The First Polarization Maps from the 857 GHz Planck Data

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mm Universe

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Scientific context & goals

Context

- ❑ Ground calibration campaign *(C. Rosset et al., 2010)* suggested a **few percent polarization sensitivity** in Planck 545 and 857 GHz bands
- ❑ Expected polarized dust emission at 857 GHz is sufficiently strong for a measurement of degree scale polarization and larger scales
- ❑ But high level of systematics control is required
- ❑ No upcoming funded experiment to produce full sky polarized sky maps at these frequencies

Our main goal:

- ❑ Extract the polarized sky at 857 GHz from Planck data
- ❑ Infer some dust properties from these maps:
  - ❑ Constrain dust polarization frequency scaling and compare with dust models
  - ❑ Measure the EE/BB spectra and constrain dust decorrelation (crucial for B-mode experiments)

Data processing formalism

We build upon the NPIPE reprocessing pipeline

Time-ordered data **Sky maps** **Templates amplitudes**

$$\mathbf{d} = \mathbf{P}\,\mathbf{m} + \mathbf{F}\,\mathbf{a} + \mathbf{n}$$

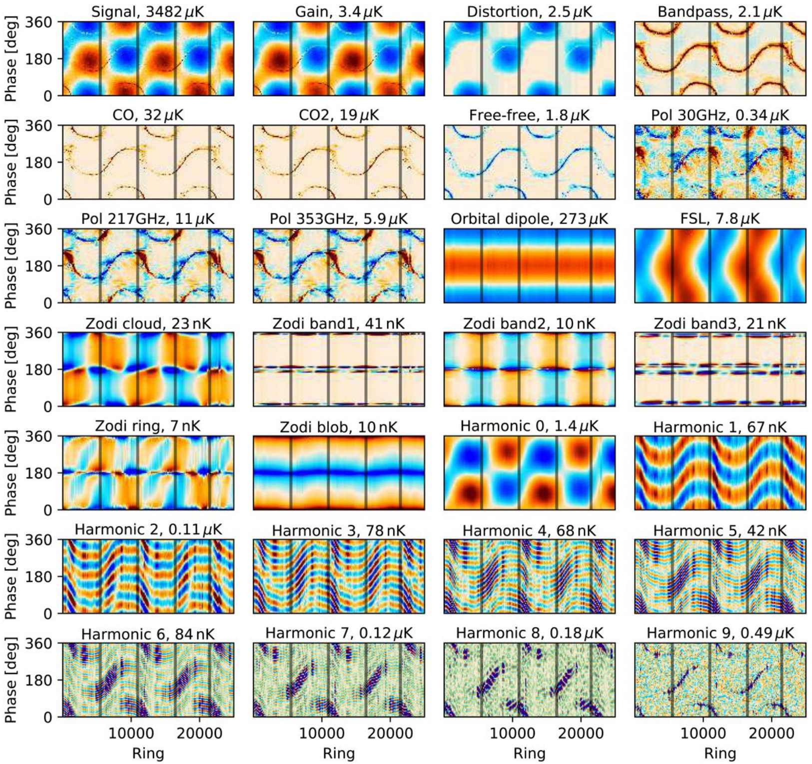
noise

Pointing matrix **Systematics templates**

Templates included:

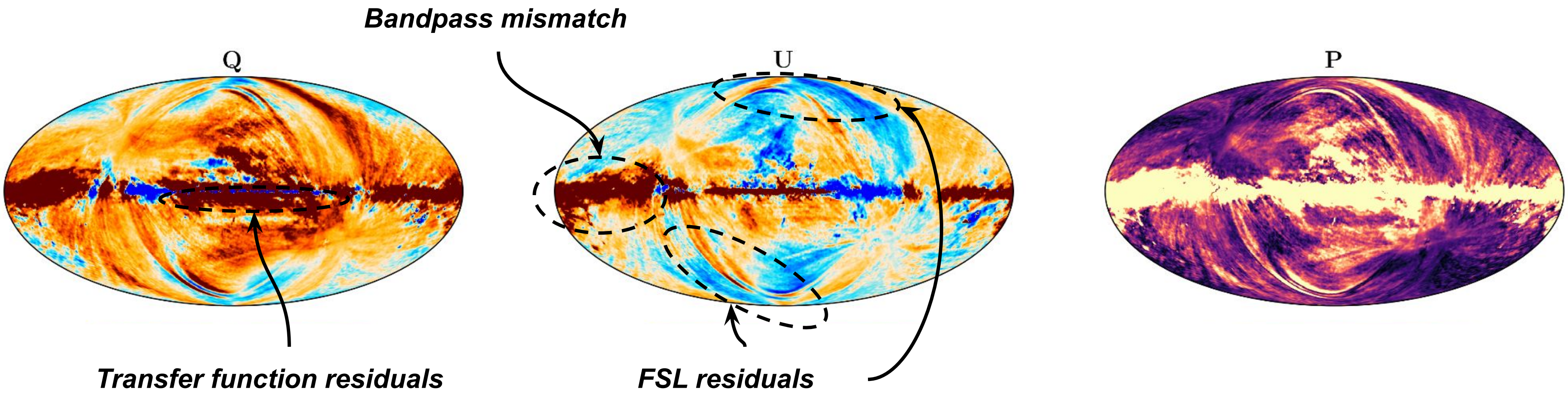
- Gain fluctuations
- Noise offsets
- HFI ADC non linearity
- Orbital dipole
- Zodiacal emission
- HFI transfer function residuals
- Bandpass mismatch
- Polarization templates
- Far sidelobes

Signal and systematic templates for 100-1a



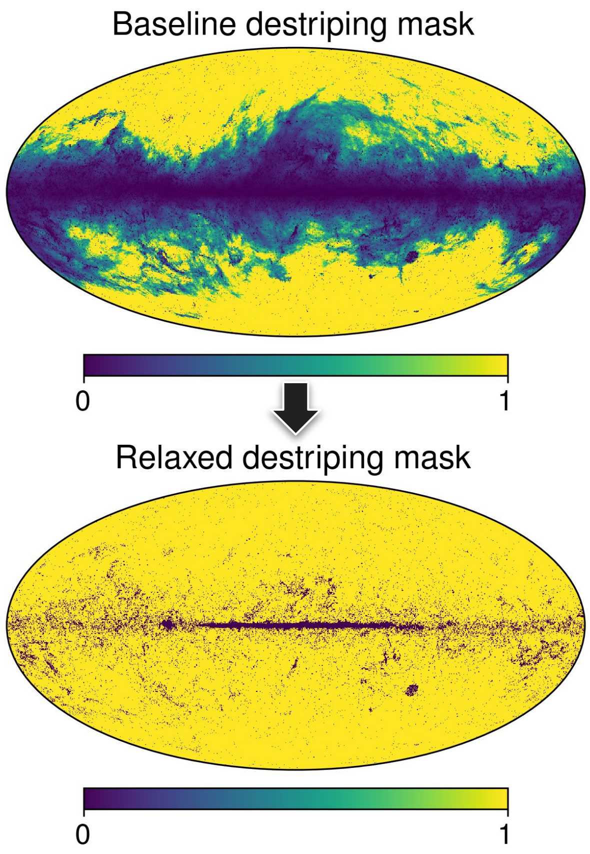
Credit: Planck Collaboration, 2020

857 GHz polarization maps from the baseline NPIPE pipeline are heavily contaminated with systematics

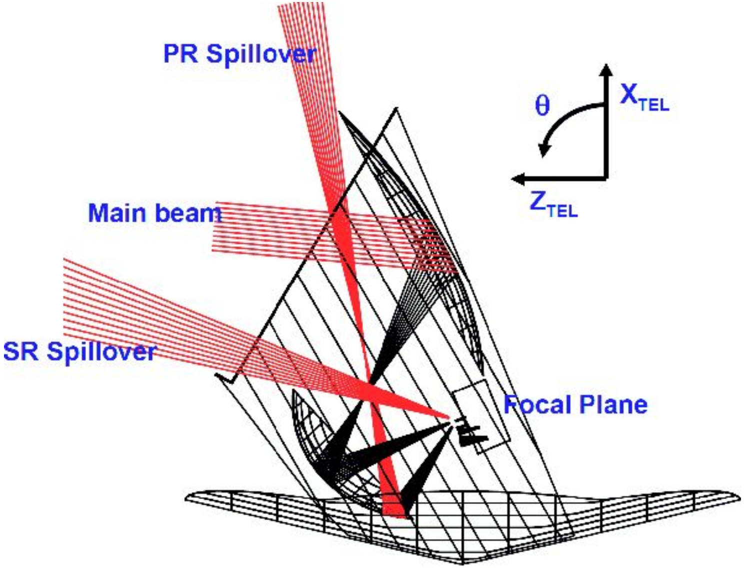


We include multiple changes in our pipeline

- ❑ Significantly **relaxed processing mask** to break template degeneracies
- ❑ Blind approach for **far sidelobe treatment**
- ❑ New **bandpass mismatch correction** template
- ❑ New relative **polarization calibration** regressed from time-domain data
- ❑ **Frequency average calibration** inferred from BLASTPol data

