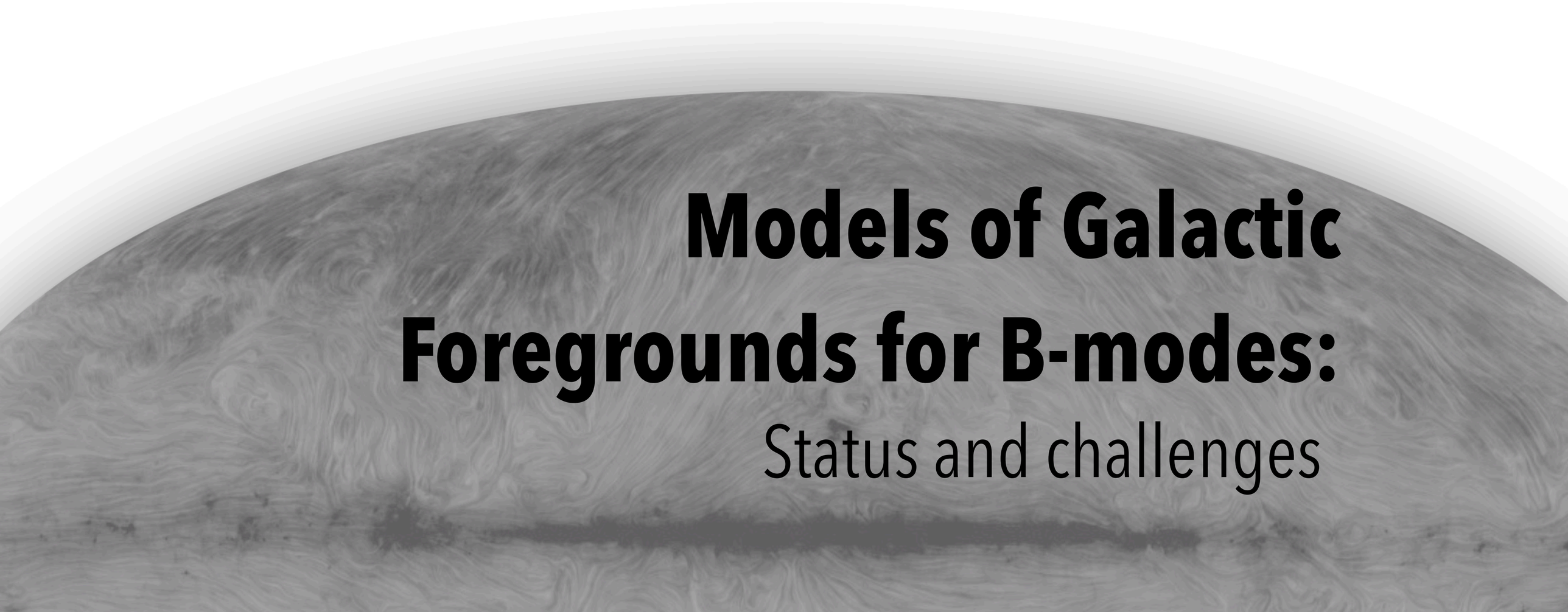
Nicoletta
Krachmalnicoff
SISSA

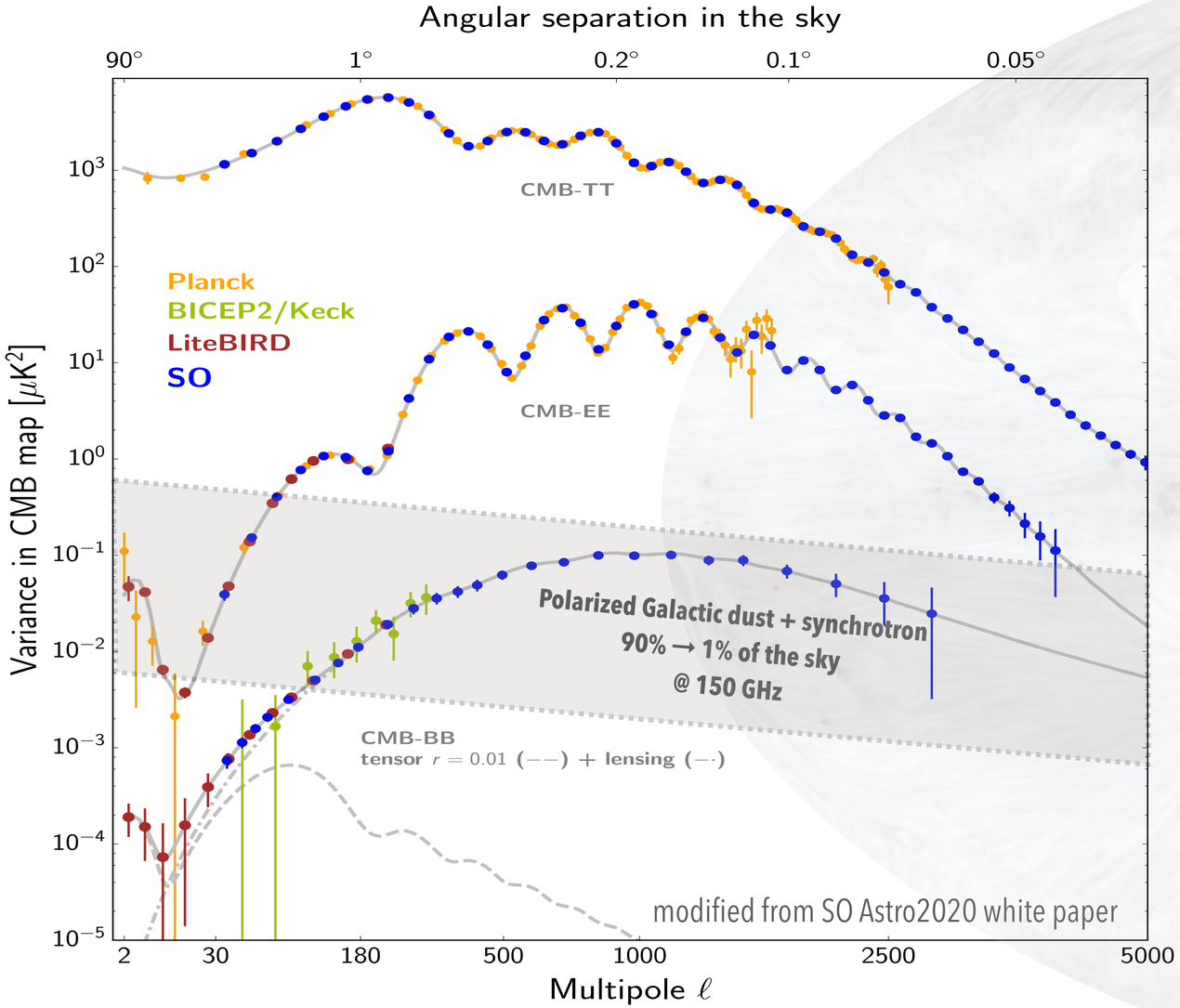
B-modes from Space
Garching - December 16th, 2019



Models of Galactic Foregrounds for B-modes:

Status and challenges

Galactic FG contamination



We need good FG models to get prepared for next generation of CMB experiments

Basic whishlist for FG modeling

i. **Large scale** signal amplitude and morphology
ii. **Small scale** signal amplitude and statistics
iii. **Global SED** model
iv. **SED** spatial **variation**

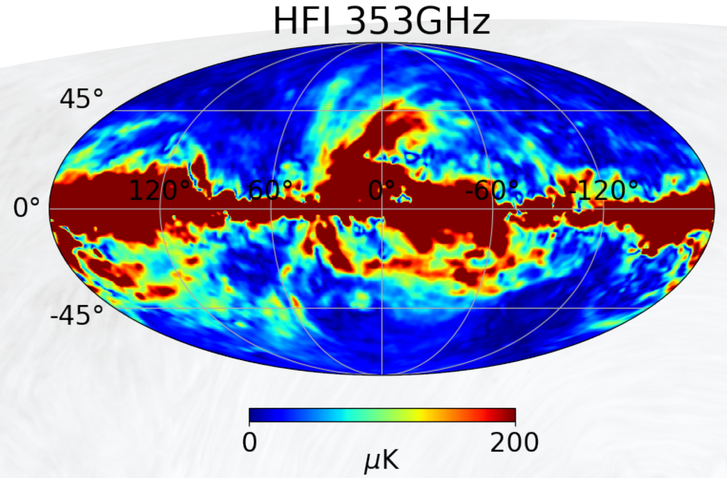
Current models (PySM)

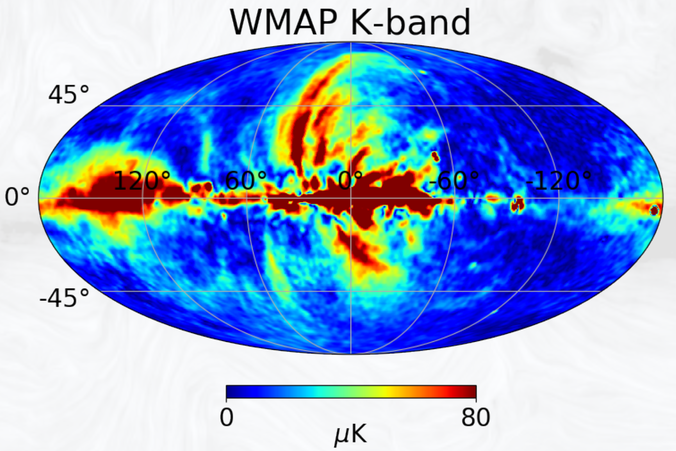
Thorne et al. 2017

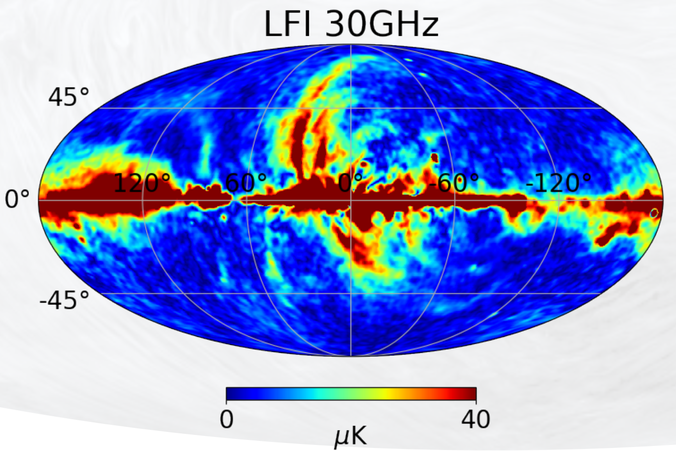
- **Baseline models** used for making forcasts, implement and test the component separation pipeline for next generation of CMB experiments are **based on Planck and WMAP data**

- **Thermal dust** template maps in polarization come from the *Commander* products at 353 GHz, smoothed at 1°

- **Synchrotron** templates are the WMAP Q and U maps smoothed at 3° angular resolution







Basic whishlist for FG modeling

i. **Large scale** signal amplitude and morphology

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Thermal Dust SED

Planck Int. 2018 LIV

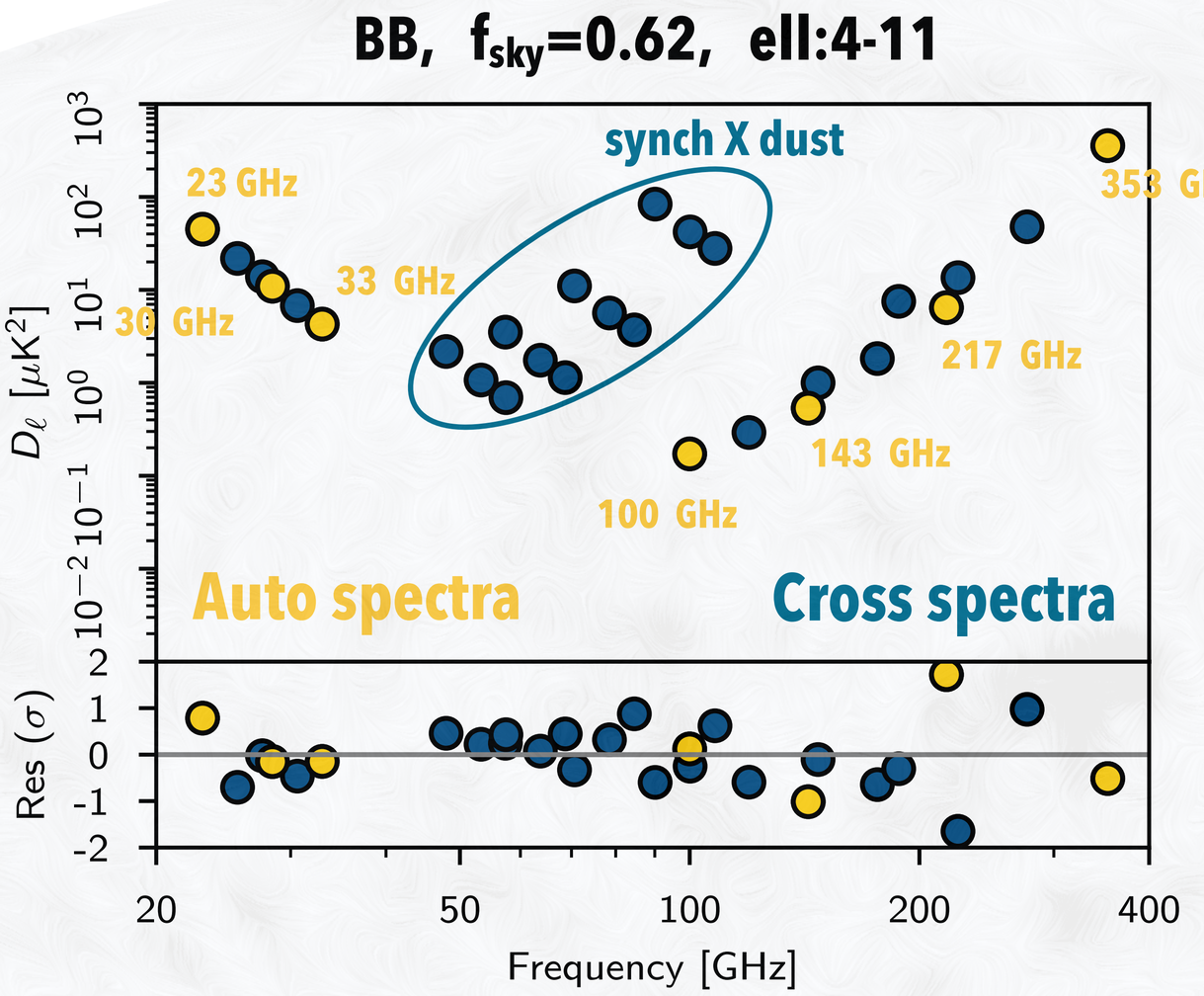
- Fit in harmonic space WMAP + Planck data
- 5 parameters model:

