Sparse estimation of model-based diffuse thermal dust emission

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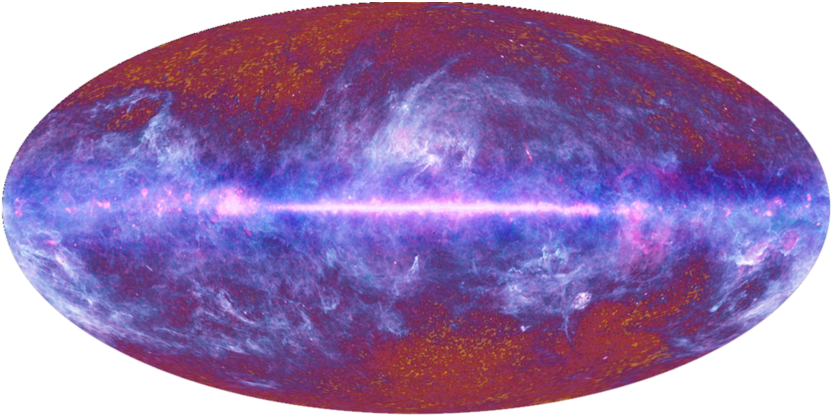
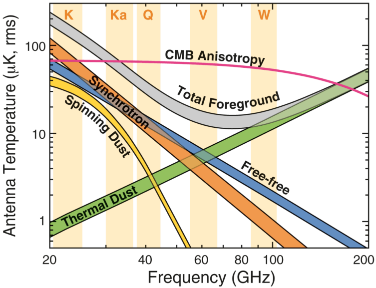
Overview

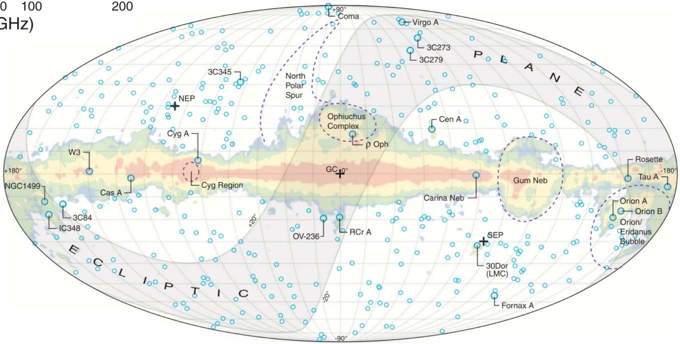
Brief introduction to CMB component separation
The problem at hand: thermal dust and the CIB
How sparsity can help
The new methodology
Validation on Planck simulation data

CMB component separation



CMB component separation

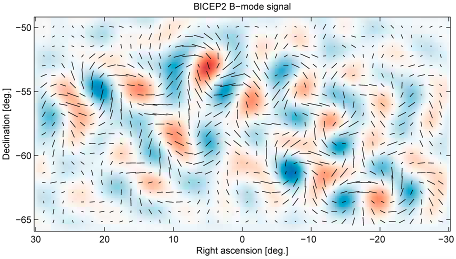




Bennett et al. 2013

Thermal dust and the CIB

BICEP2 2014



- Focus of this work:

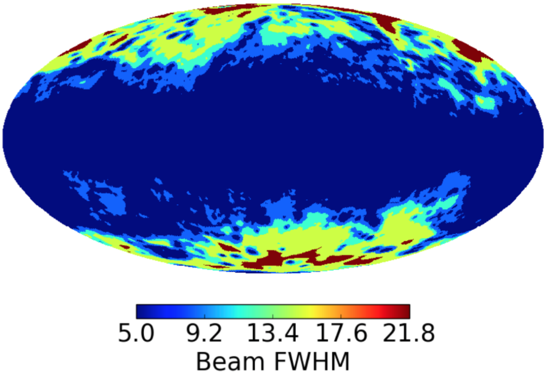
$$x_{\nu_i}^{\mathrm{dust}} = \tau_{353} \times B(T, \nu) \times \left(\frac{\nu}{353\,\mathrm{GHz}}\right)^{\beta}$$

- CIB - unresolved galaxies
- Smoothing conundrum!

