Latest Constraints on Polarized Dust and Synchrotron from Planck and S-PASS

Cosmos Foreground Workshop - SISSA
April 19th, 2018

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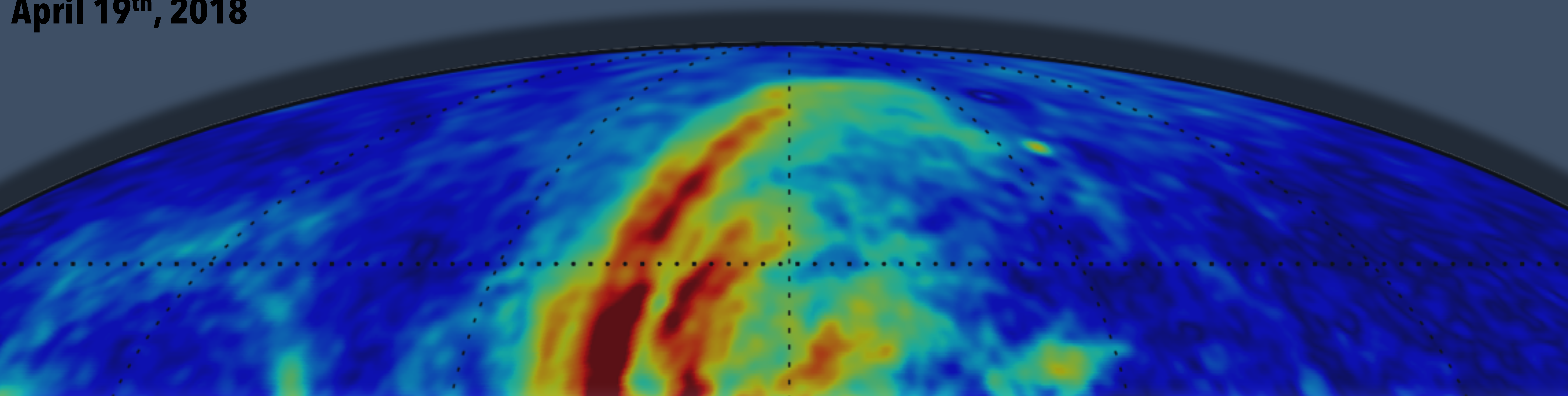
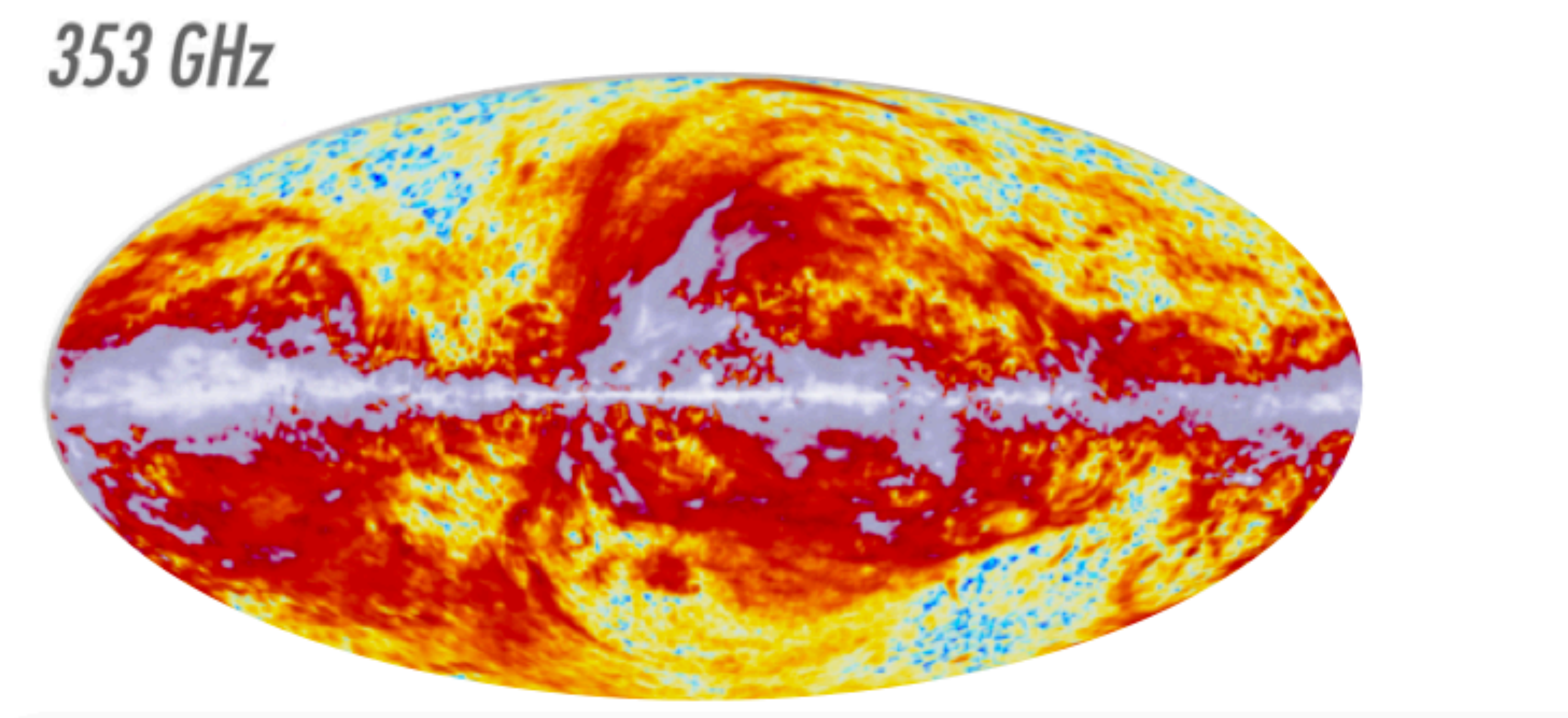
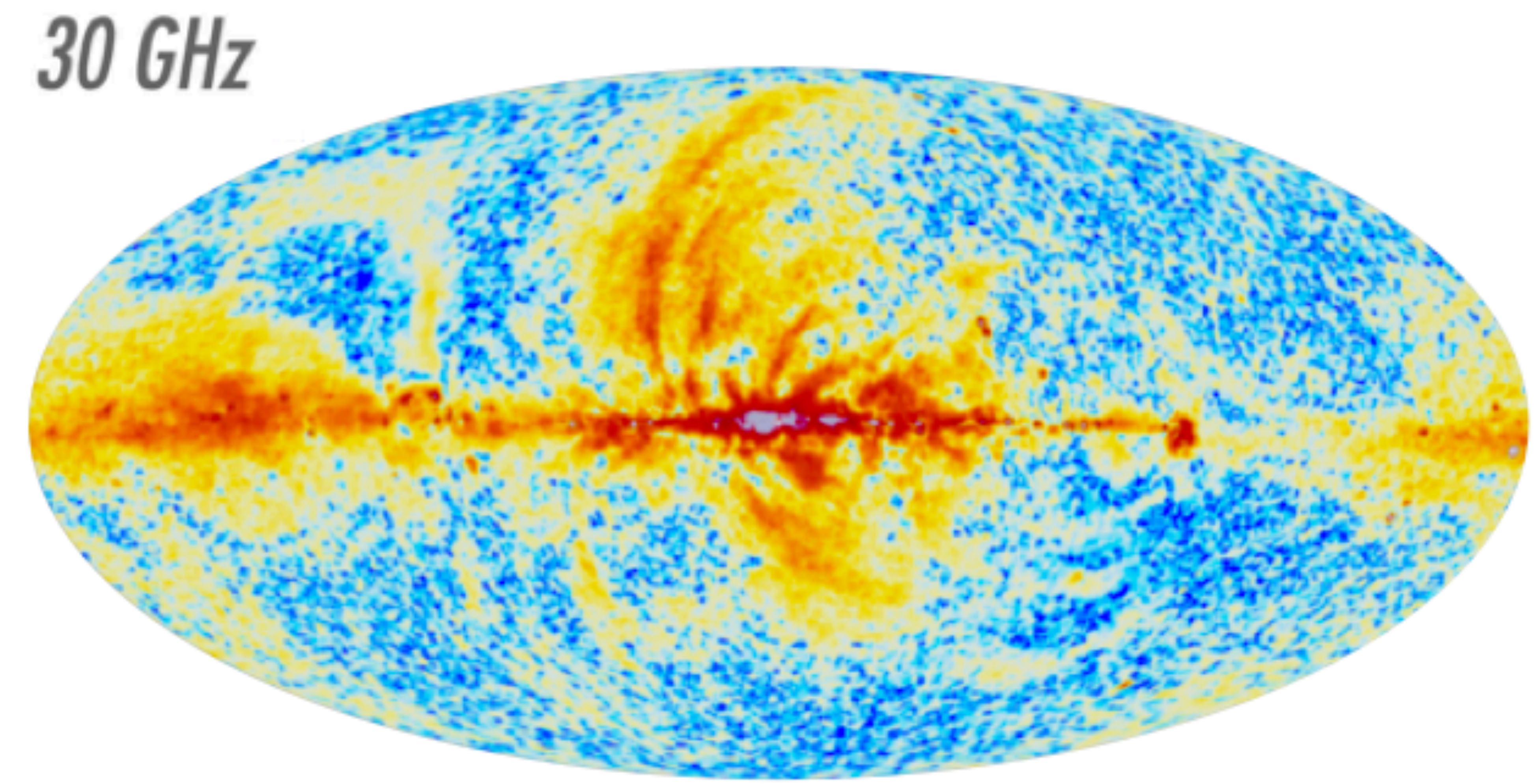






High Frequency

- **Planck 353 GHz** (Full sky)
- **Planck 217 GHz** (Full sky)

Low Frequency

- **Planck 30/44 GHz** (Full sky)
- **WMAP - K/Ka/Q 23-41 GHz** (Full sky)

- **S-PASS 2.3 GHz** (South Hemisphere)
- **C-BASS 5 GHz** (North & South Hemisphere)
- **QUIJOTE 11/13/17/19 GHz** (North Hemisphere)

