# The S-PASS view of Synchrotron at 2.3 GHz

https://arxiv.org/abs/1802.01145

Krachmalnicoff et al., A&A, in press

ma per seguir virtute e canoscenza

SISSA

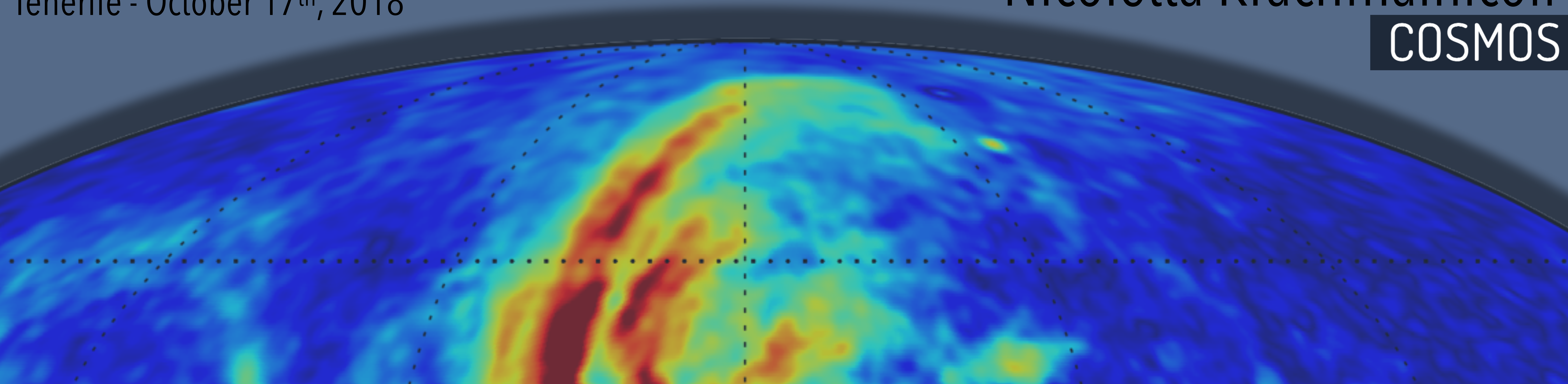
RADIO FOREGROUNDS

**CMB foregrounds for B-mode studies**

Tenerife - October 17th, 2018


Nicoletta Krachmalnicoff

COSMOS

# The S-PASS survey

see E. Carretti talk

**PARKES radio telescope**: 64 m

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

**Sky coverage ~ 50%** (South hemisphere)

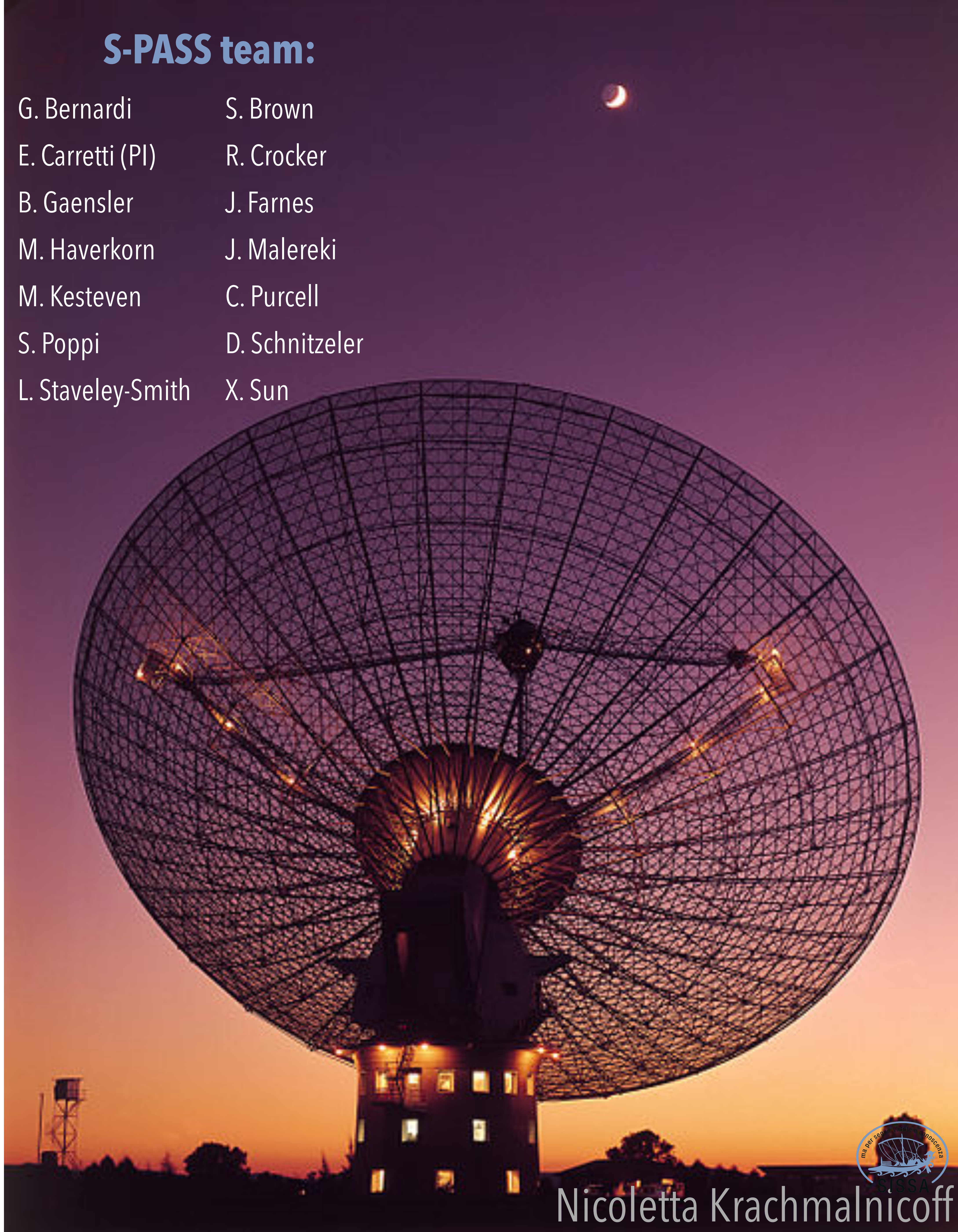
Angular resolution **~ 9 arcmin**

## S-PASS science:

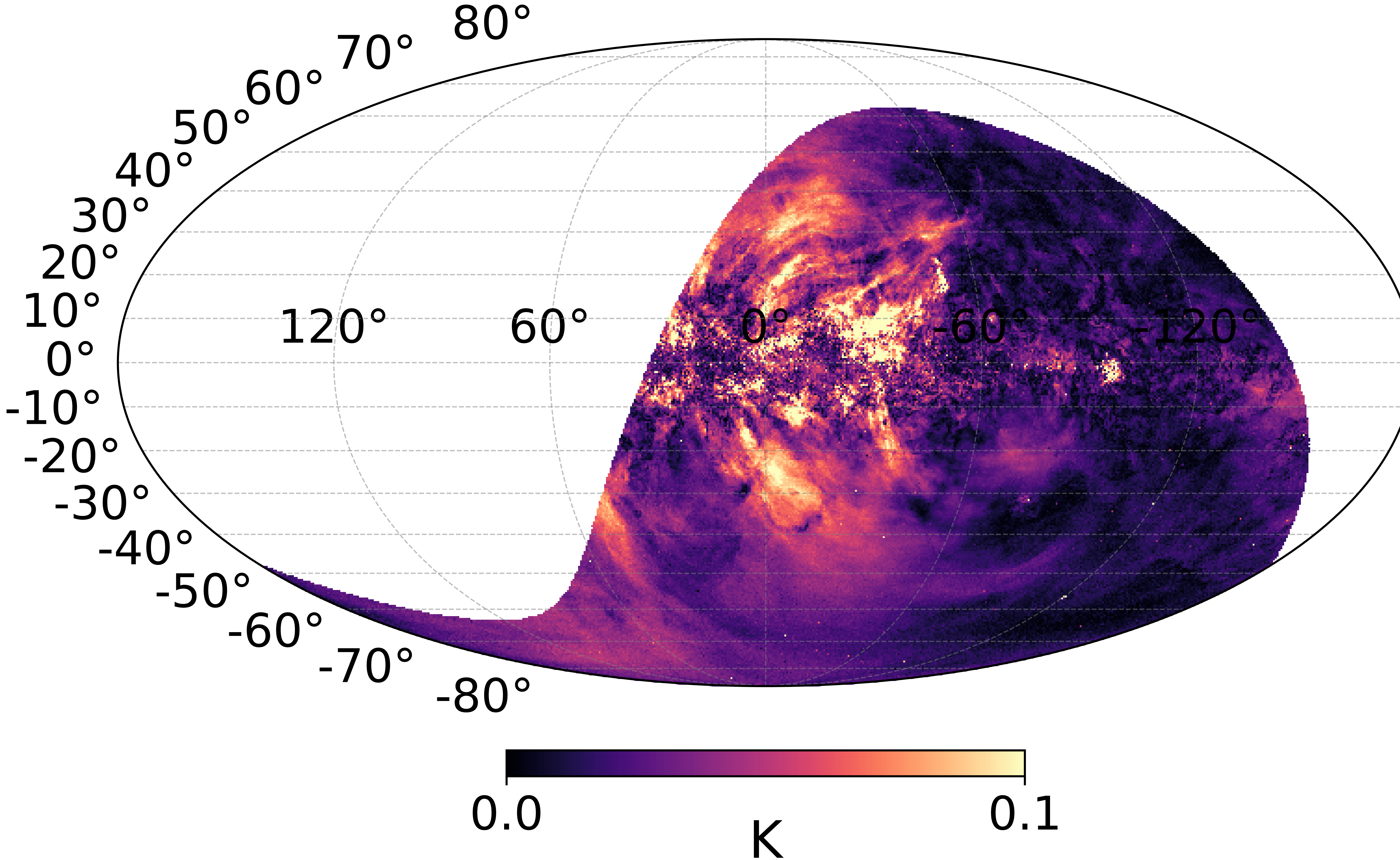
- Galactic Magnetic field
- Fermi Bubbles and Galactic structure
- ISM turbulence
- Gum Nebula
- ICM of galaxy clusters
- Extragalactic source properties
- CMB foregrounds
- ...

## S-PASS team:

| | |
|---|---|
| G. Bernardi | S. Brown |
| E. Carretti (PI) | R. Crocker |
| B. Gaensler | J. Farnes |
| M. Haverkorn | J. Malereki |
| M. Kesteven | C. Purcell |
| S. Poppi | D. Schnitzeler |
| L. Staveley-Smith | X. Sun |



# S-PASS polarized intensity map @2.3 GHz



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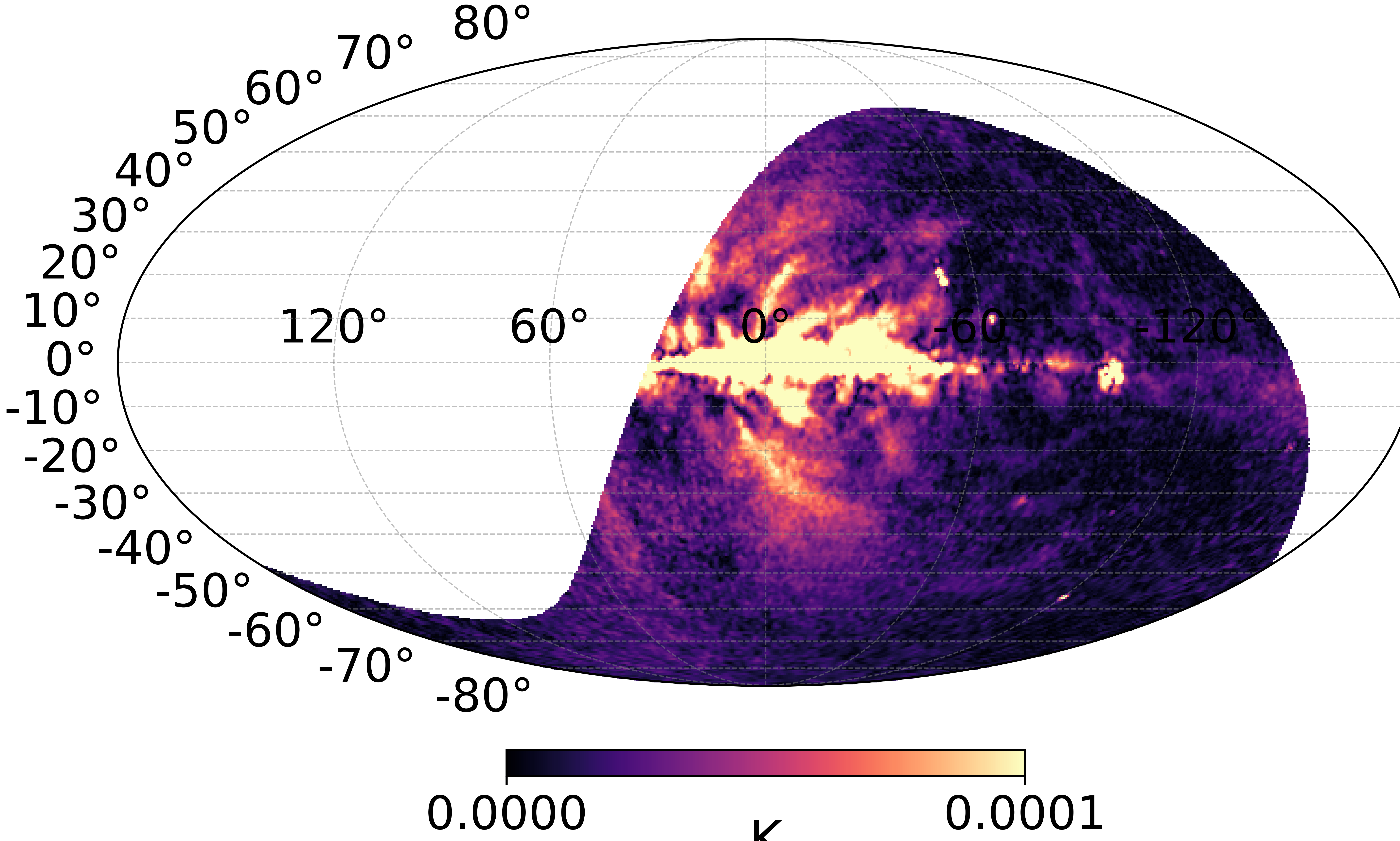
# WMAP-K polarized intensity map @23 GHz



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# **Overview** of the analysis

S-PASS auto **power spectra**

Synchrotron **Spectral Energy Distribution** (SED)