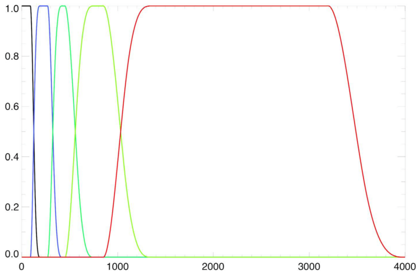
GNILC

$$\text{total flux} = \text{dust} + \underbrace{\mathrm{CIB} + \mathrm{CMB} + \mathrm{noise}}_{\text{nuisance, Gaussian approx}}$$

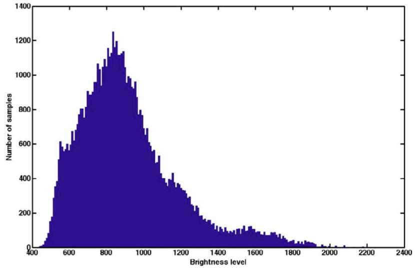
- Clever smoothing using nuisance estimates.

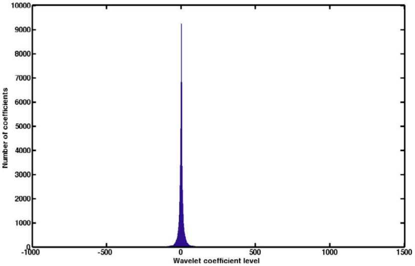


Sparsity and the wavelet domain



Bobin et al. 2013

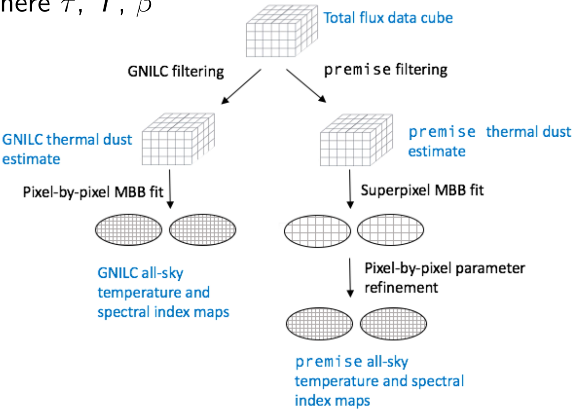




- Sparse: majority of signal is zero
- Spatially correlated source
- Wavelets filter in spherical harmonic domain (x-axis: ℓ)

PREMISE

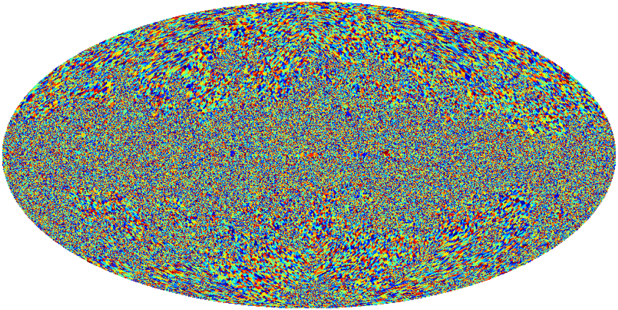
- Parameter Recovery Exploiting Model Informed Sparse Estimates
- Requires model - here τ, T, β



Filtering and Super-pixels

- Essentially GNILC filtering BUT penalise in favour of sparsity

- Accurate and fast parameter estimates from fit - τ, T, β



Refinement

- Low resolution, fast informed initial guesses
- T and β refinement - normalisation factor subject to degeneracies

$$x_{\nu_i}^{\mathrm{dust}} = \tau_{353} \times B(T,\nu) \times \left(\frac{\nu}{353\,\mathrm{GHz}}\right)^{\beta}$$

- Gradient descent at each pixel (until convergence)

