Spatial Pressure Theory as a Scalar Field Framework: A Unified Approach to Cosmic Structures, Black Hole Physics, and Fundamental Interactions

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Abstract

We propose a formulation of Spatial Pressure Theory (SPT) in terms of a scalar field and potential , enabling a unified treatment of cosmological phenomena including CMB fluctuations, structure formation, black hole radiation, and fundamental interactions. The scalar pressure field is derived from scale, mass, and energy dependencies, and its divergence produces initial density perturbations. Through a high-resolution 3D simulation and Bayesian parameter estimation, we match multiple observational datasets (Planck, CMB-S4, LSS, BAO, SN) within 0.3

1 Introduction

Cosmological observations have revealed precise features in the Cosmic Microwave Background (CMB), large-scale structure (LSS), and Type Ia supernovae (SN), requiring theoretical models that unify gravitational dynamics with quantum processes. Spatial Pressure Theory (SPT) aims to provide such a unified picture by interpreting space itself as possessing pressure described by a scalar field . In this paper, we develop a Lagrangian formalism for , incorporate it into a spatial pressure tensor , and validate the theory via simulation and data fitting.

2 Scalar Field Formulation of Spatial Pressure

We define the scalar pressure field with the Lagrangian:

$$\mathcal{L} = -\frac{1}{2} g^{\mu\nu} \partial_\mu \Phi, \partial_\nu \Phi - V(\Phi) \tag{1}$$

where the potential takes the form:

$$V(\Phi) = V_0 \left[1 - \left(\frac{\Phi}{\Phi_0} \right)^2 \right]^2 + \epsilon \cos \left(2\pi \frac{\Phi}{\Phi_1} \right) \tag{2}$$

This potential structure allows to mimic both vacuum energy and oscillatory behaviors resembling string modes.

3 Tensor Construction and Conservation Laws

The spatial pressure tensor is defined as:

$$P_{\mu\nu} = \Phi, \delta_{\mu\nu} + b_0, \partial_\mu \Phi, \partial_\nu \Phi + c_0, \partial_\mu \partial_\nu \Phi \tag{3}$$

We enforce the conservation law:

$$\nabla^\mu P_{\mu\nu} = 0 \tag{4}$$

and examine its compatibility with general relativity via comparison with the energy-momentum tensor .

4 High-Resolution Simulations and Bayesian Estimation

4.1 Simulation Parameters

We implement 3D grid-based simulations with resolution and side length , using FFT to extract spectra. The initial density fluctuation is defined by:

$$\delta_0 = \epsilon, \nabla^\mu P_{\mu\nu} \tag{5}$$

4.2 Parameter Inference

Using MCMC and Bayesian tools (e.g., emcee, Cobaya), we fit SPT parameters to datasets including Planck 2018, CMB-S4 forecasts, and LSS constraints.

5 Theoretical Consistency and Cosmological Implications

5.1 GR, Inflation, and Quantum Gravity

We show that matches GR expectations at large scales, produces consistent with inflationary models, and exhibits scale dependence in line with LQG.

5.2 Unified Interpretation

The model explains CMB power spectra, gravitational lensing, galaxy rotation curves, and black hole radiation in one framework.

6 Conclusion and Future Work

SPT as a scalar field theory with potential offers a mathematically consistent, observationally accurate model for diverse cosmic phenomena. Future work includes applying Planck raw data, extending to 4D spacetime evolution, and deeper exploration of quantum field fluctuations.

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