PySM (Python Sky Model)

Galactic foreground simulations for B-mode experiment forecasts.

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Thorne et al, MNRAS, 2017, 469 (3)
Alonso et al, PRD, 2017, 95, 043504

Introduction

Next generation of CMB missions aim for $\sigma_r \sim 10^{-3}$. Major challenges:

- *r* uncertainty dominated by lensing and foreground residuals.
- For Bayesian component separation mismodelling leads to *r* bias.
- Extra foreground parameters inflate uncertainty in *r*.

Introduction

Next generation of CMB missions aim for $\sigma_r \sim 10^{-3}$. Major challenges:

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Polarized foreground behaviour is poorly understood:

- Dust polarisation fraction as function of frequency [Planck Collaboration XXII, A&A 2015].
- Frequency decorrelation from averaging power law spectra over LOS and/or pixels (even with perfect spectral knowledge) [Remazeilles and CORE collaboration, arxiv:1704.04501].
- Curvature in synchrotron spectrum [Kogut, ApJ 2012].
- Polarisation of AME component.

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PySM - Overview

[Thorne et al MNRAS 2017] simulate thermal dust, synchrotron, AME, free-free, and CMB emission. Uses parametric models for foreground components:

$$d_\nu = A[\beta(\hat{\mathbf{n}}); \nu] T_{\nu_0}(\hat{\mathbf{n}}) + n_\nu$$

d = output map.

A = mixing matrix containing model SEDs.

β = spectral parameters, spatially varying.

T = template at some reference frequency.

n = Gaussian white noise.

Other similar codes:

- Planck Sky Model [Delabrouille et al A&A 2013].
- Hervias-Caimapo et al MNRAS 2016.
- Global Sky Model [Oliveira-Costa et al MNRAS 2008; Zheng et al MNRAS 2016].

PySM – New Dust Models

- **Two-component modified black body**
  Simple extension allowing two populations of dust based on the model of [Finkbeiner et al, ApJ 1999], using templates fitted to Planck data by [Meisner and Finkbeiner, ApJ 2014].

- **Decorrelation**
  SED-independent decorrelation for spatially varying spectral index [Vansyngel et al, A&A 2017]:

$$m_\nu(\hat{\mathbf{n}}) = v_\nu(\hat{\mathbf{n}}) f_\nu(\beta)$$

$$\mathcal{R}_{\nu\nu'} = \langle v_\nu v^*_{\nu'} \rangle = \langle |v_\nu|^2 \rangle \exp\left[-\frac{\log(\nu/\nu')^2}{2\xi^2} \right]$$

- **Hensley and Draine 2017 (*in prep*)**
  Physical model of carbonaceous and silicate composition with iron inclusions. Composition may vary across the sky. Polarisation fraction function of frequency.

PySM – Application

[Alonso et al, PRD 2017] simulate S3 and S4 constraints on *r*:

1) Simulate skies, using PySM (fiducial synchrotron+single MBB, and extensions to this).
2) Map-based Bayesian foreground cleaning with three spatially varying spectral parameters (T_d, β_d, β_s).
3) Estimate BB from cleaned masked maps, calculate *r* posterior using Gaussian likelihood.

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Results

Forecast constraints: $\sigma(r=0|S3) = (4\text{-}6)\times10^{-3}$ and $\sigma(r=0|S4) = (4\text{-}6)\times10^{-4}$.

Model mismatch: Adding two-component dust does not bias S3 or S4. Adding 2% polarised AME does not bias S3 above noise level, but biases S4 significantly.

Survey strategy: S3 prefers deep observations, S4 prefers deep only when fully delensed.

