Swirl Clocks and Vorticity-Induced Gravity

Reformulating Relativity in a Structured Æther

A Topological Fluid Mechanics Approach to Time Dilation, Mass, and Gravitation

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Abstract

This paper presents a fluid-dynamic reformulation of General Relativity using the Vortex Æther Model (VAM), wherein gravity and time dilation arise from vorticity-induced pressure gradients in an incompressible, inviscid superfluid æther. Within a Euclidean 3D space governed by an absolute causal time $\mathcal{N}$ (Aithēr-Time), mass and inertia emerge as topologically stable vortex knots. Geodesic motion is replaced by alignment along vortex streamlines with conserved circulation, and gravitational force is modeled as a Bernoulli pressure potential:

$$\nabla^2\Phi_v(\vec{r}) = -\rho_æ \left\|\boldsymbol{\omega}(\vec{r})\right\|^2$$

Time dilation is reinterpreted as an energetic effect of swirl phase and vortex pressure gradients. The measurable proper time τ—termed Chronos-Time—is derived from vortex energetics as:

$$\frac{d\tau}{dt} = \sqrt{1 - \frac{C_e^2}{c^2}e^{-r/r_c} - \frac{2G_{\text{swirl}}M_{\text{eff}}(r)}{rc^2} - \frac{C_e^2}{r_c^2c^2}e^{-r/r_c}}$$

The third term originates from circulation energy with $\Omega = \Gamma/(2\pi r^2)$ and $\Gamma = \oint \vec{v}\cdot d\vec{\ell}$, while the coupling factor $\beta = 1/c^2$ reflects ætheric inertial drag. This yields a rotational dilation term $\beta\Omega^2 \sim \frac{C_e^2}{r_c^2c^2}e^{-r/r_c}$.

VAM introduces a multilayered temporal ontology, distinguishing absolute causal time ($\mathcal{N}$), local proper time (τ), and internal vortex phase time $S(t)$ (Swirl Clock). A scale-dependent æther density governs transitions between dense core regions and asymptotic vacuum, leading to testable predictions in rotating systems, gravitational redshift anomalies, and low-energy nuclear resonance (LENR).

The model reproduces Newtonian gravity and Lense–Thirring frame-dragging in the appropriate limits and establishes a physically grounded, topologically invariant theory of time, mass, and gravitation. VAM extends analogue gravity frameworks [1, 2] by embedding them in a consistent, vortex-based æther ontology.

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Contents

Introduction

Æther Revisited: From Historical Medium to Vorticity Field

The concept of *æther* traditionally referred to an all-pervasive medium, necessary for wave propagation. In the late nineteenth century Kelvin and Tait already proposed to model matter as nodal vorticity structures in an ideal fluid [3]. After the null results of the Michelson–Morley experiment and the rise of Einstein's relativity, the æther concept disappeared from mainstream physics, replaced by curved spacetime. Recently, however, the idea has subtly returned in analogous gravitational theories, in which superfluid media are used to mimic relativistic effects [1, 2].

The *Vortex Æther Model* (VAM) explicitly reintroduces the æther as a topologically structured, inviscid superfluid medium, in which gravity and time dilation do not arise from geometric curvature but from rotation-induced pressure gradients and vorticity fields. The dynamics of space and matter are determined by vortex nodes and conservation of circulation. Unlike in General Relativity, where time dilation arises from spacetime curvature, VAM attributes it to vortex-induced energy gradients. See Appendix A for a full derivation.

Postulates of the Vortex Æther Model

1. Continuous Space	Space is Euclidean, incompressible and inviscid.
2. Knotted Particles	Matter consists of topologically stable vortex nodes.
3. Vorticity	The vortex circulation is conserved and quantized.
4. Aithēr-Time	Time $\mathcal{N}$ flows uniformly in the æther as a background causal substrate.
5. Local Time Modes	Vortex dynamics induce τ, $S(t)$, and T_v, all of which slow relative to $\mathcal{N}$ in regions of high swirl or pressure.
6. Gravity	Emerges from vorticity-induced pressure gradients.

Table 1: Postulates of the Vortex Æther Model (VAM).

The postulates replace spacetime curvature with structured rotational flows and thus form the foundation for emergent mass, time, inertia, and gravity.

Fundamental VAM constants

Symbol	Name	Value (approx.)
C_e	Tangential eddy core velocity	1.094×10^6 m/s
r_c	Vortex core radius	$1,409 \times 10^{-15}$ m
$F_{æ}^{\max}$	Maximum eddy force	29.05 N
$\rho_{æ}$	Æther density	$3,893 \times 10^{18}$ kg/m^3
α	Fine structure constant ($2C_e/c$)	$7,297 \times 10^{-3}$
G_{swirl}	VAM gravity constant	Derived from C_e, r_c
κ	Circulation quantum ($C_e r_c$)	1.54×10^{-9} m^2/s

Table 2: Fundamental VAM constants [4].

We adopt a layered temporal ontology to clearly define different manifestations of time in VAM. These are summarized later in Table 4 (see Section 4), where the roles of $\mathcal{N}$, τ, $S(t)$, T_v, $\bar{t}$, and $\mathbb{K}$ are formalized as distinct but interrelated expressions of temporal flow within vortex dynamics.

Planck scale and topological mass

Within VAM, the maximum vortex interaction force is derived explicitly from Planck-scale physics:

$$F_{æ}^{\max} = \alpha \left(\frac{c^4}{4G}\right) \left(\frac{R_c}{L_p}\right)^{-2} \tag{1}$$

where $\frac{c^4}{4G}$ is the Maximum Force in nature, the stress limit of the æther found from General Relativity. The mass of elementary particles follows directly from topological vortex nodes, such as the trefoil node ($L_k = 3$):

$$M_e = \frac{8\pi\rho_{æ} r_c^3}{C_e} L_k \tag{2}$$

These vortex knots function as **swirl clocks** $S(t)$ — storing phase and angular momentum as a temporal memory. As the knot rotates, it defines a local time standard (T_v), slowing down with increasing vortex energy.

Emergent quantum constants and Schrödinger equation

Planck's constant $\hbar$ arises from vortex geometry and eddy force limit:

$$\hbar = \sqrt{\frac{2M_e F_{æ}^{\max} r_c^3}{5\lambda_c C_e}} \tag{3}$$

The Schrödinger equation follows directly from vortex dynamics:

$$i\hbar\frac{\partial\psi}{\partial t} = -\frac{F_{æ}^{\max} r_c^3}{5\lambda_c C_e}\nabla^2\psi + V\psi \tag{4}$$

Here, t may correspond to either Chronos-Time τ or Swirl Clock phase $S(t)$ depending on the observer's scale and vortex locality. Energy levels in such systems reflect topological duration, not coordinate time.

LENR and eddy quantum effects

Created in VAM low-energy nuclear reactions (LENR) from resonant pressure reduction by vorticity-induced Bernoulli effects. These effects occur when Swirl Clocks $S(t)$ synchronize across a vortex network, leading to enhanced coherence and spontaneous topological transitions — Kairos Moments $\mathbb{K}$.

Such $\mathbb{K}$ events define irreversible transitions in the causal flow of $\mathcal{N}$, marking topological bifurcations where T_v becomes non-analytic or undergoes a state transition.

Observable	GR expression	VAM expression
Time dilation	$\sqrt{1-\frac{2GM}{rc^2}}$	$\sqrt{1-\frac{\Omega^2 r^2}{c^2}}$
Redshift	$z=\left(1-\frac{2GM}{rc^2}\right)^{-1/2}-1$	$z=\left(1-\frac{v_\phi^2}{c^2}\right)^{-1/2}-1$
Frame-dragging	$\frac{2GJ}{c^2 r^3}$	$\frac{2G\mu I\Omega}{c^2 r^3}$
Light diffraction	$\frac{4GM}{Rc^2}$	$\frac{4GM}{Rc^2}$
Vortex Clock Phase	—	$S(t)=\int\Omega(r,t)\,dt$

Table 3: Comparison of GR and VAM observables.

Summary of GR and VAM observables

Temporal Ontology in the Vortex Æther Model

Before deriving explicit time dilation relations, we summarize the key modes of time present in VAM, which reflect different physical aspects of vortex structures and æther flow. These temporal quantities appear in various field equations and define how duration and simultaneity are treated in the model.

Ætheric Time Modes — Quick Overview		
$\mathcal{N}$	**Aithēr-Time**	Absolute causal background
ν_0	**Now-Point**	Localized universal present
τ	**Chronos-Time**	Measured time in the æther
$S(t)$	**Swirl Clock**	Internal vortex phase memory
T_v	**Vortex Proper Time**	Circulation-based duration
$\mathbb{K}$	**Kairos Moment**	Topological transition point

Table 4: Ætheric Time Modes in the Vortex Æther Model

These distinct time concepts clarify how local and global phenomena are distinguished within VAM, providing a basis for the derivation of time dilation below.

Scale-dependent Æther Densities in VAM

The Vortex Æther Model distinguishes between two conceptually distinct densities:

- **Æther Fluid Density** $\rho_{æ}^{(\text{fluid})}$ — a constant background value ($\sim 7\times10^{-7}\,\text{kg/m}^3$) that governs wave propagation and inertial resistance at macroscopic scales.
- **Æther Energy Density** $\rho_{æ}^{(\text{energy})}(r)$ — a radially decaying field around vortex cores responsible for storing rotational energy and generating topological stability.

The energy density is high near vortex cores ($\sim 10^{18}\,\text{kg/m}^3$) and decays exponentially toward the fluid density background on macroscopic scales.

1. Fluid Density: Constant Background

The æther fluid density is taken to be approximately:

$$\rho_{æ}^{(\text{fluid})} \approx 7 \times 10^{-7}\,\text{kg/m}^3, \tag{5}$$

based on matching vortex energetics with known quantum properties and allowing for inertia-free propagation of signals in the far field.

2. Energy Density: Core-Localized

In contrast, the energy density near a vortex core satisfies:

$$\rho_{æ}^{(\text{energy})}(r \to 0) \sim 3.89 \times 10^{18}\,\text{kg/m}^3, \tag{6}$$

which is necessary to stabilize the core topology. This follows from the vortex energy expression:

$$E_{\text{vortex}} = \frac{1}{2}\rho_{æ}^{(\text{energy})}\Omega^2 r_c^5 \quad \Rightarrow \quad \rho_{æ}^{(\text{energy})} \sim \frac{2E}{\Omega^2 r_c^5}, \tag{7}$$

where $\Omega = \frac{C_e}{r_c}$, with $C_e \approx 1.093\,845 \times 10^6\,\text{m/s}$ and $r_c \approx 1.408\,97 \times 10^{-15}\,\text{m}$.

3. Transition Profile

The energy density transitions exponentially to the macroscopic background:

$$\rho_{æ}^{(\text{energy})}(r) = \rho_{æ}^{(\text{fluid})} + \left(\rho_{\text{core}} - \rho_{æ}^{(\text{fluid})}\right) e^{-r/r_*}, \tag{8}$$

where $r_* \sim 1 \times 10^{-12}\,\text{m}$ represents the characteristic decay scale of vortex influence.

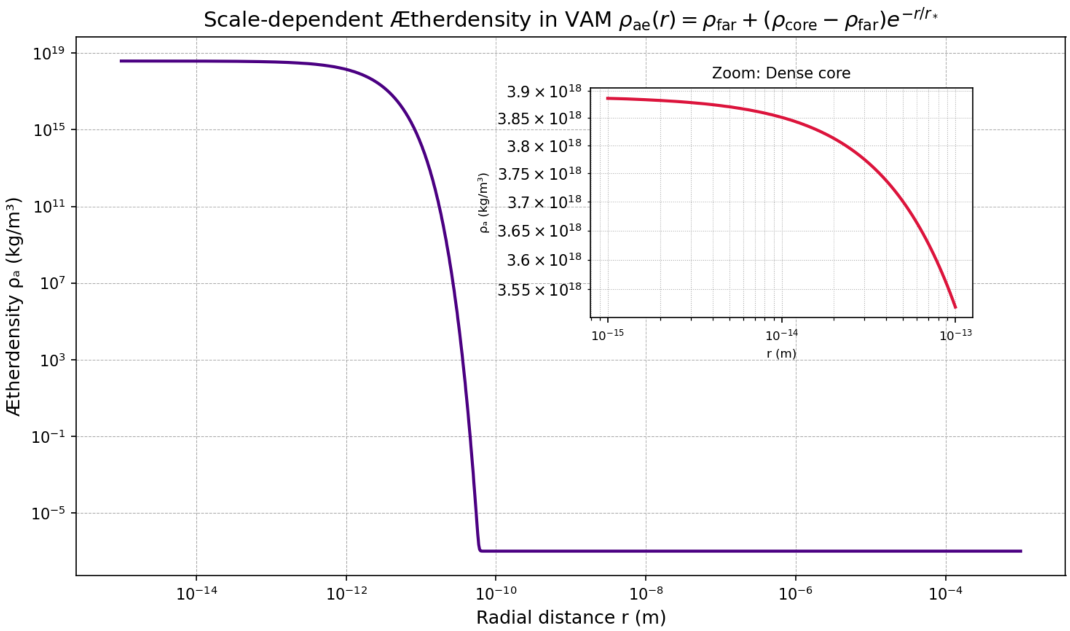

Figure 1: Energy density in the æther decreases exponentially from the vortex core and asymptotically reaches the macroscopic fluid density.

Regime	Distance r	$\rho_{æ}^{(\text{energy})}(r)$	Interpretation
Core	$r < 10^{-14}$ m	$\sim 10^{18}$ kg/m^3	Topological vortex energy
Transition	10^{-14}–10^{-11} m	Exponentially decreasing	Energy storage / swirl gradient
Macroscopic	$r > 10^{-11}$ m	$\sim 10^{-7}$ kg/m^3	Baseline fluid density

Table 5: Behavior of the æther energy density across regimes. The fluid density remains constant.

Æther Density Types in VAM

- **Fluid Density** $\rho_{æ}^{(\text{fluid})} \sim 7 \times 10^{-7}\,\text{kg/m}^3$: constant across all scales; governs inertia and wave propagation.
- **Energy Density** $\rho_{æ}^{(\text{energy})}(r)$: concentrated around vortex cores; provides topological stability; decays exponentially:

$$\rho_{æ}^{(\text{energy})}(r) = \rho_{æ}^{(\text{fluid})} + \left(\rho_{\text{core}} - \rho_{æ}^{(\text{fluid})}\right) e^{-r/r_*}$$

1 Layered Time Dilation from Swirl Dynamics

In the Vortex Æther Model (VAM), time unfolds through multiple physical layers, as summarized earlier in the Ætheric Time Modes (see Table 4). Absolute time $\mathcal{N}$ flows uniformly across the æther, while localized structures such as vortex knots experience time differently — through internal swirl clocks $S(t)$, vortex proper time T_v, and observer-perceived time τ.

We consider an invisible, irrotational superfluid æther hosting stable, knotted vortex structures. The absolute time $\mathcal{N}$ flows uniformly across the entire medium, but clocks embedded within vortex regions experience slowed progression, governed by the local vortex velocity field $v_\varphi(r)$.

This yields a distinction between the global time τ, the local swirl clock $S(t)$, and the vortex proper time T_v, each tracing different aspects of duration. The essence of time dilation in VAM is the reduction in local clock rate as a function of rotational energy density and internal circulation of the æther.

In the Vortex Æther Model (VAM), time dilation does not arise from the curvature of spacetime, but from local vortex dynamics. Each particle of matter in VAM is a vortex-node structure whose internal rotation (*swirl*) influences the local clock frequency.

The fundamental link between local vortex velocity and local time measurement follows from the Bernoulli-like relation for pressure reduction in flow fields. This local time τ is distinct from both the global causal time $\mathcal{N}$ and the far-field observer's external time $\bar{t}$. The dilation arises from the slowdown of τ relative to both $\bar{t}$ and $\mathcal{N}$ as rotational energy increases. See Equation (17) and the generalized frequency-based dilation formula $\frac{d\tau}{dt} = \omega_{\text{obs}}/\omega_0$. The local clock frequency is related to the vortex tangential velocity $v_\phi(r)$ by the formula:

$$\frac{d\tau}{dt} = \sqrt{1 - \frac{v_\phi^2(r)}{c^2}} \tag{9}$$

Where $v_\phi(r)$ is the tangential velocity of the æther medium at distance r from the center of the vortex, and c is the speed of light. This is a direct analogy with the special relativistic velocity-dependent time dilation, but without spacetime curvature and caused solely by local rotation of the æther medium.

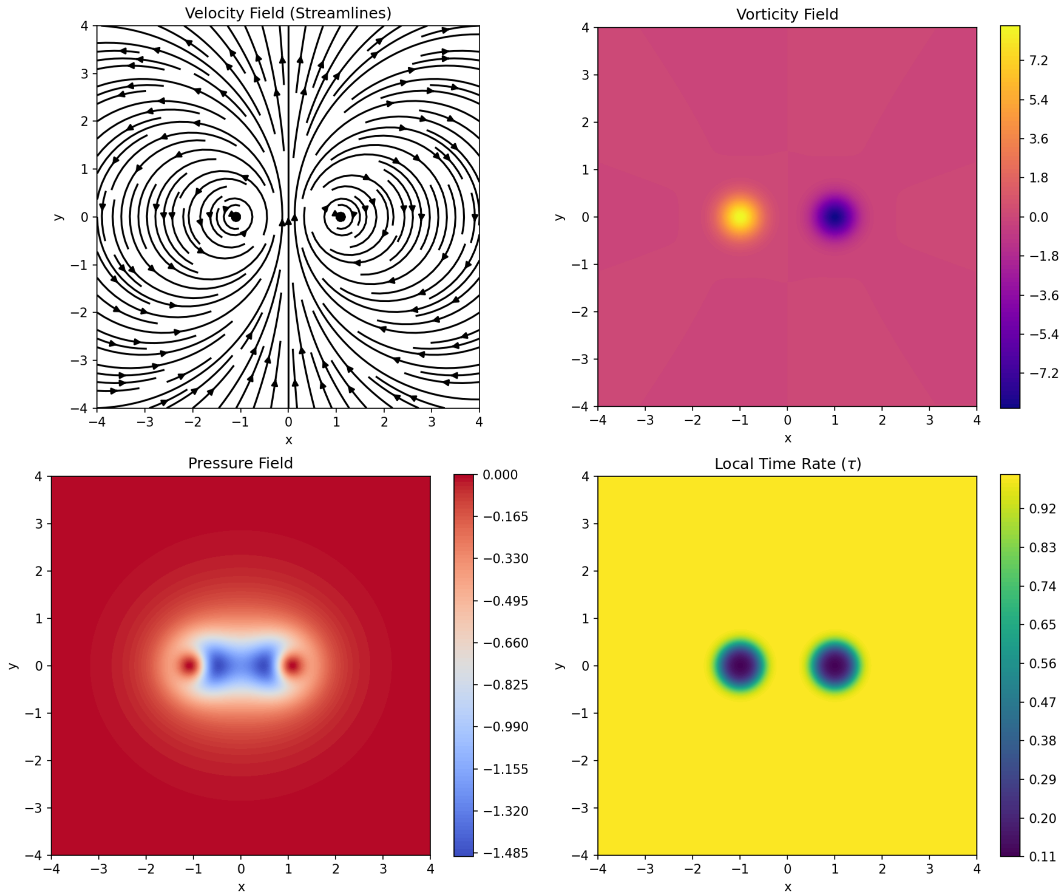

Figure 2: Velocity streamlines, vorticity, pressure and local time velocity τ for a simulated vortex pair. The pressure minimum and the time delay clearly correspond to the regions of high vorticity. This immediately illustrates the central claim of the Æther model: time dilation follows from vortex energetics and pressure reduction.