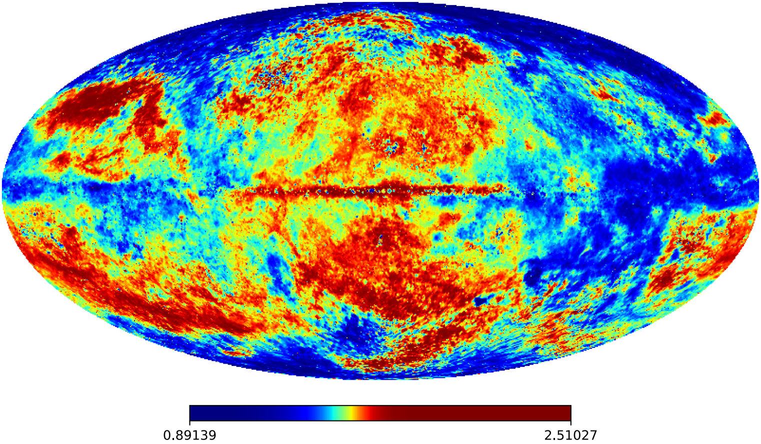
$$\beta_n/T_n = \beta_0/T_0 + \rho \times \Delta((\mathrm{Data} - \mathrm{model})\,\mathrm{w.r.t}\,\beta\,\mathrm{and\,T})$$

$$\tau_{353} = \frac{X_{857}}{B(T{,}857\,\mathrm{GHz}) \times \left(\frac{\nu}{353\,\mathrm{GHz}}\right)^{\beta}}$$

