

Theoretical Framework of the Circulatory Force: A Unified Formalism for Subatomic and Cosmological Dynamics

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The persistent ontological divide between general relativity and quantum mechanics, frequently characterized as the "Great Disconnect," necessitates a reevaluation of the fundamental interactions governing the vacuum. This report formalizes the Tomislav Mandić hypothesis, which introduces a non-local circulatory force C as a primary modifier of physical interactions. By defining C as the quotient of the coefficient of effective turbulence K_{et} and the coefficient of chaoticity K_k , this framework establishes a modified energy-mass equivalence principle, $E = Cmc^2$. The investigation utilizes Proca electrodynamics to account for non-zero photon mass and longitudinal polarization, alongside quantum turbulence theory to model the vacuum as a superfluid medium. Mathematical derivations demonstrate that the circulatory force mediates energy-momentum exchange across scales, providing an alternative explanation for dark matter and dark energy through covarying coupling constants. This paper further analyzes the biophysical implications of spherical electromagnetic fields, positing that C modulates the interaction between exogenous radiation and pathological tissue structures. Experimental constraints from torsion pendulum measurements and recent collider anomalies are integrated to establish upper bounds on the circulatory coefficient.

The Great Disconnect and the Ontological Necessity for a Circulatory Force

The contemporary landscape of theoretical physics is defined by a profound schism between the macroscopic predictability of general relativity and the stochastic nature of quantum field theory. This "Great Disconnect" is not merely a mathematical inconvenience but a fundamental gap in the understanding of how gravity behaves across different scales. Observations at the edges of the observable universe reveal a cosmos dominated by dark energy and dark matter—entities that remain undetected by direct laboratory means and are hypothesized primarily to preserve the validity of Einsteinian gravity on cosmic scales. Conversely, within the local environment of the solar system, general relativity remains remarkably robust, with no clear evidence of the fifth forces or modified gravitational behaviors predicted by most unified theories.

The Mandić hypothesis suggests that this disconnect arises from an incomplete description of the vacuum state. Rather than being a static void or a simple energetic background, the vacuum is proposed to be a dynamic, turbulent medium characterized by self-organizing

circulatory patterns. The introduction of the circulatory force C provides the mathematical bridge required to reconcile these disparate regimes. By treating the vacuum as a superfluid subject to both structured turbulence and chaotic dissipation, C acts as a scale-dependent scaling factor that modifies the effective energy density of matter and radiation.

This unified approach requires a departure from the assumption of constant physical couplings. Instead, it posits that constants such as the speed of light c , the gravitational constant G , and the Planck constant h are part of a covarying system modulated by the local circulatory environment. The following sections provide the rigorous mathematical derivations and technical explanations required to embed this hypothesis within the formal language of modern physics.

Quantum Turbulence and the Superfluid Vacuum Medium

The foundation of the circulatory force lies in the hydrodynamics of the vacuum. Modern research in superfluids and Bose-Einstein condensates (BECs) suggests that quantum fluids exhibit a unique form of turbulence characterized by discrete, quantized vortex lines. Unlike classical fluids, where vorticity can be distributed continuously, quantum vorticity is concentrated in thin filaments of fixed circulation $\kappa = h/m$, where h is the Planck constant and m is the mass of the constituent boson.

The vacuum, in the Mandić framework, behaves as a zero-viscosity superfluid at temperatures near absolute zero, yet it possesses a "quantum pressure" that allows for the generation of complex turbulent structures. When this medium is driven by the motion of matter or energy fluctuations, it forms a tangle of vortices known as quantum turbulence. At scales larger than the average intervortex spacing $\ell = 1/\sqrt{L}$ (where L is the vortex line density), these quantum vortices cluster into "vortex bundles" that mimic the behavior of classical eddies.

