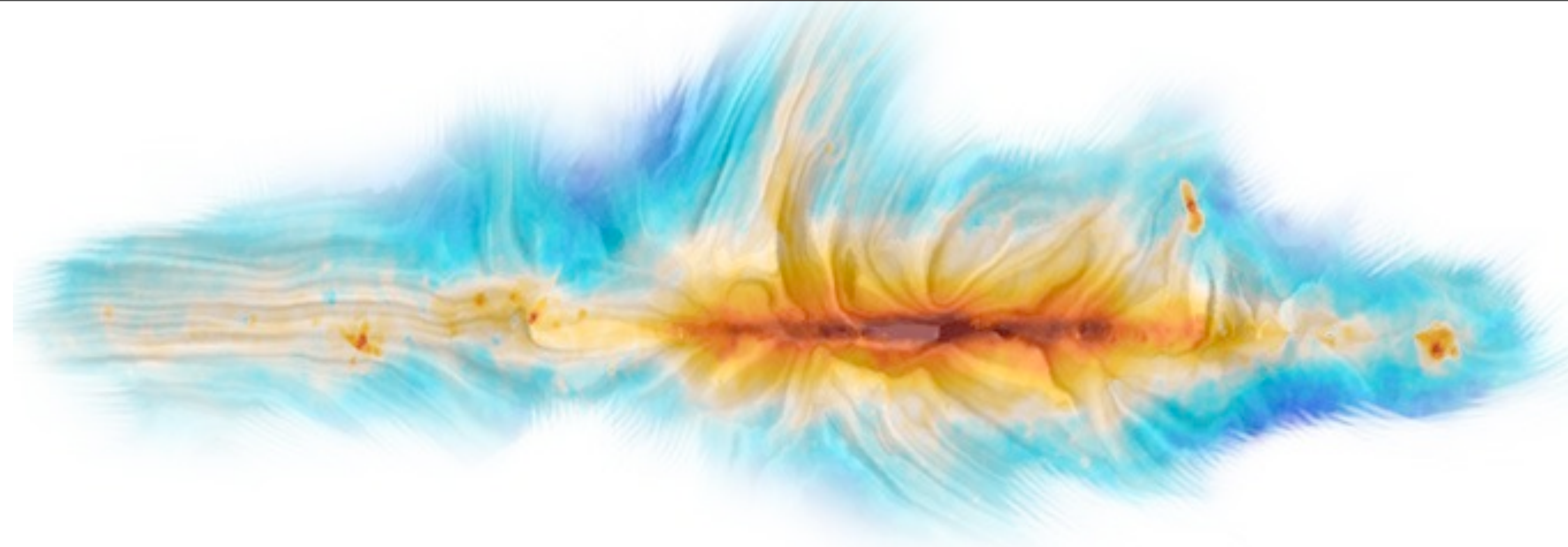


Component Separation with Neural Networks

Biuse Casaponsa, on behalf of Radioforegrounds and QUIJOTE collaboration
IFCA, Santander, Spain

CMB Radioforegrounds for B-mode studies,
15-19 October 2018, San Cristóbal de la Laguna, Spain

Outline

1. Neural networks

2. Application to simulations

3. Preliminary results with MFI - Quijote data in combination with Planck

NEURAL NETWORKS.
Introduction

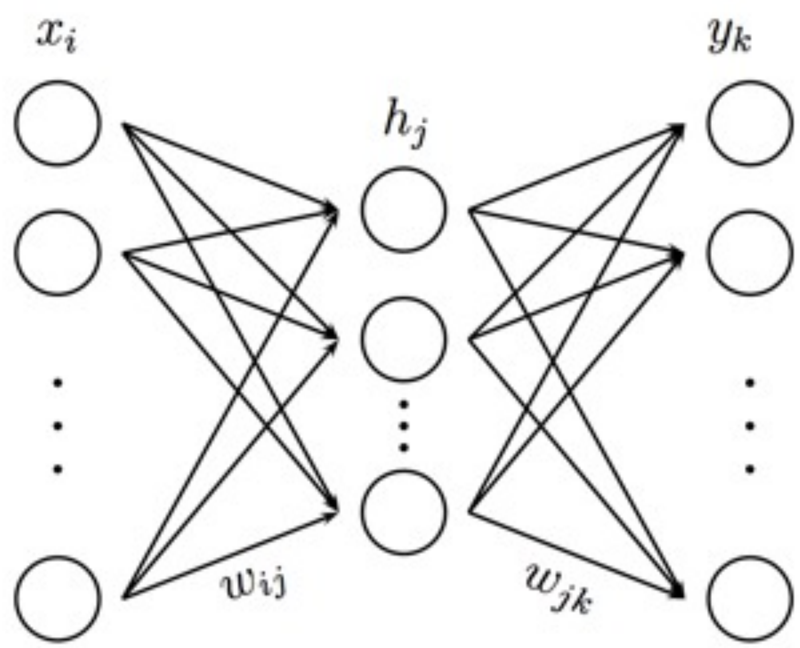
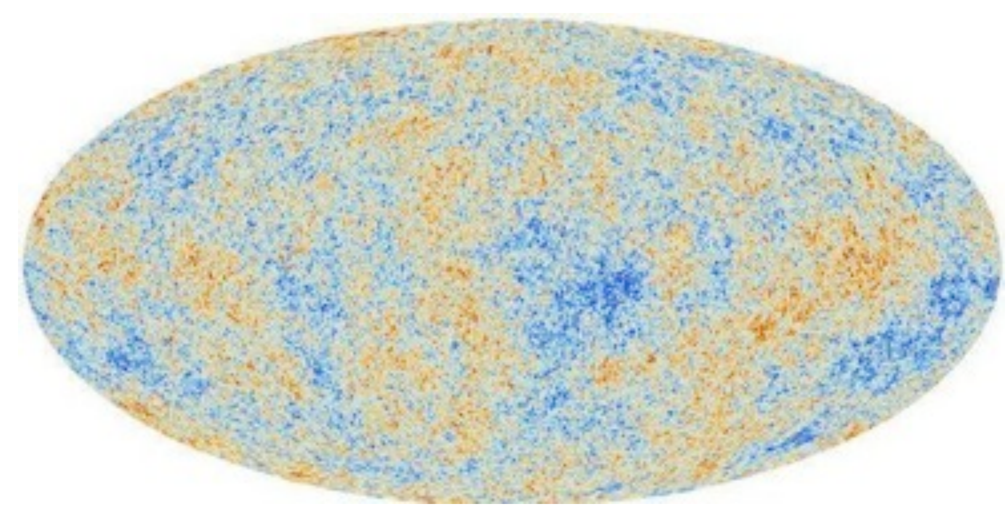


Figure 1. Schematic of a 3-layer feed-forward neural network.

Neural networks are a powerful tool for pattern recognition, predictive modeling, classification, parameter estimation...



In CMB, few applications have been proposed:

Auld et al. 2007, 2008 for cosmological parameters estimation

Casaponsa et al. 2011, 2013 Novaes et al. 2015 for primordial non-Gaussianity analyses.

Norgaard-Nielsen 2008, 2012 for CMB foreground removal

NEURAL NETWORKS. Introduction

<u>In a one hidden layer network,</u>
choosing a tanh activation function, the values on the hidden nodes will be:

$$h_j = \tanh\big(\sum_i w_{ij} x_i\big)$$

and in the output layer with a linear activation function, the output values are:

$$y_k = \sum_j w_{jk} h_j$$

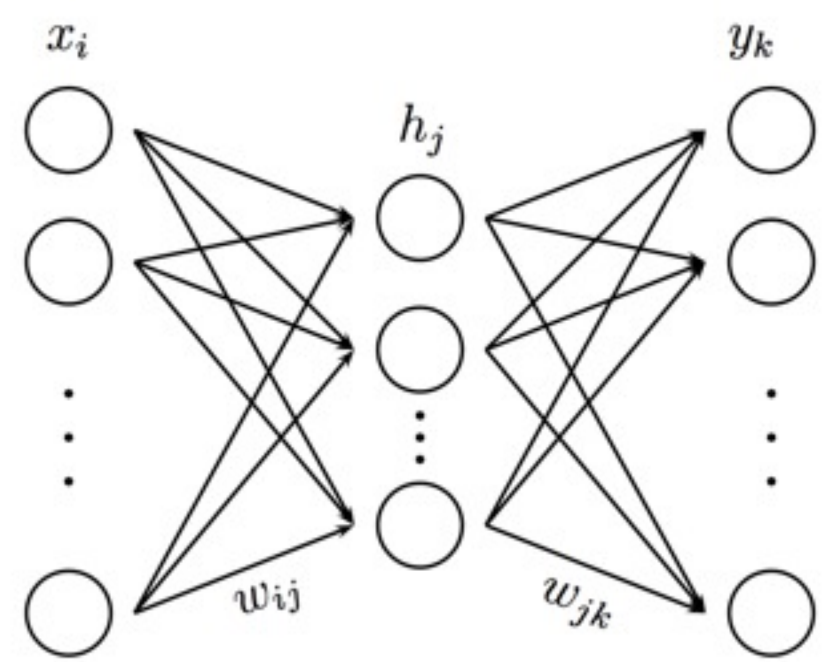


Figure 1. Schematic of a 3-layer feed-forward neural network.

Then we have the ouputs as a function of the inputs and the weights

$$\boxed{y_k = \sum_j w_{jk} \tanh\big(\sum_i w_{ij} x_i\big)}$$

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NEURAL NETWORKS. Introduction

General form $\longrightarrow$

$$y_k = g\Big((\sum_m w_{nm} ... f(\sum_i w_{ij} x_i + \theta_j) + \theta_n\Big)$$

To obtain the network parameters ($\vec{w}, \vec{\theta}$): **Training procedure**

We need a **training set**: A set of known inputs and outputs (called targets) (x,t) . y_k

NEURAL NETWORKS. Introduction

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minimize loss function:

$$E = \sum_n \sum_k \frac{(t_k^n - y_k^n)^2}{K \times N}$$

Once we have x,t for the training set, then we basically do a is a multidimensional fit

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NEURAL NETWORKS.

Parametric component separation

POLARIZATION:

What we have	What we want
S_i Q and U values in (μK_{RJ}) at each frequency for Q and U.	$A_{cmb}^{Q}, A_{cmb}^{U}, A_{s}^{Q}, A_{s}^{U}, \beta_s, A_{d}^{Q}, A_{d}^{U}, \beta_d, T_d$

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NEURAL NETWORKS.

Parametric component separation

POLARIZATION:

Draw random distribution of parameters

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NEURAL NETWORKS.

Parametric component separation

POLARIZATION:

Given a model and some noise compute de stokes parameters at each frequency

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Repeat > 100,000 times

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Repeat > 100,000 times

The training set is ready to learn

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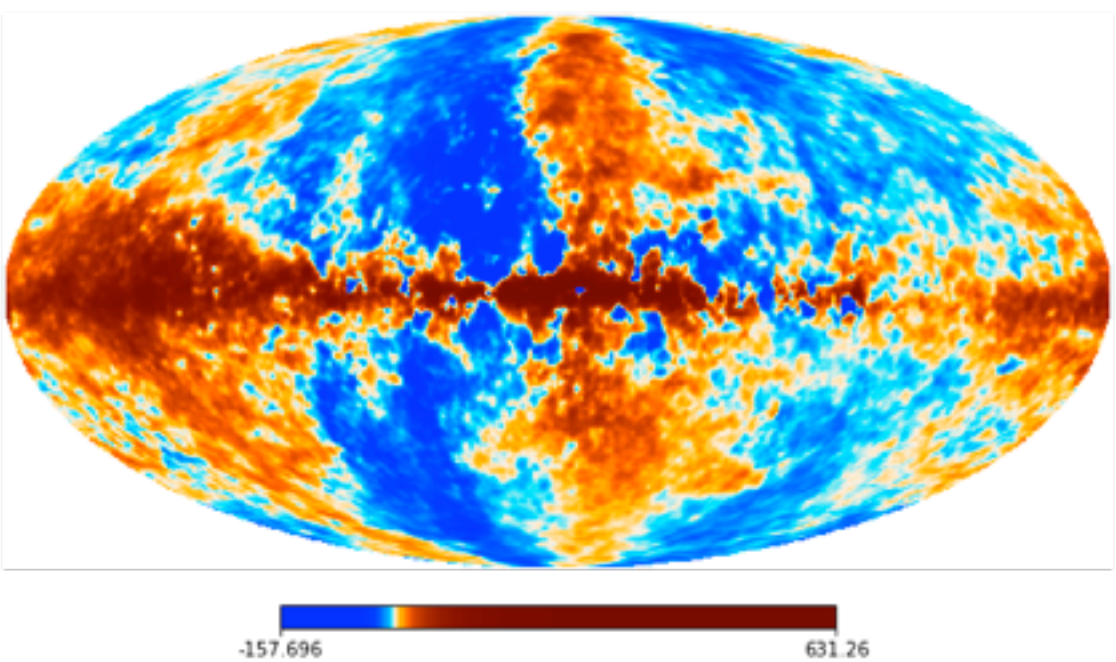
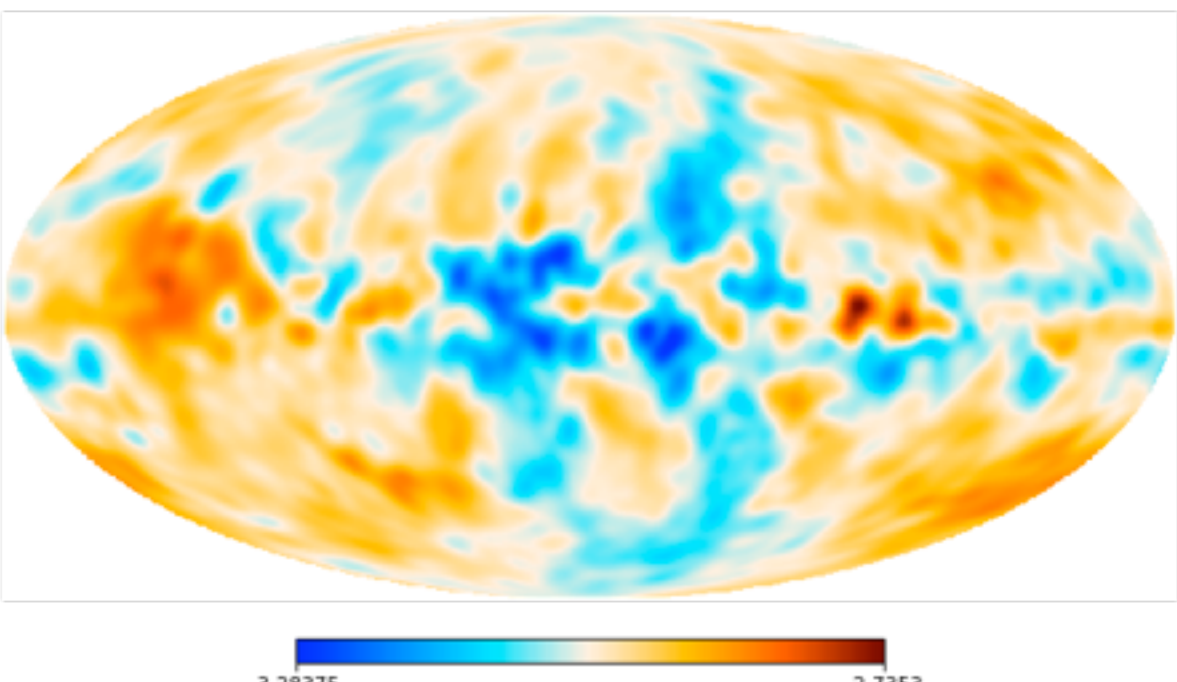
APPLICATION TO SIMULATIONS

