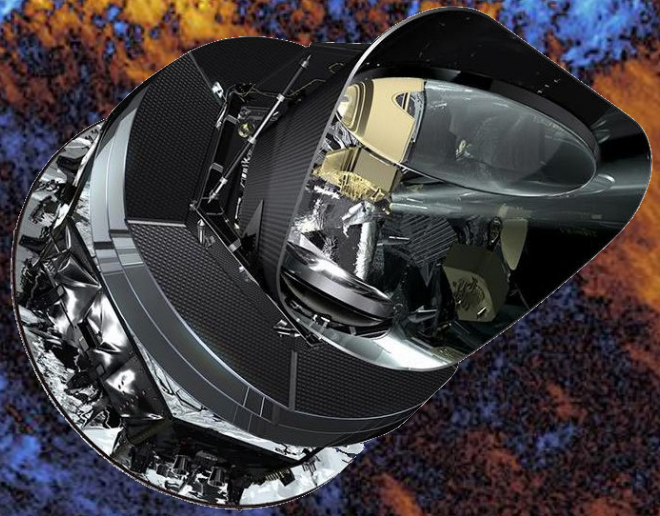
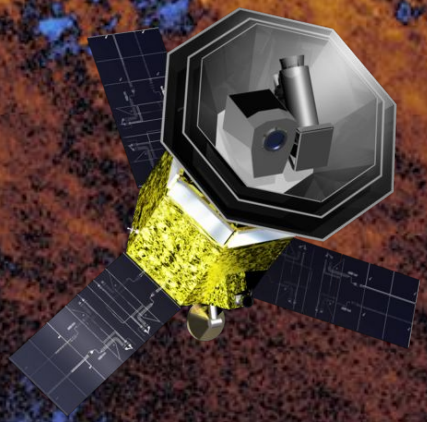
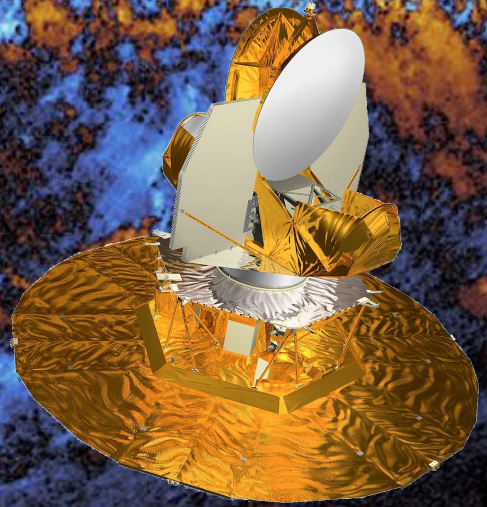
Preliminary analysis of external datasets

Duncan Watts







BeyondPlanck online release conference, November 18-20, 2020

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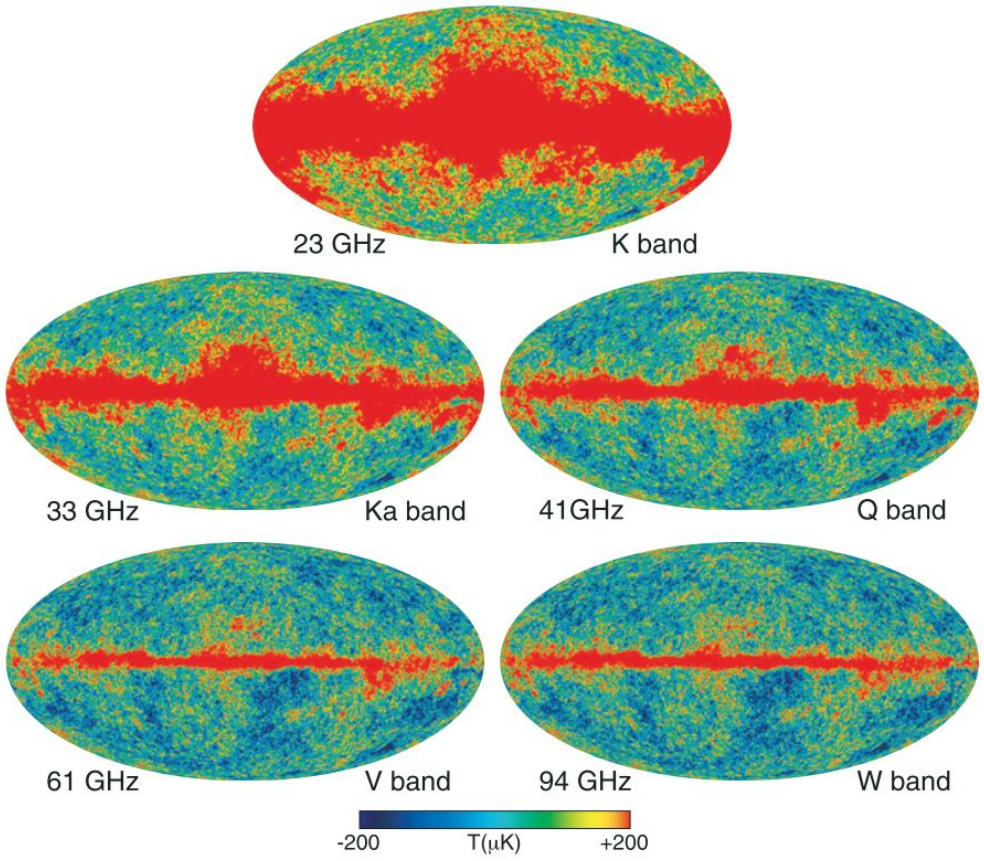
WMAP Overview

