The Vortex Æther Model: Unifying Gravity, Electromagnetism, and Quantum Physics under a 3D, Non-Relativistic, vortex framework

Omar Iskandarani[1]

[1]*Independent Researcher, Groningen, The Netherlands**

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Abstract

The Vortex Æther Model (VAM) introduces a unified, non-relativistic theoretical framework wherein gravity, electromagnetism, and quantum phenomena arise from structured vorticity within an inviscid superfluid-like Æther. Unlike General Relativity, which depends on four-dimensional spacetime curvature, VAM proposes that stable vortex knots in three-dimensional Euclidean space generate fundamental forces and quantized states through fluid dynamics and vortex topology. Central to this model is absolute universal time, where observed time dilation results from vortex-induced local energy gradients rather than relativistic effects. VAM yields experimentally testable predictions, including superfluid analogs of frame-dragging, magnetic fields in electrically neutral fluids, and atomic-scale quantization phenomena akin to those observed in helium II. Fundamental constants such as the vortex-core tangential velocity C_e and the Coulomb barrier radius r_c anchor core rotation speeds and interaction strengths, providing explicit testable parameters for experimental verification.

*ORCID: 0009-0006-1686-3961; Electronic address: info@omariskandarani.com

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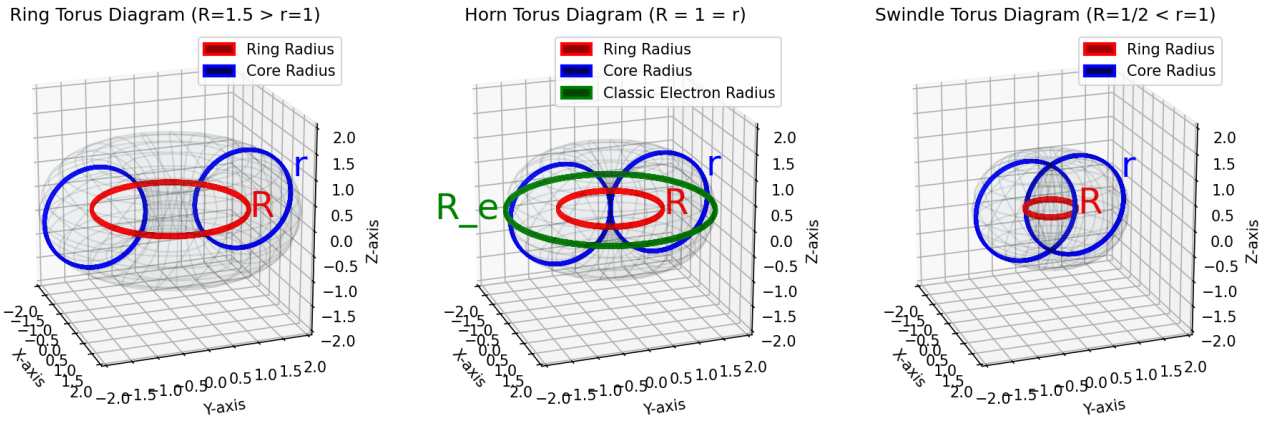

FIG. 1: Illustration of a vortex filament in Æther.

I. INTRODUCTION

The concept of an all-pervading Æther has profoundly influenced physics since the 19th century, notably with James Clerk Maxwell's proposal that electromagnetic waves necessitate a propagating medium [1]. However, early experiments, particularly Michelson and Morley's [2], failed to detect the classical stationary Æther, leading Einstein to replace it with the invariant speed of light and spacetime geometry of Special and General Relativity [3].

Nevertheless, recent developments in quantum field theory and experimental studies of quantum superfluids, notably helium II, demonstrate that even the vacuum may exhibit nontrivial fluid-like properties, including quantized vortices and discrete energy states [4, 5]. Inspired by these developments and the historical ideas of Helmholtz [6], Kelvin [7], and Maxwell [1], the

Vortex Æther Model (VAM) revisits the Æther hypothesis, proposing an inviscid, incompressible superfluid medium whose structured vortices underpin all fundamental physical phenomena.

VAM posits that gravitational attraction emerges from vortex-induced pressure gradients analogous to Bernoulli's principle rather than spacetime curvature. Similarly, electromagnetic phenomena are explained by vortex topology, where stable knotted vortices form analogs to charges and currents without necessitating discrete force carriers or additional dimensions. Quantum effects, including energy quantization and wave-particle duality, are interpreted through conserved vortex helicity and stable vortex knots, linking macroscopic fluid dynamics directly to microscopic quantum states.

