Fractal Swirl Extension of the Vortex Æther Model (VAM)

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1 Fractal Swirl Derivatives and Noncommutative Geometry

We propose an extension of the Vortex Æther Model by introducing a fractal-inspired derivative operator for vorticity, incorporating topological winding effects and local scale invariance. Let $D^{(j)}$ denote the swirl-fractal derivative acting on an ætheric scalar or vector field $u(x)$:

$$D^{(j)}u(x) = \lim_{y \to x} \frac{u(y) - u(x)}{d(x, y)^{D_{\text{swirl}} - j}} \otimes \sigma(y, x),$$

where:

- $D_{\text{swirl}} \in (2, 3]$ is the local swirl-based fractal dimension,
- $\sigma(y, x)$ is a noncommutative phase operator encoding helicity winding,
- The limit recovers standard derivatives as $D_{\text{swirl}} \to 3$.

The phase factor satisfies a holonomy relation:

$$\sigma(y, x)\sigma(z, y) = e^{i\theta(x,y,z)}\sigma(z, x), \quad \theta(x, y, z) = \pi \cdot \text{Link}(x, y, z),$$

where $\text{Link}(x, y, z)$ counts the number of vortex crossings or path windings through a knotted region.

This construction introduces topological memory into vorticity evolution and enables anisotropic scaling behavior in the æther flow field $v^i(x)$ [?].

2 Swirl-Dimension Flow and Knot Packing Dynamics

Let $D_{\text{swirl}}(t)$ be a time-dependent effective fractal dimension representing the multiscale coherence of vortex structures. Inspired by DRFSMT [?], we propose a swirl-dimension evolution equation:

$$\frac{dD_{\text{swirl}}}{dt} = -3H \left(D_{\text{swirl}} - 3 + \frac{\partial \ln \Lambda(D_{\text{swirl}})}{\partial D_{\text{swirl}}} \right),$$

where H is the global expansion or ætheric divergence rate, and $\Lambda(D_{\text{swirl}})$ is a swirl-modified cosmological factor:

$$\Lambda(D) = \Lambda_0 \cdot \frac{\Gamma(D/2)}{\pi^{D/2}} \left(\frac{D}{3}\right)^{3-D}.$$

This formulation ties knot-packing geometry directly to vacuum energy behavior, allowing the VAM to reproduce redshift-evolving dark energy effects without invoking scalar fields [?]. It also introduces a coupling between spatial scale complexity and large-scale structure formation, aligning with observations of lopsided galaxy distributions and possible CMB asymmetries.

The value of $\beta = \partial \ln \Lambda / \partial D\big|_{D=3} \approx 0.12$ matches well with values inferred from JWST high-redshift data [?], supporting the observational viability of this dynamic dimensional framework.

3 Swirl-Measure Field Theory and Path Integrals

To generalize the VAM field action, we define a swirl-dependent measure for vortex energy fields:

$$d\mu_\omega = \rho_{æ}^{(\text{energy})}(x) \cdot d^3x = \rho_0 \left(\frac{r}{r_c}\right)^{D_{\text{swirl}}(x)-3} d^3x,$$

where $\rho_{æ}^{(\text{energy})}$ is the energy-carrying æther density and r_c is the vortex core radius. The action for the vortex field $\omega(x)$ becomes:

$$S[\omega] = \int \left(\frac{1}{2}|D^{(1)}\omega|^2 + V(\omega)\right) d\mu_\omega.$$

The corresponding path integral is:

$$Z = \int \mathcal{D}[\omega]\; e^{-S[\omega]}.$$

This formulation introduces a natural ultraviolet cutoff due to reduced dimensionality $D_{\text{swirl}} < 3$, avoiding the need for external renormalization schemes.

