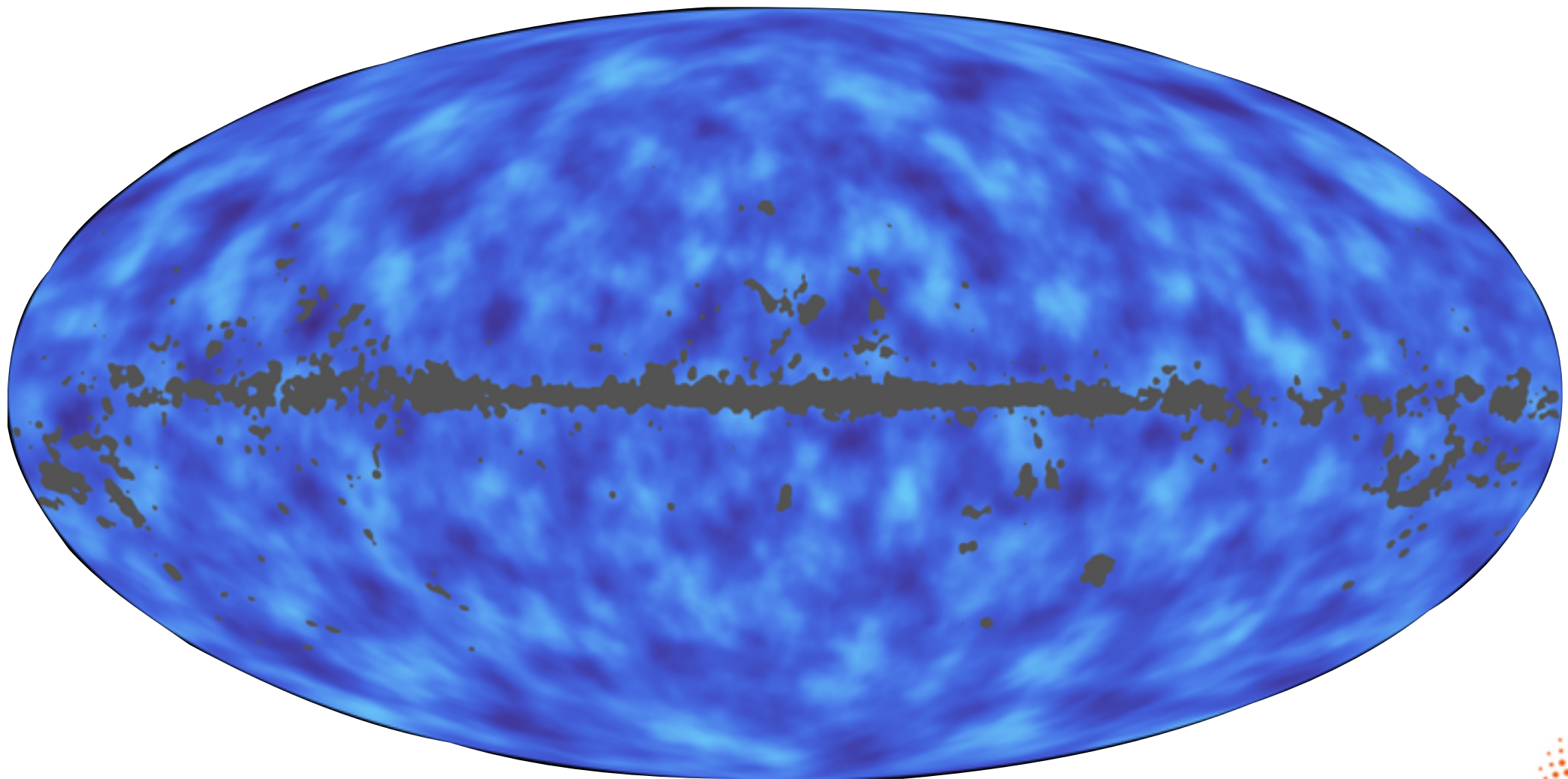
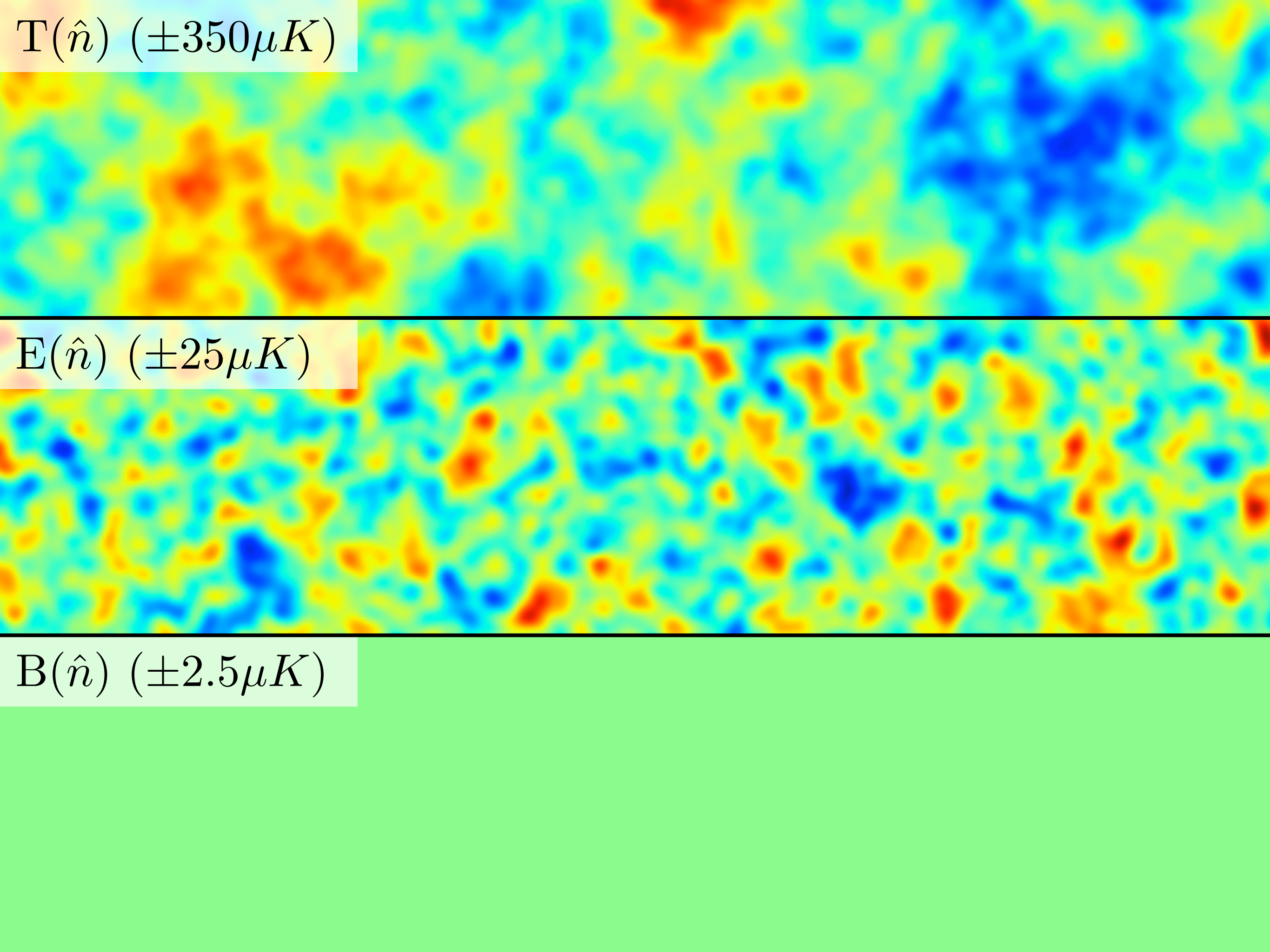


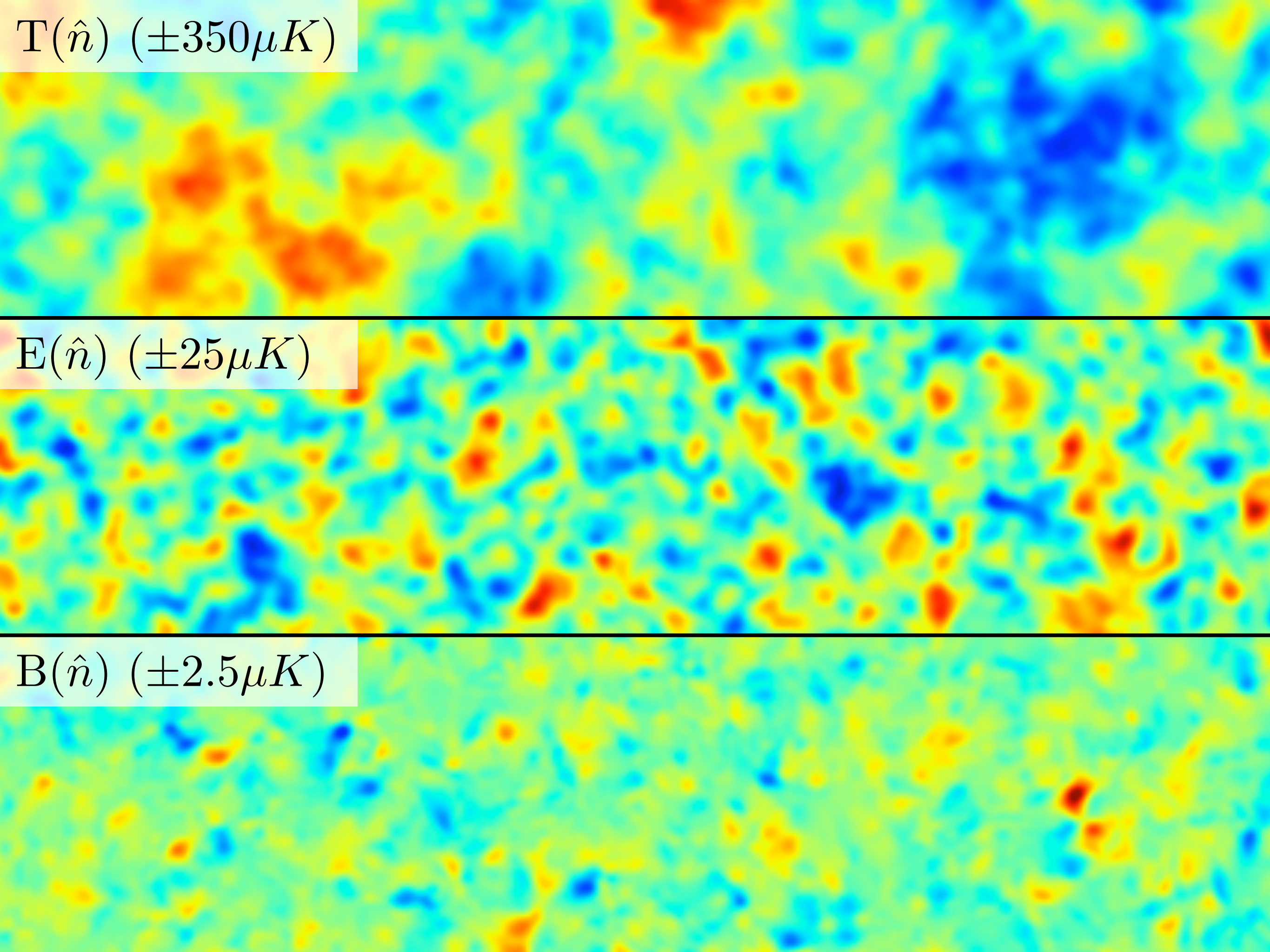
Gravitational Lensing for Planck 2014

Antony Lewis

On behalf of the Planck Collaboration







$T(\hat{n})$ $(\pm 350 \mu K)$

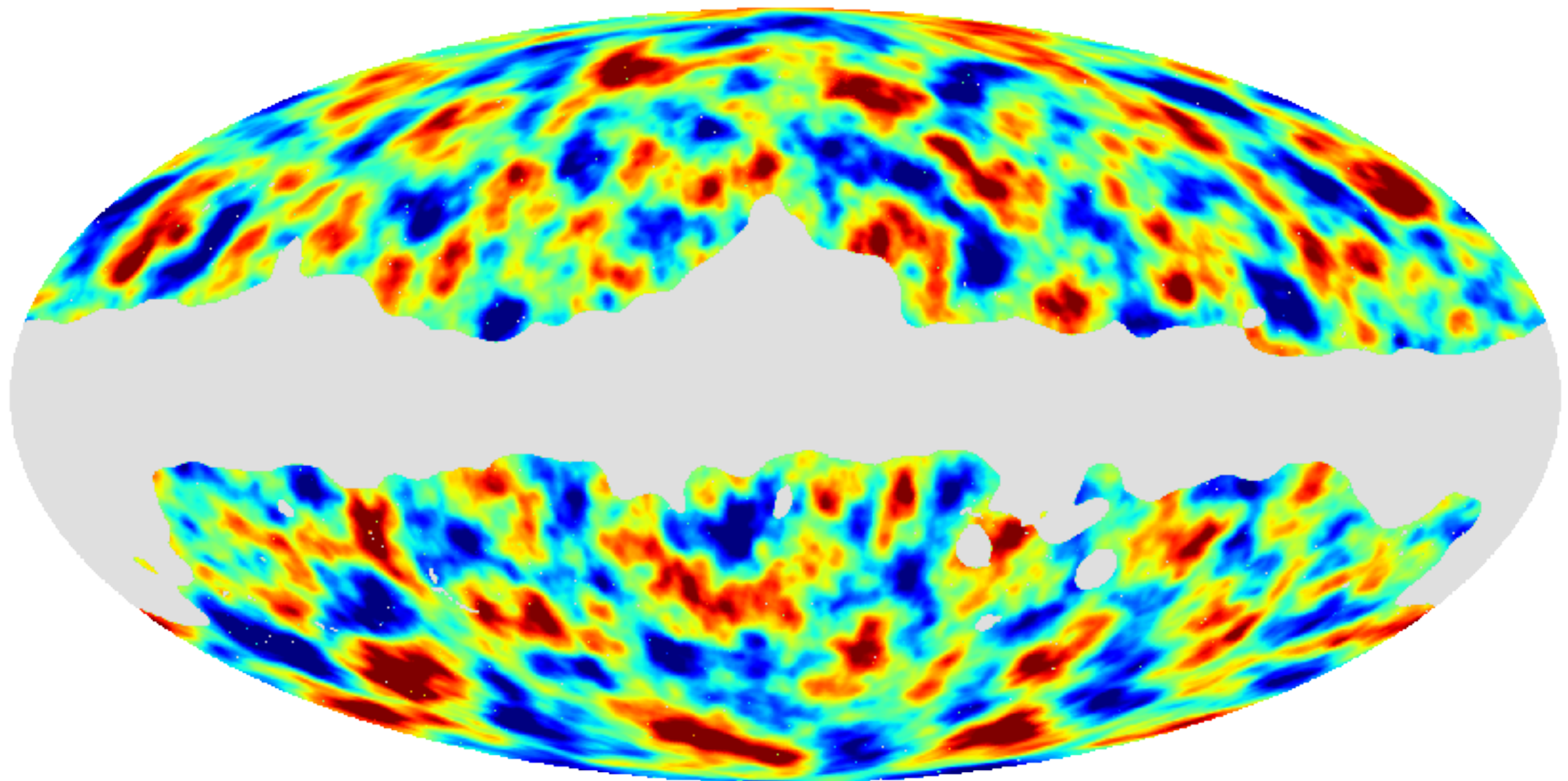
$E(\hat{n})$ $(\pm 25 \mu K)$

$B(\hat{n})$ $(\pm 2.5 \mu K)$

Main Improvements over 2013

- ★ Error bars reduced by nearly a factor of 2x.
 - Twice as much temperature data + all-new polarization data.
- ★ Full set of lensing estimators (TT, TE, EE, EB, TB) + All combined (MV)
 - Crosses give 15 possible lensing power spectrum estimators.
- ★ SMICA component-separated maps as baseline, on 67.3% sky.
- ★ Numerous analysis improvements.
 - Improved likelihood ($N^{(1)}$ theory dependence, faster)
 - Many new consistency and null tests:
 - Internal consistency of polarization and temperature estimator pairs.
 - Half-mission nulls and crosses

