Establishing the Planck only likelihood

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on behalf of the Planck collaboration

12/15/14

Overview

Updates since 2013

The low-ℓ likelihood

The high-ℓ likelihood

Part 1: Power spectra

- The Planck HFI power spectra
- Consistency checks and residuals

Part 2: Likelihood

- Likelihood construction
- Verification

What's new

- More data: 48/29 months of LFI/HFI observations, enabling further checks
- Improved data processing: systematics removal, calibration, beam reconstruction
- Improved foreground model
- Larger sky-fraction used for analysis
- More robust to systematics: based on half-mission cross power spectra
- The 2014 analysis includes polarization

The Planck hybrid likelihood

At low multipoles, $\ell < 30$:

Exact pixel space likelihood,

$$\mathcal{L}(\theta) \propto \exp\left(-1/2\, d\, \mathbf{C}^{-1} d^T\right) \, .$$

Numerically expensive, evaluations take $\mathcal{O}(\ell_{\max}^6)$ operations.

At high multipoles, $\ell \geq 30$:

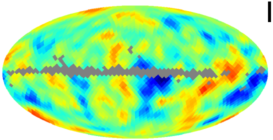
We use a fiducial Gaussian approximation, now generalized to include polarization

$\rightarrow$ We work with a pre-compressed data vector: the empirical power spectrum coefficients

Low-ℓ likelihood data set*

Temperature:

We use the Commander solution based on Planck, WMAP, and the 408 MHz Haslam map,
$f_{\mathrm{SKY}} \approx 93\%$.



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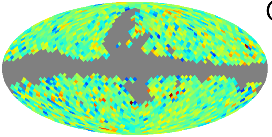
Polarization:

We use the Planck 70 GHz full mission map without survey 2, 4,
cleaned with 30 and 353 GHz maps,
$f_{\mathrm{SKY}} \approx 47\%$.



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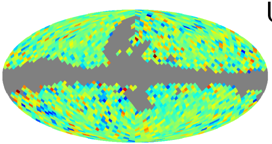

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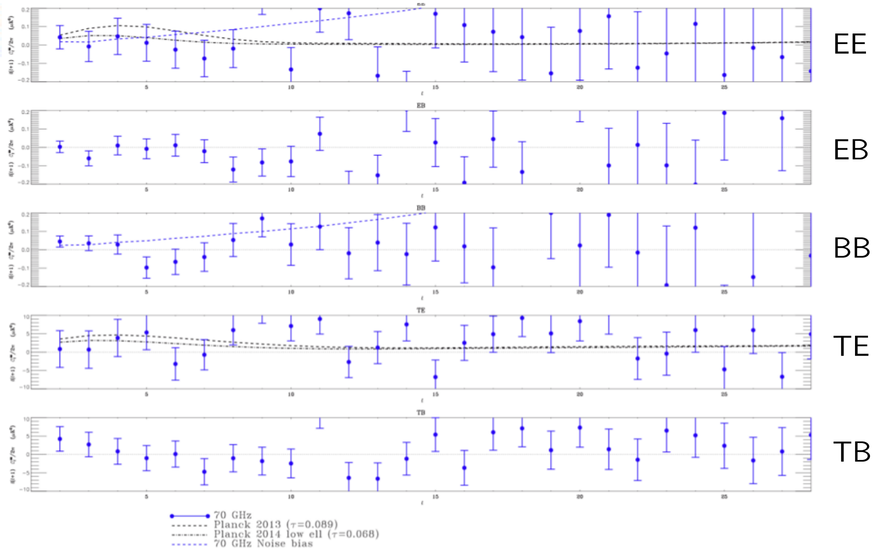
*Preliminary results