Constraint on synchrotron **curvature**

Synchrotron **spectral index map**

**Correlation** between synchrotron and **thermal dust emission**

**Contamination to CMB B-modes**



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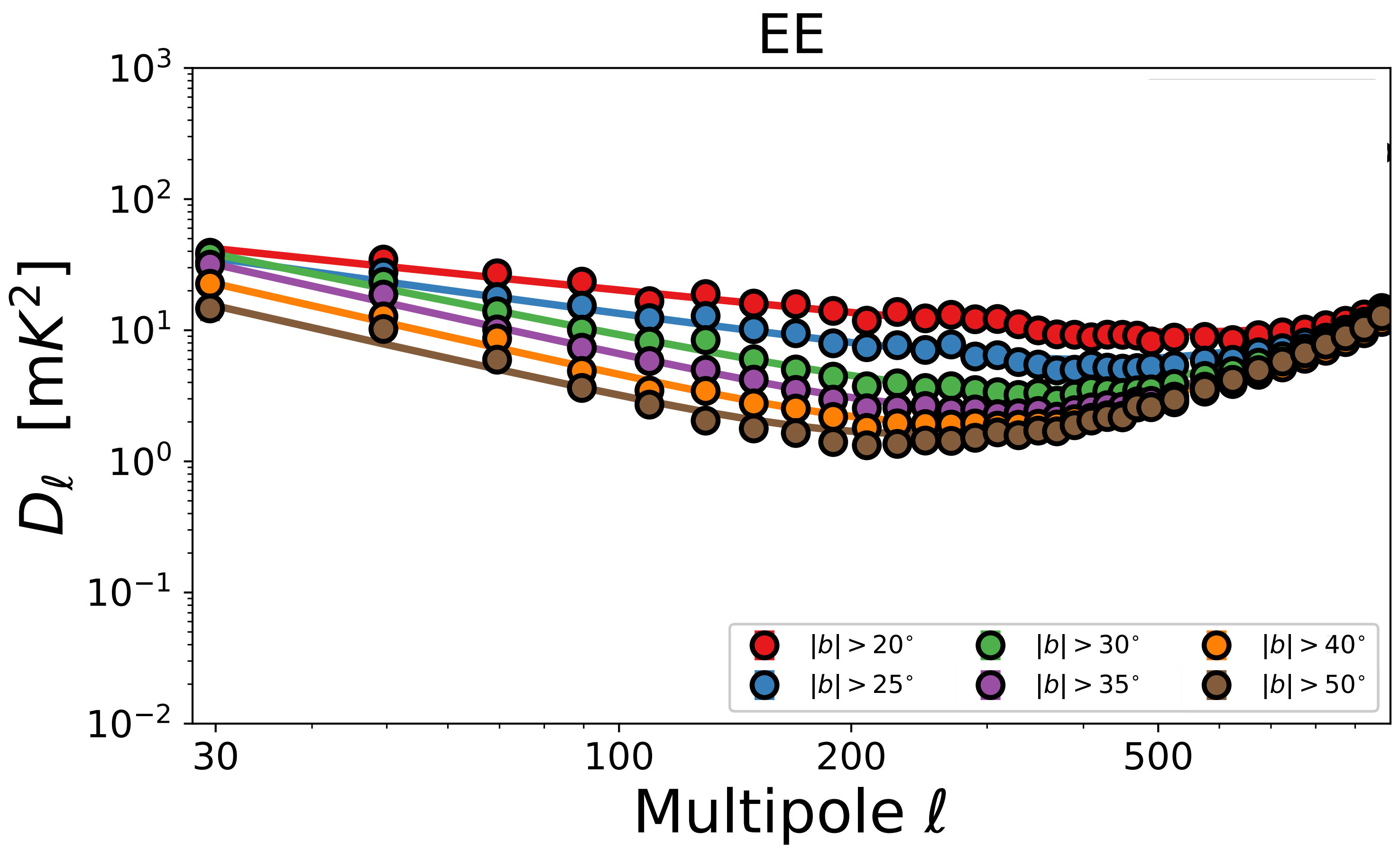
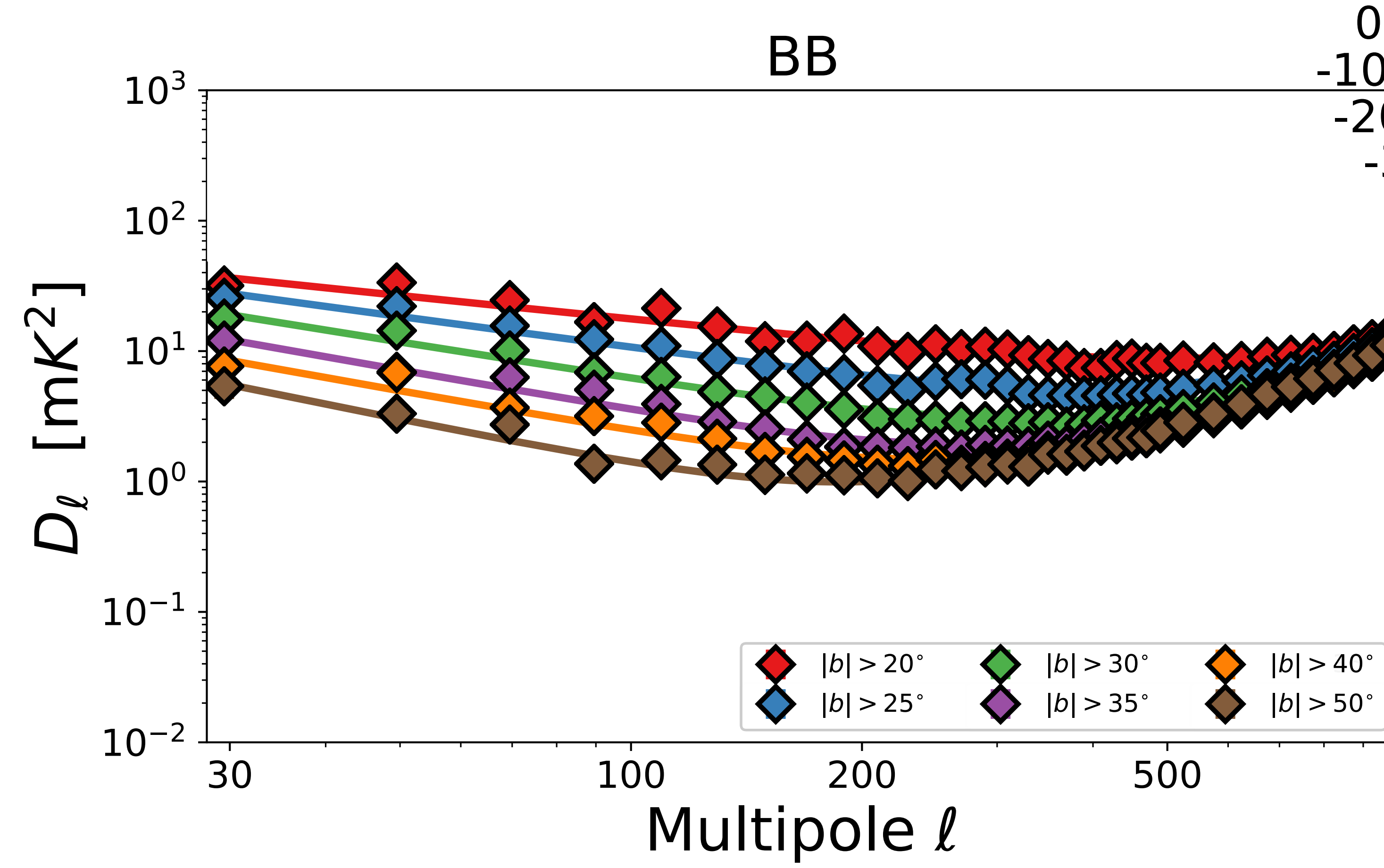
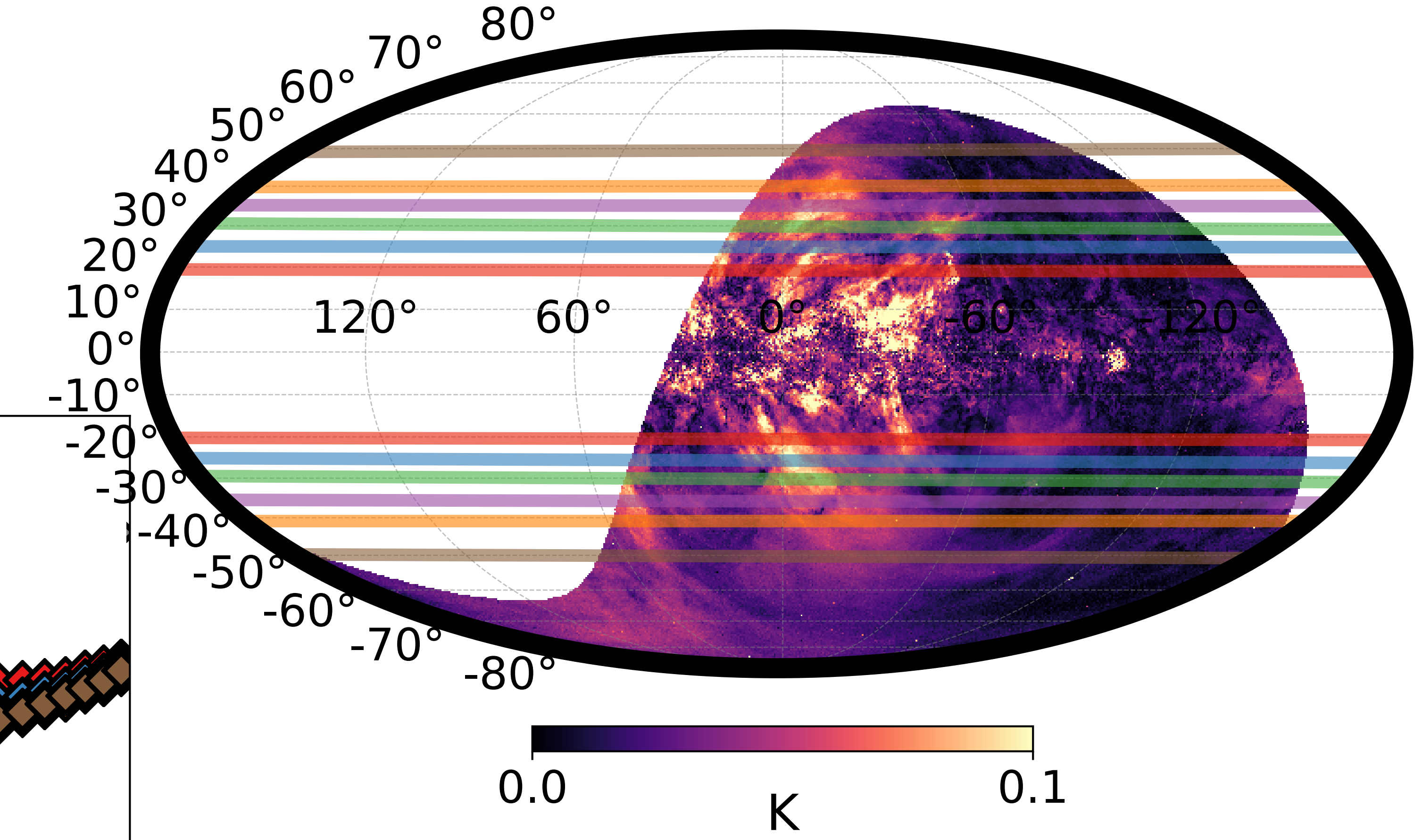
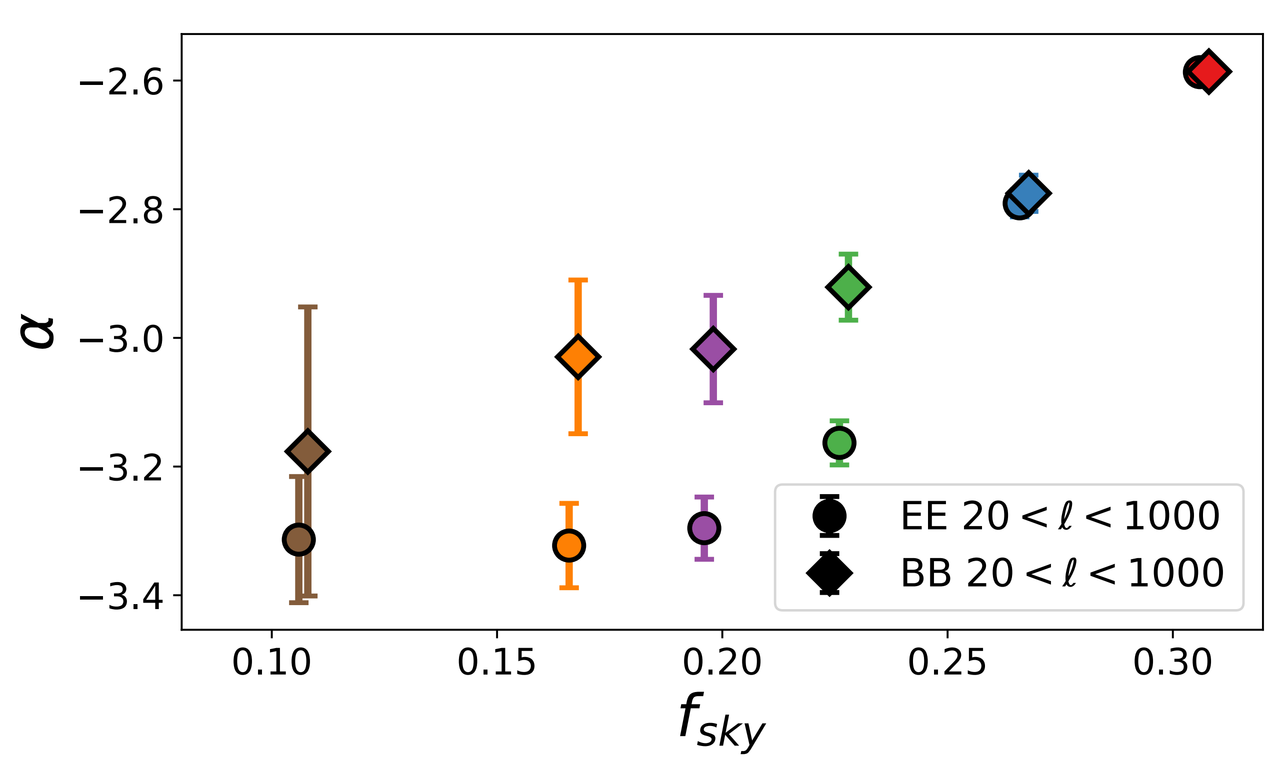
# S-PASS auto power spectra