To visualize the outer behavior of time dilation predicted by the heuristic vortex-induced model, we extend the radial domain up to macroscopic femtometer scales. This reveals the asymptotic behavior of time rate restoration in the far-field, confirming agreement with known gravitational time dilation decay profiles.

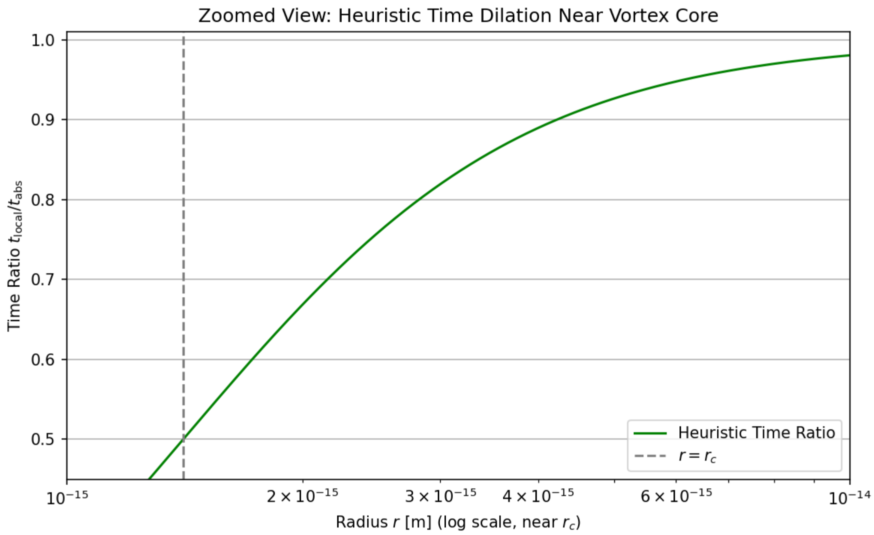

Figure 3: Zoomed radial profile of vortex-induced time dilation near the core. This heuristic plot illustrates how the normalized local clock rate $\frac{d\tau}{dt}$ rapidly increases with distance r away from the core, approaching unity asymptotically. This directly visualizes the effect of tangential vortex velocity $v_\varphi(r) \sim \kappa/r$ on the local time flow, as predicted by equation(17).

To formalize the distinct temporal flows in the Vortex Æther Model (VAM), we define the following expressions for time accumulation:

$$S(t) = \int_0^t \Omega(r(t'))\,dt' \quad \text{(Swirl Clock: internal phase accumulation)} \tag{10}$$

$$T_v = \oint \frac{dl}{v_\varphi(r)} \quad \text{(Vortex proper time: loop integral over local swirl speed)} \tag{11}$$

$$\frac{d\tau}{dt} = \sqrt{1 - \frac{v_\varphi^2(r)}{c^2}} \quad \text{(Time dilation from tangential vortex flow)} \tag{12}$$

Here, $\Omega(r) = \frac{C_e}{r_c}e^{-r/r_c}$ is the local swirl angular velocity, and $v_\varphi(r) = C_e e^{-r/r_c}$ the tangential velocity in the æther vortex.

If the swirl is stable and constant at radius r, the swirl clock becomes periodic:

$$S(t) = \Omega(r)t \bmod 2\pi$$

encoding a persistent memory of internal vortex phase.

Temporal Phase vs. Duration

While T_v measures elapsed duration along the vortex loop (akin to proper time), the swirl clock $S(t)$ accumulates internal phase, encoding rotational memory modulo full revolutions. This distinction mirrors that between a watch counting seconds and a gyroscope preserving orientation — both describe time, but with fundamentally different informational content. In systems with quantized circulation, such as knotted vortex cores, $S(t)$ may serve as a persistent state variable marking phase-locked synchronization with external æther flows.

These temporal flows distinguish between the *absolute æther time* ($\mathcal{N}$), the *external observer's clock* (τ), and the *internal vortex timing* ($S(t)$, T_v). Their interaction forms the backbone of time dilation and causality in the VAM — not as a deformation of spacetime, but as a direct expression of circulation, angular momentum, and vortex topology.

To relate Chronos-Time τ to externally measured coordinate time $\bar{t}$, we introduce a frequency ratio expression based on the local swirl profile:

$$\frac{d\tau}{d\bar{t}} = \frac{\omega_{\text{obs}}}{\omega_0} \quad \text{(Chronos vs. External Clock Time)} \tag{13}$$

We define the observed angular frequency as:

$$\omega_{\text{obs}}(r) = \Omega(r) = \frac{C_e}{r_c} e^{-r/r_c}, \quad \text{and} \quad \omega_0 = \Omega(0) = \frac{C_e}{r_c}$$

so that:

$$\frac{d\tau}{d\bar{t}} = e^{-r/r_c}$$

This result shows that local vortex clocks experience exponential slowing relative to external time $\bar{t}$ as they approach the core. It expresses time dilation purely through internal vortex angular dynamics in the æther.

Frequency-Based Time Flow Interpretation

In VAM, the clock slowdown factor e^{-r/r_c} emerges naturally from the angular velocity decay of the vortex. This replaces the gravitational redshift of General Relativity with a swirl-based causal delay, aligning τ with rotational frame evolution and $\bar{t}$ with the external æther rest frame.

$$\boxed{\frac{d\tau}{d\bar{t}} = e^{-r/r_c}} \quad \text{where } \Omega(r) = \frac{C_e}{r_c} e^{-r/r_c} \tag{14}$$

Kairos Bifurcations in Temporal Flow

A Kairos Moment $\mathbb{K}$ occurs when vortex structure or energy density transitions cause a discontinuity in T_v or $S(t)$. These are irreversible from the ætheric viewpoint and may represent causal branching, event horizons, or topological recombinations. They do not merely slow time — they reshape its structure.

1.1 Derivation from vortex hydrodynamics

The derivation follows from the Bernoulli principle for an ideal fluid flow, given by:

$$P + \frac{1}{2}\rho_{æ} v^2 = \text{constant} \tag{15}$$

With vortex flow introduced via vorticity $\vec{\omega} = \nabla \times \vec{v}$, the local pressure reduction relative to the distant environment defines a local time delay. The local vortex velocity is given by:

$$v_\phi(r) = \frac{\Gamma}{2\pi r} = \frac{\kappa}{r} \tag{16}$$

where Γ is the circulation constant, and κ is the circulation quantum. Substitution of (16) into (9) gives explicitly:

$$\frac{d\tau}{dt} = \sqrt{1 - \frac{\kappa^2}{c^2 r^2}} \tag{17}$$

This explicitly expresses the time dilation in fundamental vortex parameters.

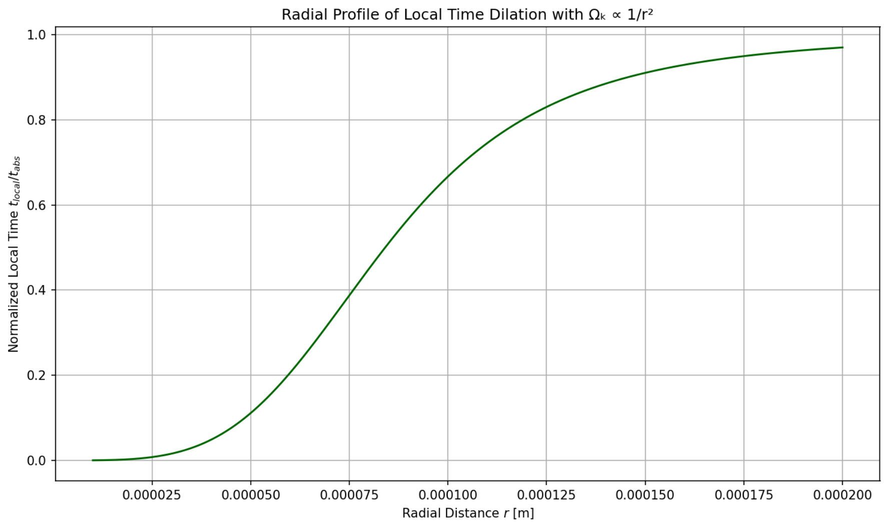

Figure 4: Radial time dilation profile due to vortex swirl velocity $v_\varphi(r) = \kappa/r$. The reduction in local clock rate $\frac{d\tau}{dt}$ scales with $1/r^2$, and asymptotically approaches 1 at large distances.

From	To	Conversion Formula
$\bar{t}$	τ	$\frac{d\tau}{d\bar{t}} = \omega_{\text{obs}}/\omega_0$
$\bar{t}$	T_v	$T_v = \oint \frac{dl}{v_\varphi(r)}$
τ	$S(t)$	$S(t) = \int \Omega(r(t))\, d\tau$
$\mathcal{N}$	T_v	$T_v = \int_0^{\mathcal{N}} \chi(r)\, d\mathcal{N}$ (if using *general time-chirality function*)

Table 6: Sample conversions between Temporal Ontology layers in VAM

1.2 GR vs VAM: Temporal Flow and Causality

For comparison, in general relativity (GR), gravitational time dilation arises from spacetime curvature, expressed by the Schwarzschild metric [5]:

$$\frac{d\tau}{dt} = \sqrt{1 - \frac{2GM}{rc^2}} \tag{18}$$

The similarities and differences are immediately apparent: GR's gravitational time dilation is related to mass M and gravitational constant G, while VAM time dilation is purely hydrodynamic and directly connected to the local rotational velocity of the æther medium via vortex circulation κ.

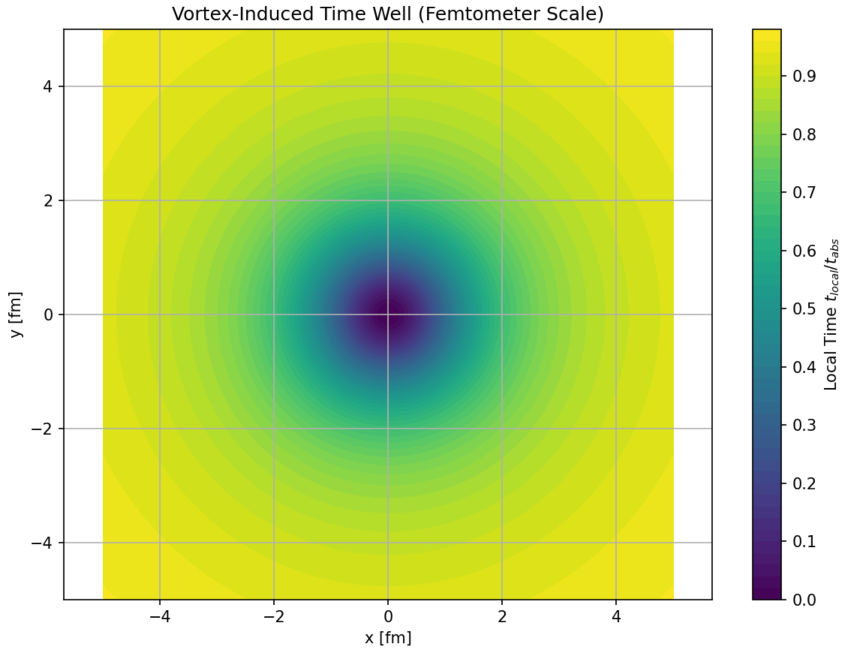

Figure 5: Comparison of VAM (vortex dynamics) and GR time dilation, as a function of distance to vortex core and Schwarzschild radius.

In Figure 5 we see that VAM time dilation is functionally comparable to GR prediction at sufficient distance. At decreasing distance (near vortex core or Schwarzschild radius) differences arise due to vortex-specific effects and topological node structures.

In summary, the VAM replaces spacetime curvature with eddy dynamics, while preserving measurable time dilation effects consistent with established experimental results such as Hafele–Keating [6], but from a fundamentally different physical explanation.

For illustration, in Figure 6 we explicitly compare VAM and GR for a neutron star with $M = 2\,M_\odot$ and radius $R = 10\,\text{km}$. The differences become clear near the surface of the object, where vortex-specific effects occur.

1.3 Practical implications and experimental testability

A practical implication of vortex-induced time dilation is that clocks would run measurably slower close to intense vortex fields. This can be tested theoretically with ultra-precise atomic clocks in laboratory vortex experiments, or indirectly via astrophysical observations of pulsars and neutron stars. The Hafele–Keating experiment provides a direct analogy for time dilation due to motion and height differences, which in VAM corresponds to local vortex variations [6].

2 Entropy and Quantum Effects in the Vortex Æther Model

The Vortex Æther Model (VAM) provides a mechanistic basis for both thermodynamic and quantum mechanical phenomena, not through postulates about abstract state spaces, but via the dynamics of knots and vortices in a superfluid æther. Two central concepts—entropy

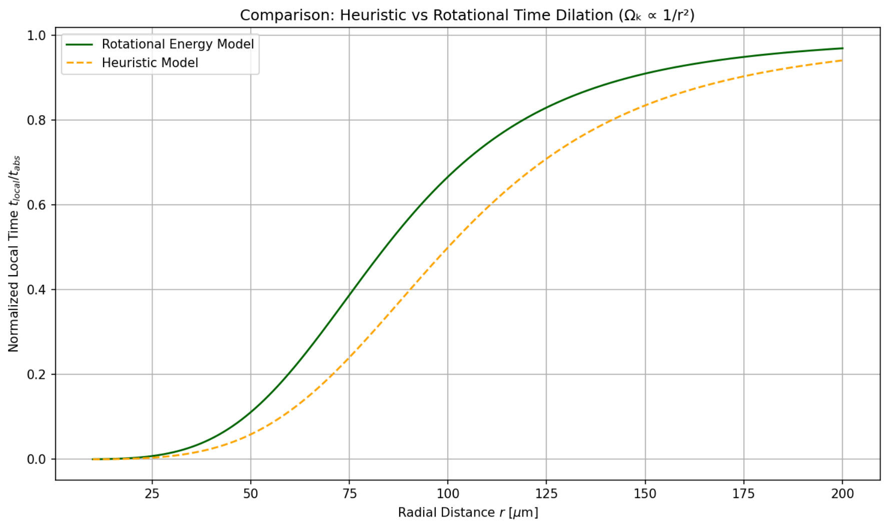

Figure 6: Difference between VAM and GR time dilation for a neutron star ($2\,M_\odot$, $R = 10$ km).

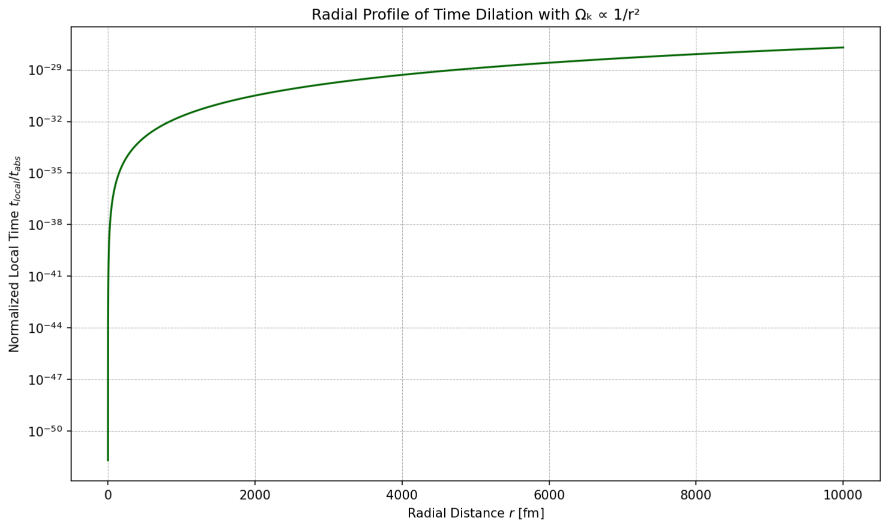

Figure 7: Extended radial time dilation profile with $\Omega_k \propto 1/r^2$, showing deep time well characteristics of vortex fields at large radius.

and quantization—are derived in VAM from vorticity distribution and knot topology, respectively.

2.1 Entropy as vorticity distribution

In thermodynamics, entropy S is a measure of the internal energy distribution or disorder. In VAM, entropy does not arise as a statistical phenomenon, but from spatial variations in vorticity. For a vortex configuration V the entropy is given by:

$$S \propto \int_V \|\vec{\omega}\|^2 \, dV, \tag{19}$$

where $\vec{\omega} = \nabla \times \vec{v}$ is the local vorticity. This means:

- **More rotation = more entropy**: Regions with strong swirl contribute to increased entropy, and these same regions experience a local slowdown in Chronos-Time τ relative to the external time $\bar{t}$:
$$\frac{d\tau}{d\bar{t}} = e^{-r/r_c}$$

- **Thermodynamic behavior arises from vortex expansion**: With the addition of energy (heat), the vortex boundary expands, the swirl decreases, and S increases—analogy with gas expansion. This expansion is accompanied by a **temporal acceleration** as local T_ω rises and time flow speeds up toward $\bar{t}$.

This interpretation connects Clausius' heat theory with æther mechanics: heat is equivalent to increased swirl spreading.

2.2 Quantum behavior from knotted vortex structures

Quantum phenomena such as discrete energy levels, spin, and wave-particle duality originate in VAM from topologically conserved vortex knots:

- **Circulation quantization:**
$$\Gamma = \oint \vec{v} \cdot d\vec{l} = n \cdot \kappa, \tag{20}$$
where $\kappa = h/m$ and $n \in \mathbb{Z}$ is the winding number.

- **Integers arise from knot topology:** The helical structure of a vortex knot (such as a trefoil) provides discrete states with certain linking numbers L_k.

- **Helicity as a spin analogue:**
$$H = \int \vec{v} \cdot \vec{\omega} \, dV, \tag{21}$$
where H is invariant under ideal flow, just as spin is conserved in quantum mechanics.

Each knotted vortex structure also encodes a dual internal temporal signature: the swirl clock $S(t)$ tracks its accumulated phase angle over time, while the vortex proper time T_v represents the inertial duration of its circulation loop. These two modes of time evolution—phase-based and inertial—govern how knots store memory, synchronize with external æther fields, and respond to perturbations.

2.3 VAM interpretation of quantization and duality

Instead of abstract Hilbert spaces, VAM considers a particle as a stable node in the æther field. This vortex configuration has:

- A **core** (nodal body) with quantum jumps (resonances).
- An **outer field** that acts as a wave (like the Schrödinger wave).
- A **helicity** that behaves as internal degrees of freedom (e.g. spin).

The wave-particle dualism thus arises from the fact that knots are both localized (core) and spread out (field). This wave-like behavior emerges from the phase evolution governed by $S(t)$, while the localized core evolves on its own vortex proper time T_v. Wave-particle duality in VAM thus reflects a dual temporal encoding: global phase memory vs. local inertial duration.

2.4 Summary

VAM thus provides a coherent, fluid-mechanical origin for both:

1. **Thermodynamics:** Entropy arises from swirl distribution.
2. **Quantum mechanics:** Quantization and duality are emergent properties of knotted vortex topologies.

This approach shows that quantum and thermodynamic phenomena are not fundamentally different, but arise from the same vortex mechanism at different scales.

Entropy as a Vorticity-Weighted Invariant

In the Vortex Æther Model (VAM), we reinterpret classical entropy as a conserved scalar related to the internal vorticity structure of knotted field regions. The classical thermodynamic differential form:

$$dS = \frac{\delta Q}{T}, \tag{22}$$

acquires a new form when heat exchange is replaced by rotational stress input into vortex knots:

$$dS = \frac{\delta \Pi_{\text{rot}}}{\mathcal{T}_\omega}, \tag{23}$$

where:

- $\delta \Pi_{\text{rot}}$ is the differential rotational energy input to the vortex core,
- $\mathcal{T}_\omega$ is the effective swirl-defined temperature field,
- $\omega = \nabla \times \vec{v}$ is the local vorticity.

