Cosmological constraints from unWISE and Planck CMB lensing cross-correlation

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CMBS4 meeting
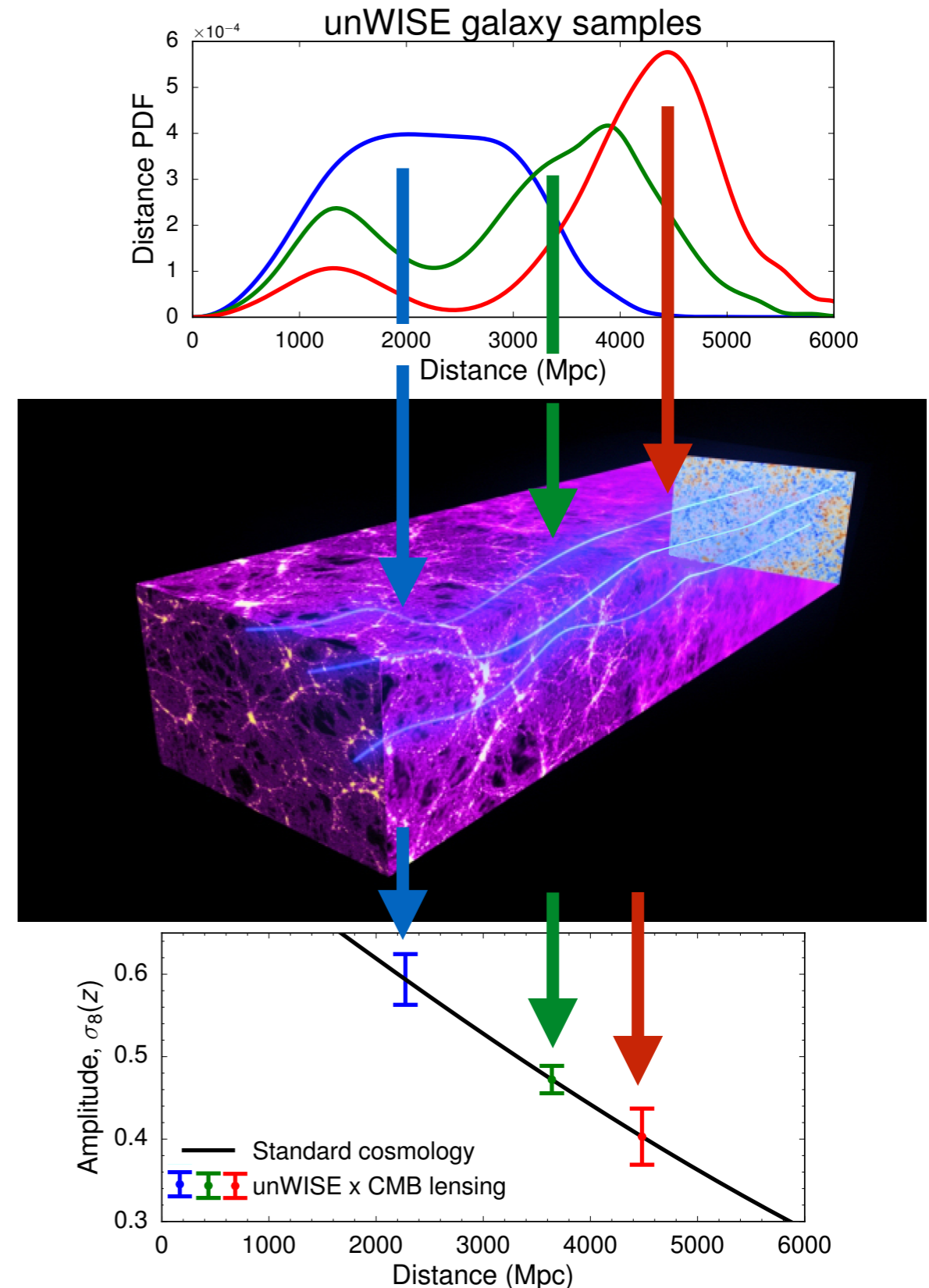*arXiv: 2105.03421 (with Simone Ferraro & Martin White)*

CMB LENSING TOMOGRAPHY

➤ Tomography: lensing by galaxy samples at different redshifts probes growth of structure

