The Simons Observatory: Bandpass and polarization angle calibration requirements for CMB B-mode searches

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CMB systematics and calibration focus workshop
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Overview

- Bandpass and polarization angle systematics
- Bias limits
- Marginalization results
- Impact on instrument design
- Frequency dependent beams

https://arxiv.org/abs/2011.02449

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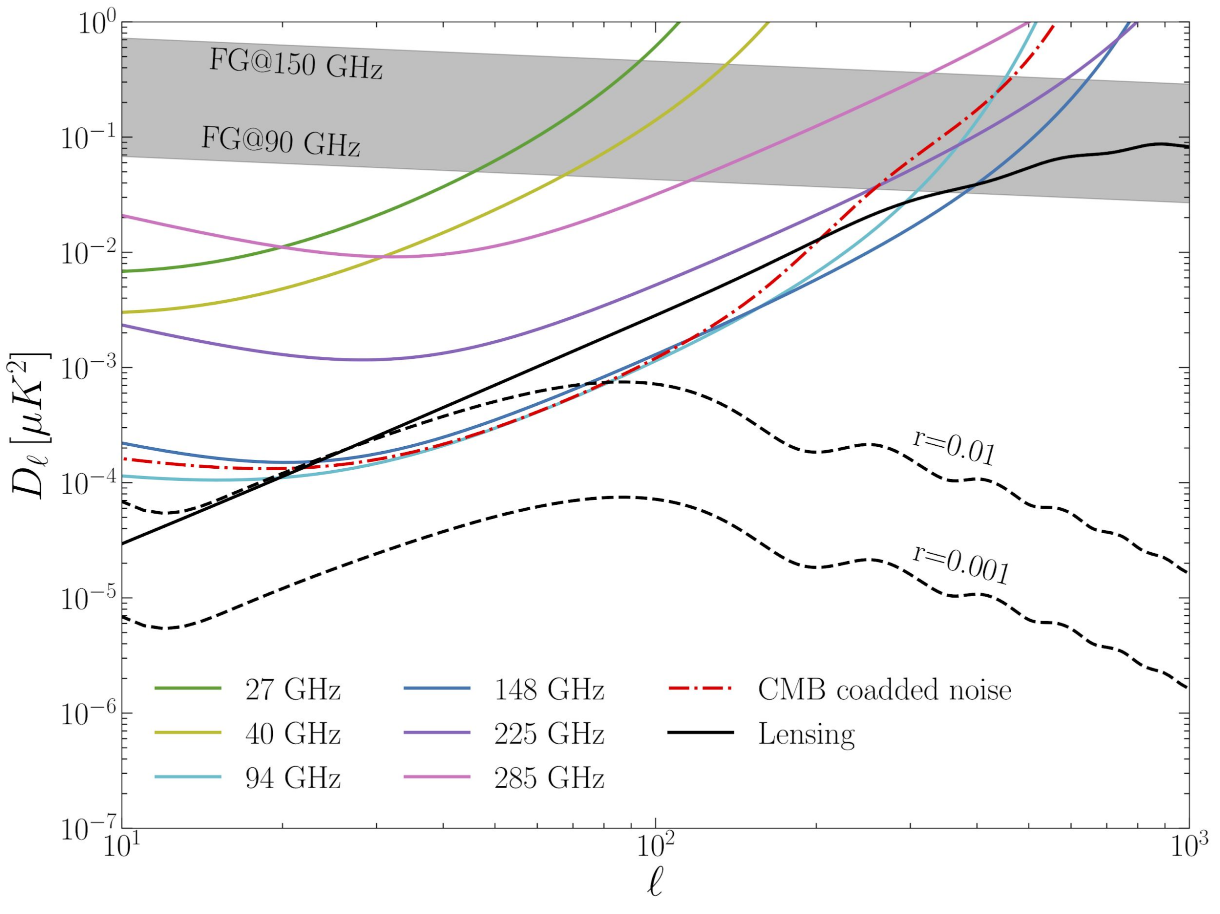
1 minute summary

- We estimate maximum acceptable systematic errors on calibration factors and polarization angles **assuming we can't model them**.
- We marginalize over residual systematics with realistic calibration priors and show that **degradation of r constraint is minimal**.
- We propagate systematic requirements onto final instrument calibration parameters.

