



**MACHINE LEARNING
FOR ASTROPHYSICS**

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Score-Based Diffusion for Low- ℓ Primordial CMB B-Mode Reconstruction

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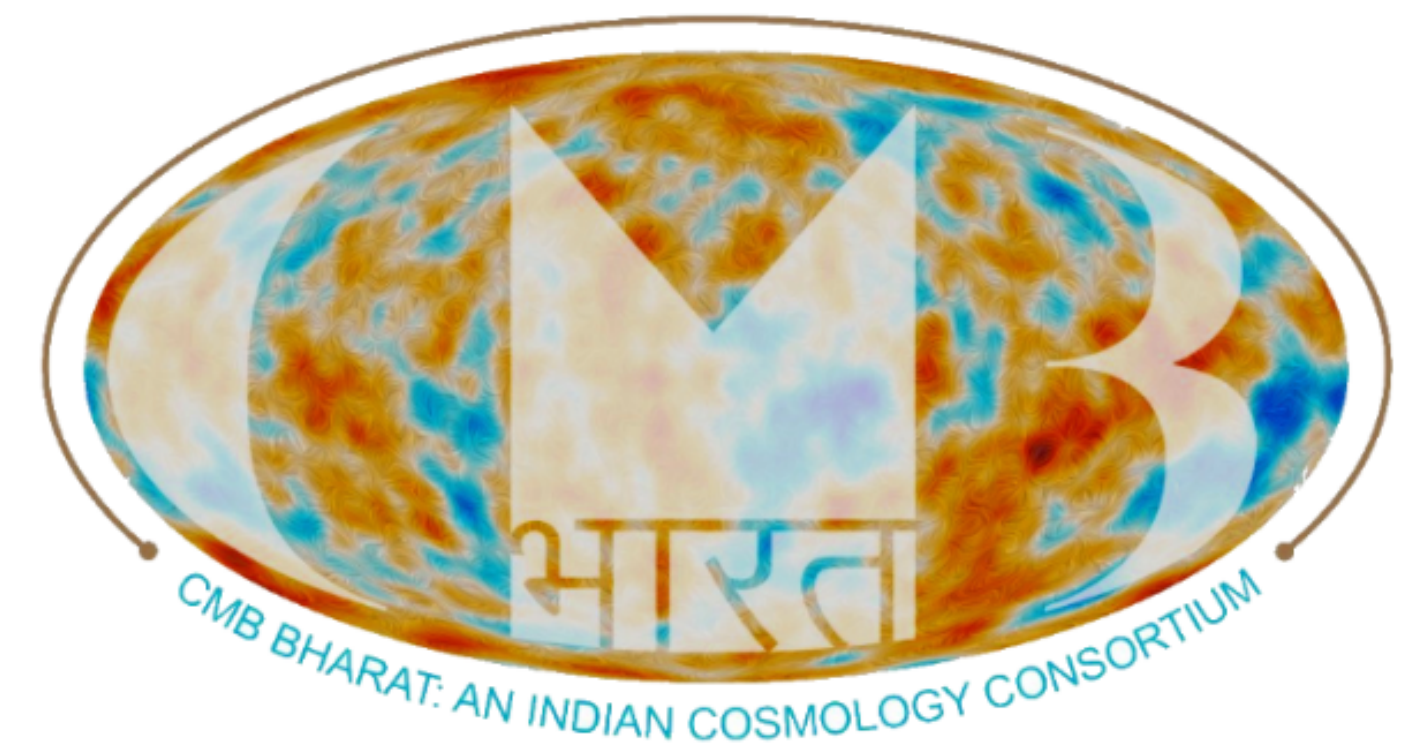
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Introduction

