Review of PICO foregrounds study with GNILC

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Hanany et al, 1902.10541

11 June 2020

PICO in Brief

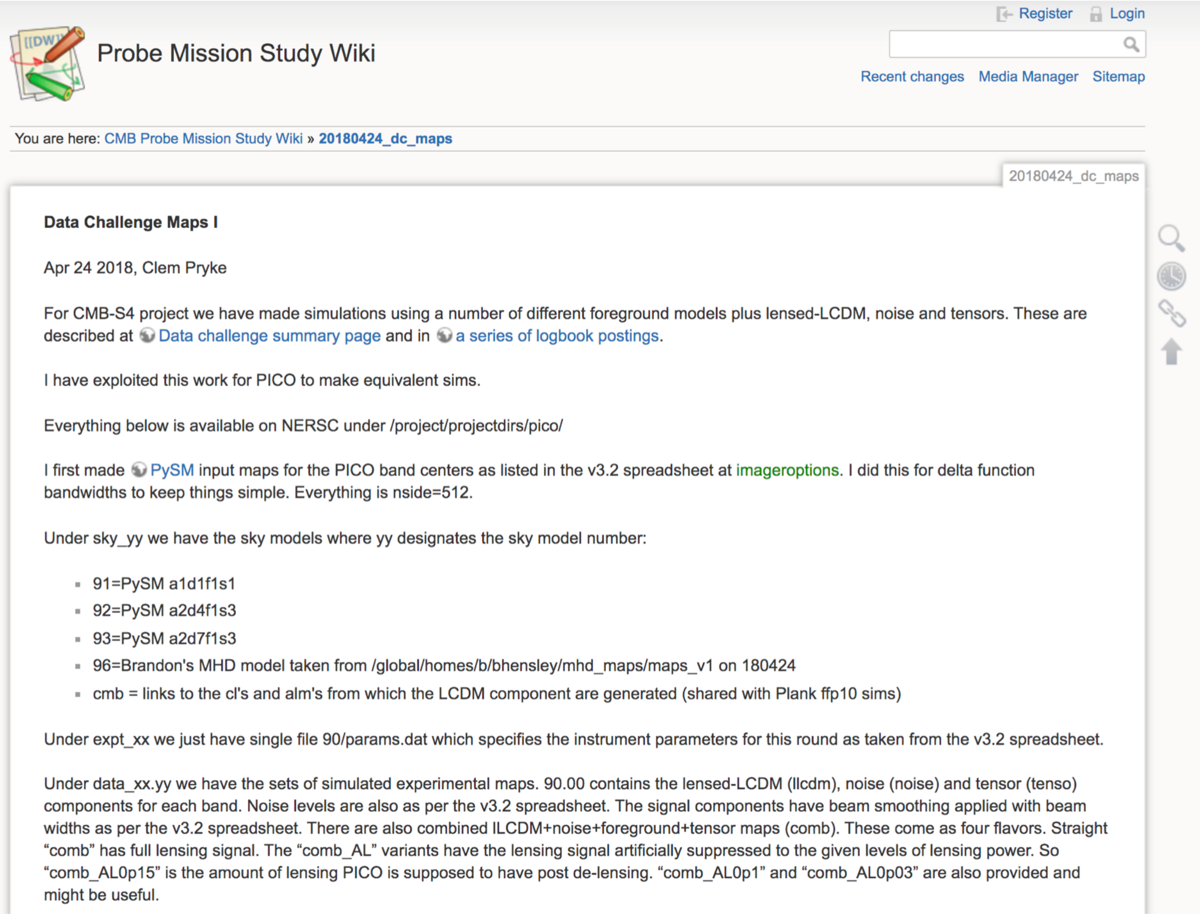
arXiv:1902.10541

- Millimeter/submillimeter-wave, polarimetric survey of the entire sky
- 21 bands between 20 GHz and 800 GHz
- 1.4 m aperture telescope
- Diffraction limited resolution: 38’ to 1’
- 13,000 transition edge sensor bolometers
- 5 year survey from L2
- 0.87 uK*arcmin requirement; 0.61 uK*arcmin goal (=CBE)

PICO data challenge map simulations:

https://zzz.physics.umn.edu/ipsig/20180424_dc_maps

NERSC: /project/projectdirs/pico/data_xx.yy/



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20180424_dc_maps

Data Challenge Maps I

Apr 24 2018, Clem Pryke

For CMB-S4 project we have made simulations using a number of different foreground models plus lensed-LCDM, noise and tensors. These are described at Data challenge summary page and in a series of logbook postings.

