Higher-Order Corrections to CMB Lensing Cross Correlations

CMB-S4 Workshop, Sept 06-08, 2018, Princeton

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Higher-Order C… to C…relations

TODAY:
Corrections to Measurements with std. Quadratic Estimator

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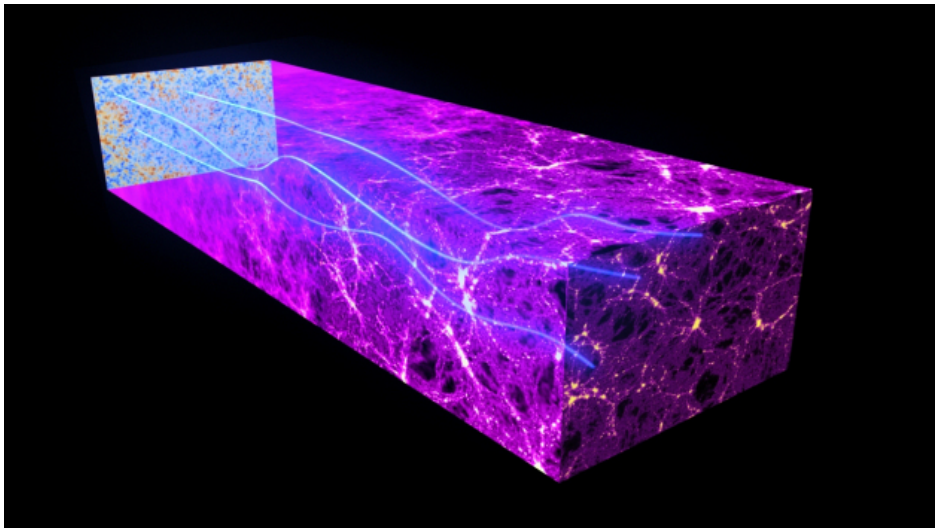
Higher Order in ?



Non-linear physical processes → Non-Gaussian lensing deflections

- Non-linear gravitational evolution
- Multiple deflections

- small corrections → perturbative modeling
- Importance for CMB-S4:
  - probably yes!
  - depends on Observable and Estimator

Higher order: Quadratic Estimator

$$\hat{\kappa} \propto \langle \tilde{T}\tilde{T} \rangle$$

Lensed CMB is non-linear in lensing

$$\tilde{T} = T(\vec{x} + \Delta\vec{x}) \sim T(\vec{x}) \left[\kappa^{(1)}(\vec{x}) + \kappa^{(2)}(\vec{x}) + \mathcal{O}\left(\delta_m^3\right) \right]$$

Higher order: Quadratic Estimator

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total (relative) deflection is non-linear in lensing

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total (relative) deflection is non-linear in lensing

non-linear gravitational evolution

Higher order in Cross Correlation

$$C_L^{\hat{\kappa}\delta_{\rm ext}} \sim \langle \tilde{T}\tilde{T}\delta_{\rm ext}\rangle$$

LO: $C_L^{\hat{\kappa}\delta_{\rm ext}} \sim \langle \kappa\delta_{\rm ext}\rangle$

NLO: $C_L^{\hat{\kappa}\delta_{\rm ext}} \sim \langle \kappa\kappa\delta_{\rm ext}\rangle$

$\delta_{\rm ext}$:
- Galaxy Clustering
- Weak Lensing
- etc.

