LiteBIRD Cross-Correlation Science

Marina Migliaccio
On behalf of the project paper team

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Rapporteur: Giovanni Signorelli

Workshop LiteBIRD Italy at INFN-LNF
22 May 2023

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GOAL: Assess the science that can be obtained from the **joint analysis of LiteBIRD** measurements and tracers of the large-scale structure by forthcoming wide and deep **galaxy surveys**, specifically **highlighting the role of cross-correlations** between different probes.

These analyses have the potential to address a diverse range of science targets, **maximizing the return from different probes**, **disentangling astrophysical and cosmological parameters**, and increasing our ability to **control systematic effects**.

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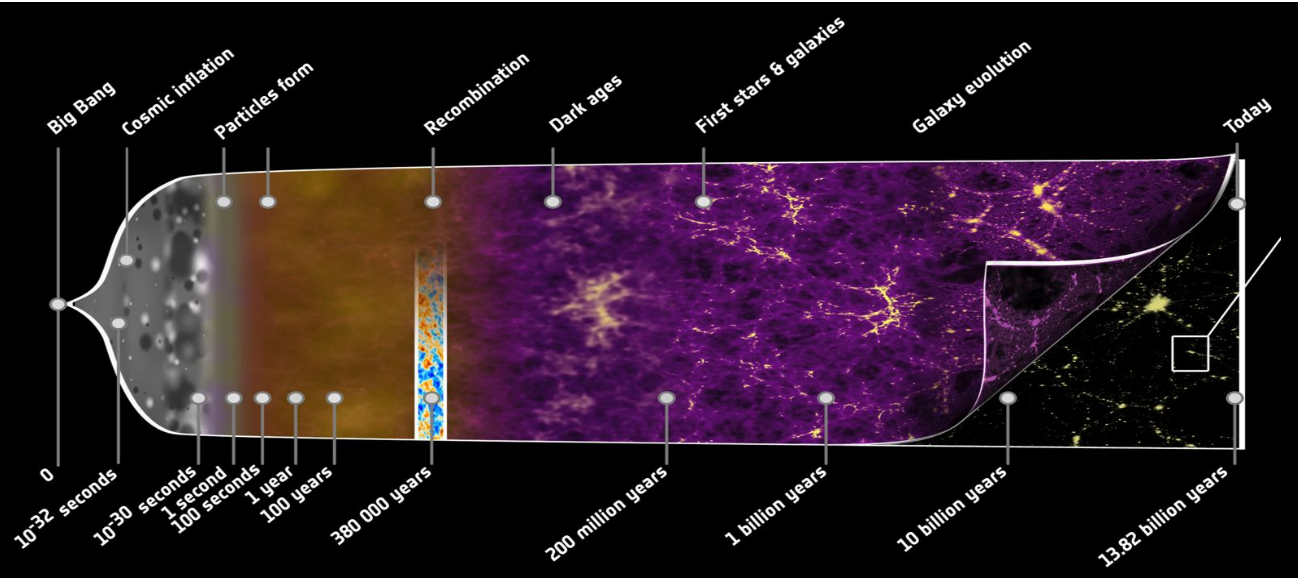

Correlations originate from Secondary Anisotropies

CMB photons interact with structures gravitationally (Paper I) or by scattering (Paper II)

Paper I: Cross-correlation science with CMB and other large-scale structure probes

Activity started with priority. Associated Project Paper Proposal approved by IPB.

Forecast cosmological constraints from combination and correlation of LiteBIRD CMB Temperature, Polarization and Lensing observations with Galaxy Clustering measurements expected by upcoming wide and deep galaxy surveys