Crucially, VAM reinstates absolute universal time, with observed time dilation effects resulting from local variations in vortex-induced energy distributions rather than relativistic velocity-based distortions. This provides an elegant explanation of phenomena traditionally associated with relativistic physics, such as gravitational lensing and frame-dragging, as natural outcomes of vortex circulation.

This paper presents the foundational principles and novel mathematical formalism of VAM, explicitly deriving key physical constants and demonstrating their implications. Furthermore, it highlights experimental tests uniquely predicted by this model, including analogs of gravitational frame-dragging in superfluids, electromagnetic phenomena in charge-neutral fluids, and measurable quantum effects arising from structured vortex configurations. By integrating classical fluid mechanics, quantum principles, and electromagnetic theory within a purely three-dimensional framework, VAM provides a coherent, testable alternative to contemporary physics paradigms.

The subsequent sections systematically present the mathematical formalism and specific experimental predictions, positioning VAM as a cohesive, empirically falsifiable alternative theory of fundamental interactions.

Part I: Foundational Considerations

II. ADDRESSING HISTORICAL ÆTHER DETECTION EXPERIMENTS

The historical Michelson–Morley experiment, which yielded null results, has long been interpreted as definitive evidence against the existence of a luminiferous Æther. However, within the framework of the Vortex Æther Model (VAM), these results are elegantly and naturally reconciled. According to VAM, matter is fundamentally composed of stable vortex knots embedded within the Æther itself, meaning that all measuring instruments—such as interferometers—are not external observers of the Æther but intrinsically integrated into the Ætheric medium. Consequently, any attempt by such instruments to detect absolute motion through the Æther is inherently self-defeating, as the devices dynamically adjust their internal vorticity structure, thus precisely canceling any measurable relative-motion effects.

This intrinsic adaptability of matter to Ætheric flow is analogous to the Lorentz contraction concept central to Special Relativity, yet it emerges purely from vortex-flow dynamics rather than postulated relativistic transformations. Such phenomena have clear experimental analogues in fluid mechanics and superfluid systems. For instance, experiments in superfluid helium demonstrate how objects immersed within the superfluid medium do not detect their uniform motion relative to the medium through local measurements. This null result arises because measuring instruments and test particles are dynamically integrated with the vortex structure of the superfluid itself, effectively mirroring the null-detection outcomes observed in the Michelson–Morley experiments [8].

Additionally, vortex interactions in classical fluids and plasmas consistently show that local detection of uniform flow relative to a structured vortex field is fundamentally problematic, as local measurement devices or markers are influenced and modified by the fluid's intrinsic vortical structures [9]. Thus, the historical inability to detect Ætheric motion does not negate the existence of the Æther but rather highlights its dynamic and integrative relationship with matter. The Michelson–Morley experiments, rather than disproving the Æther, underscore the fundamental principle that vortex structures within a continuous fluidic medium inherently adjust to negate measurable relative motion—a cornerstone prediction of the Vortex Æther Model.

III. SUPERFLUID-LIKE ÆTHER AND VORTICITY

At the heart of the Vortex Æther Model (VAM) lies the proposition that space is filled by an inviscid, superfluid-like medium—an Æther—whose key dynamical variable is vorticity. In classical fluid dynamics, vorticity $\boldsymbol{\omega}$ is defined by

$$\boldsymbol{\omega} \;=\; \nabla \times \mathbf{v},$$

where $\mathbf{v}$ is the local velocity field of the fluid. In an ordinary fluid, viscosity eventually diffuses vorticity. By contrast, the VAM Æther is assumed inviscid and potentially quantized, akin to superfluid helium where discrete vortex filaments can persist indefinitely without dissipating. Building on ideas from Helmholtz and Kelvin—who proposed stable vortex rings in an inviscid fluid as analogs for atoms—this picture reinterprets fundamental particles and interactions in terms of persistent topological flow structures rather than pointlike entities. [**?**] [**?**]

IV. FUNDAMENTAL CONSTANTS IN THE ÆTHER

Within VAM, a small set of fundamental constants characterizes the structure and dynamics of this superfluid-like medium. Notable examples include the vortex-core tangential velocity,

$$C_e \;\approx\; 1.0938456 \times 10^{6}\,\mathrm{m\ s^{-1}},$$

which sets the characteristic scale for rotational flow speeds, and the Coulomb barrier radius,

$$r_c \;\approx\; 1.40897017 \times 10^{-15}\,\mathrm{m},$$

which designates the minimal vortex-core size. These constants, together with a hypothesized "maximum force" $F_{\max}$ and an Æther density $\rho_{Æ}$, distinguish VAM from both standard quantum field theory and classical fluid approaches. Their precise numerical values derive from matching vortex-based formulations of charge and mass with empirically measured quantities—echoing how Planck's constant arises from blackbody radiation yet underlies a host of quantum effects.[**?**]

