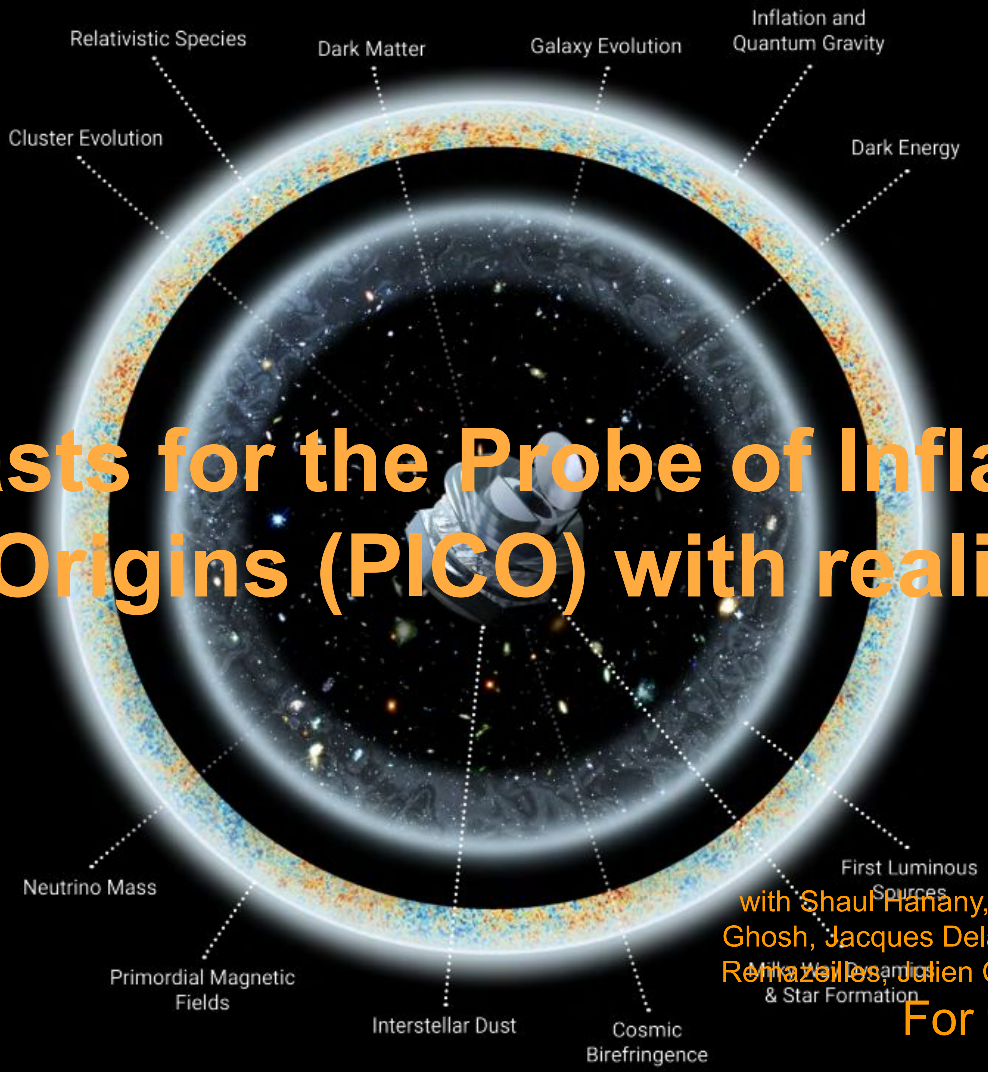
PICO report:
arXiv:1902.10541

r forecasts for the Probe of Inflation and Cosmic Origins (PICO) with realistic noise



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For the PICO collaboration

PICO: r science (arXiv 1902.10541)

Report

With **5 years** and **5σ** confidence level:

1) Reject simplest inflation models r >~ 5x 10^{-4}
2) Detect r = 5 x 10^{-4}

Previous Results (JCAP **06** (2023) 034) - white homogeneous noise, and 4 foreground models:

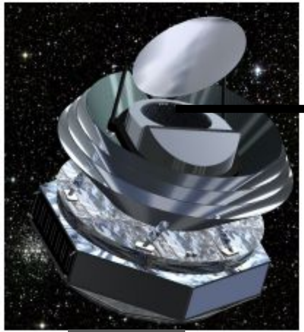
If r = 0.003, more than 15σ detection in **5 years**