Science Targets

I. Cross-correlation of CMB lensing and Galaxy Clustering

II. Late-time Integrated Sachs-Wolfe Effect (ISW)

III. Primordial Non-Gaussianity

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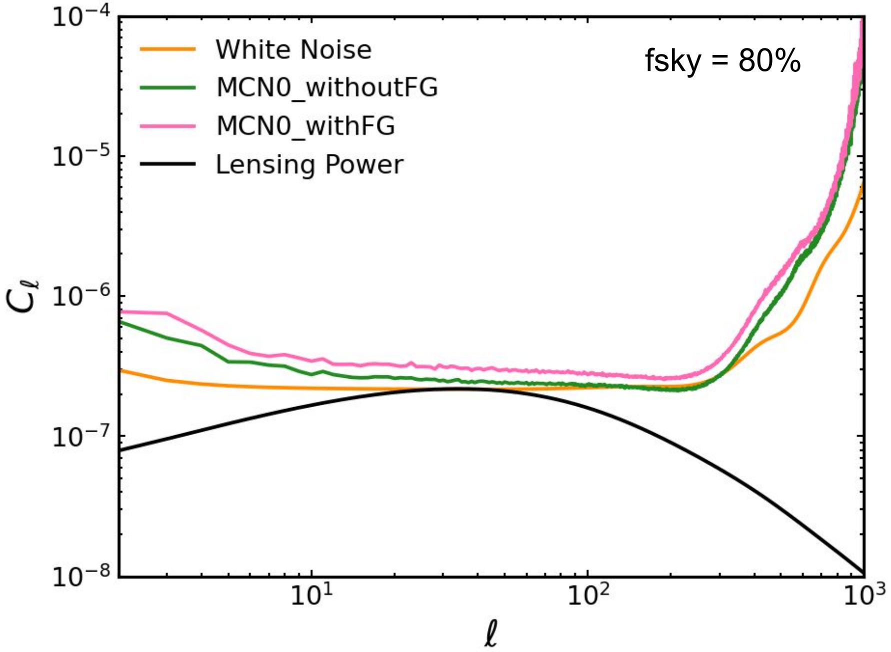
Forecast cosmological constraints from combination and correlation of LiteBIRD CMB Temperature, Polarization and Lensing observations with Galaxy Clustering measurements expected by upcoming wide and deep galaxy surveys

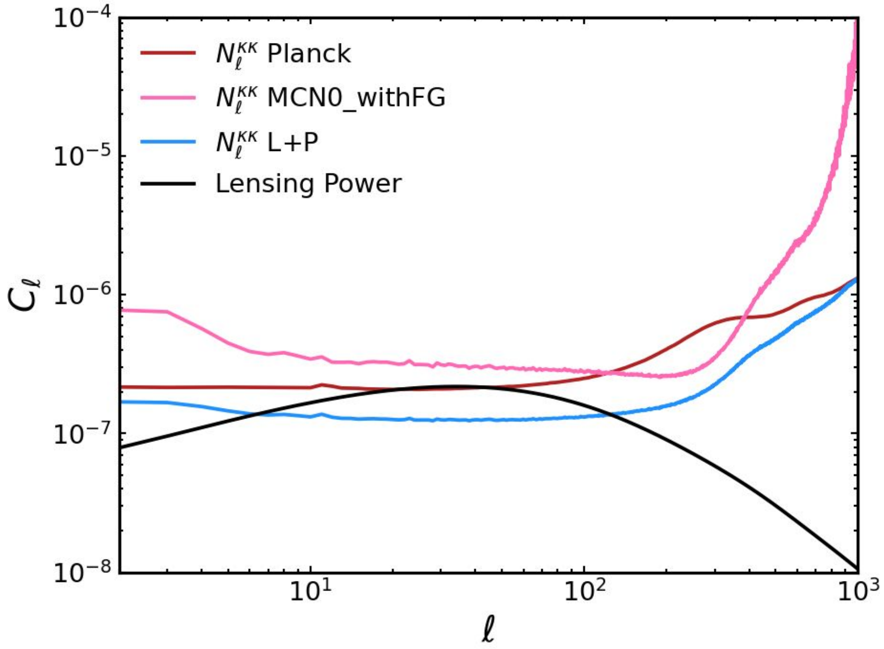
Forecasting Pipeline in place and tested

- Tools for computing theoretical angular power spectra for the different probes
- Likelihood for LiteBIRD TT TE EE KK and Galaxy Clustering GG + cross-correlations
- MCMC Sampler

I. Cross-correlation of CMB lensing and galaxy clustering

- LiteBIRD is expected to provide a CMB lensing reconstruction with a **signal-to-noise comparable to Planck**'s, but with **different systematic uncertainties** (both of instrumental and astrophysical origin. Lensing Project Study Group)

