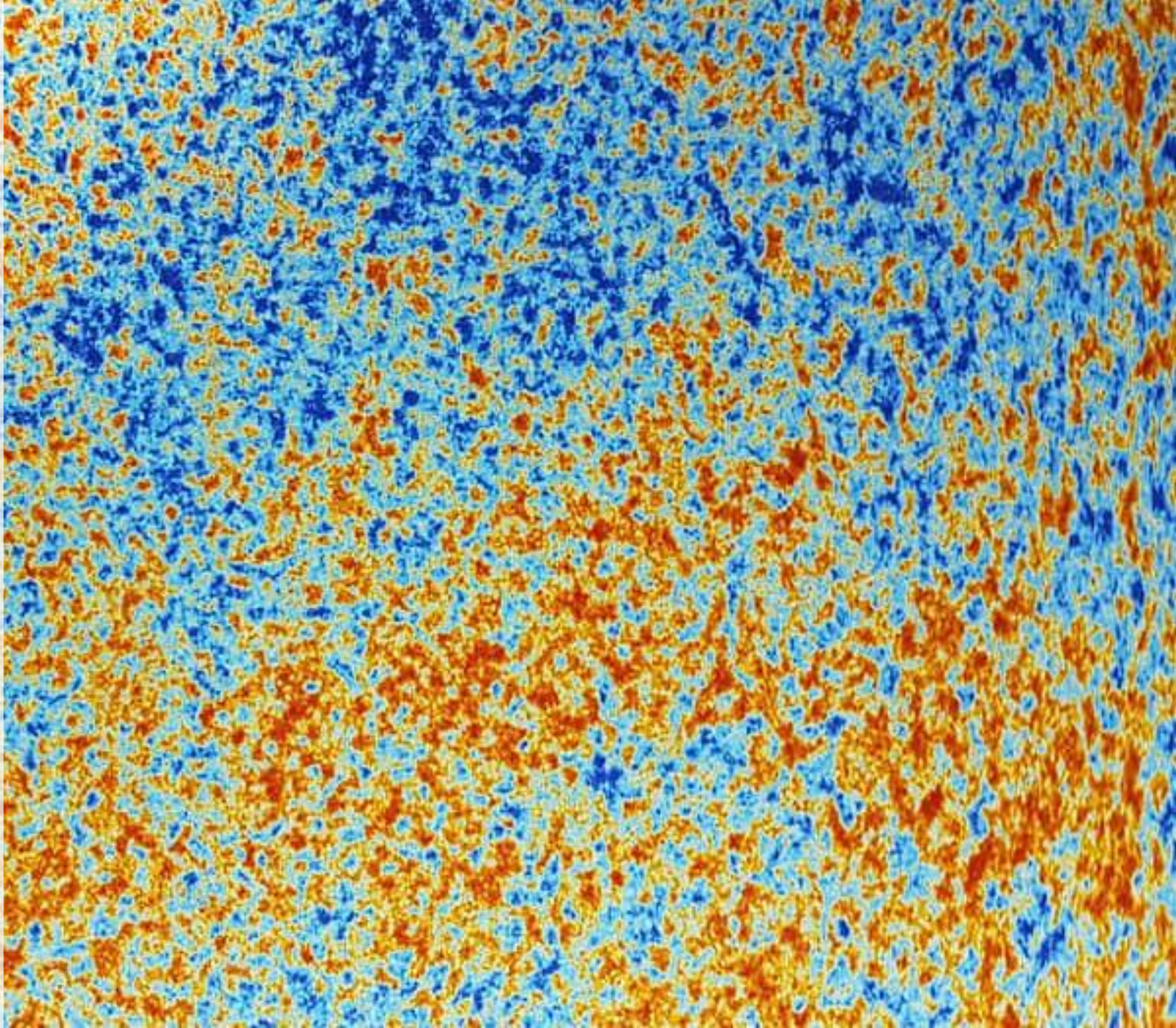
Neural Networks for CMB polarization recovery