  Synchrotron $\rightarrow$ power law: $A_s,\ \beta_s$

  Thermal dust $\rightarrow$ mod blackbody: $A_d,\ \beta_d$

  Correlation $\rightarrow$ ρ

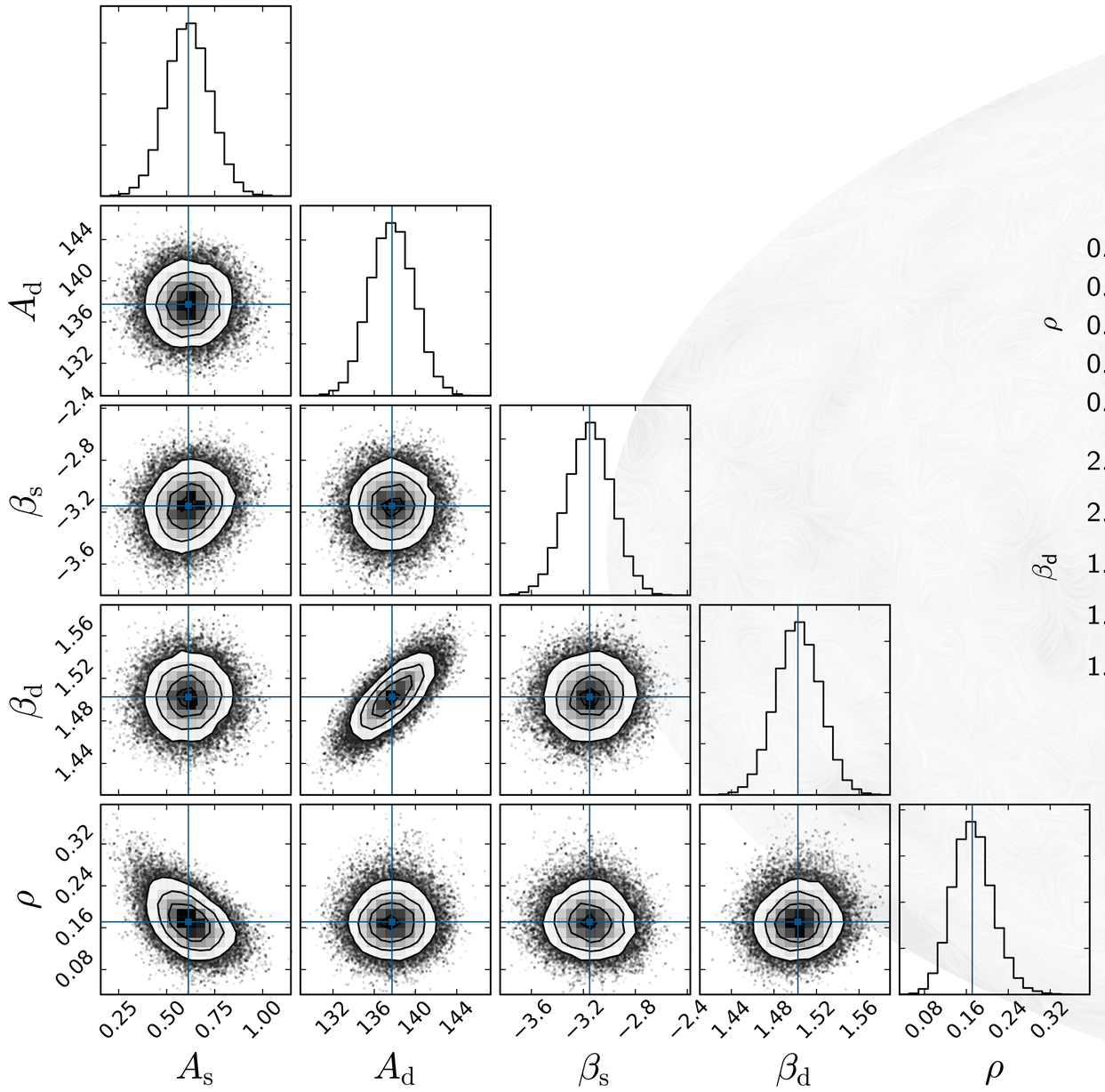
- Six sky masks $f_{sky} : 0.24 - 0.71$
- Nine multipole bins $4 < \ell < 160$