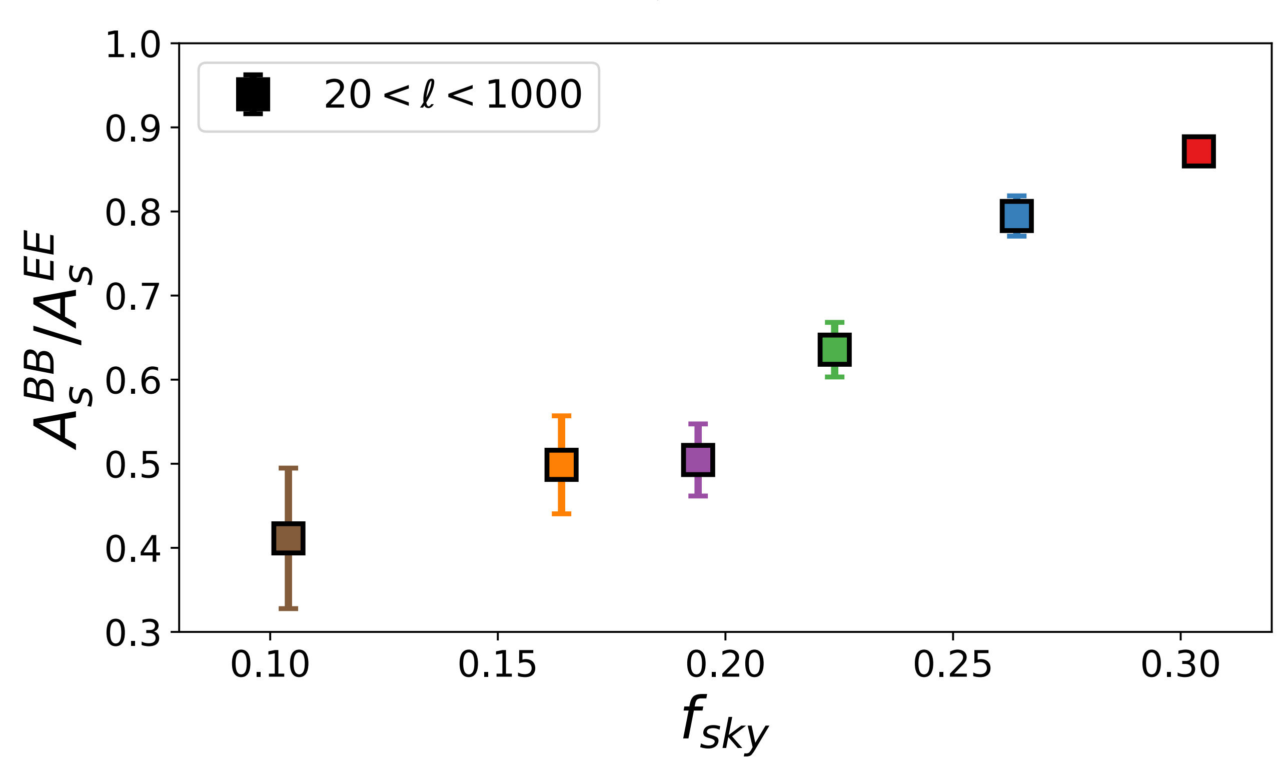


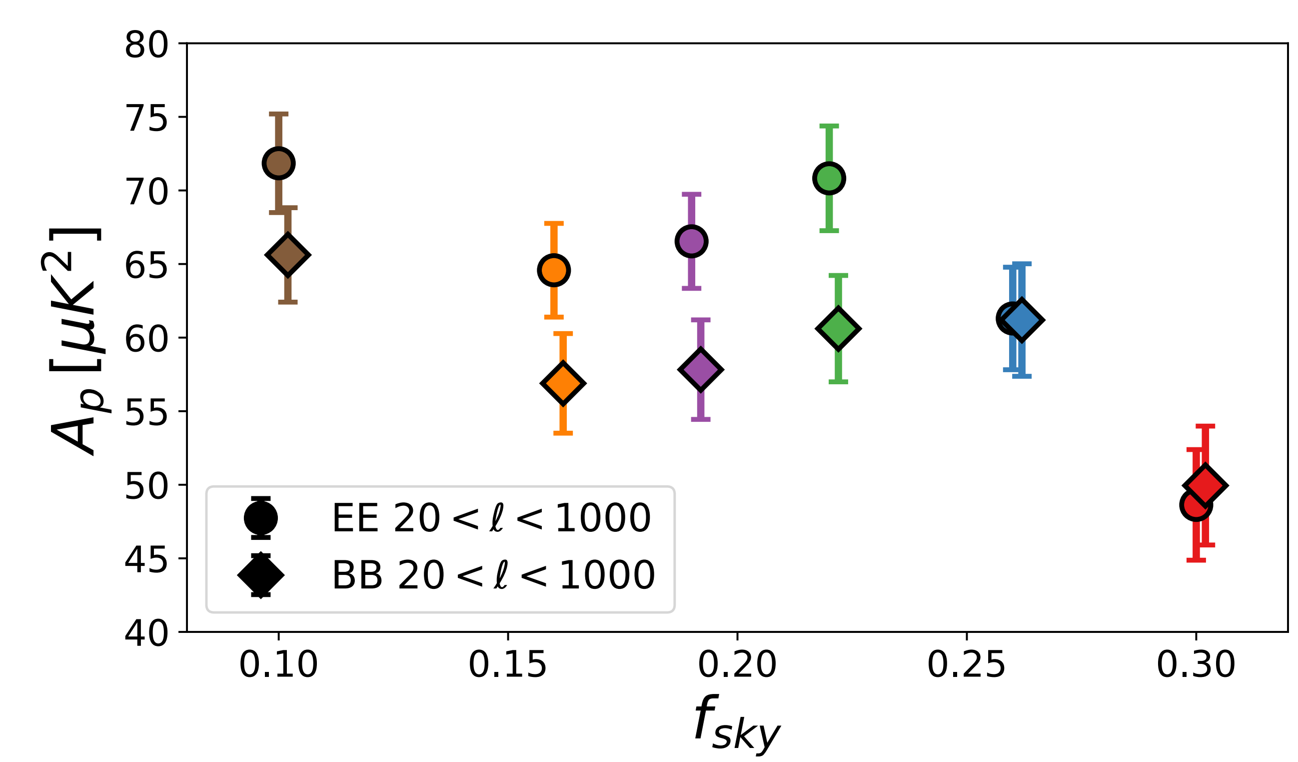




$$C_\ell = A_s \ell^\alpha + A_p$$



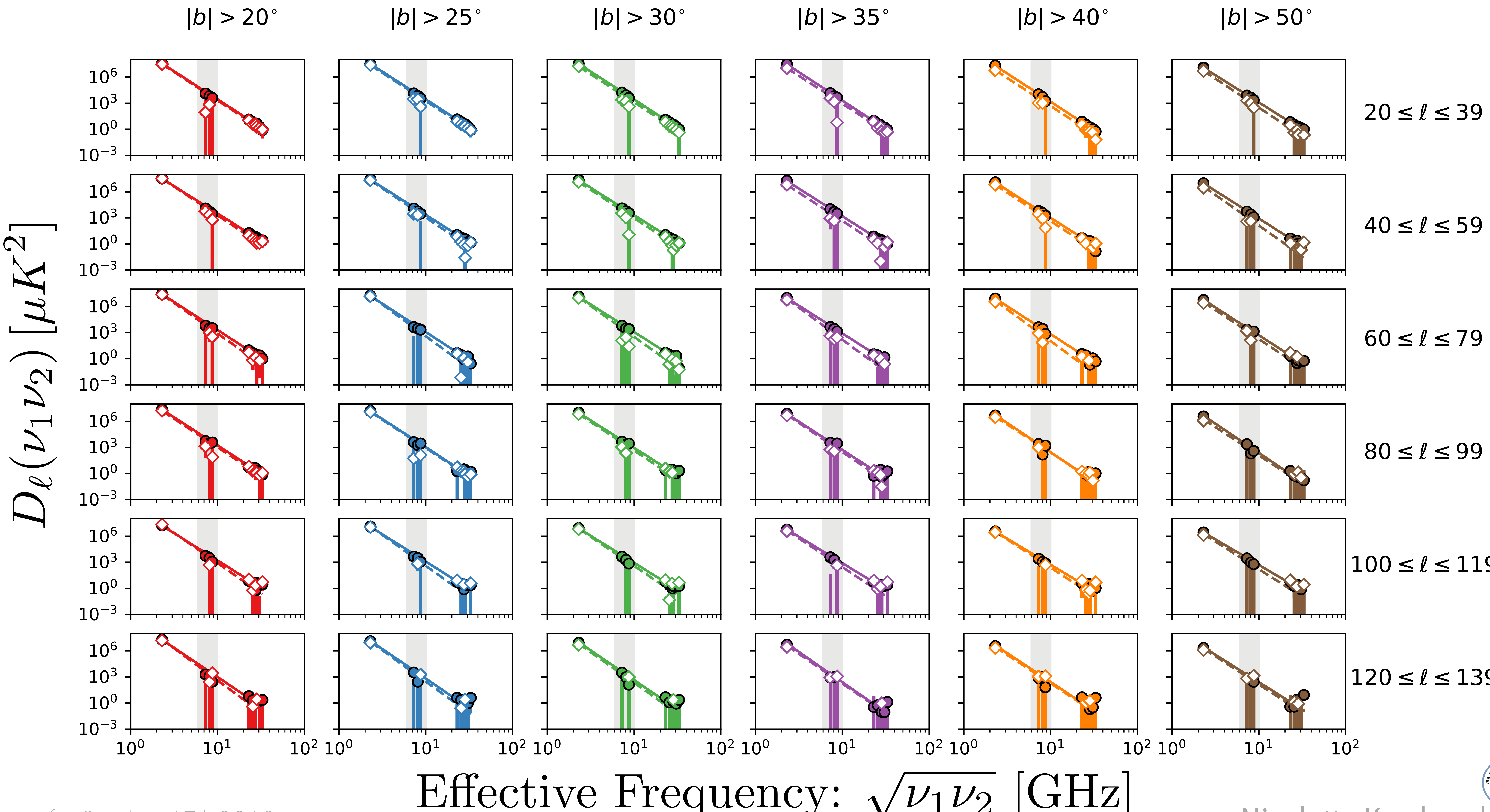



# Synchrotron **SED**

**S-PASS / WMAP-K / LFI-30 / WMAP-Ka**

2.3 GHz 23 GHz 28.4 GHz 33 GHz



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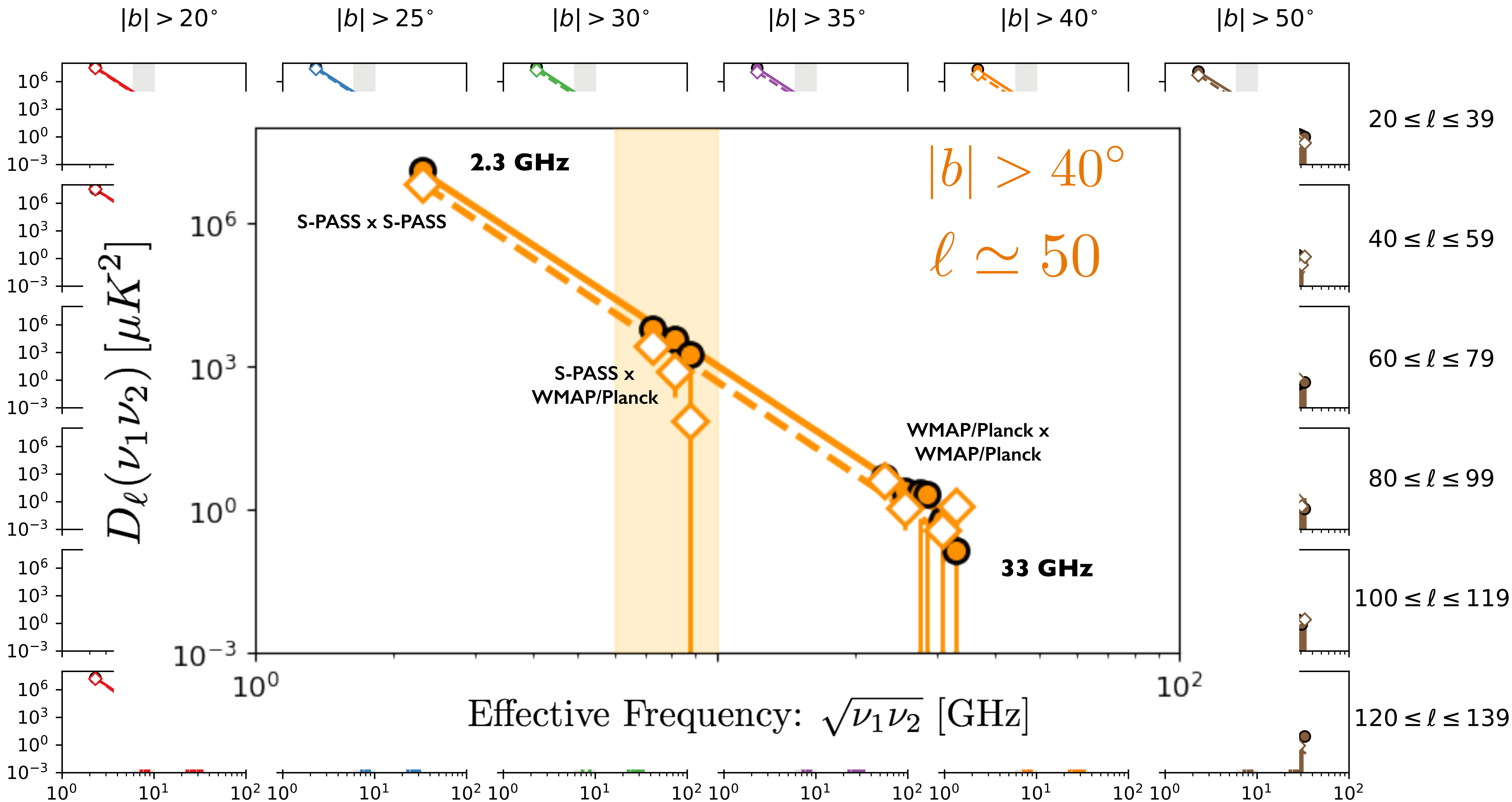

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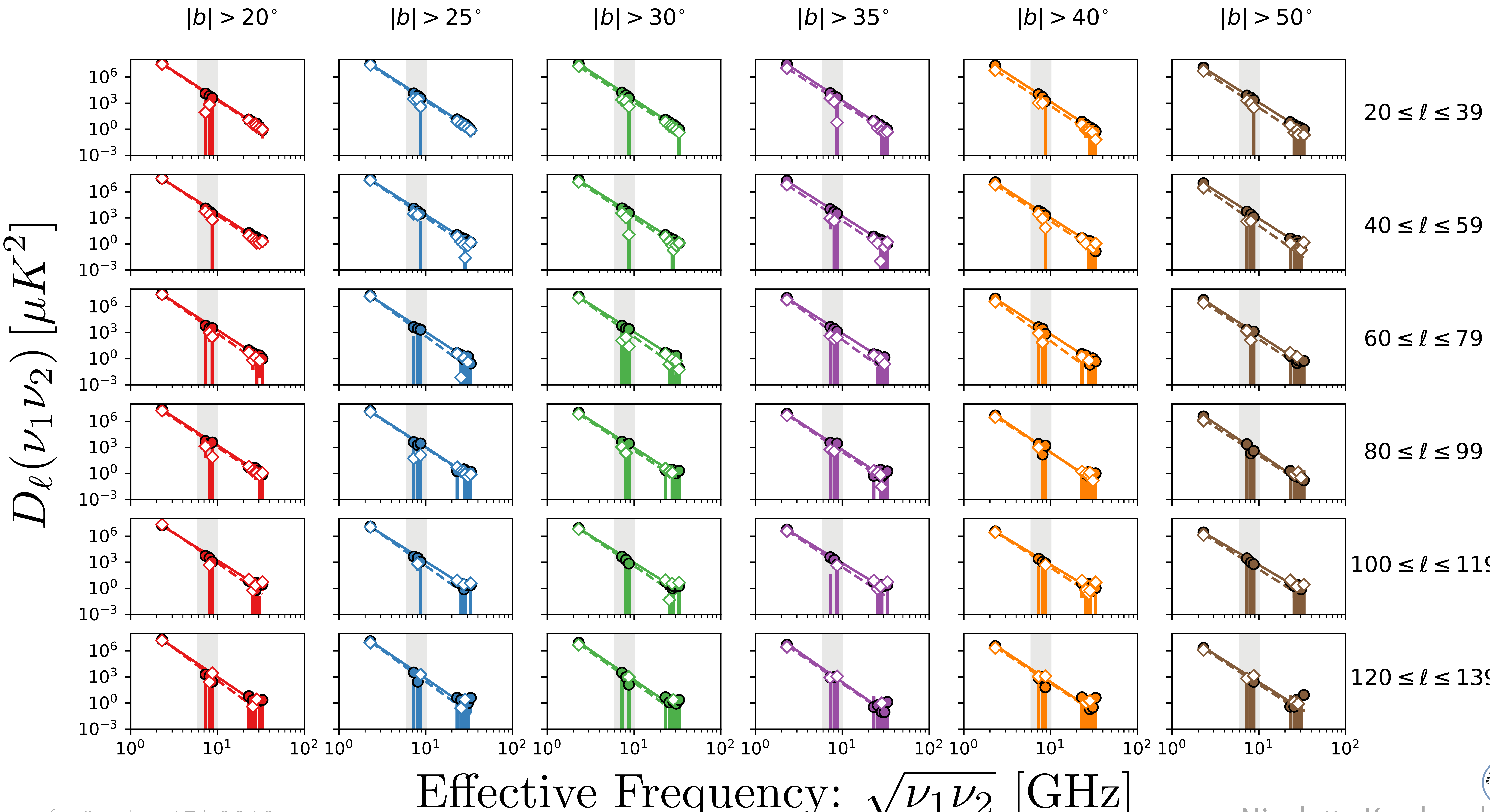




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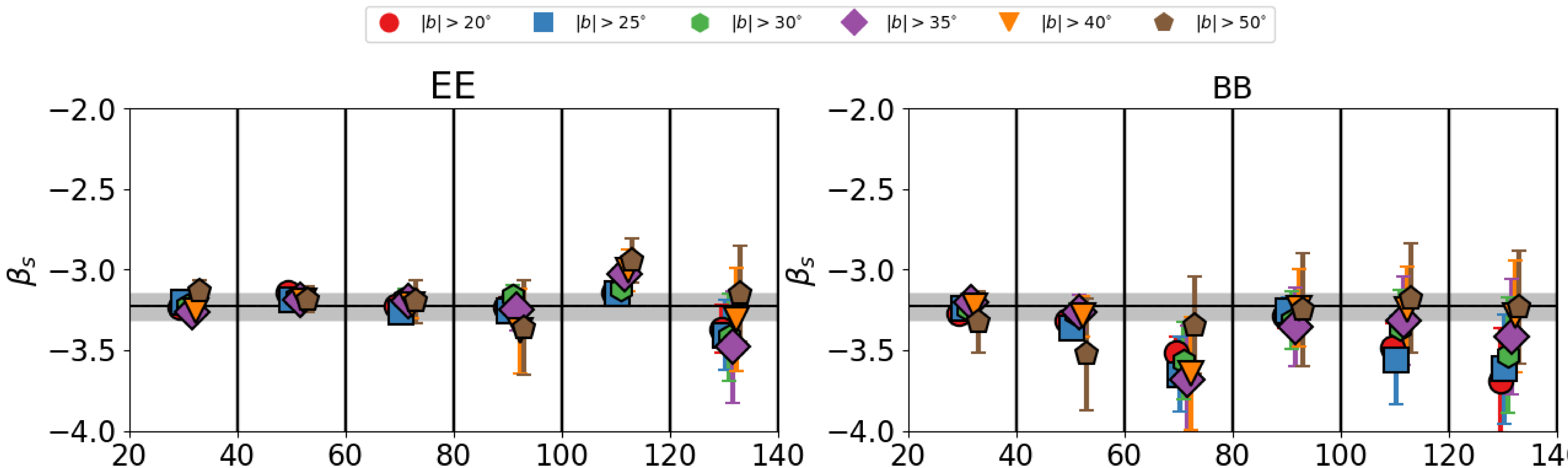
# Synchrotron **SED**

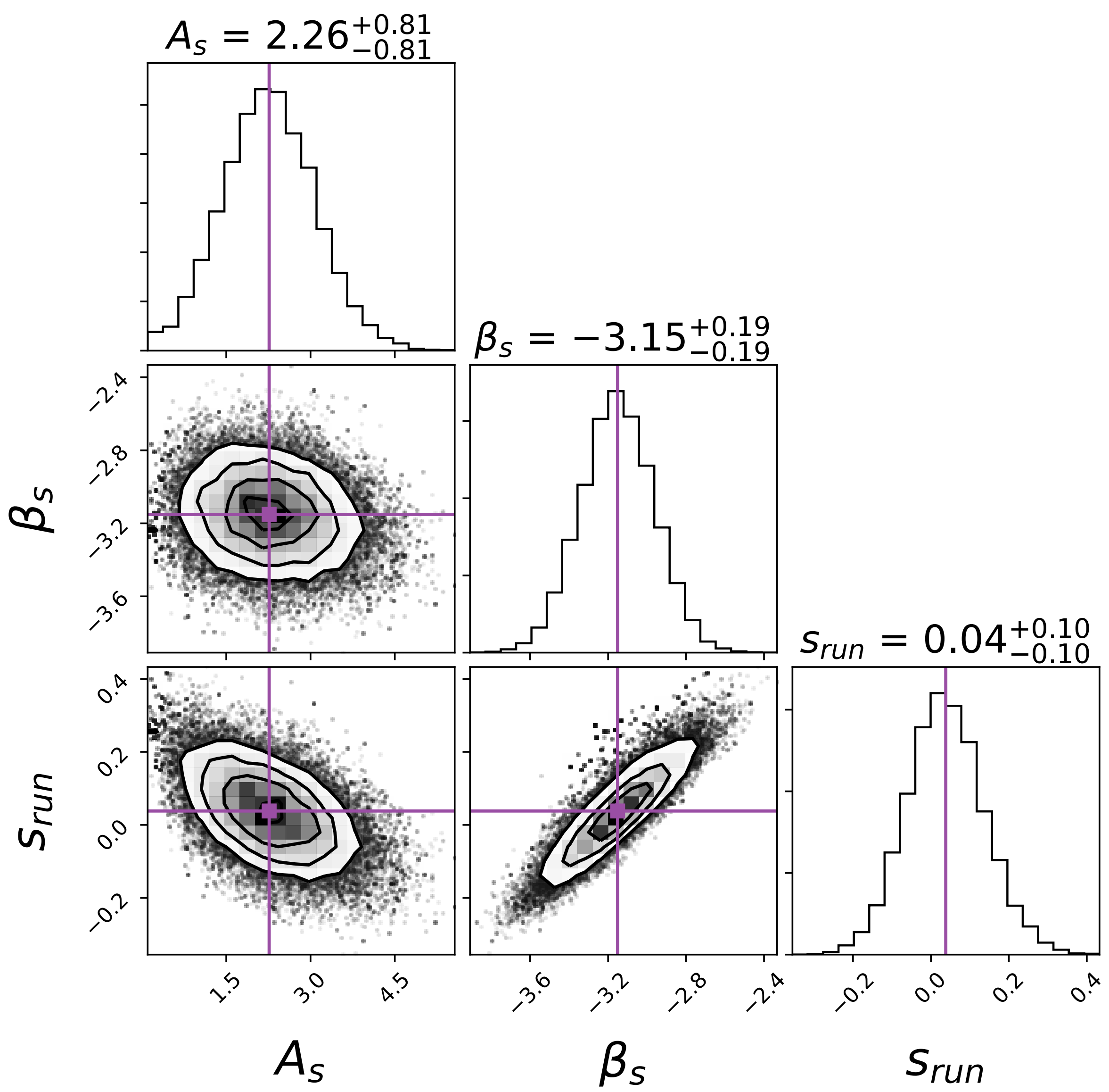



$$\beta_s = -3.22 \pm 0.08$$

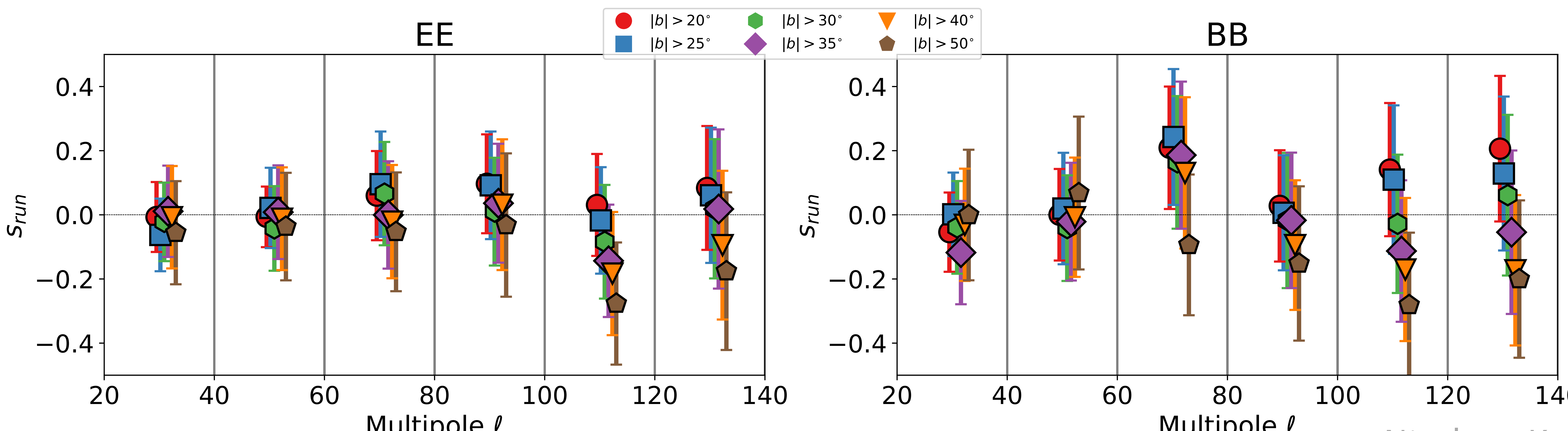
- Constant along the multipole range and for E and B-modes
- **In agreement with constraints coming from WMAP and Planck**

