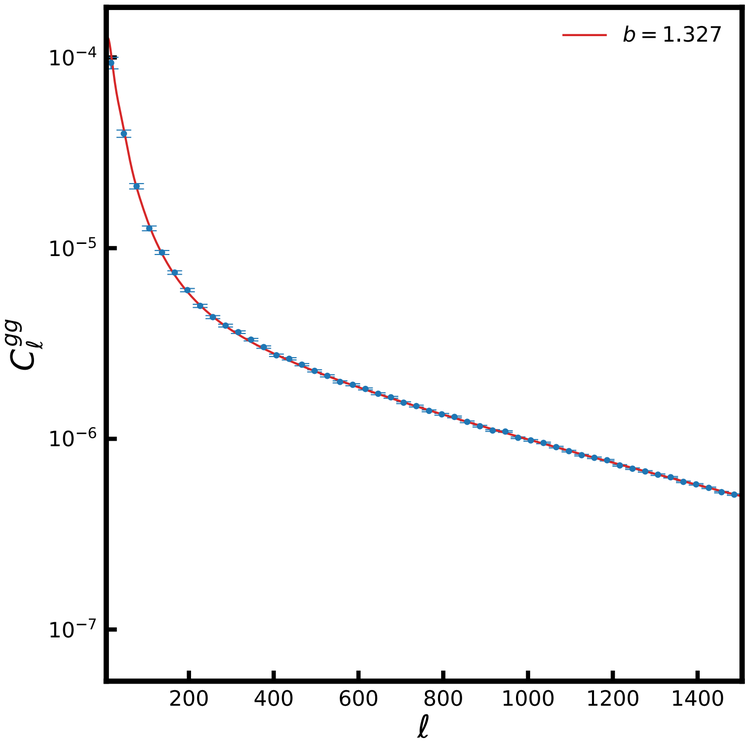
S_8 (tension)

$S_8 = 0.832 \pm 0.013$ (fiducial)