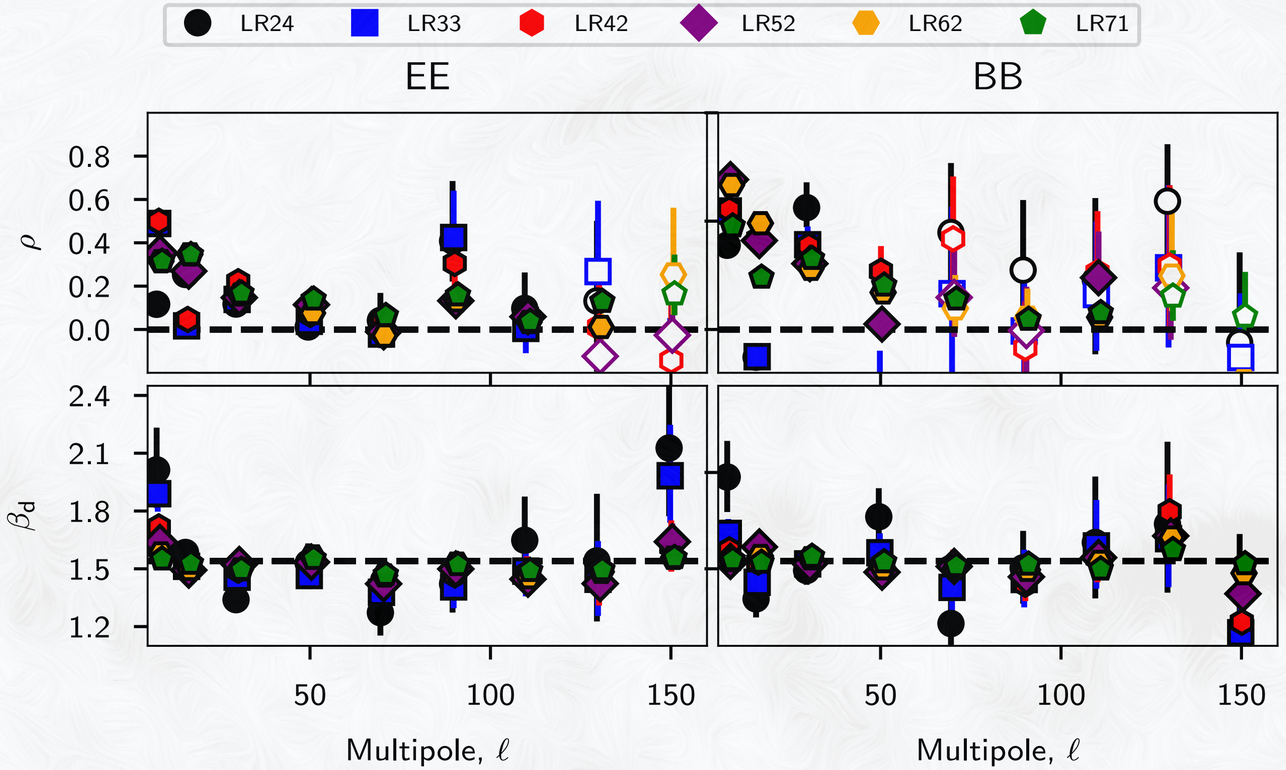


Effective frequency: $\nu_{eff} = \sqrt{\nu_1 \nu_2}$

Thermal Dust SED

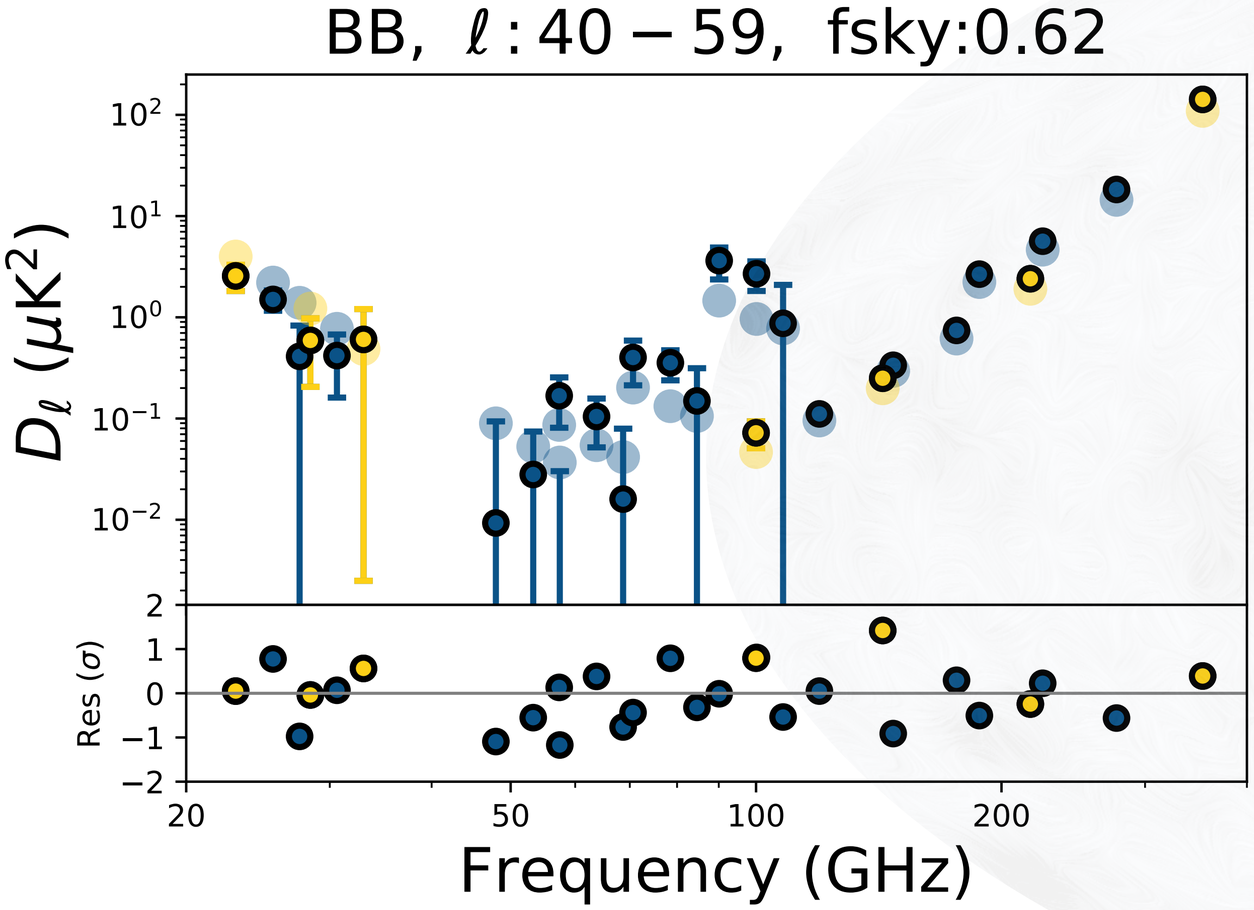
Planck Int. 2018 LIV

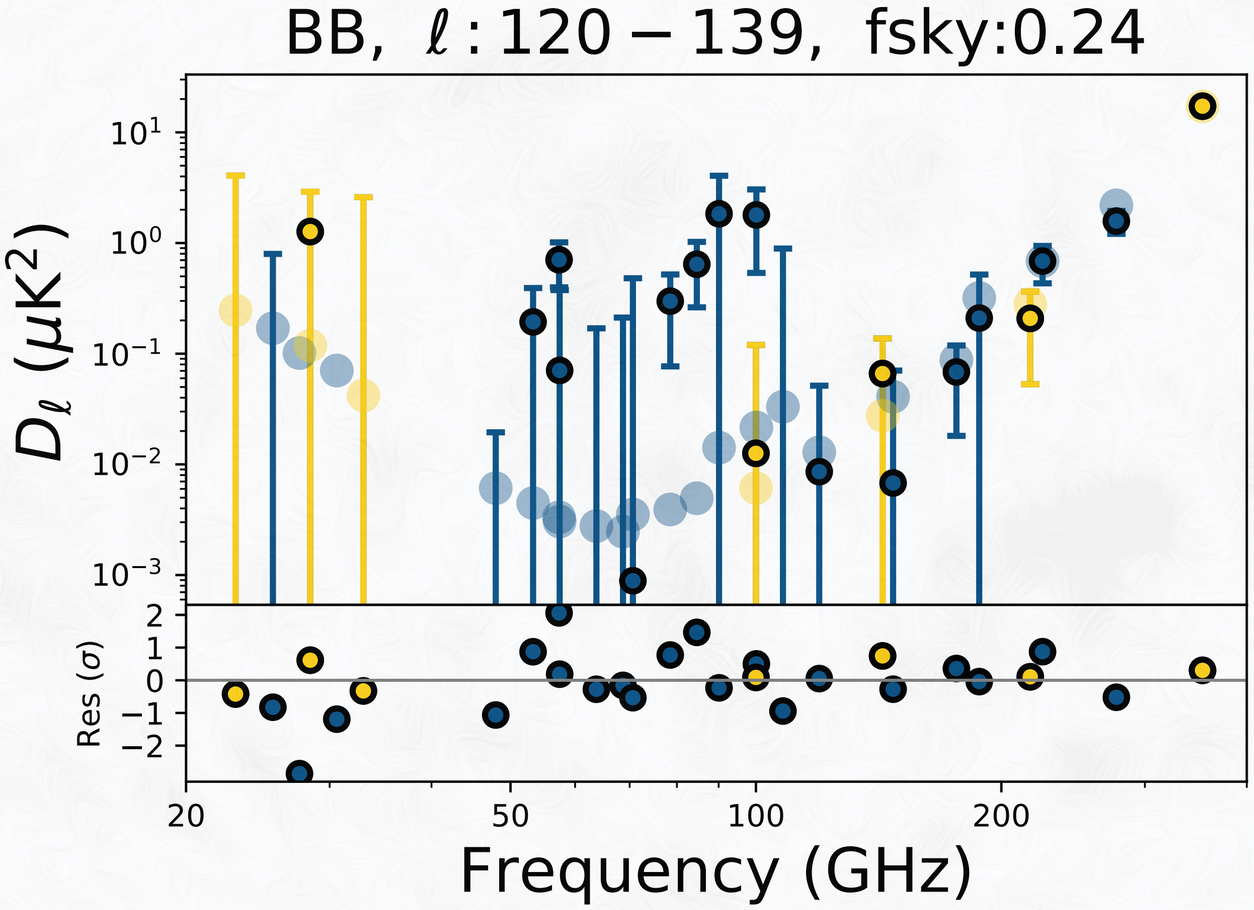




$$\beta_d = 1.53 \pm 0.02$$

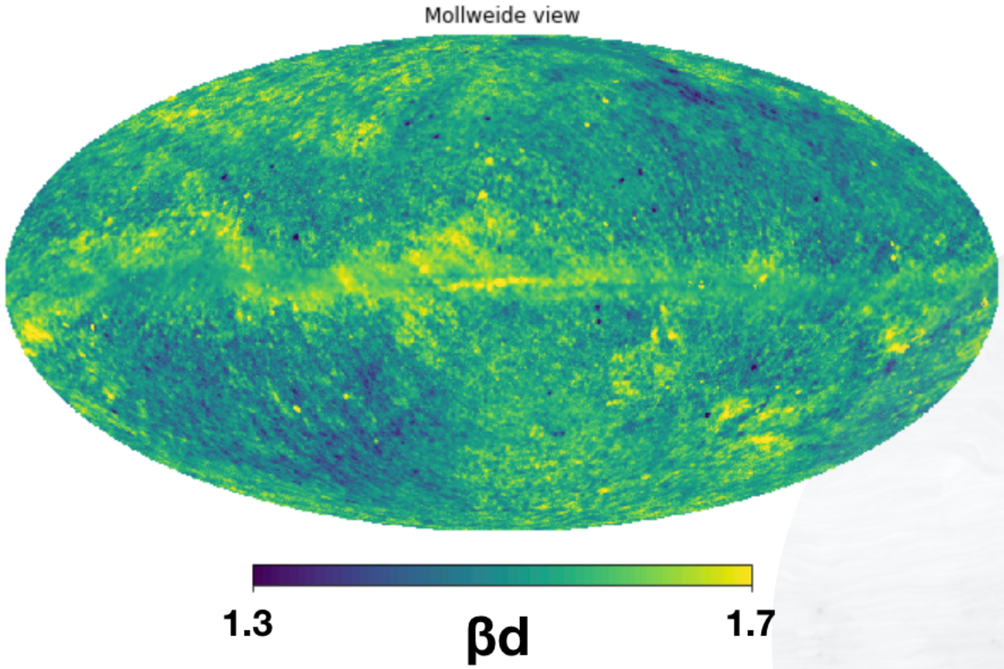
Model vs Data

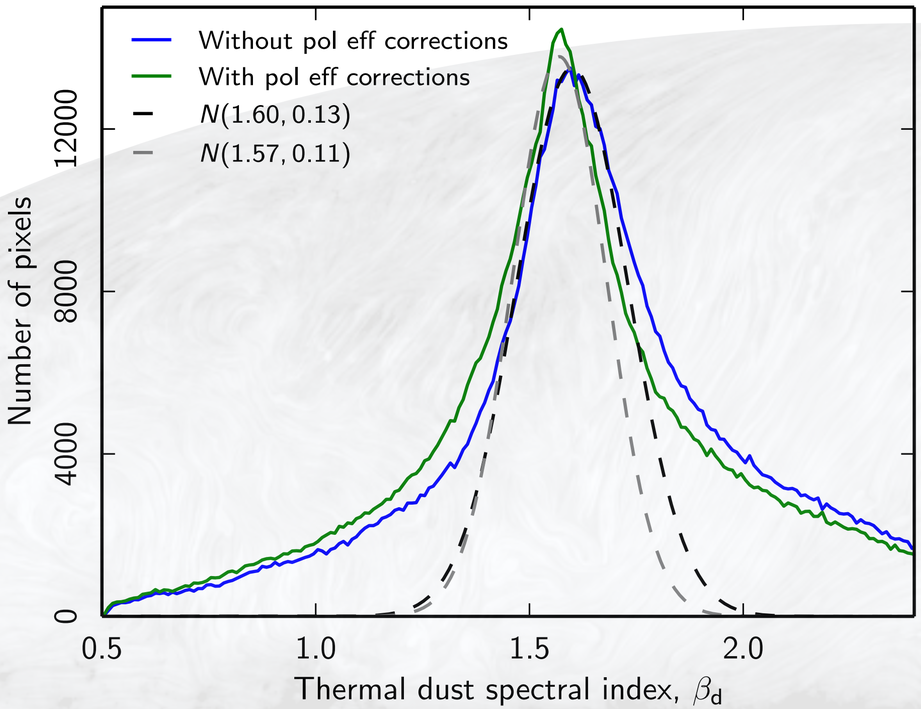


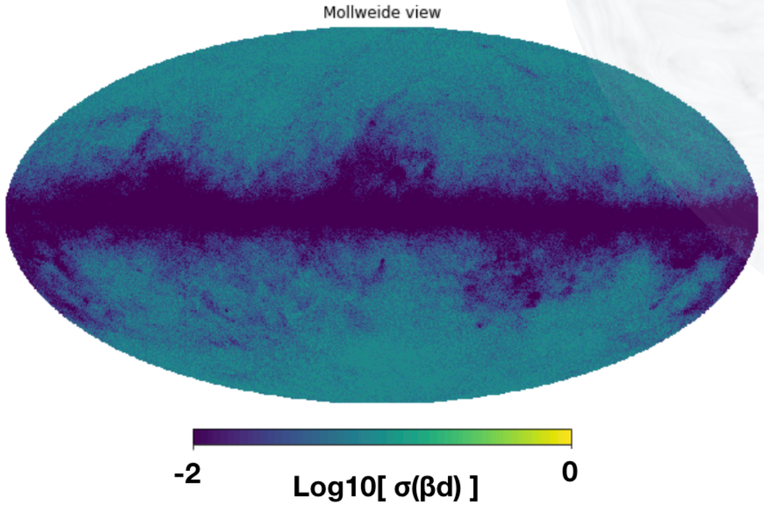


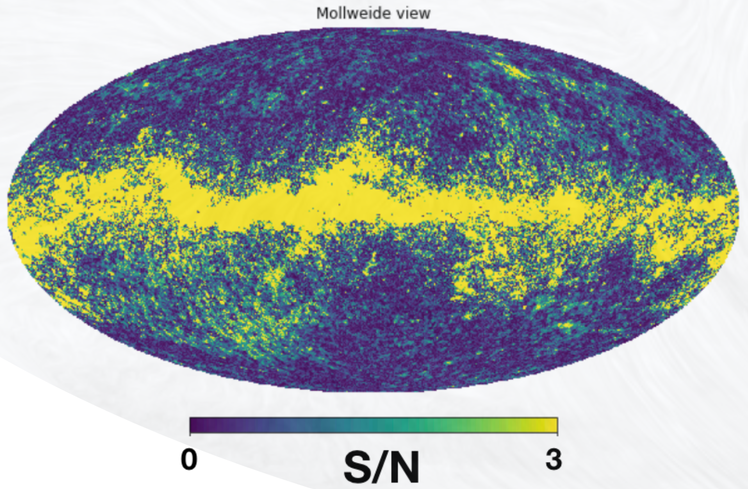
Thermal Dust SED spatial variation