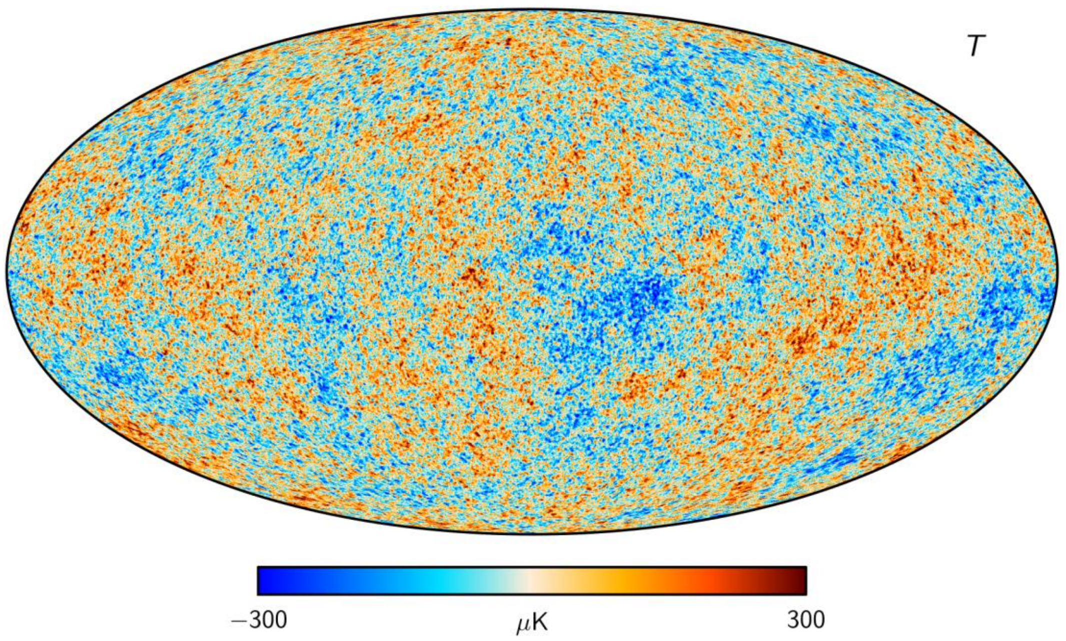
Sara Rodríguez Cabo

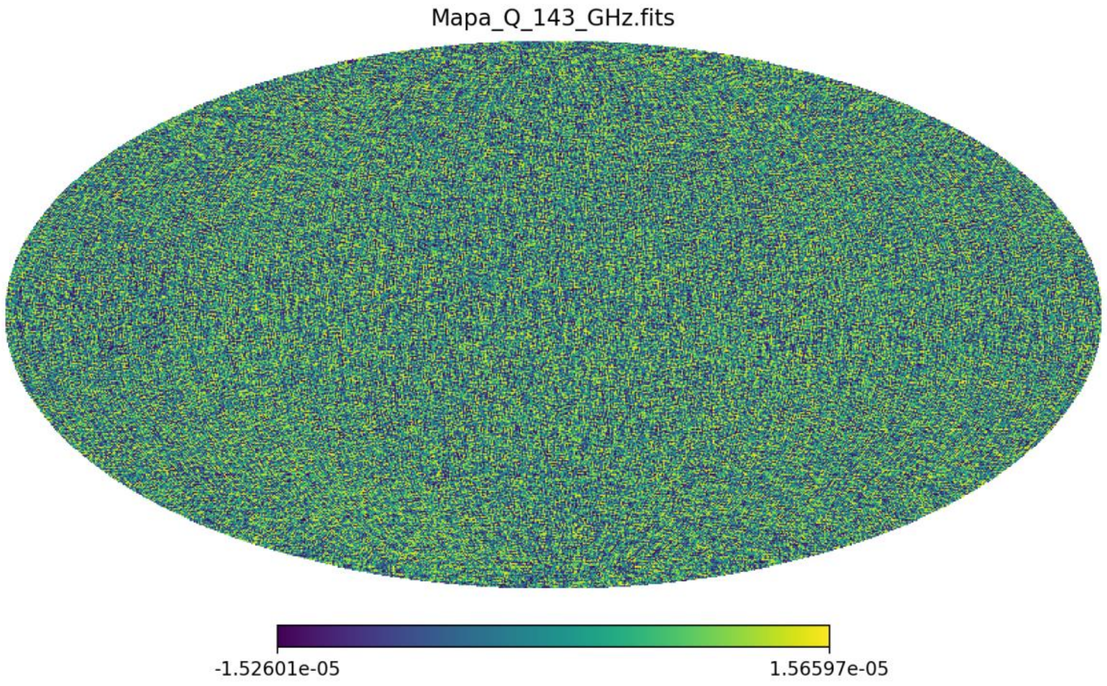


1. Fundamentals of CMB

- The cosmic microwave background is the oldest light we can observe in the universe. It gives us a snapshot of the universe about 380,000 years after the Big Bang.

- By studying its polarization, we can learn about fundamental physics, such as the early universe and processes like inflation.



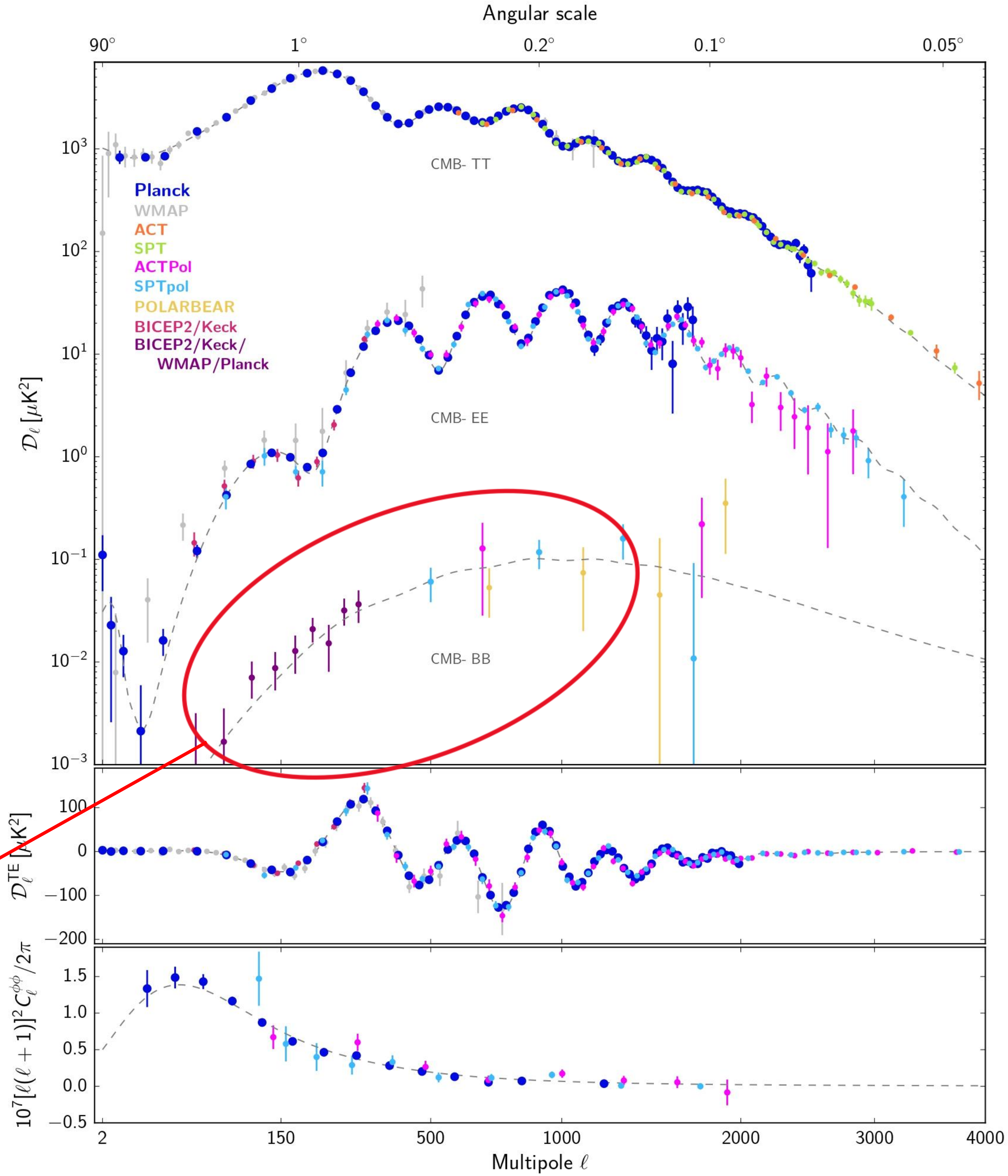


- In this work, our goal is to recover the large-scale B-mode polarization signal, which is related to the tensor-to-scalar ratio, *r*.

