Constraining B-modes with the Simons Observatory

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Gianturco Fellow, Linacre College

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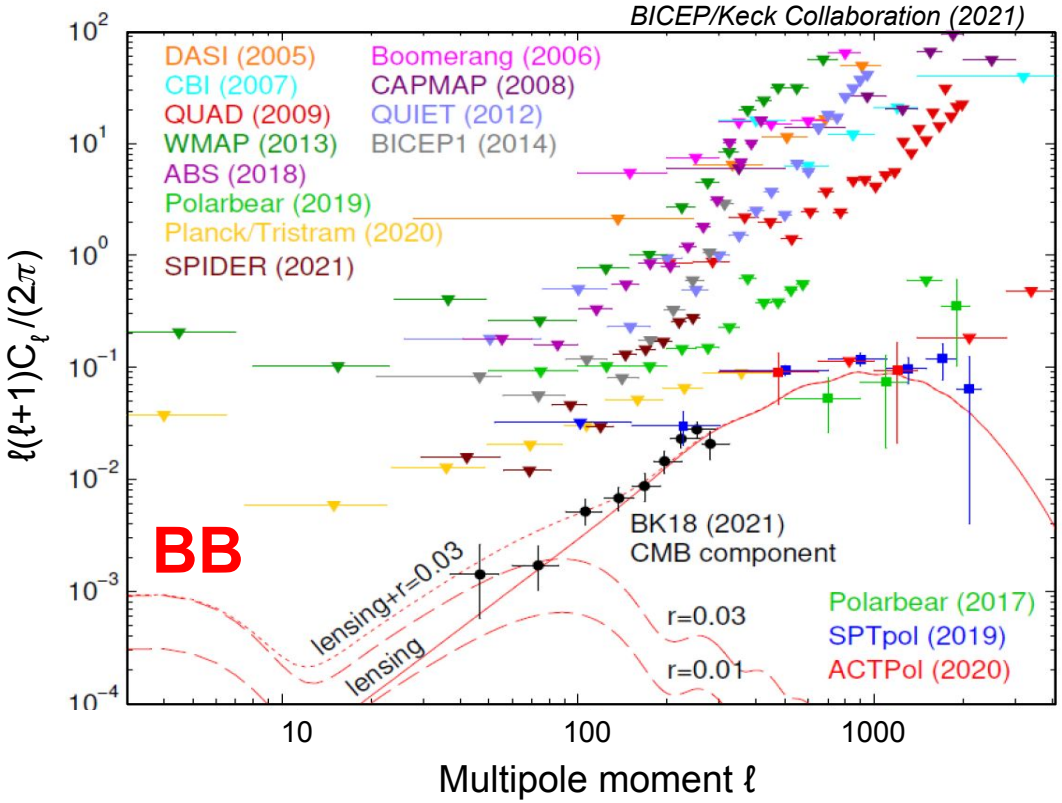
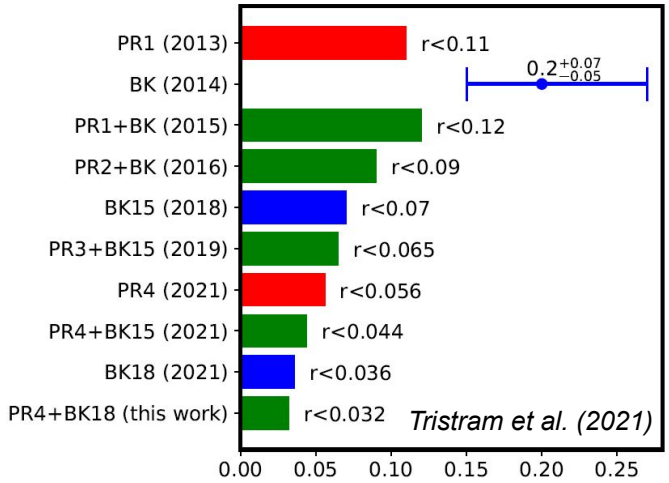
Primordial B-modes: experiments



past *r* constraints



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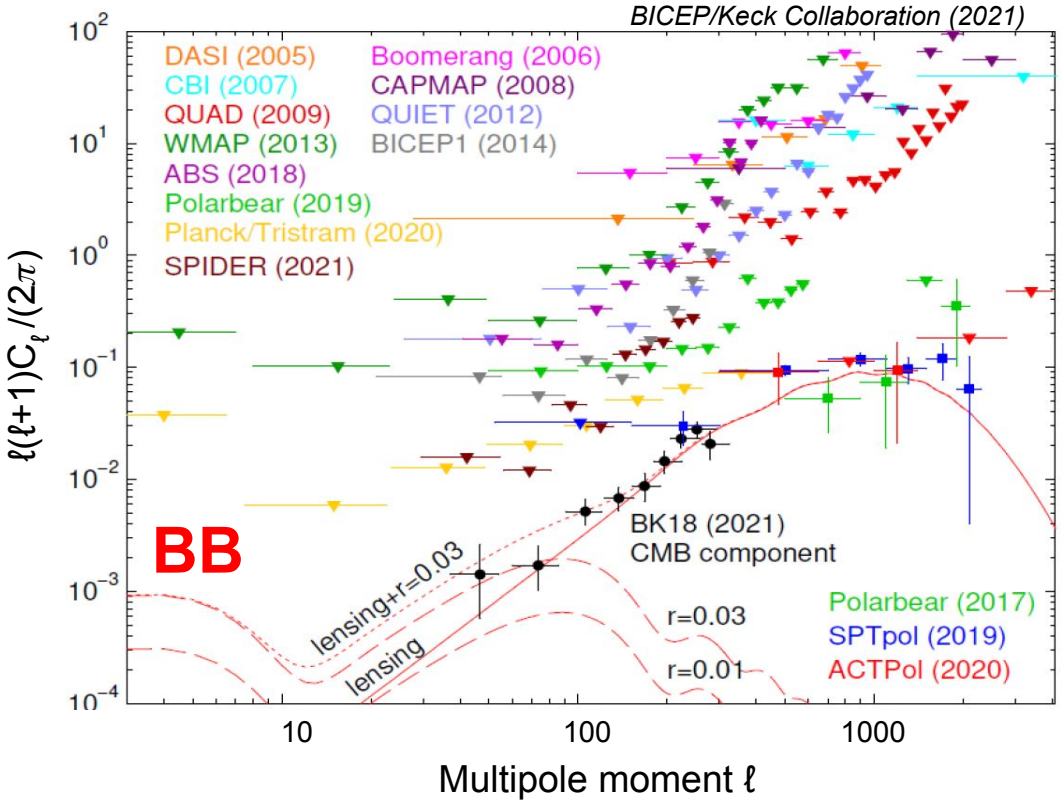
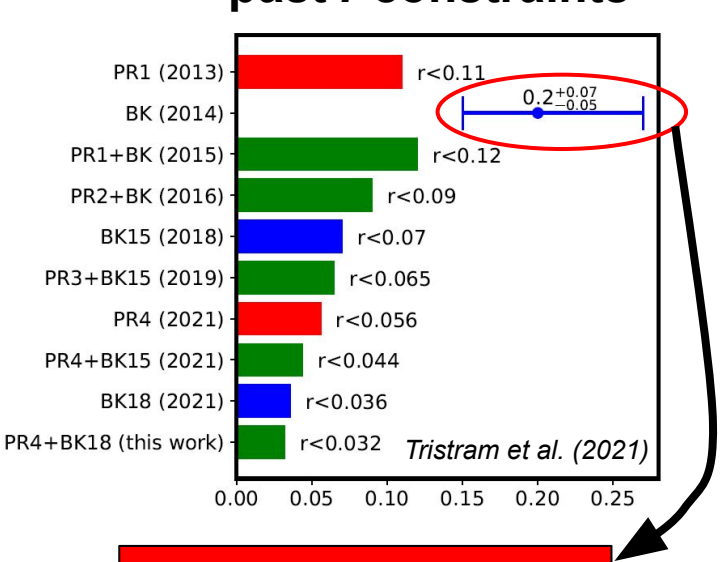




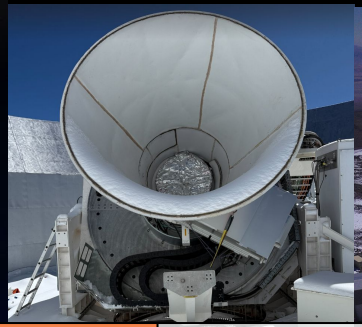
Be prepared for…
Galactic foregrounds and systematics!