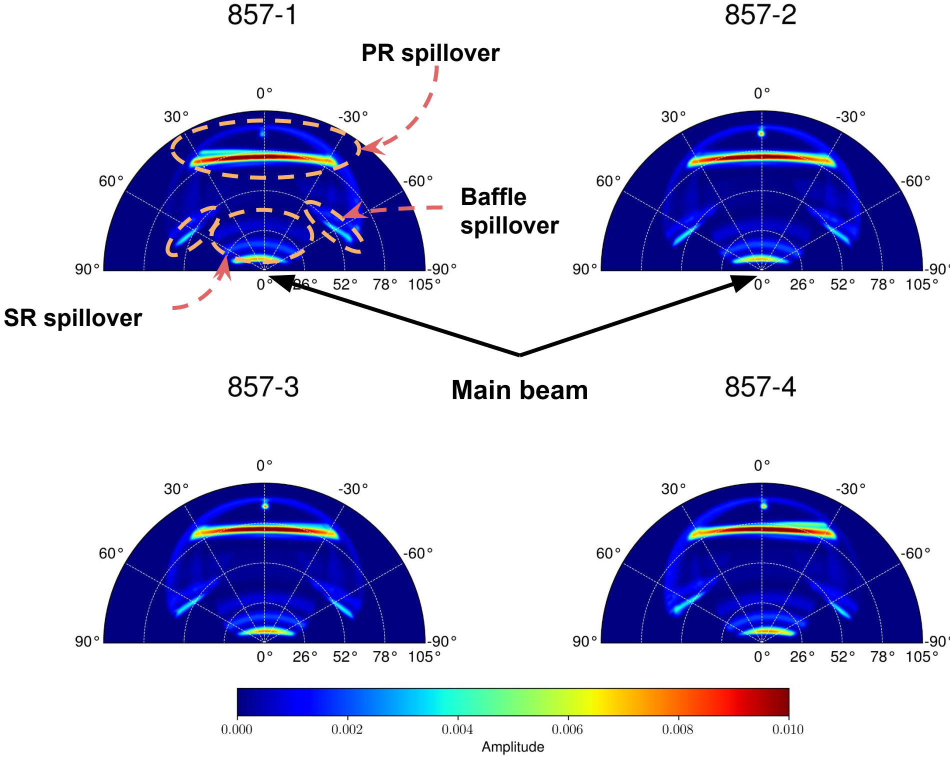


3 main far sidelobes components



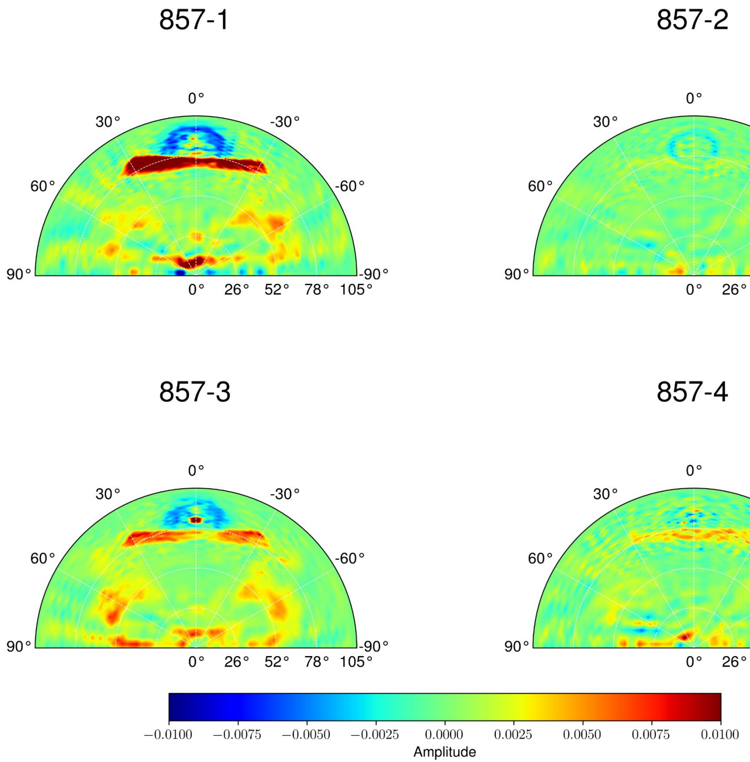
Credit: *(Tauber et al,, 2010)*

FSL beams adopted in the baseline NPIPE pipeline (from GRASP simulations of 353 GHz detectors)