This connects thermodynamic irreversibility directly to vorticity injection and local time dilation. High ω regions experience reduced swirl temperature $\mathcal{T}_\omega$ and a corresponding slowdown of Chronos-Time τ, anchoring entropy production in both energy and time gradients.

VAM Pressure Gradients and Entropy Flow

In VAM, pressure gradients are induced by angular momentum conservation in the æther. The classical Euler equation for incompressible inviscid flow:

$$\nabla P = -\rho_{æ} (\vec{v} \cdot \nabla) \vec{v}, \tag{24}$$

is used to express entropy production through vorticity current divergence:

$$\frac{dS}{dt} = \int_V \frac{\nabla \cdot \vec{J}_{\text{vortex}}}{T_\omega} \, dV, \tag{25}$$

where $\vec{J}_{\text{vortex}}$ is the swirl energy flux density. This forms the entropy production analogue of Fourier's heat conduction law within the vortex medium.

Thermal Expansion of Vortex Knots

Inspired by Clausius' treatment of thermal expansion, we define a vorticity-based expansion law for knotted vortex structures:

$$\Delta V_{\text{knot}} = \alpha_\omega V_0 \Delta T_\omega, \tag{26}$$

with:

$$\alpha_\omega = \frac{1}{r_c} \frac{dr_k}{dT_\omega} \sim \frac{C_e^2}{r_c k_B T_\omega}, \tag{27}$$

where r_k is the effective knot radius, r_c is the core radius, C_e the core swirl velocity, and k_B the Boltzmann constant. Knot inflation in VAM thus follows from ætheric heating.

Clausius Inequality and Helicity Dissipation

The Clausius inequality:

$$\oint \frac{\delta Q}{T} \leq 0, \tag{28}$$

is reinterpreted in VAM as a constraint on helicity-induced vorticity flow:

$$\oint \frac{\vec{v} \cdot d\vec{\omega}}{\mathcal{T}_\omega} \leq 0, \tag{29}$$

which implies that net swirl energy circulation around closed loops is dissipative unless compensated by external ætheric drive. This underpins the irreversibility of vortex-knot interactions.

Carnot Efficiency in Swirl Fields

Classical Carnot engine efficiency:

$$\eta = 1 - \frac{T_C}{T_H}, \tag{30}$$

can be reformulated in VAM via vorticity amplitudes:

$$\eta_{\text{VAM}} = 1 - \frac{\Omega_C^2}{\Omega_H^2}, \tag{31}$$

where Ω_H and Ω_C are internal angular velocities of vortex knots in high and low swirl zones. This formulation links macroscopic energy conversion directly to microscopic vorticity gradients. Because Ω^2 maps to time dilation via $d\tau/d\bar{t} \sim \sqrt{1 - \Omega^2 r^2/c^2}$, the Carnot efficiency η_{VAM} can also be seen as a ratio of internal clock rates — bounding how much time-dependent swirl work can be extracted between two ætheric layers of differing temporal flow.

3 Time Modulation by Rotation of Vortex Nodes

Building on the discussion of time dilation via pressure and Bernoulli dynamics in the previous section, we now focus on the intrinsic rotation of topological vortex nodes. In the Vortex Æther Model (VAM), particles are modeled as stable, topologically conserved vortex nodes embedded in an incompressible, inviscid superfluid medium. Each node possesses a characteristic internal angular frequency Ω_k, and this internal motion induces local time modulation with respect to the absolute time $\mathcal{N}$ of the æther.

Instead of warping spacetime, we propose that internal rotational energy and helicity conservation cause temporal delays analogous to gravitational redshift. In this section, these ideas are developed using heuristic and energetic arguments consistent with the hierarchy introduced in Section I.

3.1 Heuristic and Energetic Derivation

We start by proposing a rotationally induced time dilation formula based on the internal angular frequency of the vortex node:

$$\frac{d\tau}{d\mathcal{N}} = \left(1 + \beta\Omega_k^2\right)^{-1} \quad \text{(Chronos-Time slowdown due to internal vortex rotation)} \tag{32}$$

where:

- τ is the local Chronos-Time (proper time experienced by the vortex structure),
- $\mathcal{N}$ is the absolute Aithēr-Time (universal causal background),
- Ω_k is the mean core angular frequency,
- β is a coupling coefficient with units $[\beta] = \mathrm{s}^2$.

For a physical derivation of the relationship $d\tau/d\mathcal{N}$ in a rotating æther field, see Appendix A. For small angular velocities we obtain a first-order expansion:

$$\frac{d\tau}{d\mathcal{N}} \approx 1 - \beta\Omega_k^2 + \mathcal{O}(\Omega_k^4) \tag{33}$$

This mirrors the low-velocity expansion of the Lorentz factor in special relativity:

$$\frac{t_{\text{moving}}}{t_{\text{rest}}} \approx 1 - \frac{v^2}{2c^2} \tag{34}$$

We observe that internal rotation in VAM induces time dilation just as relative motion does in SR—yet from internal dynamics, not frame-relative velocity.

To support this with physical grounding, we connect time dilation to rotational energy. Suppose the vortex node has an effective moment of inertia I. The rotational energy becomes:

$$E_{\text{rot}} = \frac{1}{2} I\Omega_k^2 \tag{35}$$

This leads to the energetic expression:

$$\frac{d\tau}{d\mathcal{N}} = (1 + \beta E_{\text{rot}})^{-1} = \left(1 + \frac{1}{2}\beta I\Omega_k^2\right)^{-1} \tag{36}$$

This equation parallels the pressure-induced time modulation derived from Bernoulli dynamics earlier in the paper and supports the concept of rotational time wells induced by internal energy storage.

Temporal Mapping for Vortex Nodes

In the Vortex Æther Model:

- $\mathcal{N}$ — **Aithēr-Time:** Universal causal flow (background time),
- τ — **Chronos-Time:** Local inertial time along vortex evolution,
- $S(t)$ — **Swirl Clock:** Phase memory due to internal angular rotation.

Equation (32) captures how increasing swirl leads to slower proper time relative to the ætheric background.

3.2 Topological and Physical Justification

Topological vortex nodes are characterized not only by rotation, but also by helicity:

$$H = \int \vec{v} \cdot \vec{\omega} \, d^3x \tag{37}$$

Helicity is a conserved quantity in ideal fluids and encodes the topological linkage and twist of vortex lines. Thus, the rotation frequency Ω_k becomes a signature of the knot's identity and energy state.

Higher Ω_k values produce stronger swirl wells and deeper pressure minima, resulting in longer internal durations per unit $\mathcal{N}$. This time dilation is interpreted as a reduction in Chronos-Time, not as a change in spacetime geometry.

Each particle is a topological vortex knot, where:

- **Charge** maps to chirality and rotational direction,
- **Mass** maps to total vortex energy (and inertia),
- **Spin** maps to knot helicity and winding structure.

Knot type (e.g. Hopf, Trefoil) determines its stability and energetic minimum.

This model:

- Attributes temporal modulation to conserved rotational energy,
- Requires no relativistic reference frames,
- Embeds all time shifts within the æther's causal substrate $\mathcal{N}$,
- Provides a direct fluid-mechanical analogue to gravitational redshift.

In summary: Vortex-induced time dilation in VAM is governed by the equation

$$\frac{d\tau}{d\mathcal{N}} = \left(1 + \beta\Omega_k^2\right)^{-1}$$

showing that Chronos-Time slows as internal vortex angular velocity increases — a purely mechanical, topologically-grounded origin of time dilation, replacing the abstract spacetime curvature of general relativity.

4 Proper Time for a Rotating Observer in Æther Flow

Having established time dilation in the Vortex Æther Model (VAM) through pressure, angular velocity, and rotational energy, we now extend the formalism to rotating observers embedded in structured æther flow. This section demonstrates that fluid-dynamical time modulation in VAM can reproduce expressions structurally similar to those derived from general relativity (GR), particularly in axially symmetric rotating spacetimes such as the Kerr geometry. However, unlike GR, VAM achieves this without invoking spacetime curvature. All time modulation arises from kinetic variables defined in the æther field, measured against a universal absolute time $\mathcal{N}$.

4.1 GR Proper Time in Rotating Frames

In general relativity, the proper time $d\tau_{\mathrm{GR}}$ for an observer with angular velocity Ω_{eff} in a stationary, axially symmetric spacetime is given by:

$$\left(\frac{d\tau_{\mathrm{GR}}}{dt}\right)^2 = -\left[g_{tt} + 2g_{t\varphi}\Omega_{\mathrm{eff}} + g_{\varphi\varphi}\Omega_{\mathrm{eff}}^2\right] \tag{38}$$

where $g_{\mu\nu}$ are components of the spacetime metric (e.g., Boyer–Lindquist coordinates for the Kerr metric). This accounts for gravitational redshift and rotational frame-dragging.

4.2 Æther-Based Analogy: Velocity-Derived Time Modulation

In VAM, spacetime is flat, and all temporal effects emerge from dynamics within the superfluid æther. The local time rate experienced by an observer is Chronos-Time τ, while background time flows uniformly as Aithēr-Time $\mathcal{N}$. Observers rotating within the flow experience time modulation due to their immersion in local velocity gradients.

Let the local flow velocities be:

- v_r: radial inflow velocity,
- $v_\varphi = r\Omega_k$: tangential velocity from local vortex rotation,
- $\Omega_k = \frac{\kappa}{2\pi r^2}$: local angular velocity for circulation κ.

We introduce a correspondence between GR metric coefficients and effective kinetic terms in VAM:

$$\begin{aligned} g_{tt} &\to -\left(1 - \frac{v_r^2}{c^2}\right), \\ g_{t\varphi} &\to -\frac{v_r v_\varphi}{c^2}, \\ g_{\varphi\varphi} &\to -\frac{v_\varphi^2}{c^2 r^2} \end{aligned} \tag{39}$$

Substituting these into the GR-like expression for proper time gives the VAM-based analogue:

$$\left(\frac{d\tau}{d\mathcal{N}}\right)^2 = 1 - \frac{v_r^2}{c^2} - \frac{2v_r v_\varphi}{c^2} - \frac{v_\varphi^2}{c^2} \tag{40}$$

Grouping the terms yields:

$$\left(\frac{d\tau}{d\mathcal{N}}\right)^2 = 1 - \frac{1}{c^2}(v_r + v_\varphi)^2 \tag{41}$$

This expression demonstrates that both gravitational redshift and frame-dragging emerge in VAM as consequences of cumulative local velocity fields in the æther. Swirl angular velocity Ω_k, circulation κ, and radial inflow all contribute to **Chronos-Time contraction**.

$$\boxed{\left(\frac{d\tau}{d\mathcal{N}}\right)^2 = 1 - \frac{1}{c^2}(v_r + r\Omega_k)^2} \tag{42}$$

4.3 Physical Interpretation and Temporal Consistency

This boxed expression directly mirrors the Kerr-style GR proper time but is derived entirely from classical fluid mechanics. It reveals that as the net local æther velocity approaches c, the internal flow of time τ slows — not due to geometry, but due to energy accumulation in swirl and radial inflow.

Key observations:

- In the limit $v_r \to 0$, time modulation arises purely from rotational swirl Ω_k.
- When both v_r and Ω_k are nonzero, the cumulative velocity decreases the Chronos-Time rate τ relative to $\mathcal{N}$.
- This velocity-based model is consistent with Section II's energetic dilation $\frac{d\tau}{d\mathcal{N}} = (1 + \beta E_{\text{rot}})^{-1}$, identifying local kinetic energy as the origin of gravitational-like time wells.

Chronos-Time in a Rotating Æther

In VAM, the proper time τ of a rotating observer in æther flow is governed by the total local velocity:

$$\frac{d\tau}{d\mathcal{N}} = \sqrt{1 - \frac{(v_r + r\Omega_k)^2}{c^2}}$$

This relation defines a **fluidic redshift** effect that replicates GR's temporal structure without spacetime curvature.

Conclusion: The VAM formulation of proper time for rotating observers yields the same qualitative effects as GR's Kerr metric — including frame-dragging and redshift — but attributes them to structured velocity fields in the æther and a slowing of Chronos-Time τ relative to the universal background $\mathcal{N}$.

In the next section, we further develop this analogy by deriving VAM's version of the gravitational potential and circulation-induced redshift as a fluid dynamical replacement for the Kerr horizon structure.

5 Kerr-like Time Adjustment Based on Vorticity and Circulation

To complete the analogy between general relativity (GR) and the Vortex Æther Model (VAM), we derive a time modulation expression that mimics the redshift and frame-dragging structure of the Kerr solution. In GR, the Kerr metric describes the curved spacetime near a rotating mass, leading to gravitational time dilation and frame-dragging. In VAM, similar effects arise from local vorticity intensity and circulation in a flat æther, relative to absolute time $\mathcal{N}$.

5.1 General Relativistic Kerr Redshift Structure

In the GR-Kerr metric, the proper time $d\tau_{\text{GR}}$ for an observer is slowed by both mass-energy and angular momentum:

$$t_{\text{adjusted}} = \Delta t \cdot \sqrt{1 - \frac{2GM}{rc^2} - \frac{J^2}{r^3c^2}} \tag{43}$$

with:

- M: mass,
- J: angular momentum,
- r: radius,
- G: gravitational constant,
- c: speed of light.

5.2 VAM Analogy via Vorticity and Circulation

In VAM, we substitute GR's mass and angular momentum terms with vorticity-based quantities:

- $\langle \omega^2 \rangle$: spatially averaged squared vorticity (linked to energy density),
- κ: total circulation (encoding angular momentum).

The mapping becomes:

$$\begin{gathered} \frac{2GM}{rc^2} \to \frac{\gamma \langle \omega^2 \rangle}{rc^2}, \\ \frac{J^2}{r^3c^2} \to \frac{\kappa^2}{r^3c^2} \end{gathered} \tag{44}$$

where γ is a coupling constant derived from æther properties.

The VAM redshift-adjusted external time $\bar{t}$ observed at infinity becomes:

$$\boxed{\frac{d\tau}{d\bar{t}} = \sqrt{1 - \frac{\gamma \langle \omega^2 \rangle}{rc^2} - \frac{\kappa^2}{r^3c^2}}} \tag{45}$$

This replaces the geometric redshift of GR with a purely fluid-based expression. In the absence of vorticity and circulation, $\tau \to \bar{t}$, recovering flat time flow. In this figure:

- $\langle \omega^2 \rangle$ plays the role of energy density that produces gravitational redshift,
- κ represents angular momentum that generates temporal frame-dragging,
- The equation reduces to a flat æther time ($t_{\text{adjusted}} \to \Delta t$) when both terms vanish.

Hybrid Frame-Dragging Angular Velocity in VAM

Frame-dragging in VAM emerges from vortex coupling to surrounding flow. The effective angular velocity imposed on surrounding regions becomes:

$$\omega_{\text{drag}}^{\text{VAM}}(r) = \frac{4Gm}{5c^2 r} \cdot \mu(r) \cdot \Omega(r) \tag{46}$$

with a scale-dependent interpolation factor:

$$\mu(r) = \begin{cases} \frac{r_c C_e}{r^2}, & r < r_* \quad \text{(quantum/vortex regime)} \\ 1, & r \geq r_* \quad \text{(macroscopic limit)} \end{cases} \tag{47}$$

This allows for continuity between quantum vortex-induced frame-dragging and classical GR effects. where:

- r_c is the radius of the vortex core,
- C_e is the tangential velocity of the vortex core,
- $r_* \sim 10^{-3}$ m is the transition radius between microscopic and macroscopic regimes.

This formulation provides continuity with GR predictions for celestial bodies, while allowing VAM-specific predictions for elementary particles and subatomic vortex structures.

Gravitational Redshift from Vortex Core Rotation

Gravitational redshift in VAM arises from tangential velocity $v_\varphi = \Omega(r) \cdot r$ at the vortex periphery. The redshift becomes:

$$z_{\text{VAM}} = \left(1 - \frac{v_\varphi^2}{c^2}\right)^{-\frac{1}{2}} - 1 \tag{48}$$

This defines the deviation of external clock time $\bar{t}$ from Chronos-Time τ near the vortex. As $v_\varphi \to c$, the local observer experiences time freeze:

$$\lim_{v_\varphi \to c} z_{\text{VAM}} \to \infty$$

where:

- $v_\phi = \Omega(r) \cdot r$ is the tangential velocity due to local rotation,
- $\Omega(r)$ is the angular velocity at the measurement beam r,
- c is the speed of light in vacuum.

This expression reflects the change in time perception caused by local rotational energy, replacing the curvature-based gravitational potential Φ of general relativity with a velocity field term. It becomes equivalent to the GR Schwarzschild redshift for low v_ϕ and diverges as $v_\phi \to c$, which provides a natural limit to the evolution of the local frame:

Time Dilation Models in VAM

Velocity-based time dilation (outer observer):

$$\frac{d\tau}{d\bar{t}} = \sqrt{1 - \frac{\Omega^2 r^2}{c^2}} = \sqrt{1 - \frac{v_\varphi^2}{c^2}} \tag{49}$$

Energy-based time dilation (core structure):

$$\frac{d\tau}{d\mathcal{N}} = \left(1 + \frac{1}{2} \cdot \beta \cdot I \cdot \Omega^2\right)^{-1} \tag{50}$$

where:
- $\mathcal{N}$ is Aithēr-Time, - τ is Chronos-Time, - $I = \frac{2}{5}mr^2$, $\beta = \frac{r_c^2}{C_e^2}$.

This dual-model captures both peripheral redshift (via $\bar{t}$) and intrinsic time contraction (via $\mathcal{N}$).

In the Vortex Æther Model (VAM), local time dilation is interpreted as the modulation of absolute time by internal vortex dynamics, not by spacetime curvature. Depending on the system scale, two physically based formulations are used:

1. Time dilation based on velocity fields This model relates the local time flow to the tangential speed of the rotating ætheric structure (vortex node, planet or star):

$$\frac{d\tau}{d\bar{t}} = \sqrt{1 - \frac{v_\phi^2}{c^2}} = \sqrt{1 - \frac{\Omega^2 r^2}{c^2}} \quad \text{(external observer)} \tag{51}$$

whereby:

- $v_\phi = \Omega \cdot r$ is the tangential speed,
- Ω is the angular velocity at radius r,
- c is the speed of light.

This expresses how a local observer's Chronos-Time τ slows down relative to a distant clock, as seen in:

- redshift measurements
- external clocks
- comparisons to signals emitted from afar.

2. Time dilation based on rotational energy On large scales or with high rotational inertia, time dilation arises from stored rotational energy, leading to:

$$\frac{d\tau}{d\mathcal{N}} = \left(1 + \frac{1}{2} \cdot \beta \cdot I \cdot \Omega^2\right)^{-1} \quad \text{(background time)} \tag{52}$$

with:

- $I = \frac{2}{5}mr^2$: moment of inertia for a uniform sphere,
- $\beta = \frac{r_c^2}{C_e^2}$: coupling constant of vortex-core dynamics,
- m is the mass of the object.

This describes how the local vortex structure's internal clock slows due to stored rotational energy, measured relative to the universal causal background $\mathcal{N}$ — i.e., the absolute time field of the æther. It reflects internal modulation of a structure's proper time due to internal dynamics — not relative motion.

Temporal Ontology Integration Summary

- $\mathcal{N}$ — Universal Aithēr-Time,
- $\bar{t}$ — External Clock Time (distant observer),
- τ — Local Chronos-Time (experienced time),
- $S(t)$ — Swirl Clock phase evolution,
- T_v — Vortex Proper Time along internal loop.

The combined time dilation structure can be captured schematically as:

$$\boxed{\frac{d\tau}{d\bar{t}} = \sqrt{1 - \frac{\gamma\langle\omega^2\rangle}{rc^2} - \frac{\kappa^2}{r^3c^2}} \cdot \left(1 + \frac{1}{2}\beta I\Omega^2\right)^{-1}} \tag{53}$$

Interpretation These models imply that time slows down in regions of high local rotational energy or vorticity, consistent with gravitational time dilation effects in GR. In VAM, however, these effects arise exclusively from the internal dynamics of the æther flow, under flat 3D Euclidean geometry and absolute time.