# Constraints on **curvature**

$$D_\ell(\nu_1 \times \nu_2) = A_s \left(\frac{\nu_1}{\nu_0}\right)^{\beta_s + s_{run}\log(\nu_1/\nu_0)} \left(\frac{\nu_2}{\nu_0}\right)^{\beta_s + s_{run}\log(\nu_2/\nu_0)}$$




- Strong degeneracy between $\beta_s$ and $s_{run}$
- **Gaussian prior on spectral index** from WMAP and Planck: $\boldsymbol{\beta_s = -3.13\pm0.13}$
- **$s_{run}$ compatible with zero**, with 1$\sigma$ errors between 0.07 and 0.14
- More data at intermediate frequencies are needed (C-BASS in south, QUIJOTE and C-BASS in north)

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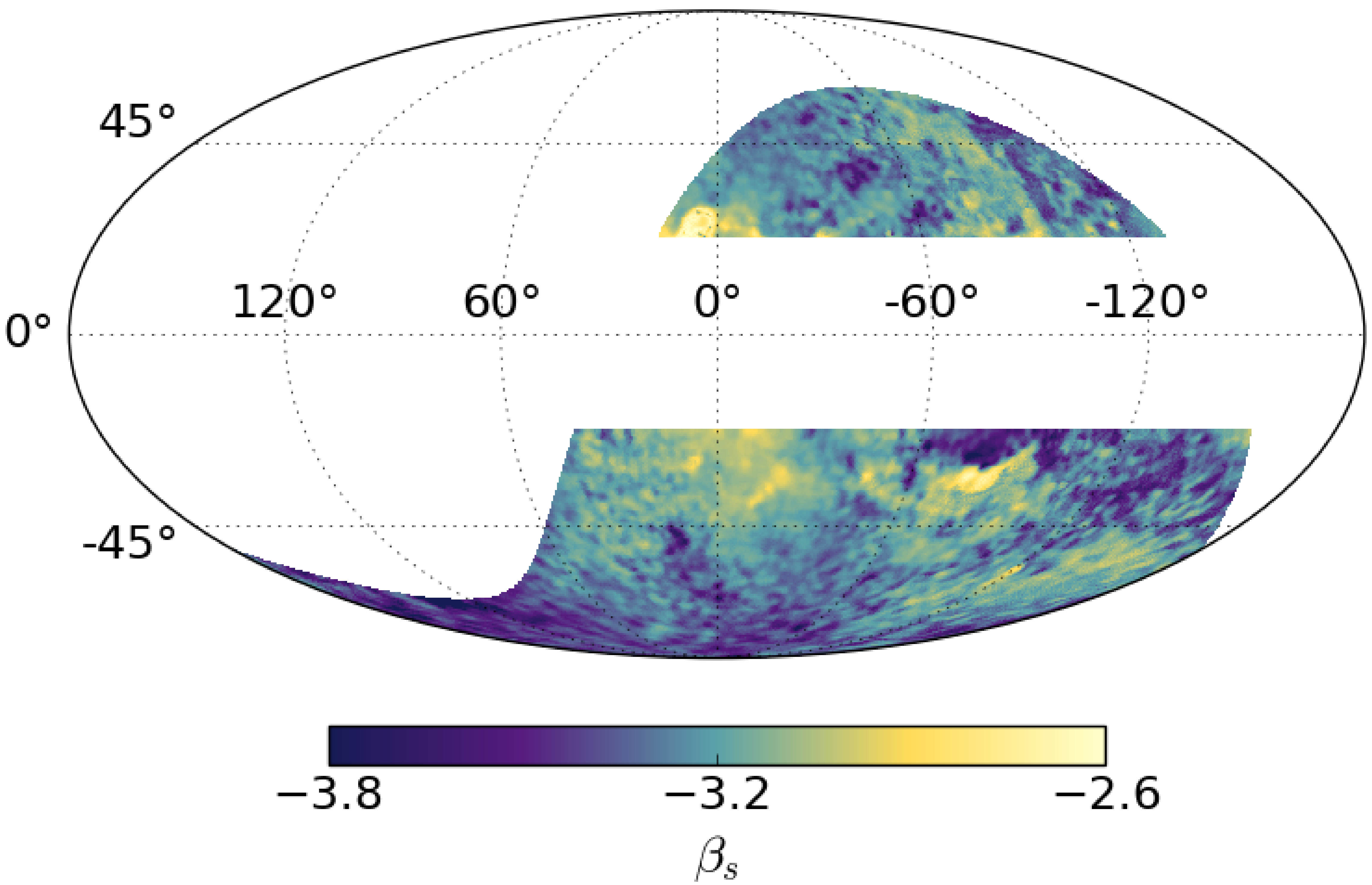
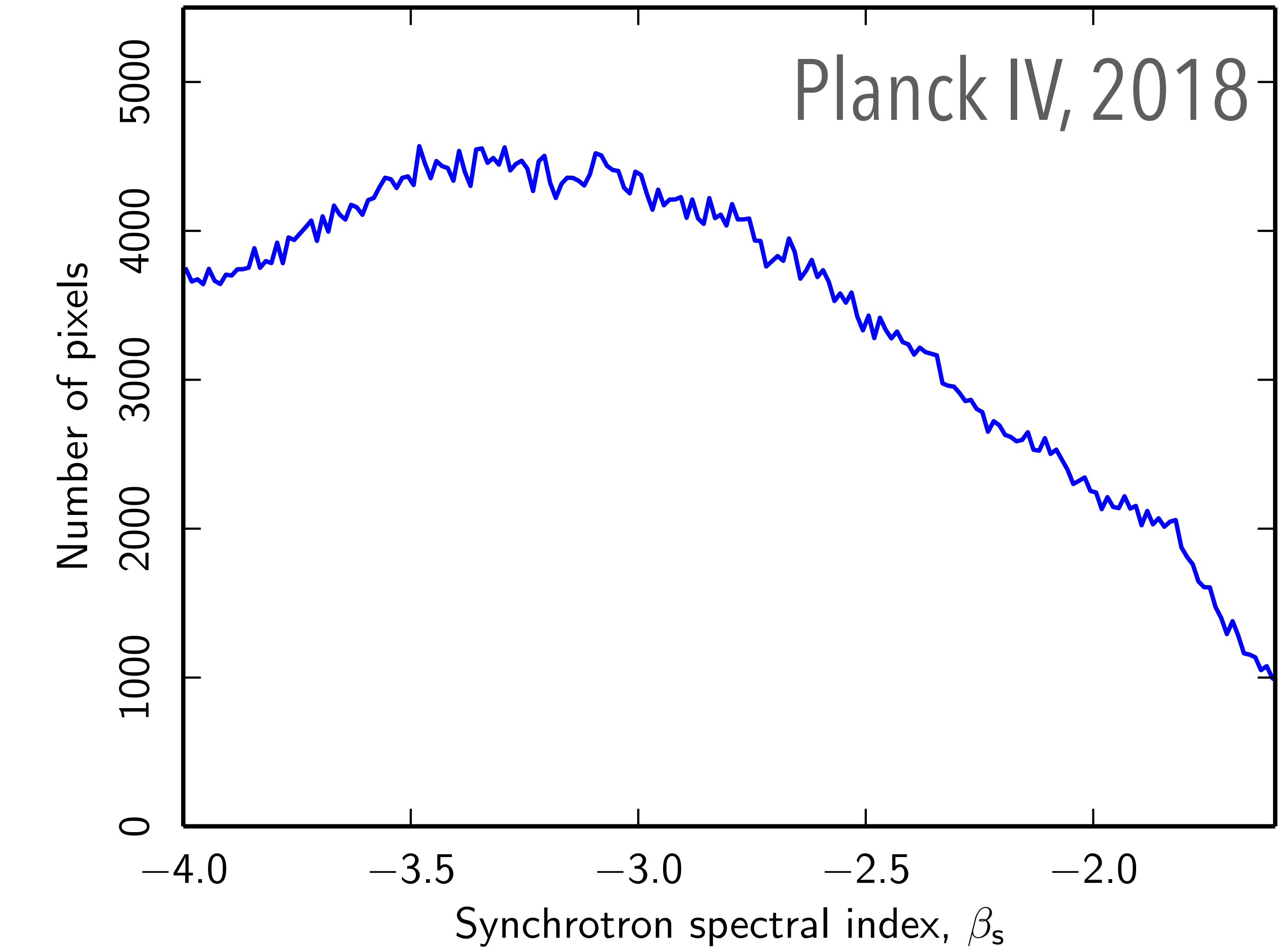
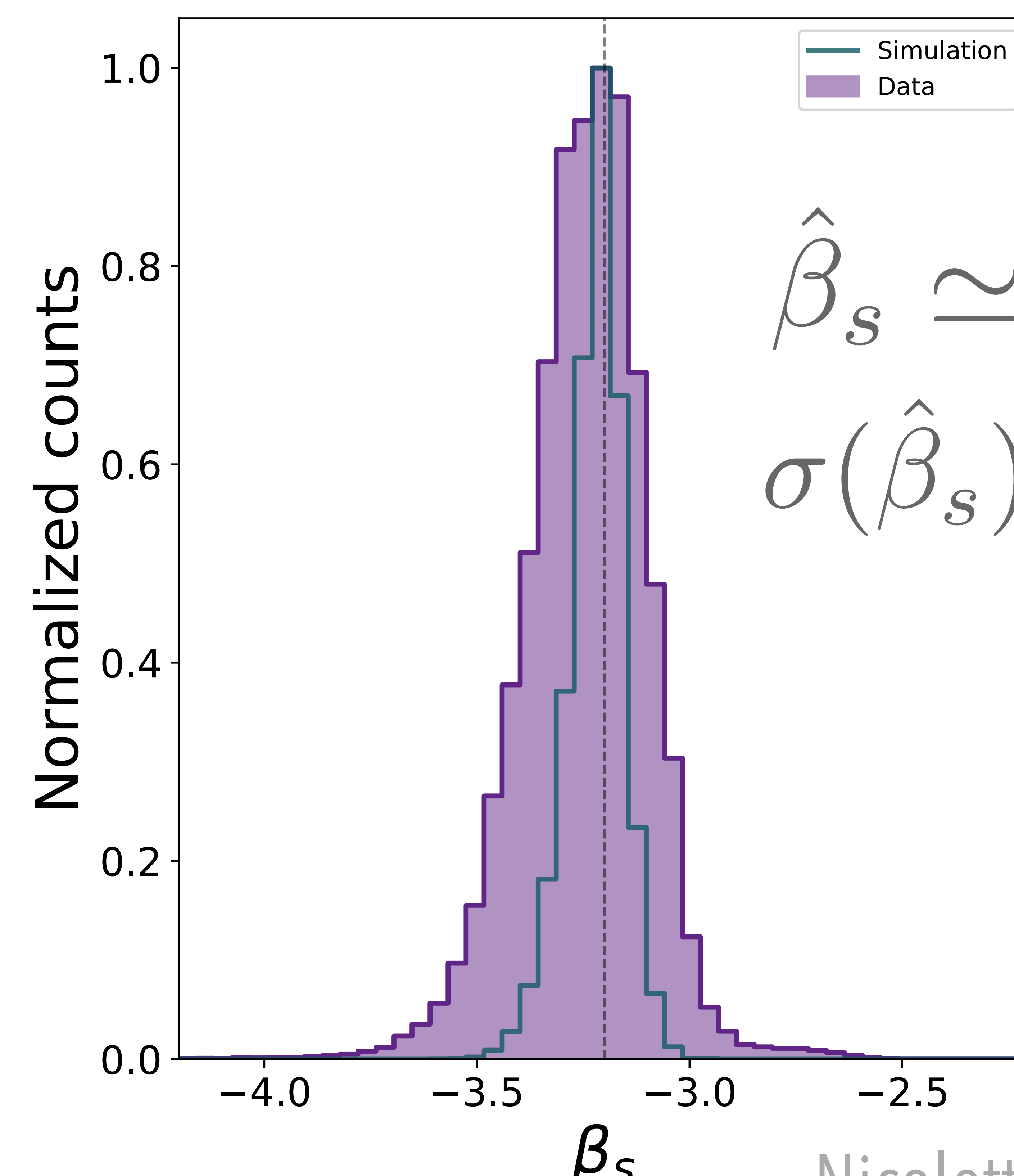
# Synchrotron **spectral index map**



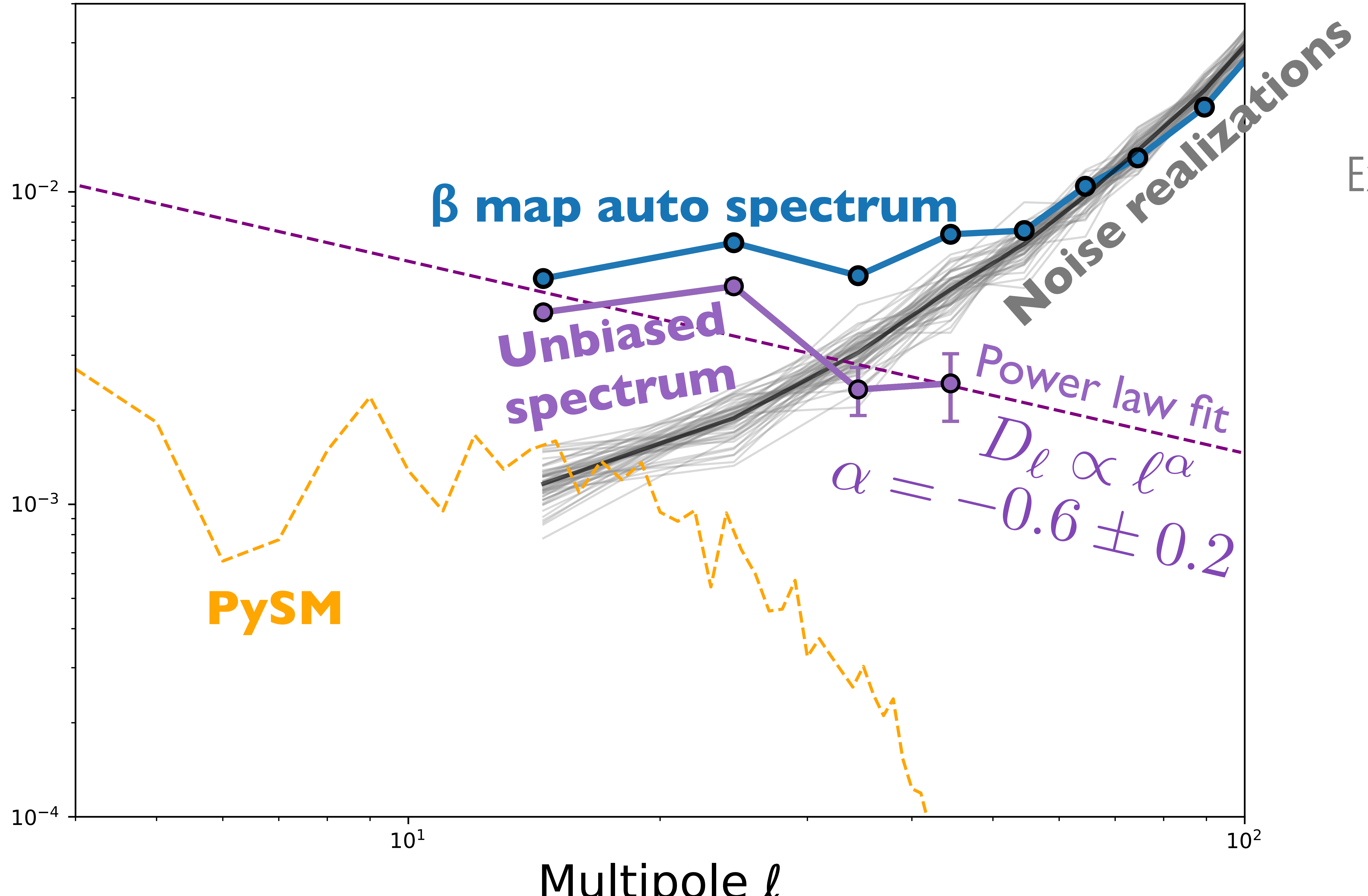

- **Power law fit in range** **2.3 - 33 GHz**
- Fit in each pixel in **total polarized intensity** taking into account the noise bias
- **Angular resolution of 2°**
- Sky coverage ~ 30%
- No prior