Planck Collaboration IV, 2018



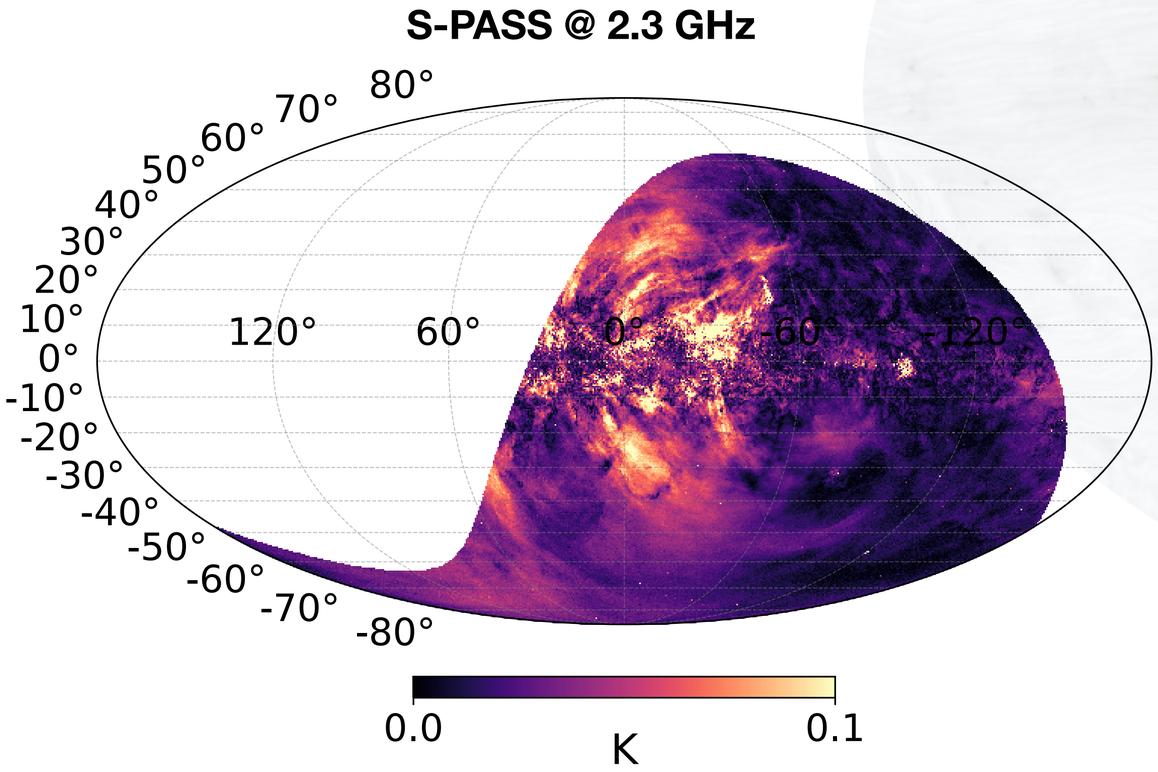


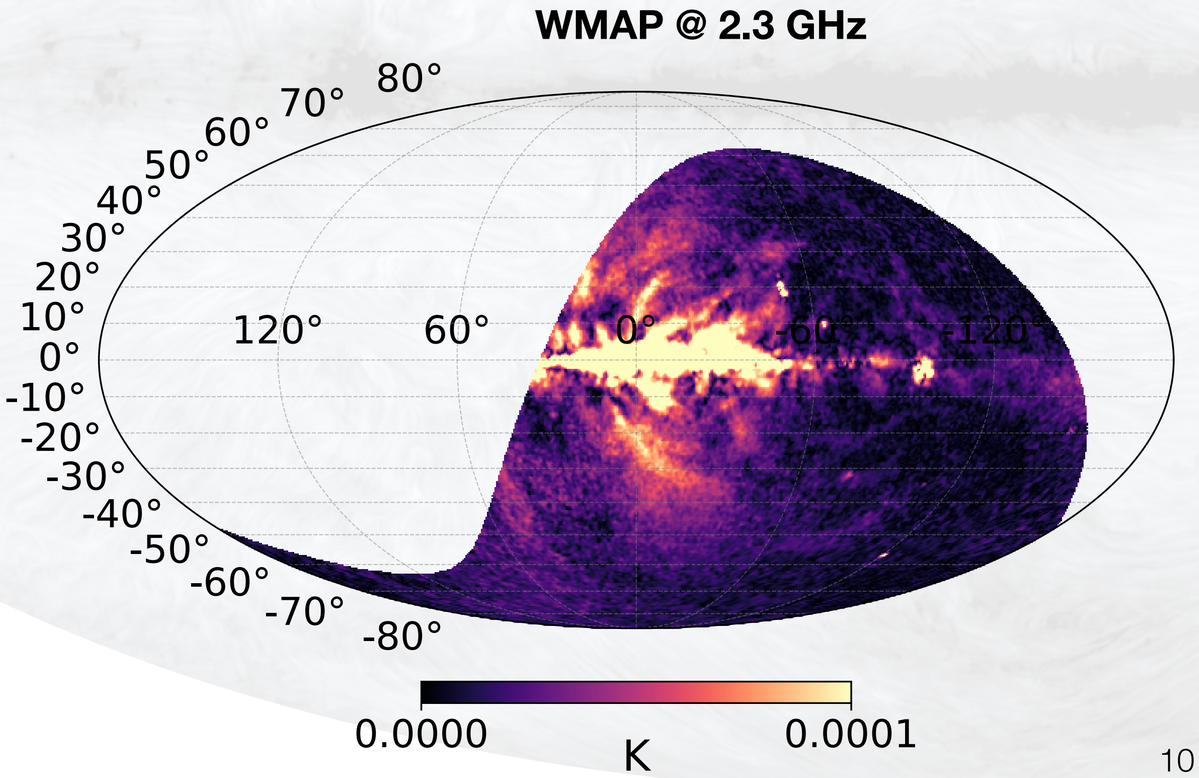




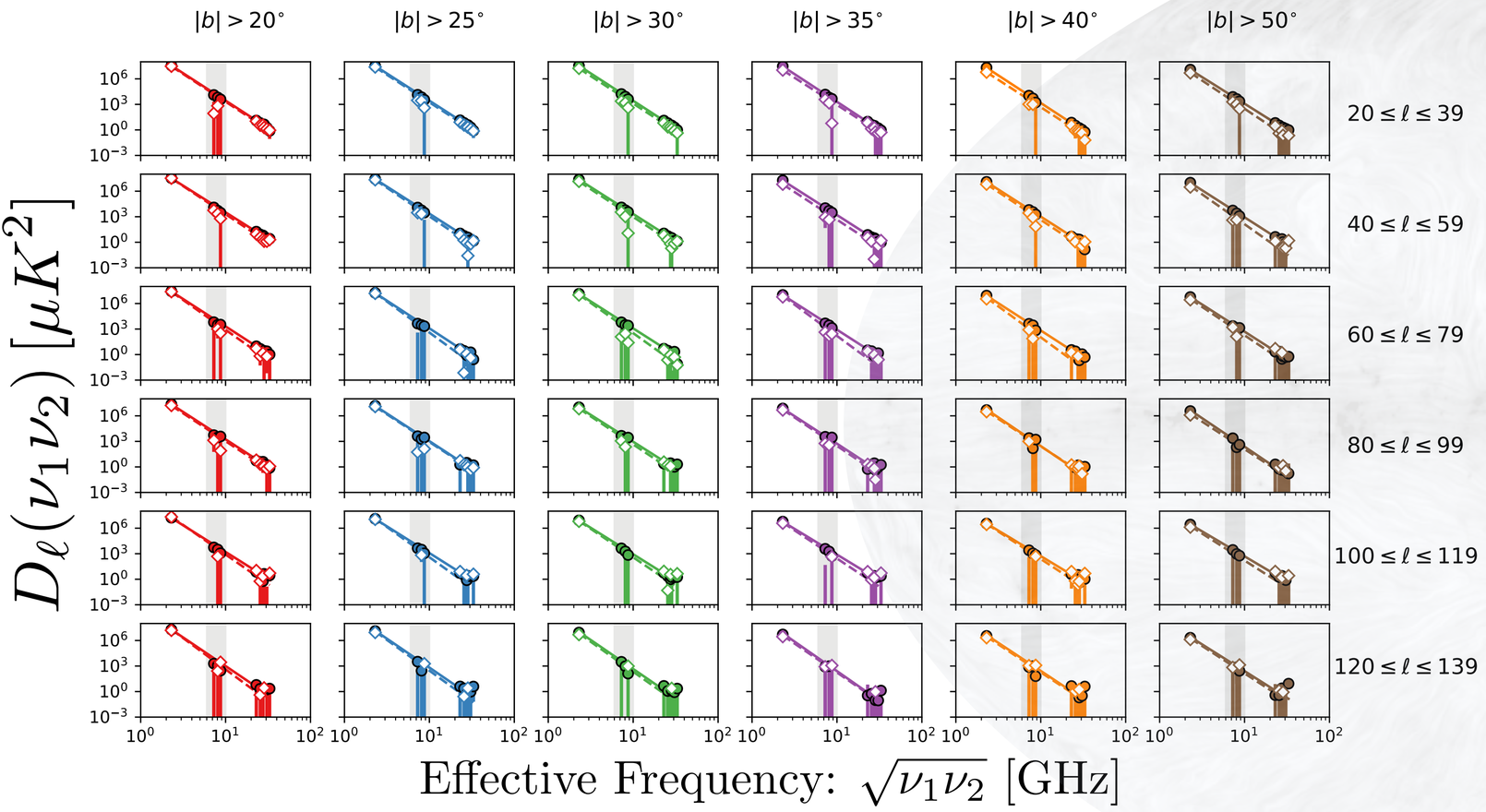
Synchrotron SED

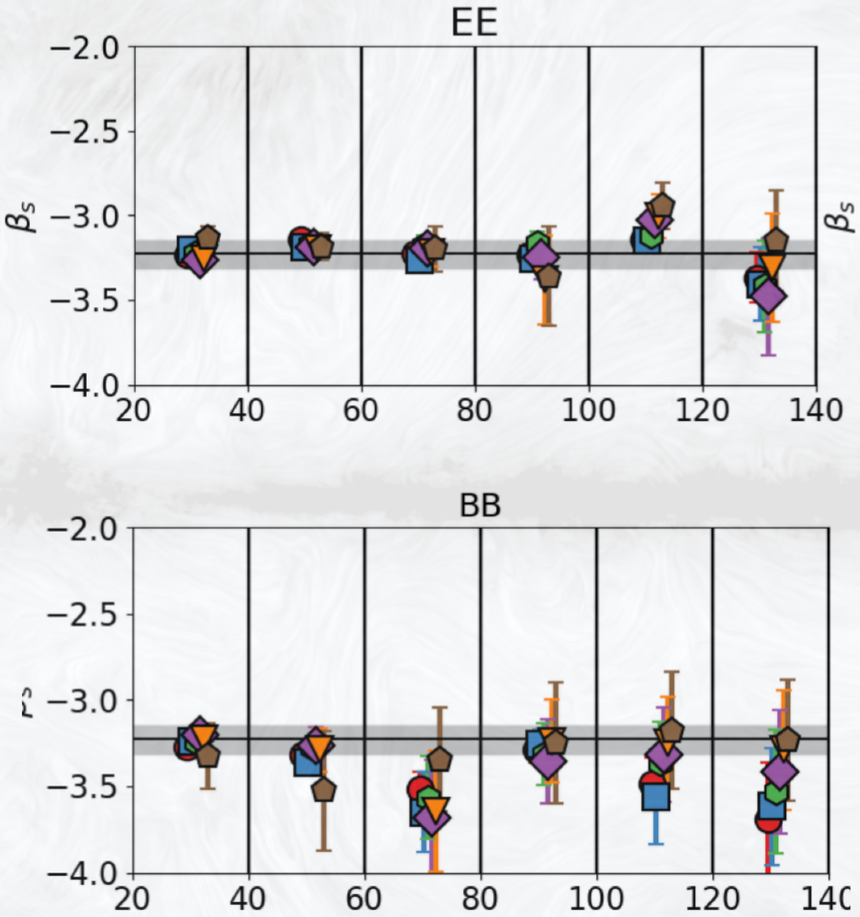
- Global synchrotron SED can be constrain with Planck and WMAP data: $\beta_s = -3.13 \pm 0.13$
- Additional information can come from low frequency ground based surveys
- **S-PASS**: 2.3 GHZ, 9 arcmin angular resolution, 50% sky coverage (Carretti et al. 2019)