The Simons Observatory (SO)

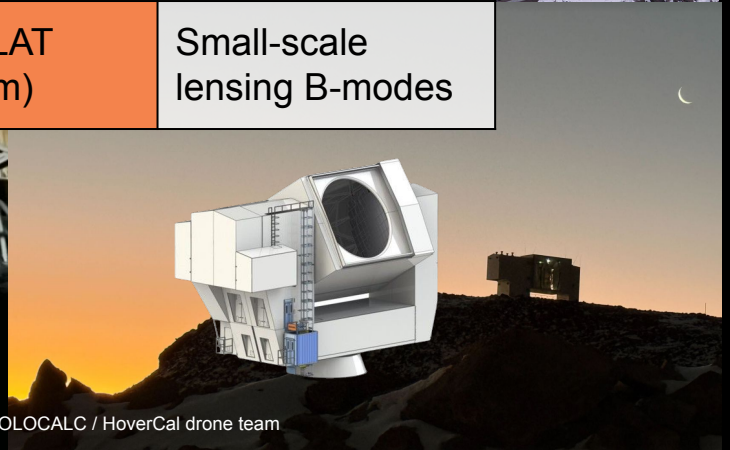
Ongoing CMB polarisation experiment, Atacama

Full observations
2024-29

Goal:
3x tighter *r* bounds
or $\sigma(r) = 0.003$



3+ SATs (0.4m)	Degree-scale B-modes → *r*
1 LAT (6m)	Small-scale lensing B-modes



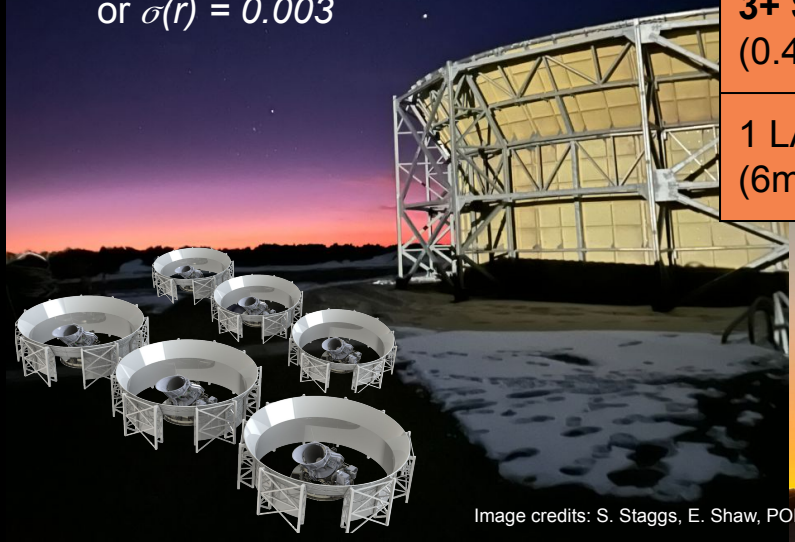


Image credits: S. Staggs, E. Shaw, POLOCALC / HoverCal drone team

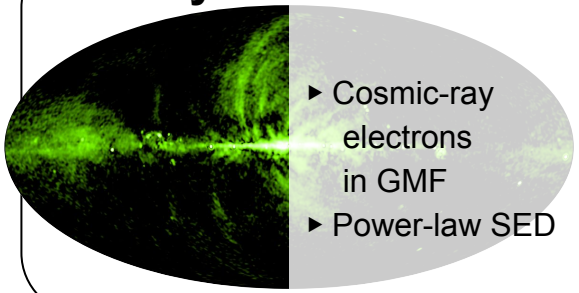
2029

Today

2024

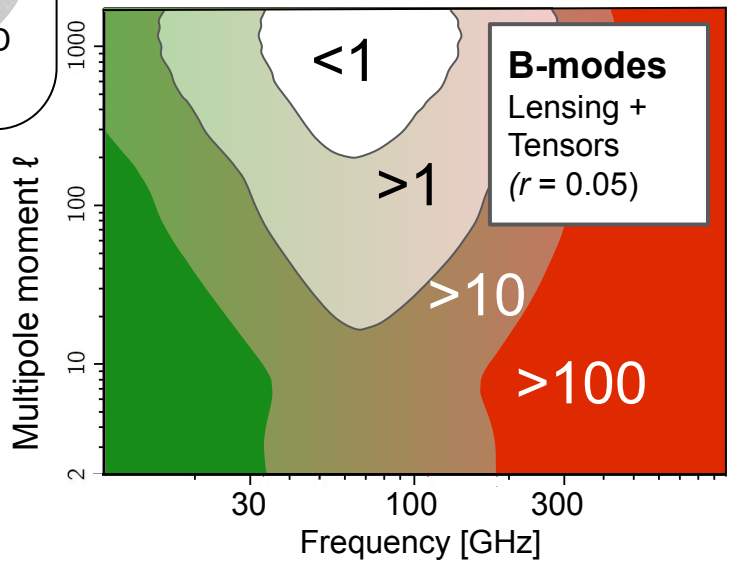
Galactic polarized foregrounds

Synchrotron

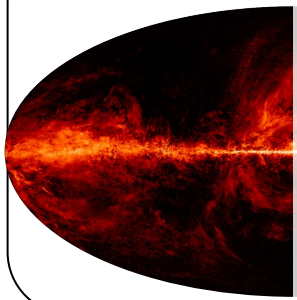


- Cosmic-ray electrons in GMF
- Power-law SED

Foreground-to-CMB ratio (rms)



Thermal dust

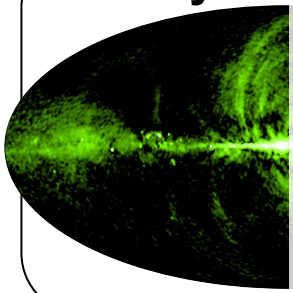


- Thermal dust grains aligned with GMF
- Mod. Blackbody

Planck Collaboration IV (2020) (adapted)

Galactic polarized foregrounds

Synchrotron



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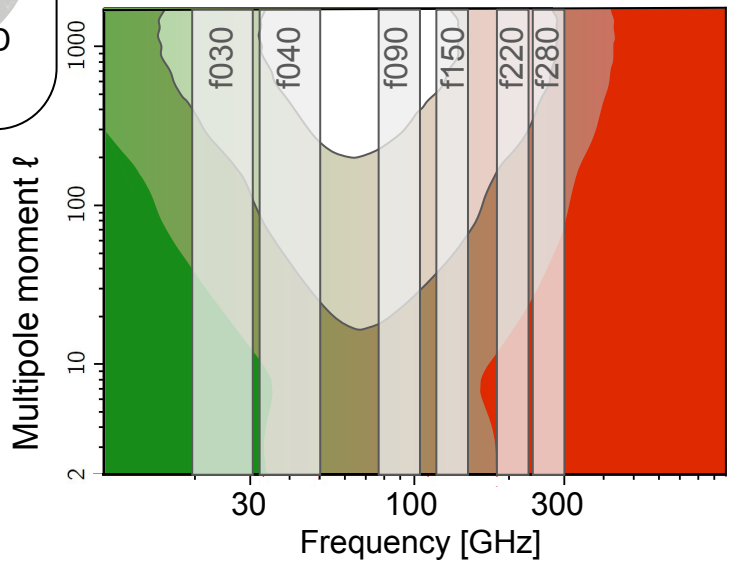

