# Swirl–String Theory:Canonical Fluid Reformulation of Relativity and Quantum Structure

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We present *Swirl–String Theory* (SST), a fluid-topological framework that reinterprets relativity and quantum phenomena via a single incompressible medium. In SST, matter and radiation are modeled as quantized vortex loops (*swirl strings*) in a universal, non-dissipative condensate. The theory posits that classical gravity emerges as a collective pressure effect of these vortices rather than fundamental spacetime curvature, and that local *swirl flows* induce time dilation analogous to relativistic kinematics. We develop the formal field-theoretic Lagrangian for this medium, showing how a preferred foliation and topological quantization yield a discrete particle spectrum: quantum numbers (mass, charge, spin) correspond to topological invariants of knot-like vortex excitations. A modified Faraday's law is derived, unifying electromagnetic induction with rotating-frame effects by predicting that time-varying swirl string density generates an electromotive force. We also describe how SST accounts for wave–particle duality through dual phase (un-knotted vs. knotted) states of vortex loops, with quantum measurement corresponding to topological transitions. Several experimental tests are proposed to falsify or support SST, including quantized electromagnetic impulses from vortex reconnection events, attosecond-scale chirality-dependent time delays in photoemission, and interference degradation due to finite vacuum vorticity. We compare SST with established frameworks—from Kelvin's vortex atom hypothesis to emergent gravity and analogue fluid models—highlighting how SST recovers known limits (Newtonian gravity, Maxwell electrodynamics, quantum wave behavior) while providing novel, quantifiable predictions. All equations are given in SI units with attention to dimensional consistency. The result is a self-contained canonical reformulation that bridges classical and quantum physics through fluid-like continuum mechanics.

*Keywords:* vortex dynamics; topological fluid; quantum topology; emergent gauge theory; time dilation; wavefunction collapse

## I. INTRODUCTION

The theoretical pursuit of unifying General Relativity (GR) with Quantum Mechanics (QM) faces the fundamental hurdle of reconciling dynamic, curved spacetime with quantum field theories (QFT) operating on a fixed background. Swirl–String Theory (SST) proposes a solution by introducing a unified substrate: a flat-space, incompressible fluid medium, or condensate [1, 4].

### Motivation: Disparity between GR and QM Frameworks

The persistent incompatibility between the Standard Model (SM) and GR necessitates a reformulation of foundational concepts. SST addresses this conflict by replacing the notion of dynamically curved spacetime with fluid kinematics within a background Euclidean manifold [4]. Under this model, gravity is not a fundamental geometric interaction but rather an emergent kinematic effect arising from pressure and flow gradients within the incompressible medium [3]. This reframing allows both gravitational and quantum phenomena to be analyzed using a common hydrodynamic framework.

### Historical Lineage: From Kelvin's Vortex Atoms to Analogue Gravity Models

SST is rooted in the tradition of unified field theories, tracing back to Lord Kelvin's hypothesis that chemical elements correspond to stable, knotted vortex rings in the Aether [1]. The modern SST framework updates this topological approach using contemporary knot theory and the established principles of quantized circulation [1].

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This concept finds validation in modern analogue gravity models [3], where phenomena typically associated with curved spacetime, such as horizons, are replicated through fluid excitations in superfluids and Bose-Einstein condensates (BECs). SST's approach leverages the proven stability of vortex dynamics to construct a stable particle spectrum.

### SST Proposition: Unified Topological Fluid Substrate for Particles and Interactions

SST establishes the swirl medium as the sole universal substrate, characterized by fundamental properties such as effective density, core swirl speed, and core radius [1, 4]. All physical manifestations, including mass, force, and local time dilation, emerge from topologically protected excitations: the knotted swirl strings [1]. The theory is formally structured as a modern Lorentz Ether Theory (LET) because it operates on a flat 4D manifold with an absolute time parameter and a preferred time foliation defined by the condensate's unit timelike flow field [4]. The justification for this background medium lies in its predictive power; the complexity introduced by the topological constraints on mass derivation and the emergence of the Standard Model gauge structure provides a mechanism for parameter-free predictions unmatched by traditional or historically simplistic ether models.