➤ Need gg and kg to break b-σ_8 degeneracy
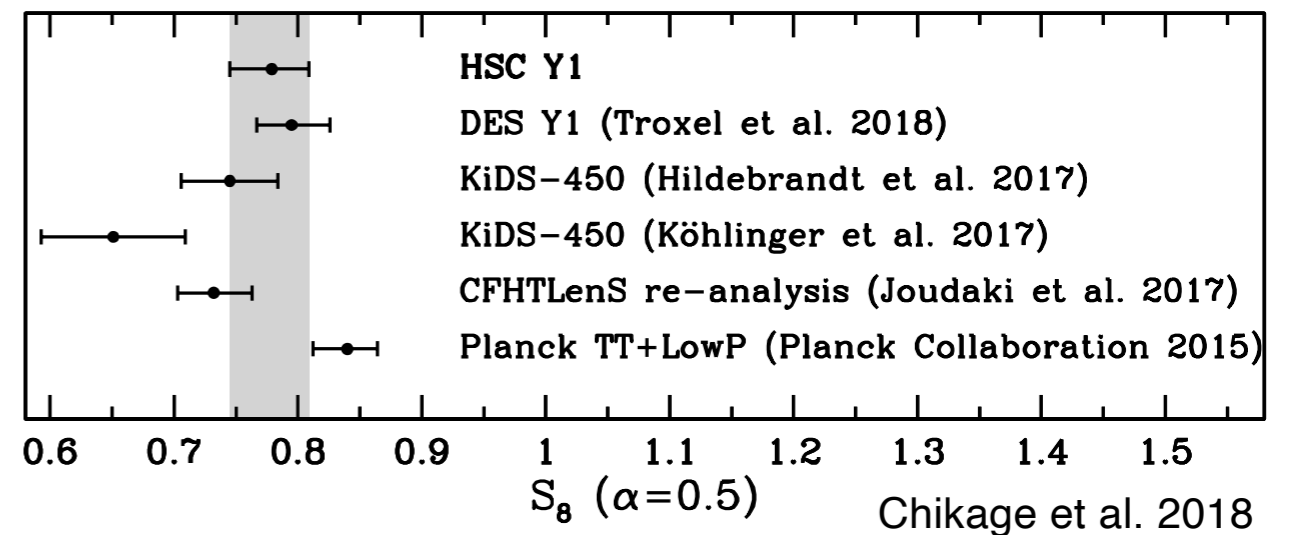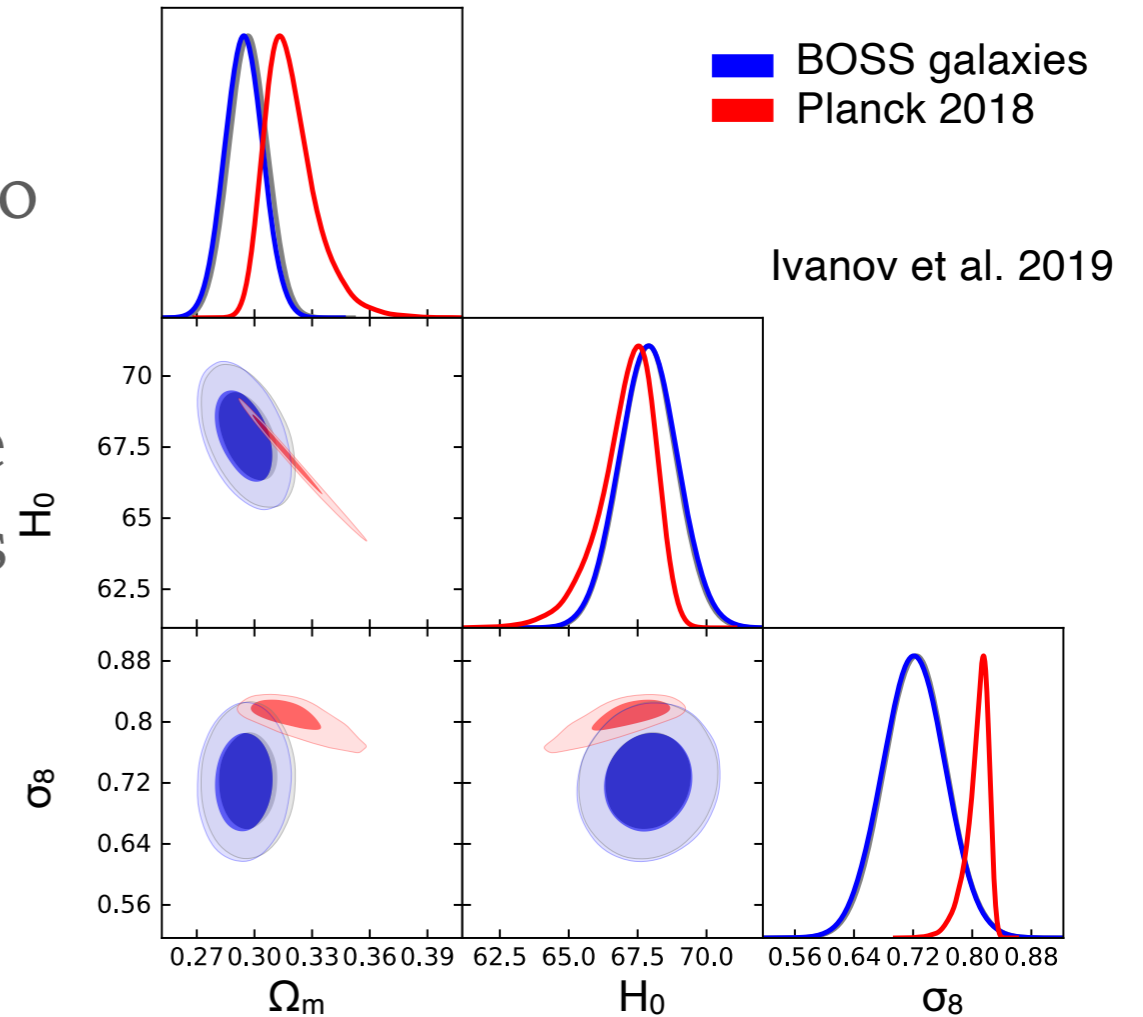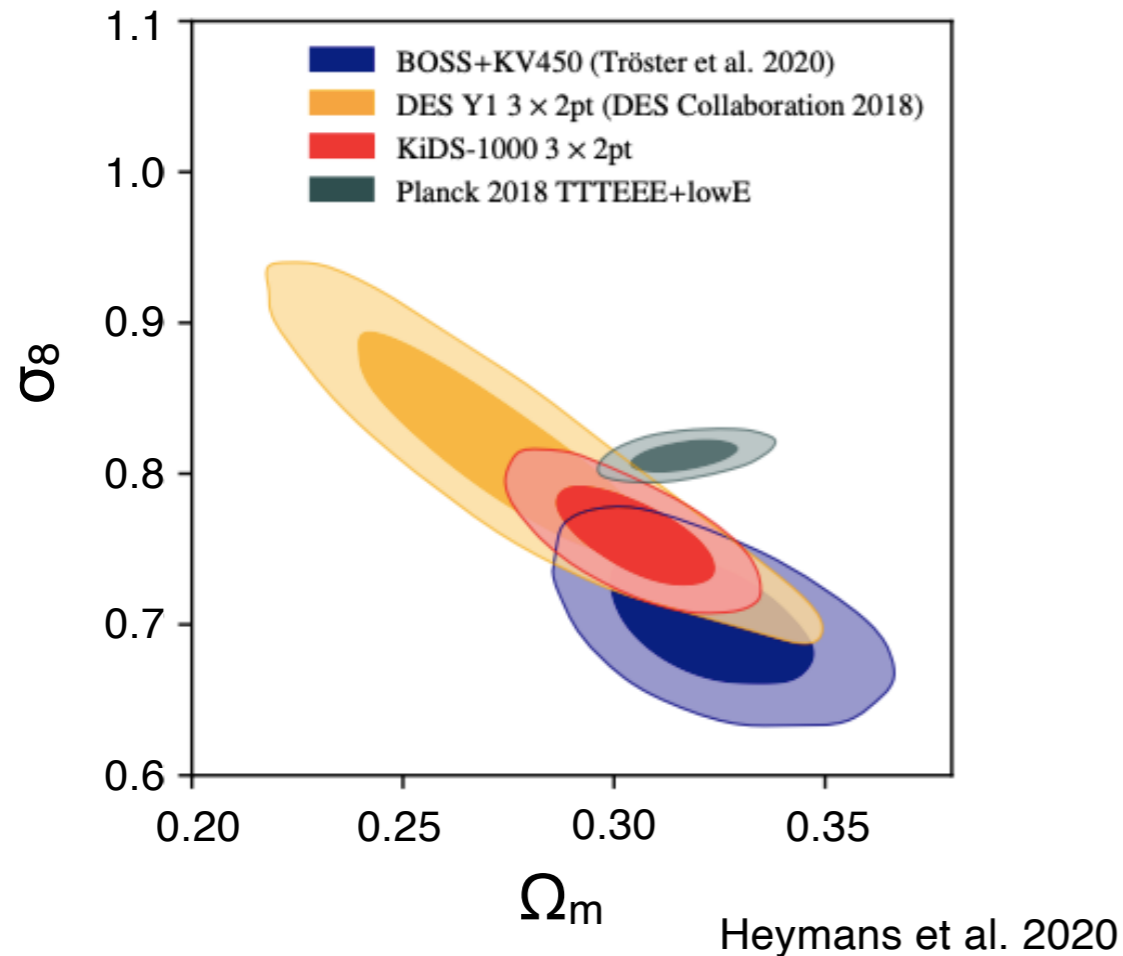
$$P_{gg} \propto b(k,z)^2 \sigma_8^2 P_m$$

$$P_{\kappa g} \propto b(k,z) \sigma_8^2 P_m$$

$$\longrightarrow \sigma_8 \propto \frac{C_\ell^{\kappa g}}{\sqrt{C_\ell^{gg}}}$$

unWISE galaxy samples

Standard cosmology
unWISE x CMB lensing

S₈ TENSION IN WEAK LENSING

➤ Weak lensing surveys find $S_8 \equiv \sigma_8 \sqrt{\Omega_m}$ $\sim 10\%$ (~ 2-3σ) lower than Planck (+ also some galaxy clustering analyses)

