COSMOS

Cosmic Orbital and Suborbital Microwave ObservationS

CMB data analysis: from foregrounds to Neural Networks

SISSA

Nicoletta Krachmalnicoff

Overview

- Analysis of S-PASS data
- Validation of FG models for LiteBIRD
- Neural Networks applied to CMB

S-PASS data analysis

Krachmalnicoff et al., A&A, 2018

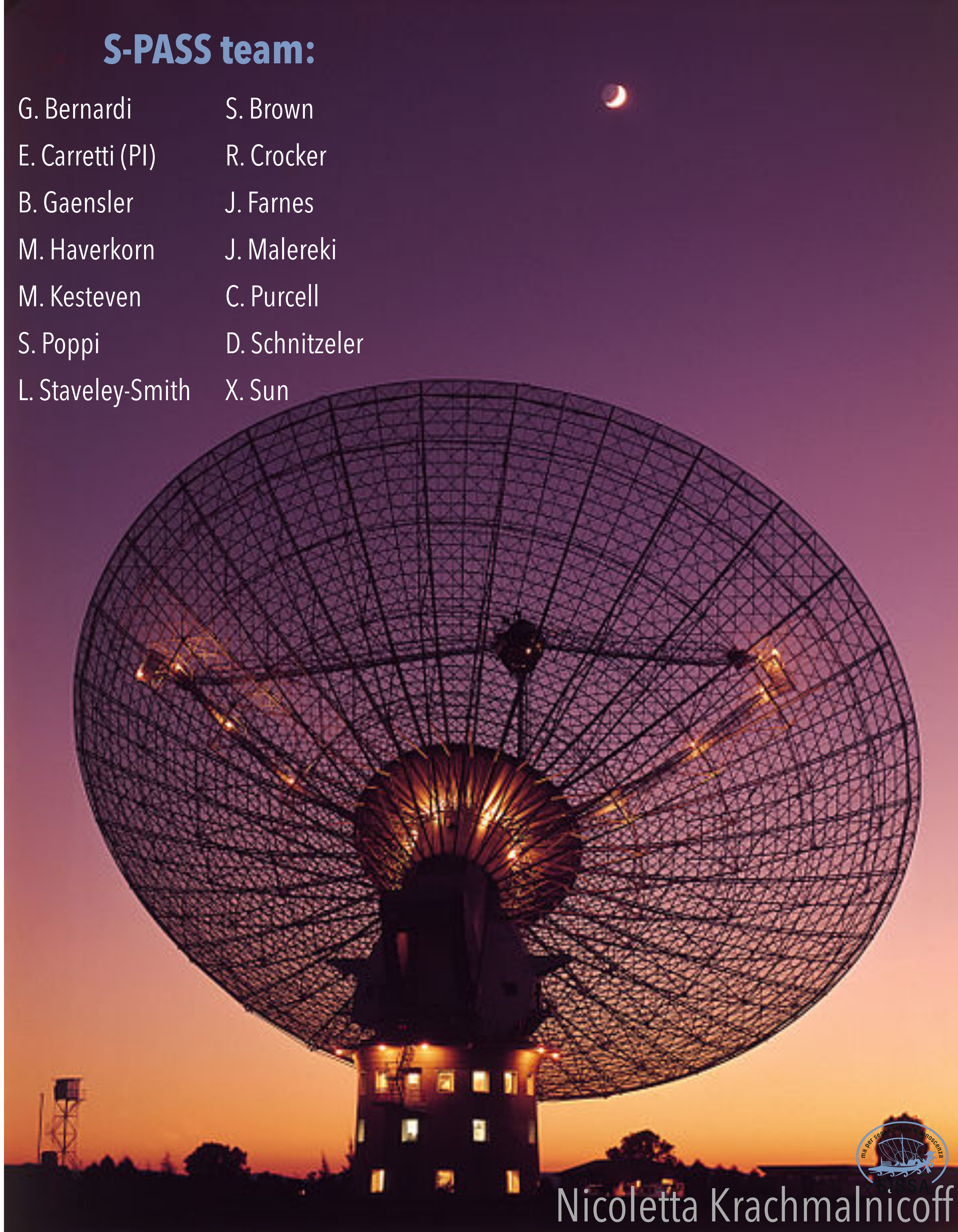
https://arxiv.org/abs/1802.01145

PARKES radio telescope: 64 m

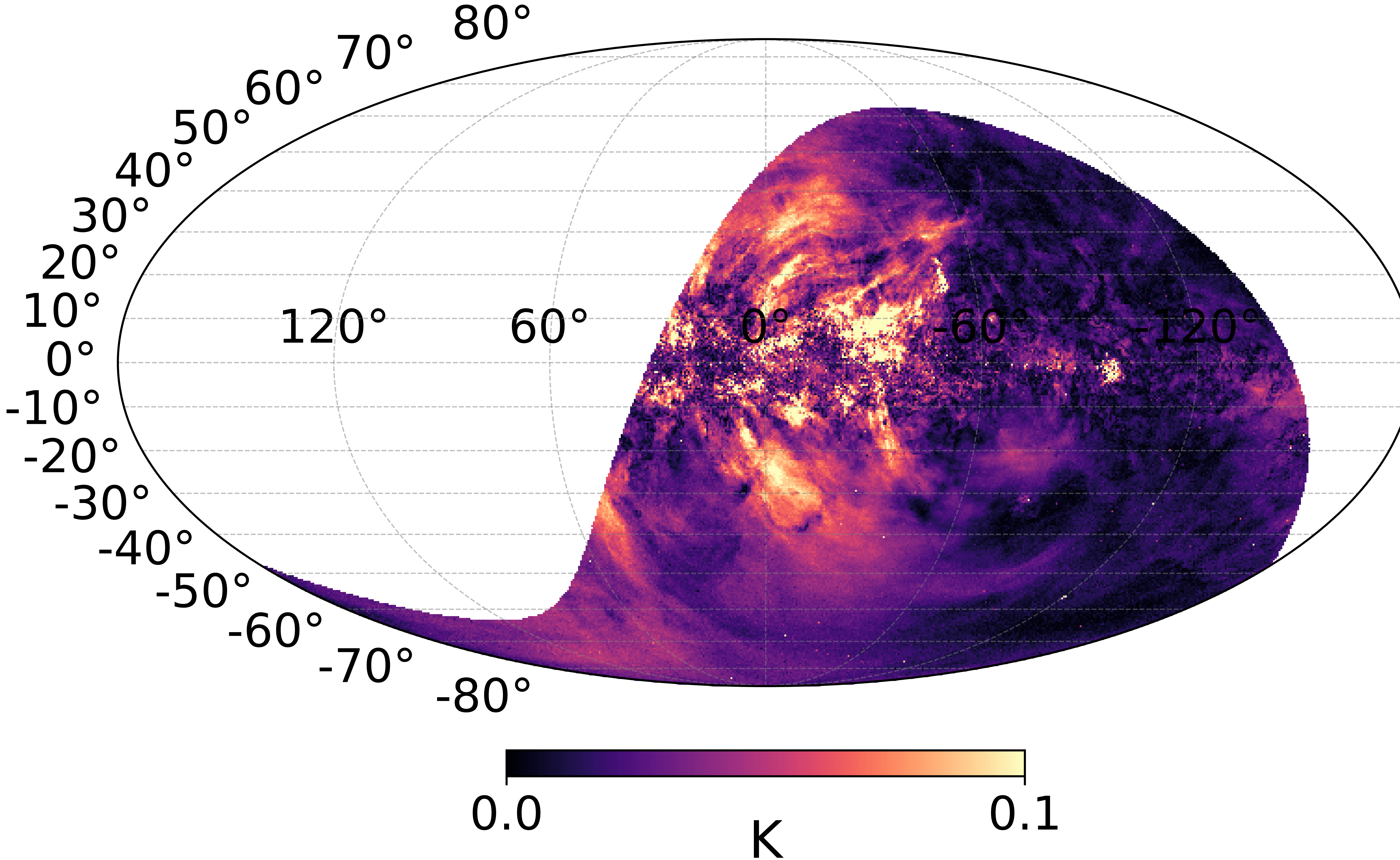
Frequency: **2.3 GHz** (224 MHz BW)

Sky coverage ~ 50% (South hemisphere)

Angular resolution **~ 9 arcmin**



S-PASS polarized intensity map @2.3 GHz



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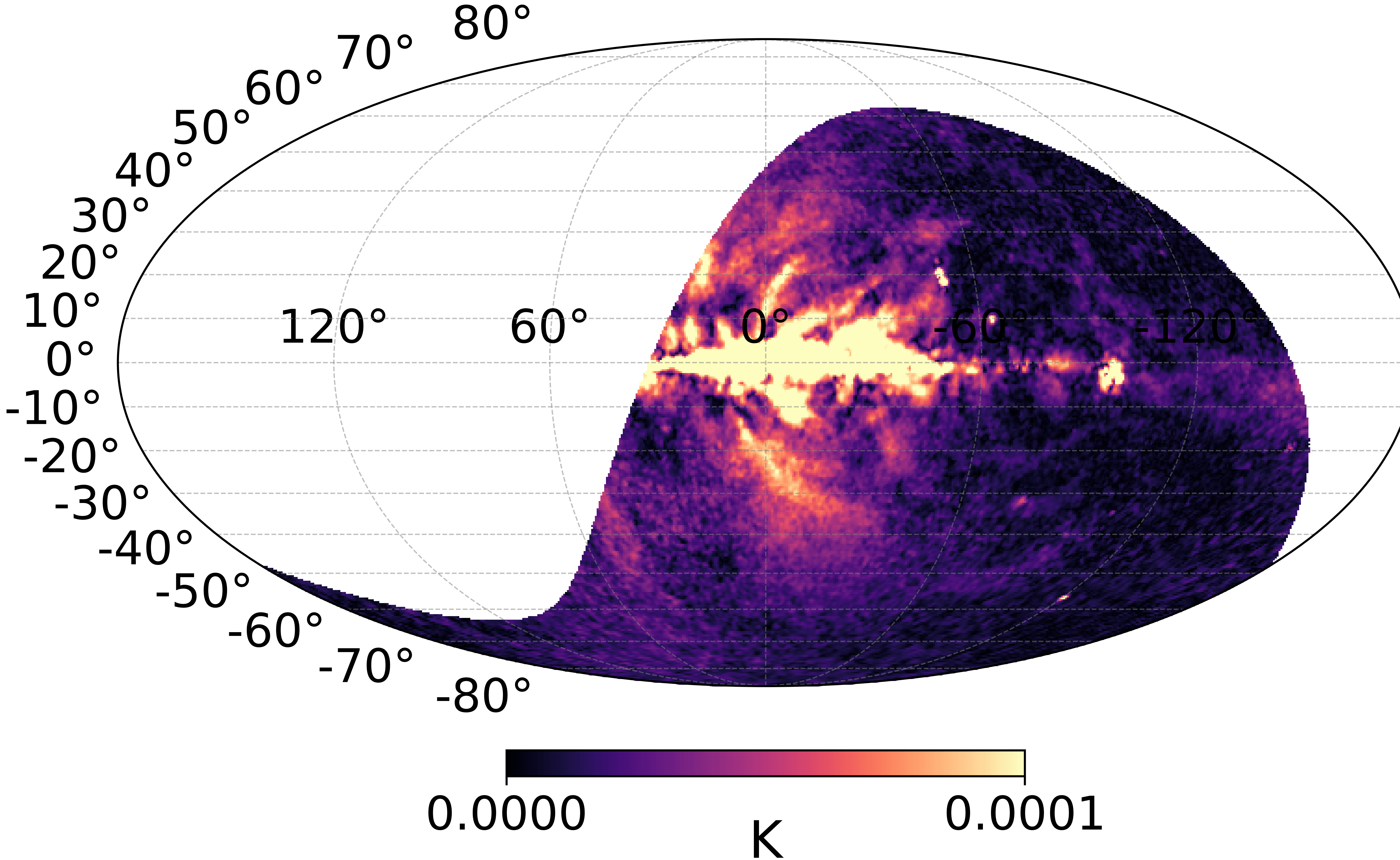
WMAP-K polarized intensity map
@23 GHz



