CMB Lensing x Galaxies

Cross-correlation science for the CMB-S4 Science Book 2nd edition

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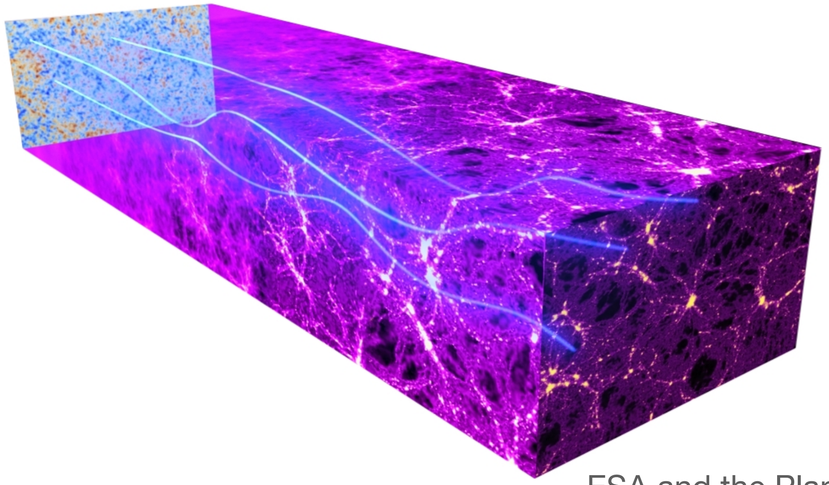
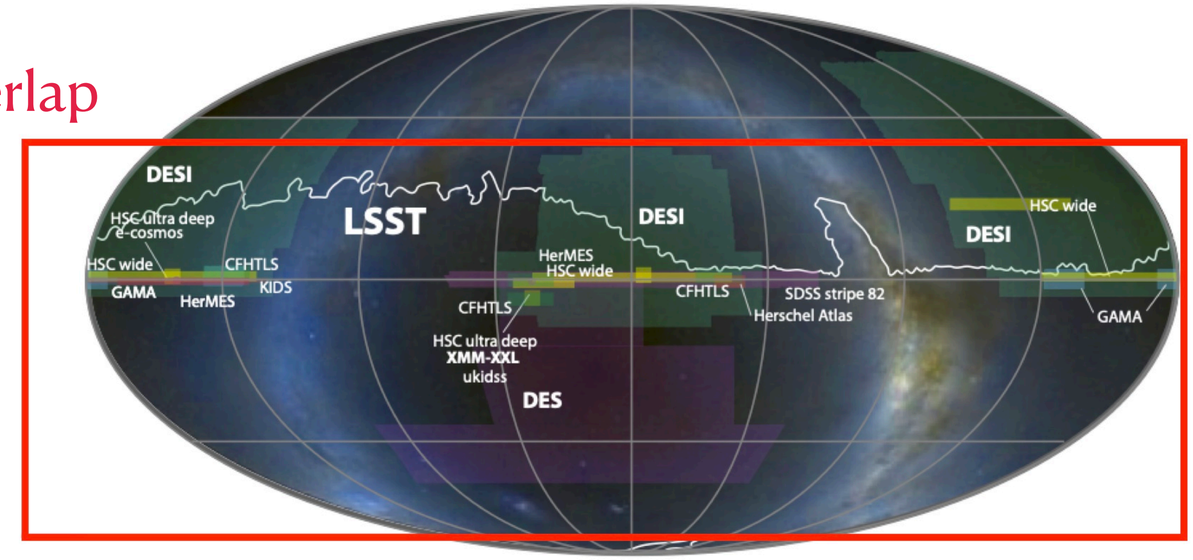
CMB-S4 Lensing X Galaxies



ESA and the Planck Collaboration

Overlap

X



CMB-S4 Collaboration

+ SPHEREx, Euclid, MegaMapper, …

High-significance cross-correlations out to high-z and small scales.

Why CMB lensing - galaxy cross-correlations?

What can we learn?

Matter amplitude in function of redshift

Sum of neutrinos masses

Primordial non-Gaussianity

Dark energy, galaxy-halo connection

...

