SAT systematics

Colin Bischoff // May 2022 collab meeting

CMB-S4

Review of past studies

The r forecast paper (arXiv:2008.12619) includes a treatment of systematic errors that was first developed for the CDT report in 2017.

"Additive systematics" show up as bias on the BB spectra (like an unmodeled noise term), which could have correlations across frequency and different shapes in ℓ (white or red spectrum).

Table 4

Map-based simulation results for dedicated simulations containing systematics (DC3). Simulations here assume the Science Book Configuration (Abazajian et al. 2016), i.e., an instrument configuration including a (low-resolution) 20-GHz channel, a survey of 3% of the sky with 1.0×10^6 150-GHz-equivalent detector-years, and $A_L = 0.1$. We report sky Model 3 and $r = 0$ **(no decorrelation)**, with additive systematic effects in varying combinations, the amplitudes of which are specified as percentages of survey noise, for the white (A) and $1/\ell$ (B) components. **The r bias columns list the bias due solely to systematic effects, i.e. the shift relative to the "None" case.**

	Uncorrelated		Correlated		ILC		Parametric	
Systematic	A [%]	B [%]	A [%]	B [%]	$\sigma(r) \times 10^{-4}$	r bias $\times 10^{-4}$	$\sigma(r) \times 10^{-4}$	r bias $\times 10^{-4}$
None	0	0	0	0	5.3	—	7.2	—
Uncorrelated white	3.3	0	0	0	6.0	0.84	8.0	0.63
Uncorrelated $1/\ell$	0	6.8	0	0	5.0	0.99	7.0	0.85
Correlated white	0	0	5.8	0	6.3	1.2	7.3	1.4
Correlated $1/\ell$	0	0	0	11	5.2	1.0	6.7	0.97
Uncorrelated white + $1/\ell$	1.6	3.5	0	0	5.6	0.89	7.5	0.76
Correlated white + $1/\ell$	0	0	2.9	5.3	5.5	0.98	6.9	1.0
Both, white + $1/\ell$	0.8	1.7	1.5	2.6	5.6	1.1	7.9	0.98

Review of past studies

The r forecast paper (arXiv:2008.12619) includes a treatment of systematic errors that was first developed for the CDT report in 2017.

"Multiplicative systematics" cause us to mis-measure existing B-mode signals. Example is errors in bandpass calibration that hurt our ability to model foregrounds. See 2017-09-13 logbook posting.

- For random errors that are uncorrelated between frequency bands, found that 0.89% standard deviation error in band center leads to bias on r ~ 1e-4
- For errors that are fully correlated across frequency bands, i.e. systematic calibration error, ~2% band center error leads to bias on r ~ 1e-4

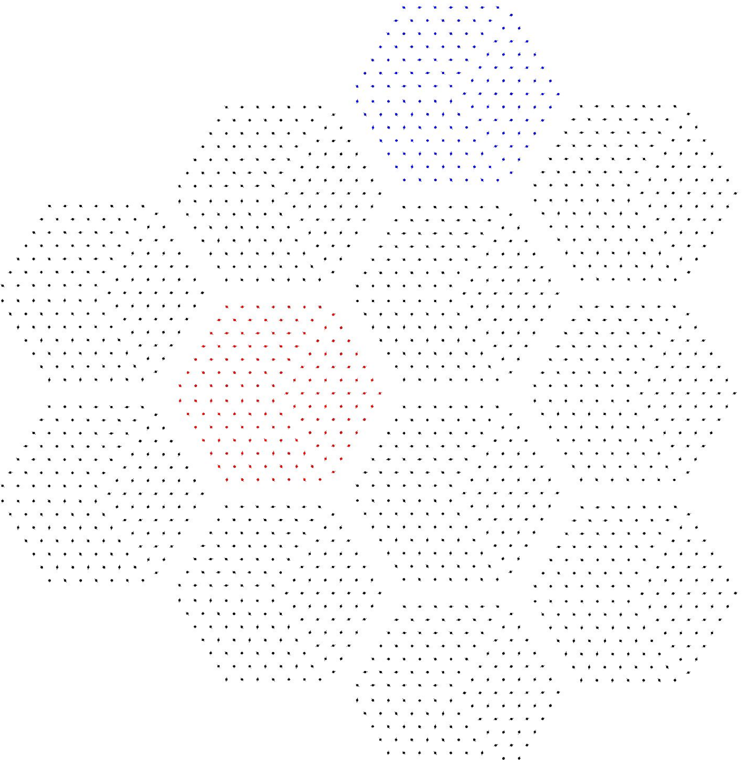
Now following up on this analysis to update experiment configuration and explore discrepancies with SO analysis of the same systematic.

