LiteBIRD's Projected Constraints of Inflationary Models

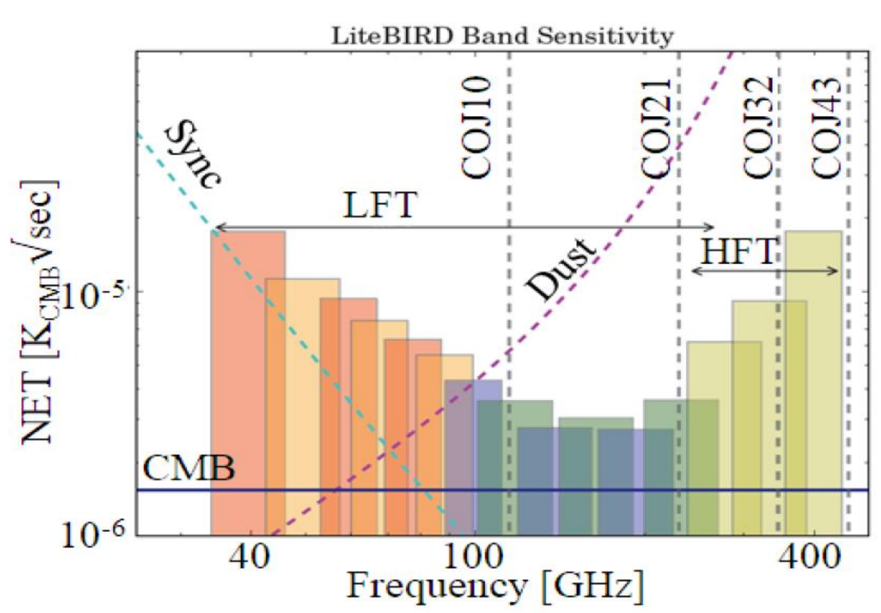
Simran Nerval[1,2,★], Renée Hložek[1,2], Victor Chan[1,2], Matthew Dobbs[3], Joshua Montgomery[3], Graeme Smecher[4] ★ simran.nerval@gmail.com

1. Department of Astronomy and Astrophysics, University of Toronto
2. Dunlap Institute for Astronomy and Astrophysics, University of Toronto
3. Department of Physics, McGill University
4. Three Speed Logic

LiteBIRD and Cosmological Parameters

LiteBIRD

- LiteBIRD is a proposed Japanese satellite with the primary objective to measure the B-mode polarization of the cosmic microwave background (CMB).



Left: Summary plot of LiteBIRD systematics. It shows the sensitivity of each of the fifteen frequency bands, which bands are covered by the low frequency telescope (LFT) and the high frequency telescope (HFT), and the signal levels of the CMB, synchrotron radiation, and dust.

- The data from LiteBIRD will be used to map the CMB in the multipole range of $2 \leq \ell \leq 200$ (full sky to 1^o).
- **This work (funded by the CSA), helps achieve LiteBIRD's goal of placing upper limits on gravitational waves from inflation.**

Above: Artist rendition of LiteBIRD.

Parameters of Interest

- The scalar spectral index (n_s) corresponds to the slope of the scalar power spectrum.

$$\mathrm{P}_s(k) = \mathrm{A}_s(k_*)\left(\frac{k}{k_*}\right)^{n_s - 1}$$

- The tensor-to-scalar ratio (r) is the measure of these tensor perturbations (from primordial gravitational waves) compared to scalar perturbations (density of matter). In other words, it is the changes in spacetime compared to the density of matter.

$$\mathrm{P}_T(k) = \mathrm{A}_T(k_*)\left(\frac{k}{k_*}\right)^{n_T}, \qquad r = \frac{\mathrm{P}_T}{\mathrm{P}_s}$$

- For this study $r = 0.01$ and $n_s = 0.9655$ was used.