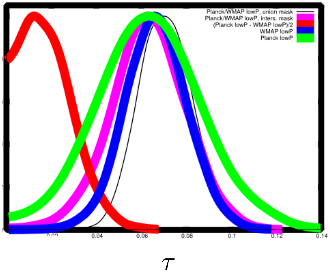
Low-ℓ power spectra*



*Preliminary results

Low-ℓ results*

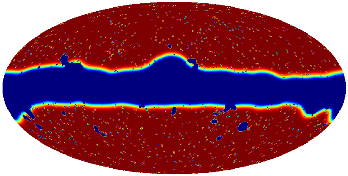
- The low-ℓ likelihoods helps breaking the degeneracy between τ and A_{S}.
- Using 353 GHz for dust cleaning, WMAP constraints become consistent with Planck.
- Constraints on τ will improve substantially with large scale HFI data.



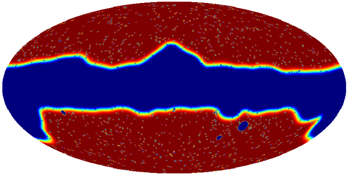
green:	Planck polarization
blue:	WMAP polarization, 353 GHz cleaned
red:	Null test

*Preliminary results

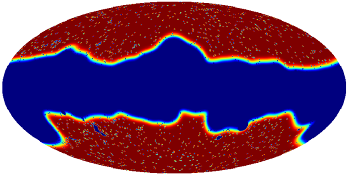
High-ℓ masks: Temperature



100 GHz:
Galactic + point source + CO
$f_{\text{SKY}} \approx 66\%$

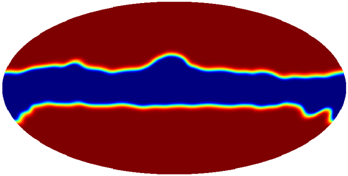


143 GHz:
Galactic + point source
$f_{\text{SKY}} \approx 57\%$

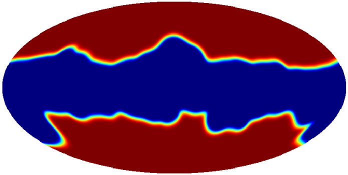


217 GHz:
Galactic + point source + CO
$f_{\text{SKY}} \approx 47\%$

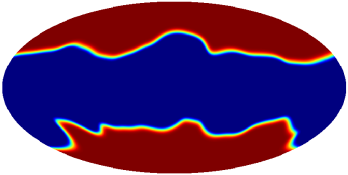
High-ℓ masks: Polarization



100 GHz:
Galactic
$f_{\mathrm{SKY}} \approx 70\%$