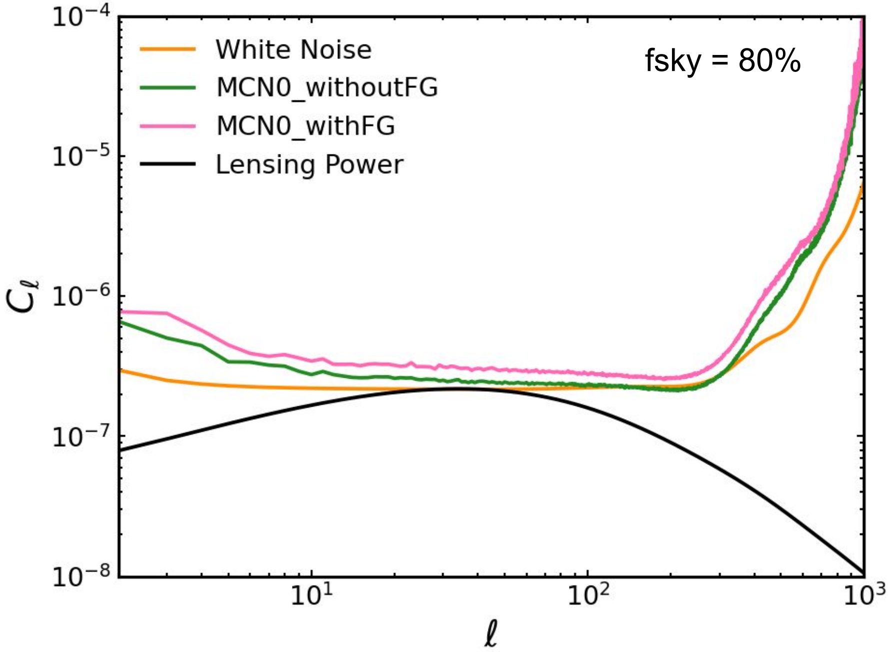


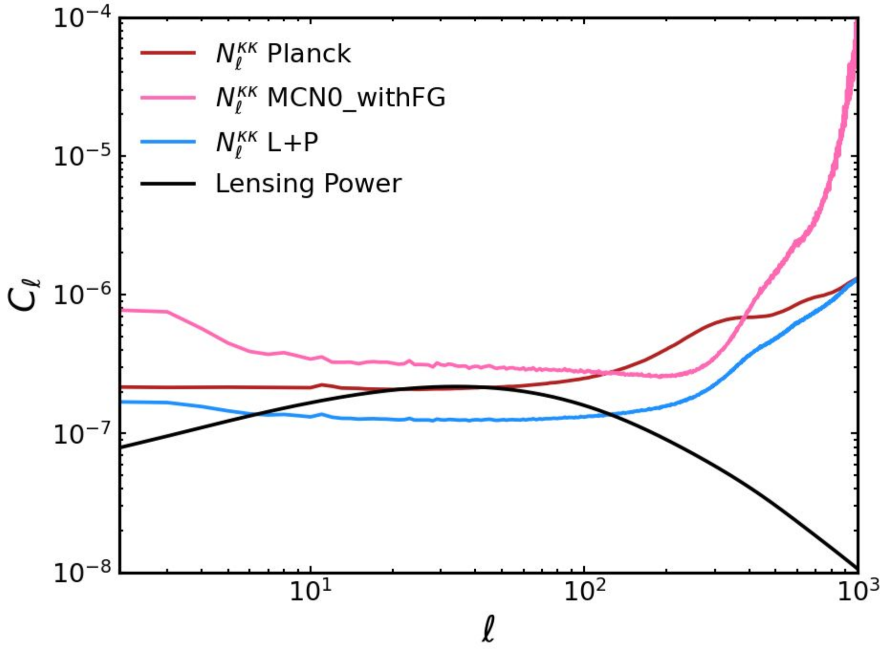


I. Cross-correlation of CMB lensing and galaxy clustering

- LiteBIRD is expected to provide a CMB lensing reconstruction with a **signal-to-noise comparable to Planck**'s, but with **different systematic uncertainties** (both of instrumental and astrophysical origin. Lensing Project Study Group)

