Analyzing the Tianlai Survey by Gibbs Sampling and Maximum Likelihood Techniques

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Collaboration partners:

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1 BAYESIAN ANGULAR POWER SPECTRUM ANALYSIS OF INTERFEROMETRIC DATA

P. M. Sutter[1,2,3], Benjamin D. Wandelt[2,3,1,4] and Siddharth S. Malu[5]

ABSTRACT

We present a Bayesian angular power spectrum and signal map inference engine which can be adapted to interferometric observations of anisotropies in the cosmic microwave background, 21 cm emission line mapping of galactic brightness fluctuations, or 21 cm absorption line mapping of neutral

arXiv:1109.464

2 BAYESIAN INFERENCE OF POLARIZED CMB POWER SPECTRA FROM INTERFEROMETRIC DATA

Ata Karakci[1], P. M. Sutter[2,3,4,5], Le Zhang[6], Emory F. Bunn[7], Andrei Korotkov[1], Peter Timbie[6], G. S. Tucker[1], and Benjamin D. Wandelt[3,4,2,8]

ABSTRACT

Detection of B-mode polarization of the cosmic microwave background (CMB) radiation is one of the frontiers of observational cosmology. Because they are an order of magnitude fainter than E-modes, it

see arXiv tomorrow

3 MAXIMUM LIKELIHOOD ANALYSIS OF SYSTEMATIC ERRORS IN INTERFEROMETRIC OBSERVATIONS OF THE COSMIC MICROWAVE BACKGROUND

Le Zhang[1], Ata Karakci[2], Paul M. Sutter[3,4,5,6], Emory F. Bunn[7], Andrei Korotkov[2], Peter Timbie[1], Gregory S. Tucker[2], and Benjamin D. Wandelt[4,5,3,8]

ABSTRACT

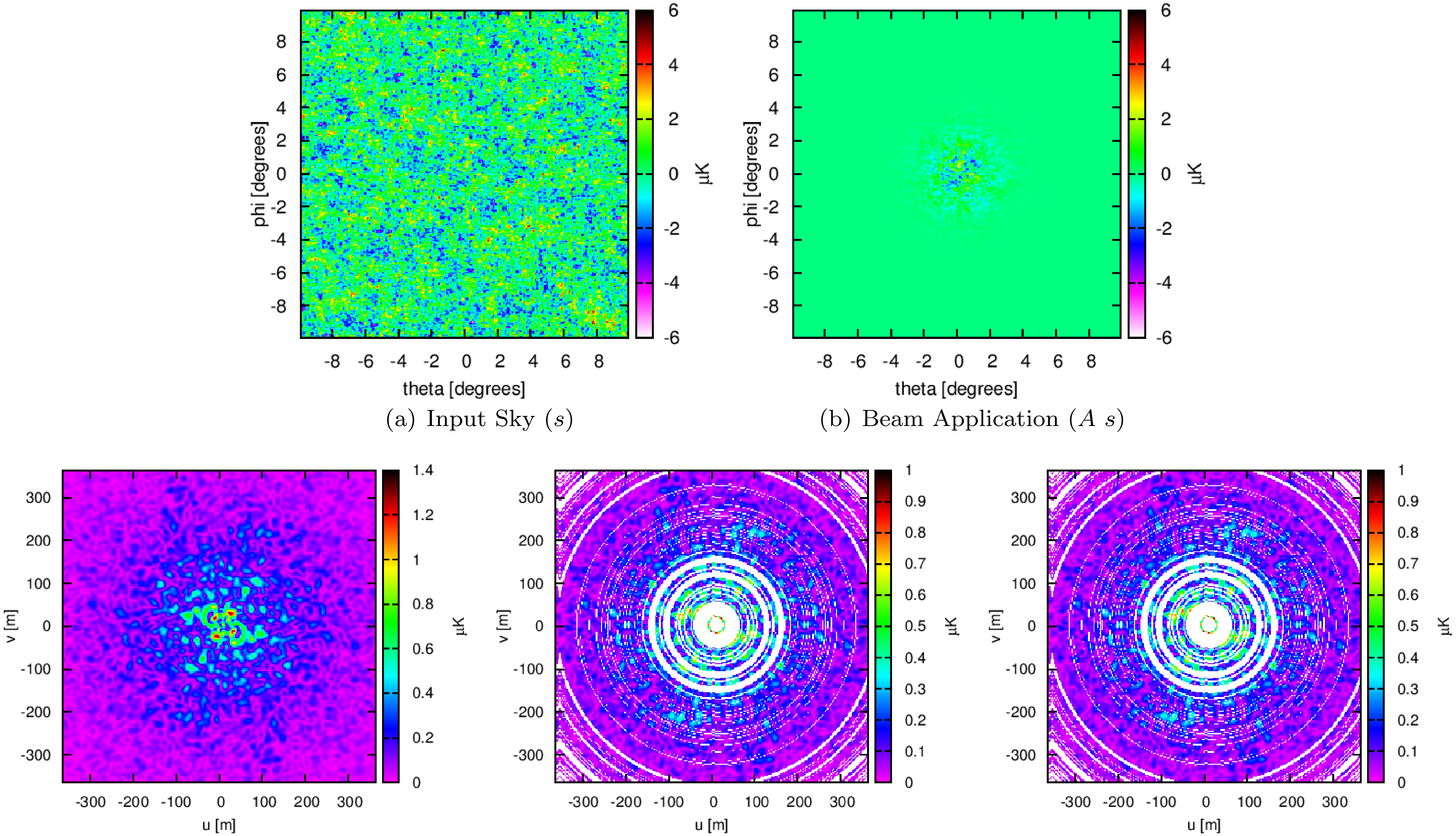
We investigate the impact of instrumental systematic errors in interferometric measurements of the cosmic microwave background (CMB) temperature and polarization power spectra. We simulate

