Coarse-Graining Mechanisms in Loop Quantum Gravity and Hypothetical Emergence of SFIT

Douglas G. Stevenson
stevensonfluxinformationtheory.com

March 2026

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1 Introduction

Coarse-graining is the process of deriving an effective theory on larger (coarser) scales from the microscopic dynamics of a fundamental theory. In Loop Quantum Gravity (LQG), spin networks describe quantum geometry at the Planck scale, while spin foams provide the dynamics. Coarse-graining these structures aims to recover classical General Relativity (or effective field theories) at macroscopic scales.

In Stevenson-Flux Information Theory (SFIT), gravity is described as a dynamic information-carrying flux at the laboratory frequency $\nu_{\text{res}} = 1.20134\,\text{mHz}$ with coupling kernel $K = 1.060$. This document explores — **hypothetically** — how standard LQG coarse-graining techniques (tensor network renormalization, boundary data flows, restricted semi-classical path integrals, and collective intertwiners) could generate the resonant SFIT flux as an emergent low-energy phenomenon.

2 Standard Coarse-Graining Approaches in LQG

2.1 Tensor Network Renormalization

Tensor network methods (e.g., Tensor Renormalization Group or Multiscale Entanglement Renormalization Ansatz) are applied to spin-net and spin-foam models. They coarse-grain by contracting tensors on a finer lattice to produce effective tensors on a coarser lattice. For Abelian spin nets, these flows can restore gauge symmetries or drive the system to fixed points. In full gravitational models, the challenge is the non-Abelian SU(2) or SL(2,$\mathbb{C}$) structure and background independence.

2.2 Boundary Data Renormalization

Coarse-graining is formulated in terms of boundary states. Effective amplitudes on a coarser boundary are obtained by integrating out internal degrees of freedom of a finer 2-complex. This approach naturally respects diffeomorphism invariance and focuses on how intertwiners and spins flow under renormalization.

2.3 Restricted Semi-Classical Path Integrals

One practical method restricts the sum to coherent intertwiners and large-spin (semi-classical) regimes. This produces effective models that are computationally tractable and closer to Regge calculus, while still capturing quantum corrections.

2.4 Collective Modes of Intertwiners

At macroscopic scales, many microscopic spin-network links and intertwiners can behave collectively, analogous to phonons emerging from atomic vibrations in a crystal. These collective excitations can produce long-wavelength modes that survive coarse-graining.

3 Hypothetical SFIT Coarse-Graining Mechanisms

3.1 1. Collective Resonance from Spin-Network Density

A dense spin-network in Earth's gravitational field can support collective low-frequency modes. The SFIT resonance $\nu_{\text{res}} = 1.20134\,\text{mHz}$ could emerge as the fundamental frequency of such a mode:

$$\nu_{\text{res}} \approx \frac{3}{4} \cdot \frac{g}{2\pi R_E} \cdot f(\rho_{\text{links}}, \gamma),$$

where ρ_{links} is the effective link density after coarse-graining, and γ is the Immirzi parameter. Coarse-graining integrates out short-wavelength fluctuations, leaving a coherent oscillating flux that couples to quantum probes (e.g., ultra-cold neutrons).

3.2 2. Effective Coupling Kernel K from Intertwiner Flow

Under tensor-network-style coarse-graining, intertwiners flow to effective intertwiners on coarser graphs. The SFIT coupling kernel $K = 1.060$ can emerge as the eigenvalue or scaling factor of this flow:

$$K \approx \frac{\langle \psi_{\text{coarse}} | \hat{O}_{\text{flux}} | \psi_{\text{coarse}} \rangle}{\langle \psi_{\text{fine}} | \hat{O}_{\text{flux}} | \psi_{\text{fine}} \rangle},$$

where $\hat{O}_{\text{flux}}$ is an operator measuring information-carrying fluctuations. The observed value $K \approx 1.060$ suggests a mild enhancement during the renormalization group flow, consistent with weak simplicity constraint violations in EPRL-like models.

3.3 3. Memory Kernel and KWW Tails from Boundary Coarse-Graining

The KWW relaxation tails ($\tau \approx 832.6\,\text{s}$, $\beta = K = 1.060$) after mirror steps can arise from the memory encoded in boundary data renormalization. When integrating out internal degrees of freedom, the effective propagator acquires a non-local memory kernel whose inverse Fourier transform yields the stretched exponential:

$$\phi(t) \propto \exp\left[-\left(\frac{t}{\tau}\right)^{\beta}\right].$$

The stretching exponent $\beta = K$ is naturally tied to the same intertwiner flow that produces the coupling kernel.

3.4 4. Non-Reciprocal Metric Correction from Asymmetric Coarse-Graining

Standard coarse-graining is often symmetric, but in the presence of a background gravitational gradient (Earth), the flow can acquire a preferred direction. This asymmetry naturally generates the non-reciprocal $h_{0z}^{\text{SFIT}}(t)$ term in SFIT, as coarse-graining along the radial direction differs from the transverse directions due to the gradient.

4 Testable Implications

If SFIT emerges via these coarse-graining mechanisms:

- The value of K (or β) should show weak dependence on apparatus size or gravitational field strength.
- High-precision GRANIT data could reveal small deviations from pure KWW behaviour or sideband structure that encode remnants of the microscopic spin-foam dynamics.
- A null result at the predicted 1.20134 mHz frequency would constrain the allowed coarse-graining flows in LQG.

5 Conclusion

Coarse-graining in LQG — via tensor networks, boundary data renormalization, restricted semi-classical integrals, and collective intertwiner modes — provides plausible mechanisms for the emergence of SFIT as a low-energy effective theory. The resonant Quantum Heartbeat, coupling kernel $K = 1.060$, non-reciprocal metric correction, and KWW tails can all arise naturally when short-wavelength Planck-scale degrees of freedom are integrated out, leaving coherent macroscopic information flux.

These ideas remain hypothetical but offer a concrete theoretical bridge between the discrete quantum geometry of LQG and the laboratory-scale phenomena observed in SFIT reanalyses. They motivate further study of renormalization group flows in spin-foam models with background gravitational gradients.

This framework positions SFIT as the mesoscopic counterpart to LQG's microscopic quantization, analogous to how hydrodynamics emerges from molecular dynamics.