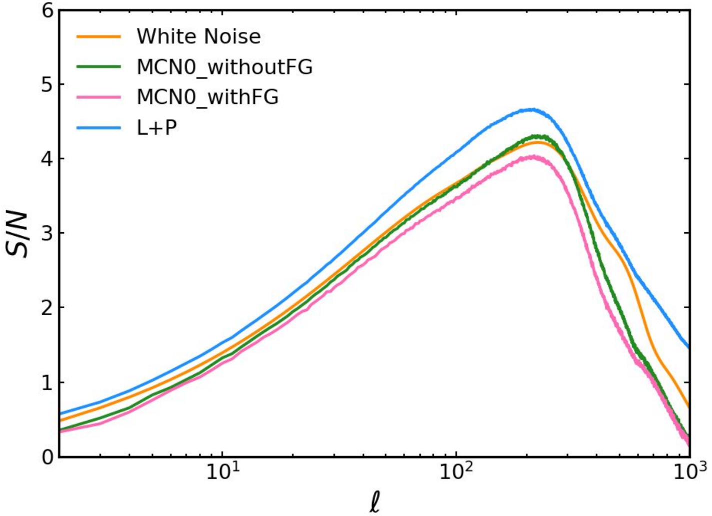
- With its **full-sky coverage**, LiteBIRD will allow analyses that are complementary to those from ground-based experiments.





I. Cross-correlation of CMB lensing and galaxy clustering

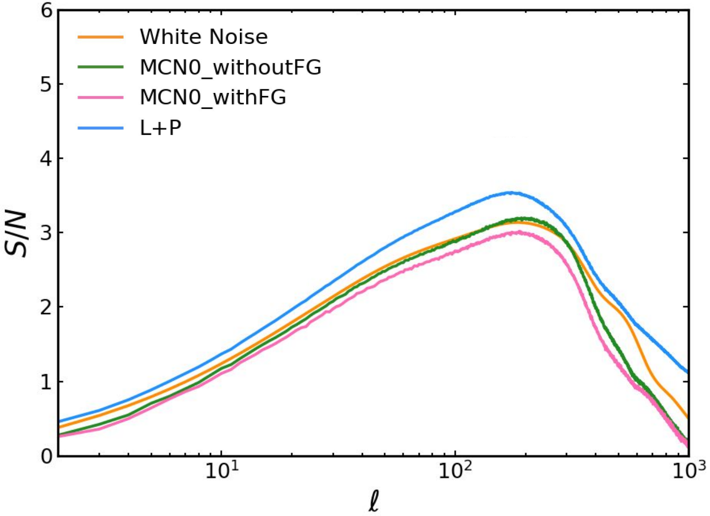
LiteBIRD × Euclid



TOTAL S/N

	w/o Tomography	Tomography
WN	77.3	87.6
noFG	71.8	81.1
FG	65.9	74.4
L+P	87.7	97.7

LiteBIRD × LSST



TOTAL S/N

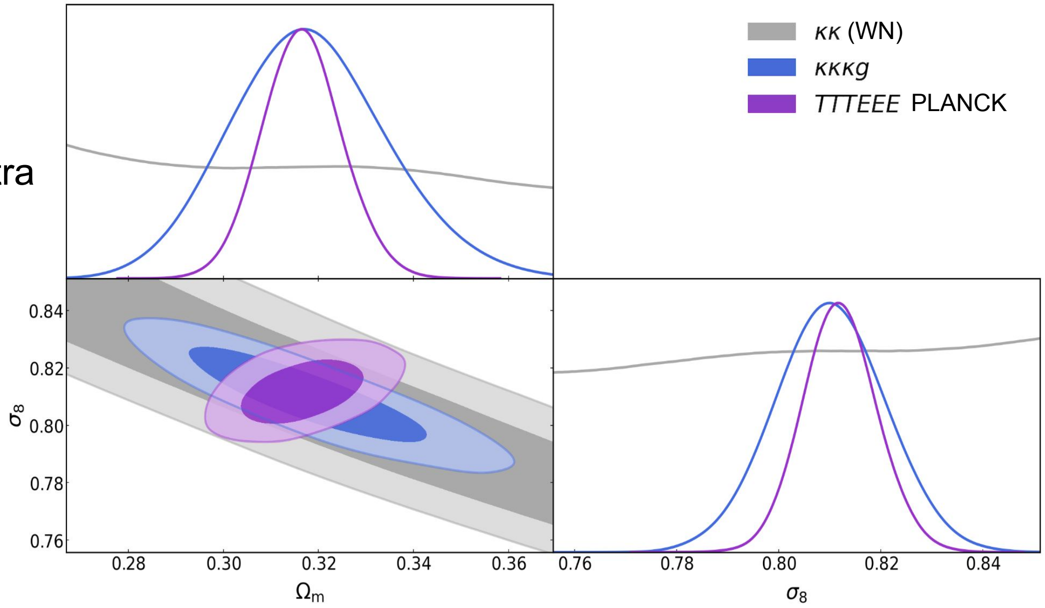
	w/o Tomography	Tomography
WN	61.2	64.8
noFG	57.0	60.3
FG	52.3	55.3
L+P	69.7	73.6