Once the neural network is trained we have a non-linear function that relates any vector (S_i) to the corresponding parameters $\beta_j = f(S_i)$

and we can apply this function to each pixel of a simulation





APPLICATION TO SIMULATIONS

o Simple cmb + synchrotron + dust simulations with white noise, using PSM amplitudes and spectral indices.

- o Synchrotron: power law
- o Dust: one component grey body

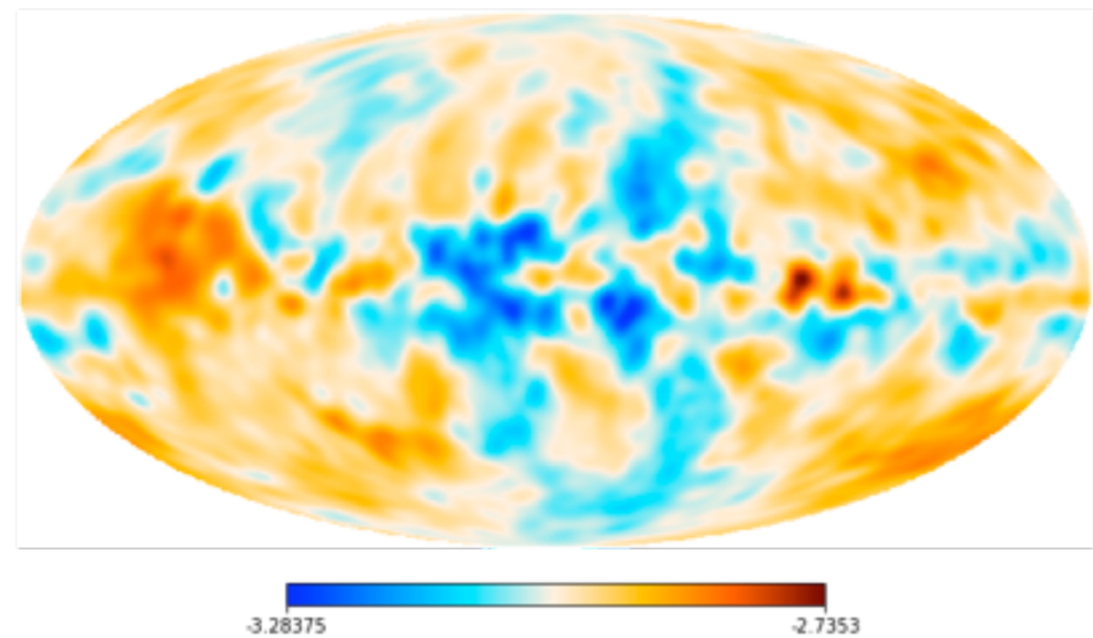
o MFI and Planck channels (11GHz + Planck)

o 1 set of simulations at 1deg and one set at 10 deg

o Since we are interested in the low frequency, dust spectral parameters are fixed.

APPLICATION TO SIMULATIONS

β_s



If we use a uniform distribution for the spectral index from -4 to -2, the method finds a large bias in PLANCK.

we train 2 networks:
-one with the 7 Planck frequencies
-one with 8 frequencies 11 + Planck

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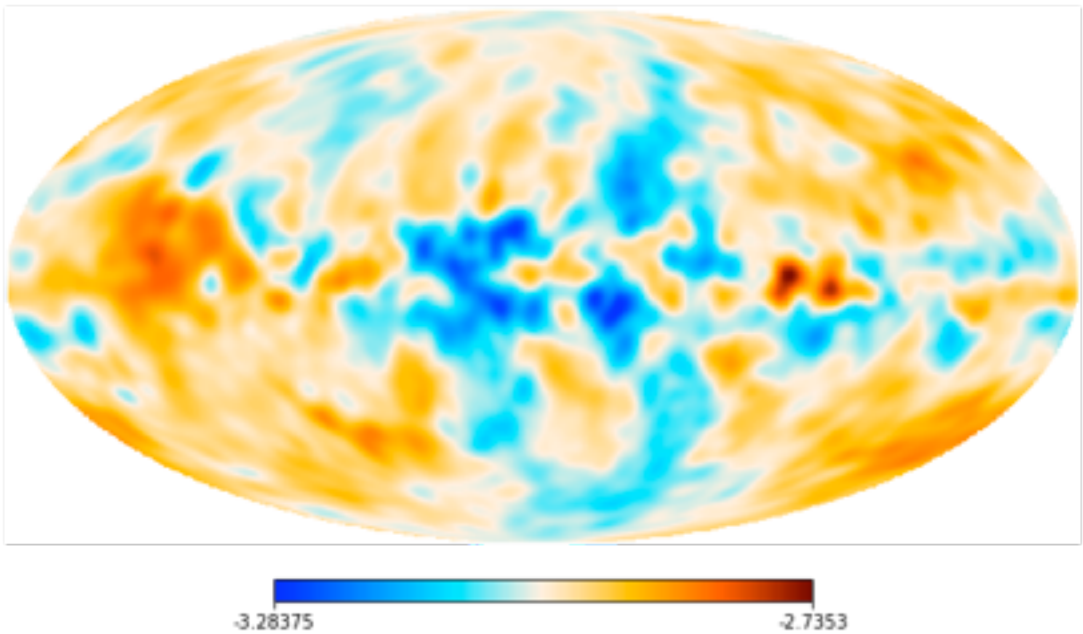
APPLICATION TO SIMULATIONS

β_s



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APPLICATION TO SIMULATIONS

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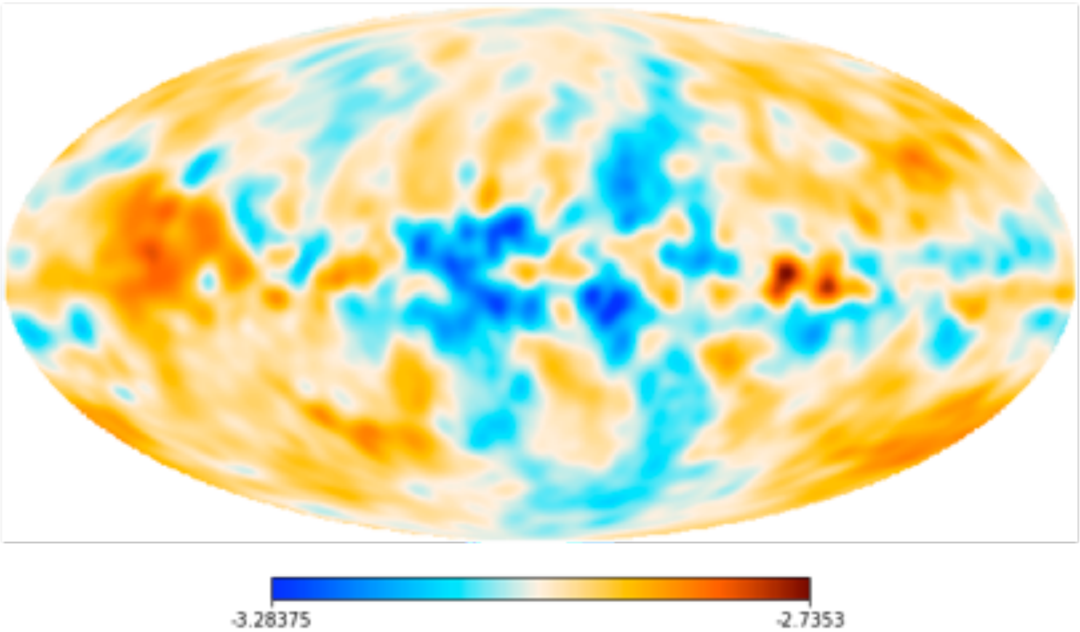

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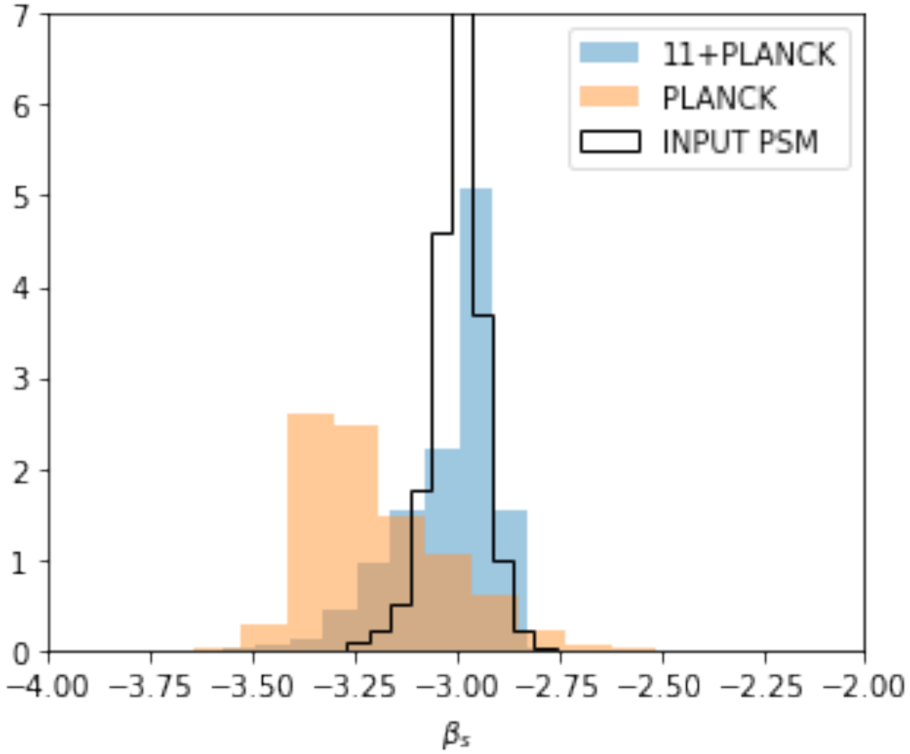

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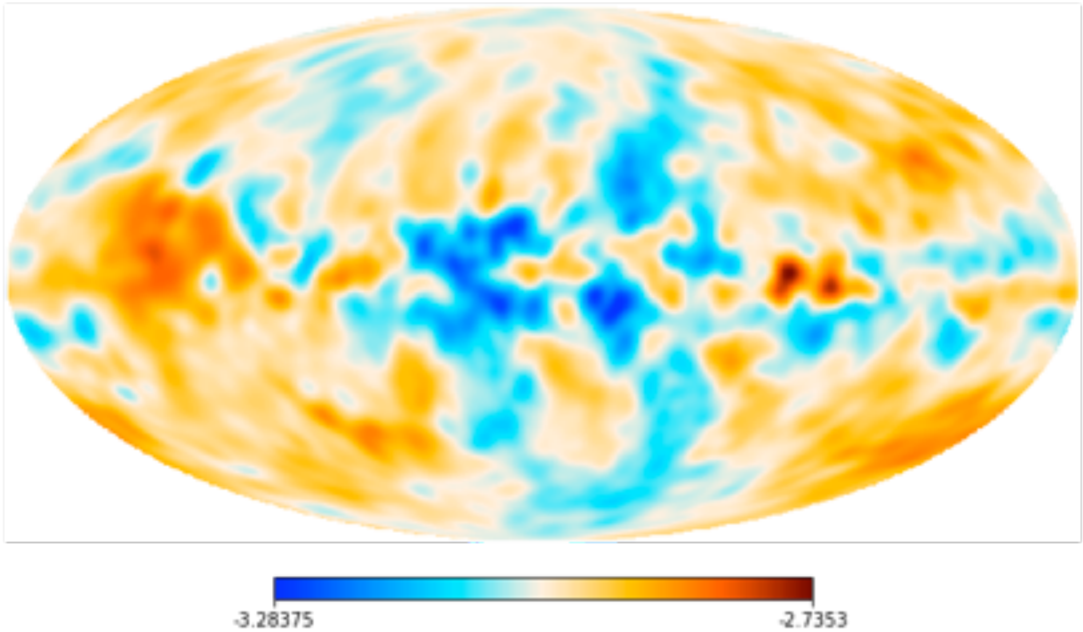
APPLICATION TO SIMULATIONS

