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). Spin foams are 2-complexes whose faces carry irreducible representations of SU(2) (or SL(2,C) in the covariant formulation) and whose amplitudes define transition probabilities between spin-network states.

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 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. 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.

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

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

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.

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

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. The effective non-reciprocal metric correction

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

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

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

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

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

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

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

3.1 Leading Spin-Foam Correction to K

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

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

with

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

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. 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}.

4 Spin-Foam Corrections to KWW Relaxation Tails

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

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

where the higher-order terms c_n arise from multi-vertex spin-foam processes. 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.

5 Numerical Illustration

Using $\gamma \approx 0.2375$, $\ell_{\mathrm{P}} = 1.616\,255 \times 10^{-35}$ 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

$$\delta\alpha_z \approx 10^{-6} \times \left(\frac{R_E}{\ell_{\mathrm{P}}}\right)^{-1} \approx 2.5 \times 10^{-41}.$$

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. Future GRANIT runs with improved statistics could begin to probe these tiny corrections.

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.
- Deviations from exact KWW behaviour (e.g., small oscillatory residuals in the tails) would constitute direct evidence of higher-order spin-foam effects.
- A null result at the predicted 1.20134 mHz frequency would constrain the magnitude of spin-foam vertex amplitudes at macroscopic scales.

7 Conclusion

Spin-foam corrections provide a natural microscopic mechanism by which the macroscopic SFIT information flux and its parameters ($K = 1.060$, $\nu_{\mathrm{res}} = 1.20134\,\mathrm{mHz}$, non-reciprocal h_{0z}, and KWW tails) can emerge from the underlying LQG quantum geometry. 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.

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