I. Cross-correlation of CMB lensing and galaxy clustering

Advantages of the cross-correlation κG

- Complementary late-time probe
- More robust to systematics than autospectra
- Most of the signal at quasi-linear scales

LiteBIRD Lensing × Euclid compared to Planck TTTEEE data



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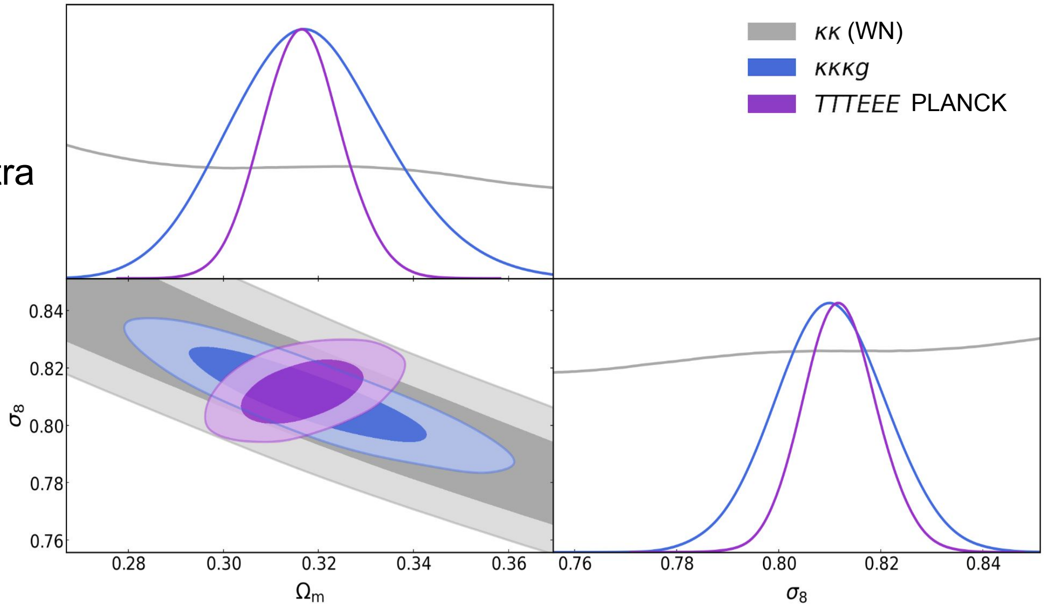
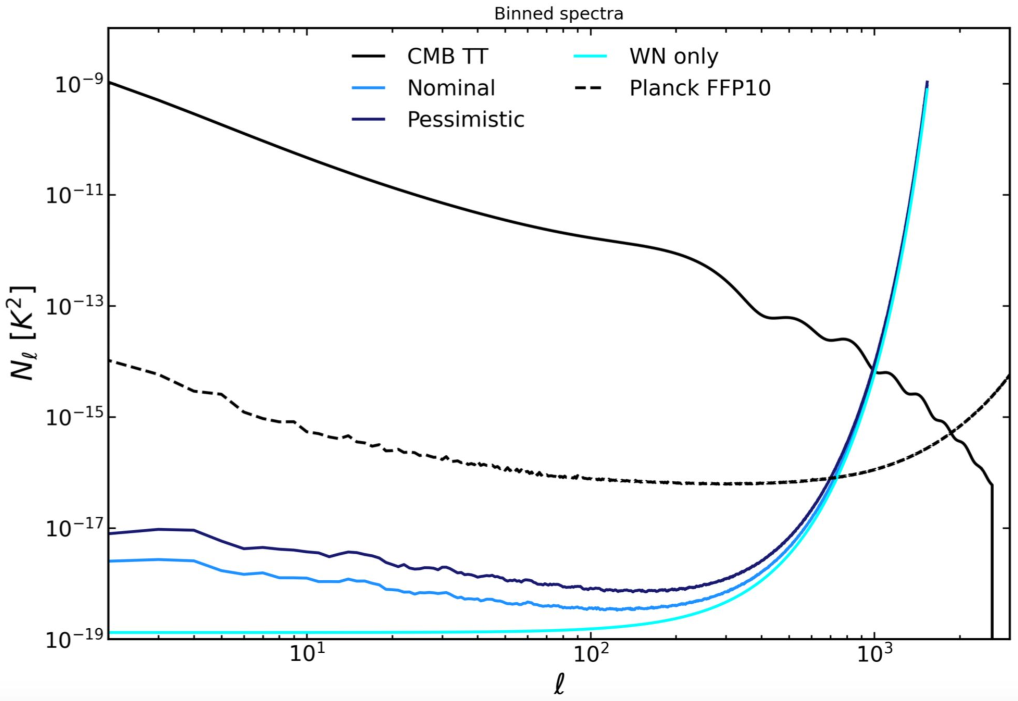