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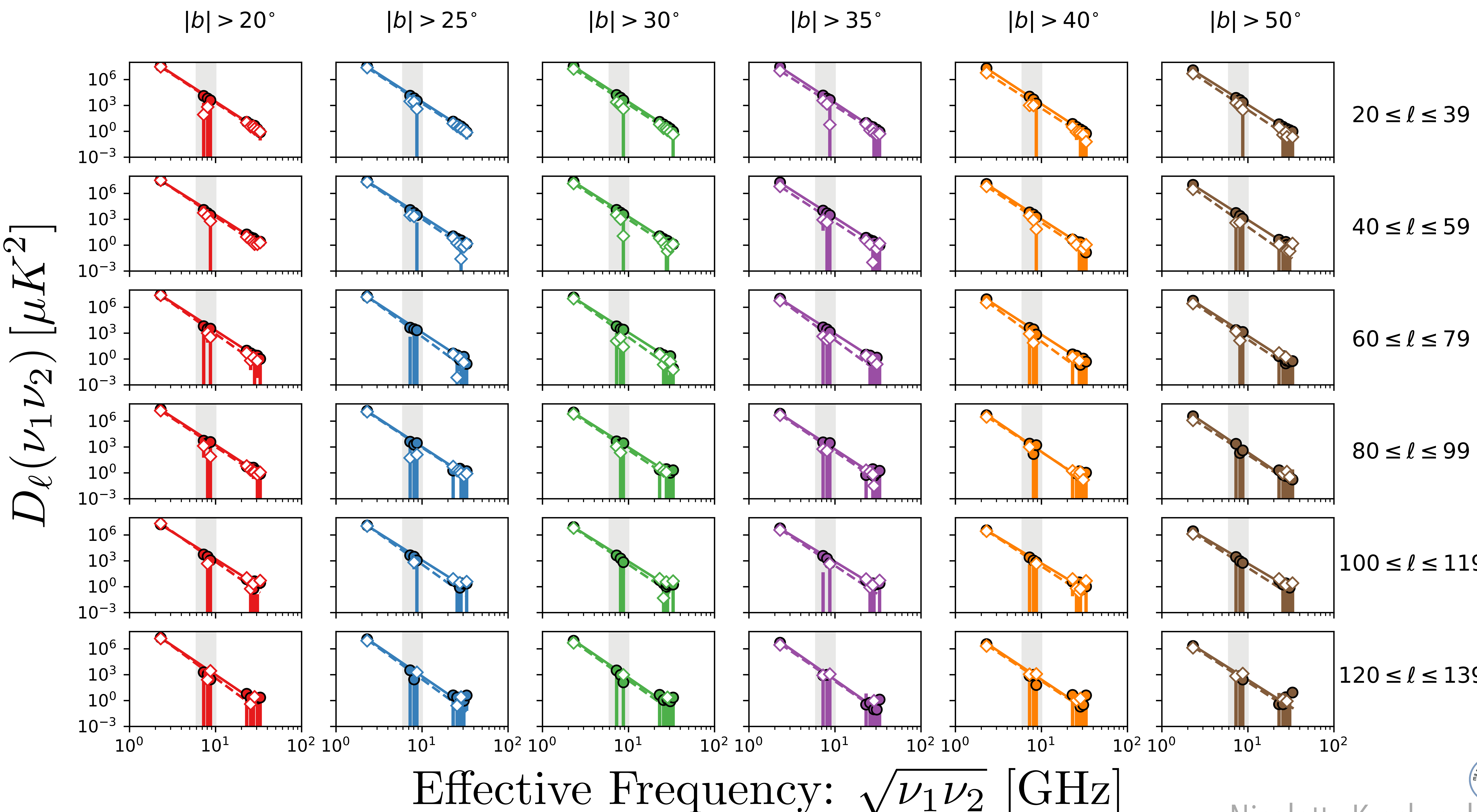
Synchrotron **SED**

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

2.3 GHz 23 GHz 28.4 GHz 33 GHz



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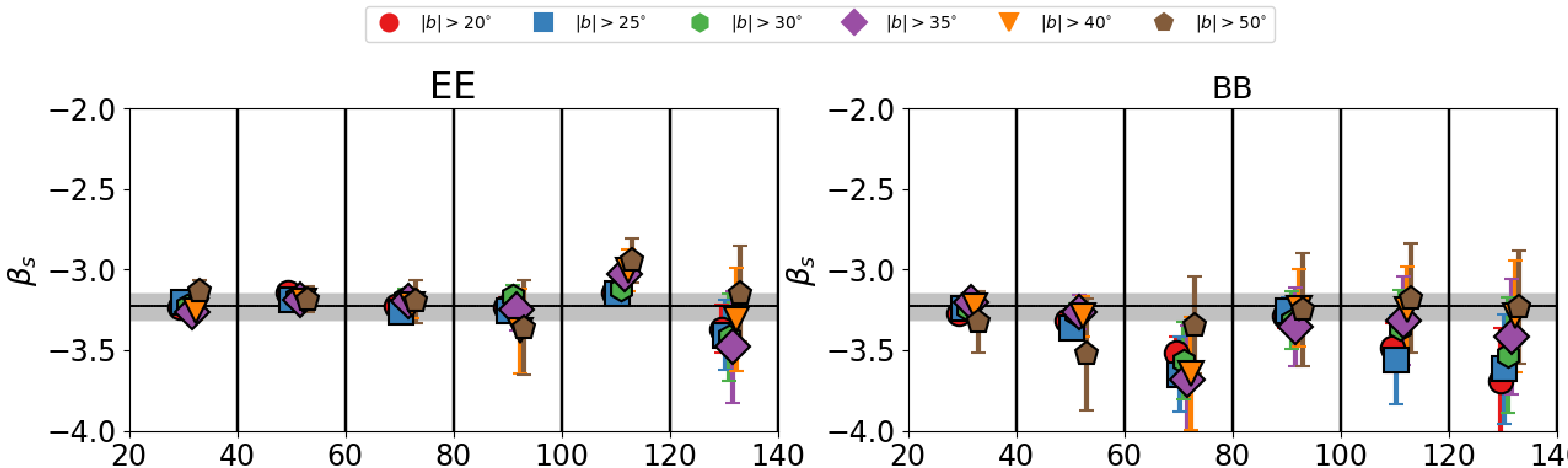
Synchrotron **SED**