Model Scope and Outlook

These expressions assume:F - Ideal incompressible superfluid, - Irrotational flow outside vortex cores, - Neglect of turbulence and boundary-layer effects.

Appendix H provides detailed derivations of energy transfer across interacting vortex layers. In future work, quantized circulation and ætheric boundary effects may refine these models further.

6 Unified Framework and Synthesis of Time Dilation in VAM

This section unifies all time dilation mechanisms developed throughout this work under the Vortex Æther Model (VAM). Instead of relying on spacetime curvature, VAM attributes temporal effects to classical fluid dynamics, rotational energy, and topological vorticity embedded in an absolute superfluid medium.

6.1 Hierarchical Structure of Time Dilation Mechanisms

Each mechanism introduced in previous sections corresponds to a physically distinct layer of time modulation in the æther:

1. **Bernoulli-Induced Time Depletion:** Time slows down in low-pressure regions due to vortex-induced kinetic fields. When $\rho_æ/p_0 \sim 1/c^2$, the Bernoulli velocity field reproduces SR-like time dilation.
2. **Heuristic Angular Frequency Dilation:** A first-order expansion in internal angular frequency Ω_k yields:
$$\frac{d\tau}{d\mathcal{N}} \approx 1 - \beta\Omega_k^2$$
mimicking Lorentz factor expansions.

3. **Energetic Time Dilation from Rotational Inertia:**

$$\boxed{\frac{d\tau}{d\mathcal{N}} = \left(1 + \frac{1}{2}\beta I \Omega_k^2\right)^{-1}}$$

based on rotational energy of a vortex node.

4. **Proper Time in a Vortex Flow Field:**

$$\boxed{\left(\frac{d\tau}{d\bar{t}}\right)^2 = 1 - \frac{1}{c^2}(v_r + r\Omega_k)^2}$$

deriving GR-like behavior from tangential + radial æther velocity.

5. **Kerr-Like Redshift with Vorticity and Circulation:**

$$\boxed{\frac{d\tau}{d\bar{t}} = \sqrt{1 - \frac{\gamma\langle\omega^2\rangle}{rc^2} - \frac{\kappa^2}{r^3c^2}}}$$

fluid-based replacement for GR Kerr redshift structure.

Together, these span from microscale vortex energetics to macroscale rotation and redshift analogies, offering a complete and experimentally accessible formulation of time dilation in a flat 3D ætheric medium.

6.2 Time as a Vorticity-Derived Observable

Across all levels, time modulation in VAM reduces to local energetics:

- Pressure, velocity, and swirl induce local slowing of Chronos-Time τ.
- Core angular frequency Ω_k governs vortex Proper Time T_v.
- Accumulated swirl phase $S(t)$ encodes vortex history and coherence.
- Background evolution proceeds along absolute Aithēr-Time $\mathcal{N}$.

Time becomes an emergent fluid quantity, shaped by:

- Kinetic flow energy,
- Rotational inertia,
- Vorticity intensity $\langle\omega^2\rangle$,
- Topologically conserved circulation κ.

This leads to a boxed synthesis:

$$\boxed{\frac{d\tau}{d\bar{t}} = \sqrt{1 - \frac{\gamma\langle\omega^2\rangle}{rc^2} - \frac{\kappa^2}{r^3c^2}} \cdot \left(1 + \frac{1}{2}\beta I \Omega_k^2\right)^{-1}} \tag{54}$$

6.3 Experimental Implications and Prospects

The following systems may be used to validate aspects of this framework:

- Rotating superfluid droplets (helium-II, BECs),
- Plasma vortex lifters and EHD propulsion systems,
- Magneto-fluidic toroidal devices or photonic vortex rings,
- Rotating dielectric experiments with Swirl Clock analogs.

Future directions:

- Measure vortex-induced clock drift in rotating superfluids.
- Apply to neutron star precession, Lense–Thirring analogs.
- Derive feedback models of interacting vortex clocks in multi-body ætheric networks.

6.4 Conceptual Challenges and Reception

Assumptions:

- Existence of absolute time $\mathcal{N}$,
- Incompressible, inviscid superfluid æther,
- Structured vortex knots as physical particles.

Resistance:

- Contradicts mainstream relativistic orthodoxy,
- Requires reinterpretation of spacetime as emergent, not fundamental.

6.5 Paths to Scientific Rigor and Acceptance

- **Testable predictions:** where VAM diverges from GR.
- **Integration:** recover GR/QM limits for boundary cases.
- **Redefinition:** modern æther = structured field, not rigid ether.
- **Open review:** encourage formal peer critique and simulation.
- **Clarity:** maintain symbolic and dimensional transparency.

6.6 Concluding Perspective

The Vortex Æther Model (VAM) replaces the geometry of curved spacetime with a dynamic, energetic æther in which time flows at different rates due to vorticity and circulation. This provides a coherent, layered framework in which relativistic effects arise naturally from fluid variables, with internal clocks modulated by swirl dynamics and structure-preserving topology.

As a next step, a Lagrangian formalism incorporating τ, T_v, $S(t)$, and $\mathcal{N}$ can unify gravity, quantum behavior, and thermodynamics under a common ætheric field theory.

7 Applications of VAM to Quantum and Nuclear Processes

LENR via Resonance Tunneling and Temporal Modulation

In the Vortex Æther Model (VAM), gravitational decay due to local vorticity temporarily lowers the Coulomb barrier, shifting the rate of local *Chronos-Time* (τ) and inducing a transient *Kairos Moment* (κ)—a topological and energetic bifurcation—where irreversible tunneling becomes energetically favorable:

$$V_{\text{Coulomb}} = \frac{Z_1 Z_2 e^2}{4\pi\varepsilon_0 r}, \quad \Delta P = \frac{1}{2}\rho_{æ} r_c^2 (\Omega_1^2 + \Omega_2^2) \tag{55}$$

Resonance occurs when:

$$\Delta P \geq \frac{Z_1 Z_2 e^2}{4\pi\varepsilon_0 r_t^2} \tag{56}$$

Rather than invoking purely probabilistic tunneling, VAM attributes the transition to real pressure gradients in a structured æther. This echoes the causal flow picture of Holland [7], in which trajectories are guided by underlying fields rather than collapsed by observation.

Resonant Ætheric Tunneling and LENR in VAM

LENR events are thus reinterpreted as phase-locked vortex interactions within the æther, where pressure minima—caused by Bernoulli-type deficits from vortex swirl—transiently erase the Coulomb barrier [8, 9].

The classical Coulomb repulsion between two nuclei is:

$$V_{\text{Coulomb}}(r) = \frac{Z_1 Z_2 e^2}{4\pi\varepsilon_0 r} \tag{57}$$

In VAM, two rotating vortex nodes near $r \sim 2r_c$ generate a pressure drop:

$$\Delta P = \frac{1}{2}\rho_{æ} r_c^2 (\Omega_1^2 + \Omega_2^2) \tag{58}$$

The effective potential becomes:

$$V_{\text{eff}}(r) = V_{\text{Coulomb}}(r) - \Phi_\omega(r) \tag{59}$$

with the vorticity (eddy) potential defined as:

$$\Phi_\omega(r) = \gamma \int \frac{|\vec{\omega}(r')|^2}{|\vec{r} - \vec{r}'|} d^3r', \quad \text{where} \quad \gamma = G\rho_{æ}^2 \tag{60}$$

Resonant tunneling occurs when:

$$\frac{1}{2}\rho_{æ} r_c^2 (\Omega_1^2 + \Omega_2^2) \geq \frac{Z_1 Z_2 e^2}{4\pi\varepsilon_0 r_t^2} \tag{61}$$

This process manifests as a local disruption in the vortex-phase evolution $S(t)$, corresponding to a *Kairos Moment* (κ)—a non-reversible, quantized transition in the topology of the field structure. The tunneling does not proceed by stochastic amplitude leakage, but via real-time phase-coherent alignment of swirl dynamics.

Temporal Interpretation: At the critical separation r_t, the reduction in $\bar{t}$-duration (as seen by external observers) corresponds to a locally accelerated evolution in the Swirl Clock $S(t)$, while the internal Chronos-Time τ of the system undergoes inflection. This manifests as a moment of energetic coincidence across temporal layers, enabling otherwise forbidden nuclear transitions.

This mechanism offers a testable, topologically anchored alternative to conventional quantum tunneling, and may help explain anomalous energy release observed in some LENR experiments [10].

VAM Quantum Electrodynamics (QED) Lagrangian

In the Vortex Æther Model (VAM), the interaction between vortex structures and electromagnetic fields emerges from the helical motion of knotted vortex cores. These structures induce localized vector potentials in the surrounding æther, and thus replace the conventional QED framework with a topological fluid-dynamic interpretation.

The VAM analog of the standard QED Lagrangian is:

$$\mathcal{L}_{\text{VAM-QED}} = \bar{\psi} \left[i\gamma^\mu \partial_\mu - \gamma^\mu \left(\frac{C_e^2 r_c}{\lambda_c} \right) A_\mu - \left(\frac{8\pi \rho_{æ} r_c^3 \,\text{Lk}}{C_e} \right) \right] \psi - \frac{1}{4} F_{\mu\nu} F^{\mu\nu} \tag{62}$$

In this formulation:

- The **mass term** emerges from the topological helicity (linking number Lk) of connected vortex cores, interpreted as a geometric invariant tied to conserved Vortex Proper Time T_v [9].
- The **electromagnetic coupling** arises not from a fundamental charge, but from ætheric circulation that induces the gauge potential A_μ.
- The **field tensor** $F_{\mu\nu}$ remains unchanged and still encodes the curl of the velocity field—interpreted now as the rotation of the superfluid æther medium rather than of spacetime.

This Lagrangian directly couples spinor fields to ætheric vorticity and replaces the usual constants m and q with emergent expressions involving core radius r_c, tangential velocity C_e, and topological helicity Lk. Mass and charge thus arise as vortex-induced effective quantities rather than as primitive attributes.

The resulting Euler–Lagrange equation yields:

$$\boxed{\left(i\gamma^\mu \partial_\mu - \gamma^\mu q_{\text{vortex}} A_\mu - M_{\text{vortex}} \right) \psi = 0} \tag{63}$$

This is structurally identical to the Dirac equation, but its parameters originate in the vortex configuration of the æther. Thus, VAM reinterprets the origin of inertial mass and electric charge as byproducts of topological flow in a superfluid medium [8, 9].

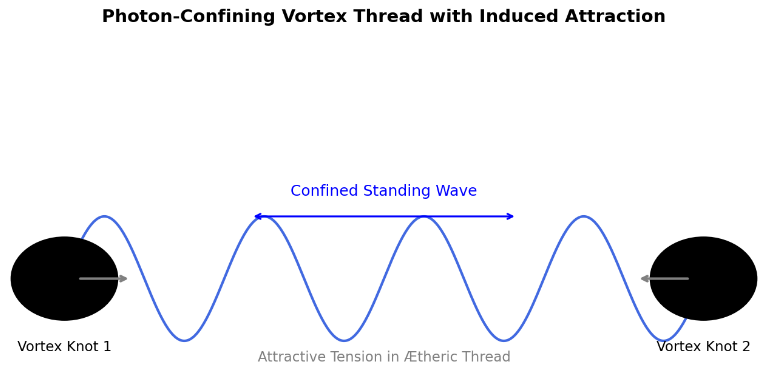

Figure 8: Photon confinement and guidance along vortex threads in the æther. This visualizes the VAM interpretation of electromagnetic propagation, where the photon exhibits localized trajectory bending and resonance around structured vortex lines. The confinement arises naturally from topological pressure minima and circulating æther flow, replacing the abstract field representation with a tangible vortex-based channel.

8 Emergent Bohr Radius from Vortex Swirl Pressure

To demonstrate how atomic structure arises in the Vortex Æther Model (VAM), we derive the Bohr radius from first principles using fluid dynamic forces. In this model, the electron is a knotted vortex core circulating with tangential speed C_e, and atomic stability arises from pressure gradients and swirl quantization.

Standard Quantum Bohr Radius

In canonical quantum mechanics, the Bohr radius is the radius of the lowest energy orbit in the hydrogen atom, balancing centripetal and Coulomb forces:

$$a_0 = \frac{4\pi\varepsilon_0\hbar^2}{m_e e^2} \tag{64}$$

Swirl Dynamics and Force Balance in VAM

In VAM, swirl flow replaces wavefunction orbitals. The tangential velocity at radius r due to vortex circulation is:

$$v_\phi(r) = \frac{\Gamma}{2\pi r}, \quad \text{with} \quad \Gamma = 2\pi r_c C_e \tag{65}$$

Thus:

$$v_\phi(r) = \frac{r_c C_e}{r} \tag{66}$$

Force balance between centrifugal and Coulomb-like tension in the æther gives:

$$\frac{m_e v_\phi^2}{r} = \frac{e^2}{4\pi\varepsilon_0 r^2} \tag{67}$$

Substituting:

$$\frac{m_e (r_c C_e)^2}{r^3} = \frac{e^2}{4\pi\varepsilon_0 r^2} \tag{68}$$

Multiply both sides by r^3 and solve for r:

$$a_0 = \frac{4\pi\varepsilon_0 m_e r_c^2 C_e^2}{e^2} \tag{69}$$

Numerical Evaluation

$$\begin{aligned}
\varepsilon_0 &= 8.854187817 \times 10^{-12}\ \mathrm{F/m} \\
m_e &= 9.1093837015 \times 10^{-31}\ \mathrm{kg} \\
r_c &= 1.40897017 \times 10^{-15}\ \mathrm{m} \\
C_e &= 1.09384563 \times 10^{6}\ \mathrm{m/s} \\
e &= 1.602176634 \times 10^{-19}\ \mathrm{C}
\end{aligned}$$

Substituting, we recover:

$$a_0 \approx 5.29 \times 10^{-11}\ \mathrm{m}$$

Swirl Clock Quantization and Stable Orbits

This equilibrium radius coincides with the **first harmonic phase-lock** of the Swirl Clock $S(t)$, where the angular phase of the circulating vortex completes a stable winding over vortex proper time T_v. Each quantized orbit corresponds to a resonance in $S(t)$ such that:

$$S(t) = 2\pi n, \quad n \in \mathbb{Z}^+$$

$$\Rightarrow \Omega_n T_v = 2\pi n \quad \text{(Quantized vortex phase winding)}$$

Thus, the Bohr radius is the radial location where a full swirl-phase cycle completes within a stable energetic well. This is not arbitrary but reflects æther-tuned topological resonance, producing **standing swirl modes** tied to the vortex knot's structure.

Temporal Interpretation

- Local **Chronos-Time** τ inside the vortex slows relative to the external $\bar{t}$ due to swirl-induced dilation:

$$\frac{d\tau}{d\bar{t}} = \sqrt{1 - \frac{v_\phi^2}{c^2}}$$

- The Bohr radius marks the radius where T_v and τ evolve stably under a quantized $S(t)$, enabling persistent atomic states.

Interpretation

$$\boxed{\text{Bohr radius in VAM} = \text{Stable tidal resonance of swirl pressure in a vortex-induced æther cavity}} \tag{70}$$

This reproduces quantum mechanical results through fluid analogs and structured vortex flows. No probability waves are invoked—only energetically balanced circulation under absolute time evolution.

Future Work

- Generalize to multi-electron atoms via nested swirl clock harmonics.
- Derive fine structure constant from coupling between $C_e, r_c, \rho_æ$.
- Quantize transitions as topological bifurcations in $S(t)$ — marking **Kairos Moments** κ.

9 VAM Vorticity Scattering Framework (inspired by elastic theory)

9.1 Governing equations of VAM Vorticity dynamics

Vorticity transport equation (linearized form)

In the Vortex Æther Model (VAM), the dynamics of the vorticity field $\vec{\omega} = \nabla \times \vec{v}$ is governed by the Euler equation and the associated vorticity form:

$$\frac{\partial \omega_i}{\partial t} + v_j \partial_j \omega_i = \omega_j \partial_j v_i$$

This nonlinear structure implies vortex deformation by stretching and advection. For small perturbations $\delta\omega$ near a background vortex node field $\omega^{(0)}$ linearization yields:

$$\frac{\partial(\delta\omega_i)}{\partial t} + v_j^{(0)} \partial_j(\delta\omega_i) \approx \omega_j^{(0)} \partial_j(\delta v_i)$$

Define the linear response operator of VAM $\mathcal{L}_{ij}$:

$$\mathcal{L}_{ij}\, \delta v_j(\vec{r}) = \delta F_i^{\text{vortex}}(\vec{r})$$

Green Tensor Vorticity Equation

$$\mathcal{L}_{ij}\, \mathcal{G}_{jk}(\vec{r}, \vec{r}') = -\delta_{ik}\, \delta(\vec{r} - \vec{r}')$$

The induced velocity field v_i of a source vortex force $F_k(\vec{r}')$ is then:

$$v_i(\vec{r}) = \int \mathcal{G}_{ik}(\vec{r}, \vec{r}')\, F_k^{\text{vortex}}(\vec{r}')\, d^3r'$$

9.2 Vortex filament interaction

Interactions arise from exchange of vortex force or Reconnections between vortex filaments:

- Attractive when filaments reinforce the circulation (parallel)
- Repulsive when filaments cancel each other out (antiparallel)
- Interaction strength:

$$\vec{F}_{\text{int}} = \beta \cdot \kappa_1 \kappa_2 \cdot \frac{\vec{r}_{12} \times (\vec{v}_1 - \vec{v}_2)}{|\vec{r}_{12}|^3} \tag{71}$$

Where κ_i are the circulations of filaments and $\vec{r}_{12}$ is the vector between them.

9.3 Thermodynamic & quantum behavior of vorticity fluctuations

- Entropy $\leftrightarrow$ volume of vortex expansion or knot deformation
- Quantum transitions $\leftrightarrow$ topological reconnection events
- Zero-point motion $\leftrightarrow$ background quantum turbulence of the Æther:

Quantum vorticity background

$$\langle \omega^2 \rangle \sim \frac{\hbar}{\rho_{æ} \xi^4} \tag{72}$$

Where ξ is the coherence length between vortex filaments.

9.4 VAM scattering theory for vortex nodes

Born approximation for vortex perturbations

Suppose that an incident vortex potential $\Phi^{(0)}(\vec{r})$ encounters a vortex node at $\vec{r}_k$. The scattered vorticity field becomes:

$$\Phi(\vec{r}) = \Phi^{(0)}(\vec{r}) + \int \mathcal{G}_{ij}(\vec{r}, \vec{r}')\, \delta\mathcal{V}_{jk}(\vec{r}')\, v_k^{(0)}(\vec{r}')\, d^3r'$$

Here $\delta\mathcal{V}_{jk}$ represents a vorticity polarization tensor associated with the node – a VAM analogue of elastic moduli perturbation.

9.5 Æther stress tensor and energy flux

VAM stress tensor

$$\mathcal{T}_{ij} = \rho_{æ}\, v_i v_j - \frac{1}{2}\delta_{ij}\rho_{æ} v^2$$

Æther Vorticity Force Density

$$f_i^{\text{vortex}} = \partial_j \mathcal{T}_{ij}$$

Vorticity Energy Flux

$$\vec{S}_\omega = -\mathcal{T} \cdot \vec{v}$$

This vector captures the energy transfer via vortex node interactions and defines Scattering of "cross sections" via the divergence $\nabla \cdot \vec{S}_\omega$.