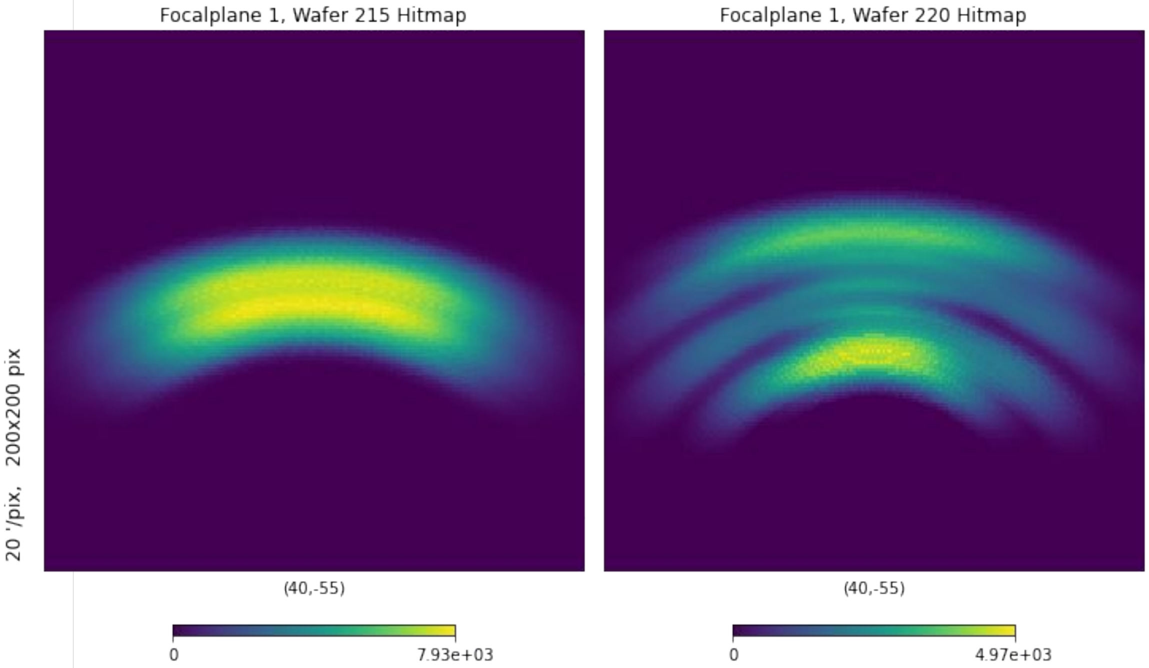
Framework for wafer/detector variations

- Use TOD simulation and mapmaking tools to generate per-wafer (and eventually per-detector) hit maps for a representative set of observations.
- Generate simple map-based sims of CMB, foregrounds, and noise and use hit maps to “paint on” systematic effects.
  - Potential simplifications include “fake delensing”, zeroing out E modes to avoid the need for pure-B estimators, etc.
- Analyze map-based sims using tools developed in Low-ell BB AWG. Measure realization-by-realization shifts in maximum likelihood value of r between sims with and without systematic effect.

Framework for wafer/detector variations

Worked example by Jeremy Webb (Cincinnati undergrad): per-wafer variations in band center frequency (1% or 5% random errors)





Framework for wafer/detector variations

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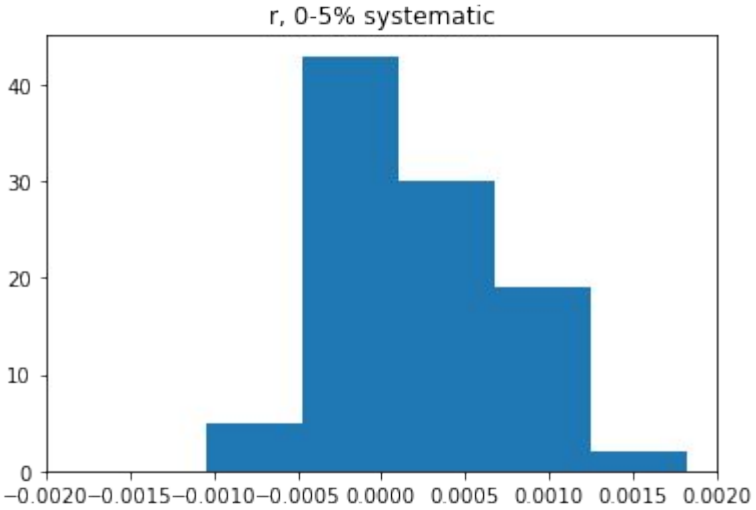
- Finds that 1% random errors (across all wafers, all frequency bands ≥ 85 GHz) causes random shifts in r ~ 1e-4 and doesn't significantly increase σ(r).
- Finds that 5% random errors causes random shifts in r ~ 6e-4 and severely degrades σ(r).
- Would be interesting to see if this effect shows up as dust decorrelation in analysis.
- Could repeat with LF bands and synchrotron.



Framework for wafer/detector variations

Additional systematics that could be explored with this framework:

- Polarization angle errors
- Gain and/or beam size variations
- Additive systematic from residual T→P leakage

Potential technical improvements

- Per-detector hit maps
- Draw detector weights from distributions that capture imperfect yield and variation in sensitivity across detectors, time.
- Better integration with Low-ell BB analysis pipelines.

Lessons learned from systematics studies can inform choices made for DC2.