$$\hat{\beta}_s \simeq -3.20$$

$$\sigma(\hat{\beta}_s) \simeq 0.15$$

# **Power spectrum** of spectral index map




## **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

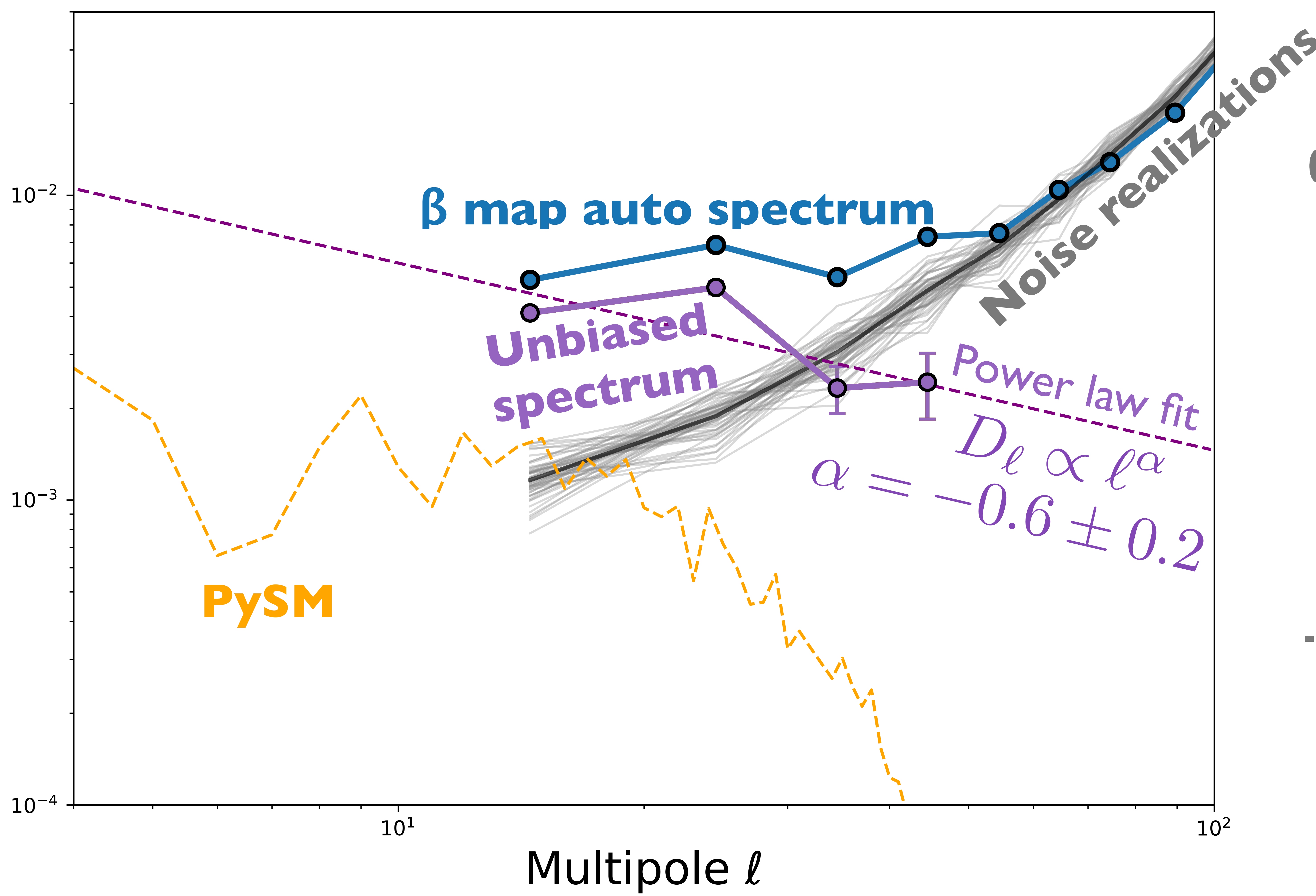
↓

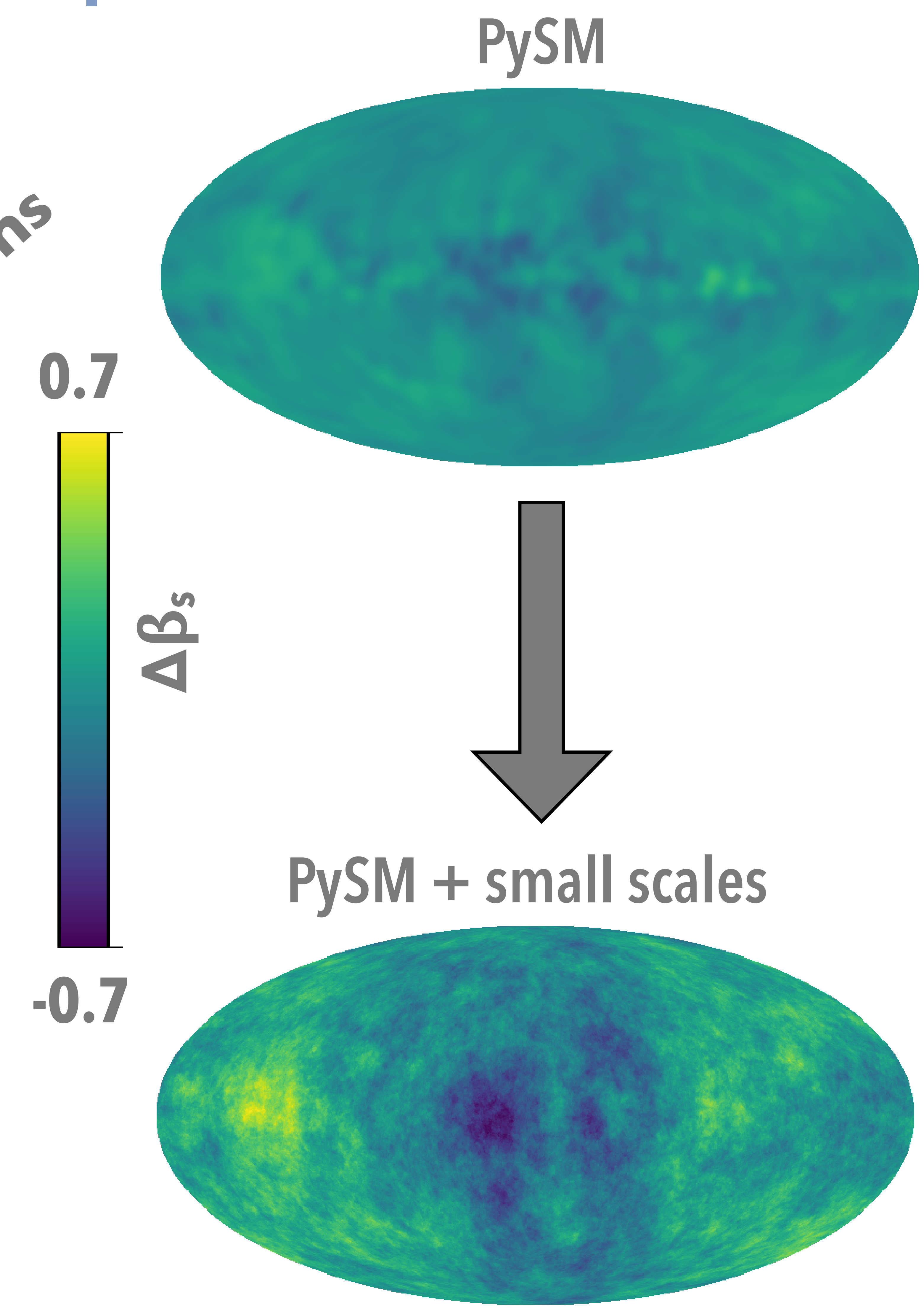
Estimate $\beta^*$

↓

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

# **Power spectrum** of spectral index map



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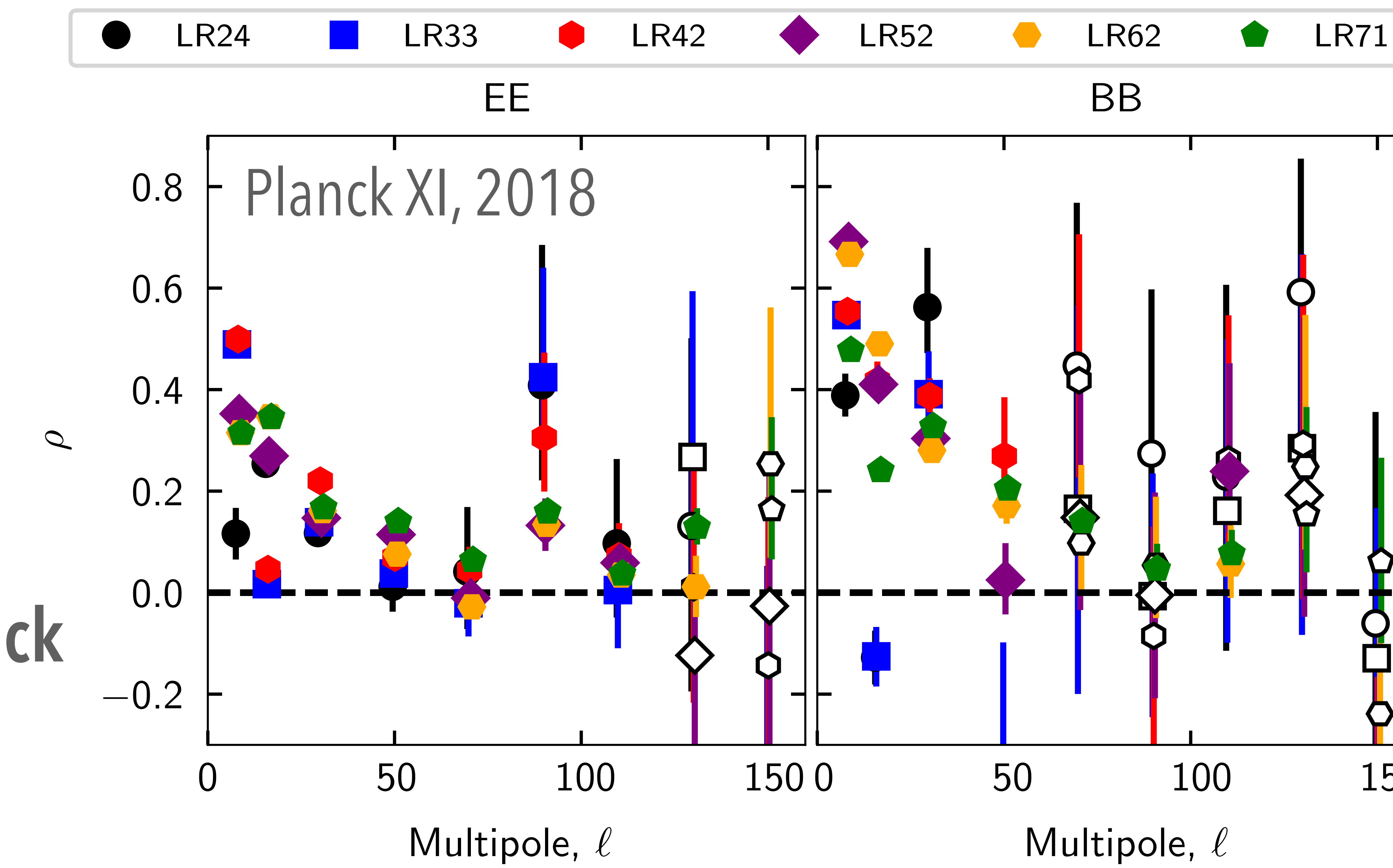
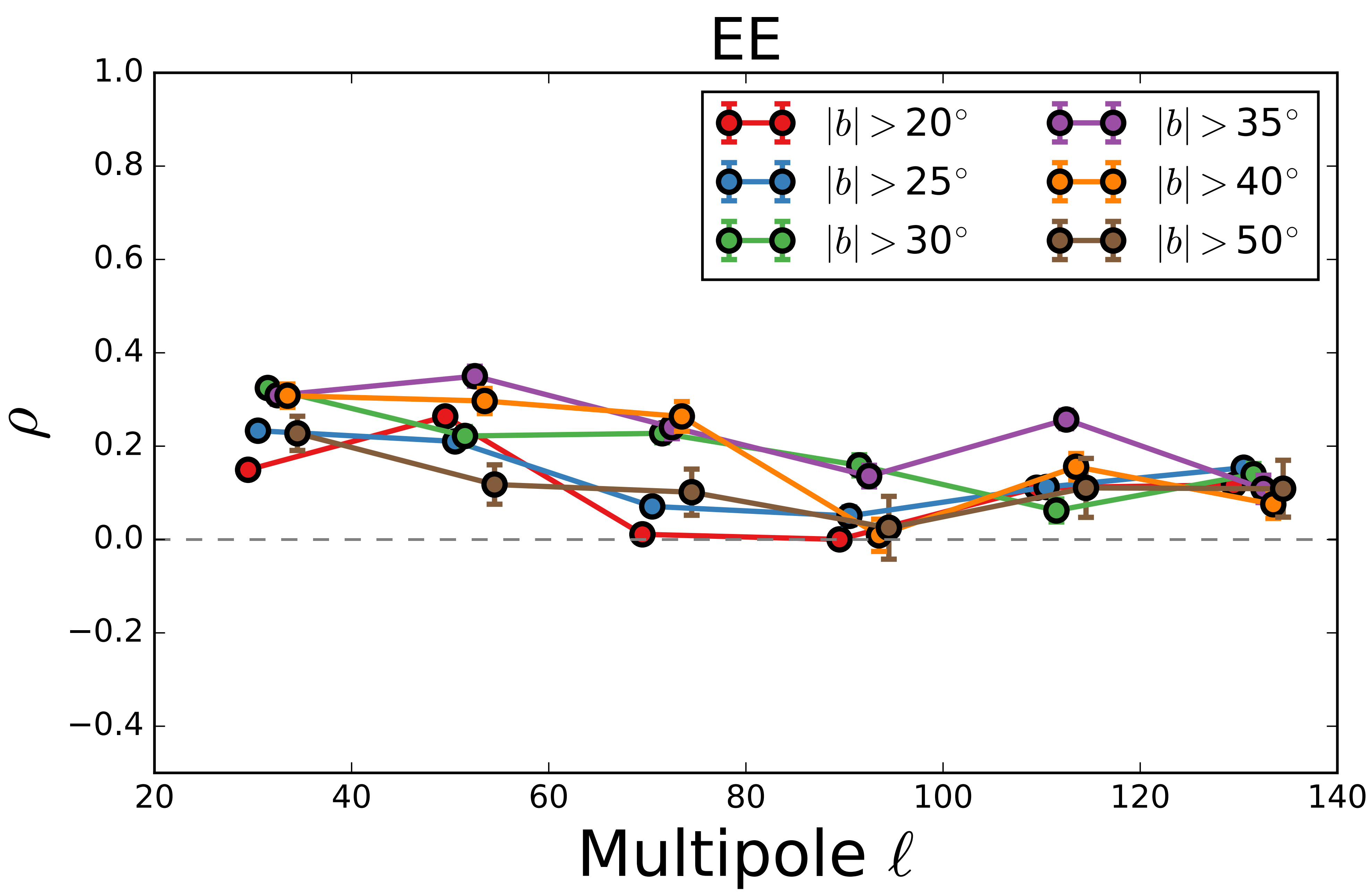
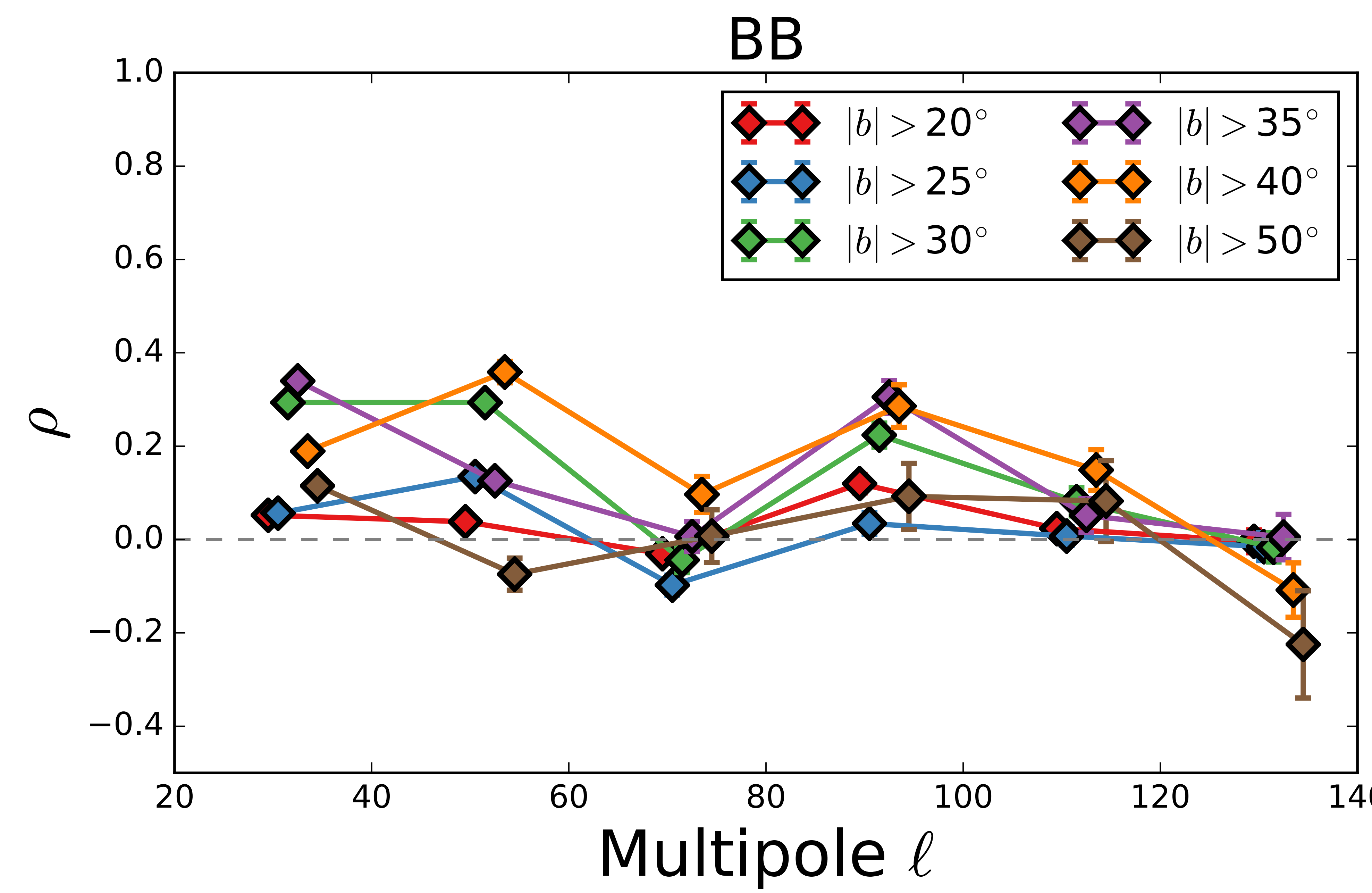
# Synch x Dust