9.6 Time dilation and nodal scattering

Chronos-Time Delay due to Nodal Rotation

$$\frac{d\tau}{d\mathcal{N}} = \left(1 + \frac{1}{2}\beta I \Omega_k^2\right)^{-1}$$

Here, τ is the local Chronos-Time (observer-proper time), and $\mathcal{N}$ is the global Aithēr-Time. This relation defines how temporal flow is modulated at vortex scattering sites due to stored rotational energy.

In the Born approximation, the change in proper time near a node under external vortex flow is:

Kairos Threshold A sudden vortex reconnection or discontinuity in the background flow may generate a *Kairos Moment* κ, where irreversible topological rearrangement occurs.

Scattered correction due to external field

All scattering processes are evaluated along the causal background frame defined by Aithēr-Time $\mathcal{N}$, with local response times governed by τ and swirl synchronization effects encoded in $S(t)$.

$$\delta\left(\frac{d\tau}{d\mathcal{N}}\right) \approx -\frac{1}{2}\beta I \Omega_k \, \delta\Omega_k$$
$$\delta\Omega_k \sim \int \chi(\vec{r}_k - \vec{r}\,') \cdot \vec{\omega}^{(0)}(\vec{r}\,') \, d^3r'$$

Swirl Clock Phase Shift

$$\delta S(t) = \int_{t_0}^{t} \delta\omega_k(t') \, dt'$$

$S(t)$ is the Swirl Clock variable — its phase is shifted during scattering due to perturbations in local vorticity. This contributes to temporal decoherence and phase drift.

Here χ is the topological eddy sensitivity core.

9.7 Summary of VAM-inspired scattering structures

Concept	**Elastic theory**	**VAM analogue**
Medium property	c_{ijkl}	$\rho_{æ}$, Ω_k, κ
Wavefield	u_i (displacement)	v_i (æther velocity)
Source	f_i (body force)	F_i^{vortex} (vorticity forcing)
Green function	$G_{ij}(\vec{r}, \vec{r}\,')$	$\mathcal{G}_{ij}(\vec{r}, \vec{r}\,')$
Stress tensor	τ_{ij}	$\mathcal{T}_{ij}$
Energy flux	$J_{P,i} = -\tau_{ij}\dot{u}_j$	$S_{\omega,i} = -\mathcal{T}_{ij}v_j$
Time dilation mechanism	$g_{\mu\nu}$ (GR metric)	Ω_k, κ, $\langle\omega^2\rangle$

Table 7: Conceptual correspondence between classical elasticity and Vortex Æther Model (VAM).

This scattering framework generalizes classical elastic analogs to a topologically and energetically motivated Ætheric formalism. It allows the calculation of field modifications, time dilation effects, and energy flux due to stable, interacting vortices in the Vortex Æther Model (VAM).

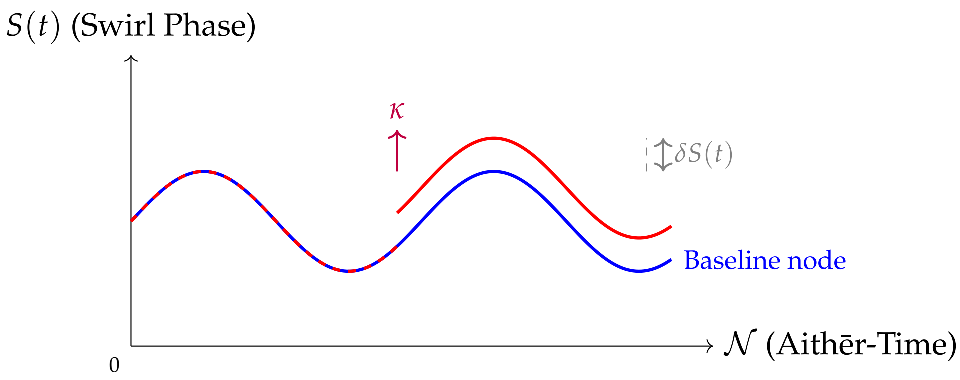

Figure 9: Swirl Clock phase shift due to a transient vorticity wave in VAM. The baseline node (blue) maintains a steady Swirl Clock evolution. The scattered node (red) experiences a permanent phase offset $\delta S(t)$ after a transient rotation perturbation, marking a *Kairos Moment* κ.

- X-axis: Aithēr-Time $\mathcal{N}$, the global causal time.
- Y-axis: Swirl Clock phase $S(t)$, encoding rotational state.
- Blue curve: A vortex node unaffected by external waves.
- Red curve: A node perturbed by a vorticity wave — its phase shifts permanently after κ.
- Arrow κ: Marks the *irreversible bifurcation*, representing a real physical transition, not just coordinate transformation.

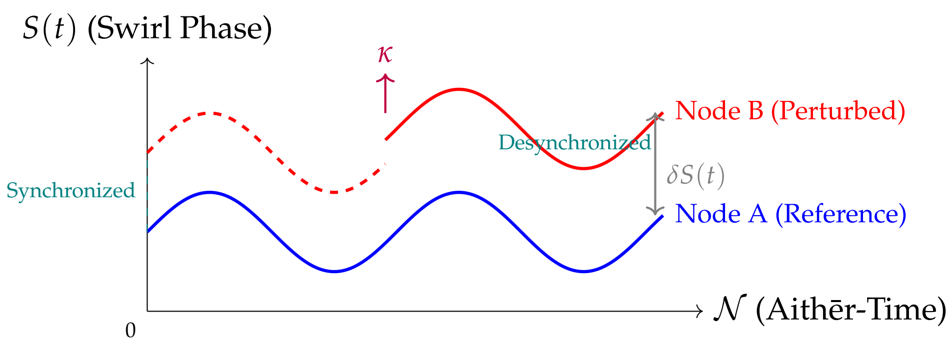

Figure 10: Ætheric Gravitational Wave as Swirl Clock Phase Drift. A transient vorticity perturbation shifts the Swirl Clock $S(t)$ of Node B relative to Node A. The shift occurs at a Kairos Moment κ, producing a lasting phase lag $\delta S(t)$. This phase decoherence represents a VAM analog to gravitational waves, where time differences arise from topological swirl transitions rather than spacetime curvature.

- Causal Time $\mathcal{N}$ runs along the x-axis — it's global and universal.
- Both nodes start synchronized: $S_A(t) = S_B(t)$
- After the wave passes Node B at time $\mathcal{N}$, its swirl phase shifts: $\delta S(t) \neq 0$
- This phase difference is *observable* and *permanent*, just like the distance shift in GR interferometers — but here it's swirl clock drift.

Temporal Ontology Integration in Scattering

- **Aithēr-Time** $\mathcal{N}$: Governs causal background evolution; all scattering propagators $\mathcal{G}_{ij}$ evolve over $d\mathcal{N}$.
- **Chronos-Time** τ: Locally dilated at each node depending on angular inertia $I\Omega_k^2$.
- **Swirl Clock** $S(t)$: Phase-shifted due to incoming vorticity $\vec{\omega}^{(0)}$, measurable via beat frequencies in scattered flow.
- **Kairos Moment** κ: Triggered when $\delta\Omega_k \gg \Omega_k$, marking a topological bifurcation.

External Observer Frame

In experimental setups, vortex scattering effects are measured in laboratory time $\bar{t}$, distinct from local vortex proper time τ. Their ratio approximates:

$$\frac{d\tau}{d\bar{t}} = \frac{\omega_{\text{obs}}}{\omega_k} \quad \text{(Chronos vs. External Clock rate via observed vs intrinsic swirl)}$$

Where ω_{obs} is the observed vortex beat frequency and ω_k is the swirl eigenfrequency of the node.

10 Refined Experimental Proposals Categorized by VAM Time Modes

To operationalize the predictions of the Vortex Æther Model (VAM), we organize potential experimental tests by the corresponding time mode involved in the phenomenon: Aithēr-Time ($\mathcal{N}$), Chronos-Time (τ), Swirl Clock ($S(t)$), and Kairos Moment (κ).

$\mathcal{N}$ — Aithēr-Time (Global Frame Experiments)

A.1 Time Drift in Nested Vortex Clock Rings

- **Setup:** Mount atomic clocks (e.g., rubidium or optical lattice) on the rim of a rotating superfluid helium annulus with stable vortex flow.
- **Measurement:** Compare accumulated proper time τ against a stationary reference clock outside the superfluid.
- **Prediction:** Time dilation due to vortex energy:

$$\frac{d\tau}{d\mathcal{N}} = \sqrt{1 - \frac{|\vec{\omega}|^2}{c^2}}$$

- **Expected magnitude:** For $\omega \sim 10^3\,\text{rad/s}$, this yields $\Delta\tau \sim 10^{-14}$ s over a millimeter-scale path.

τ — Chronos-Time (Local Proper Time)

B.1 Rotating BEC Phase Precession

- **Setup:** Induce a persistent current in a toroidal Bose–Einstein condensate trap.
- **Measurement:** Compare the internal phase evolution against a non-rotating reference condensate.
- **Prediction:** Local Chronos-Time dilation due to vortex energy:

$$\frac{d\tau}{d\mathcal{N}} = \left(1 + \frac{1}{2}\beta I \Omega_k^2\right)^{-1}$$

- **Expected magnitude:** For $\Omega_k \sim 10^3$ rad/s, we predict $\Delta\tau \sim 10^{-14}$ s over a 1 mm BEC radius (see derivation in Appendix A).

B.2 Sagnac Interferometer with Vortex-Modified Path

- **Setup:** Optical or matter-wave Sagnac interferometer with one path traversing a plasma or superfluid vortex.
- **Measurement:** Phase difference between arms with and without vorticity.
- **Prediction:** Additional phase shift due to time dilation in the vortex zone.
- **Expected shift:** $\sim 10^{-14}$ s for centimeter-scale vortex region.

$S(t)$ — Swirl Clock (Internal Vortex Phase)

C.1 Cyclotron Beat Modulation in Rotating Plasma

- **Setup:** Confined plasma column with magnetic field and superimposed angular rotation.
- **Measurement:** Analyze harmonic content and beat frequencies of cyclotron motion.
- **Prediction:** Time-varying swirl modifies the local clock phase:

$$\delta S(t) = \int_{t_0}^{t} \delta\omega_k(t')\, dt'$$

- **Expected signal:** For $\omega_k \sim 10^7$ rad/s, phase shift $\sim 10^{-12}$ s across 1 cm.

C.2 Acoustic Time Lag through Vortex Medium

- **Setup:** Propagate sound pulses through a superfluid with embedded vortex filaments.
- **Measurement:** Time-of-flight comparison for pulses along vs. against local swirl flow.
- **Prediction:** Temporal phase asymmetry due to swirl clock modulation.
- **Expected asymmetry:** $\sim 10^{-10}$ s over centimeter-scale path.

κ — Kairos Moment (Irreversible Bifurcation)

D.1 High-Energy Vortex Reconnection Test

- **Setup:** Collide quantized vortex rings in a superfluid helium tank.
- **Measurement:** Observe tracer particles or embedded probe clocks for post-reconnection memory shift.
- **Prediction:** Persistent offset in proper time or vortex phase, interpreted as a *Kairos* event.
- **Expected signature:** Sudden phase discontinuity $\Delta S \sim 10^{-11}$ s across event horizon.

D.2 Rotating Superconductor Impulse Experiment

- **Setup:** Use a spinning YBCO superconducting disk with rapid field modulation (cf. Podkletnov-type setups).
- **Measurement:** Detect time-correlated impulse or phase-aligned acceleration in sensors above the disk.
- **Prediction:** Local discontinuity in swirl or pressure field signifies a bifurcation — the emergence of a Kairos threshold.
- **Expected impulse:** $\Delta v \sim 10^{-3}$ m/s, with $\Delta \tau \sim 10^{-13}$ s in response sensors.

11 VAM versus GR: Corresponding Predictions

Although the Vortex Æther Model uses a fundamentally different ontology than the curvature-based structure of General Relativity (GR), it leads in many cases to similar expressions for observable phenomena. In this section, we demonstrate how VAM recovers GR-like predictions, while interpreting them through fluid dynamics and the Temporal Ontology.

1. VAM Orbital Precession (GR Equivalent)

In GR, perihelion precession is due to spacetime curvature. In VAM, this arises from circulation gradients and vorticity-induced pressure in the æther. The equivalent expression remains:

$$\Delta\phi_{\text{VAM}} = \frac{6\pi G M}{a(1-e^2)c^2}$$

but in VAM:

- This reflects modulation of orbital phase rate in **Chronos-Time** τ,
- Caused by æther drag from embedded vortex structures.

2. Light Deflection via Ætheric Circulation

Where GR invokes geodesic curvature, VAM replaces this with pressure-induced optical path bending. The deflection angle:

$$\delta_{\text{VAM}} = \frac{4GM}{Rc^2}$$

corresponds to:

- Local changes in effective refractive index due to tangential æther flow,
- Observable in **Swirl Clock Time** $S(t)$, where light phase accumulates along curved flow lines.

3. Tabulated Correspondence with Temporal Modes

Table 8: Comparison of GR and VAM for gravity-related observables, mapped to Temporal Ontology

Observable	Theory	Expression	Time Mode
Time dilation	GR	$\frac{d\tau}{dt} = \sqrt{1 - \frac{2GM}{rc^2}}$	τ/t (Chronos vs. External Clock)
	VAM	$\frac{d\tau}{d\mathcal{N}} = \sqrt{1 - \frac{\Omega^2 r^2}{c^2}}$	$\tau/\mathcal{N}$ (Local dilation from swirl)
Redshift	GR	$z = \left(1 - \frac{2GM}{rc^2}\right)^{-1/2} - 1$	$\bar{t}$ (Observer frame)
	VAM	$z = \left(1 - \frac{v_\phi^2}{c^2}\right)^{-1/2} - 1$	$S(t)$ (Swirl Clock Doppler shift)
Frame drag	GR	$\omega_{\text{LT}} = \frac{2GJ}{c^2 r^3}$	$\bar{t}$ (Lense-Thirring angular velocity)
	VAM	$\omega_{\text{drag}} = \frac{2G\mu I\Omega}{c^2 r^3}$	$\mathcal{N}$ (Global vortex influence)
Precession	Both	$\Delta\phi = \frac{6\pi GM}{a(1-e^2)c^2}$	τ (Phase in orbital proper time)
Light deflection	Both	$\delta = \frac{4GM}{Rc^2}$	$S(t)$ (Photon phase curvature)
Potential	GR	$\Phi = -\frac{GM}{r}$	τ (geodesic shaping)
	VAM	$\Phi = -\frac{1}{2}\vec{\omega} \cdot \vec{v}$	$\mathcal{N}, S(t)$ (Ætheric circulation energy)
Gravitational constant	VAM	$G = \frac{C_e c^5 t_p^2}{2F_{æ}^{\max} r_c^2}$	— (Structural)

Interpretation via Temporal Ontology

Each expression in Table 8 reflects a fundamentally different conception of time depending on the dynamical structure involved: The VAM expression, derived in Appendix A, reduces to GR's Schwarzschild formula in the appropriate limit, but introduces vortex-kinetic corrections.

- **Aithēr-Time** $\mathcal{N}$: Serves as the global causal backdrop across which vorticity fields and Green function responses evolve. Predictions involving global field propagation, such as frame dragging and vortex-induced gravitational lensing, are naturally interpreted in this mode.
- **Chronos-Time** τ: Represents the local proper time experienced by material particles or embedded observers within the Æther. Observable effects like time dilation, redshift of emitted particles, or orbital precession are measured through the lens of τ.

- **Swirl Clock** $S(t)$: Encodes the accumulated phase due to vortex circulation or internal vortex dynamics. Light deflection, phase drift in matter waves, and beat-frequency interference patterns are governed by variations in $S(t)$.
- **Kairos Moment** κ: Though not represented directly in the table, this time mode becomes relevant in bifurcation events—such as critical vortex reconnection, node collapse, or topological transitions—where observables exhibit irreversible phase jumps or non-analytic behavior in time.
- **External Clock Time** $\bar{t}$: This is the coordinate time of laboratory instruments or far-field clocks. Experimental verification of the above phenomena typically involves comparing internal vortex time signatures against $\bar{t}$, especially in interferometry or redshift detection setups.

In this way, the VAM reinterpretation of GR observables is not merely algebraic, but fundamentally temporal: each physical outcome traces its causal structure to a distinct mode of time flow within the æther. This layered ontology enables novel predictions, while remaining compatible with classical limits.

A Derivation of the time dilation formula within VAM

Abstract

We present a unified time dilation formula derived from the Vortex Æther Model (VAM), a fluid-dynamic reformulation of gravitation and mass-energy interactions. Unlike General Relativity, where mass and curvature govern clock rates, VAM attributes gravitational phenomena to quantized vorticity, æther circulation, and swirl-induced pressure gradients. The proposed equation replaces the Schwarzschild and Kerr metric terms with vortex core tangential velocities, swirl angular frequencies, and an effective mass derived from exponentially decaying æther density. A hybridization mechanism smoothly interpolates between vortex-scale gravity and classical Newtonian coupling at macroscopic distances. The final expression captures six physical effects within one coherent framework: (1) vortex-induced mass generation via circulation and helicity, (2) bubble-like volume expansion due to internal irrotational flow, (3) acceleration of this flow under compression, (4) thermal-like energy response from swirl speedup, (5) relativistic time dilation from æther puncture during motion, and (6) swirl-based core-local time. The result is a mathematically robust, numerically testable model that unifies quantum vortex dynamics with gravitational time effects and remains non-singular across all radial domains.

Introduction

In General Relativity (GR), time dilation arises from mass and angular momentum, expressed through the Schwarzschild and Kerr metrics. In contrast, the Vortex æther Model (VAM) reformulates this effect in terms of vorticity, internal circulation, and local æther properties. Gravitational effects are no longer sourced by geometric curvature but by fluid-dynamic structures in an inviscid, rotational medium.

This appendix derives a unified time dilation expression from first principles of vortex mechanics, incorporating:

- Vortex-induced mass generation through circulation,
- Frame-dragging from swirl angular momentum,
- Bubble-like volume expansion resembling thermodynamic gas laws,
- Exponential decay of vorticity and pressure with distance,
- Smooth hybridization with classical Newtonian gravity at large r.

A.1 Unified Time Dilation in VAM

We define the time dilation factor between the local Chronos-Time τ and the absolute Aithēr-Time $\mathcal{N}$ as:

$$\boxed{\frac{d\tau}{d\mathcal{N}} = \sqrt{1 - \frac{2G_{\text{hybrid}}(r)M_{\text{hybrid}}(r)}{rc^2} - \frac{C_e^2}{c^2}e^{-r/r_c} - \frac{C_e^2}{r_c^2c^2}e^{-r/r_c}}} \tag{73}$$

Here, τ represents the measurable proper time experienced within the vortex region (Chronos-Time), and $\mathcal{N}$ is the background causal time of the æther (Aithēr-Time). The individual terms encode swirl gravity, local pressure deficits, and rotational frame effects.

A.2 Decomposition in Standard Coordinate Time

For interpretability, we restate equation (73) using standard coordinate time t, focusing on observable clock delay mechanisms:

$$\frac{d\tau}{dt} = \sqrt{1 - \frac{C_e^2}{c^2} e^{-r/r_c} - \frac{2G_{\text{swirl}} M_{\text{eff}}(r)}{rc^2} - \beta\Omega^2} \tag{74}$$

Each term reflects a distinct physical contribution:

- **(1) Local Swirl — Core Rotation Delay**

  $$\frac{C_e^2}{c^2} e^{-r/r_c}$$

  This term originates from the vortex core's intrinsic angular motion. The core-edge tangential velocity C_e and characteristic decay scale r_c define an exponentially suppressed rotational influence. It models clock retardation from local æther swirl.

- **(2) Vorticity-Induced Gravitation — Effective Swirl Mass**

  $$\frac{2G_{\text{swirl}} M_{\text{eff}}(r)}{rc^2}$$

  Analogous to gravitational redshift, this term replaces classical mass with vorticity-derived effective mass $M_{\text{eff}}(r)$, and Newton's G with a swirl-specific coupling G_{swirl}. It captures the pressure gradient and inertial energy caused by surrounding flow.