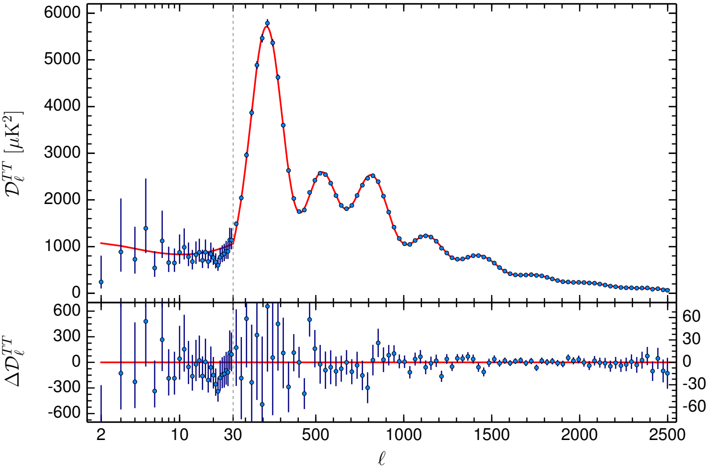


143 GHz:
Galactic
$f_{\mathrm{SKY}} \approx 50\%$



217 GHz:
Galactic
$f_{\mathrm{SKY}} \approx 41\%$

Foreground subtracted TT power spectrum*

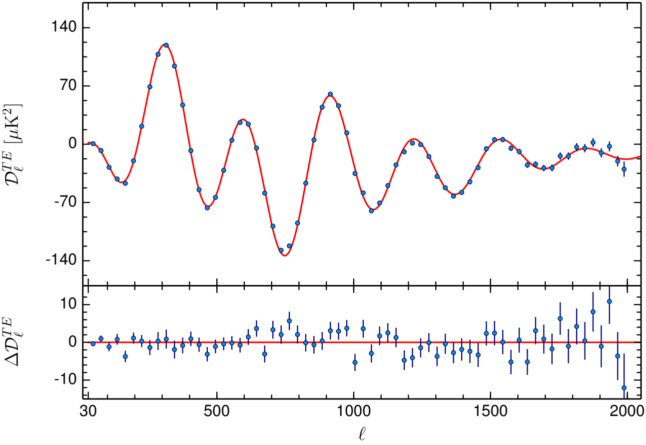


Frequency averaged spectrum reduced $\chi^2 = 1.03$

*Preliminary results

Foreground subtracted TE power spectrum*

Disclaimer: There are unmodeled residual systematics

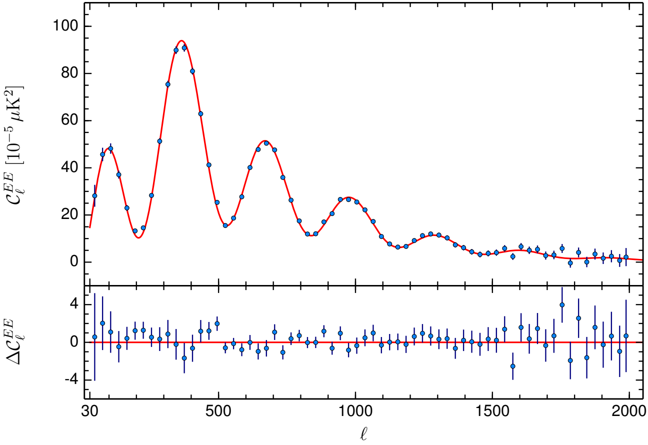


Frequency averaged spectrum reduced $\chi^2 = 1.04$

*Preliminary results

Foreground subtracted EE power spectrum*

Disclaimer: There are unmodeled residual systematics



Frequency averaged spectrum reduced $\chi^2 = 1.01$

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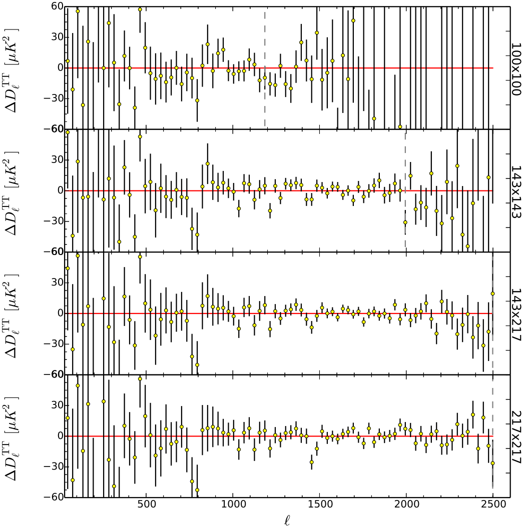
*Preliminary results

Consistency check: TT frequency power spectra*



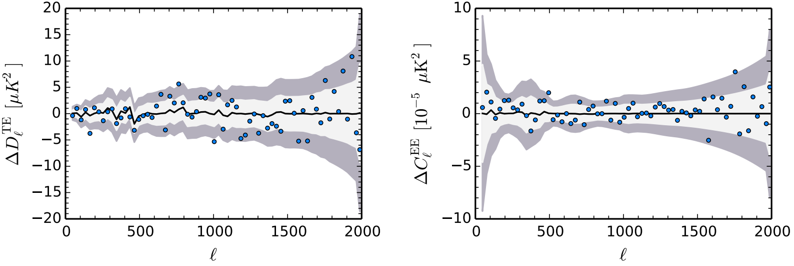
*Preliminary results

Consistency check: polarization given temperature spectra*

Conditional spectra and covariances:

$$C_\ell^{PP}|_{C_\ell^{TT}} = \langle C_\ell^{PP} \rangle + \mathbf{C}_{PP,TT}\mathbf{C}_{TT,TT}^{-1}(C_\ell^{TT} - \langle C_\ell^{TT} \rangle)$$

$$\mathbf{C}_{PP,PP}|_{C_\ell^{TT}} = \mathbf{C}_{PP,PP} - \mathbf{C}_{PP,TT}\mathbf{C}_{TT,TT}^{-1}\mathbf{C}_{TT,PP}$$



*Preliminary results

Data selection for the high-ℓ likelihood

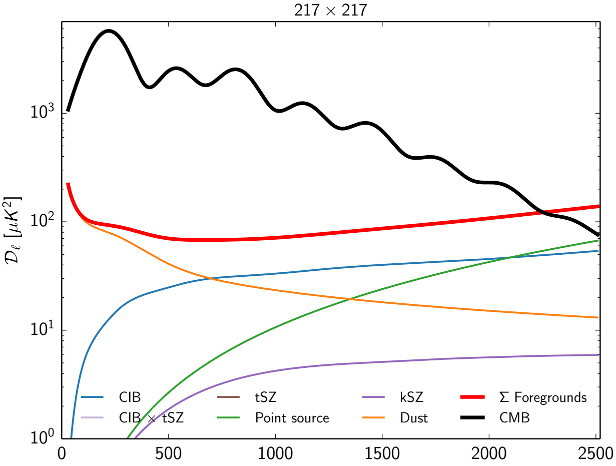
Frequency	beam [arcmin]	noise $[\mu K^2]^*$	ℓ-range
100 GHz	9	$\frac{D^{\rm TT}_{\ell=1800}}{b^2_{\ell=1800}} \approx 20000$	T: $30 \leq \ell \leq 1200$ P: $30 \leq \ell \leq 1000$
143 GHz	7	$\frac{D^{\rm TT}_{\ell=1800}}{b^2_{\ell=1800}} \approx 700$	T: $30 \leq \ell \leq 2000$ P: $30 \leq \ell \leq 2000$
217 GHz	5	$\frac{D^{\rm TT}_{\ell=1800}}{b^2_{\ell=1800}} \approx 400$	T: $30 \leq \ell \leq 2500$ P: $500 \leq \ell \leq 2000$
100 $\times$ 143			T: $\emptyset$ P: $30 \leq \ell \leq 1000$
100 $\times$ 217			T: $\emptyset$ P: $500 \leq \ell \leq 1000$
143 $\times$ 217			T: $30 \leq \ell \leq 2500$ P: $500 \leq \ell \leq 2000$

$^*D_\ell = \ell(\ell+1)/2\pi\, C_\ell,\ b_\ell$: beam

The high-ℓ likelihood

We construct a fiducial Gaussian likelihood, using

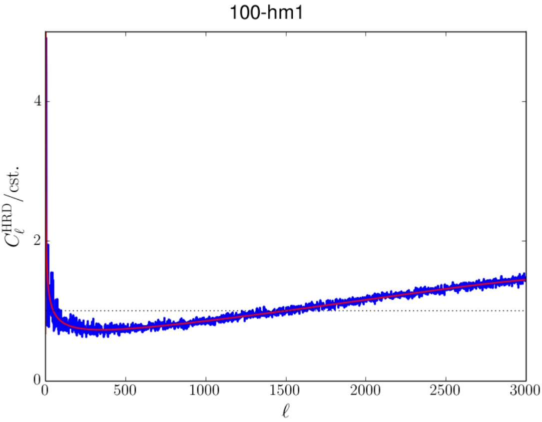
- a parametric foreground model to marginalize over (12 parameters)