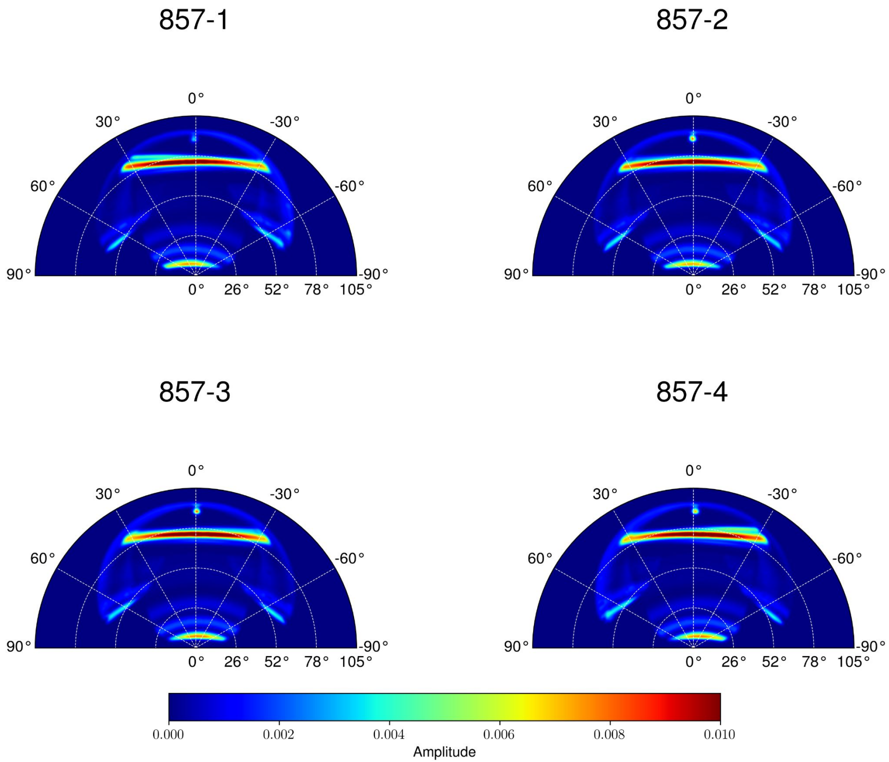


We can robustly fit the three far sidelobes components

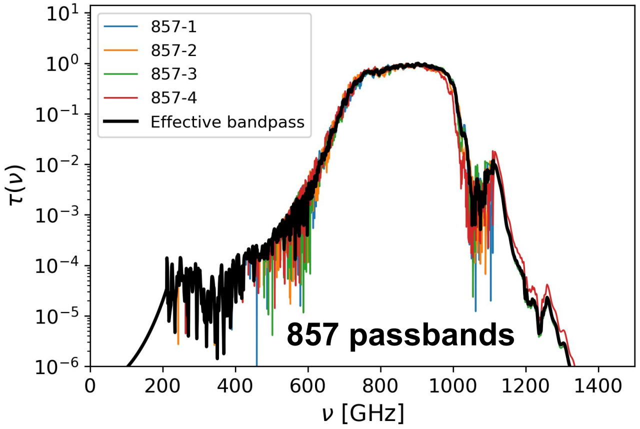
FSL time-domain best-fit



FSL beam model in baseline NPIPE

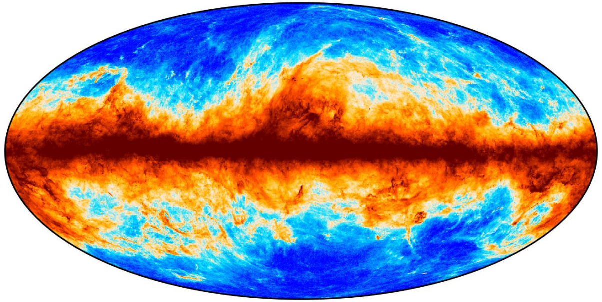


Bandpass mismatch modeling

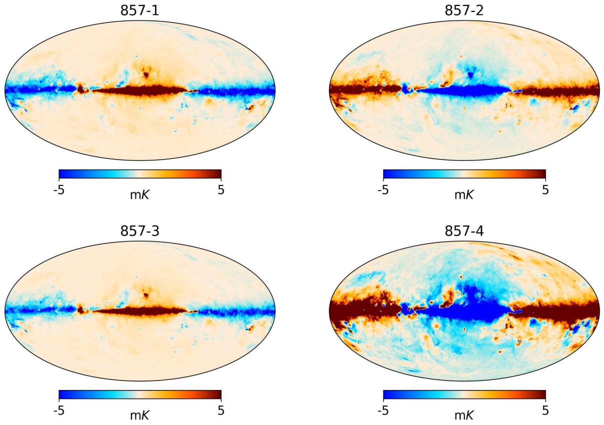


*

PR4 commander dust sky model

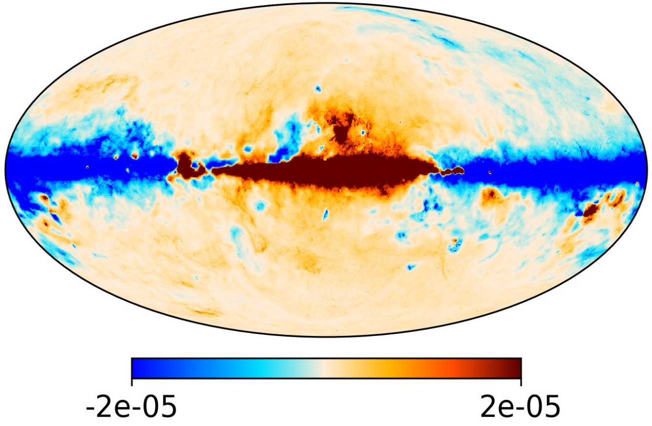


Single detector bandpass mismatch residuals



Leading PCA mode from single detector bandpass mismatch residuals

(~500 times stronger than the second mode)



Calibration

Polarization template

Polarization template derivative

Polarized sky signal

$$\mathbf{s}_d = a_d\,\tilde{\eta}_d\,\tilde{\mathbf{P}}_d + b_d\,\tilde{\eta}_d\,\frac{\partial \tilde{\mathbf{P}}_\mathbf{d}}{\partial \psi}$$

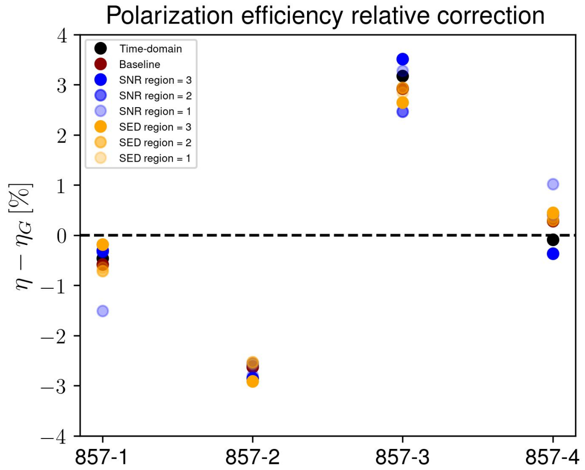
Relative corrections:

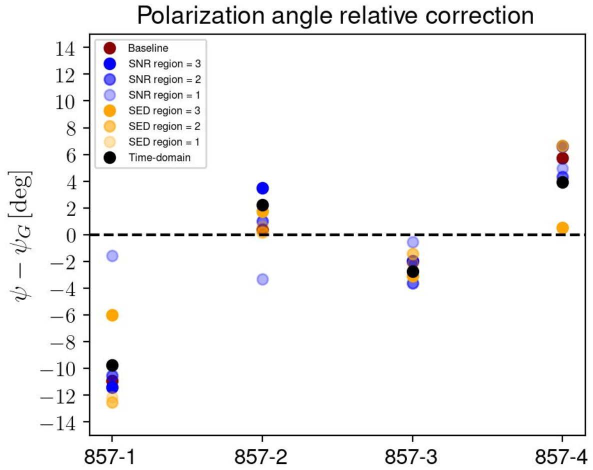
$$1 + \frac{\Delta\eta_d}{\tilde{\eta}_d} = a_d\,\frac{\bar{\tilde{\eta}}}{a\,\tilde{\eta}}, \qquad \Delta\psi_d = b_d/a_d$$

Frequency average polarization efficiency:

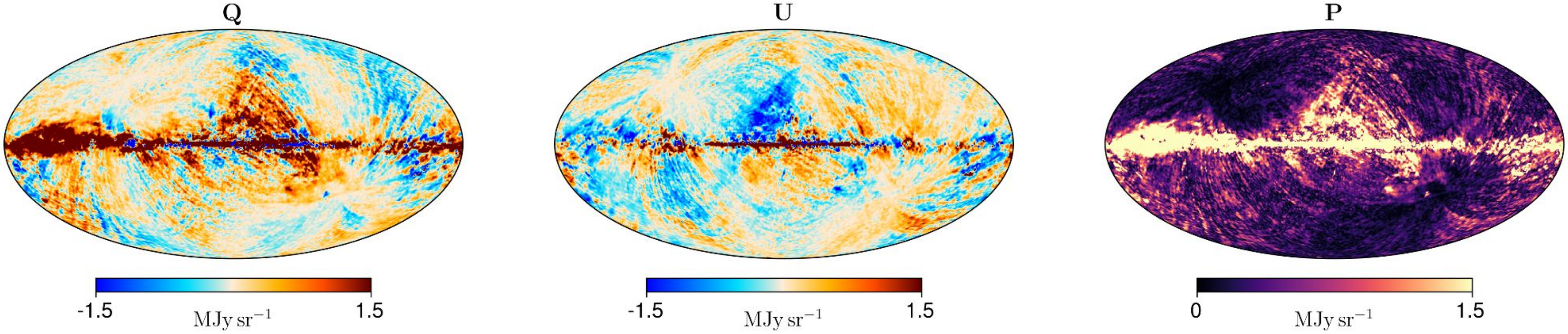
$$\bar{\eta} = \mathbf{1.9}\%$$

Calibrated against BLASTPol
Vela C polarization maps at 350 μm

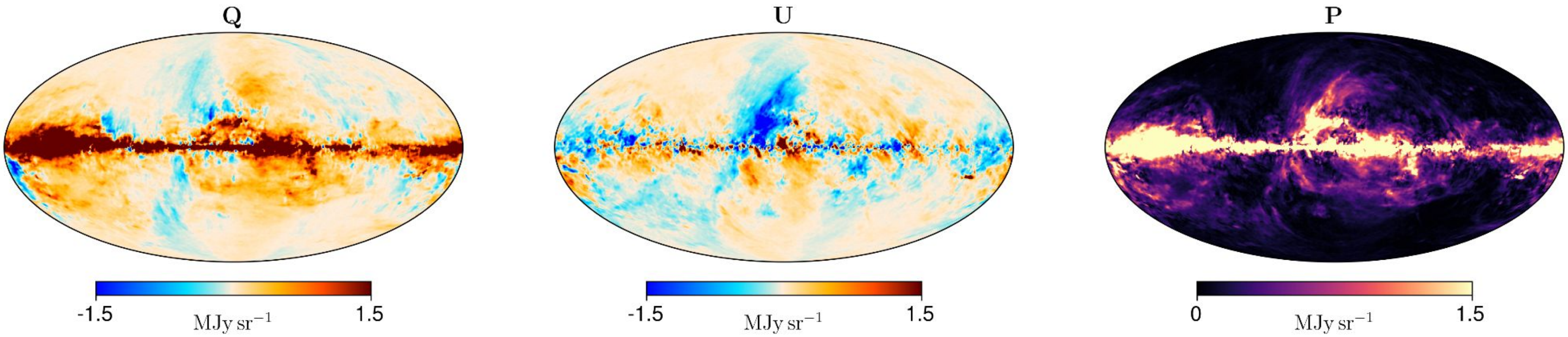




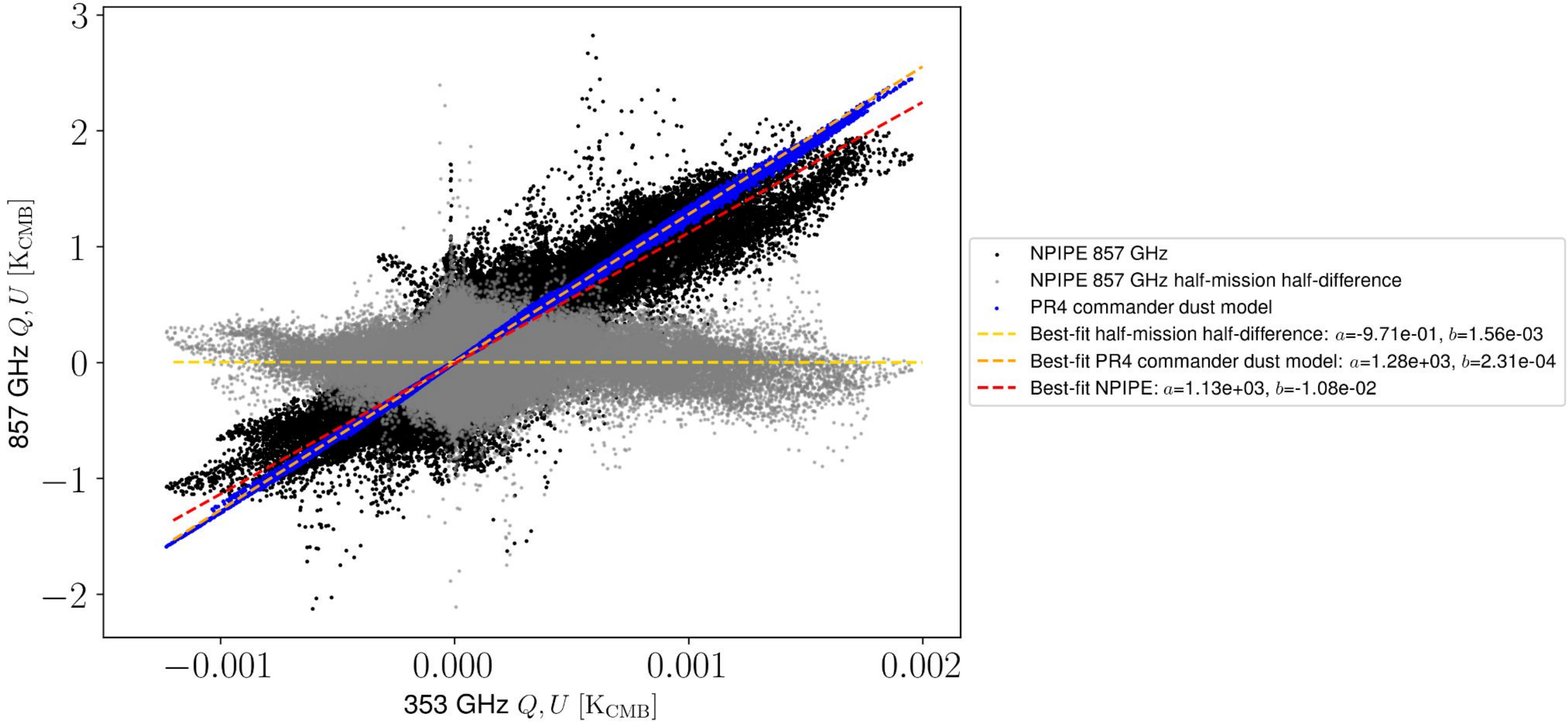
857 GHz polarization maps



PR4 Commander dust sky model evaluated at 857 GHz

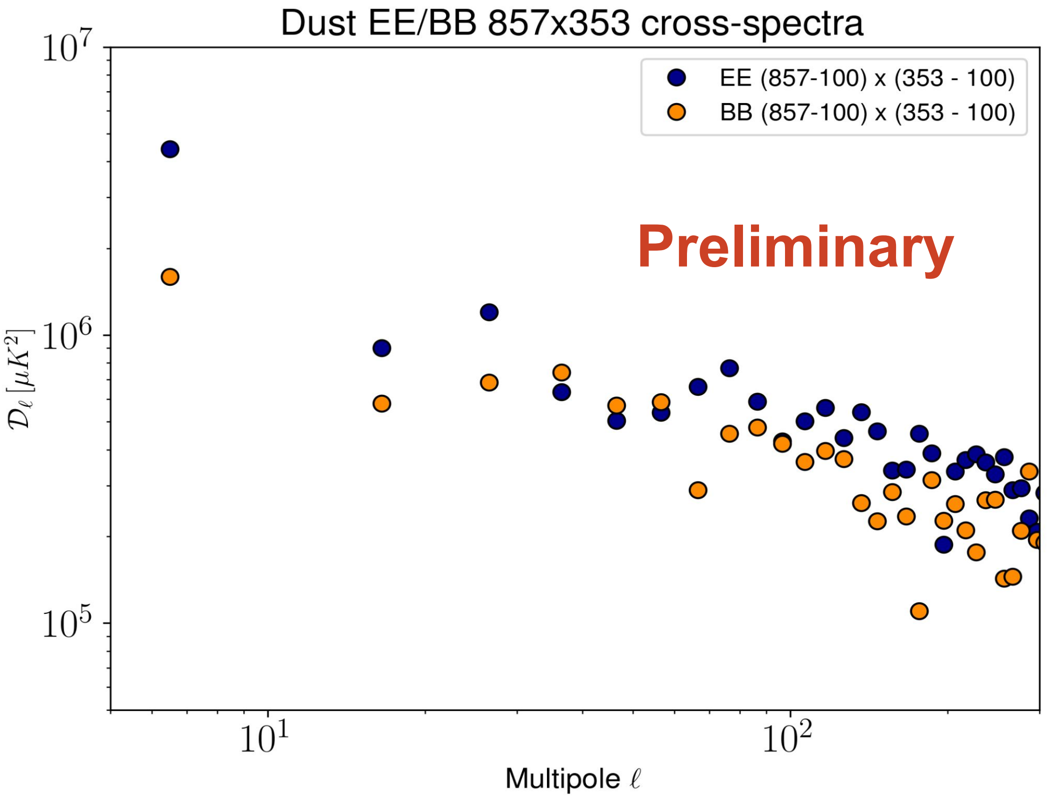


Correlation with Planck 353 GHz



Plot made by undergraduate student at PU

We detect EE/BB in cross-correlation with Planck 353 GHz



Caitlyn Flexer

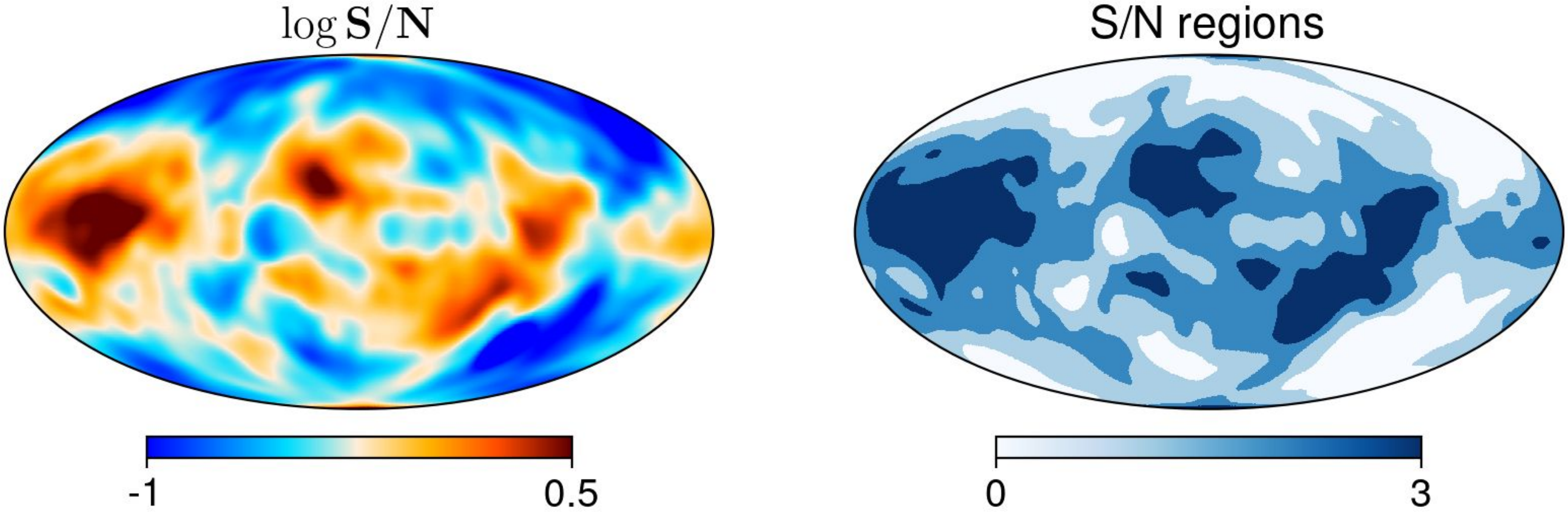
Summary

- ★ ***Upgrades to NPIPE*** *reprocessing pipeline*
- ★ *Significant* ***suppression of systematics***
- ★ *Clear* ***detection of 857 GHz polarized dust signal*** *at degree scales and above*
- ★ *We measure a band* ***average polarization efficiency of 1.9%***
- ★ *Positive correlation with Planck 353 and* ***scaling in agreement with expectation*** *from PR4 Commander dust sky model*
- ★ **Measurement of EE/BB** signal in cross-correlation with Planck 353 GHz
- ★ Monte Carlo simulations campaign ongoing to characterize noise and systematics
- ★ **Ongoing effort to constrain decorrelation**, careful assessment of bias from residual systematics is required in addition to the evaluation of statistical uncertainties