Polarized

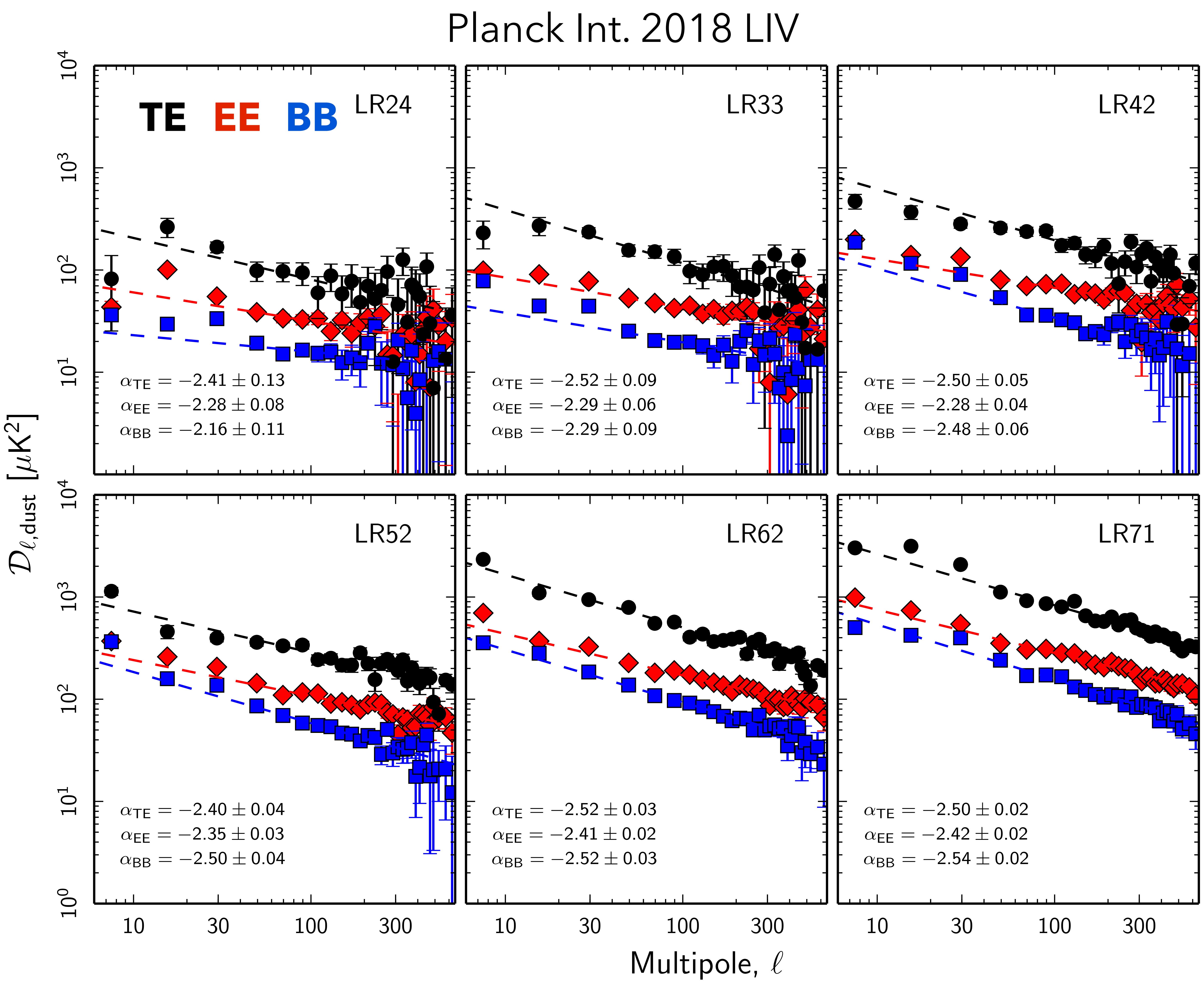
Thermal Dust

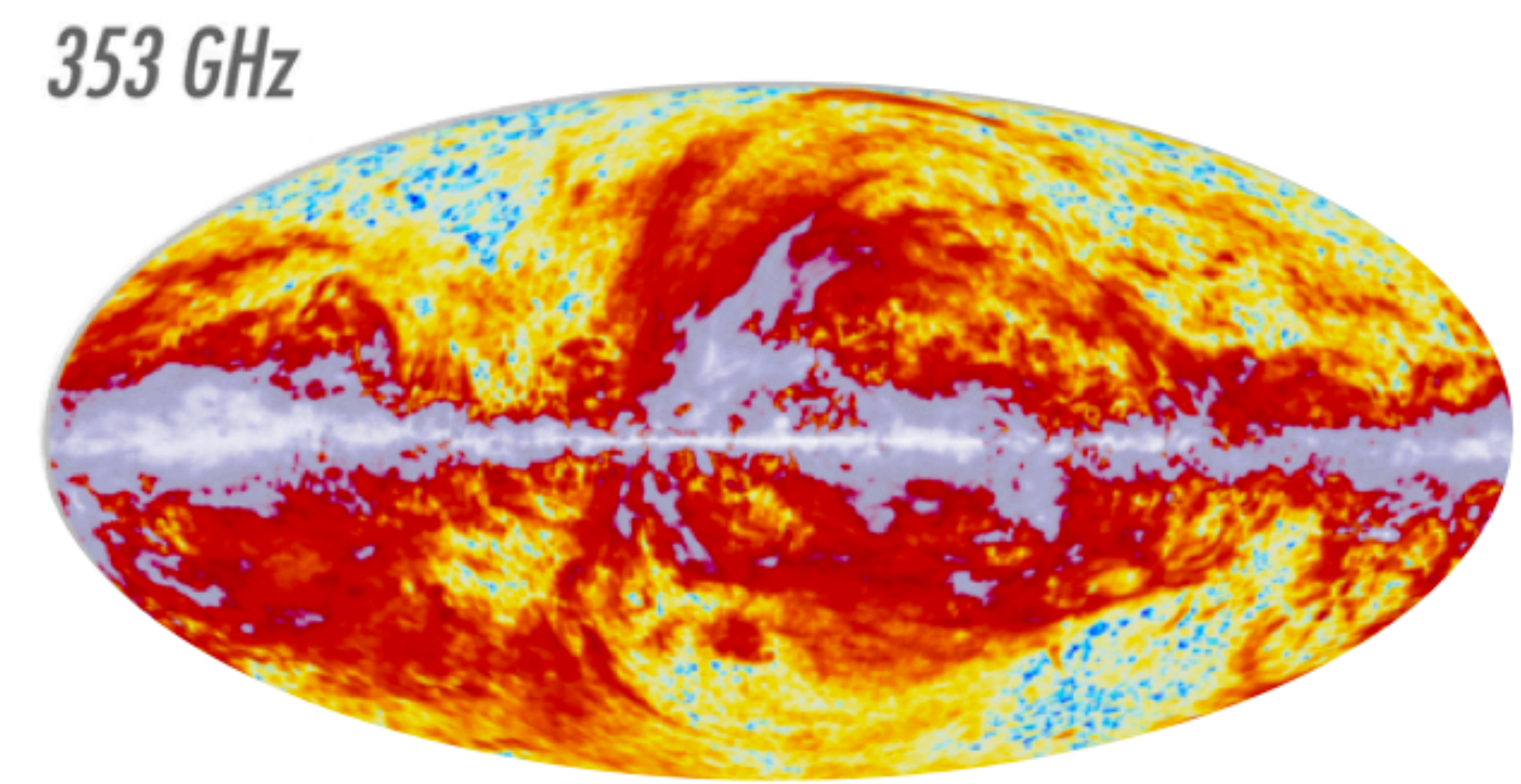
emission

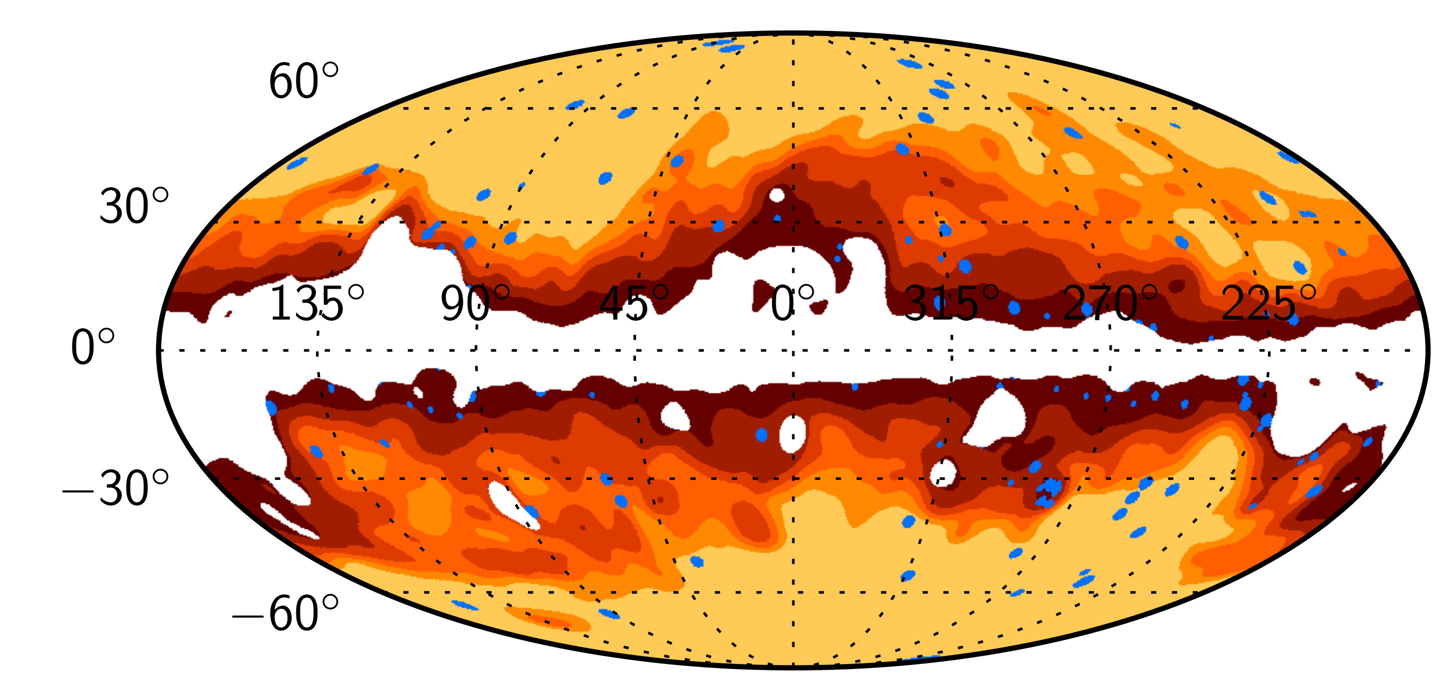
<u>**Planck Int. results LIV 2018**</u>

<u>**arXiv:1801.04945**</u>

Thermal dust: power spectra







Sky masks

Frequency scaling

Model with 5 parameters:

- **Synchrotron** — power law A_s, β_s

+

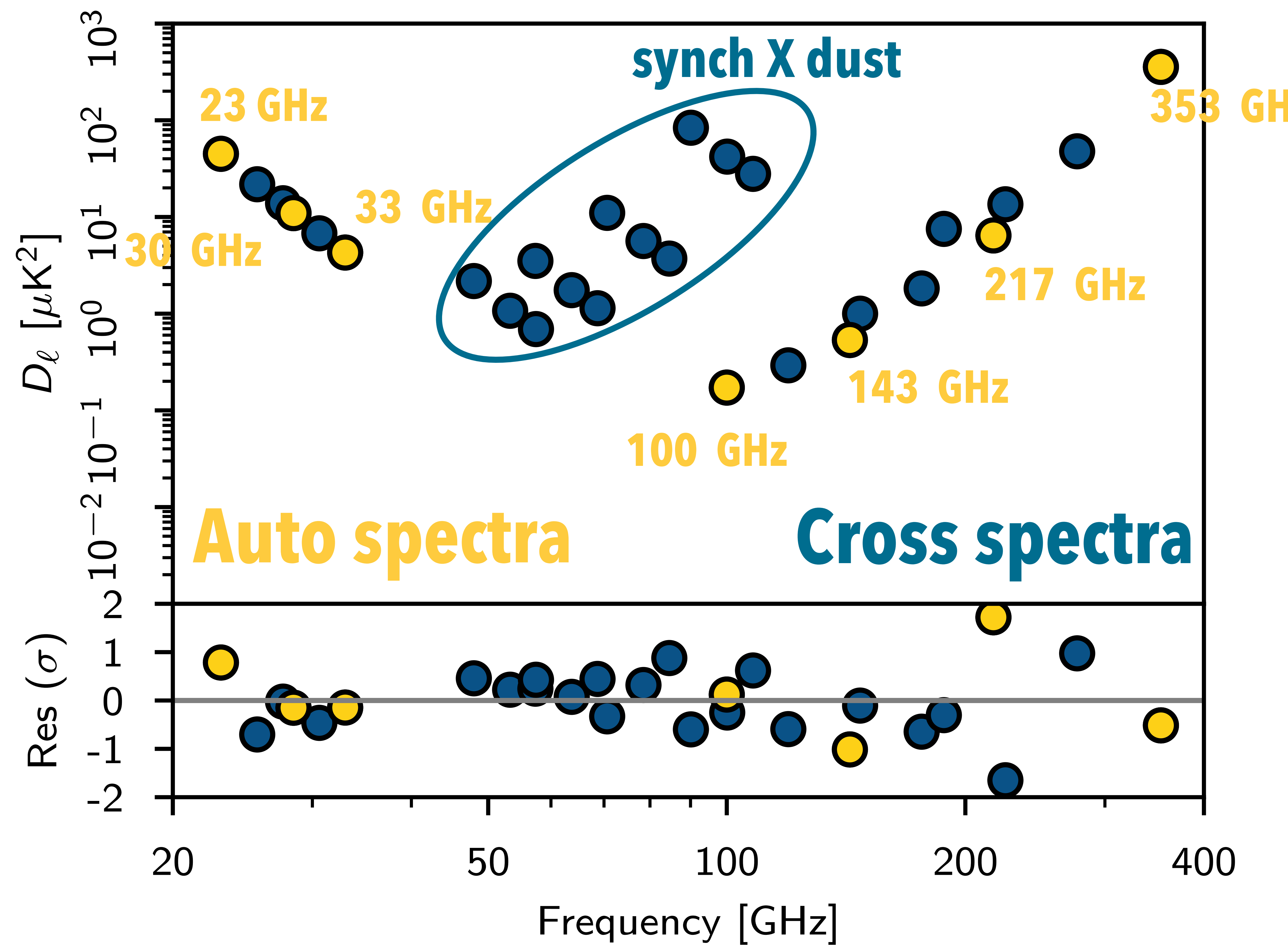
- **Thermal dust** — modified black body A_d, β_d

+

- **Correlation** — synch X dust ρ

Planck Int. 2018 LIV, Choi & Page 2016

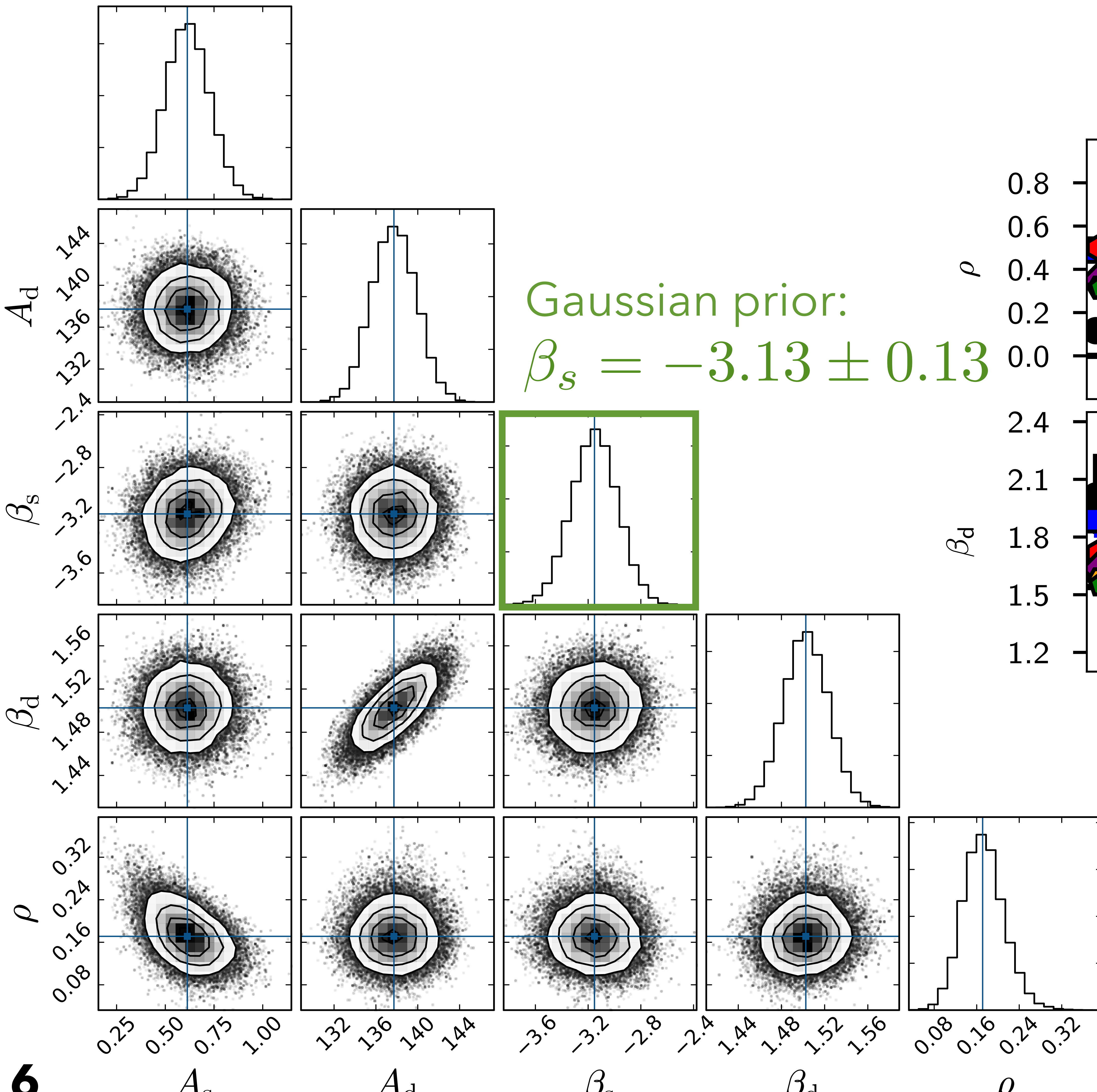
BB, f_{sky}=0.62, ell:4-11



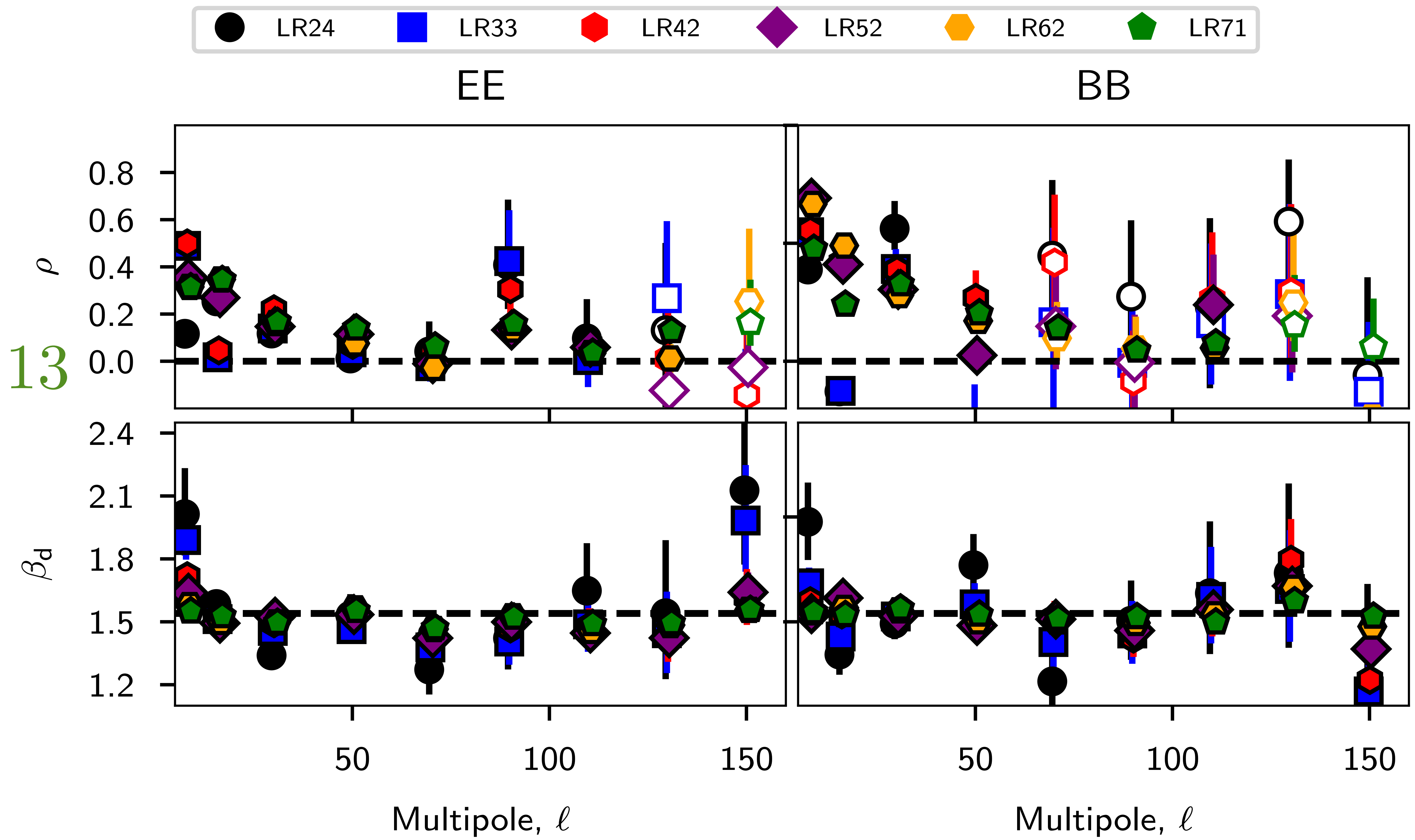
Effective frequency: $\nu_{eff} = \sqrt{\nu_1 \nu_2}$

Frequency scaling

5 parameters model fit for **E and B-modes**, **6 sky masks** and **9 multipole bins** (from ell=2 to ell=160)



Gaussian prior:
$\beta_s = -3.13 \pm 0.13$



$$\beta_d = 1.53 \pm 0.02$$

Polarized

Synchrotron

emission

[Krachmalnicoff, N. et al. 2018](https://arxiv.org/abs/1802.01145)

[arXiv:1802.01145](https://arxiv.org/abs/1802.01145)