➤ CMB lensing cross-correlation: test of the lensing tension with different systematics

Ivanov et al. 2019

Heymans et al. 2020

Chikage et al. 2018

unWISE: BUILDING THE BEST CMB–LSS CORRELATION

➤ Advantages of WISE:
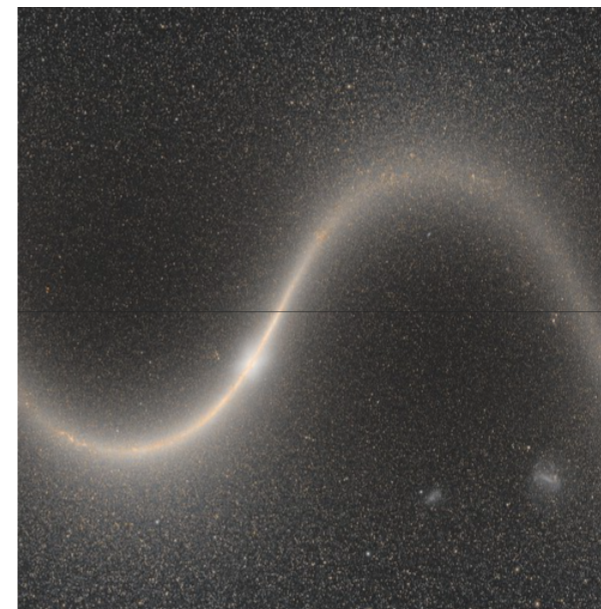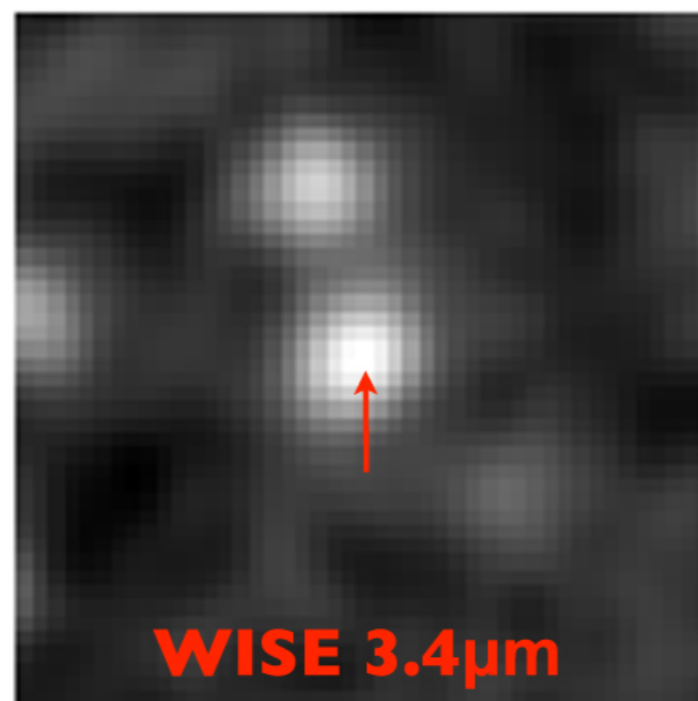
  ➤ All-sky satellite mission

  ➤ Infrared survey (3.4, 4.6 μm): negative K-correction for old stellar populations—measure galaxies out to z~2

2B galaxies publicly available at
catalog.unwise.me

catalog paper: Schlafly et al. (2020), 1901.03337
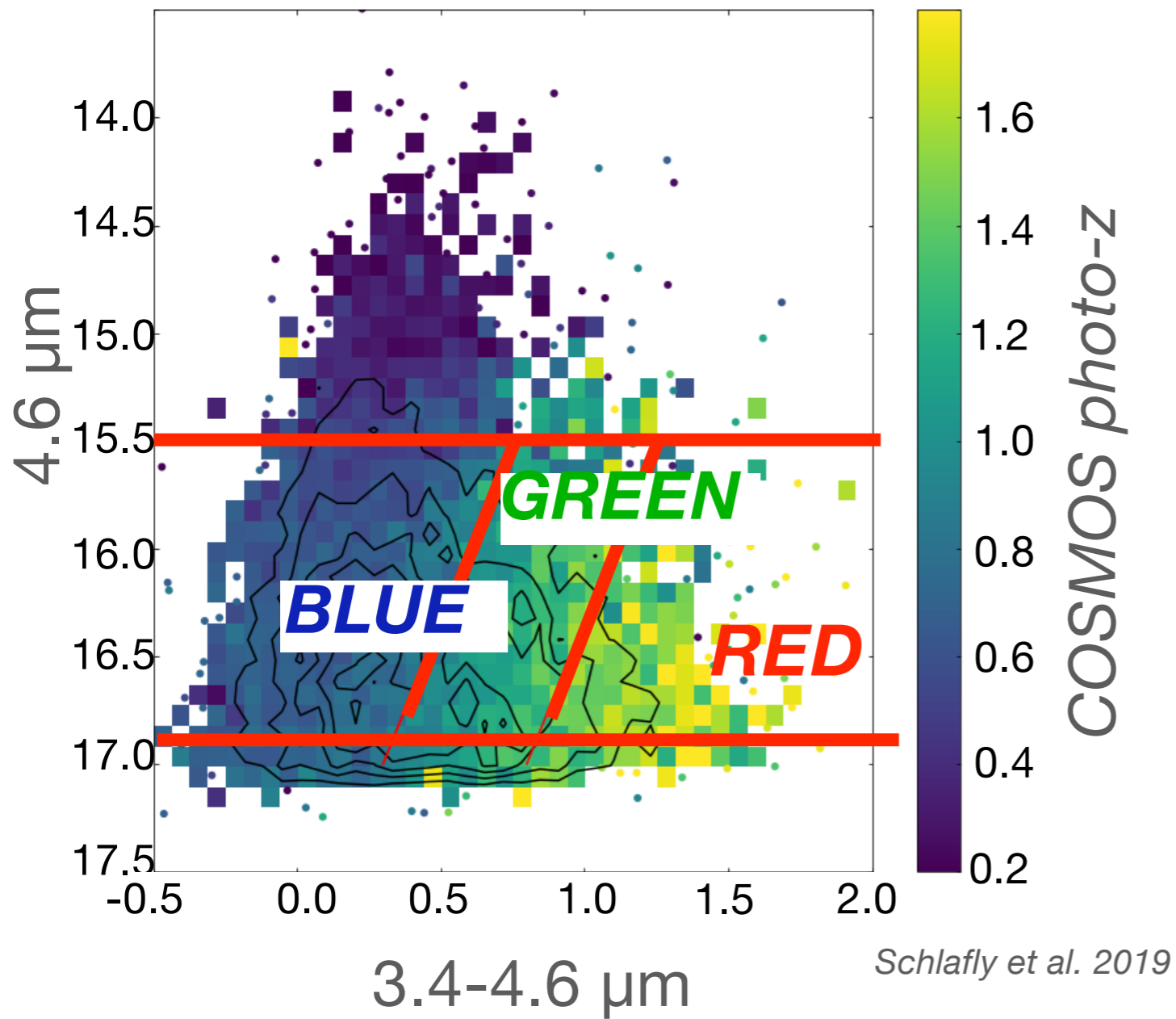
coadd paper: Meisner et al. (2020), 1909.05444

500 million galaxies!