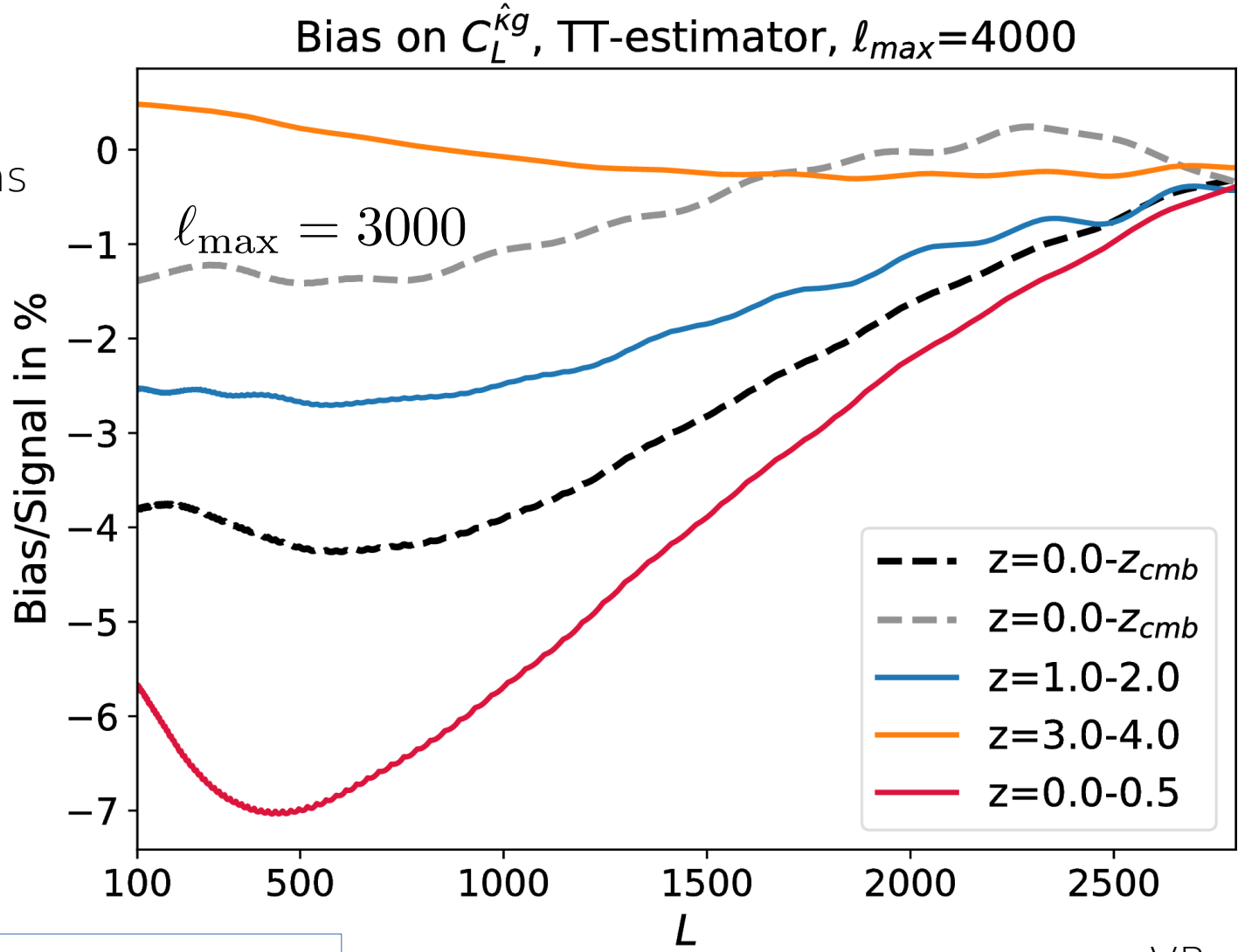
→ estimator picks up cross-bispectra

→ all combination of $\mathcal{O}(\delta^4_{\rm lin}) \sim \mathcal{O}\left[(P^{\rm lin}_\delta)^2\right]$

→ results in 'bias'

Non-linear Bias for CMB-S4 on X with Galaxy Clustering

- LSST-like
- linear bias



Total Bias/Noise up to 15 σ

VB et al in prep.