β_s



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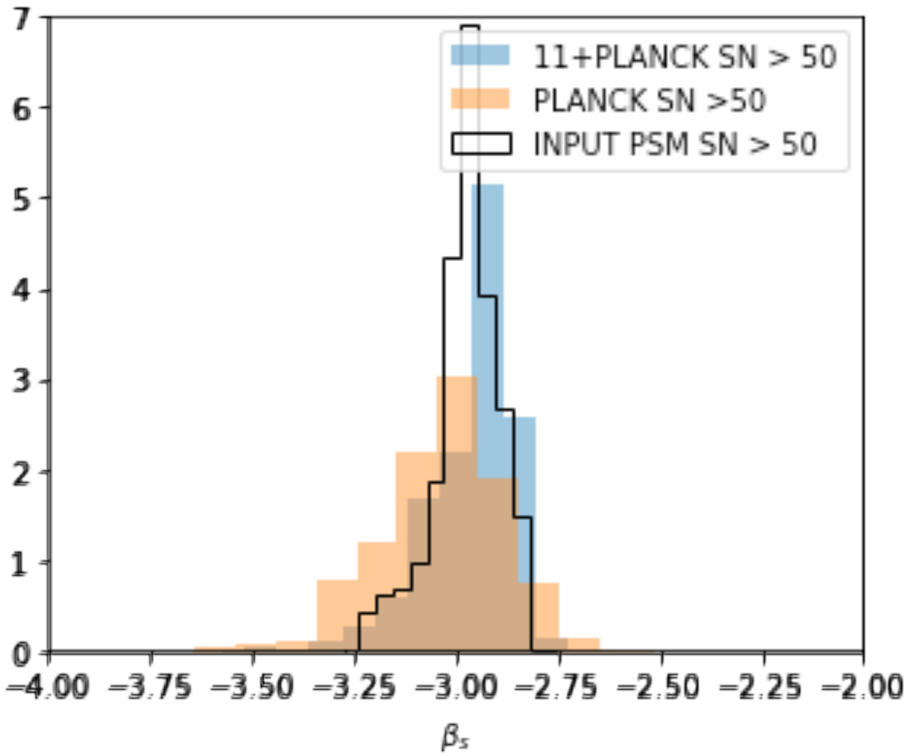

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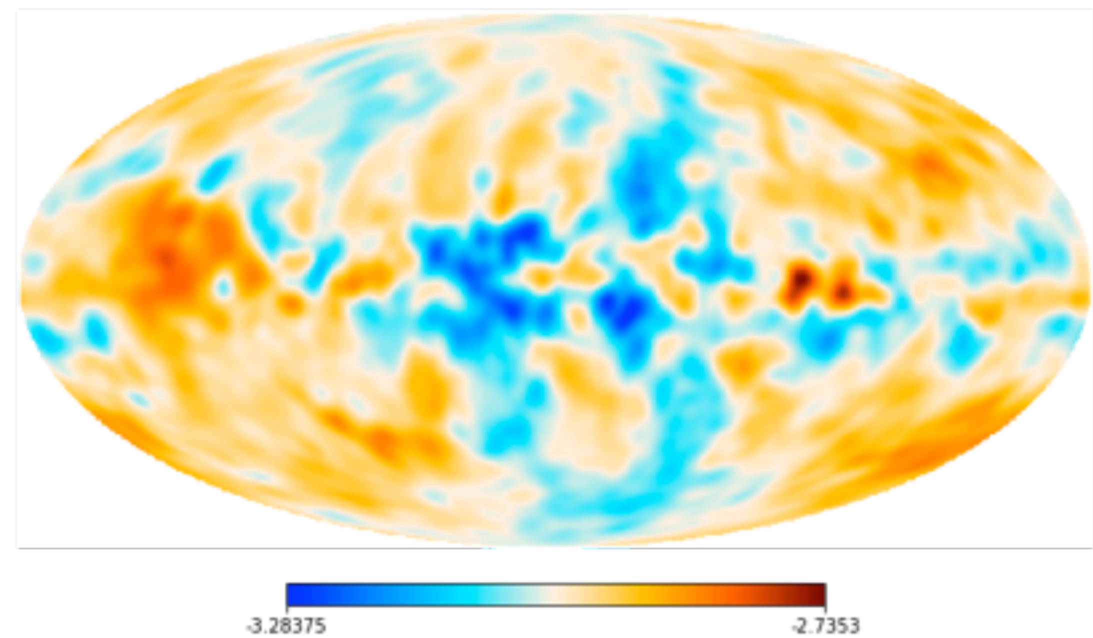
APPLICATION TO SIMULATIONS

β_s



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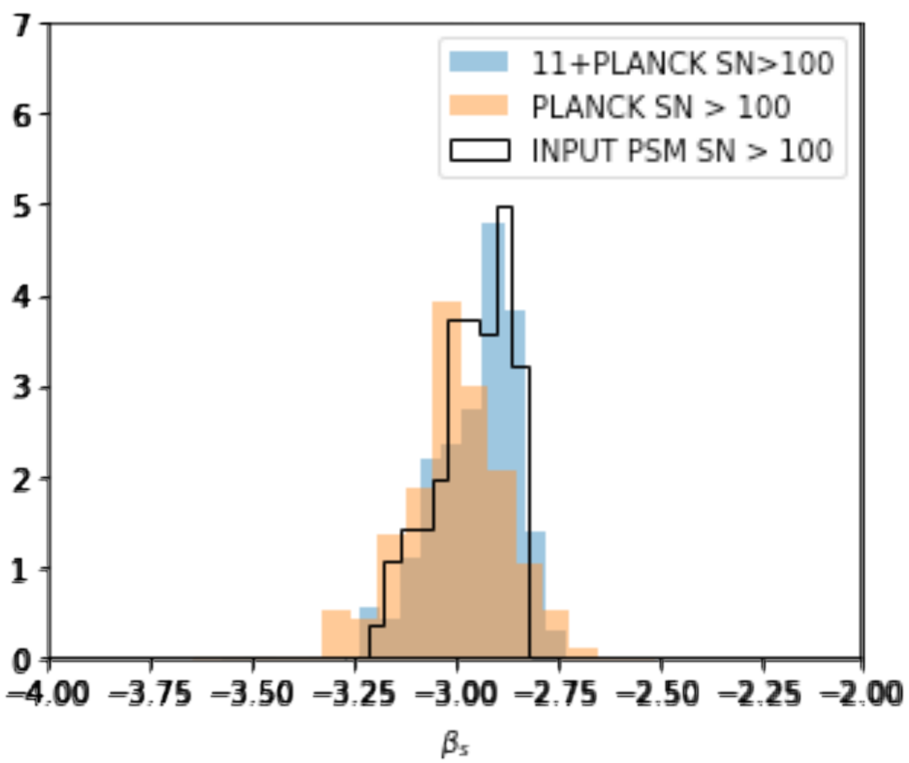

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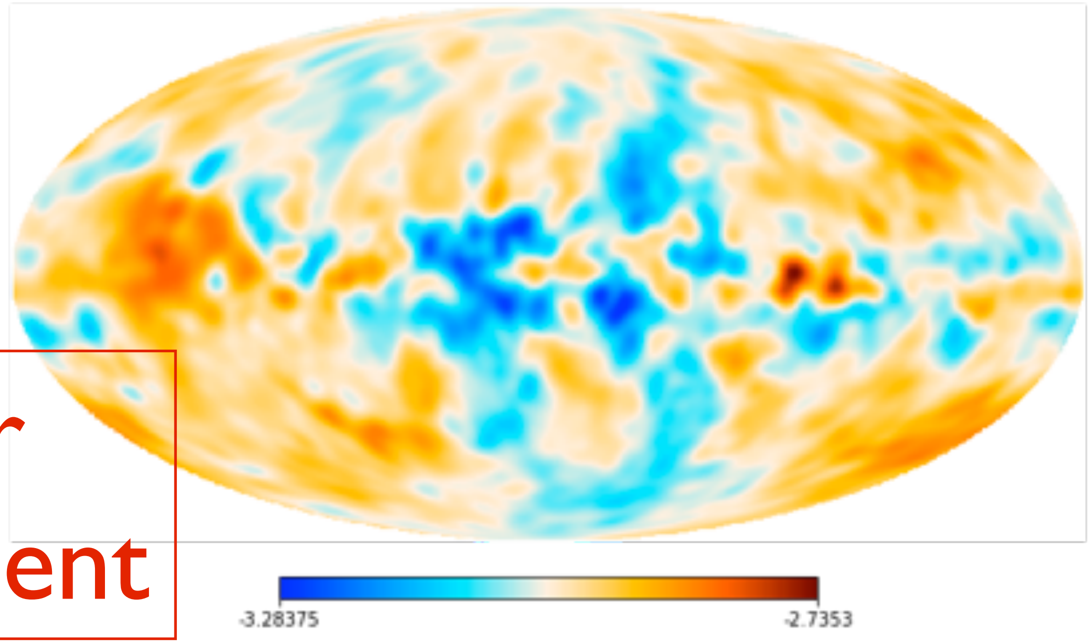
APPLICATION TO SIMULATIONS

β_s



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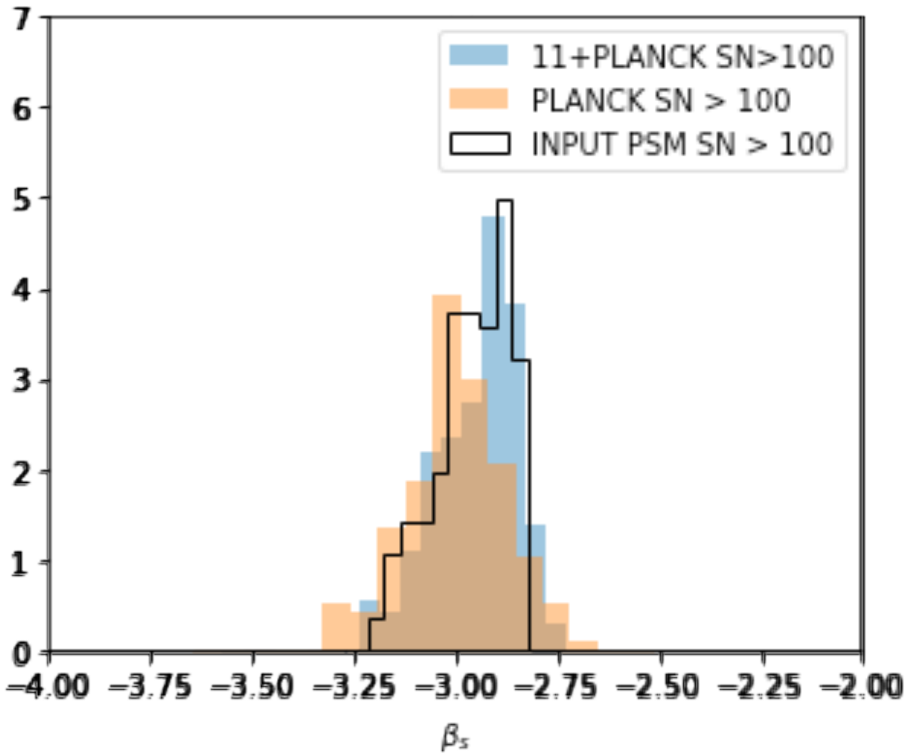
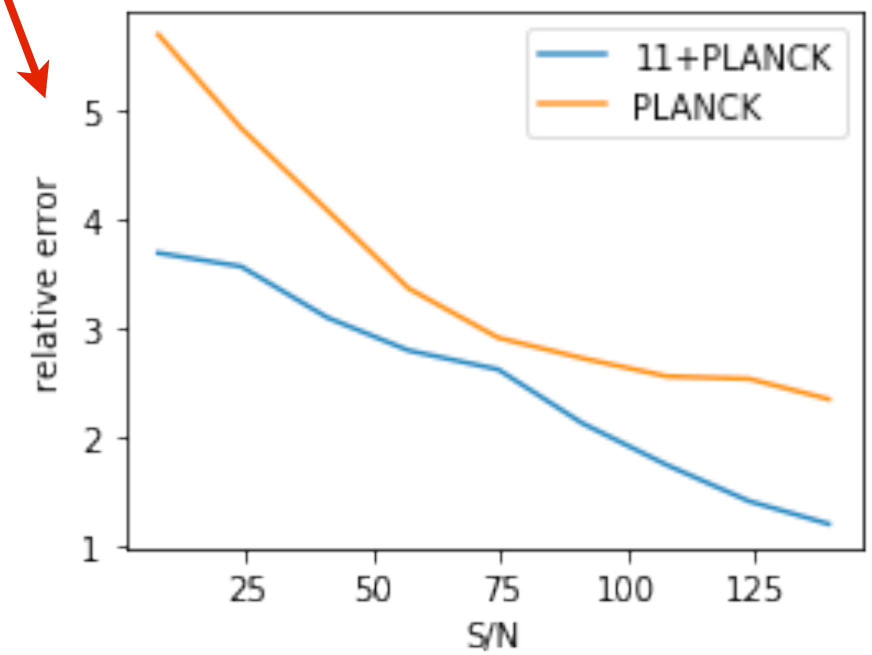