Why CMB lensing - galaxy cross-correlations?

Some advantages?

Break degeneracies between parameters

More robust to systematics

Overcome cosmic variance limits

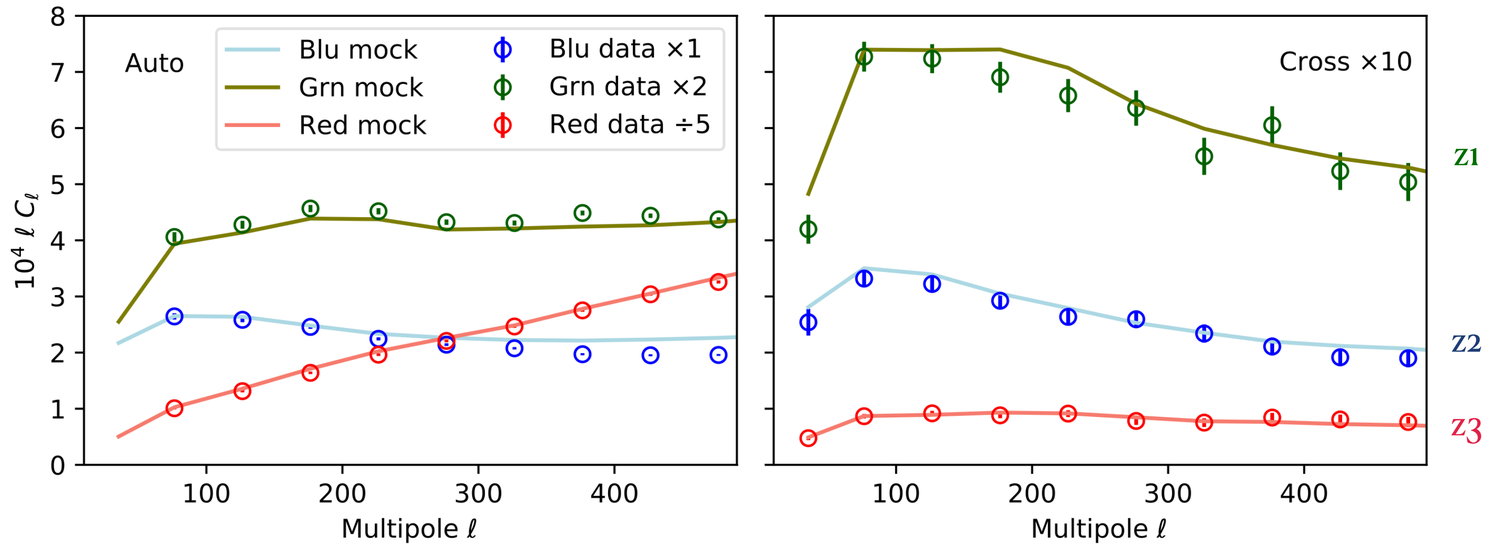
Tomography

No noise bias

....