Non-linear Bias for CMB-S4 on X with Galaxy Clustering

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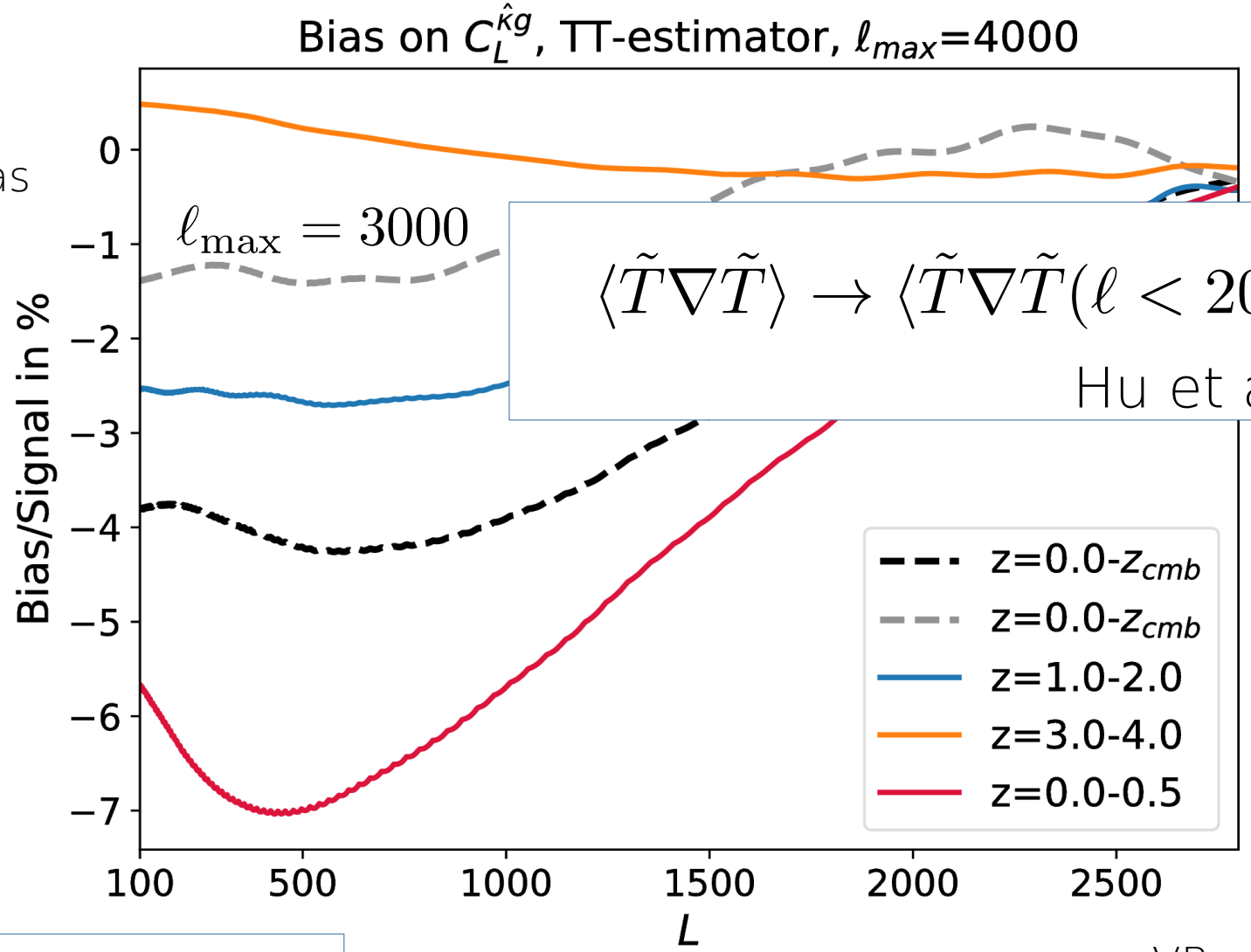


