Systematic Biases on N_{eff}, H_0, and Other Parameters due to Nonlinear CMB Lensing

Colin Hill

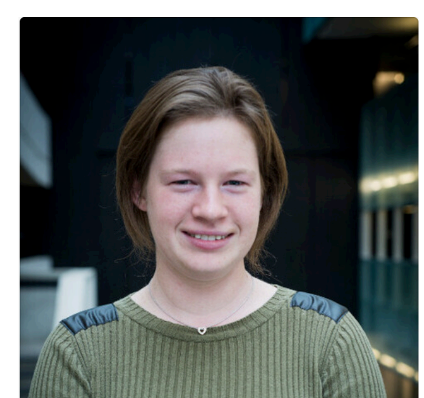
Columbia University

Flatiron Institute - Center for Computational Astrophysics

CMB-S4 Collaboration Meeting, Zoom, March 2021

arXiv:2103.05582

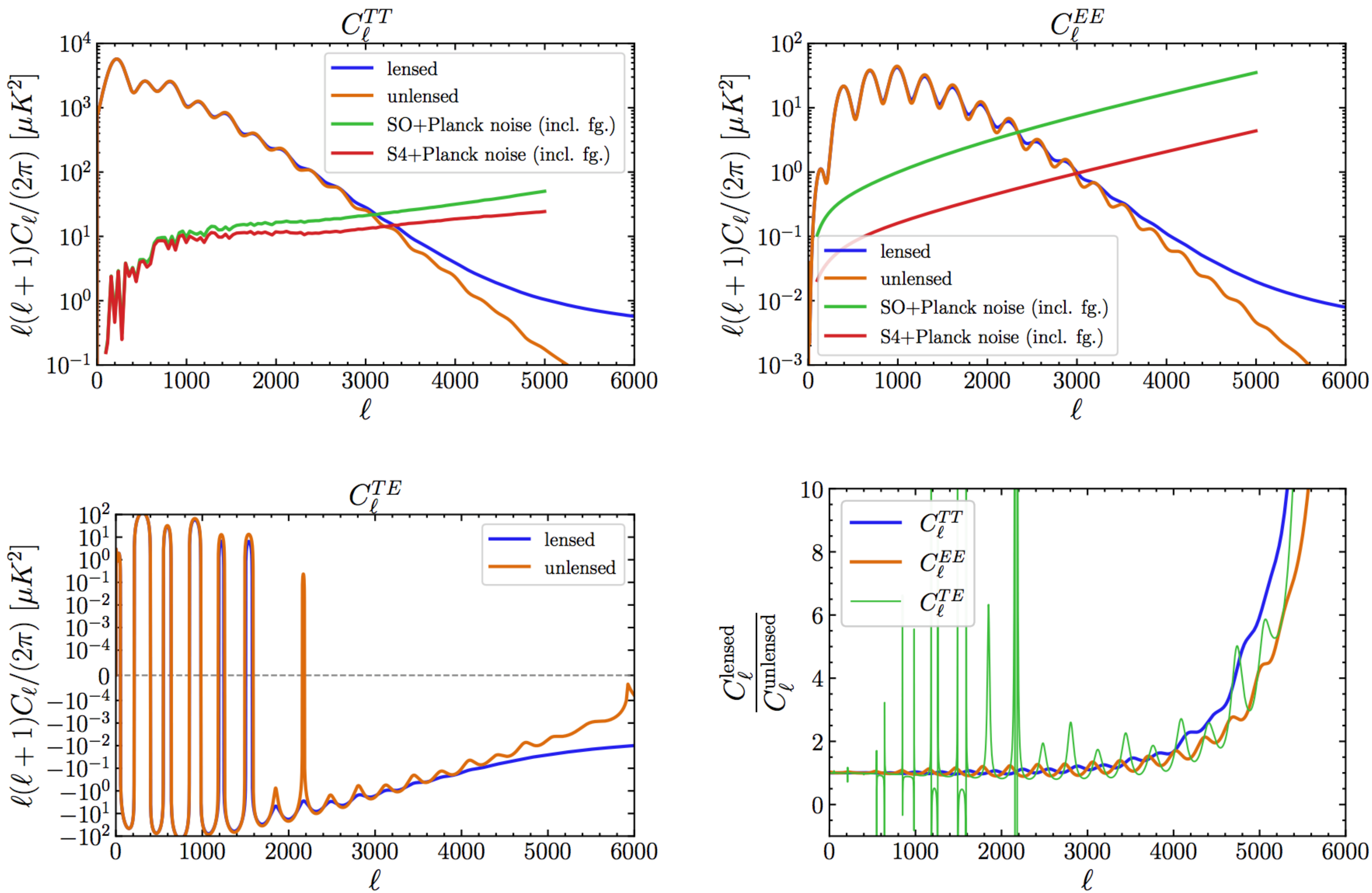
w/ Fiona McCarthy, Mathew Madhavacheril



Colin Hill
Columbia/CCA

CMB Lensing

Extremely important effect on primary CMB power spectra at high ell



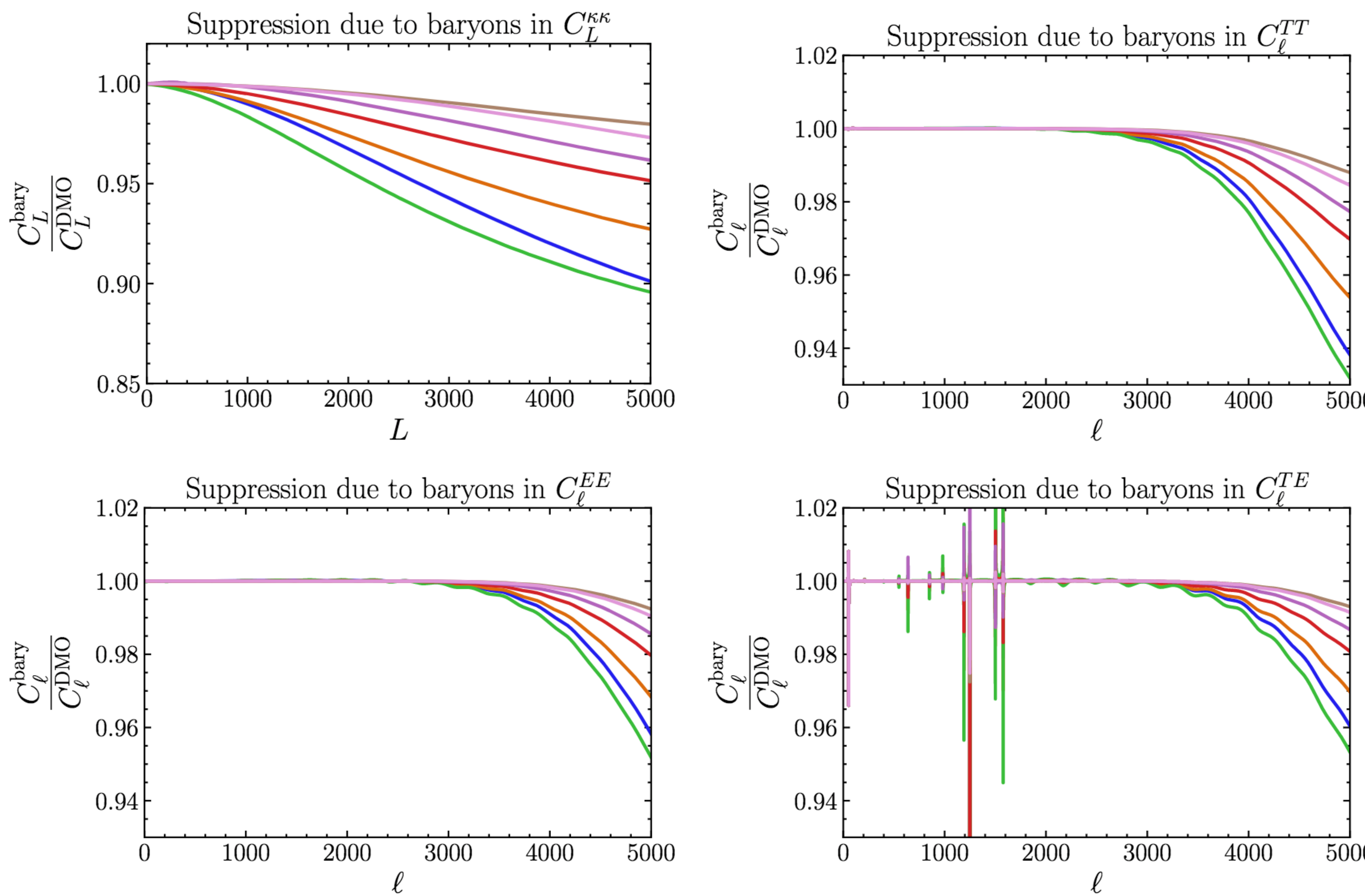
McCarthy, JCH, & Madhavacheril (2021)