If r = 0, 95% upper limits between 1 - 2 x 10^{-4} in **5 years**

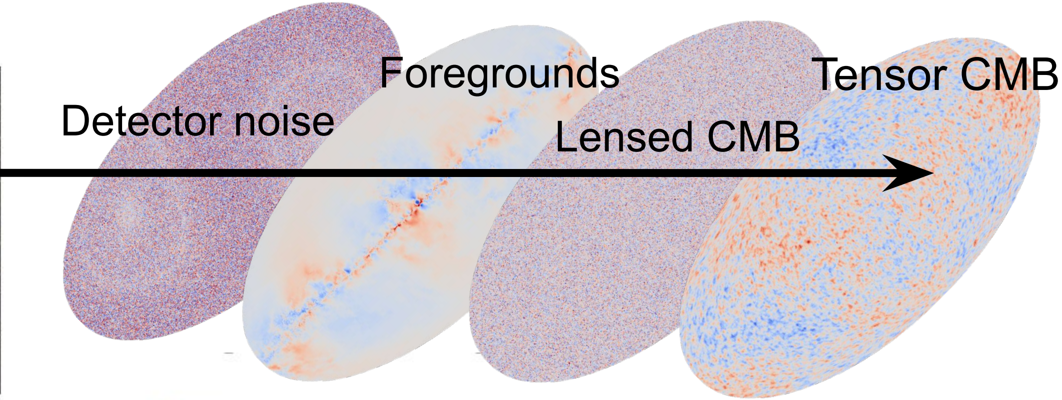
Current project:

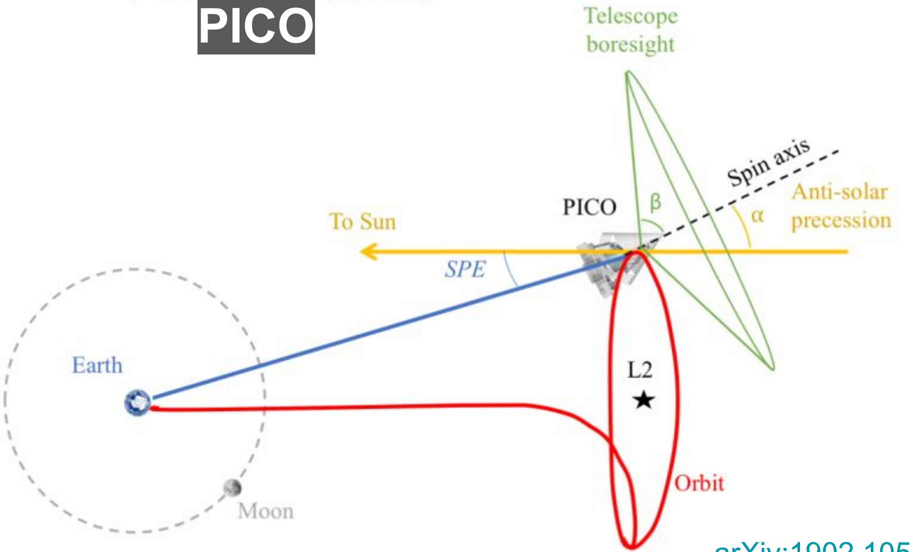
Realistic noise (+1/f) and as-designed scan strategy

Modeling sources of contamination for PICO



PICO



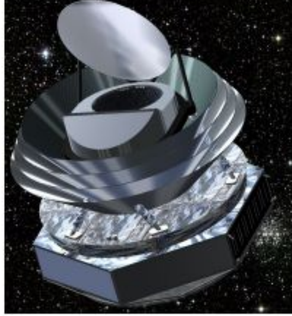


PICO scanning strategy

Designed for polarization science without a wave-plate

arXiv:1902.10541 **[astro-ph.IM]**

Instrument Characteristics



- Lowest noise, all-sky instrument among next generation experiments (e.g. ~10000 Planck years to reach PICO's sensitivity)
- Large frequency range with a single 13,000 detector focal plane

Sky coverage	**Full sky**
Duration [years]	**5**
Frequency range [GHz]	**21 — 799 GHz (21 bands)**
Angular resolution [arcmin]	**38.4 — 1.1**
Noise sensitivity [μK.arcmin]	**0.61**

Large frequency range, high resolution, high sensitivity

Data: Simulated observations

CMB: r = 0 and r = 0.003

+

Foreground maps:

PySM low, medium and high complexity

+

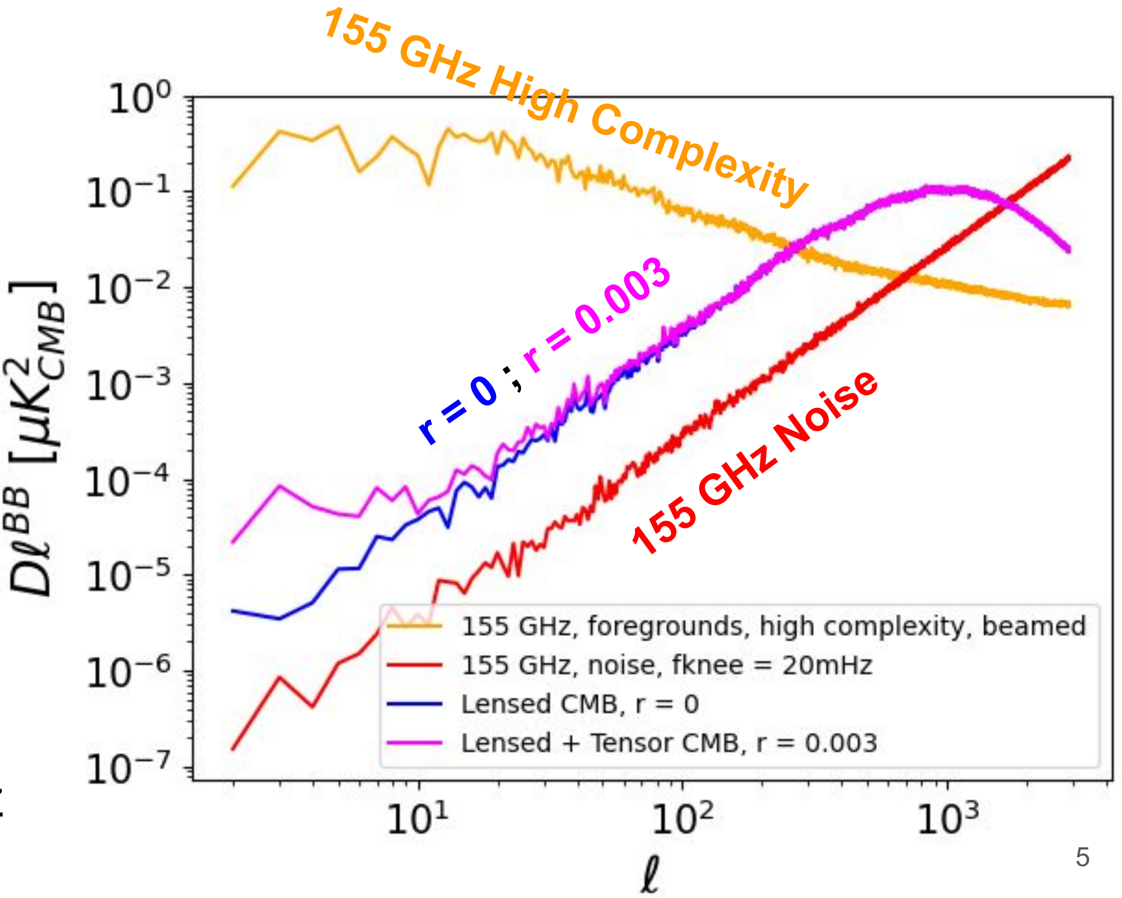
Noise:

TOAST: 20 mHz, 50 mHz, 100 mHz, 200 mHz

=

21 frequency maps: 21-799 GHz

B-mode spectra, fsky = 46%



Foreground models

Generated with PySM; three complexity levels

PySM 3 paper out soon!

	Low	Medium	High
Dust	MBB, fixed T_d = 19.6 K β_d = 1.48	MBB T_d, β_d from GNILC PR2	3D model of polarized dust emission with 6 layers
Synchrotron	Power law, fixed β_s = -3.1	Power law β_s from Haslam, S-PASS, WMAP	Curved power law β_s from Haslam, S-PASS, WMAP c_s from ARCADE
AME	Unpolarized	2% polarized	2% polarized