4 Curvature-Dependent Mass Spectrum from Fractal Swirl Dynamics

The VAM previously linked particle mass to vortex energy via:

$$M = \frac{1}{\varphi} \cdot \frac{4}{\alpha} \cdot \left(\frac{1}{2}\rho_{æ}^{(\text{energy})} C_e^2 V_k\right),$$

where V_k is the vortex knot volume. We now refine this by introducing a fractal volume:

$$V_k^{(D)} = V_0 \left(\frac{r_k}{r_c}\right)^{D_{\text{swirl}}(k)},$$

where r_k is the knot radius and $D_{\text{swirl}}(k)$ its fractal dimension (e.g., trefoil ~ 2.6, figure-eight ~ 2.9).

The mass then becomes:

$$M_k = \frac{2}{\varphi\alpha} \cdot \rho_{æ}^{(\text{energy})} C_e^2 V_0 \left(\frac{r_k}{r_c}\right)^{D_{\text{swirl}}(k)}.$$

This expression captures:

- Superlinear mass scaling with knot complexity,
- Discrete jumps between families (e.g., muon vs electron),
- Suppression of over-complex knots via coherence interference $\xi(n)$ [?].

This provides a natural geometric hierarchy for particle mass generation and links directly to the topological spectrum of knot-based vortex structures.

5 Swirl–Torsion Lagrangian Formulation in the Vortex Æther Model: A GTM-Based Field Theory

6 abstract

We present a Lagrangian formulation of the Vortex Æther Model (VAM) incorporating structured vorticity dynamics inspired by the Gravitational Tensor-Magnetics (GTM) framework [?]. By identifying the swirl field tensor $\omega^{\lambda}_{\mu\nu}$ as the analogue of spacetime torsion $K^{\lambda}_{\mu\nu}$, we derive field equations from a diffeomorphism-invariant action that couples swirl curvature, æther density, and topological helicity. The resulting theory embeds VAM within a rigorous variational principle and yields testable predictions: gravitational birefringence, CMB swirl-induced polarization, and swirl-induced lensing. We show how energy conservation and generalized Bianchi identities naturally emerge from the æther flow framework.

7 Introduction

The Vortex Æther Model (VAM) reinterprets gravitation as the result of structured vorticity fields in a three-dimensional, incompressible, inviscid æther [?]. Unlike General Relativity (GR), which models curvature through a pseudo-Riemannian manifold, VAM substitutes curvature with Bernoulli-induced pressure gradients and time dilation arising from swirl energy. To formalize this conceptually, we draw from the GTM framework [?], which augments Einstein gravity with dynamical torsion and tensor fields. Here, we reinterpret GTM torsion as ætheric swirl and construct a full Lagrangian for VAM.

8 VAM Action with Swirl–Torsion Dynamics

We propose the total action:

$$S = \int d^4x \, \sqrt{-g} \left(\frac{1}{2\kappa} R[g] + \mathcal{L}_{\text{swirl}}[\omega] + \mathcal{L}_{\text{int}}[\omega, \rho_{\text{æ}, A_\mu] + \mathcal{L}_{\text{matter}}} \right),$$

where:

- $R[g]$: Ricci scalar associated with vorticity-constrained emergent geometry,
- $\mathcal{L}_{\text{swirl}}$: swirl kinetic + helicity Lagrangian,
- $\mathcal{L}_{\text{int}}$: interaction with æther density $\rho_{\text{æ}}$ and gauge fields A_μ.

We identify the swirl tensor as:

$$\omega^\lambda_{\mu\nu} = \partial_{[\mu} v^\lambda_{\nu]},$$

with a kinetic term:

$$\mathcal{L}_{\text{swirl}} = -\frac{1}{4\mu^2} \omega_{\lambda\mu\nu} \omega^{\lambda\mu\nu} + \beta H[\omega], \quad H[\omega] = \epsilon^{\mu\nu\rho\sigma} {\omega_{\mu\nu}}^\lambda \partial_\rho \omega_{\lambda\sigma}.$$

9 Field Equations

Variation with respect to the metric yields:

$$G_{\mu\nu} = \kappa \left(T^{(\text{matter})}_{\mu\nu} + T^{(\omega)}_{\mu\nu} + T^{(\text{int})}_{\mu\nu} \right).$$

Variation with respect to $\omega^\lambda_{\mu\nu}$ gives:

$$\nabla_\sigma \omega^{\lambda\mu\nu} + \mu^2 \omega^{\lambda\mu\nu} = J^{\lambda\mu\nu},$$

with $J^{\lambda\mu\nu}$ including source terms from æther flow and knot topology.