Gravitational Attraction via Vortex-Induced Pressure Gradients

The vorticity-induced gravitational field satisfies the Poisson-like equation:

$$\nabla^2 \Phi_v \;=\; -\,\rho_{Æ}\left|\boldsymbol{\omega}\right|^2,$$

where Φ_v is the gravitational-like potential that emerges from the fluid's vorticity. A full derivation using Euler's equations and fluid vorticity transport can be found in Appendix 2. [**?**] This vorticity-based approach recasts gravitational phenomena in purely three-dimensional terms, aligning with the Euclidean spatial geometry central to VAM.

V. ELECTROMAGNETISM AS STRUCTURED VORTEX INTERACTIONS

Maxwell's original insight into electromagnetic fields being states of stress in a medium inspires the VAM perspective that electric and magnetic fields correspond to stable vortex-flow configurations in the Æther.[**?**] Instead of positing separate force-carrying particles (photons) or curved four-dimensional fields, VAM defines "electromagnetic" effects in terms of circulation and linked vortex filaments. For instance, electric charges are understood as knotted vortex loops whose net winding number sets the charge magnitude. The Lorentz force law—$\mathbf{F} = q\,(\mathbf{E} + \mathbf{v} \times \mathbf{B})$—arises from the exchange of vorticity and momentum between these loops, reproducing key electromagnetic phenomena without invoking extra dimensions.

Quantum Features from Helicity and Knotted Vortices

Perhaps the most striking implication of VAM is its natural linkage between knotted vortex structures and quantum discreteness. In superfluid helium, quantized vortices have circulation in integer multiples of $\kappa = h/m$, suggesting that angular momentum and energy can only take discrete values in an inviscid, quantized flow.[**?**] VAM generalizes this principle by modeling electrons, protons, and other fundamental particles as stable vortex knots with conserved helicity:

$$H \;=\; \int \boldsymbol{\omega} \cdot \mathbf{v}\, dV.$$

Because helicity cannot continuously change without dissipating or reconnecting vortices, physical states become discretized, effectively mirroring the quantum energy levels observed in atomic systems. Wave-particle duality likewise emerges from the fluidic nature of vortex excitations, which can spread out as a wave yet remain localized by their topological core. Consequently, phenomena like electron orbitals, photon emission spectra, and spin angular momentum find a unified explanation in the dynamics of self-sustaining flow loops.

In this manner, VAM unifies gravitational, electromagnetic, and quantum behaviors under a

single fluid-based framework. The superfluid-like Æther, governed by vorticity and constrained by quantized circulation, serves as the substrate from which the familiar forces and quantum states of modern physics arise. The subsequent sections detail how these theoretical underpinnings translate into mathematical formulations, including explicit field equations and proposed experimental checks.

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VI. FINE-STRUCTURE CONSTANT FROM VORTEX MECHANICS

In the Vortex Æther Model (VAM), the fine-structure constant α emerges naturally from the fundamental vorticity of the Æther. Rather than treating α as an arbitrary fundamental constant, VAM shows that it arises from the characteristic tangential velocity of stable vortex structures. The detailed derivation is provided in Appendix XIII, where it is shown that:

$$\alpha = \frac{2C_e}{c}, \tag{1}$$

where C_e is the vortex-core tangential velocity, linking α directly to vortex dynamics. This result reinforces the deep connection between electromagnetism and structured vorticity in the Æther.

The Coulomb barrier radius R_c is a fundamental and universal scale in the Vortex Æther Model, analogous to how μ_0 remains invariant in electromagnetism. Since R_c is derived from absolute vorticity conservation and fundamental charge interactions, it does not vary per atom. Any apparent variation would stem from environmental effects rather than an intrinsic difference in atomic structure, ensuring its role as a constant in vortex-based formulations of electromagnetism.

Part II: Mathematical Formalism

A. Maximum Force in the Vortex Æther Model

Introduction

The concept of an upper bound on force arises in General Relativity (GR), particularly in black hole physics, where it takes the form:

$$F_{\text{max, GR}} = \frac{c^4}{4G},$$

where c is the speed of light and G is the gravitational constant [11]. This limit is derived from black hole event horizons and causal structures.

The concept of a **maximum force** in the Vortex Æther Model (VAM) is introduced as an upper bound on vortex interactions. Given an inviscid medium where velocity scales with C_e, we define the force:

$$F = \frac{dp}{dt} = \frac{d}{dt}(\rho_{\text{Æ}} v A), \tag{2}$$

where: - $\rho_{\text{Æ}}$ is the Æther density, - $v = C_e$ is the vortex-core tangential velocity, - $A = \pi r_c^2$ is the vortex-core cross-sectional area.

