Vibrational Information Field Theory (VIFT): A Unified Framework for Quantum Measurement, Relativity, and Gravity

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Abstract

This paper develops a formal conceptual and mathematical foundation for the *Vibrational Information Field Theory* (VIFT) — a hypothesis proposing that the most primitive constituents of reality are *vibrations of an underlying information field*. In VIFT, quantum superposition corresponds to the absence of informational exchange; measurement is the interaction-mediated transfer of information between localized vibrational modes; relativistic time dilation modulates the rate of information flow and thereby influences coherence lifetimes; and black holes are regions of frozen or non-oscillatory information where vibration amplitude tends to zero. The cosmological origin (Big Bang) is modelled as the primordial excitation that seeded all stable and metastable vibrational modes. This draft presents conceptual definitions, candidate field equations, variational principles, phenomenological predictions, experimental proposals, and connections to existing frameworks including quantum information theory, quantum field theory, general relativity, and the author's prior hypotheses (Spacetime Vortex Gravity and Cosmogenesis Hypothesis). The goal is to provide a rigorous starting point for mathematical development, numerical simulation, and experimental testing.

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1 Introduction

1.1 Motivation

Important unresolved tensions exist between quantum mechanics and general relativity, and between our operational definitions of measurement/information and the ontological status of quantum states. VIFT proposes a parsimonious ontology: information is physical and realized as vibrations of a fundamental information field $\mathcal{I}$ defined over spacetime. This ontology intends to (1) ground the quantum measurement process in a physically explicit interaction, (2) link coherence lifetimes to relativistic effects, (3) provide a novel interpretation of black hole information behavior, and (4) offer cosmological insight into the emergence of forces and particles as mode structures of $\mathcal{I}$.

1.2 Overview of paper

We proceed by defining the core objects and axioms of VIFT, proposing candidate dynamics via Lagrangian densities and effective field equations, and deriving phenomenological consequences. Sections detail measurement, relativistic modulation of information flow, black hole horizons as vibration sinks, cosmogenesis as primordial excitation, experimental predictions, and mathematical appendices.

2 Core Concepts and Axioms

2.1 Axioms

We state the core axioms of VIFT as starting points for mathematical development.

1. **Information Field Axiom:** There exists a fundamental scalar-tensor field $\mathcal{I}(x^\mu)$ (or a set of fields) defined on spacetime whose local excitations correspond to the presence of *information vibrations*. These excitations are the primitive ontological entities.

2. **Vibration-Particle Correspondence:** Localized stable vibrational modes of $\mathcal{I}$ correspond to what we call "particles" in effective theories. The amplitude and phase of these modes carry operationally accessible information.

3. **Superposition as Non-Informational Isolation:** A system is in a superposition if and only if the localized vibrational modes encoding its state do not exchange net information with an environment; formally, an information current $J^\mu_{\mathcal{I}}$ must vanish or be negligibly small.

4. **Measurement as Information Exchange:** Measurement is any physical process that results in non-negligible information flux between the system's localized vibrational modes and distinct environmental modes, producing effective decoherence and selection of basis states.

5. **Relativistic Modulation:** Proper time dilation changes the local dynamics of $\mathcal{I}$ by slowing the internal phase evolution of modes and the rate of information flux, thereby prolonging coherence under high relative velocity or gravitational potential.

6. **Black Hole Information Stasis:** Regions bounded by horizons correspond to boundary conditions where vibrational amplitudes of $\mathcal{I}$ approach non-oscillatory (frozen) configurations, effectively halting outgoing information flux.

2.2 Physical vocabulary

Define essential terms: *information vibration*, *information current* $J^\mu_{\mathcal{I}}$, *coherence lifetime* τ_c, *measurement flux* Φ_m, and *vibration amplitude* $A(x,t)$.

3 Mathematical Preliminaries and Candidate Field Equations

3.1 Representation of the information field

We model $\mathcal{I}$ as a set of real scalar (or complex) fields $I^a(x)$ where a indexes internal degrees of freedom (polarization, mode-type). In simplest form consider a single complex scalar field $\Psi(x)$ representing local information amplitude and phase:

$$\Psi(x) = A(x)e^{i\phi(x)}, \tag{1}$$

where $A(x)$ is the local vibrational amplitude and $\phi(x)$ is the phase encoding cyclical informational dynamics.

3.2 Effective Lagrangian

A candidate minimal Lagrangian density combining vibrational dynamics and coupling to spacetime metric $g_{\mu\nu}$ is:

$$\mathcal{L}[\Psi, g] = -\frac{1}{2}g^{\mu\nu}(\nabla_\mu \Psi^*)(\nabla_\nu \Psi) - V(|\Psi|) - \frac{1}{2}\xi R|\Psi|^2 + \mathcal{L}_{\text{int}}[\Psi, \Phi_{SM}], \tag{2}$$

where $V(|\Psi|)$ is a self-potential stabilizing modes, ξ is a nonminimal coupling constant to Ricci scalar R, and $\mathcal{L}_{\text{int}}$ denotes interaction terms with Standard Model fields Φ_{SM} responsible for information exchange (measurement channels).