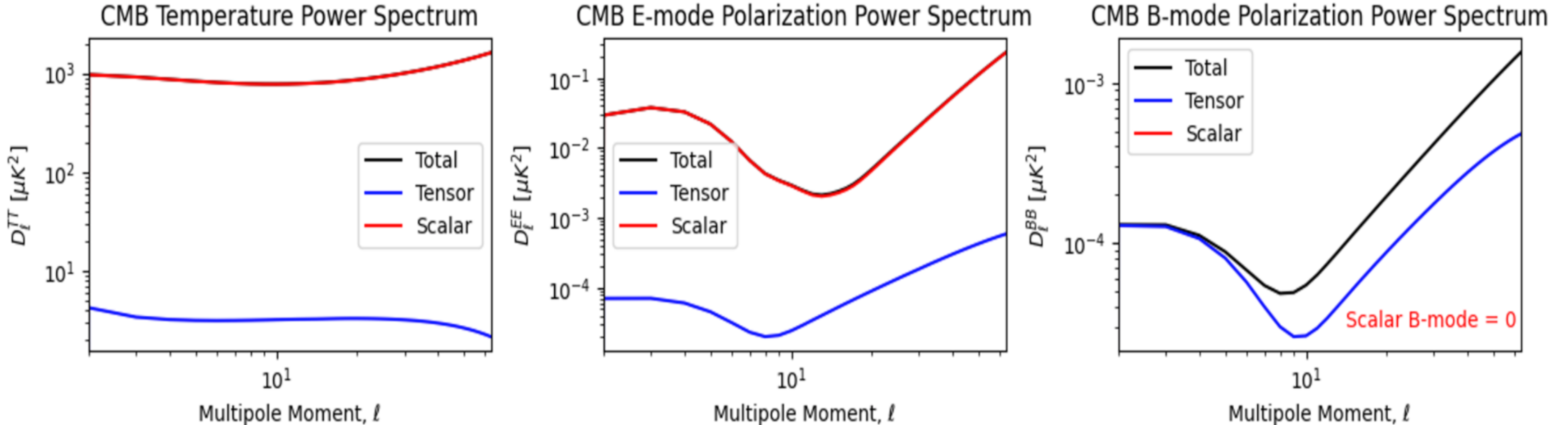
Cosmic Inflation is the rapid expansion of the early Universe that stretched quantum fluctuations to cosmic scales and can generate **primordial gravitational waves** from tensor perturbations.

The Cosmic Microwave Background (CMB) is the oldest observable light in the Universe. Scattering in the early Universe polarized this radiation into **E-mode and B-mode patterns**.

Exploring Cosmic History and Origin (CMB-Bharat) is a proposed next-generation CMB polarization mission with **22 frequency bands spanning 60–900 GHz**, targeting a combined polarization sensitivity of about **2 $\mu\text{K}\cdot\text{arcmin}$** and sensitivity to primordial B-modes corresponding to $r \sim 0.001$



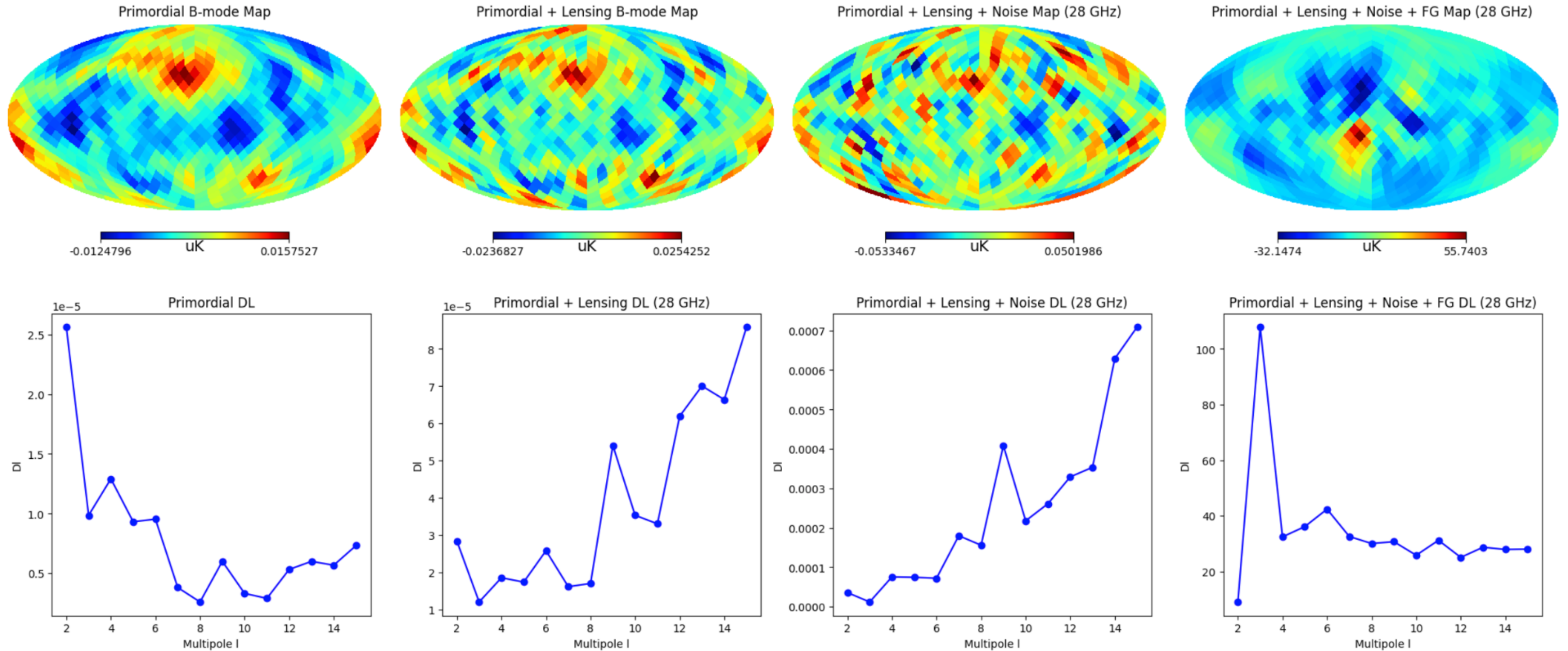
CMB B Mode Polarization : Probe to PGW's