SDSS *gri*

WISE 3.4μm

See all the unWISE galaxies at:

legacysurvey.org/viewer
(credit to Dustin Lang)
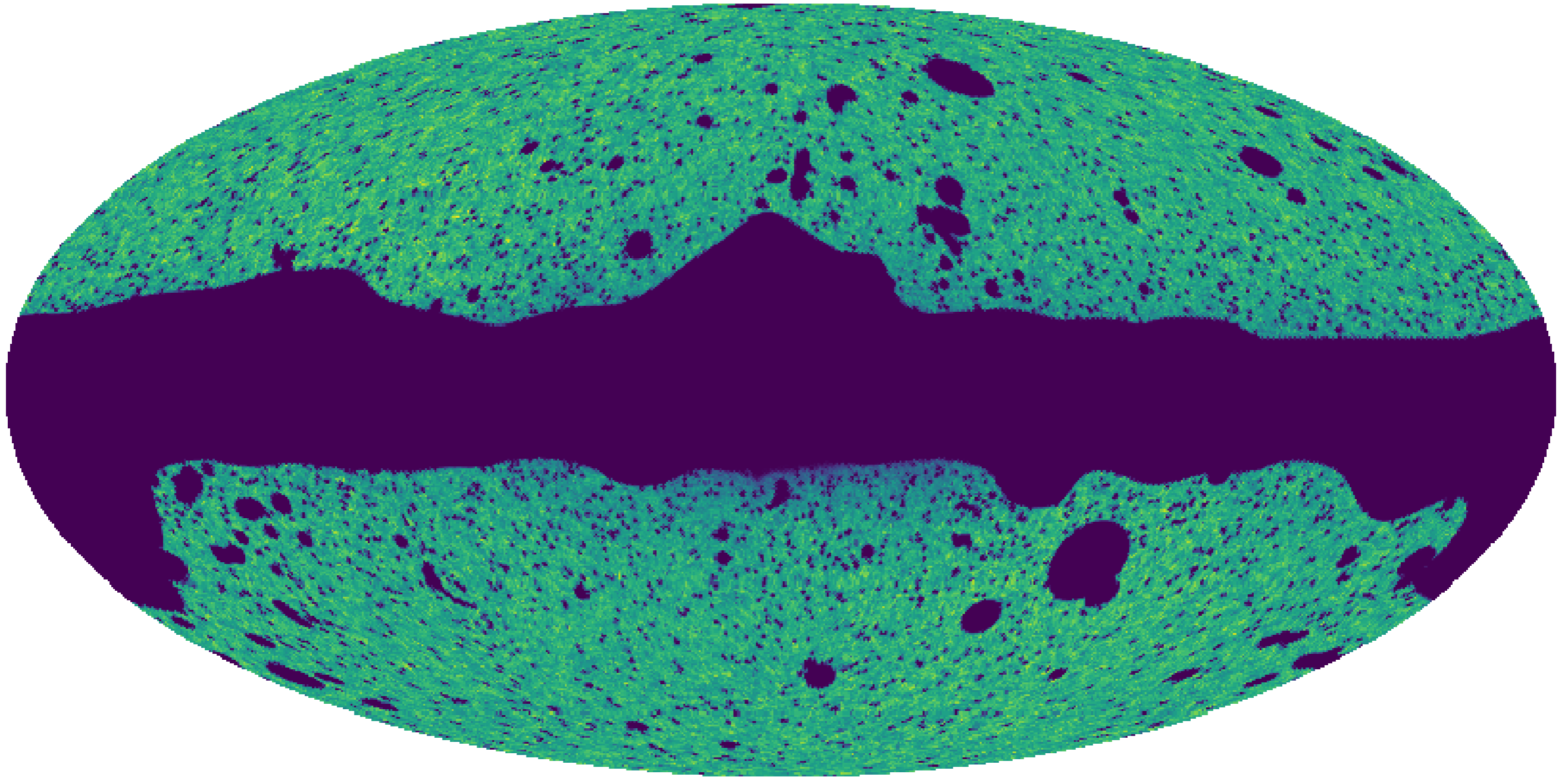
unWISE GALAXY SAMPLES

Selecting unWISE galaxies

Schlafly et al. 2019

Sample	\<z\>	Number density (deg^{-2})
Blue	0.6	3409
Green	1.1	1868
Red	1.5	144

➤ Define 3 samples using unWISE colors and remove stars using GAIA photometry (1% residual stellar contamination)
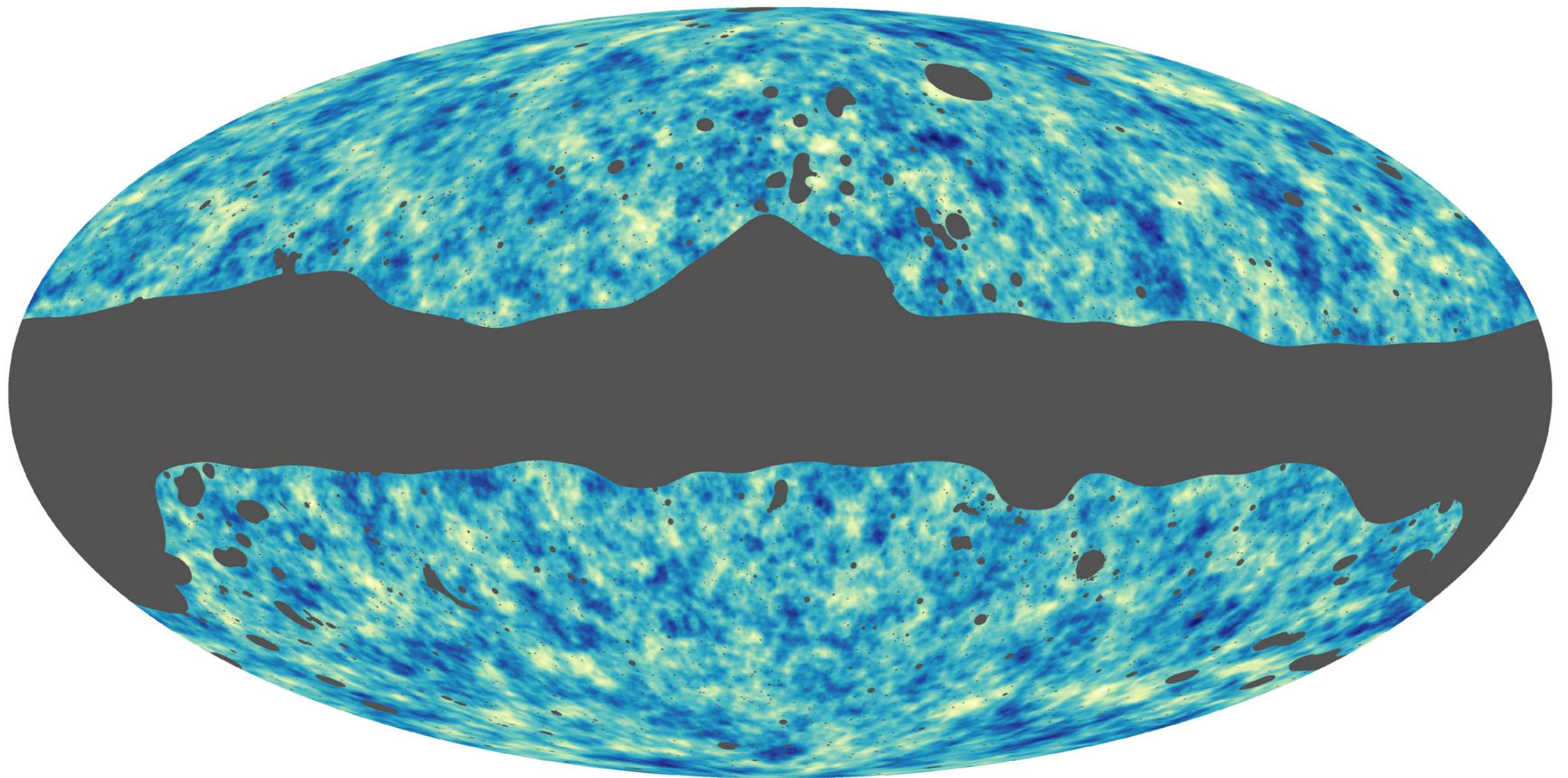
unWISE SKY DISTRIBUTION