Prior dependent



Besides that, we see a bias also in the 11+PLANCK estimation for low SN if we shift the training distribution

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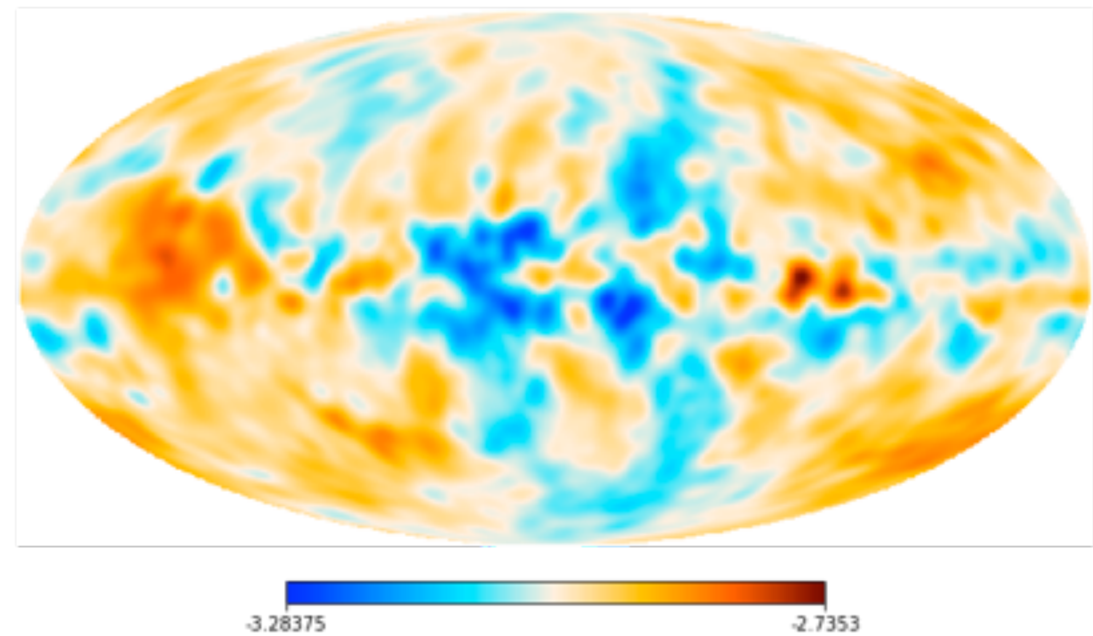
APPLICATION TO SIMULATIONS

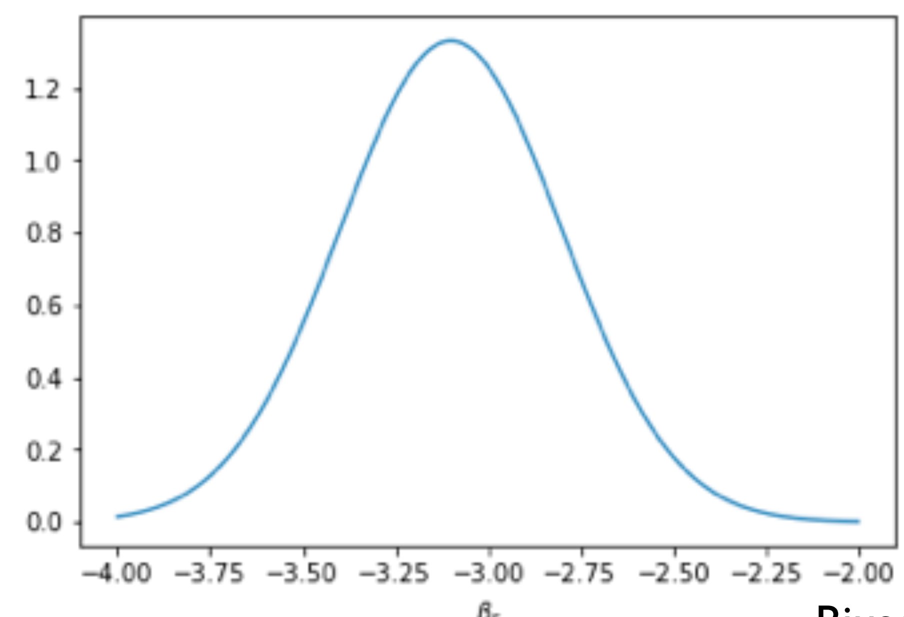
β_s



to increase SN:

- Work at lower resolution
- Add more data
- Keep doing observations

When we can't, we use a tight Gaussian distribution to perform a component separation at high latitudes



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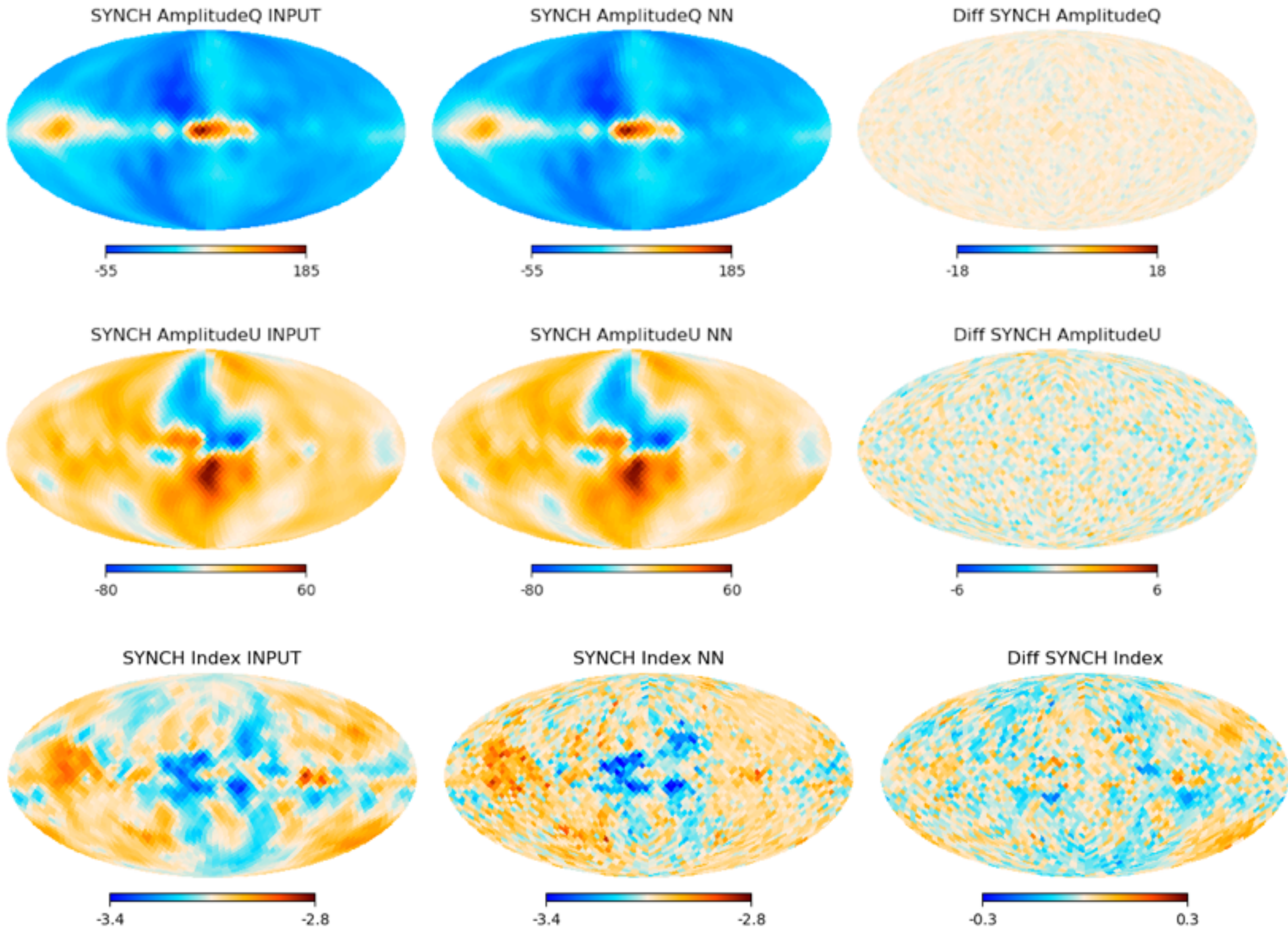
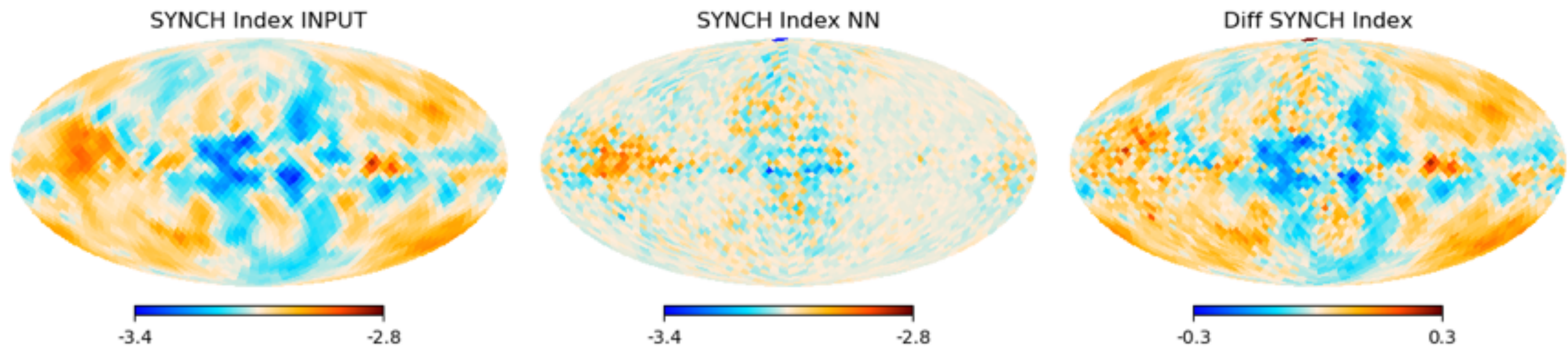
APPLICATION TO SIMULATIONS. **SYNCHROTRON**