Ongoing Activities

- Assess the impact of LiteBIRD realistic lensing reconstruction noise.
- Include Planck lensing.
- Extend to other galaxy surveys.

II. Late-Time Integrated Sachs-Wolfe Effect

From post-PTEP simulations: 1/f noise has only a small impact on low multipoles in temperature and it is at a lower level than Planck's (wiki)



II. Late-Time Integrated Sachs-Wolfe Effect

LiteBIRD expected to provide a competitive full-sky temperature dataset for ISW studies

Using polarization information from LiteBIRD can improve significance of the ISW measurement. This was not possible with Planck due to systematic effects on large-scales in polarization.

ISW from LiteBIRD x Euclid (TG)

S/N = 4.0 w/o Polarization

S/N = 4.6 w/ Polarization

ISW x Lensing from LiteBIRD (Tκ)

S/N = 3.9 w/o Polarization

S/N = 4.6 w/ Polarization

TG + Tκ

S/N = 4.9 w/o Polarization

S/N = 5.7 w/ Polarization

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S/N = 4.9 w/o Polarization
S/N = 5.7 w/ Polarization

Ongoing Activities

- Extend the ISW TG analysis to other galaxy surveys like Vera Rubin-LSST, SKA/EMU, Roman
- ISW × SZ cross-correlation (Taburet+2011)

  In principle can provide a detection from CMB-only data at S/N = 5, but need to verify Galactic and extragalactic foregrounds can be properly controlled