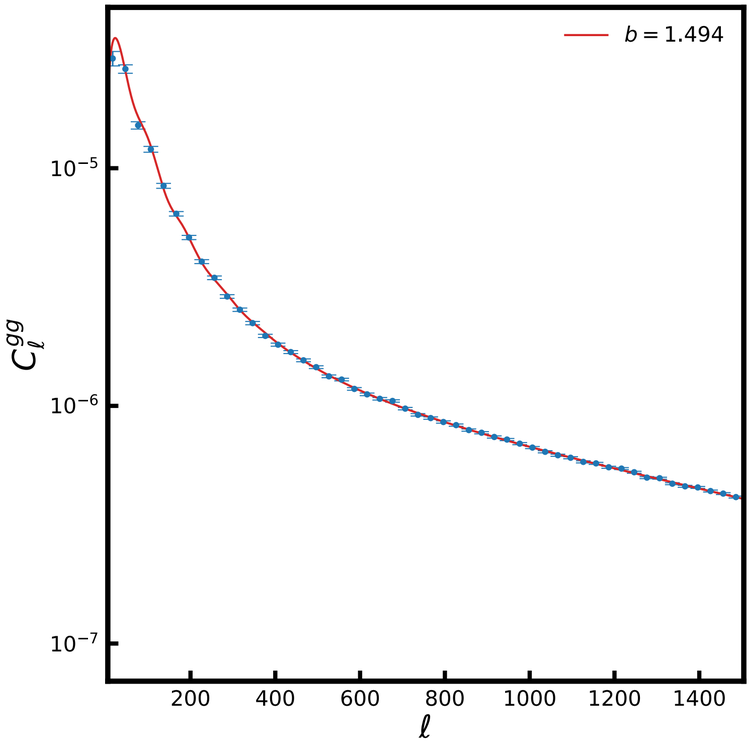
$S_8 = 0.792 \pm 0.013$



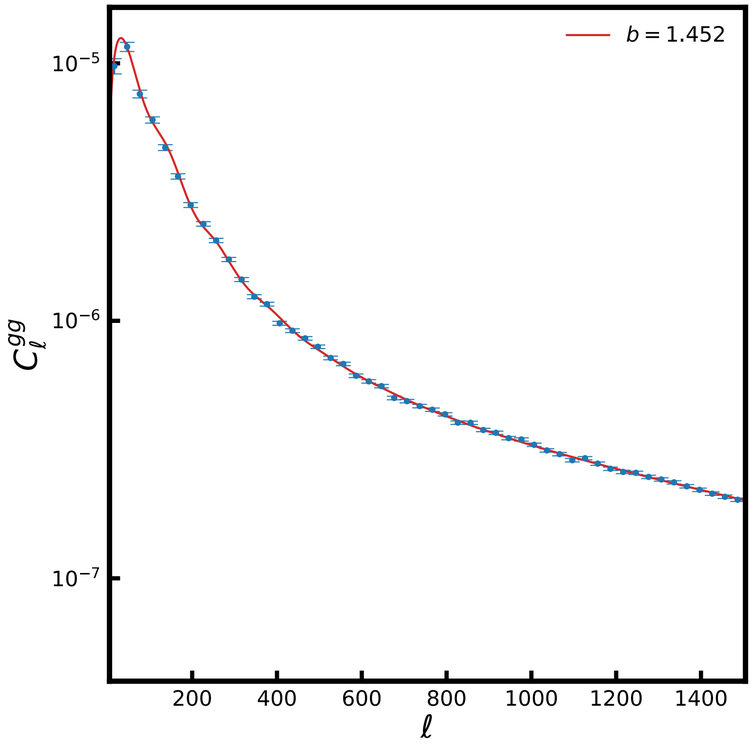
Galaxy auto power spectra



$0.2 \leq z < 0.3$

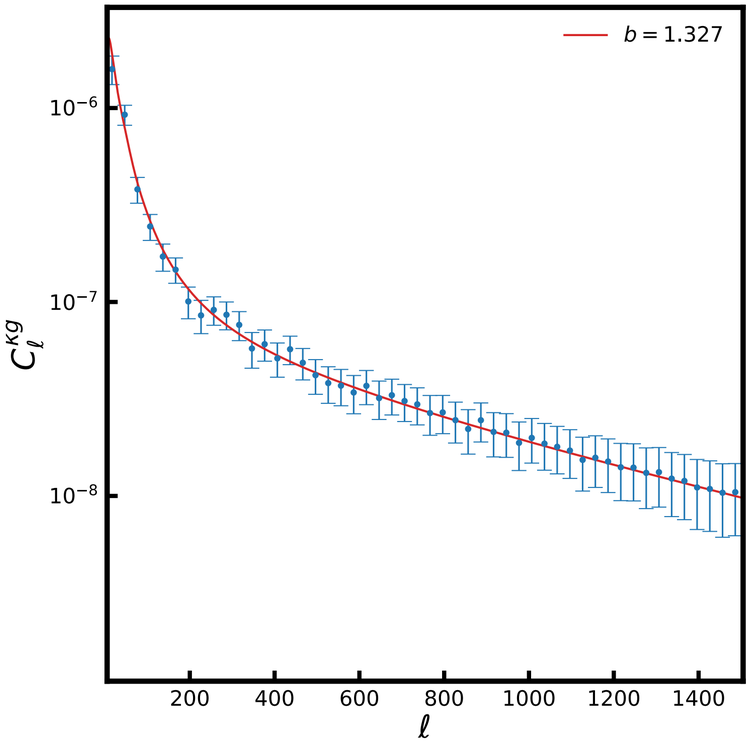