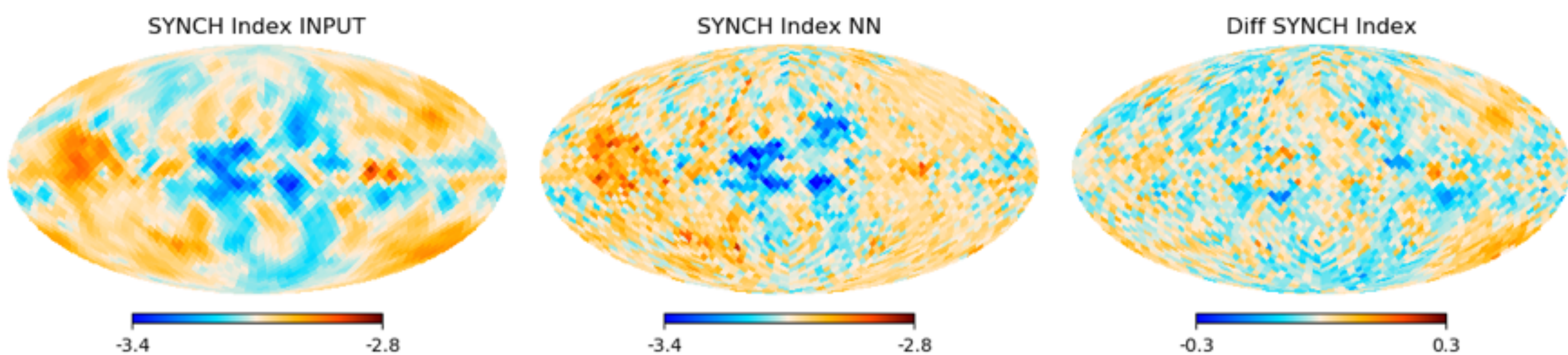


de studies,

APPLICATION TO SIMULATIONS. SYNCHROTRON

Only Planck frequencies





MFI + Planck frequencies

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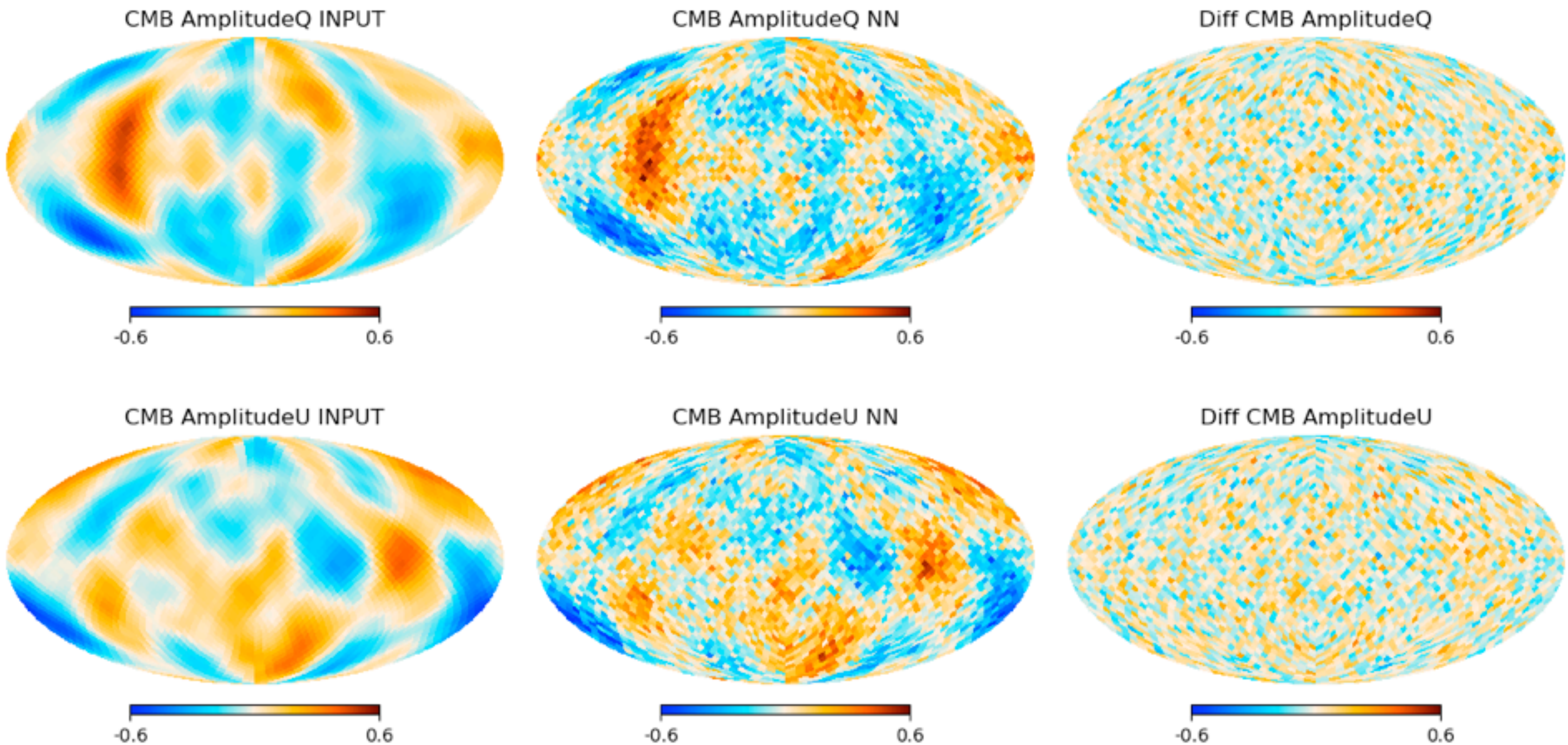
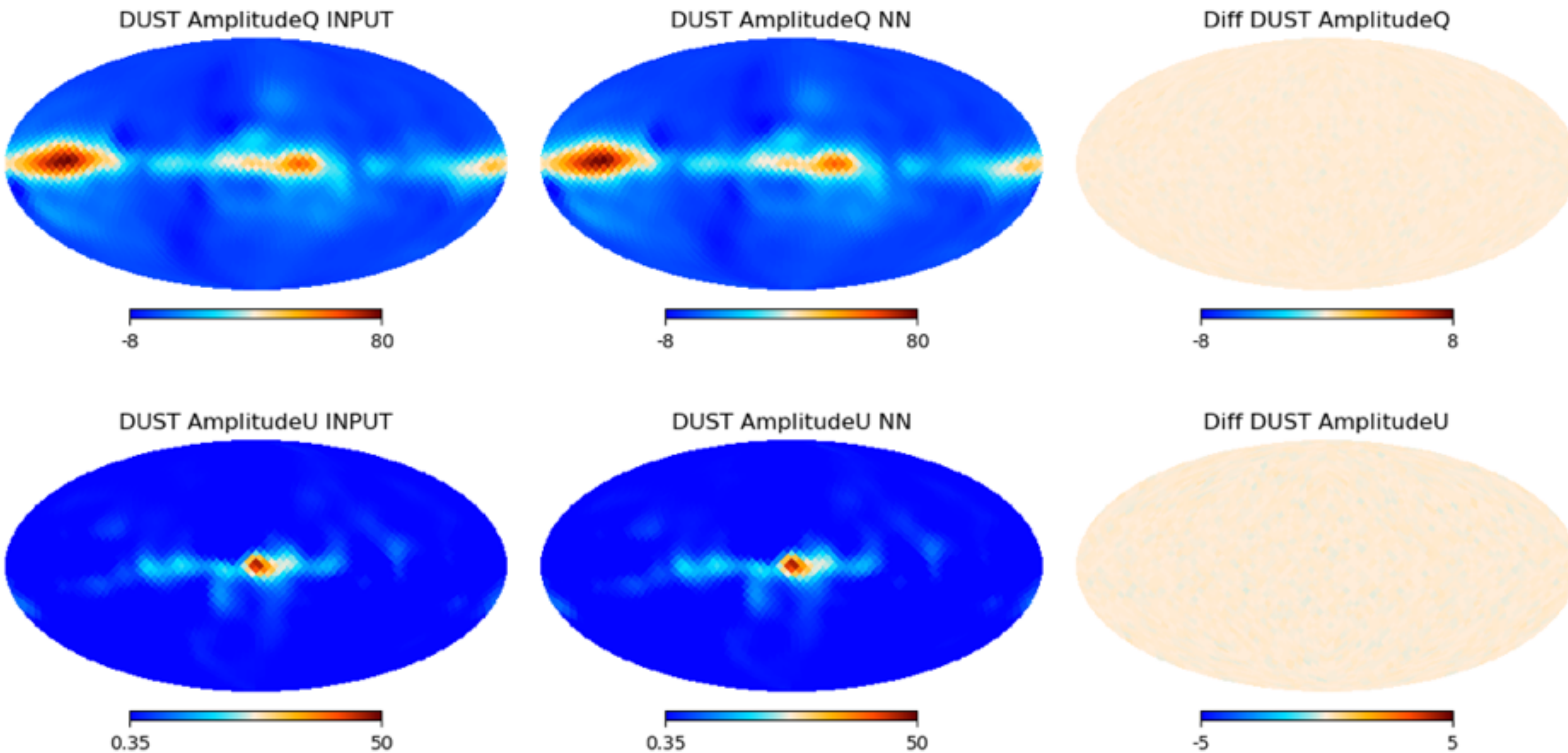
APPLICATION TO SIMULATIONS. **CMB**



APPLICATION TO SIMULATIONS. **DUST**



APPLICATION TO SIMULATIONS. Correlations coefficients

NN vs Input

- CMB r~ 0.83
- Synchrotron Amplitude r>0.999
- Synchrotron Index r~0.69
  (SN >50 r~0.89)
- Dust Amplitudes r>0.9999

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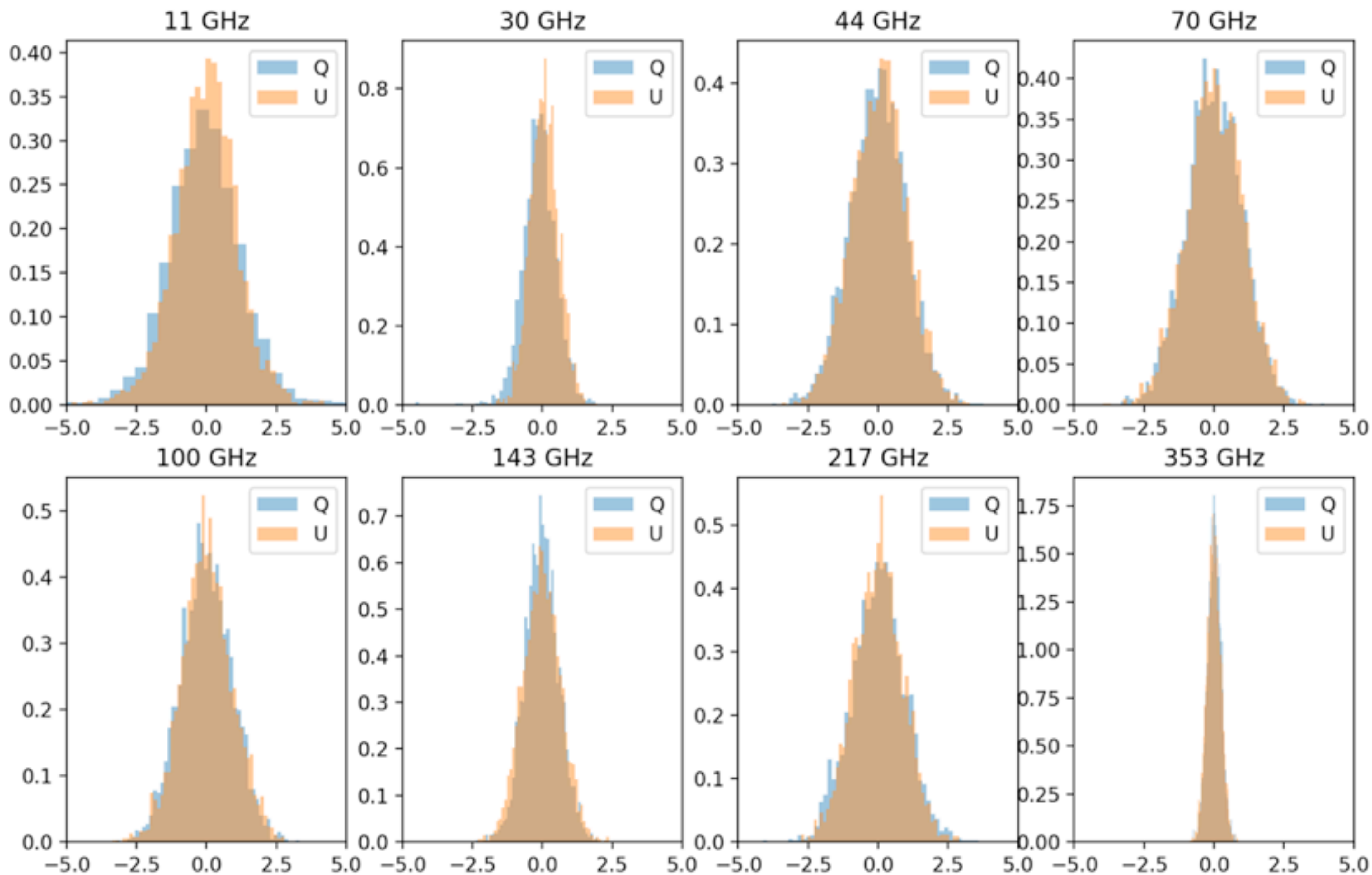
APPLICATION TO SIMULATIONS. **Residuals**



dies,

APPLICATION TO THE DATA.
MFI QUIJOTE channels

o Planck 2018 release polarization maps and 11GHz+QUIJOTE internal release at nside =256 with a common resolution of 1deg.

o Spectral index is recovered at 10 degrees resolution and this is udgraded to nside=256 to recover the amplitudes of the components at 1 deg resolution