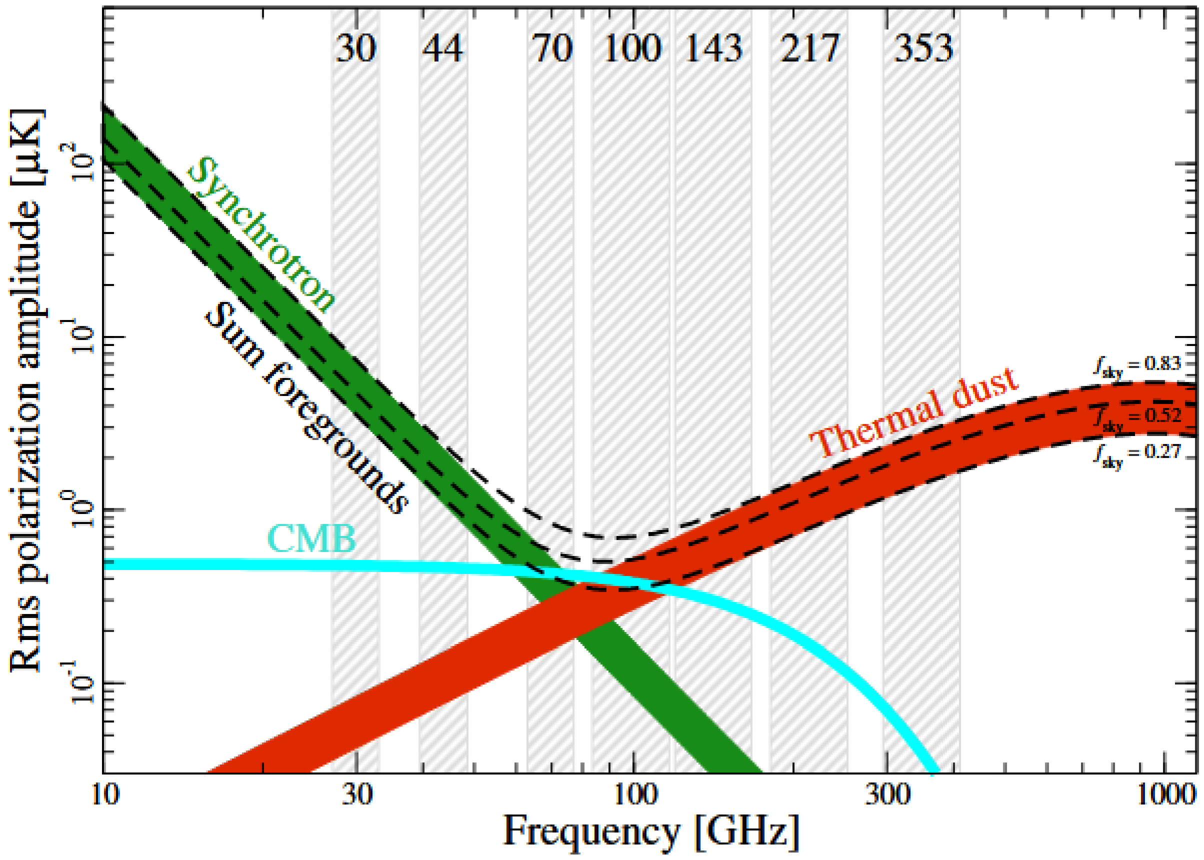
- The B-mode signal is much weaker than the other components, which makes it very challenging to recover.

- It can provide valuable information about primordial gravitational waves and inflation.