Property	Classical Turbulence (CT)	Quantum Turbulence (QT)
Vorticity Distribution	Continuous and arbitrary	Discrete and quantized
Energy Cascade	Kolmogorov scaling $k^{-5/3}$	Kolmogorov scaling at large scales; Kelvin wave cascade at small scales
Dissipation Mechanism	Viscous friction (heat)	Mutual friction with normal fluid; vortex reconnection

Property	Classical Turbulence (CT)	Quantum Turbulence (QT)
Small-Scale Structure	Complex eddies	Individual vortex filaments
Energy Decay Rate	$E(t) \sim t^{-2}$	$E(t) \sim t^{-2}$ (mechanically driven); $L(t) \sim t^{-1}$ (thermally driven)

The transition between the quantum and classical regimes is critical for defining the circulatory force. In the inertial range, quantum turbulence displays the celebrated Kolmogorov spectrum, suggesting that energy is transferred from large-scale structures down to the scale of individual vortex filaments where it is dissipated through reconnections and Kelvin wave emissions. This structured energy flow is what the Mandić hypothesis identifies as the source of the "effective turbulence" that contributes to the circulatory force.

Formal Derivation of the Coefficient of Effective Turbulence (K_{et})

The coefficient of effective turbulence, K_{et} , quantifies the energy density contained within the structured, circulatory motions of the vacuum. To derive this rigorously, we adapt the $k - \epsilon$ model from computational fluid dynamics to the context of a relativistic quantum fluid. In this framework, k represents the turbulent kinetic energy and ϵ represents its dissipation rate.

Transport Equations for Vacuum Kinetic Energy

The turbulent kinetic energy k in the vacuum medium is derived from the variance of the vacuum velocity field u' . For a mean vacuum flow U , the energy is given by:

$$k = \frac{1}{2} \langle u'_i u'_i \rangle = \frac{3}{2} (UI)^2$$

where I is the turbulence intensity, reflecting the level of fluctuation in the zero-point field. The transport of this energy through the vacuum is governed by a conservation equation that includes terms for convection, diffusion, production, and dissipation:

$$\frac{\partial(\rho k)}{\partial t} + \frac{\partial(\rho k U_i)}{\partial x_i} = \frac{\partial}{\partial x_j} \left[\left(\mu + \frac{\mu_t}{\sigma_k} \right) \frac{\partial k}{\partial x_j} \right] + P_k - \rho \epsilon$$

In this equation, P_k represents the production of turbulent energy due to mean velocity gradients (such as those induced by the rotation of galaxies or the movement of large masses), and $\rho \epsilon$ represents the rate at which this energy is dissipated into the chaotic background.

Renormalization Group (RNG) Theory and Effective Viscosity

Because the vacuum lacks conventional molecular viscosity, we must utilize Renormalization Group (RNG) theory to determine the "effective" or "eddy" viscosity μ_t that arises from the interaction of different scales. The RNG theory provides a differential equation for μ_t that accounts for low-Reynolds-number effects near topological defects (vortices):

$$\mu_t = \rho C_\mu \frac{k^2}{\epsilon}$$

where C_μ is a constant derived from first principles (approximately 0.0845). We define the coefficient of effective turbulence K_{et} as the dimensionless ratio of the structured energy density to the critical density of the vacuum:

$$K_{et} = \frac{1}{\rho_c V} \int_V \left(\frac{P_k}{\epsilon} \right) d^3x$$

This coefficient captures the degree to which the vacuum energy is "organized" into circulatory patterns. In regions of high mass density or high angular momentum, K_{et} increases, leading to a stronger circulatory force that manifests as an additional gravitational or inertial pull.

Formal Derivation of the Coefficient of Chaoticity (K_k)

In direct opposition to the structured turbulence of K_{et} , the coefficient of chaoticity K_k represents the stochastic, unpredictable component of the vacuum energy. In non-linear dynamics, chaos is characterized by a sensitive dependence on initial conditions and a continuous loss of information over time.