Growth of structure over redshift

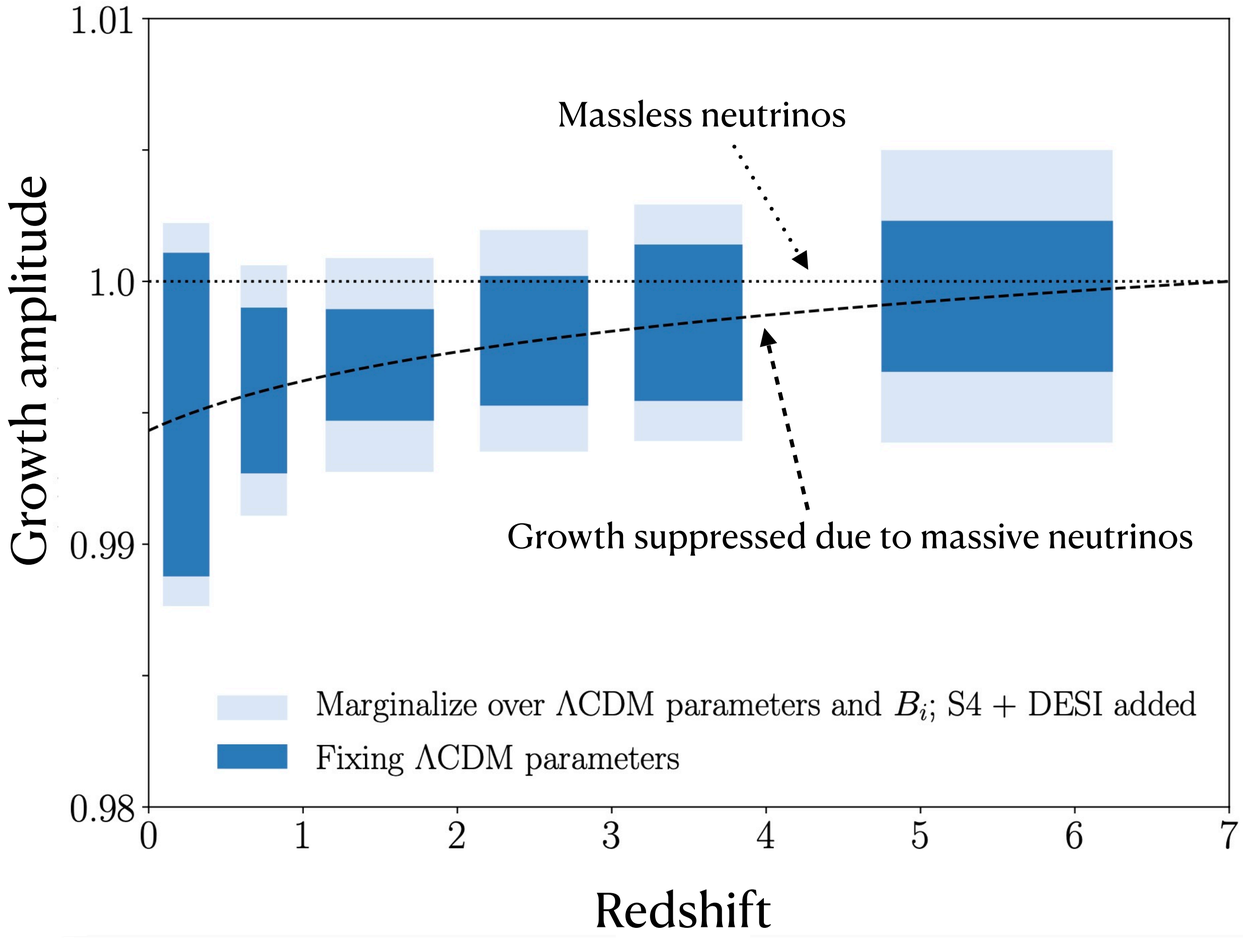
$$C_l^{gg} \sim b^2(z)\sigma^2(z) \qquad C_l^{\kappa g} \sim b(z)\sigma^2(z)$$



Krolewski+ (2021)