Fisher Forecasts and Satellite Simulations

Fisher Matrix and Noise

Fisher Matrix

$$F_{ij} = \sum_{\ell} \frac{\partial C_\ell^T}{\partial \theta_i} C_\ell^{-1} \frac{\partial C_\ell}{\partial \theta_j}$$

Knox's Formula

N_{white} in formula below

$$\Delta C_\ell = \sqrt{\frac{2}{(2\ell+1)f_{\text{sky}}}}\left[C_\ell + (\Delta T)^2 \exp\left(\frac{\ell(\ell+1)\theta^2_{\text{FWHM}}}{8\ln 2}\right)\right]$$

Replace white noise term above with this

$$N_\ell = N_{\text{white}}\left(1 + \left(\frac{\ell}{\ell_{\text{knee}}}\right)^{\alpha_{\text{knee}}}\right)$$

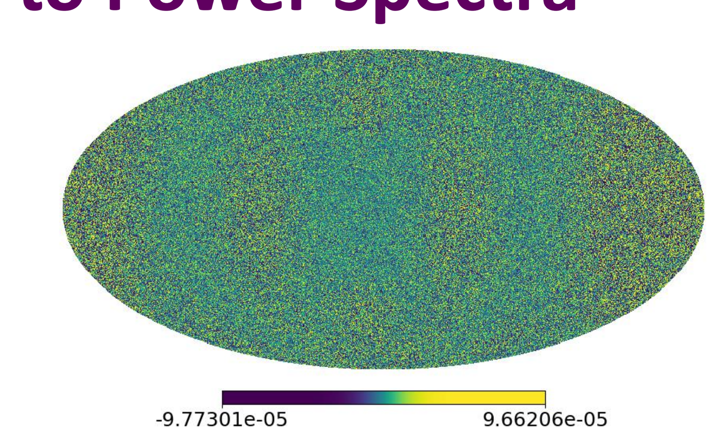
$1/f$ Noise contribution

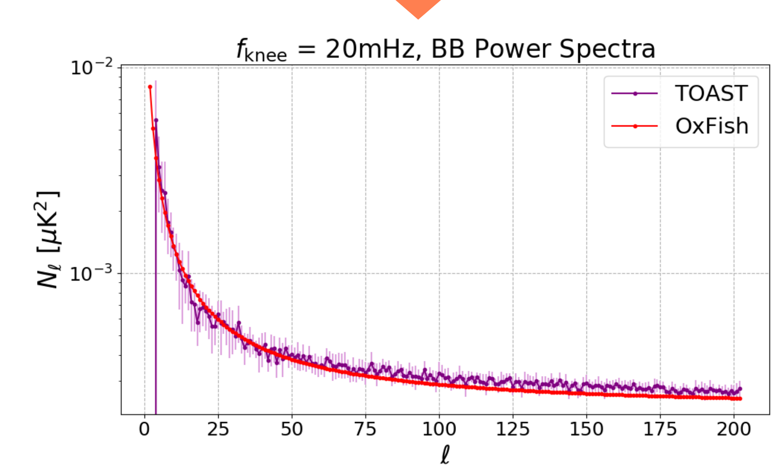
Covariance matrix of the parameters

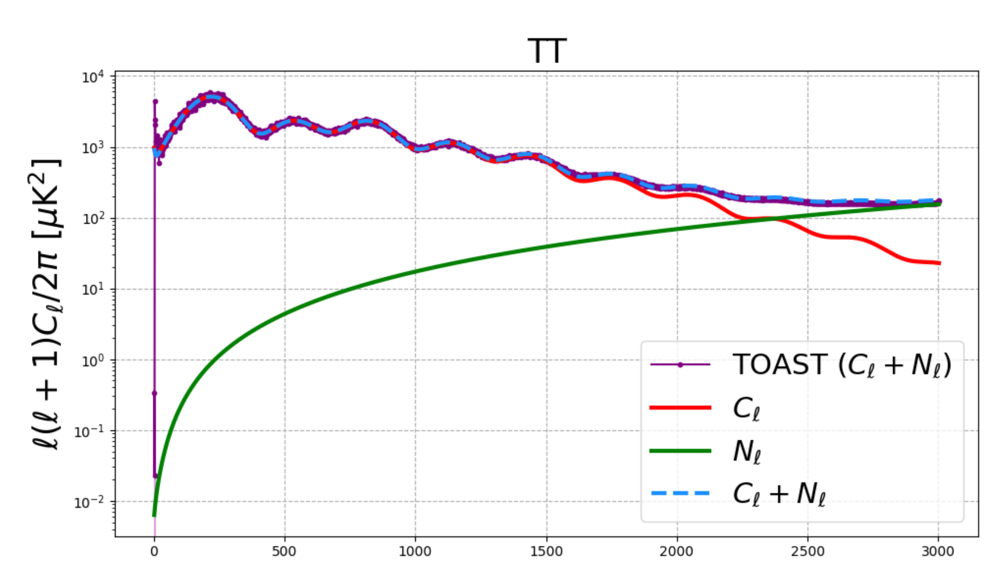
$$\mathbb{C}_{ij} = \left(F^{-1}\right)_{ij}$$

Simulated Maps to Power Spectra

1. Simulate noise maps using CMB simulation software (TOAST).
2. Make power spectra (TT, EE, and BB) and characterize noise parameters.
3. Use noise parameter values found with TOAST in Fisher Forecasting Code (OxFish) and confirm that the simple noise model describes the true power spectrum of the simulations.