Simons Obs. post-comp.-sep. noise computed by JCH in 1808.07445
CMB-S4 post-comp.-sep. noise computed by JCH in 1907.04473

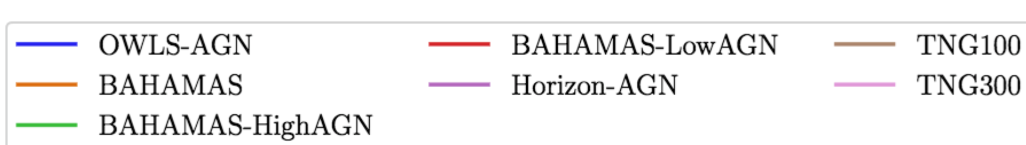
Colin Hill
Columbia/CCA

CMB Lensing

Nonlinear evolution and baryonic effects alter the lensing power



Seven hydro sims:



McCarthy, JCH, & Madhavacheril (2021)

see also McCarthy et al. (2020)

Colin Hill
Columbia/CCA

Potential Parameter Biases

This can produce surprisingly large biases on, e.g., H_0, ω_c, and $N_{\rm eff}$ for upcoming CMB experiments (not current!)

Usual approach in primary CMB analyses to date:
"set it (default Halofit or HMcode in CAMB or CLASS) and forget it"

This will not suffice for CMB-S4! (or Simons Observatory)

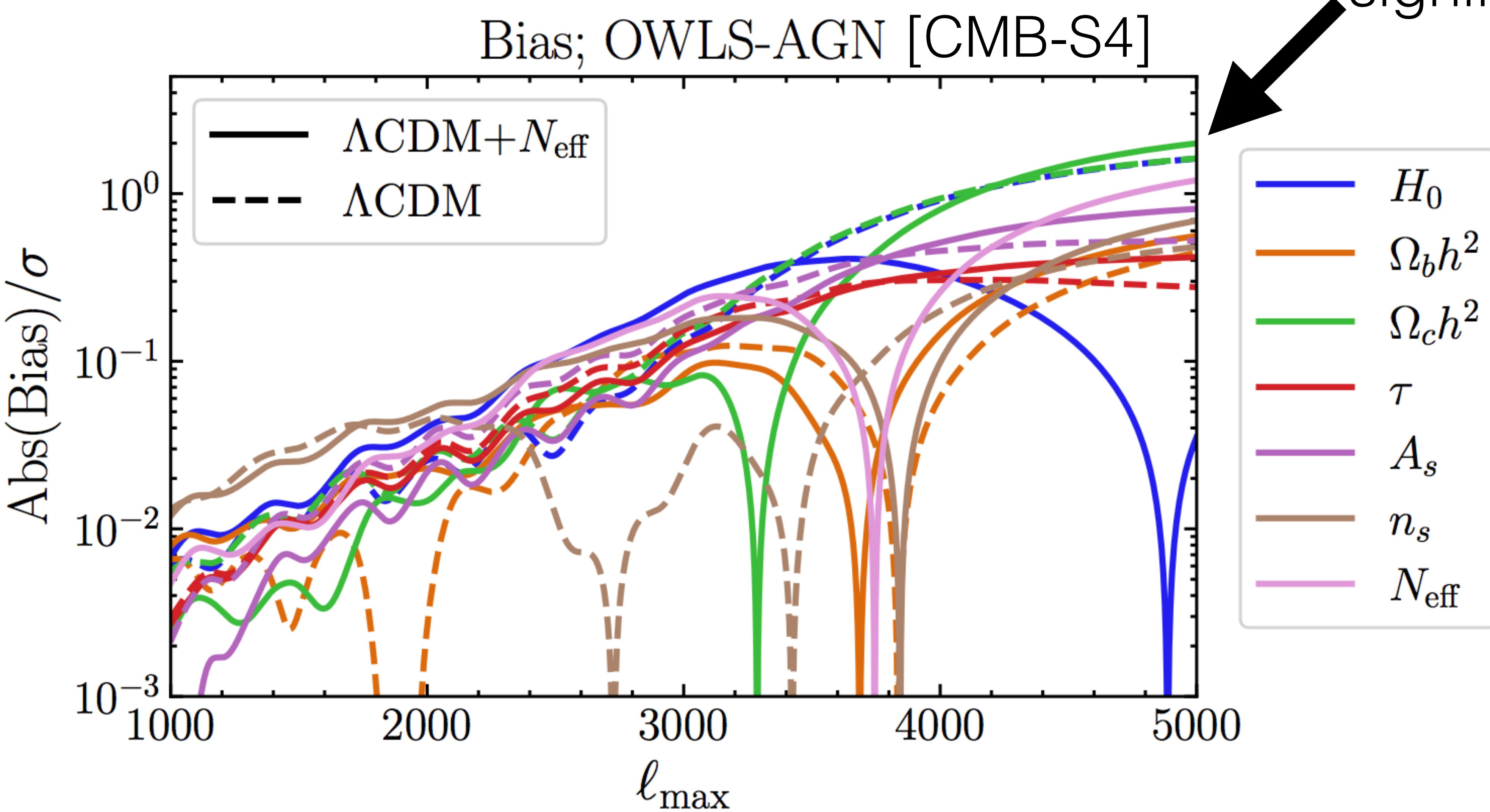
McCarthy, JCH, & Madhavacheril (2021)