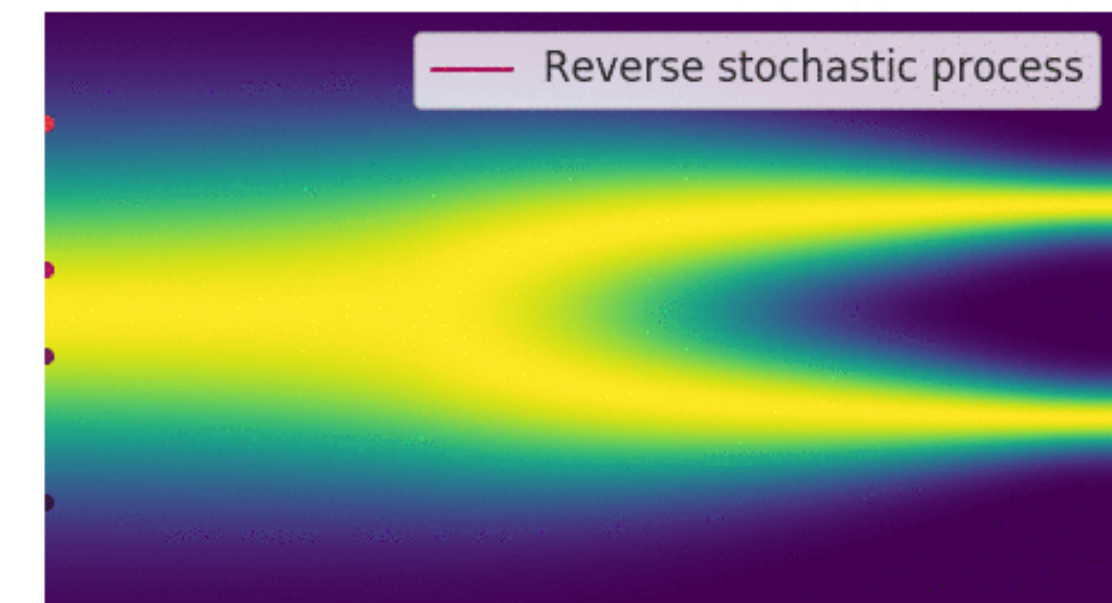
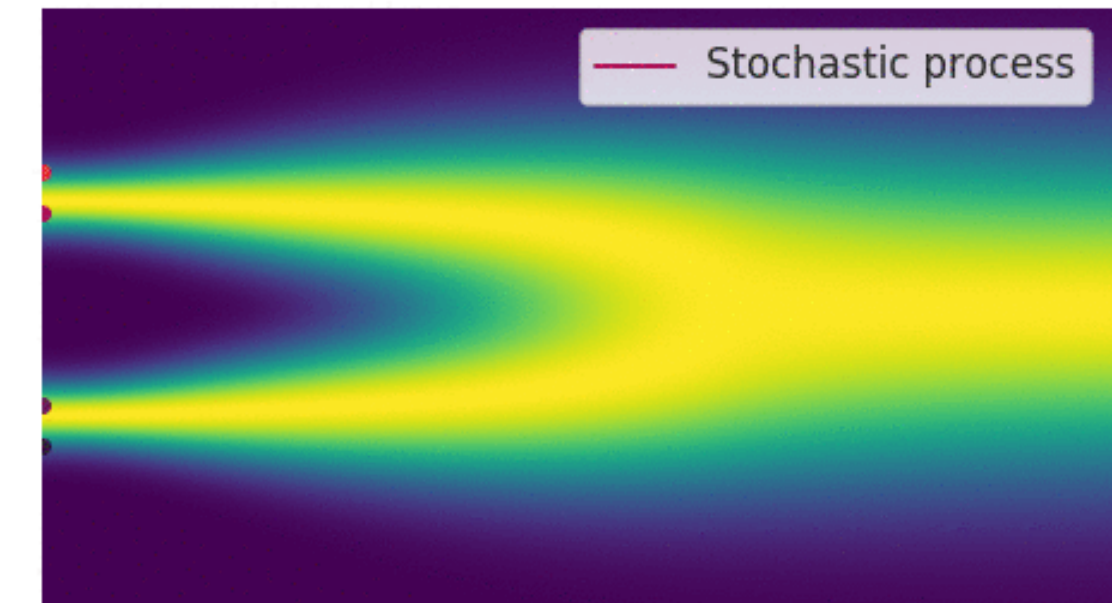
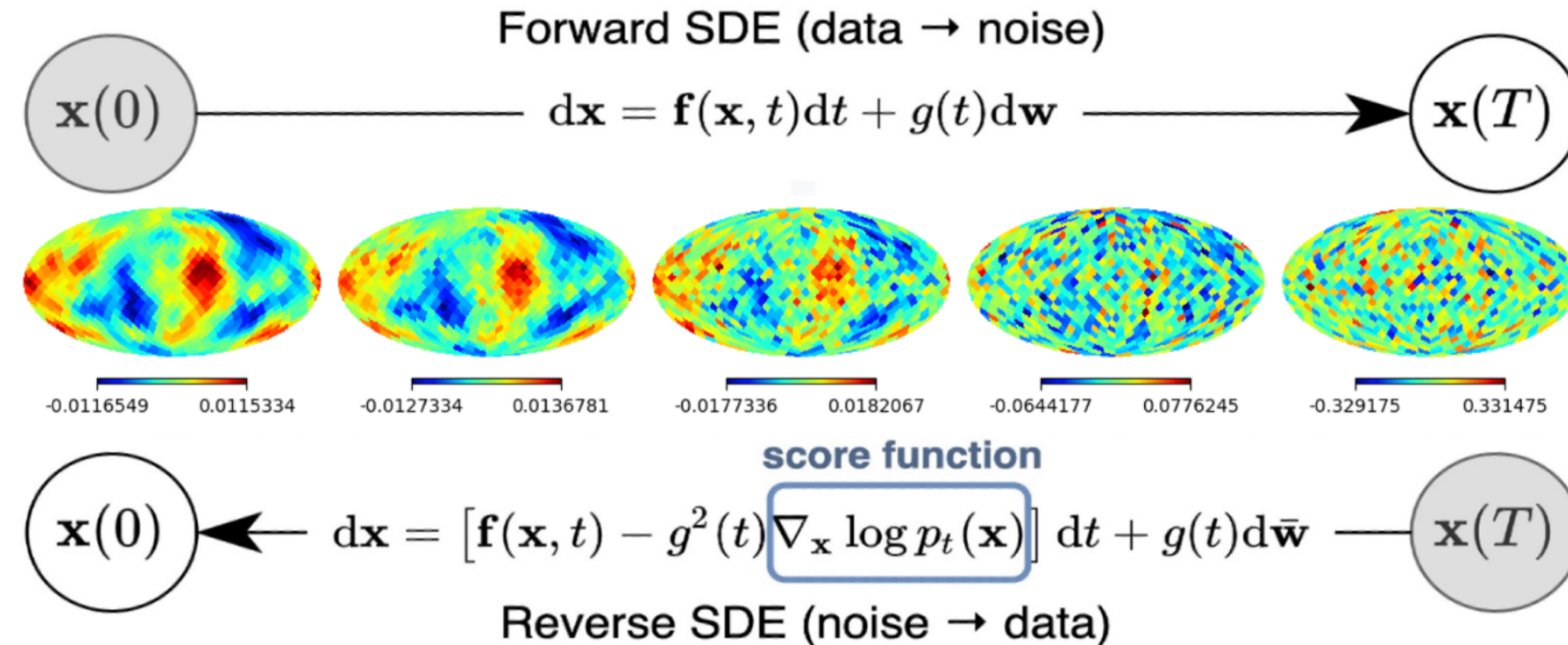
- Scalar perturbations generate only E-modes, whereas tensor perturbations produce both E- and B-modes.