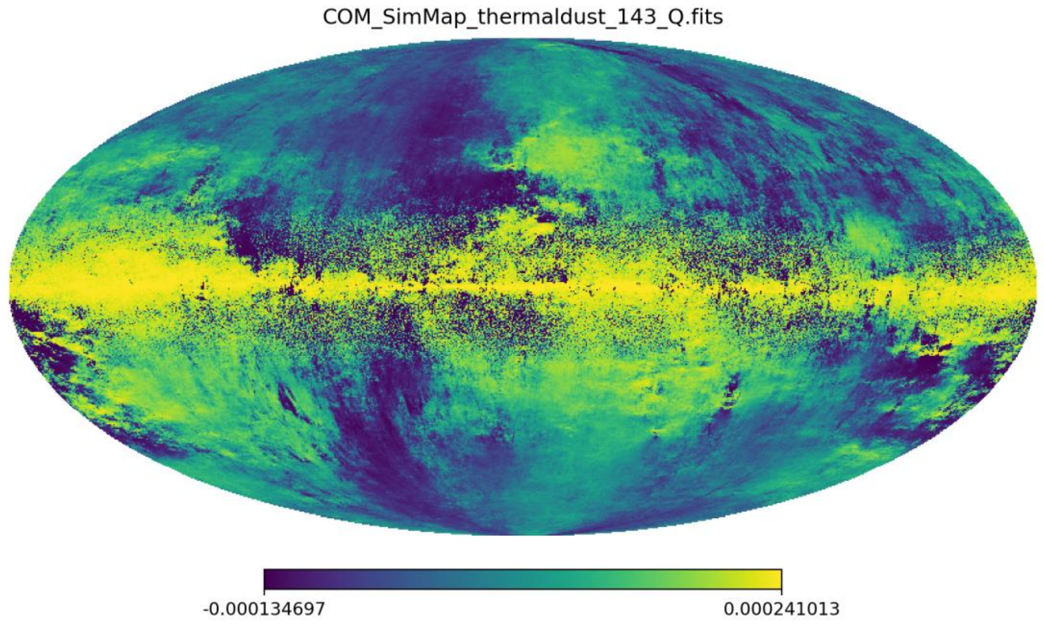
Large scale B-mode

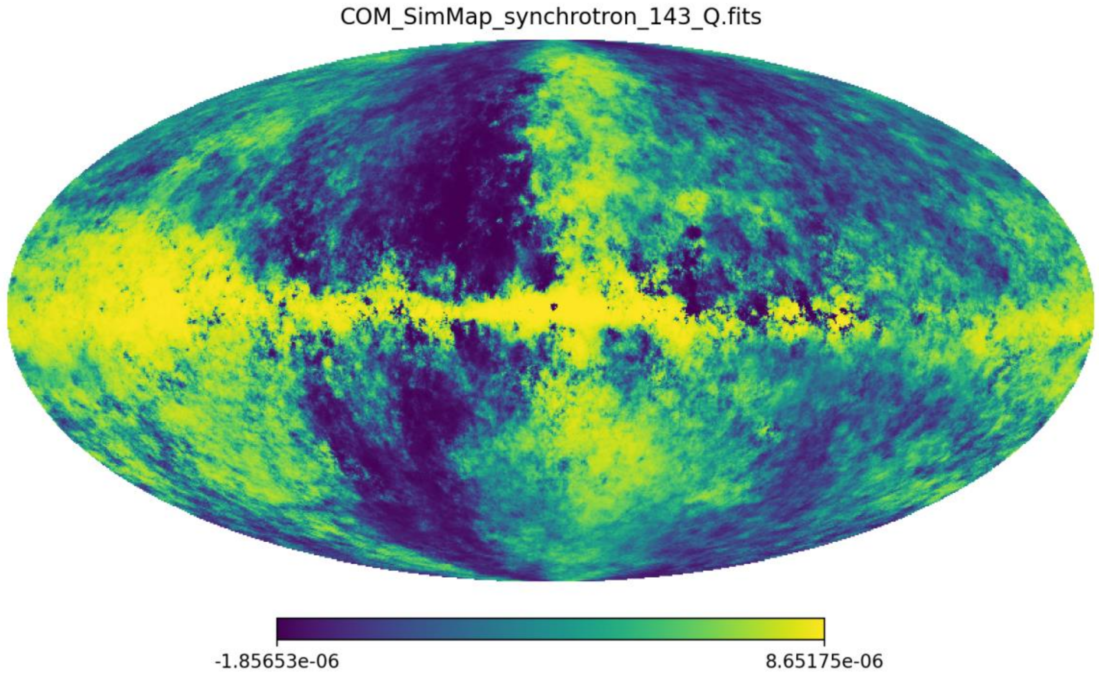


2. Contaminants



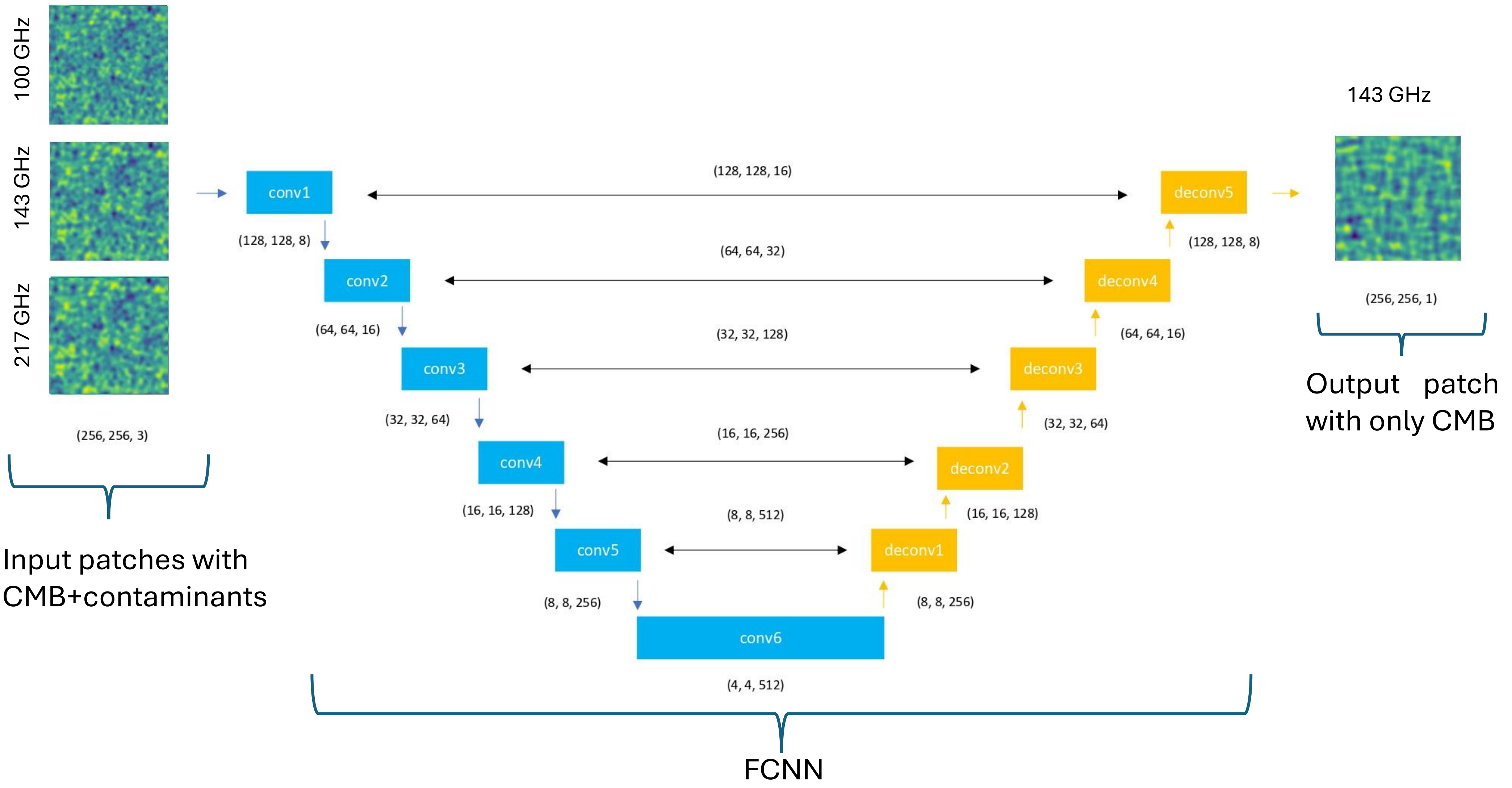
Galactic dust, synchrotron emission, extragalactic point sources, and instrumental noise contaminate the CMB signal we aim to recover.





