Chile *r*-forecasting: Delensing and map based validation

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2024 Summer Collaboration Meeting

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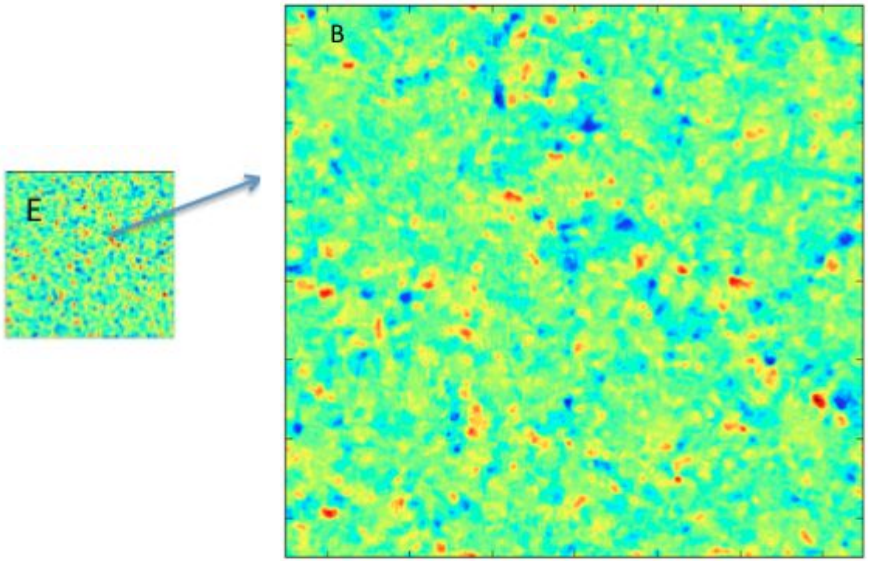
CMB-S4

Lensing

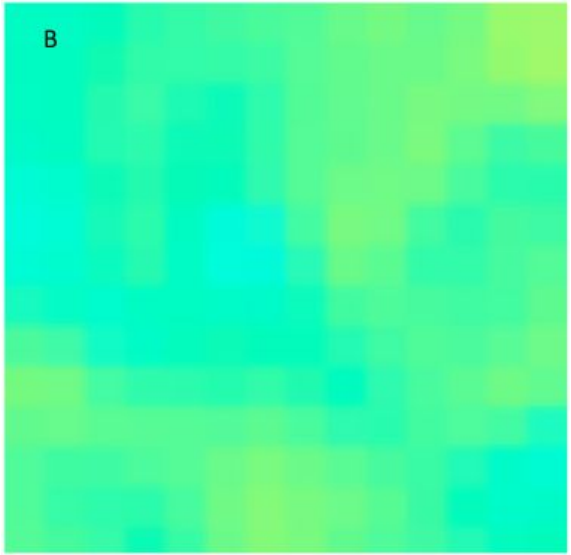
Weak Gravitational lensing converts *E*-modes to *B*-modes and obscures the primordial signal