Green: z~1.0 sample

0   1.57461

Krolewski, Ferraro, White, Schlafly 2020

CMB LENSING FROM PLANCK

➤ Planck 2018 minimum-variance lensing maps + masks

Planck 2018, arxiv: 1807.06210

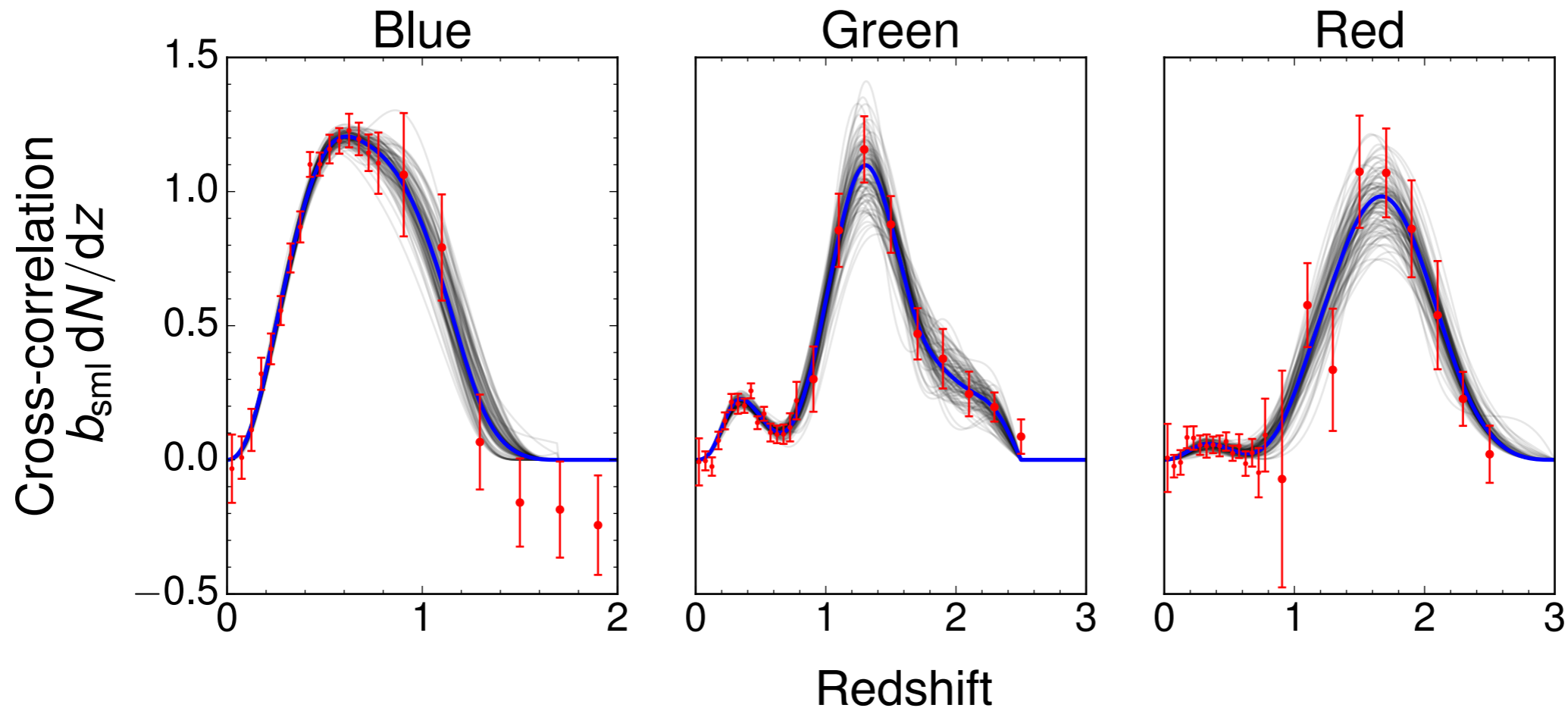-0.0016   0.0016

unWISE REDSHIFT DISTRIBUTION

➤ Spectroscopic-photometric cross-correlation gives b(z) * dN/dz (uncertainty is propagated to cosmological constraints)

➤ Fully consistent with dN/dz from deep-field photometric surveys (given plausible bias evolution)

THEORY MODEL

➤ Hybrid PT/empirical model: linear bias times Halofit, plus higher bias terms

$$P_{gg} = b_1^2 P_{mm,\text{Halofit}} + \text{higher bias} + \text{Shot Noise}$$

$$P_{gm} = b_1 P_{mm,\text{Halofit}} + \text{higher bias}$$

➤ Fix cosmology & $b_2(z)/b_s(z)$ in higher bias terms

➤ Magnification bias also included, with 10% prior on the slope (s)

