



# Realistic Beams, Non-Ideal HWPs: Quantifying Systematics and Cosmic Birefringence for Next-Gen CMB Cosmology

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Next-generation CMB experiments are designed to measure CMB polarisation with unprecedented precision, targeting new physics beyond the Standard Model, like the **Cosmic Birefringence effect**. Achieving these goals requires exquisite control of instrumental systematic effects. Therefore, it is crucial to quantify the impact of **realistic Beam and Half-Wave Plate (HWP) systematics** for future data.

## beamconv: TOD WITH REAL HWP AND FULL-SKY BEAM CONVOLUTION

### beamconv

**FIRST TIME-DOMAIN SIMULATIONS THAT INCLUDE BOTH HWP NON-IDEALITIES AND REALISTIC FULL-SKY BEAM CONVOLUTION**

Open-source spherical harmonic beam convolution algorithm

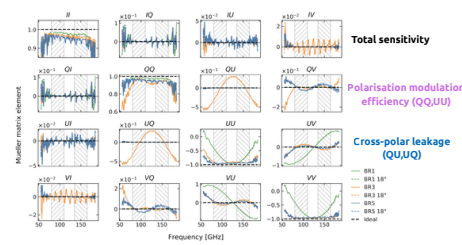
- **Harmonic** representations of the polarised **beam** response and **sky** to generate simulated CMB **time-order data**
- **Arbitrarily shaped beams**
- **Real HWP modulation**



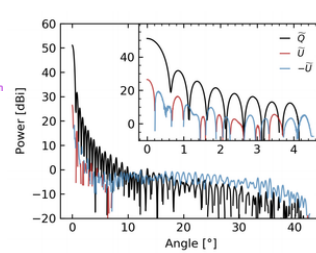
### CONTAMINATION OF THE BB POWER SPECTRUM

TOD simulation of a two-lens refractor telescope with (achromatic) HWPS and PO beam

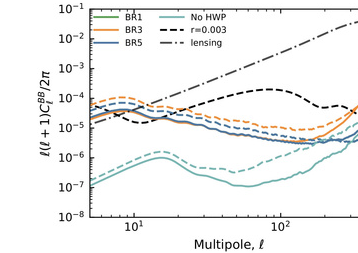
#### HWP MUELLER MATRIX



#### BEAM PROFILE



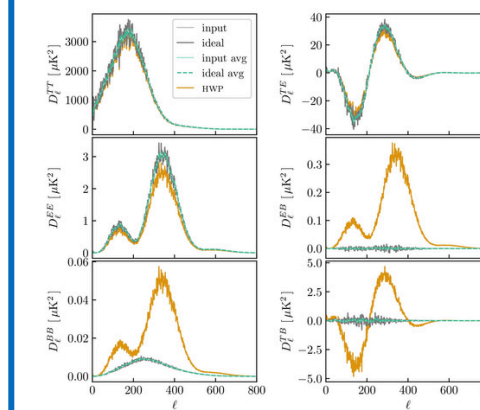
#### RESIDUAL BB SPECTRA



**HWPs RESIDUALS COMPARABLE TO THE B-MODE AMPLITUDE WITH  $r=0.003$**

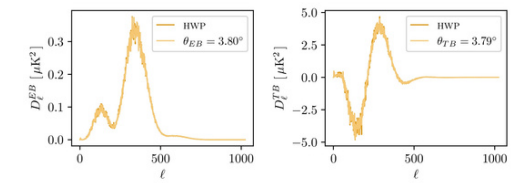
### IMPACT OF HWPS NON-IDEALITIES ON CB ANGLE

Investigating the impact of realistic HWP systematics on isotropic CB using beamconv simulations.