I have exploited this work for PICO to make equivalent sims.

Everything below is available on NERSC under /project/projectdirs/pico/

I first made PySM input maps for the PICO band centers as listed in the v3.2 spreadsheet at imageroptions. I did this for delta function bandwidths to keep things simple. Everything is nside=512.

Under sky_yy we have the sky models where yy designates the sky model number:

- 91=PySM a1d1f1s1
- 92=PySM a2d4f1s3
- 93=PySM a2d7f1s3
- 96=Brandon's MHD model taken from /global/homes/b/bhensley/mhd_maps/maps_v1 on 180424
- cmb = links to the cl's and alm's from which the LCDM component are generated (shared with Plank ffp10 sims)

Under expt_xx we just have single file 90/params.dat which specifies the instrument parameters for this round as taken from the v3.2 spreadsheet.

Under data_xx.yy we have the sets of simulated experimental maps. 90.00 contains the lensed-LCDM (llcdm), noise (noise) and tensor (tenso) components for each band. Noise levels are also as per the v3.2 spreadsheet. The signal components have beam smoothing applied with beam widths as per the v3.2 spreadsheet. There are also combined lLCDM+noise+foreground+tensor maps (comb). These come as four flavors. Straight "comb" has full lensing signal. The "comb_AL" variants have the lensing signal artificially suppressed to the given levels of lensing power. So "comb_AL0p15" is the amount of lensing PICO is supposed to have post de-lensing. "comb_AL0p1" and "comb_AL0p03" are also provided and might be useful.

Band#	nu (GHz)	nu_low (GHz)	nu_high (GHz)	del nu (GHz)	FWHM (arcmin)	PolWeight (uK*arcmin)
1	21	18.2	23.4	5.2	38.4	16.9
2	25	21.9	28.1	6.3	32.0	11.8
3	30	26.3	33.8	7.5	28.3	8.1
4	36.0	31.5	40.5	9.0	23.6	5.7
5	43.2	37.8	48.6	10.8	22.2	5.8
6	51.8	45.4	58.3	13.0	18.4	4.1
7	62.2	54.4	70.0	15.6	12.8	3.8
8	74.6	65.3	84.0	18.7	10.7	2.9
9	89.6	78.4	100.8	22.4	9.5	2.0
10	107.5	94.1	120.9	26.9	7.9	1.6
11	129.0	112.9	145.1	32.3	7.4	1.6
12	154.8	135.4	174.1	38.7	6.2	1.3
13	185.8	162.5	209.0	46.5	4.3	2.6
14	222.9	195.0	250.8	55.7	3.6	3.0
15	267.5	234.0	300.9	66.9	3.2	2.1
16	321.0	280.9	361.1	80.3	2.6	2.9
17	385.2	337.0	433.3	96.3	2.5	3.5
18	462.2	404.4	520.0	115.6	2.1	7.4
19	554.7	485.3	624.0	138.7	1.5	34.6
20	665.6	582.4	748.8	166.4	1.3	143.7
21	798.7	698.9	898.5	199.7	1.1	896.4

PICO foreground models

- 91: PySM **`a1d1f1s1` (*Planck*'s state-of-the-art)**
  - ✓ Thermal dust: single MBB with variable $\beta_d(\vec{n})$ and variable $T_d(\vec{n})$
  - ✓ Synchrotron: power-law with variable $\beta_s(\vec{n})$