➤ Redshift distribution measured from cross-correlations with spectroscopic galaxies: linear bias evolution automatically included
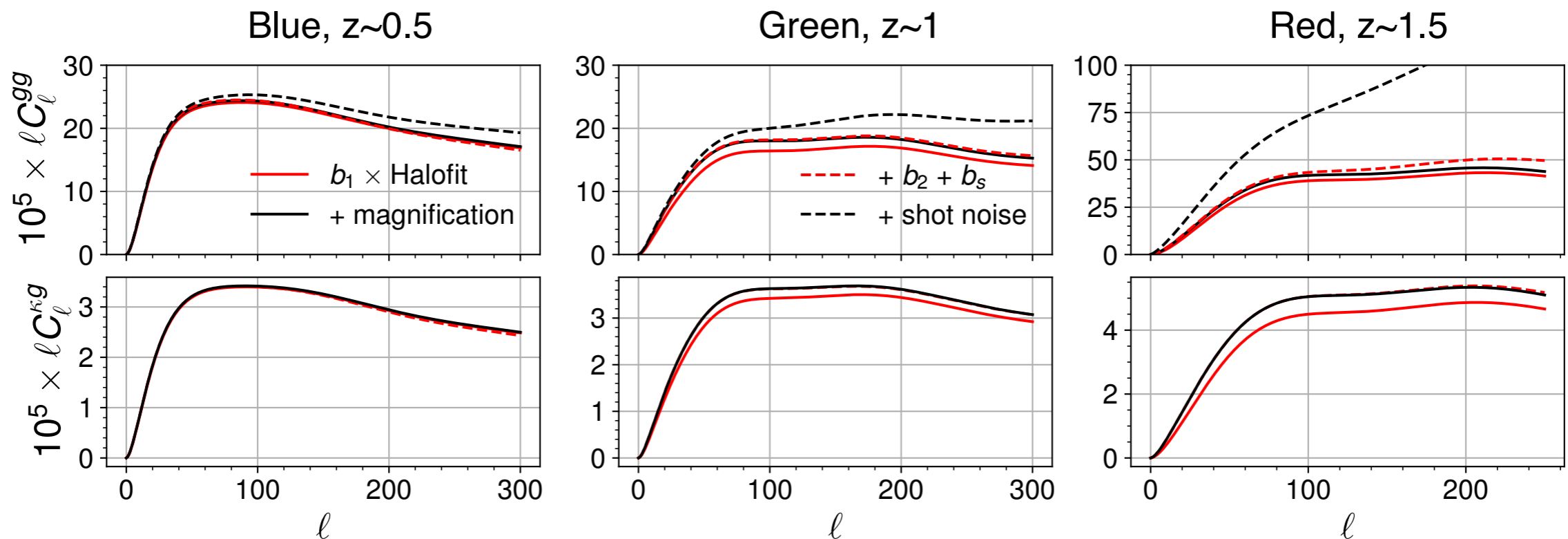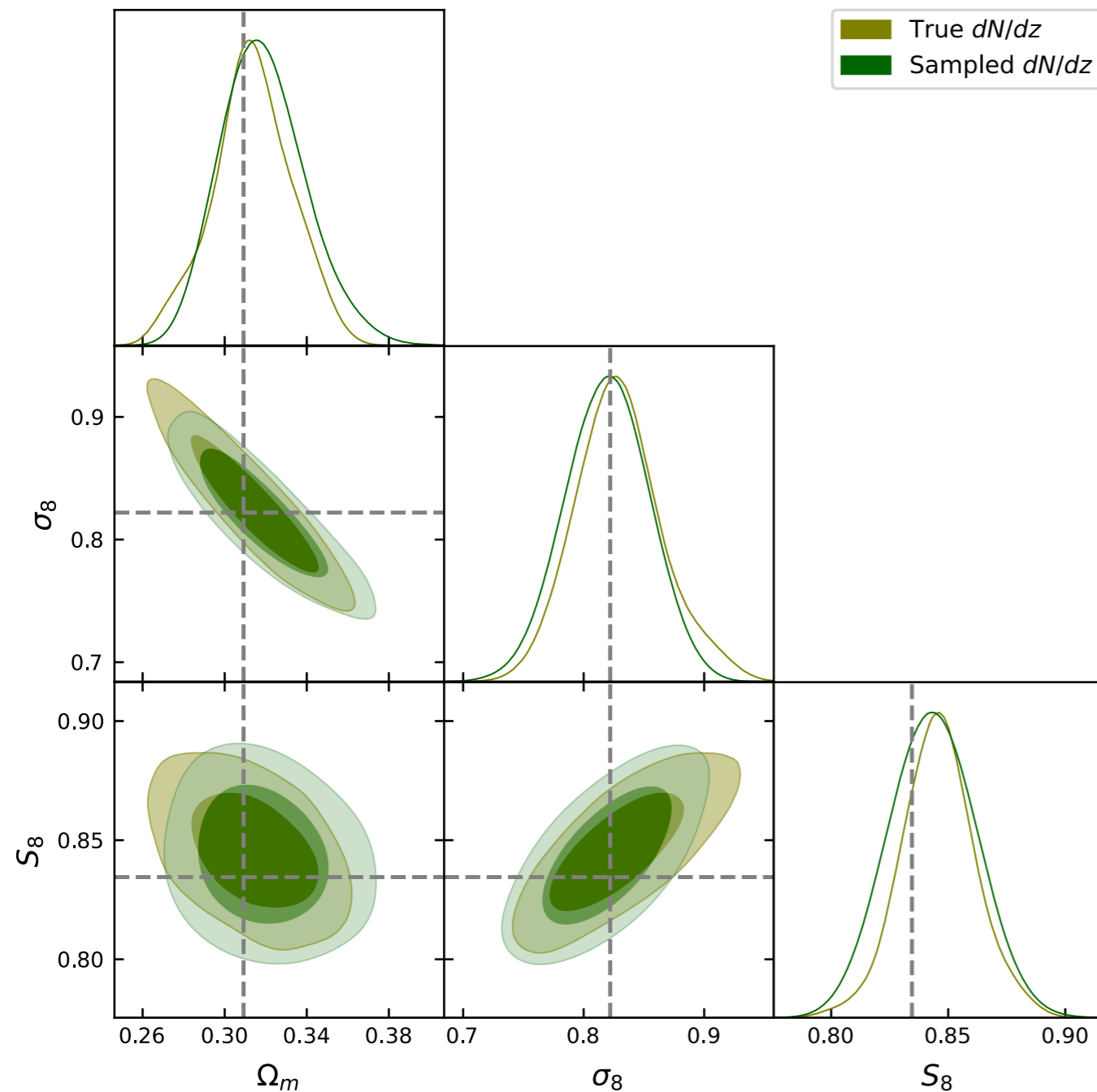
RECOVERING UNBIASED COSMOLOGY ON MOCKS

➤ Goal: plausible mocks to test theory model (not to calibrate model or covariances)

➤ Match the number density, bias evolution, and b(z) * dN/dz (i.e. from clustering redshifts)

➤ Can recover unbiased cosmology to ℓ_{max} = 300 for blue, green (250 for red)