Sky signals and SO noise



Bandpasses and frequency dependent polarization angles

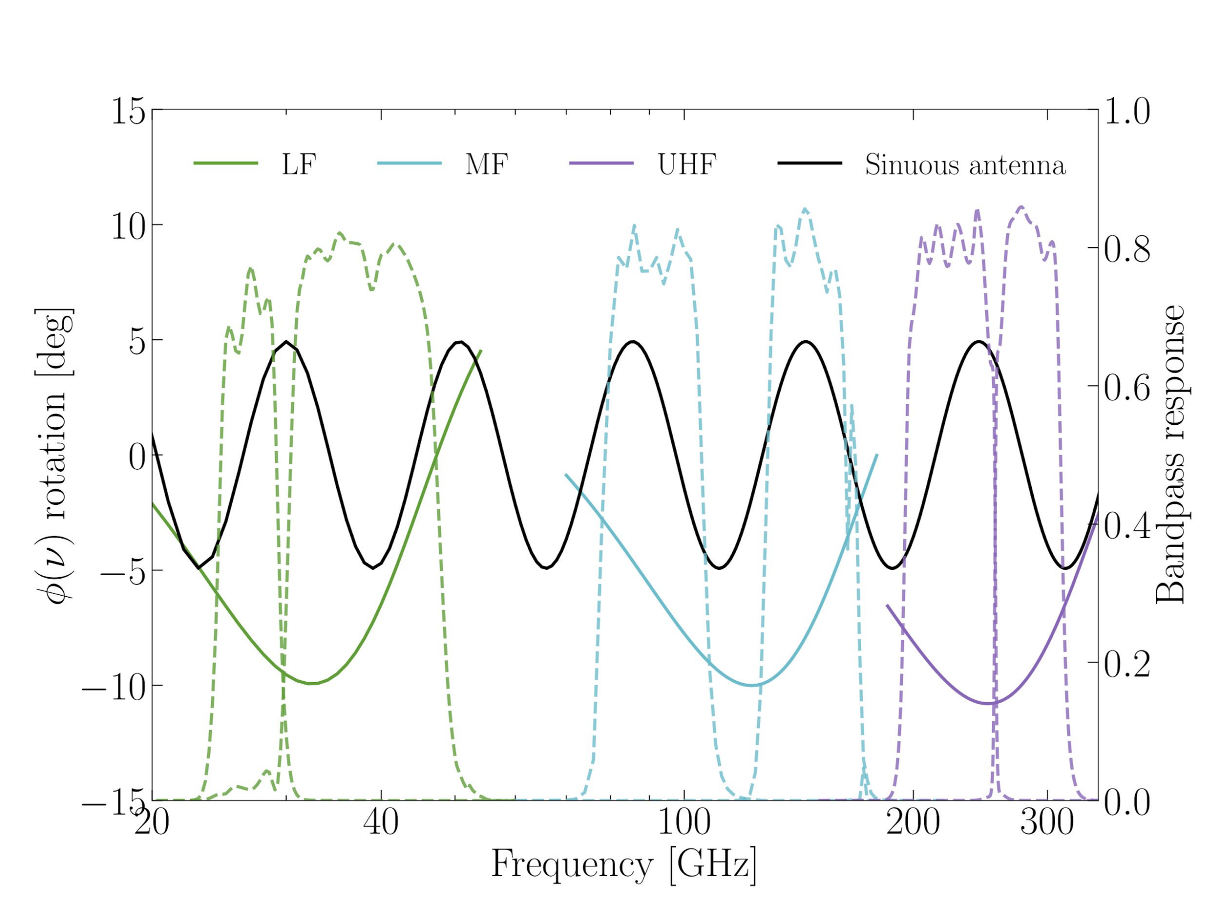
$$C_\ell^{bb',pp'} = \sum_q \int d\nu\, \nu^2\, \mathcal{W}_b^{pq}(\nu) \sum_{q'} \int d\nu'\, \nu'^2\, \mathcal{W}_{b'}^{p'q'}(\nu')\, C_\ell^{\nu\nu',qq'}$$

$$\mathcal{W}_b^{pq}(\nu) \equiv [\mathsf{R}(\phi_b(\nu))]^{pq}\, \frac{1+\Delta g_b}{N_b} W_b(\nu + \Delta\nu_b)$$

$$\phi_b(\nu) = \Delta\phi_{0,b} + \Delta\phi_{1,b}\frac{\nu - \bar{\nu}_b}{\bar{\nu}_b}$$

- Gain shifts
- Bandpass center shifts
- Polarization angle frequency dependence

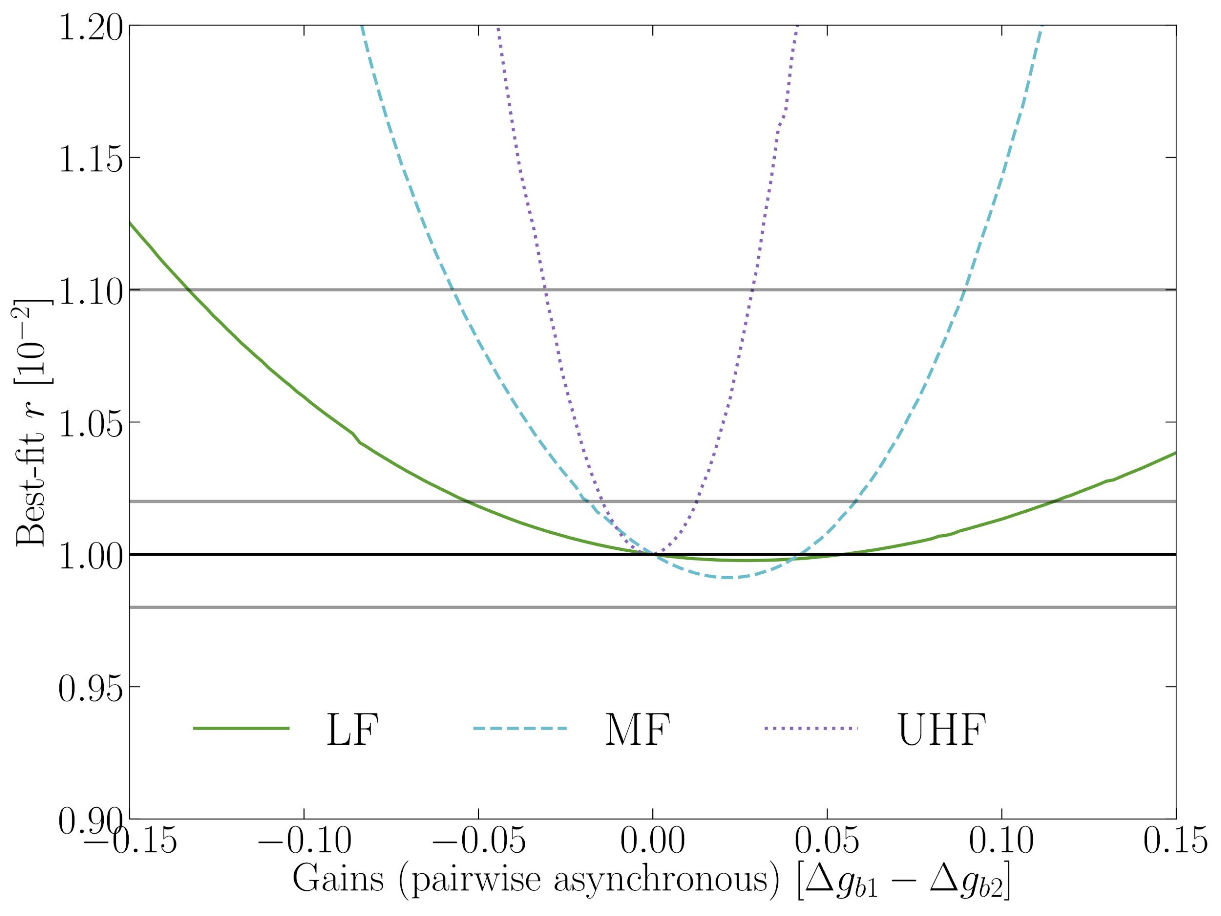
Bandpasses and frequency dependent polarization angles



