ID 262

Systematic effects and foreground cleaning for LiteBIRD satellite

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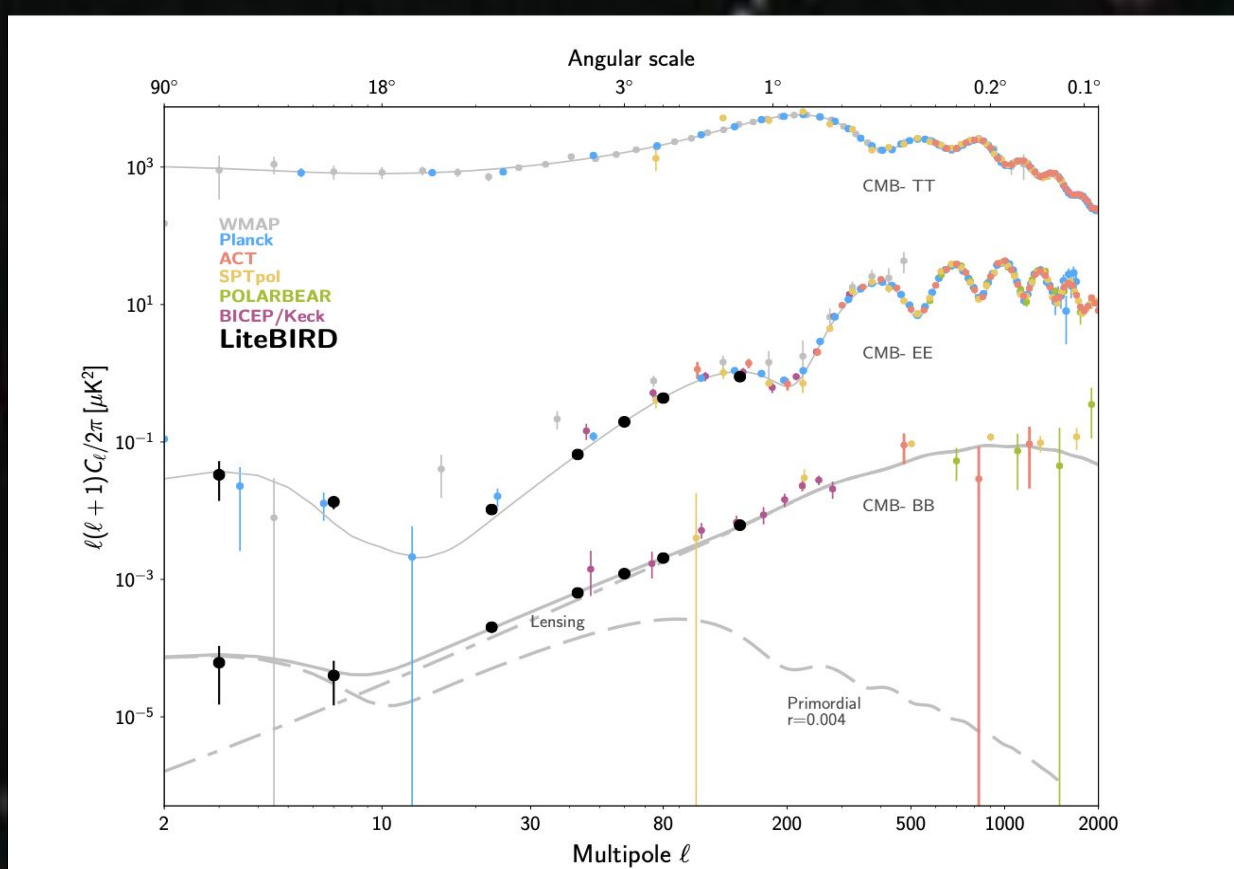
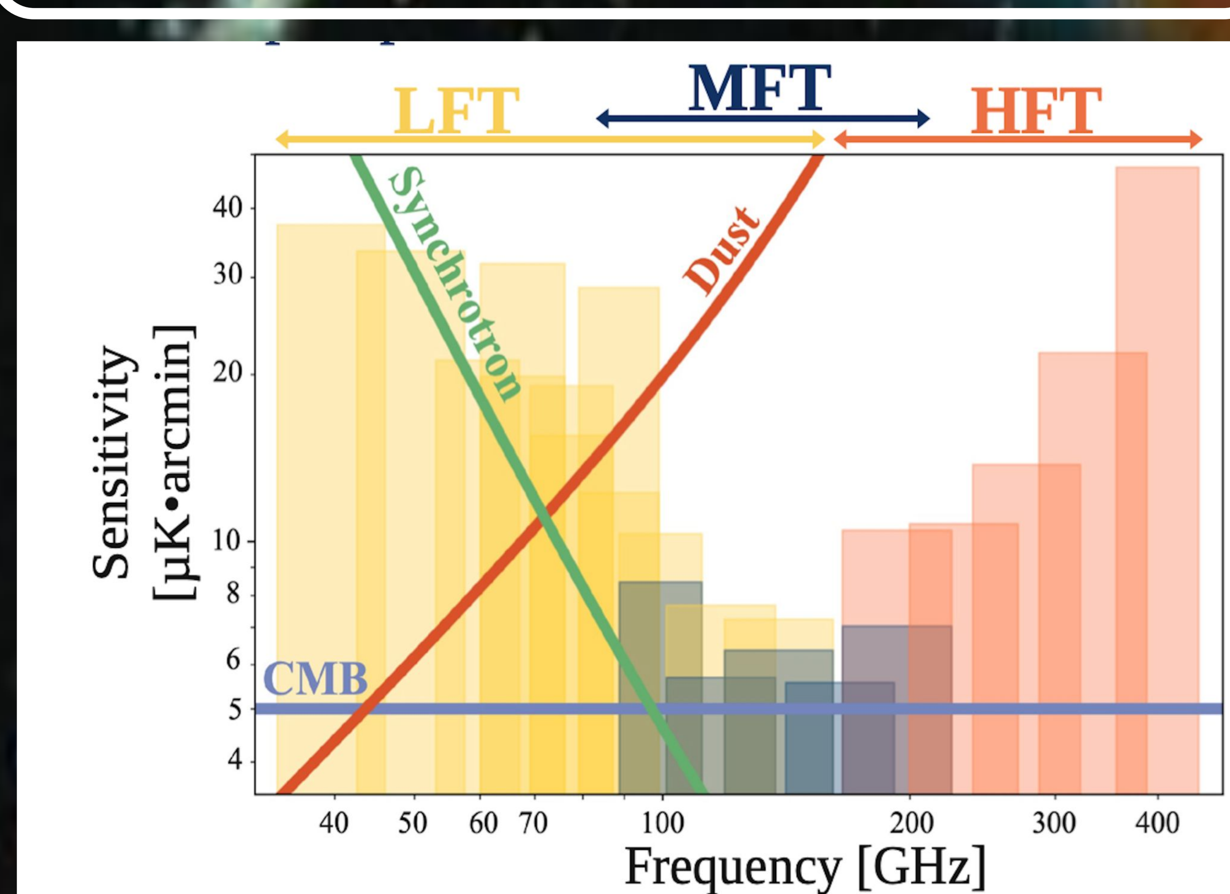
LiteBIRD is a space-borne experiment proposed by the Japanese Aerospace Exploration Agency (JAXA) and gathering a worldwide collaboration. This satellite aim at detecting CMB B-modes polarization which could contain an imprint of primordial gravitational waves generated by cosmic inflation. LiteBIRD will target the tensor-to-scalar ratio r, associated to the amplitude of primordial tensor perturbations (compared to scalar fluctuations) with a total uncertainty of $\sigma_r < 10^{-3}$ by measuring both reionization and recombination bumps of the CMB B-modes power spectrum.

