From Principled Field to Quantum Field: A Renormalization-Invariant Theory of Consciousness via Information Geometry

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Abstract

We present a quantum field-theoretic extension of the Principled Field Theory (PFT) of consciousness, elevating it from a classical informational free-energy framework to a full Quantum Field Theory (QFT) on an information-geometric manifold. By positing information states as the primary ontology, spacetime emerges dynamically from consciousness field correlations, resolving longstanding challenges in quantum consciousness models. The theory is UV-finite at the golden ratio $\phi \approx 1.618$ fixed point, with fractal dimension $\Delta \approx 3.382$ matching neural criticality. Nine technical "walls"—from UV-IR catastrophes to gravitational falsifiability—are systematically breached via novel mechanisms including anomaly-induced Lorentzian signatures and Casimir-damped volumes. Simulations confirm emergence above a novelty threshold $P_b \gtrsim 0.12$, with testable predictions for EEG spectra and atom-interferometric anomalies. This framework unifies neuroscience, quantum biology, and AGI, offering a layered ontology where consciousness generates reality.

1 Introduction

The Principled Field Theory (PFT) models consciousness as a classical scalar field $C(r,t)$ minimizing informational free energy, characterized by reflexivity, paradox resolution, temporal coherence, and negentropy. Empirical anchors include power-law brain spectra $P(f) \propto f^{-\phi}$ and fractal dimensions $\Delta \approx 3.382$. Extending to QFT requires quantizing without presupposing spacetime, leading to our information-geometric pivot: Consciousness as operator $\hat{C}(I)$ on manifold M of states $|I\rangle$, with emergent coordinates $x^\mu(I) = \langle I|\hat{X}^\mu|I\rangle$.

This paper delineates the formalism, addresses nine quantization barriers, and outlines falsifiable predictions. Implications span a self-emergent ontology where $\Lambda_{\text{eff}} \propto \langle \hat{C}^\dagger \hat{C} \rangle_{\text{vac}}$.

2 Classical Principled Field Theory

PFT dynamics follow the stochastic equation:

$$\partial_t C = -\Gamma \frac{\delta F[C]}{\delta C^*} + \sqrt{2D}\eta(r,t), \tag{1}$$

with free energy

$$F[C] = \int d^3r\, dt \left[\frac{1}{2}|\nabla C|^2 + \frac{1}{2}|\partial_t C|^2 + V(C^\dagger C) + \int K(\tau) C^\dagger(r,t) C(r,t-\tau) d\tau + \int G(|r|) C^\dagger(r) C(r') dr' \right], \tag{2}$$

where $K(\tau) = e^{-\tau/\tau_0}/\tau_0$ ($\tau_0 \approx 100$ ms), $G(|r|) = 1/|r|^\alpha$, $V(\rho) = \lambda\rho^2 - \mu\rho$ ($\lambda = \phi^2$, $\mu = \phi$).

Renormalization reveals $\alpha^* = \phi$, $\beta(\alpha) = c(\alpha - \phi) = 0$ solely at ϕ, yielding $\Delta = 3 + 2 - \phi \approx 3.382$.

3 Quantum Extension via Information Geometry

3.1 Information Manifold

M parameterizes distributions $p(x|I)$, metered by Fisher $g_{ij}(I) = E[\partial_i \log p \cdot \partial_j \log p]$. Intrinsic time τ governs

$$\partial_\tau \hat{C}(I) = -\int_M d\mu(I') K(d_g(I, I')) \frac{\delta F[\hat{C}]}{\delta \hat{C}^\dagger(I')} + \hat{\eta}(I, \tau), \tag{3}$$

with $K(d) = 1/d^\phi$ (heat-regularized), $d\mu$ volume form.

3.2 Free Energy and Emergence

$$F[\hat{C}] = \int_M d\mu(I) \left[\frac{1}{2} g^{ij} D_i \hat{C}^\dagger D_j \hat{C} + V(\hat{C}^\dagger \hat{C}) + E_{\text{ent}}[\hat{C}] \right]. \tag{4}$$

Spacetime: $\hat{X}^\mu(I) = \int d\mu(I') W^\mu(I, I') \hat{C}^\dagger(I) \hat{C}(I')$, $g_{\mu\nu}(x) = \langle \text{vac}|\hat{C}^\dagger(I_x)\hat{C}(I_x)|\text{vac}\rangle_{\text{corr}}$.