Bias limits: gains

For Δr < 2e-4:

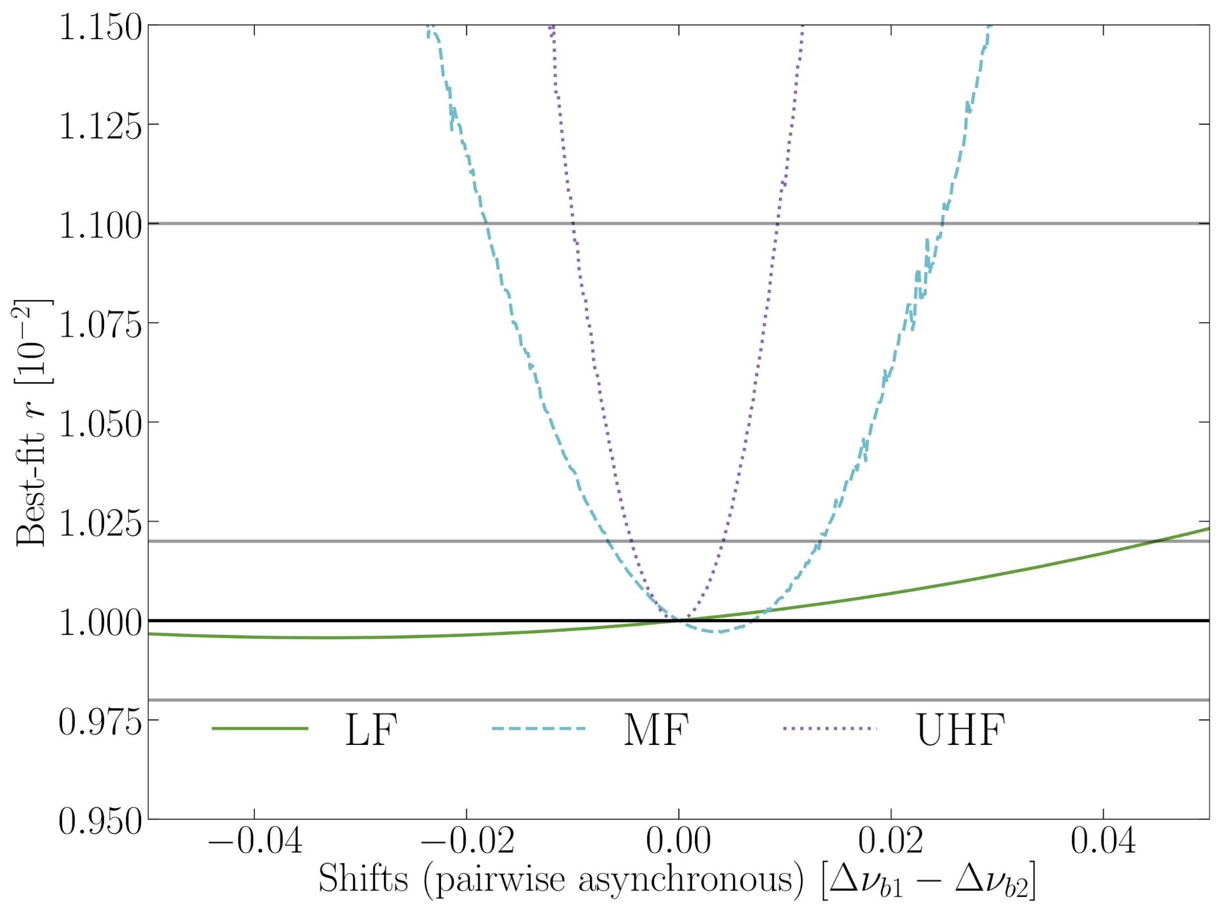
- LF: 2.6%
- MF: 0.9%
- UHF: 0.6%



Bias limits: shifts

For Δr < 2e-4:

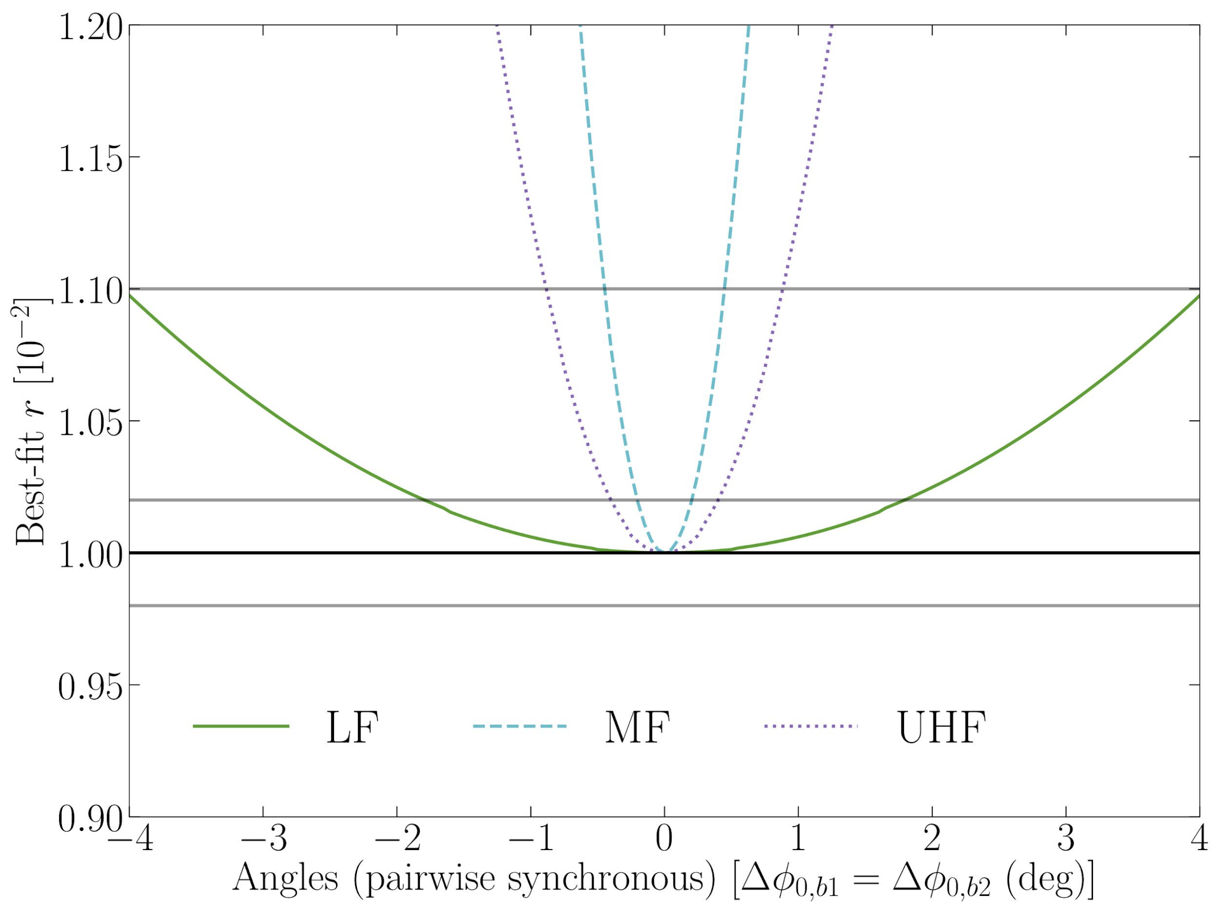
- LF: 2.20%
- MF: 0.33%
- UHF: 0.20%



Bias limits: polarization angles

For Δr < 2e-4:

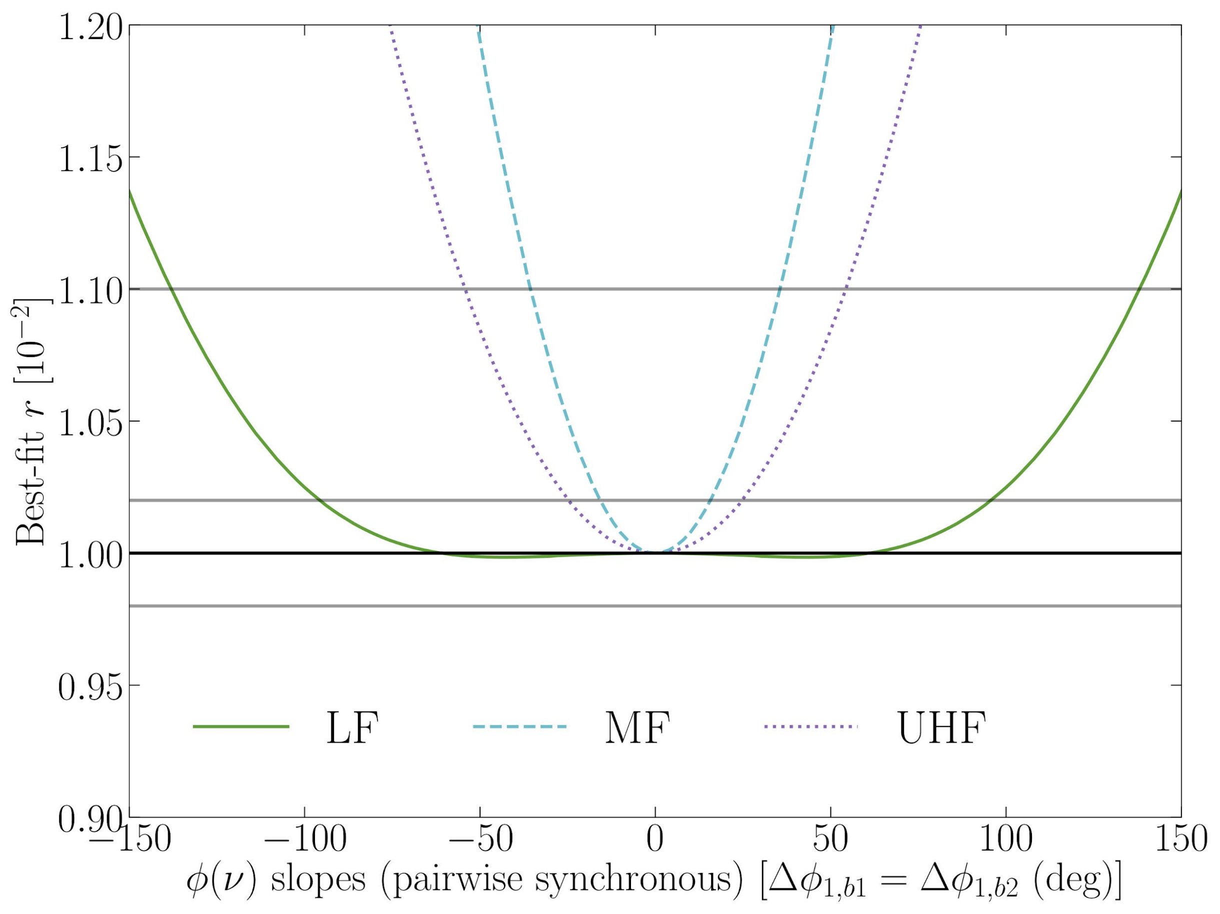
- LF: 1.75 deg
- MF: 0.20 deg
- UHF: 0.40 deg