Synchrotron SED





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

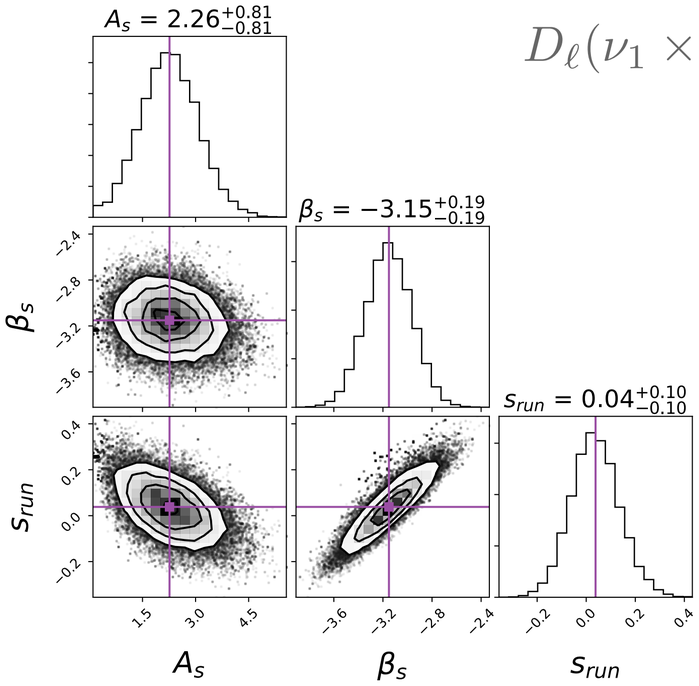
2.3 GHz 23 GHz 28.4 GHz 33 GHz

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

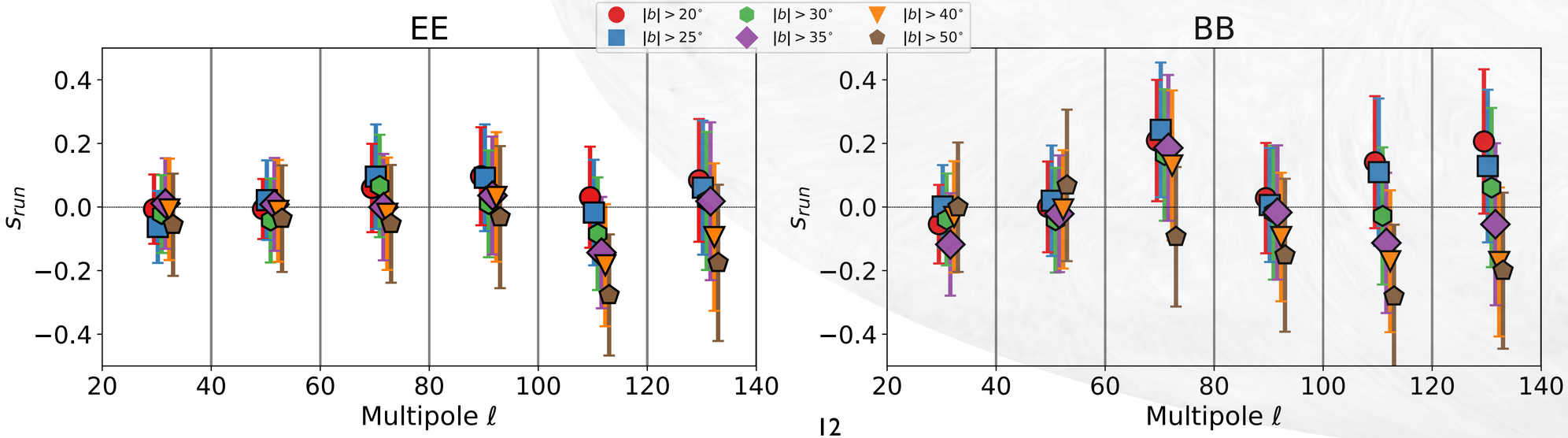
Krachmalnicoff et al. 2018

Synchrotron curvature

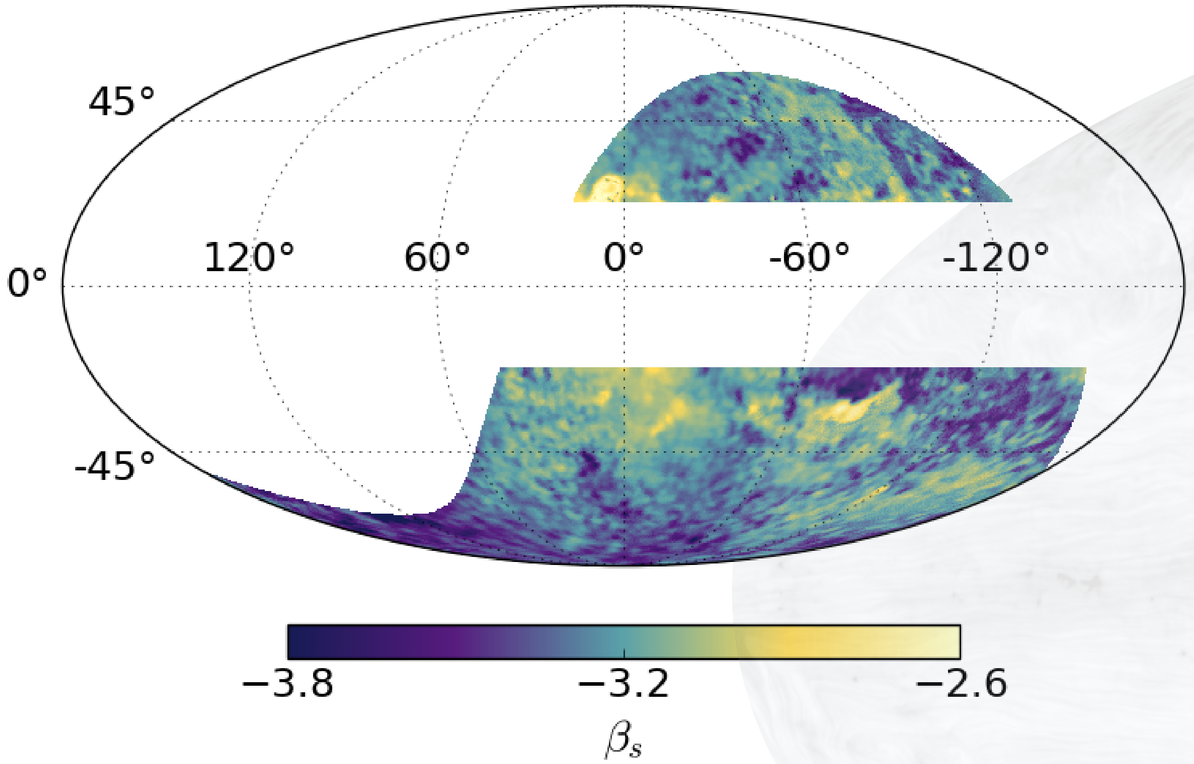
$$D_\ell(\nu_1 \times \nu_2) = A_s \left(\frac{\nu_1}{\nu_0}\right)^{\beta_s + s_{run}\log(\nu_1/\nu_0)} \left(\frac{\nu_2}{\nu_0}\right)^{\beta_s + s_{run}\log(\nu_2/\nu_0)}$$

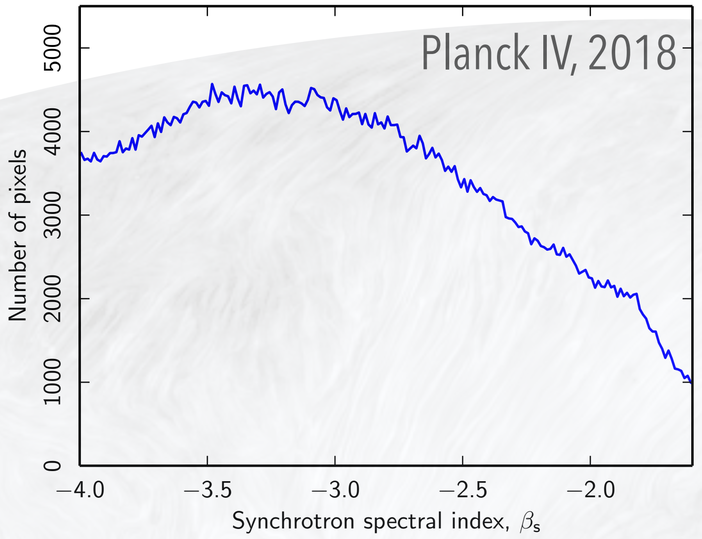


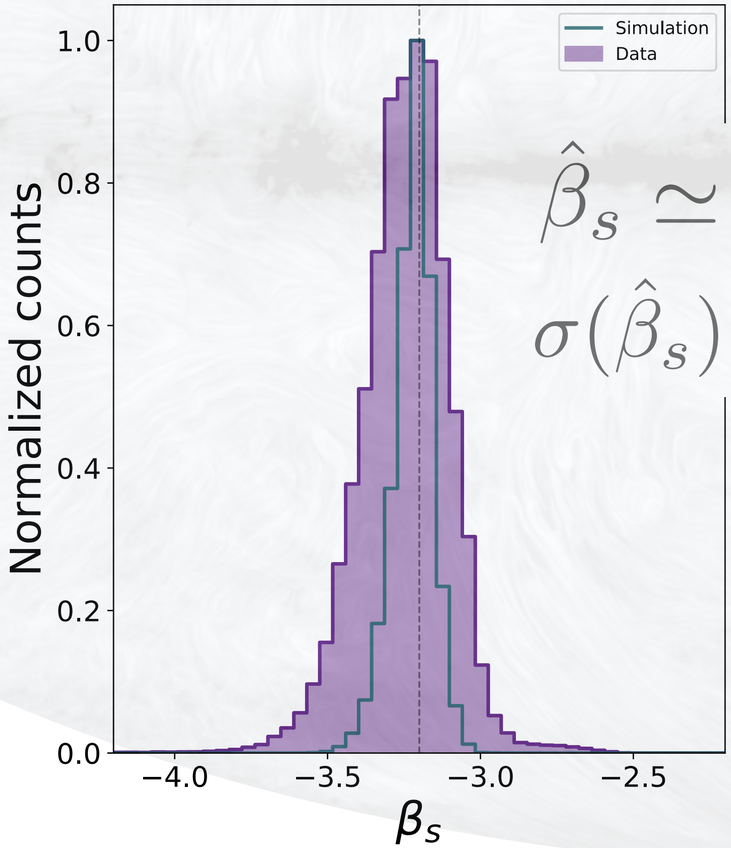
- **Gaussian prior on spectral index** from WMAP and Planck: **β_s = -3.13±0.13**
- **s_{run} compatible with zero**, with 1σ errors between 0.07 and 0.14
- More data at intermediate frequencies are needed (QUIJOTE and C-BASS in north)



