

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

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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 [1]. In Loop Quantum Gravity (LQG), spin networks describe quantum geometry at the Planck scale, while spin foams provide the dynamics [2]. Coarse-graining these structures aims to recover classical General Relativity (or effective field theories) at macroscopic scales [2].

In Stevenson-Flux Information Theory (SFIT), gravity is described as a dynamic information-carrying flux at the laboratory frequency  $\nu_{\text{res}} = 1.20134$  mHz with coupling kernel  $K = 1.060$  [3]. 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 [4, 8].

## 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 [4]. They coarse-grain by contracting tensors on a finer lattice to produce effective tensors on a coarser lattice [4]. For Abelian spin nets, these flows can restore gauge symmetries or drive the system to fixed points [4]. In full gravitational models, the challenge is the non-Abelian  $SU(2)$  or  $SL(2, \mathbb{C})$  structure and background independence [5].

### 2.2 Boundary Data Renormalization

Coarse-graining is formulated in terms of boundary states [6]. Effective amplitudes on a coarser boundary are obtained by integrating out internal degrees of freedom of a finer 2-complex [6]. This approach naturally respects diffeomorphism invariance and focuses on how intertwiners and spins flow under renormalization [6].

### 2.3 Restricted Semi-Classical Path Integrals

One practical method restricts the sum to coherent intertwiners and large-spin (semi-classical) regimes [7]. This produces effective models that are computationally tractable and closer to Regge calculus, while still capturing quantum corrections [7].

### 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 [8]. These collective excitations can produce long-wavelength modes that survive coarse-graining [8].

## 3 Hypothetical SFIT Coarse-Graining Mechanisms

### 3.1 Collective Resonance from Spin-Network Density

A dense spin-network in Earth's gravitational field can support collective low-frequency modes [8]. The SFIT resonance  $\nu_{\text{res}} = 1.20134$  mHz could emerge as the fundamental frequency of such a mode [8]:

$$\nu_{\text{res}} \approx \frac{3}{4} \cdot \frac{g}{2\pi R_E} \cdot f(\rho_{\text{links}}, \gamma), \quad (1)$$

where  $\rho_{\text{links}}$  is the effective link density after coarse-graining, and  $\gamma$  is the Immirzi parameter [9]. Coarse-graining integrates out short-wavelength fluctuations, leaving a coherent oscillating flux that couples to quantum probes (e.g., ultra-cold neutrons) [9, 11].

### 3.2 Effective Coupling Kernel $K$ from Intertwiner Flow

Under tensor-network-style coarse-graining, intertwiners flow to effective intertwiners on coarser graphs [6]. The SFIT coupling kernel  $K = 1.060$  can emerge as the eigenvalue or scaling factor of this flow [6]:

$$K \approx \frac{\langle \psi_{\text{coarse}} | \hat{O}_{\text{flux}} | \psi_{\text{coarse}} \rangle}{\langle \psi_{\text{fine}} | \hat{O}_{\text{flux}} | \psi_{\text{fine}} \rangle}, \quad (2)$$

where  $\hat{O}_{\text{flux}}$  is an operator measuring information-carrying fluctuations [6]. 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 [7, 6].

### 3.3 Memory Kernel and KWW Tails from Boundary Coarse-Graining

The KWW relaxation tails ( $\tau \approx 832.6$  s,  $\beta = K = 1.060$ ) after mirror steps can arise from the memory encoded in boundary data renormalization [6, 10]. When integrating out internal degrees of freedom, the effective propagator acquires a non-local memory kernel whose inverse Fourier transform yields the stretched exponential [6, 10]:

$$\phi(t) \propto \exp \left[ - \left( \frac{t}{\tau} \right)^\beta \right]. \quad (3)$$

The stretching exponent  $\beta = K$  is naturally tied to the same intertwiner flow that produces the coupling kernel [6, 10].

### 3.4 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 [4, 6]. 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 [6].

## 4 Testable Implications

If SFIT emerges via these coarse-graining mechanisms [4, 9]:

- The value of  $K$  (or  $\beta$ ) should show weak dependence on apparatus size or gravitational field strength [10].
- High-precision GRANIT data could reveal small deviations from pure KWW behavior or sideband structure that encode remnants of the microscopic spin-foam dynamics [11].
- A null result at the predicted 1.20134 mHz frequency would constrain the allowed coarse-graining flows in LQG [12].

## 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 [4, 8, 13]. 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 [8, 9, 10].

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 [11, 13]. They motivate further study of renormalization group flows in spin-foam models with background gravitational gradients [13].

This framework positions SFIT as the mesoscopic counterpart to LQG’s microscopic quantization, analogous to how hydrodynamics emerges from molecular dynamics [1, 8].

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