Component Separation:

Large-Aperture Frequency Channel Distribution (T + P)

Colin Hill

Institute for Advanced Study

Flatiron Institute - Center for Computational Astrophysics

CMB-S4 Meeting, Harvard

25 August 2017

Optimizely

Colin Hill
IAS/CCA

Sky Model: Temperature

Model constructed from full-sky numerical sims. + data

Components:

$N_{side}=4096$

- Lensed CMB (via ray-traced N-body simulation)
- Thermal Sunyaev-Zel'dovich
- Kinematic Sunyaev-Zel'dovich
- Cosmic infrared background (CIB)
- Radio point sources (flux cut = 7 mJy at 150 GHz)
- Galactic dust
- Galactic synchrotron (Planck Commander template)
- Galactic free-free (Planck Commander template)
- Galactic anomalous microwave emission (Planck Commander)
- Atmosphere ($l_{knee}=3400$, $\alpha_{knee} = -4.7$) [frequency-independent]

tSZ and CIB rescaled to match recent data

caveat: no power in Commander above ell~400

Sehgal et al. (2010);
Planck Collaboration (2016)

All components are properly correlated

Colin Hill
IAS/CCA

Sky Model: Polarization

Analytic model based on BICEP2 foreground analysis

Components:

- Galactic dust (modified blackbody SED and ~$\ell^{-2.4}$)
- Galactic synch (power-law SED in antenna temp and ~$\ell^{-2.3}$)
  - Includes a dust-correlated component ($r_{dust\text{-}synch}=0.7$)
- Polarized radio point sources (power-law SED in flux units)
- Lensed CMB (r=0)
- Atmosphere ($l_{knee}=330$, $\alpha_{knee} = -3.8$) [frequency-independent]

Assumptions:

- Dust and synch. amplitudes match BICEP2 region for $f_{sky}=0.01$
- Dust and synch. amplitudes scale as sqrt(f_{sky}) for larger f_{sky}
- (Dust or synch EE amplitude)/(Dust or synch BB amplitude) = 2

Flauger, JCH, & Spergel (2014)

Colin Hill
IAS/CCA

Internal Linear Combination (ILC)

relatively agnostic approach, flexible choice of domain

$$\Delta T_i(p) = a_i y(p) + n_i(p)$$

i ⟷ frequency

observed temperature fluctuation — component of interest — noise+ contaminants

minimum variance estimator with unit response to desired component:

$$\hat{y}(p) = w_i \Delta T_i(p) \qquad w_j = \frac{a_i (\hat{R}^{-1})_{ij}}{a_k (\hat{R}^{-1})_{kl} a_l}$$

$$\hat{R}_{ij} = N_{\rm pix}^{-1} \sum_p \Delta T_i(p) \Delta T_j(p)$$

flexibility = choice of domain on which to compute covariance

e.g. Eriksen+ (2004)

Constrained ILC

Colin Hill
IAS/CCA

extension: explicitly remove other component(s) as well

$$\Delta T_i(p) = a_i y(p) + b_i s(p) + n_i(p)$$

observed temperature fluctuation | component of interest | component to remove | noise + other contaminants

minimum variance estimator with unit response to desired component and zero response to undesired component:

$$w_j = \frac{\left(b_k(\hat{R}^{-1})_{kl}b_l\right) a_i(\hat{R}^{-1})_{ij} - \left(a_k(\hat{R}^{-1})_{kl}b_l\right) b_i(\hat{R}^{-1})_{ij}}{\left(a_k(\hat{R}^{-1})_{kl}a_l\right)\left(b_m(\hat{R}^{-1})_{mn}b_n\right) - \left(a_k(\hat{R}^{-1})_{kl}b_l\right)^2}$$

- can be extended to explicitly remove N components
- advantage: can remove contaminants that could bias some analysis
- disadvantage: variance in final ILC map is larger

e.g. Remazeilles+ (2011), JCH (to appear)