Potential Parameter Biases

Colin Hill
Columbia/CCA

This can produce surprisingly large biases on, e.g., H_0, ω_c, and N_{eff} for upcoming CMB experiments (not current!)

significant bias



CMB-S4 [ΛCDM]

1.6σ bias on H_0

1.6σ bias on ω_c

CMB-S4 [N_{eff}]

1.2σ bias on N_{eff}

2σ bias on ω_c

Not an issue for Planck or for current ACT/SPT data

McCarthy, JCH, & Madhavacheril (2021)

Colin Hill
Columbia/CCA

Mitigation Methods

Three strategies

1) Explicitly cut all TT data at ell>3000 (w/ small penalty in final parameter error bars) — 13% increase in $\sigma(N_{\mathrm{eff}})$ for S4

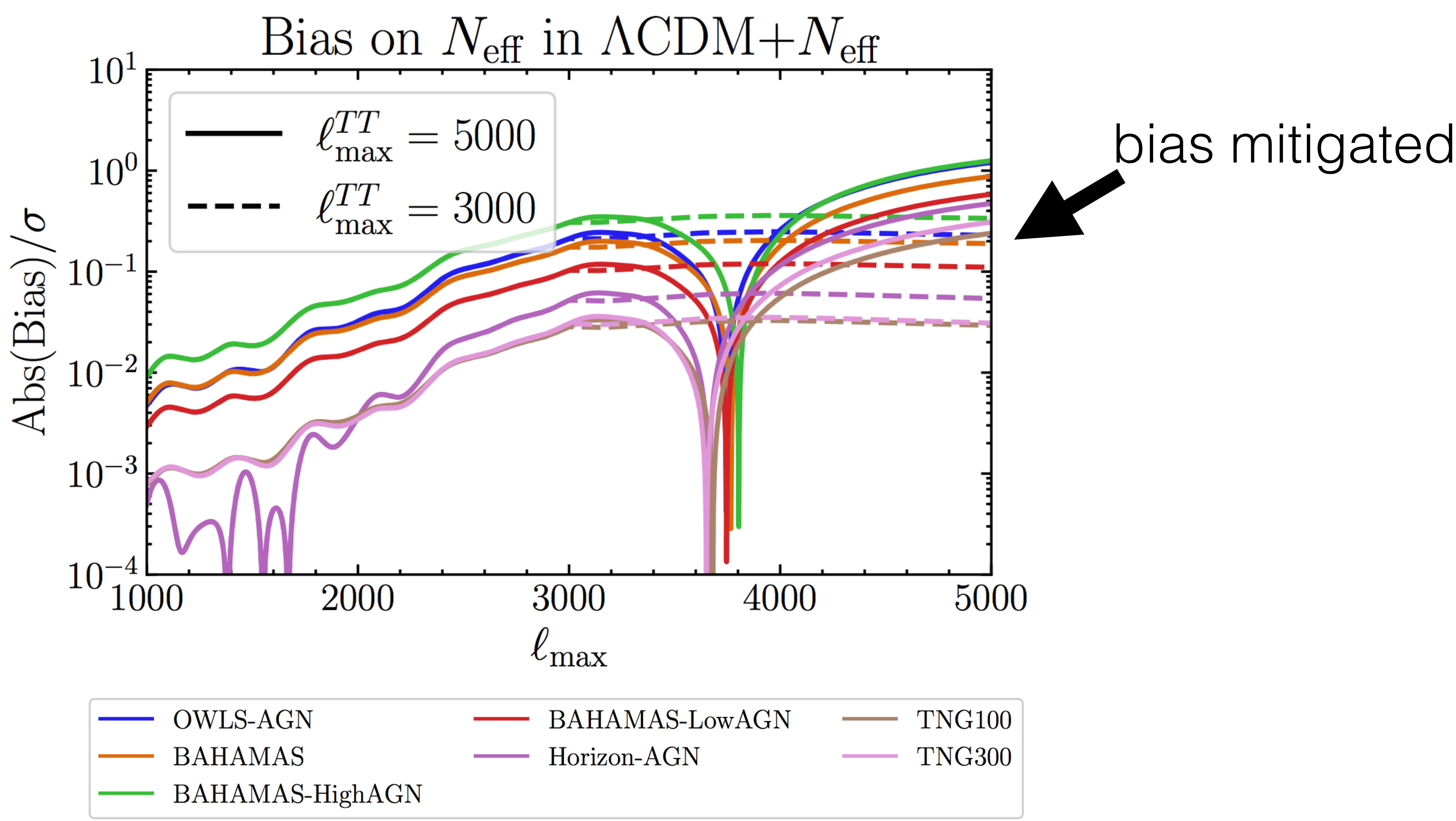
McCarthy, JCH, & Madhavacheril (2021)

Colin Hill
Columbia/CCA

Mitigation Methods

Three strategies

1) Explicitly cut all TT data at ell>3000 (w/ small penalty in final parameter error bars) — 13% increase in σ(N_{eff}) for S4



McCarthy, JCH, & Madhavacheril (2021)

Colin Hill
Columbia/CCA

Mitigation Methods

Three strategies

1) Explicitly cut all TT data at ell>3000 (w/ small penalty in final parameter error bars) — 13% increase in $\sigma(N_{eff})$ for S4

2) Marginalize over parameters describing baryonic effects

McCarthy, JCH, & Madhavacheril (2021)

