Design Validation: Tensor-to-scalar ratio (r)

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for the Low-ell BB Analysis Working Group
2021-03-11 // CMB-S4 Collaboration Meeting
Validation across 6 Data Challenges, including multiple foreground models.

- Achieved Performance from S3 datasets
- Scalable Instrument Specification & Sky model
- Semi-analytic Forecasting Framework
- Optimized Forecasting for \( r \)
- Optimized Detector Allocation
- Baseline Survey Definition
- DC parameter recovery:
  - sensitivity
  - biases
  - derivatives w.r.t. survey design
- Independent Analysis Methods
- DC map synthesis:
  - standardized, version-numbered, data challenge map sets
- Cost Model:
  - cost scaling of instrument specification

(Well-attended session: 50+ attendees)

Walked through how the relative hitmaps from BK and from DM PBDR are used to generate this set of noise maps: simpler method than previous DCs.

Outstanding issue: effects that produce $\ell_{\text{knee}}$ and $\alpha_{\text{knee}}$ in $N_{\ell}$ in current experiments may scale less quickly with number of detectors. Current experiment folks need to do deep dive in these data to produce useful input for S4 sims.

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**Generation of simulated maps a la performance-based forecasting**

$$N_{\ell,S4} = \frac{N_{\ell,BK} w_{\text{BK}, \text{achieved}}}{w_{\text{S4}, \text{projected}}} \frac{B_{\ell,S4}^2}{B_{\ell,BK}^2}$$

Where data cuts from e.g. weather, systematic cuts, and observing efficiency enters

$$\frac{w_{\text{S4}, \text{projected}}}{w_{\text{BK}, \text{achieved}}} = \frac{n_{\text{det-yr}}}{n_{\text{det-yr}}} \frac{N_{\text{NET}_{\text{BK}, \text{ideal}}^2}}{N_{\text{NET}_{\text{S4}, \text{ideal}}^2}}$$

Where det counts and years of obs enter

Where instrument parameters that controls det NET can enter: currently 100mK bath temperature, different bandwidths

- Walked through how the the relative hitmaps from BK and from DM PBDR are used to generate this set of noise maps: simpler method than previous DCs.
- Outstanding issue: effects that produce $\ell_{\text{knee}}$ and $\alpha_{\text{knee}}$ in $N_{\ell}$ in current experiments may scale less quickly with number of detectors. Current experiment folks need to do deep dive in these data to produce useful input for S4 sims.
DM design tool sims incorporate effects on data cuts using inputs from current experiments (on-sky time, data cut fraction)

- Ratio of noise between the two approaches are close to 1, but should be even closer given that the overall efficiency numbers are taken from BK.

Discussion:
- How should we approach modeling the Chilean SAT noise?
- What are entry points to granularize this scaling to aid margin building?
**Data Challenge 06 results**

- Map-based sims following the DSR instrument configuration (06)
  - 00, 07, 09 denote three Galactic foreground models
  - 95GHz vs ILC denote input map for lensing B template construction

<table>
<thead>
<tr>
<th></th>
<th>without decorr</th>
<th>with decorr</th>
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</thead>
<tbody>
<tr>
<td>ILC Gauss fg</td>
<td>0.08 ± 0.45</td>
<td>0.09 ± 0.53</td>
</tr>
<tr>
<td>ILC Vansyngel fg</td>
<td>2.8 ± 0.6</td>
<td>0.28 ± 0.67</td>
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(values multiplied by 1000)
Most recently, incorporating realistic delensing with foreground cleaning and iteratively reconstructed lensing templates.
Lensing templates on DC06 sims

- First real map-based delensing validation including foregrounds and using curved-sky iterative lensing map algorithm on S4 sims.
- Residual AL goal of 0.1 met for all three foreground models; using input maps that are ILC of the input freq.
- More complex foreground models?

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<thead>
<tr>
<th>(values multiplied by 1000)</th>
<th>r=0</th>
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Continuing to work on systematics (SAT and LAT), improved foreground models, alternate analysis techniques, support of PBD.
Foreground model updates

- Pan-experiment Galactic Science group + PySM3 development
- Updated templates for dust: use GNILC dust to avoid CIB contamination
- Currently filling in small-scale polarization using Frolov model, a recipe that generate non-Gaussianity in Q/U space.
  - Next steps include using ML, MHD, and basing on other ancillary data (HI, WISE)
- Adding CO polarization
- Towards building 3D/multi-layer models to capture LOS effects

Fig by Giuseppe Puglisi
Bayesian r analysis

- Jointly sample phi, CMB, fg fields, cosmological and nuisance parameters given SAT and LAT data.
- At S4 noise levels, flat-sky analysis with curvature correction recovers similar residual AL as curved-sky analysis.
- Bayesian sampling possible for S4 deep survey.

Frolov model dust
Sketch towards incorporating SAT and LAT systematics

- Many instrumental systematic effects
  - Need prioritization informed by experience and measurements from current experiments
  - Potentially an infinite task; early coordination with various instrument group important
- For CDT, looked into modeling SAT systematics as additive and multiplicative effects in spectra.
- Effort with John R. and Jeff M. to generate map-based systematics maps
  - Overlap with DM simulation of systematics, which is timestream-based.
- Highly cross-cutting activity -- intersections with flowdown, SAT/LAT (esp. calibration), detectors/readout/modules, sites/EMI, and data management (for analysis mitigation and perhaps sims).

PBDR prep

- Groundwork in place for low-ell BB data challenge 07 updating the noise numbers (esp. the LAT; SAT noise similar) to match those in the PBD instrument.