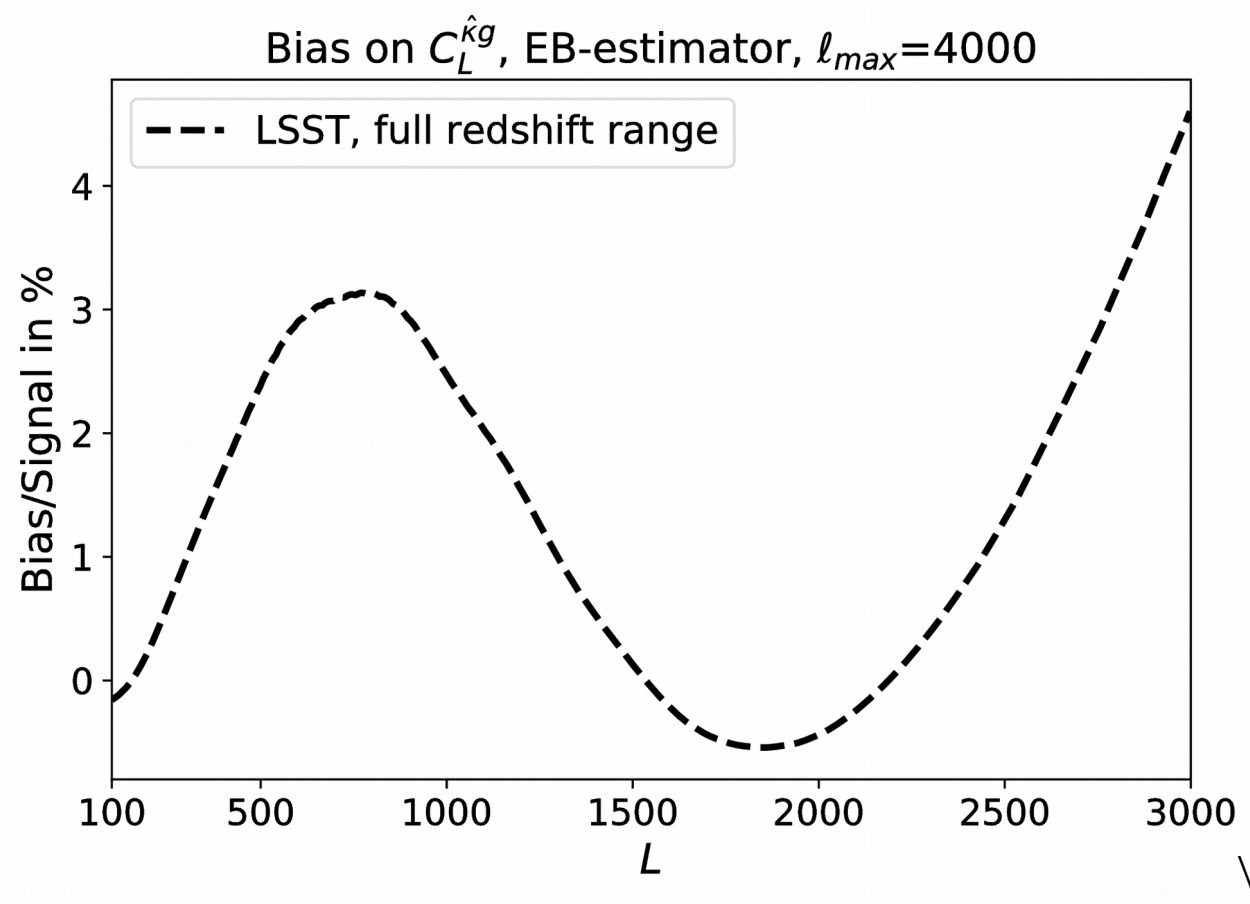
$$\langle \tilde{T}\nabla\tilde{T}\rangle \rightarrow \langle \tilde{T}\nabla\tilde{T}(\ell < 2000)\rangle$$

Hu et al. 2007

Total Bias/Noise up to 15 σ

VB et al in prep.

Non-linear Bias for CMB-S4 on X with Galaxy Clustering



total S/N ~480

total bias/noise ~9

VB et al in prep./ Prelim!

Conclusions & More

- All corrections?

$$C_L^{\hat{\kappa}\delta_{\rm ext}} \sim \langle \tilde{T}\tilde{T}\delta_{\rm ext} \rangle$$

Correlation is with deflected fields!