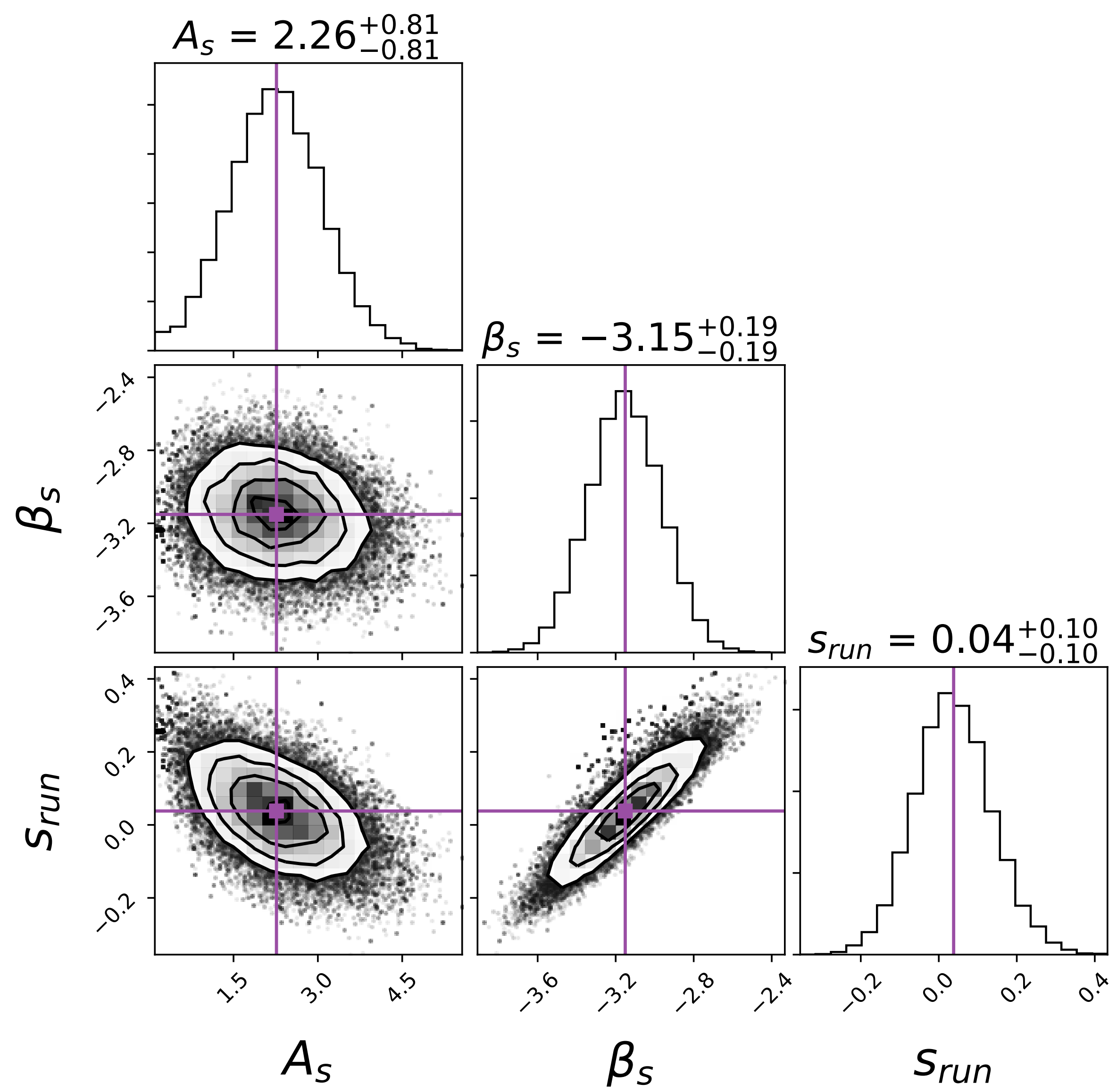


$$\beta_s = -3.22 \pm 0.08$$

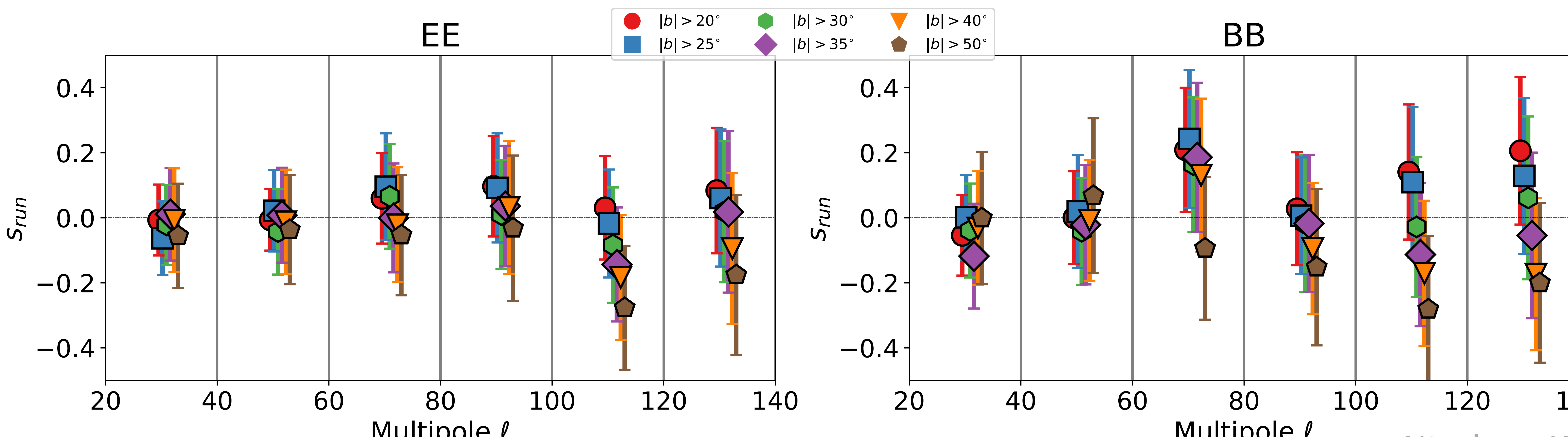
- Constant along the multipole range and for E and B-modes
- **In agreement with constraints coming from WMAP and Planck**

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 β_s and s_{run}
- **Gaussian prior on spectral index** from WMAP and Planck: **β_s = -3.13±0.13**
- **s_{run} compatible with zero**, with 1σ 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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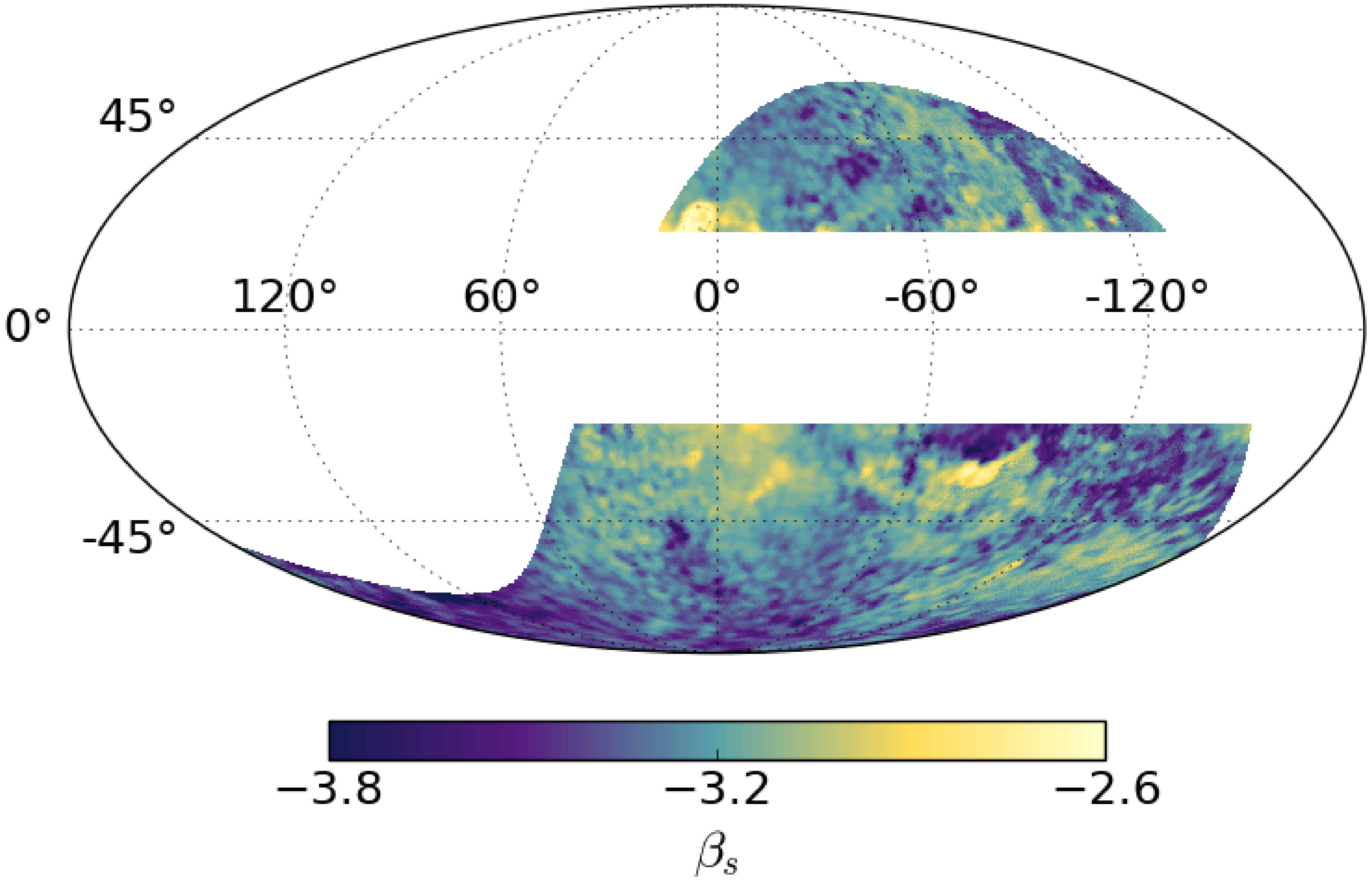
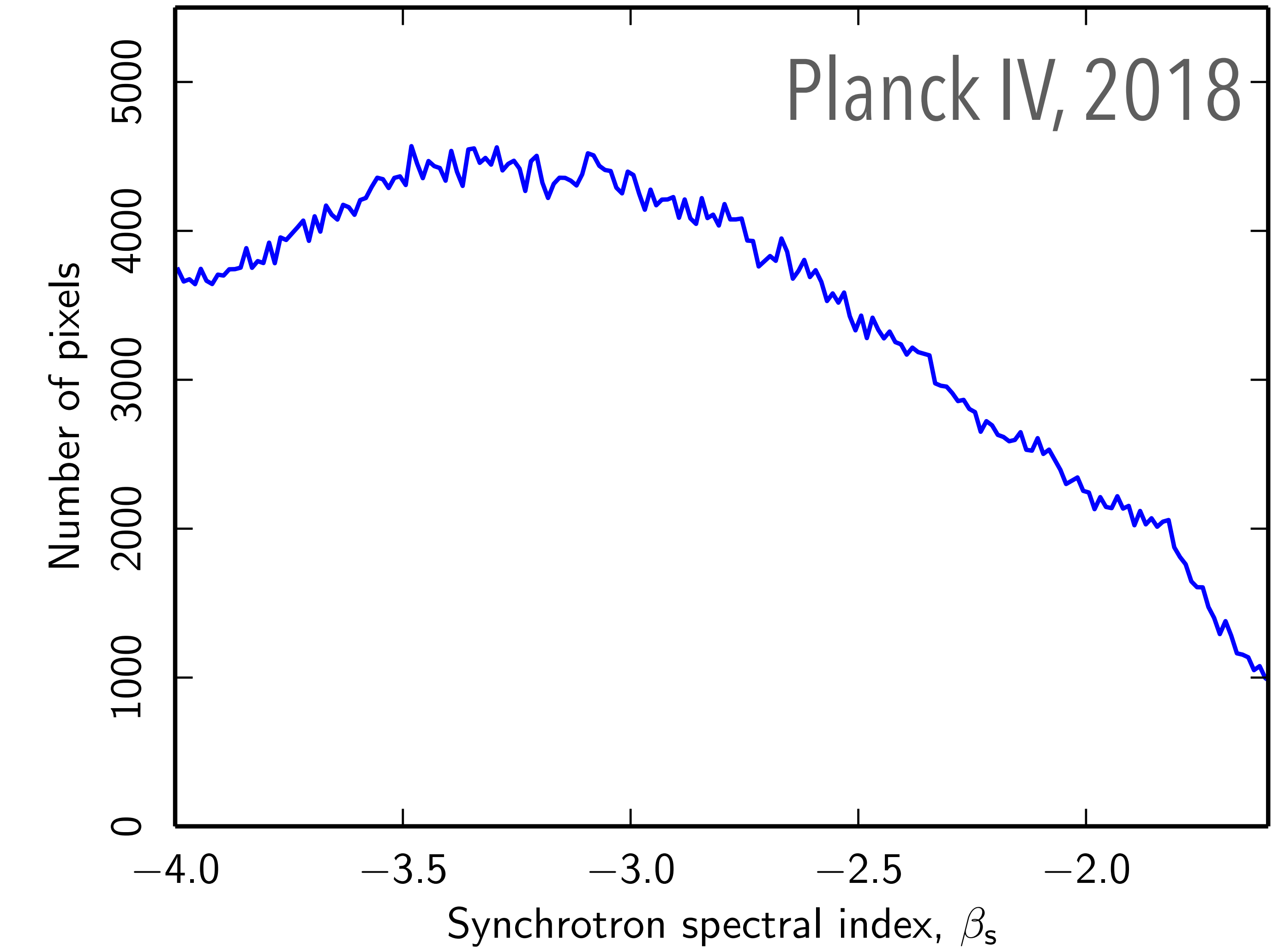
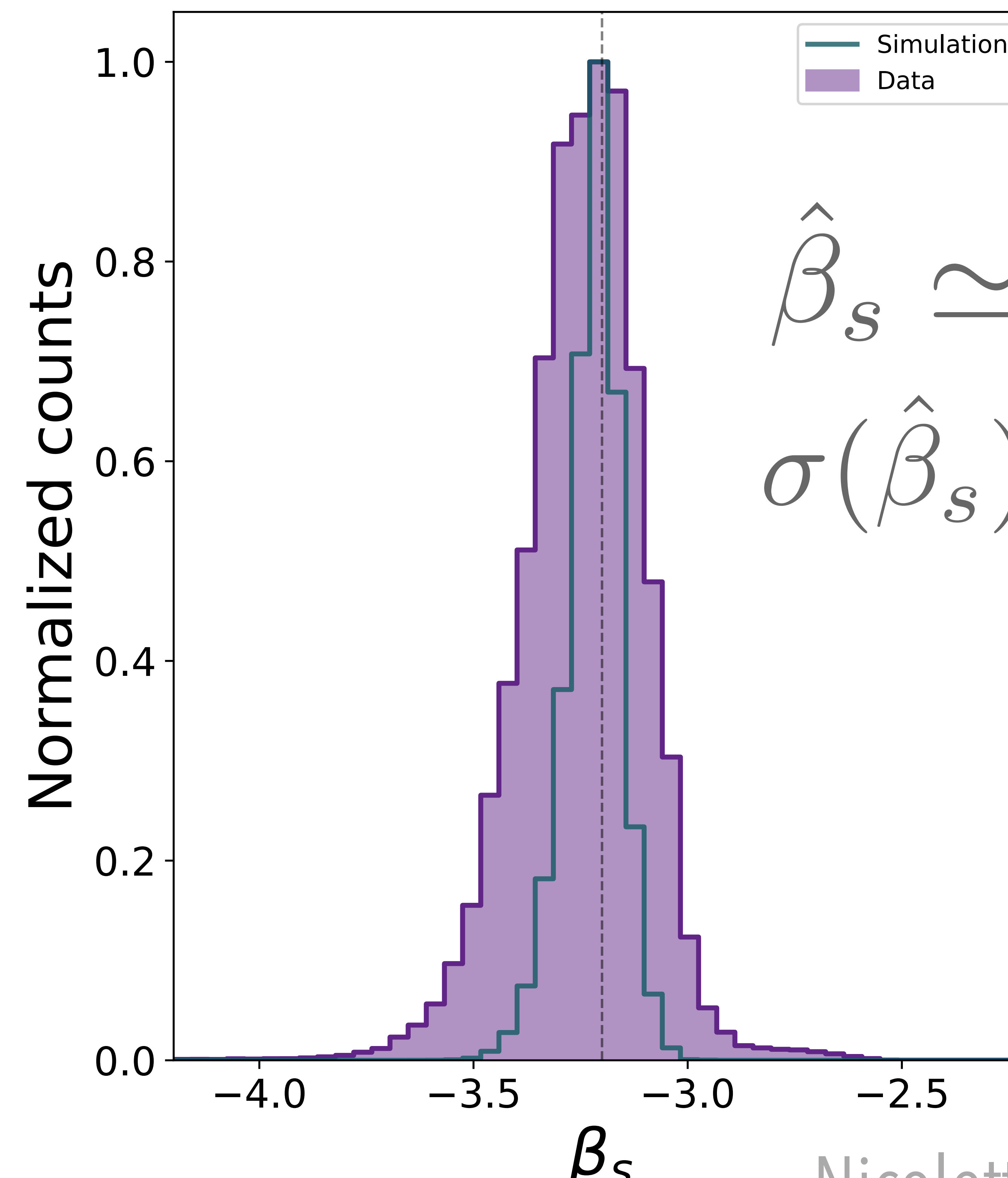
Synchrotron **spectral index map**