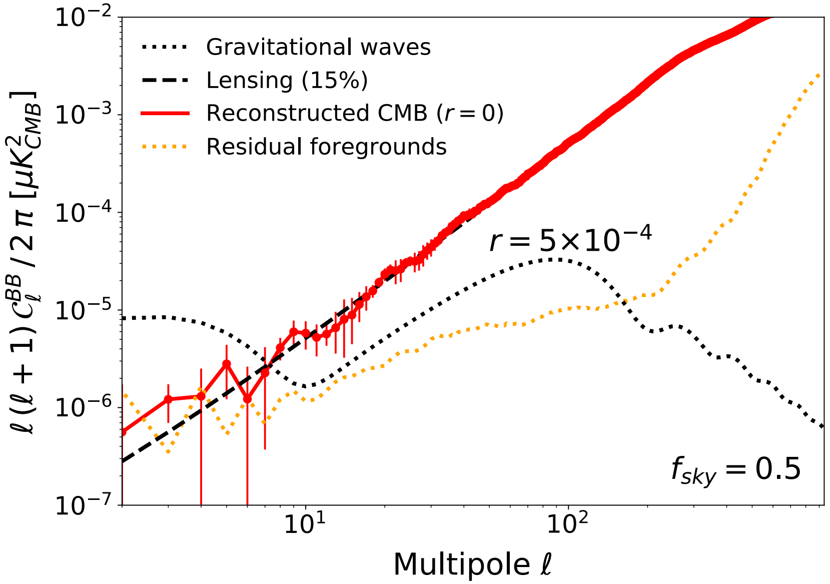
- 92: PySM **`a2d4f1s3` (Model A)**
  - ✓ Thermal dust: two MBB components with uniform $\beta_d^{(1)}, \beta_d^{(2)}$ and variable $T_d^{(1)}(\vec{n}), T_d^{(2)}(\vec{n})$
  - ✓ Synchrotron: curved power-law with variable $\beta_s(\vec{n})$ and uniform curvature C_s
  - ✓ AME: 2% polarization

- 93: PySM **`a2d7f1s3` (Model B)**
  - ✓ Thermal dust: Hensley & Draine's physical model of thermal dust (*Hensley's PhD, 2015*)
  - ✓ Synchrotron: curved power-law with variable $\beta_s(\vec{n})$ and uniform curvature C_s
  - ✓ AME: 2% polarization

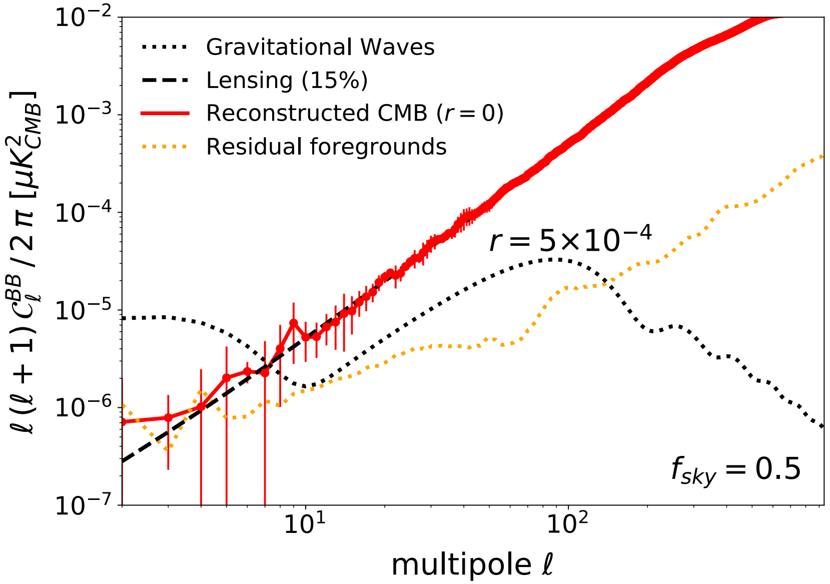
- 96: **MHD (Model C)**
  - ✓ Thermal dust & synchrotron consistently derived from MHD simulations (*Kritsuk et al 2018*, *Kim et al 2019*)
  - ✓ Multiple MBBs integrated along the line-of-sight (dust model from *Hensley's PhD, 2015*)