2013 TT



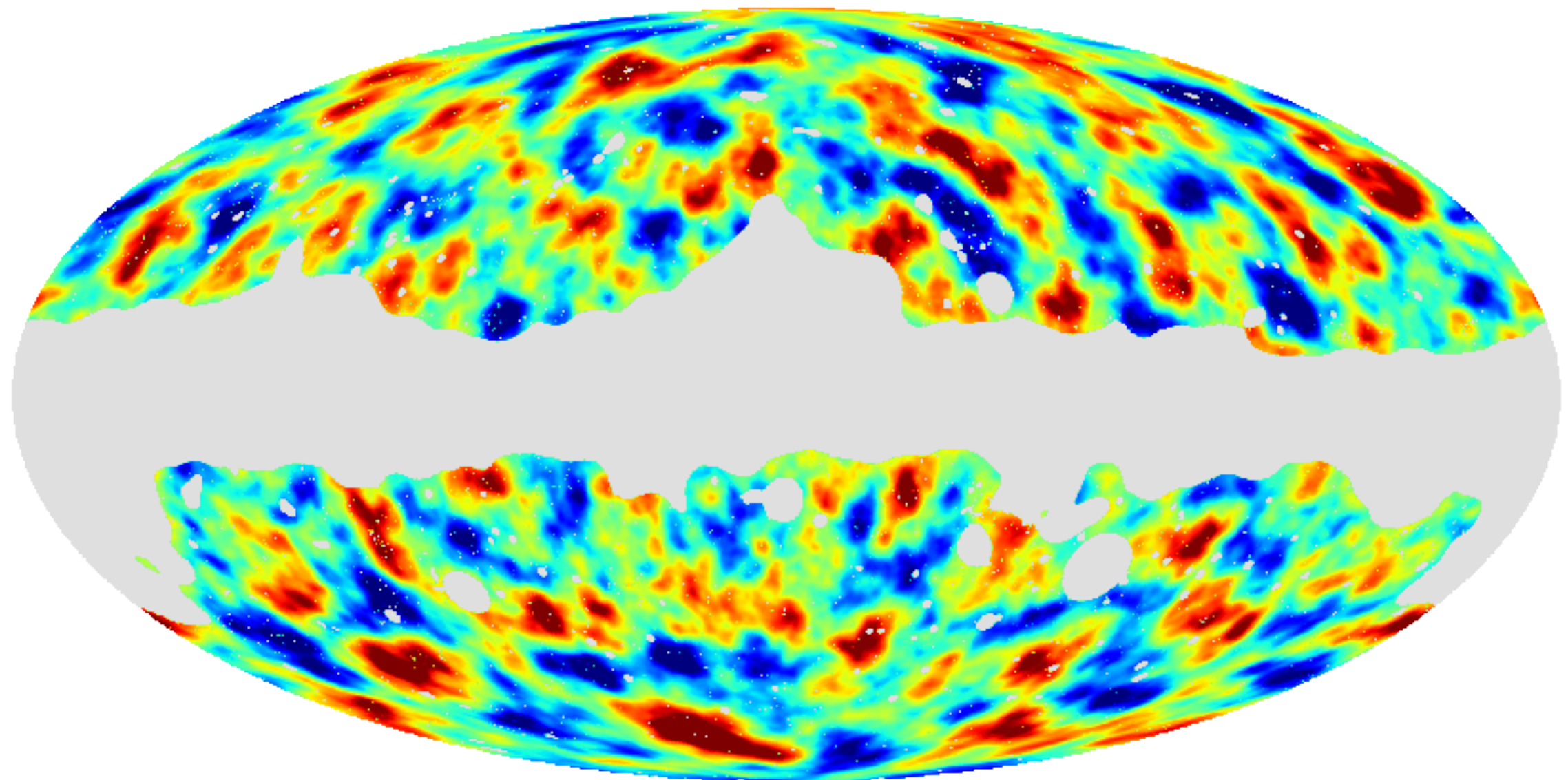
-4e-05

4e-05 rad.

S/N-filtered, $10 \leq L \leq 2048$

(based on SMICA CMB map)

2014 TT



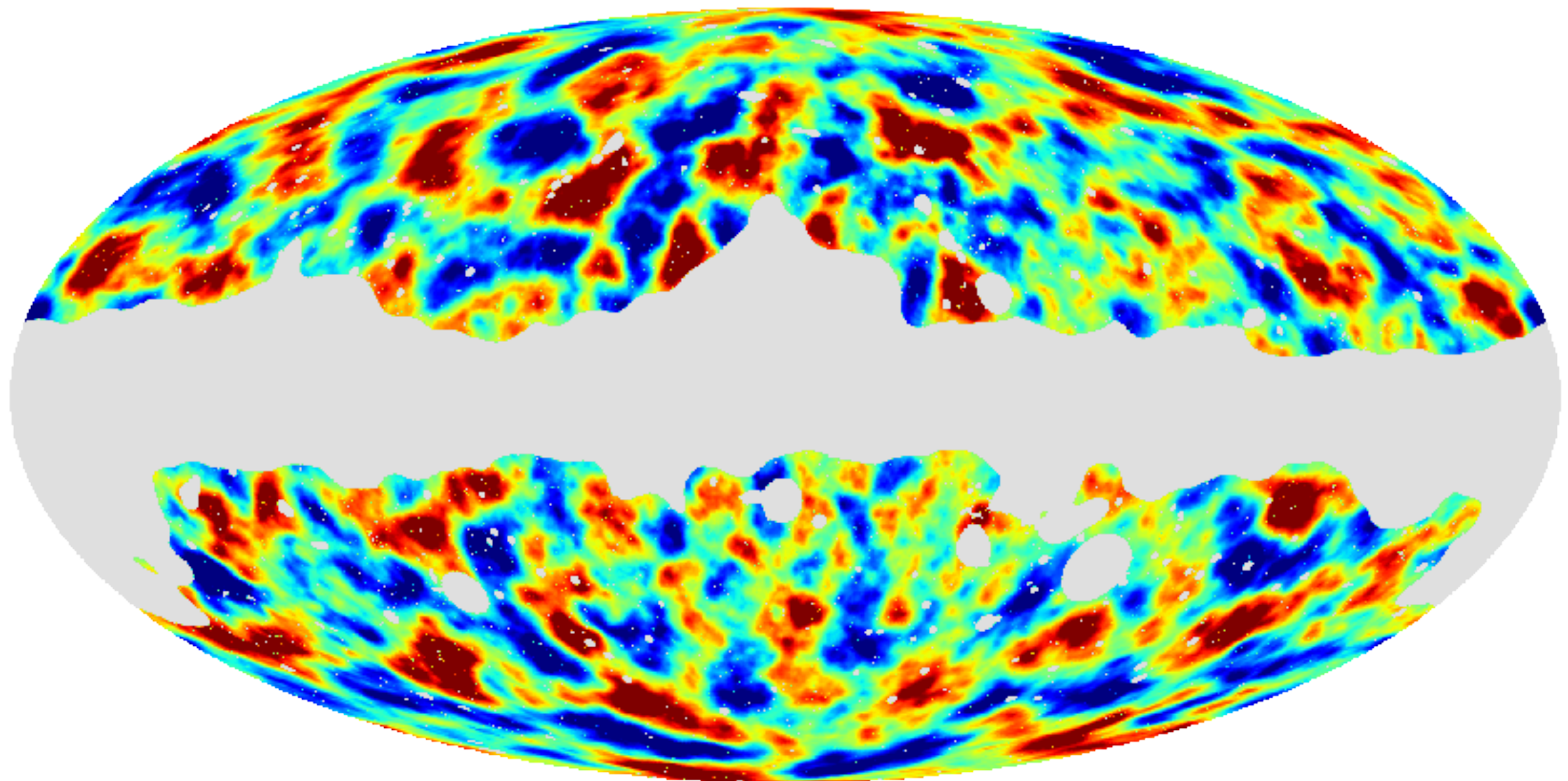
-4e-05

4e-05 rad.

S/N-filtered, $10 \leq L \leq 2048$

(based on SMICA CMB map)

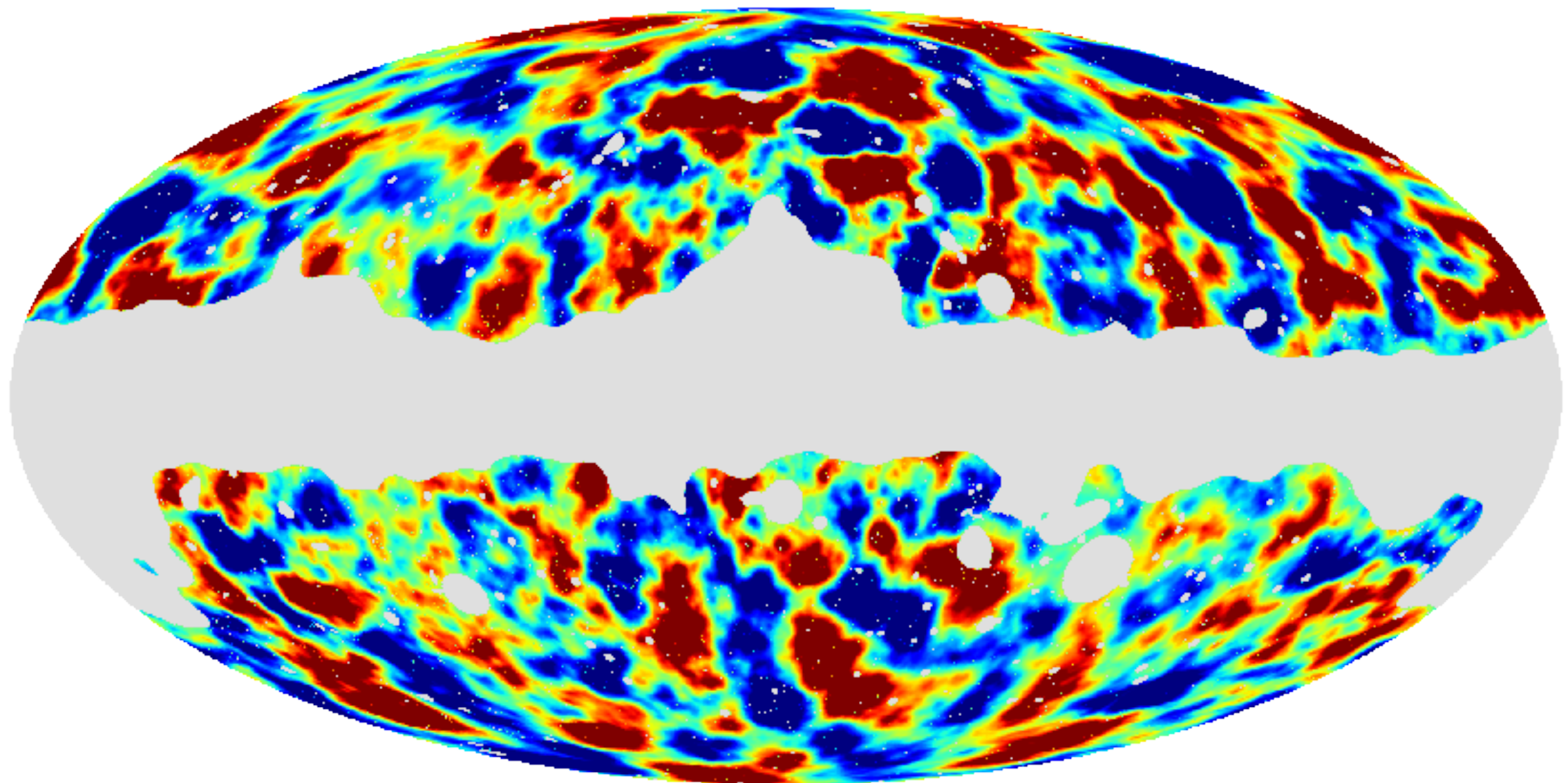
2014 TE



(based on SMICA CMB map)