- 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

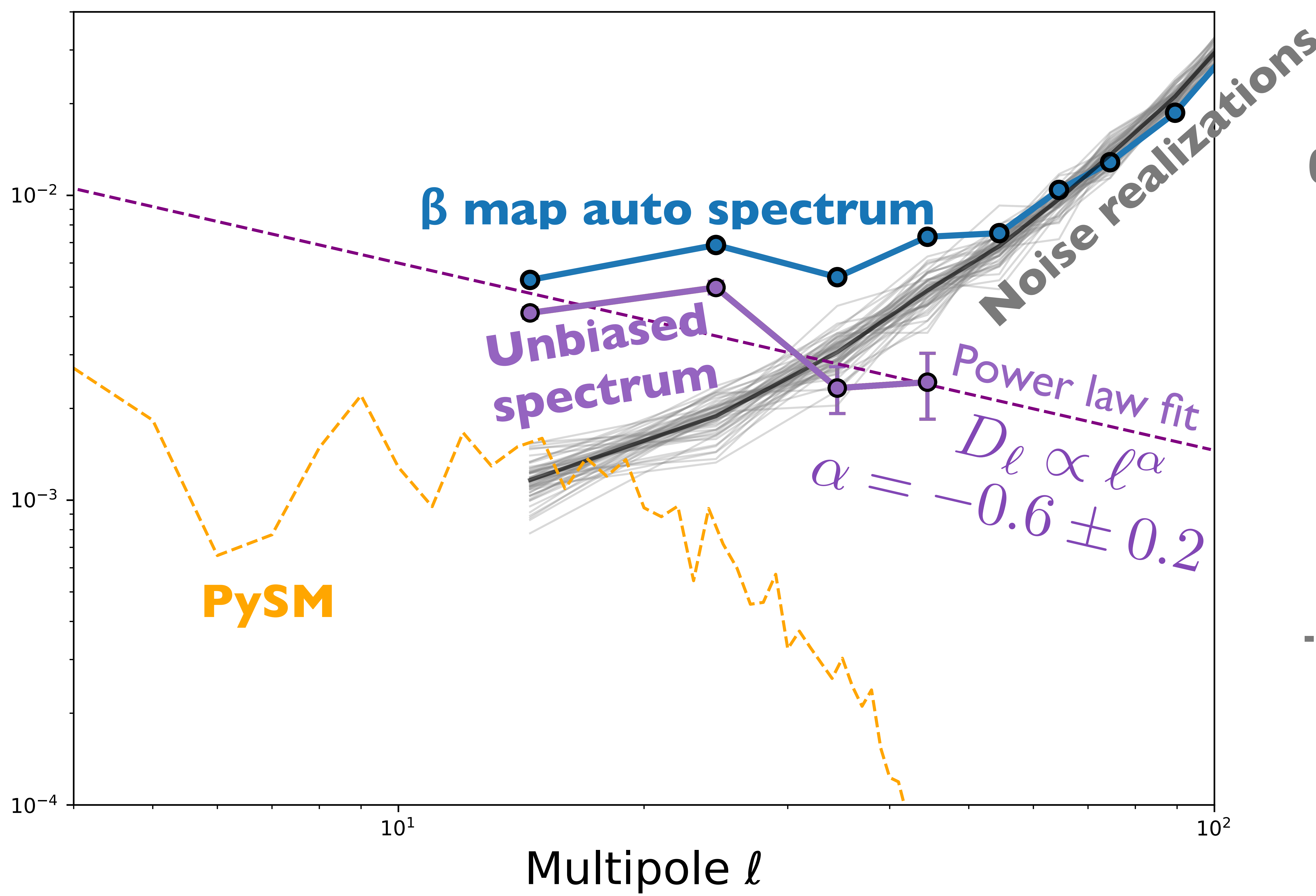


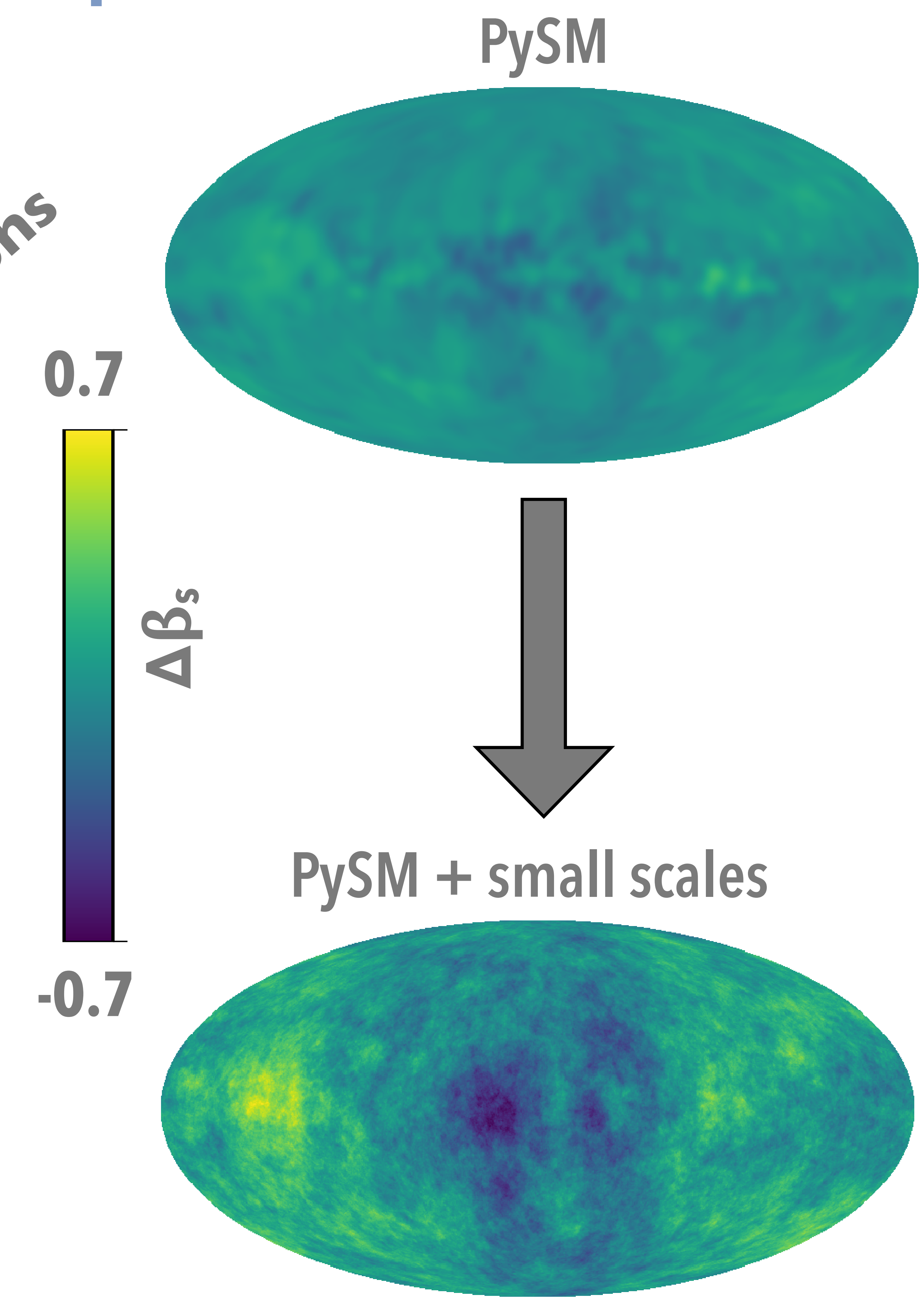


$$\hat{\beta}_s \simeq -3.20$$

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

Power spectrum of spectral index map





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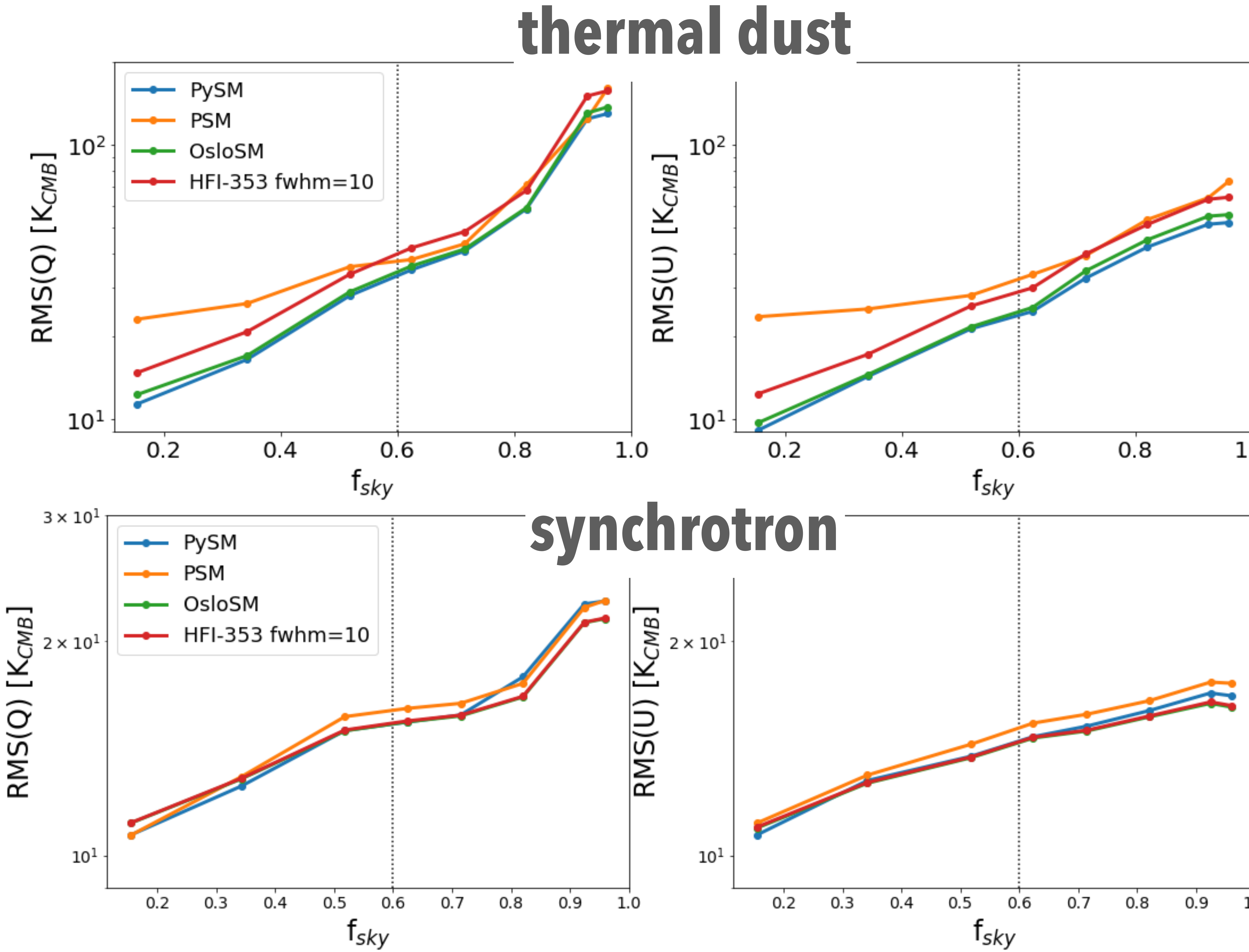