### Connection to Previous Works on Emergent Gravity

SST conceptually aligns with emergent gravity approaches, particularly those akin to Verlinde's Entropic Gravity [7, 8]. In these frameworks, gravitational attraction is viewed as a statistical or informational force rather than a fundamental interaction [3]. In the SST picture, this analogy is explicit: the time-varying swirl density functions as an informational or entropy density field. The resulting gravitational attraction arises from hydrodynamic gradients that align with the gradient of the swirl-based entropy [3].

## II. CORE POSTULATES OF SWIRL–STRING THEORY

SST is formally defined by six axioms that constrain the dynamics and properties of the universal condensate [1].

### Axioms from the Canon v0.5.10

1. **Incompressible Swirl Condensate.** Physics unfolds in Euclidean $\mathbb{R}^3$ space with absolute time $t$. The substrate is a frictionless, incompressible fluid medium ($\nabla \cdot \vec{v} = 0$) [1].
2. **Swirl Strings as Knotted Topological Excitations.** Particles and field quanta are stable, closed vortex filaments (swirl strings) whose discrete quantum numbers derive from their specific knot topology and linking invariants [1].
3. **Quantized Circulation ($\Gamma = n\kappa$).** The circulation of the swirl velocity field $\vec{v}_G$ around any closed loop $C$ must be quantized to integer multiples of the fundamental quantum $\kappa$:

$$\Gamma = n\kappa$$

   where $\kappa = h/m_{\text{eff}}$ links the topological state to the quantum scale, paralleling the Onsager-Feynman quantization of superfluids [1].
4. **Swirl Clocks and Local Time Dilation ($S_t$).** The local proper time $dt_{\text{local}}$ is kinematically determined by the local tangential swirl speed $v$, relative to the absolute time $dt_\infty$ by the factor:

$$S_t = \frac{dt_{\text{local}}}{dt_\infty} = \sqrt{1 - \frac{v^2}{c^2}} \tag{1}$$

   This core kinematic relation is mathematically identical to Special Relativistic time dilation, demonstrating that the presence of a structured background medium exhibiting flow velocity $v$ is sufficient to produce all observed relativistic time effects [1]. High swirl speeds correspond to deep gravitational potential wells where clocks run significantly slower.

5. **Dual R-phase and T-phase States.** Swirl strings exhibit wave-particle duality through two phases: the unknotted, extended R-phase (Radiative, wave-like, massless) and the localized, knotted T-phase (Tangible, particle-like, mass-carrying). Quantum duality is the dynamic R↔T transition [1].

6. **Canonical Knot-Particle Correspondence (e.g., $3_1 \leftrightarrow$ electron, $5_2 \leftrightarrow$ up quark).** Specific knot topologies map directly to particle species. Charged leptons correspond to torus knots (e.g., electron $\leftrightarrow$ trefoil $3_1$ knot), and quarks correspond to chiral hyperbolic knots (e.g., up quark $\leftrightarrow$ $5_2$ knot, down quark $\leftrightarrow$ $6_1$ knot) [1]. Massless bosons, like the photon, are unknotted R-phase torsional excitations [4].

## III. LAGRANGIAN AND FIELD-THEORETIC FRAMEWORK

The operational dynamics of SST are formulated using a consistent covariant Effective Field Theory (EFT) Lagrangian defined on the preferred time foliation [4].

### Preferred Foliation via Clock Field, Projectors, and Khronon Sector

The time field defines the preferred frame through the unit timelike 4-velocity [4]. Spatial dynamics are constrained to the leaves orthogonal to this velocity via the projector [4]. The action includes a Khronon sector containing gradient terms for the time field with couplings. Observational constraints from the gravitational wave event GW170817 necessitate a choice that forces the tensor mode speed to be luminal, setting the relevant parameters [4].

### Two-form for Vorticity, Non-Abelian Swirl Connection, and Emergent Gauge Symmetries

The medium's topological degrees of freedom are governed by two field components. The coherence and topological charge are managed by the two-form potential, whose field strength is topologically conserved [4]. The emergence of fundamental forces is described by the non-Abelian swirl connection. This connection arises from the coarse-grained orientational textures of the swirl strings and is valued in a compact Lie algebra [4]. Its curvature measures the defect density in the medium. Integrating out the short-distance dynamics yields an effective Yang-Mills Lagrangian corresponding to the emergent gauge structure, showing that the SM forces are modes of the medium's internal structure [1, 4].