Lensing



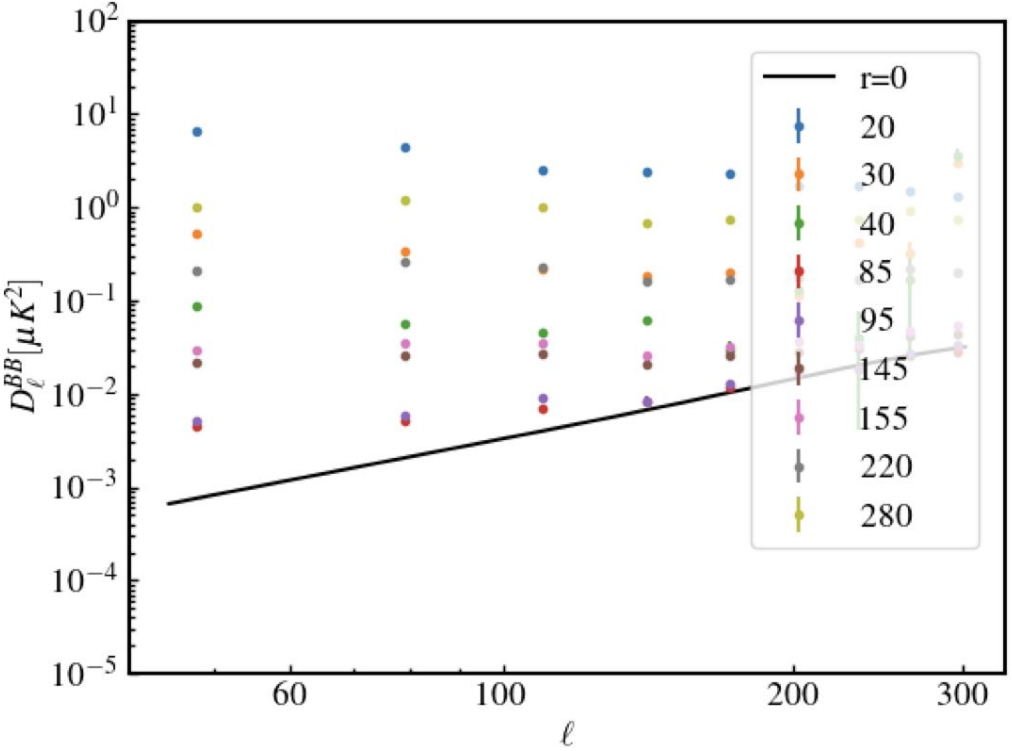
vs

Primordial



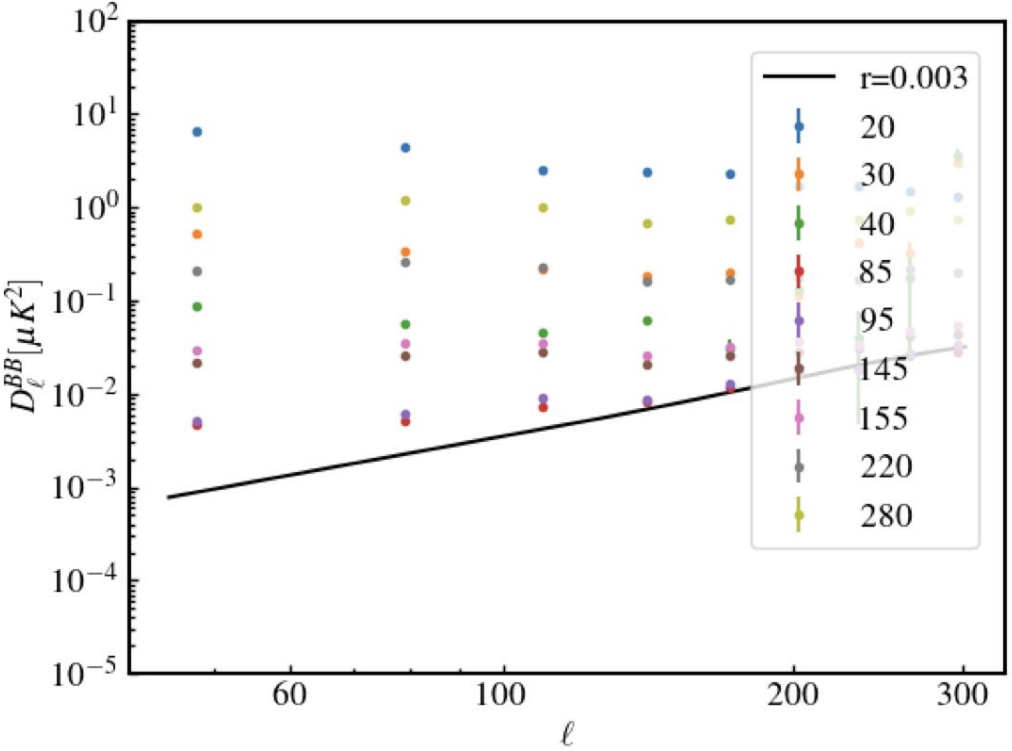
Delensing

In the presence of lensing B-modes, the challenge is to distinguish



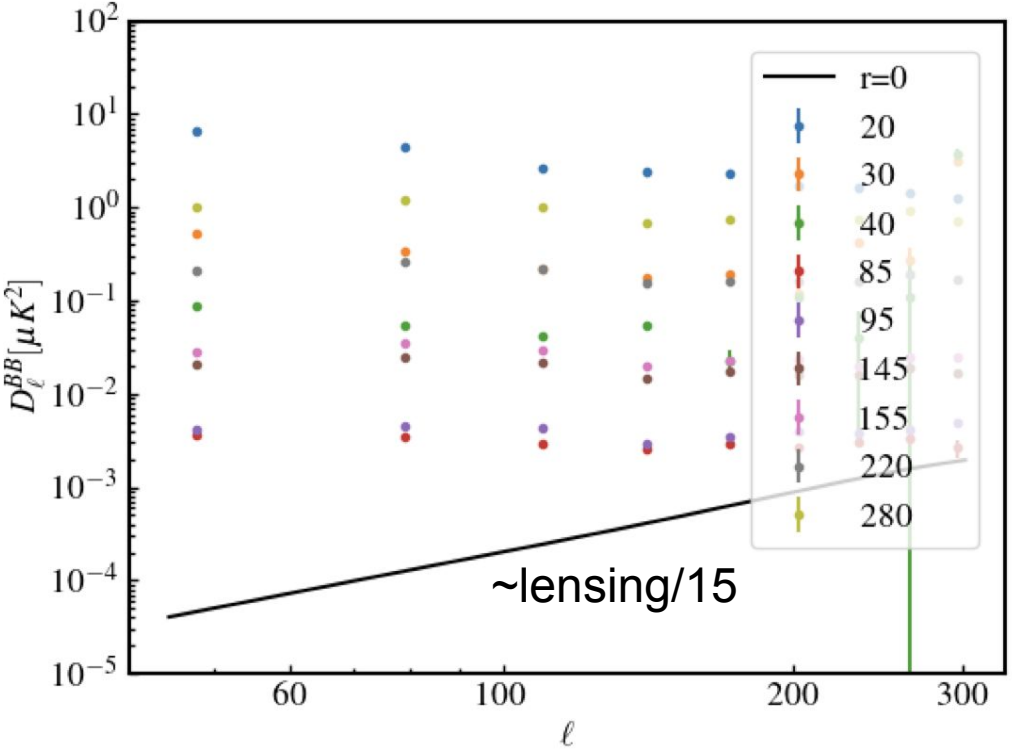
Delensing

… and (r=0.003).



Delensing

Delensing provides a clearer view of the primordial signal



Delensing