arXiv:1209.2676

What the codes can do?

- simulate CMB Stokes fields I,Q,U
- simulate interferometric CMB observations to generate mock visibilities (instrumental noise, beam pattern, uv-coverage, systematics)
- using two techniques Gibbs sampling(GS)/maximum likelihood(ML) to recover the underlying power spectra
- provide optimal sky map reconstruction
- we would like to apply to 21cm signals

Simulation Pipeline



(a) Input Sky (s) (b) Beam Application ($A\ s$)

(c) Fourier Transform ($FA\ s$) (d) Interferometer Application ($IFA\ s$) (e) Data ($IFA\ s + I\ n$)

Gibbs sampling (GS):

$s^{i+1} \leftarrow P(s|C^i_l,d)$

(Wiener filtered map + Gaussian fluctuations)

$C^i_l+1 \leftarrow P(C_l|s^{i+1},d)$

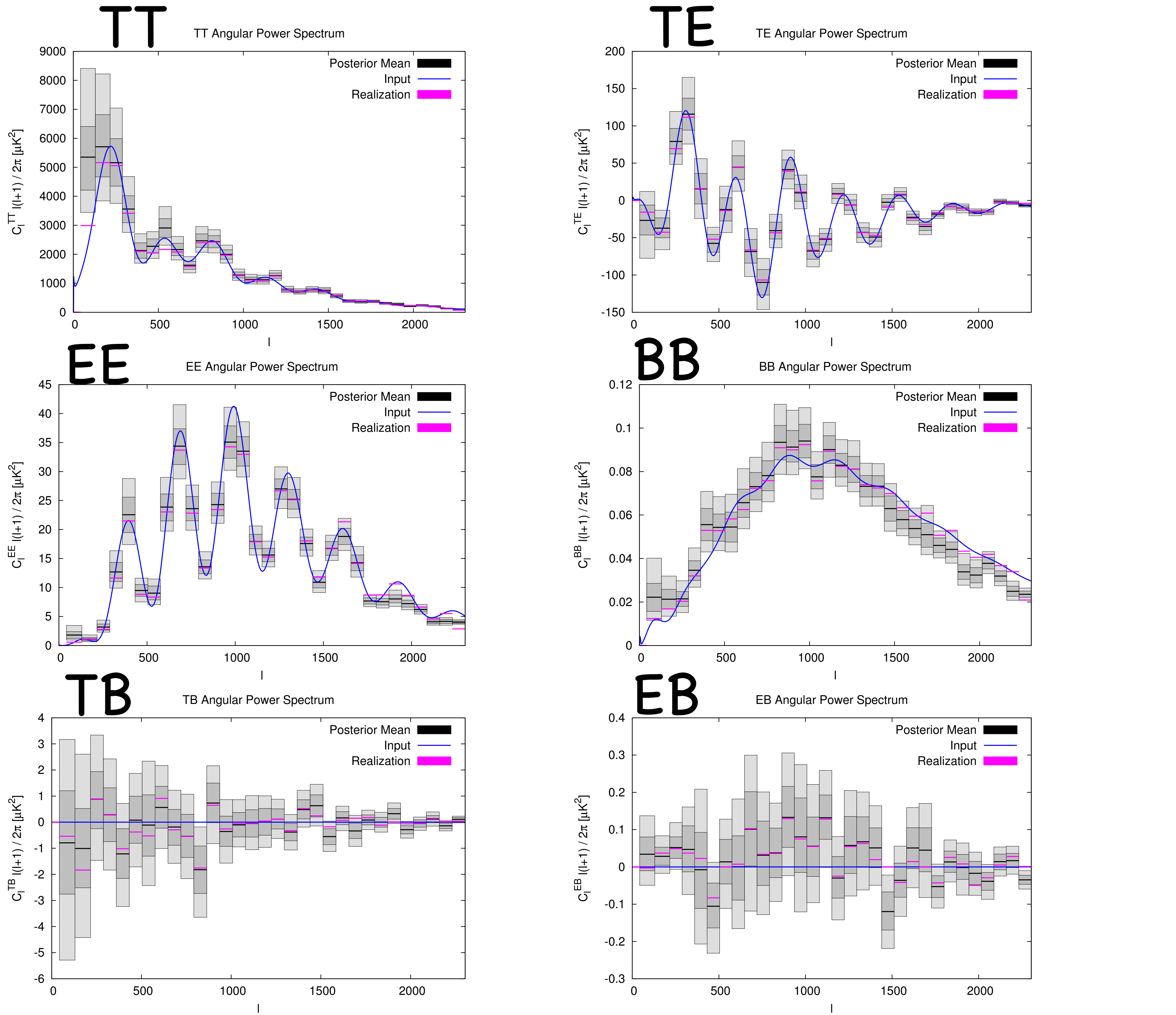
(inverse gamma distribution)