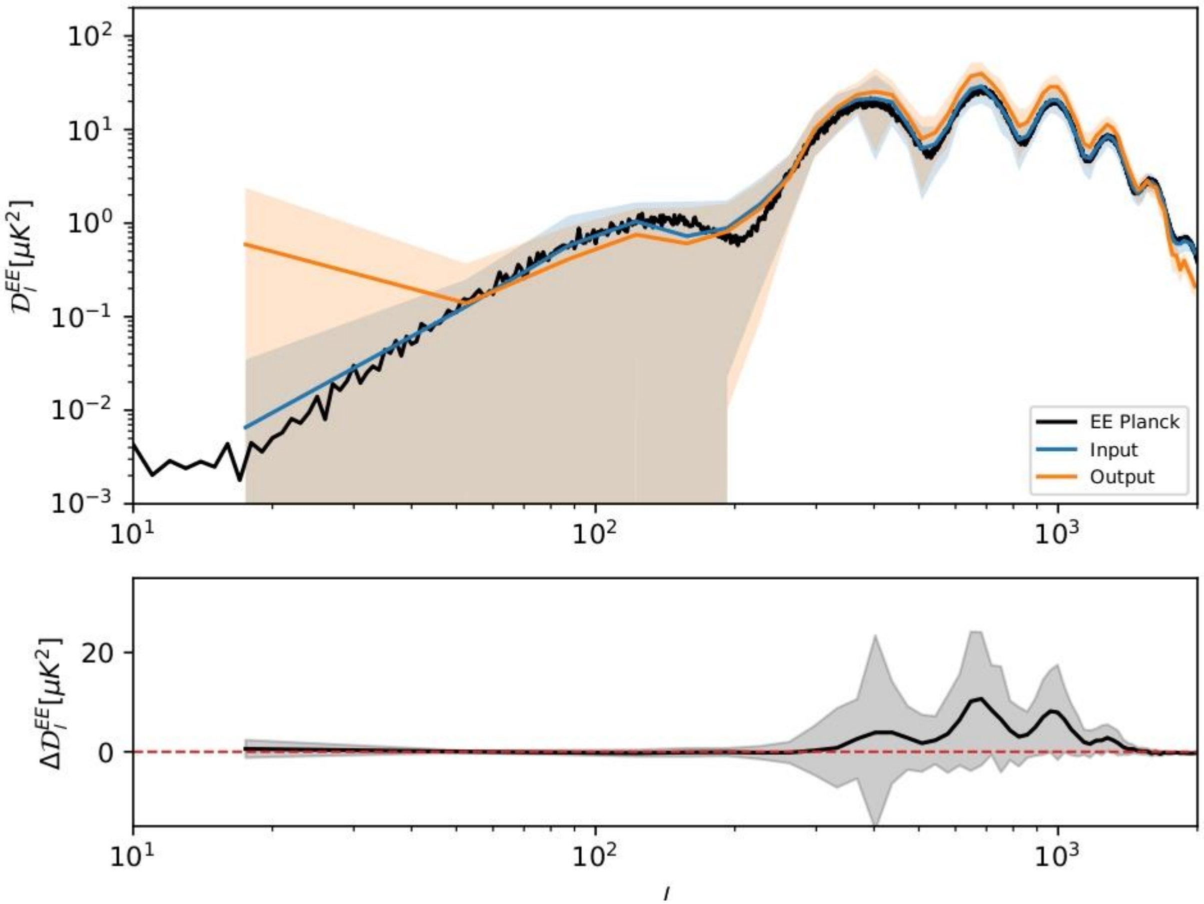
3. Methodology: Neural Network

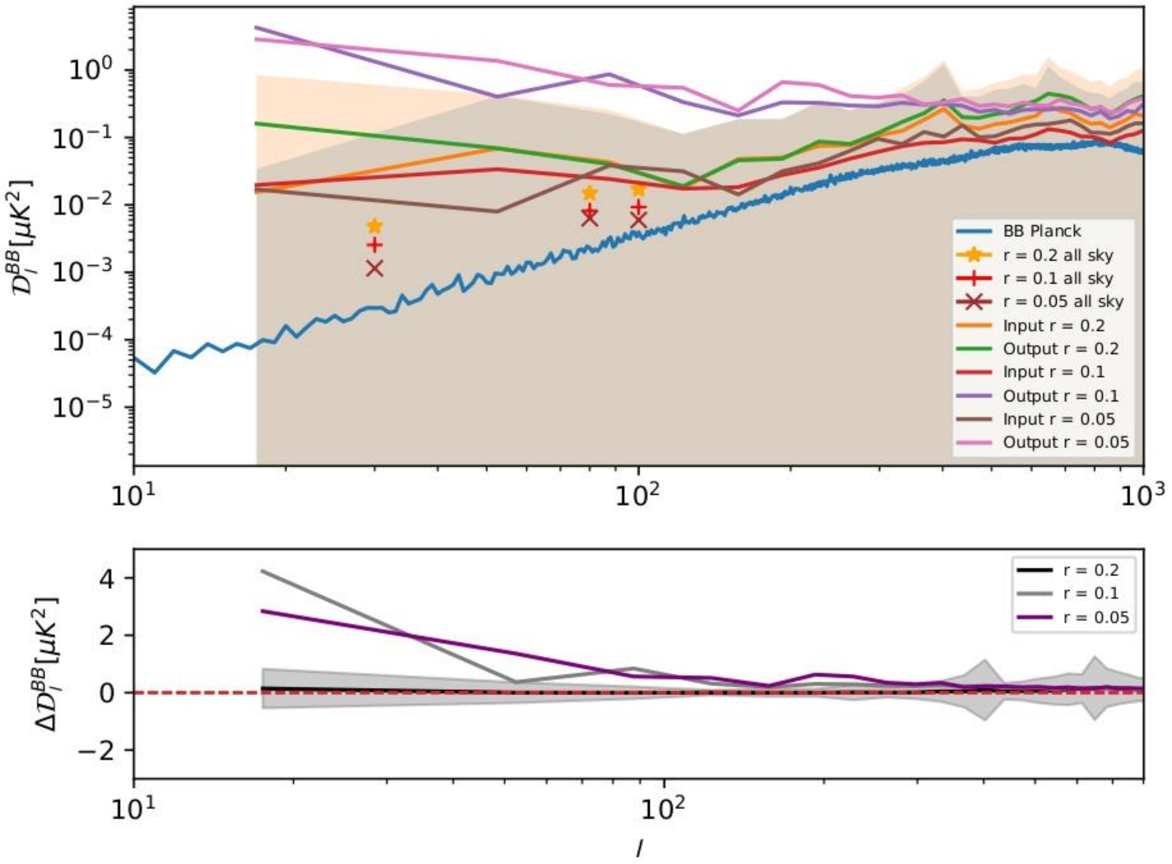
We use a Fully Convolutional Neural Network (FCNN) to recover only the CMB signal from multi-frequency observations contaminated by various foregrounds and instrumental noise.



4. Results: Q and U patches

The E and B polarization modes can be derived from the Stokes Q and U parameters.