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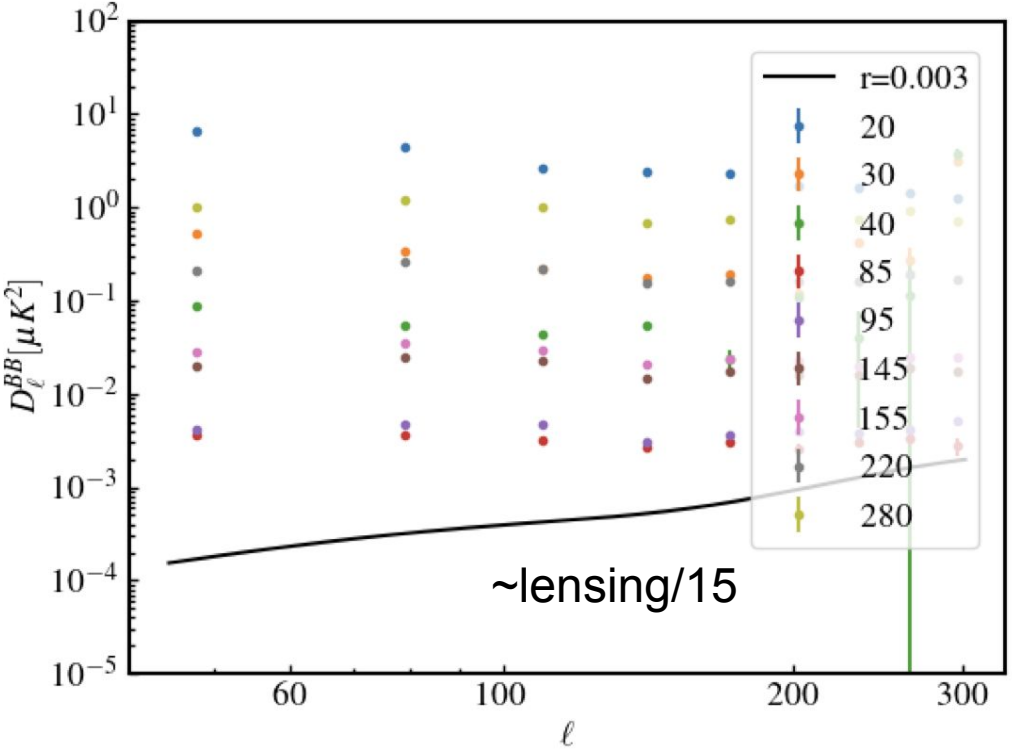

Forecasting Methodology

- For a given LAT configuration, survey, and foreground model, LAT frequency cross-spectra are computed and a spectral ILC is performed.
  (White noise levels and sky fractions are extracted from surveys, noise model is taken from PBDR.)