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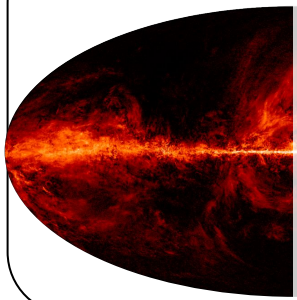

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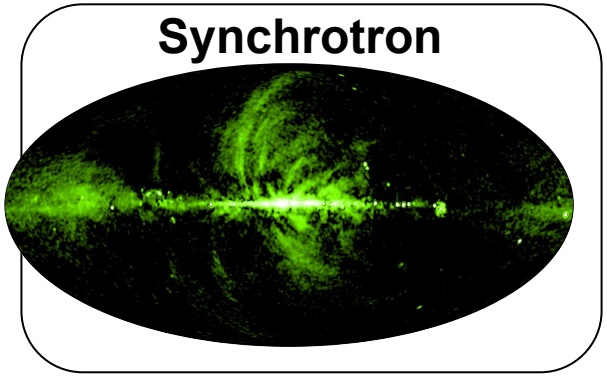
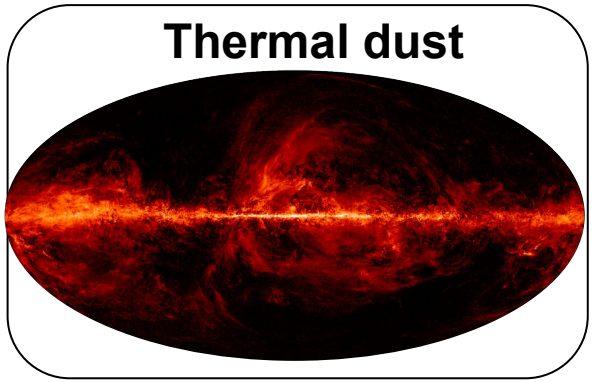
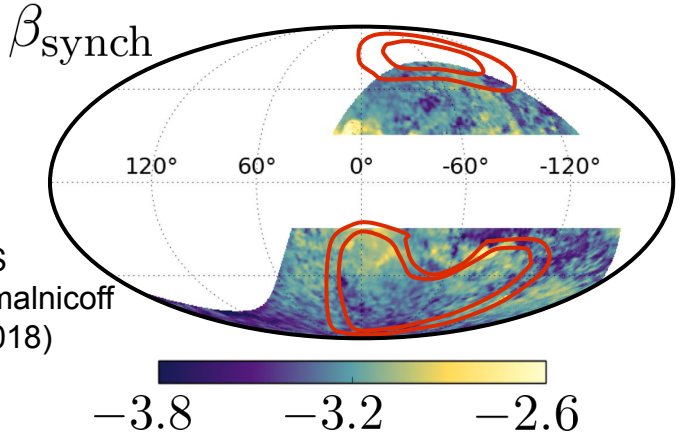
Galactic polarized foregrounds

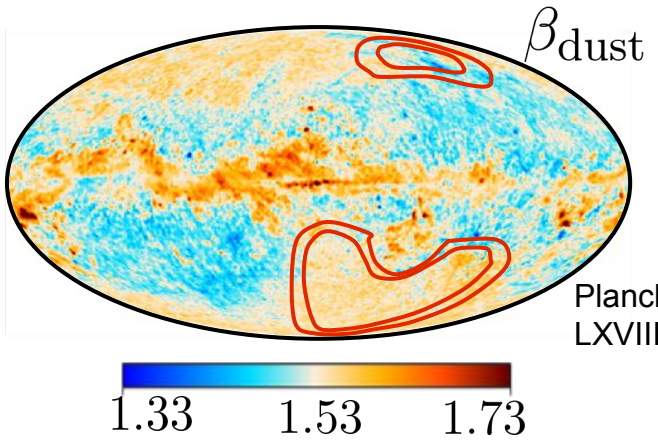


Anisotropic
SED spectral index



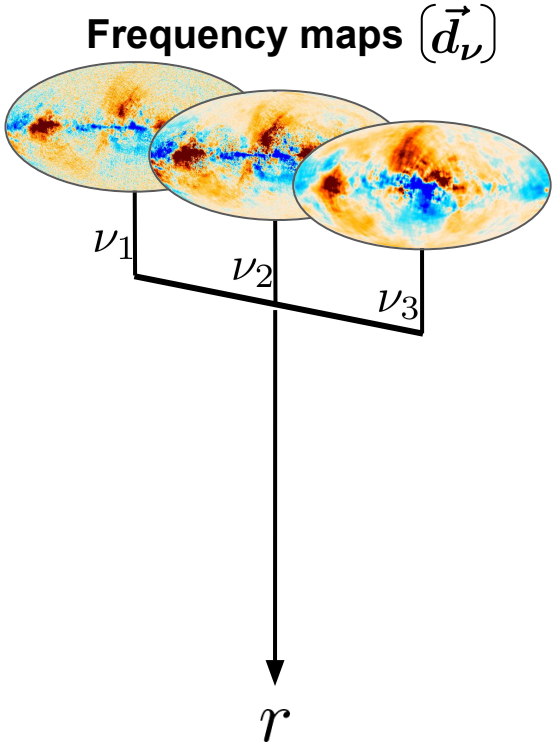


S-PASS
(Krachmalnicoff
et al. 2018)



Planck Interm.
LXVIII (2016)

SO component separation pipelines



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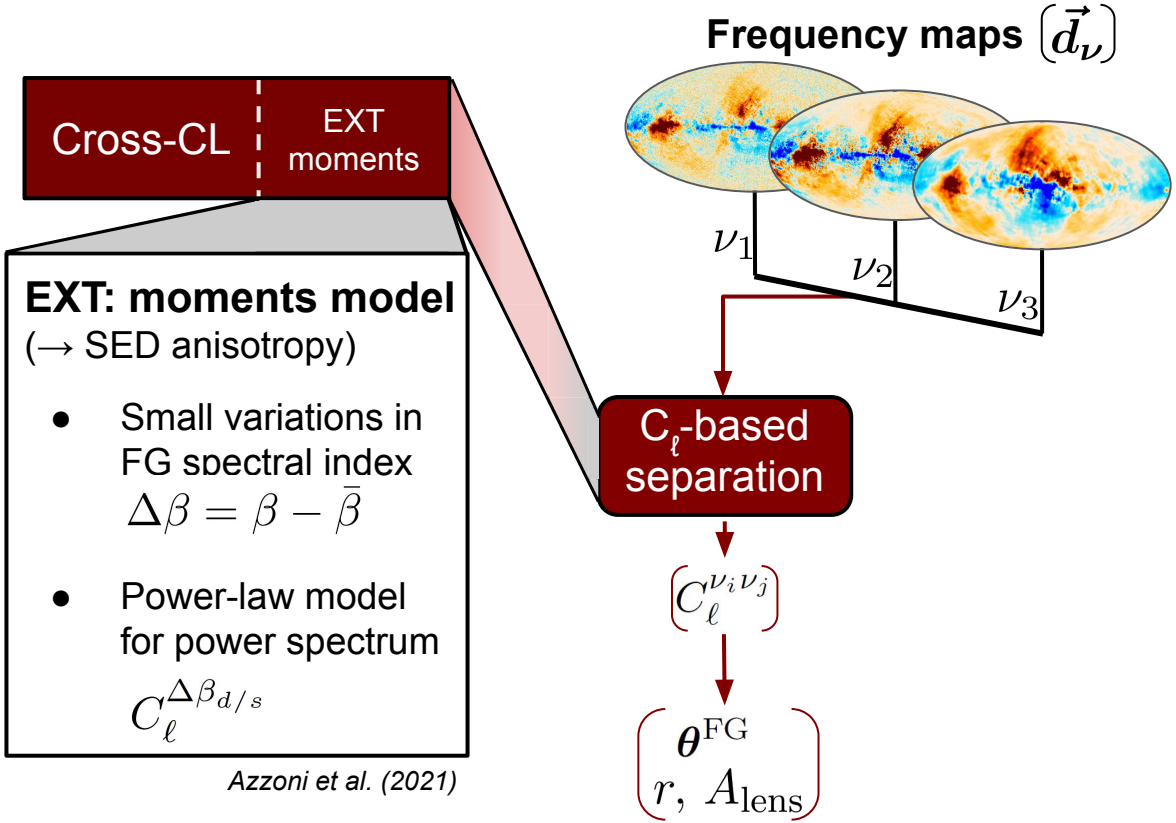

