Extending Galactic foreground models for CMB experiments with GANs

Nicoletta Krachmalnicoff* & Giuseppe Puglisi+

Abstract: We present *ForSE* (Foreground Scale Extender), a novel package which aims at overcoming the current limitations in the simulation of diffuse Galactic radiation, in the context of Cosmic Microwave Background experiments (CMB). *ForSE* exploits the ability of generative adversarial neural networks (GANs) to learn and reproduce complex features present in a set of images, with the goal of simulating realistic and non-Gaussian foreground radiations at sub-degree angular scales. We have applied our algorithm to Galactic thermal dust emission in both total intensity and polarization. Our results show how FORSE is able to generate small scale features (at 12 arc-minutes) having as input the large scale ones (80 arc-minutes). The injected structures have statistical properties in excellent agreement with the ones of the real sky and which show the correct amplitude scaling as a function of the angular dimension.

1. Introduction

(i) The Cosmic Microwave Background (CMB) radiation is one of the greatest source of knowledge about the history of our Universe [1].

(ii) One of the main liminting factor in the observation of the CMB polarized signal is the contamination from Galactic emission [2].

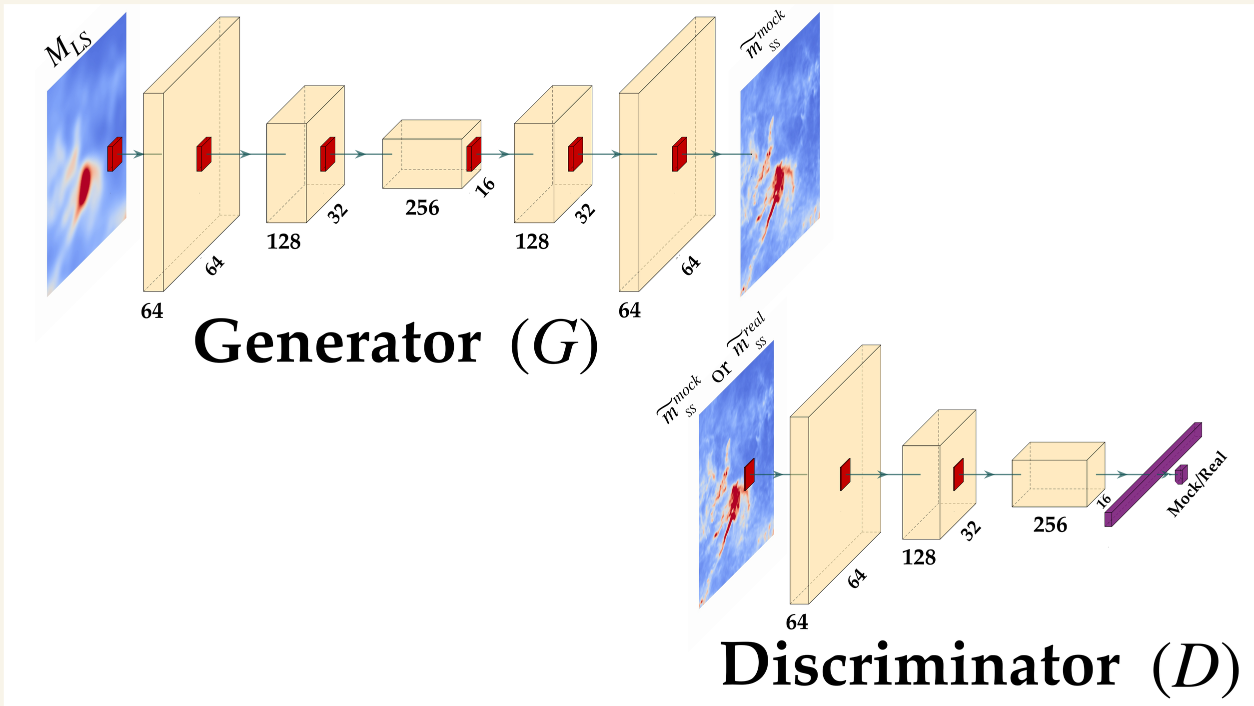
(iii) Reliable models of the Galactic emission are fundamental to develop the alghoritms responsble for removing its contamination to the CMB signal.