The S–pass Survey

Carretti et al. 2013

Carretti et al. 2018 in preparation

PARKES radio telescope: 64 m

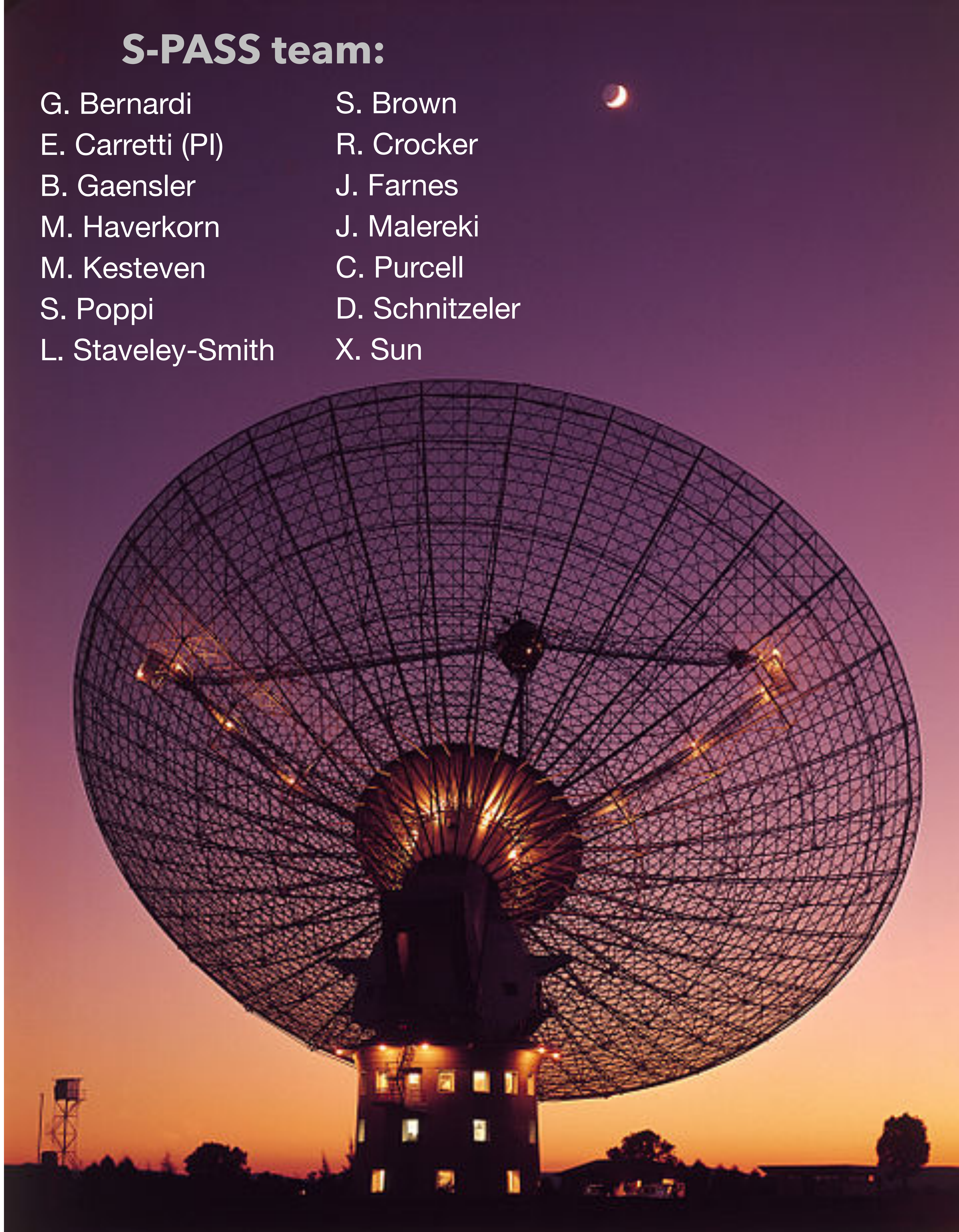
Frequency: **2.3 GHz** (224 MHz BW)

Sky coverage ~ 50% (South hemisphere)

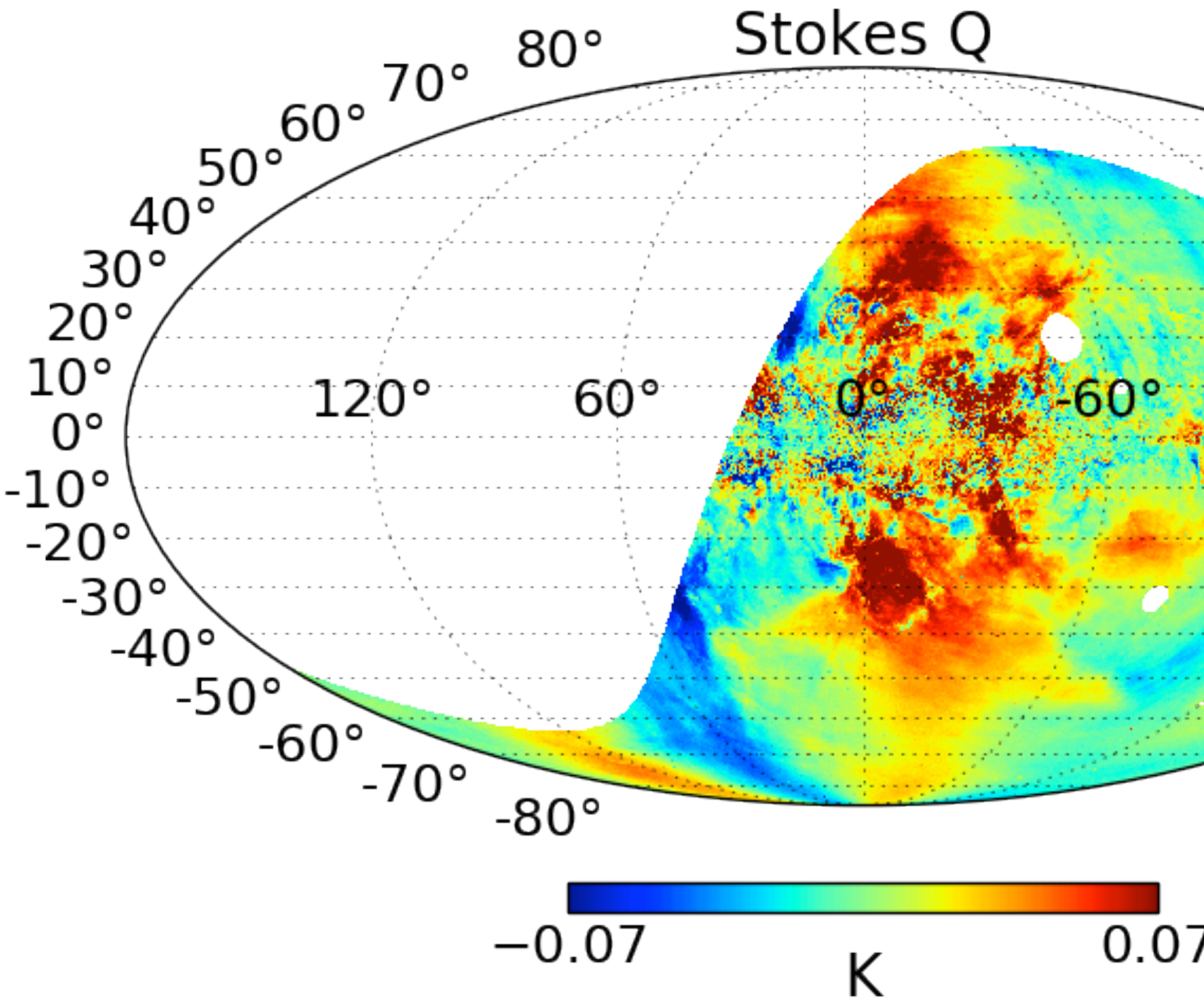
Angular resolution **~ 9 arcmin**

S-PASS science:

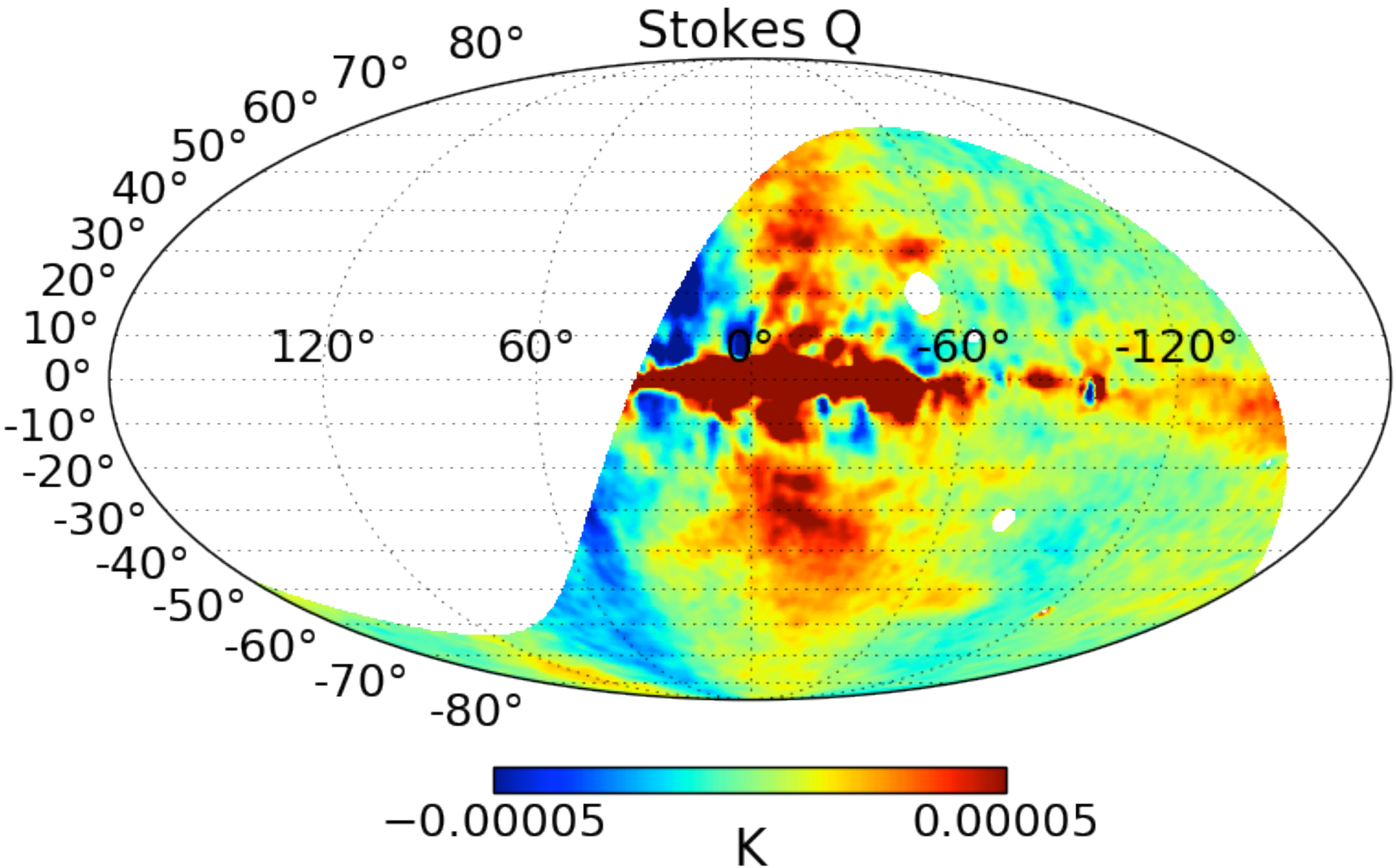
- Galactic Magnetic field
- Fermi Bubbles and Galactic structure
- ISM turbulence
- Gum Nebula
- ICM of galaxy clusters
- Extragalactic source properties
- Synchrotron Cosmic Web
- RM catalogue
- **CMB foregrounds**
- ...



S-PASS polarization maps



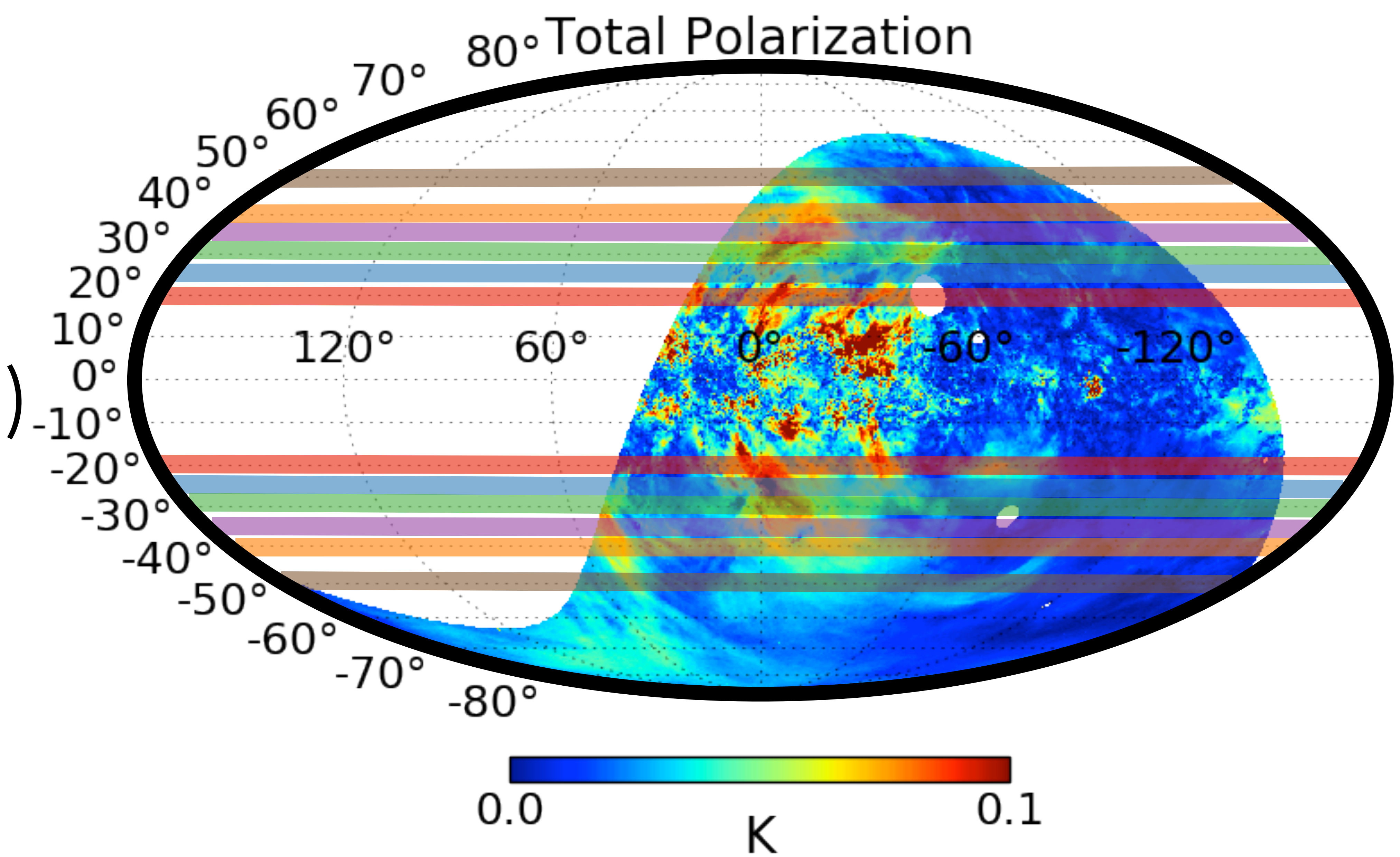
WMAP @ 23 GHz (smoothed at 2°)