Azzoni et al. (2021)

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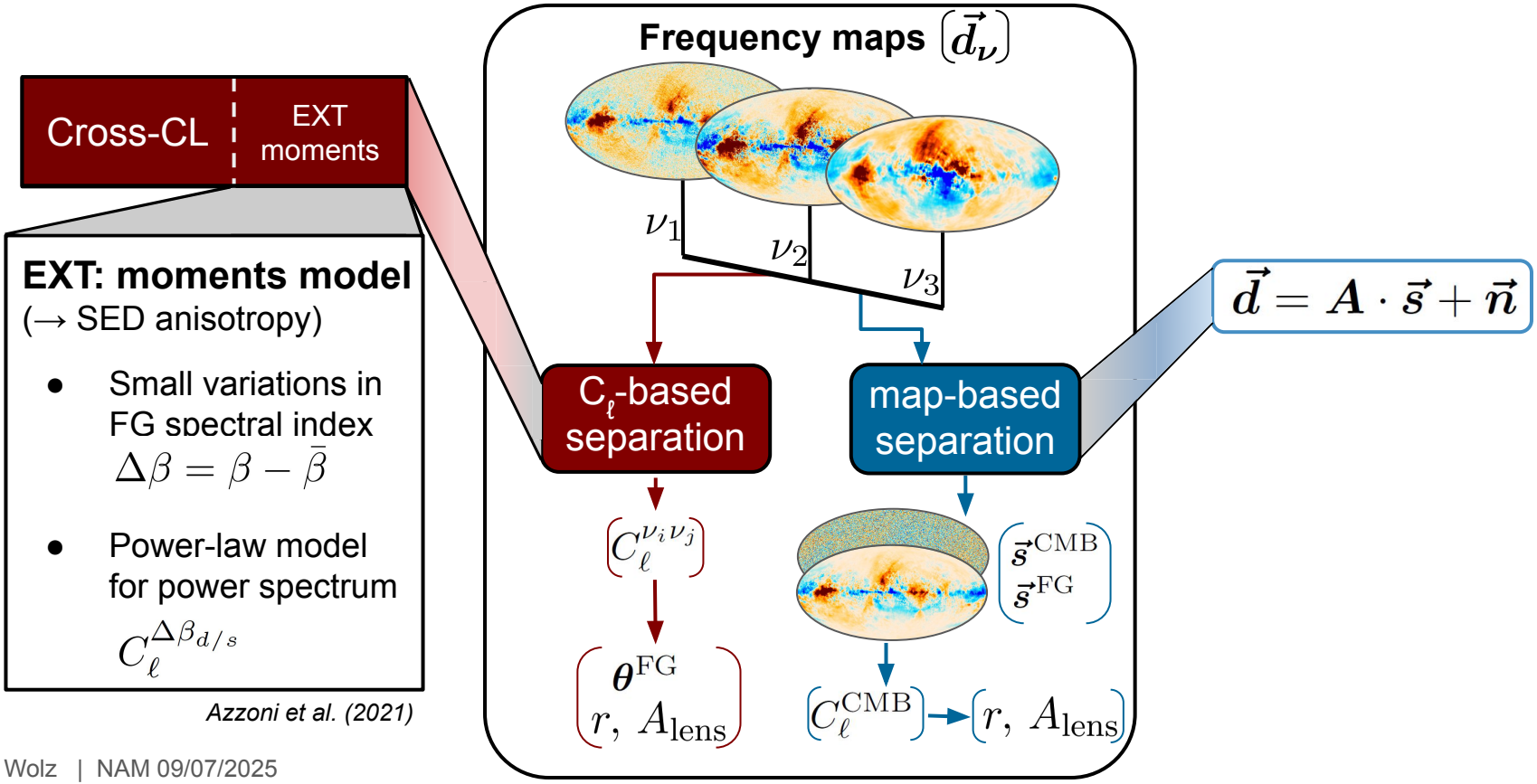