The high-ℓ likelihood

We construct a fiducial Gaussian likelihood, using

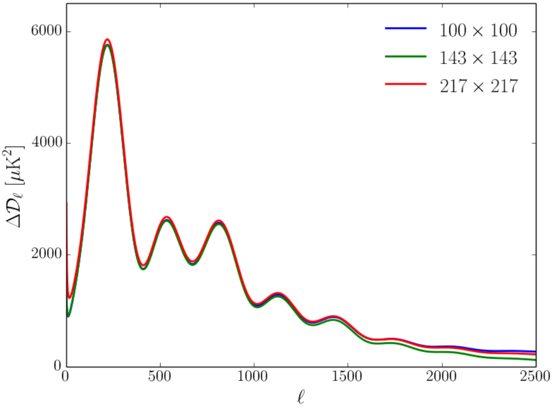
- a parametric foreground model to marginalize over
- noise estimates of the data, obtained from half-ring difference maps, corrected for bias using the difference between auto and cross spectra



The high-ℓ likelihood

We construct a fiducial Gaussian likelihood, using

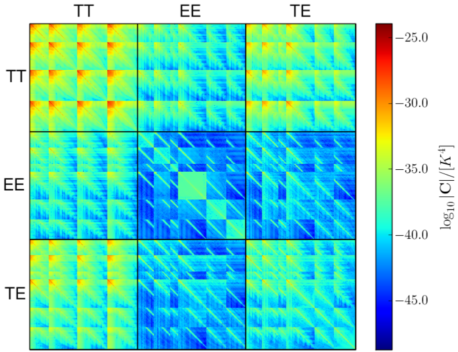
- a parametric foreground model to marginalize over
- noise estimates of the data, obtained from half-ring difference maps, corrected for bias
- a set of best fit power spectra at each frequency



The high-ℓ likelihood

We construct a fiducial Gaussian likelihood, using

- a parametric foreground model to marginalize over
- noise estimates of the data, obtained from half-ring difference maps, corrected for bias
- a set of best fit power spectra at each frequency
- analytical approximations to compute C_ℓ covariance matrices

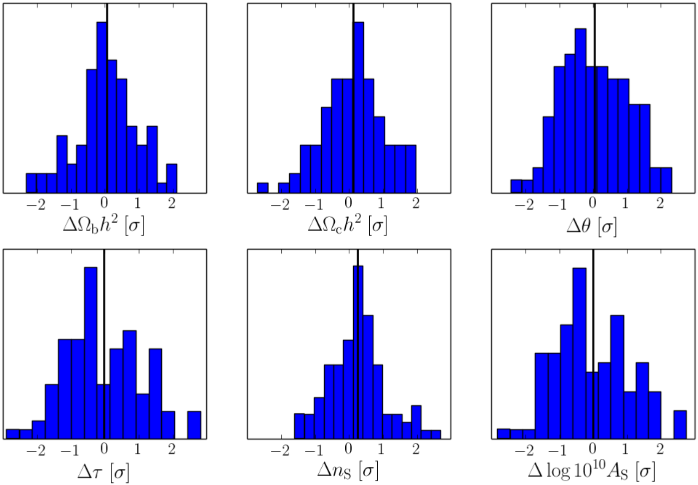


Binned matrix with 2300×2300 elements

Condition number: $\mathcal{O}(10^{11})$

Likelihood verification on simulations

We computed cosmological parameters from 100 simulated HFI data sets, marginalizing over 12 foreground parameters.



Likelihood verification on data

We checked that results are robust with respect to

- different likelihood code implementations:
  Plik, Camspec, Hillipop, Mspec, Xfaster
- the multipole range used for analysis
- removing individual frequency power spectra
- the choice of analysis masks
- different foreground treatments:
  parametric modeling vs. map based cleaning

Acknowledgments

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