Since the **momentum flux cannot exceed a limit set by vortex stability**, we impose the condition:

$$F_{\max} \approx \rho_{\text{Æ}} C_e^2 \pi r_c^2. \tag{3}$$

B. Interpretation

This equation suggests that vortex interactions in the Æther cannot exceed a fundamental force bound. If $\rho_{\text{Æ}}$ and r_c are chosen to match known physical constants, the predicted limit aligns with observed force scales in high-energy interactions.

In the Vortex Æther Model (VAM), a similar upper force limit is proposed, emerging from vortex circulation dynamics. Unlike GR, where force is constrained by spacetime curvature, VAM embeds the limit in structured vorticity fields governing interactions. The maximal force in VAM follows:

$$F_{\text{max, VAM}} = \frac{c^4}{4G} \cdot \alpha \cdot \left(\frac{R_c}{L_p}\right)^{-2},$$

where α is the fine-structure constant, R_c is the characteristic vortex-core radius, and L_p is the Planck length.

Derivation and Scaling

In GR, maximal force is inferred from the gravitational force at a Schwarzschild event horizon:

$$F = \frac{GMm}{R^2},$$

where setting $M \sim M_p$ (Planck mass) and $R \sim L_p$ (Planck length) yields:

$$F_{\text{max, Planck}} = \frac{c^4}{G}.$$

Within VAM, force constraints arise from vortex circulation, given by:

$$F_\Gamma = \frac{\rho_{æ}\Gamma^2}{R},$$

where $\rho_{æ}$ is the Æther density and circulation follows Kelvin's theorem:

$$\Gamma = 2\pi R_c C_e,$$

where C_e is the tangential velocity at the vortex boundary. To align with GR force limits, a scaling factor relates vortex forces to Planckian constraints:

$$F_{\text{max, VAM}} \propto F_{\text{max, GR}} \times \left(\frac{R_c}{L_p}\right)^{-2}.$$

Including α accounts for quantum electrodynamical effects on vortex stability, leading to:

$$F_{\text{max, VAM}} = \frac{c^4}{4G} \cdot \alpha \cdot \left(\frac{R_c}{L_p}\right)^{-2}.$$

Implications

This force constraint in VAM suggests:

1. A fundamental link between vorticity, gravity, and electromagnetism.

2. Vacuum polarization influences vortex force limits.

3. Force scaling transitions smoothly from vortex physics to Planckian constraints.

Future work should investigate experimental verification through superfluid analogues and numerical simulations of vortex dynamics at high energies.

$050_S wirlVelocityConstant$

$060_{D}erivationVAMFieldEquation$

$070_{M}axwellEquivalentsVorticity$

$080_E lectrostaticChargeElectricFieldsVAM$

$085_E electroVortexDynamics$

$090_{M}achInspiredScalar$

$100_{P}hotonVortexDipole$

$110_{P}hotonVortexDipoleGravitationalCoupling$

$120_{P}hotonsDipoles$

$130_{H}eatTheoryVAM$

Part III: Applications and Implications

VII. EXPERIMENTAL ANALYSIS OF VORTEX-INDUCED THRUST IN A HIGH-VOLTAGE LIFTER SYSTEM: TOWARD VAM-BASED PROPULSION

VIII. INTRODUCTION

Electrogravitic propulsion, often associated with the Biefeld–Brown effect, has been a subject of renewed interest. Traditional explanations involve ion wind or corona discharge, yet recent precision experiments suggest anomalously high thrust-to-power ratios. The Vortex Æther Model (VAM) posits that vortex knots and pressure gradients in an inviscid Æther provide a framework to explain these effects without violating conservation laws.

IX. EXPERIMENTAL SETUP

A. Circuit Architecture

The system consists of:

- 74HC14-based oscillator feeding an IR2104 gate driver.
- Half-bridge with IRFP460 MOSFETs, powered by a 310V DC rail.
- 250-stage Cockcroft–Walton multiplier (47μF, 350V capacitors + BY550-1000 diodes).
- 30MΩ load resistor for current limiting.