Bias limits: frequency dependent polarization angles

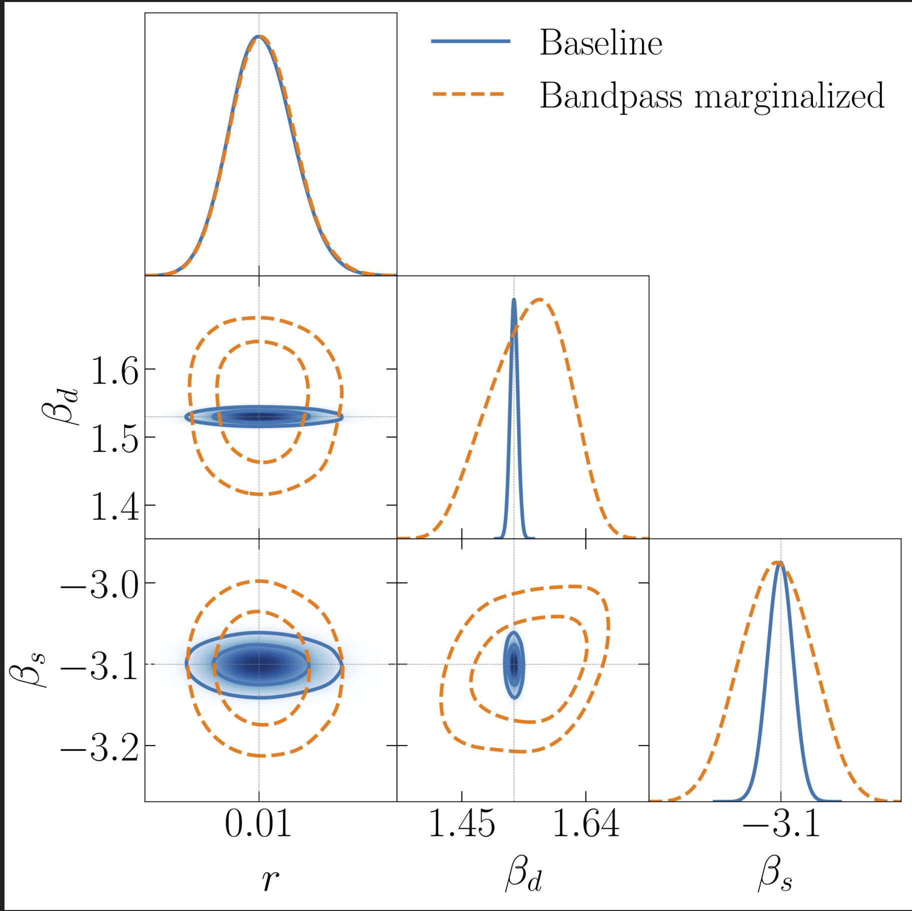
For Δr < 2e-4:

- LF: 94 deg
- MF: 14 deg
- UHF: 24 deg

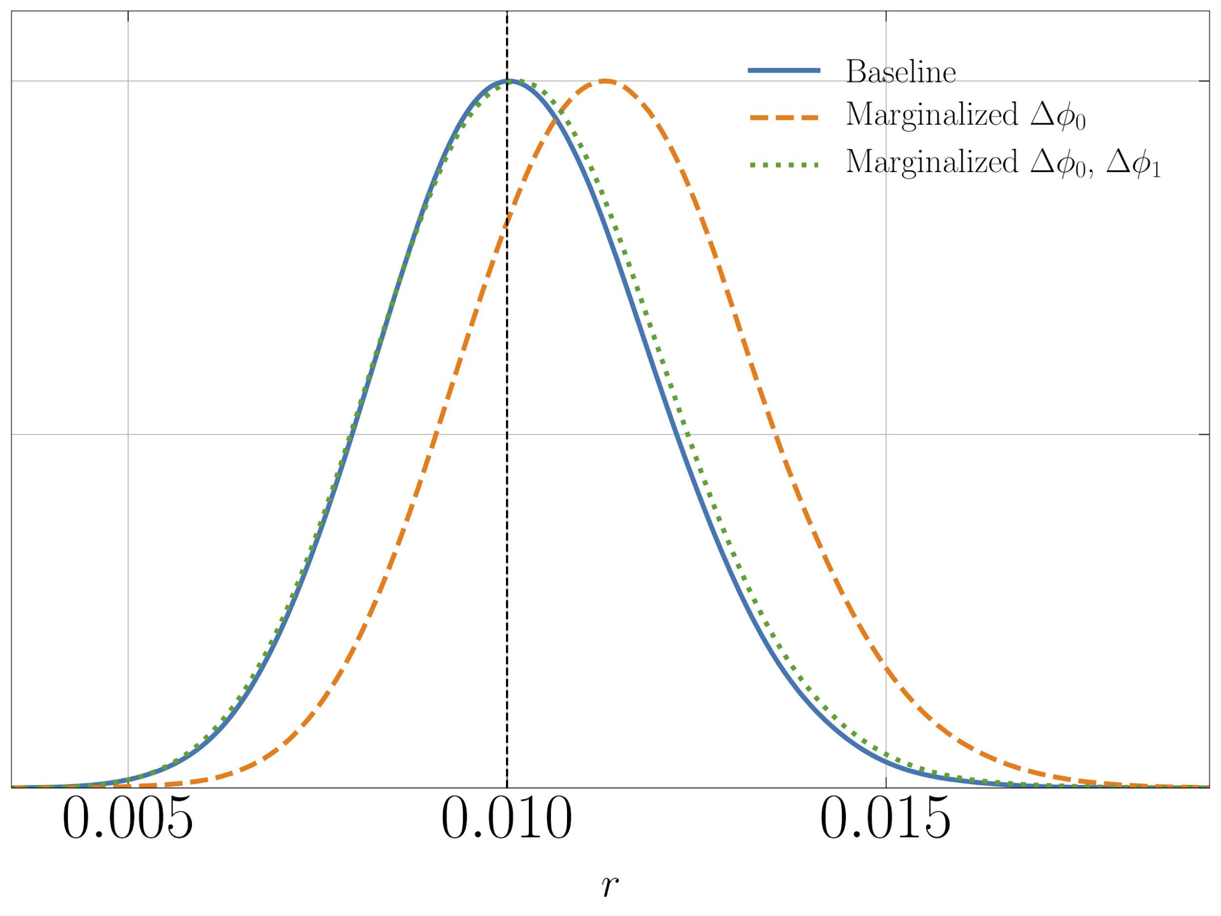


Marginalization results: bandpasses

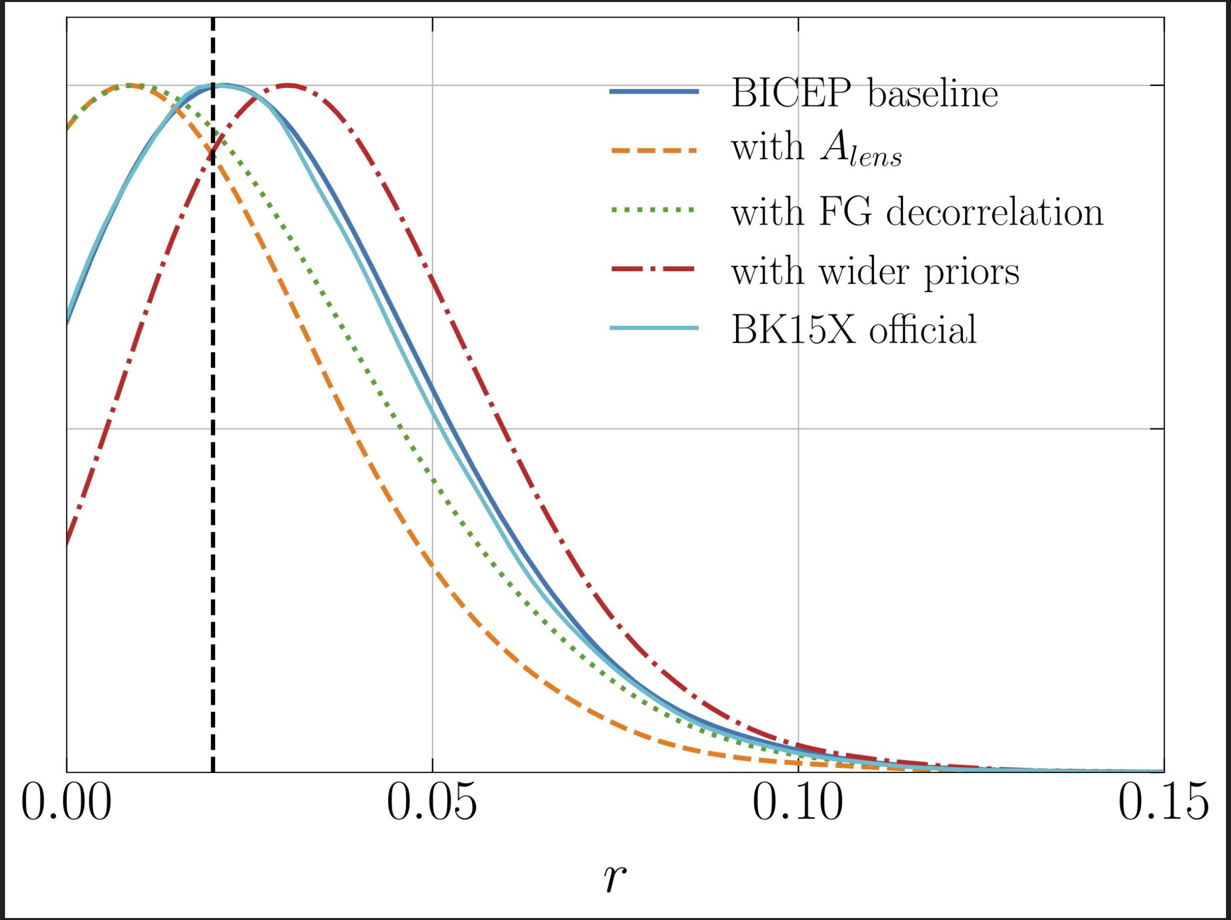
Baseline σ(r) = 1.8e-3
Marginalized σ(r) = 1.9e-3



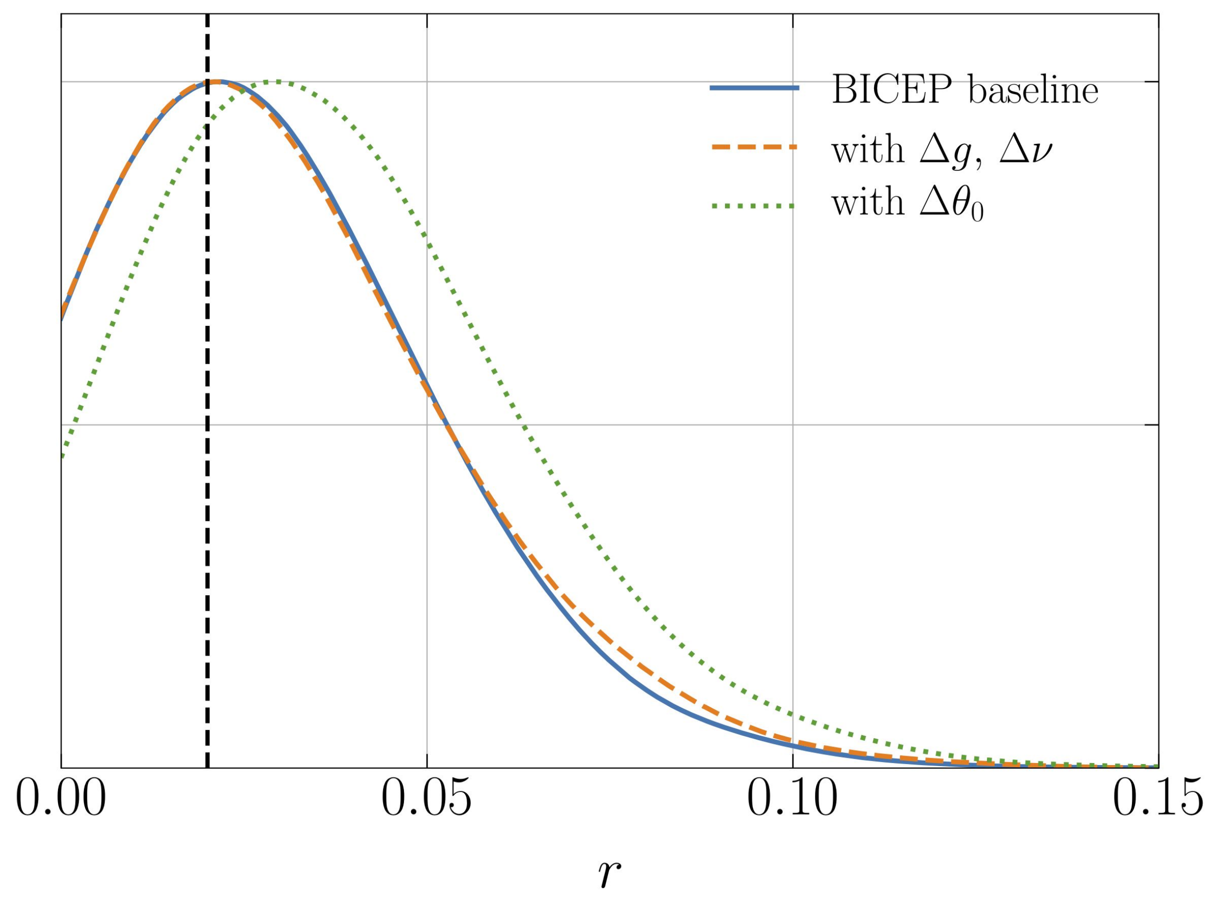
Marginalization results: sinuous antennas