$0.5 \leq z < 0.6$

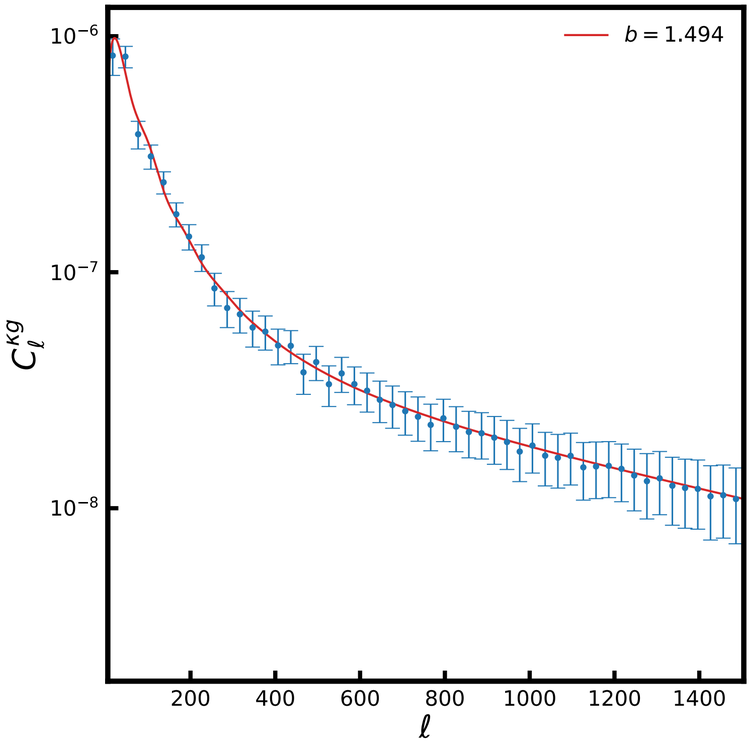


$0.8 \leq z < 0.9$

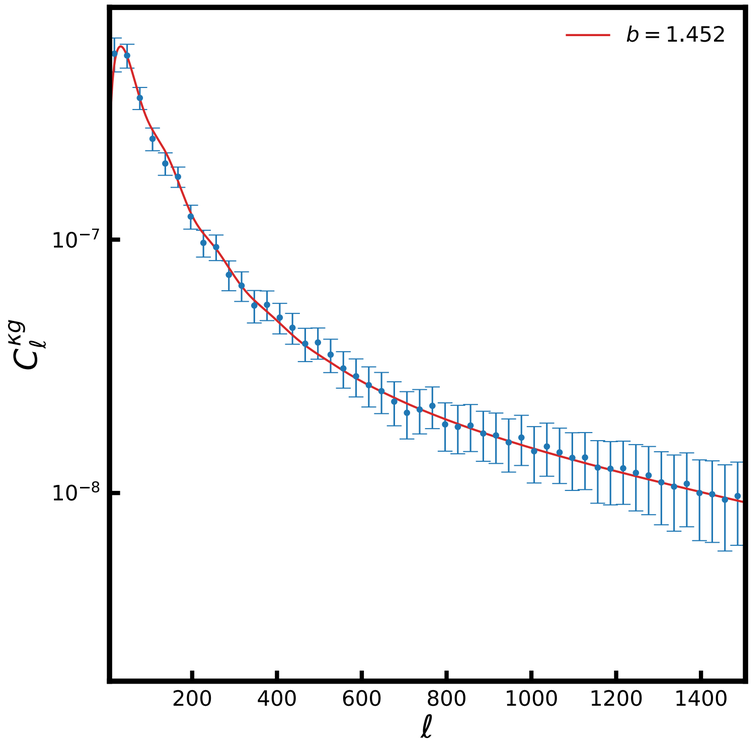
Cross power spectra



$0.2 \leq z < 0.3$