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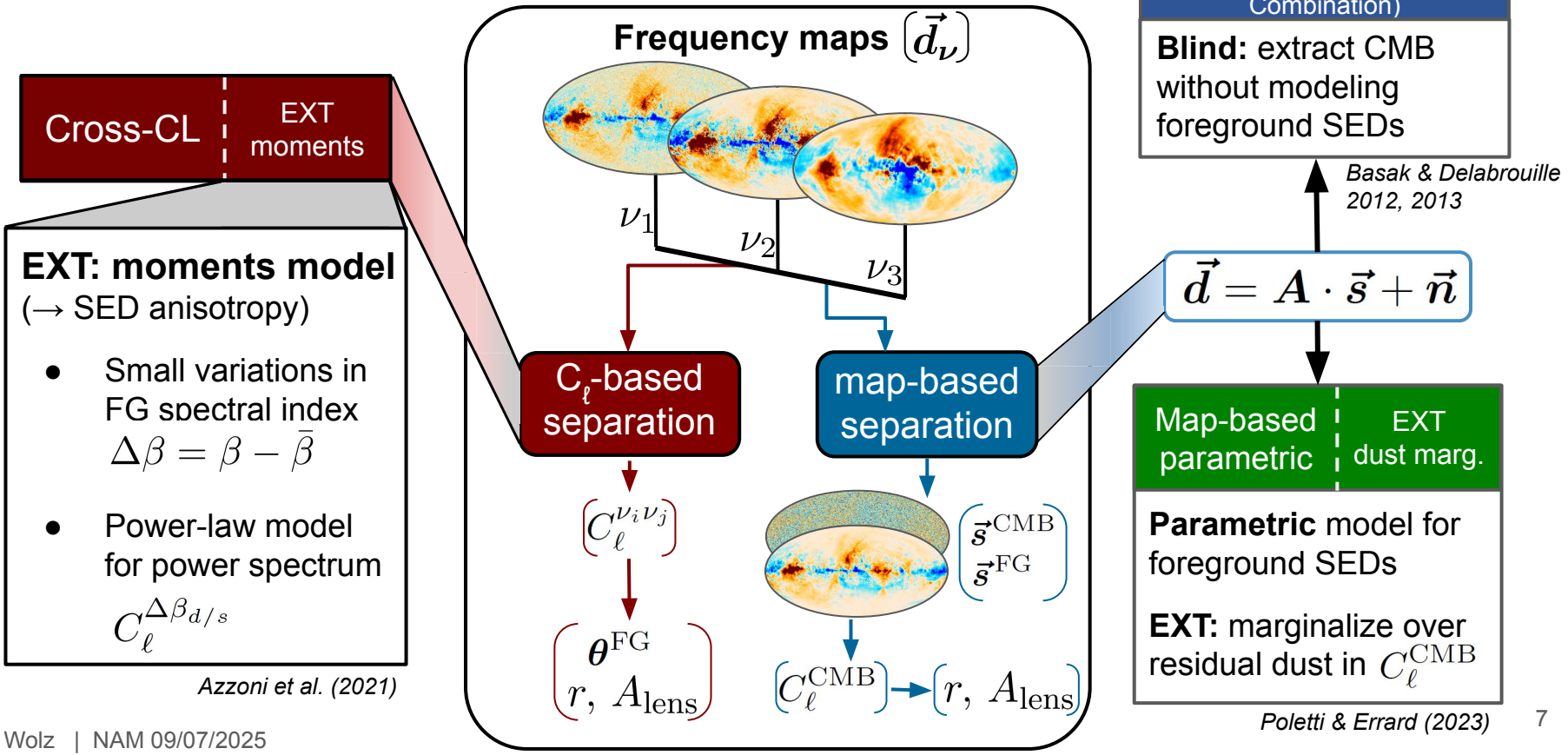
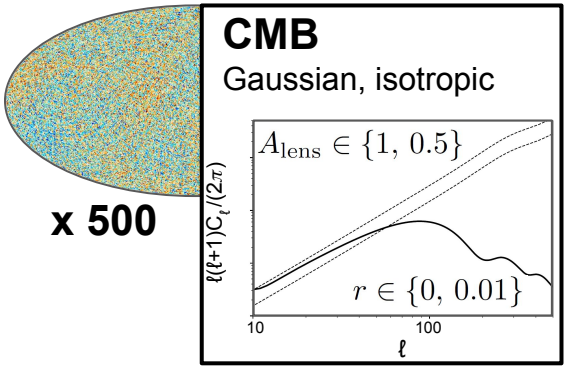
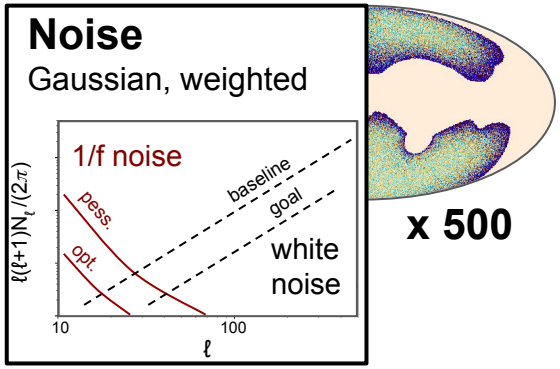
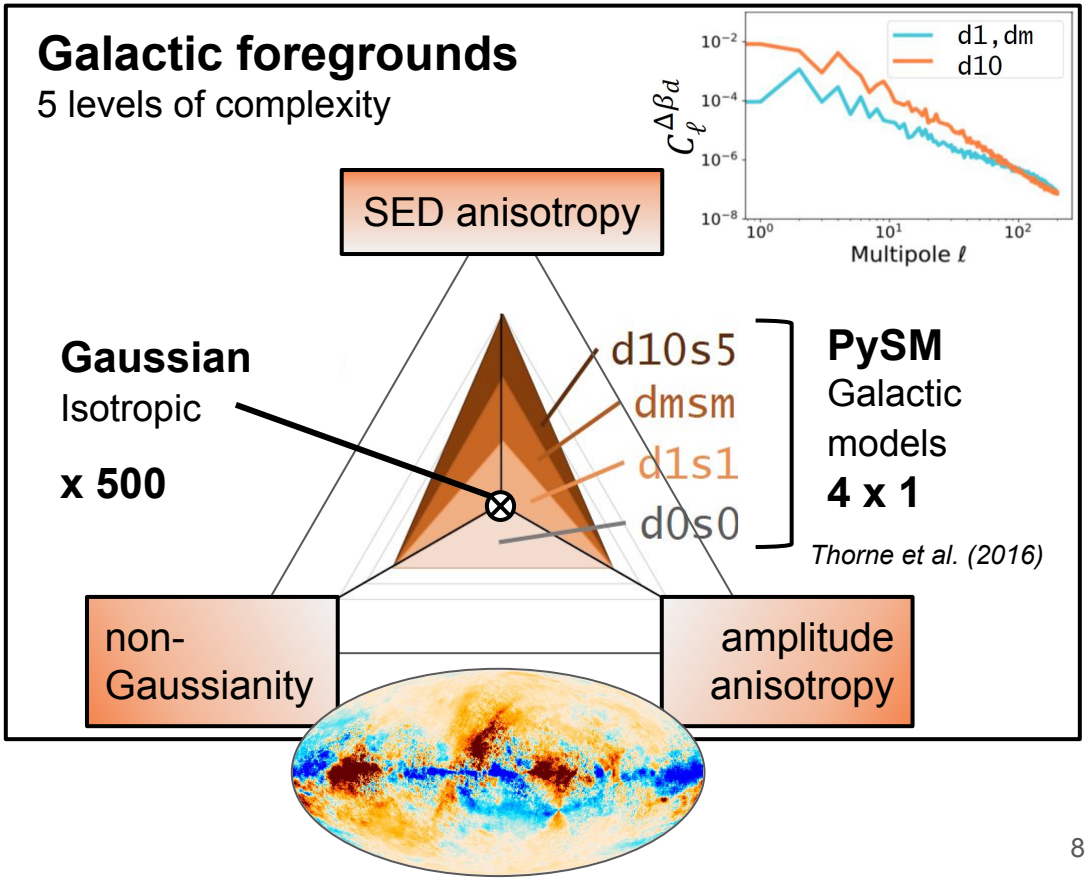