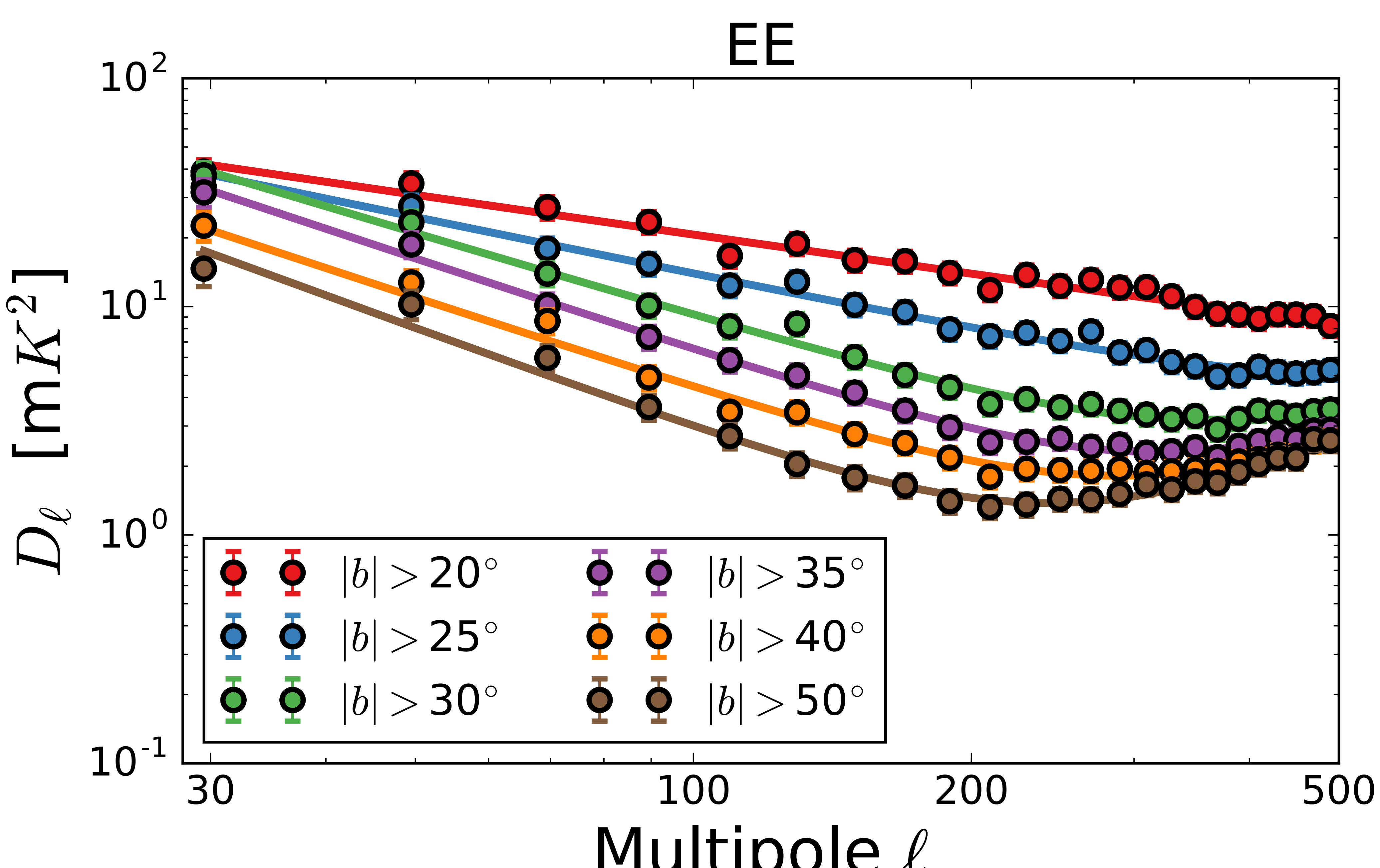


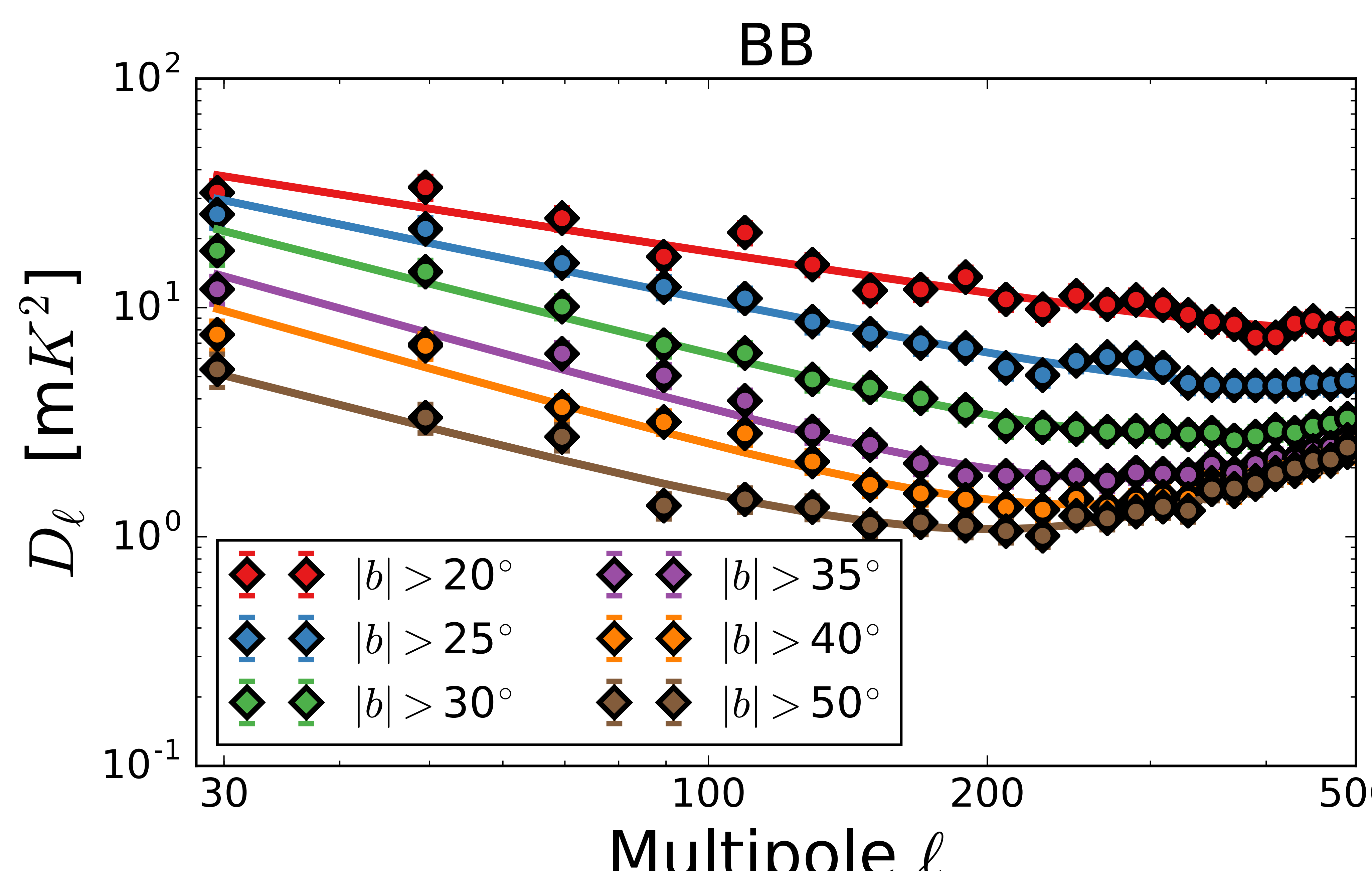
S–PASS Power Spectra

- Sky masks: **6 iso-latitude cuts**
- Fit considering **power law decay** (diffuse emission) **+ point sources**