Validation of FG sky models (for LB but not only)



Q and U RMS of **thermal dust** and **synchrotron templates** as a function of the sky masks

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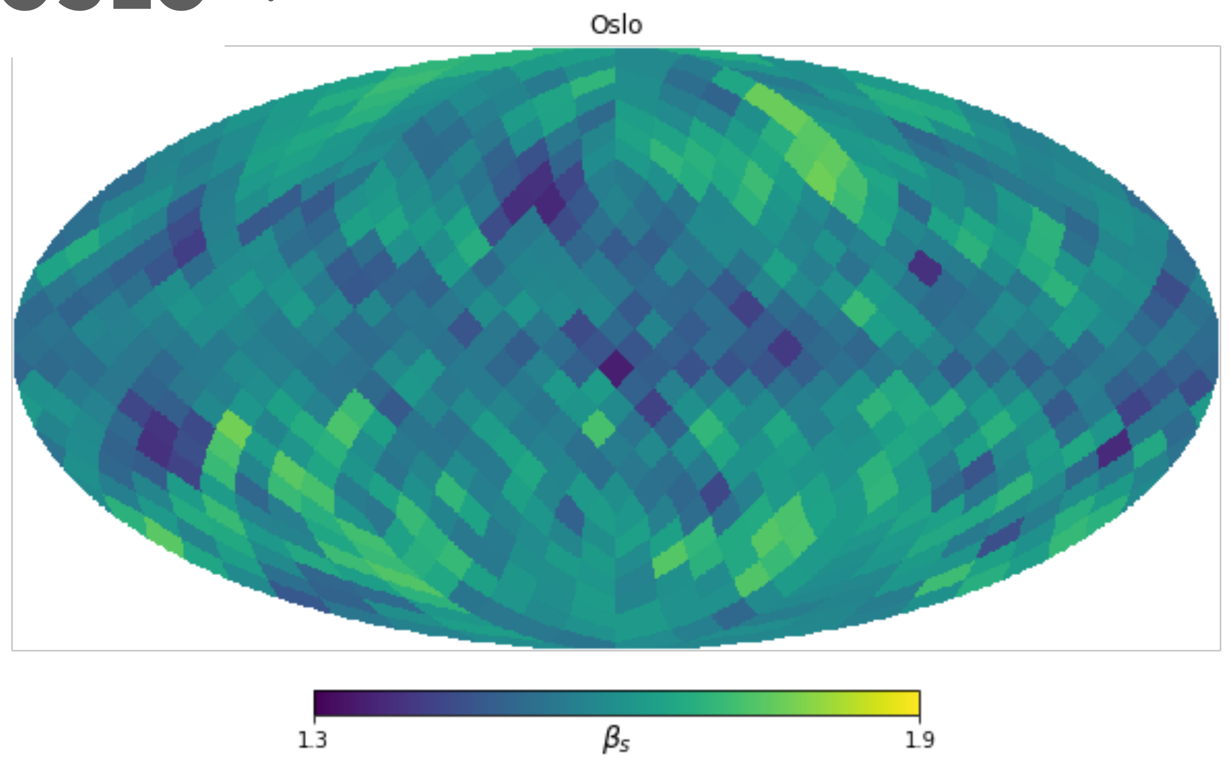
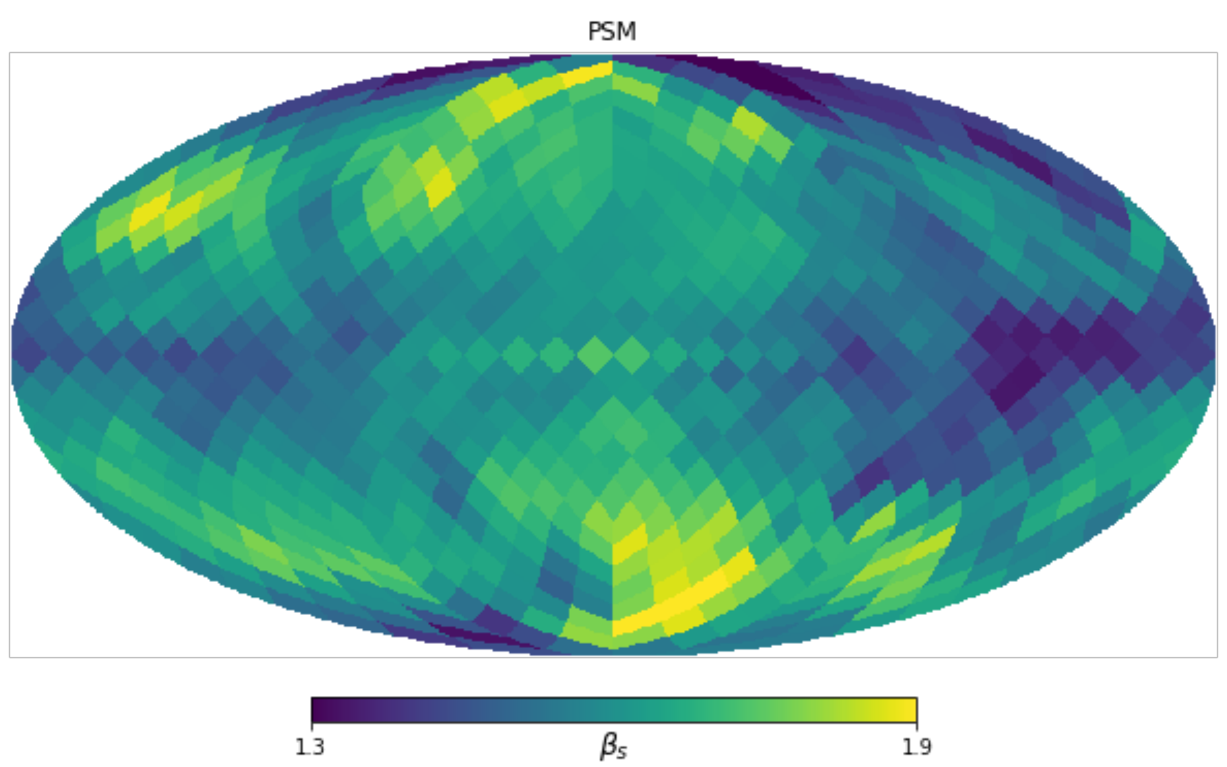
β_d maps

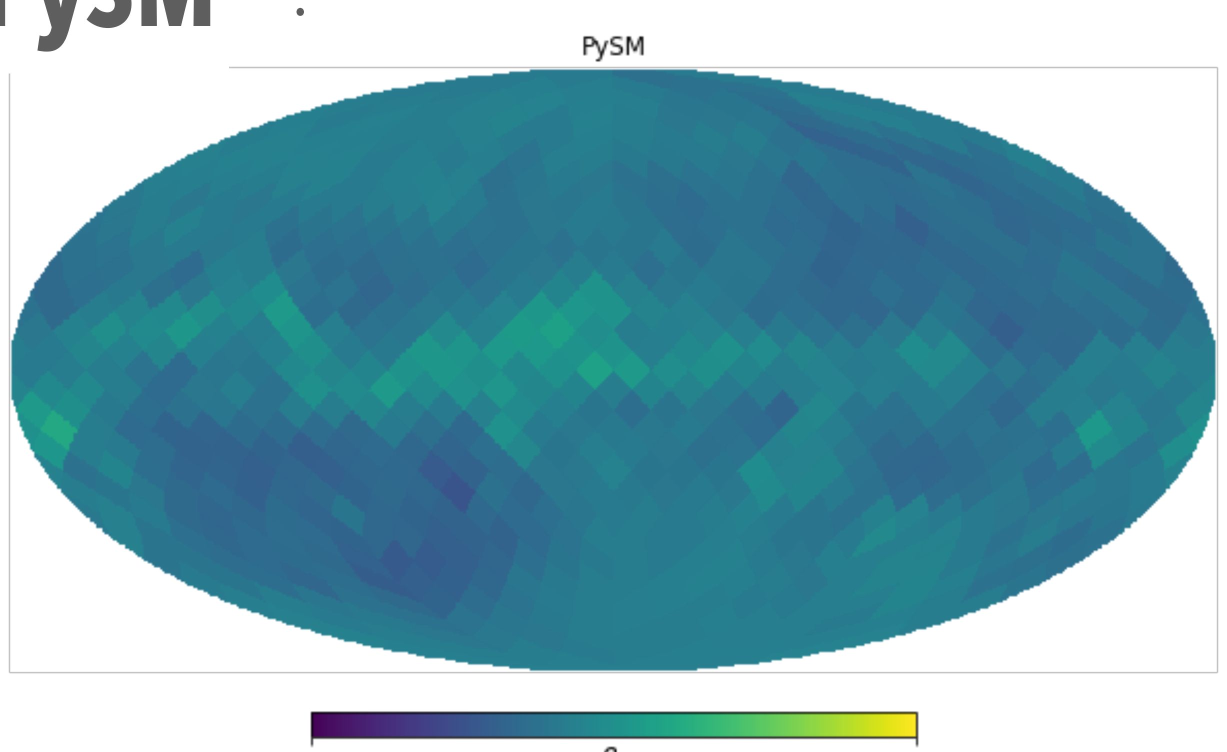
OSLO ?