GNILC results with PICO

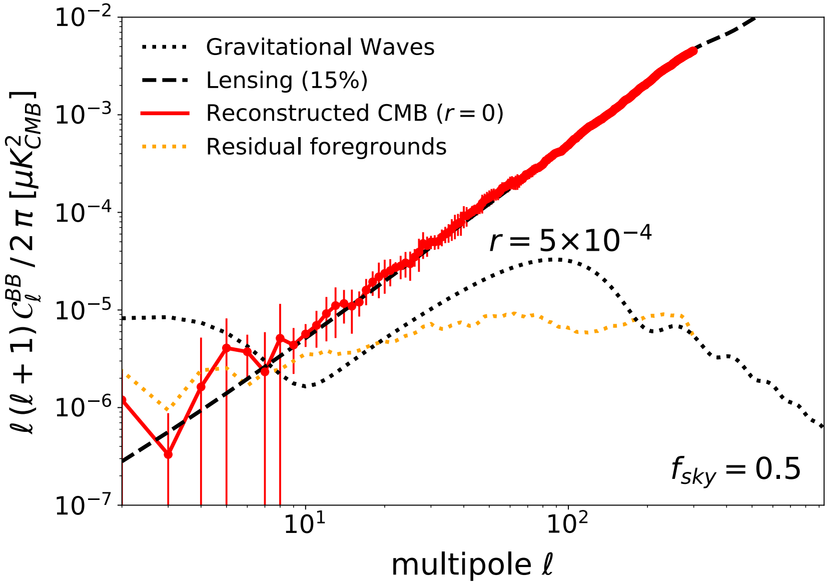
Model A



Model B

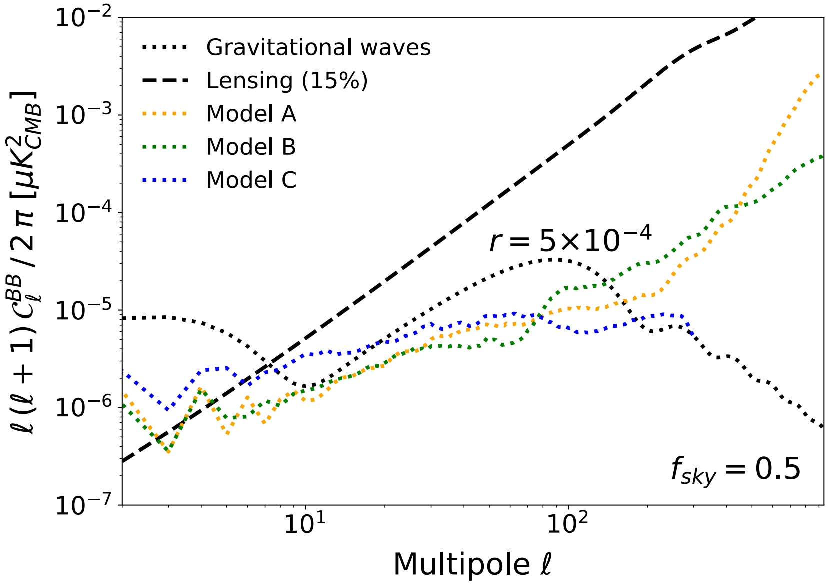


Model C



$r = 0$

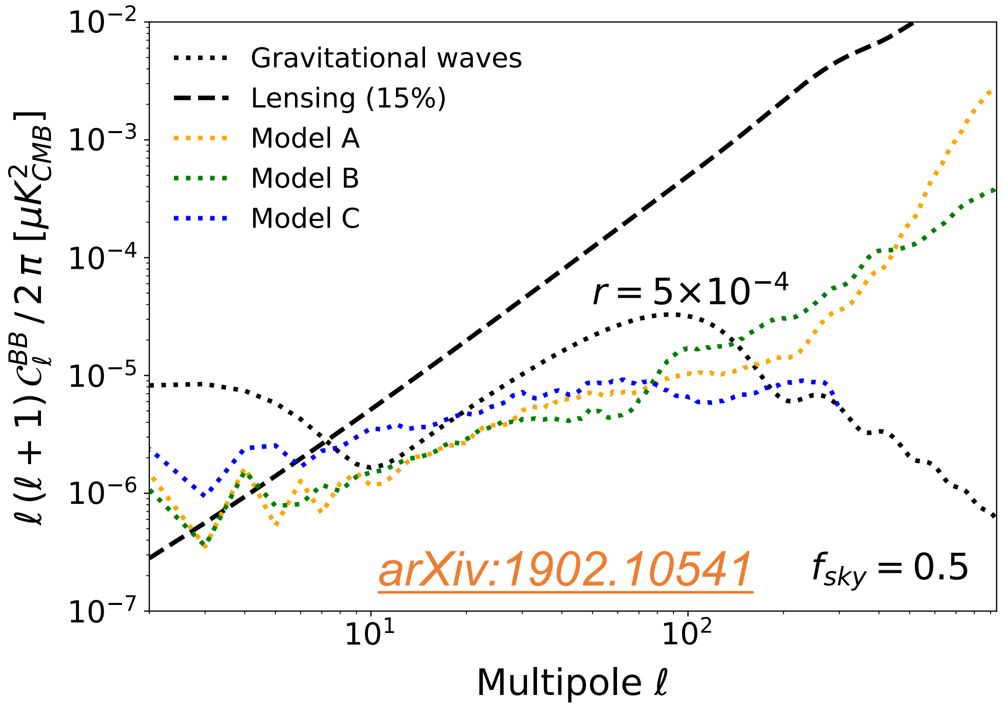
$A_L = 0.15$



arXiv:1902.10541

What has been done so far? ($\gtrsim$ 1.5 years ago)

- ✓ Several foreground models of different complexity already passed through GNILC, with quite robust results
- ✓ Residual foreground contamination reduced well below $r = 5\times10^{-4}$ across multipoles $2 \leq \ell \lesssim 200$



Next steps to make a PICO paper?

- Transform GNILC results into likelihood constraints on r (quite easy on my side)

  → It is essential to quantify both biases $(r - r^{\mathrm{true}})/\sigma(r)$ and uncertainties $\sigma(r)$

- Add more independent component separation methods for robustness:

  → COMMANDER (parametric), GNILC (blind), other methods?