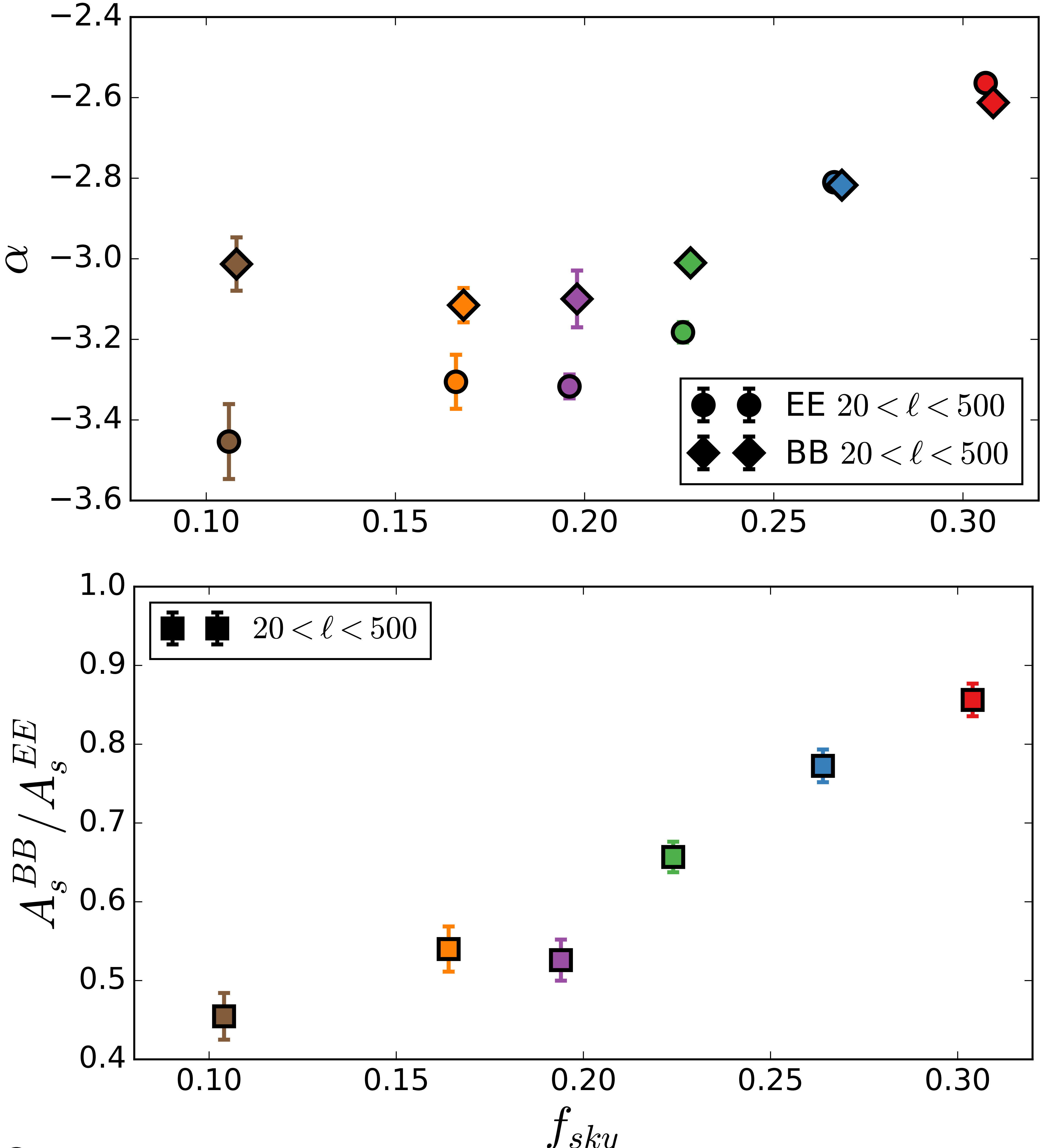
$$C_\ell = A_s \ell^\alpha + A_p$$







S-PASS Power Spectra



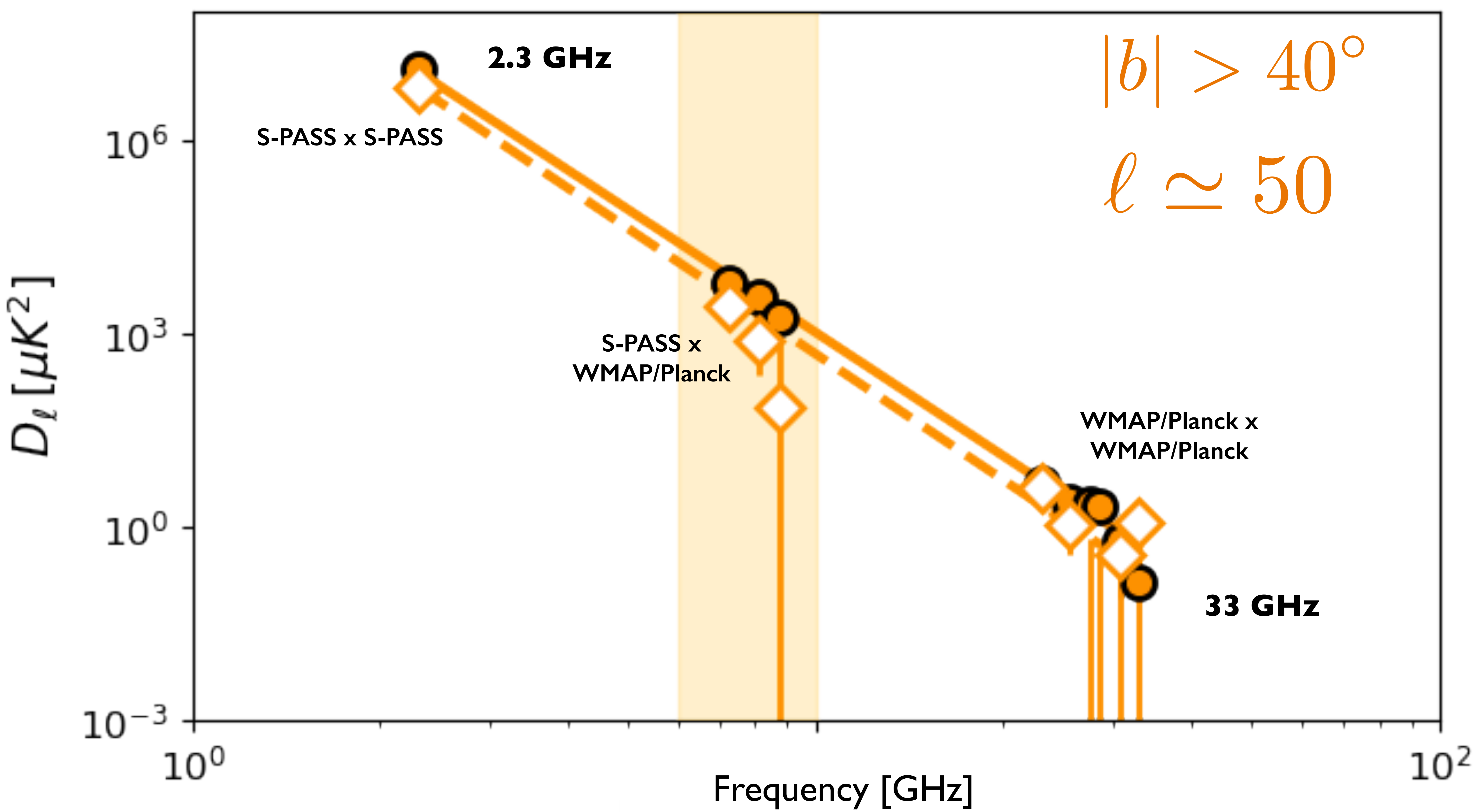
$$C_\ell = A_s \ell^\alpha + A_p$$

$$\alpha \simeq -3.0$$

$$A_s^{BB}/A_s^{EE} \simeq 0.5$$

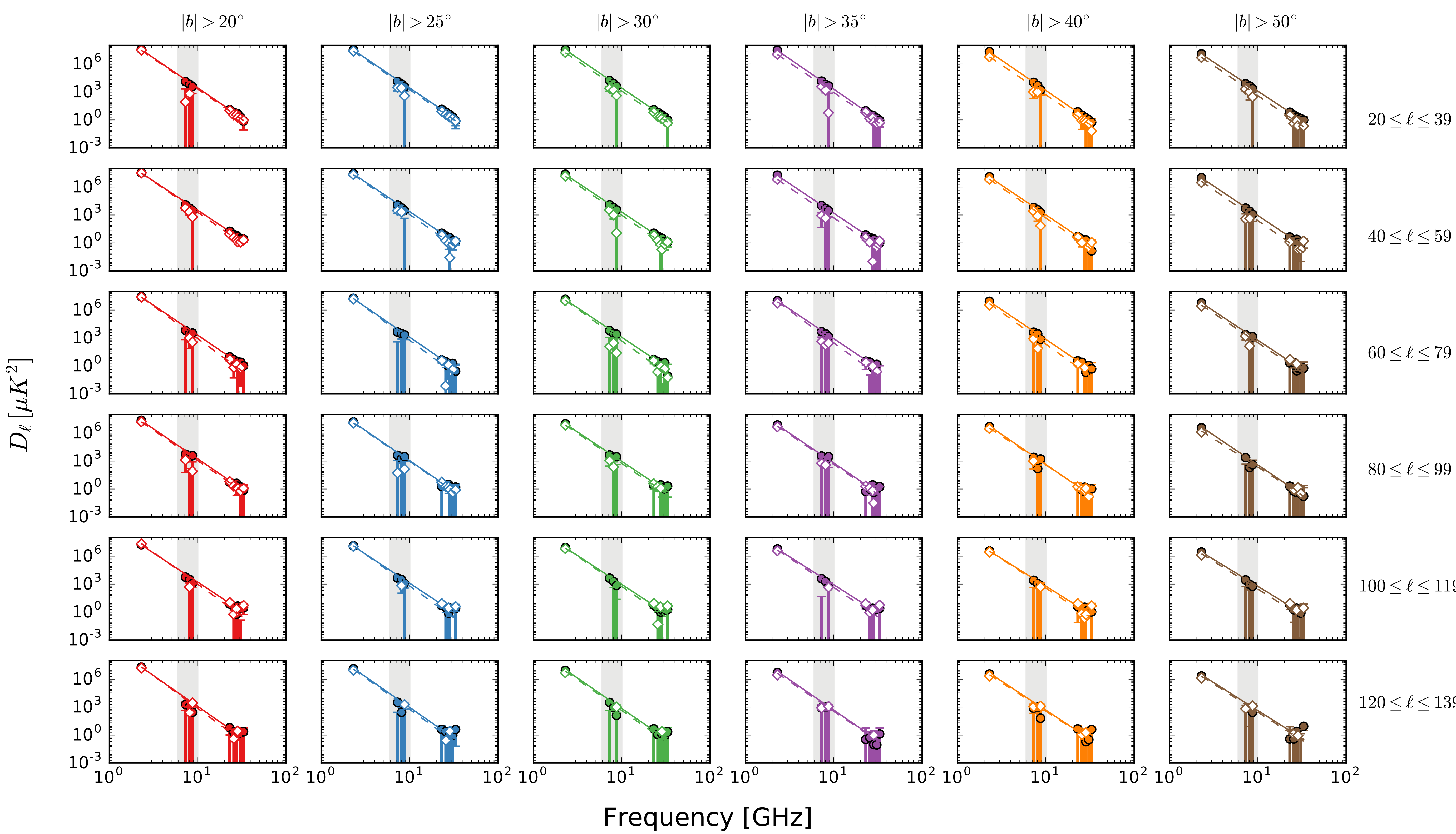
for |b|>35°

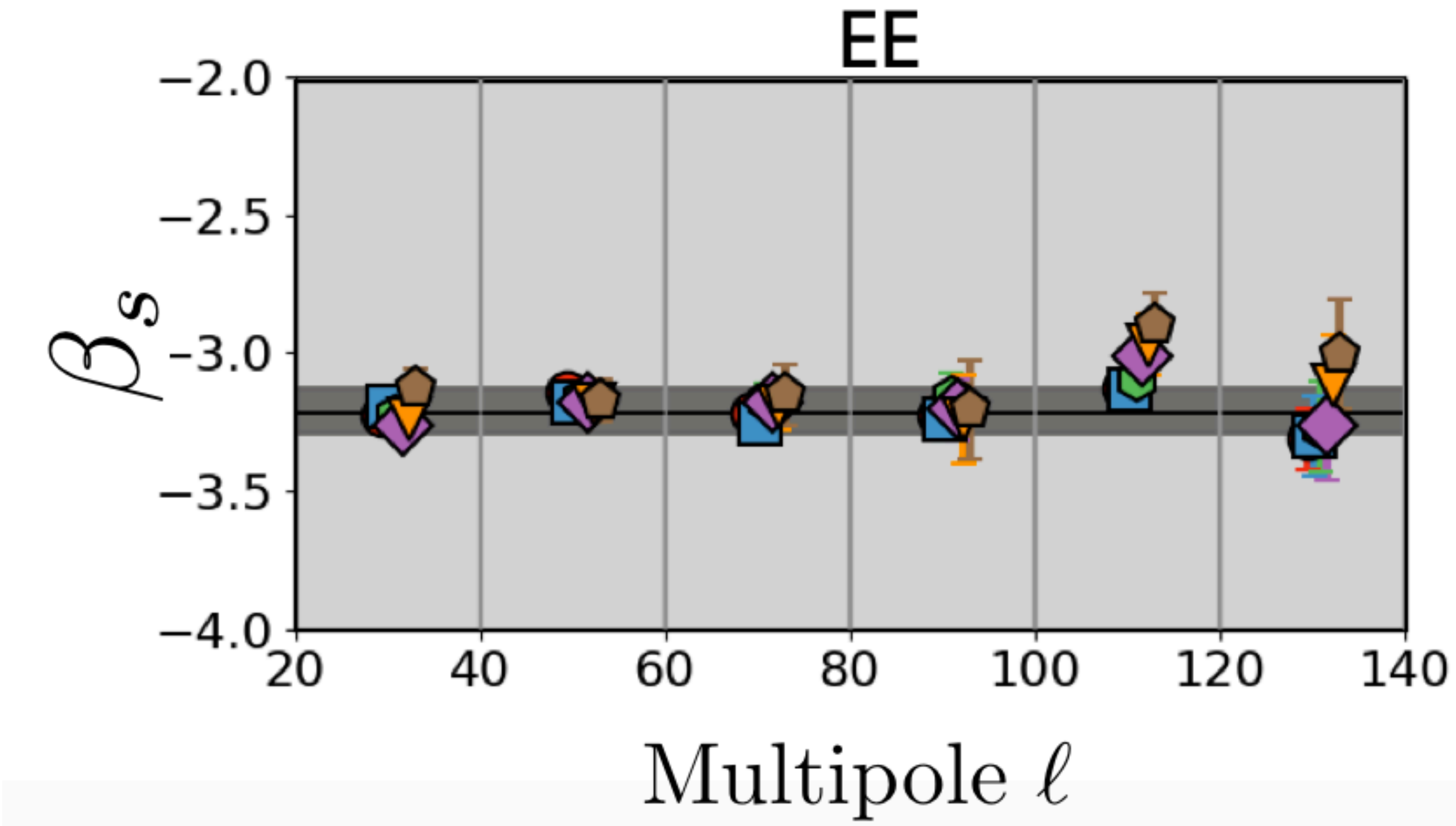
Frequency scaling

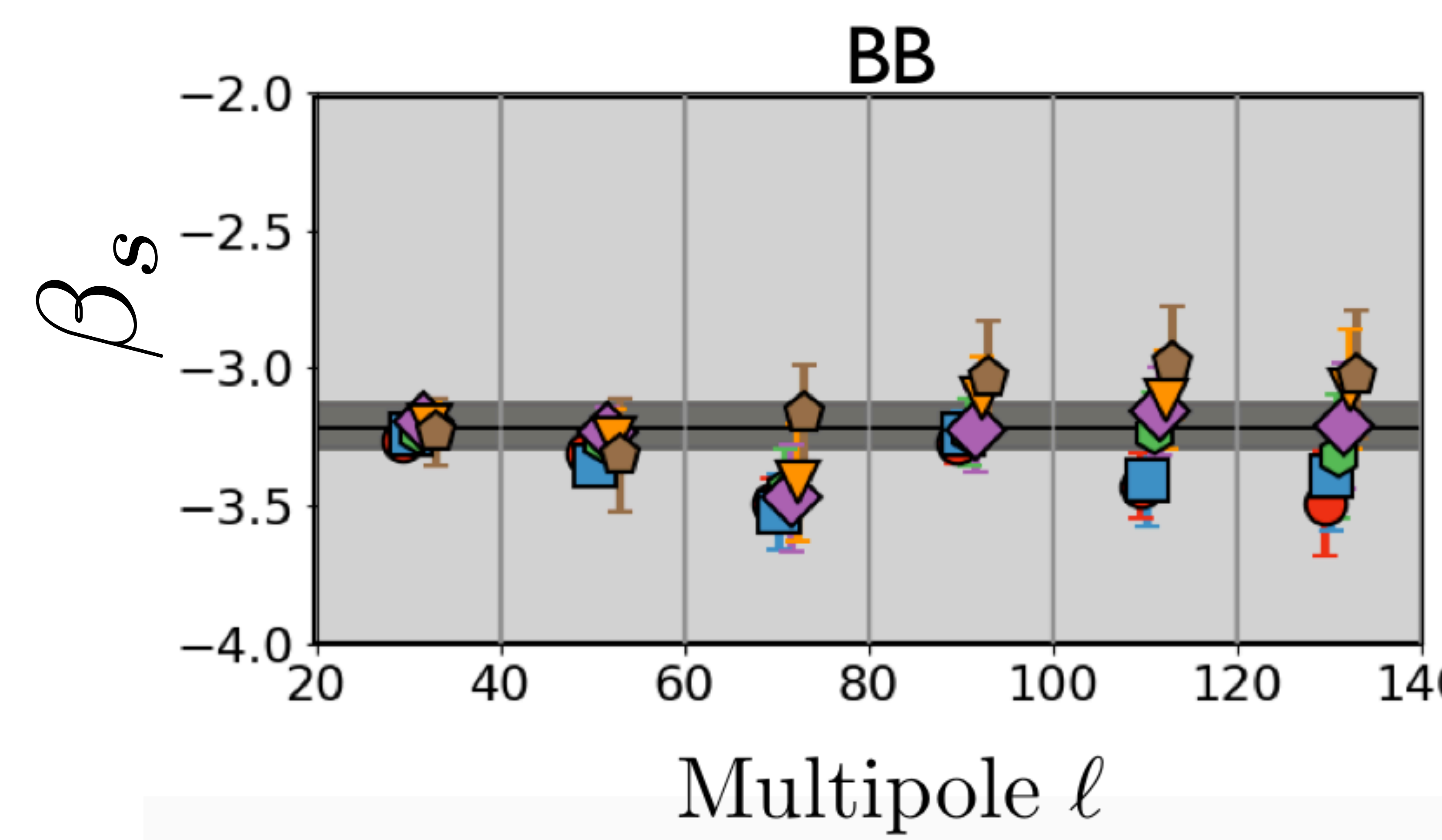


Power law fitting from 2.3 to 33 GHz

FREQUENCY SCALING





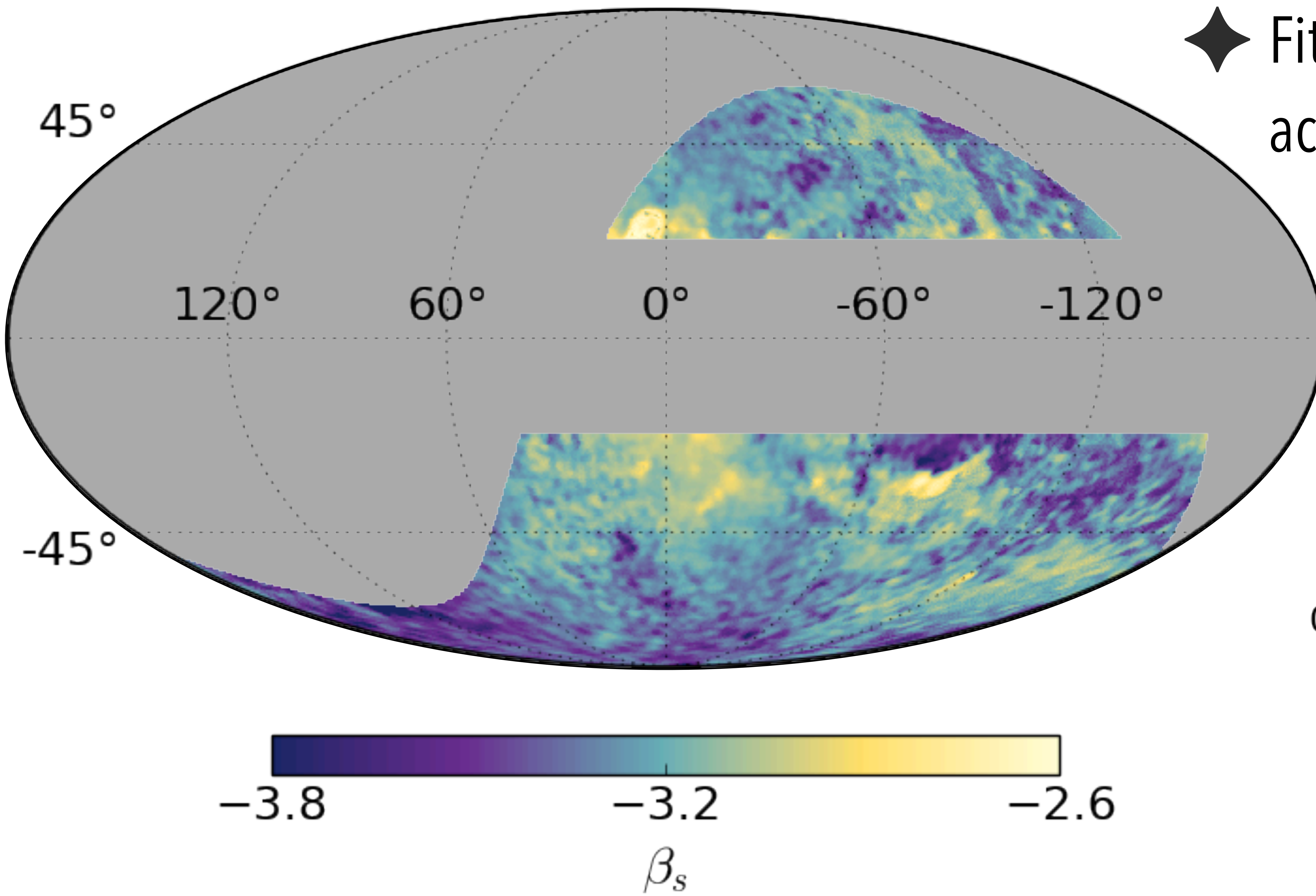


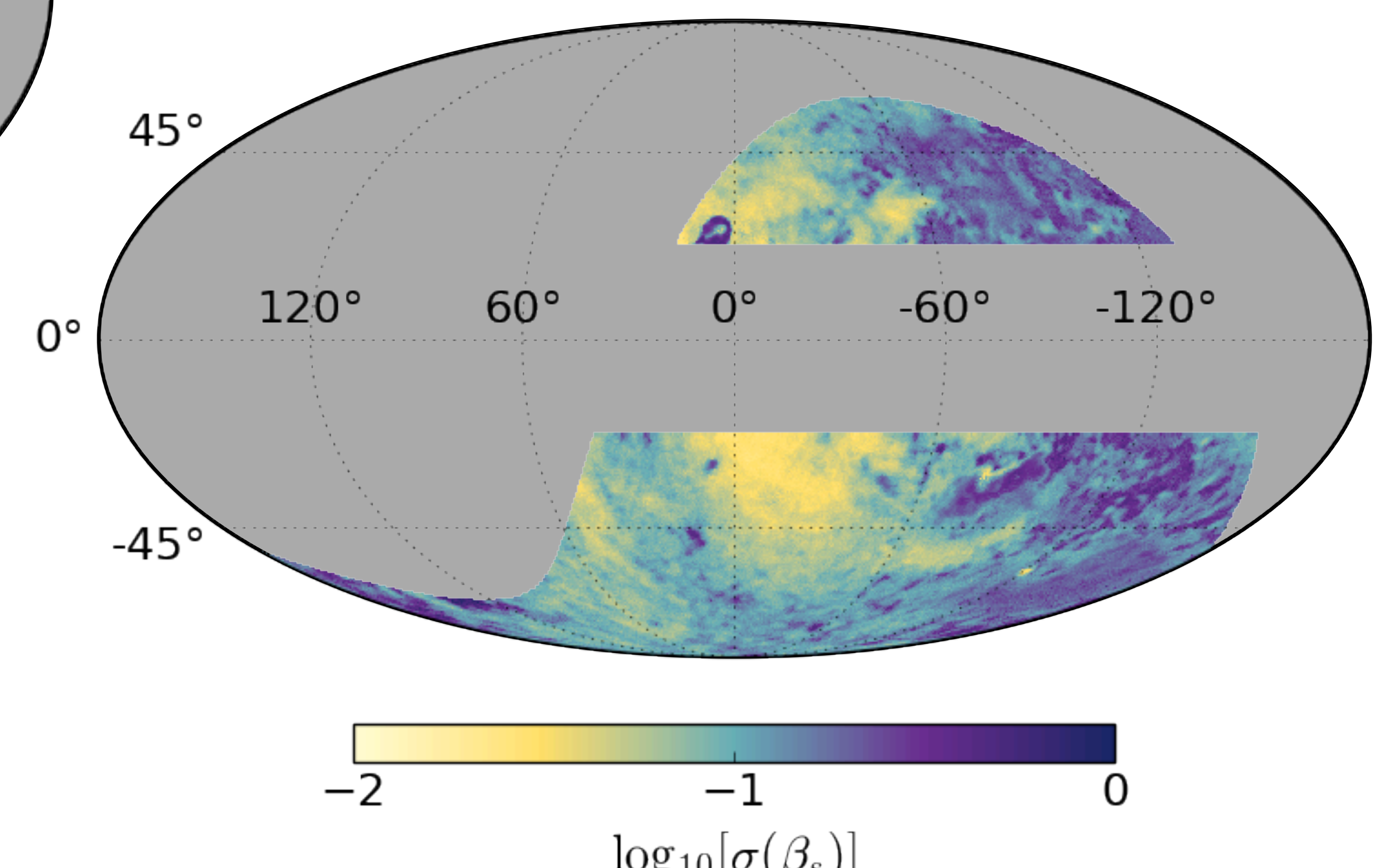
$$\beta_s = -3.22 \pm 0.08$$

In agreement with the value we get from the Planck/WMAP analysis (Planck LIV):