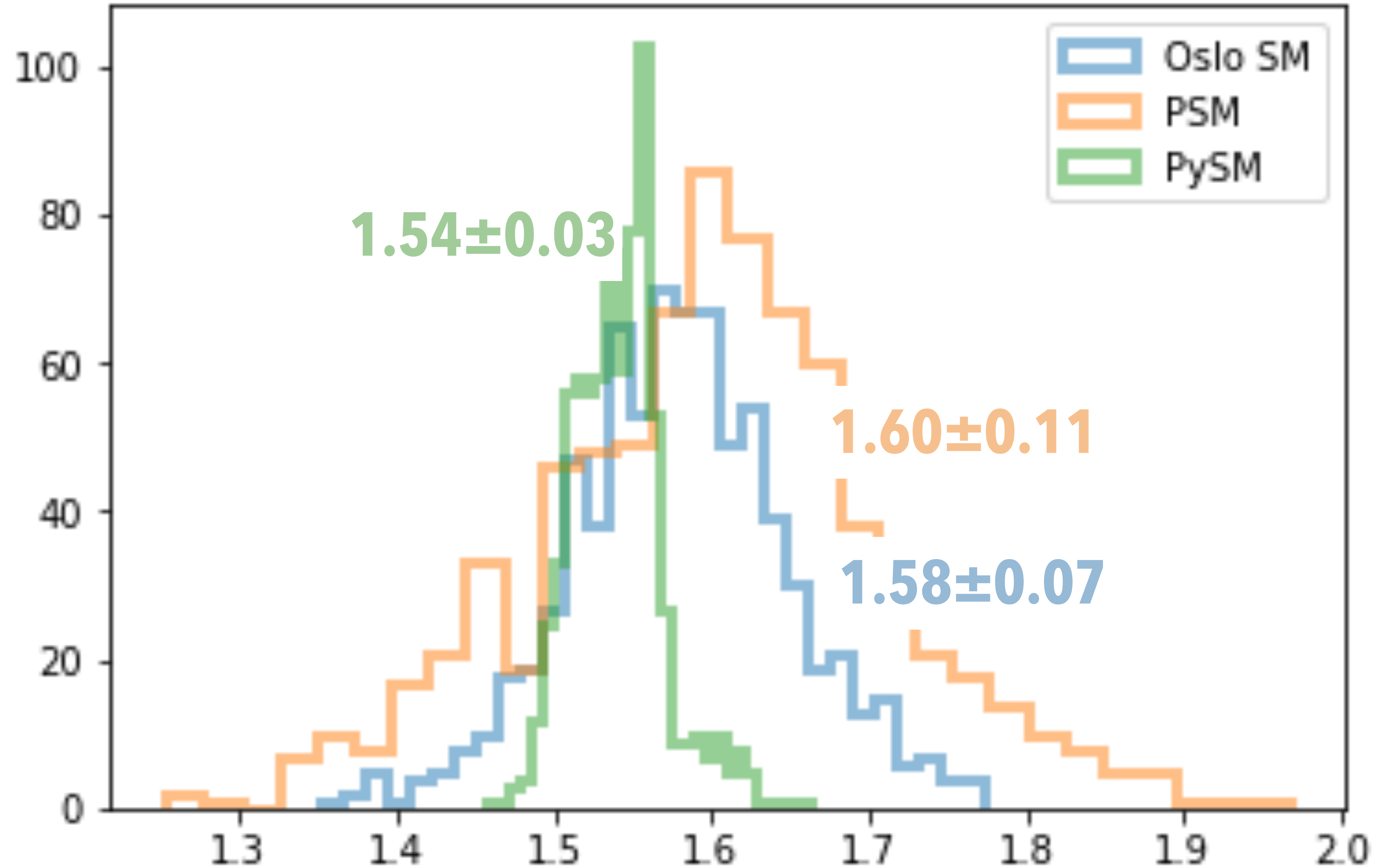


PSM GNILC from temperature?



PySM ?





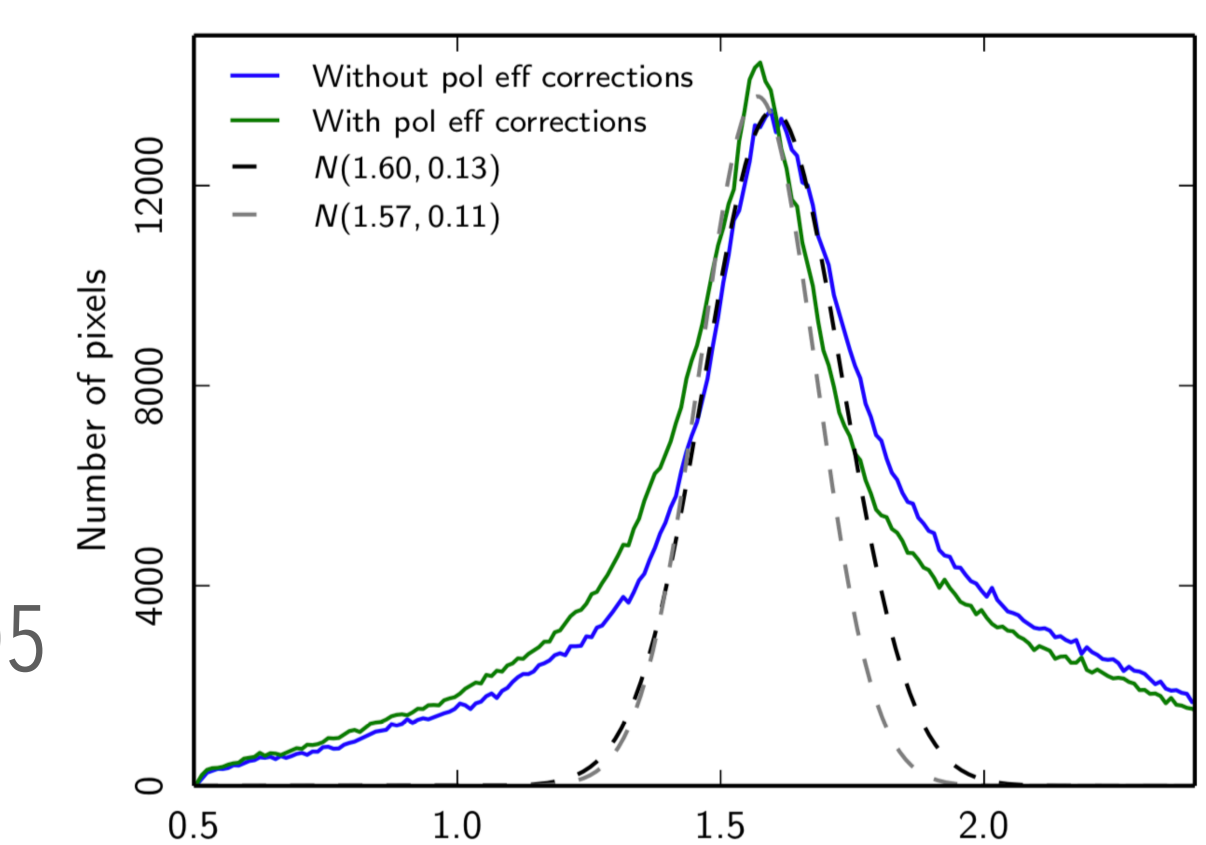
Constraints from data:

Planck 2018, XI: $\beta_d = 1.53 \pm 0.02$

(from spectra) $\beta_d^P - \beta_d^I = 0.05 \pm 0.03$

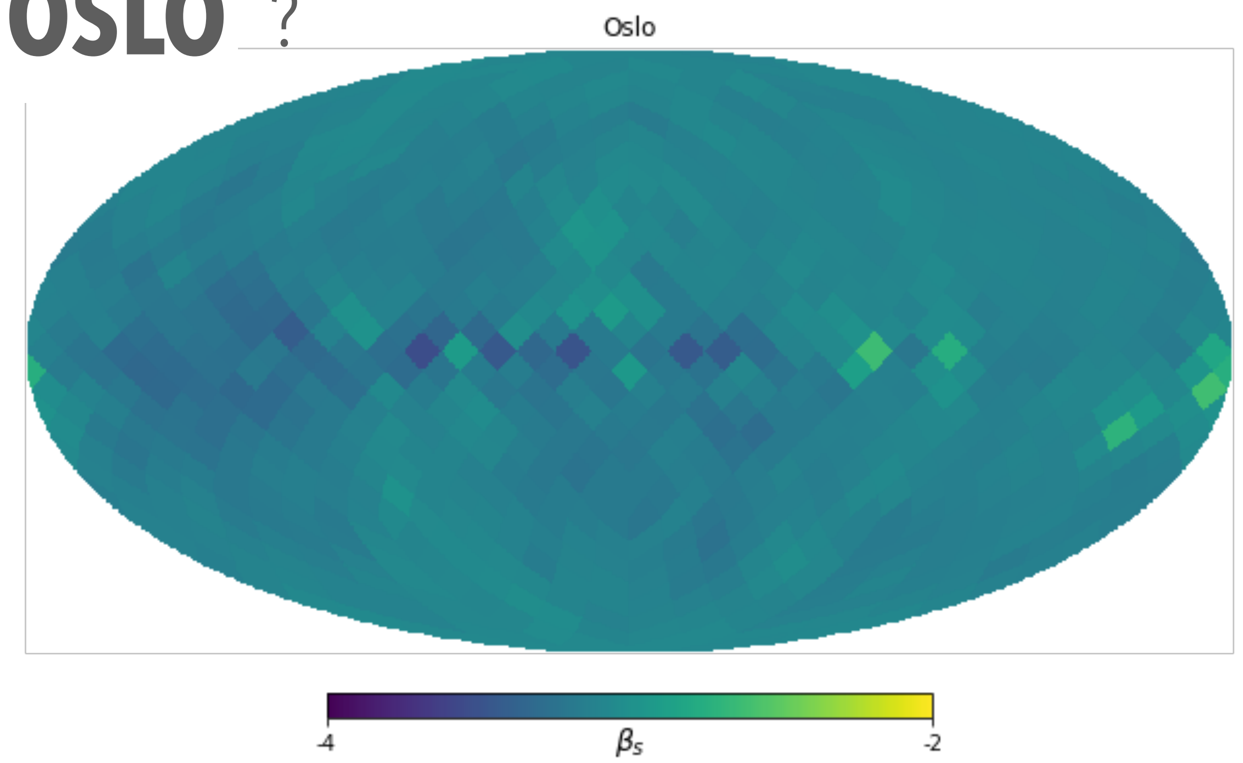
Planck 2018, IV: $\beta_d = 1.55 \pm 0.05$

(from spectra)