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




- level of **correlation between 2.3 and 353 GHz** is **compatible with what measured with WMAP and Planck** channels

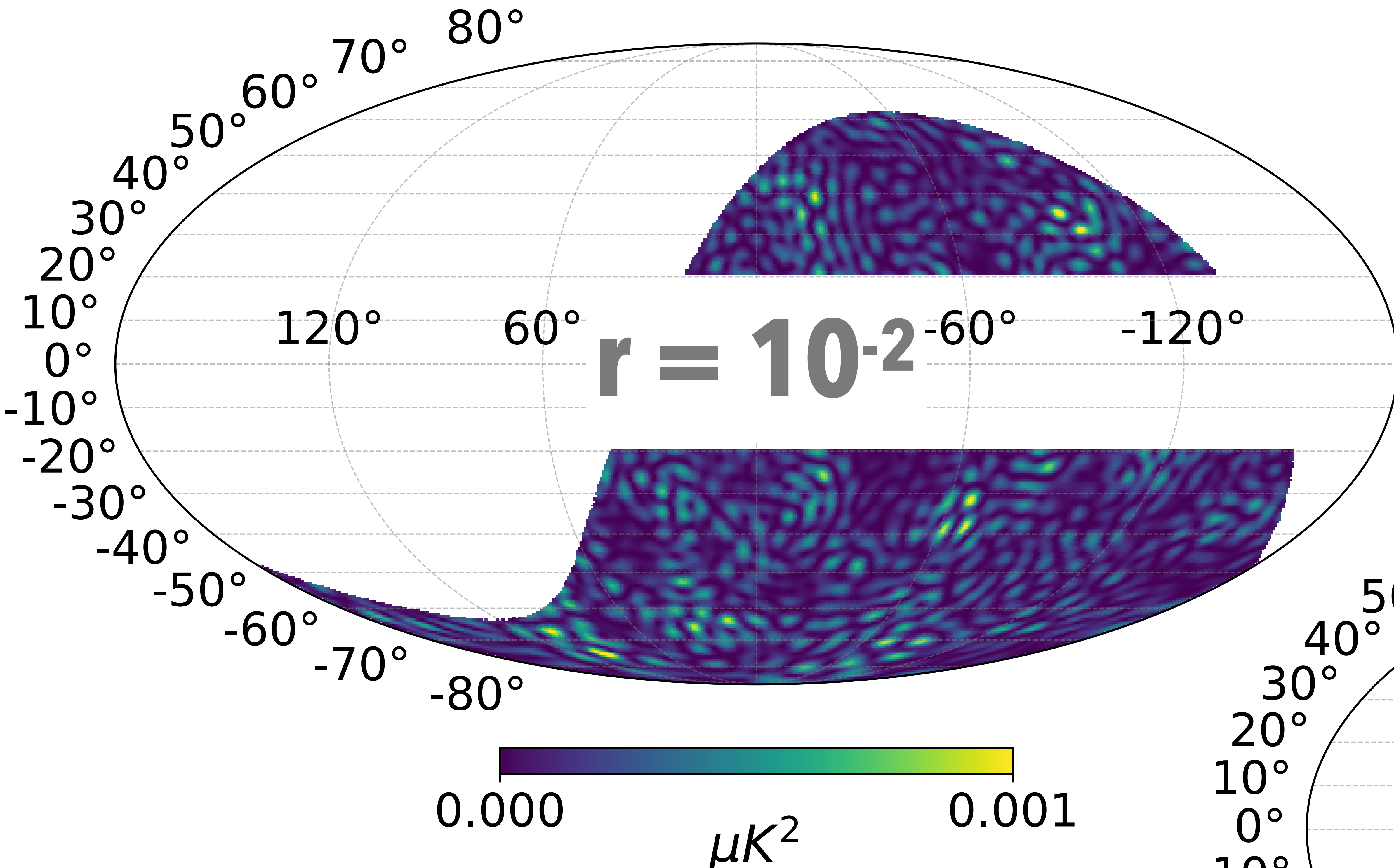


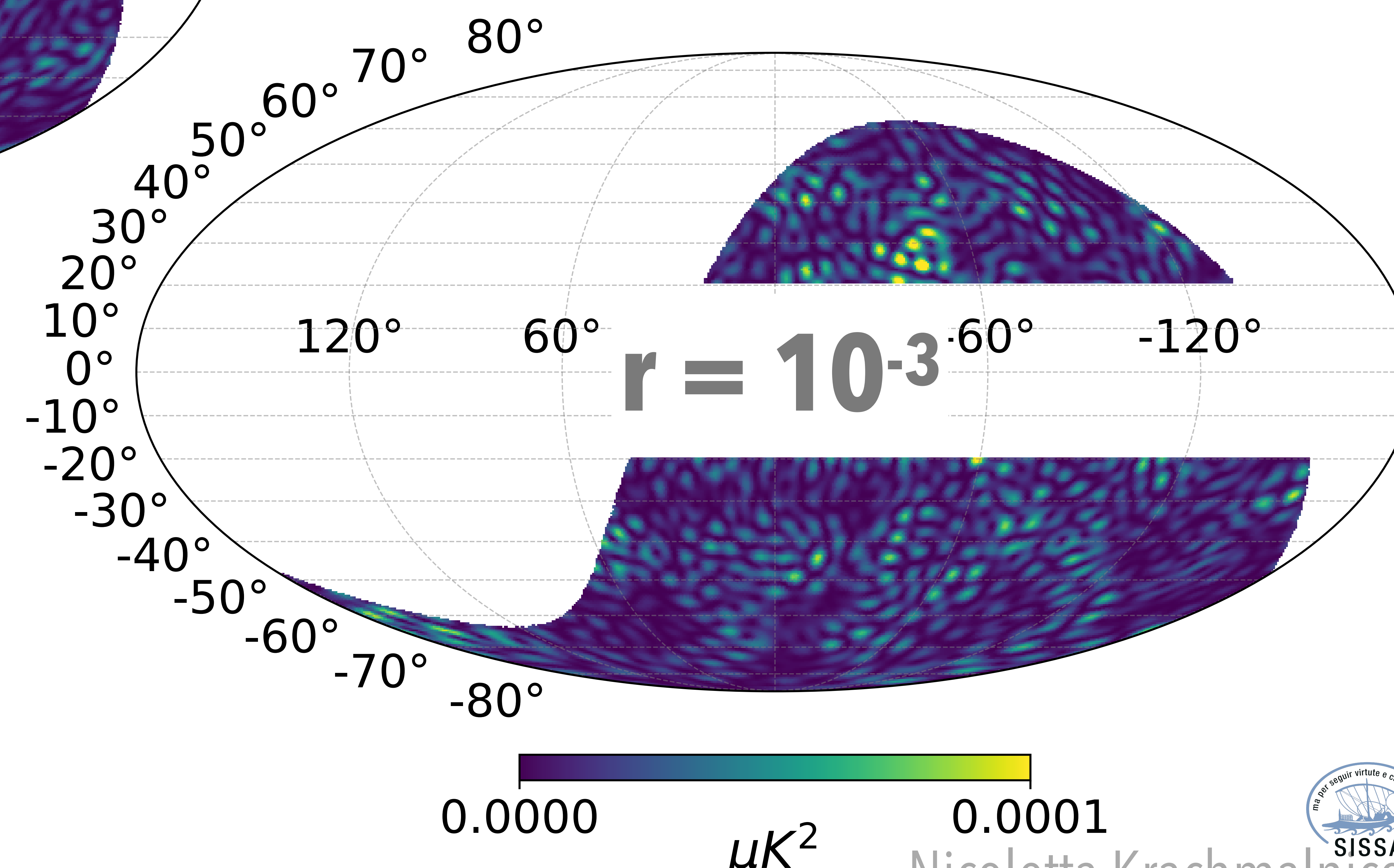



# Synch contamination to CMB B-modes

CMB maps - only B-modes
(Total polarized intensity)$^2$

$$\ell \simeq 40$$



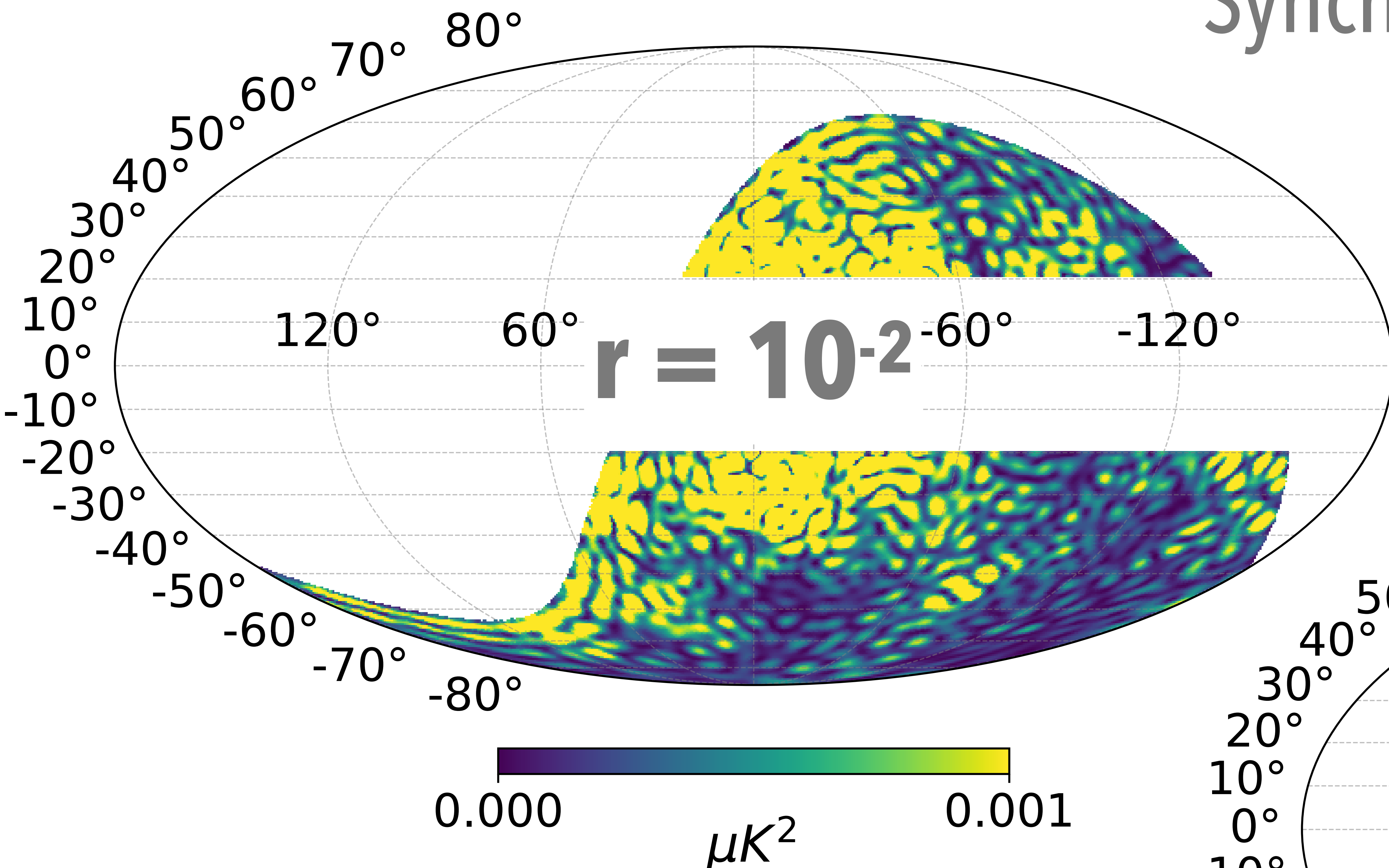



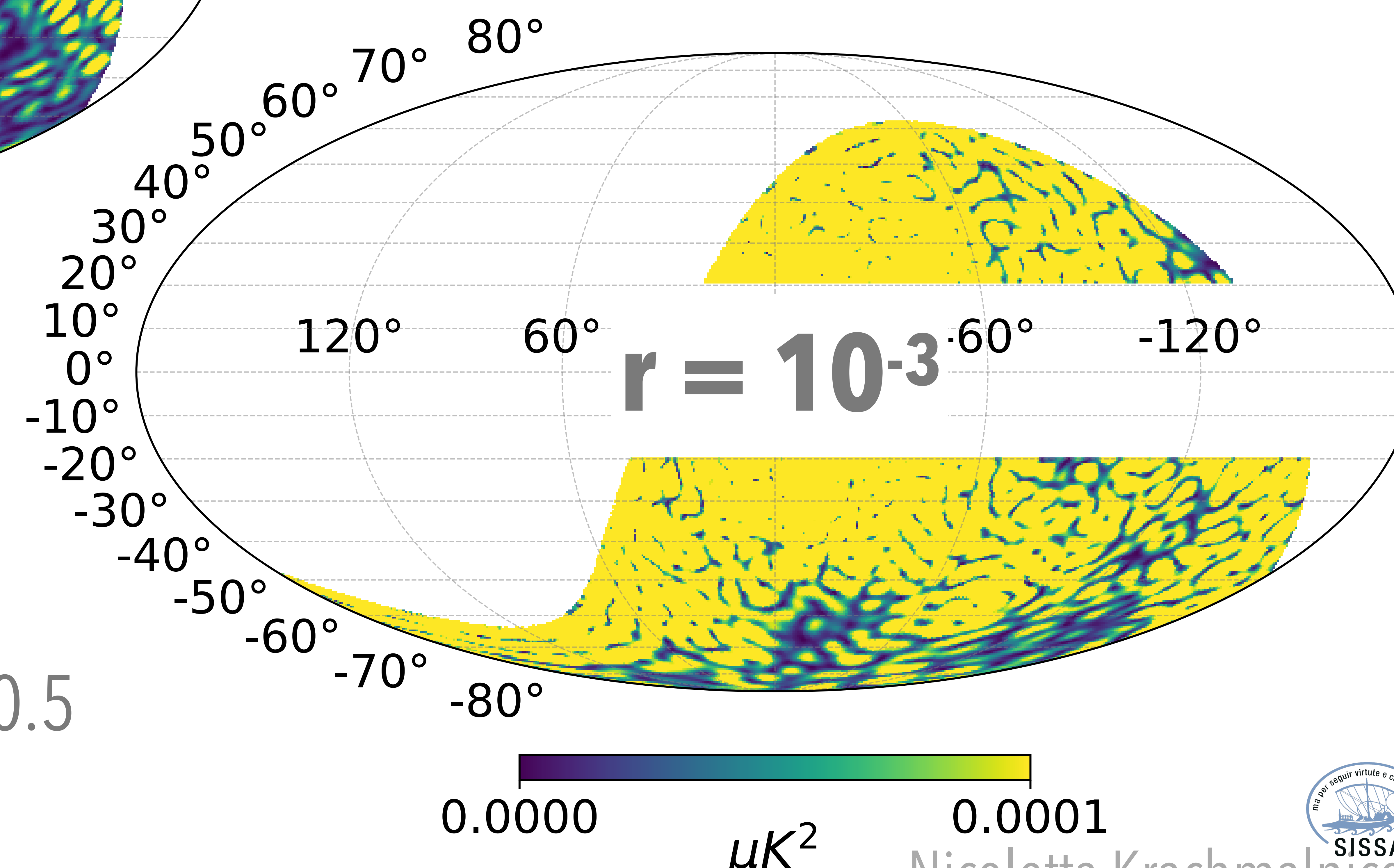
# Synch contamination to CMB B-modes

Synchrotron @ 90 GHz * + CMB B-modes