Colin Hill
IAS/CCA

Pipeline Summary

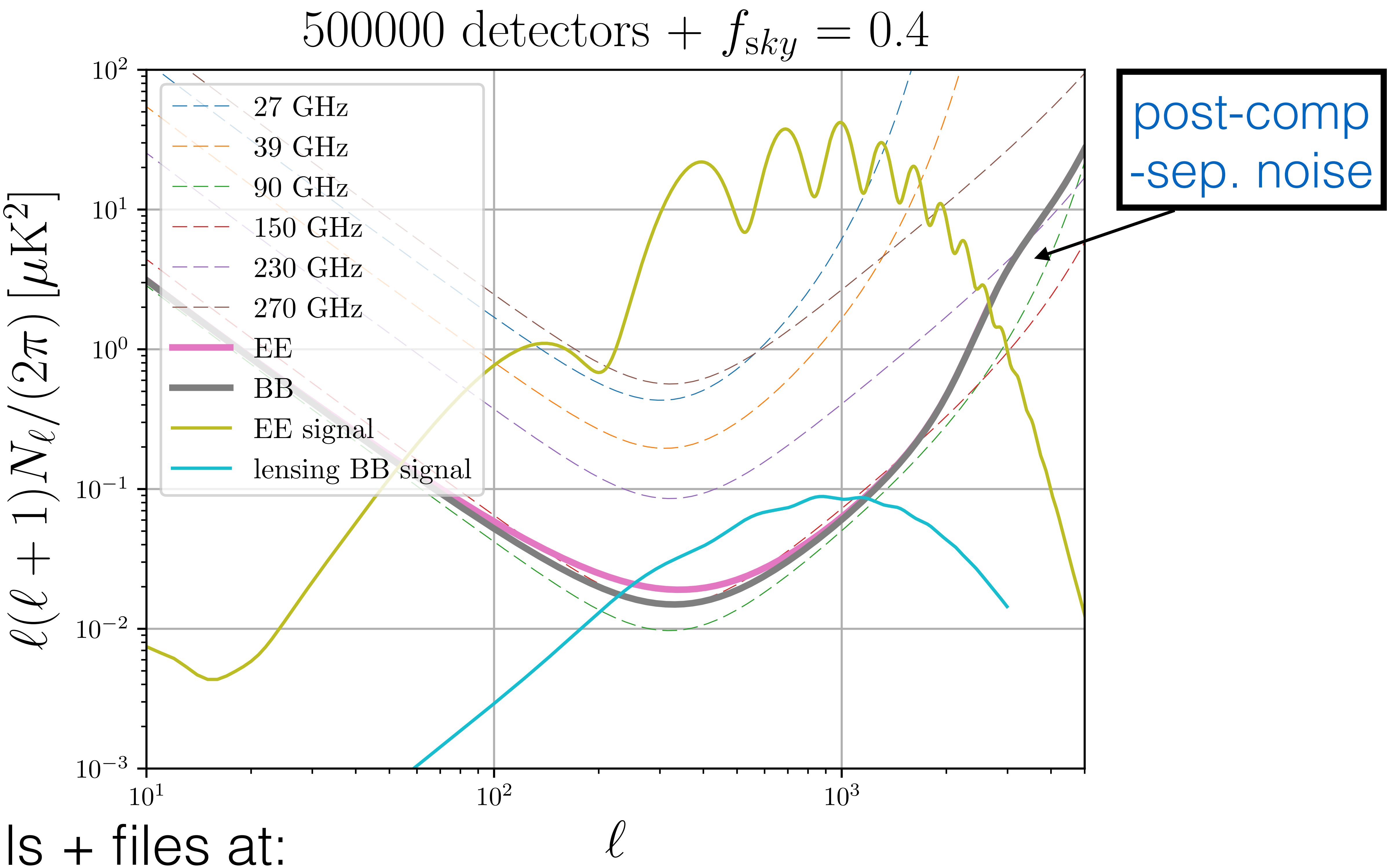
1. Compute signal auto- and cross-power spectra [TT/EE/BB] at all frequencies for all f_{sky} options
2. Compute map noise power spectra for all channel configuration options **SO Calculator** can be re-done for any desired channel config.
3. Run harmonic-space [constrained] ILC to obtain post-component-separation noise for CMB, kSZ, and tSZ signals
4. Evaluate signal-to-noise of desired observables:
    1. Total Blackbody Power Spectrum [CMB+kSZ+ISW] (l_{max} = 10000)
    2. Kinematic SZ Power Spectrum ($3000 < l < 10000$)
    3. Thermal SZ Power Spectrum (proxy for tSZ cluster probes) (l_{max} = 10000)
    4. CMB Lensing Power Spectrum via TT Estimator (l_{max} = 3000)
    5. CMB Lensing Power Spectrum via EB Estimator (l_{max} = 5000)
    6. Lensing BB Power Spectrum (l_{max} = 5000)

`quicklens` (D. Hanson)

Example: Pol. Noise Curves

Colin Hill
IAS/CCA

explicit deprojection of [fiducial] dust and synchrotron components
optimization for EB lensing S/N



Details + files at:

https://cmb-s4.org/CMB-S4workshops/index.php/R-forecasting:_high_and_low_ell_coordination