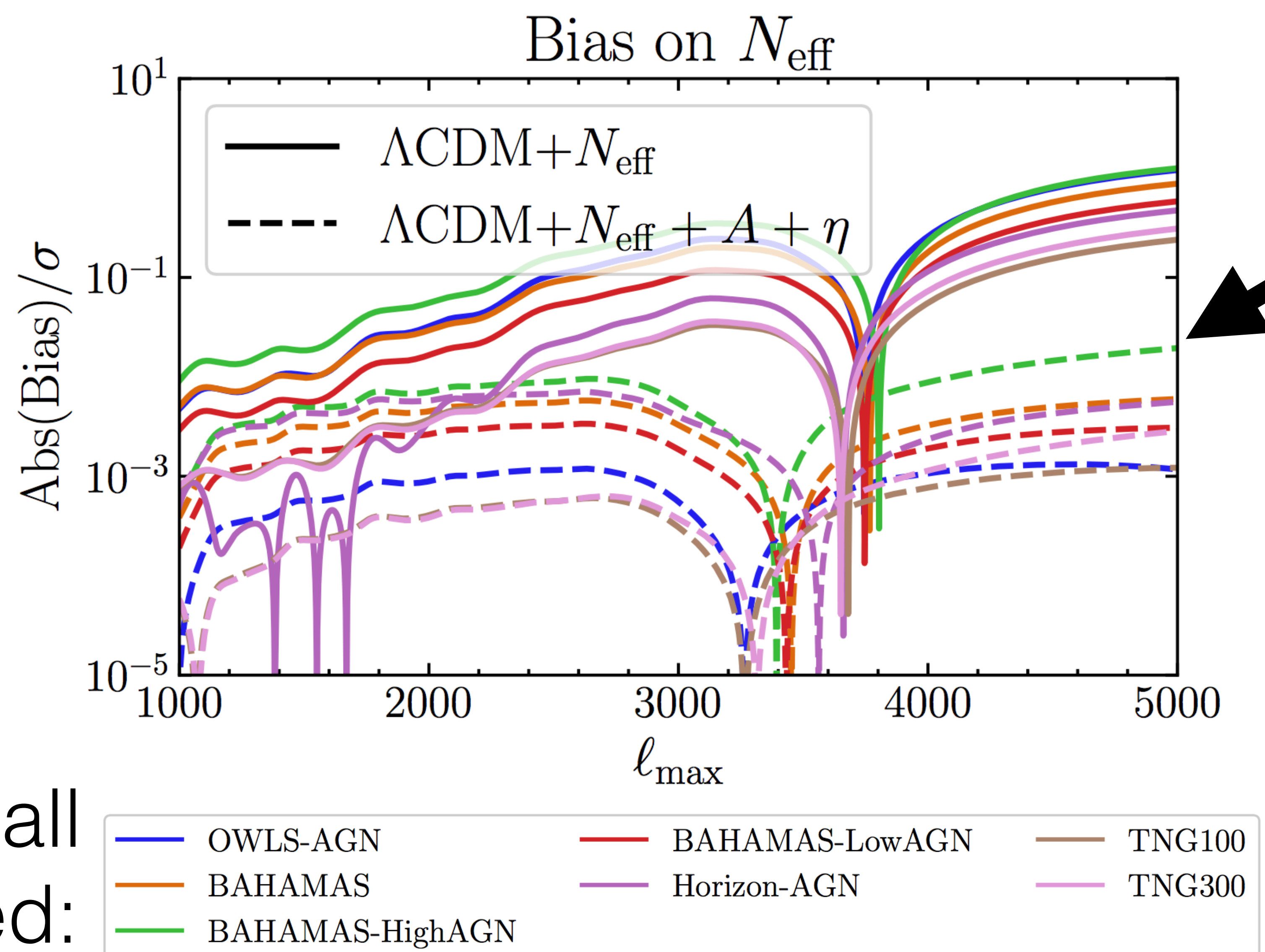
Mitigation Methods

Colin Hill
Columbia/CCA

Three strategies

1) Explicitly cut all TT data at ell>3000 (w/ small penalty in final parameter error bars) — 13% increase in σ(N_{eff}) for S4

2) Marginalize over parameters describing baryonic effects



bias mitigated by factor of >100

Works for all sims tested:

Colin Hill
Columbia/CCA

Mitigation Methods

Three strategies

1) Explicitly cut all TT data at ell>3000 (w/ small penalty in final parameter error bars) — 13% increase in $\sigma(N_{eff})$ for S4

2) Marginalize over parameters describing baryonic effects — but pay a penalty in parameter error bars: 13% increase in $\sigma(N_{eff})$ for S4 [coincidentally same as above]

McCarthy, JCH, & Madhavacheril (2021)

Colin Hill
Columbia/CCA

Mitigation Methods

Three strategies

1) Explicitly cut all TT data at ell>3000 (w/ small penalty in final parameter error bars) — 13% increase in $\sigma(N_{\rm eff})$ for S4

2) Marginalize over parameters describing baryonic effects — but pay a penalty in parameter error bars: 13% increase in $\sigma(N_{\rm eff})$ for S4 [coincidentally same as above]