(Total polarized intensity)$^2$

$$\ell \simeq 40$$




* extrapolated with $\beta_s$ = -3.2, BB/EE = 0.5



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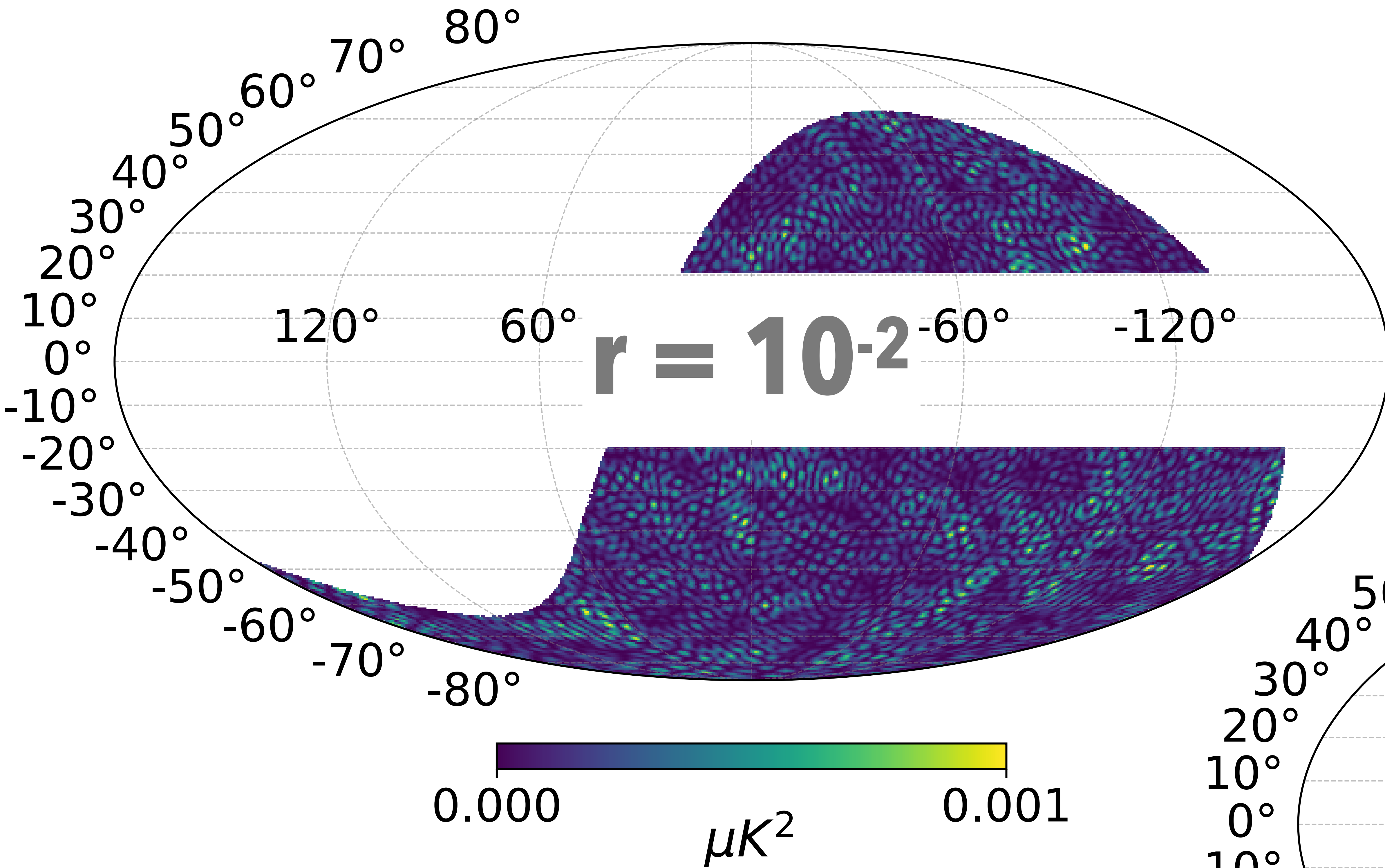
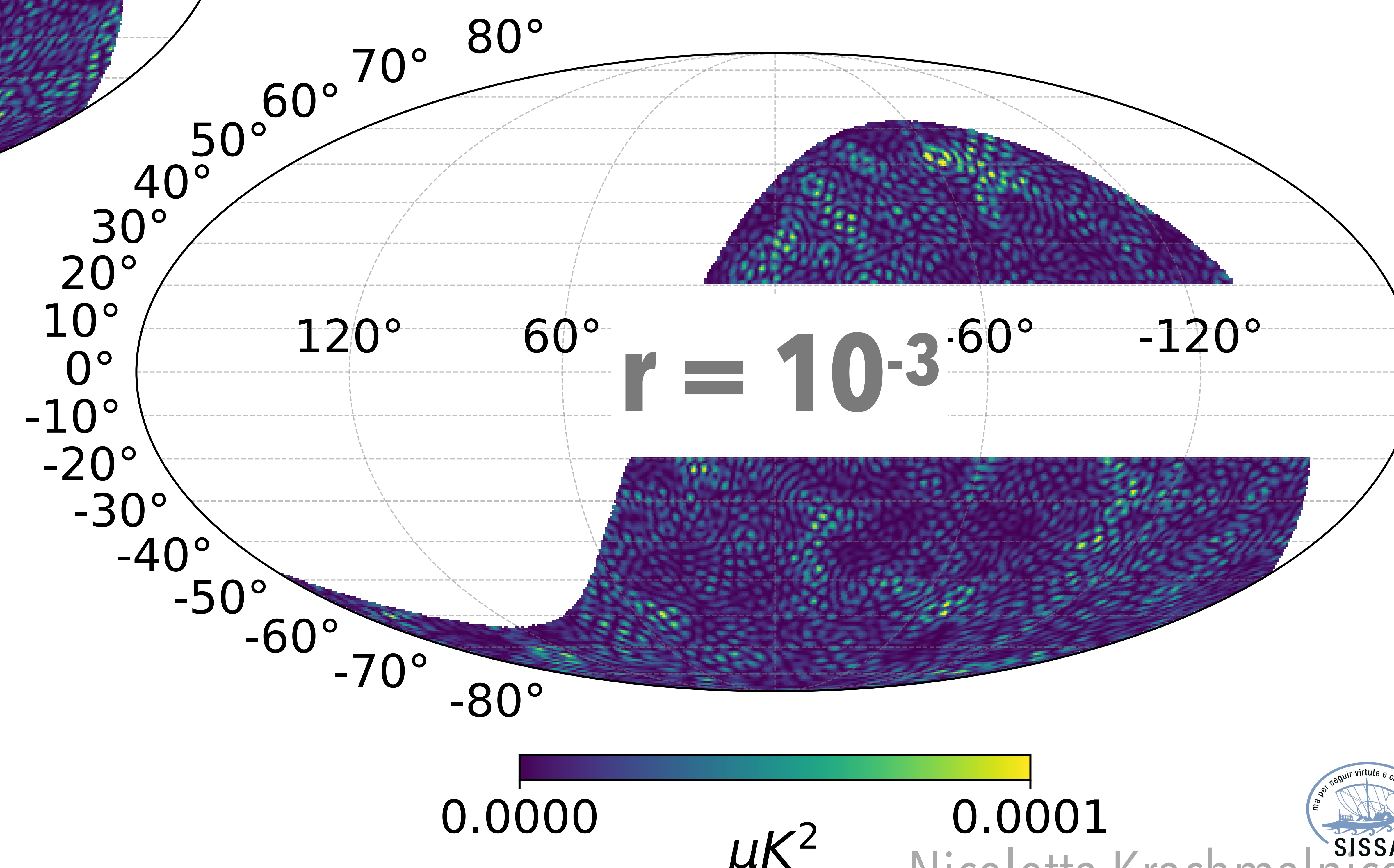
# Synch contamination to CMB B-modes

CMB maps - only B-modes

(Total polarized intensity)$^2$

$$\ell \simeq 80$$



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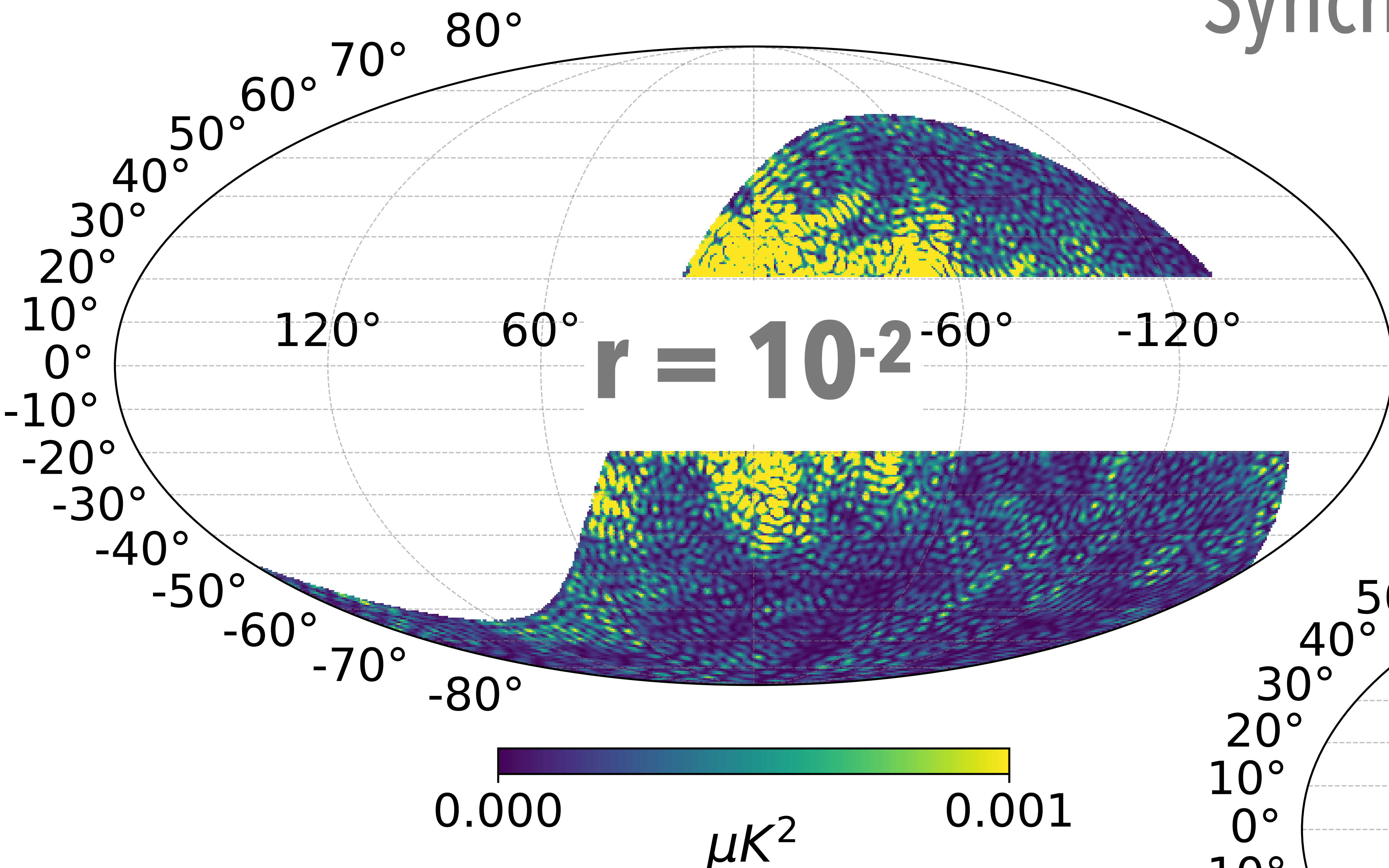
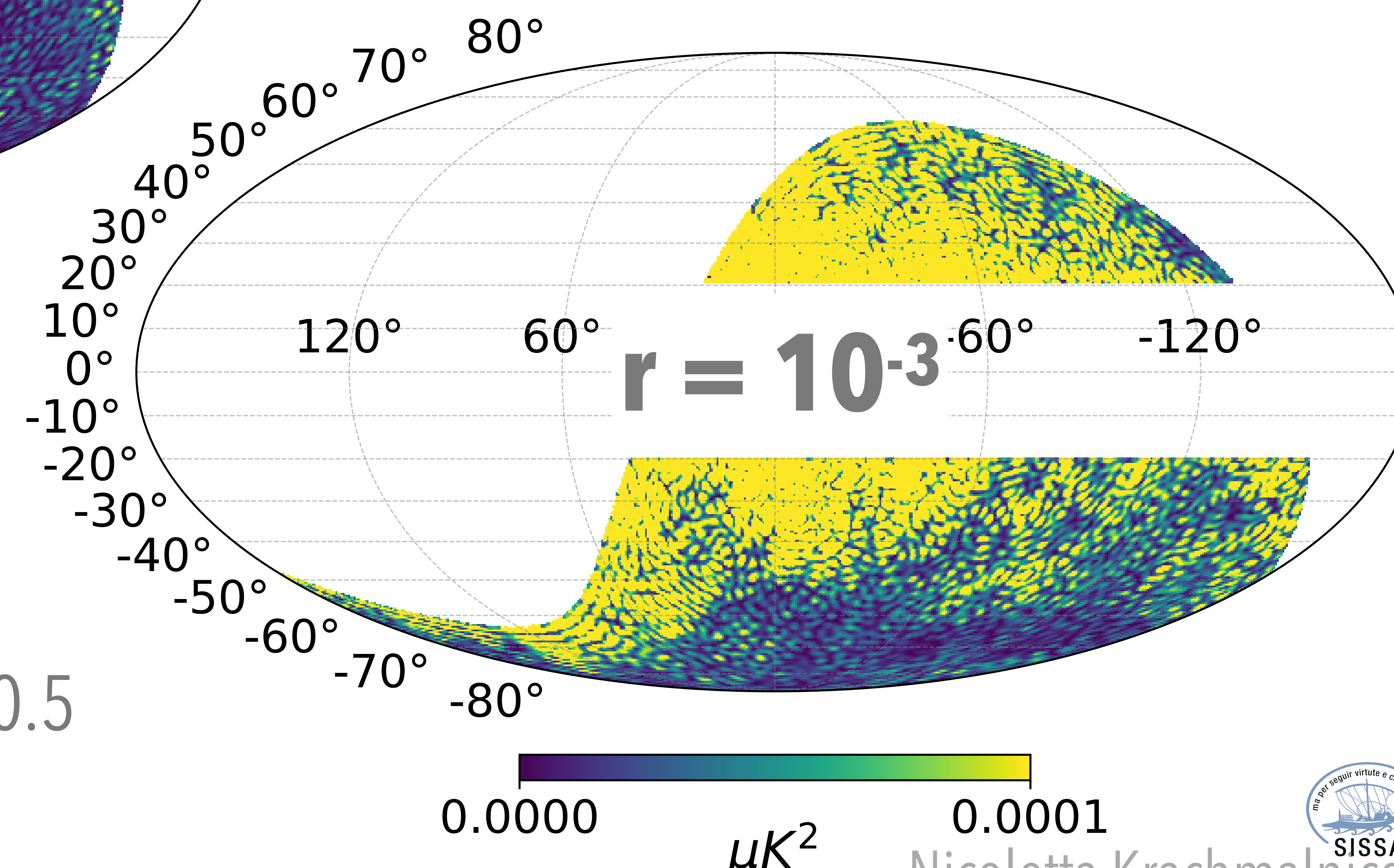
# Synch contamination to CMB B-modes