- *WMAP* observed for 9 years at 5 frequency bands
- Lower sensitivity than *Planck*, but its frequencies are interleaved with the *Planck* LFI's bands
- *WMAP*'s scan strategy is complementary to *Planck*'s, and can break degeneracies in both datasets' mapmaking
- TOD processing has been very well documented, and can easily be reproduced[1]



Bennett et al. (2013) arXiv:1212.5225

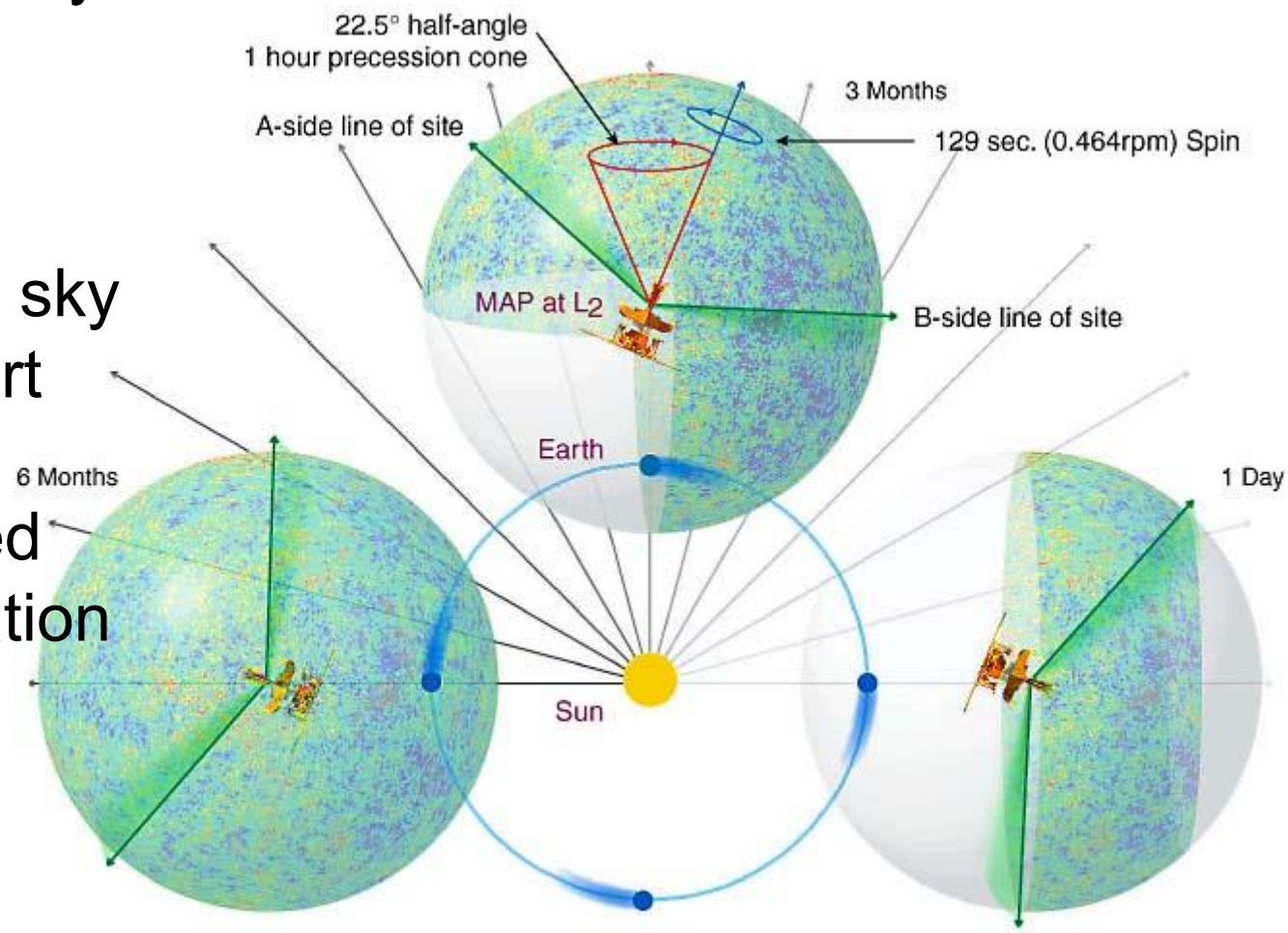
[1] https://lambda.gsfc.nasa.gov/product/map/dr5/pub_papers/nineyear/supplement/WMAP_supplement.pdf