$0.5 \leq z < 0.6$



$0.8 \leq z < 0.9$

Redshift bin mismatch

CSS and P. Bielewicz, 2024; CSS et al 2024

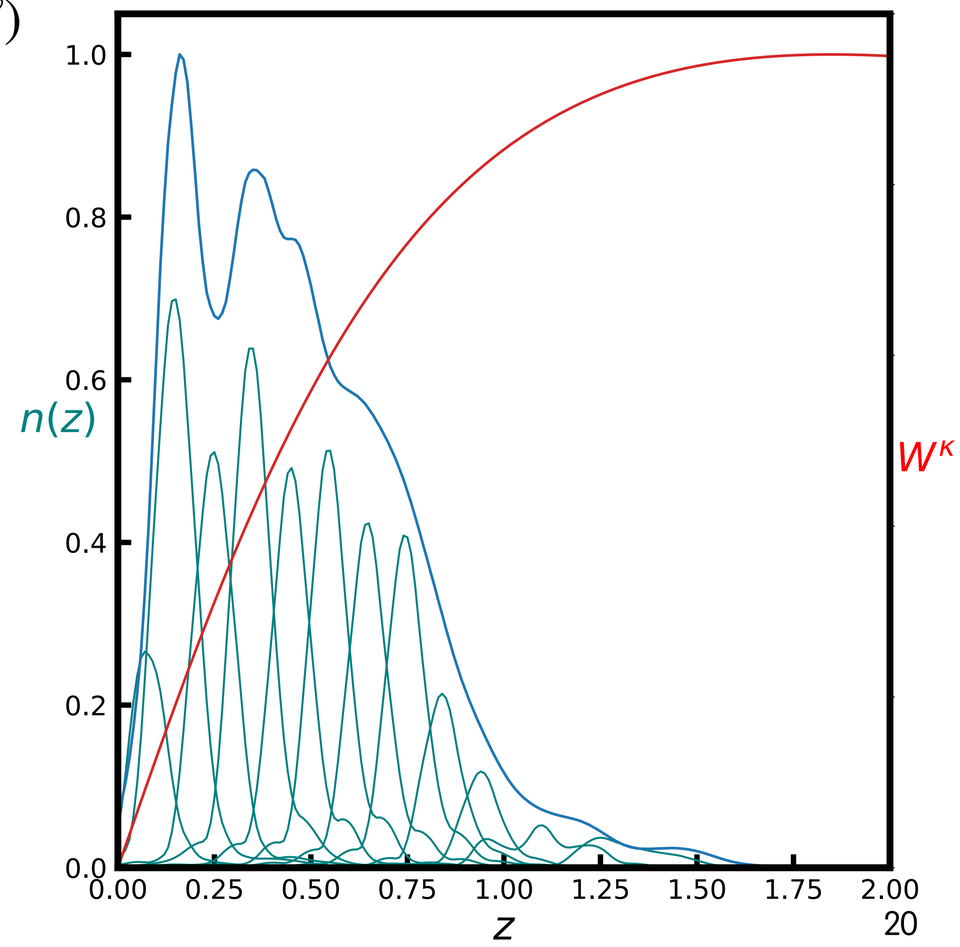
from photometric bins

(Zhang et al., 2010)