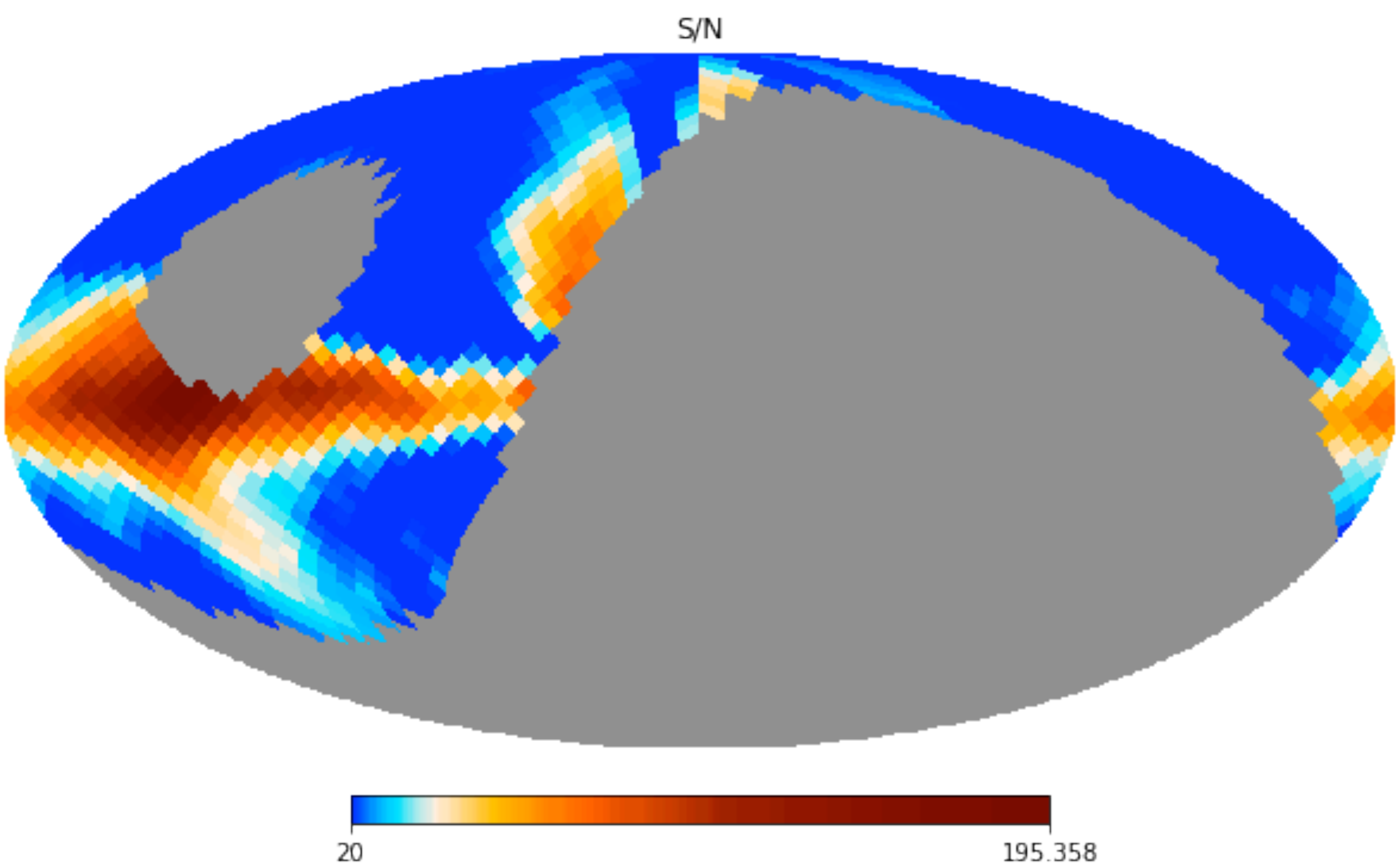
o Td and β_d fixed to the COMMANDER estimation (Planck collaboration IV, 2018)

PREPARING TO APPLY THE METHOD TO DATA

For the full sky component separation we are using a tighter distribution for beta_s : -3.5 to -2.6

Given what we know with simulation the S/N of the data, we can know which areas we can trust.

Blue area values are highly dependent on the distribution of the training set.



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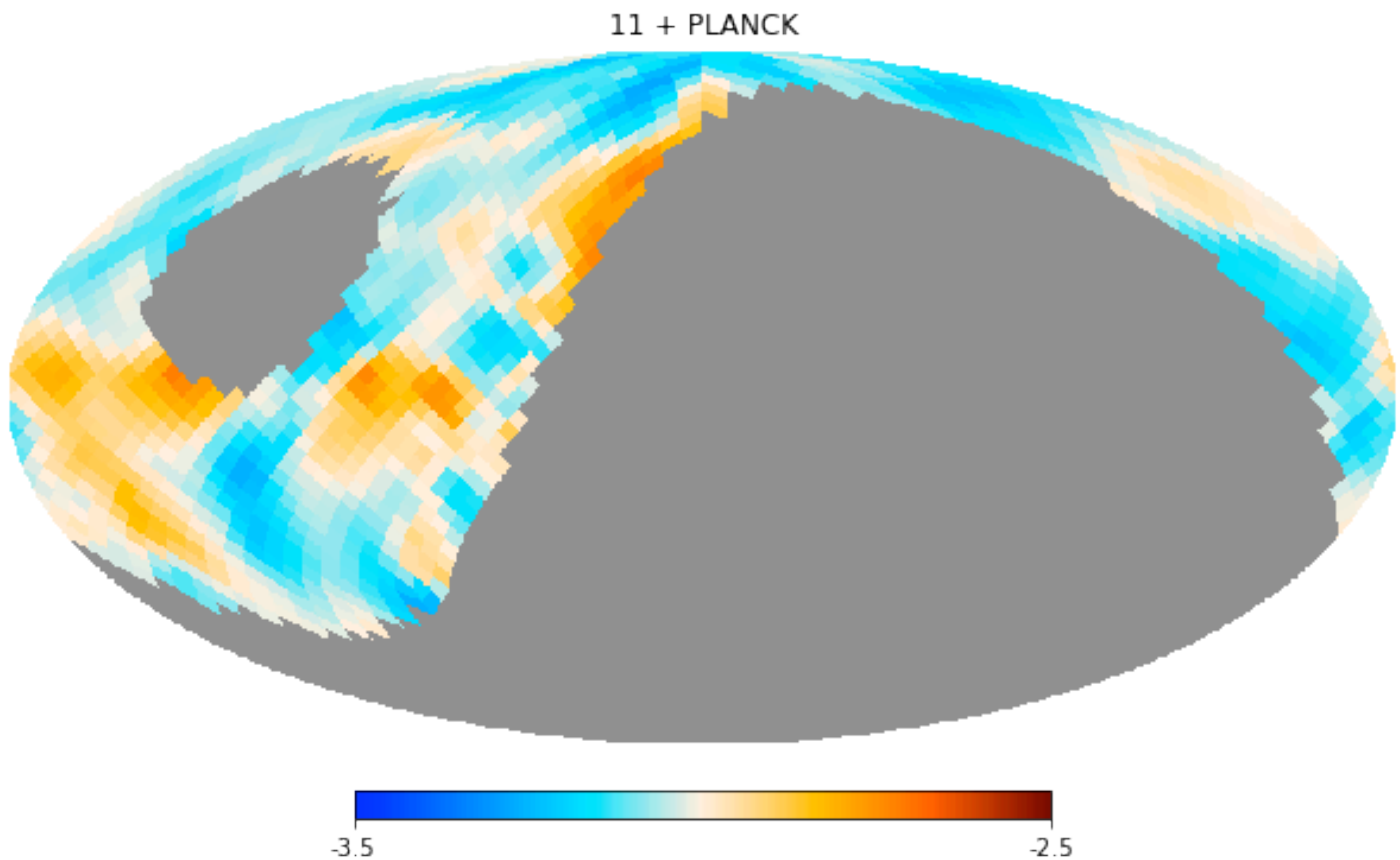
APPLICATION TO THE DATA.
Synchrotron spectral index

PRELIMINARY



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APPLICATION TO THE DATA.
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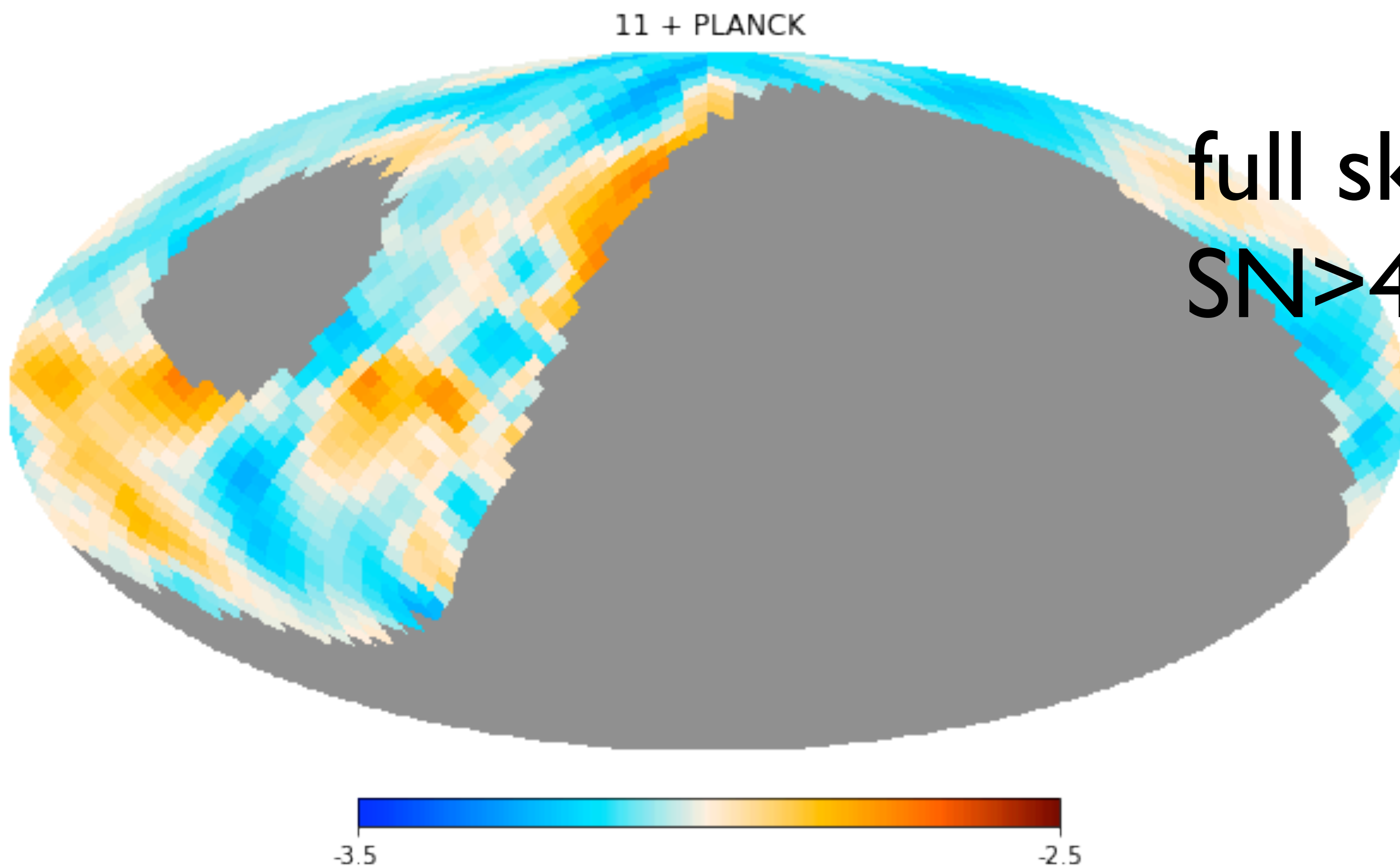
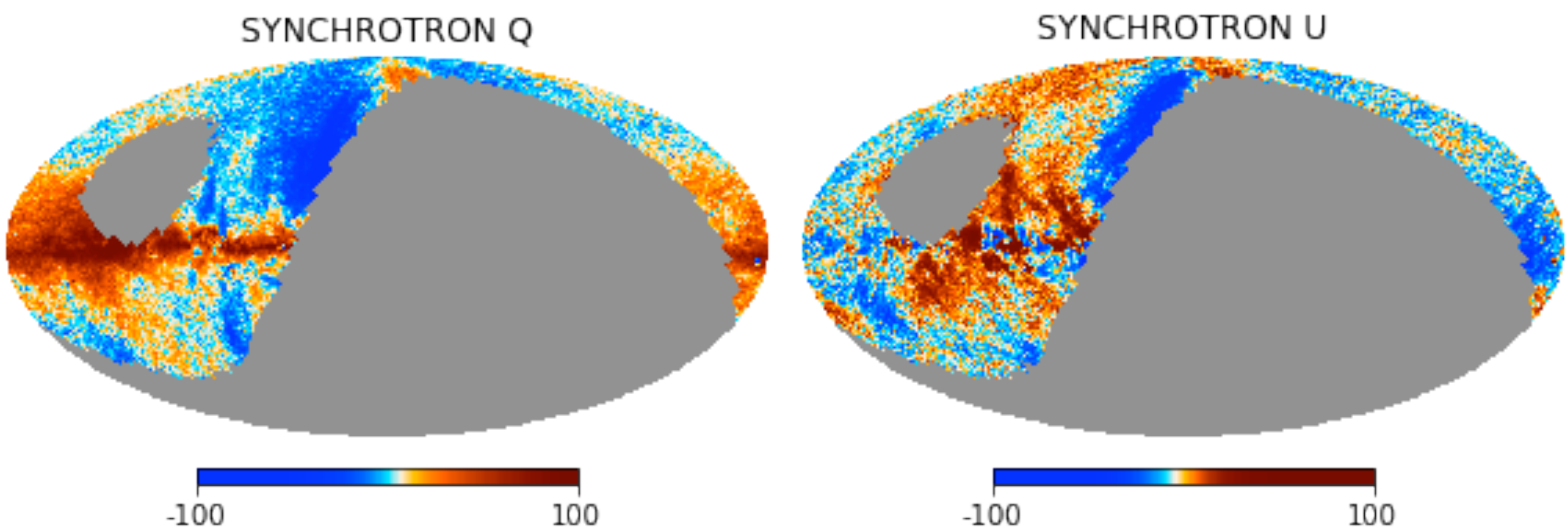