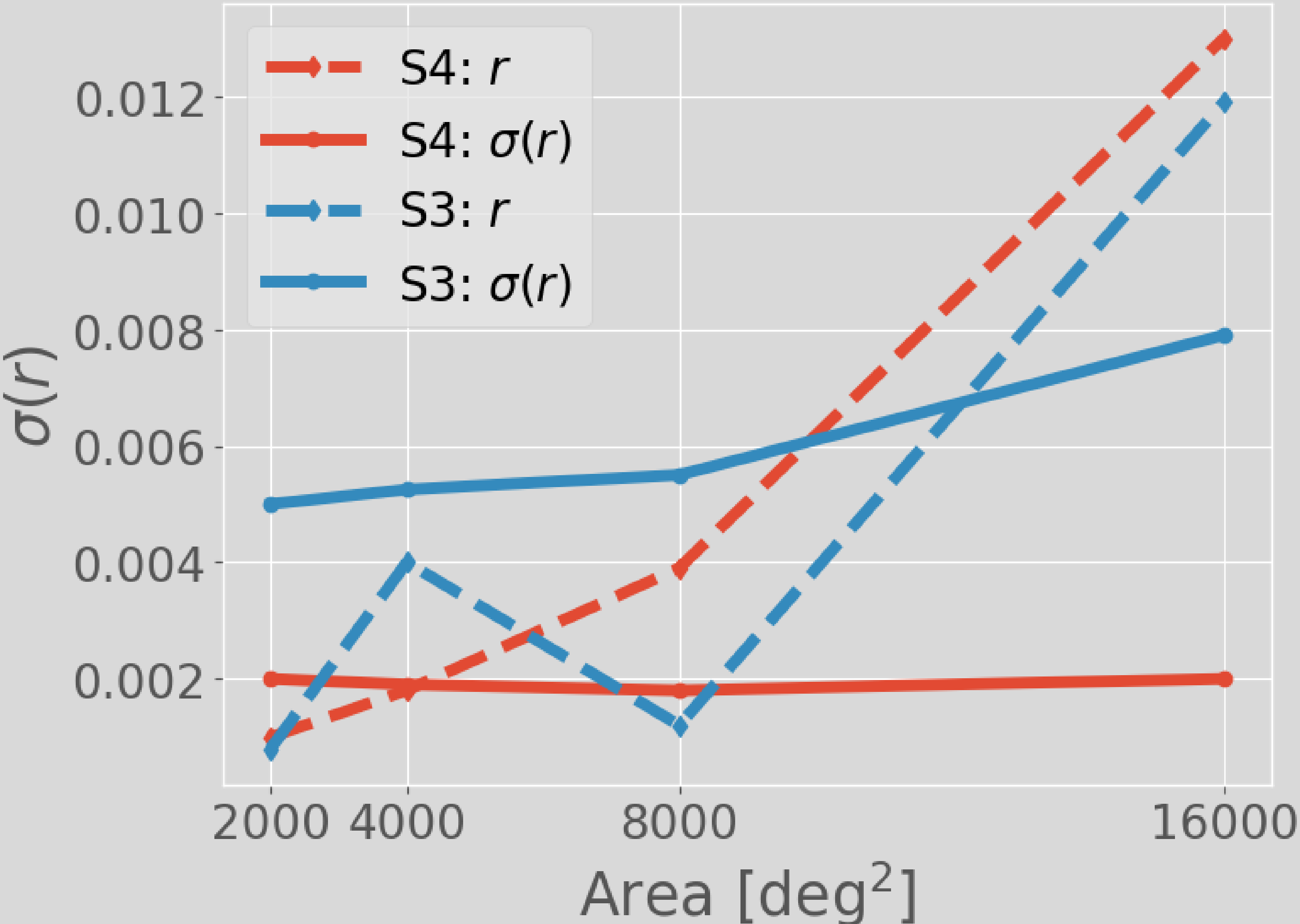
Conclusions

- Foreground separation now primary barrier to constraints on *r*.
- Broader frequency coverage to understand low frequency contributions (e.g. AME polarisation).
- Given suitable delensing, constraints from S4 may reach $\sigma \sim 5 \times 10^{-4}$.

Ongoing Work

- Applying similar techniques to LiteBIRD to investigate optimal sensitivity distribution for B-mode reconstruction.
- Understanding impact of more complex foreground models than considered here, e.g. decorrelation.

PySM – Application



PySM – New Models