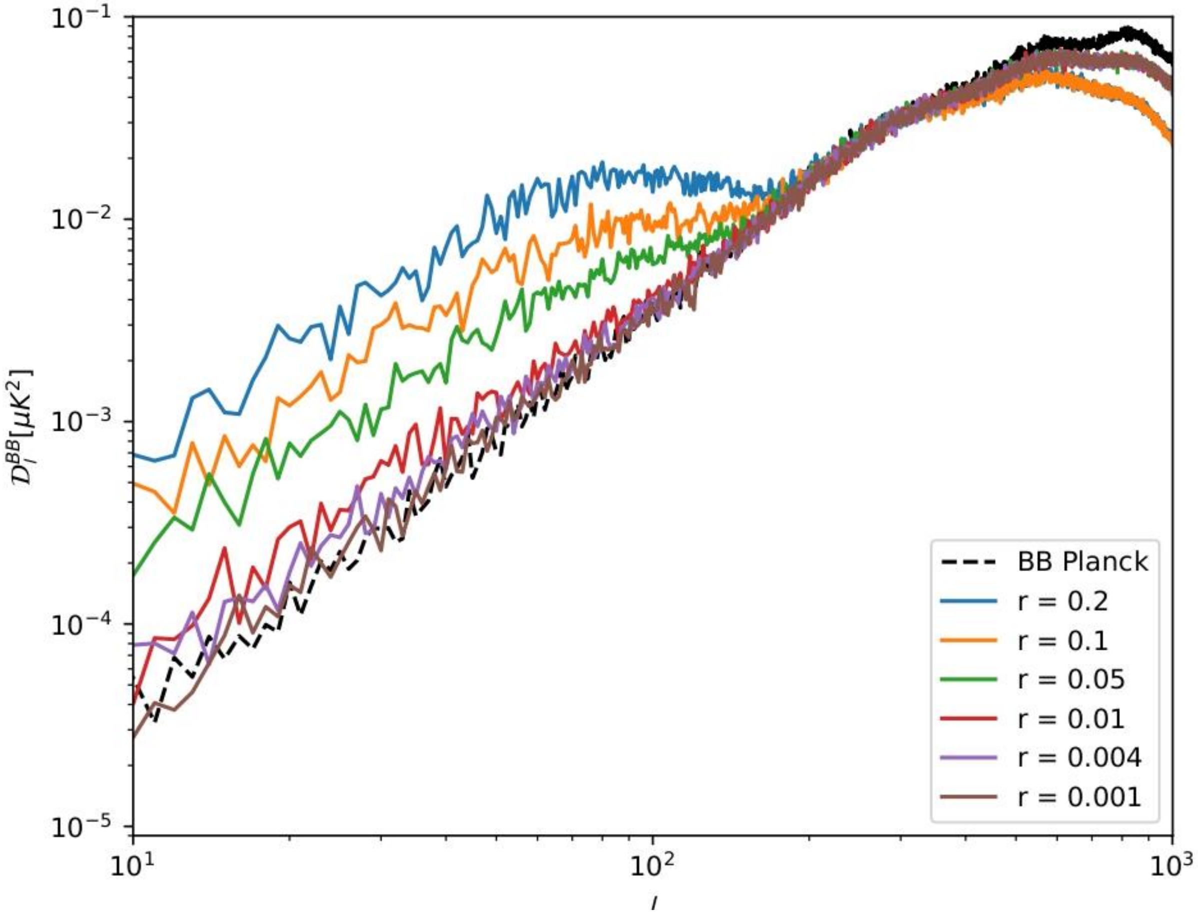


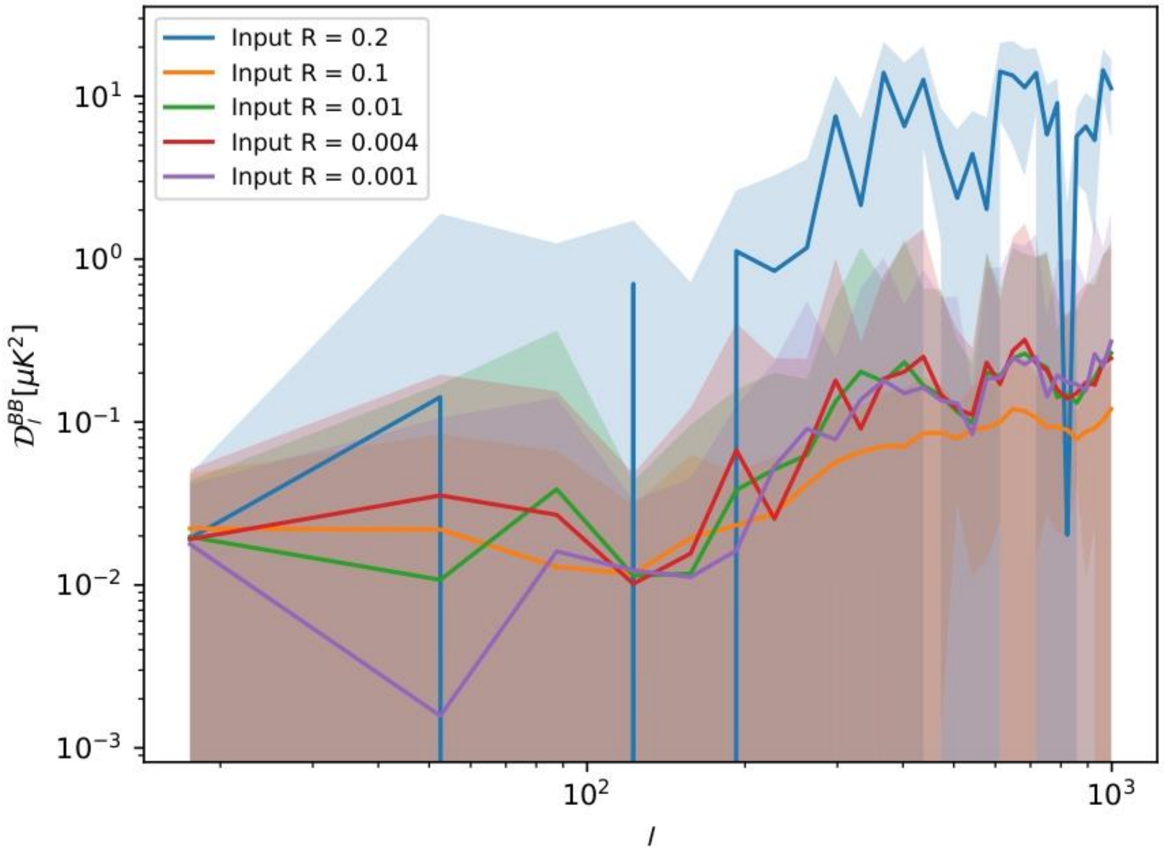


Good recovery of the E-mode polarization is achieved.

We observe a systematic overestimation of the B-mode signal across all values of r.