- Confront all methods to several foreground models of different complexity

  → Set of models already available on NERSC: /project/projectdirs/pico/data_xx.yy/

- Consider not only $r = 0$ in forecasts, but also e.g. $r = 10^{-3}$

  → How well can we recover the shape of the primordial signal across multipoles?

- Quantify the importance of extended spectral coverage: 20-800 GHz (baseline) vs 40-400 GHz (descope)

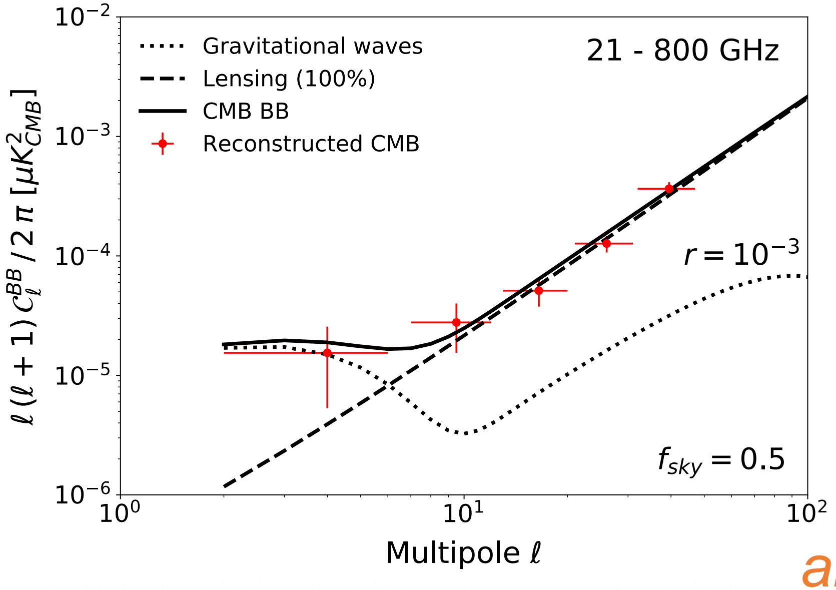
  → More leverage than increased sensitivity?
  → Allows to break model degeneracies / Provide evidence for incorrect modelling & false detections of r

- *Do we want to include real delensing on maps, with residual foregrounds degrading lensing reconstruction?*
  Do we want to focus on B-modes or extend the foreground study to other PICO science, e.g. SZ effects, etc?