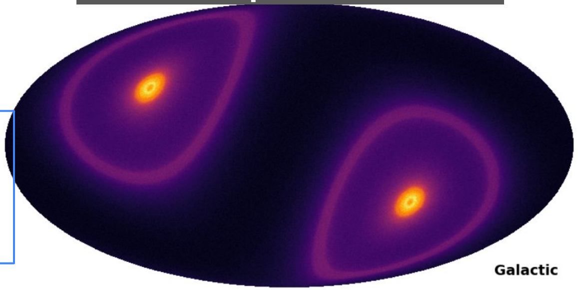
Data: Generation of the realistic noise

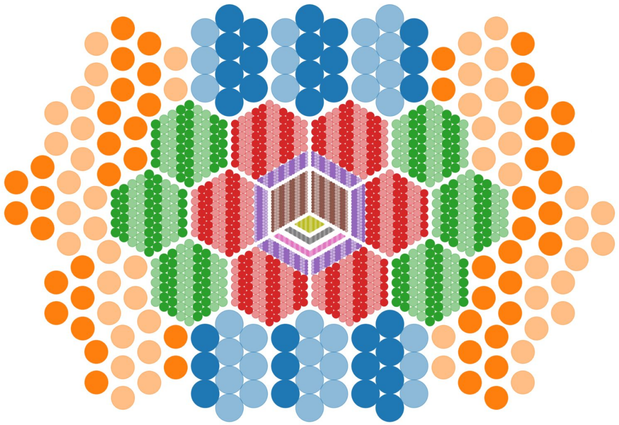
Parameters of the mission

- 5 years
- 90% detector yield
- 95% survey efficiency

Time-Ordered Data generated from TOAST

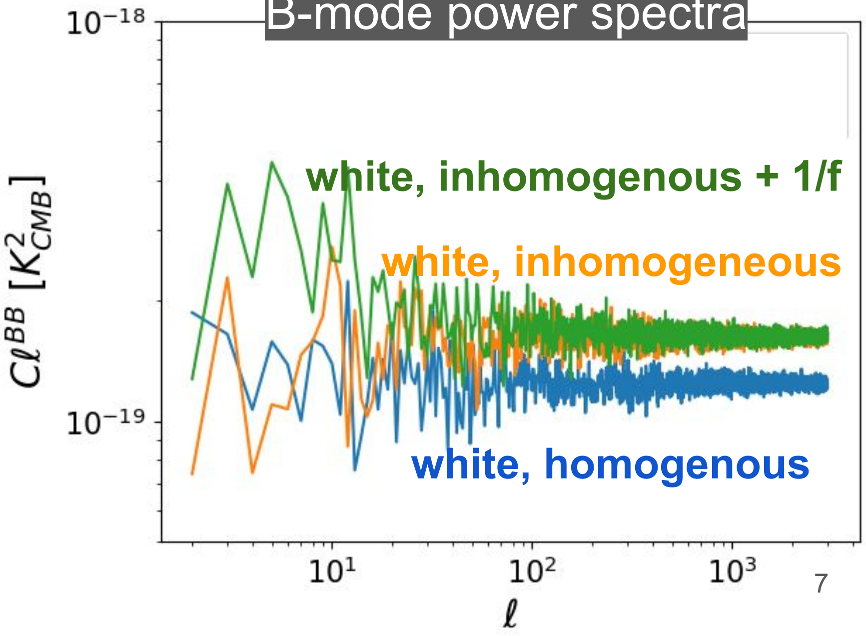
Hits map, 155 GHz





PICO focal plane

B-mode power spectra



Methodology

Frequency maps

Component separation: Blind method: NILC: Needlet Internal Linear Combination
A&A 493, 835-857 (2009)

CMB lensed B mode map

Delensing: Power spectra level, 73% suppression assumed

Map level, Iterative lensing reconstruction, on-going
Sebastian Belkner *et al* 2024 *ApJ* 964 148

CMB delensed B mode map

r likelihood

Results: r constraints

One simulation, medium complexity, 73% delensing:

- r = 0: **σ(r) ~ 2.5 x 10^{-4} depending on fknee→ minor change compared to white homogeneous noise (mostly due to the noise inhomogeneity)**

  The impact of fknee is small: **20% increase in σ(r) for 50 - 200 mHz**

- r = 0.003, **σ(r) ~ 3 x 10^{-4}** = **10σ** detection in 5 years

- No detection of significant bias for one CMB and noise simulation

	Assumptions and Methods	Results (all in 5 years)
PICO report (2019) arXiv:1902.10541 **[astro-ph.IM]**	Pen & paper forecasts	With a **5σ** confidence level: **Reject** simplest inflation models **r ~ 0.001** or **detect r = 5 x 10^{-4}**
r forecasts with white homogeneous noise (2023) JCAP **06** (2023) 034	Map-based simulations with white homogeneous noise Component separation methods: NILC and Commander Delensing: Power spectra level delensing Gaussian likelihood	If r = 0, 95% upper limits between 1 - 2 x 10^{-4} If r = 0.003, more than 15σ detection
r forecasts with realistic noise (current)	Map making: destriping Realistic noise: 1/f + inhomogeneous noise (PICO scanning) Component separation method: NILC Rest same as above	If r = 0, **σ(r) ~ 2.5 × 10^{-4}** depending on fknee If r = 0.003, **~10σ** detection

Conclusion

- PICO is a inflation probe space mission concept with 21 frequency bands, noise of 0.61 μK.arcmin over the full sky, and 5 years of observations
- We are evaluating r predictions in the presence of realistic noise and scan strategy
- We developed an end-to-end pipeline including map-making, component separation, delensing, and r likelihood

- Preliminary: we find a detection of $r = 0.003$ with more than 10σ confidence in 5 years
- Preliminary: polarization modulator is not necessary.