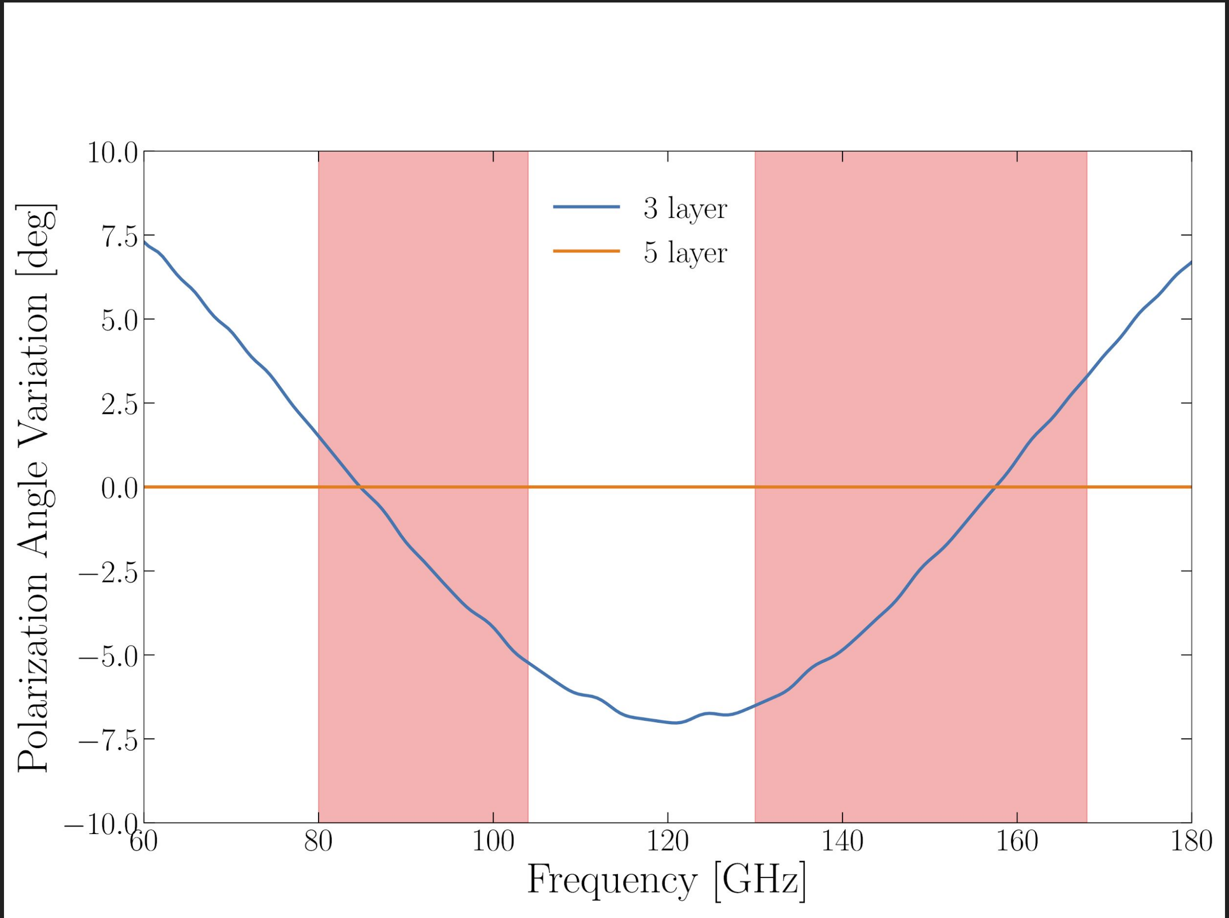
Marginalization results: BICEP/Keck 2015 X - foreground assumptions