S/N-filtered, $10 \leq L \leq 2048$

2014 EE+EB



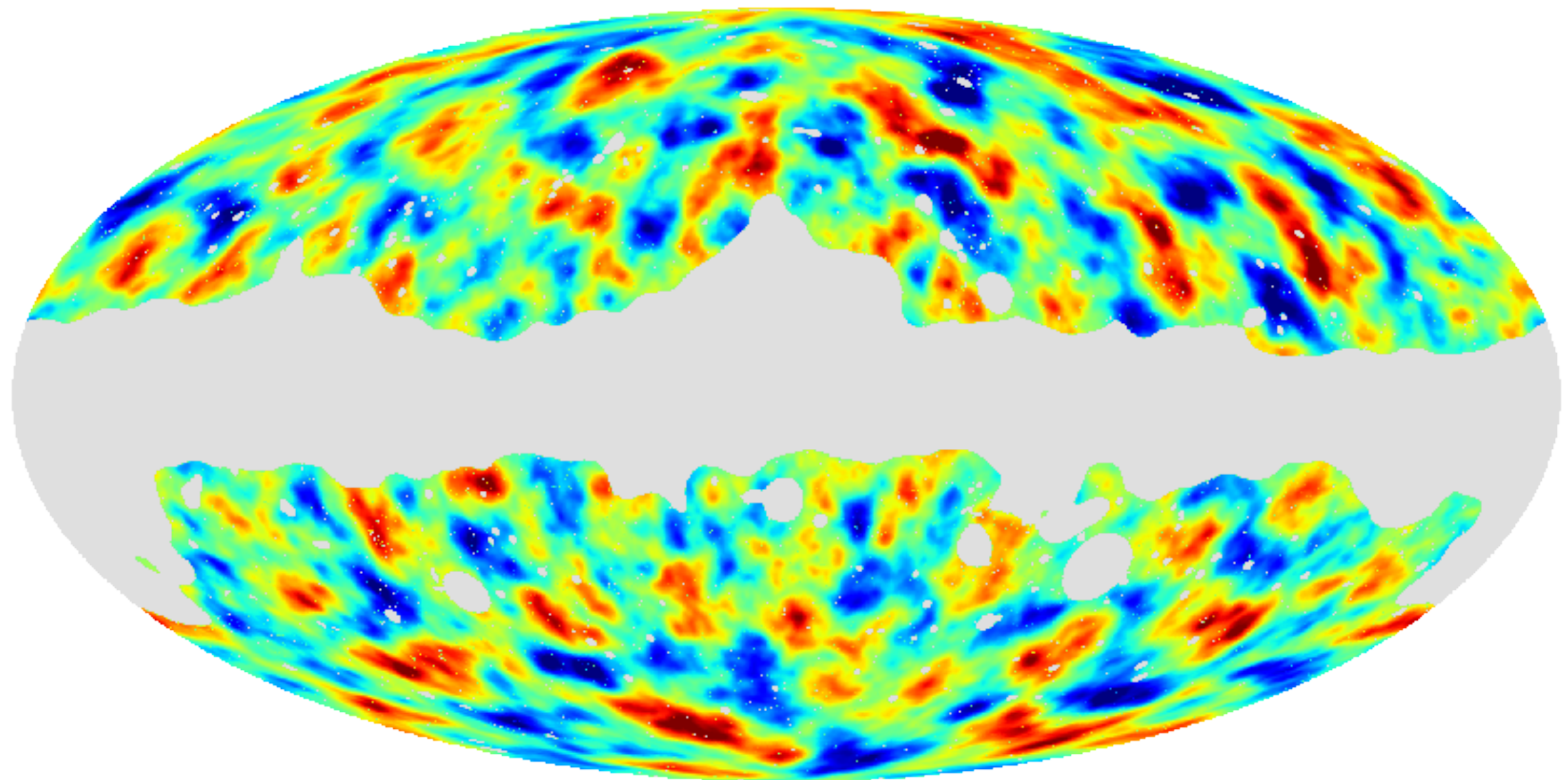
-4e-05 4e-05 rad.

S/N-filtered, $10 \leq L \leq 2048$

(based on SMICA CMB map)

Preliminary

2014 "MV"



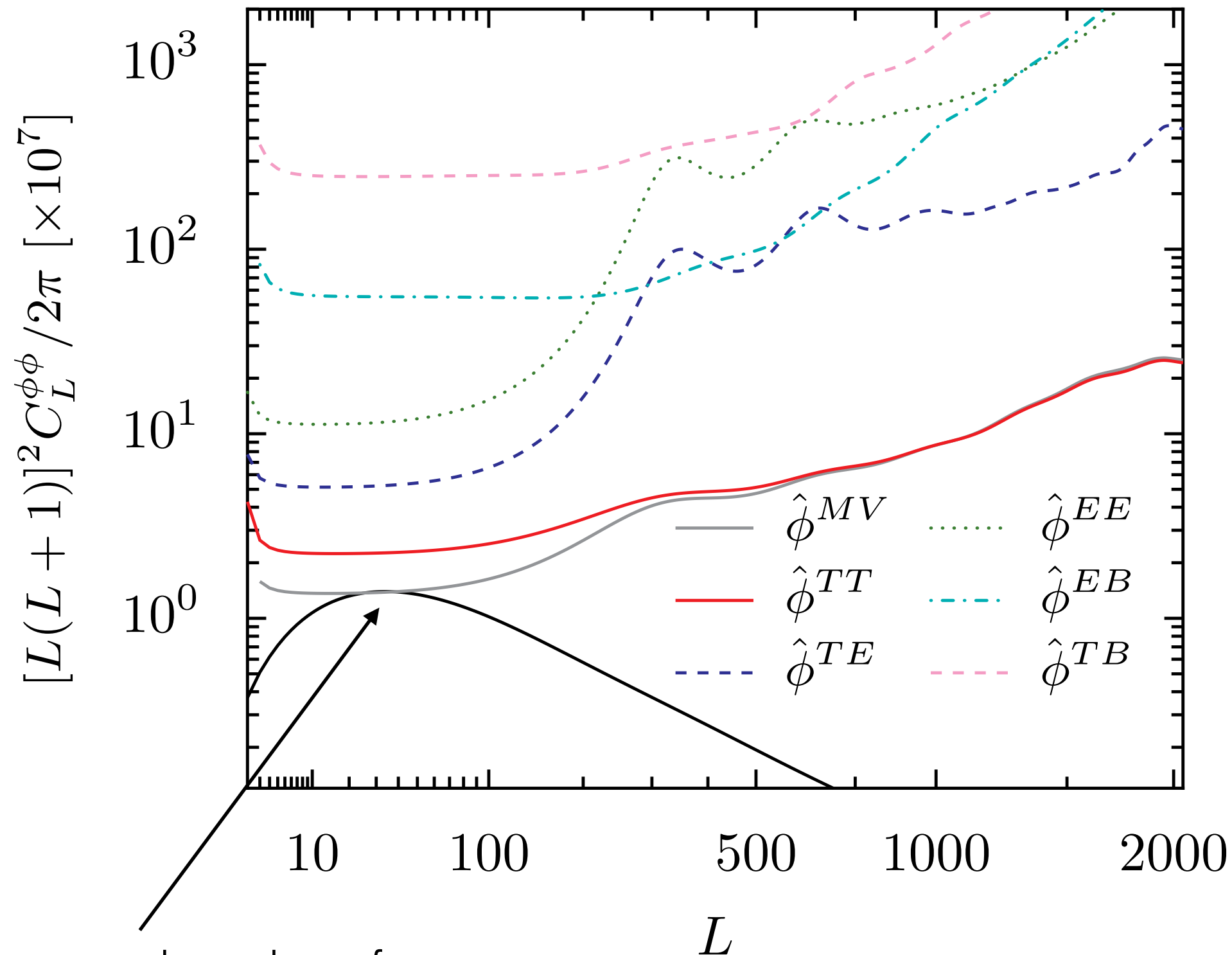
$-4\text{e-}05$

$4\text{e-}05$ rad.

(based on SMICA CMB map)

S/N-filtered, $10 \leq L \leq 2048$

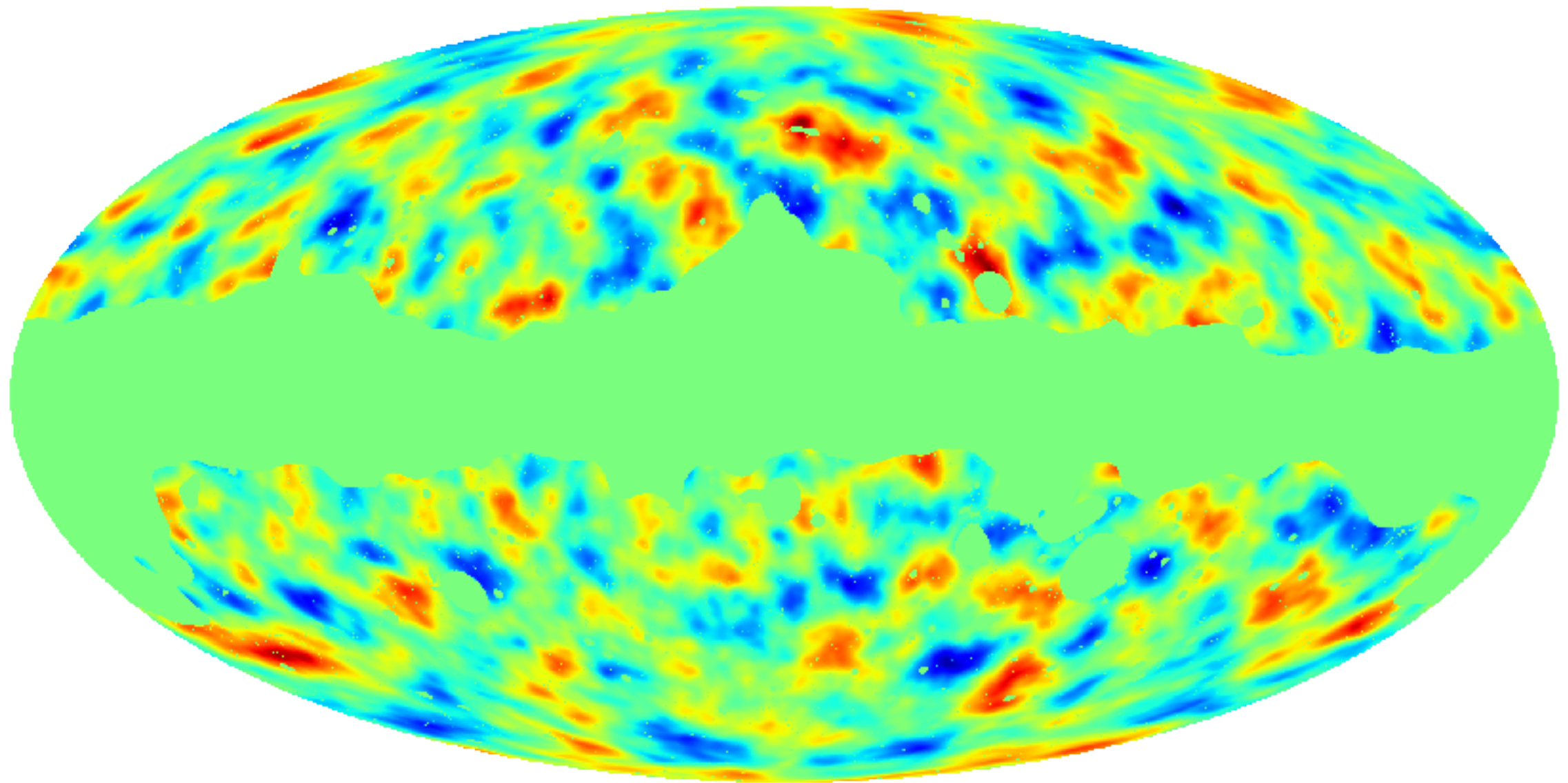
Noise power spectra for lensing estimators.



Best measured modes of
MV estimator have S/N=1.