Scientific target of LiteBIRD



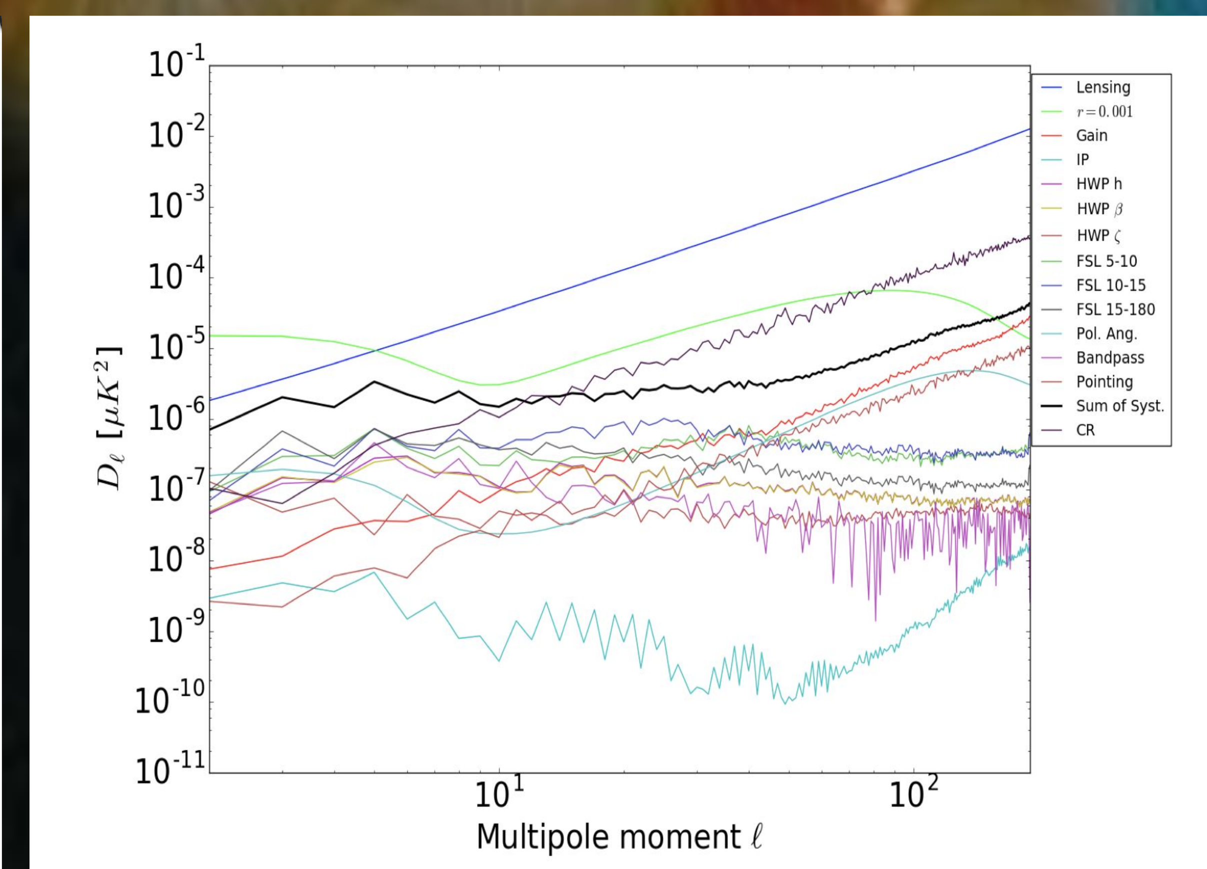
TT, EE and BB CMB angular power spectra
LiteBIRD will cover a multipole range up to ℓ = 200 to measure the reionization and recombination bumps of the CMB BB power spectrum.

Contamination by Galactic foregrounds



Sensitivity of LiteBIRD over the frequency bands
LiteBIRD will observe the sky in a frequency range from 34 to 448 GHz to characterize synchrotron (dominant at LF), dust emission (dominant at HF) and the CMB signal.