WMAP K-band re-analysis

- *WMAP K*-band is a natural candidate to extend the BP pipeline
- Its 23 GHz map gives the current best publicly available template for polarized synchrotron emission
- The dataset itself is well-understood and the analysis process is well-documented by the *WMAP* Science team.
- The uncalibrated uncompressed *WMAP* data is 626 GB, which we can easily hold in memory all at once, which was not the case during the *WMAP* Science team's original analysis.
- Original *WMAP* data was processed year-by-year; code has been rewritten to process entire data set at once

Observing strategy

- *WMAP* observes the sky at ~141° separation, making the data inherently differential
- Large fractions of the sky are covered over short periods of time
- Pixels are re-observed with different polarization orientation for good characterization of systematics



https://map.gsfc.nasa.gov/mission/observatory_scan.html

Overview of data model

Each differencing assembly (DA) consists of four radiometers, with i={1,2} representing orthogonal polarizations and j={3,4} the two differenced timestreams for a single polarization mode.

The gain, $\boldsymbol{g}(t)$ was calibrated using the orbital dipole in the original *WMAP* analysis, as were the time-independent beam transmission coefficients, $\alpha_{i\mathrm{A}}$ and $\alpha_{i\mathrm{B}}$, while baselines $\boldsymbol{b}_{ij}$ were fit hourly.

$$\boldsymbol{c}_{ij}(t) = \boldsymbol{g}_{ij}(t)\Big[\alpha_{i\mathrm{A}}\{T[p_{\mathrm{A}}(t)] + (-1)^i P[p_{\mathrm{A}}(t), \gamma_{\mathrm{A}}(t)]\} - \alpha_{i\mathrm{B}}\{T[p_{\mathrm{B}}(t)] + (-1)^i P[p_{\mathrm{B}}(t), \gamma_{\mathrm{B}}(t)]\}\Big] + \boldsymbol{b}_{ij}$$

Adjustments for differential mapmaking

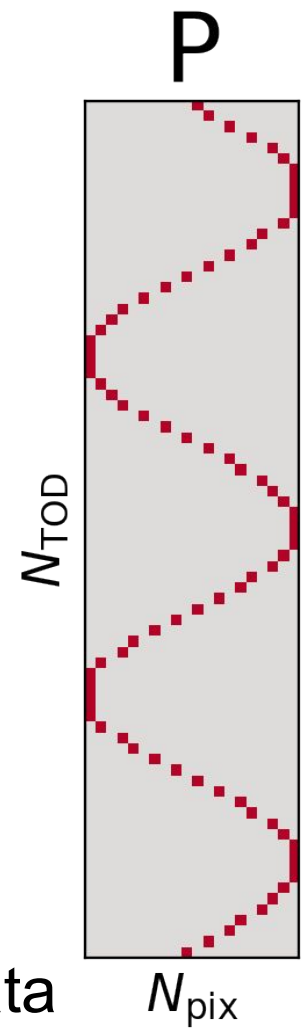
An idealized single-horn instrument has a relatively straightforward mapmaking equation that can be solved one pixel at a time

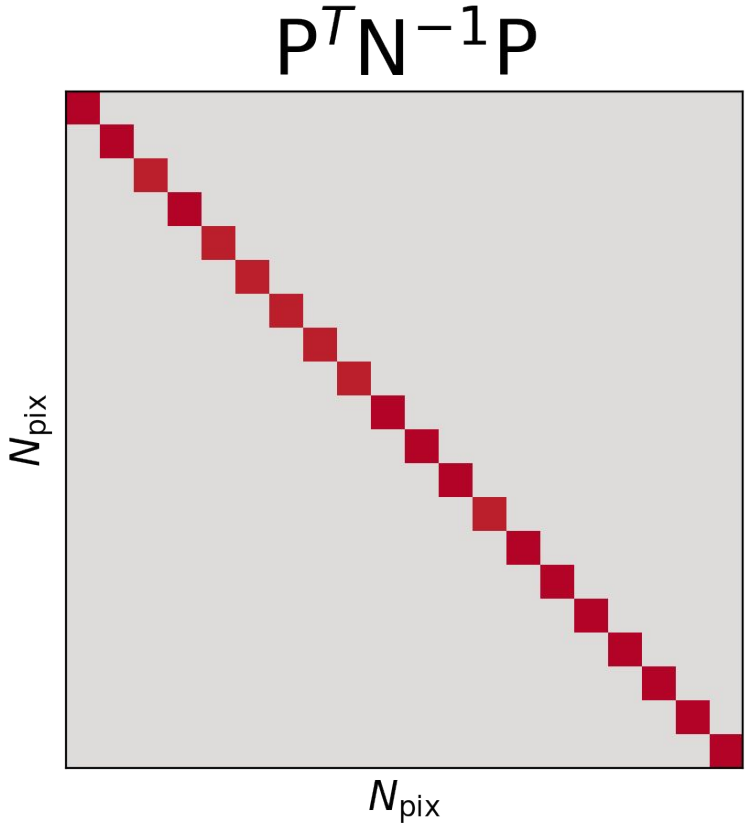
$$\boldsymbol{d} = \mathrm{P}\boldsymbol{s} + \boldsymbol{n}$$