full sky -3.03 +/- 0.10
SN>40 -2.95 +/- 0.11

APPLICATION TO THE DATA.
Synchrotron at 23GHz in uKRJ



PRELIMINARY

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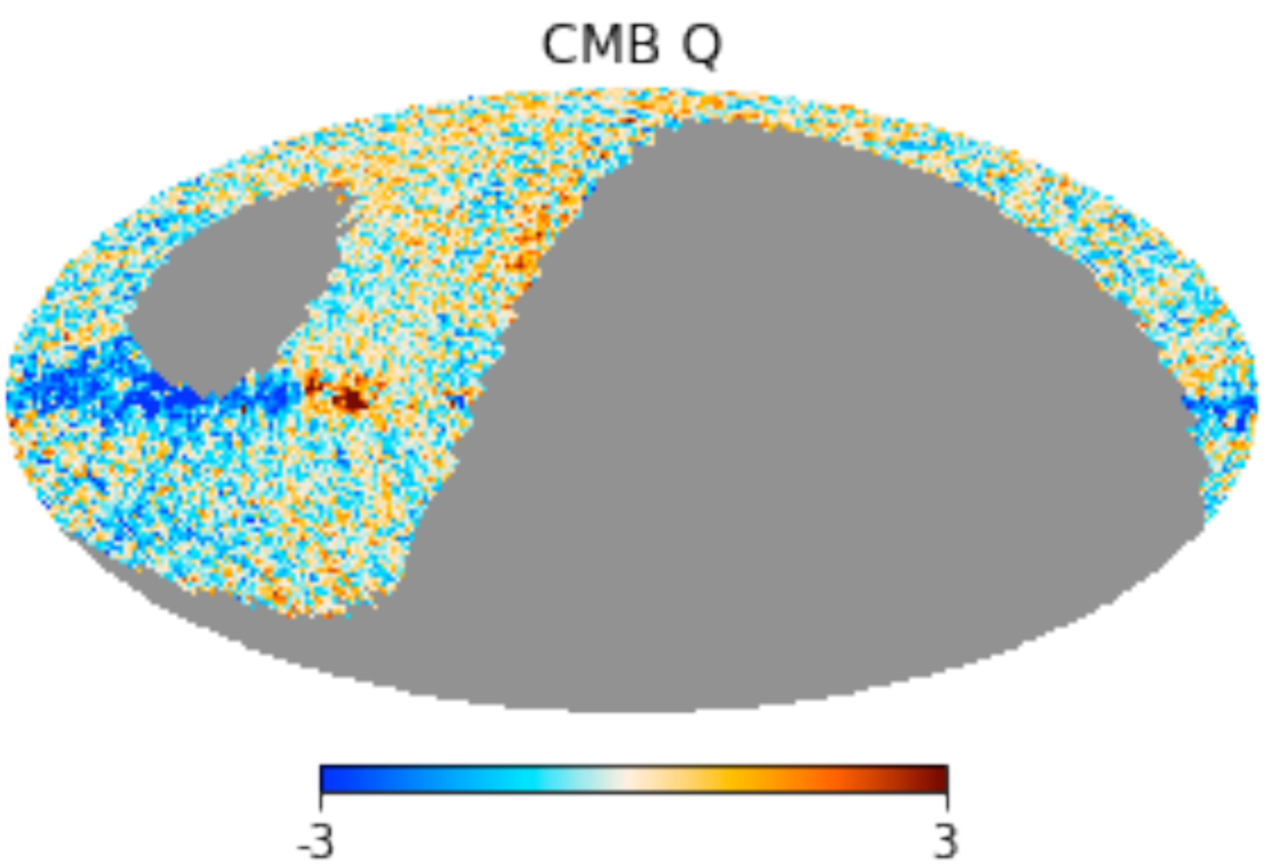
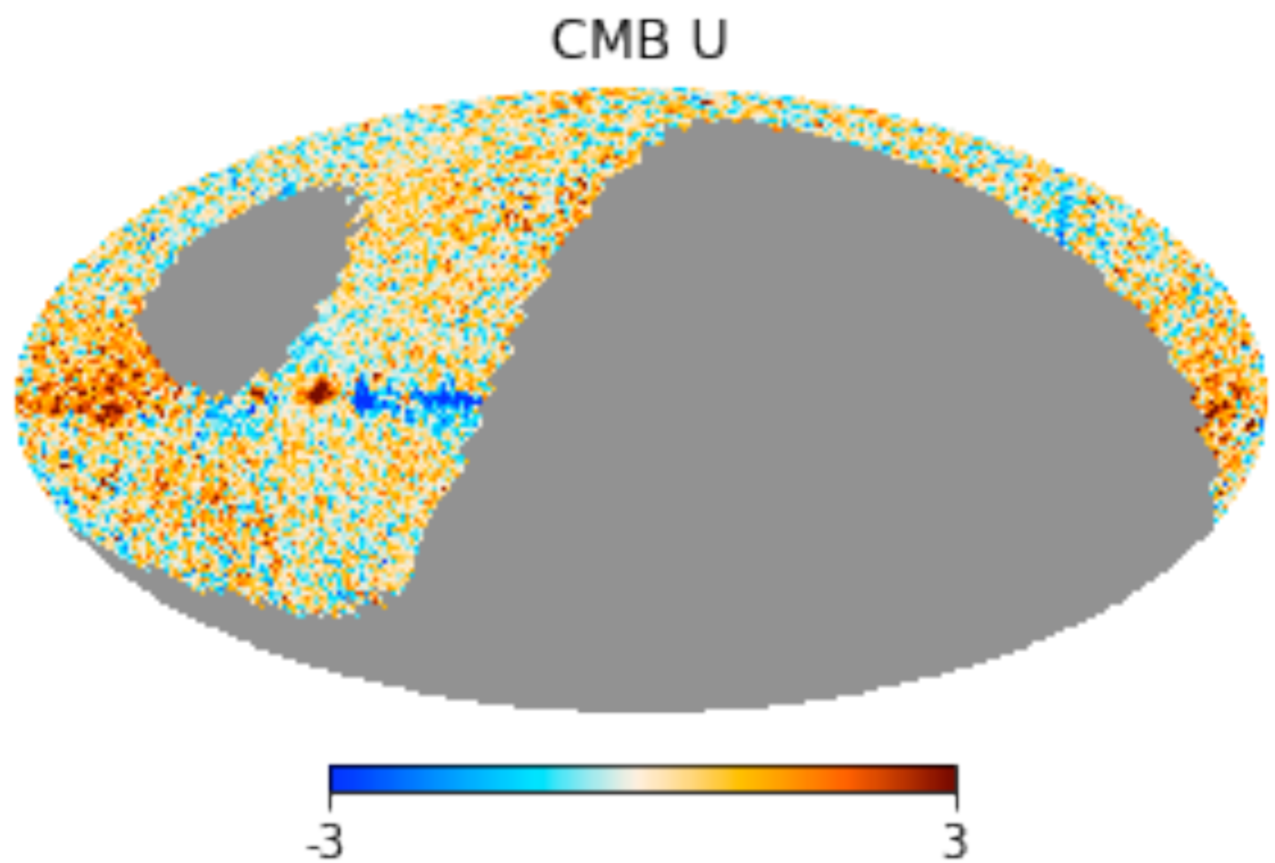
APPLICATION TO THE DATA.
CMB





PRELIMINARY

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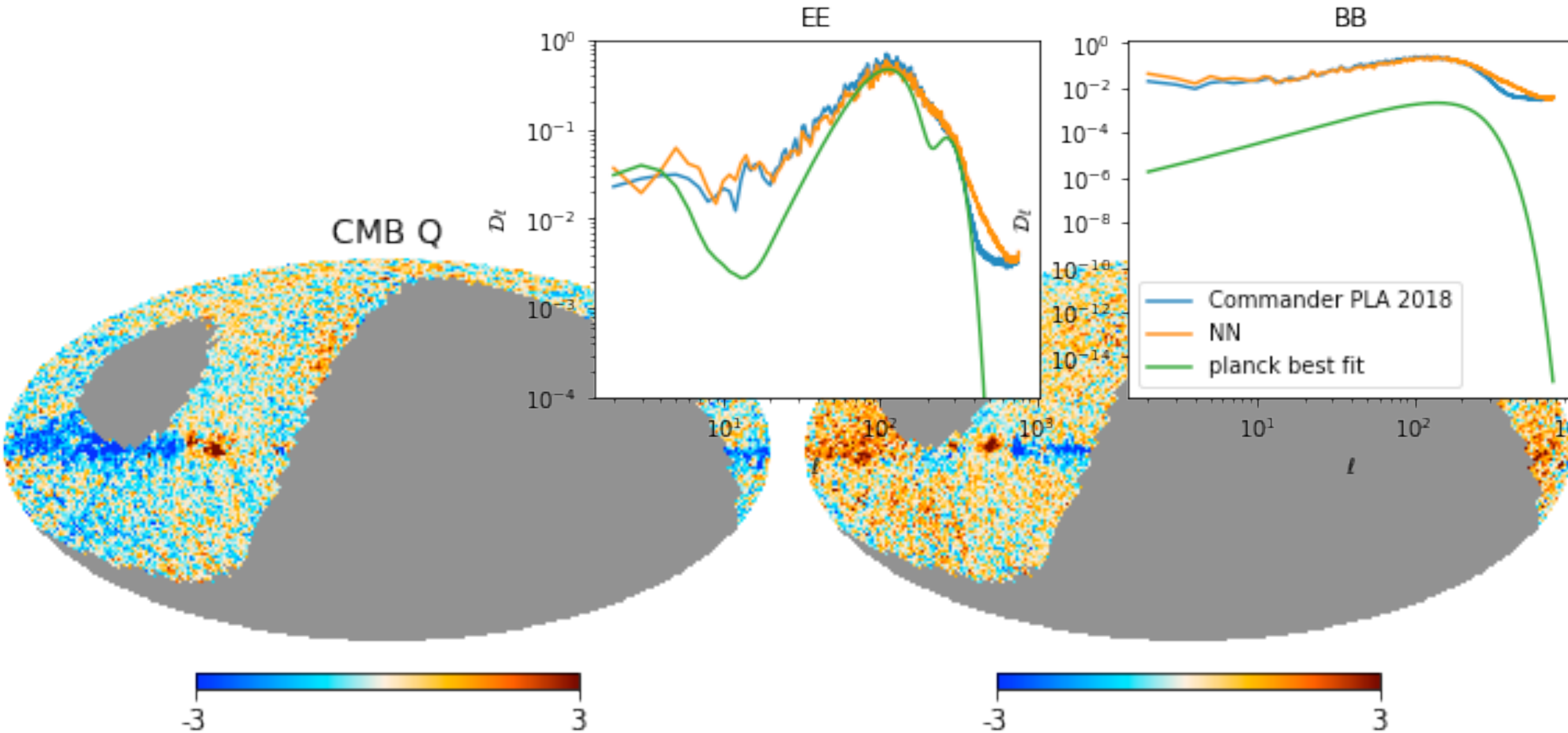
APPLICATION TO THE DATA.
CMB