unWISE halo mass

Angular power spectra

Bias evolution
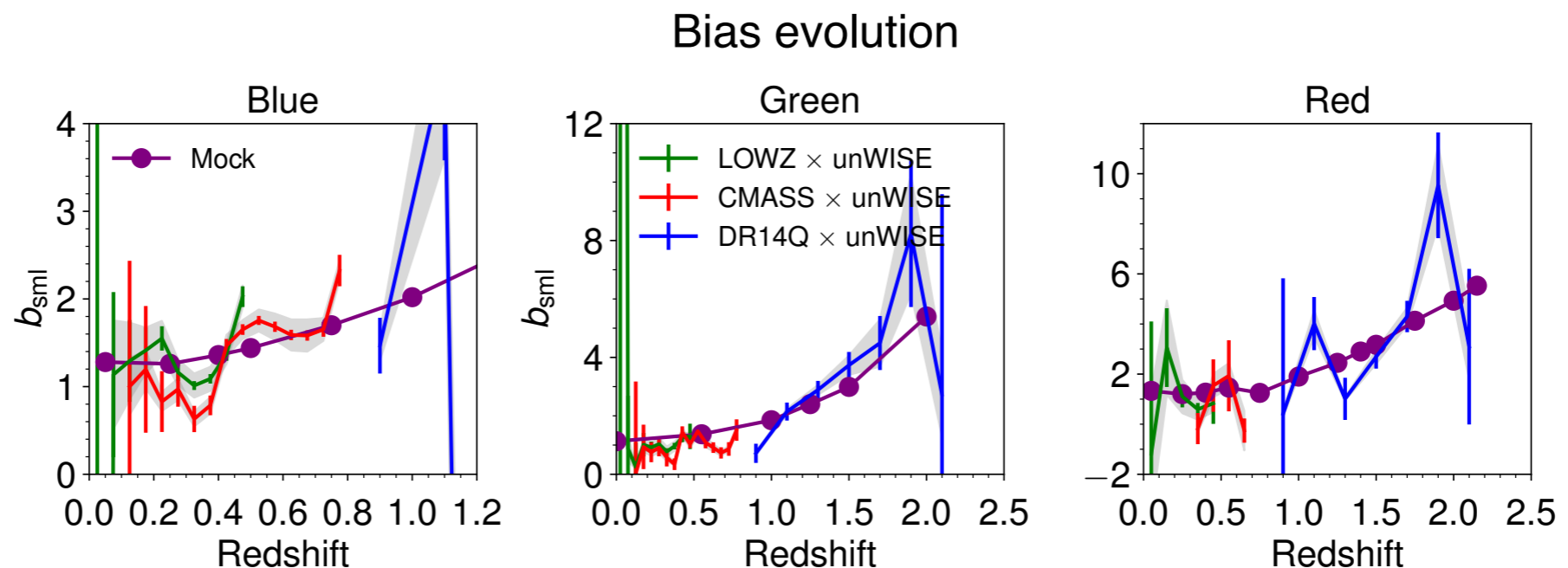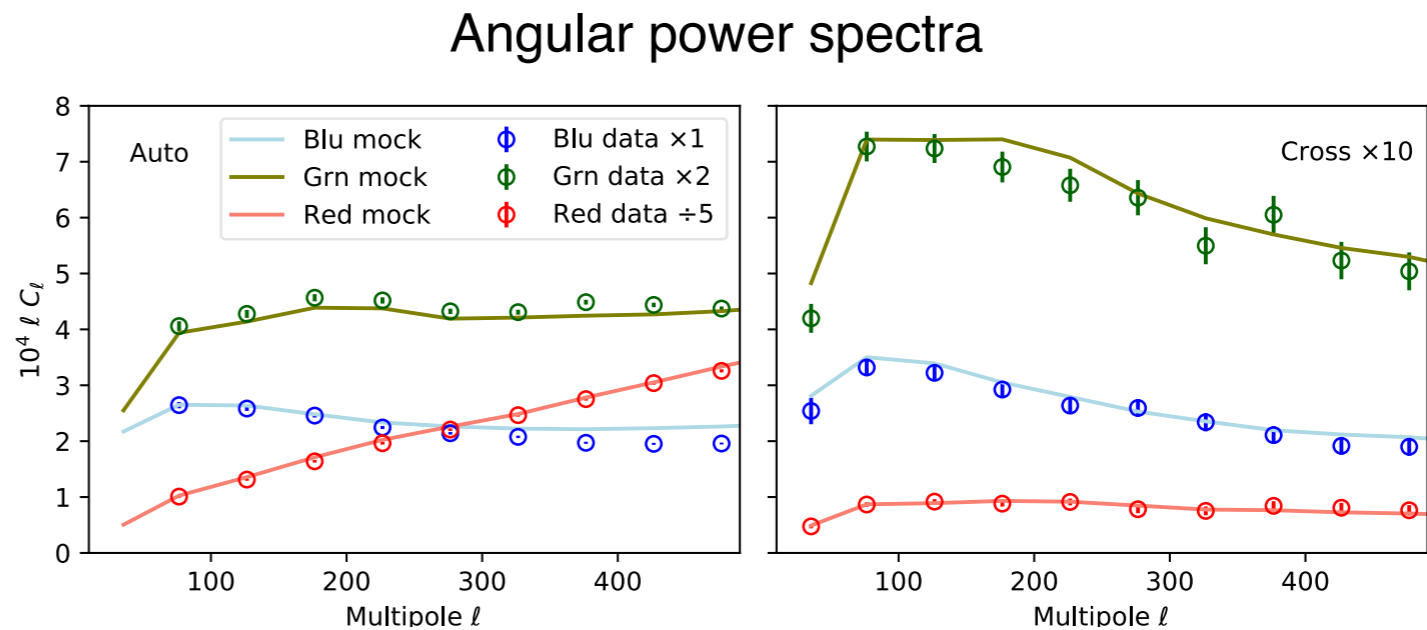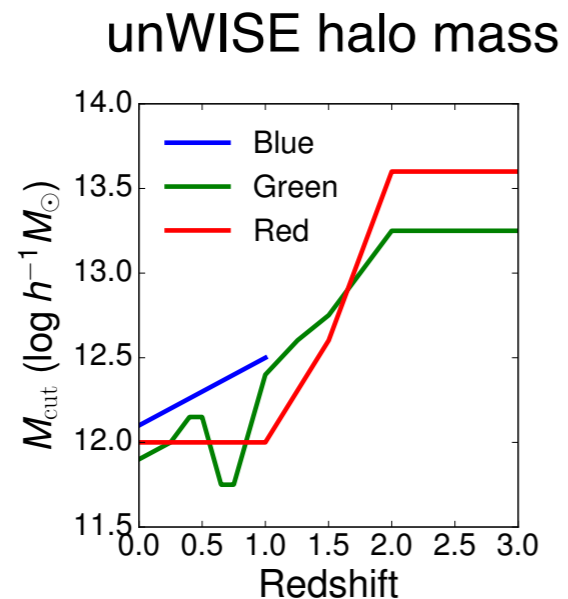
IMPACT OF REDSHIFT UNCERTAINTY

- Legend: **True *dN/dz*** (olive), **Sampled *dN/dz*** (dark green)

➤ Marginalize over redshift distribution uncertainty by sampling noise-realizations of b(z) * dN/dz

➤ <15% impact on marginalized Ω_m and σ_8

➤ 20-50% impact on S_8 (largest for blue)