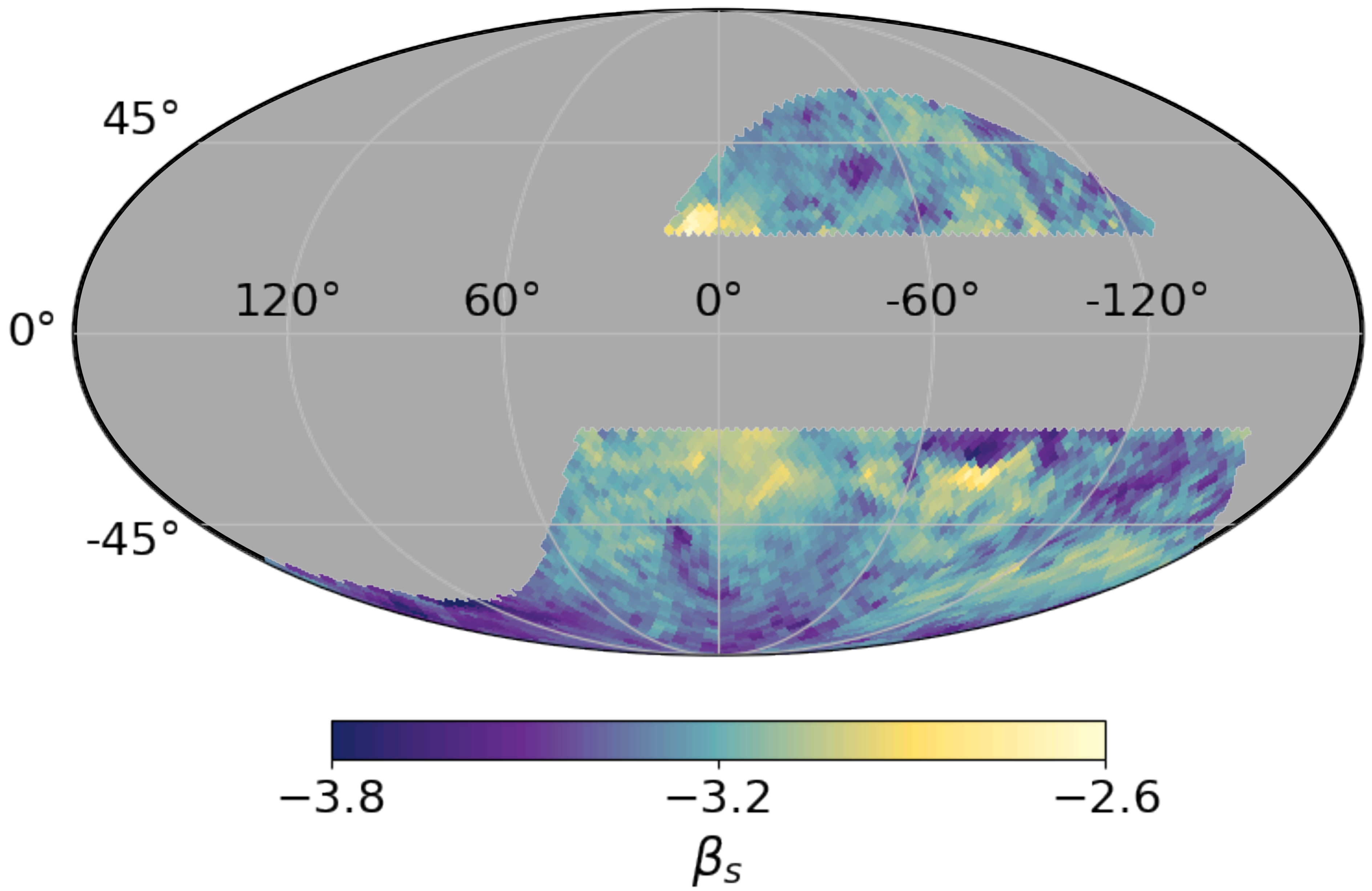
Spectral index map

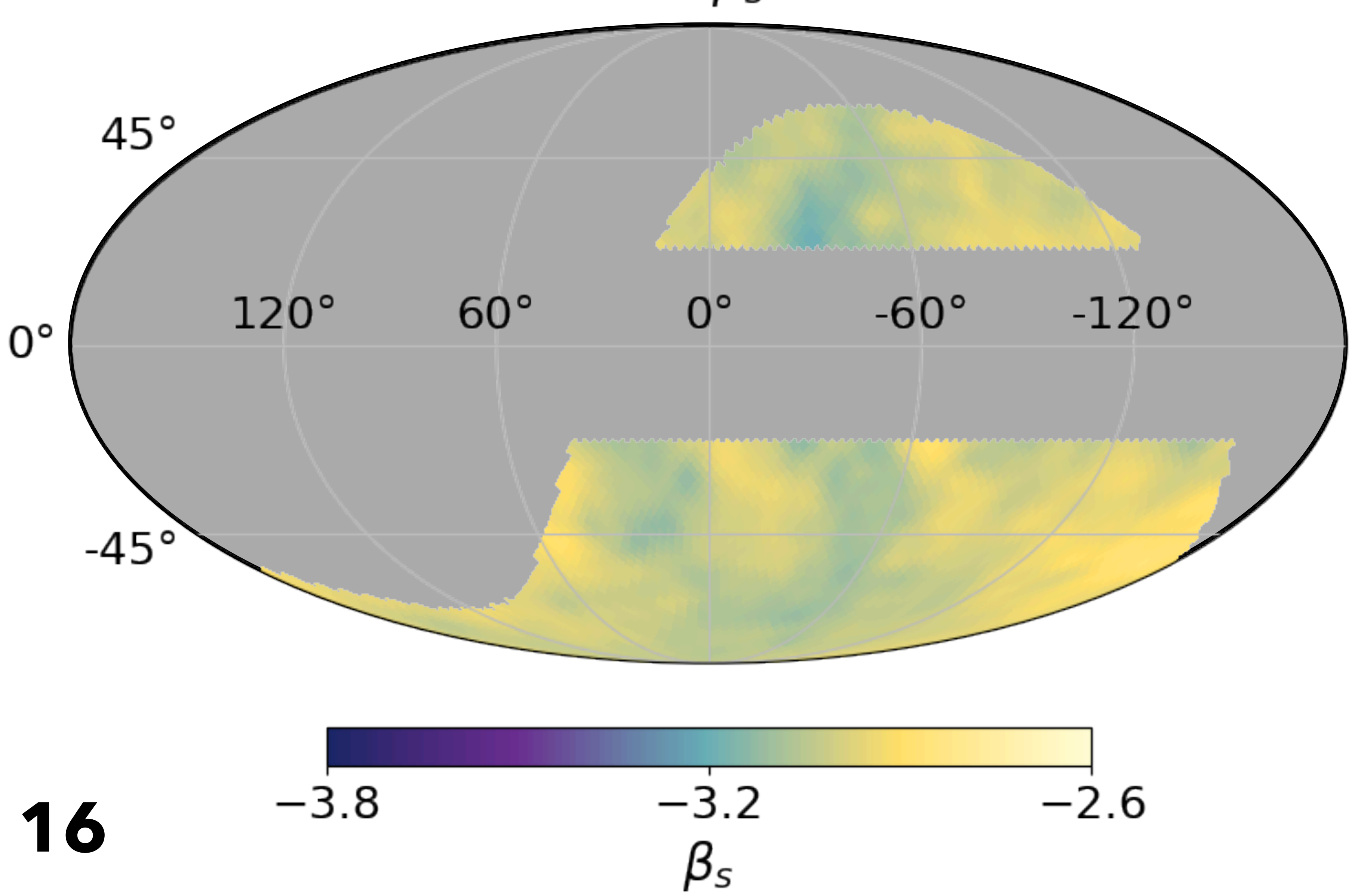
- First β_s map computed only from polarization data
- Power law fit S-PASS, WMAP-K/Ka, Planck-30
- Fit in each pixel in total polarization taking into account the noise bias
  - Angular resolution of 2°
  - Sky coverage ~ 30%

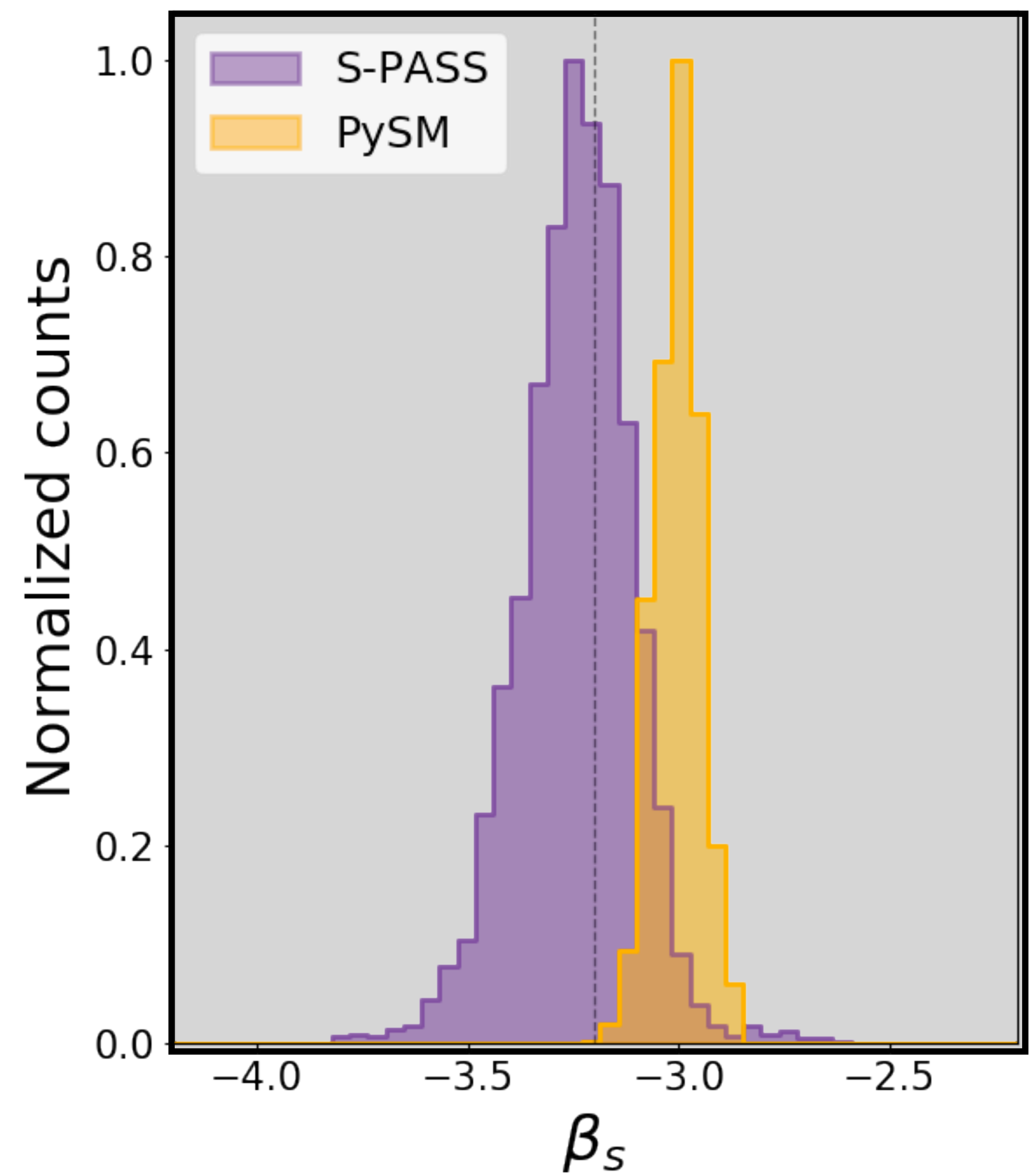




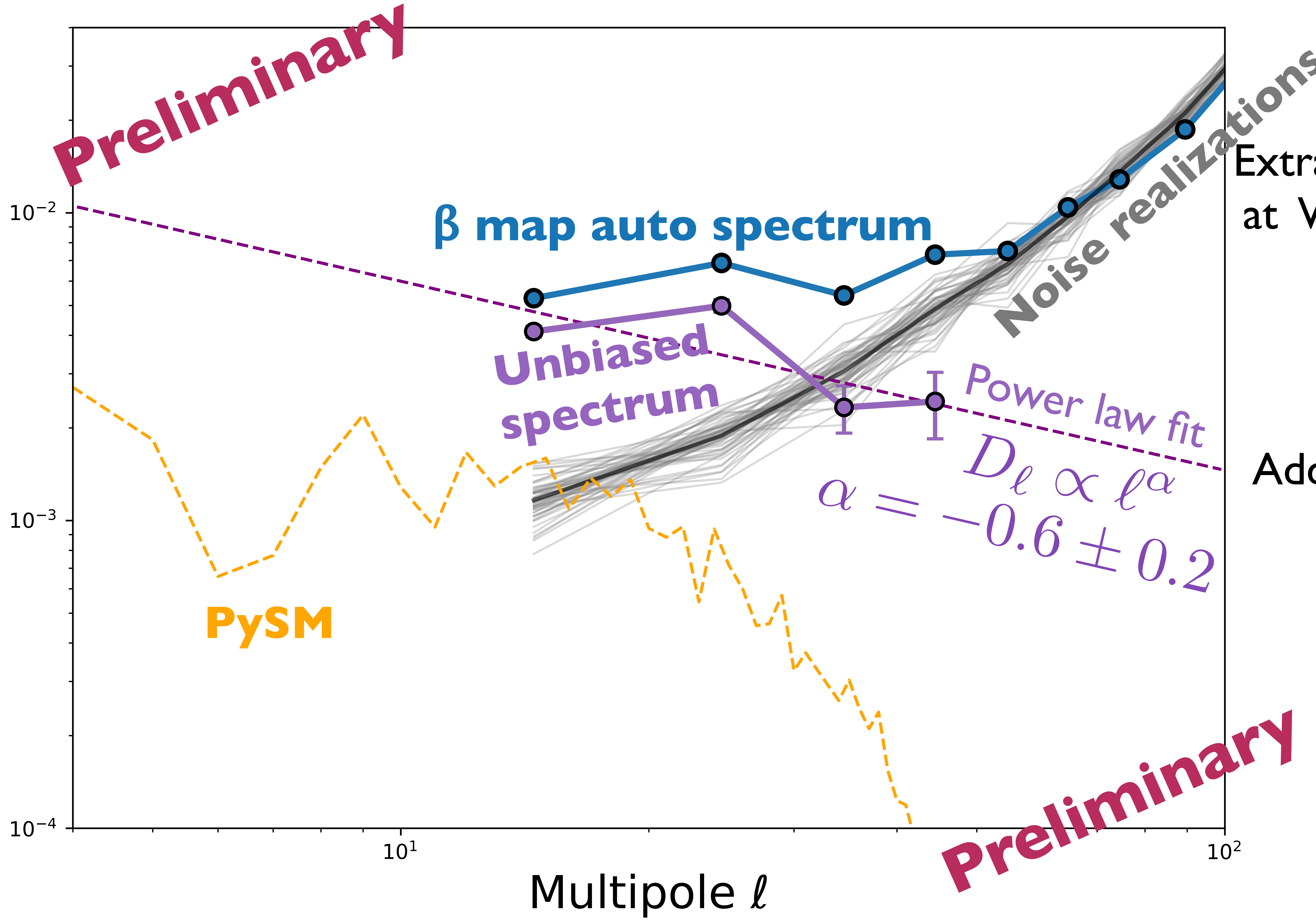
Comparison with PySM







Spectral index map: power spectrum



Noise realizations:

S-PASS maps @ 2.3 GHz

↓

Extrapolate in frequency using β map at WMAP-K/Ka, LFI-30 frequencies

↓

Add noise on extrapolated maps

↓

Estimate β^*

↓

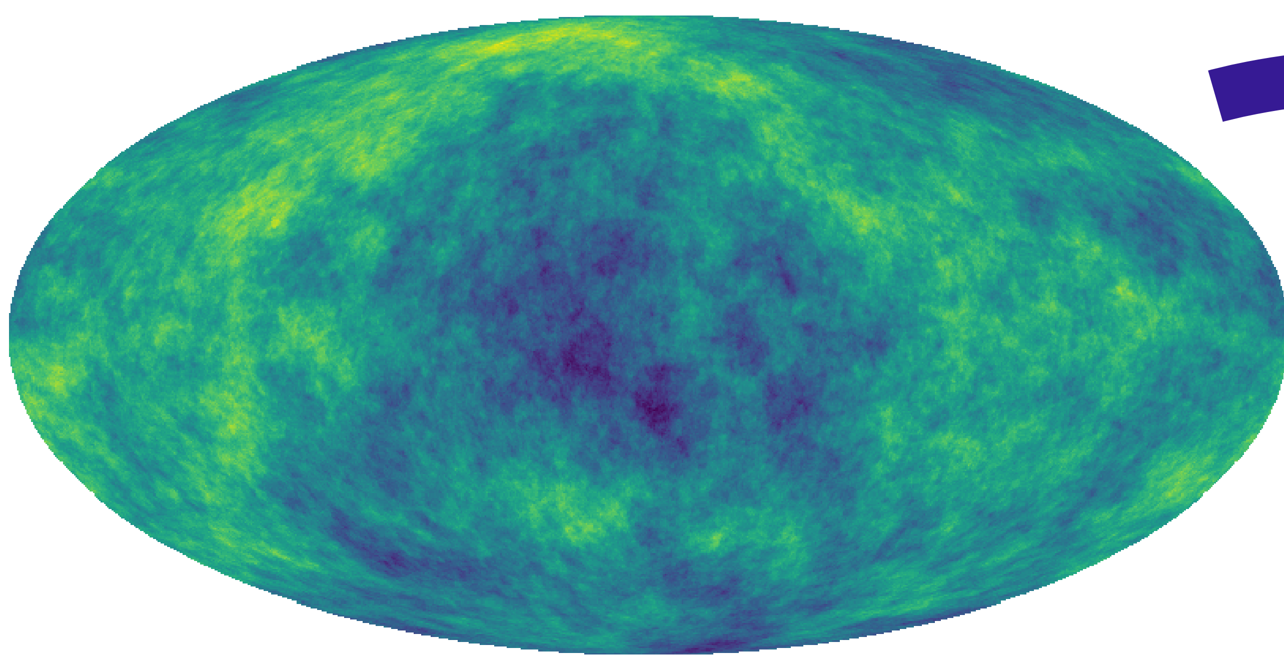
Compute spectrum of $(\beta^* - \beta)$

Spectral index map: simulations

Update the PySM beta map by rescaling it and adding small angular scales from Gaussian realization of the fitted power spectrum