(iv) We present a novel approach that uses GAN to extend the current available models to sub-degree angular scales [3].

2. Method

(i) We built a modified version of the Deep Convolutional GAN [4].

(ii) Our GAN takes as input patches of the sky representing the observed low resolution signal (80 arcmin) of the thermal dust emission.



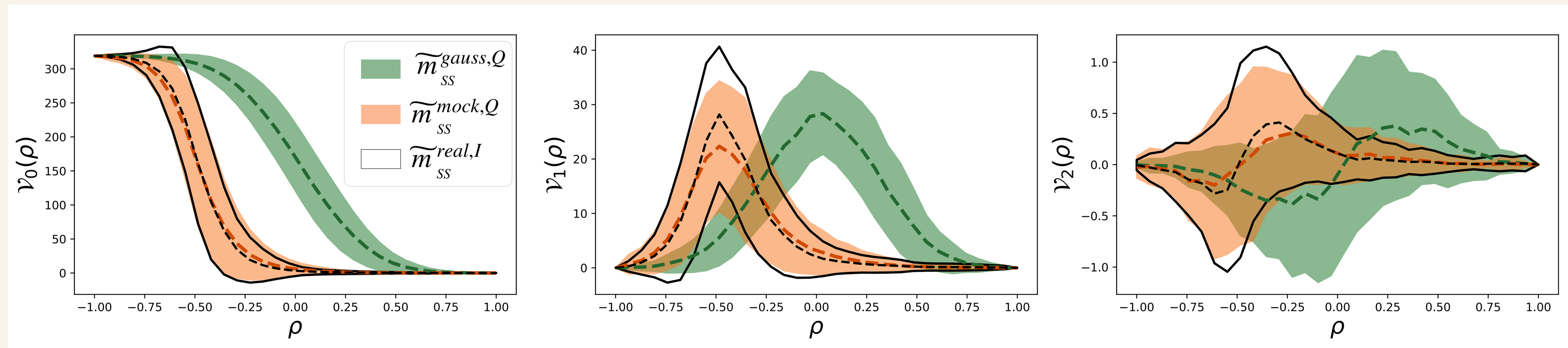
(iii) The *Generator* predicts realistic small scale structures (12 arcmin) that are compared by the *Discriminator* with the real ones, taken from the sky regions where high resolution data are available.

(iv) The GAN architecture is deterministic: the generated small scale structures depend only on the input large scale ones.