Sky simulations

Wolz++ 2024, *2302.04276*

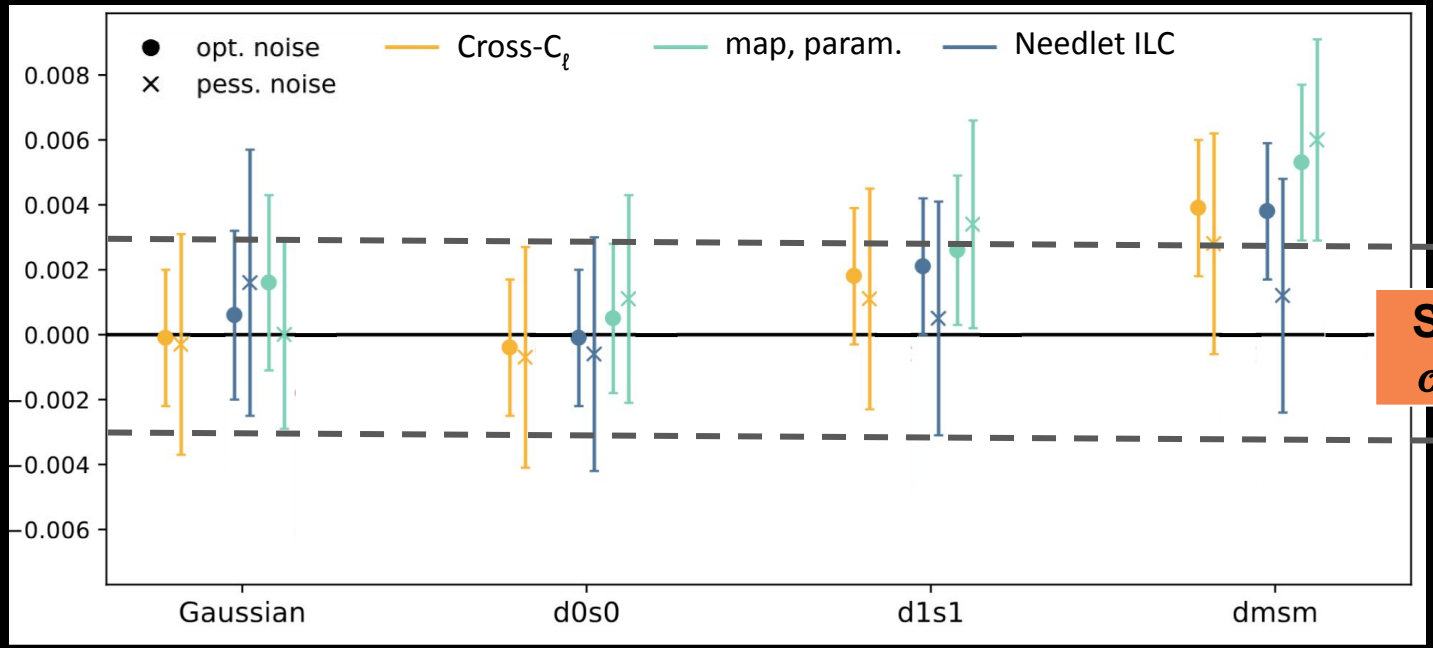






Removing the veil of Galactic foregrounds

500 sims of coadded CMB (r=0, no delensing), foregrounds, noise



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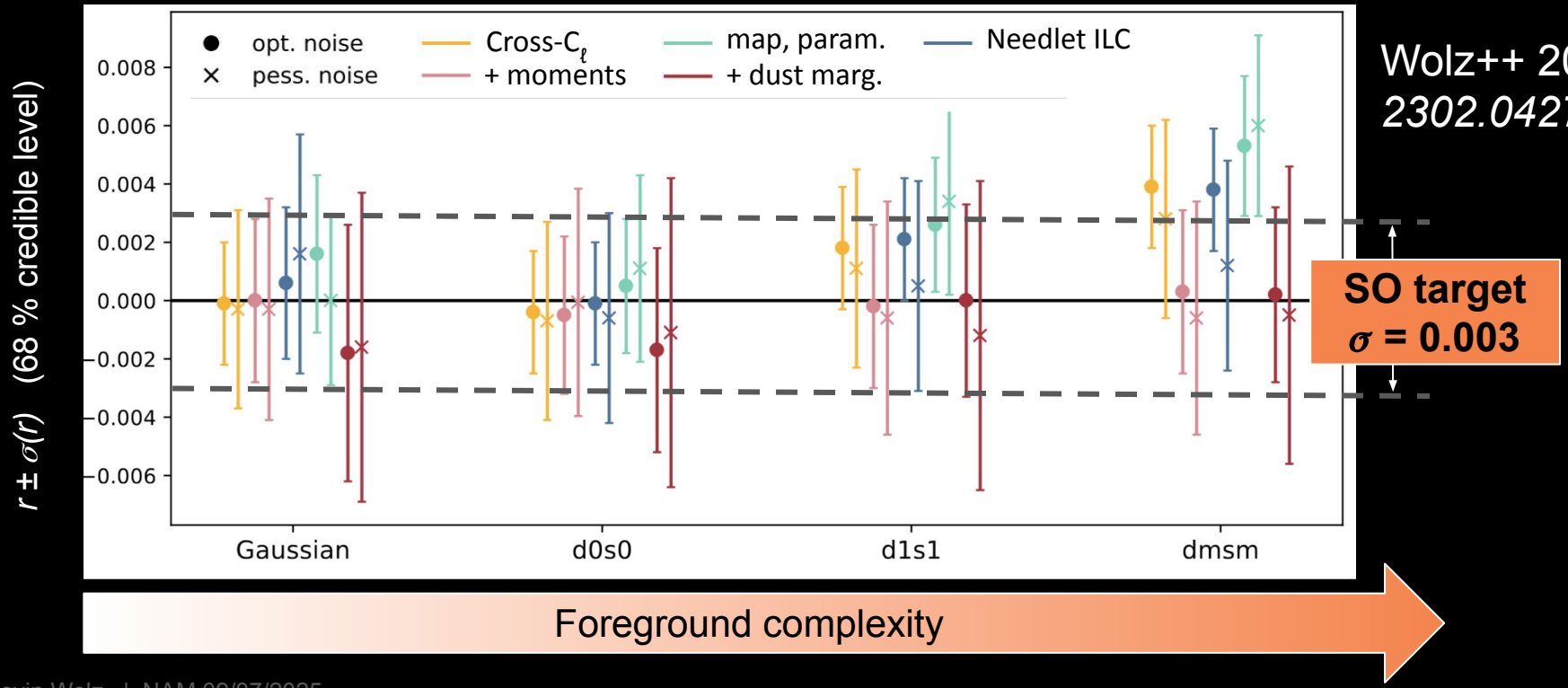
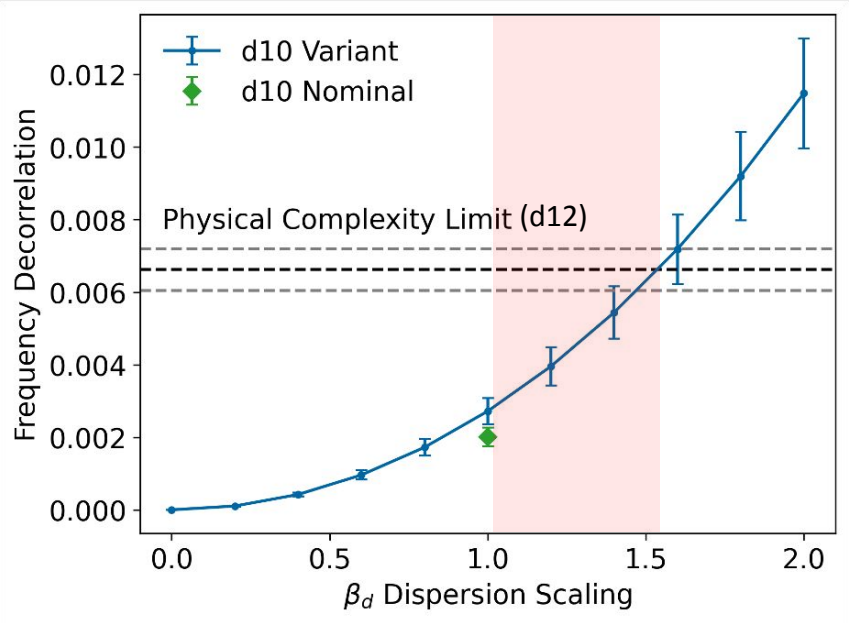


Wolz++ 2024
2302.04276

Cross-C_ℓ : impact of dust complexity

Liu++ (*in prep.*)



(This figure is derived from d10 PySM simulations with a scaling of the spatial variation in dust index map)

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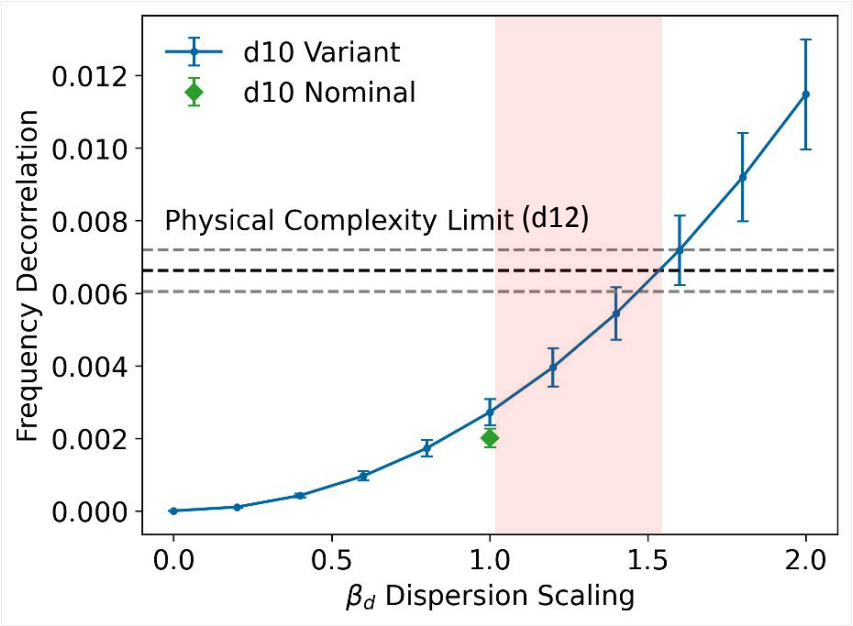