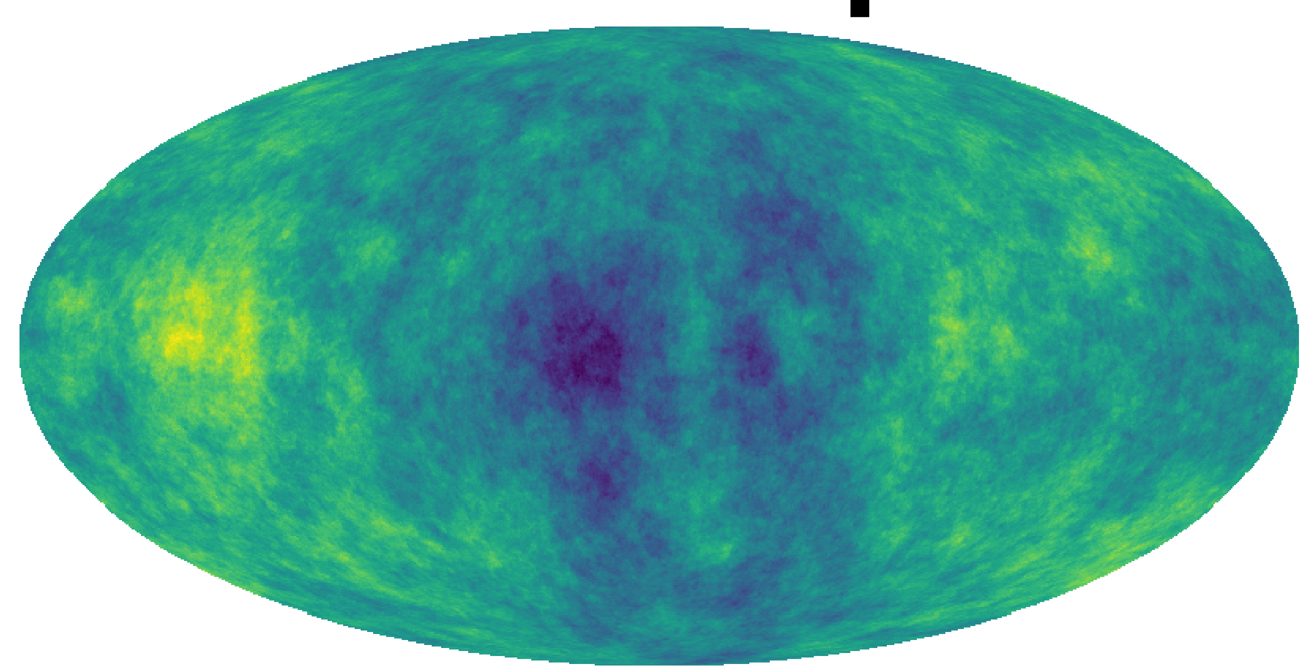
Preliminary

Gaussian realization

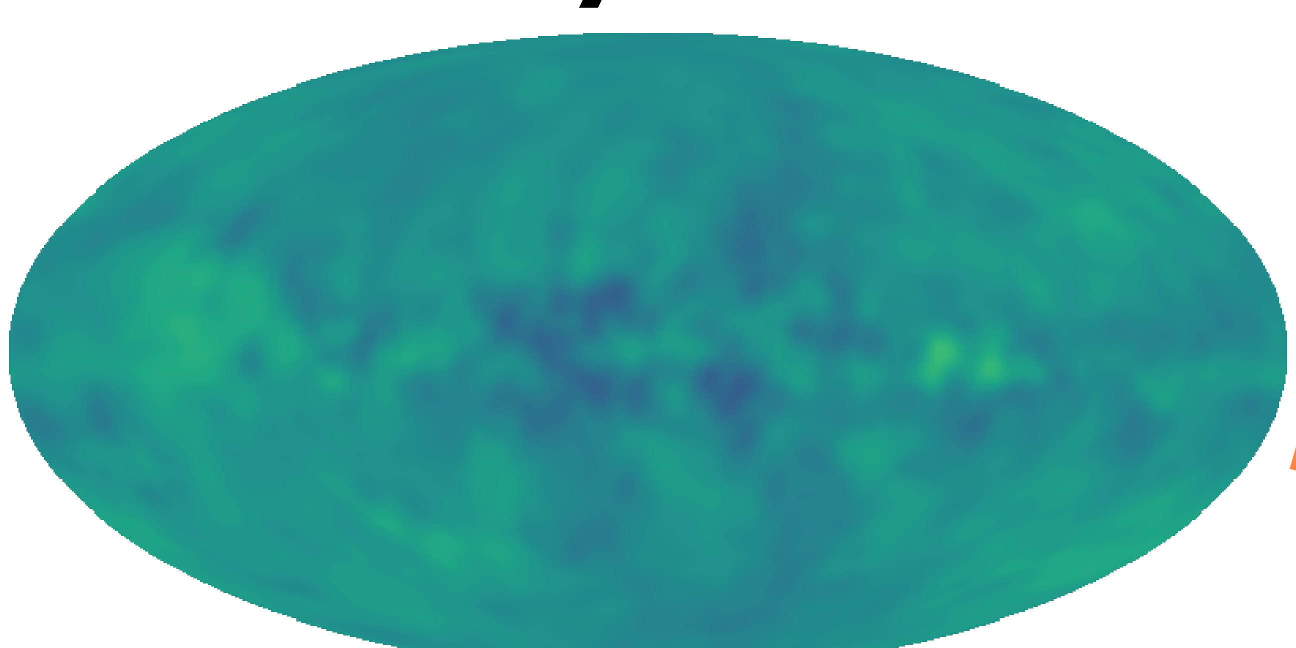


ell > 10

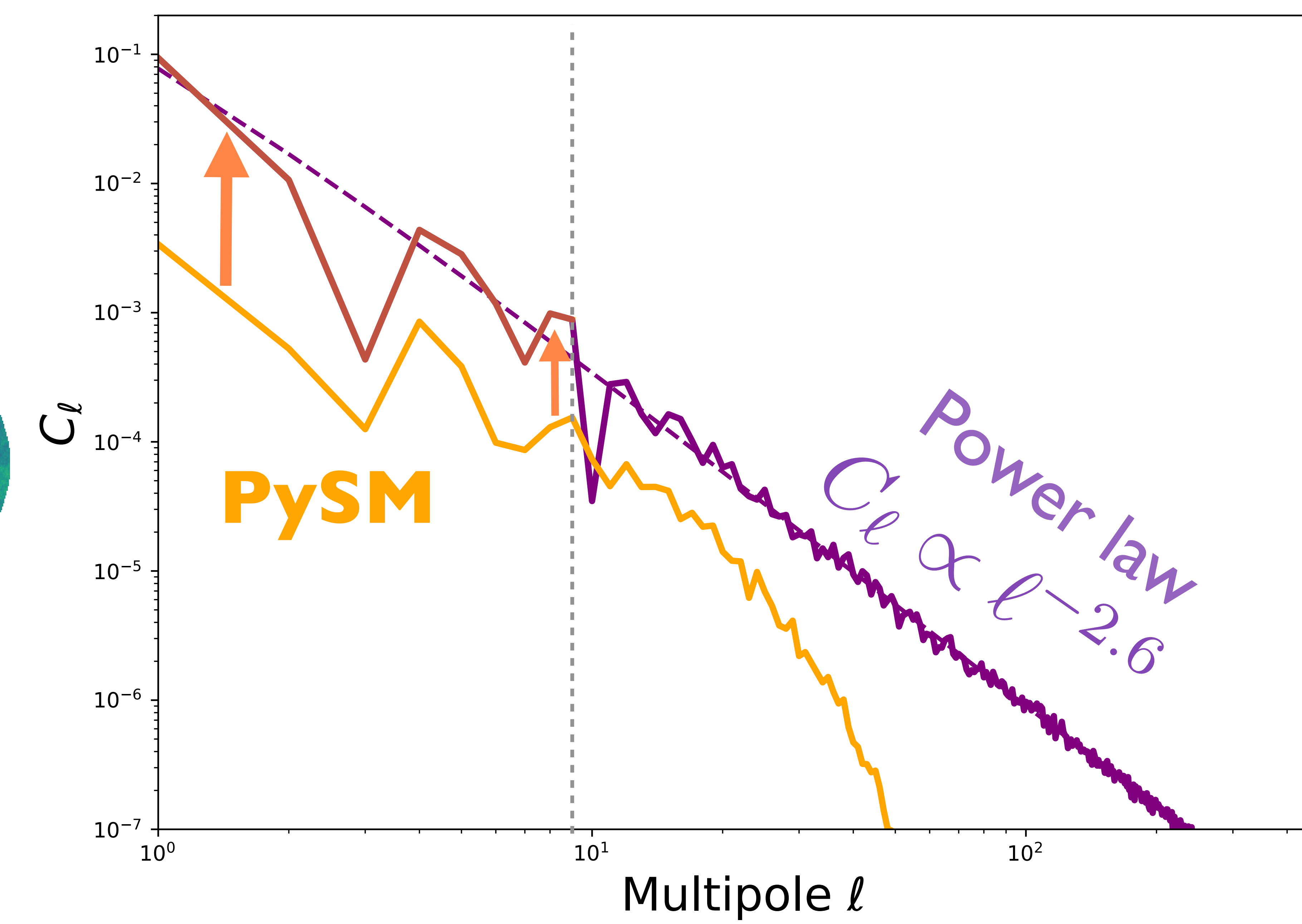
New Map



PySM

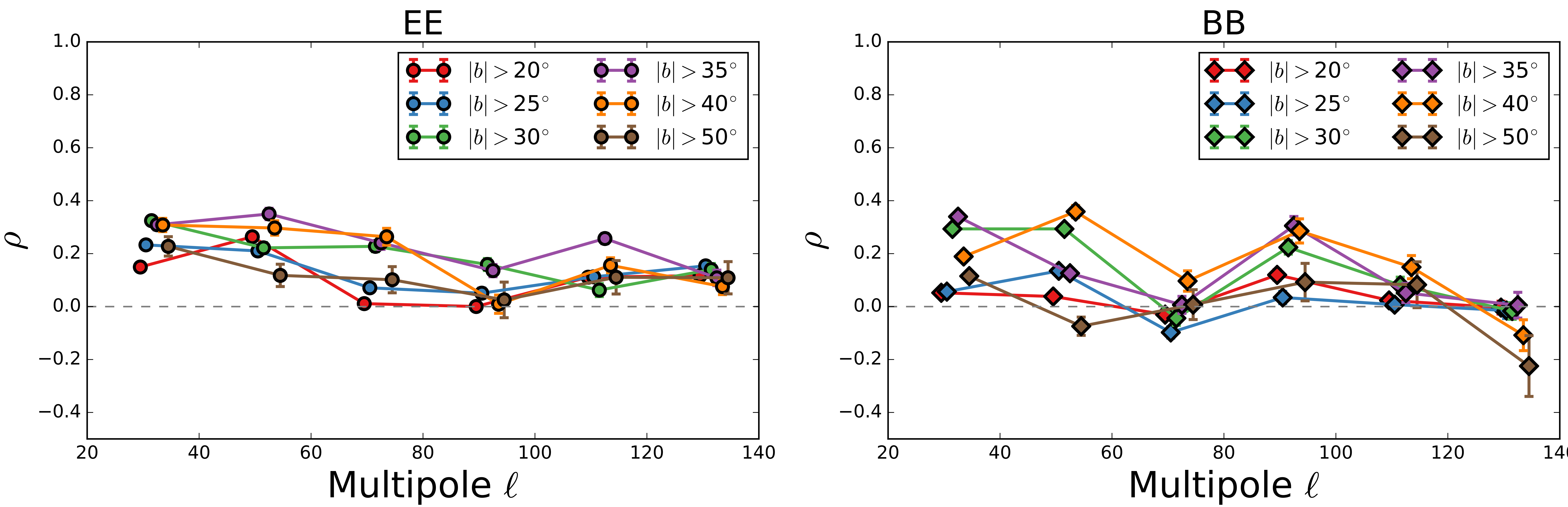


ell < 10
rescaled



Synch x Dust

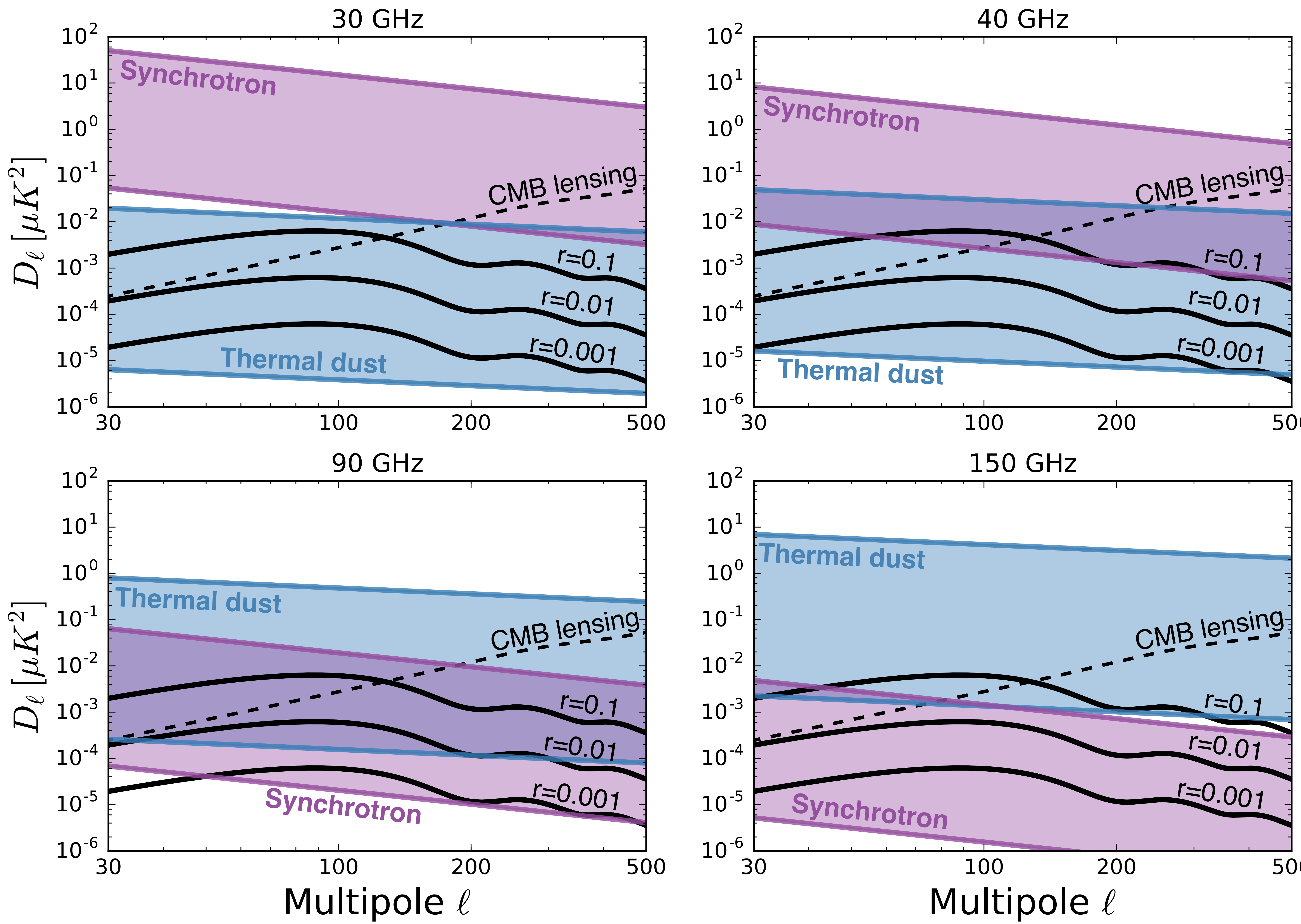
$$\rho_\ell = \frac{D_\ell(2.3 \times 353)}{\sqrt{D_\ell(2.3)\, D_\ell(353)}}$$



- ✦ Correlation between synchrotron and dust observable over the huge frequency range 2.3-353 GHz

Contamination to B-modes

- **184 circular regions with f_{sky} ~ 1%**
- Computation of **S-PASS** auto spectra and **Planck-353**
- **Fit** of B-modes spectra **with power law** for 40<ℓ<140
- **Extrapolation in frequency** of synchrotron and dust amplitudes