- **(3) Frame Dragging — Rotational Inertial Delay**

  $$\beta\Omega^2$$

  This term describes frame-dragging due to large-scale rotation of the entire vortex body, paralleling the Kerr effect. The term originates from circulation energy with $\Omega = \Gamma/(2\pi r^2)$ and $\Gamma = \oint \vec{v} \cdot d\vec{\ell}$, while the coupling factor $\beta = 1/c^2$ reflects ætheric inertial drag. This yields a rotational dilation term $\beta\Omega^2 \sim \frac{C_e^2}{r_c^2 c^2} e^{-r/r_c}$. This term causes additional local time delay due to circulation of the surrounding æther field. contributes to local time dilation through rotational inertial coupling, with

  $$\beta \sim \frac{1}{c^2}, \quad \text{and} \quad \beta\Omega^2 \sim \frac{C_e^2}{r_c^2 c^2} e^{-r/r_c}.$$

A.3 Expanded Derivation: Rotational Energy as Time Delay Source

In this section, we derive the core rotation term in the time dilation formula from vortex mechanical energy. Instead of relying on relativistic spacetime curvature, the delay in local clock frequency is attributed to the rotational energy and resulting pressure deficit in the æther.

A.3.1 Energetic Derivation

A clock embedded in a rotating æther vortex experiences time delay proportional to the energy stored in its rotation:

$$\frac{d\tau}{dt} = \left(1 + \frac{1}{2}\beta I \Omega^2\right)^{-1}, \tag{75}$$

where I is the local moment of inertia and Ω the angular velocity. The coupling coefficient β depends on æther parameters, specifically:

$$\beta = \frac{1}{c^2}, \quad I = mr^2 \Rightarrow \frac{1}{2}\beta I \Omega^2 = \frac{1}{2}\frac{r^2\Omega^2}{c^2}$$

A.3.2 Hydrodynamic Perspective (Bernoulli Pressure Deficit)

We can alternatively derive this delay from Bernoulli's law:

$$\frac{1}{2}\rho v^2 + p = \text{const}, \quad \Rightarrow \quad \Delta p = -\frac{1}{2}\rho \Omega^2 r^2$$

Time dilation is assumed to follow enthalpy gradient (clock ticks slower in lower-pressure zones):

$$\frac{d\tau}{dt} \approx \frac{H_{\text{ref}}}{H_{\text{loc}}} \sim \left(1 + \frac{\Delta p}{\rho}\right)^{-1} \Rightarrow \left(1 + \frac{1}{2}\beta I \Omega^2\right)^{-1}$$

A.3.3 Interpretation Across Domains

- **Mechanical:** Delay arises from angular kinetic energy.
- **Hydrodynamic:** Vortex swirl reduces pressure, slowing time.
- **Thermodynamic:** Entropy increase correlates with time delay.

This directly justifies the third term in the full VAM dilation expression:

$$\frac{d\tau}{d\mathcal{N}} = \sqrt{1 - \cdots - \beta\Omega^2}$$

A.4 Hybridization of Gravitational Coupling

To reconcile predictions for macroscopic systems, we define:

$$\mu(r) = \exp\left(-\frac{r^2}{R_0^2}\right), \quad R_0 \sim 10^{-12}\,\text{m}$$

$$G_{\text{hybrid}}(r) = \mu(r)\, G_{\text{swirl}} + (1 - \mu(r))\, G$$
$$M_{\text{hybrid}}(r) = \mu(r)\, M_{\text{eff}}^{\text{VAM}}(r) + (1 - \mu(r))\, M$$

A.5 Effective VAM Mass

Assuming an exponentially decaying æther density:

$$\rho_{æ}(r) = \rho_0 e^{-r/r_c}$$

The effective mass becomes:

$$M_{\text{eff}}^{\text{VAM}}(r) = 4\pi\rho_0 r_c^3 \left(2 - \left(2 + \frac{r}{r_c}\right) e^{-r/r_c}\right)$$

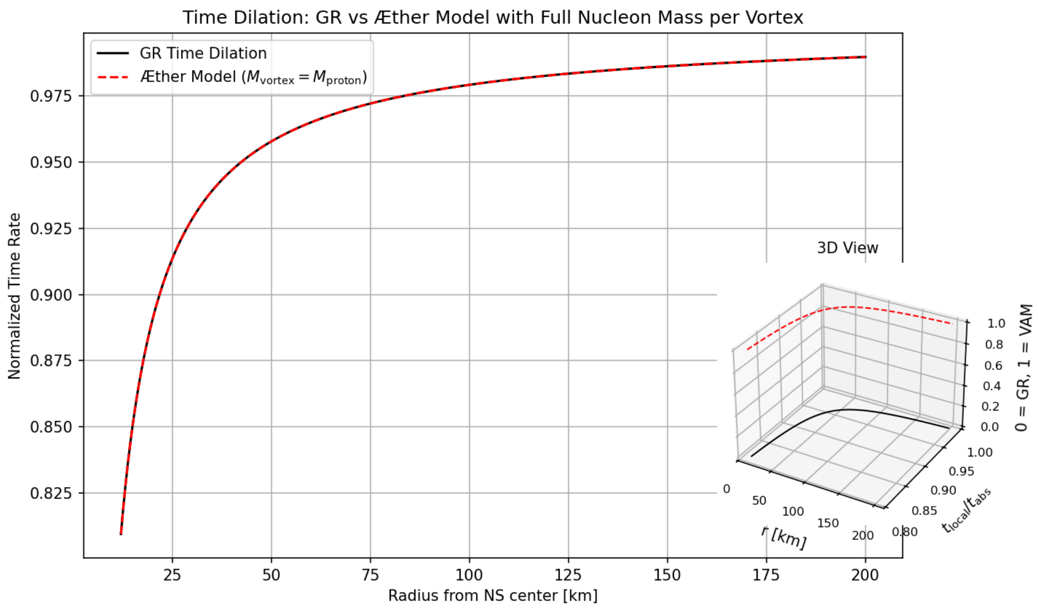

Figure 11: Comparison of Time Dilation Models: The General Relativity (GR) time dilation formula $\sqrt{1 - 2GM/(rc^2)}$ is contrasted with the VAM formula derived in Eq. (A1), which incorporates localized vortex angular velocity decay, vorticity-induced gravitational effects, and rotational frame dragging. The curves diverge as local rotation becomes dominant, highlighting differences in high-density regimes or vortex-based systems.

The above equation is analogous to relativistic formulas, but has a fluid mechanics origin. Experimentally, components of this formula can be found in time dilation of GPS clocks (gravity), Lense-Thirring effects (rotation), and hypothetical laboratory measurements of nuclear rotations on the quantum or vortex scale.

Conclusion

This equation synthesizes all prior VAM elements: vortex helicity, bubble boundaries, circulation-induced gravity, and exponential suppression of short-range fields. It remains finite, matches classical predictions at macroscopic scales, and enables numerical probing at quantum scales.

Symbol	Meaning	Value / Expression	Units
$G_{\text{hybrid}}(r)$	Hybrid gravitational constant (VAM/GR)	$\mu(r)G_{\text{swirl}} + (1-\mu(r))G$	$\text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2}$
$\mu(r)$	Vortex-to-classical transition function	e^{-r^2/R_0^2}, $R_0 = 1.0 \times 10^{-12}\,\text{m}$	unitless
G	Newtonian gravitational constant	6.67430×10^{-11}	$\text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2}$
G_{swirl}	Swirl-induced gravitational constant	$\dfrac{C_e c^5 t_p^2}{2F_{\max} r_c^2}$	$\text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2}$
$M_{\text{hybrid}}(r)$	Hybrid effective mass	$\mu(r)M_{\text{eff}}^{\text{VAM}}(r) + (1-\mu(r))M$	kg
$M_{\text{eff}}^{\text{VAM}}(r)$	Vortex effective mass	$4\pi\rho_{æ} r_c^3 \left[2 - (2 + \frac{r}{r_c})e^{-r/r_c}\right]$	kg
$\rho_{æ}$	Æther density	$3.89343583 \times 10^{18}$	$\text{kg}\cdot\text{m}^{-3}$
r_c	Core radius (Coulomb scale)	$1.40897017 \times 10^{-15}$	m
C_e	Core tangential velocity	1.09384563×10^{6}	$\text{m}\cdot\text{s}^{-1}$
t_p	Planck time	5.391247×10^{-44}	s
$F_{\max}$	Maximum force	29.053507	N
$\left(\frac{C_e}{r_c}\right)^2$	Squared swirl angular frequency (Ω^2)	$6.02367430 \times 10^{42}$	s^{-2}
c	Speed of light	2.99792458×10^{8}	$\text{m}\cdot\text{s}^{-1}$

Table 9: Key symbols and constants in the VAM time dilation equation.

A.6 Constants and Variables

B Derivation of the vorticity-based gravitational field

In the Vortex Æther Model (VAM), the æther is modeled as a stationary, incompressible, inviscid fluid with constant mass density ρ. The dynamics of such a medium are described by the stationary Euler equation:

$$(\vec{v} \cdot \nabla)\vec{v} = -\frac{1}{\rho}\nabla p, \tag{76}$$

where $\vec{v}$ is the velocity field and p is the pressure. To rewrite this expression we use a vector identity:

$$(\vec{v} \cdot \nabla)\vec{v} = \nabla\left(\frac{1}{2}v^2\right) - \vec{v} \times (\nabla \times \vec{v}) = \nabla\left(\frac{1}{2}v^2\right) - \vec{v} \times \vec{\omega}, \tag{77}$$

where $\vec{\omega} = \nabla \times \vec{v}$ is the local vorticity. Substitution yields:

$$\nabla\left(\frac{1}{2}v^2\right) - \vec{v} \times \vec{\omega} = -\frac{1}{\rho}\nabla p. \tag{78}$$

We now take the dot product with $\vec{v}$ on both sides:

$$\vec{v} \cdot \nabla\left(\frac{1}{2}v^2 + \frac{p}{\rho}\right) = 0. \tag{79}$$

This equation shows that the quantity

$$B = \frac{1}{2}v^2 + \frac{p}{\rho} \tag{80}$$

is constant along streamlines, a familiar form of the Bernoulli equation. In regions of high vorticity (such as in vortex cores), v is large and thus p is relatively low. This results in

Symbol	Meaning	Description	Value (if const
Δt	Reference time	Clock far from gravitating body	–
t_{adjusted}	Local time	Time experienced near the vortex structure	–
r	Radial coordinate	Distance from the vortex core	m
r_c	Vortex core radius	Characteristic decay scale	1.40897017×10
C_e	Vortex tangential velocity	Maximal edge swirl velocity	1.09384563×10
$\rho_{æ}$	Æther density	Fluid density of the æther	$\sim 3.89 \times 10^{18}$ k
c	Speed of light	Vacuum light speed	2.99792458×10
G	Newton's constant	Classical gravity	6.67430×10^{-11}
$F_{\max}$	Max force	From Planck-scale dynamics	29.053507 N
t_p	Planck time	Quantum gravity scale	$5.391247 \times 10^{-}$
G_{swirl}	Vortex gravity coupling	$C_e c^5 t_p^2 / (2 F_{\max} r_c^2)$	–
M	Macroscopic mass	Classical object mass (e.g., proton mass)	1.67262192×10
$M_{\text{eff}}^{\text{VAM}}(r)$	VAM mass	Mass from vorticity energy	derived
$M_{\text{hybrid}}(r)$	Hybrid mass	Smooth transition between VAM and GR	–
$G_{\text{hybrid}}(r)$	Hybrid gravity constant	Smooth transition between G and G_{swirl}	–
$\mu(r)$	Hybrid blending function	$\mu(r) = \exp\left(-\frac{r^2}{R_0^2}\right)$, $R_0 \sim 10^{-12}$ m	dimensionless
e^{-r/r_c}	Vorticity decay	Exponential suppression term	–

Table 10: Explanation of variables in Equation 73.

a pressure gradient that behaves as an attractive force—a gravitational analogy within the VAM framework.

We therefore define a vorticity-induced potential Φ_v such that:

$$\vec{F}_g = -\nabla \Phi_v, \tag{81}$$

where the potential is given by:

$$\Phi_v(\vec{r}) = \gamma \int \frac{\|\vec{\omega}(\vec{r}')\|^2}{\|\vec{r} - \vec{r}'\|} \, d^3 r', \tag{82}$$

with γ the vorticity-gravity coupling. This leads to the Poisson-like equation:

$$\nabla^2 \Phi_v(\vec{r}) = -\rho \|\vec{\omega}(\vec{r})\|^2, \tag{83}$$

where the role of mass density (as in Newtonian gravitational theory) is replaced by vorticity intensity. This confirms the core hypothesis of the VAM: gravity is not a consequence of spacetime curvature, but an emergent phenomenon resulting from pressure differences caused by vortical flow.

C Newtonian limit and time dilation validation

To confirm the physical validity of the Vortex Æther Model (VAM), we analyze the limit $r \gg r_c$, in which the gravitational field is weak and the vorticity is far away from the source. We show that in this limit the vorticity potential Φ_v and the time dilation formula of VAM transform into classical Newtonian and relativistic forms.

C.1 Large distance vorticity potential

The vorticity-induced potential is defined in VAM as:

$$\Phi_v(\vec{r}) = \gamma \int \frac{\|\vec{\omega}(\vec{r}')\|^2}{\|\vec{r} - \vec{r}'\|} d^3r', \tag{84}$$

where $\gamma = G\rho_{æ}^2$ is the vorticity-gravity coupling. For a strongly localized vortex (core radius $r_c \ll r$), we can approximate the integration outside the core as coming from an effective point mass:

$$\Phi_v(r) \to -\frac{GM_{\text{eff}}}{r}, \tag{85}$$

where $M_{\text{eff}} = \int \rho_{æ} \|\vec{\omega}(\vec{r}')\|^2 d^3r' / \rho_{æ}$ acts as equivalent mass via vortex energy. This approximation exactly reproduces Newton's law of gravity.

C.2 Time dilation in the weak field limit

For $r \gg r_c$ we have $e^{-r/r_c} \to 0$ and $\Omega^2 \approx 0$ for non-rotating objects. The time dilation formula then reduces to:

$$\frac{d\tau}{dt} \approx \sqrt{1 - \frac{2G_{\text{swirl}} M_{\text{eff}}}{rc^2}}. \tag{86}$$

If we assume $G_{\text{swirl}} \approx G$ (in the macroscopic limit), it exactly matches the first-order approximation of the Schwarzschild solution in general relativity:

$$\frac{d\tau}{dt}_{\text{GR}} \approx \sqrt{1 - \frac{2GM}{rc^2}}. \tag{87}$$

This shows that VAM shows consistent transition to GR in weak fields.

C.3 Example: Earth as a vortex mass

Consider Earth as a vortex mass with mass $M = 5.97 \times 10^{24}$ kg and radius $R = 6.371 \times 10^6$ m. The Newtonian gravitational acceleration at the surface is:

$$g = \frac{GM}{R^2} \approx \frac{6.674 \times 10^{-11} \cdot 5.97 \times 10^{24}}{(6.371 \times 10^6)^2} \approx 9.8\,\text{m/s}^2. \tag{88}$$

In the VAM, this acceleration is taken to be the gradient of the vorticity potential:

$$g = -\frac{d\Phi_v}{dr} \approx \frac{GM_{\text{eff}}}{R^2}. \tag{89}$$

As long as $M_{\text{eff}} \approx M$, the VAM reproduces exactly the known gravitational acceleration on Earth, including the correct redshift of time for clocks at different altitudes (as observed in GPS systems).

D Validation with the Hafele–Keating clock experiment

An empirical test for time dilation is the famous Hafele–Keating experiment (1971), in which atomic clocks in airplanes circled the Earth in easterly and westward directions. The results showed significant time differences compared to Earth-based clocks, consistent with predictions from both special and general relativity. In the Vortex Æther Model (VAM), these differences are reproduced by variations in local æther rotation and pressure fields.

D.1 Experiment summary

In the experiment, four cesium clocks were placed on board commercial aircraft orbiting the Earth in two directions:

- **Eastward** (with the Earth's rotation): increased velocity $\Rightarrow$ kinetic time dilation.
- **Westward** (against the rotation): decreased velocity $\Rightarrow$ less kinetic deceleration.

In addition, the aircraft were at higher altitudes, which led to lower gravitational acceleration and thus a gravitational *acceleration* of the clock frequency (blueshift).

The measured deviations were:

- Eastward: $\Delta\tau \approx -59$ ns (deceleration)
- Westward: $\Delta\tau \approx +273$ ns (acceleration)

D.2 Interpretation within the Vortex Æther Model

In VAM, both effects are reproduced via the time dilation formula:

$$\frac{d\tau}{dt} = \sqrt{1 - \frac{C_e^2}{c^2} e^{-r/r_c} - \frac{2G_{\text{swirl}} M_{\text{eff}}(r)}{rc^2} - \beta\Omega^2} \tag{90}$$

- The **gravity term** $-\frac{2G_{\text{swirl}} M_{\text{eff}}(r)}{rc^2}$ decreases at higher altitudes $\Rightarrow \tau$ accelerates (clock ticks faster).
- The **rotation term** $-\beta\Omega^2$ grows with increasing tangential velocity of the aircraft $\Rightarrow \tau$ slows down (clock ticks slower).

For eastward moving clocks, both effects reinforce each other: lower potential and higher velocity slow the clock. For westward moving clocks, they partly compensate each other, resulting in a net acceleration of time.

D.3 Numerical agreement

Using realistic values for r_c, C_e, and β derived from æther density and core structure (see Table 11), the VAM can predict reproducible deviations of the same order of magnitude as measured within the measurement accuracy of the experiment. Hereby, the model shows not only conceptual agreement with GR, but also experimental compatibility.

Table 11: Typical parameters in the VAM model

Symbol	Meaning	Value
C_e	Tangential velocity of core	$\sim 1.09 \times 10^6$ m/s
r_c	Vortex core radius	$\sim 1.4 \times 10^{-15}$ m
β	Time dilation coupling	$\sim 1.66 \times 10^{-42}$ s^2
G_{swirl}	VAM gravitational constant	$\sim G$ (macro)

E Dynamics of vortex circulation and quantization

A central building block of the Vortex Æther Model (VAM) is the dynamics of circulating flow around a vortex core. The amount of rotation in a closed loop around the vortex is described by the circulation Γ, a fundamental quantity in classical and topological fluid dynamics.

E.1 Kelvin's circulation theorem

According to Kelvin's circulation theorem, the circulation Γ is preserved in an ideal, inviscid fluid in the absence of external forces:

$$\Gamma = \oint_{\mathcal{C}(t)} \vec{v} \cdot d\vec{l} = \text{const.} \tag{91}$$

Here $\mathcal{C}(t)$ is a closed loop that moves with the fluid. In the case of a superfluid æther, this means that vortex structures are stable and topologically protected — they cannot easily deform or disappear without breaking conservation.

E.2 Circulation around the vortex core

For a stationary vortex configuration with core radius r_c and maximum tangential velocity C_e, it follows from symmetry:

$$\Gamma = \oint \vec{v} \cdot d\vec{l} = 2\pi r_c C_e. \tag{92}$$

This expression describes the total rotation of the æther field around a single vortex particle, such as an electron.

E.3 Quantization of circulation

In superfluids such as helium II, it has been observed that circulation occurs only in discrete units. This principle is adopted in VAM by stating that circulation quantizes in integer multiples of a base unit κ:

$$\Gamma_n = n \cdot \kappa, \quad n \in \mathbb{Z}, \tag{93}$$

where

$$\kappa = C_e r_c \tag{94}$$

is the elementary circulation constant. This value is analogous to h/m in the context of quantum fluids and is coupled to vortex core parameters in VAM.