Combination breaks degeneracy between bias and amplitude

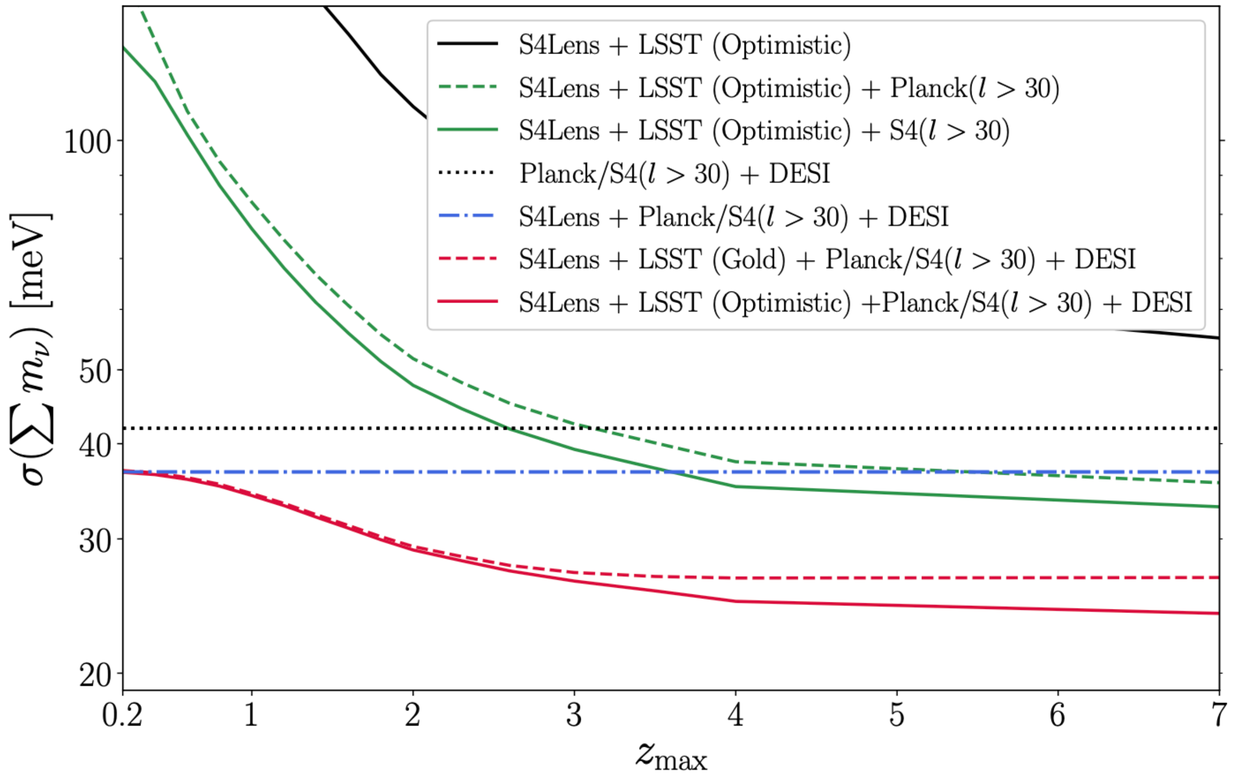
Growth of structure over redshift



CMB-S4 lensing x LSST ~ 400 sigma

Yu+ (2018)

Growth of structure over redshift



Yu+ (2018)

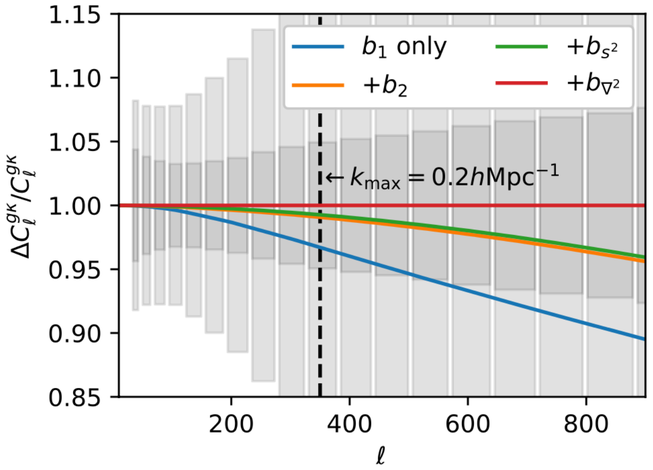
CMB-S4 lensing x LSST ~ 400 sigma

Alternative constraint without optical depth to CMB
(Independent of any tau systematics)