3) Delens the T and E-mode maps using the reconstructed κ map (and/or external tracers like the CIB)

—> Most robust, data-driven approach, and can actually improve the error bars on parameters [Green et al. (2016)]

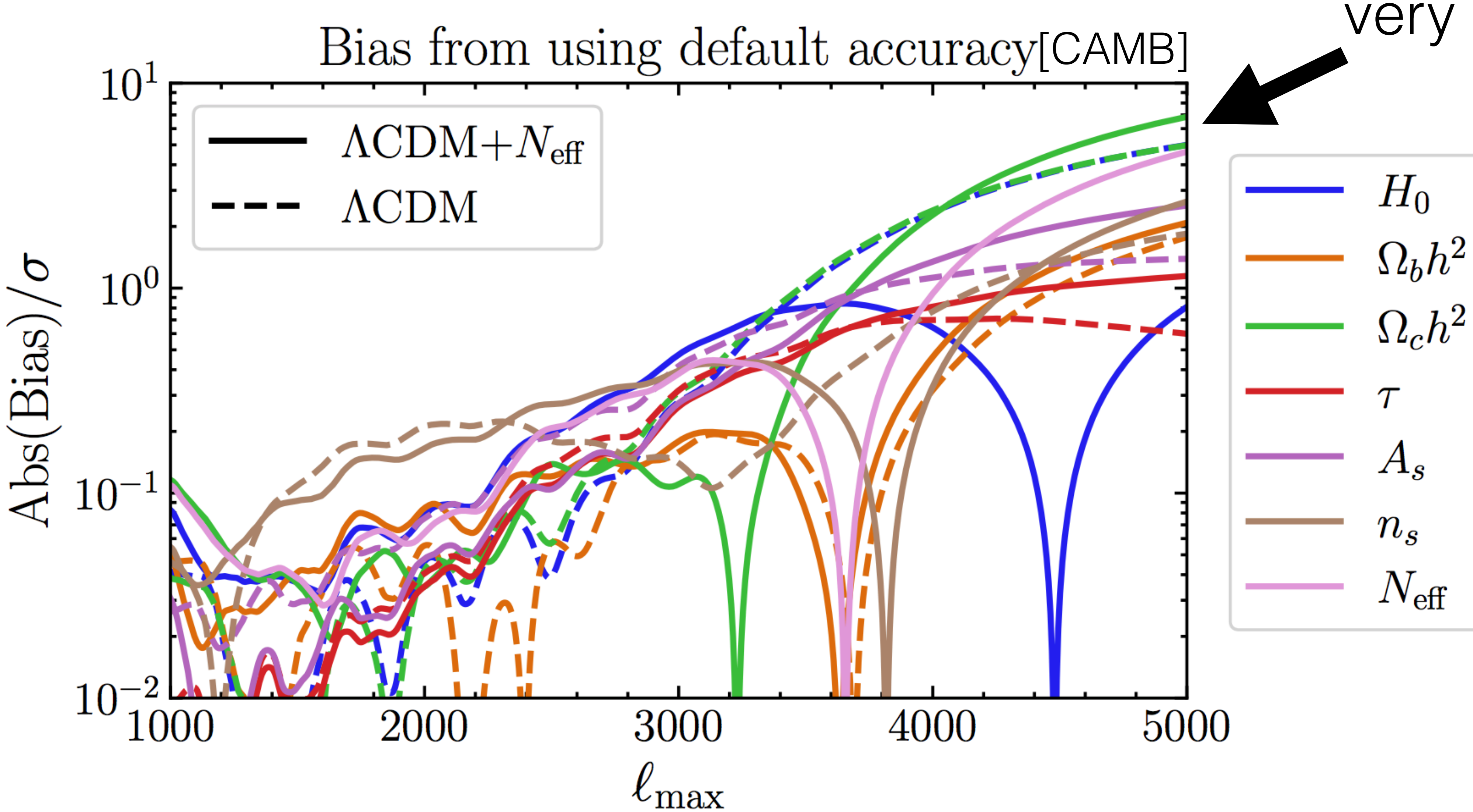
—> Challenge: need very high-L κ information!