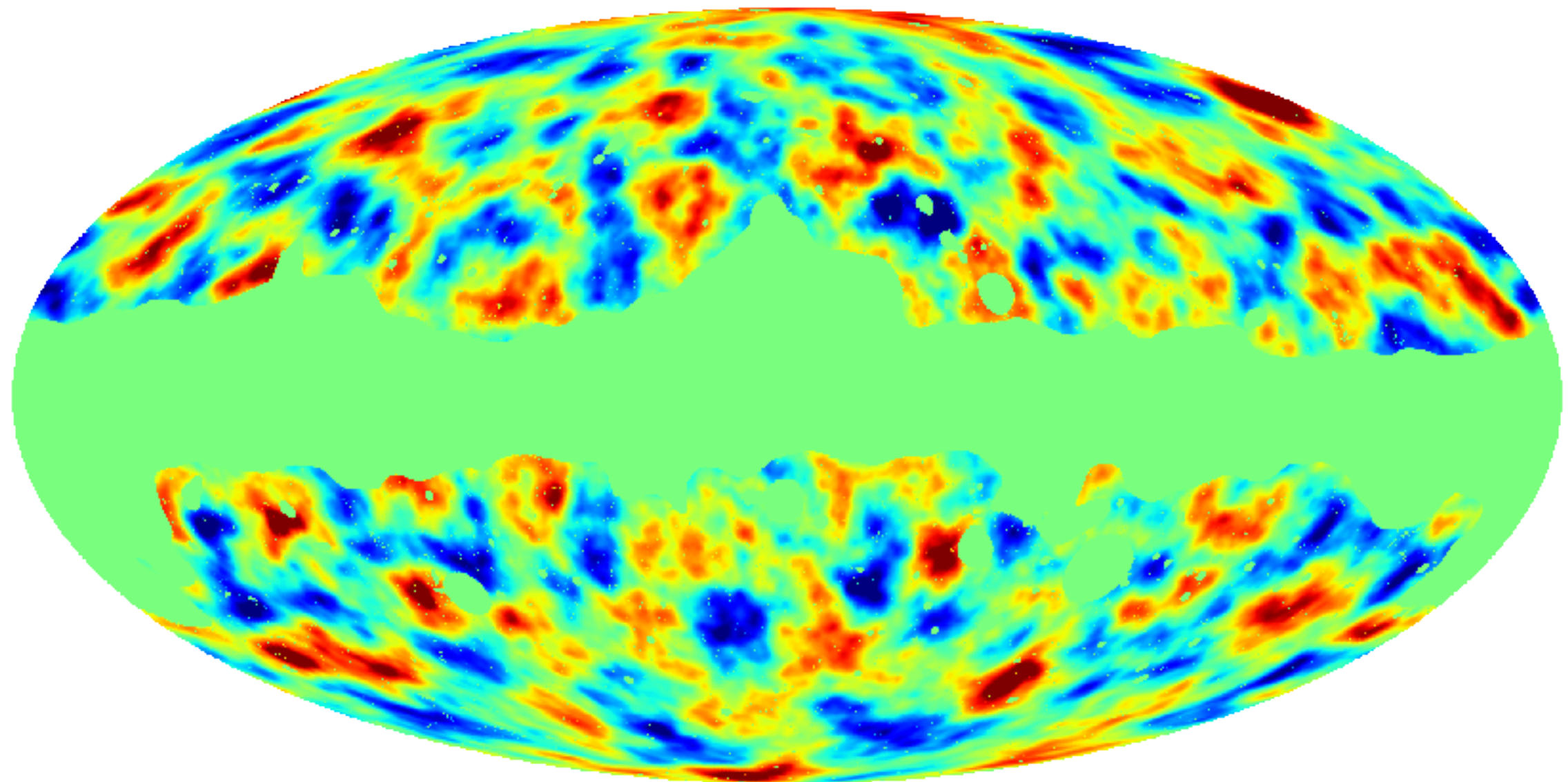
Preliminary

Simulated Lensing Potential ϕ



S/N-filtered, $10 \leq L \leq 2048$

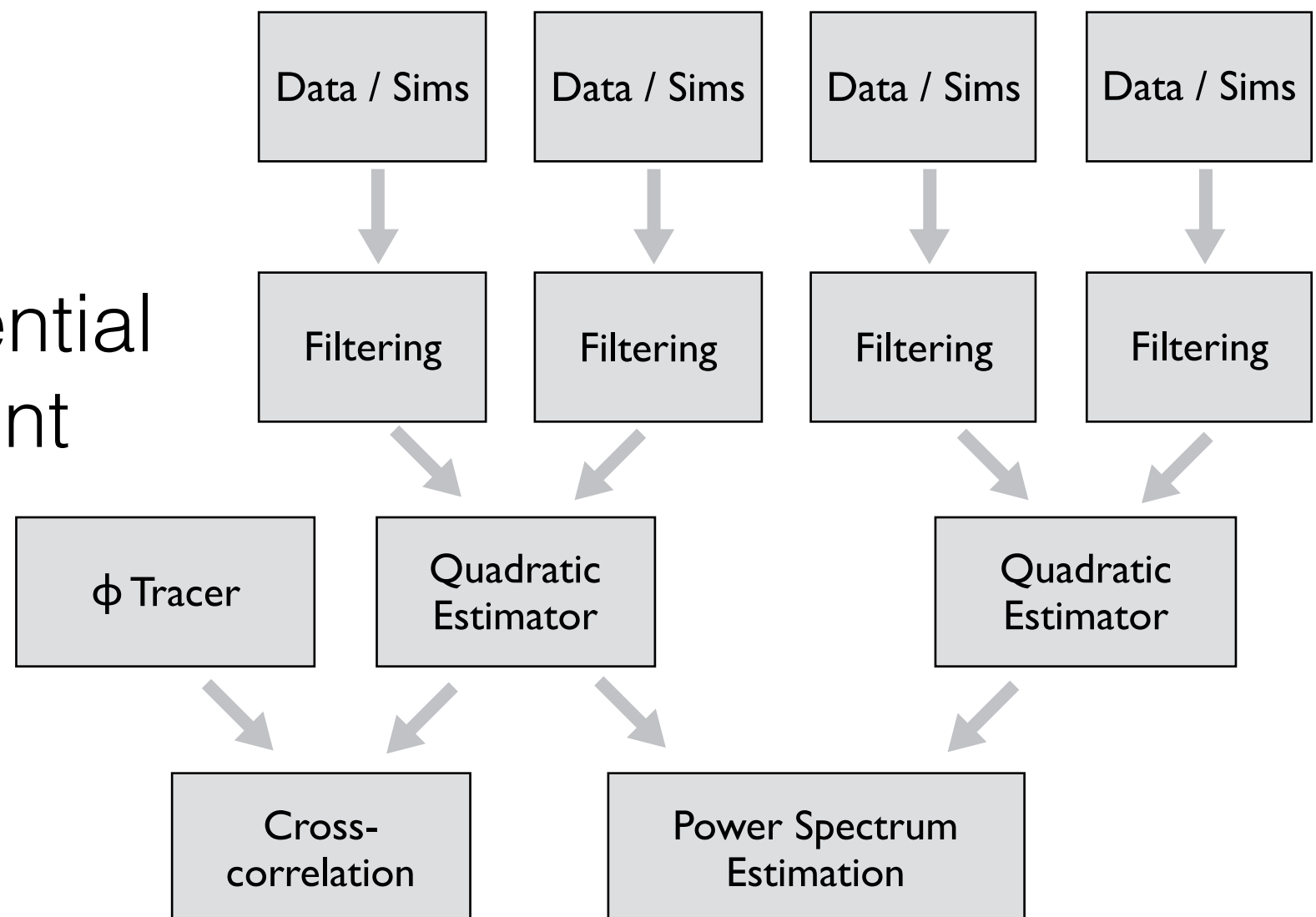
Simulated MV Estimate



S/N-filtered, $10 \leq L \leq 2048$

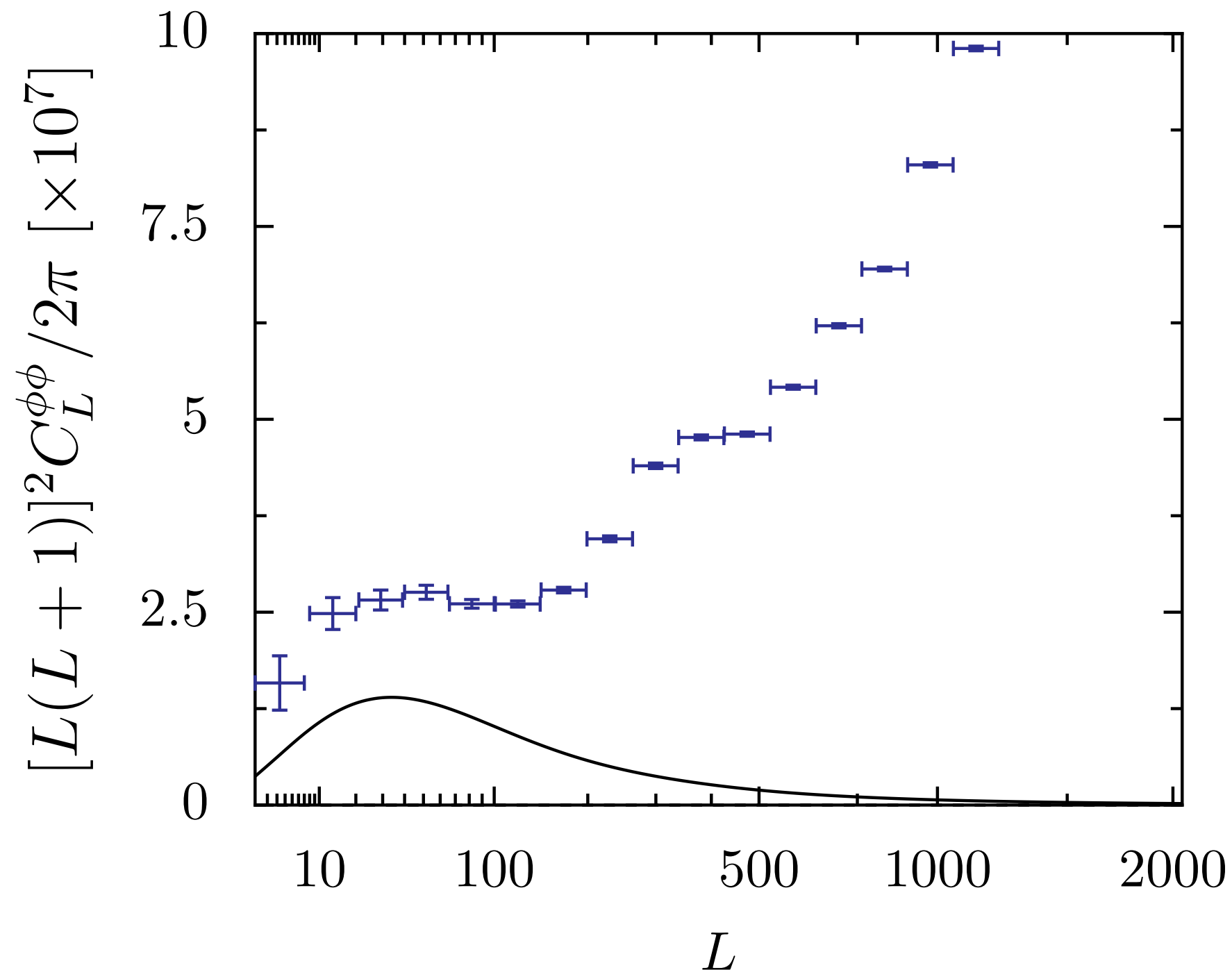
Lens Reconstruction Pipeline

- process input maps
- estimate lensing potential from anisotropic 2-point
- estimate lensing power spectrum.



Power Spectrum Estimation

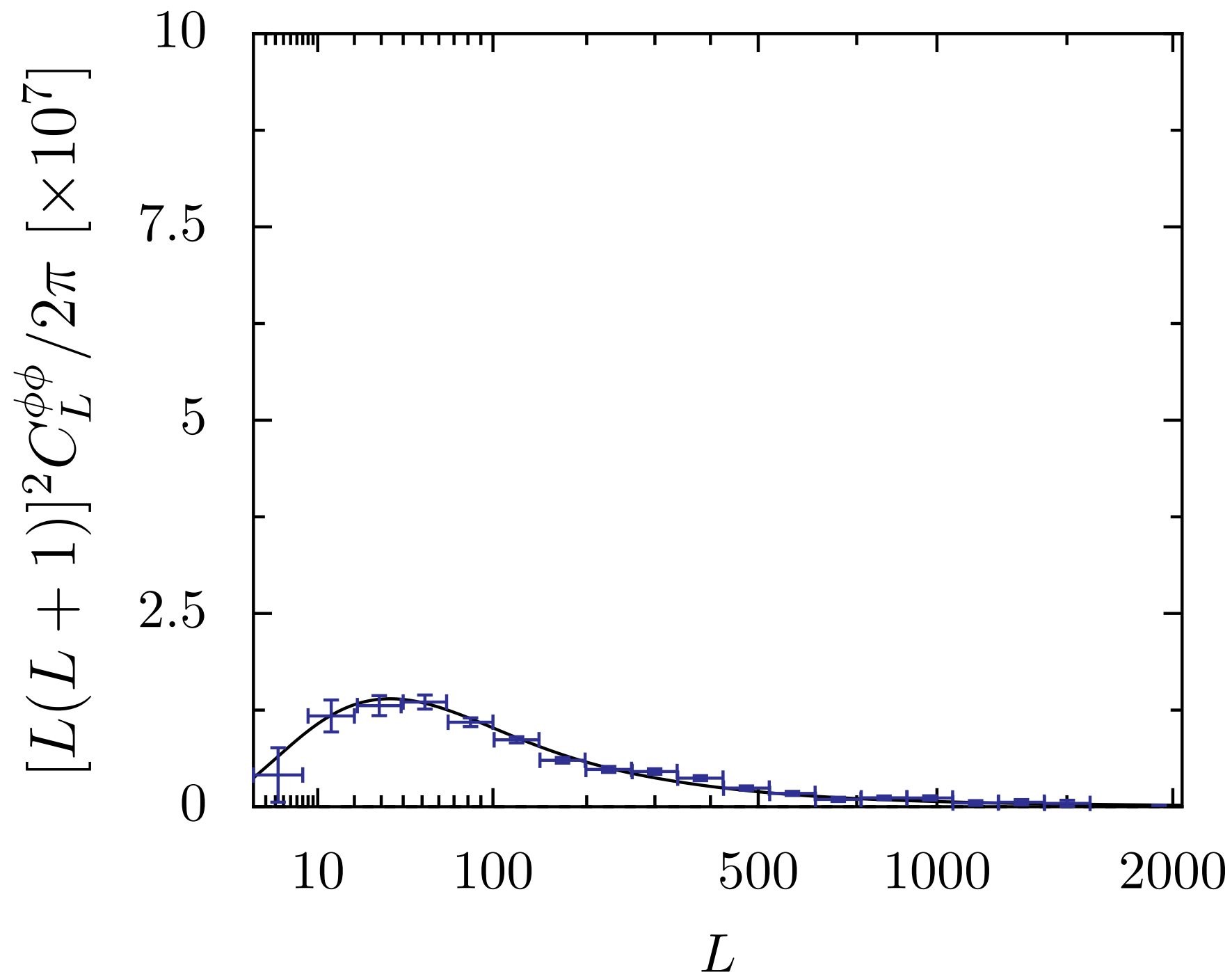
Preliminary



1) Raw power spectrum of quadratic estimates.