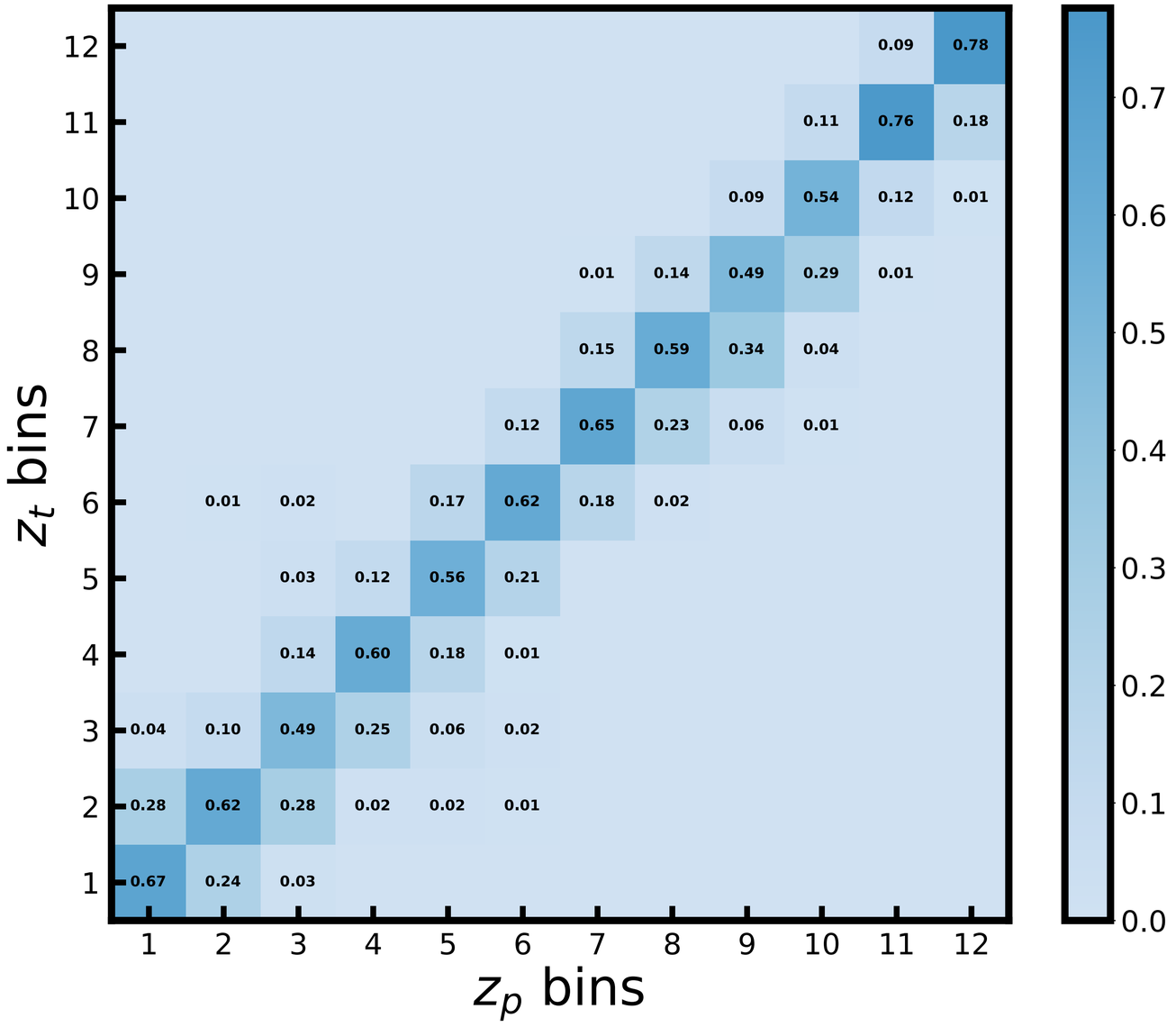
$$C_{ij}^{gg,\mathrm{Ph}}(\ell) = \sum_k P_{ki} P_{kj} C_{kk}^{gg,\mathrm{Tr}}(\ell), \qquad C_i^{\kappa g,\mathrm{Ph}}(\ell) = \sum_k P_{ki} C_{kk}^{\kappa g,\mathrm{Tr}}(\ell)$$

from true bins (unknown)