- For the resulting ILC signal and noise spectra

$$N_\ell^{\phi\phi} = \left[\frac{1}{2\ell+1}\sum_{\ell_1\ell_2}|f^{EB}_{\ell_1\ell_2\ell}|^2\left(\frac{1}{C_{\ell_1}^{B_{\rm res}}+N_{\ell_1}^{BB}}\right)\left(\frac{(C_{\ell_2}^{EE})^2}{C_{\ell_2}^{EE}+N_{\ell_2}^{EE}}\right)\right]^{-1}$$

$$C_{\ell_1}^{B_{\rm res}} = \frac{1}{2\ell_1+1}\sum_{\ell_2\ell}|f^{EB}_{\ell_1\ell_2\ell}|^2\left[C_{\ell_2}^{EE}C_\ell^{\phi\phi}-\left(\frac{(C_{\ell_2}^{EE})^2}{C_{\ell_2}^{EE}+N_{\ell_2}^{EE}}\right)\left(\frac{(C_\ell^{\phi\phi})^2}{C_\ell^{\phi\phi}+N_\ell^{\phi\phi}}\right)\right]$$

  are iterated to determine A_L.

- These values of A_L are then used in the subsequent Fisher and map-based forecasts to determine the sensitivity to r for a given SAT configuration.

Residual lensing power

Delensing Chile SATs from Chile

- Deep patch

Duration (yrs)	7	10	20	30	40	50
2 CD x Wide + 1 CD x S4-like	0.129	0.109	0.0785	0.0649	0.0569	0.0514
2 CD x Wide + 2 CD x S4-like	0.0958	0.0809	0.0586	0.0488	0.0430	0.0390
2 CD x Wide + 2 CD x S4-like	0.0795	0.0672	0.049	0.041	0.0362	0.0329

(For comparison, A_L =0.0611 for the deep patch from the pole for 7 years.)

Residual lensing power

Delensing Chile SATs from Chile

- Field 2

Duration (yrs)	7	10	20	30	40	50
2 CD x Wide + 1 CD x S4-like	0.162	0.14	0.101	0.0836	0.0729	0.0656
2 CD x Wide + 2 CD x S4-like	0.131	0.111	0.0797	0.0658	0.0576	0.0521
2 CD x Wide + 2 CD x S4-like	0.112	0.0945	0.0679	0.0563	0.0495	0.0448

Residual lensing power

Delensing Chile SATs from Chile

- Field 3

Duration (yrs)	7	10	20	30	40	50
2 CD x Wide + 1 CD x S4-like	0.159	0.137	0.0992	0.0817	0.0713	0.0642
2 CD x Wide + 2 CD x S4-like	0.130	0.111	0.0794	0.0656	0.0574	0.051
2 CD x Wide + 2 CD x S4-like	0.112	0.0947	0.0681	0.0565	0.0496	0.0449

Residual lensing power

Delensing Chile SATs from Chile

- Field 4

Duration (yrs)	7	10	20	30	40	50
2 CD x Wide + 1 CD x S4-like	0.191	0.169	0.126	0.104	0.0908	0.0816
2 CD x Wide + 2 CD x S4-like	0.162	0.139	0.101	0.0833	0.0726	0.0654
2 CD x Wide + 2 CD x S4-like	0.141	0.120	0.0863	0.0712	0.0622	0.0562

Map-based validation

By now a significant amount of work by Julien Carron and Sebastian Belkner has gone into map-based validation

For example, see the postings

AoA - delensing, all foregrounds (alternative 1)

AoA - delensing, all foregrounds (alternative 2)

AoA - delensing, all foregrounds (alternative 3)

The agreement has so far been very good.

Summary

- To achieve its science goal of σ(r)<0.0005, CMB-S4 relies on delensing
- We have studied several delensing options, for both the Pole and Chile surveys
- Forecasts presented here are for iterative delensing and performed in the spectral domain. The method has been validated by map-based delensing for some configurations.
- Properties of foregrounds on scales of importance for delensing remain unknown, but are not expected to play the same critical role as for the degree survey simply because the lensing signal is brighter than the primordial B-modes.
- Delensing is important and remains an area of active study, but is not foreseen to be a problem.