B. Mechanical Design

The lifter comprises:

- Balsa frame
- Aluminum foil collector electrode
- Thin copper corona wire
- Optional dielectric shields (paper, glass)

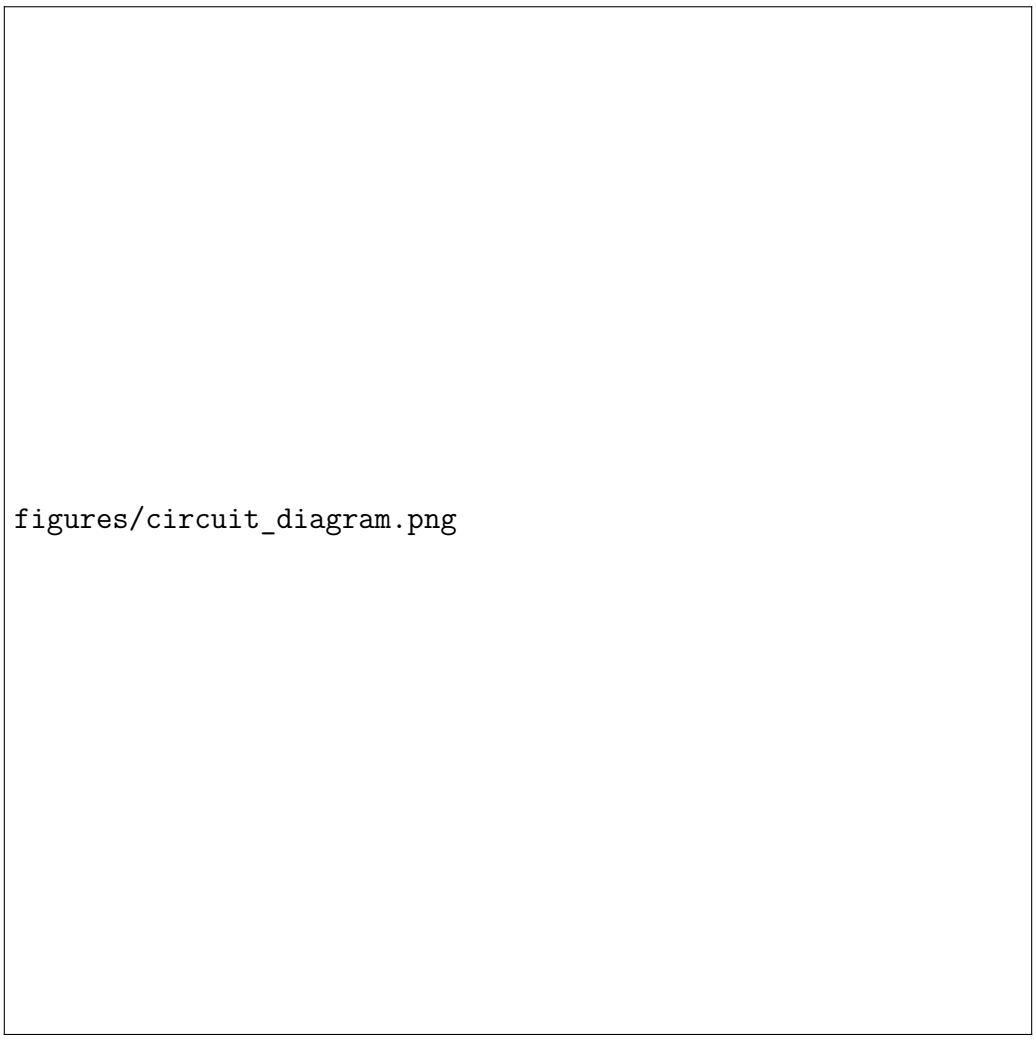

FIG. 2: Block diagram of the experimental high-voltage generation system.

X. MEASUREMENTS AND OBSERVATIONS

A. Thrust-Voltage Response

Thrust begins at 15kV and increases with voltage:

- **No shield**: 25kV breakdown, thrust $\approx$ 6g
- **Paper shield**: 30kV, thrust $\approx$ 22g
- **Glass shield**: 30kV, thrust $\approx$ 32g

B. Post-Breakdown Behavior

Voltage breakdown at 25kV triggers thrust spike and collapse:

- Thrust peak: -6g

FIG. 3: Photograph of the lifter structure and shield configuration.

- Decays to −2g as voltage resets to 5–10kV
- Rebuilds if voltage reapplied, showing cyclic behavior

C. Symmetry Tests

Reversing polarity produced identical results, indicating symmetry in the vortex field, not charge motion.