Marginalization results: BICEP/Keck 2015 X - systematics

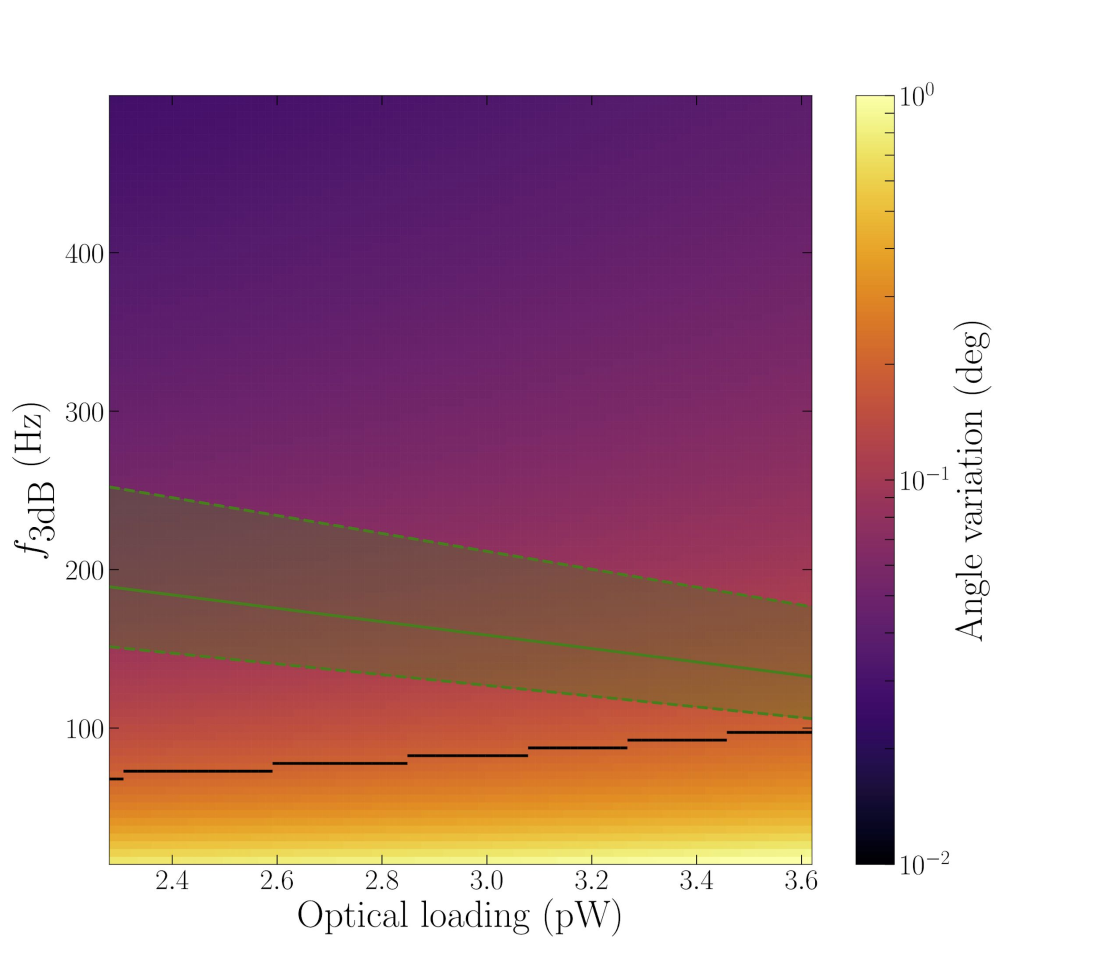


Impact on instrument: HWP



Impact on instrument: detector time constants

See talk by K. T. Crowley



Frequency dependent beams: overview

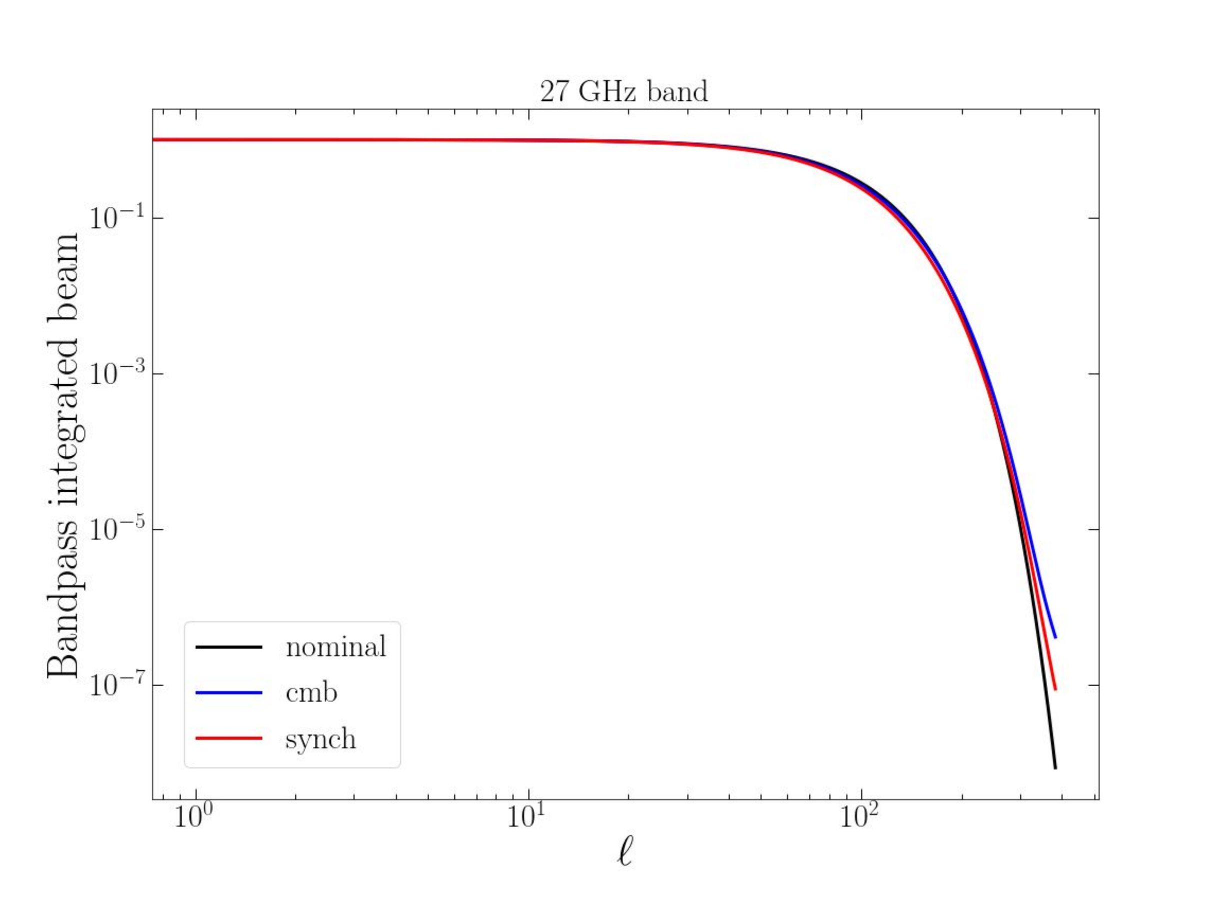
Issue:

- Beams are frequency dependent (and asymmetrical etc but just look at freq. dep.)
- Given the finite bandpass and foregrounds with different frequency dependence, each sky signal (CMB, synch, dust), effectively sees a different beam size.
- This couples the frequency dependence of the sky signals to the ell dependence.

Check:

- Considered a Gaussian circular beam, with diffraction limited frequency dependence.
- Compute data with full frequency dependence, ignore it and see what happens to r.
- Compute data with full freq. dep., correct for the CMB beam, and calculate r.
- Full frequency dependent beam in model.

Frequency dependent beams: SO 27 GHz example



Frequency dependent beams: signal power spectra

r bias ~= 1e-5.