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ISOCURVATURE FORECASTS FOR PLANCK, CMB S4, AND PIXIE, AND MAYBE CONSTRAINTS FOR ACTPOL

Zack Li and Jo Dunkley
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ABSTRACT

We provide forecasts of cold dark matter isocurvature (CDI) constraints for combinations of Planck, CMB S4, and PIXIE. Using MCMC methods on fiducial power spectra, we find substantial improvements in the measurement of the large scale isocurvature power.

1. INTRODUCTION

The primordial cosmological perturbations are primarily adiabatic fluctuations, which come from a spatially uniform equation of state and initial velocity field and lock together the density perturbations of the different components (Planck Collaboration et al. 2014). Several scenarios allow for spatially varying equations of state or initial velocity fields, producing isocurvature perturbations.

Motivations. Inflation with a single scalar field and slow-roll initial conditions excites only adiabatic perturbations. However, multiple field inflation can produce an isocurvature spectrum as well as an adiabatic spectrum, with possible correlations between the two (Langlois 1999). Commonly studied isocurvature perturbations arise from variations between photon density, cold dark matter (CDM) density, neutrino density, and neutrino velocity. Quantum fluctuations can also lead to the curvaton scenario, which also generating isocurvature perturbations correlated with the adiabatic modes (**?**). Some string theory axions can also carry isocurvature fluctuations from quantum fluctuations, leading to uncorrelated adiabatic and isocurvature perturbations.

In this paper we forecast constraints on CDM isocurvature using fiducial power spectra and simulations of future CMB experiments. The CDM isocurvature contribution to TT, TE, and EE power spectra is out of phase with the adiabatic perturbations in C_l, so improvements in CMB polarization measurements can considerably improve upon current constraints.

- broad motivations for what produces isocurvature. axions / curvaton / inflation (done!)
- heuristic description of isocurvature effects on CMB power spectra. maybe I include something like the dD_l/dP^j_{II} plots. (short description here done, will need to elaborate in the methods section)
- previous CMB measurements: Planck 2015, WMAP (Komatsu et al, Bean et al, Moodley 2004)
- other forecasting papers? Do these exist?

2. METHODS

2.1. *Perturbations and Power Spectra*

I should include the description of PII and PRI.

For a set of the standard cosmological parameters with the additional isocurvature parameters, we compute a theoretical power spectrum with CLASS, a fast Boltzmann code written in C (citation). The adiabatic and isocurvature are contained in three functions, $\mathcal{P}_{\mathcal{RR}}(k)$, $\mathcal{P}_{\mathcal{II}}(k)$, and $\mathcal{P}_{\mathcal{RI}}(k)$, the curvature, isocurvature, and cross-correlation power spectra, respectively (cite Planck 2015 XX). Like Planck, we specify these power spectra through two scales, $k_1 = 0.002$ Mpc^{-1} and $k_2 = 0.100$ Mpc^{-1}. We use the same uniform priors as Planck,

$$\mathcal{P}^{(1)}_{\mathcal{RR}}, \mathcal{P}^{(2)}_{\mathcal{RR}} \in (10^{-9}, 10^{-8}), \tag{1}$$

$$\mathcal{P}^{(1)}_{\mathcal{II}}, \mathcal{P}^{(2)}_{\mathcal{II}} \in (0, 10^{-8}), \tag{2}$$

$$\mathcal{P}^{(1)}_{\mathcal{RI}} \in (-10^{-8}, 10^{-8}). \tag{3}$$

We follow Planck 2015 XX's convention of fixing $\mathcal{P}^{(2)}_{\mathcal{RI}}$ from these parameters. Then we sample over the ΛCDM scenario, but replace A_s and n_s with $\mathcal{P}^{(1)}_{\mathcal{RR}}$, $\mathcal{P}^{(2)}_{\mathcal{RR}}$ and add the three isocurvature parameters $\mathcal{P}^{(1)}_{\mathcal{II}}$, $\mathcal{P}^{(2)}_{\mathcal{II}}$, $\mathcal{P}^{(1)}_{\mathcal{RI}}$.

$$\{\Omega_b h^2, \Omega_c h^2, \theta_A, \tau_{reio}, \mathcal{P}^{(1)}_{\mathcal{RR}}, \mathcal{P}^{(2)}_{\mathcal{RR}} \tag{4}$$

$$\mathcal{P}^{(1)}_{\mathcal{II}}, \mathcal{P}^{(2)}_{\mathcal{II}}, \mathcal{P}^{(1)}_{\mathcal{RI}}\} \tag{5}$$

Should I describe the perturbation stuff of how the CLASS isocurvature code works?

2.2. *Forecasting*

- explanation of how we got these numbers in Table 1
- how do you turn the numbers in Table 1 into a likelihood
- atmospheric noise model
- choosing a fiducial power spectrum.
- comparing the fiducial power spectrum Planck parameter estimates with real Planck (do we we need this?)

TABLE 1
FORECASTING PARAMETERS

Experiment	l_{min} - l_{max}	f_{sky}	θ FWHM	σ_T (μK arcmin)	σ_P (μK arcmin)
CMB S4	30-3000	0.40	3.0	1.0	1.4
PIXIE	2 - 150	0.8	120	2.9	4.0
Planck 2017 high_l	30 - 2500	0.65	10,7.1,5.0	65.0, 43.0, 66.0	103.0, 81.0, 134.0

NOTE. — These forecasts are based on blahblahblah.

2.3. *ACTPol Likelihood*

We use the same methods as in Louis et al. 2016 for the ACT likelihood, marginalizing the ACTPol spectrum from $350 < l < 4000$ to construct a Gaussian likelihood function with an overall calibration parameter. We produce our parameter constraints by summing this with the Planck 2015 log-likelihood. We use the public CMB-marginalized 'plik-lite' Planck 2015 likelihood which uses TT for $30 \leq l \leq 2508$, a likelihood generated from CMB lensing, and a joint TT, EE, BB, and TE likelihood for the range $2 \leq l < 30$.

$$
\begin{aligned}
-2\ln L = & -2\ln L(\text{ACTPol}) && (6)\\
& -2\ln L(\text{Planck TT}_{30<l<2508}) && (7)\\
& -2\ln L(\text{Planck TEB}_{2\leq l<30}) && (8)\\
& -2\ln L(\text{Planck Lensing}) && (9)
\end{aligned}
$$

In addition to the ΛCDM and isocurvature parameters, we need two nuisance parameters coming from the normalizations of the two instruments we use data from (Planck and ACT),

$$\{A_{planck}, Y_p\}. \tag{10}$$

3. RESULTS

- a triangle plot with all of the forecasts
- derived parameters plot, overplot all forecasts
- ACTPol measurements

4. CONCLUSION

REFERENCES

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