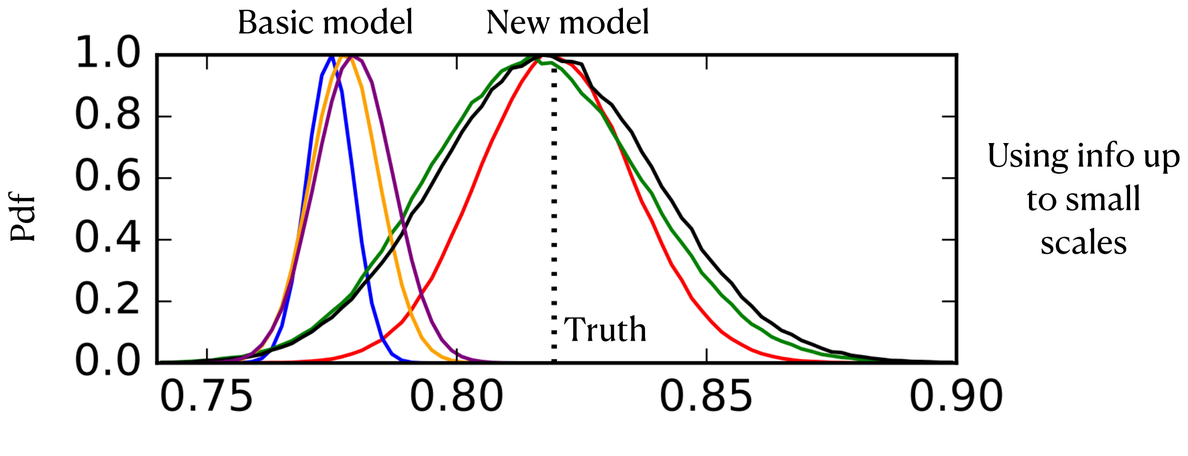
~24 meV uncertainty

Growth of structure over redshift: modelling challenge

For high-precision cross-correlations such as with CMB-S4 modelling of non-linear bias and matter is important.



Chen+ (2022)



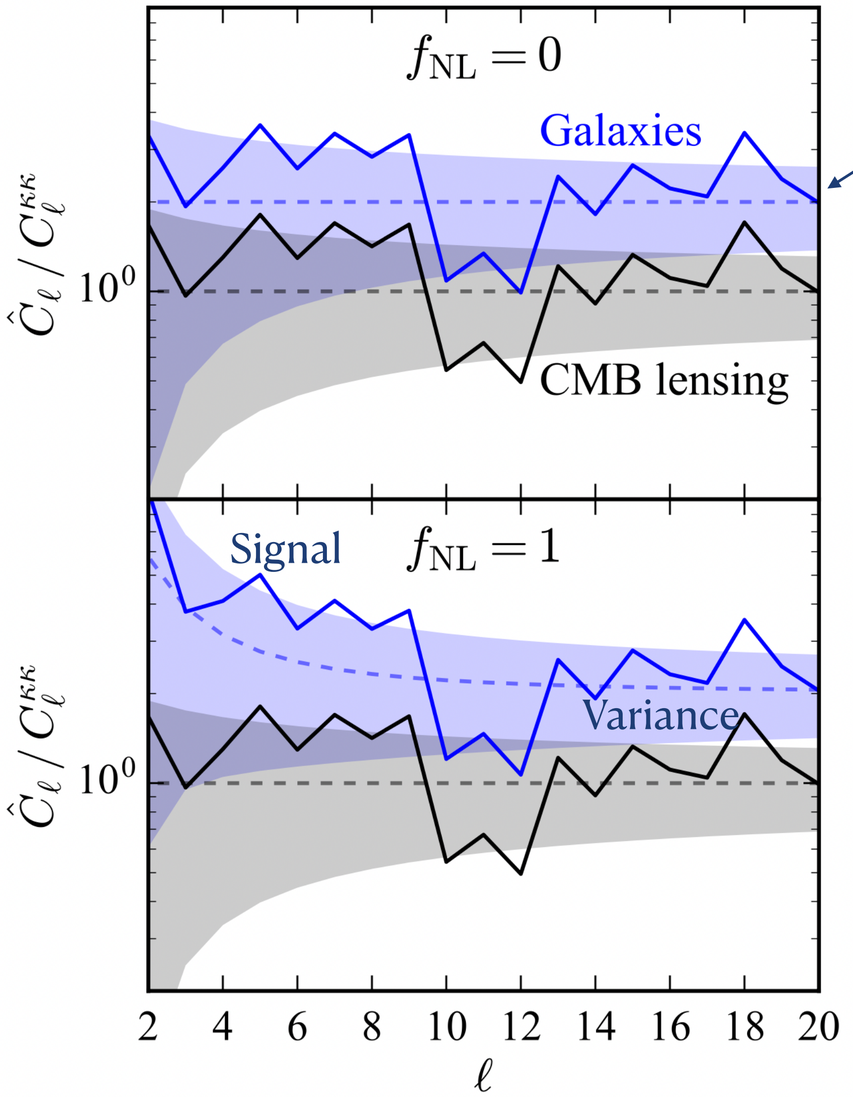
Using info up to small scales

Modi+ (2017)