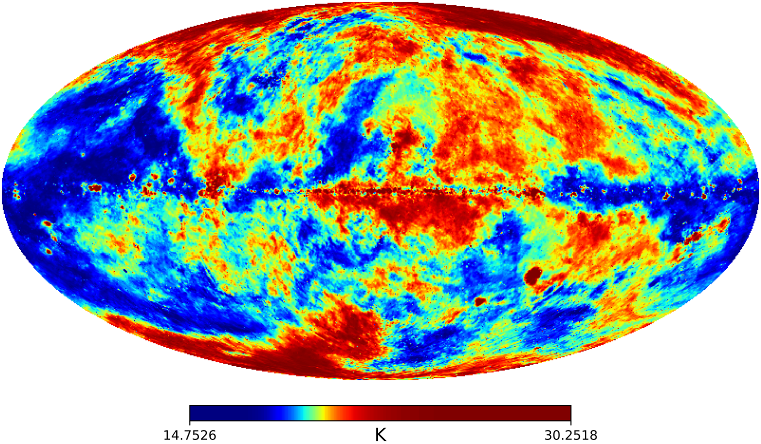
Validation

SIMULATION data only

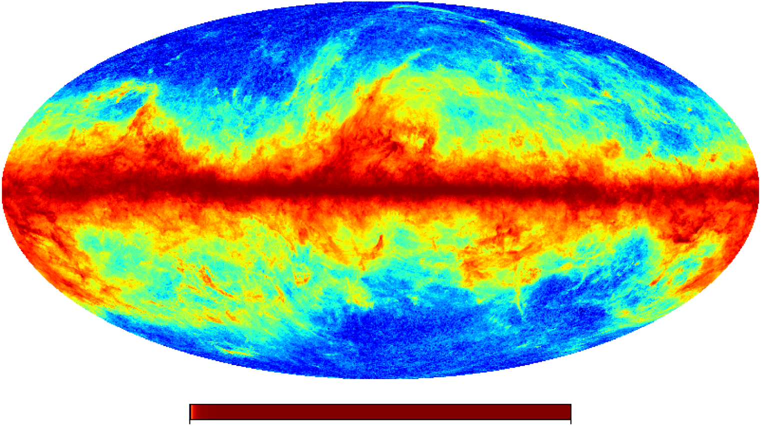
Full-sky β estimate - 5 arcmin



Full-sky T estimate - 5 arcmin

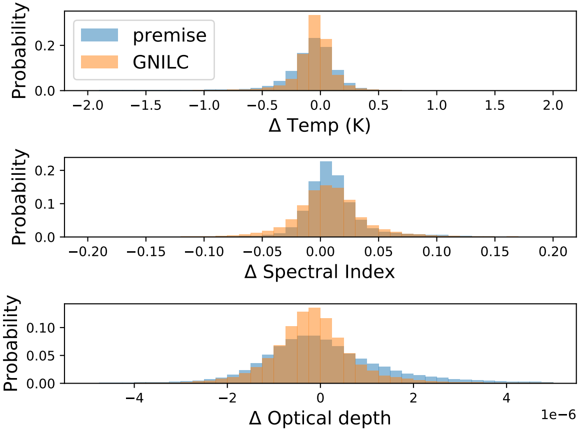


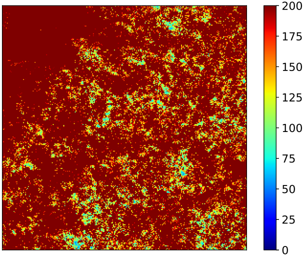
Full-sky τ_{353} estimate - 5 arcmin



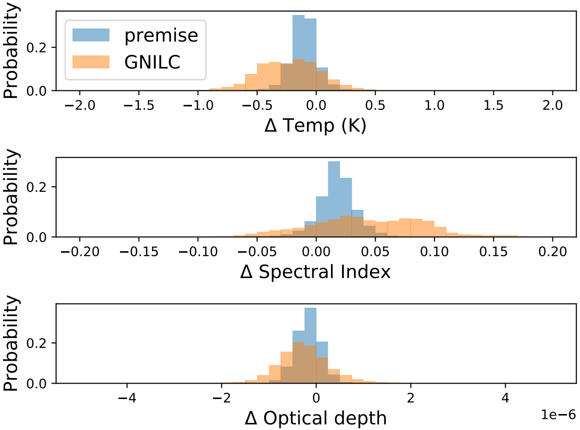
Value	Medium %Δ	1σ %Δ	2σ %Δ	3σ %Δ
Temperature	1.7	2.8	8.0	16.5
Spectral index	3.4	5.7	15.4	25.6
Optical depth (353 GHz)	3.7	7.2	31.2	77.0

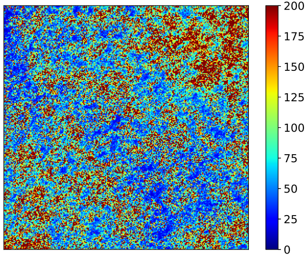
Region 1 - High SNR



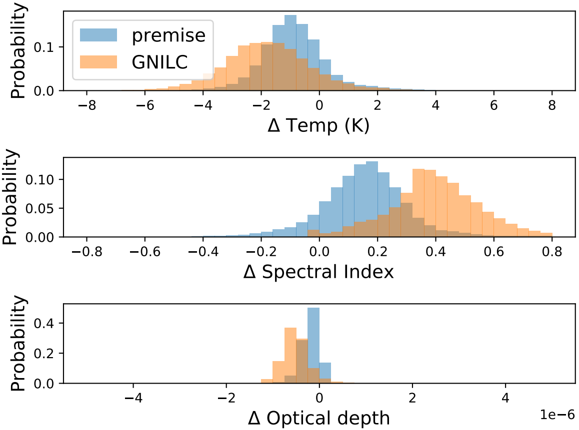


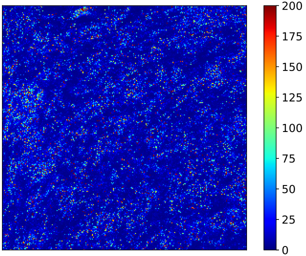
Region 2 - Medium SNR





Region 3 - Low SNR





Conclusion

- Fast recovery of model parameters: full sky (varying signal to noise) at full resolution
- Sparsity in place of smoothing
- Improvement for all but the largest signal to noise regions