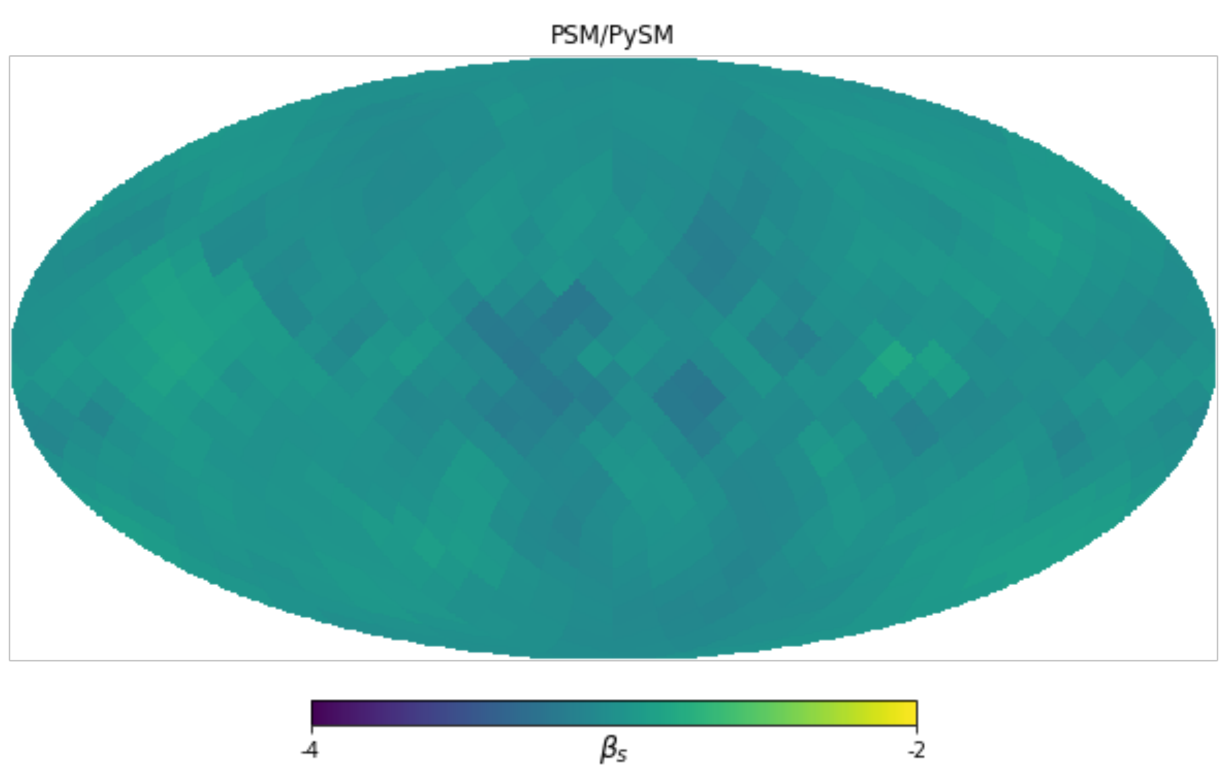


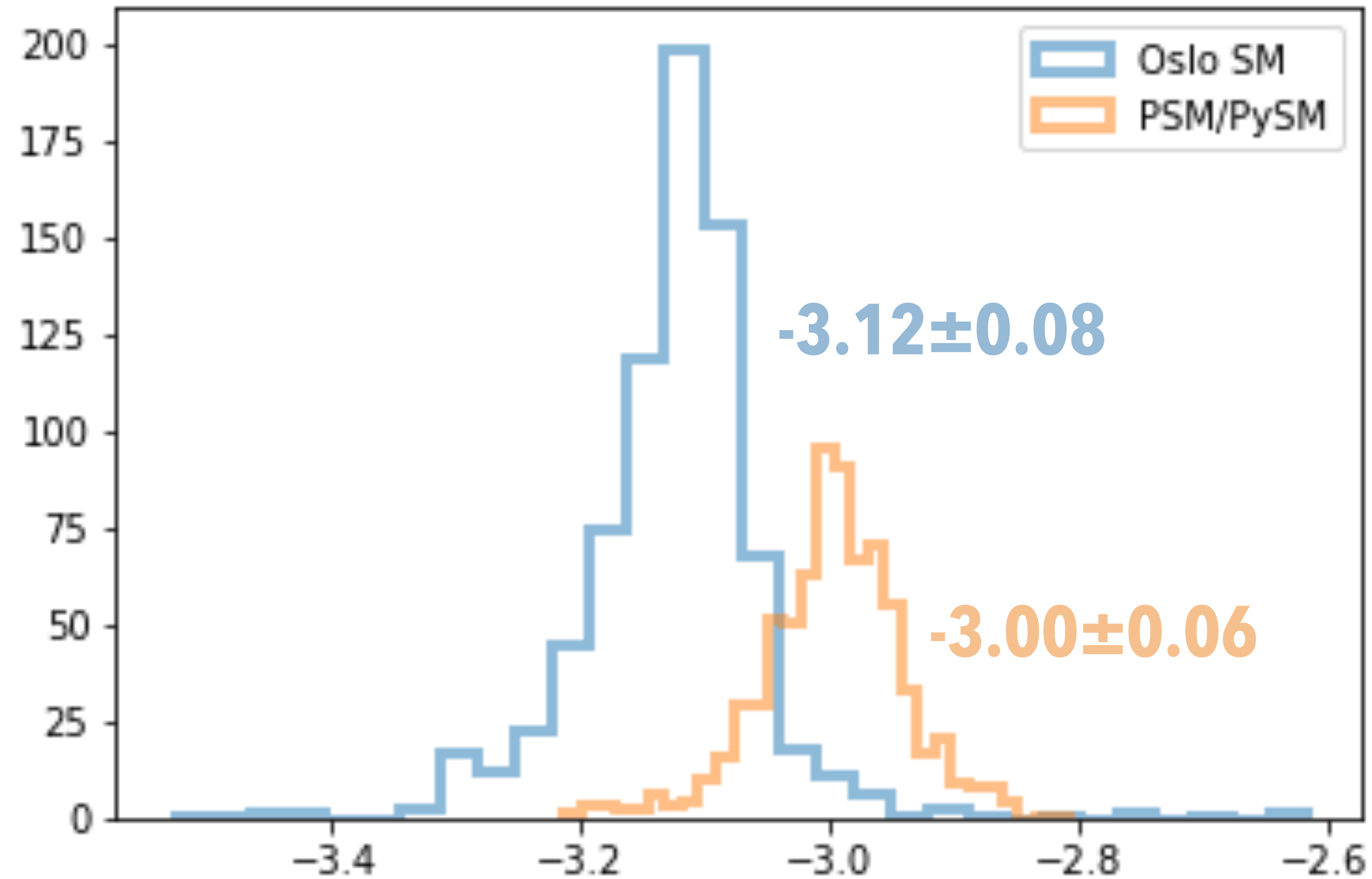
β_s maps

OSLO ?



PSM/PySM from WMAP pol + Haslam I





Constraints from data:

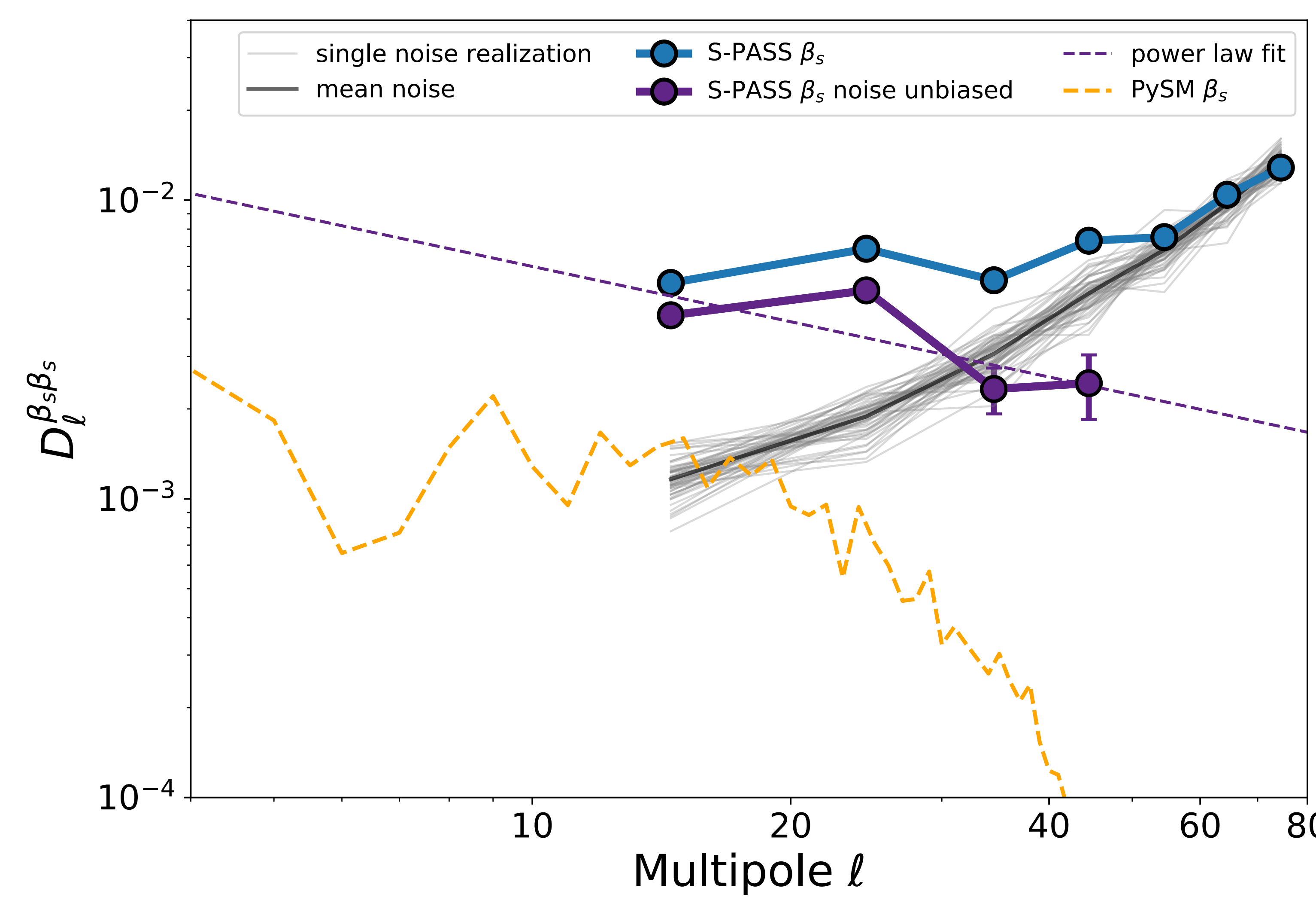
Planck 2018, XI: β_s = -3.13 ± 0.13
(from spectra)

Planck 2018, IV: β_s = -3.10 ± 0.10
(from spectra)

S-PASS: β_s = -3.22 ± 0.08
(from spectra)

S-PASS: β_s = -3.20 ± 0.15
(from maps)