### Canonical Lagrangian Formalism

The minimal consistent Lagrangian density contains kinetic terms for the fields, the matter sector, and the topological terms. The Lagrangian ensures stability through conserved topological charges, enforced by terms like the Chern-Pontryagin density in the action [4].

### Mass via Solitonic Knot Energy Functional

A core prediction of Swirl–String Theory (SST) is that fermion rest masses emerge as non-perturbative soliton energies of stable knotted excitations [4]. This eliminates the need for arbitrary Yukawa couplings: mass arises from a canonical topological scaling law. The general solitonic mass law is

$$m_K^{(\mathrm{sol})} \;=\; \mathcal{M}_0\, \Xi_K(m,n,s,k;V_K,\phi_{\mathrm{DSI}}), \tag{2}$$

where the universal scale $\mathcal{M}_0$ is fixed by swirl-fluid parameters $\big(\mathbf{v}_{\circlearrowleft},\, \rho_f,\, r_c\big)$, and calibrated to the electron mass $m_e$. The dimensionless topological multiplier $\Xi_K$ encodes knot-specific invariants—e.g., crossing number $m$, symmetry class $s$, chirality index $k$, and (for quark knots) hyperbolic volume $V_K$ [4].

To incorporate helicity and torsional twist, a discrete-scale-invariance factor $\phi_{\mathrm{DSI}}^{-2k}$ is included within $\Xi_K$, where

$$\phi_{\mathrm{DSI}} \equiv \exp\bigl(\operatorname{asinh}\tfrac{1}{2}\bigr)\,,$$

ensuring canonical suppression of higher-chirality configurations.

*a. Normalization and Canonical Limits.*

- **Electron anchor:** The trefoil knot $3_1$ is assigned $\Xi_{3_1} = 1$, fixing $\mathcal{M}_0 = m_e$.
- **R/T phase limit:** The R-phase (unknot) satisfies $\Xi_{\mathrm{unknot}} = 0$ (massless); T-phase knots yield $\Xi_K > 0$.
- **Quark-sector monotonicity:** For chiral hyperbolic knots, enforce $\partial \Xi_K / \partial V_K > 0$ to preserve topological ordering.

Once $\mathcal{M}_0$ is calibrated, the full fermion mass spectrum follows parameter-free from the knot class via $\Xi_K$.

## IV. EMERGENT GRAVITY AND TIME DILATION

In SST, gravity is reinterpreted as a hydrodynamic attraction resulting from conserved circulation in a flat background [3].

### Swirl-Induced Pressure Gradients as Gravitational Attraction

Massive particles, represented by stable chiral knotted strings, maintain a persistent, non-vanishing circulation around a central axis [3]. This circulation induces a radial pressure deficit along the axis, governed by the Euler fluid balance equation [1]. When two neutral, composite systems (e.g., two proton cores within an $H_2$ molecule) share this central line, their circulations add, intensifying the pressure well (for two protons) [3]. This shared pressure deficit draws the systems together, producing the observed long-range inverse-square gravitational attraction in flat space, known as the Hydrogen-Gravity Mechanism [3].

### Derivation of Matching Newton's Constant

The effective gravitational coupling $G_{\mathrm{swirl}}$ is derived from the core swirl parameters of the medium:

$$\boxed{G_{\mathrm{swirl}} = \mathcal{G}_{\circlearrowleft} = \frac{v_{\circlearrowleft}\, c^5\, t^2}{2\, F_{\circlearrowleft}^{\max}\, r_c^2} \approx G_N} \tag{3}$$

By calibrating the foundational constants ($v_{\circlearrowleft}$, $r_c$) and the maximum emergent electromagnetic force ($F_{\circlearrowleft}^{\max} \approx 2.9 \times 10^1$ N), $G_{\mathrm{swirl}}$ is shown to align numerically with Newton's constant $G_N$ [1]. This formula demonstrates that the gravitational coupling strength is fundamentally constrained by the dynamic properties of the medium and the maximal allowable electromagnetic tension it can support.