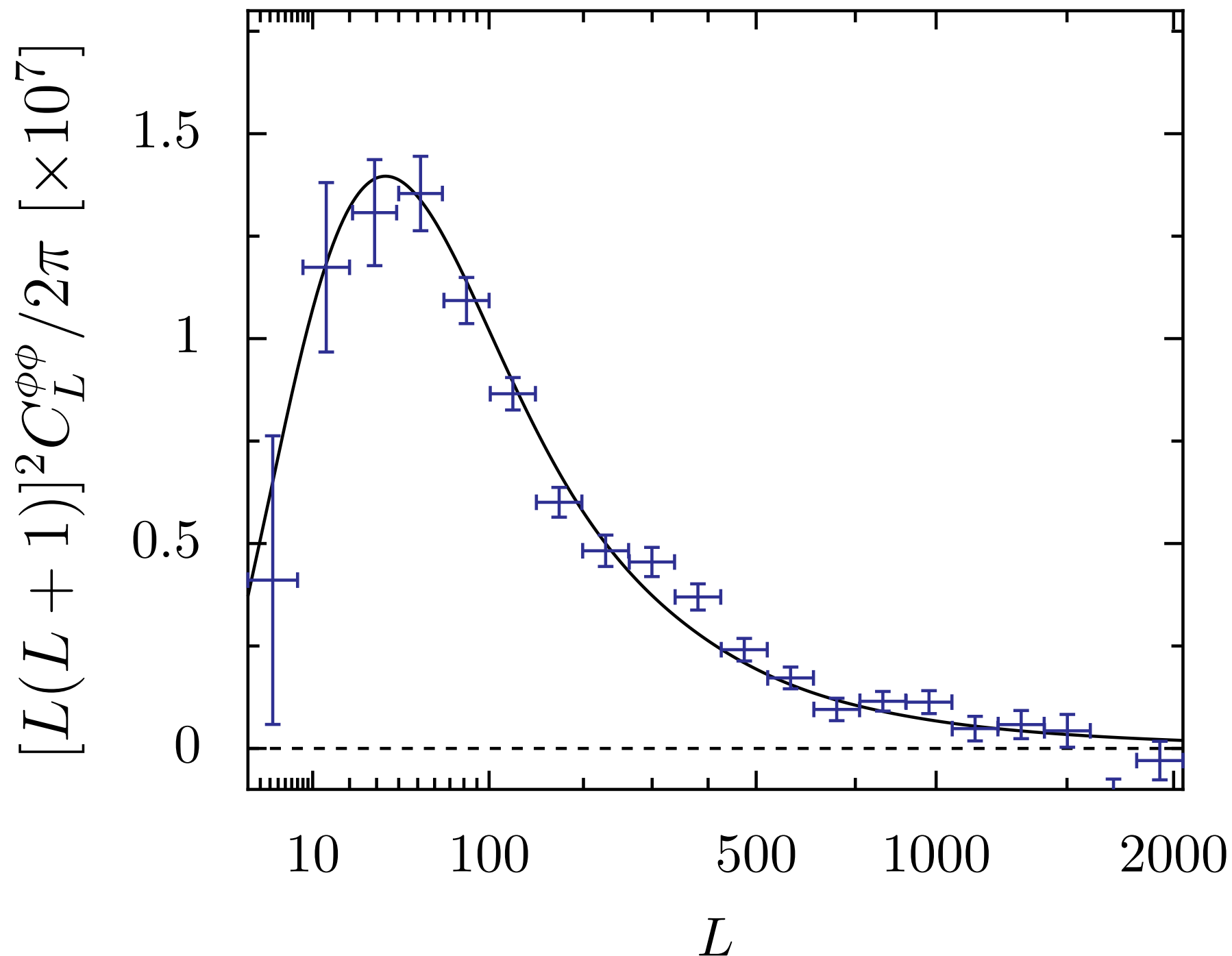
Power Spectrum Estimation

Preliminary



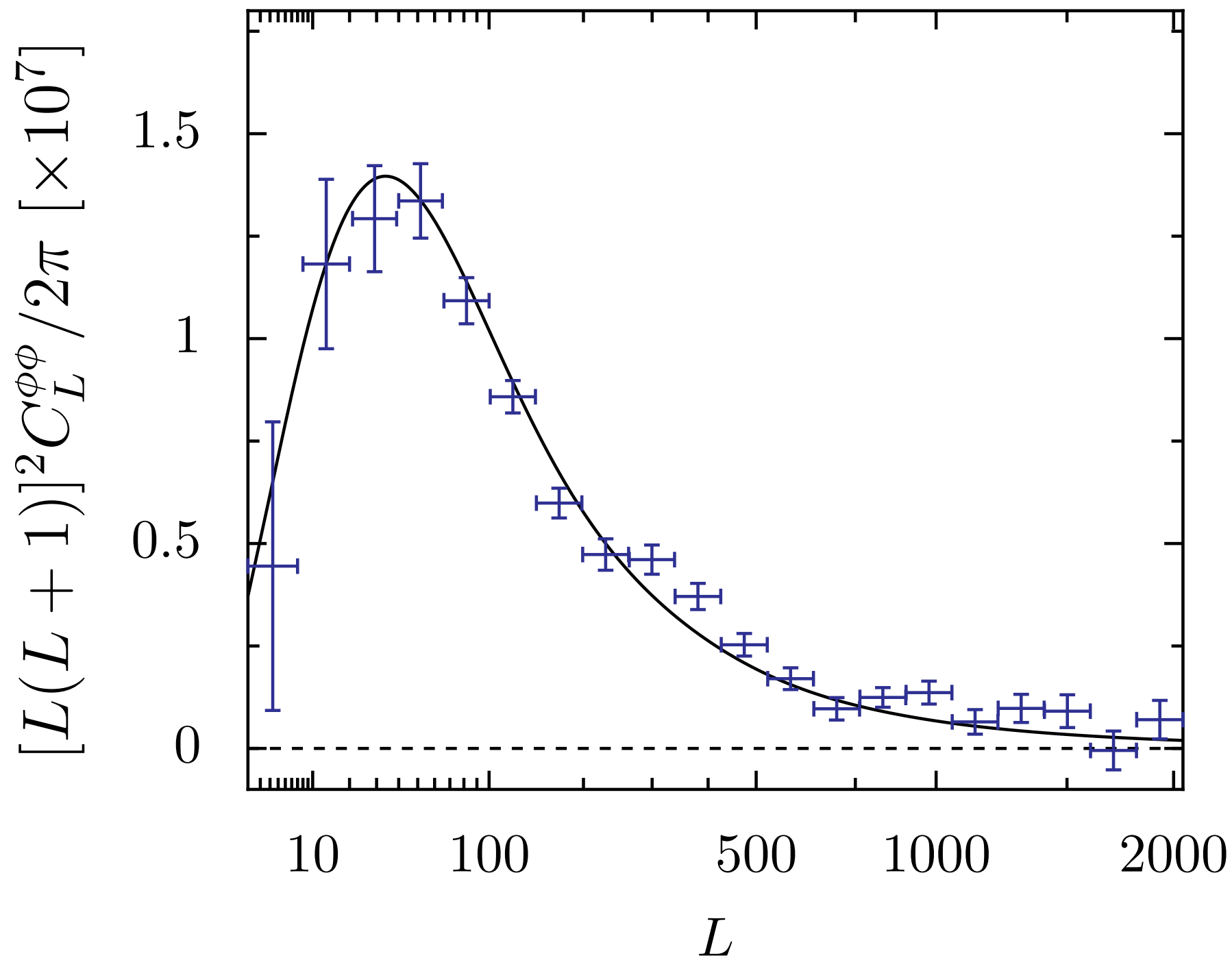
2) Correct for noise bias estimated from sims.

Power Spectrum Estimation



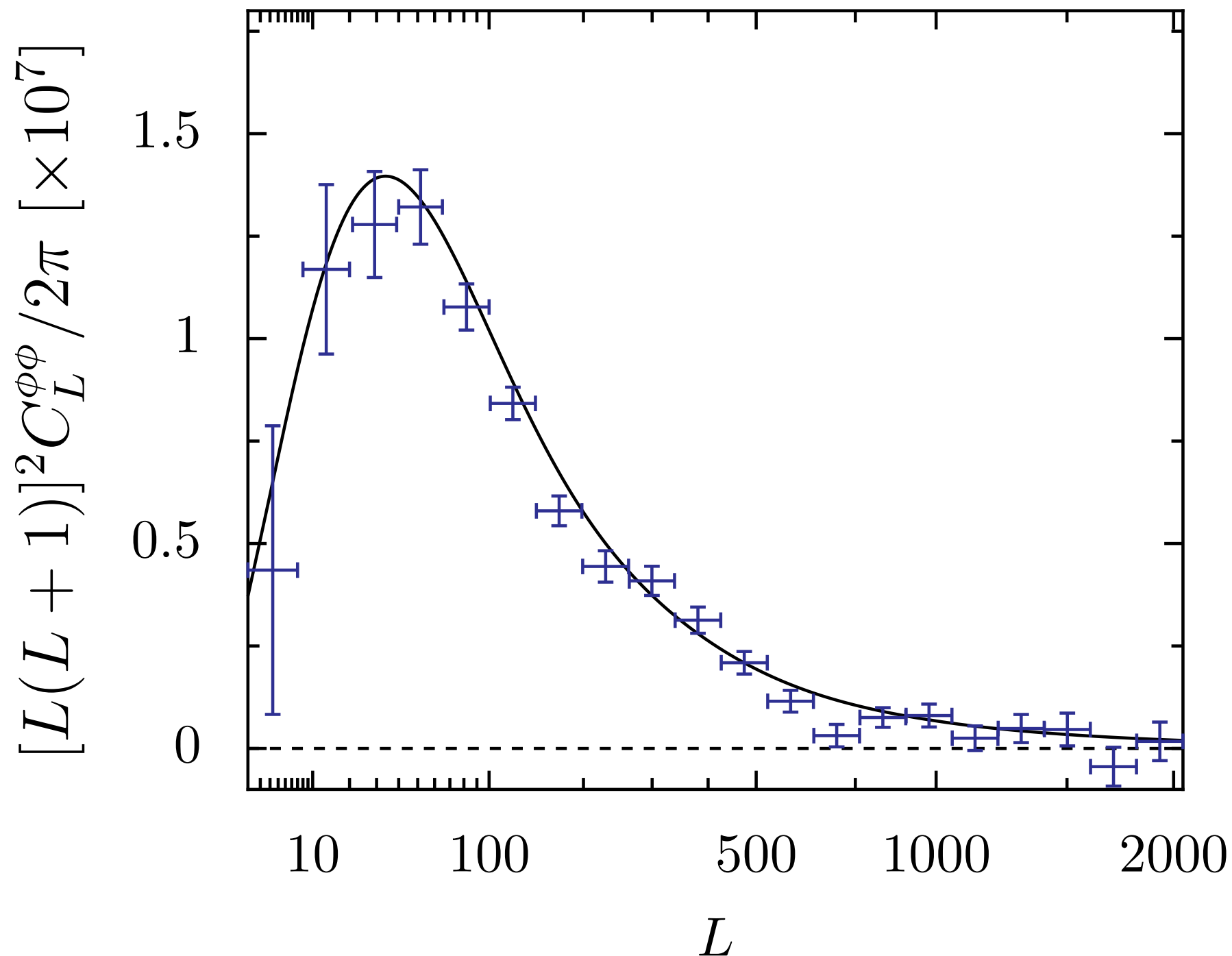
2) Correct for noise bias estimated from sims.

Power Spectrum Estimation



3) Apply further data-based estimate of noise bias to reduce sensitivity to inaccuracy of sims.

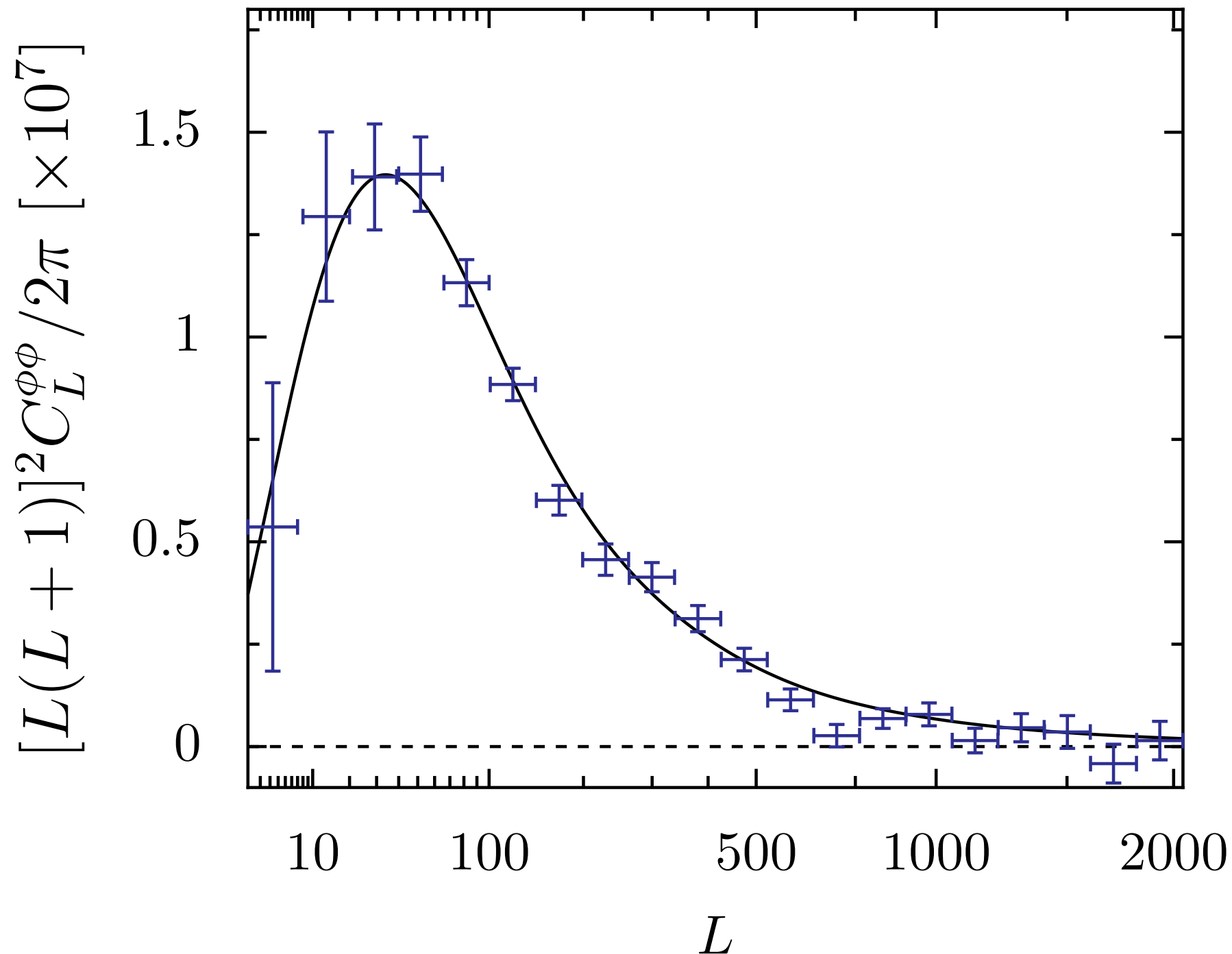
Power Spectrum Estimation



4) Correct for "N1" bias.