Need to jointly model bias and matter at a high-precision to squeeze most SNR, including neutrinos. Already true for current and near-future cross-correlations.

e.g. Kitanidis+ (2020), Krolewski+ (2021), White+ (2021), Farren+

Sample variance cancellation to measure scale-dependent bias



Schmitfull+ (2018)

$\delta_g \sim b\kappa$

Scale dependent bias due to primordial non-Gaussianity mainly on large scales

Detection of fnl O(1) would rule out standard slow roll single field inflation

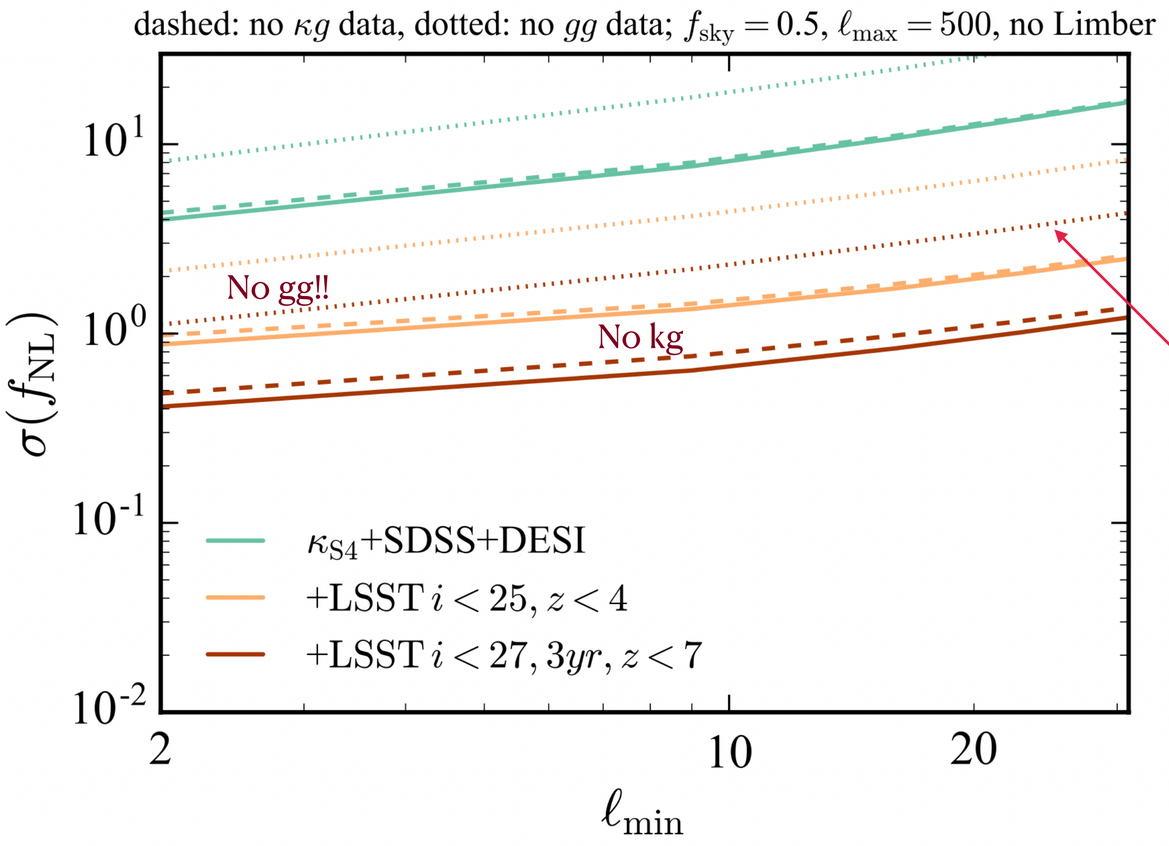
But few long-wavelength modes

Look for signal through cross-correlation by taking "ratio"

$$\delta_g / \kappa \sim b$$

Seljak (2008)