Synchrotron @ 90 GHz * + CMB B-modes
(Total polarized intensity)$^2$

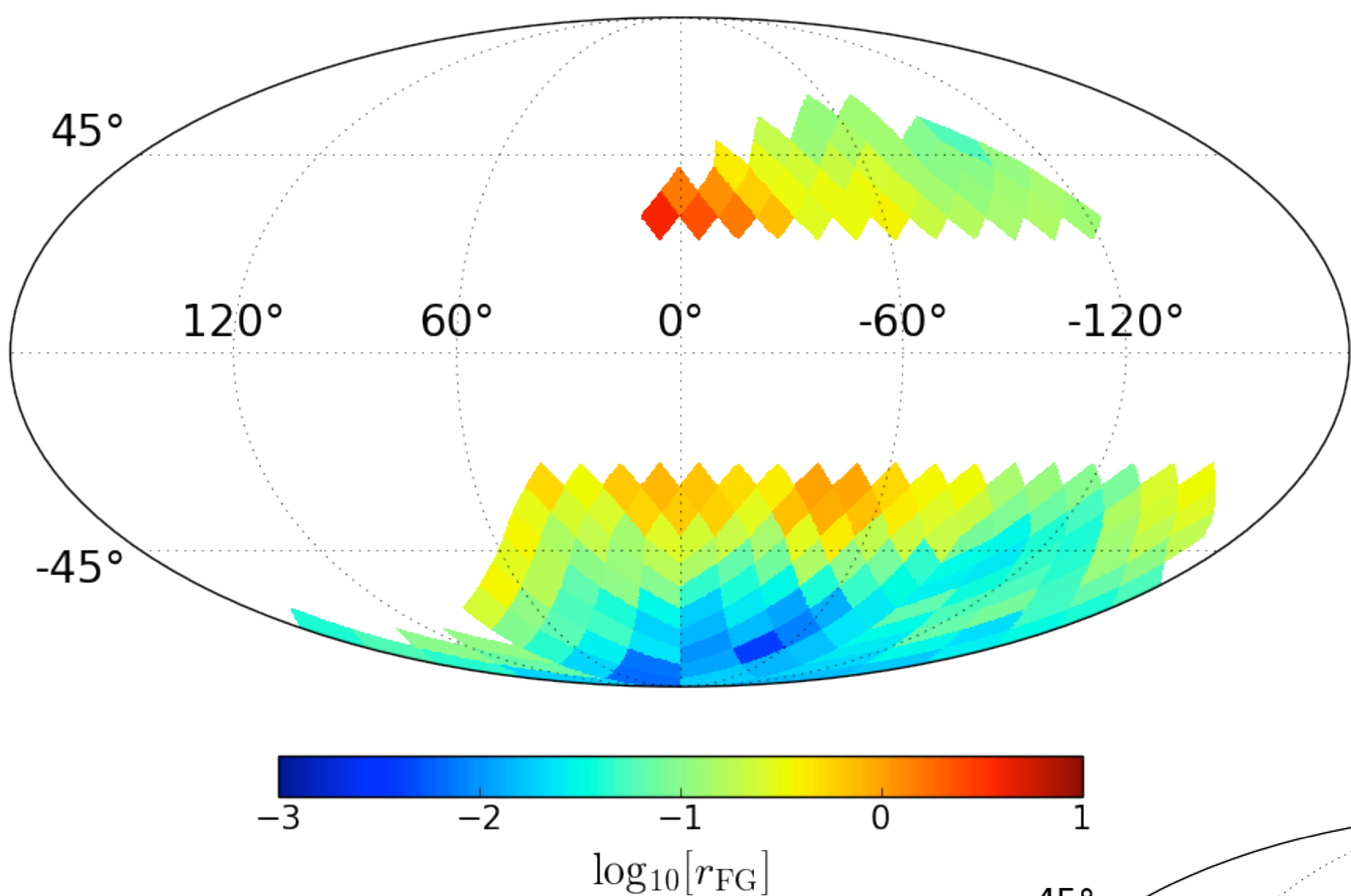
$$\ell \simeq 80$$

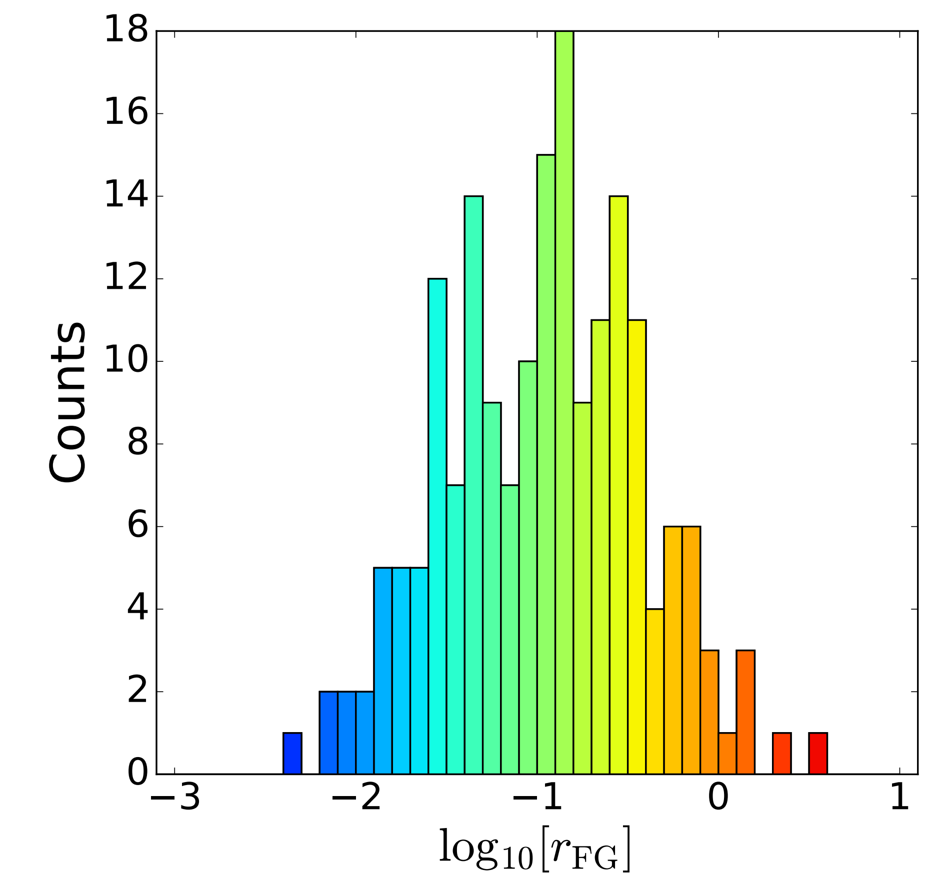


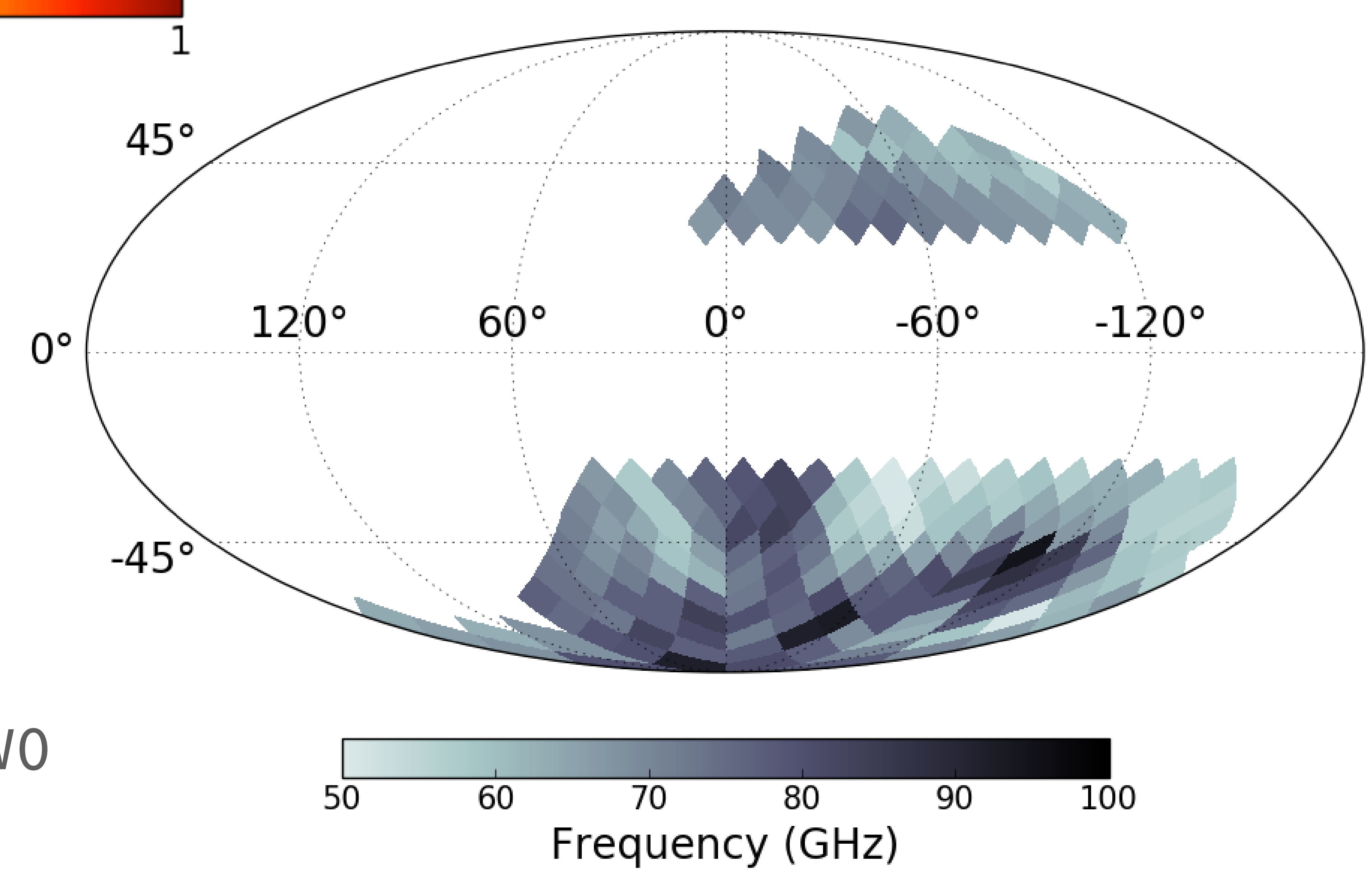



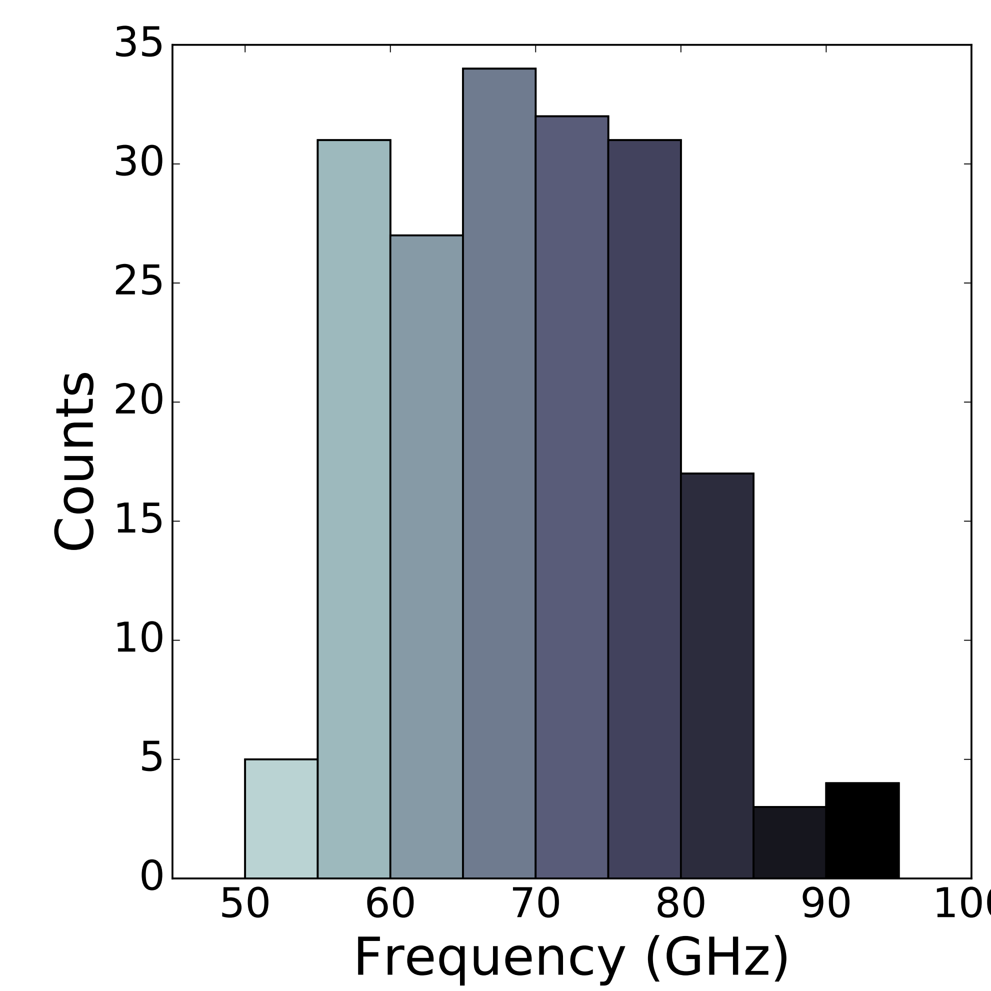

* extrapolated with βs = -3.2, BB/EE = 0.5

# FG contamination to CMB B-modes




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

# Conclusions and prospective

**S-PASS** is an **excellent dataset** for investigating synchrotron emission in **southern hemisphere** at **high Galactic latitudes** (|b| >30°)

**High S/N power spectra**: steep decay at small angular scales ➡ $C_\ell \propto \ell^\alpha$ with $\alpha < -3$

**Synchrotron SED** for E and B-modes as a function of multiple ➡ $\beta_s = -3.22 \pm 0.08$

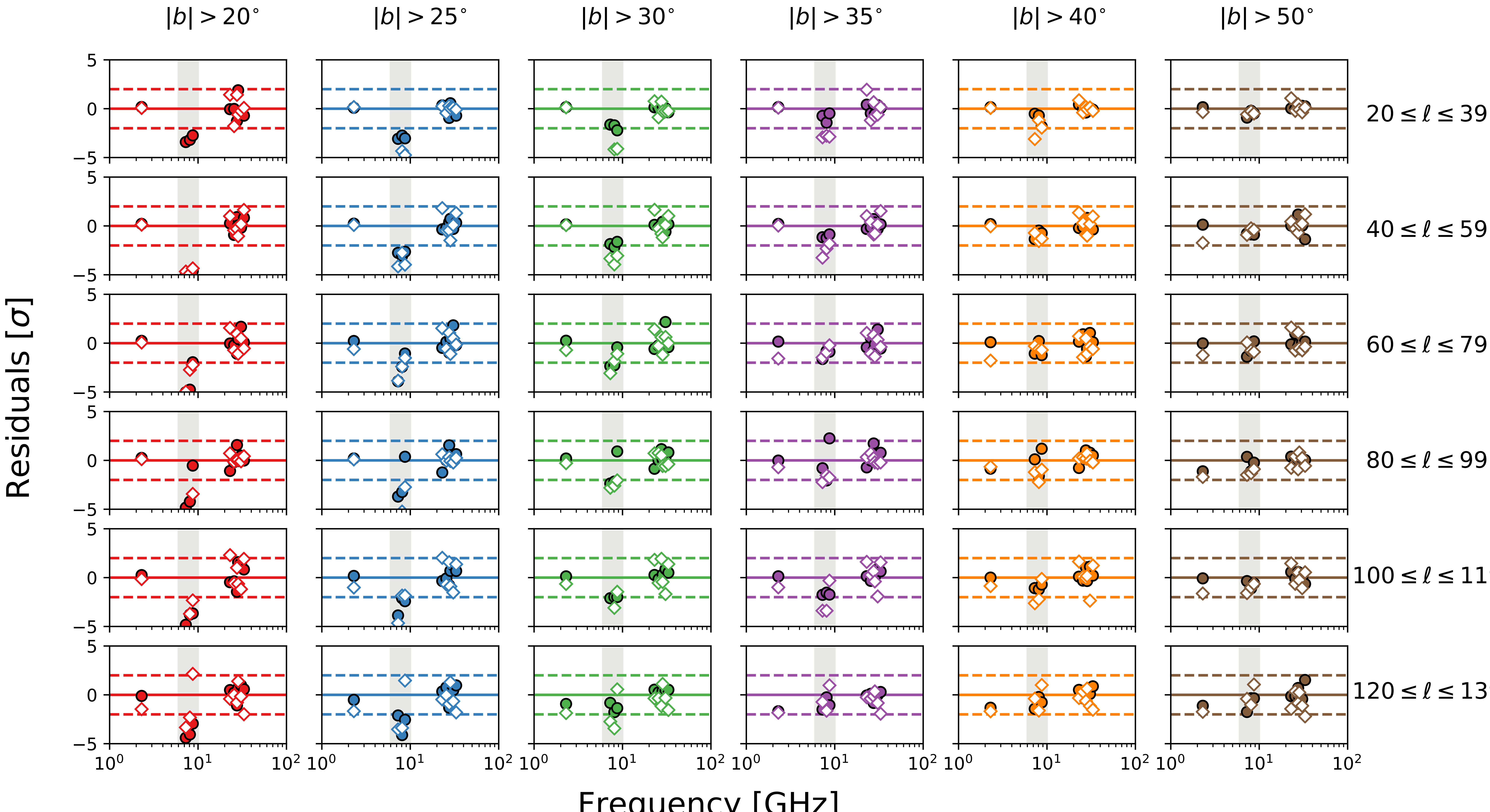
First **constraints on synchrotron curvature** in polarization ➡ compatible with zero, more data at intermediate frequencies are needed (C-BASS South)

First **spectral index map in polarization** allowing extrapolation of fluctuation at small angular scales ➡ test on component separation

Better characterization of **contamination to CMB B-modes** ➡ Important to optimize instrument sky scanning strategy

# Backup Slides

# Synchrotron **SED**: residuals




Tenerife, October 17th 2018

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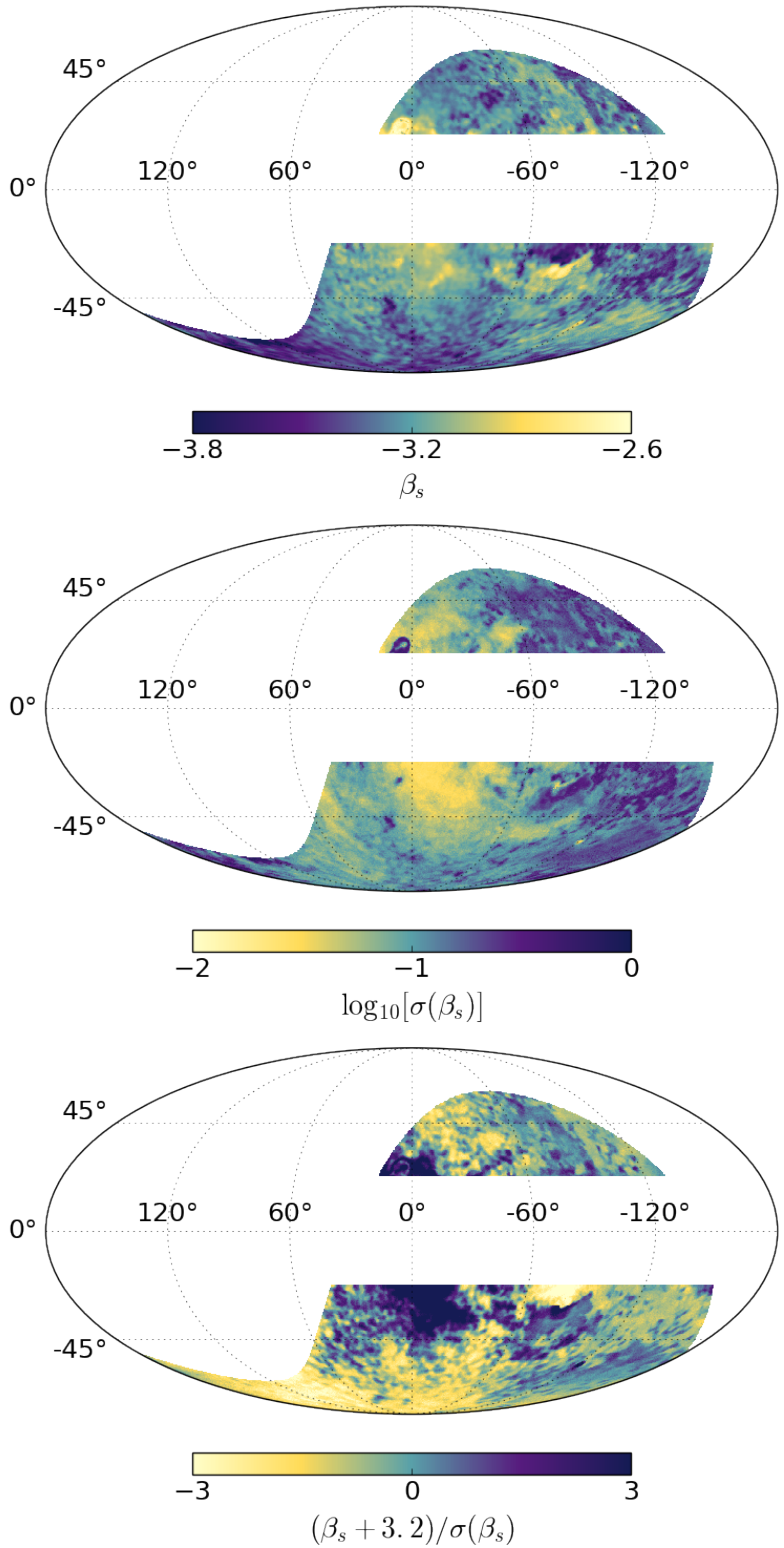
# Synchrotron **spectral index map**




Minimizing:

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

with:

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