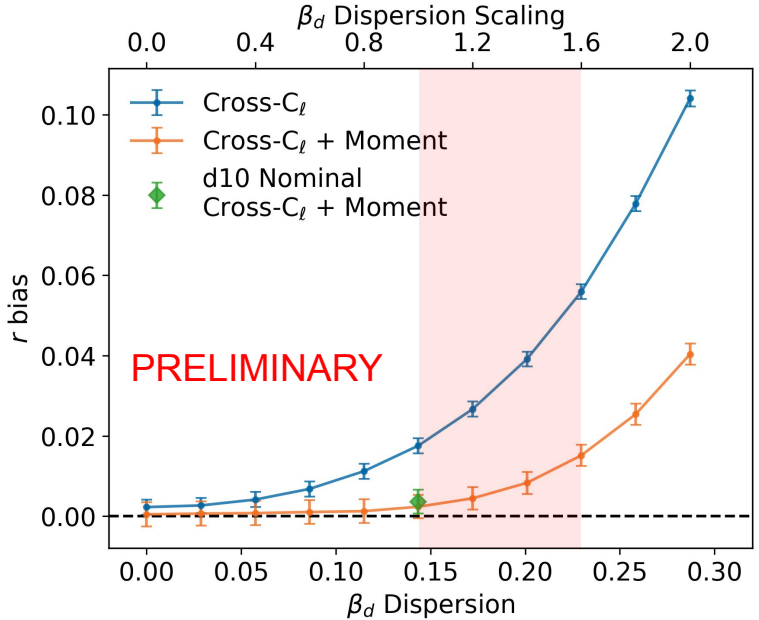

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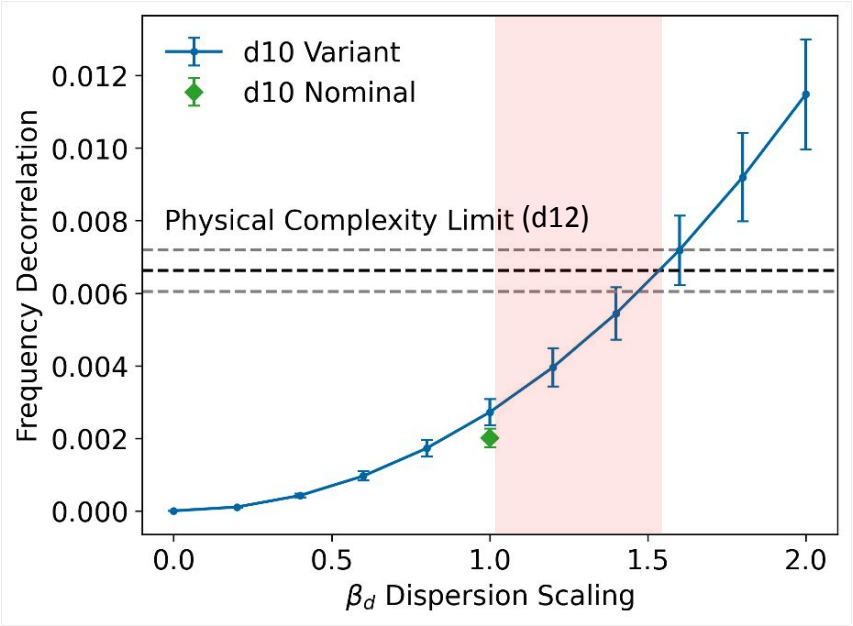

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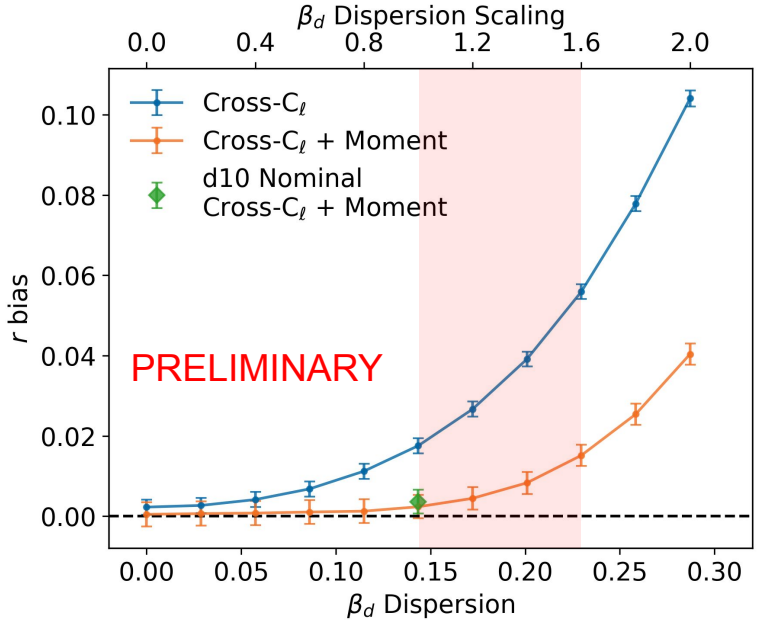
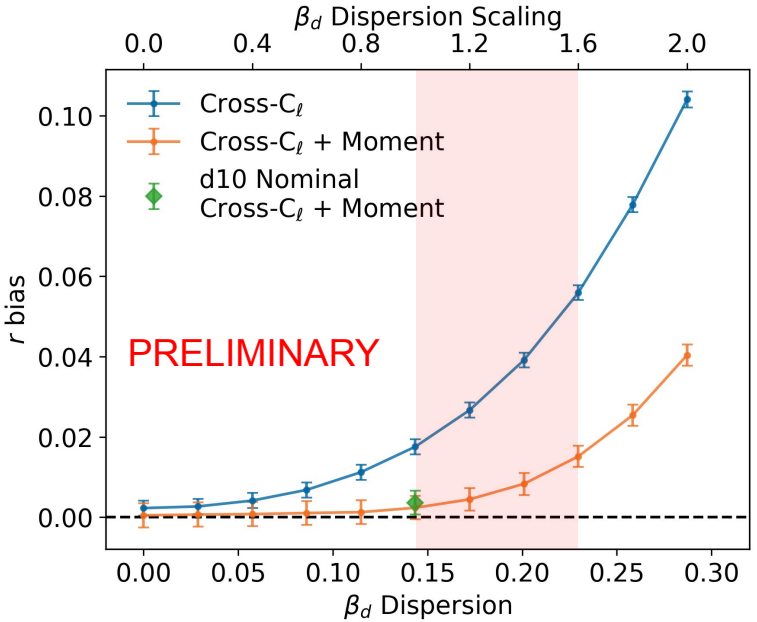


Potential for more refined models
e.g. hybrid map-based x cross-CL
(Azzoni++ 2023, *2309.09978*)

Cross-C_ℓ : impact of dust complexity

Liu++ (*in prep.*)

Dust property	Impact on r bias	Impact on χ^2
$\beta_{\rm dust}$ anisotropy	high	high
$C_\ell^{\rm dust} \neq$ power law	low	low
non-Gaussian amplitude		



Cross-C_ℓ : impact of dust complexity

Abril-Cabezas++ 2023
2309.09978

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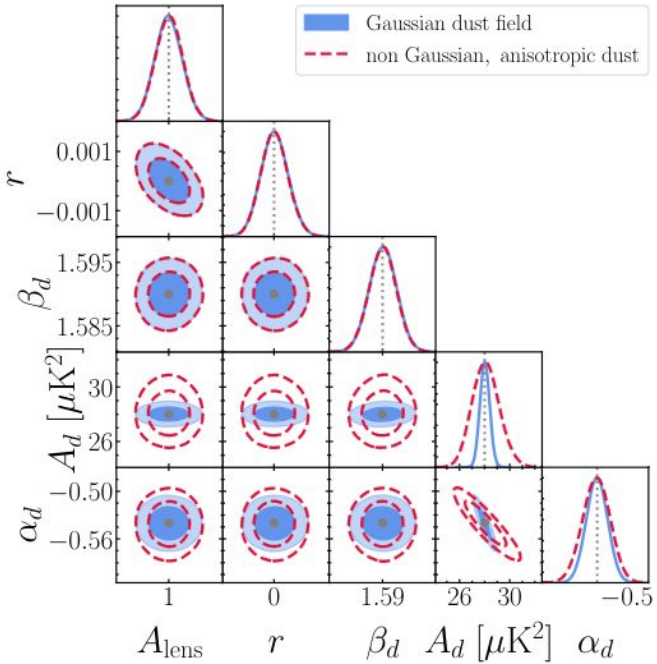