CMB Temperature and E mode Polarization : Tensor Component <<< Scalar Component !!!

Reconstructing the Faint B-Mode



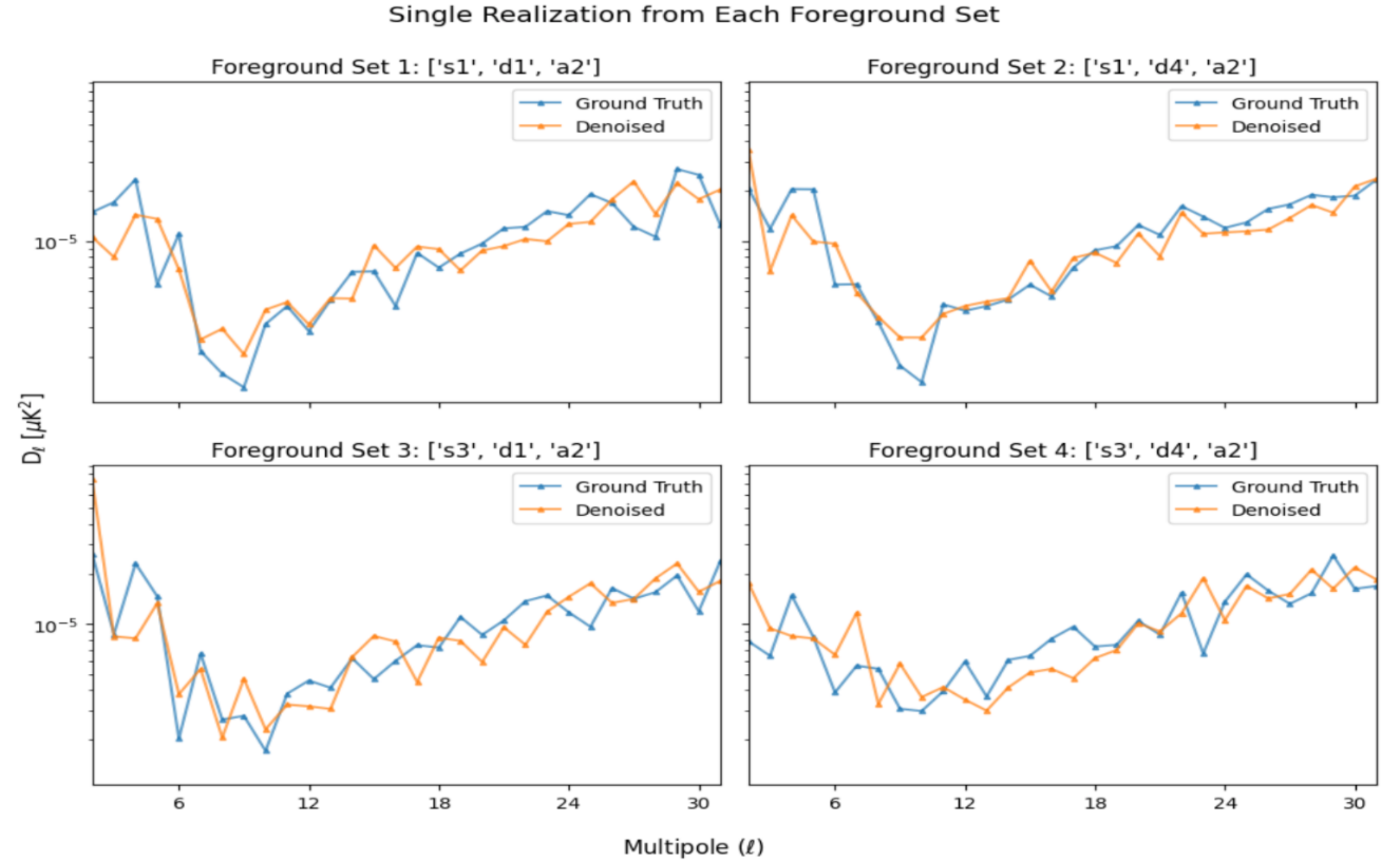
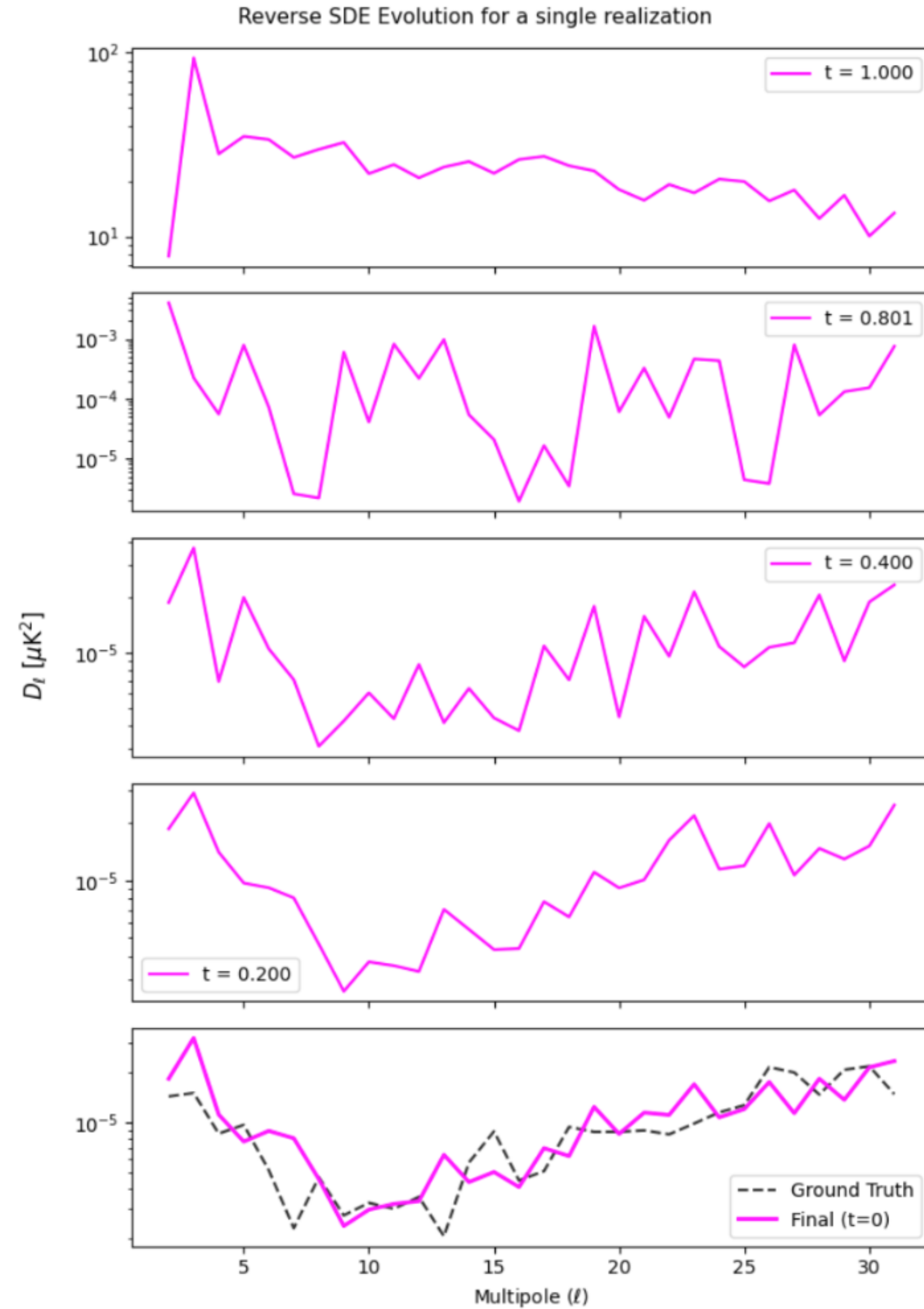
Score Based Diffusion Models using Stochastic Differential Equations