McCarthy, JCH, & Madhavacheril (2021)

Aside: Boltzmann Accuracy

Colin Hill
Columbia/CCA

The default accuracy settings in CAMB or CLASS will no longer suffice for upcoming CMB data sets — higher-accuracy lensing is needed (easy to fix!)



very significant bias

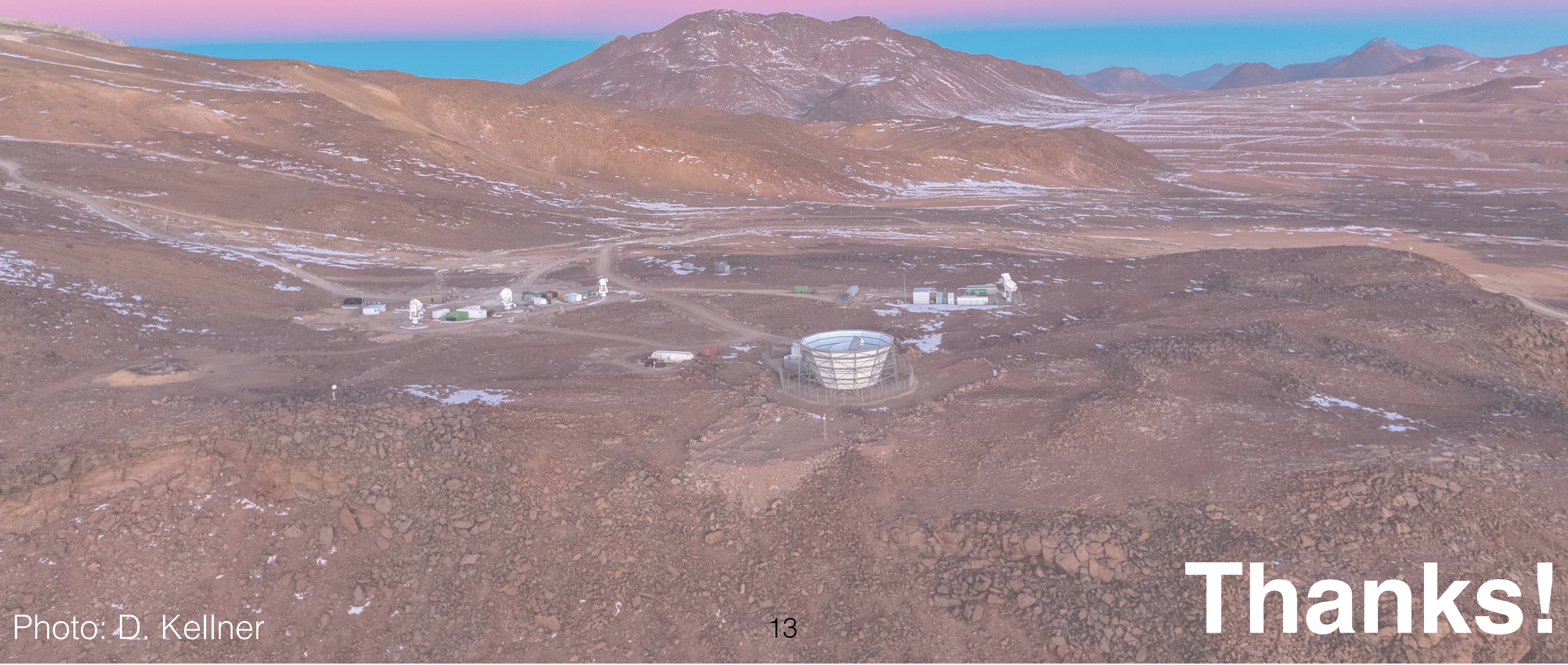
Even for current data from ACT/SPT, using high-accuracy settings is necessary for precise χ² comparison of ΛCDM to some extended models (EDE, etc.)

McCarthy, JCH, & Madhavacheril (2021)

Take-Home Messages

Colin Hill
Columbia/CCA

1) Baryonic feedback effects must be accounted for in upcoming *primary* CMB power spectrum analyses
2) Crank up your precision settings in CAMB/CLASS
3) What other effects do we need to be thinking about at this level of precision? [for discussion]



Thanks!

Photo: D. Kellner