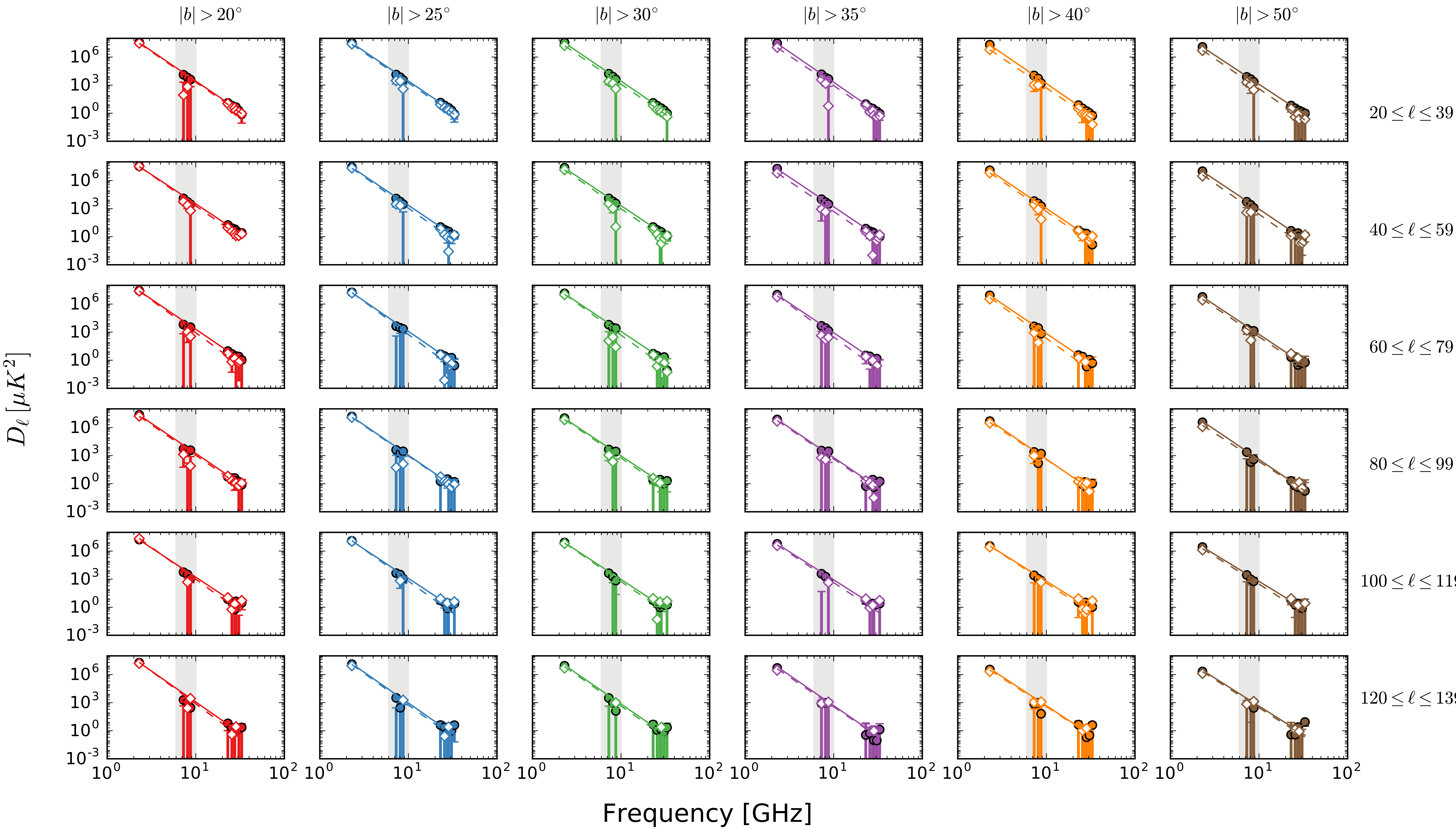


Conclusions

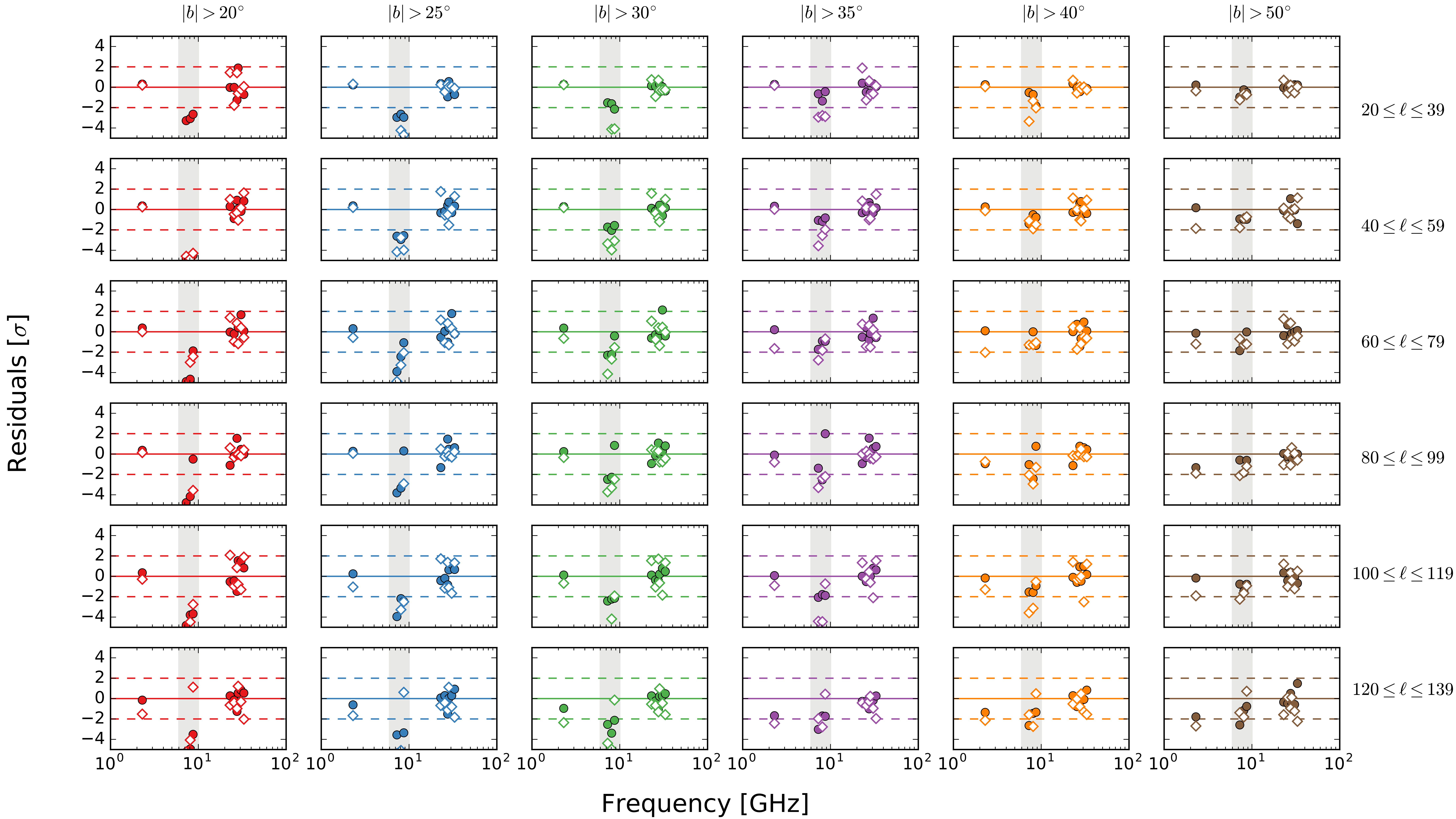
- One of the legacy of the Planck mission is represented by the high frequency data essential to constrain thermal dust emission:
  - characterization of polarization power spectra
  - dust SED and correlation with synchrotron

- For low frequency Planck and WMAP data sensitivity is not enough to characterize synchrotron signal at high Galactic latitudes
- Very low frequency observations (< 20 GHz) can help
- S-PASS data at 2.3 GHz allowed characterization of synch with high signal-to-noise:
  - polarization power spectra
  - synchrotron SED in range 2.3-33 GHz: β_s= -3.22± 0.08
  - first β_s map based on polarization data
  - synch - dust correlation over the range 2.3-353 GHz

Back-up slides



$|b| > 20°$
$|b| > 25°$
$|b| > 30°$
$|b| > 35°$
$|b| > 40°$
$|b| > 50°$
$20 \leq \ell \leq 39$
$40 \leq \ell \leq 59$
$60 \leq \ell \leq 79$
$80 \leq \ell \leq 99$
$100 \leq \ell \leq 119$
$120 \leq \ell \leq 139$
$D_\ell\ [\mu K^2]$
Frequency [GHz]



$|b| > 20^\circ$
$|b| > 25^\circ$
$|b| > 30^\circ$
$|b| > 35^\circ$
$|b| > 40^\circ$
$|b| > 50^\circ$
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$40 \leq \ell \leq 59$
$60 \leq \ell \leq 79$
$80 \leq \ell \leq 99$
$100 \leq \ell \leq 119$
$120 \leq \ell \leq 139$
Residuals [σ]
Frequency [GHz]

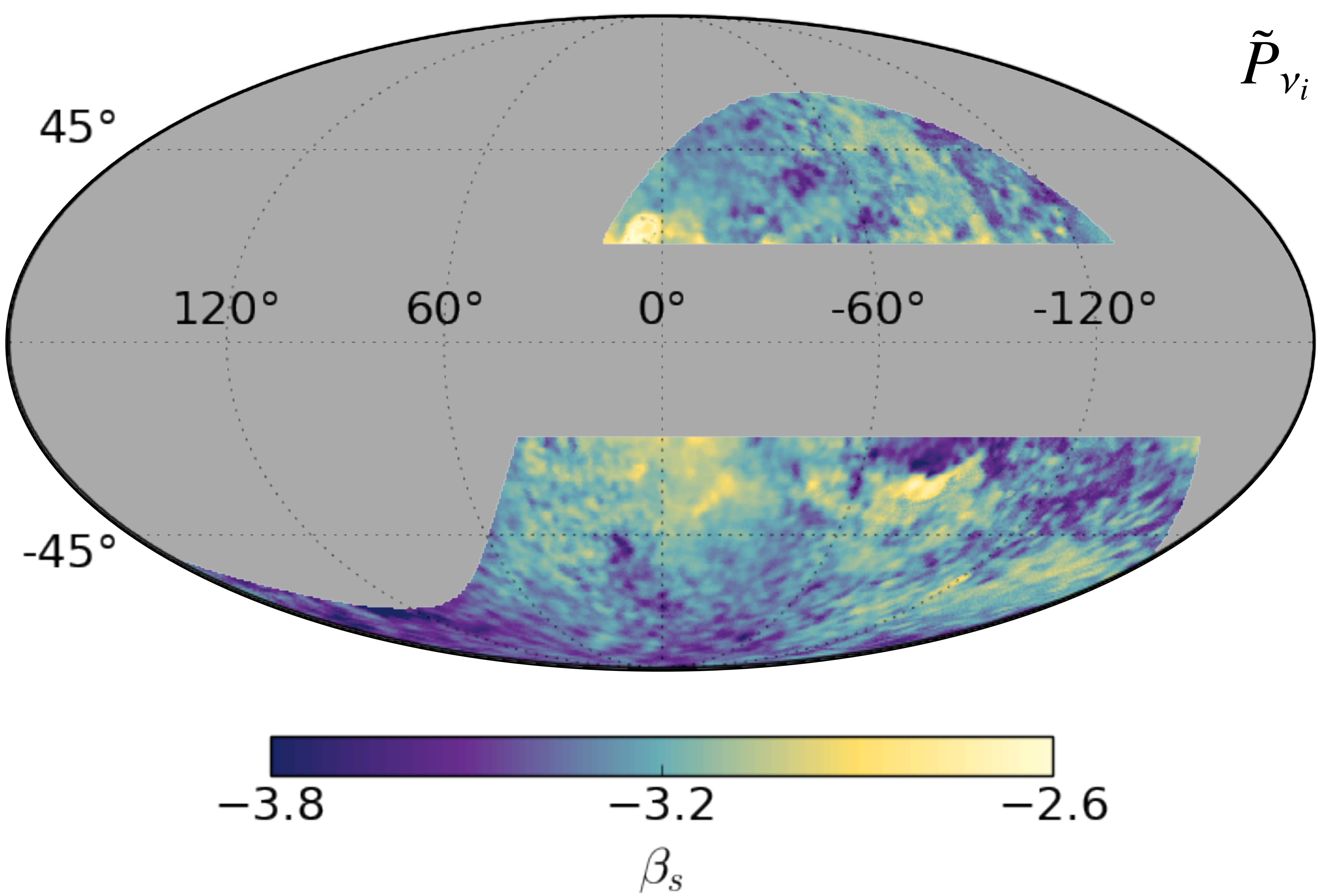
Noise bias in spectral index map

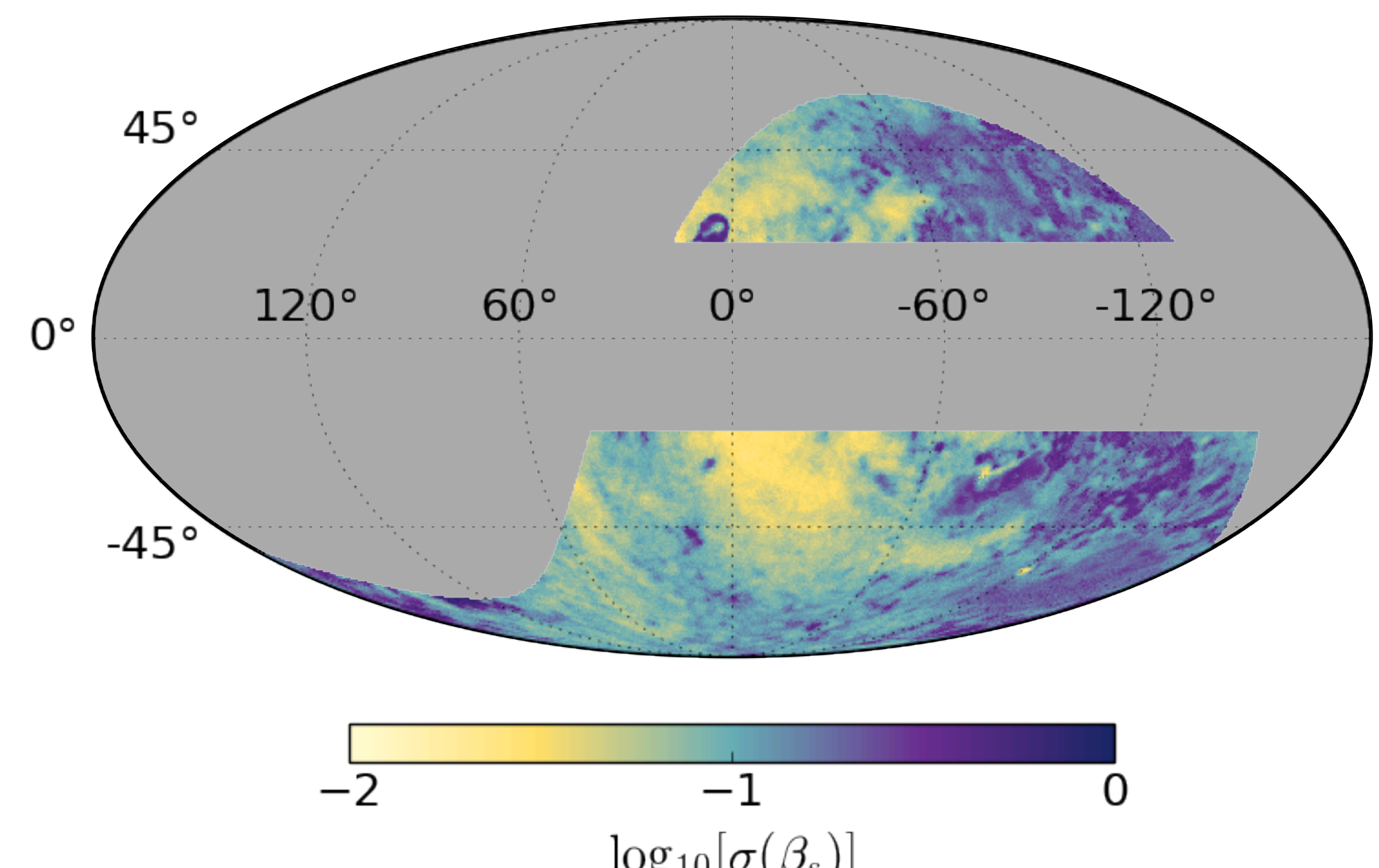
Minimizing:

$$\sum_{\nu_i} (\tilde{P}_{\nu_i} - P_{\nu_i})^2$$

with:

$$\tilde{P}_{\nu_i} = \sqrt{\left[Q_{2.3}\left(\frac{2.3}{\nu_i}\right)^{\beta_s} + n^Q_{\nu_i}\right]^2 + \left[U_{2.3}\left(\frac{2.3}{\nu_i}\right)^{\beta_s} + n^U_{\nu_i}\right]^2}$$





Contamination to B-modes

- **Foreground minumum** as sum of synch and dust amplitudes **at ℓ=80** neglecting correlation between the two