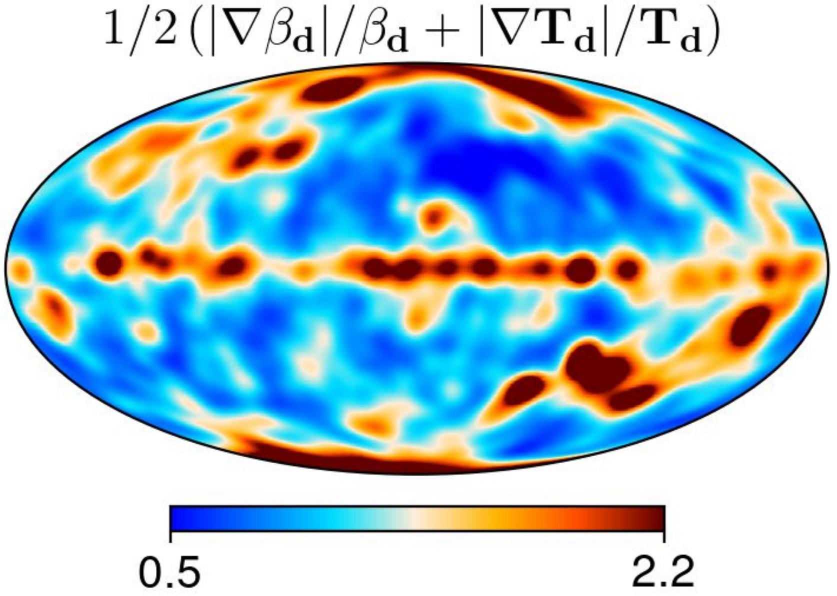
Paper(s) on the horizon, stay tuned!

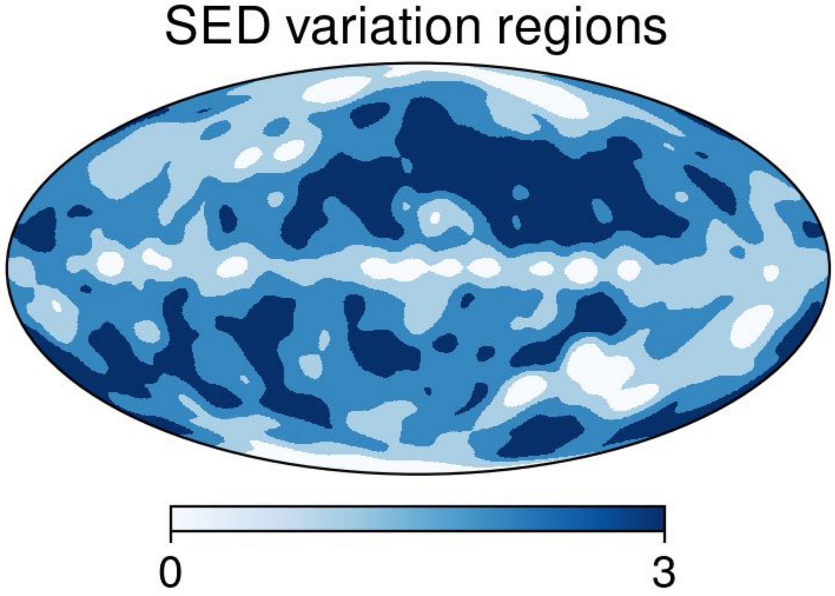
Backup slides

3 regions: S/N > 1.0 / 0.5 / 0.25 *(fsky = 0.16 / 0.33 / 0.30)*



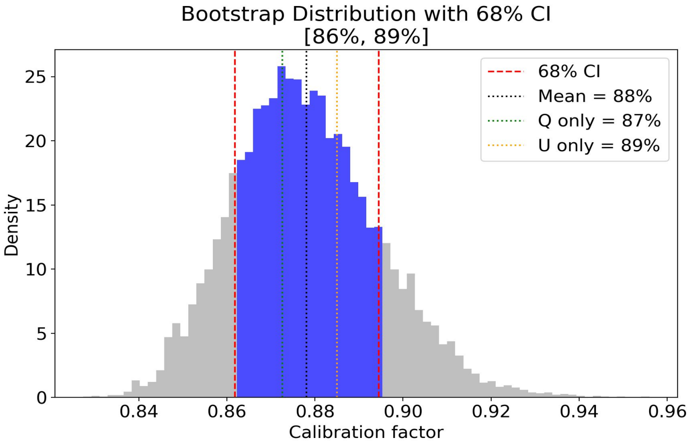
3 regions: <grad> <= 0.9 / 1.3 / 2.0 *(fsky = 0.23 / 0.41 / 0.29)*