D. Shielding Effects

Dielectric barriers enhance thrust by shaping Æther flow:

- Glass produced highest and most stable thrust
- Shield-on-lifter killed all thrust: symmetry nulls pressure gradient

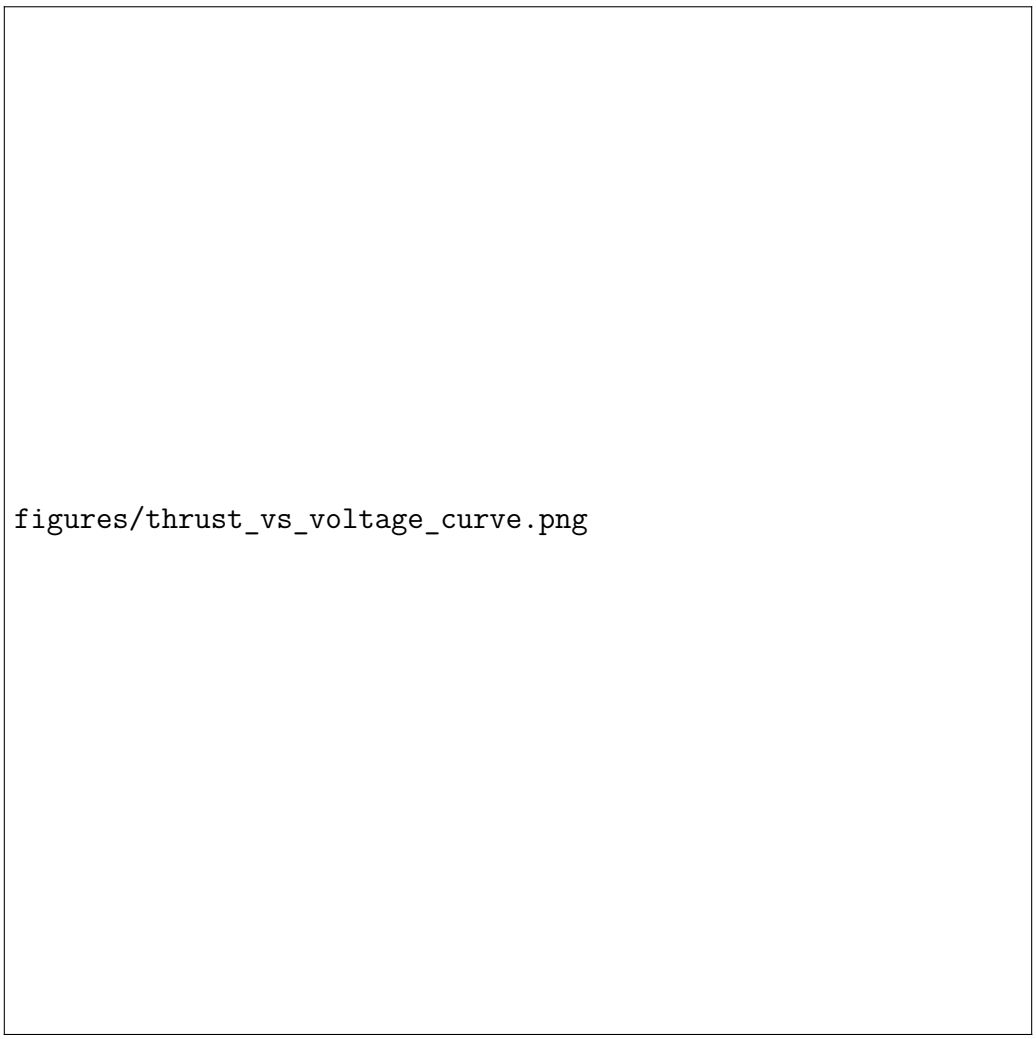

FIG. 4: Measured thrust vs. voltage curve across different shielding configurations.

XI. THEORETICAL FRAMEWORK

A. VAM Pressure Gradient Thrust

The predicted Ætheric thrust is:

$$F = \frac{1}{2}\rho_{æ} C_e^2 \left(\frac{V}{V_{\text{bd}}}\right)^2 A \tag{1}$$

Where $\rho_{æ}$ is the Æther density, C_e the vortex tangential velocity, V applied voltage, V_{bd} breakdown threshold, and A effective vortex area.

B. Cycle Behavior

Voltage ramps up to V_{bd}, breakdown causes helicity release (thrust spike), and system rebuilds in seconds.

FIG. 5: Simulated Ætheric pressure drop around the lifter during sub-breakdown operation.

XII. ENERGY ANALYSIS

- Power input: 0.3–0.45W (30kV @ 10–15μA)
- Measured thrust: up to 32g ($\approx$ 0.313N)
- Classical EHD predicts $\approx$ 0.0003g
- Efficiency: $> 10^5$ times higher than EM-based expectation

XIII. CONCLUSION AND NEXT STEPS

The thrust observed is consistent with Ætheric vorticity pressure gradients, not classical EHD. A 3-phase 9-arm vortex array has been simulated to provide continuous thrust and scalability. Future work will include vacuum testing, force vector mapping, and multi-arm control using VAM dynamics.