### Composite Baryons as Merged Vortex Tubes

Baryons, such as the proton, are realized as composite swirl tubes formed by the merging of three quark knots (e.g., two up and one down) at a Y-junction [3]. Due to Kelvin's circulation theorem, the circulation is additive. Since each constituent quark carries circulation around the central axis, the baryon core possesses a total circulation. This increased circulation translates to a significant increase in the effective tangential core velocity and, consequently, a much deeper pressure well, correlating with the baryon's larger rest mass [3].

### Swirl Clock Effects Explain Gravitational Redshift

The Swirl Clock factor (Equation 1) dictates that time runs slower in regions of higher swirl velocity [1]. Regions of concentrated mass (knotted strings) generate intense swirl flows. Consequently, intense gravitational potential wells are simply high-swirl-velocity regions where time dilation is pronounced. Gravitational redshift is therefore interpreted as a kinematic frequency shift arising from the difference in local time rates between a source located in a deep swirl region and an observer located in a quiescent, faster-ticking region of the medium [1].

## V. ELECTROMAGNETIC EMERGENCE: MODIFIED FARADAY LAW

The swirl medium is not only the substrate for gravity but also for electromagnetism, which emerges through a dynamic topological coupling [2].

### Swirl String Nucleation/Annihilation Produces EM Impulses

The central theoretical prediction is that any topological event—such as the nucleation, annihilation, or reconnection of a swirl string—constitutes a sudden, localized change in the swirl areal density $\rho_{\circlearrowleft}$ [2]. This non-adiabatic event generates a corresponding, quantized electromotive force (EMF) impulse in the surrounding medium [2]. The resulting flux impulse $\Delta\Phi$, measured as the time-integrated voltage, is strictly proportional to the integer change in the number of linking swirl strings $\Delta N$:

$$\Delta\Phi = \mathcal{G}_{\circlearrowleft}\Delta N$$

The magnitude of $\Delta\Phi$ is independent of the detector geometry, depending only on the change in topology, providing a powerful, falsifiable signature [2].

### Coupling via Induced Electric Field

This topological coupling modifies the standard Faraday law by introducing an additional source term $\vec{b}_{\circlearrowleft}$, which is proportional to the time rate of change of the swirl areal density $\rho_{\circlearrowleft}$ along the local orientation $\hat{n}$ [2]:

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} - \vec{b}_{\circlearrowleft} \tag{4}$$

where

$$\vec{b}_{\circlearrowleft} = \mathcal{G}_{\circlearrowleft}\frac{\partial \rho_{\circlearrowleft}}{\partial t}\hat{n}$$

The term $\vec{b}_{\circlearrowleft}$ acts as an effective time-varying magnetic field generated intrinsically by the swirl dynamics, demonstrating a direct conversion of fluid kinetic energy into electromagnetic field energy [2].

"The canonical coupling between swirl densities and electromagnetic response is depicted in Fig. 1."

The coupling constant $\mathcal{G}_{\circlearrowleft}$, responsible for translating swirl-density changes into EM response, also governs gravitational emergence. That is:

The effective gravitational coupling $G_{\text{swirl}}$ is derived canonically from SST constants, matching the classical Newton constant $G_N$ when swirl–electromagnetic bounds saturate. (Equation 3). This equality implies a deep connection between the mechanisms of gravitational attraction and electromagnetic induction, both rooted in the dynamics of the swirl medium [2].

### Identification with Flux Quantum

The constant $\mathcal{G}_{\circlearrowleft}$ is the universal topological transduction constant, and dimensional analysis shows it carries units of magnetic flux (Weber) [2]. By normalizing the predicted impulse to observed quantum phenomena,