Synchrotron SED spatial variation





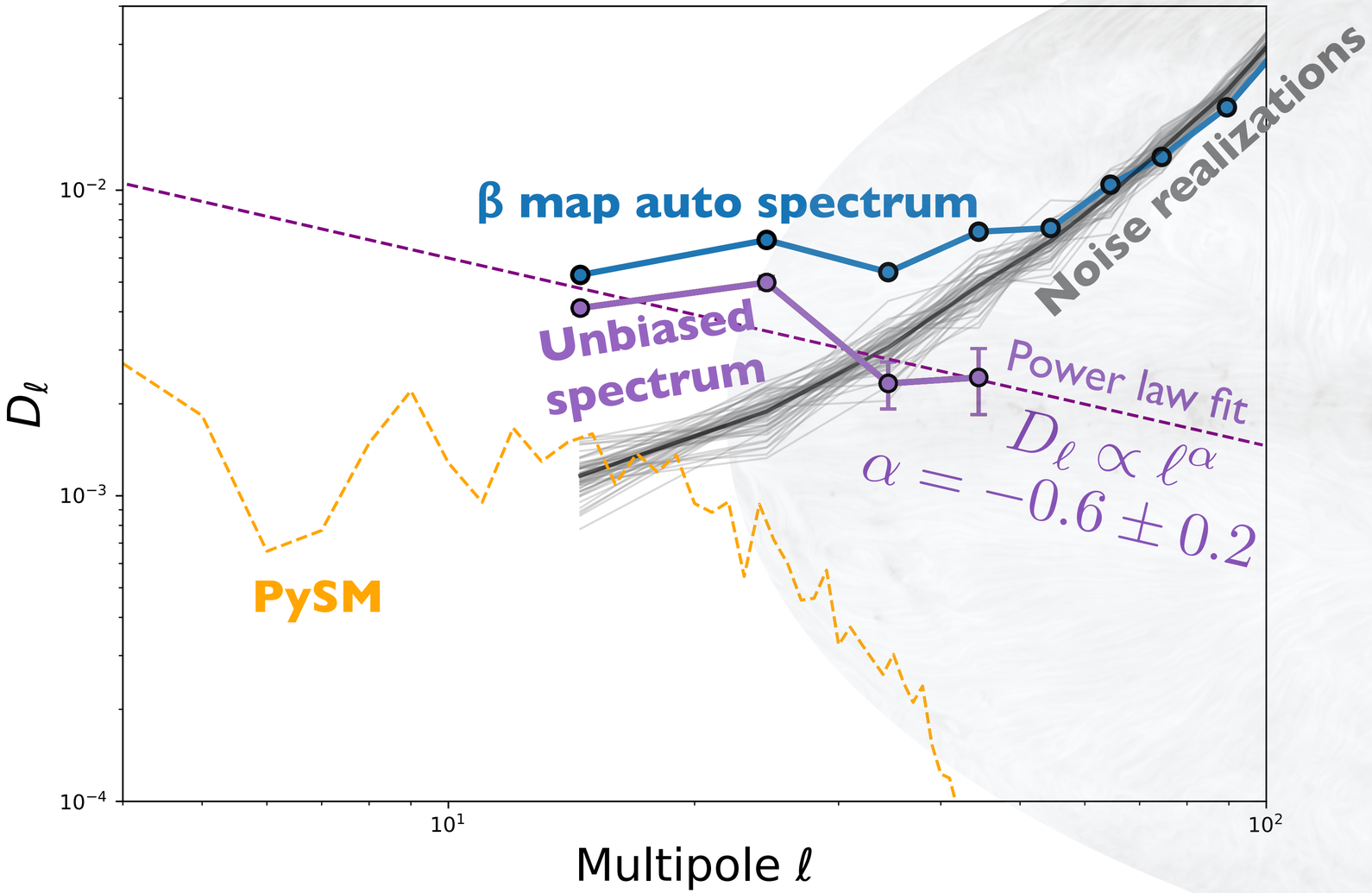


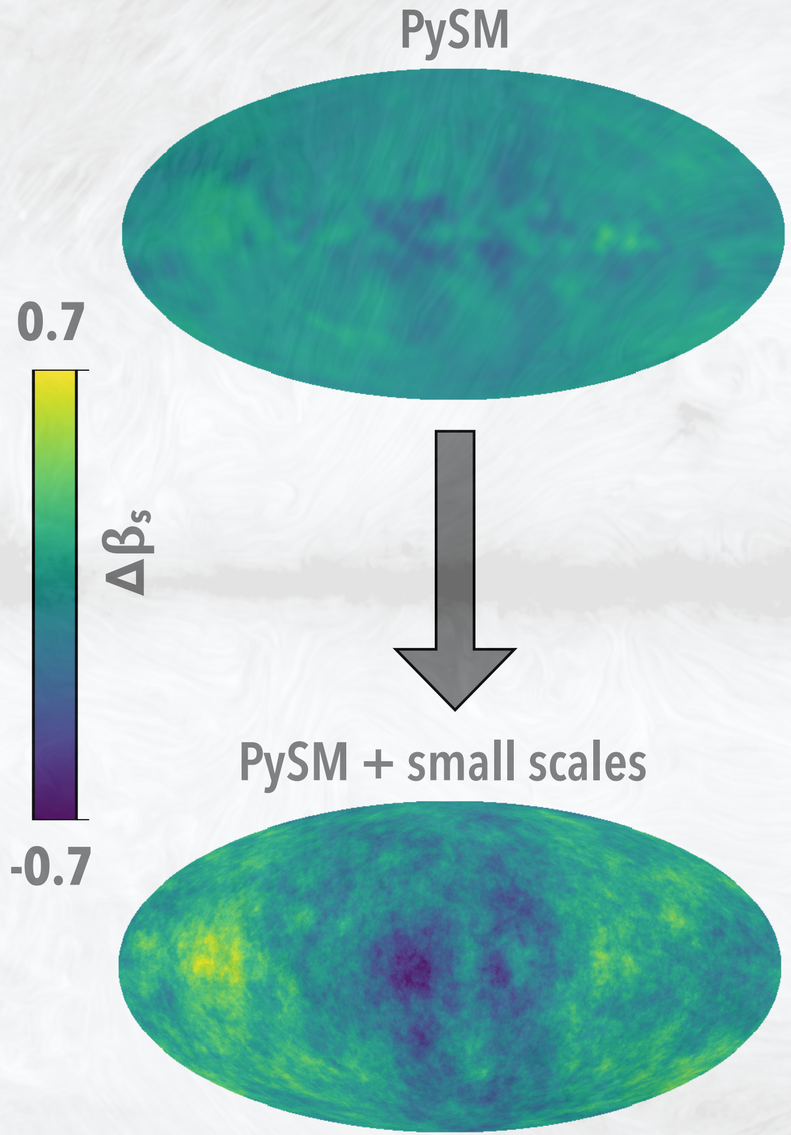
$$\hat{\beta}_s \simeq -3.20$$

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

- 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

Synchrotron SED spatial variation





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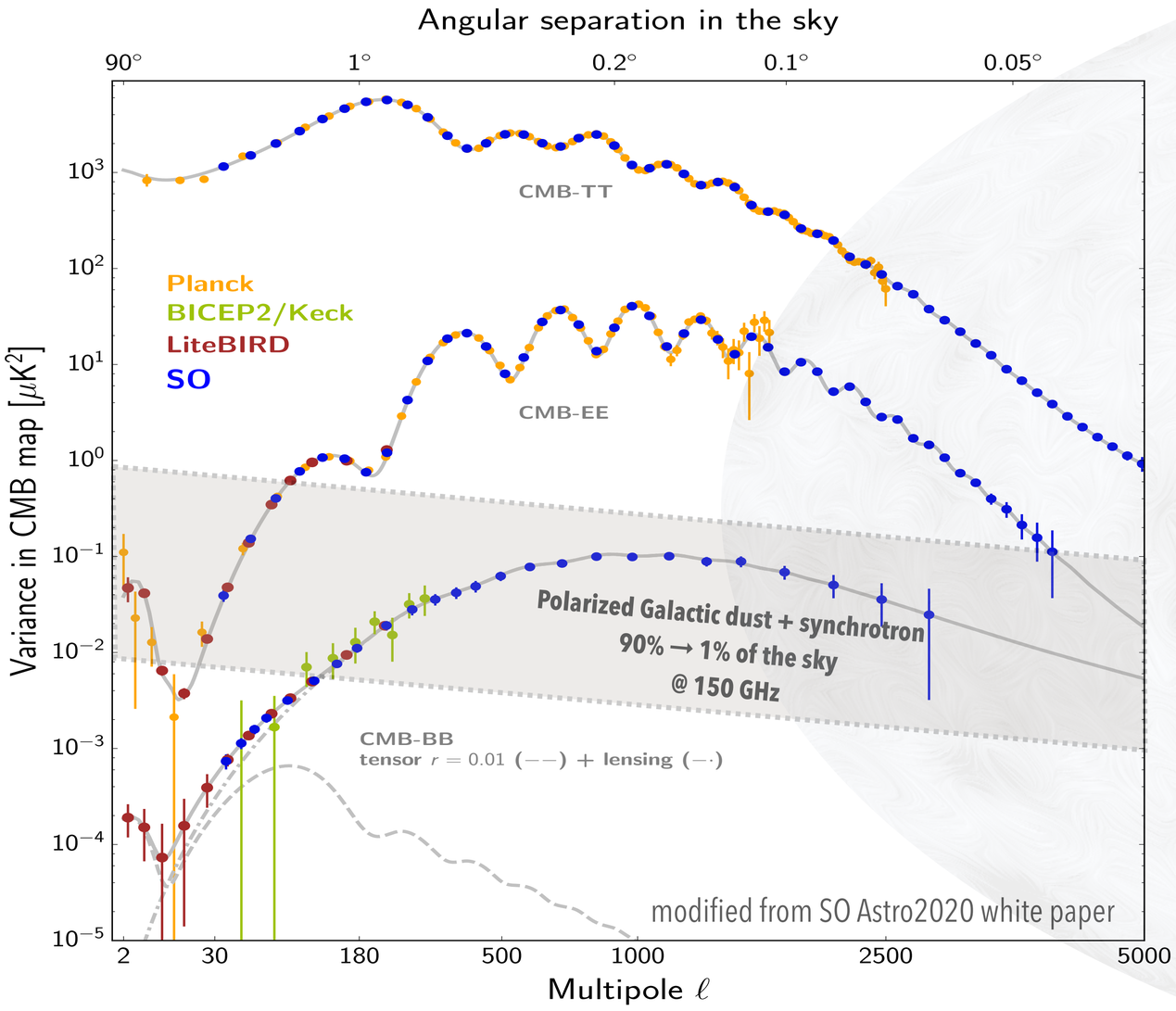
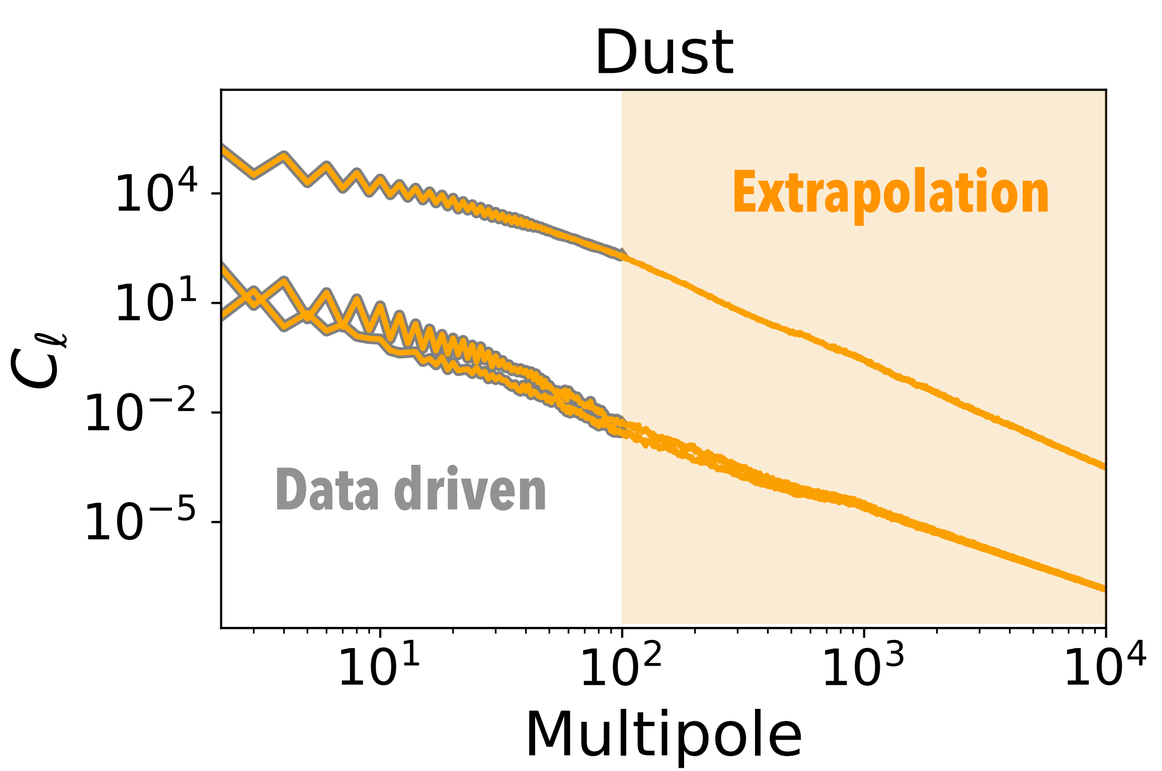
FG small scales



- Small scales (< 1°) are added as Gaussian realizations of power law spectra
- We expect FGs to be highly non-Gaussian also at small scales, and we must understand their impact on lensing recontruction
- Few data are available and MHD simulations are not ready to be plugged in our models yet



Can we use **Neural Networks to add realistic non-Gaussian small scales** to current Galactic models?

ForSE

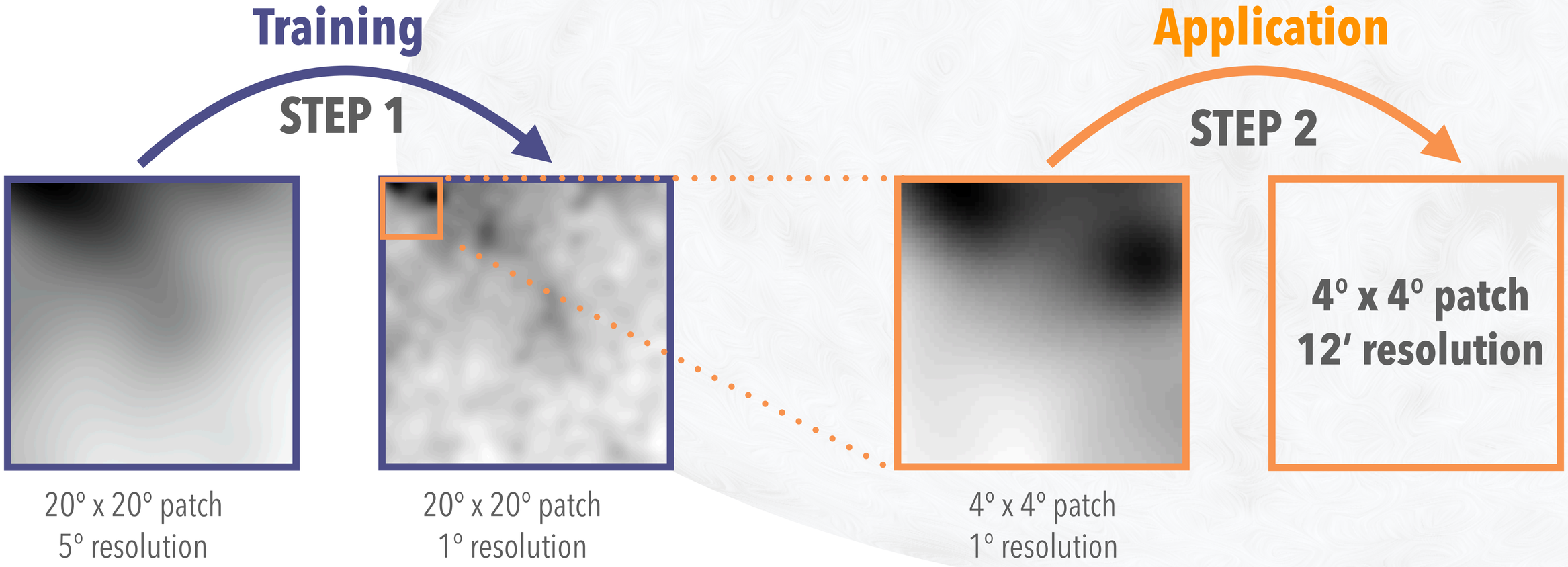
("Maybe" in Italian)

Foreground **S**cale **E**xtender

In collaboration with **Cosmology x Data Science group at CCA** and **Giuseppe Puglisi**

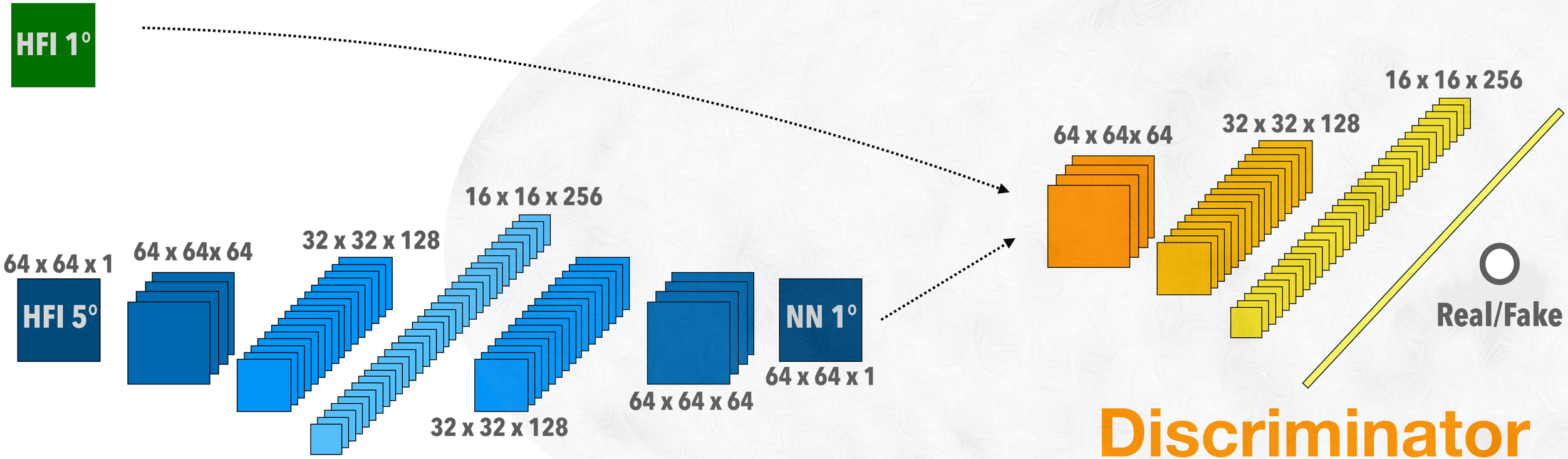
The idea

- Use **Neural Networks to learn the statistics of FGs at the degree scale** (where we still have data) and **reproduce it at smaller ones**
- Assumption that FGs are scale invariant



Generative adversarial Networks (GANs)