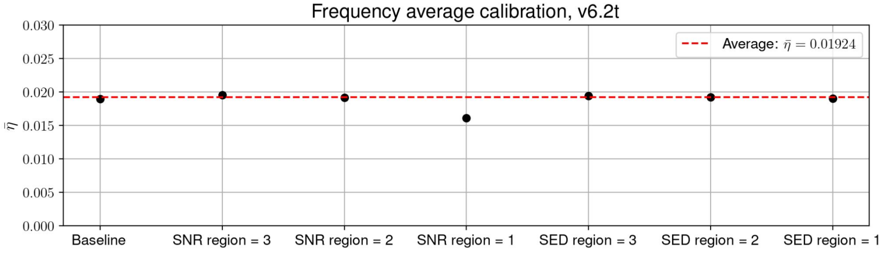




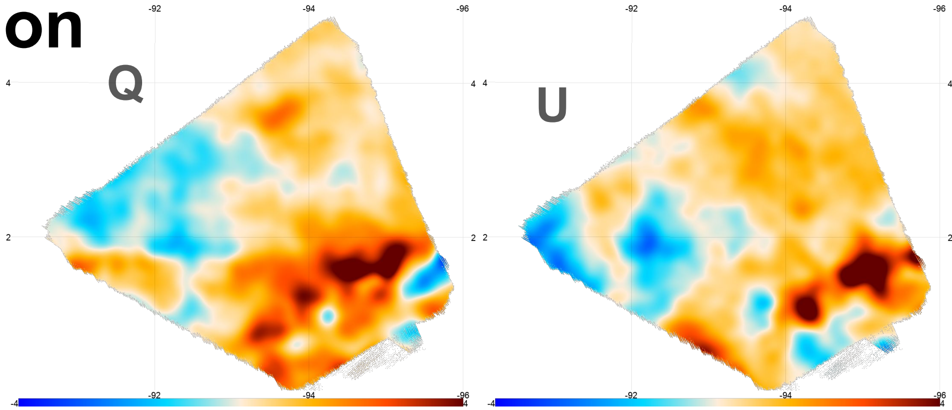
Frequency average calibration

Cal. factor = 87.8% +/- 1.6%

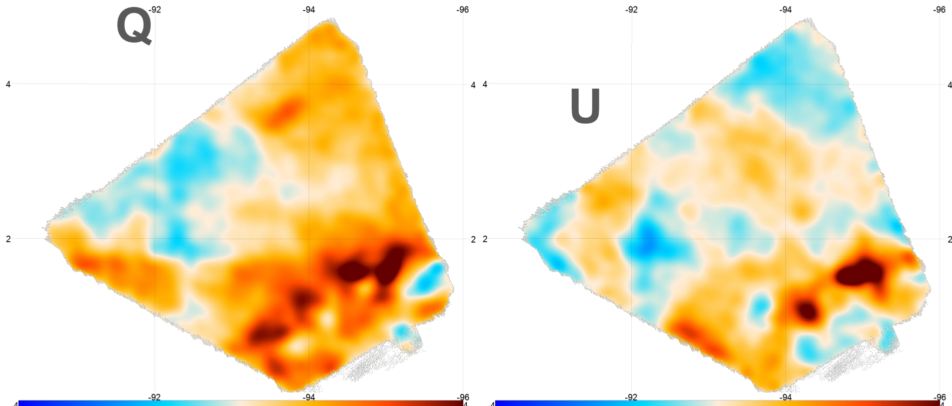




PR4 Commander dust maps smoothed to 10 arcmin



BLASTPol maps smoothed to 10 arcmin



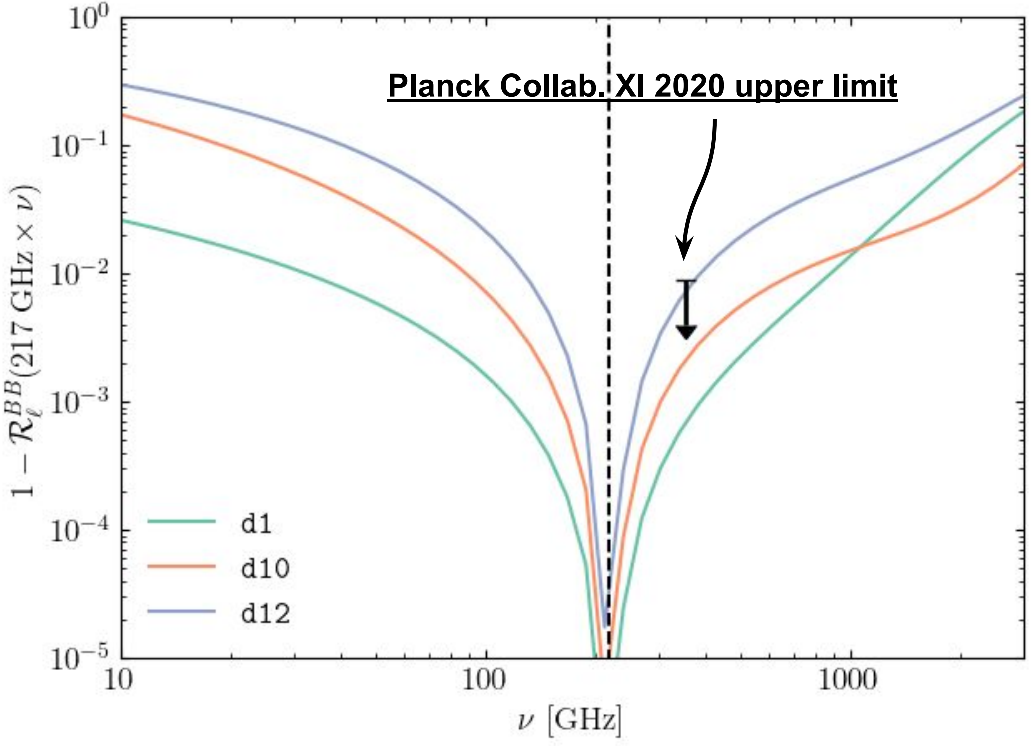
Calibration results:

Polarization efficiency		Polarization angle	
Ground:	**This work:**	**Ground:**	**This work:**
eta1 = 6.0	eta1 = 1.7	psi1 = 146.1	psi1 = 136.3
eta2 = 6.2	eta2 = 1.1	psi2 = 107.1	psi2 = 109.4
eta3 = 7.8	eta3 = 3.3	psi3 = 173.3	psi3 = 170.5
eta4 = 5.4	eta4 = 1.6	psi4 = 177.8	psi4 = 181.6
mean = 6.3	**mean = 1.9**	**mean = 151.1**	**mean = 149.5**

Average efficiency 3x lower than expected

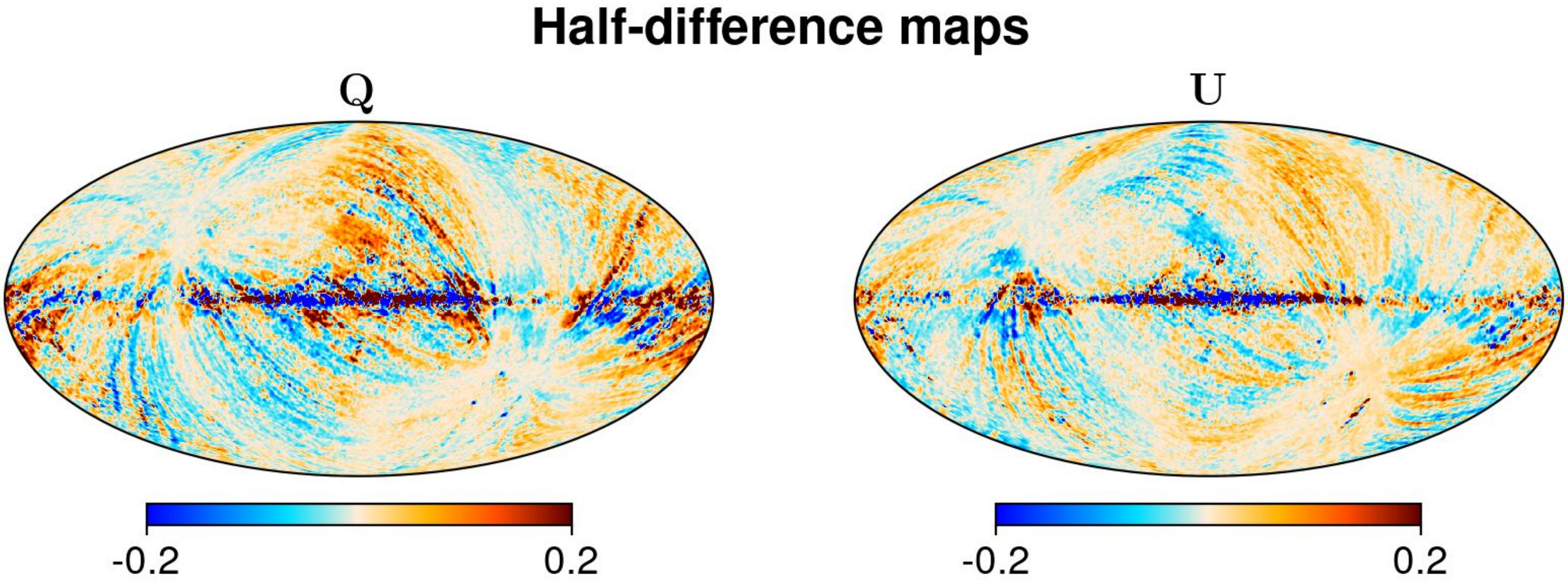
Very consistent

Decorrelation with 217 GHz for different dust models

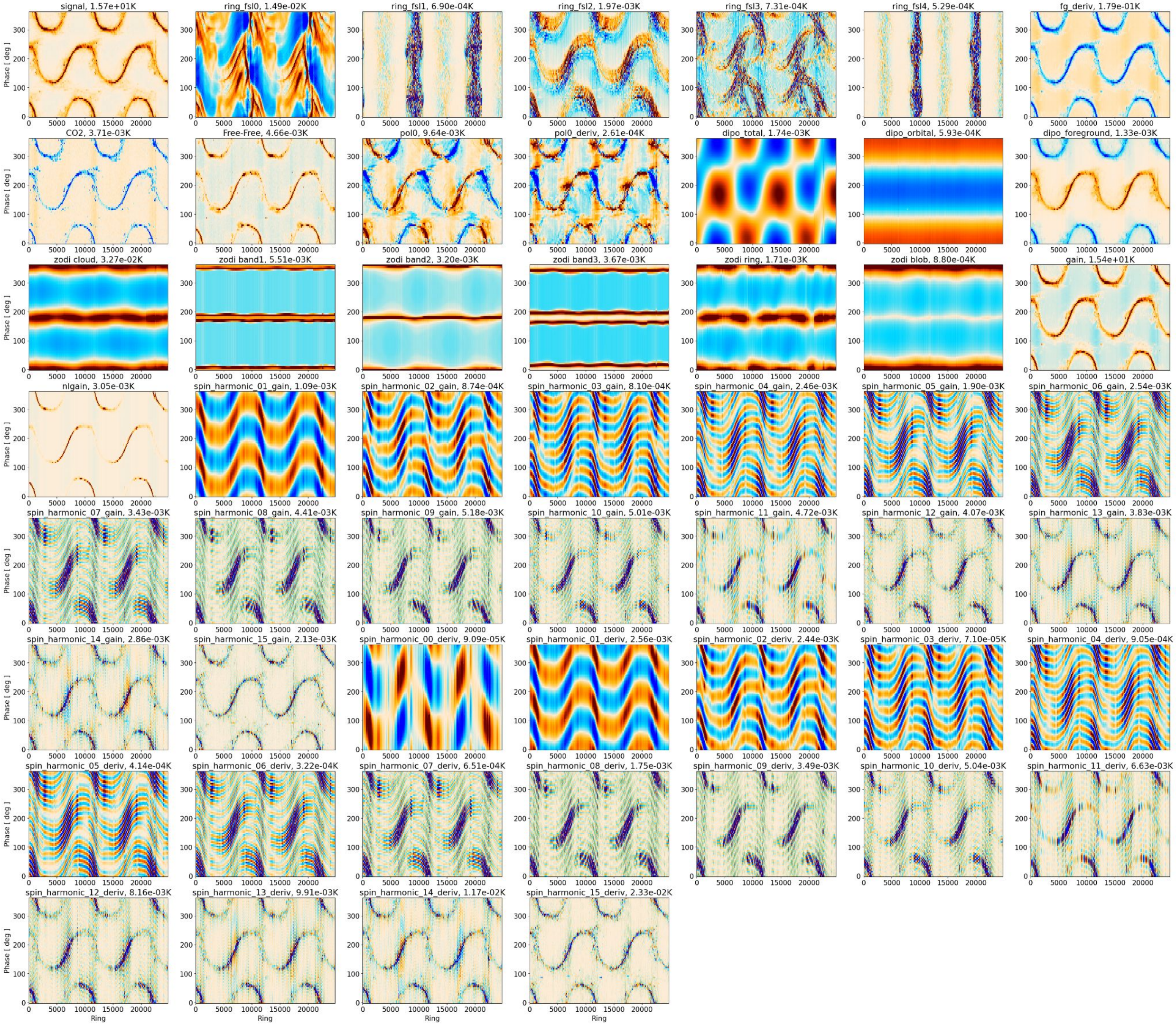


Credit: (The Pan-Experiment Galactic science group, 2025)