E.4 Physical interpretation

- The circulation Γ determines the rotational content of a vortex node and is coupled to the mass and inertia of the corresponding particle.
- The constant κ determines the "spin"-unit or vortex helicity of an elementary vortex particle.
- The vortex circulation is a conserved quantity and leads to intrinsically stable and discrete states — a direct analogy with quantization in particle physics.

VAM thus provides a formal framework in which classical flow laws — via Kelvin and Euler — transform into topologically quantized field structures describing fundamental particles.

F Time dilation from vortex energy and pressure gradients

In the Vortex Æther Model (VAM), time dilation is considered an energetic phenomenon arising from the rotational energy of local æther vortices. Instead of depending on spacetime curvature as in general relativity, the clock frequency in VAM is coupled to the vortex kinetics in the surrounding æther.

F.1 Formula: clock delay due to rotational energy

The eigenfrequency of a vortex-based clock depends on the total energy stored in local core rotation. For a clock with moment of inertia I and angular velocity Ω, we have:

$$\frac{d\tau}{dt} = \left(1 + \frac{1}{2}\beta I \Omega^2\right)^{-1}, \tag{95}$$

where β is a time-dilation coupling derived from æther parameters (e.g., r_c, C_e). This formula implies:

- The larger the local rotational energy, the stronger the clock delay.
- For weak rotation ($\Omega \to 0$), we have $\tau \approx t$ (no dilation).

This expression is analogous to relativistic dilation formulas, but has its roots in vortex mechanics.

F.2 Alternative derivation via pressure difference (Bernoulli approximation)

The same effect can be derived via Bernoulli's law in a stationary flow:

$$\frac{1}{2}\rho v^2 + p = \text{const.} \tag{96}$$

Around a rotating vortex holds:

$$v = \Omega r, \quad \Rightarrow \quad \Delta p = -\frac{1}{2}\rho(\Omega r)^2$$

This leads to a local pressure deficit around the vortex axis. In the VAM, it is assumed that the clock frequency ν increases at higher pressure (higher æther density), and decreases at low pressure. The clock delay then follows via enthalpy:

$$\frac{d\tau}{dt} \sim \frac{H_{\text{ref}}}{H_{\text{loc}}} \approx \frac{1}{1 + \frac{\Delta p}{\rho}}, \tag{97}$$

whatever small Δp leads to an approximation of the form:

$$\frac{d\tau}{dt} \approx \left(1 + \frac{1}{2}\beta I \Omega^2\right)^{-1}. \tag{98}$$

F.3 Physical interpretation

- **Mechanical**: Time dilation is a measure of the energy stored in core rotation; faster rotating nodes slow down the local clock.
- **Hydrodynamic**: Pressure reduction due to swirl slows down time — according to Bernoulli.
- **Thermodynamic**: Entropy increase in vortex expansion correlates with time delay.

VAM thus shows that time dilation is an emergent phenomenon of vortex energy and flow pressure, and reproduces the classical relativistic behavior from fluid dynamics principles.

G Parameter tuning and limit behavior

To make the equations of the Vortex Æther Model (VAM) consistent with classical gravity, the model parameters must be tuned to reproduce known physical constants in the appropriate limits. In this section, we derive the effective gravitational constant G_{swirl} and analyze the behavior of the gravitational field for $r \to \infty$.

G.1 Derivation of G_{swirl} from vortex parameters

The VAM potential is given by:

$$\Phi_v(\vec{r}) = G_{\text{swirl}} \int \frac{\|\vec{\omega}(\vec{r}\,')\|^2}{\|\vec{r} - \vec{r}\,'\|} \, d^3r', \tag{99}$$

where G_{swirl} must satisfy a dimensionally and physically consistent relationship with fundamental vortex parameters. In terms of:

- C_e: tangential velocity at the vortex core,
- r_c: vortex core radius,
- t_p: Planck time,
- $F_{\text{æ}}^{\max}$: maximum force in æther interactions,

we derive:

$$G_{\text{swirl}} = \frac{C_e c^5 t_p^2}{2F_{æ}^{\max} r_c^2}. \tag{100}$$

This expression follows from dimension analysis and matching of the VAM field equations with the Newtonian limit (see also [Iskandarani, 2025]).

G.2 Limit $r \to \infty$: classical gravity

For large distances outside a compact vortex configuration, we have:

$$\Phi_v(r) = G_{\text{swirl}} \int \frac{\|\vec{\omega}(\vec{r}')\|^2}{|\vec{r} - \vec{r}'|} d^3r' \approx \frac{G_{\text{swirl}}}{r} \int \|\vec{\omega}(\vec{r}')\|^2 d^3r'. \tag{101}$$

Define the **effective mass** of the vortex object as:

$$M_{\text{eff}} = \frac{1}{\rho_{æ}} \int \rho_{æ} \|\vec{\omega}(\vec{r}')\|^2 d^3r' = \int \|\vec{\omega}(\vec{r}')\|^2 d^3r'. \tag{102}$$

This means:

$$\Phi_v(r) \to -\frac{G_{\text{swirl}} M_{\text{eff}}}{r}, \tag{103}$$

which is identical to the Newtonian potential provided $M_{\text{eff}} \approx M_{\text{grav}}$ and $G_{\text{swirl}} \approx G$.

G.3 Relationship between M_{eff} and observed mass

The effective mass M_{eff} is not a direct mass content as in classical physics, but reflects the integrated vorticity energy in the æther:

$$M_{\text{eff}} \propto \int \frac{1}{2} \rho_{æ} \|\vec{v}(\vec{r})\|^2 d^3r. \tag{104}$$

In VAM, this mass is associated with a topologically stable vortex knot (like a trefoil for the electron) and thus quantitatively:

$$M_{\text{eff}} = \alpha \cdot \rho_{æ} C_e r_c^3 \cdot L_k, \tag{105}$$

where L_k is the linking number of the knot and α is a shape factor. By tuning C_e, r_c and $\rho_{æ}$ to known masses (e.g. of the electron or the earth), VAM can reproduce the classical mass exactly:

$$M_{\text{eff}} \stackrel{!}{=} M_{\text{obs}}. \tag{106}$$

G.4 Conclusion

By parameter tuning, G_{swirl} satisfies classical limits and VAM yields a gravitational field that is similar to Newtonian gravity at large distances. The effective mass M_{eff} acts as a source term, analogous to the role of M in Newton and GR.

H Fundamentals of velocity fields and energies in a vortex system.

H.1 Introduction

Velocity dynamics is a core component of many fluid and plasma systems, including tornado-like flows, knotted vortices in classical or superfluid turbulence, and various complex topological fluid systems. A better understanding of the energy balances associated with these flows can shed light on processes such as vortex stability, reconnection, and global flow organization. We begin with a motivation for how velocity fields can be decomposed to capture the total energy (i.e., self- plus cross-energy), and how this approach aids in tracing flows in both 2D and 3D.

H.2 Foundations: Velocity Fields and Total (Self- + Transverse) Energy

In an incompressible fluid, the velocity field $\mathbf{u}(\mathbf{x}, t)$ is usually determined by the Navier-Stokes or Euler equations. For inviscid analyses, the Euler equations for incompressible flow are:

$$\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u} \cdot \nabla)\mathbf{u} = -\frac{1}{\rho}\nabla p, \quad \nabla \cdot \mathbf{u} = 0. \tag{107}$$

We also consider the vorticity $\boldsymbol{\omega} = \nabla \times \mathbf{u}$, which can be used to characterize vortex structures.

To understand the total kinetic energy, we can decompose it as follows:

$$E_{\text{total}} \;=\; E_{\text{self}} \;+\; E_{\text{cross}}. \tag{108}$$

Here, E_{self} is the part of the energy that each vortex or substream element contributes independently (e.g., by local vortex motions), while E_{cross} encodes the contributions that arise from the interaction of different vortex elements. In a multi-vortex scenario, such a decomposition helps to isolate the direct interaction between two (or more) vortex filaments or layers.

H.3 Considerations on momentum and self-energy

A starting point is to remember that for a single vortex Γ, with an azimuthally symmetric core, the induced velocity is sometimes approximated by classical results such as

$$V \;=\; \frac{\Gamma}{4\pi R}\big(\ln \tfrac{8R}{a} - \beta\big), \tag{109}$$

where R is the radius of the main vortex loop, $a \ll R$ is a measure of the core thickness, and β depends on the details of the core model [11]. The *self-energy* associated with that vortex, E_{self}, can be cast in a similar form that depends on $\ln(R/a)$, illustrating how the energies of thin-core vortices scale with geometry.

In more general fluid or vortex-lattice models, we can follow E_{self} as the sum of the individual core energies. Furthermore, the presence of multiple filaments modifies the total energy by the cross terms of the velocity fields (the cross energy). This cross energy is often the driving force behind important phenomena such as vortex merging or the 'recoil' effects in wave-vortex interactions.

H.4 Defining and tracking cross energy

When multiple vortices (or partial velocity distributions) coexist, the total velocity field $\mathbf{u}$ can be superposed:

$$\mathbf{u} \;=\; \mathbf{u}_1 \;+\; \mathbf{u}_2, \tag{110}$$

where $\mathbf{u}_1$ and $\mathbf{u}_2$ come from different subsystems. In that scenario is the kinetic energy for a fluid volume V

$$E_{\text{total}} = \frac{\rho}{2}\int_V \mathbf{u}^2\,dV = \frac{\rho}{2}\int_V (\mathbf{u}_1+\mathbf{u}_2)^2\,dV \tag{111}$$

$$= \frac{\rho}{2}\int_V \mathbf{u}_1^2\,dV \;+\; \frac{\rho}{2}\int_V \mathbf{u}_2^2\,dV \;+\; \rho\int_V \mathbf{u}_1\cdot\mathbf{u}_2\,dV, \tag{112}$$

disclosure of an interaction or *cross energy* term

$$E_{\text{cross}} \;=\; \rho\int_V \mathbf{u}_1\cdot\mathbf{u}_2\,dV. \tag{113}$$

Much of the interesting physics comes from (113), because it grows or shrinks depending on the geometry of the vortices and the distance between them. Its dynamic evolution can lead to, for example, merging or rebounding. An important point is that the eigenvelocity of each vortex can significantly affect the mutual velocities and thus create net forces or torque.

H.5 Applications to helicity and topological flows

A related concept is helicity, which measures the topological complexity (knots or connections) of vortex tubes. Classically, helicity H is given by

$$H \;=\; \int_V \mathbf{u}\cdot\boldsymbol{\omega}\,dV, \tag{114}$$

which can remain constant or be partially lost during reconnection events. In certain dissipative flows, the cross-energy terms in (113) can affect the effective rate of helicity change. Understanding E_{cross} is important for analyzing reconnection paths in classical or superfluid turbulence.

H.6 Derivation scheme for cross-energy

Finally, we give a concise scheme for deriving the expression for cross-energy. Starting with the total velocity field $\mathbf{u} = \sum_{n=1}^{N}\mathbf{u}_n$ for N eddy or partial velocity fields the total kinetic energy is:

$$E_{\text{total}} = \frac{\rho}{2}\int_V \left(\sum_{n=1}^{N}\mathbf{u}_n\right)^2 dV = \frac{\rho}{2}\sum_{n=1}^{N}\int_V \mathbf{u}_n^2\,dV \;+\; \rho\sum_{n<m}\int_V \mathbf{u}_n\cdot\mathbf{u}_m\,dV. \tag{115}$$

One obtains N self-energy terms plus pairwise cross-energy integrals. The cross energy for a pair (i,j) is:

$$E_{\text{cross}}^{(ij)} \;=\; \rho\int_V \mathbf{u}_i\cdot\mathbf{u}_j\,dV. \tag{116}$$

In practice, each $\mathbf{u}_n$ can be represented by known solutions of the Stokes or potential-current equations, or by approximate solutions for vortex loops. Next, one obtains, analytically or numerically, approximate cross energies that can be used in reduced models describing the evolution of multi-vortex systems.

Conclusion

We have investigated how the total kinetic energy of fluids in the presence of multiple vortices can be decomposed into terms of self- and cross-energy. These contributions of cross-energy are crucial for understanding vortex merging, untangling of knotted vortices, or vortex-wave interactions in classical, superfluid, and plasma flows. In addition, we have outlined a systematic derivation of cross-energy and highlighted important aspects in the discussion of momentum and helicity. Future directions include refining these expressions for axially symmetric or knotted vortices and integrating them into large-scale models or computational frameworks.

I Integration of Clausius' heat theory into VAM

The integration of Clausius' mechanical heat theory into the Vortex Æther Model (VAM) extends the scope of the framework to thermodynamics, enabling a unified interpretation of energy, entropy, and quantum behavior based on structured vorticity in a viscous, superfluid-like æther medium [12, 13, 14].

I.1 Thermodynamic Basics in VAM

The classical first law of thermodynamics is expressed as follows:

$$\Delta U = Q - W, \tag{117}$$

where ΔU is the change in internal energy, Q is the added heat, and W is the work done by the system [12]. Within VAM this becomes:

$$\Delta U = \Delta \left(\frac{1}{2}\rho_{æ} \int v^2 \, dV + \int P \, dV \right), \tag{118}$$

with $\rho_{æ}$ the æther density, v the local velocity and P the pressure within equilibrium vortex domains [15].

I.2 Entropy and structured vorticity

VAM states that entropy is a function of vorticity intensity:

$$S \propto \int \omega^2 \, dV, \tag{119}$$

where $\omega = \nabla \times v$ [16]. Entropy thus becomes a measure of the topological complexity and energy dispersion encoded in the vortex network.

I.3 Thermal response of vortex nodes

Stable vortex nodes embedded in equilibrium pressure surfaces behave analogously to thermodynamic systems:

- **Heating (**$Q > 0$**)** expands the node, decreases the core pressure, and increases the entropy.
- **Cooling (**$Q < 0$**)** causes a contraction of the node, concentrating energy and stabilizing the vorticity.

This provides a fluid mechanics analogy for gas laws under energetic input.

I.4 Photoelectric analogy in VAM

Instead of invoking quantized photons, VAM interprets the photoelectric effect via vortex dynamics. A vortex must absorb enough energy to destabilize and eject its structure:

$$W = \frac{1}{2}\rho_{æ} \int v^2 \, dV + P_{\text{eq}} V_{\text{eq}}, \tag{120}$$

where W is the threshold for disintegration work. If an incident wave further modulates the internal vortex energy, ejection occurs [15].

The critical force for vortex ejection is:

$$F_{æ}^{\max} = \rho_{æ} C_e^2 \pi r_c^2, \tag{121}$$

where C_e is the edge velocity of the vortex and r_c is the core radius. This provides a natural frequency limit below which no interaction occurs, comparable to the threshold frequency in quantum photoelectricity [17].

Conclusion and integration

This thermodynamic extension of VAM enriches the model by integrating classical heat and entropy principles into fluid dynamics. It not only bridges the gap between vortex physics and Clausius laws, but also provides a field-based reinterpretation of light-matter interactions, unifying mechanical and electromagnetic thermodynamics without discrete particle assumptions.

J Topological Charge in the Vortex Æther Model

J.1 Motivation from Hopfions and Magnetic Skyrmions

Recent developments in chiral magnetism have led to the experimental observation of stable, three-dimensional topological solitons called *hopfions*. These are ring-shaped, twisted skyrmion strings with a conserved topological invariant known as the *Hopf index* $H \in \mathbb{Z}$. These structures are characterized by nontrivial couplings of field lines under mappings of $\mathbb{R}^3 \to S^2$ and remain stable due to the Dzyaloshinskii–Moriya interaction (DMI) and the underlying micromagnetic energy functional [18]. Within the Vortex-Æther Model (VAM), elementary particles are considered as knotted vortex structures in an unflowable, ideal superfluid (Æther). In this framework, we formulate a VAM-compatible topological charge based on vortex helicity.

J.2 Definition of the VAM Topological Charge

Let the Æther be described by a velocity field $\vec{v}(\vec{r})$, with an associated vorticity field:

$$\vec{\omega} = \nabla \times \vec{v}. \tag{122}$$

The **vortex helicity**, or the total coupling amount of vortex lines, is then defined as:

$$H_{\text{vortex}} = \frac{1}{(4\pi)^2} \int_{\mathbb{R}^3} \vec{v} \cdot \vec{\omega} \, d^3x. \tag{123}$$

This quantity is conserved in the absence of viscosity and external torques, and represents the Hopf-type coupling of vortex tubes in the Æther continuum.

To make this dimensionless, we normalize with the circulation Γ and a characteristic length scale L:

$$Q_{\text{top}} = \frac{L}{(4\pi)^2\Gamma^2} \int \vec{v} \cdot \vec{\omega}\, d^3x, \tag{124}$$

where $Q_{\text{top}} \in \mathbb{Z}$ is a dimensionless topological charge that classifies stable vortex knots (such as trefoils or torus knot structures).

J.3 Topological Energy Term in the VAM Lagrangian

The VAM Lagrangian can be extended with a topological energy density term based on Eq. (123):

$$\mathcal{L}_{\text{top}} = \frac{C_e^2}{2} \rho_{æ}\, \vec{v} \cdot \vec{\omega}, \tag{125}$$

where $\rho_{æ}$ is the local Æther density, and C_e is the maximum tangential velocity in the vortex core. The total energy functional then becomes:

$$\mathcal{E}_{\text{VAM}} = \int \left[\frac{1}{2}\rho_{æ}|\vec{v}|^2 + \frac{C_e^2}{2}\rho_{æ}\, \vec{v} \cdot \vec{\omega} + \Phi_{\text{swirl}} + P(\rho_{æ}) \right] d^3x. \tag{126}$$

Here Φ_{swirl} is the vortex potential, and $P(\rho_{æ})$ describes thermodynamic pressure terms, possibly based on Clausius entropy.

J.4 Comparison with the Micromagnetic Energy Functional

In hopfion research, the total energy is written as:

$$\mathcal{E}_{\text{micro}} = \int_V \left[A|\nabla \vec{m}|^2 + D\vec{m} \cdot (\nabla \times \vec{m}) - \mu_0 \vec{M} \cdot \vec{B} + \frac{1}{2\mu_0}|\nabla \vec{A}_d|^2 \right] d^3x, \tag{127}$$

Where:

- A is the exchange stiffness,
- D is the Dzyaloshinskii–Moriya coupling,
- $\vec{m} = \vec{M}/M_s$ is the normalized magnetization vector,
- $\vec{A}_d$ is the magnetic vector potential of demagnetization fields.

We propose to interpret the DMI term $D\vec{m} \cdot (\nabla \times \vec{m})$ within VAM as analogous to the helicity term:

$$\vec{v} \cdot \vec{\omega} \sim \vec{m} \cdot (\nabla \times \vec{m}), \tag{128}$$

which allows us to consistently describe chiral vortex configurations in Æther, with nodal structures energetically protected by this topologically coupled behavior.

J.5 Quantization and Topological Stability

Quantization of helicity implies stability of vortex nodes against perturbations:

$$H_{\text{vortex}} = nH_0, \quad n \in \mathbb{Z}, \tag{129}$$

where H_0 is the minimum helicity unit associated with a single trefoil node. This reflects the discrete spectrum of particle structures within VAM.

J.6 Relation to Vortex Clocks and Local Time Dilation

The swirl clock mechanism for time dilation in VAM is:

$$dt = dt_\infty \sqrt{1 - \frac{U_\text{vortex}}{U_\text{max}}}, \quad \text{met} \quad U_\text{vortex} = \frac{1}{2}\rho_\text{æ}|\vec{\omega}|^2. \tag{130}$$

We assume that H_vortex modulates local time flows via additional constraints on the vortex structure — leading to deeper time dilation depending on the topology of the vortex node.