3.3 Information current and superposition criterion

We define an information current:

$$J^\mu_{\mathcal{I}} = -\frac{i}{2m}(\Psi^* \nabla^\mu \Psi - \Psi \nabla^\mu \Psi^*) + \dots \tag{3}$$

This resembles a conserved current in field theory; VIFT posits that superposition requires the local net exchange across a subsystem boundary be below a threshold: $\oint_{\partial V} J^\mu_{\mathcal{I}} d\Sigma_\mu \approx 0$.

3.4 Relativistic time-dilation coupling

Proper time τ controls the internal phase evolution. For a localized mode with proper time parameterization, the internal phase evolves as $\phi(\tau) = \omega_0 \tau$. Under Lorentz factor γ, an external observer's coordinate time is $t = \gamma\tau$, so the perceived phase evolution rate slows by $1/\gamma$. This leads to a red-shifted effective interaction rate with environment modes. Phenomenologically, we include an explicit γ-dependence in decoherence terms.

4 Measurement, Decoherence, and Information Flux

4.1 Decoherence model

Couple Ψ weakly to an environmental bath of modes $\{E_k\}$. The reduced density matrix ρ_S of a subsystem obeys a master equation with decoherence rates Γ that scale with the information flux magnitude.

$$\dot{\rho}_S = -\frac{i}{\hbar}[H_S, \rho_S] + \mathcal{D}[\rho_S], \tag{4}$$

with

$$\mathcal{D}[\rho_S] = -\sum_{\alpha,\beta} \Gamma_{\alpha\beta}(O_\alpha O_\beta \rho_S + \rho_S O_\alpha O_\beta - 2O_\beta \rho_S O_\alpha). \tag{5}$$

In VIFT, Γ is determined by boundary flux of $J^\mu_{\mathcal{I}}$ and scales inversely with local proper time flow: $\Gamma \propto |\Phi_m|/\gamma$ (heuristic form).

4.2 Measurement as information channel

Measurement apparatus are modes M engineered to have large coupling g_{SM} to Ψ leading to rapid nonzero $J^\mu_{\mathcal{I}}$ across the system–apparatus boundary. We propose a qualitative measurement condition:

$$\Phi_m = \oint_{\partial V} J^\mu_{\mathcal{I}} d\Sigma_\mu > \Phi_c \;\Rightarrow\; \text{measurement (collapse-like update)} \tag{6}$$

with threshold Φ_c determined by environmental sensitivity.

5 Relativity, Time Dilation, and Coherence

5.1 Principle: Relativistic Preservation of Superposition

Principle (VIFT-R): A subsystem undergoing proper time dilation by factor γ experiences a proportionate reduction in its information exchange rate with external environments, leading to an extended coherence lifetime approximately scaling as $\tau_c^{(lab)} = \gamma\tau_c^{(proper)}$ under isolated motion.

5.2 Quantitative estimate

Consider a single qubit (two-mode vibration) moving with Lorentz factor γ. Let the decoherence rate in the qubit's rest frame be Γ_0. Observed in lab frame with time coordinate t, the effective decoherence rate becomes $\Gamma_{\text{lab}} \approx \Gamma_0/\gamma$ leading to extended decoherence time $\tau_{c,lab} = \gamma/\Gamma_0$.

5.3 Implications for experiments

This predicts measurable increases in coherence time for rapidly moving quantum systems (ions, trapped particles, atomic clocks) beyond simple relativistic time dilation of internal clocks — specifically in environments where coupling to measurement channels is dominated by local time-driven interaction rates rather than Lorentz-invariant scattering cross-sections.

6 Black Holes: Event Horizons as Vibration Sinks

6.1 Hypothesis statement

VIFT posits that as one approaches a classical event horizon, boundary conditions on Ψ and $J_{\mathcal{I}}^{\mu}$ force oscillatory modes to damp and approach non-oscillatory stationary configurations. From an external observer's viewpoint, outgoing information flux vanishes.

6.2 Modeling near-horizon behavior

Adopt Schwarzschild coordinates; near the horizon $r \to r_s$, redshift causes outgoing mode frequencies to redshift toward zero. If Ψ's dynamics include dissipative coupling to the geometry (e.g., through $\xi R|\Psi|^2$ terms or horizon boundary conditions), then amplitude $A(r,t) \to A_0$ (constant) and phase dynamics freeze: $\partial_t \phi \to 0$ as $r \to r_s$ in external coordinates. This formalizes the "zero-vibration" picture.

6.3 Information paradox reinterpretation

Rather than information being destroyed, VIFT suggests that information becomes encoded into non-oscillatory configurations within the horizon that are inaccessible to external information currents. Matter falling into the horizon undergoes conversion from oscillatory to stationary informational states; Hawking radiation then becomes a separate low-frequency channel possibly weakly correlated to interior non-oscillatory degrees of freedom.