Systematic effects



Angular power spectrum of the systematic effects
The systematic effect arise from an imperfect characterization/calibration of the instrument. Oneway to control the impact of systematics is to set requirements on the calibration of a specific effect.

Setting requirements on the gain calibration accuracy

- **Simulate multi-frequency B-modes maps of CMB (r=0), synchrotron and dust + gaussian white noise**
- **Inject a gain mis-match at a specific channel and let the other channels unperturbed $g = 1 + N(0,\Delta g)$**
- **Apply component separation on the set of maps containing the systematic effect and on the twin set of maps with ideal calibration (g=1)**
- **Estimate the tensor-to-scalar ratio value in both cases and determine the systematic bias**
- **Find the value of the gain calibration accuracy Δg for which the resulting mean bias is equal to the gain systematic budget per channel** ($6.5.10^{-6}/22$)

Foreground cleaning : Needlet Internal Linear Combination (NILC)

ILC-type methods consist in performing a linear of frequency data to minimize the variance of the output.

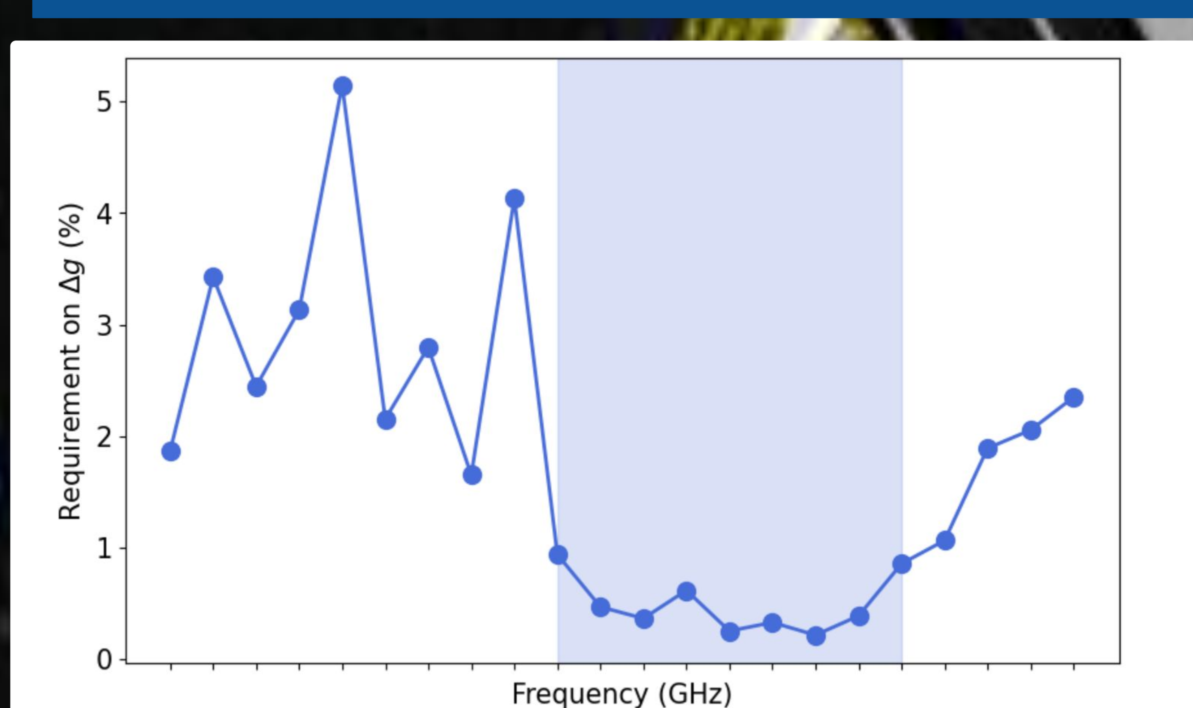
$$X_{CMB} = \sum \omega_\nu . X^\nu = \sum w_\nu . (a_{CMB} X_{CMB} + X_{fg}^{\ \nu} + X_n^{\ \nu})$$

