Peer Review Report on "Robust CMB B-mode Analysis with Needlet-ILC"

A Variational Consistency Assessment

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This report evaluates the manuscript entitled "Robust CMB B-mode analysis with Needlet-ILC and simulation-based inference". The assessment focuses on structural consistency, variational closure, physical completeness, and dependence on non-generative model assumptions. The conclusion is that the work is not based on a self-contained physical theory and relies entirely on phenomenological parametrizations. Recommendation: Reject.

REFEREE REPORT (CONFIDENTIAL)

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Manuscript: Robust CMB B-mode analysis with Needlet-ILC and Simulation-Based Inference
Journal: Physical Review D

1. General Assessment

The manuscript presents a numerical pipeline for extracting large-scale CMB B-modes using a Needlet-ILC algorithm and simulation-based inference. The work is technically competent, but it does not contain fundamental physics. It is a data-processing exercise entirely dependent on external assumptions.

The central issue is structural: the analysis requires an a priori cosmological model (LCDM + inflation) that does not satisfy variational closure, does not derive its operators from first principles, and requires patchwork parametrizations (spectral indices, dust SED parameters, tensor-to-scalar ratio r). Therefore the pipeline can only recover what the initial model imposes.

In other words, the work is model-driven rather than physics-driven.

2. Major Concerns

(A) No variational closure. The manuscript assumes a metric background and a primordial tensor spectrum, but no derivation is provided. The entire formalism is non-self-contained: the statistical machinery operates on inputs that are not generated by a closed field equation.

(B) Foregrounds are modeled by parametrization, not physics. Dust complexity is introduced through phenomenological parameters beta, alpha, decorrelation terms, and frequency scaling laws. These parameters do not arise from a fundamental Lagrangian. As a consequence, the resulting inference cannot be physically interpretable beyond the fitting model.

(C) NILC is mathematically agnostic to physical origin. The Needlet-ILC solution is a linear regression in needlet space that minimizes variance. It does not enforce any physical constraint and is fully compatible with unphysical residuals. All B-mode "detections" remain conditional on the statistical model, not on a field-theoretic derivation.

(D) Simulation-based inference amplifies model bias. The use of neural posterior estimation presupposes that the simulated training set spans the true physical distribution. This is not justified. Since the training set is generated from the same LCDM + dust model, the posterior is guaranteed to inherit all prior assumptions.

3. Fundamental Issue

The manuscript implicitly assumes that the primordial tensor spectrum exists because the chosen cosmological model requires it. No mechanism is derived. No generative equation is presented. No closure condition is verified. Therefore the work cannot confirm nor falsify the existence of B-modes.

It can only reproduce the structure already imposed by the simulation pipeline.

4. Recommendation

Recommendation: Reject.

The manuscript does not meet the criteria for physical originality required for Physical Review D. It relies entirely on external assumptions without deriving the relevant quantities from a variationally closed theory.

The analysis is methodologically interesting but not conceptually meaningful for fundamental physics.

APPENDIX D: DIRECT COMPARISON BETWEEN THE UNIVERSAL PSI EQUATION AND CMB B-MODE MODELS

D.1 Conceptual Scope

The CMB B-mode pipelines (NILC, Bayesian component separation, simulation-based inference) aim to estimate the tensor-to-scalar ratio r. Their structure is purely statistical and not derived from a fundamental field equation.

The Universal Psi Equation,

$$\frac{\delta}{\delta\Psi^\dagger(x)}\left\{\left|\sum_{i,j}\Psi_i^\dagger\Gamma\Psi_j\right|^2-\lambda_1\sum_i(\Psi_i^\dagger\Psi_i-1)^2-\lambda_2\sum_{i,j,k}\mathrm{Tr}\left[\Gamma(\Psi_i\Psi_j^\dagger-\Psi_k\Psi_i^\dagger)\right]^2\right\}=0,$$

is variationally closed and self-generated: no external parameters, no metric input, no phenomenological spectral functions.

D.2 Structural Comparison Table

Criterion	**CMB B-mode Pipelines**	**Universal Psi Equation**
Variational closure	No	Yes
Metric derivation	Assumed LCDM	Emergent
Tensor spectrum	Parametrized	Generated by Psi coherence
Foreground model	Phenomenological	Emergent constraints
Free parameters	Many (r, beta, alpha, etc.)	None
Physical completeness	No (patchwork)	Yes (self-consistent)
Operator origin	Fitted or imported	Self-generated Gamma
Predictive power	Model-limited	Field-theoretic

D.3 Interpretation

The B-mode analyses are conditional on a model that is neither fundamental nor generative. The Psi framework does not require foreground parametrization, tensor templates, or metric priors: all structures emerge from the coherent Psi sector.

Therefore the two approaches are not comparable in scientific depth. The Psi framework is foundational; the B-mode pipelines are statistical tools operating on a non-closed model.