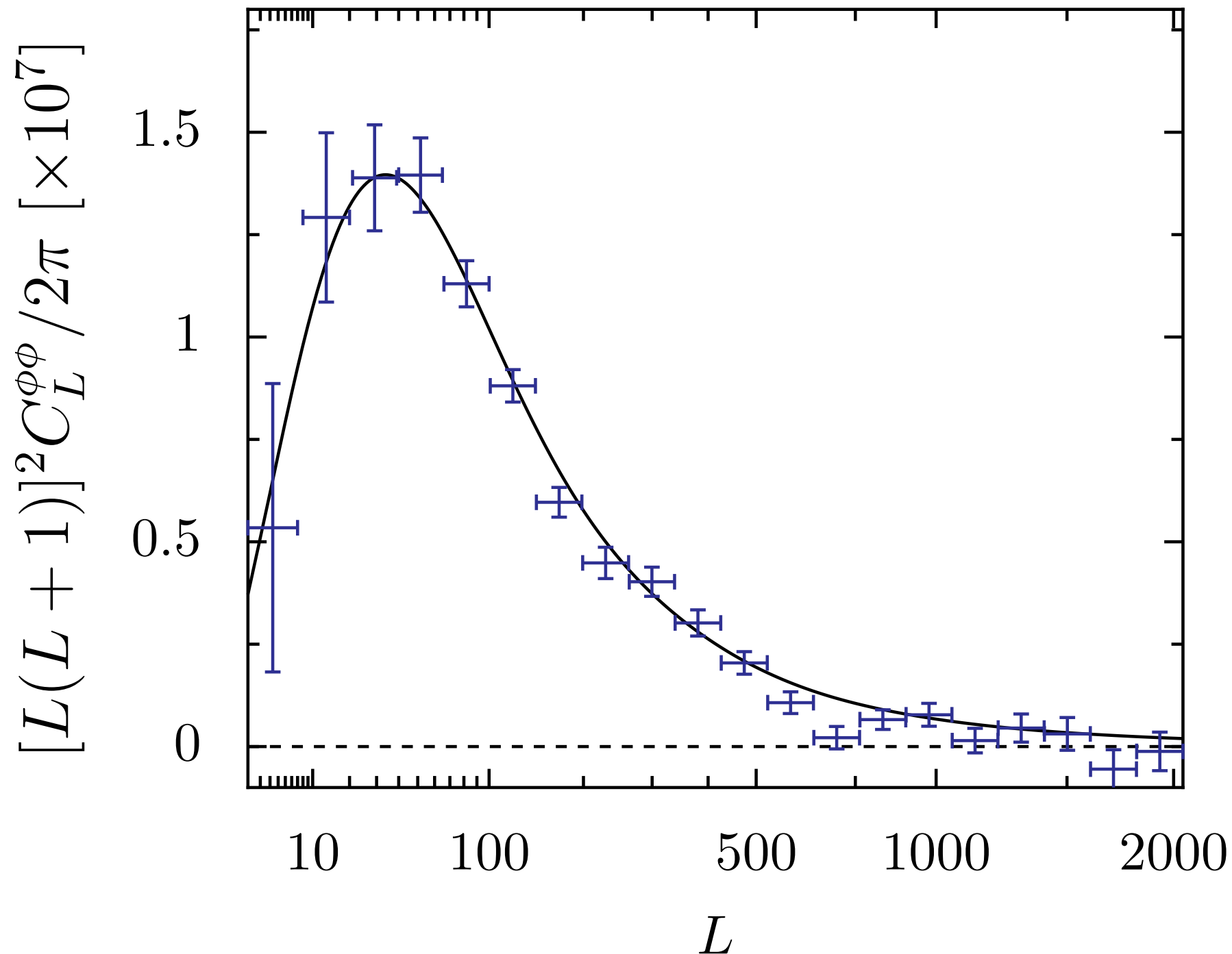
(cosmetic: likelihood uses full result and calculates N1)

Power Spectrum Estimation



5) MC correction for mode mixing / inaccuracies in normalization.

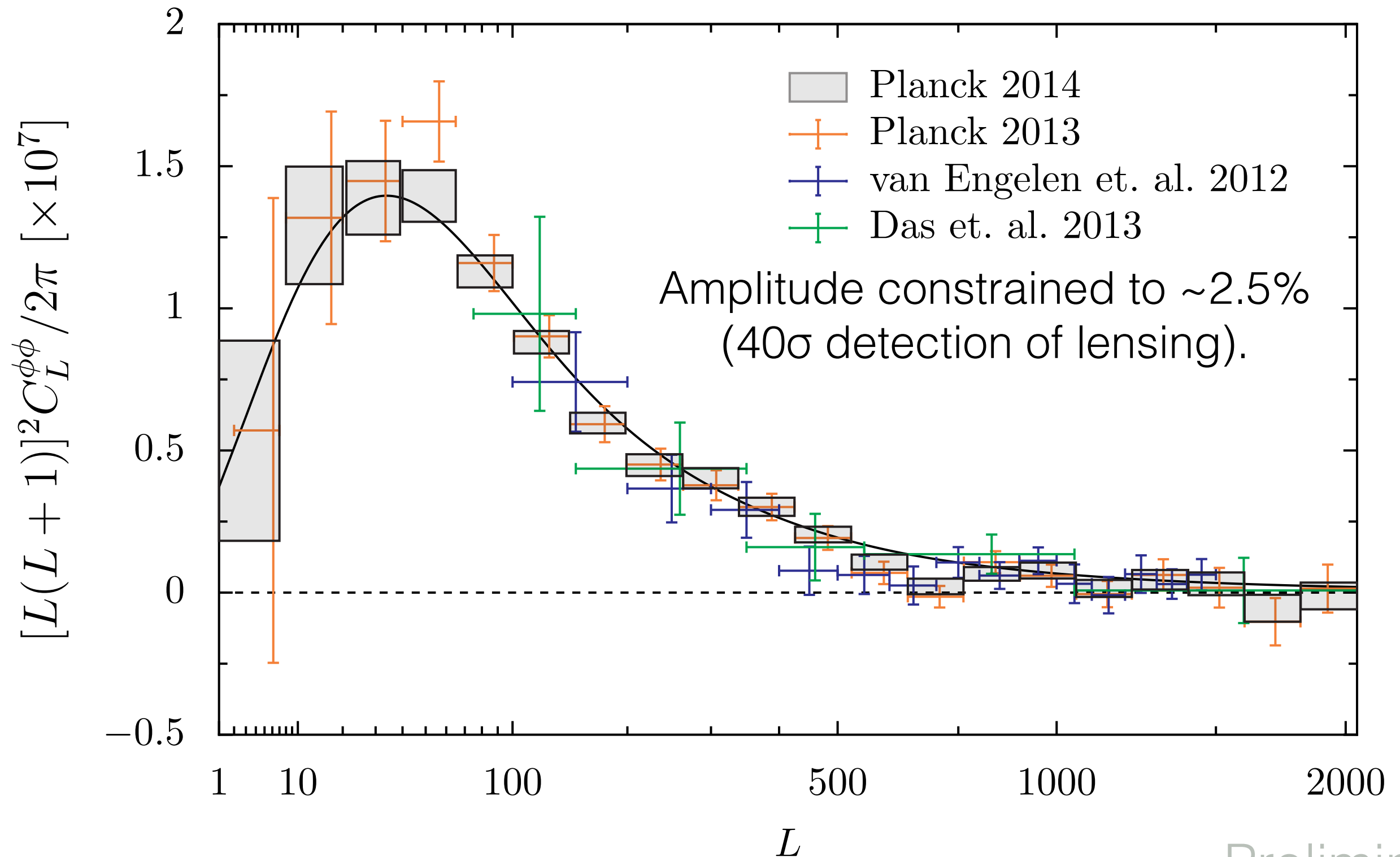
Power Spectrum Estimation



6) Correct for
"PS" bias.

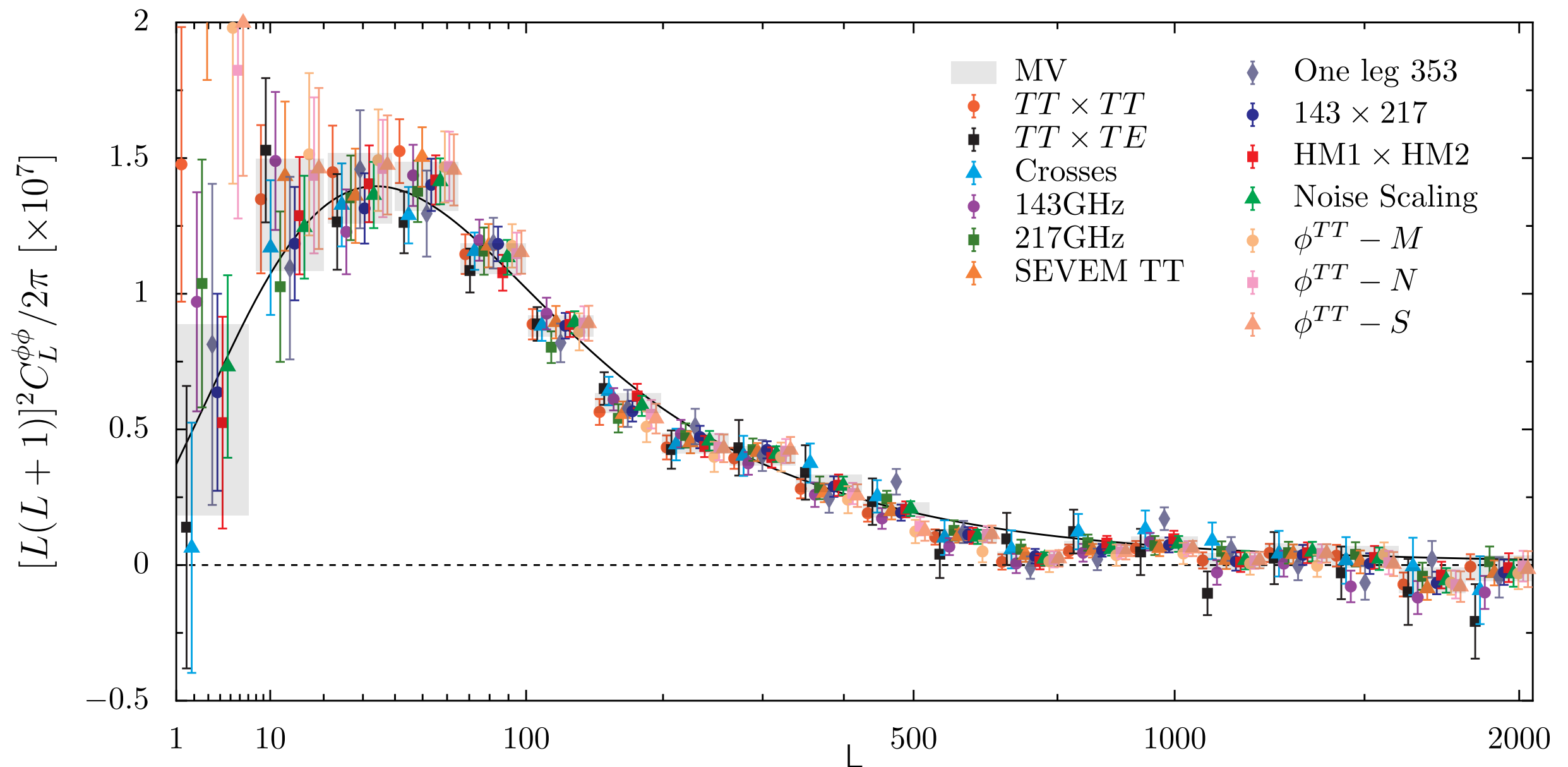
Done!

Lensing Power Spectrum



Preliminary

Reconstruction passes many internal consistency tests.

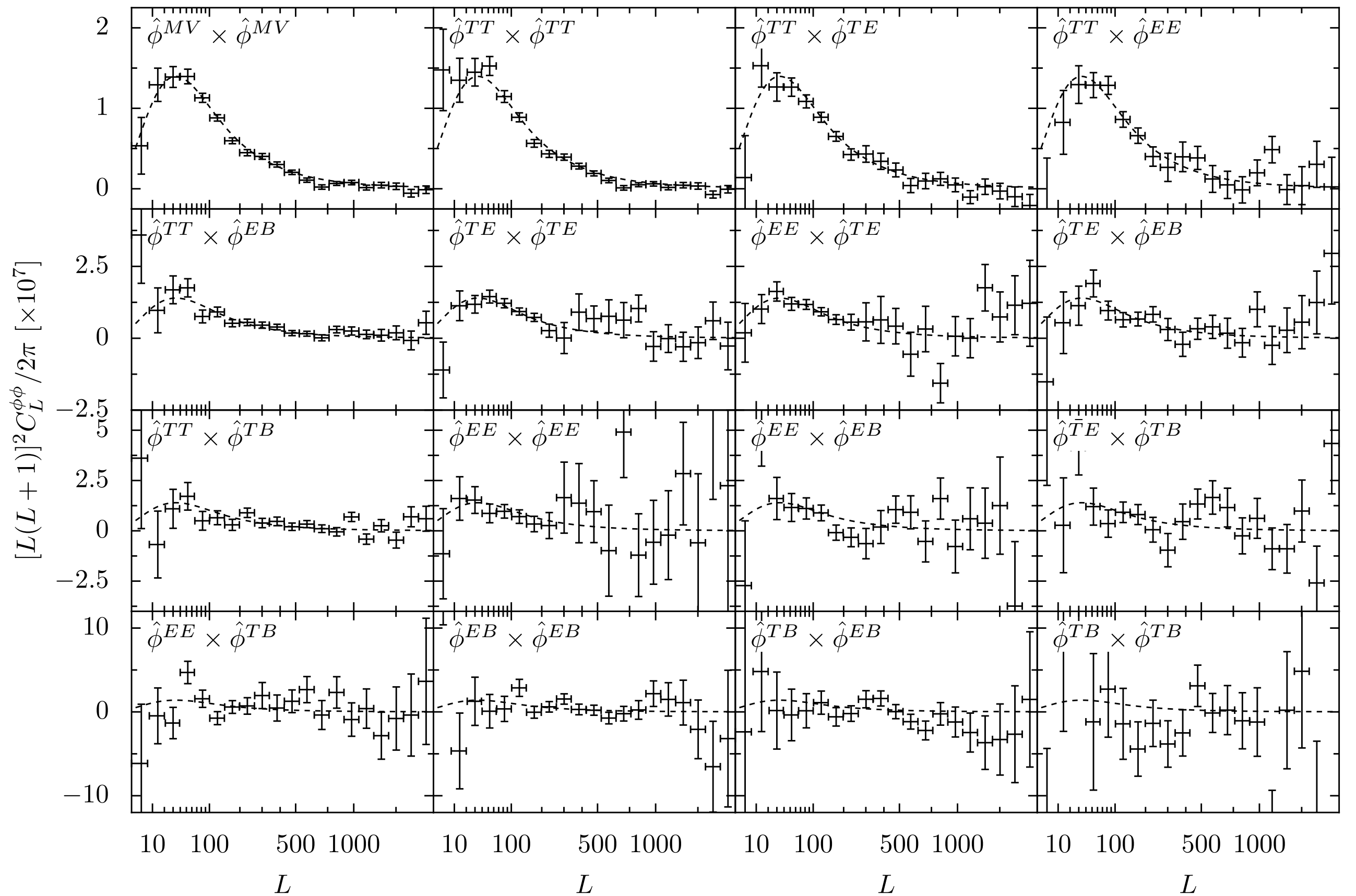


Highlights:

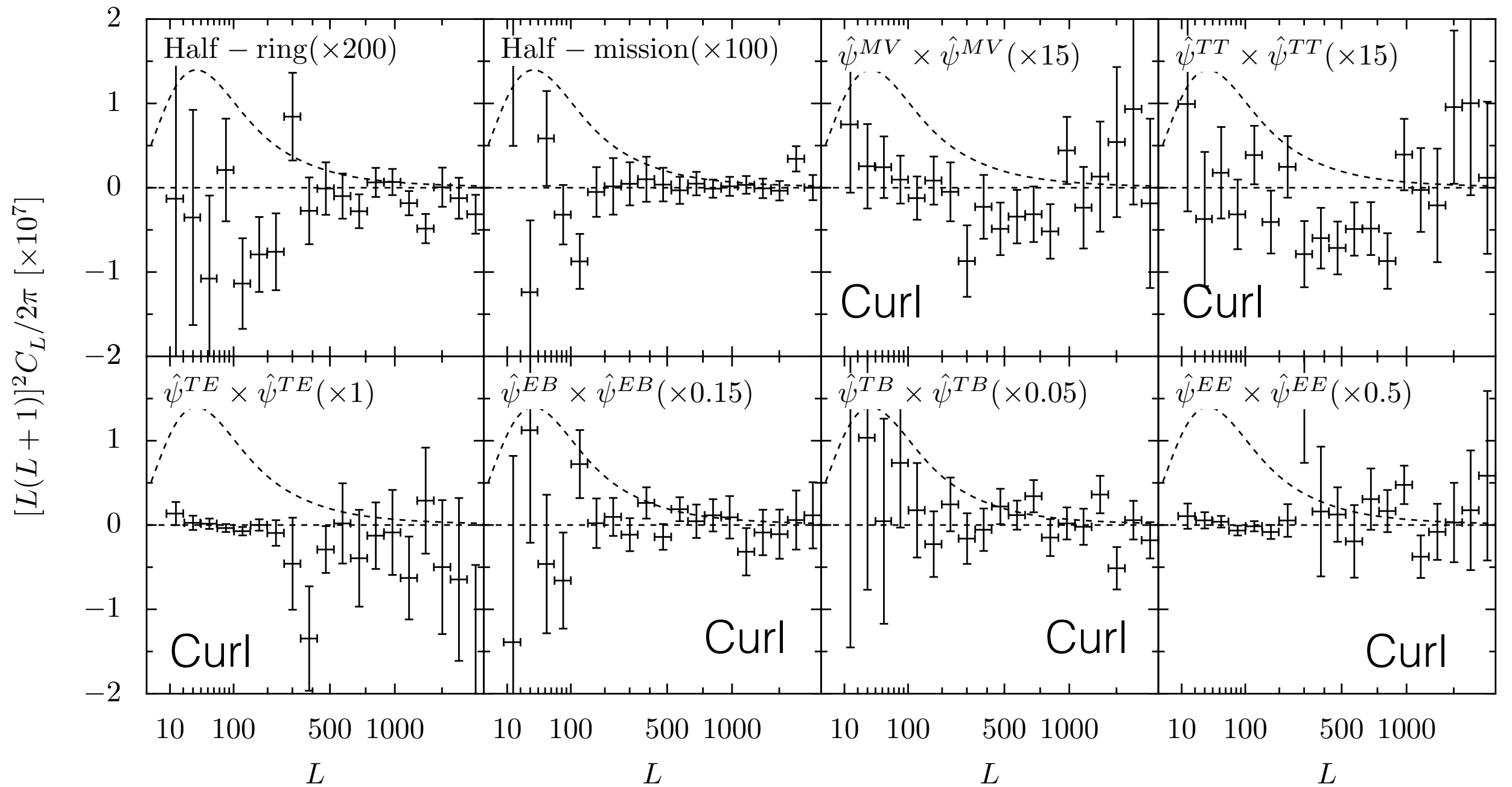
- Half-mission cross.
- Individual estimators.
- Replace one of four points in trispectrum with 353GHz.

Preliminary

Individual Cross-spectra

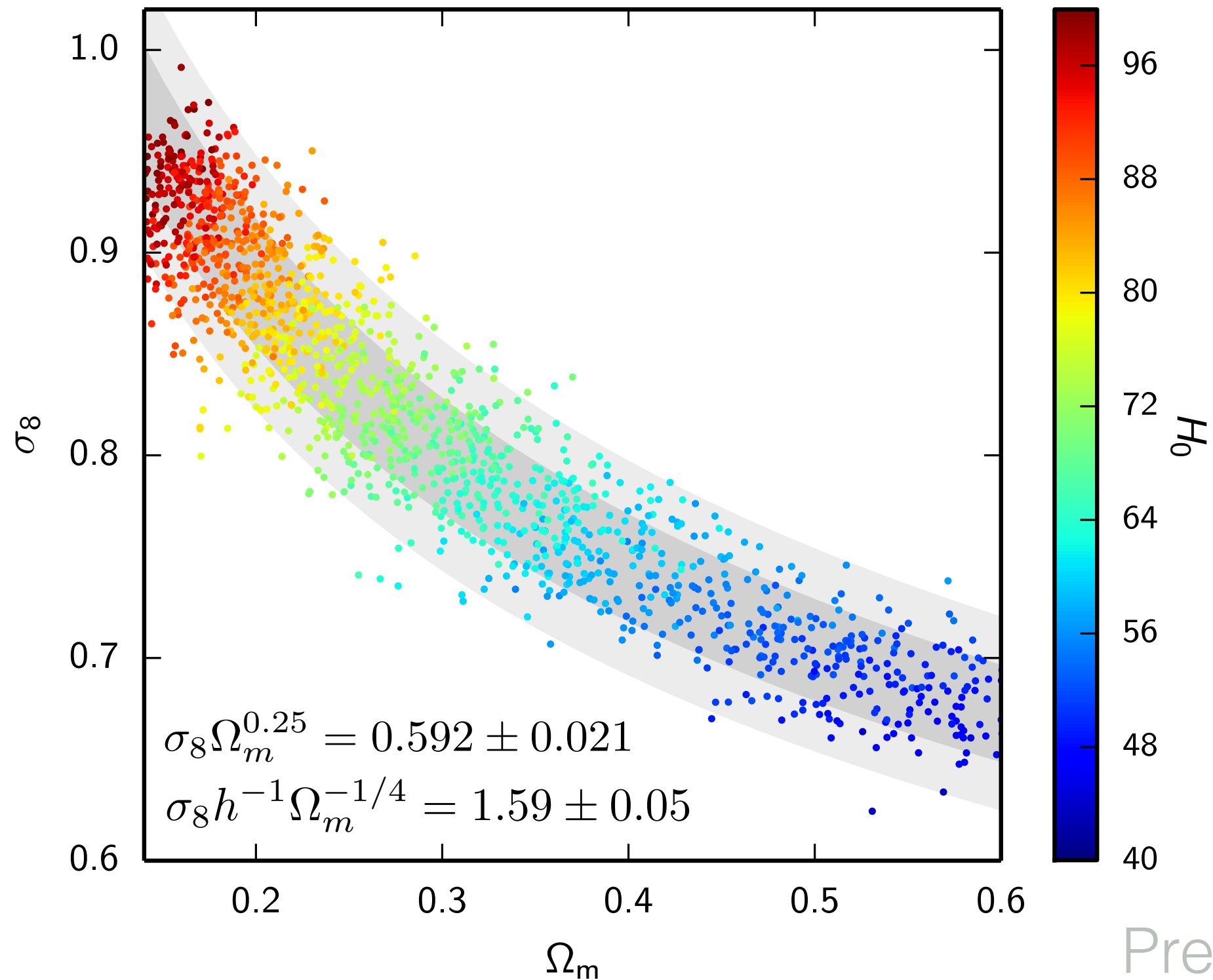


Null Tests



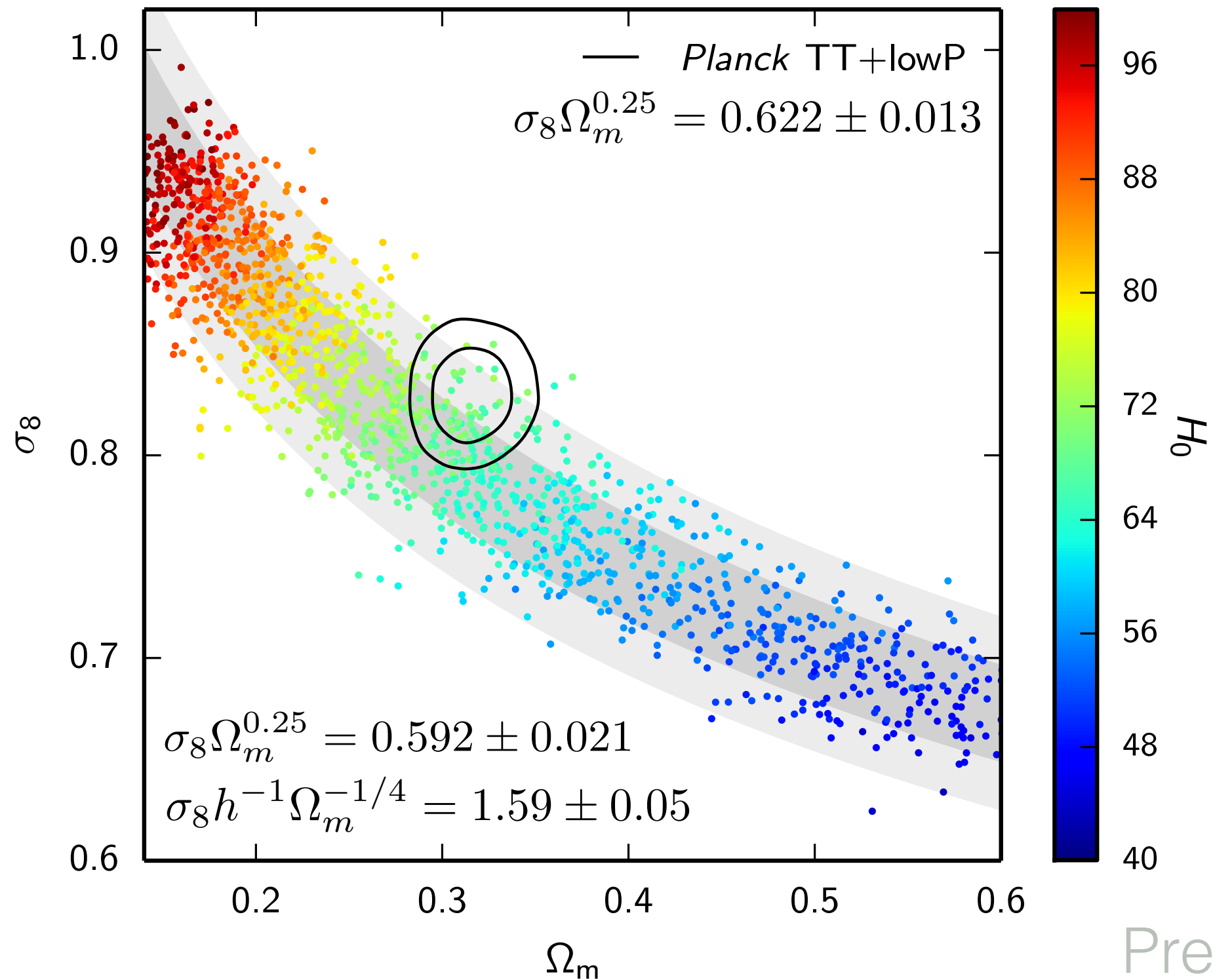
Conservative likelihood uses $40 \leq L \leq 400$