7 Cosmological Genesis: Big Bang as Primordial Disturbance

7.1 Primordial excitation

The Big Bang is modelled as the initial global excitation of Ψ which seeded a spectrum of eigenmodes. Mode decomposition in an expanding Friedmann-Robertson-Walker background yields a set of evolving vibrational modes with effective masses and couplings. The early high-energy disturbance sets initial conditions for mode occupation numbers.

7.2 Emergence of forces and particles

Different stable vibration patterns correspond to distinct effective particle species and interaction carriers. Gravity in VIFT is a macroscopic manifestation of coherent long-wavelength distortions in the information field (consistent with Spacetime Vortex Gravity themes). The gravitational coupling strength emerges from collective response properties of Ψ under mass-energy concentrations.

8 Connections to Spacetime Vortex Gravity and Cosmogenesis Hypothesis

We include an explicit mapping between VIFT and the author's earlier models.

- Spacetime Vortex Gravity (SVG): the macroscopic vortex structures in spacetime geometry correspond to phase patterns in Ψ whose circulation produces effective gravitational attraction. VIFT provides a field-theoretic carrier for those vortex phenomena.
- Cosmogenesis Hypothesis (Anas Limit): the primordial disturbance amplitude and critical density thresholds for exotic EoS map to initial conditions on Ψ and $V(|\Psi|)$ enabling scenarios of universe-seeding collapse.

9 Predictions, Experimental Proposals, and Observational Signatures

9.1 Prediction 1: Relativistic coherence enhancement

Rapidly moving quantum systems will show coherence times extended by factor roughly equal to Lorentz gamma in regimes where environmental coupling is primarily time-rate limited. Proposed tests: entangled ion pairs where one ion is accelerated in a storage ring while the other remains stationary; interferometry with relativistic electron beams.

9.2 Prediction 2: Horizon analogue experiments

Using analogue gravity setups (Bose-Einstein condensates, nonlinear optics), create horizons where outgoing excitations experience strong redshift; measure the damping of oscillatory modes to detect approach to stationary informational configurations.

9.3 Prediction 3: Black hole remnant information encoding

Look for low-frequency correlations in Hawking-like emission from analogue systems that indicate interior stationary modes weakly coupling to emission channels.

9.4 Prediction 4: Cosmological signatures

If gravity is a collective vibration of Ψ, early-universe mode coupling could leave imprints in primordial fluctuation spectra differing subtly from standard inflationary predictions. Search for scale-dependent deviations in CMB power spectra and non-Gaussianities traceable to mode-mode coupling functions.

10 Mathematical Appendix: Formal Development

10.1 Action and Euler-Lagrange equations

From Lagrangian (2), varying Ψ^* yields:

$$\Box_g \Psi - \frac{dV}{d\Psi^*} - \xi R \Psi + \frac{\delta \mathcal{L}_{\mathrm{int}}}{\delta \Psi^*} = 0, \tag{7}$$

with $\Box_g$ the covariant d'Alembertian.

10.2 Coupling to metric and backreaction

Compute stress-energy tensor $T^{\mathcal{I}}_{\mu\nu}$ for Ψ and include backreaction on Einstein equations:

$$G_{\mu\nu} = 8\pi G(T^{\mathcal{I}}_{\mu\nu} + T^{SM}_{\mu\nu}). \tag{8}$$

Investigate stationary solutions where Ψ phase gradients create vortex-like terms contributing to effective gravitational potential.

10.3 Quantization and effective Hamiltonian

Outline canonical quantization for perturbative modes around a background Ψ_0: decompose $\Psi = \Psi_0 + \delta\Psi$ and quantize $\delta\Psi$. Show interaction Hamiltonians with SM fields produce decoherence kernels.

11 Philosophical and Foundational Remarks

Discuss observer role reframed: observers are complex information-processing subsystems whose interactions with Ψ produce the experienced classical world. Address implications for free will and metaphysical realism.

12 Conclusions and Future Work

Summarize contributions and enumerate next steps: derive explicit $V(|\Psi|)$ consistent with particle spectra, perform numerical GR+VIFT simulations of collapse/horizon formation, design and carry out analogue-horizon experiments, and compute precise decoherence scalings for relativistic quantum systems.

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References

References

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A Suggested Numerical Simulation Plan

Provide pseudocode and parameter suggestions for simulating VIFT field collapse in spherical symmetry, coupling to GR via 1+1 dimensional codes (e.g., Baumgarte-Shapiro-type approaches). Include initial conditions, boundary conditions, metrics, and discretization notes.

B Suggested Experimental Protocols

Detailed experimental design for ion-storage-ring coherence test, analogue gravity BEC horizon setup, optical cavity redshift analogues, and atomic-clock network coherence comparison across relativistic velocities.