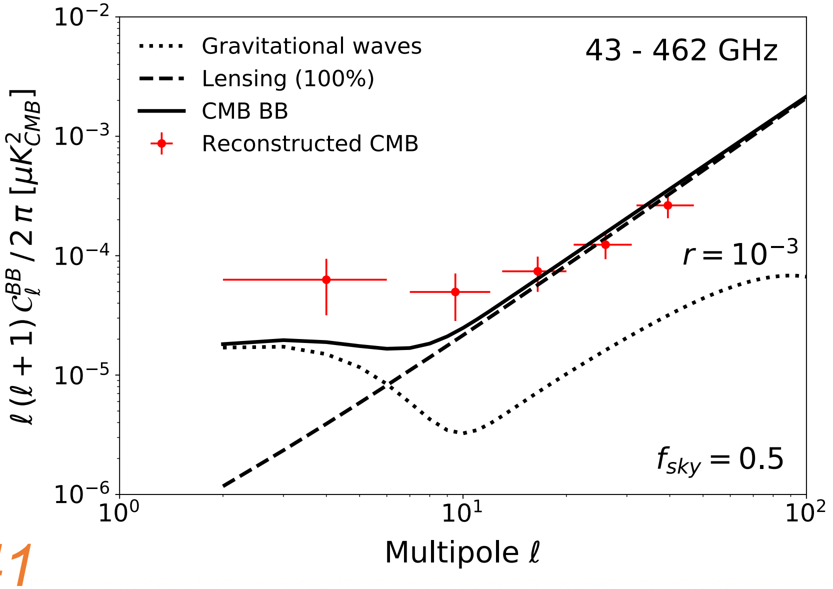
COMMANDER results with PICO

On the importance of broad spectral coverage

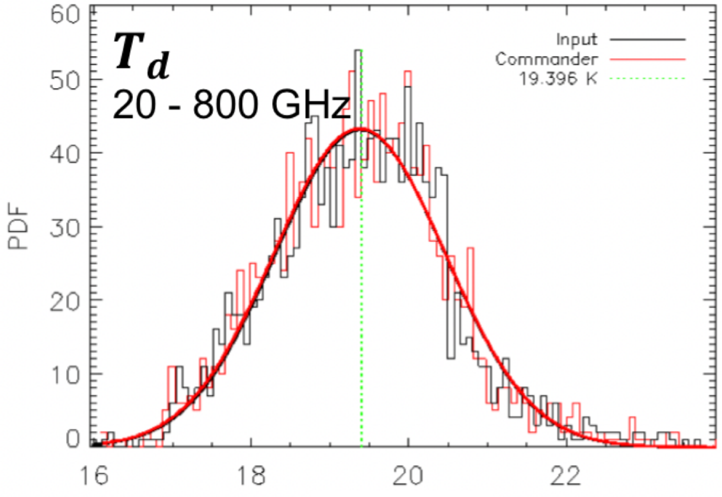
21 - 800 GHz

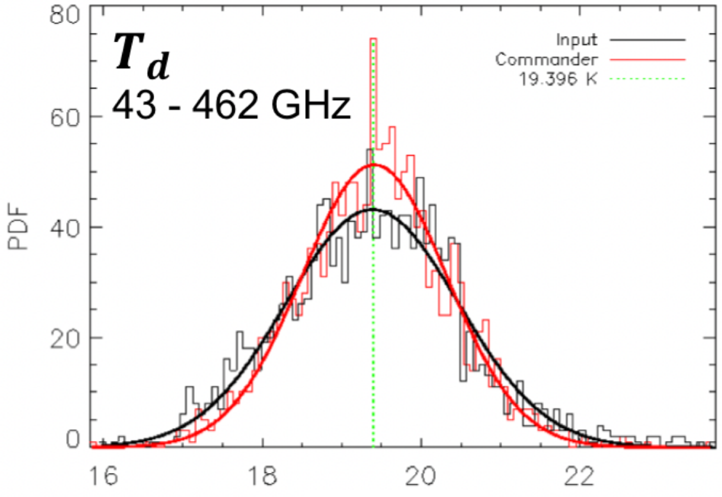


43 - 462 GHz



arXiv:1902.10541





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