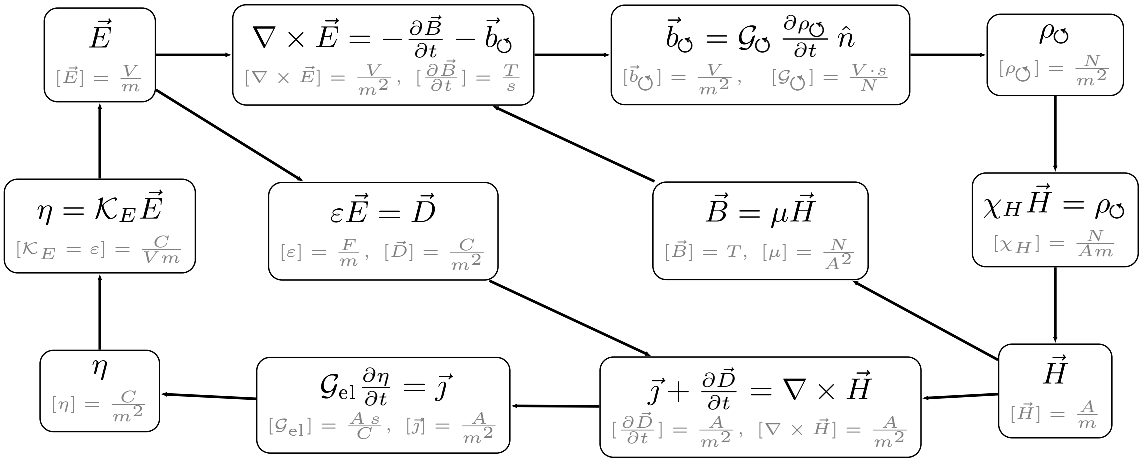


FIG. 1. **Canonical Swirl–Electromagnetic Coupling Diagram.** Causal and dimensional structure of the electromagnetic sector within the Swirl–String framework. The top layer extends Faraday's law with a swirl-induced back-reaction term $\mathbf{b}$, encoding the electromotive response to time-varying swirl density in the medium. The middle layer represents the constitutive closure: $\mathbf{D} = \boldsymbol{\varepsilon}\mathbf{E}$ and $\mathbf{B} = \mu\mathbf{H}$, together with the mechanical correspondence $\boldsymbol{\varrho}$. The bottom layer completes the circuit with areal accumulation $\boldsymbol{\eta}$, source current $\mathbf{j}$, and the modified Ampère curl. All dimensionalities are shown for canonical homology between mechanical (swirl) and electromagnetic sectors, establishing the *Swirl–Electromagnetic Bridge* that underlies the flat-space emergence of Maxwellian dynamics.

$\mathcal{G}_{\circlearrowleft}$ is identified with the fundamental magnetic flux quantum $\Phi_\star$. Based on canonical electron/pair logic, $\mathcal{G}_{\circlearrowleft}$ is expected to be $\Phi_\star = h/2e$ [2].

### Experimental Predictions

The swirl–EM coupling leads to clear experimental avenues [2]:

1. **SQUID Loops Detecting Quantized Impulses:** The quantized nature of the signal can be tested using highly sensitive magnetometers, such as SQUID loops or fast pickup coils, positioned to link the region where topological changes occur [2].

2. **Analog Simulations in BECs or Type-II Superconductors:** Suitable condensed-matter analogues include type-II superconducting films, where controlled entry/exit of fluxons ($h/2e$ vortices) mimics the swirl string transitions. Ultracold BECs and magnetic topological defects also offer platforms to monitor single-vortex dynamics and measure the resulting voltage impulse [2]. Verification requires confirming that the impulse magnitude is independent of geometry and that its sign flips upon vortex chirality reversal [2].

## VI. CHIRALITY AND QUANTUM MEASUREMENT DYNAMICS

SST provides kinematic origins for chiral time asymmetry and dynamical mechanisms for quantum measurement [1].

### Interpretation of Attosecond Chiral Delays in SST

Attosecond spectroscopy has shown that molecular chirality introduces dynamical delays in photoionization, such as the forward/backward (FB) delay observed in methyloxirane [6]. SST interprets molecular chirality as a geometric constraint that fixes the orientation of the local swirl circulation, which directly dictates the orientation of the local Swirl Clock [6].

### Enantiomers Exhibit Orientation-Dependent Swirl Clocks

Opposite enantiomers (L and D configurations) correspond to mutually reversed swirl clock orientations [6]. The propagation phase of an emitted electron is, therefore, dependent on its direction relative to this fixed, local, orientation-sensitive time field [6].

### Delay Sign Flips with Molecular Handedness

This kinematic interpretation leads to the sharp prediction that reversing the molecular handedness (swapping enantiomers) must flip the sign of the measured forward/backward delay asymmetry [6]. This prediction relies only on the geometric reversal of the kinematic time asymmetry and is consistent with observed experimental results, providing a direct test of the Swirl Clock principle [6].