PRELIMINARY

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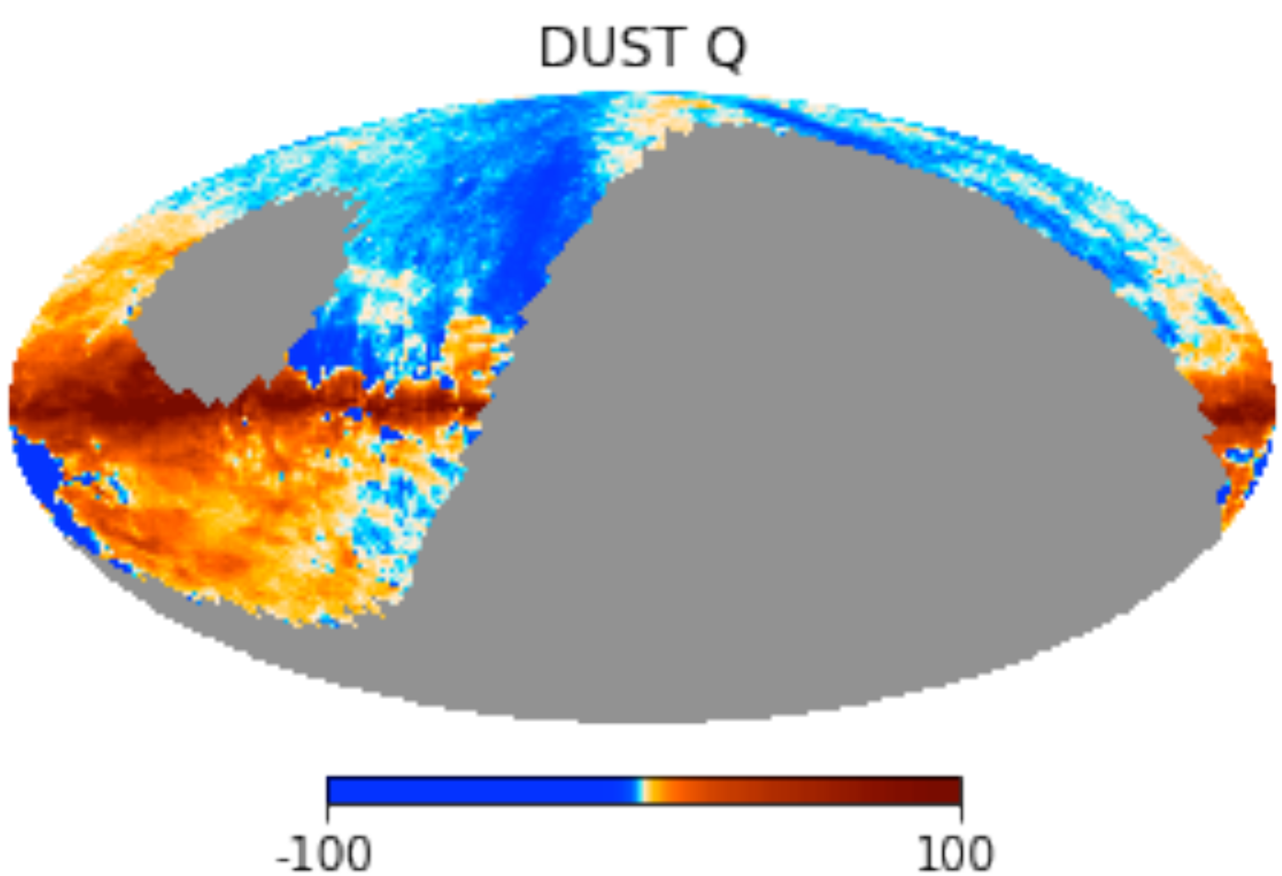
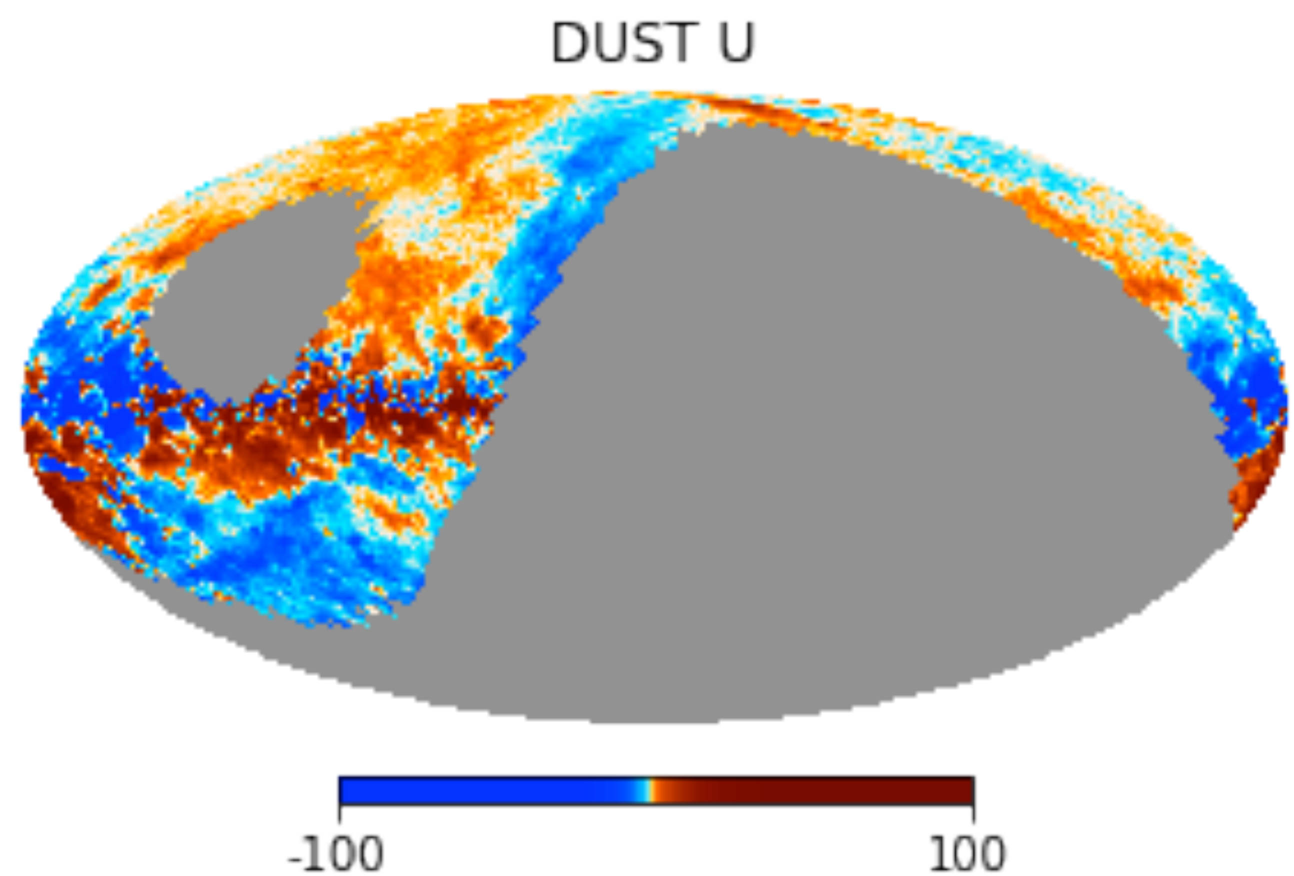
APPLICATION TO THE DATA.
DUST at 353GHz in uKRJ





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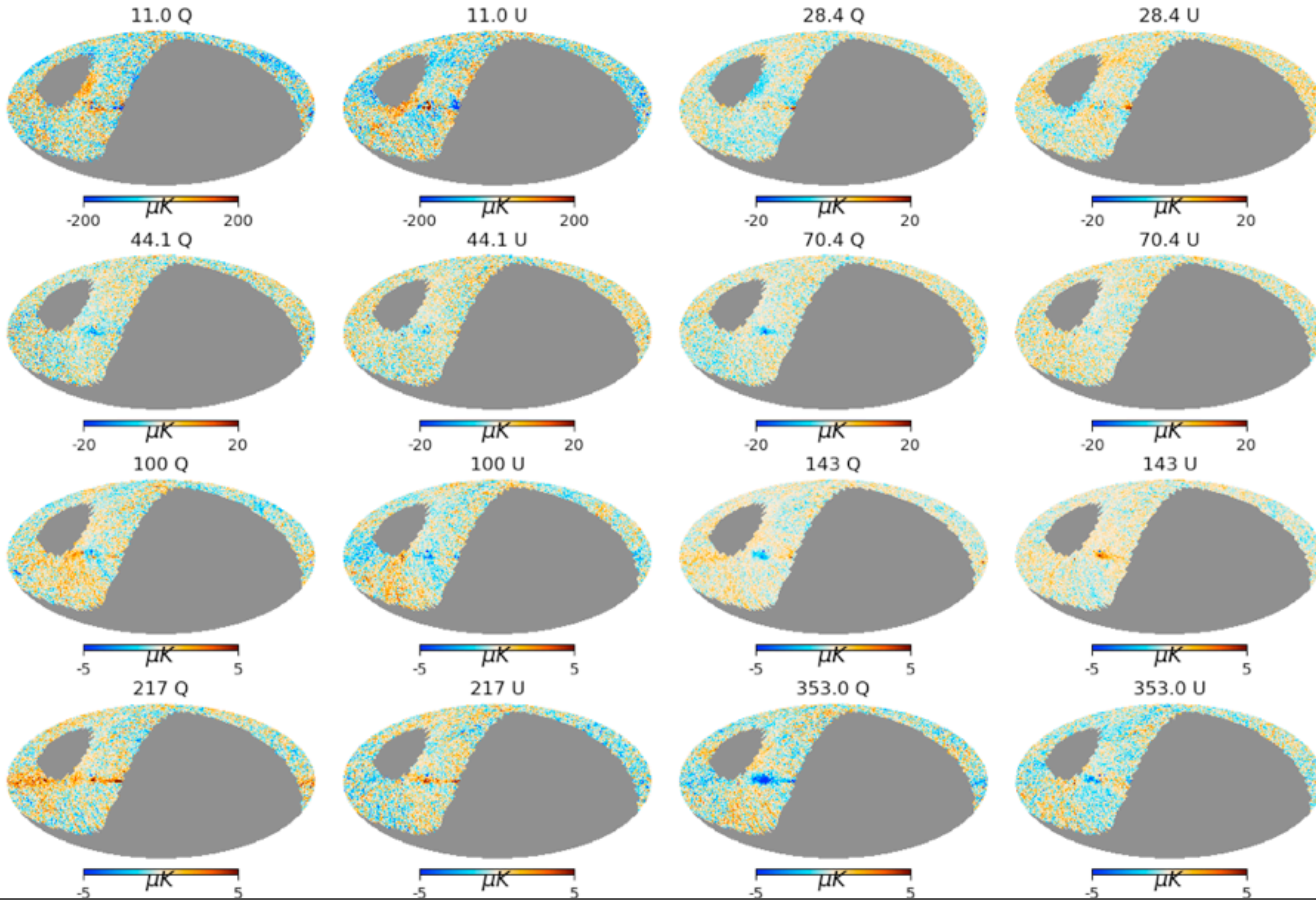
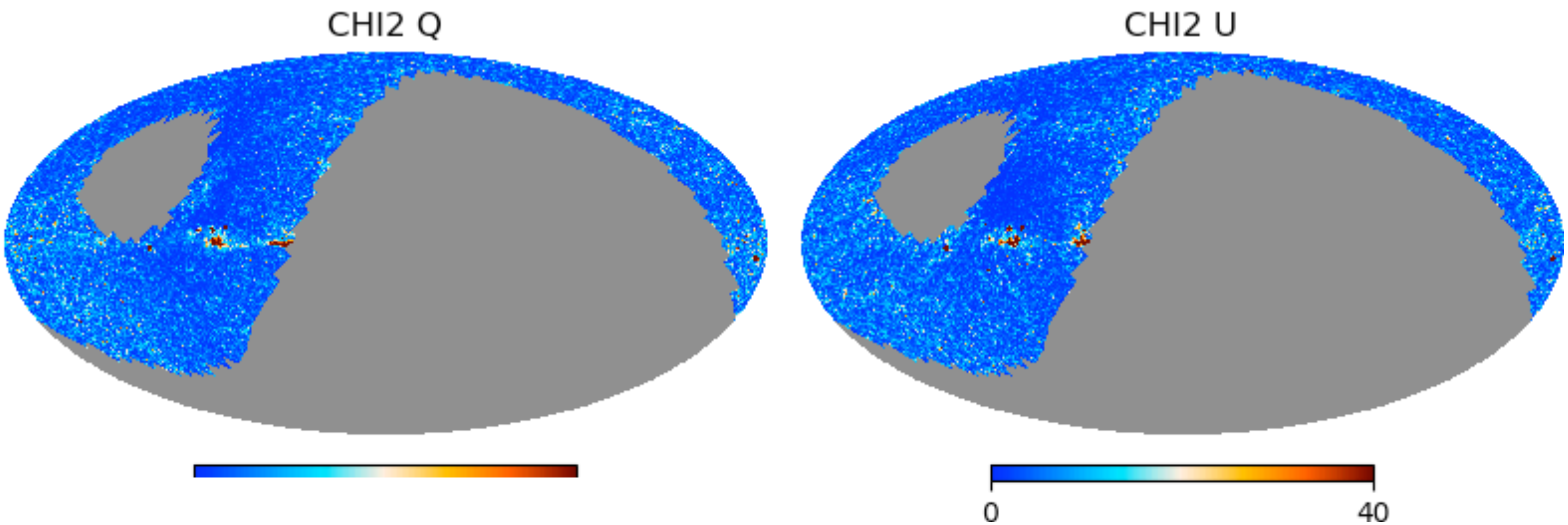
APPLICATION TO THE DATA. **Residual maps**

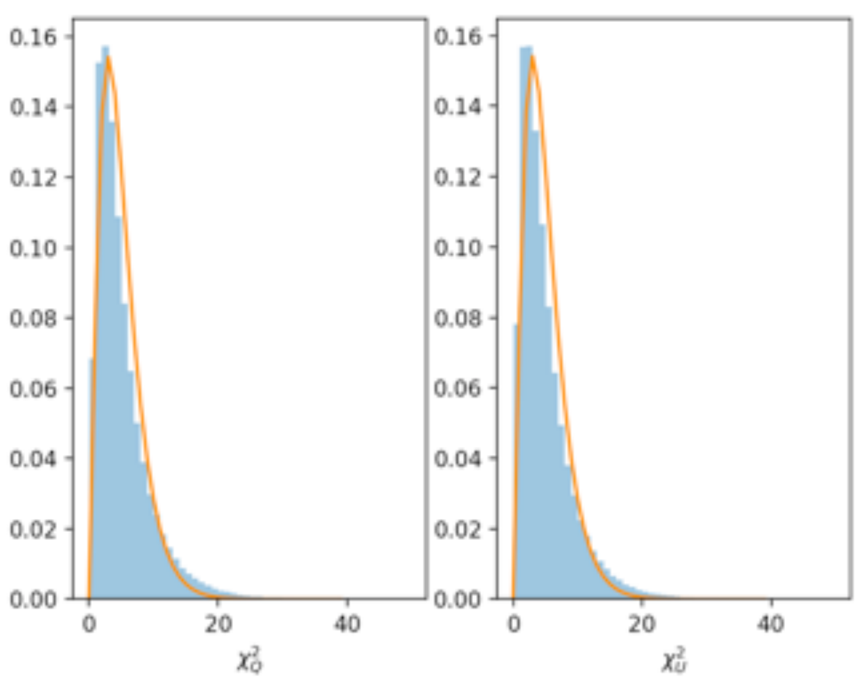


udies,

APPLICATION TO THE DATA.

χ^2





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Conclusions and ongoing work

- The NN are a useful tool to perform component separation. Main advantadge: fast, Main handicap: new method, tests on simulations to fully understand it at low SN are still in place (Casaponsa et al. in preparation)
- MFI channels help to the reconstruction of the synchrotron, we need to reduce the noise for high latitudes spectral index estimation
- Several improvements of the method are in mind
    - work at native resolutions
    - use multi-resolution information
    - train with more realistic simulations (foreground correlations, bandpass, correlated noise,...)
- Include more low frequency data
- Temperature analyses ongoing
- ....

Thanks!