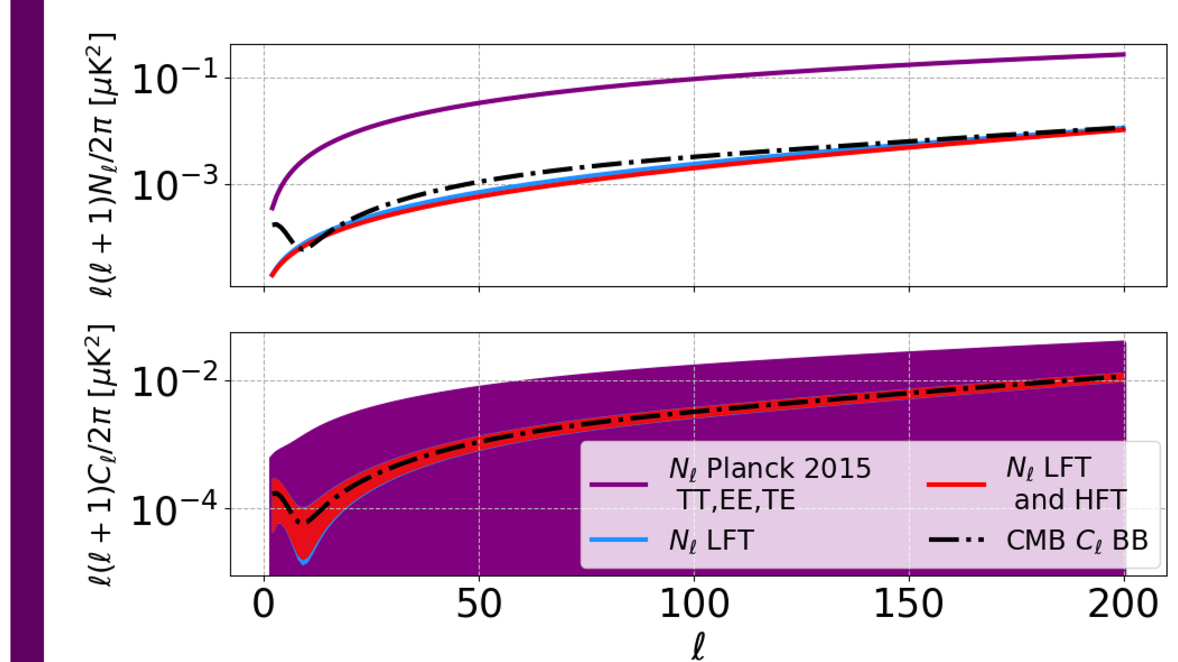


Left: Example of TOAST TT power spectra with CMB signal and noise for the 89 GHz band. Over-plotted is a noise curve from OxFish, the theory TT power spectra, and their sum.