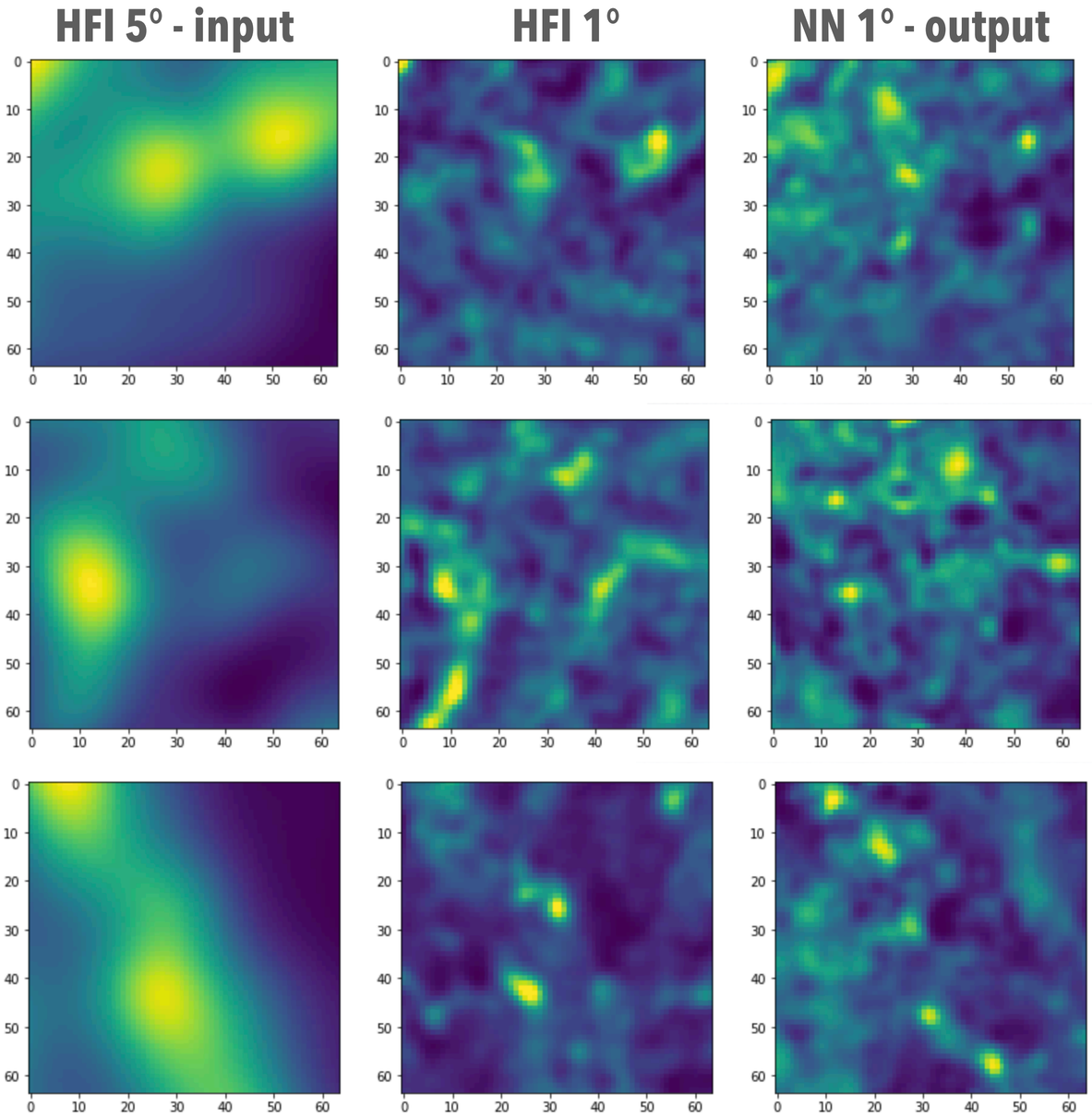
Modified DCGAN (Radford et al. 2015)



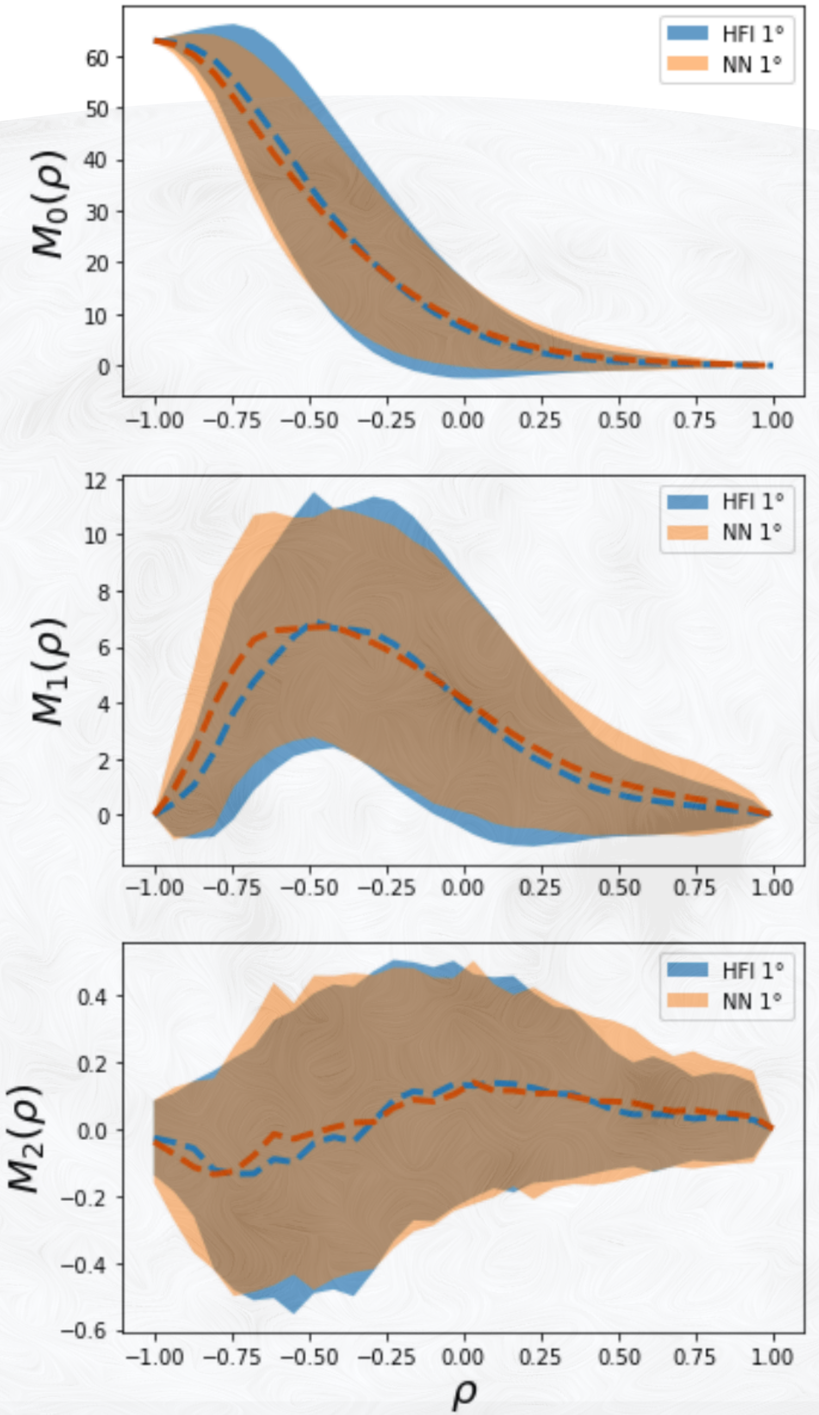
Generator

Discriminator

Training on data

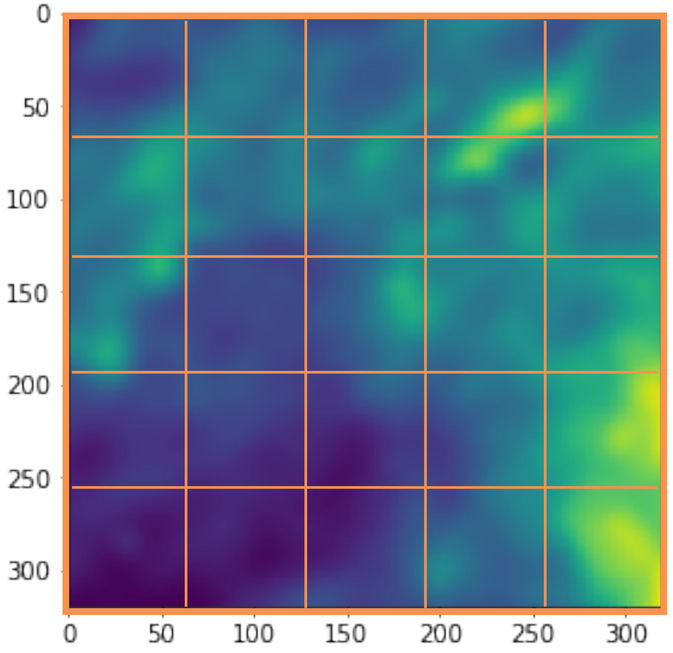


Minkowski functionals

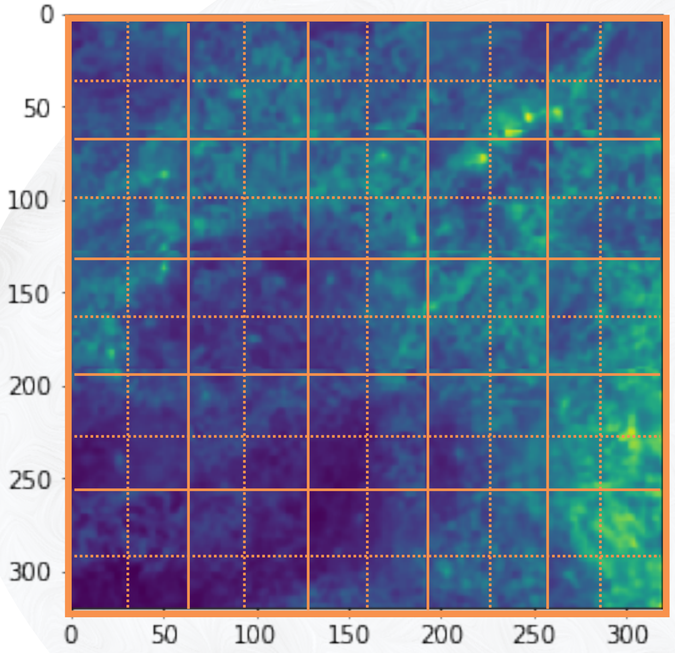


Application to sims

Inputs at 1°

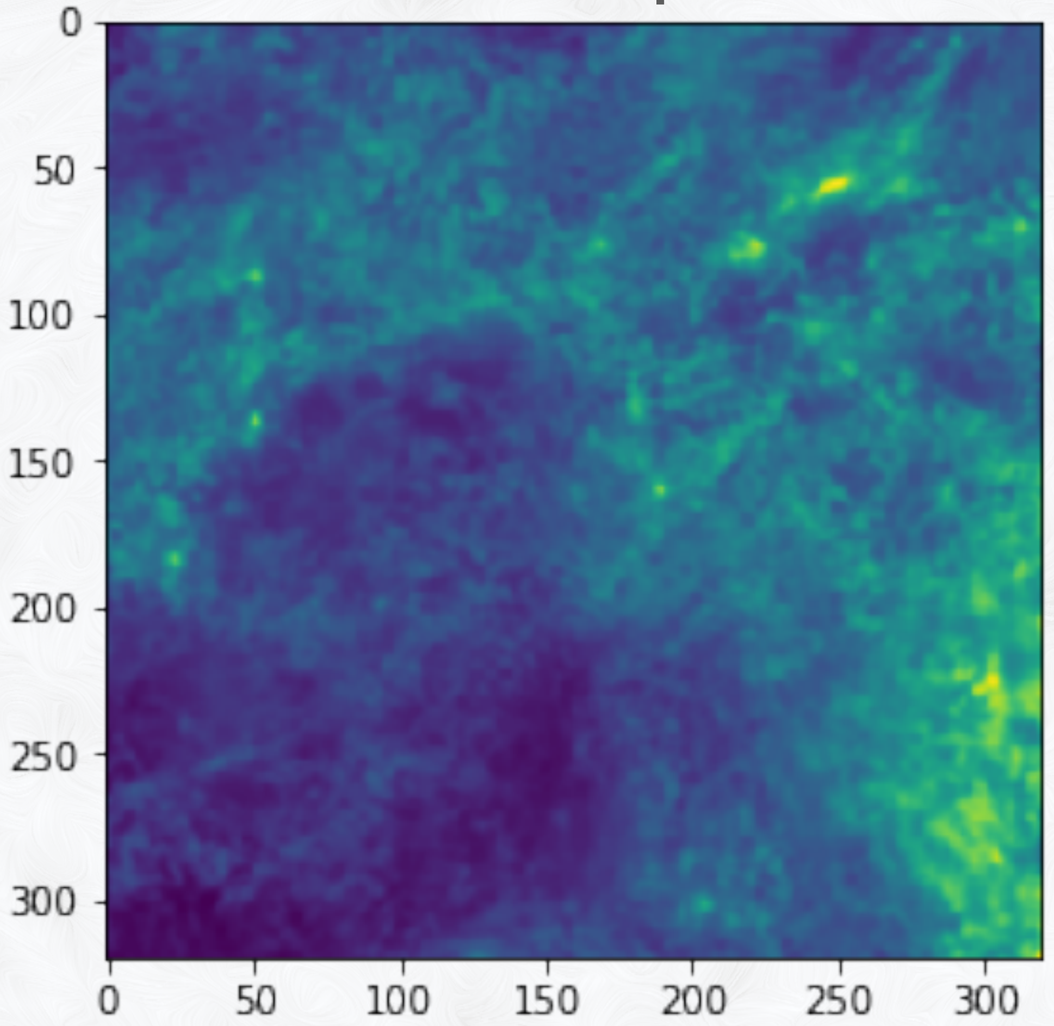


Outputs at 12′



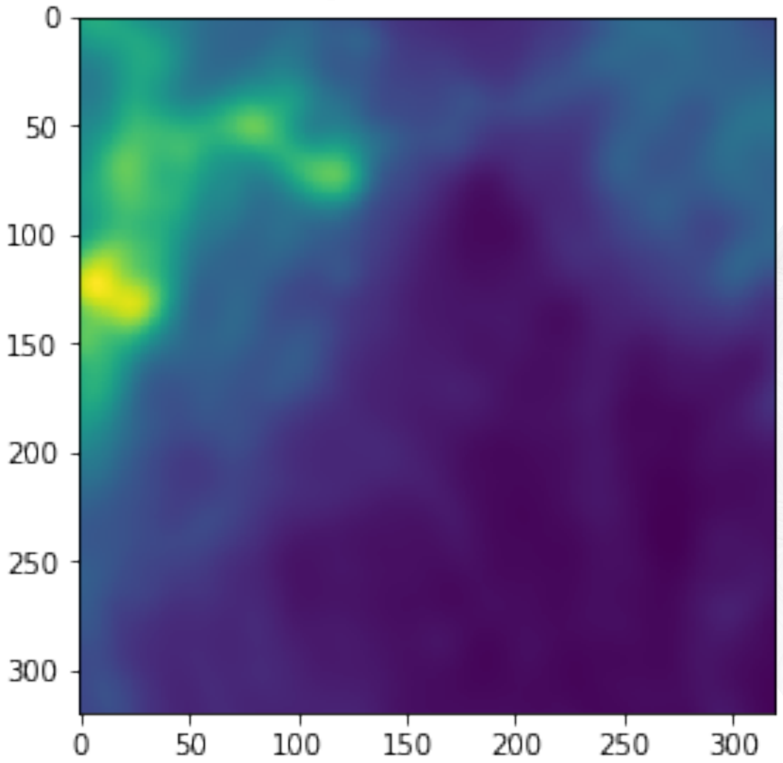
Oversampling and apodization to minimize border effects