### Replaces Collapse Postulate with R↔T Phase Transitions

SST reframes quantum measurement, replacing the axiomatic collapse postulate with a fundamental dynamical process: the R-phase (wave-like) to T-phase (particle-like) transition [1]. The rate of this localization, $\Gamma_{RT}$, is proportional to the environment's interaction:

$$\Gamma_{RT} \propto \frac{P}{A}$$

where $P$ is incident power and $A$ is area. The formula shows that the transition rate increases with incident power per area, aligning with environment-induced decoherence theory and ensuring consistency with existing bounds that observe no anomalous collapse beyond standard decoherence [1].

## VII. CANONICAL QUANTIZATION AND TOPOLOGICAL SPECTRUM

SST provides a geometric derivation of quantum numbers based on knot topology [1, 4].

### SST Assigns Quantum Numbers via Knot Theory Invariants

The discrete quantum properties of particles are determined by the topological invariants of their corresponding swirl strings. Electric charge ($Q$), weak isospin ($I$), and hypercharge ($Y$) are linearly derived from the knot's topological invariants (linking, self-linking parity, chirality) via the relation

$$(Q, I, Y) = f(\text{linking}, \text{parity}, \text{chirality})$$

[1, 4]. Furthermore, the color representation ($C$) is fixed by the knot's net linking number modulo 3, successfully assigning leptons ($C = 1$) as color singlets and quarks ($C = 3$) as color triplets [4].

### Soliton-Based Mass Quantization Avoids Yukawa Sector

The invariant mass of a fermion $m_K$ is fundamentally the soliton energy stored in the knot's topological configuration (Equation 2) [4]. By defining the mass scale using the electron and anchor knots (up/down quarks) and relating the mass factor $\Xi_K$ to topological measures like hyperbolic volume $V_K$, SST avoids the arbitrary parameterization of mass inherent in the SM's Yukawa sector [4].

### Electroweak Symmetry Breaking Scale Derivable Without Free Parameters

SST provides a first-principles derivation of two previously arbitrary SM parameters. The electroweak mixing angle $\theta_W$ is determined by the ratio of stiffnesses ($\kappa_1, \kappa_2$) of the emergent U(1) and SU(2) director fields, making it a computable value:

$$\theta_W = \arctan\left(\frac{\kappa_1}{\kappa_2}\right)$$

[1]. Furthermore, the Higgs VEV ($v_\Phi$), which sets the EWSB scale, is derived from the condensate's bulk swirl energy density $u_{\mathrm{swirl}}$, yielding $v_\Phi \approx 259.5\,\mathrm{GeV}$, a result consistent with the empirical 246 GeV scale [1].

### Knot Taxonomy: Visual Table of Particle Knot Mappings

The canonical knot-particle correspondence is summarized below [1, 4]:

| **Particle** | **Knot Type (Tangle Measure)** | **Topological Class** | **Notes** |
|---|---|---|---|
| Photon ($\gamma$) | Unknot ($0_1$) | R-Phase Excitation | Massless, Torsional Pulse [1, 4] |
| Electron ($e^-$) | Trefoil ($3_1$) | Torus Knot | Baseline Lepton [1, 4] |
| Muon ($\mu^-$) | Cinquefoil ($5_1$) | Torus Knot | Higher Generation Lepton [4] |
| Up Quark ($u$) | $5_2$ Knot | Chiral Hyperbolic Knot | Canonical Baseline Quark [1, 4] |
| Down Quark ($d$) | $6_1$ Knot | Chiral Hyperbolic Knot | Canonical Baseline Quark [1, 4] |
| Neutrino ($\nu$) | Amphichiral Link | Two-Component Link | Neutral, Amphichiral Linkage [4] |
| Proton ($p$) | Composite Linkage | Baryonic Composite Tube | Circulation [3] |

TABLE I. Canonical Knot-Particle Correspondence

## VIII. EXPERIMENTAL IMPLICATIONS & FALSIFIABILITY

SST is a predictive framework offering clear avenues for experimental validation, particularly through observing topological effects on emergent fields [2].