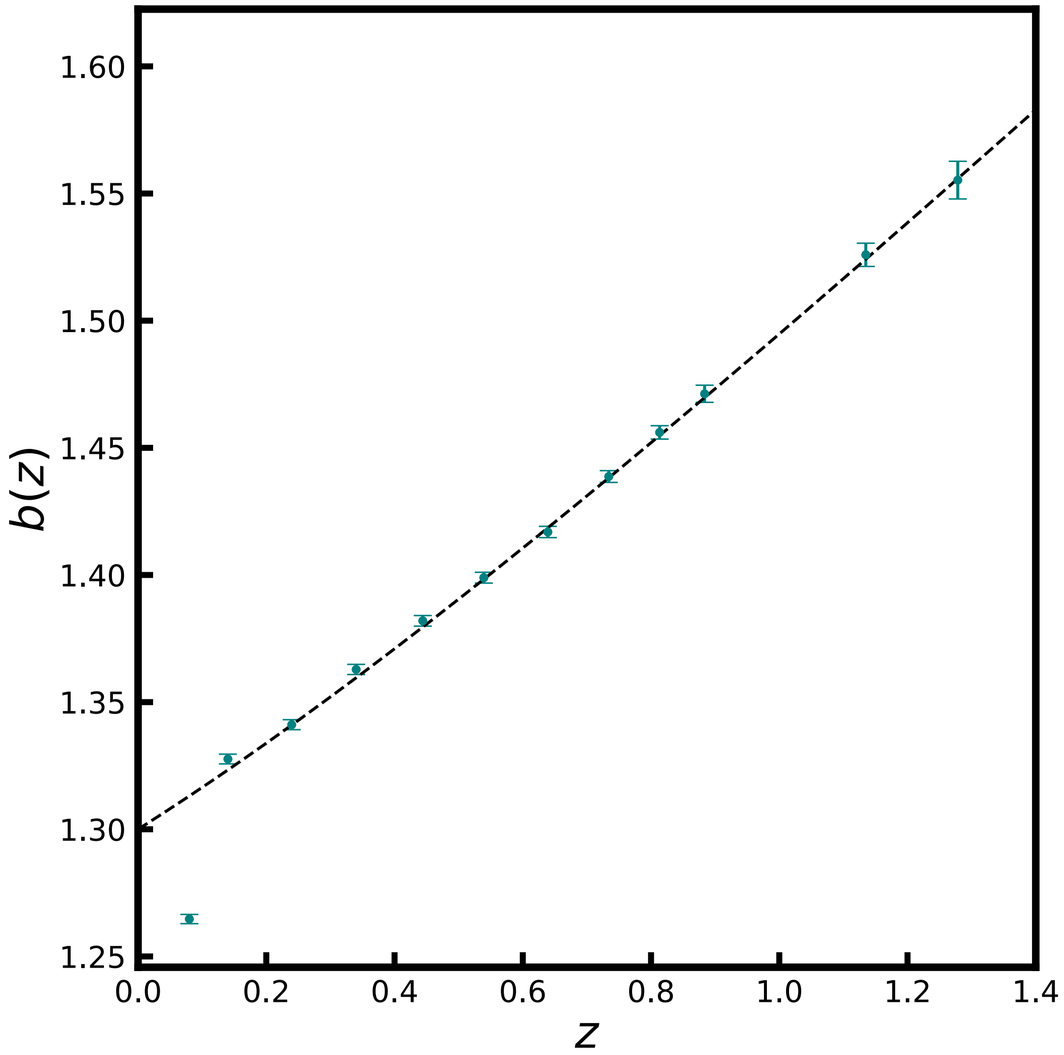
Scattering matrix: (unknown) $P_{ij} \equiv \dfrac{N_{i\to j}}{N_j^{\mathrm{Ph}}}$