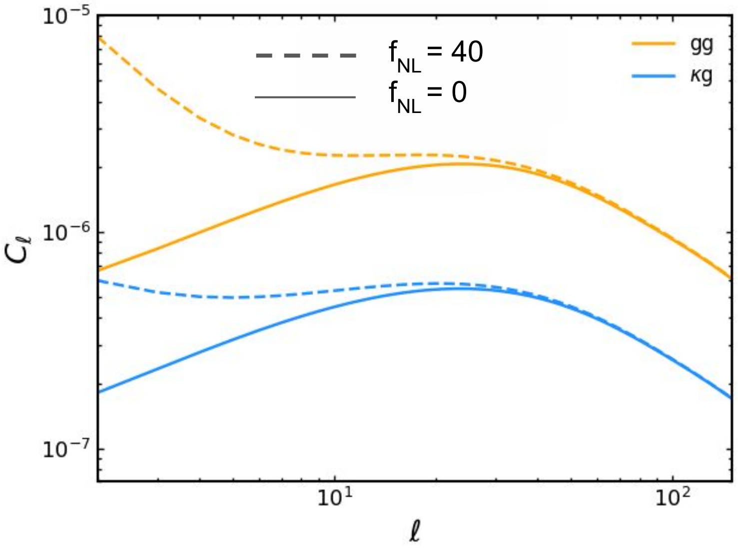
III. Primordial Non-Gaussianity

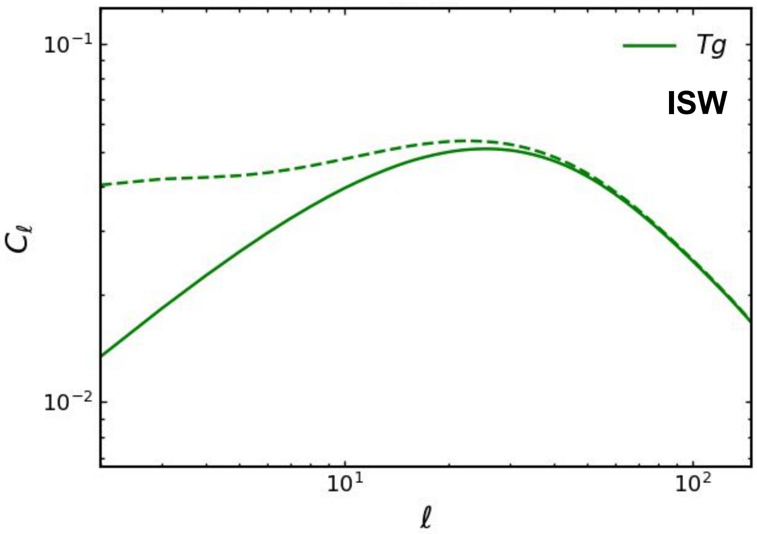
Local type non-Gaussian correlations between short-scale modes (which form halos) and long-scale modes in the primordial potential induce a **scale-dependent galaxy bias**:

$$b_g(z) \rightarrow b_g(z)[\,1 + f_{NL}\beta(k,z)\,]$$

$$\beta(k,z) = 3\frac{(b_g - 1)}{b_g}\frac{\Omega_{m,0}\delta_c}{k^2 T(k) D(z)}\frac{H_0^2}{c^2}$$

LiteBIRD × Euclid (w/o Tomography)





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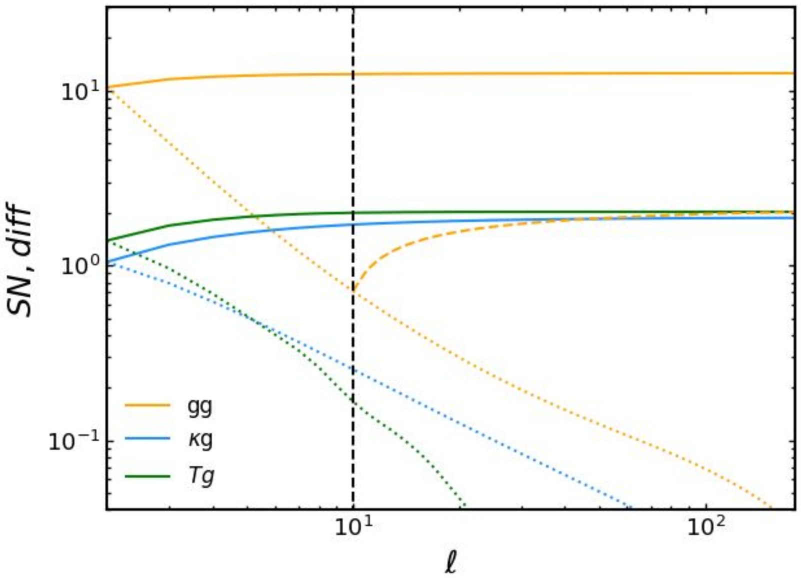

Diff between f_{NL} = 40 and f_{NL} = 0

- ········ S/N per ell
- ——— S/N cumulative
- – – – – S/N cumulative, ell > 10

Signal on large angular scales
→ LiteBIRD with its full-sky coverage is in a unique position to constrain this effect