5. Patch projection problematic



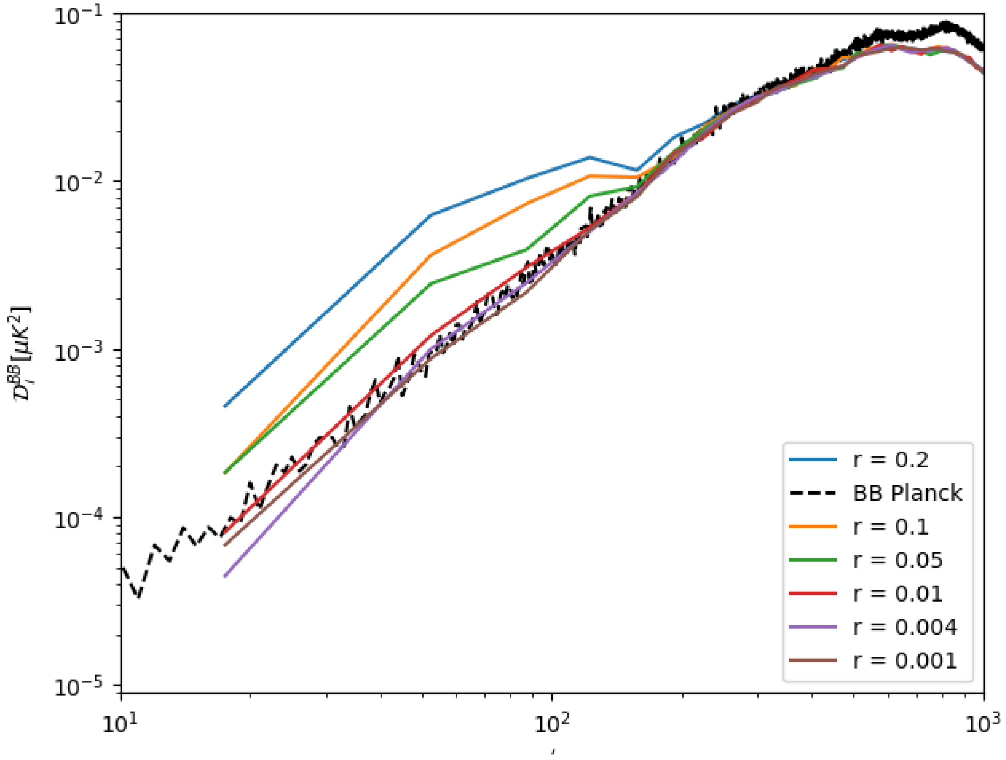


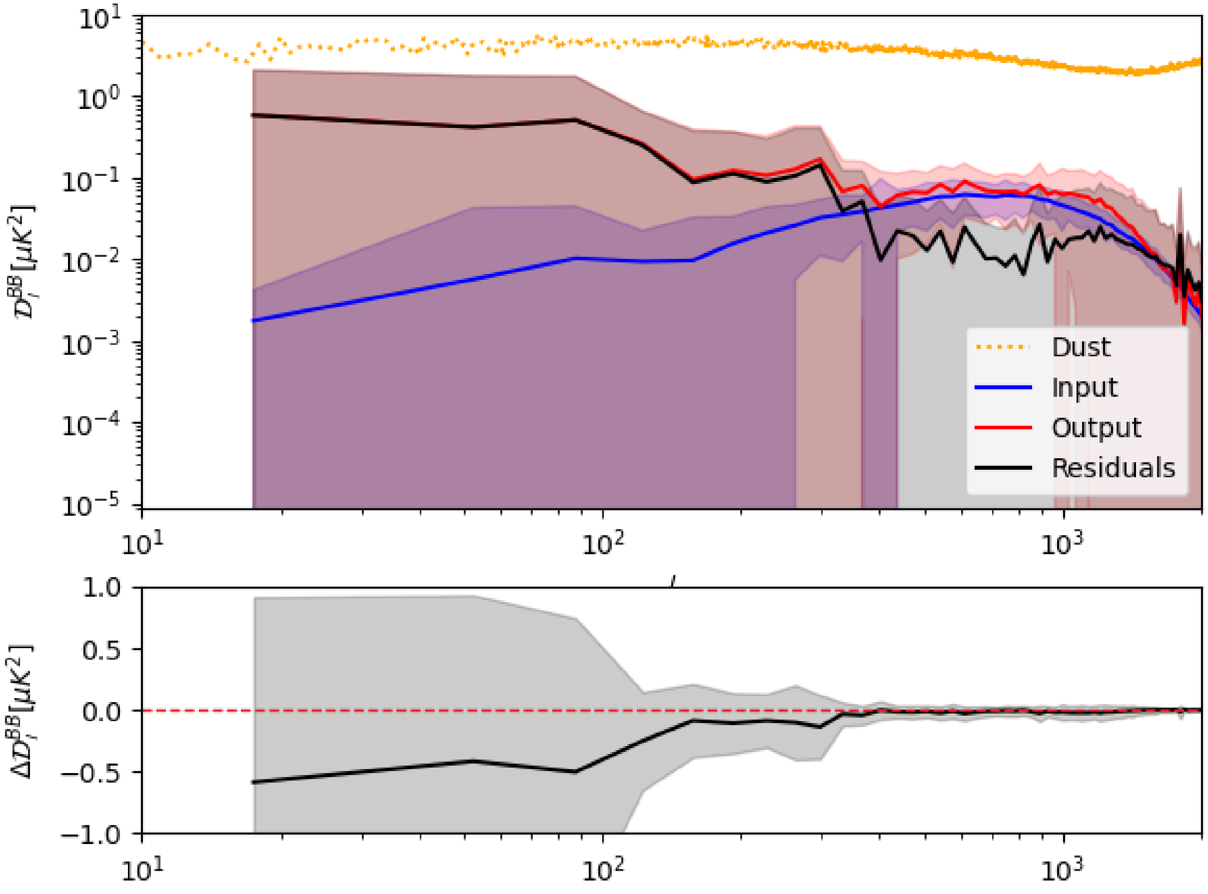
The lower the value of r, the weaker the B-mode power spectrum signal.

This behavior is not observed when calculating the spectra from patches.

Patch projection leads to a loss of information on large scales.