combined output at 12′

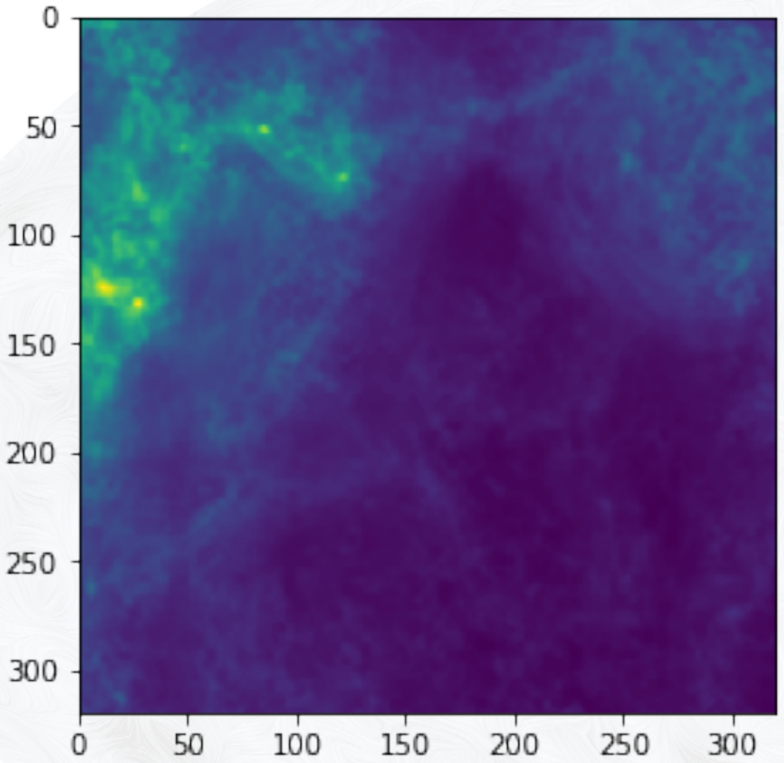


Application to sims

inputs at 1°

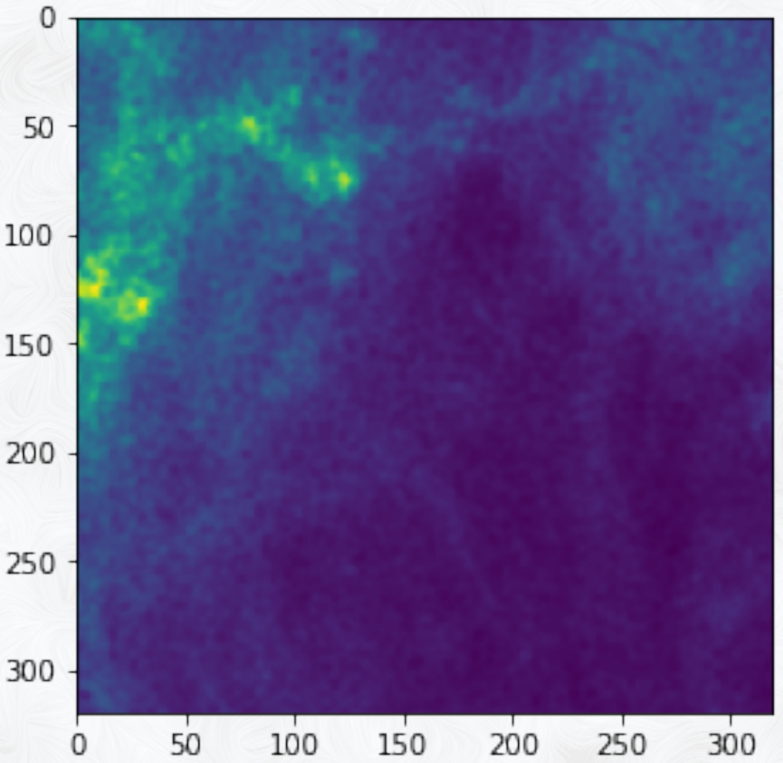


combined output at 12′

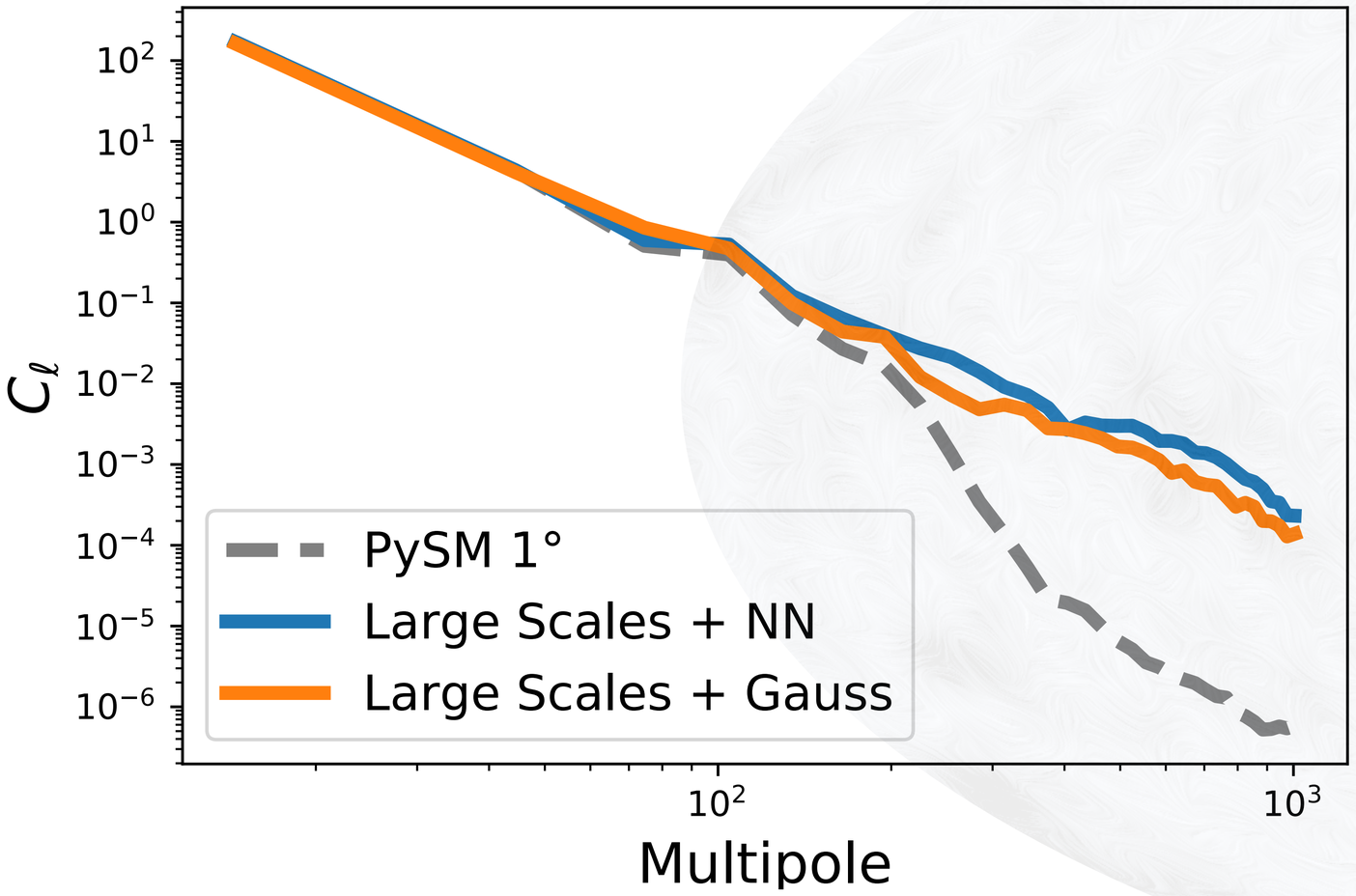


For comparison

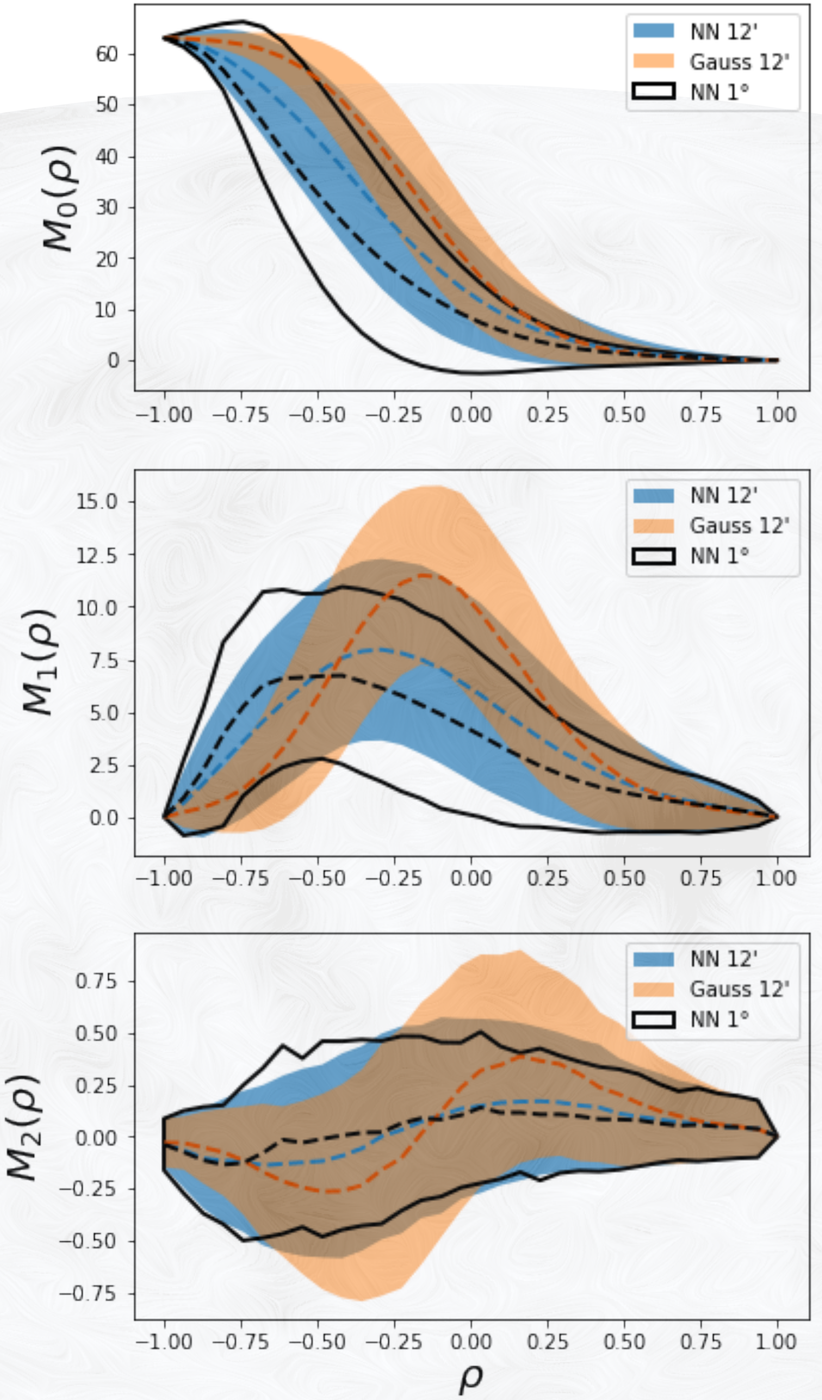
current sims at 12′ with gaussian small scales



Preliminary validation of results



Minkowski functionals



Take home messages

- The **current models** of Galctic Polarized emission are **based on** full sky **Planck and WMAP** maps
- **Large scale amplitude, morphology and global SED are OK** (at the first order)
- **Spatial variation of SEDs are contaminated by noise**
- For synchrotron we can rely on ground based **low frequency surveys**
- **Neural Networks** could be a useful tool **to extend our models**, **combine** different **datasets** or combine data with **numerical sims**