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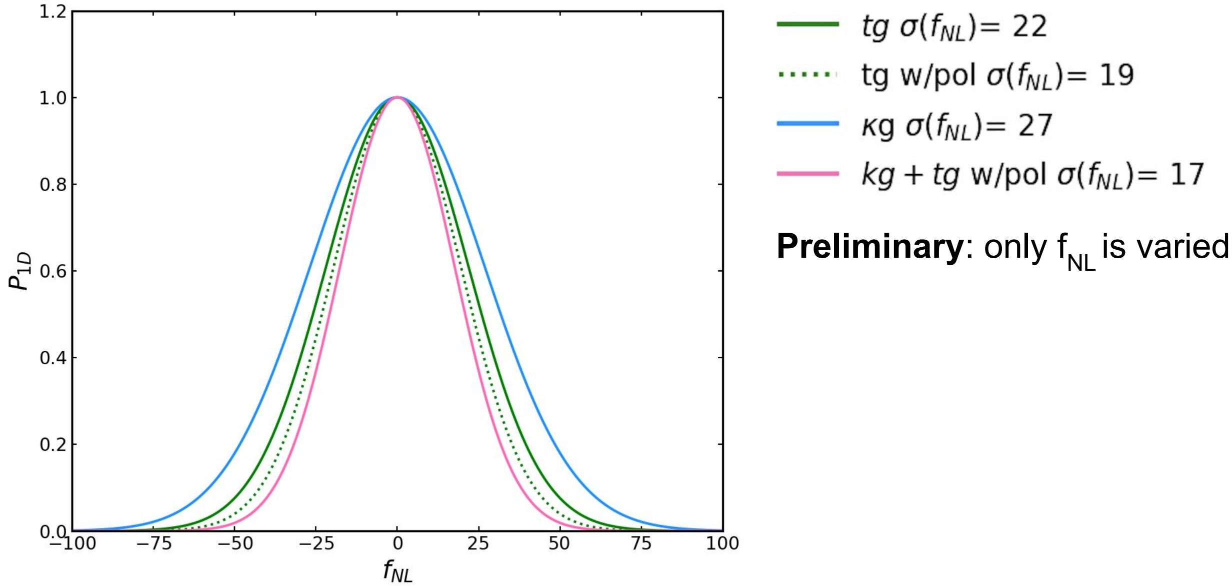

Preliminary: only f_{NL} is varied in the fit

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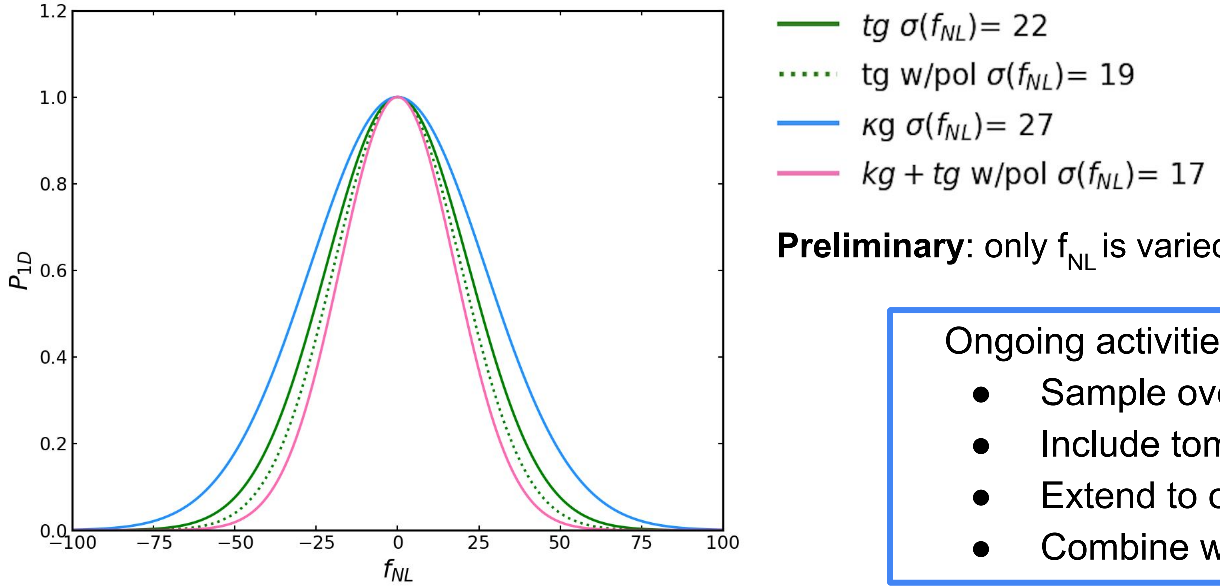

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Ongoing activities:

- Sample over other parameters
- Include tomography and GG (l_{min} = 10)
- Extend to other galaxy surveys
- Combine with Planck Lensing

Planned activities

➢ **Consolidate the Science Case**

I. Cross-correlation of CMB lensing and Galaxy Clustering
II. Late-time Integrated Sachs-Wolfe Effect
III. Primordial Non-Gaussianity

➢ **Extend the studies to other galaxy surveys**

- Up to now we mainly focused on Euclid, include e.g. Vera Rubin-LSST, Radio Continuum Surveys, Roman.

Check Dedicated Wikipage for Project Updates