C-BASS ?: β_s ~ -3.0



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Neural Networks

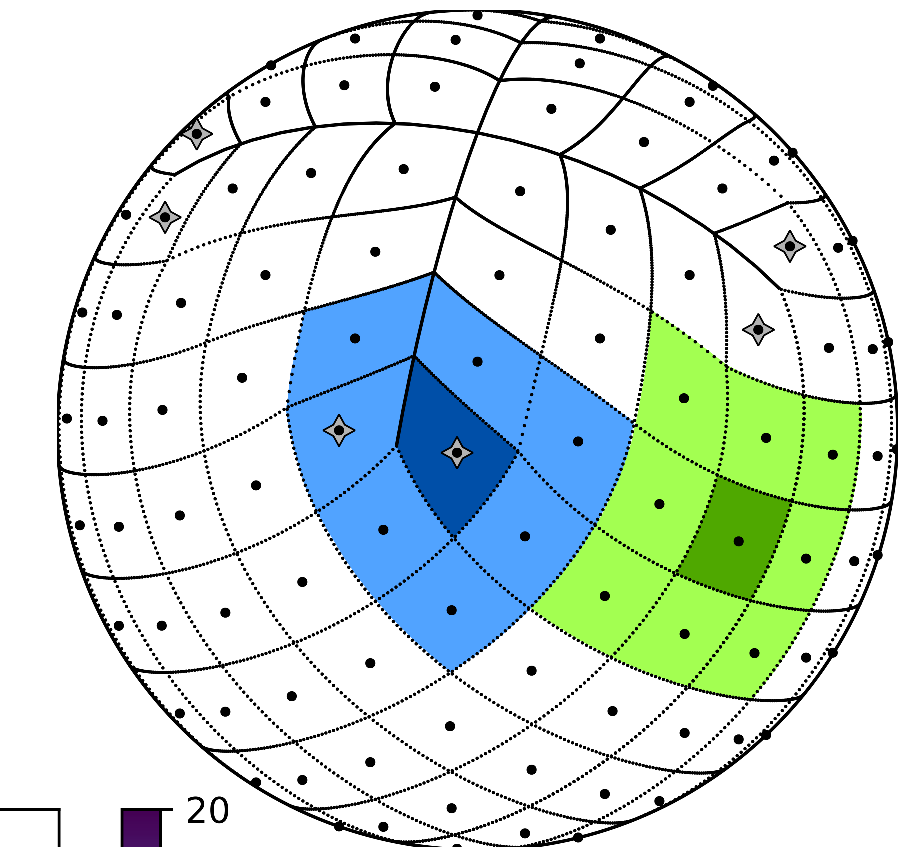
- **What are Neural Networks?**
  - mathematical operators able to approximate complex functions that map input into output

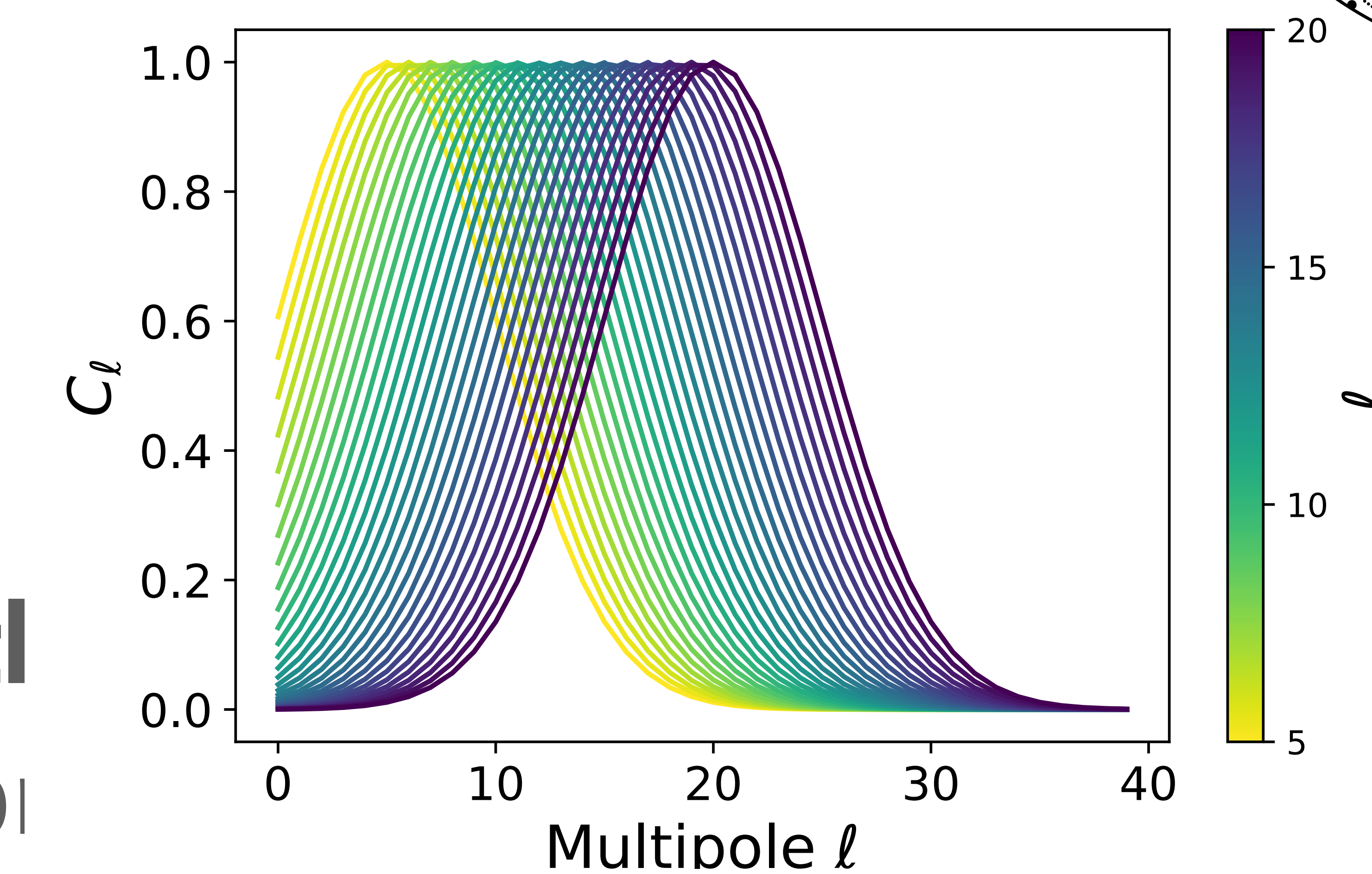
- **How do they work?**
  - by recursevly applying non-linear functions to linear combination of input elements
  - weights of the linear combination must be optimized during training
  - set if inputs for which the output is known is needed to do the training

- **Why to apply NNs to CMB data analysis?**
  - NNs are experiencing fast growth in many field of science
  - Many applications (from data flagging to component separation and parameter estimation) could be performed with NNs
  - Different approach with respect to stadard methods, good for validation!

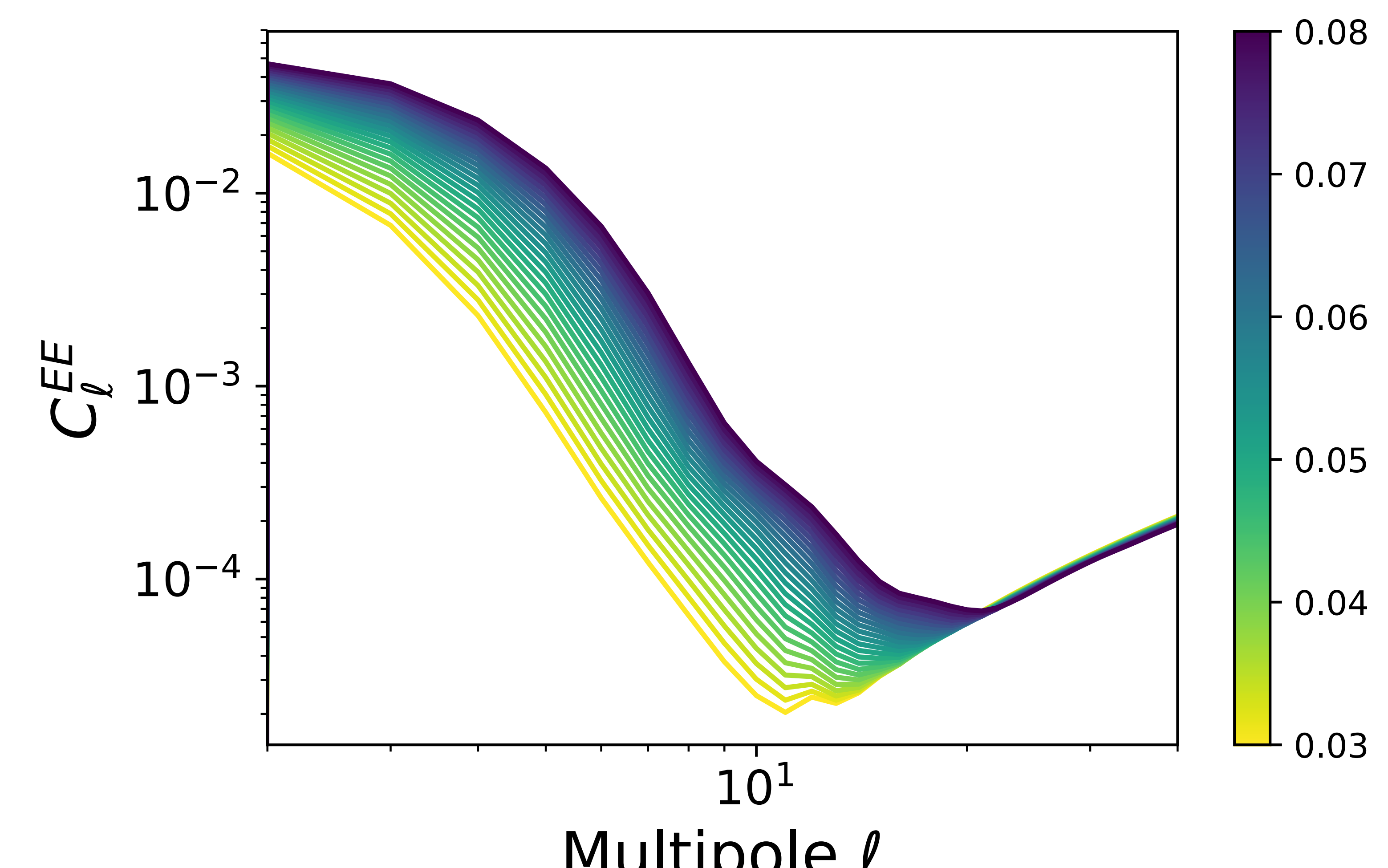
NNs for parameter estimation

Krachmalnicoff & Tomasi, 2019, submitted to A&A
https://arxiv.org/abs/1902.04083





- Developed **pixel-based alghoritm to apply Convolutional Neural Network to HEALPix maps**
- Able to **fit for cosmological parameters directl from maps** on full/partial sky, from temperature o polarization map, and in presence of noise
- first **test on estimation of tau on simple simulations** showing promising results



Summary and prospective

- **S-PASS data analysis at 2.3 GHz**
  - most advance characterization of synchrotron emission in polarization for CMB
  - synchrotron is complex
  - joint analysis with C-BASS and QUIJOTE
- **FG model validation**
  - ongoing work for LiteBIRD
  - important also for other CMB experiments, setting the framework for a common sky modeling
- **NNs applied to CMB**
  - preliminary work proved the feasibility of the approach
  - full test on tau to be done soon, with detailed comparison with standard methods in realistic case
  - Possibile application also for component separation under study