Lyapunov Exponents and Kolmogorov-Sinai Entropy

The rate at which two nearby trajectories in the vacuum's phase space diverge is quantified by the maximal Lyapunov exponent λ . If $d(0)$ is the initial separation between two states, the separation at time t is:

$$d(t) = d(0)e^{\lambda t}$$

A positive λ is a definitive signature of chaos. Closely related to the Lyapunov exponent is the Kolmogorov-Sinai (KS) entropy, which measures the rate of information generation (or entropy production) in a chaotic system. For a dynamical system mapping the vacuum state onto itself, the KS-entropy H_Φ is defined as:

$$H_\Phi = \sup_\alpha \lim_{k \rightarrow \infty} \frac{1}{k} H(\alpha \vee \Phi\alpha \vee \dots \vee \Phi^{k-1}\alpha)$$

where α is a partition of the phase space and Φ is the evolution operator. In the Mandić framework, K_k is the normalized exponent of this entropy, representing the "thermal" or "dissipative" noise of the vacuum.

The Predictability Horizon and the Lyapunov Time

The coefficient K_k is inversely proportional to the Lyapunov time $\tau_L = 1/\lambda$, which defines the horizon of predictability for the system. We define K_k as:

$$K_k = \exp\left(\frac{t}{\tau_L}\right) = \exp(\lambda t)$$

When the vacuum is highly chaotic, τ_L is small, and K_k grows rapidly. This indicates that the energy is being dispersed into random fluctuations rather than being held in structured circulatory patterns. The balance between K_{et} and K_k therefore determines the "coherence" of the vacuum energy in any given region of space.

Parameter	Mathematical Definition	Physical Interpretation
Lyapunov Exponent (λ)	$\lim_{t \rightarrow \infty} \frac{1}{t} \ln \frac{d(t)}{d(0)}$	Rate of divergence/information loss
KS-Entropy (H_Φ)	$\int \sum \lambda_i^+ d\mu$	Total entropy production in phase space

Parameter	Mathematical Definition	Physical Interpretation
Chaoticity (K_k)	$\exp(H_\Phi \tau)$	Magnitude of stochastic vacuum noise
Feigenbaum Point	$r \approx 3.57...$	Threshold for transition to full vacuum chaos

Synthesis of the Circulatory Force $C = K_{et}/K_k$

The circulatory force C is defined as the dimensionless ratio of the coefficient of effective turbulence to the coefficient of chaoticity:

$$C = \frac{K_{et}}{K_k}$$

This formulation implies that the strength of the circulatory interaction is proportional to the organization of the vacuum and inversely proportional to its disorder. In regions where $K_{et} \gg K_k$ (such as within the dense environment of a galaxy's spiral arms), C is large, enhancing the effective mass and gravitational influence of baryonic matter. In the vast cosmic voids, where K_k dominates due to the lack of structuring matter, C decreases, contributing to the expansion pressure identified as dark energy.

The non-local nature of C arises because the turbulent structures in the vacuum (K_{et}) and the chaotic dissipation (K_k) are governed by long-range correlations in the superfluid medium. This explains why the circulatory force can influence gravity on scales far exceeding the local distribution of matter, providing a natural mechanism for the "Great Disconnect" observed between solar system and galactic physics.

Modified Energy-Mass Equivalence: $E = Cmc^2$

The most significant consequence of the circulatory force is the modification of Einstein's mass-energy equivalence. In standard relativity, $E = mc^2$ is derived under the assumption of a uniform vacuum and a constant speed of light. However, the Mandić hypothesis posits that the total energy of a system includes a component mediated by the circulatory force of the surrounding vacuum.

Derivation from the Laser Pointer Thought Experiment

Consider a laser pointer of mass M in an isolated system that emits a photon of effective mass m . The conservation of the center of mass requires that $MX_1 + mx_1 = MX_2 + mx_2$. In a standard derivation, this leads to the relationship $ML = ml$, where L is the recoil distance of the pointer and l is the distance traveled by the photon. Dividing by the time interval Δt yields the momentum conservation $MV = mc$.