J.7 Outlook

This formal derivation provides a topological framework for classifying stable states of matter in VAM. The bridge between classical vortex helicity, modern soliton theory and circulation quantization opens the way to numerical simulations with topological charge conservation.

K Split Helicity in the Vortex Æther Model

K.1 Motivation and Context

In classical fluid dynamics, helicity describes the topological complexity of vortex structures. In the Vortex Æther Model (VAM), in which matter is viewed as nodes in a superfluid Æther, helicity is essential for stability, energy distribution, and time dilation.

Based on the work of Tao et al. [19], we split the total helicity H of a vortex tube into two components:

$$H = H_C + H_T, \tag{131}$$

where:

- H_C: the **centerline helicity**, associated with the geometric shape of the vortex axis;
- H_T: the **twist helicity**, determined by the rotation of vortex lines around this axis.

K.2 Formulation of the Helicity Components

For a vortex tube with vorticity flux C along its central axis, holds:

$$H_C = C^2 \cdot \mathrm{Wr}, \tag{132}$$

$$H_T = C^2 \cdot \mathrm{Tw}, \tag{133}$$

$$H = C^2(\mathrm{Wr} + \mathrm{Tw}), \tag{134}$$

where:

- Wr: the **writhe**, a measure of the global curvature and self-coupling of the vortex axis;
- Tw: the **twist**, a measure of the internal torsion of vortex lines about the axis.

The writhe is calculated as:

$$\mathrm{Wr} = \frac{1}{4\pi} \int_C \int_C \frac{\left(\vec{T}(s) \times \vec{T}(s')\right) \cdot (\vec{r}(s) - \vec{r}(s'))}{|\vec{r}(s) - \vec{r}(s')|^3} \, ds\, ds', \tag{135}$$

with $\vec{T}(s)$ the tangent vector of the curve C.

K.3 Application in VAM time dilation

The split helicity affects the local clock frequency of a vortex particle. We propose:

$$dt = dt_\infty \sqrt{1 - \frac{H_C + H_T}{H_{\max}}} = dt_\infty \sqrt{1 - \frac{C^2(\mathrm{Wr} + \mathrm{Tw})}{H_{\max}}}. \tag{136}$$

This formulation generalizes the previous energy-based time dilation formula, by explicitly linking topological information to the time course.

L VAM Lagrangian Based on Incompressible Schrödinger Flow

L.1 Complex Vortex Waves in Æther

We model a vortex particle as a normalized two-fold complex wavefunction:

$$\psi(\vec{r}, t) = \begin{pmatrix} a + ib \\ c + id \end{pmatrix}, \quad |\psi|^2 = 1,$$

from which the spin vector $\vec{s} = (s_1, s_2, s_3)$ and vortex field $\vec{\omega}$ are defined via a Hopf mapping.

L.2 Lagrangian with Landau–Lifshitz-like term

We define the VAM wavefunction Lagrangian as:

$$\mathcal{L}_{\mathrm{VAM}}[\psi] = \frac{i\hbar}{2}\left(\psi^\dagger \partial_t \psi - \psi \partial_t \psi^\dagger\right) - \frac{\hbar^2}{2m}|\nabla\psi|^2 - \frac{\alpha}{8}|\nabla\vec{s}|^2, \tag{137}$$

where:

- $\hbar$ is replaced by a VAM-conformal quantization constant,
- α is a dimensionless vortex coupling constant,
- $\vec{s}$ is the Hopf spin vector, calculated from ψ via:

$$s_1 = a^2 + b^2 - c^2 - d^2, \quad s_2 = 2(bc - ad), \quad s_3 = 2(ac + bd).$$

L.3 Derivation of the VAM field equation

Variation with respect to ψ^* yields the modified ISF equation:

$$i\hbar\frac{\partial\psi}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\psi + \frac{\alpha}{4}\frac{\delta}{\delta\psi^*}|\nabla\vec{s}|^2.$$

The derived Euler-Lagrange equation contains topological feedback of the nodal structure on the time evolution of the wave.

L.4 Physical Interpretation

This formulation allows us to:

1. Describe quantum superposition of vortex particles;
2. Derive VAM time delay from the helicity of $\vec{s}$;
3. Coupling stability of vortex nodes to an effective potential $V(\vec{s}) \sim |\nabla\vec{s}|^2$;
4. Simulate evolution without using classical Navier–Stokes dissipation.

M Derivation of the Fine-Structure Constant from Vortex Mechanics

In this section, we derive the fine-structure constant α within the Vortex Æther Model (VAM), showing that it arises from fundamental circulation and vortex geometry in the æther medium.

M.1 Quantization of Circulation

The circulation around a quantum vortex is quantized:

$$\Gamma = \oint \vec{v} \cdot d\vec{\ell} = \frac{h}{m_e} = \frac{2\pi\hbar}{m_e}. \tag{138}$$

For a stable vortex core of radius r_c and tangential speed C_e:

$$\Gamma = 2\pi r_c C_e. \tag{139}$$

Equating the two:

$$2\pi r_c C_e = \frac{2\pi\hbar}{m_e} \quad \Rightarrow \quad C_e = \frac{\hbar}{m_e r_c}. \tag{140}$$

M.2 Relating Vortex Radius to Classical Electron Radius

Let $r_c = \frac{R_e}{2}$, where the classical electron radius is:

$$R_e = \frac{e^2}{4\pi\varepsilon_0 m_e c^2}. \tag{141}$$

Substitute into C_e:

$$C_e = \frac{\hbar}{m_e \cdot \frac{R_e}{2}} = \frac{2\hbar}{m_e R_e}. \tag{142}$$

Substitute R_e into the above:

$$C_e = \frac{2\hbar}{m_e} \cdot \frac{4\pi\varepsilon_0 m_e c^2}{e^2} = \frac{8\pi\varepsilon_0\hbar c^2}{e^2}. \tag{143}$$

M.3 Recovering the Fine-Structure Constant

From the standard definition:

$$\alpha = \frac{e^2}{4\pi\varepsilon_0\hbar c}, \tag{144}$$

take the inverse:

$$\frac{1}{\alpha} = \frac{4\pi\varepsilon_0\hbar c}{e^2}. \tag{145}$$

Now observe:

$$\boxed{\alpha = \frac{2C_e}{c}} \tag{146}$$

Conclusion

The fine-structure constant α emerges as a ratio between swirl velocity and light speed, grounded entirely in the geometry and circulation of æther vortices. This connects quantum electrodynamics with vortex fluid mechanics and supports the broader VAM thesis: that constants like α, $\hbar$, and c are emergent from a structured æther.

N Temporal Constructs in the Vortex Æther Model (VAM)

Abstract

This appendix defines and formalizes temporal constructs crucial to the Vortex Æther Model (VAM). By introducing a structured temporal ontology—from absolute universal time (Æther-Time) to locally measurable constructs (Chronos-Time, Swirl Clocks, Vortex Proper Time) and critical transition events (Kairos Moments)—we clarify the dynamics of temporality within structured vortex fields. These constructs form the temporal-topological triad supporting VAM's description of mass, gravity, and quantum phenomena.

N.1 Hierarchical Temporal Ontology

VAM utilizes a layered temporal ontology illustrated in Figure 12:

Ætheric Time Modes — Quick Overview

$\mathcal{N}$	**Aithēr-Time**	Absolute causal background
ν_0	**Now-Point**	Localized universal present
τ	**Chronos-Time**	Measured time in the æther
$S(t)$	**Swirl Clock**	Internal vortex phase memory
T_v	**Vortex Proper Time**	Circulation-based duration
$\mathbb{K}$	**Kairos Moment**	Topological transition point

[1]

[1] Ξ_0 denotes the stationary reference frame of the universal superfluid æther. All temporal constructs evolve relative to this frame.

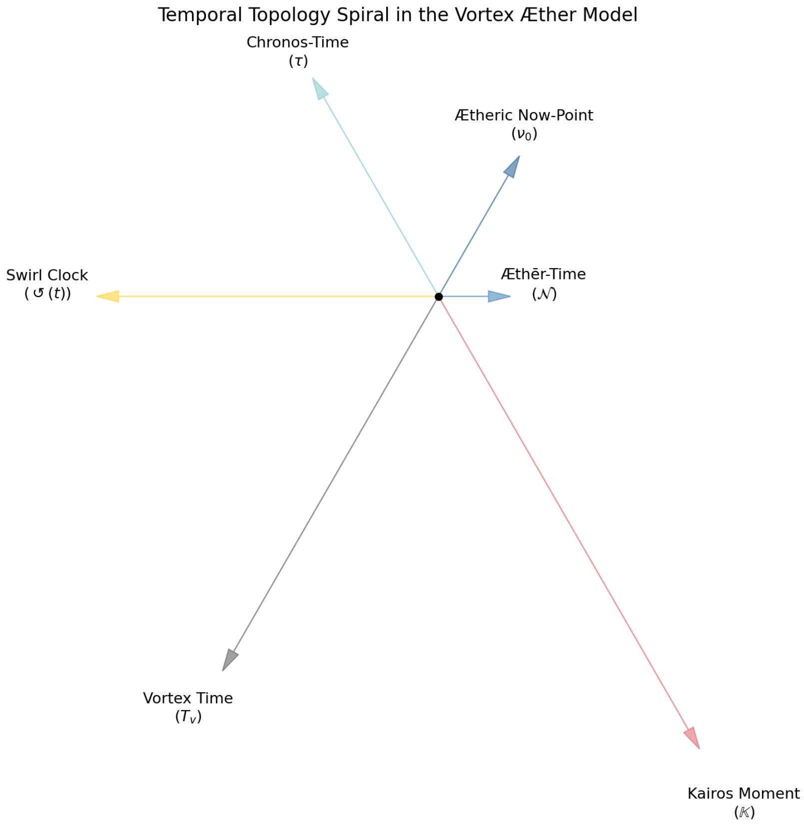

Figure 12: Temporal Topology in the Vortex Æther Model (VAM). All constructs of time emerge radially from a central ætheric origin. Each node represents a different mode of temporal existence in the VAM framework.

N.2 Mathematical Definitions

We define the following cornerstone temporal equations:

1. **Chronos-Time evolution:**
$$\frac{d\tau}{d\mathcal{N}} = \gamma^{-1}(\vec{v}) \tag{147}$$

2. **Swirl Clock gradient dynamics:**
$$\nabla S(t) = \frac{\partial \vec{S}}{\partial \mathcal{N}} + \omega(\tau)\hat{n} \tag{148}$$

3. **Æther-relative field tensor modulation:**
$$F^{\mu\nu}(\Xi_0) = \partial^\mu A^\nu - \partial^\nu A^\mu + \phi(\circlearrowleft)\delta^{\mu\nu} \tag{149}$$

4. **Ætheric causality surface:**
$$\Sigma_{\nu_0} = \{x^\mu \mid \tau(x) = \mathcal{N}\} \tag{150}$$

5. **Energy conservation with Kairos trigger:**
$$\frac{dE}{d\mathcal{N}} + \nabla \cdot \vec{J} = \mathbb{K}(\vec{x}, \tau) \tag{151}$$

These equations formalize how temporality in VAM emerges from vortex energetics, field topology, and critical transitions.

N.3 Interpretation of Temporal Constructs

Each temporal construct serves distinct roles:

- **Æther-Time** ($\mathcal{N}$)**:** Foundation for universal causality.
- **Chronos-Time** (τ)**:** Measures local dilations in vortex fields.
- **Swirl Clock** ($S(t)$)**:** Defines cyclic stability and identity of vortex particles.
- **Vortex Proper Time** (T_v)**:** Determines internal loop resonances and knot stability.
- **Kairos Moments** ($\mathbb{K}$)**:** Marks measurable critical transitions such as quantum jumps and vortex reconnections.

N.4 Practical and Experimental Relevance

Temporal constructs enable precise experimental predictions:

- **Chronos-Time** provides measurable dilations testable via atomic clocks in rotating superfluids.
- **Kairos Moments** predict discrete energy transitions observable in controlled vortex experiments, potentially providing empirical signatures differentiating VAM from classical models.

This structured temporal framework not only clarifies the theoretical underpinning of VAM but significantly enhances experimental testability.

O Temporal-Topological Dynamics in the Vortex Æther Model

Equation (1): Ætheric Energy Conservation with Kairos Trigger

$$\frac{dE}{d\mathcal{N}} + \nabla \cdot \vec{J} = \mathbb{K}(\vec{x}, \tau) \tag{152}$$

Interpretation: The rate of energy change in universal time $\mathcal{N}$ is balanced by flux divergence and a local "Kairos event" $\mathbb{K}$. When $\mathbb{K} \neq 0$, topological transitions (e.g., knot formation, decay) occur—this term models time-symmetric violations or energy "pinches."

Equation (2): Swirl Clock Phase Evolution

$$\nabla \vec{S}(t) = \frac{d}{d\mathcal{N}} \vec{S}(t) + \omega(\tau)\hat{n} \tag{153}$$

Interpretation: The spatial gradient of the internal swirl phase $\vec{S}(t)$ is composed of a universal clock drift plus intrinsic vortex angular velocity. $\omega(\tau)$ is locally defined, modulated by proper time τ.

Equation (3): Æther-Modulated Field Tensor

$$F^{\mu\nu} = \partial^\mu A^\nu - \partial^\nu A^\mu + \phi(\circlearrowleft)\delta^{\mu\nu} \tag{154}$$

Interpretation: This modified gauge field equation includes a scalar modulation based on internal swirl phase, representing helicity injection or topological memory from prior knot interactions.

Unified Interpretation

Together, these equations constitute the dynamic triad of the Vortex Æther Model: energy, phase, and field interactions modulated through temporal flow ($\mathcal{N}, \tau$) and internal vortex topology.

Concrete Examples

Example 1: Trefoil Vortex and Energy Dissipation

Consider a trefoil knot vortex with $T_v = 1.5 \times 10^{-21}$ s, circulation $\Gamma = 6.6 \times 10^{-8}$ m^2/s, and flux divergence $\nabla \cdot \vec{J} = 1.2 \times 10^{-13}$ W/m^3. At a Kairos moment $\mathbb{K} = 3.3 \times 10^{-12}$ W/m^3, the net energy change is 2.1×10^{-12} W/m^3, indicating topological energy restructuring.

Example 2: Swirl Clock Interference

Two vortex clocks with frequencies $\omega_1 = 4\pi$ rad/s and $\omega_2 = 5\pi$ rad/s produce interference with a beat structure occurring at integer multiples of 2 s. This illustrates phase coherence phenomena relevant to quantum spinor analogies.

Example 3: Swirl-Modified Gauge Field

With vector potential $A_x = e^{-x^2}\cos(\omega t)$ and swirl potential $\phi(\circlearrowleft) = \lambda \sin(\theta)$, the gauge field tensor component F^{10} becomes swirl-phase-modulated, demonstrating how internal angular structures influence observable fields.

Visualizing Temporal Dynamics in VAM

1. Swirl Clock Interference Pattern

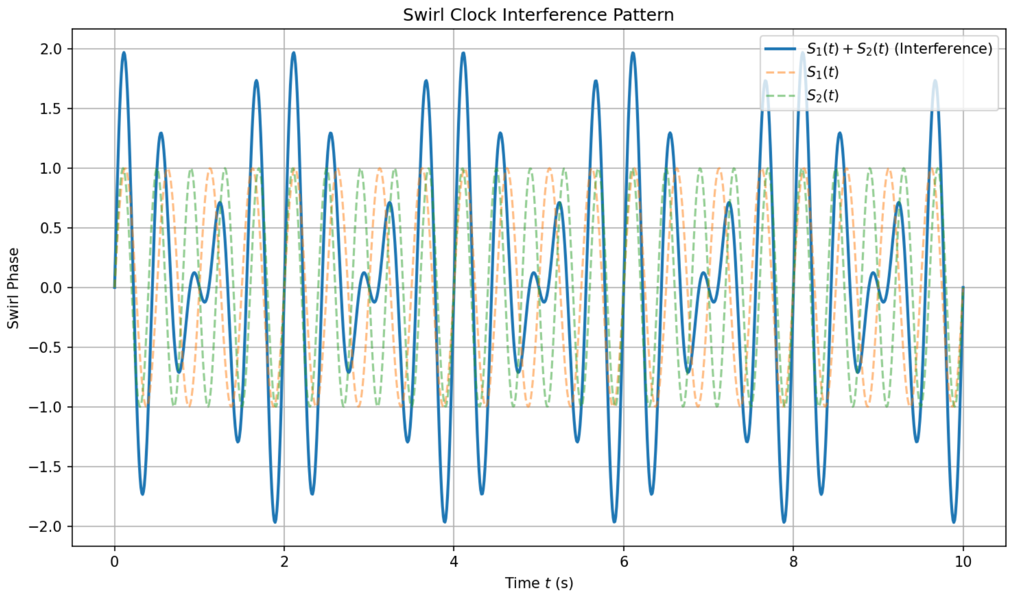

Figure 13: Interference between two swirl clocks with angular frequencies $\omega_1 = 4\pi$ and $\omega_2 = 5\pi$. The phase difference leads to beat structures and modulation patterns—analogous to quantum spinor dynamics and timing gates in ætheric systems.

2. Energy Growth from Kairos Moment

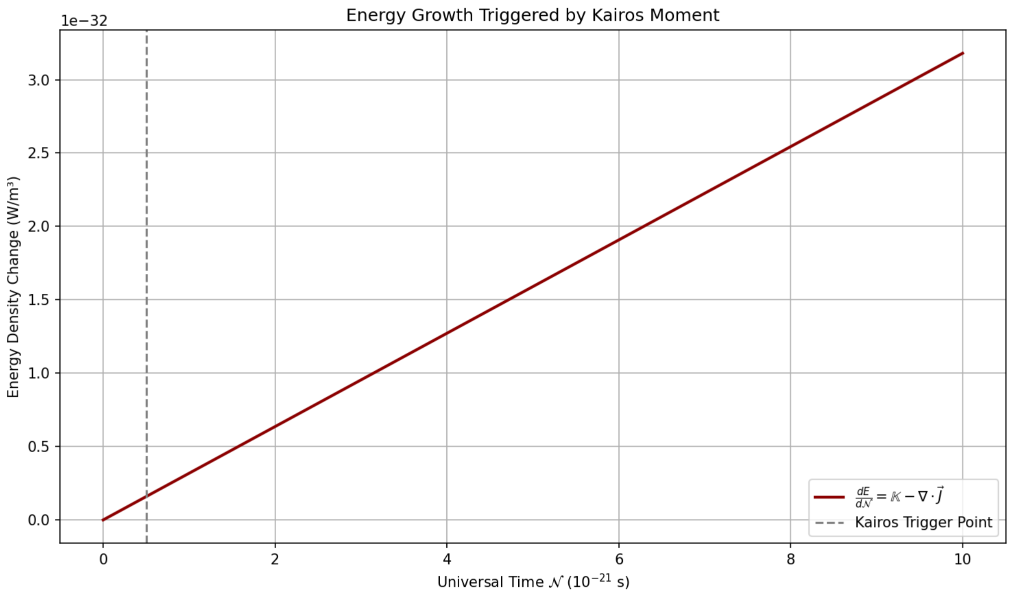

Figure 14: Temporal evolution of energy density in æther, showing energy injection at a Kairos moment ($\mathbb{K}$) minus the divergence of energy flux $\nabla \cdot \vec{J}$. The slope reflects the conservation law $\frac{dE}{d\mathcal{N}} + \nabla \cdot \vec{J} = \mathbb{K}$.

3. Swirl-Modulated Field Tensor

Figure 15: Spatial variation of the gauge field tensor component F^{10} under the influence of a swirl-phase-modulated potential $\phi(\circlearrowleft) = \lambda \sin(\theta(x))$ and a vector potential $A_x(t) = e^{-x^2} \cos(\omega t)$. This illustrates how topological internal structures alter observable field properties.

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