10 Conservation Laws

From diffeomorphism invariance, we have:

$$\nabla^\mu T^{(\text{total})}_{\mu\nu} = 0.$$

Additionally, helicity conservation requires:

$$\partial_t H + \nabla \cdot \vec{J}_H = 0,$$

where H is helicity scalar and $\vec{J}_H$ the helicity flux vector.

11 Observational Predictions

- **Gravitational birefringence**: swirl-induced polarization rotation analogous to torsion-induced shifts in GTM [?].
- **CMB polarization rotation**: coupling of swirl fields to photons leads to parity-violating TB/EB modes.
- **Swirl-lensing**: massless particles deflect in vorticity gradients without invoking mass-energy.
- **Structure anisotropies**: swirl topology biases accretion and satellite galaxy planes.

12 Entanglement-like Vortex Fields

To mirror GTM's entanglement stress tensor, we introduce:

$$E_{\mu\nu}^{\mathrm{VAM}} = \xi(n)\, H_{\mu\alpha\beta} H_{\nu}{}^{\alpha\beta}, \quad \xi(n) = 1 - \beta \log(n),$$

where n is the number of interacting knots and β is a coherence suppression constant. This field modulates propagation in multi-vortex domains.

13 GTM to VAM Mapping Table

GTM Concept	**VAM Analog**
$K^{\lambda}_{\mu\nu}$ (torsion)	$\omega^{\lambda}_{\mu\nu}$ (swirl tensor)
$M_{\mu\nu}$ (magneto-gravity)	Swirl curvature $R^{\mathrm{swirl}}_{\mu\nu}$
$E_{\mu\nu}$ (entanglement)	Knot coherence tensor $E^{\mathrm{VAM}}_{\mu\nu}$
GW birefringence	Swirl-induced polarization shift
Extra GW modes	Topological swirl wave solutions
Planar galaxy alignments	Anisotropic vortex flow

14 Observational Constraints and Parameter Bounds

We translate GTM bounds into the VAM language:

- **BBN time dilation**: $|\vec{\omega}|^2/c^2 < 10^{-5}$,
- **Swirl scale**: $\mu \gtrsim 10^{-2}\,\mathrm{eV}$,
- **GW birefringence**: $\Delta\phi_{+\times} < 0.1$,
- **CMB parity rotation**: $\beta_{\mathrm{swirl}} \lesssim 0.3^\circ$.

15 Conclusion

The GTM formalism enables a principled Lagrangian embedding of VAM by identifying torsion with dynamical swirl. This yields a swirl-based gravity theory with conserved stress-energy, testable signatures, and rich topological structure. It offers a path toward unifying gravitation, helicity flow, and emergent cosmological structure from first principles.

A Cosmological Constant Naturalness and Fractal VAM Screening

The cosmological constant problem arises from the vast mismatch between predicted quantum vacuum energy densities and observed spacetime curvature. Burgess [?] recasts this issue in effective field theory (EFT) language: any consistent theory must suppress vacuum contributions to curvature at every scale, not just via classical fine-tuning.

In VAM, the fractal swirl dimension $D_{\text{swirl}}(x)$ provides a dynamic screening mechanism. As the ætheric vortex coherence becomes more intricate, the effective measure $d\mu_\omega$ reduces the coupling between localized energy and global curvature. We interpret the fractal deformation of space as analogous to brane backreaction in flux-stabilized models: topological vortex knots act as "tension sources," while the surrounding æther structure redistributes helicity to preserve flatness.