4. Use these noise parameter values in Fisher Forecasts.

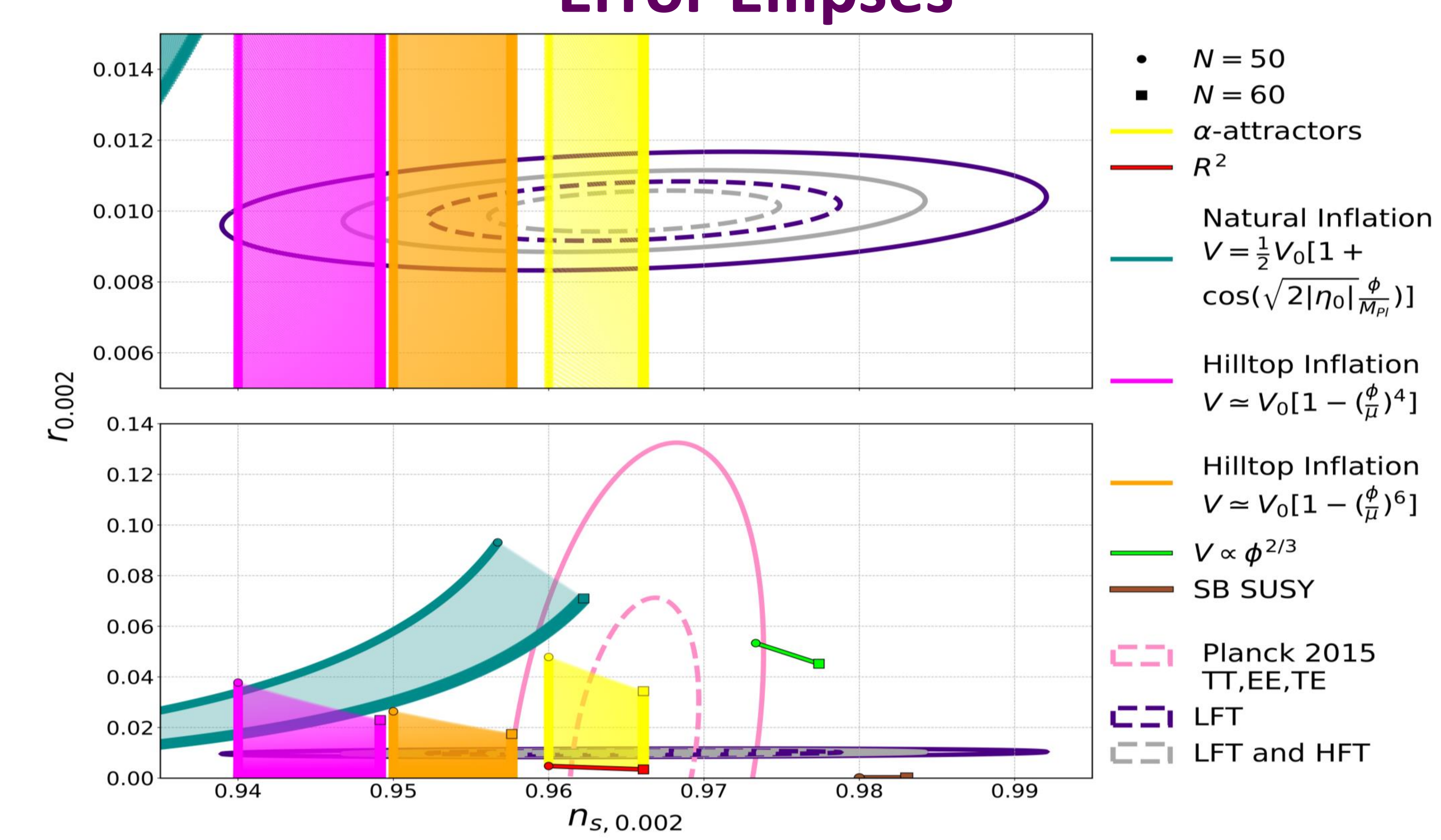
Results and Next Steps

Noise Power Spectra



Left: Top: The Planck 2015 and the projected noise curves for LiteBIRD the LFT and the LFT and HFT. The black dotted line is the BB power spectrum. Bottom: The BB power spectrum with 1σ error contours.

Error Ellipses



Above: Top: Projected LiteBIRD error computed using the TT, EE, and BB spectra with $f_{sky} = 0.9$. The allowed values of r and n_s for different models of inflation are over-plotted. Bottom: The same as the top plot but with the Planck 2015 results as well.

Next Steps

- Use simulated LiteBIRD data perform model comparison to determine relative probabilities between models.
- Combine $1/f$ and cross-talk analyses in order to determine LiteBIRD's projected constraints on inflationary models.

References:

[1] Ade, P., Aguirre, J., Ahmed, Z., et al. 2018, ArXiv e-prints, arXiv:1808.07445.

[2] LiteBIRD. internal documents, Science from LiteBIRD

[3] Suzuki, A., Ade, P. A. R., Akiba, Y., et al. 2018, Journal of Low Temperature Physics, 124

[4] Allison, R., Caucal, P., Calabrese, E., Dunkley, J., & Louis, T. 2015, PhRvD, 92, 123535

[5] Kisner, T. 2018, Time Ordered Astrophysics Scalable Tools (TOAST), https://toast-cmb.readthedocs.io/en/latest/index.html

[6] Tanabashi, M., Hagiwara, K., Hikasa, K., et al. 2018, Phys. Rev. D, 98, 030001

Astronomy & Astrophysics UNIVERSITY OF TORONTO

DUNLAP INSTITUTE for ASTRONOMY & ASTROPHYSICS

McGill Department of Physics Département de Physique

THREE SPEED LOGIC

CSA ASC