$$\mathrm{P}^T\mathrm{N}^{-1}\mathrm{P}\boldsymbol{s} = \mathrm{P}^T\mathrm{N}^{-1}\boldsymbol{d}$$

An idealized differential induces off-diagonal pixel correlations, and requires indirect inversion of a large matrix, which requires all data to be processed at once.

One horn





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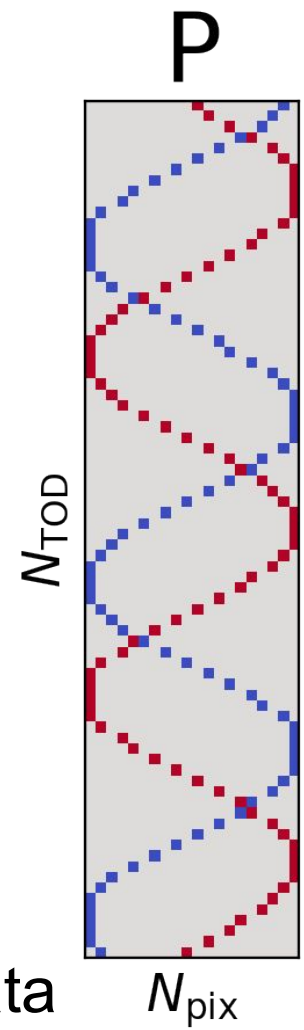
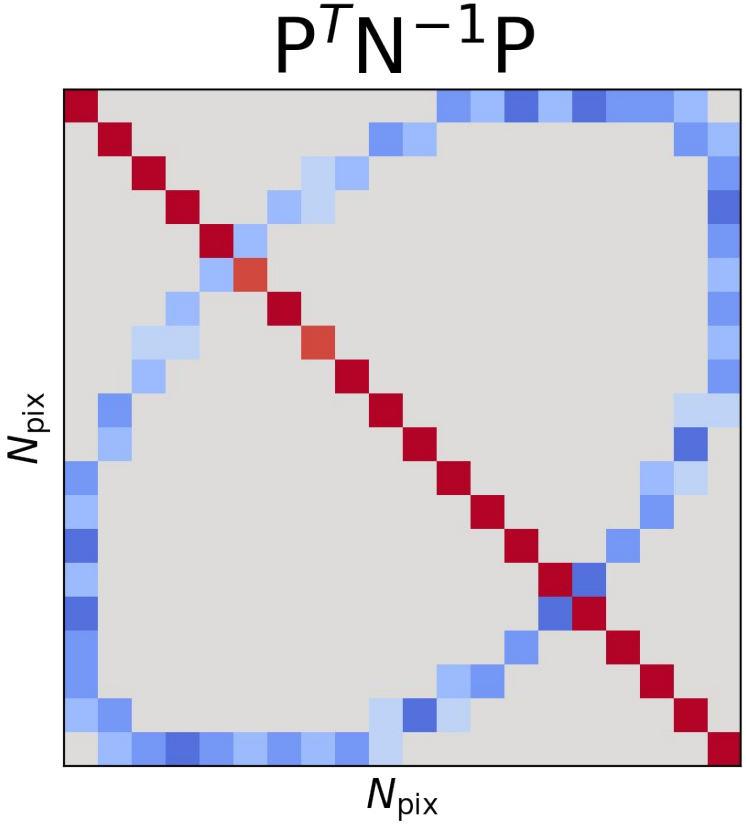
Two horns