LCDM Parameter Constraints from CMB Lensing Only



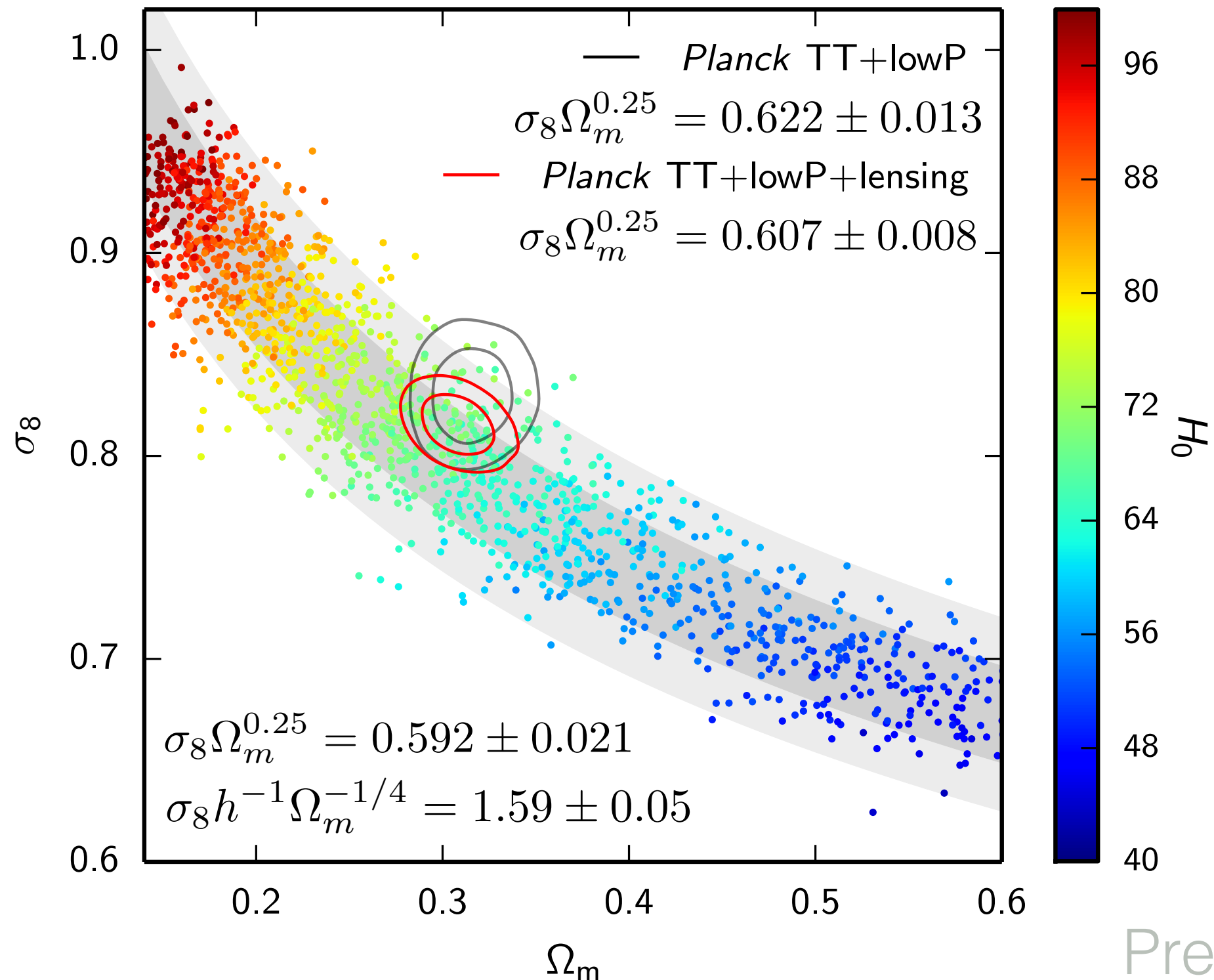
Preliminary

LCDM Parameter Constraints from CMB Lensing Only



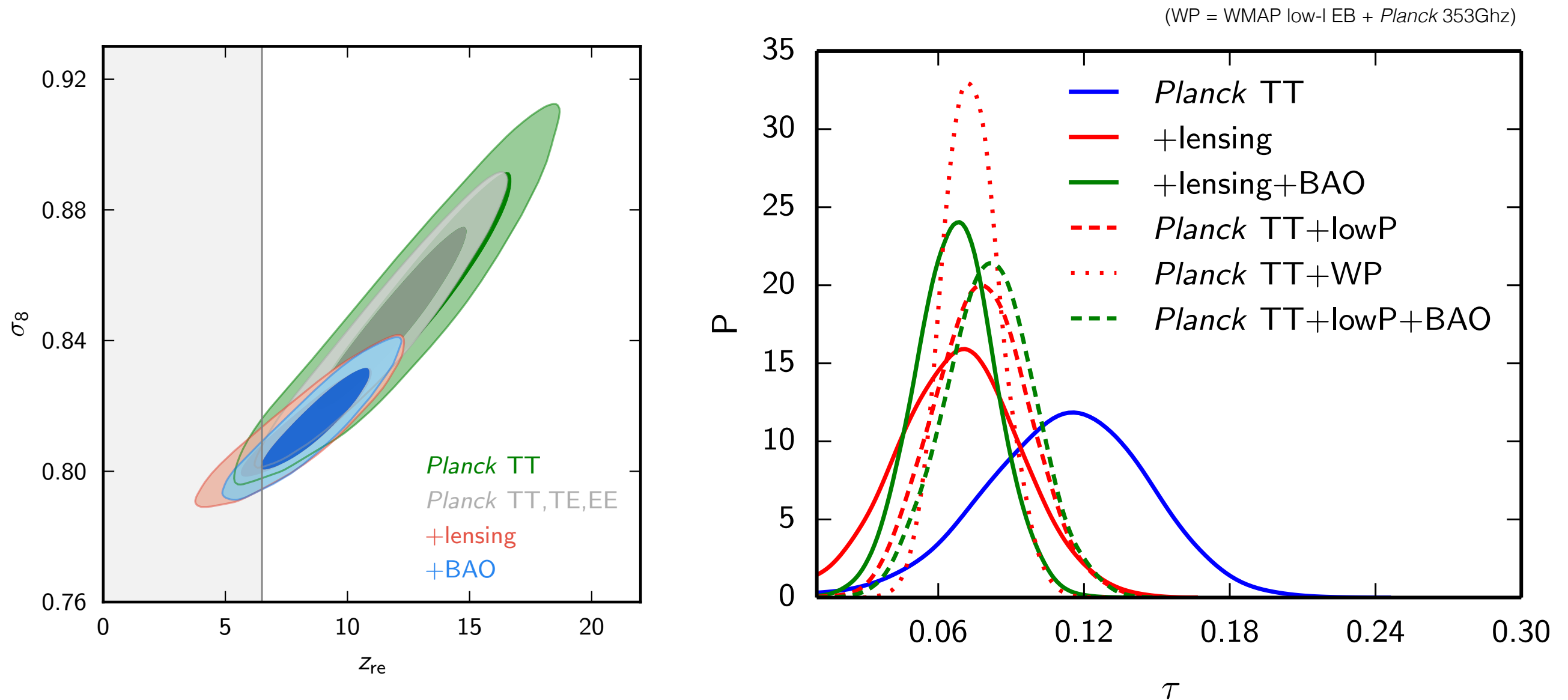
Preliminary

LCDM Parameter Constraints from CMB Lensing Only



Preliminary

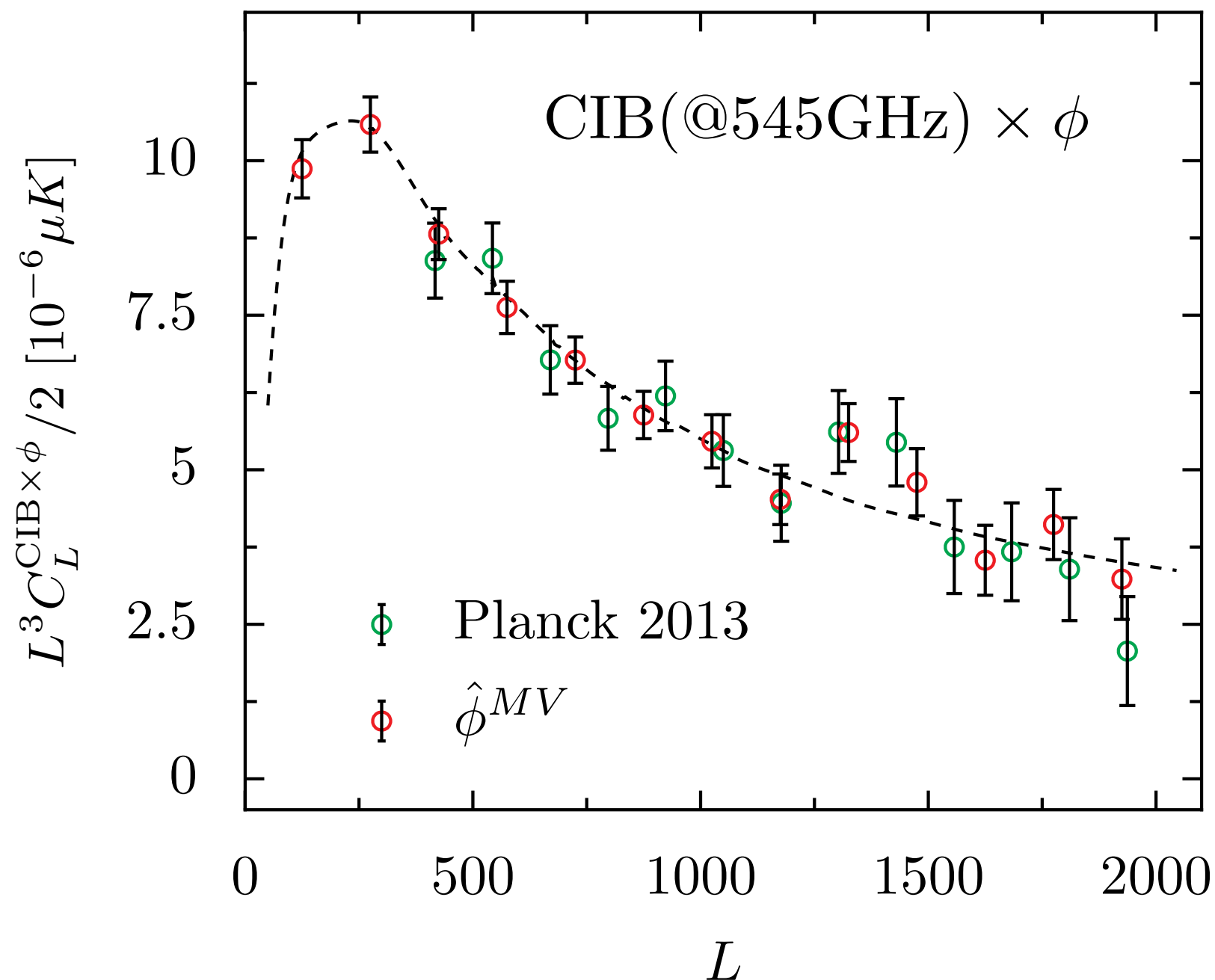
Optical Depth Constraints



... are consistent with low-L polarization.

Preliminary

Cross-correlation with the Infrared Background



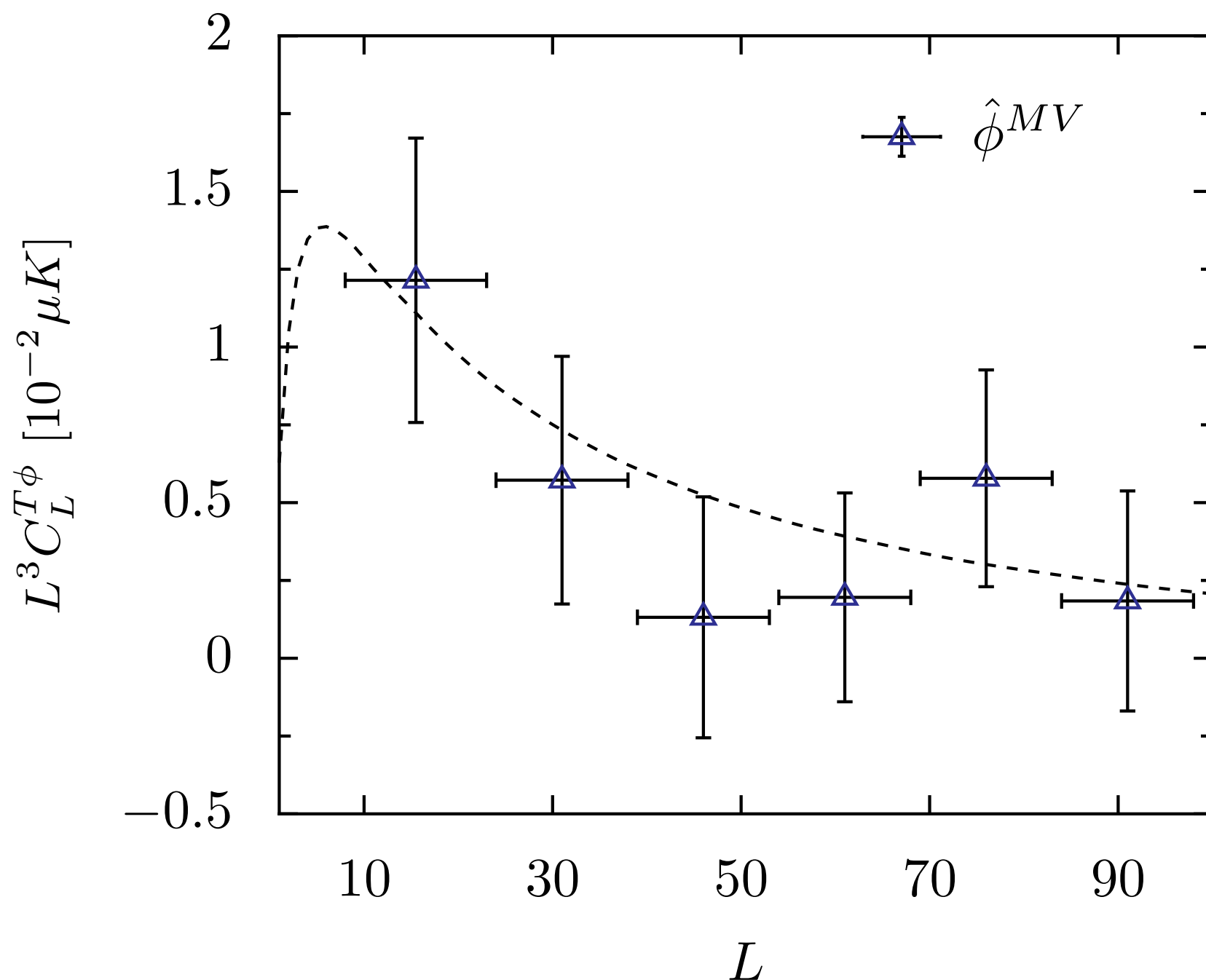
Now detected
at $\sim 50\sigma$.

CIB provides an
independent,
high S/N probe
of ϕ , useful for
lensing B-mode
estimates.

Preliminary

CMB cross-correlation

(lensing bispectrum)



ISW-lensing at 3σ

Lensing potential estimate also combined with other tracers in dedicated ISW paper.

Preliminary



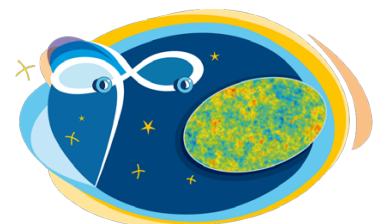
planck



DTU Space
National Space Institute



Science & Technology
Facilities Council



National Research Council of Italy



Deutsches Zentrum
für Luft- und Raumfahrt e.V.



UK SPACE
AGENCY



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DI MILANO



UNIVERSITY OF HELSINKI