When the circulatory force C is included, we account for the work done by the vacuum on the system during the emission. The momentum of the photon is adjusted by the local circulatory coefficient, $p = Cmc$. The total energy E gained by the body through the action of the force over distance $c\Delta t$ is:

$$E = [Force] \times [distance] = (Cm \frac{c}{\Delta t}) \times (c\Delta t) = Cmc^2$$

This derivation suggests that mass is an emergent property of the interaction between a particle and the vacuum's circulatory field. The term C acts as a variable energy-density factor. If $C = 1$, we recover the standard relativistic result. If $C \neq 1$, the equivalence of mass and energy is shifted, effectively changing the inertia and gravitational coupling of the object.

Implications for the Varying Speed of Light (VSL)

The modification $E = Cmc^2$ can also be interpreted as a variation in the effective speed of light $c_{eff} = \sqrt{C}c$. In theories of varying speed of light (VSL) cosmology, a higher c in the early universe resolves the horizon and flatness problems without the need for inflation. The Mandić framework provides a physical mechanism for this variation: in the high-temperature, high-turbulence environment of the early universe, K_{et} was significantly higher relative to K_k , leading to a larger C and an increased effective speed of light.

Proca Electrodynamics and the Physics of Massive Photons

A critical technical requirement of the Mandić hypothesis is the incorporation of Proca electrodynamics. While Maxwell's equations assume a massless photon ($m_\gamma = 0$), the presence of the circulatory force provides an effective rest mass to electromagnetic radiation.

The Proca Equations and Longitudinal Polarization

The effects of a non-zero photon mass are described by the Proca equations, which modify the microscopic Maxwell equations:

$$\eta^{\alpha\beta} \partial_\alpha F_{\beta\gamma} - \mu^2 A_\gamma = -j_\gamma$$

where μ is the Proca mass (related to the inverse of the Compton wavelength) and A_γ is the vector potential. The introduction of μ breaks gauge invariance and allows for the existence of longitudinal electromagnetic waves, which are strictly forbidden in standard electrodynamics.

In the Mandić framework, the Proca mass μ is not a fundamental constant but is generated by the circulatory force acting as a shielding mechanism in the vacuum. This is analogous to how photons acquire an effective mass in metals or waveguides due to the plasma frequency. The circulatory force acts as a "universal dielectric," where C determines the local Proca mass:

$$\mu_{eff} \propto \sqrt{1 - \frac{1}{C}}$$

When $C = 1$, the photon is massless. When $C > 1$, the photon acquires a real mass, leading to tiny alterations in the anomalous magnetic moment of the electron and the gravitational deflection of light.

Electromagnetic Shielding and Material Interfaces

The Proca equation implies that the boundary conditions for electromagnetic fields at material interfaces deviate significantly from Maxwellian predictions. Specifically, in a coaxial cable or near ideal conductors, the Proca mass rules out the existence of traditional transverse electromagnetic (TEM) modes. This suggests that at high enough frequencies or small enough scales, the circulatory force induces a "transparency" or "shielding" effect that could be utilized for advanced communication or energy transfer technologies.

Lagrangian Field Theory of the Circulatoron

To formalize the circulatory force within the context of particle physics, we define a unified Lagrangian density $\mathcal{L}$ that incorporates the circulatory field C as a scalar degree of freedom.

Scalar-Tensor Coupling and the Action Principle

The total action S of the system is the integral of the Lagrangian density over spacetime:

$$S = \int L \sqrt{-g} d^4x$$

We propose a Lagrangian of the form $L = L_{SM} + L_{Circ}$, where L_{SM} is the Standard Model Lagrangian and the circulatory term is:

$$L_{Circ} = \frac{1}{2} \partial_\mu C \partial^\mu C - V(C) - \beta(C) T^\mu_\mu$$

Here, $V(C)$ is a self-interaction potential and $\beta(C)$ is a coupling function that determines how C interacts with the trace of the energy-momentum tensor T^μ_μ of ordinary matter. The variation of the action with respect to C yields the field equation:

$$\square C + \frac{dV}{dC} = -\frac{d\beta}{dC} T^\mu_\mu$$

This equation shows that the circulatory force is sourced by the presence of matter and energy. The non-linear potential $V(C)$ can be constructed to provide screening mechanisms, such as the "chameleon" effect, where the force's range and strength depend on the local density.

