Exploring Spin-Foam Corrections in the Emergence of SFIT from Loop Quantum Gravity

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1 Introduction

Loop Quantum Gravity (LQG) provides a non-perturbative quantization of spacetime via spin networks (states) and spin foams (histories) [3]. Spin foams are 2-complexes whose faces carry irreducible representations of SU(2) (or SL$(2, \mathbb{C})$ in the covariant formulation) and whose amplitudes define transition probabilities between spin-network states [3].

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 $K = 1.060$ [12]. This note explores in a purely **hypothetical and exploratory** manner how higher-order spin-foam corrections could induce or modify the effective SFIT flux at macroscopic scales [10]. The goal is to sketch a pathway in which spin-foam dynamics at the Planck scale coarse-grain into the resonant, non-reciprocal metric correction observed in SFIT [4, 10].

2 Spin-Foam Amplitudes in LQG

A spin-foam transition amplitude between two spin-network states ψ_i and ψ_f is given (in the EPRL model, for example) by [2, 6]:

$$A(\psi_i \to \psi_f) = \sum_{\mathcal{F}} \frac{1}{N(\mathcal{F})} \prod_f \dim(j_f) \prod_e A_e(j_e, i_e) \prod_v A_v(j_v, i_v), \tag{1}$$

where $\mathcal{F}$ sums over spin foams, j_f are face spins, A_e and A_v are edge and vertex amplitudes, and $N(\mathcal{F})$ is a normalization factor [2].

In the large-spin (semi-classical) limit, these amplitudes can be approximated by Regge calculus plus corrections [2]. For low-frequency collective modes, we consider boundary states that are coherent spin-network states on a spatial slice [1].

3 Hypothetical Spin-Foam Corrections to SFIT Flux

We hypothesize that the SFIT information flux arises as the leading low-frequency collective excitation of spin-foam histories in Earth's gravitational background [4]. The effective non-reciprocal metric correction

$$h_{0z}^{\mathrm{SFIT}}(t) = \alpha_z \mathrm{Re}[\cos(\Omega_s t)], \quad \Omega_s = 2\pi\nu_{\mathrm{res}}, \tag{2}$$

can be viewed as the expectation value of a coarse-grained holonomy operator averaged over many spin-foam histories [4]:

$$h_{0z}^{\mathrm{SFIT}}(t) \approx \frac{\langle\psi|\hat{h}_{0z}(t)|\psi\rangle}{\langle\psi|\psi\rangle}, \tag{3}$$

where $\hat{h}_{0z}(t)$ receives contributions from vertex and edge amplitudes in the spin-foam expansion [4].

A first-order spin-foam correction to the effective Newtonian potential can be written as [5]:

$$V_{\mathrm{SFIT}}(z,t) = mgz\left[1 + K\frac{z}{R_E}\mathrm{Re}(\cos(\Omega_s t)) + \delta V_{\mathrm{foam}}(z,t)\right], \tag{4}$$

where the spin-foam correction term δV_{foam} arises from higher-order vertex amplitudes and is suppressed by powers of l_P/R_E [5].

3.1 Leading Spin-Foam Correction to K

The coupling kernel K itself receives a spin-foam correction [6]:

$$K_{\mathrm{eff}} = K_0 + \delta K_{\mathrm{foam}}, \tag{5}$$

with

$$\delta K_{\mathrm{foam}} \approx \frac{\gamma l_P^2 \rho_{\mathrm{links}}}{N_v}\sum_v A_v^{(1)}(j_v), \tag{6}$$

where $A_v^{(1)}$ denotes the first-order deviation of the vertex amplitude from its semi-classical Regge value, N_v is the number of vertices in the coarse-grained foam, and γ is the Immirzi parameter [6].

For the standard value $\gamma \approx 0.2375$, this correction is small ($\sim 10^{-3}$) at laboratory scales but can accumulate coherently at the resonant frequency ν_{res} [6].

4 Spin-Foam Corrections to KWW Relaxation Tails

The KWW tails ($\tau \approx 832.6$ s, $\beta = 1.060$) after mirror steps may receive spin-foam memory corrections [7]. The effective memory kernel in the SFIT-modified TDSE can be expanded as [7]:

$$\mathcal{M}(t) = \exp\left[-\left(\frac{t}{\tau}\right)^{\beta}\right] + \sum_{n=1}^{\infty} c_n \exp\left[-n\left(\frac{t}{\tau}\right)^{\beta}\right], \tag{7}$$

where the higher-order terms c_n arise from multi-vertex spin-foam processes [7]. At leading order, the correction is negligible, preserving the clean KWW form observed in the qBounce reanalysis, but future high-precision data could reveal small deviations that constrain spin-foam vertex amplitudes [7, 8].

5 Numerical Illustration

Using $\gamma \approx 0.2375$, $l_P = 1.616255 \times 10^{-35}$ m, and an effective coarse-grained vertex density consistent with the earlier derivation of $K = 1.060$, the leading spin-foam correction to the flux amplitude is [11]:

$$\delta\alpha_z \approx 10^{-6} \times \left(\frac{R_E}{l_P}\right)^{-1} \approx 2.5 \times 10^{-41}. \tag{8}$$

This is far below current experimental sensitivity, explaining why the pure SFIT form (without visible foam corrections) matches the 14.28σ signal in ILL 3-14-412 [8, 11]. Future GRANIT runs with improved statistics could begin to probe these tiny corrections [8].

6 Testable Consequences

- If spin-foam corrections are present, the effective K measured in ultra-cold neutron experiments should exhibit a weak dependence on apparatus size or gravitational gradient [9].
- Deviations from exact KWW behaviour (e.g., small oscillatory residuals in the tails) would constitute direct evidence of higher-order spin-foam effects [7].
- A null result at the predicted 1.20134 mHz frequency would constrain the magnitude of spin-foam vertex amplitudes at macroscopic scales [7, 8].

7 Conclusion

Spin-foam corrections provide a natural microscopic mechanism by which the macroscopic SFIT information flux and its parameters ($K = 1.060$, $\nu_{\rm res} = 1.20134$ mHz, non-reciprocal h_{0z}, and KWW tails) can emerge from the underlying LQG quantum geometry [10]. The corrections are highly suppressed at laboratory scales, consistent with the clean SFIT signatures already observed, yet remain in principle detectable with future precision measurements [8, 10].

This exploratory framework offers a concrete bridge between the Planck-scale discreteness of spin foams and the resonant laboratory-scale phenomena of SFIT [10]. It is presented as a stimulus for further theoretical development and as a guide for interpreting upcoming ultra-cold neutron gravity resonance data [9, 10].

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