Sample variance cancellation to measure scale-dependent bias



Schmitfull+ (2018)

Achievable thanks to high cross-correlation coefficient given by CMB-S4

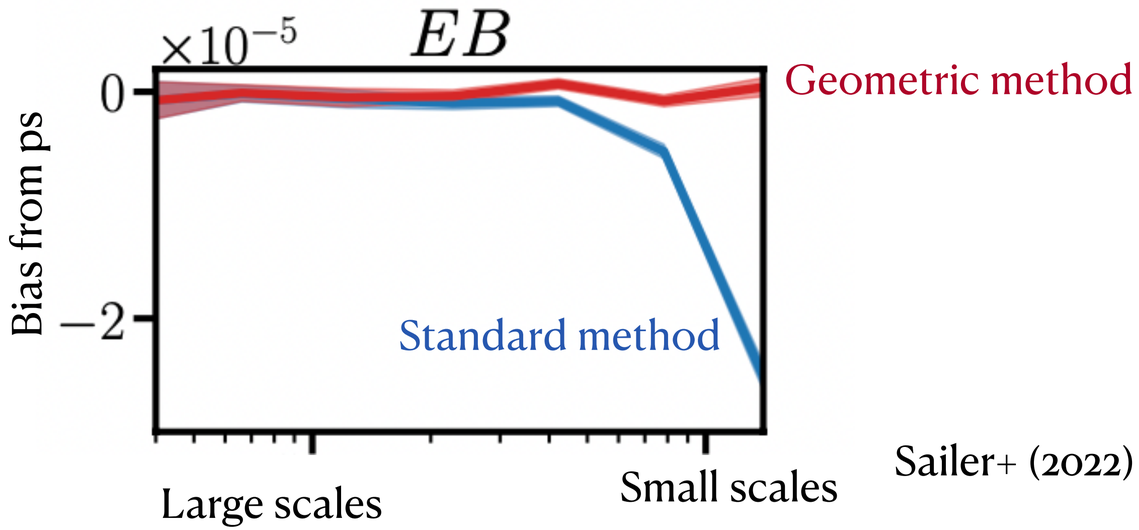
Cross-correlation (in principle) is immune from some bad galaxy auto (additive) systematics!

For application e.g. McCarthy+ (2022)

Foregrounds challenge

For polarisation based optimal estimators: impact from dust might modulate observed galaxy field, correlating with residuals in CMB lensing reconstructions, or polarised sources. Needs investigation for cross-correlations.

Similar methods developed in Sailer+ (2022)? (see also Beck+ (2020))

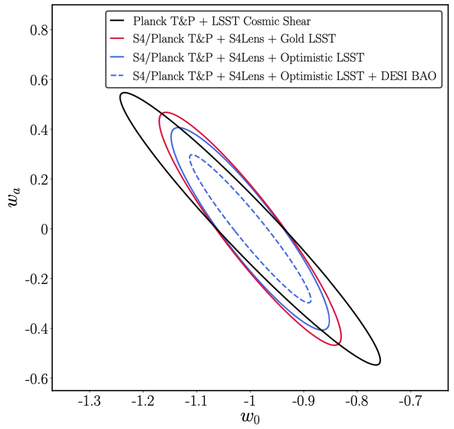


To squeeze SNR for cross-correlations at higher Ls need TT: important to assess foregrounds impact on optimal methods.