$$\delta_{\rm ext}(\vec{x} + \Delta\vec{x})$$

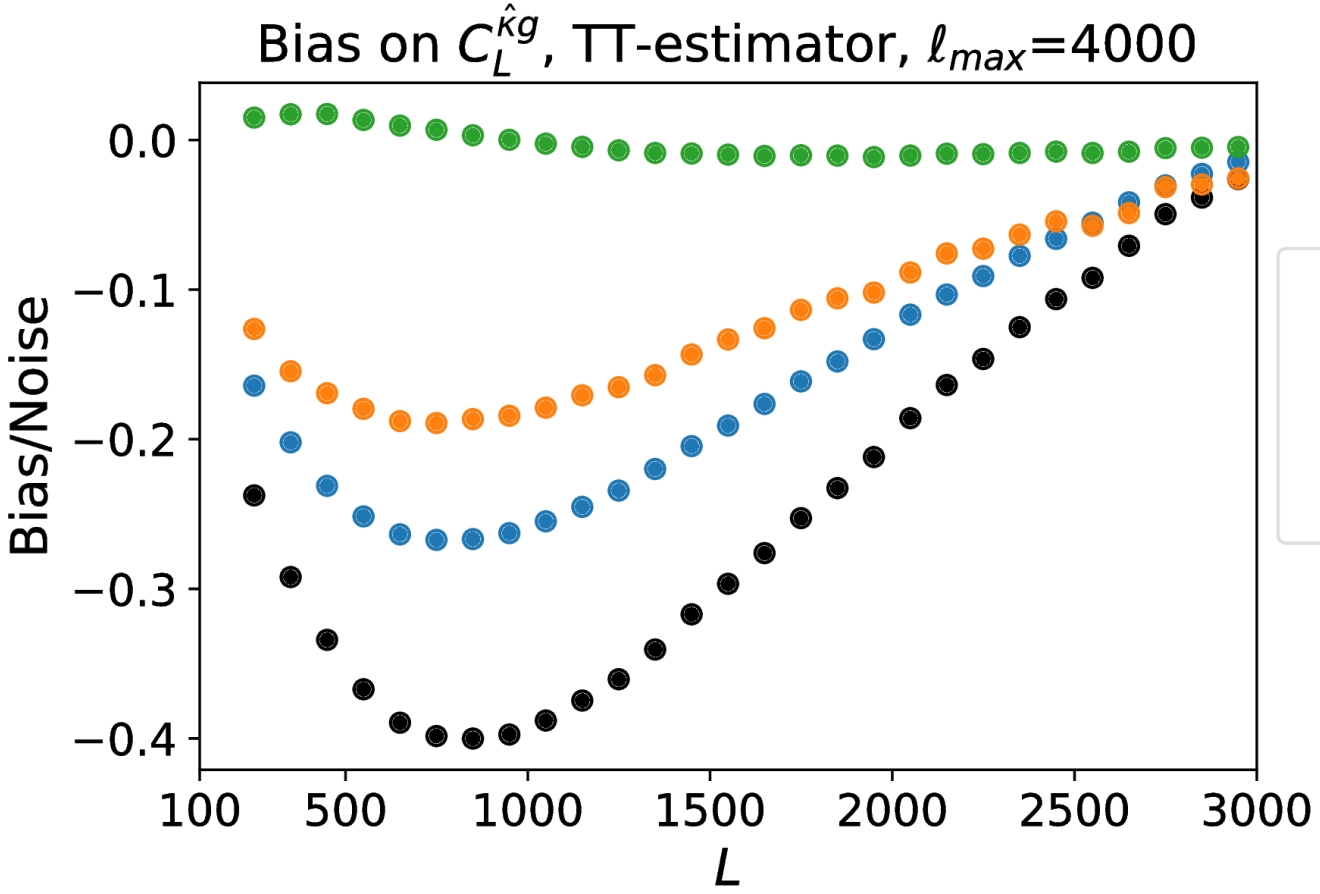
VB, Chirag Modi and Emanuele Castorina in prep.

