Testing the Relativistic Scalar-Vector Plenum (RSVP) Theory: Experimental Validation of Cosmic Geometry

Abstract

The Relativistic Scalar-Vector Plenum (RSVP) theory posits that cosmic structure formation arises from the interaction of a scalar entropy field Φ, vector baryon flow $\mathbf{v}$, and a Voronoi-Delaunay tessellation, governed by relativistic dynamics. This paper presents a rigorous experimental framework to test RSVP theory, integrating laboratory analogues, astronomical observations, numerical simulations, and quantum turbulence experiments. These tests evaluate RSVP's predictions against the ΛCDM model, focusing on void ellipticity, filament shear alignment, and halo lensing profiles, with an emphasis on quantitative metrics and mathematical formulations.

1 Introduction

The Relativistic Scalar-Vector Plenum (RSVP) theory proposes that the universe's large-scale structure emerges from the interplay of a scalar entropy field Φ, vector baryon flow $\mathbf{v}$, and a Voronoi-Delaunay tessellation, described by relativistic field equations. Unlike the ΛCDM model, RSVP eliminates dark matter halos, predicting unique geometric and dynamic signatures. This paper outlines experiments to test RSVP, employing mathematical formulations to quantify predictions.

2 Laboratory Analogue: Quantum Dot Systems

A two-dimensional electron gas (2DEG) in a gallium arsenide heterostructure models cosmic dynamics. The scalar field Φ is represented by a disorder potential, and the vector field $\mathbf{v}$ by directed electron flow. Local entropy S is derived from density fluctuations via shot-noise spectroscopy, with power spectrum $P(f) \propto S$.

The experimental procedure comprises:

1. Patterning gate electrodes to impose a Voronoi tessellation potential, $V(\mathbf{r}) = \sum_i \phi_i \exp(-|\mathbf{r} - \mathbf{r}_i|^2/\sigma^2)$, where $\mathbf{r}_i$ are Voronoi cell centers.
2. Applying a thermal gradient $\nabla T \parallel \mathbf{v}$ to drive entropy dynamics, modeled as $\partial_t S = -\nabla \cdot (\mathbf{v}S)$.
3. Measuring electron density $n_e(\mathbf{r})$ at Delaunay vertices via scanning tunneling microscopy, testing the RSVP prediction $\rho_b \propto |\nabla \cdot \mathbf{v}|$, where ρ_b is baryon density.

The electron density at vertices is expected to satisfy:

$$n_e(\mathbf{r}_v) \propto \int |\nabla \cdot \mathbf{v}| \, dA,$$

where $\mathbf{r}_v$ are Delaunay vertices and dA is the area element.

3 Astronomical Observations: Cosmic Shear and Void Geometry

Using data from the Euclid space telescope and the Large Synoptic Survey Telescope (LSST), we measure cosmic shear γ_{obs}. RSVP predicts:

- **Filament Shear Alignment**: Shear aligns with baryon flow, with:

$$\gamma_{\text{RSVP}} = \int \rho_b \mathbf{v} \cdot d\mathbf{l},$$

maximized at $\theta \approx 0$ (flow-filament alignment), unlike ΛCDM's $\theta \approx \pi/4$. The correlation function is:

$$C(\theta) = \langle \gamma_{\text{obs}} \cdot \gamma_{\text{RSVP}} \rangle \propto \cos\theta.$$

- **Void Ellipticity**: Void shapes depend on entropy, with ellipticity:

$$e = \frac{a-b}{a+b} \propto S^{-1},$$

where a and b are void semi-axes, contrasting with ΛCDM's $e \approx 0.05$. Cross-correlating weak lensing with 21cm hydrogen data from CHIME and the Square Kilometre Array tests:

$$\langle eS \rangle = \int e(\mathbf{r}) S(\mathbf{r})\, dV.$$

4 Numerical Simulations: Computational Cosmology

Modified cosmological codes (e.g., AREPO, GADGET-4) incorporate dynamic Voronoi-Delaunay tessellation and entropy diffusion:

$$\frac{\partial S}{\partial t} = \nabla^2 S + \alpha(\mathbf{v} \cdot \nabla S) + \beta R,$$

where R is the Ricci scalar accounting for relativistic effects. Initial conditions use Gaussian random fields for Φ, with power spectrum $P(k) \sim k^n$, $n \in [-2.5, -1.0]$. Control simulations omit $\mathbf{v}$-coupling. Metrics include:

- Betti number ratios b_1/b_2, quantifying filament-to-void balance:

$$b_1/b_2 = \frac{\text{Number of filaments}}{\text{Number of voids}}.$$

- Wasserstein distance W_1 between simulated and observed galaxy cluster distributions:

$$W_1(\mu, \nu) = \inf_{\gamma \in \Gamma(\mu,\nu)} \int |\mathbf{x} - \mathbf{y}|\, d\gamma(\mathbf{x}, \mathbf{y}).$$

5 Quantum Turbulence: Superfluid Helium-3

Superfluid helium-3 at millikelvin temperatures models cosmic filaments via vortex lines. The experimental setup involves:

- Imprinting a vortex lattice with Voronoi tessellation, where vortex positions satisfy $\mathbf{r}_i = \arg\min V(\mathbf{r})$.
- Modulating rotation rate $\Omega(t)$ to drive $\partial_t \Phi$, with dynamics:

$$\partial_t \Phi = -\mathbf{v} \cdot \nabla \Phi + \kappa \nabla^2 \Phi.$$

- Tracking vortex reconnection via NMR spectroscopy, testing vortex accumulation:

$$N_v(\mathbf{r}_v) \propto \Omega^{1/2},$$

mirroring $\rho_b(\Phi)$.

6 Discriminating RSVP from ΛCDM

Key observables include:

- **Void Ellipticity**: RSVP predicts $e \approx 0.3$, with $\langle eS \rangle \neq 0$, versus ΛCDM's $e \approx 0.05$.
- **Filament Shear Alignment**: RSVP requires $C(\theta) \propto \cos\theta$, peaking at $\theta \approx 0$, versus ΛCDM's uniform $C(\theta)$.
- **Halo Lensing Profiles**: RSVP predicts $\gamma \propto \rho_b$, unlike ΛCDM's $\gamma \propto \rho_{\mathrm{DM}}$ (NFW profile).

7 Future Directions

The experimental roadmap includes:

- **Laboratory**: Quantifying n_e statistics in 2DEG systems, targeting microscopy resolution $<$ 10 nm.
- **Observational**: Reanalyzing Planck CMB for $\mathbf{v}$-aligned B-mode polarization, $\langle B \cdot \mathbf{v} \rangle$, and proposing JWST void observations for $e(S)$.
- **Numerical**: Releasing TARTAN-RSVP code, benchmarking against IllustrisTNG for b_1/b_2 at high redshifts.

8 Conclusion

The RSVP theory proposes a relativistic framework for cosmic structure, eliminating dark matter halos. The proposed experiments—quantum dots, astronomical surveys, simulations, and superfluids—test predictions with precise mathematical formulations. Positive results could redefine cosmic evolution, while negative results would constrain theoretical models, advancing our understanding of the universe.