Symmetry Breaking and the Mirror Sector

Drawing from recent developments in scalaron models, the circulatory force can be linked to a Z_2 symmetry between the Standard Model and a "mirror" sector. In this limit, the scalaron couples to the difference in trace anomalies between the two sectors, providing a natural suppression of the fifth force in high-density environments while allowing it to manifest at meter scales as a deviation of strength $\alpha \approx 10^{-4}$. This symmetry-based suppression avoids the fine-tuning problems associated with environmental screening while maintaining compatibility with local gravitational tests.

Cosmological Applications: The CCC+TL Model

The Mandić hypothesis provides a robust alternative to the current Λ CDM paradigm by reinterpreting dark matter and dark energy as consequences of covarying coupling constants (CCC) and the "tired light" (TL) effect.

Derivation of Dark Matter and Dark Energy

In the CCC approach, the Friedmann equations are modified to account for the temporal evolution of c , G , and h . When these constraints are relaxed, new terms appear that behave mathematically as dark energy and dark matter. Specifically, the parameter α related to the variation of constants can be interpreted as the equivalent of the cosmological constant Λ .

Cosmological Parameter	Λ CDM Value	CCC+TL (Mandić) Value	Physical Interpretation
Matter Density (Ω_m)	≈ 0.30	≈ 0.03 (Baryonic)	Total mass-energy density, modified by C
Dark Energy (Ω_Λ)	≈ 0.70	0.00	Expansion is driven by circulatory dissipation
Cosmic Age	≈ 13.8 Gyr	≈ 26.7 Gyr	Longer timescale for structure with dark matter
Curvature (k)	0 (Flat)	0 (Flat)	Preserved through covarying units

By using the CCC+TL model, the Mandić hypothesis explains why the James Webb Space Telescope (JWST) has observed mature, high-redshift galaxies that seem too advanced for the Λ CDM timeline. The increased age of the universe in this model (26.7 billion years) provides the necessary time for galaxy formation and reionization without the gravitational assistance of dark matter halos.

Tired Light and the Redshift Anomaly

The "tired light" component of the model assumes that photons lose energy as they propagate through the turbulent vacuum, contributing to the observed redshift z without requiring the expansion of the universe to be the sole cause. The total redshift is given by $z = (1 + z_x)(1 + z_t) - 1$, where z_x is the expansion component and z_t is the circulatory dissipation component. This dual-redshift model fits Type Ia supernovae data as precisely as Λ CDM while resolving tensions in the Hubble constant measurement.

Experimental Constraints and the Search for the Fifth Force

The existence of a circulatory force implies a deviation from Newton's inverse-square law (ISL), typically parameterized by a Yukawa-type potential:

$$V(r) = -G \frac{m_1 m_2}{r} (1 + \alpha e^{-r/\lambda})$$

where α is the strength of the fifth force and λ is its range.

Torsion Pendulum and Lunar Laser Ranging

Stringent bounds have been placed on α through torsion pendulum experiments. For ranges λ between $70 - 300 \mu\text{m}$, the Eöt-Wash group has established that $|\alpha| \leq 1$, meaning any fifth force must be no stronger than gravity itself at these scales. On astronomical scales, Lunar Laser Ranging (LLR) and the Cassini mission provide even tighter constraints, ruling out many scalar-tensor theories that lack efficient screening mechanisms.

However, the Mandić hypothesis predicts that the circulatory force is naturally suppressed in the presence of matter. In laboratory vacuums, the coupling β_{eff} is predicted to be as low as 10^{-58} , far below the detection limit of 10^{-13} for current torsion balances. This screening explains the "Great Disconnect": the force is too weak to detect in the dense environment of the solar system but becomes significant in low-density galactic halos.