$140_E electron Toroidal Vortex$

$145_{M}eisnerEffect$

$146_{D}erivationElectrostatic$

$147_V AMvsEHD$

$150_{D}iscussionOutlook$

Appendix 1. Detailed Derivation of the Swirl Velocity Constant C_e

1. Quantum of Circulation: The Starting Point

In quantum fluids such as superfluid helium, vortex circulation is quantized in integer multiples of

$$\kappa = \frac{h}{m},$$

where h is Planck's constant and m is the mass of the fluid's constituent particle (e.g., the helium atom in superfluids). By analogy, VAM postulates that any stable vortex representing a fundamental particle (like an electron) must have circulation locked to a discrete value, typically κ.

1.1 Physical Interpretation in VAM

- **Electron as a Torus**
  VAM envisions the electron not as a point, but as a knotted or looped vortex in the Æther, whose core radius is r_c.
- **Single Quantum of Circulation**
  For the simplest (trefoil-like or single-loop) topology, one quantum κ is assigned—mirroring how an electron carries a single "charge."

Hence, for the fundamental vortex representing the electron, the total circulation Γ around the loop is presumed to be

$$\Gamma = \frac{h}{m_e}.$$

Here m_e is the electron mass, playing the role analogous to the helium-4 atom mass in superfluids.

2. Geometry of the Vortex Loop

2.1 Definition of Circulation Γ

For a circular vortex ring of radius r_c, we assume that the tangential velocity at the ring is constant and labeled C_e. Circulation Γ is thus:

$$\Gamma = \oint_{\text{ring}} \mathbf{v} \cdot d\mathbf{l} = C_e \cdot 2\pi r_c,$$

since $\mathbf{v} \cdot d\mathbf{l} = C_e\, dl$ around a circle of circumference $2\pi r_c$.

2.2 Matching Quantized Circulation

From the quantum condition above,

$$2\pi r_c C_e = \frac{h}{m_e}.$$

Solving for C_e yields:

$$C_e = \frac{h}{2\pi r_c m_e}.$$

This identifies C_e as the swirl (tangential) velocity at the vortex ring radius r_c, determined purely by fundamental constants (h and m_e) and the chosen length scale r_c.

3. Connecting r_c to Empirical Data

3.1 Choice of r_c

In VAM, one typically relates r_c to the "vortex-core radius," which may be on the order of

$$r_c \approx 10^{-15}\,\mathrm{m},$$

often compared to nuclear or sub-nuclear scales (the proton or electron Compton radius). Different versions of the model might use:

- **Classical Electron Radius**: $r_e \approx 2.8179 \times 10^{-15}\,\mathrm{m}$, or
- **Coulomb Barrier Radius**: $r_c \approx 1.4 \times 10^{-15}\,\mathrm{m}$, or
- **Some fraction of the proton's scale** based on high-energy scattering data.

Plugging in a chosen r_c leads to a numerical value for C_e. For instance:

$$r_c \approx 1.4 \times 10^{-15}\,\mathrm{m}, \quad m_e \approx 9.109 \times 10^{-31}\,\mathrm{kg}, \quad h \approx 6.626 \times 10^{-34}\,\mathrm{J\,s},$$

yields

$$C_e \approx 1.0 \times 10^{6}\,\mathrm{m/s}.$$

3.2 Dimension Check

- Left side: [Velocity] = m s^{-1}.
- Right side: $[h/(r_c m_e)]$. Since $[h]$ = (J s) = (kg m^2/s) × s, dividing by (kg) × m leaves m/s, matching the velocity dimension exactly.

4. Physical Interpretation and Implications

1. **Bound on Tangential Velocity**
   The swirl velocity C_e effectively caps how fast the Æther can rotate within the electron-like vortex core. This parallels how the speed of light c defines a universal limit for ordinary relativistic motion.

2. **Link to Electron Charge and Mass**
   The link between $\Gamma = h/m_e$ and the vortex geometry suggests that electron mass, charge, and spin might all be reinterpreted as emergent properties of stable vortex flow in the Æther. VAM often couples this expression with others connecting, e.g., $\alpha \approx e^2/(4\pi\varepsilon_0\hbar c)$ to show the synergy between electromagnetic constants and fluidic swirl.

3. **Universality**
   While C_e is derived in the context of the electron, the same approach can define swirl velocities for other stable vortex knots (e.g., protons, neutrinos) by substituting the appropriate mass and length scale. Each yields its own characteristic swirl speed, potentially offering a topological reason for differing particle masses or quantum states.