$$\sum w_\nu . a_{CMB} X_{CMB} = X_{CMB}$$

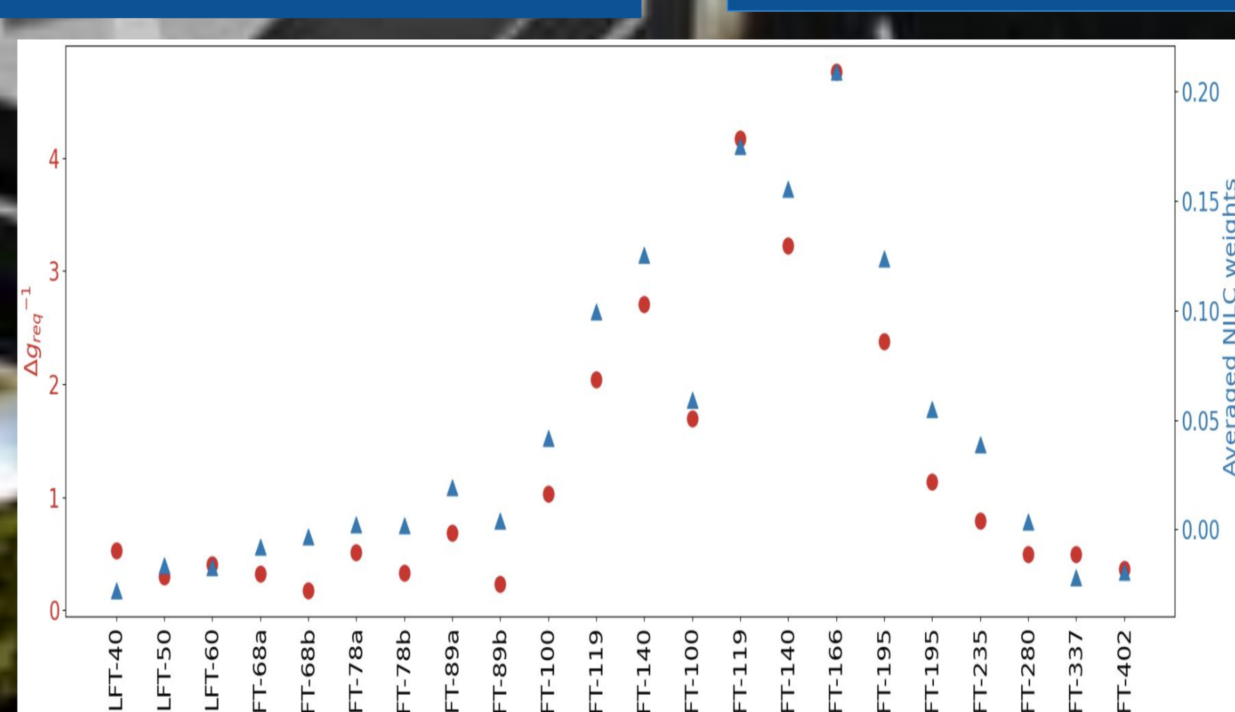
Likelihood estimation of the tensor-to-scalar ratio

Probability distribution function for an observed power spectrum C_ℓ^{obs} to match a theoretical model C_ℓ^{th}