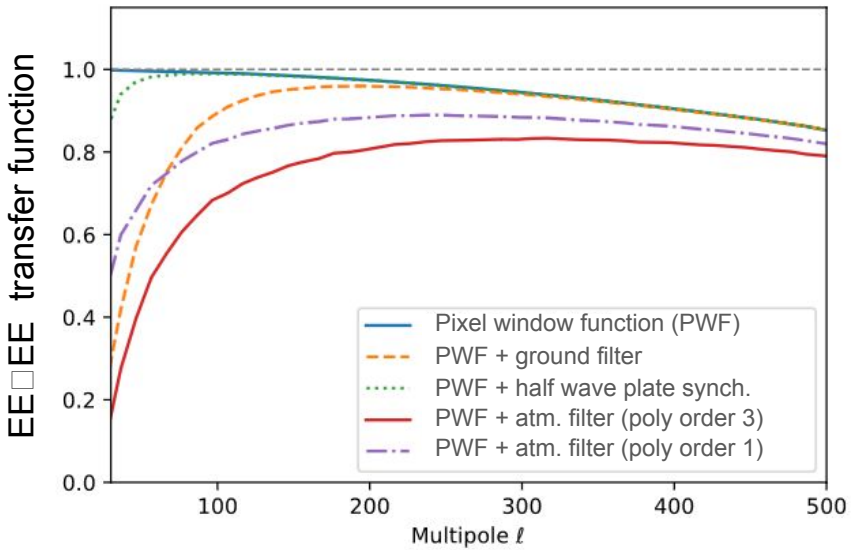
Cross-C_ℓ : impact of time-domain filtering

Approximation: $C_\ell^{\rm obs} = \sum_{\ell'} M_{\ell\ell'} T_{\ell'} C_{\ell'}$

masking filtering

Hervías-Caimapo++ 2025
2502.00946

Isotropic power suppression



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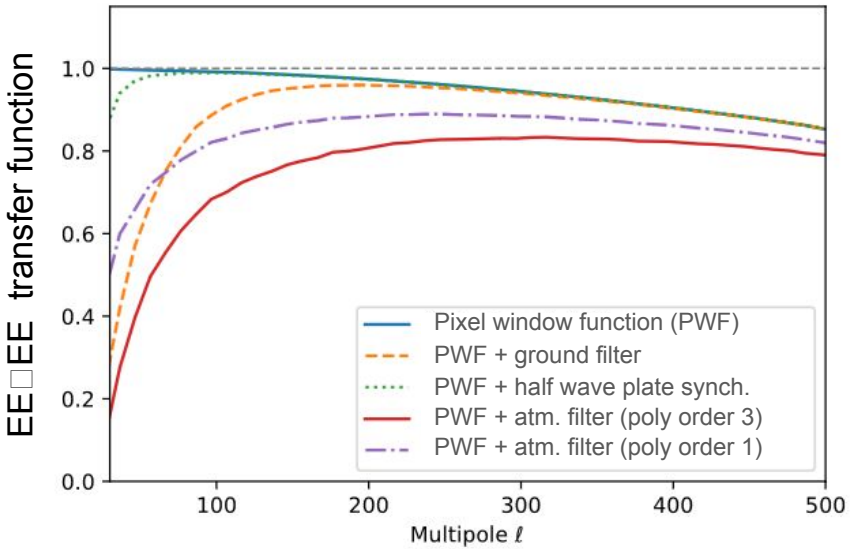
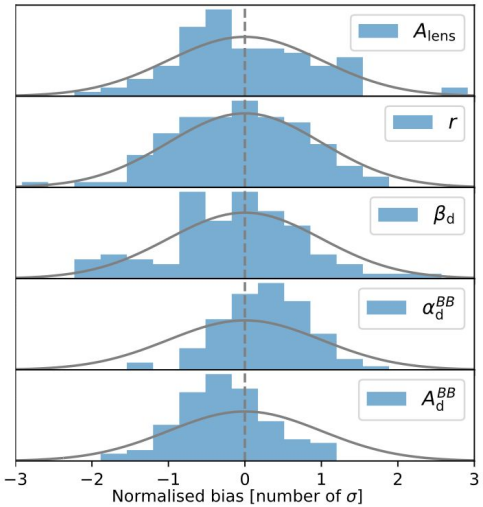
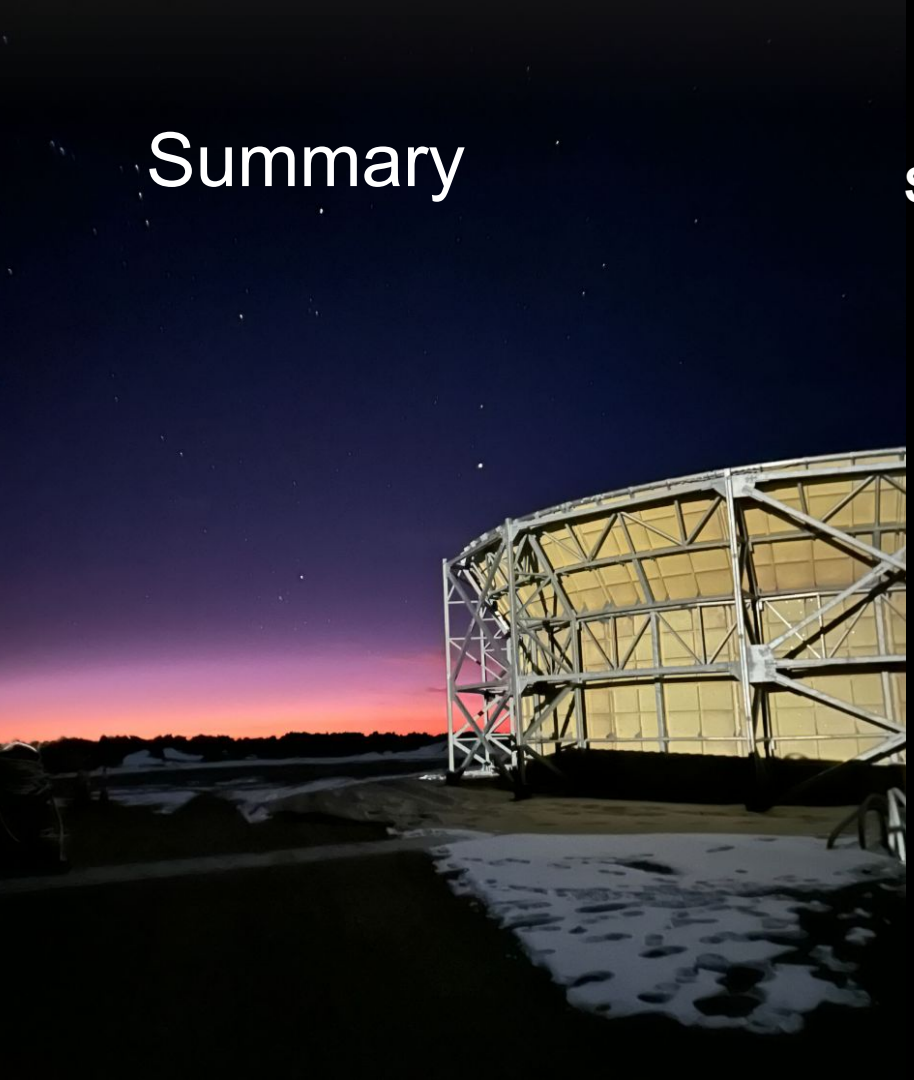


Anisotropic filtering of anisotropic sky
(SO 1-year simulations)



Filtered:
Planck 353
100 SO sims
(90+150 GHz
CMB + d1s1)

Summary



Science observations ongoing!

- Component separation pipelines: Cross-CL, map-based parametric, NILC
- Moderate SED anisotropy: methods in place (moments, dust marginalisation)
- Extreme SED anisotropy may require more advanced methods (e.g. hybrid map+C_ℓ, higher order moments)
- Anisotropic filtering: transfer function approach validated on first-year sims

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