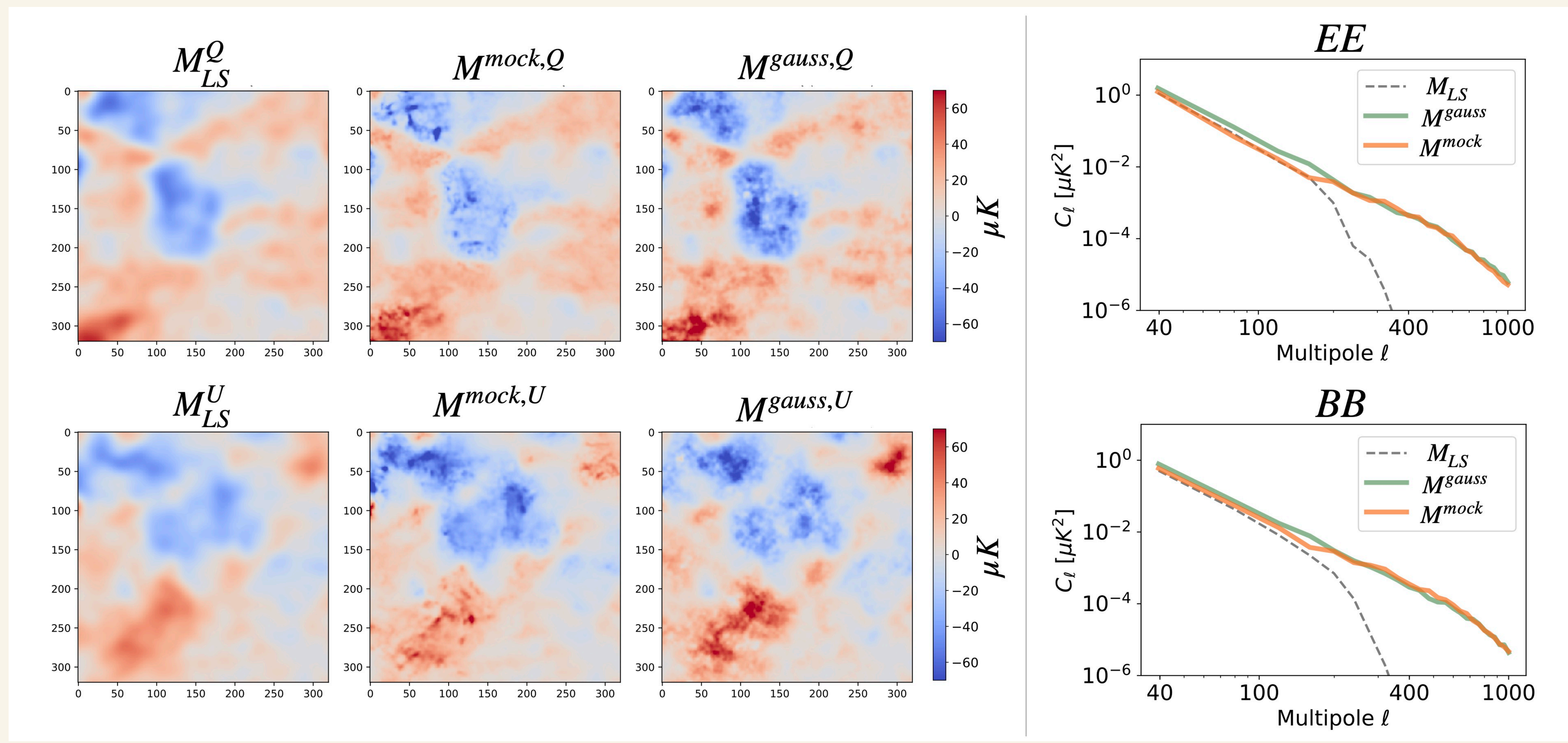
3. Results

(i) In polarization we trained the GAN having as input low resolution Q or U maps, and generating small scale structures with the same statistics as the real ones in total intensity (I).

(ii) We evaluate the GAN peformance by means of the Minkowski functionals. The distributions of the generated structures (orange) are in good agreement with the target ones (black lines), and different from a simple Gaussian signal (green). This proves that the GAN generates small scale structures with the correct statistical properties.



(iii) The Figure below shows, for one patch in Q and U, the the low resolution input maps (left column), the combination with the generated small scale structures (middle column) compared with maps with Gaussian small scales (right column). The obtained maps show the correct scaling as a function of the angular scale as seen from the power spectra (right panel) [5].



[1] Planck Collaboration VI. 2020, A&A, 641, A6
[2] Krachmalnicoff, N., et al. 2018, A&A, 618, A166
[3] Radford, A., et al. 2016, ICLR Conference Track Proceedings
[4] see also Krachmalnicoff, N. & Puglisi, G. 2020, https://arxiv.org/abs/2011.02221
[5] polarization full sky maps are available at https://portal.nersc.gov/project/sobs/users/ForSE/

* SISSA/IFPU/INFN, Trieste (Italy)
+ University of California/LBNL, Berkeley (CA, USA)