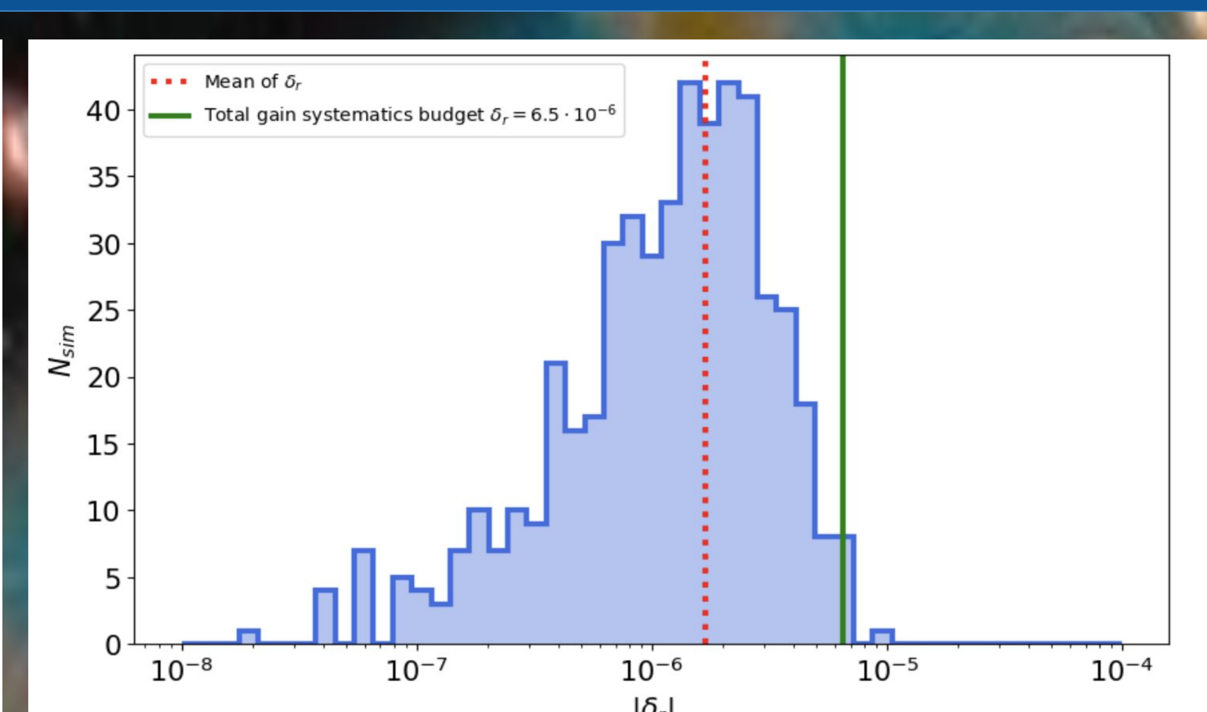
$$\mathcal{L}(C_\ell^{obs}|r) = \sum 2\ell+1 \, f_{sky} \, [C_\ell^{obs}/C_\ell^{th} + \ln(C_\ell^{th}) - 2\ell-1/2\ell+1 \, . \, \ln(C_\ell^{obs}) \,]$$



Requirements on the gain calibration accuracy
The most sensitive frequency channels are those at CMB frequencies (0.22% for the 166 GHz) while low and high frequency channels possess a requirement larger than 1%.



Anti-correlation between the requirements on the gain calibration accuracy and the NILC weights
The frequency channels most affected by gain mis-calibration are those contributing the most to the CMB reconstruction process : characteristic of an analysis with ILC, the observation is different when employing parametric component separation.



Bias distribution obtained when all channels are mis-calibrated simultaneously by their corresponding requirements
The resulting mean bias is below the total gain systematic budget by a factor of 3.5

F.Carralot, N.Krachmalnicoff, A.Carones et al. *Requirements on the relative polarization gain calibration for LiteBIRD with blind component separation* (in prep.)
T.Ghigna, T.Mastumura, G.Patanchon . *Requirements for future CMB satellite missions : photometric and band-pass response calibration (2020)*
M.Hazumi *LiteBIRD: A Satellite for the Studies of B-Mode Polarization and Inflation From Cosmic Background Radiation Detection* (2019)
A.Carones, M.Migliaccio, G.Puglisi et al. *Multi-Clustering Needlet ILC for CMB ℬ-mode component separation* (2023)
J.Dick, M.Remazeilles, J.Delabrouille *Impact of calibration errors on CMB component separation using FastICA and ILC* (2009))