6. Results: E and B patches





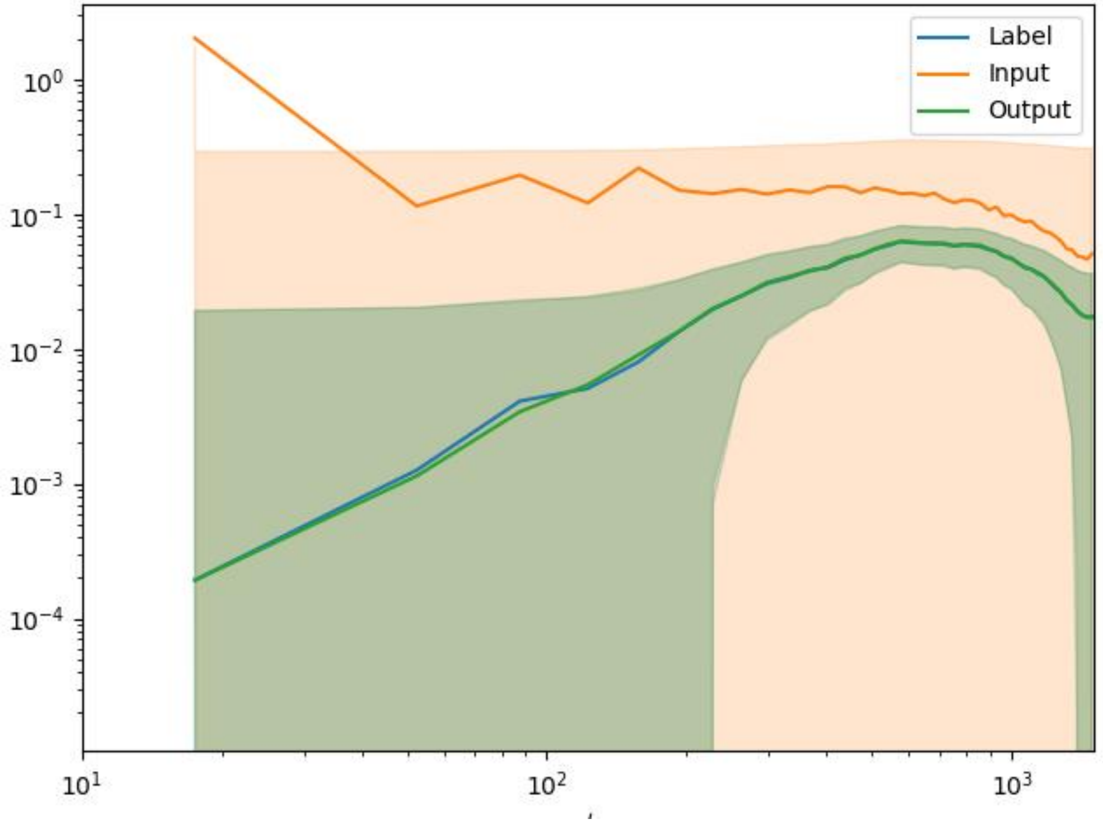
When E and B patches are used directly instead of Q and U, the desirable behavior is recovered.

Even with this improvement, the network fails to accurately recover the CMB structure, as the dust emission is too dominant on medium and large scales.

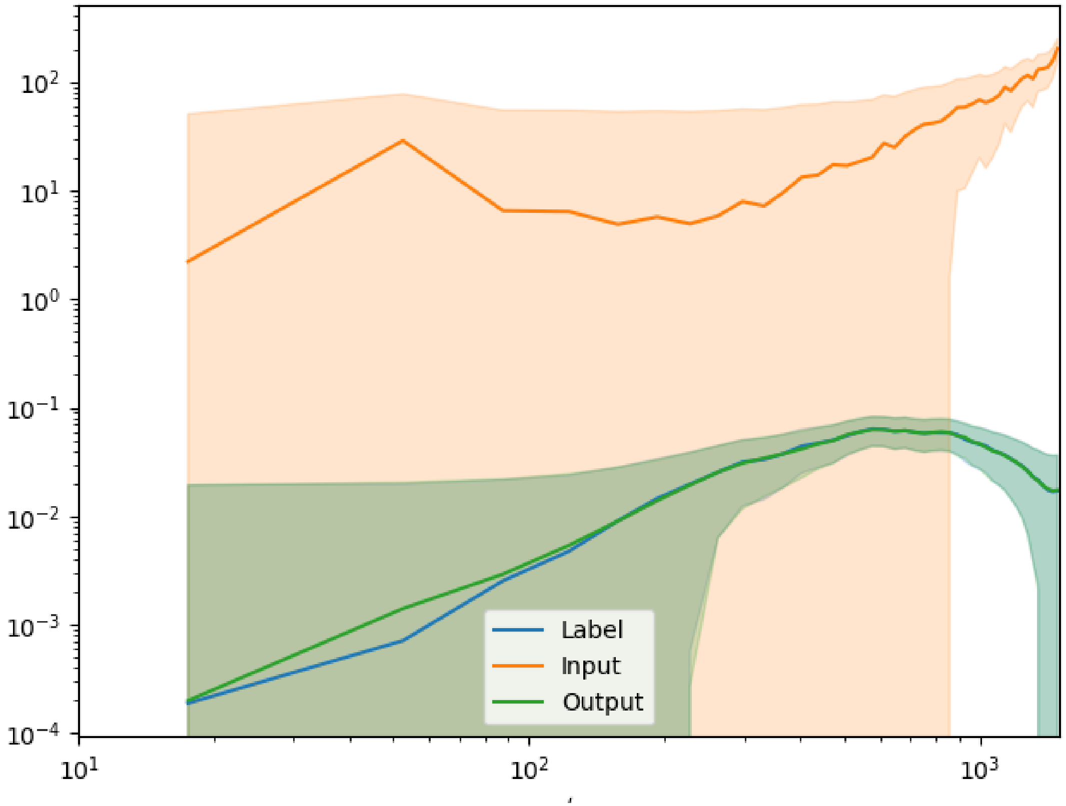
7. Results: Power spectrum MLP

The methodology is modified: a Multi-Layer Perceptron (MLP) is used to learn the power spectrum values computed from each patch instead of processing the entire patch. This simplifies the network architecture, allowing for much faster training and the use of significantly larger training datasets.

CMB + contaminants



CMB + contaminants + instrumental noise



Very promising results. I have to keep exploring in this direction...

Conclusions

- Recovering the B-mode polarization and constraining the tensor-to-scalar ratio r are key goals in CMB studies, as they provide crucial information about primordial gravitational waves and the early Universe.

- A Fully Convolutional Neural Network (FCNN) was able to recover the CMB signal but struggled with B-mode reconstruction due to dominant dust contamination at medium and large scales.

- Using E and B patches instead of Q and U improved the performance, but the network still failed to accurately recover the CMB structure.

- Switching to a Multi-Layer Perceptron (MLP) that learns the power spectrum values of each patch greatly simplified the model, enabling faster training and larger training datasets.

Thank you for
your attention