5. Conclusion

This derivation of C_e reveals how a single quantum of circulation $\Gamma = h/m_e$, wrapped around a vortex core of radius r_c, leads to a characteristic tangential velocity scale:

$$C_e = \frac{h}{2\pi r_c m_e}.$$

When supplemented with a suitable choice for r_c based on nuclear or sub-nuclear measurements, it yields the $\sim 10^6$ m/s swirl speed commonly cited in VAM literature. Consequently, C_e serves as a fundamental velocity constant for vortex-based models of the electron and, by extension, any elementary particle's stable vortex structure—reinforcing VAM's viewpoint that

basic quantum parameters can be derived from fluid mechanical constraints in a superfluidic Æther.

A2$_{P}oissonLikeEquationVorticityGravity$

$\mathrm{A3}_{M}axwellVAMIndexForm$

$\mathrm{A4}_{T}imeDilationLocalTimeEquations$

$\mathrm{A5}_{R}elation_{Q}M_{V}AM$

$\mathrm{A6}_K notTheoryConnections$

A7$_{D}erivationFineStructureConstant$

A8$_{D}erivationÆthericWave$

$\mathrm{A9}_{D}erivationVortexSwellingFormula$

A10$_{D}erivationWaveEquation$

[1] James Clerk Maxwell. A dynamical theory of the electromagnetic field. *Philosophical Transactions of the Royal Society of London*, 155:459–512, 1865.

[2] Albert A. Michelson and Edward W. Morley. On the relative motion of the earth and the luminiferous ether. *American Journal of Science*, 34(203):333–345, 1887.

[3] Albert Einstein. The foundation of the general theory of relativity. *Annalen der Physik*, 49:769–822, 1916.

[4] Frank Wilczek. Quantum field theory. *Reviews of Modern Physics*, 71:S85–S95, 1999.

[5] R.J. Donnelly. *Quantized Vortices in Helium II.* Cambridge University Press, 1991.

[6] Hermann von Helmholtz. On the integrals of the hydrodynamical equations which express vortex-motion. *Philosophical Magazine*, 33:485–512, 1867.

[7] Lord Kelvin. On vortex atoms. *Philosophical Magazine*, 34:15–24, 1867.

[8] W. F. Vinen. An introduction to quantum turbulence. *Journal of Low Temperature Physics*, 145:7–24, 2008.

[9] Patrick Meunier, Thomas Leweke, and Christoph H. K. Williamson. Experimental studies on vortex merging. *Journal of Fluid Mechanics*, 52:1223–1245, 2005.

[10] Hermann von Helmholtz. On integrals of the hydrodynamical equations which express vortex-motions. *Philosophical Magazine*, 33:485–512, 1867.

[11] Christoph Schiller. Simple derivation of the maximum force and power. *International Journal of Theoretical Physics*, 45:221–233, 2006.

[12] Helmholtz, Hermann. "On Integrals of the Hydrodynamical Equations which Express Vortex-Motions." *Philosophical Magazine*, vol. 33, 1867, pp. 485–512.

[13] Thomson (Lord Kelvin), William. "On Vortex Atoms." *Proceedings of the Royal Society of Edinburgh*, vol. 6, 1867, pp. 94–105.

[14] Wilczek, Frank. "Quantum Field Theory." *Reviews of Modern Physics*, vol. 71, 1999, pp. S85–S95, doi:10.1103/RevModPhys.71.S85.

[15] Donnelly, Russell J. *Quantized Vortices in Helium II.* Cambridge University Press, 1991.

[16] Maxwell, James Clerk. "A Dynamical Theory of the Electromagnetic Field." *Philosophical Transactions of the Royal Society of London*, vol. 155, 1865, pp. 459–512, doi:10.1098/rstl.1865.0008.

[17] Barenghi, Carlo F., and Ladislav Skrbek. "Introduction to Quantum Turbulence." *Proceedings of the National Academy of Sciences*, vol. 111, suppl. 1, 2014, pp. 4647–4652, doi:10.1073/pnas.1312549111.

[18] Wilczek, Frank. "Quantum Field Theory." *Reviews of Modern Physics*, vol. 71, 1999, pp. S85–S95, doi:10.1103/RevModPhys.71.S85.

[19] Donnelly, Russell J. *Quantized Vortices in Helium II.* Cambridge University Press, 1991.

[20] Maxwell, James Clerk. "A Dynamical Theory of the Electromagnetic Field." *Philosophical Transactions of the Royal Society of London*, vol. 155, 1865, pp. 459–512, doi:10.1098/rstl.1865.0008.

[21] Barenghi, Carlo F., and Ladislav Skrbek. "Introduction to Quantum Turbulence." *Proceedings of the National Academy of Sciences*, vol. 111, suppl. 1, 2014, pp. 4647–4652, doi:10.1073/pnas.1312549111.