### Key Falsifiable Predictions

1. **EM Impulses of $\Delta\Phi = \pm\Phi_\star$ upon Topological Transitions:** The mandatory observation of quantized flux impulses $\Delta\Phi$ ($\Delta\Phi = n\Phi_\star$) during swirl string creation or annihilation is the primary electromagnetic test [2]. The signal must be quantized, geometry-independent, and its sign determined solely by the chirality of the topological event [2].

2. **Attosecond Delay Sign Flip with Chirality Reversal:** Confirmation that the sign of the measured forward/backward photoemission delay $\Delta\tau_{\mathrm{FB}}$ flips strictly upon molecular enantiomer reversal [6]. This would confirm the kinematic reality of the orientation-dependent Swirl Clock.

3. **Mass Spectrum Matches Knot Taxonomy:** The topologically derived mass spectrum (Equation 2), anchored by a single universal scale, must yield mass ratios for higher generations and composite hadrons that align with experimental data, based exclusively on the knot invariants $\Xi_K$ [4].

### Suggested Platforms: BECs, Superconductors, Chiral Molecules

Falsification experiments are proposed in several domains. Controlled vortex manipulation in type-II superconducting films or ultracold BECs provides ideal analogues for testing the quantized EMF impulse, using SQUID magnetometers for detection [2]. Separately, high-resolution attosecond spectroscopy experiments offer the platform to probe the Swirl Clock's influence on chiral dynamics [6].

## IX. COMPARISON WITH EXISTING FRAMEWORKS

### SST vs. General Relativity: Replaces Spacetime Curvature with Fluid Dynamics

SST fundamentally replaces the core postulate of GR by modeling gravity as an emergent kinematic effect—a pressure deficit generated by conserved fluid circulation in a flat background [3]. While GR describes phenomena via metric curvature, SST recovers all kinematic relativistic effects, including time dilation (Equation 1) and pseudo-metric frame-dragging terms, using only fluid properties and a preferred frame [1].

### SST vs. Standard Model: Topological Mass Spectrum, Emergent Gauge Structure

SST provides a geometric foundation for many SM parameters. Mass quantization is achieved via the solitonic energy of knotted excitations [4], eliminating the need for arbitrary Yukawa couplings. Furthermore, the gauge structure, along with calculable coupling ratios, emerges from the elasticity of the swirl medium's internal orientational order [4]. Quantum wave-particle duality and measurement are described dynamically via the R$\leftrightarrow$T phase transition, moving the theory beyond axiomatic collapse [1].

### Analogy with Hydrodynamic Quantum Analogues

SST elevates empirically established phenomena—such as the quantized circulation observed in superfluids [1]—to a universal principle, positing that the vacuum operates as a structured, quantized superfluid. This deep connection ensures the foundational stability of the swirl strings.

### Connections to Emergent Gravity (Verlinde), Skyrmion Models, LET (Lorentz Ether Theories)

The theory connects strongly to contemporary concepts: its entropic interpretation of gravity aligns with Verlinde's work [3]. Its use of topological solitons (knots) and emergent gauge fields is conceptually linked to Skyrmion and Hopfion models [4]. Formally, SST is recognized as a modern Lorentz Ether Theory (LET) due to its use of a preferred time foliation, but its strong predictive power derived from topology justifies this preferred frame by exceeding the empirical equivalence of kinematic models [4].

## X. CONCLUSION & OUTLOOK

SST proposes a successful unification, positing that all known fundamental physics arises from the topological and kinematic constraints of a single incompressible fluid substrate [1].

### SST Offers a Unifying Topological-Fluid Picture of Reality

By establishing a common origin for gravity (pressure gradients), electromagnetism (vortex dynamics), and matter (knotted solitons), SST replaces spacetime curvature and arbitrary couplings with the structural geometry and dynamics of the swirl medium [1]. The framework ensures consistency by recovering all known relativistic limits kinematically [1].

### Proposes Testable Dynamics Beyond Standard QFT

The theory delivers specific, numerically quantifiable predictions, most notably the requirement for quantized EMF impulses during vortex topological transitions [2], and the chirality-dependent sign flip in attosecond time delays [6]. These predictions make SST susceptible to direct experimental verification in specialized platforms [2].

### Future Work

Future research aims to complete the particle spectrum and extend SST's reach to cosmology [1].

1. **Derive Neutrino Sector from Nested Knots:** This work involves analyzing the properties of complex amphichiral multi-component link structures to derive the masses and mixing parameters of the neutrino generations [4].