RESULTS
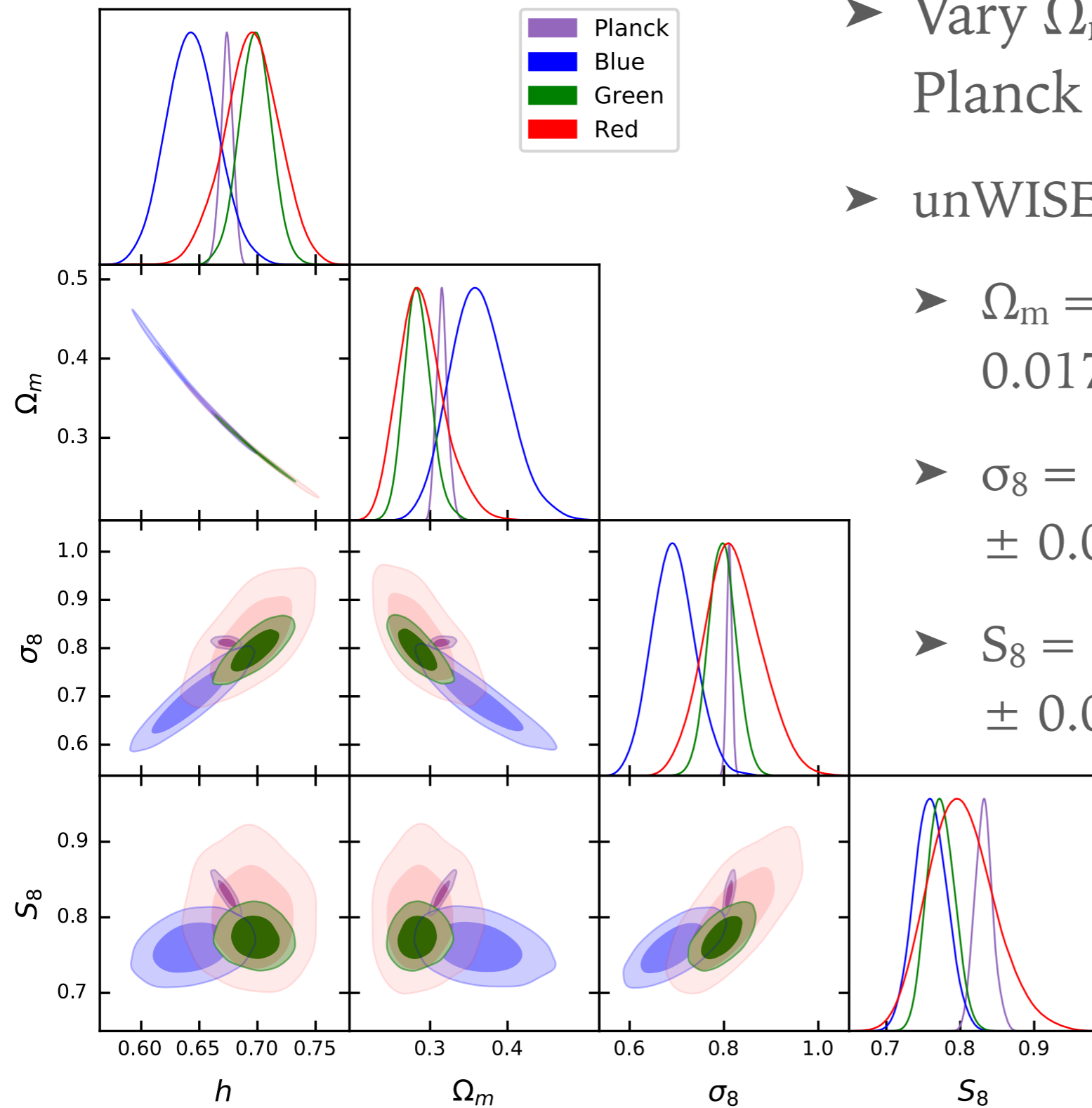
- ➤ Vary Ω_m, logA; fix n_s and Ω_b to Planck values; fix $\Omega_m h^3 = 0.09633$
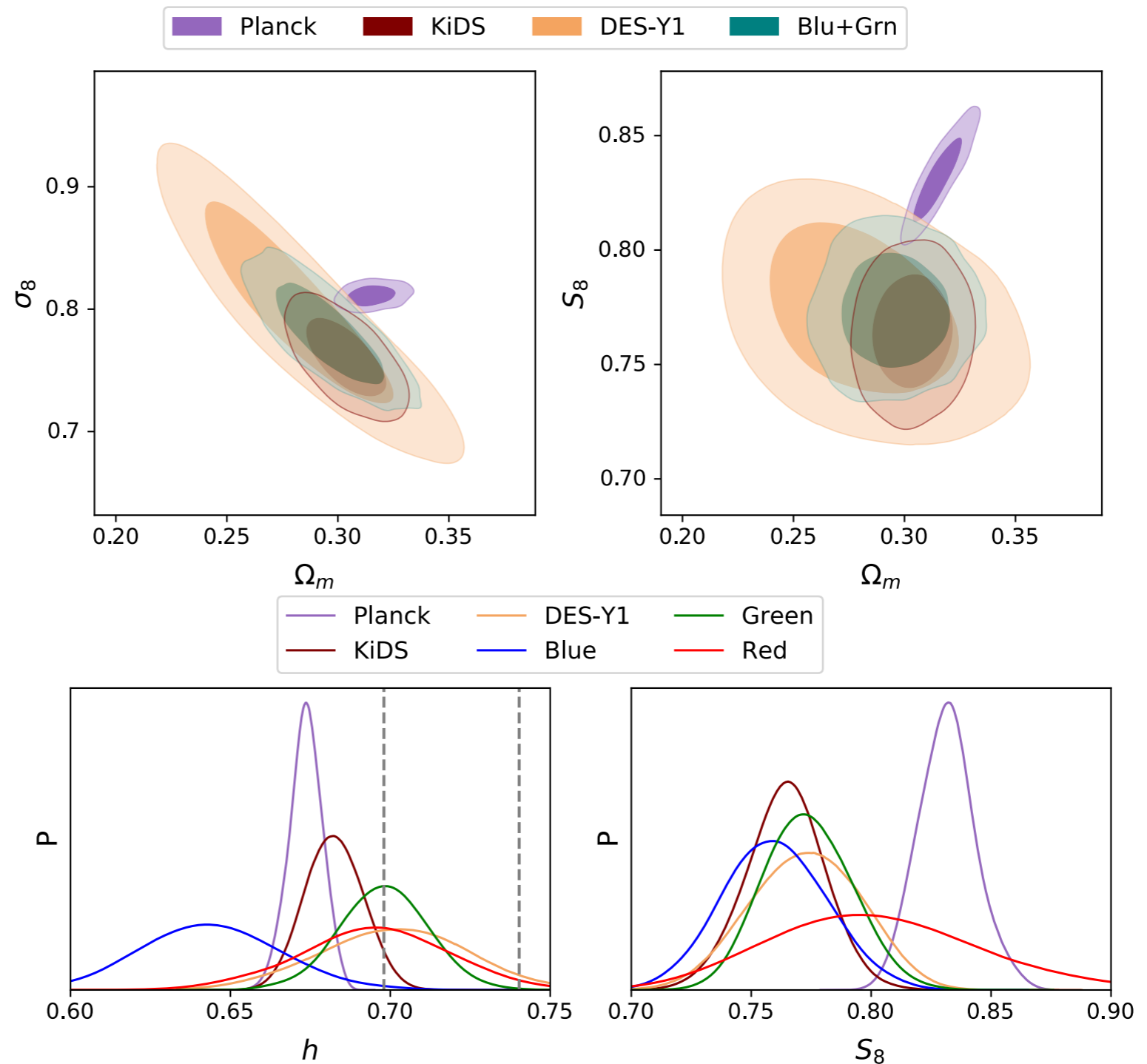
- ➤ unWISE constraints:

  - ➤ $\Omega_m = 0.295 \pm 0.017$ (P18: 0.315 ± 0.017)

  - ➤ $\sigma_8 = 0.783 \pm 0.028$ (P18: 0.811 ± 0.006)

  - ➤ $S_8 = 0.776 \pm 0.017$ (P18: 0.832 ± 0.013)

RESULTS

➤ We find ~2.6σ tension with Planck in S_8 for our fiducial blue+green combined constraint (similar to KiDS, DES-Y1, DES-Y3 results)

STATUS OF THE LENSING TENSION