$\mathbf{f}(\mathbf{x}, t)$ is the drift coefficient $g(\mathbf{x}, t)$ is the diffusion coefficient

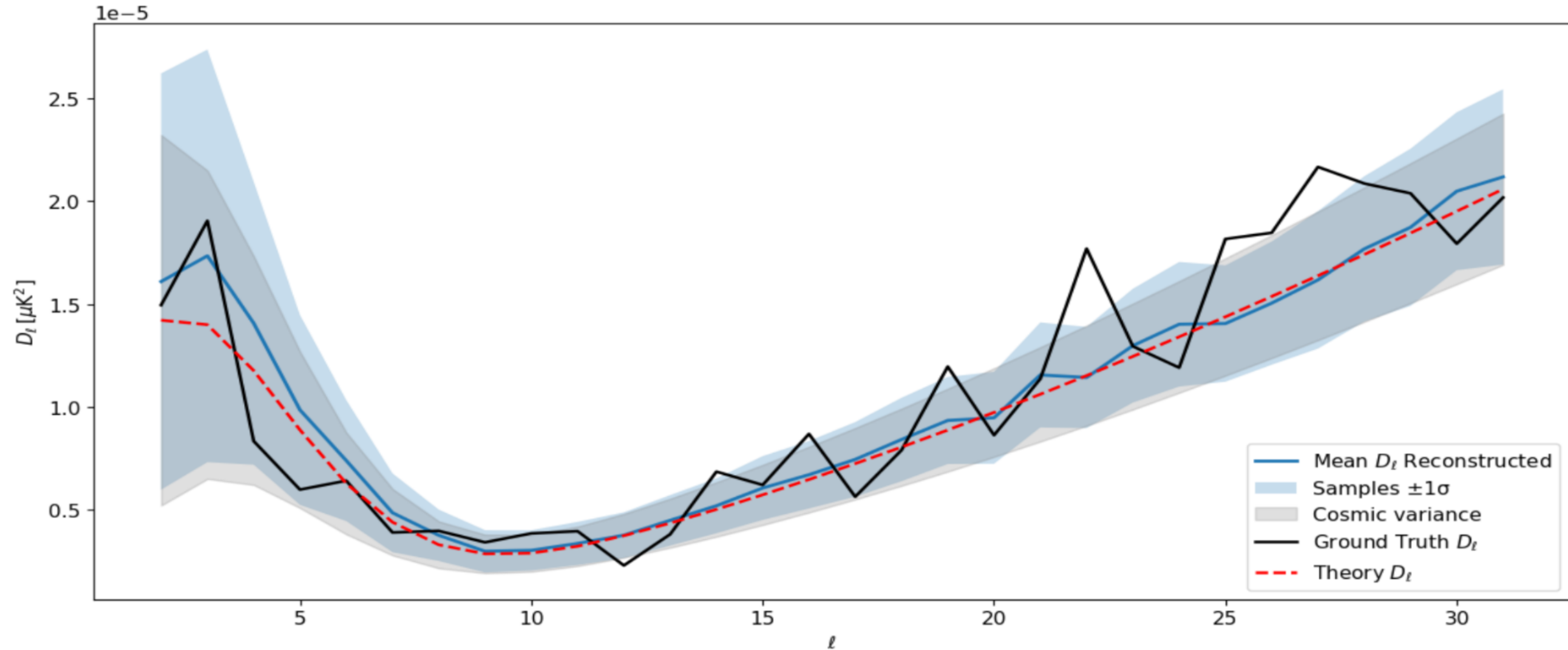
$d\mathbf{w}$ represents the differential of a standard Wiener process (a.k.a. Brownian motion)

Results



- o The reconstructed D_ℓ follows the underlying primordial B-mode spectrum over the low- ℓ range.

Ensemble Reconstruction



- The ground-truth realization is largely consistent with the reconstructed ensemble and expected cosmic variance.
- Score-based diffusion provides a promising generative prior for reconstructing faint primordial CMB B-mode signals.

Thank You !!!



scan to read the paper