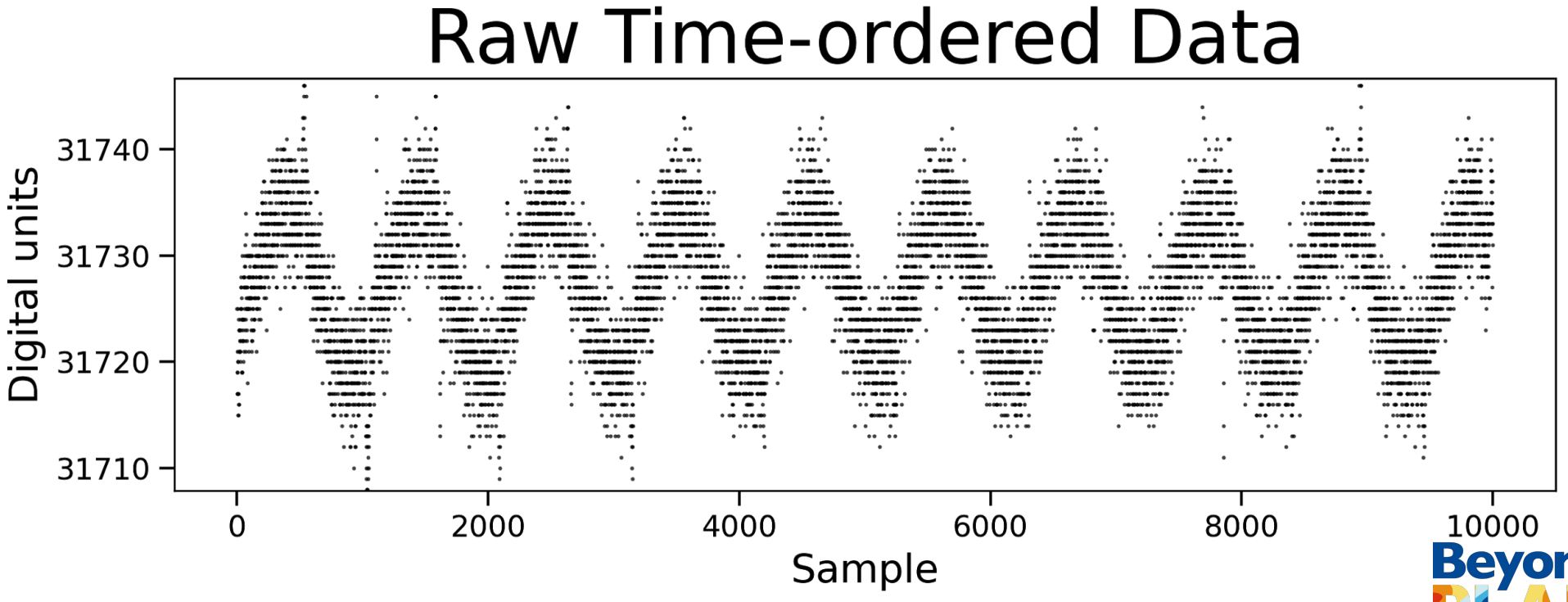


WMAP analysis updates

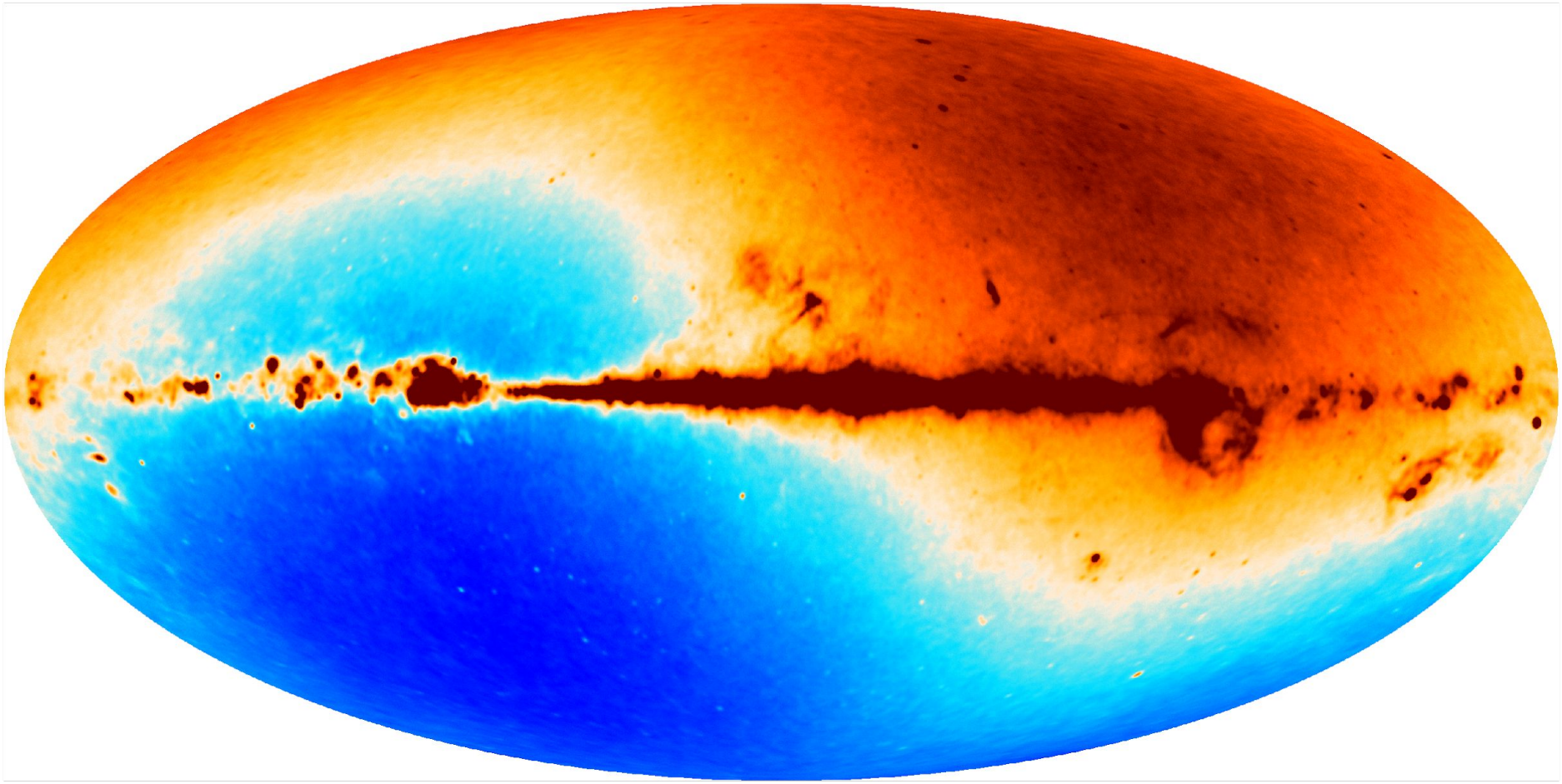
Highly compressible data, raw data are stored as floats, but are recorded as discrete values