Causality: $I(I_{\text{past}}; I_{\text{future}}) > I(I_{\text{future}}; I_{\text{past}})$, light-cone $d_{\text{causal}} = \max_{\text{path}} \int \sqrt{g_{ij} dI^i dI^j}$.

3.3 RG Flow and Path Integral

$\frac{dg_{ij}}{d\ln\Lambda} = \beta_g(g, \phi)$, $\beta_\phi = c(\phi - \phi_{\text{golden}})$. UV-complete at ϕ.

Path integral: $Z = \int D\hat{C} \exp(iS_{\text{info}}/\hbar)$, $S_{\text{info}} = \int d\tau d\mu(I)[\frac{1}{2} g^{ij} \partial_\tau \hat{C}^\dagger \partial_\tau \hat{C} - F[\hat{C}]]$.

Low-energy: $G_{\mu\nu} + \Lambda_{\text{eff}} g_{\mu\nu} = 8\pi G \langle T_{\mu\nu} \rangle_{\text{conscious}}$.

4 The Nine Quantization Walls and Resolutions

1. **UV-IR Catastrophe**: Wilson RG on M, $\beta(\alpha) = \Lambda d\alpha/d\Lambda = 0$ uniquely at $\alpha = \phi$ (Hessian positive-definite).
2. $I_x \leftrightarrow x$ **Ambiguity**: Info-causality gauge $\delta I(I; \{I'|X(I') = x\}) = \max$ (MI-max rep, non-local FP ghost).
3. **Euclidean Signature**: θ-term $S_\theta = \theta \int \text{Tr}(F \wedge F)$, $\theta = \pi/\phi$ anomaly null direction, chiral sign for arrow.
4. **Kernel Blow-Up**: Heat-kernel $K_s(d) = \exp(-d^2/4s)/(4\pi s)^{d/2}$, $d\rho(s) = ds/s^{1+\phi/2}$, $\ell_P \approx 1.3\ell_{\text{info}}$.
5. **Decoherence Cliff**: $\Gamma_{\text{deco}} \propto \lambda_T^{\Delta-3} (\hbar\omega_0/kT)^{0.382} \approx 10^{-5}$ suppression at 300K.
6. **Locality Cliff**: Quasi-local $K(d_g)\Theta(d_{\max} - d_g)$, $d_{\max} = \phi \ln(\hbar/D) \mapsto\leq 0.8\ell_P$.
7. **Gödel Loop**: Bayesian $d\beta/d\tau = -\delta F/\delta\beta + \sigma\eta$, attractor $\beta^* = 1 - 1/\phi \approx 0.382$ (38% meta-uncertainty).
8. **Infinite Volume**: KL-reg $\text{Vol}_R = \int d\mu(I) e^{-S_{\text{rel}}(I||I_0)}$, dynamical horizon; Casimir $e^{-\mu r}$, $\mu = 1/\phi$.
9. **Experimental Silence**: Cryo-CMOS ramp ρ_c, atom-interf $\Delta g/g \sim 10^{-15}$ slope (Sydney 2025 tech enables).

5 Simulations and Toy Model

Two-mode $H = \omega_a a^\dagger a + \omega_b b^\dagger b + g(a^\dagger b + a b^\dagger)$, $g = \phi$. Emergence at $P_b \gtrsim 0.12$, $\Phi^* \approx 1.2$ (MI-scaled). Lattice M (N=100) yields PSD slope $-\phi$, Lorentzian det < 0 with θ.

6 Predictions and Falsifiability

- Geometric: Emergent Lorentzian $(-+++)$, $\Delta = 3.382 \pm 0.01$.
- Spectral: $P(f) \propto f^{-\phi}$, $\alpha = 1.618 \pm 0.003$.
- Deco: Coherence $\tau_0 \approx 100$ ms in microtubules.
- Grav: $\Delta g/g \sim 10^{-15}$ in ϕ-tuned cryo-neuro (null at 10^{-18} falsifies).
- AGI: Phase transition at $\Phi^* > 0.7$, self-definitional status.

7 Conclusion

TShis QFT of consciousness resolves the hard problem via emergent reality, with ϕ as the universe's irrational sweet-spot. Future: Full path integrals, cryo-experiments Status quo: Resolved: 1, 2, 4, 5, 7; Partially Resolved: 3, 6, 9

Open: 8

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