**SIMULATION SETUP:**  
2-year satellite LiteBIRD-like scanning with 160 detectors at 140 GHz

**HWP NON-IDEALITIES INDUCES A MISCALIBRATION POLARISATION ANGLE WHICH CAN MIMIC CB**



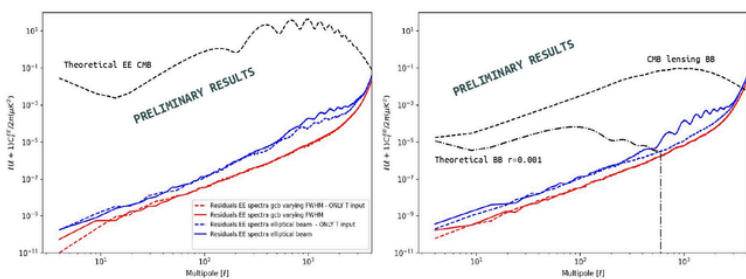
## BEAM SYSTEMATICS within SO and LiteBIRD collaborations

### TIME-ORDERED DATA (TOD) BEAM-CONVOLVED SIMULATIONS USING THE SOTODLIB AND LITEBIRD\_SIM FRAMEWORKS

we utilise **4π beam convolution** to simulate TODs and compare arbitrary beams with Gaussian models: this approach enables us to isolate and quantify beam-induced systematics

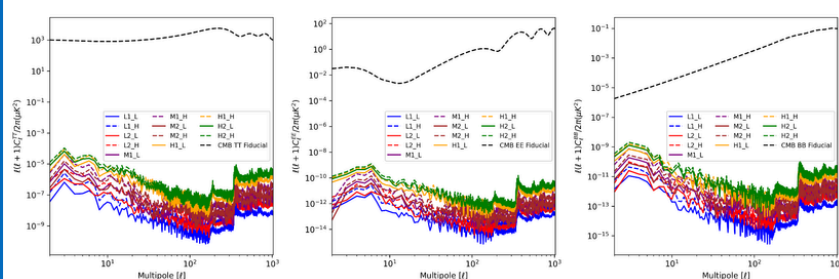
#### SO LAT: MAIN BEAM SYSTEMATICS

#### RESIDUALS POWER SPECTRA FOR LAT WAFER 13 AT 150 GHZ



#### LITEBIRD MDR2 SIMS: FSL BEAM SYSTEMATICS

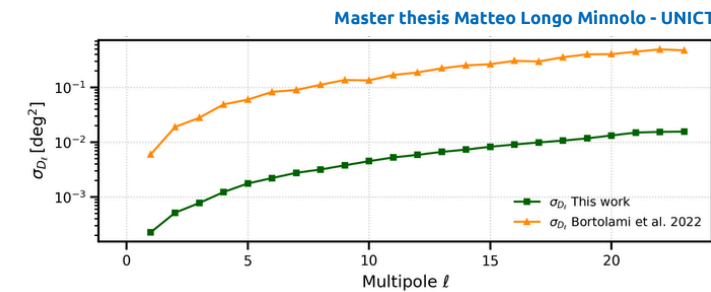
#### RESIDUALS POWER SPECTRA vPOSTKDP2 Option1



## Anisotropic Cosmic Birefringence with Planck data and future forecasts

### SATs-like and LiteBIRD-like forecasts

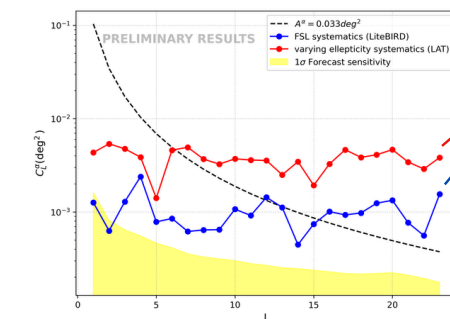
Application of this approach to forecast constraints on the **CB spectrum** for next-generation CMB experiments: simulating observations with a null intrinsic signal and a **white noise level of 2 μK-arcmin**



**COMPARISON WITH THE PLANCK DATA UNCERTAINTIES: CRITICAL INCREASE IN THE CONSTRAINING POWER**

### INSTRUMENTAL SYSTEMATICS ON ANISOTROPIC CB

#### IMPACT OF EXTENDED FSL ON ANISOTROPIC CB MEASUREMENT



Level of systematic evaluated by applying the localisation of the D-estimators to the output maps:  
• **red line:** LAT systematics due to 5% beam ellipticity variation across the focal plane;  
• **blue line:** LiteBIRD systematics due to beam toy model with FSL.

Forecasts for future LiteBIRD-like experiments (white-noise 2 μK-arcmin - Longo's thesis)