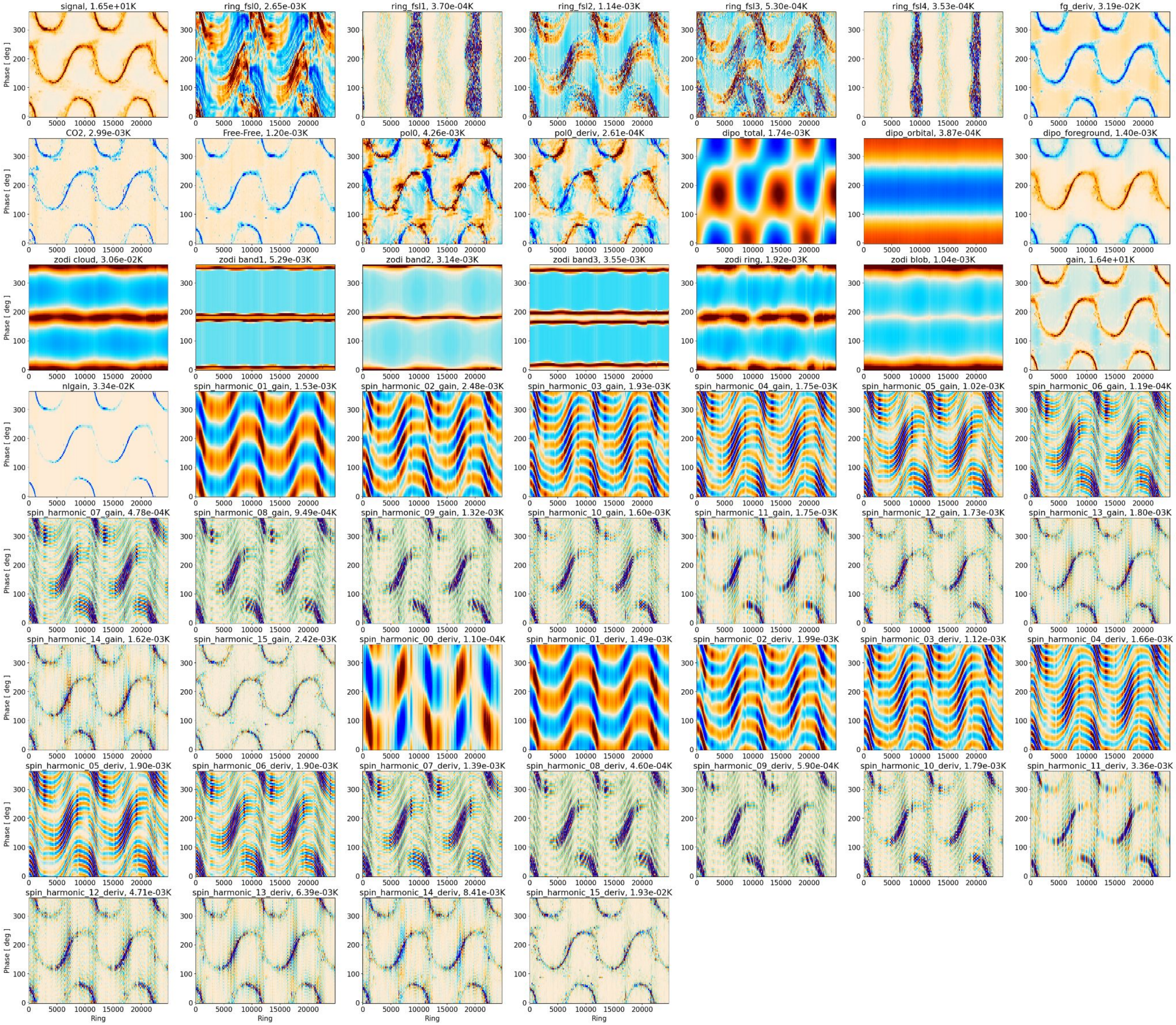
Noise estimate from half mission maps



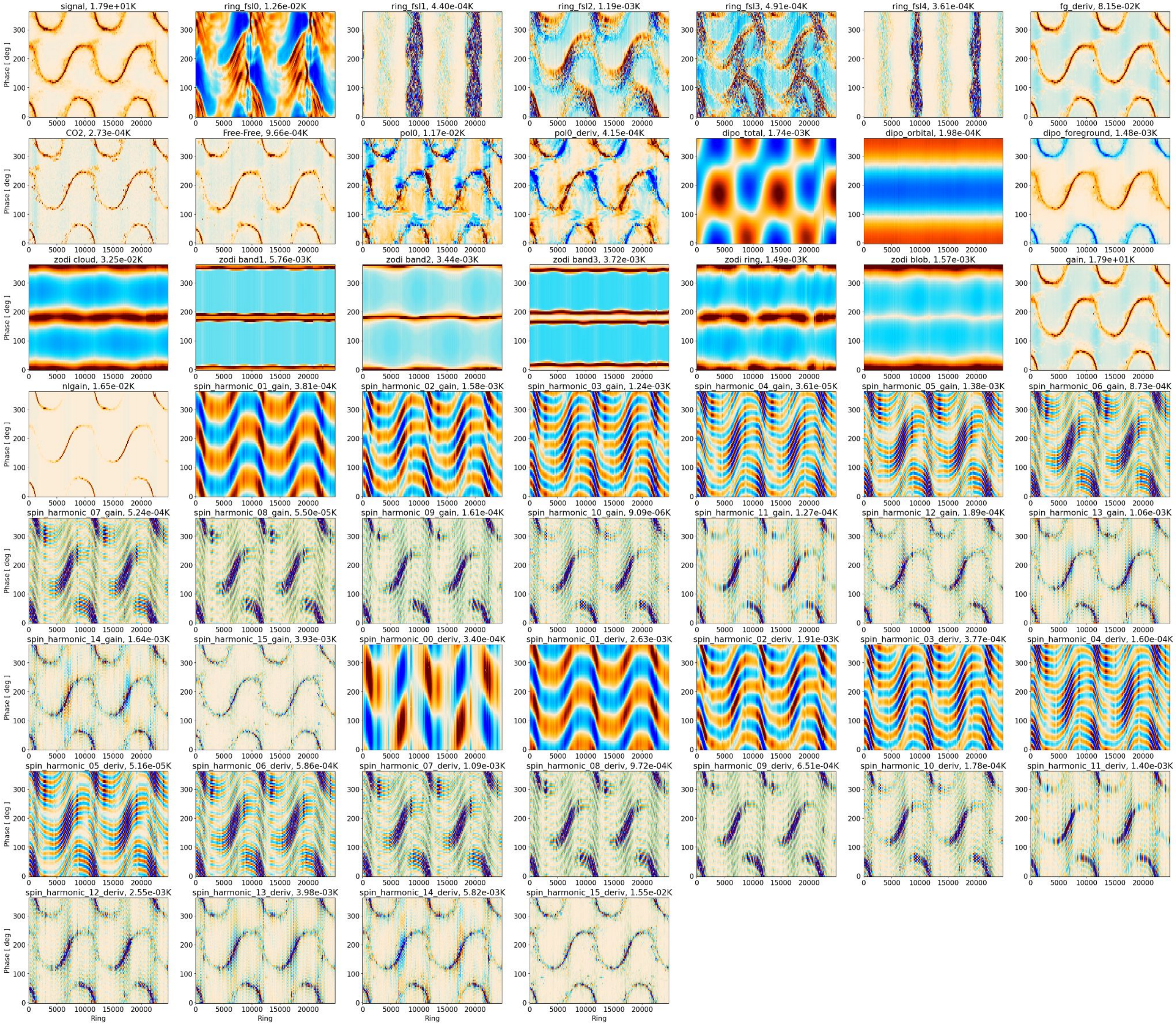
Phase-space templates for 857-1



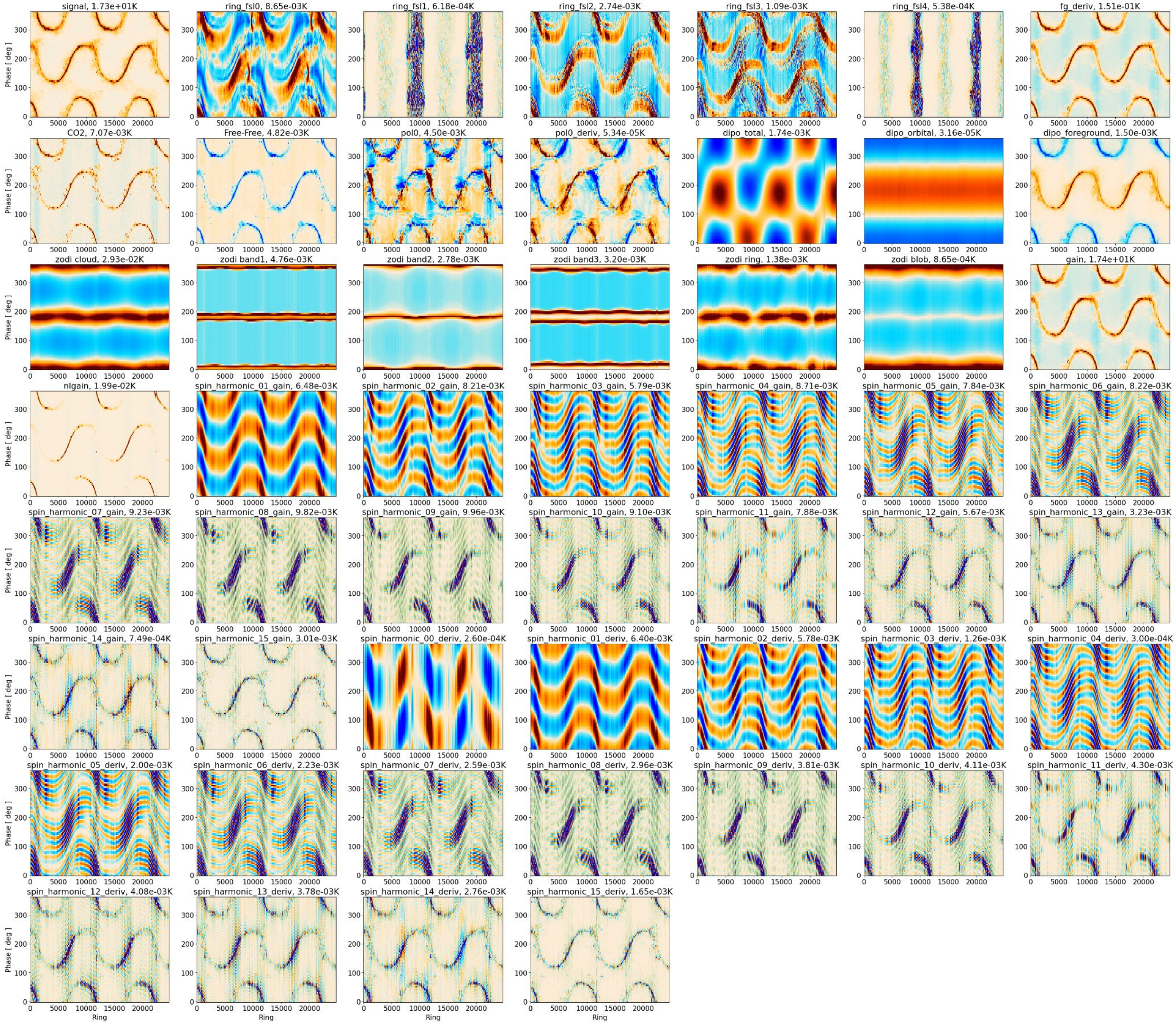
Phase-space templates for 857-2



Phase-space templates for 857-3

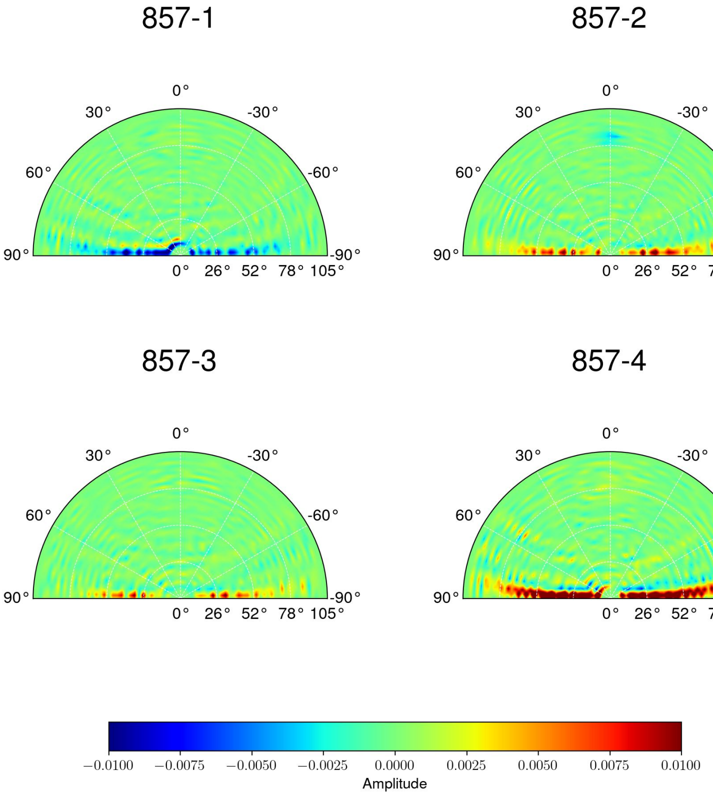