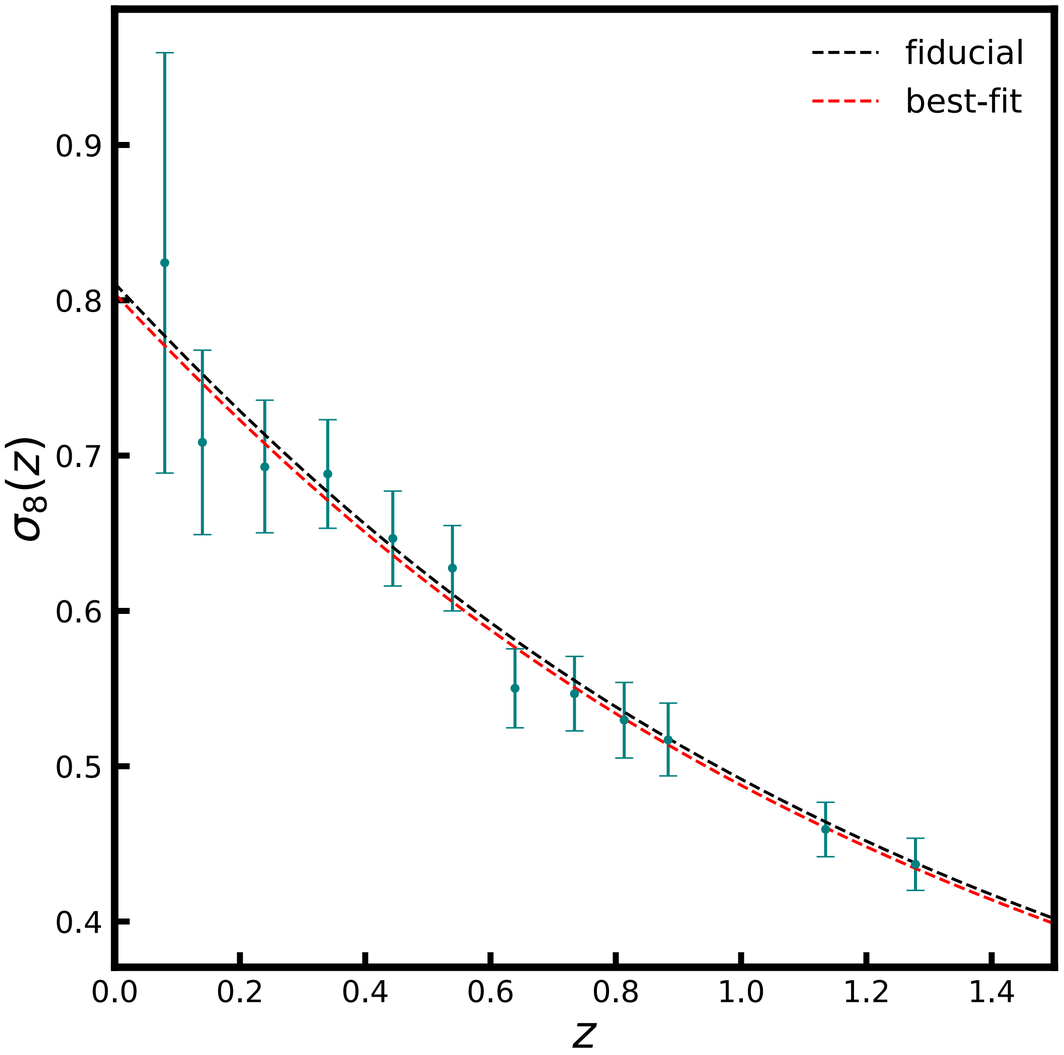


Scattering matrix



Corrected galaxy bias and σ_8



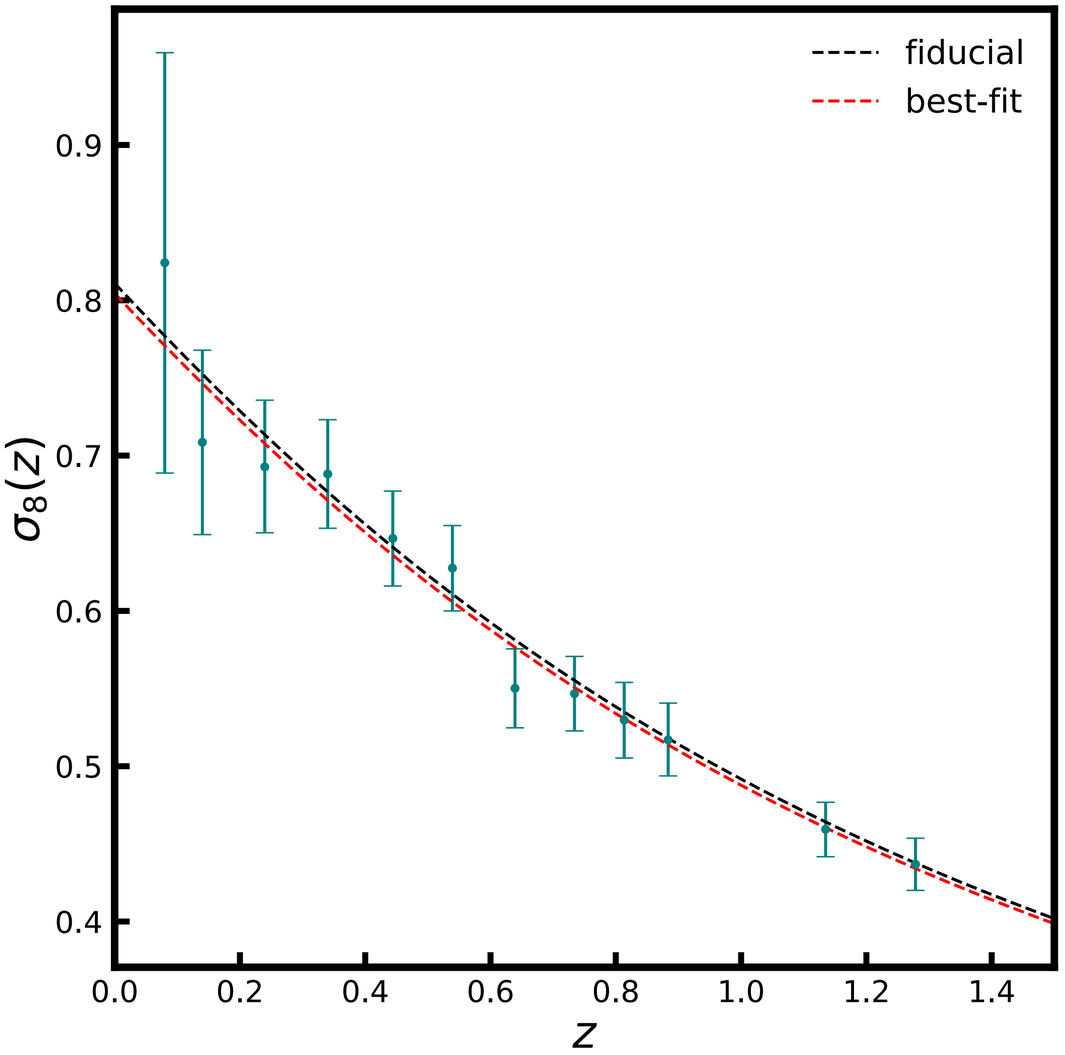


S_8

$S_8 = 0.832 \pm 0.013$ (fiducial)

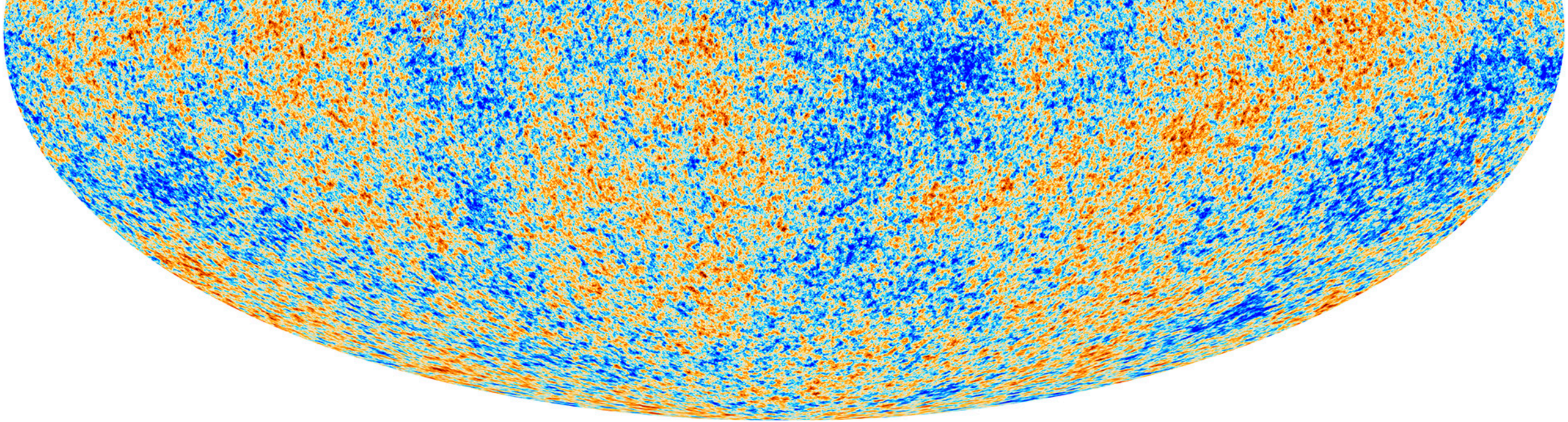
$S_8 = 0.792 \pm 0.013$ (wout corr)

$S_8 = 0.823 \pm 0.016$ (with corr)



Summary

- Tomographic cross-correlation between CMB lensing map and galaxy surveys useful for tracing time evolution of the large-scale structure.
- Redshift bin mismatch can lead to apparent S_8-tension.
- LSST Y1 simulations predict $\sim 3\sigma$ tension on S_8 parameter due to bin mismatch
- Our scattering matrix formalism can be used to correct for bin mismatch.
- A potential solution to the S_8-tension in cosmology (?)



THANK YOU

Planck X DESI-LIS

CSS and P. Bielewicz, 2024