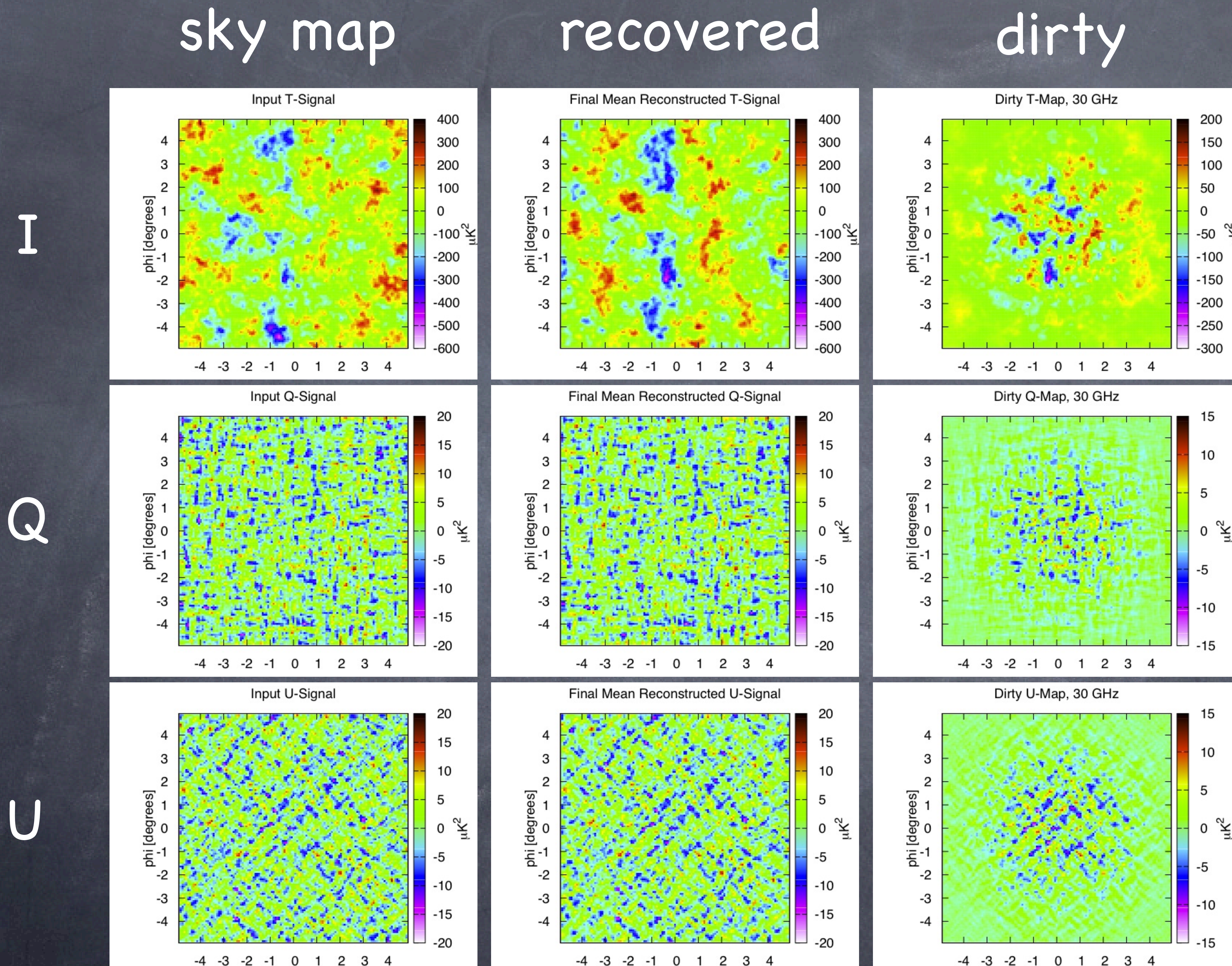
3. Repeat previous steps 1 and 2
4. After some "burn-in", $\{C^i_l,s^i\}$ converge to being samples from full joint distribution $P(C_l,s|d)$

Maximum likelihood (ML):

evaluate the likelihood to find "best-fitted" C_l

$$\ln \mathcal{L}(C_\ell) = n \log \pi - \log |C_V + C_N| - \mathbf{V}^\dagger (C_V + C_N)^{-1} \mathbf{V}$$


TT
TT Angular Power Spectrum
Posterior Mean
Input
Realization
C_l^{TT} l(l+1) / 2π [μK²]
l
TE
TE Angular Power Spectrum
Posterior Mean
Input
Realization
C_l^{TE} l(l+1) / 2π [μK²]
l
EE
EE Angular Power Spectrum
Posterior Mean
Input
Realization
C_l^{EE} l(l+1) / 2π [μK²]
l
BB
BB Angular Power Spectrum
Posterior Mean
Input
Realization
C_l^{BB} l(l+1) / 2π [μK²]
l
TB
TB Angular Power Spectrum
Posterior Mean
Input
Realization
C_l^{TB} l(l+1) / 2π [μK²]
l
EB
EB Angular Power Spectrum
Posterior Mean
Input
Realization
C_l^{EB} l(l+1) / 2π [μK²]
l



(a) Signal Realization (c) Final Mean Posterior Map (c) Dirty Map

What about the 21cm?

Different about 21cm vs. CMB analysis

- 3D vs. 2D
- stronger diffuse and point-source foregrounds; RFI
- curved vs. flat sky
- bigger datasets (need efficient data compression, e.g. S/N eigenmodes analysis)

What is the same?

- visibility data
- same calculations and algorithms for extracting the C_l

Summary

- GS gives self-consistent way to do power spectrum inference and signal reconstruction at the same time, including full propagation of the uncertainties.

- Computational complexity: $O(n^{3/2})$ for GS, $O(n^3)$ for ML, but for small data set ML run faster. For ~4000 visibilities, ML takes 20 hrs for C_l estimates (36 band-powers) and GS requires 3 days.

- We would like to extend both GL and ML to 21 cm applications.