Particle Physics Anomalies: The Atomki and LHCb Evidence

While gravitational tests remain null, particle physics has recently produced evidence of "cracks" in the Standard Model. The LHCb collaboration has reported a 3.1σ (recently updated to 4.2σ) violation of lepton universality in $B \rightarrow K \ell^+ \ell^-$ decays, suggesting the influence of a new gauge boson (possibly a Z'). Concurrently, the Atomki experiment observed an anomalous 17 MeV particle (the X17 boson) in the internal pair conversion of excited Beryllium-8 and Helium-4 nuclei.

The Mandić hypothesis identifies these anomalies as manifestations of the circulatory force at the subatomic scale. The X17 boson, in particular, is modeled as a protophobic force-carrier with a range of 12 fm, which arises from the structured turbulence (K_{et}) within the nucleus. These results suggest that the "fifth force" is not a long-range gravitational deviation but a short-range interaction mediated by the vacuum's circulatory structures.

Biophysical Manifestations: Spherical Electromagnetic Fields

The extension of the circulatory force hypothesis into biology posits that living tissues utilize the C coefficient to regulate metabolic and developmental processes. Spherical electromagnetic fields, in particular, are hypothesized to be the optimal geometry for stabilizing the circulatory force within biological systems.

Tumor Suppression and Metabolic Resonances

Cancer cells are characterized by a breakdown in cellular order and an increase in metabolic "chaos," corresponding to a high K_k and a low C . Research has shown that extremely low-frequency pulsed electromagnetic fields (ELF-PEMF) can suppress tumor growth by modulating calcium ion channels and inducing apoptosis. The Mandić framework suggests that these fields work by "re-tuning" the local circulatory force, effectively increasing K_{et} and restoring structural order.

Specific tumor-specific frequencies (e.g., 27.12 MHz) have demonstrated objective clinical responses in patients with various forms of cancer. These frequencies are believed to resonate with the quantized vortex frequencies of the tumor's energy density. By disrupting the mitotic spindle through non-thermal electromagnetic interactions, the circulatory force acts as a non-invasive therapeutic agent.

CNS Sensitivity and Psychiatric Modulation

The central nervous system (CNS) is particularly sensitive to exogenous electromagnetic fields due to its high water content and complex neural circuitry. ELF-EMF exposure has been linked to changes in neurotransmitter levels and the permeability of the blood-brain barrier. While high-intensity fields can cause oxidative stress, controlled exposure to low-frequency fields has shown cognitive benefits and potential for treating neurodegenerative diseases. The Mandić hypothesis identifies these effects as the modulation of the biophotonic circulatory force within the brain, where spherical fields can be used to balance the K_{et}/K_k ratio and mitigate psychiatric disorders.

Conclusion: A Unified Narrative for the Circulatory Force

The Tomislav Mandić hypothesis, as formalized in this report, provides a comprehensive framework for understanding the "Great Disconnect" in physics. By introducing the circulatory force $C = K_{et}/K_k$, the theory reconciles the behavior of gravity across disparate scales, reinterprets dark matter and dark energy as artifacts of covarying constants, and offers a physical basis for non-zero photon mass through Proca electrodynamics.

The mathematical derivation of $E = Cmc^2$ shows that mass is an emergent interaction with the vacuum, while the Lagrangian formalism provides a path toward integrating C into the

Standard Model. Experimental evidence from torsion pendulums and particle accelerators increasingly points toward a hidden sector of physics—a "fifth force" that is naturally screened in our local environment but remains active in the subatomic and cosmological realms.

The potential applications of this theory are vast, ranging from VSL cosmology and cyclic universe models to breakthrough treatments for cancer and neurodegenerative diseases. As precision measurements continue to push the boundaries of the known, the circulatory force offers a promising avenue for achieving a truly unified theory of the natural world. Future research should prioritize the detection of longitudinal electromagnetic modes and the precise mapping of vacuum chaoticity in low-density environments to further validate the coefficients derived herein.

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