Phase-space templates for 857-4

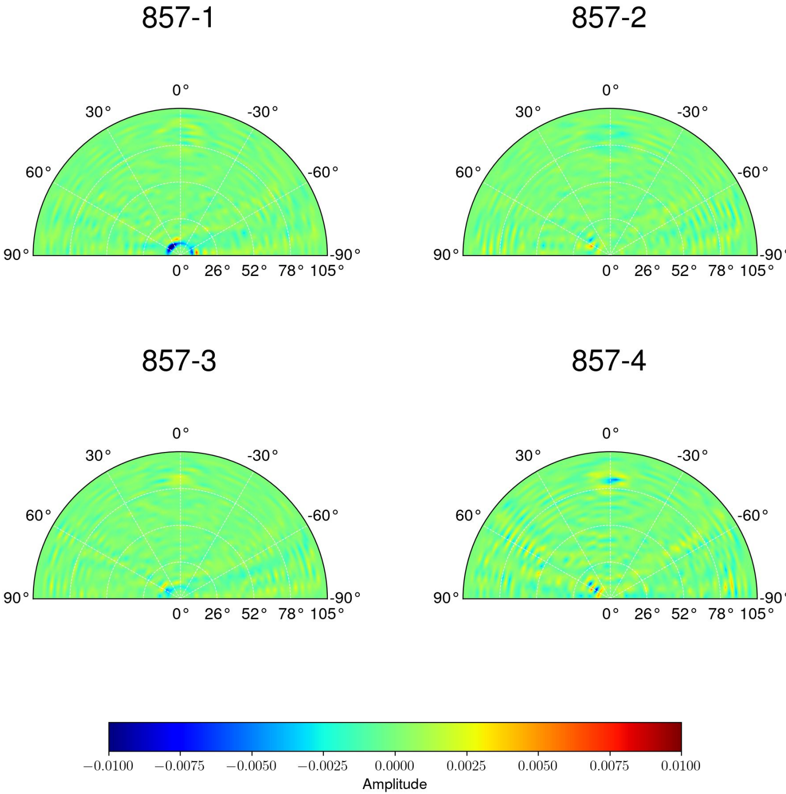


FSL secondary vs harmonic templates degeneracy

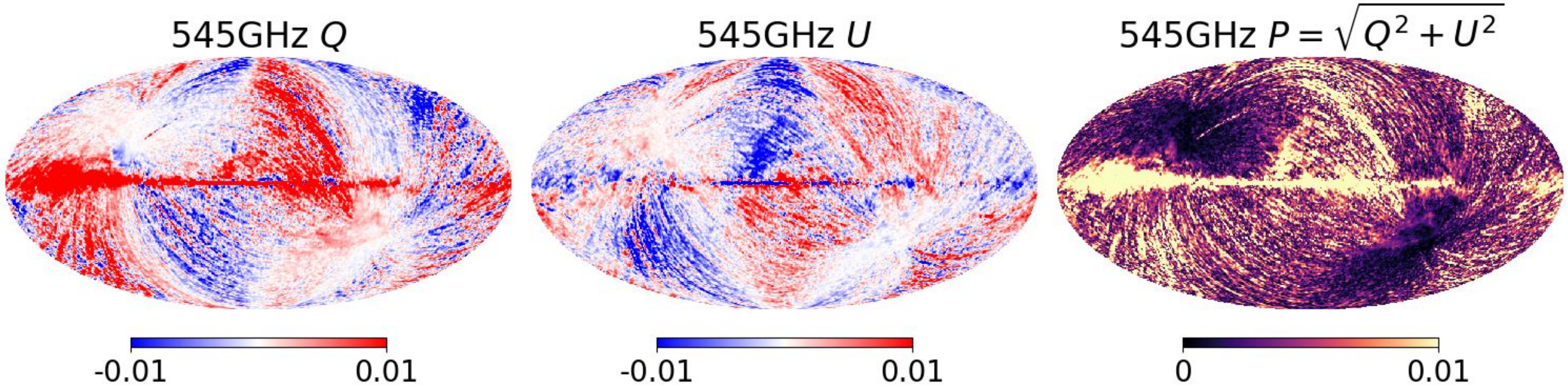
Noise sim. with harmonic templates



Noise sim. without harmonic templates



Simulation example of 545 GHz maps



Beam deconvolved 857 GHz T map: lmax=3000, mmax=8