Can yield a factor of ~5 reduction in data volume simply by storing data as integers

- Baseline sampling has been replaced with correlated noise fitting (Ihle et al. 2020)
- Gain fitting uses formalism of Gjerløw et al. 2020



Current results



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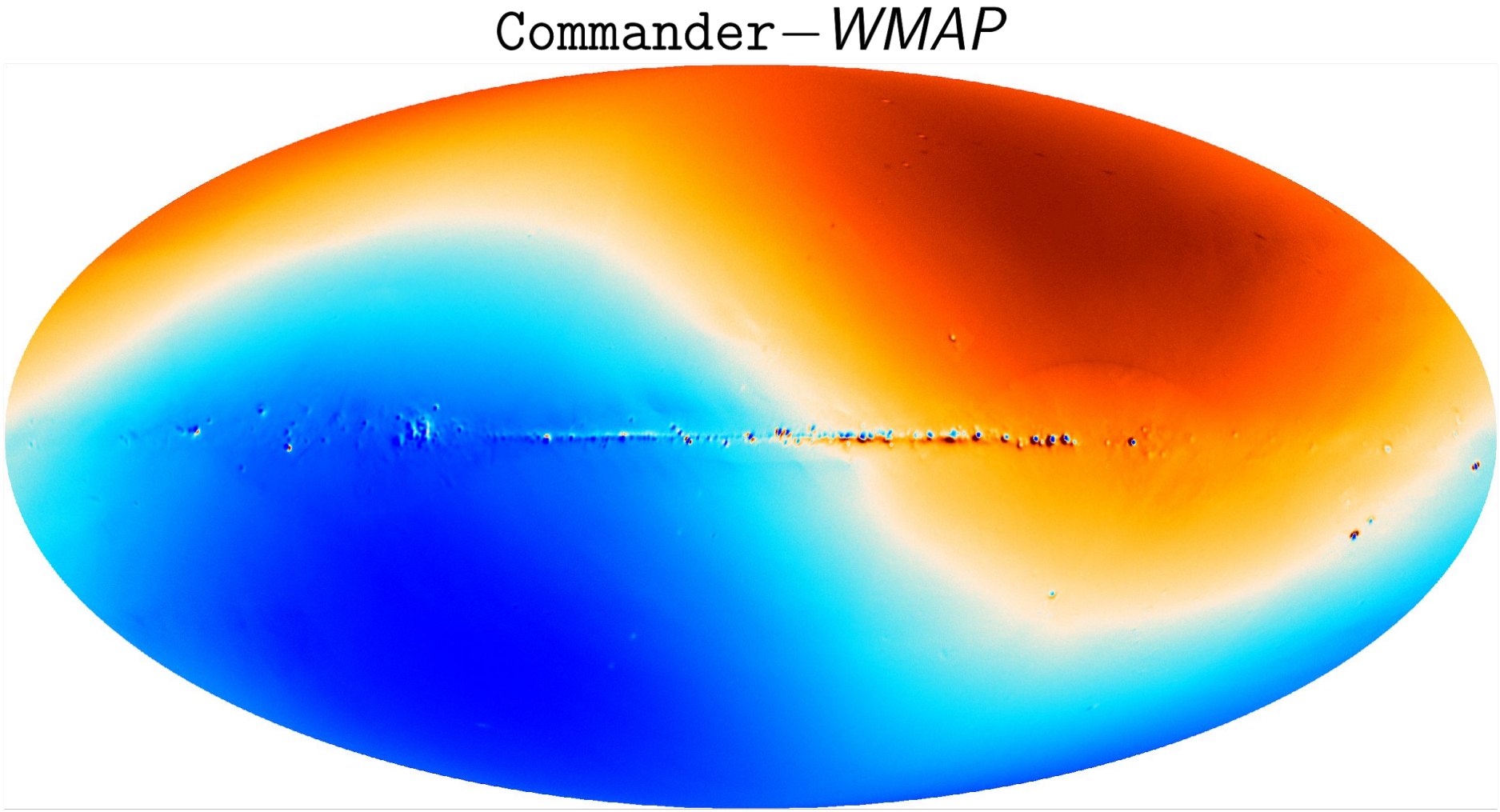