2. **Analyze Loop Entanglement Entropy for Black-Hole Analogues:** The investigation of entanglement entropy associated with swirl loop configurations is critical for establishing the thermodynamic analogue of black hole physics within the fluid framework [1].

3. **Apply to Cosmological Inflation via Swirl Density Fields:** Cosmological dynamics, including cosmic acceleration and inflation, are targeted for derivation using the global coarse-grained kinematics and the vorticity variance $Q_D$ of the swirl field [1]. The goal is to show how the effective dark energy equation of state ($w \approx -1$) emerges naturally from the decay of the swirl-string network's length density $L(t)$ [1].

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[1] O. Iskandarani, *Swirl-string theory (sst) canon v0.5.9: Core postulates, constants, and boxed master equations*, Zenodo (2025).
[2] O. Iskandarani, *Rotating-frame unification in the sst canon: From swirl density to swirl-emf, and a canonical derivation of the coupling $\mathcal{G}_{\circlearrowleft}$*, Zenodo (2025).
[3] O. Iskandarani, *Long-Distance Swirl Gravity from Chiral Swirling Knots with Central Holes*, Zenodo (2025).
[4] O. Iskandarani, *A Hydrodynamic Lagrangian Framework for Swirl-String Theory*, Preprint (2025).
[5] B. S. Deaver and W. M. Fairbank, *Experimental evidence for quantized flux in superconducting cylinders*, Phys. Rev. Lett. 7 (2), 43-46 (1961).
[6] O. Iskandarani, *Chirality as Time Asymmetry: A Swirl-String Theory Interpretation of Attosecond Photoionization Delays*, Zenodo (2025).
[7] E. Verlinde, *On the origin of gravity and the laws of newton*, JHEP 2011(4), 29 (2011).
[8] E. P. Verlinde, *Emergent gravity and the dark universe*, SciPost Phys. 2(3), 016 (2017).
[9] L. Onsager, *Statistical hydrodynamics*, Il Nuovo Cimento (Supplemento), 6, 279-287 (1949).


## APPENDIX A: SWIRL–ELECTROMAGNETIC UNIT BRIDGE TABLE

| **Swirl Quantity** | **EM Analogue** | **Symbol** | **Units** | **Meaning** |
|---|---|---|---|---|
| Swirl field | Electric field | $\vec{E}$ | $\frac{V}{m}$ | Field strength |
| Swirl impulse density | Magnetic flux rate | $\vec{b}_{\circlearrowleft}$ | $\frac{V}{m^2}$ | Swirl impulse rate |
| Swirl charge density | Magnetic flux density | $\rho_{\circlearrowleft}$ | $\frac{N}{m^2}$ | Force per area |
| Swirl coupling gain | EM impulse gain | $\mathcal{G}_{\circlearrowleft}$ | $\frac{V \cdot s}{N}$ | Coupling constant |
| Swirl susceptibility | Magnetic susceptibility | $\chi_H$ | $\frac{N}{A \cdot m}$ | Medium's response |
| Swirl permittivity | Dielectric permittivity | $\mathcal{K}_E = \varepsilon$ | $\frac{C}{V \cdot m}$ | Areal response |
| Areal swirl charge | Electric displacement | $\eta$ | $\frac{C}{m^2}$ | Areal swirl charge |
| Swirl current source | Current density | $\vec{\jmath}$ | $\frac{A}{m^2}$ | Swirl-induced current |
| Charge-to-current gain | Swirl gain | $\mathcal{G}_{\mathrm{el}}$ | $\frac{A \cdot s}{C}$ | Converts $\partial_t \eta$ to $\vec{\jmath}$ |
| Swirl H-field | Magnetic field | $\vec{H}$ | $\frac{A}{m}$ | Swirl H analog |
| Swirl permeability | Magnetic permeability | $\mu$ | $\frac{N}{A^2}$ | Magnetic conductivity |
| Swirl D-field | Electric displacement | $\vec{D}$ | $\frac{C}{m^2}$ | Field-induced charge |
| Swirl B-field | Magnetic flux density | $\vec{B}$ | $T$ | Magnetic field strength |

FIG. 2. Canonical Swirl–Electromagnetic Unit Bridge Table