- Non-linear corrections can be important for any CMB lensing estimator*

  → Tests on suitable simulations

*that does not model the lensing non-linearities

Non-linear Bias for CMB-S4 on X with Galaxy Clustering



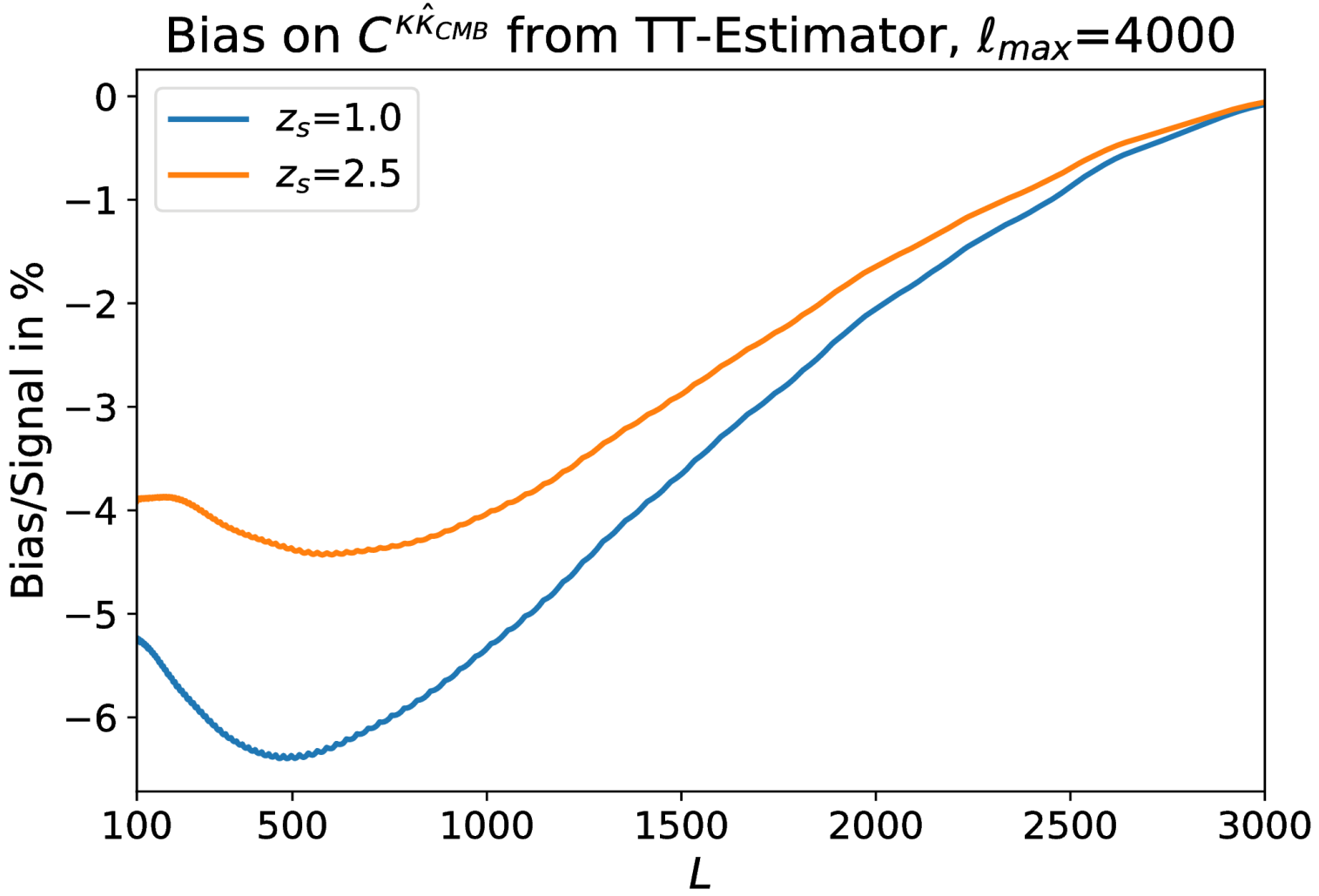
$f_{\rm sky} = 0.5$

- z=0.0-z_{cmb}, n=65.7 arcmin^{-2}
- z=0.0-0.5, n=14.3 arcmin^{-2}
- z=1.0-2.0, n=21.6 arcmin^{-2}
- z=3.0-4.0, n=1.5 arcmin^{-2}

Total Bias/Noise up to 15 σ

Non-linear Bias for CMB-S4

CMB Lensing X Weak Lensing



Redshift Distribution