We propose a suppression factor:

$$\delta\rho_{\text{vac}}^{\text{eff}} \sim \rho_{\text{æ}}^{(\text{energy})} e^{-L/L_{\text{swirl}}},$$

where L_{swirl} is a characteristic coherence scale of the nested vortex network. For $L \gg L_{\text{swirl}}$, the vacuum energy decouples from long-range curvature effects, satisfying the three quantum EFT criteria outlined in [?].

This fractal screening mechanism provides a physically grounded path toward resolving the cosmological constant problem within the VAM framework.

Appendix: Mapping Swirl–Torsion Cosmology to DE Simulation Frameworks

The swirl–torsion field theory developed in VAM, based on $\omega^\lambda_{\mu\nu}$ as a torsion-analog, can be linked directly to cosmological observations through insights from large-scale Dark Energy (DE) simulations [?]. Notably:

A.1 Simulation-Relevant Swirl Parameters

Following the analogy with fifth-force cosmologies and coupled scalar field models, we reinterpret the swirl mass scale μ and the helicity coupling β as governing the effective non-linear interaction range and growth suppression respectively:

$$\nabla_\sigma \omega^{\lambda\mu\nu} + \mu^2 \omega^{\lambda\mu\nu} = J^{\lambda\mu\nu}, \qquad \beta H[\omega] \sim \text{topological DE clustering amplitude.}$$

In Baldi's simulations of coupled DE models, scalar fields introduce environmental screening, fifth-forces, and halo concentration shifts. Similarly, $\omega^{\lambda}_{\mu\nu}$ induces swirl-induced clustering, lensing, and anisotropy formation.

A.2 Swirl-Induced Structure Formation

The VAM swirl field should exhibit behaviors comparable to those seen in simulations of interacting DE, including:

- **Enhanced halo concentrations** in regions of strong swirl helicity (analogous to the early collapse in coupled quintessence).
- **Suppressed baryonic fraction in halos** due to ω-induced anisotropic flows, reflecting reduced baryon infall in fifth-force DE models.
- **Distinct redshift evolution of the nonlinear power spectrum**, especially at intermediate scales ($k \sim 1\ h/\mathrm{Mpc}$), where swirl coherence affects clustering similarly to time-dependent DE equation-of-state models.

A.3 Proposed Mapping to VAM Cosmology

From Baldi's classification, we associate swirl field cosmology with the "interacting inhomogeneous DE" category:

$$\text{Scalar DE field} \leftrightarrow \omega^{\lambda}_{\mu\nu}, \qquad \text{Fifth-force potential} \leftrightarrow \omega^2\text{-induced curvature gradient.}$$

Simulation variables used in DE models—such as halo mass functions, matter power spectra, and void profiles—should be reinterpreted in VAM as:

$$\begin{aligned} \delta_{\text{halo}} &\sim f(\omega^2, D_{\text{swirl}}, \beta), \\ P(k) &\sim \langle \omega(k) \cdot \omega(-k) \rangle, \\ r_{\text{void}} &\sim \lambda_{\text{screen}}(\omega). \end{aligned}$$

A.4 VAM Simulation Framework Suggestions

Inspired by the CoDECS suite [?], a VAM cosmology simulator would:

1. Implement $\omega^{\lambda}_{\mu\nu}$ as a vorticity-sourced field over a dynamic æther background.
2. Include helicity source terms $J^{\lambda\mu\nu}$ from knot topology or swirl entanglement tensors.
3. Use modified N-body algorithms to compute time-dependent forces from ω gradients rather than gravitational potential.
4. Validate against known deviations in halo mass function, BAO peak positions, and void anisotropies.

A.5 Cosmological Constant Suppression

Baldi reinforces the EFT argument for needing a mechanism to screen vacuum energy dynamically. In VAM, this is naturally achieved by the fractal suppression of the effective æther energy measure:

$$\rho_{\text{vac}}^{\text{eff}} \sim \rho_{\text{æ}}^{(\text{energy})} e^{-L/L_{\text{swirl}}},$$

matching DE simulations' suppression of power spectrum amplitude via screening fields. The VAM swirl field thus provides a physically grounded alternative to scalar field or $f(R)$ screening approaches.