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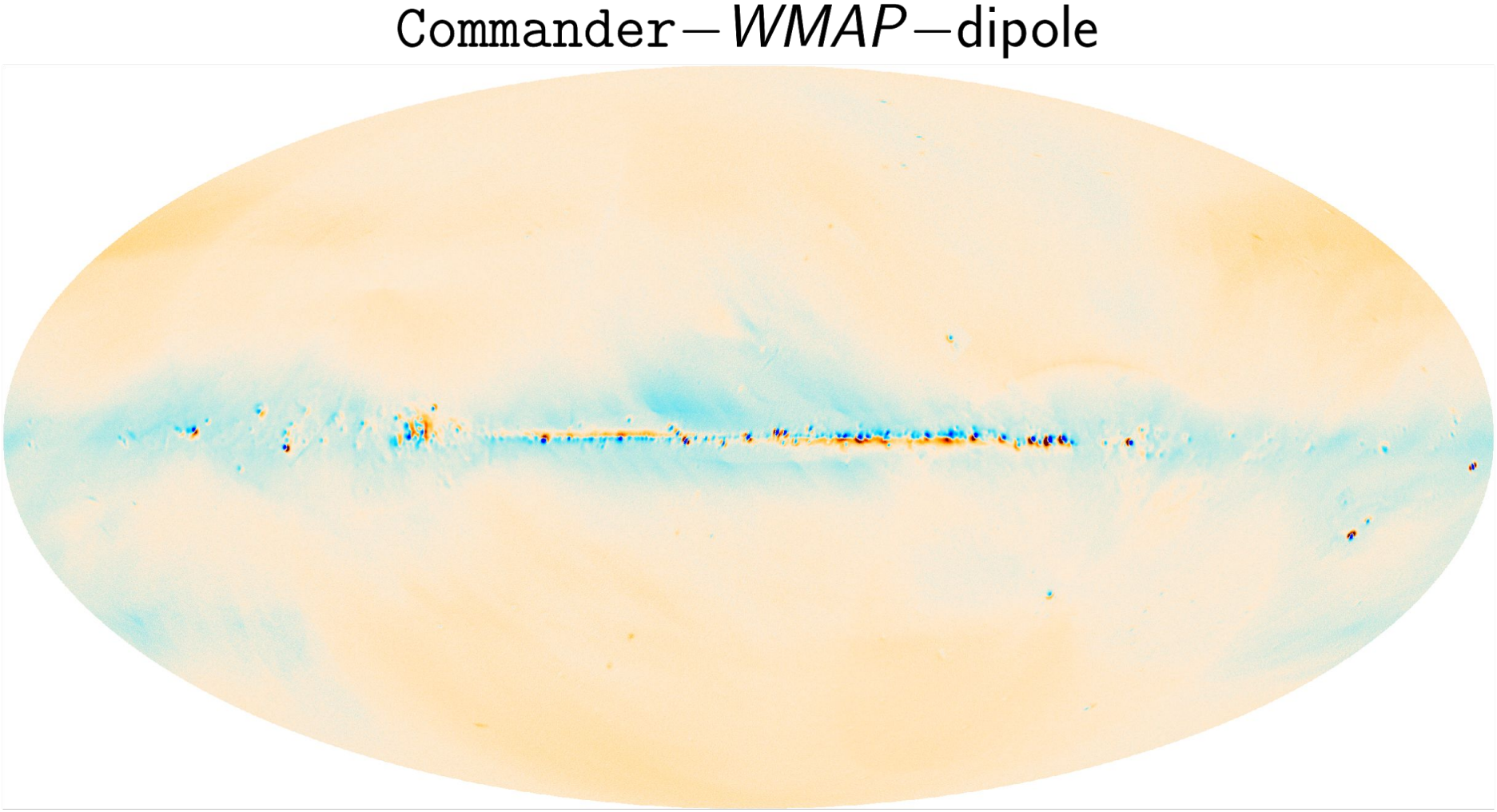
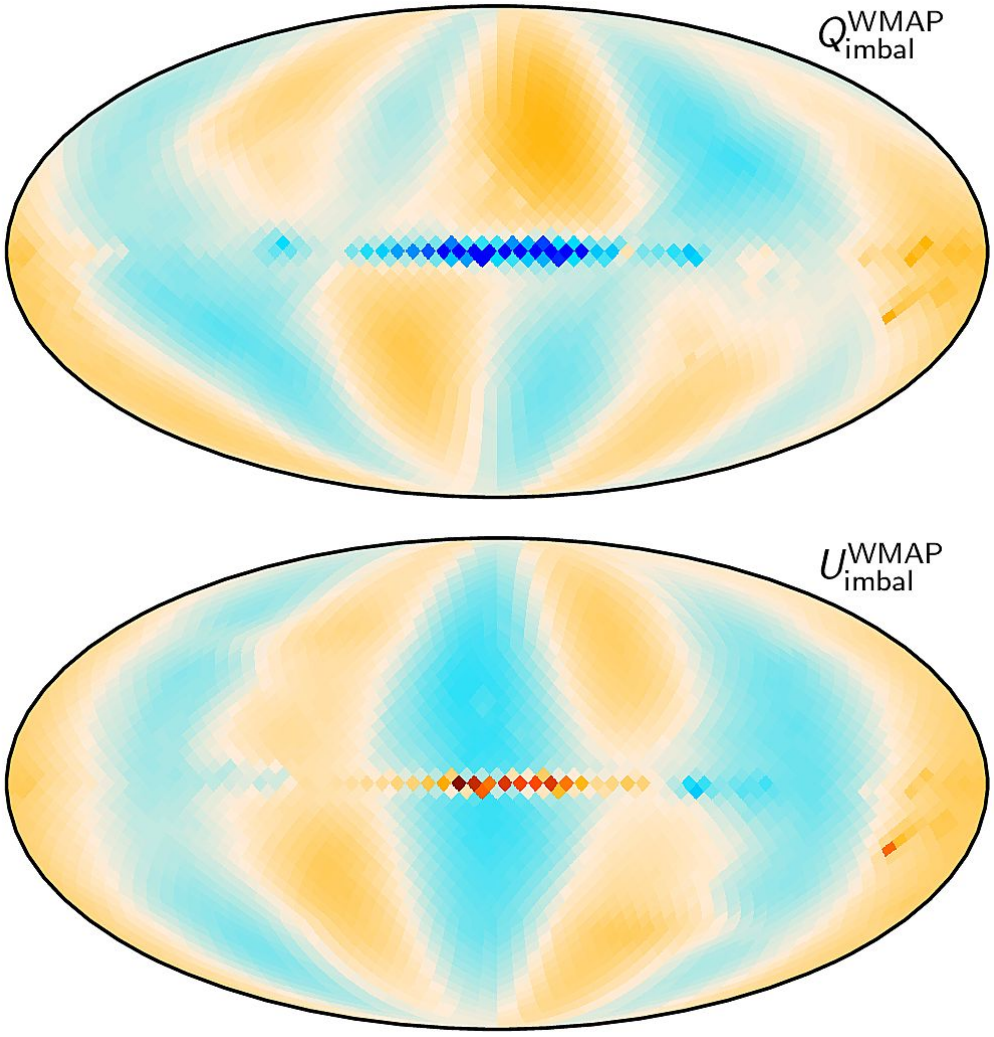


Cost per Gibbs sample

Data volume	81 GB on disk 177 GB of RAM
Initialization time	63 seconds of data I/O 141 seconds to read in model
Gibbs sampling cost	160 seconds per CG iteration $\mathcal{O}(5)$ iterations to converge
Total cost per sample	800 seconds using 64 2 GHz AMD cores

Future Work

- Instrument parameters are taken as fixed from *WMAP* nine year analysis; when combined with *Planck* data, we will be able to sample these parameters directly in the Gibbs chain
- TOD-level understanding of *WMAP* data set will allow for higher-quality maps



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- "*BeyondPlanck*"
  - COMPET-4 program
  - PI: Hans Kristian Eriksen
  - Grant no.: 776282
  - Period: Mar 2018 to Nov 2020

Collaborating projects:

- "*bits2cosmology*"
  - ERC Consolidator Grant
  - PI: Hans Kristian Eriksen
  - Grant no: 772 253
  - Period: April 2018 to March 2023
- "*Cosmoglobe*"
  - ERC Consolidator Grant
  - PI: Ingunn Wehus
  - Grant no: 819 478
  - Period: June 2019 to May 2024

Questions?

Beyond PLANCK

Commander

Cosmoglobe