Other things

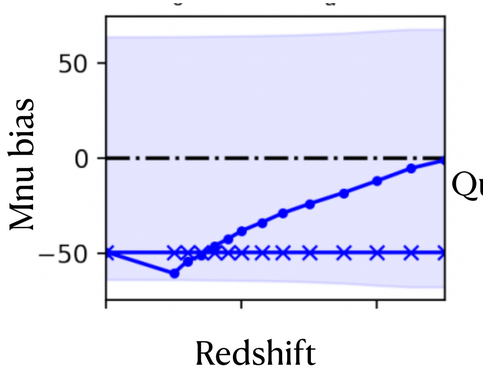
- Dark Energy constraints

(geometry+P(k))



Yu+ (2022)

- CMB lensing cleaning for more robust measurements



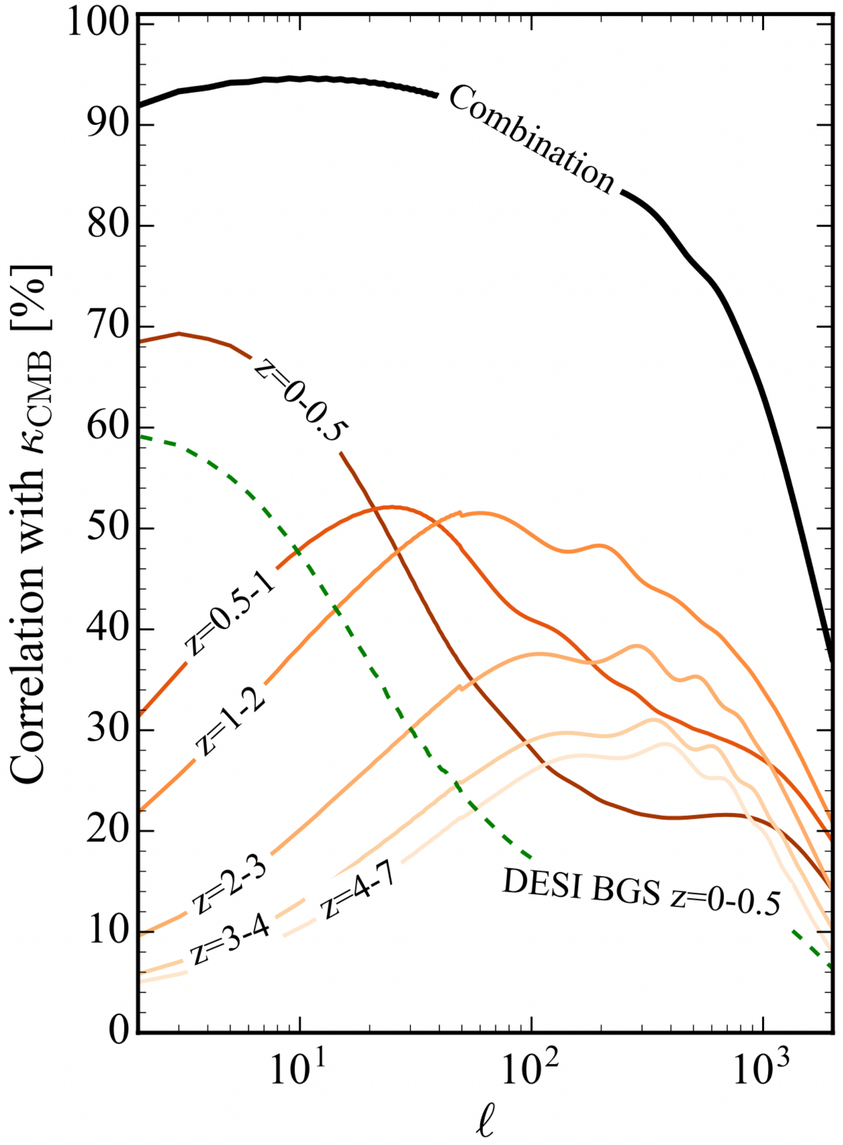
Qu+ (2022)

Also e.g. Modi+ (2017), McCarthy+ (2021), Zhang+ (2022), Lizancos+ (2023)

- Post-born plus non-linear effects in cross-correlation (in particular optimal estimators, joint (cheap) simulations, non-Limber approx, redshift-uncertainties, systematics ….

Summary

- CMB-S4 great potential for CMB lensing cross-correlation science
- Alternative tau-free neutrino mass constraints
- Potential for fNL
- Need more foregrounds investigation, especially for optimal methods
- Modelling under control, systematics, and so on
- But lots of opportunities!



Schmitfull+ (2018)

Ideas?

Extra slides