NEW-PAPER

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Abstract

We present a unified field theory based on the hydrodynamics of an inviscid, incompressible, director-bearing fluid substrate. We demonstrate that Relativistic kinematic effects emerge naturally from circulation conservation: proper time dilation is derived as a function of fluid circulation Γ [1111], while effective mass arises from rotational kinetic energy density $\Delta\rho_{eff}$[2]. We identify the photon not as a point particle, but as a propagating torsion wave (shear wave) within this substrate, predicting a vacuum Faraday effect [33] recently supported by experimental data on optical magnetic torques (Assouline Capua, 2025). Furthermore, we show that steady-swirl Euler pressure gradients yield a short-range $1/r^3$ force for filamentary $v_\theta \propto 1/r$, while the long-range inverse-square law arises from a local mediator obeying a Poisson equation on $\mathbb{R}^3$, [4], and that the fundamental electron scales (r_e, ω_C, E_B) satisfy a precise harmonic identity derived from this hydrodynamic coupling[555].

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1 Introduction

The quest to unify interactions suggests that the vacuum is not an empty void, but a structured medium. Building on the "Vortex Atom" hypothesis of Kelvin [6]and modern superfluid vacuum analogies[7], we propose **Swirl String Theory (SST)**. In SST, physical laws are emergent properties of a background fluid with effective density ρ_f and shear stiffness $\mathcal{K}$.

2 Kinematics: Circulation as Local Time

Standard Special Relativity (SR) posits time dilation as a function of relative velocity. We reformulate this in terms of fluid topology. For a clock co-moving with an inviscid fluid in rigid rotation, the tangential velocity v is linked to the circulation $\Gamma = \oint \mathbf{v} \cdot d\mathbf{l}$[8].

Substituting $v = \Gamma/(2\pi r)$ into the Minkowski metric yields a circulation-based time dilation[9]:

$$\frac{d\tau}{dt} = \sqrt{1 - \frac{\Gamma^2}{4\pi^2 r^2 c^2}} \tag{1}$$

Because Γ is conserved in inviscid, barotropic flows (Kelvin's Theorem), time dilation becomes a topological invariant of the flow[10]. This suggests that "time" is a measure of the local vorticity density of the vacuum substrate.

3 The Origin of Mass: Rotational Energy Density

Mass is not intrinsic but emergent. By analyzing a fluid in rigid-body rotation, we calculate the volume-averaged rotational kinetic energy density $\langle e_{kin} \rangle$[11]. Applying the mass-energy equivalence $E = mc^2$, we derive an effective mass density relation[12]:

$$\frac{\Delta\rho_{eff}}{\rho} = \frac{1}{4}\left(\frac{v_{edge}}{c}\right)^2 \tag{2}$$

This confirms that rotational motion contributes to the inertial mass of extended systems at order $(v/c)^2$[13]. In SST, fundamental particles are modeled as knotted vortex loops[14]. These loops possess finite energy, impulse, and an effective mass $M_{eff} = \|I\|/U$ defined by their hydrodynamic impulse I and self-induced velocity U[15].

4 Electromagnetism: Photons as Torsion Waves

We reject the point-particle photon. Using Cartan's structure equations in a teleparallel geometry, we identify the electromagnetic field tensor $F_{\mu\nu}$ as the projection of the substrate's torsion 2-form T^a[16]. The photon emerges as a massless transverse shear wave of the substrate's director field[17].

The wave speed is determined by the substrate's effective stiffness and density[18]:

$$c = \sqrt{\frac{\mathcal{K}}{\rho_{eff}}} \tag{3}$$

A key prediction of this hydrodynamic model is the Vacuum Faraday Effect, where the vacuum exhibits a linear-in-B magnetic optical response[19].

External Validation: This hydrodynamic mechanism is strongly supported by recent findings by Assouline & Capua (2025), who demonstrated that the optical magnetic field contributes significantly to the Faraday effect, distinct from the electrical component, particularly at ultrafast timescales[20]. This breaks the classical reciprocity of the vacuum, exactly as predicted by SST when the local swirl velocity (time scaling) is perturbed.

5 Emergent Gravity (Corrected): near-field Euler vs far-field mediator

Steady, axisymmetric Euler balance gives

$$\frac{1}{\rho}\frac{dp}{dr} = -\frac{v_\theta^2(r)}{r}.$$

For filamentary circulation $v_\theta = \Gamma/(2\pi r)$ this implies $dp/dr \propto -1/r^3$ and therefore a pressure deficit $\Delta p \propto -1/r^2$, yielding forces $\propto 1/r^3$. This is a *short-range* interaction and does not produce a Newtonian inverse-square law.

Long-range gravity is modeled by a local mediator ϕ (clock/foliation mode) with static action

$$S_{\rm stat}[\phi] = \int d^3x \left[\frac{\kappa}{2}(\nabla\phi)^2 - \lambda\,\rho_m(\mathbf{x})\,\phi\right], \qquad \kappa\nabla^2\phi = -\lambda\rho_m,$$

whose Green-function solution for localized sources gives $\phi(r) \propto 1/r$ and hence $|\nabla\phi| \propto 1/r^2$.

6 The Grand Unified Scale Identity

The consistency of SST is verified by a single harmonic identity connecting classical, relativistic, and atomic scales. We derive a maximal Hooke-law force F_{max} using the electron mass m_e, Compton frequency ω_C, and fine-structure constant α[25]:

$$F_{max} = m_e \left(\frac{\omega_C}{\alpha}\right)^2 r_e \tag{4}$$

Multiplying this force by a Compton-scale radius r_c, we recover the Hydrogen ground state energy E_B and the electron rest mass exactly[26]:

$$F_{max} r_c = \frac{1}{2} m_e c^2 = \frac{E_B}{\alpha^2} \tag{5}$$

This identity serves as the "Rosetta Stone" of SST, proving that atomic structure (E_B), relativity (c), and electrodynamics (α) are geometrically coupled via the fluid properties of the vacuum.

7 Conclusion

By treating the vacuum as a physical fluid, we have unified proper time dilation, effective mass, electromagnetism, and gravity under a single hydrodynamic framework. The recent observation of optical magnetic torque (Assouline & Capua, 2025) provides the necessary empirical bridge between this hydrodynamic theory and modern magneto-optics.

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