KWW Relaxation in Quantum Gravity
with Application to Stevenson-Flux Information Theory (SFIT)

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1 Introduction

The Kohlrausch-Williams-Watts (KWW) function, also known as the stretched exponential, is one of the most ubiquitous empirical descriptions of non-exponential relaxation in complex physical systems [1]. While traditionally associated with classical disordered materials (glasses, polymers, dielectrics) [1], KWW-like behavior also appears in quantum gravity contexts as an emergent phenomenon when microscopic quantum geometry is coarse-grained to macroscopic scales [4, 11].

This document explains the physics of KWW relaxation and its relevance to quantum gravity, with particular emphasis on its role in Stevenson-Flux Information Theory (SFIT) [7].

2 The KWW Function

The KWW relaxation function is defined as [2]:

$$\phi(t) = A \exp\left[-\left(\frac{t}{\tau}\right)^{\beta}\right], \quad \text{for } t \geq 0, \tag{1}$$

where:

- A is the amplitude (often normalized to 1) [2],
- τ is the characteristic relaxation time [2],

- β ($0 < \beta \leq 1$ or $\beta > 1$ for compressed dynamics) is the stretching exponent [2, 10].

When $\beta = 1$, it reduces to a simple exponential decay [2]. When $\beta < 1$, the decay develops a slower, longer tail at large t [2]. When $\beta > 1$, it describes compressed exponential relaxation associated with active or driven processes [10].

3 Physical Origin of KWW Relaxation

KWW behavior typically arises from one or more of the following mechanisms [3, 9]:

- **Heterogeneous dynamics:** A superposition of many simple exponentials with a broad distribution of relaxation times τ_i [9]. The overall decay is the Laplace transform of this distribution [3, 9].
- **Memory effects:** Non-Markovian evolution where the relaxation rate depends on the history of the system.
- **Cooperative or hierarchical processes:** Relaxation involves correlated degrees of freedom that reorganize in a cascaded manner.

Mathematically, the classical KWW function is the inverse Laplace transform of a one-sided Lévy-stable distribution of relaxation rates [3]. This broad, asymmetric distribution naturally produces the characteristic slow tail [3].

4 KWW in Quantum Gravity

Direct use of KWW is uncommon in fundamental quantum gravity formulations, but it emerges in several effective or coarse-grained descriptions [4]:

- **Loop Quantum Gravity and Spin Foams:** Coarse-graining of spin networks can produce memory kernels and distributed relaxation timescales, leading to stretched-exponential behavior in effective dynamics [4, 11].
- **Holographic Models (AdS/CFT):** Relaxation of perturbations near black holes or critical points sometimes exhibits stretched-exponential tails due to the complex spectrum of quasinormal modes [5].
- **Quantum Cosmology:** Relaxation of cosmological perturbations after a quantum bounce can deviate from pure exponential decay [6].

5 KWW in SFIT

In Stevenson-Flux Information Theory, the KWW function plays a central and predictive role [7]. After each mirror step in the qBounce experiment, the neutron counting rate exhibits relaxation tails well-described by [8]:

$$\phi(t) \propto \exp\left[-\left(\frac{t}{\tau}\right)^{\beta}\right], \tag{2}$$

with observed parameters:

- $\tau \approx 832.6$ s
- $\beta = 1.060 = K$ (exactly equal to the coupling kernel)[cite: 29]

Physical interpretation in SFIT: The mirror step perturbs the neutron wavefunction in the gravitational potential [8]. The dynamic information-carrying flux at the geometric resonance frequency $\nu_{\text{res}} = 1.20134$ mHz introduces a non-local memory kernel [9]. The inverse Laplace transform of this kernel yields the relaxation profile, with the stretching exponent β directly tied to the flux coupling strength K[cite: 29]. The near-equality of $\tau \approx 1/\nu_{\text{res}} \approx 832.4$ s strongly suggests that the relaxation is driven by the Quantum Heartbeat itself[cite: 29].

The slightly super-stretched (compressed) value $\beta = 1.060 > 1$ is consistent with an **active, reinforcing** information flux rather than passive disorder [10].

6 Summary Table

Table 1: Comparison of Classical KWW and SFIT KWW[cite: 29]

Aspect	**Classical KWW**	**SFIT KWW**
Typical origin	Disorder, heterogeneity [1]	Dynamic information flux [7]
Stretching exponent β	Usually ≤ 1 [2]	$= K = 1.060 > 1$ (compressed) [10]
Relaxation time τ	Material-dependent [1]	≈ 832.6 s $\approx 1/\nu_{\text{res}}$[cite: 29]
Physical driver	Passive distribution of rates [3]	Active gravitational flux [7]
Observational context	Glasses, polymers, dielectrics [1]	Ultra-cold neutron gravity resonance [8]

7 Conclusion

KWW relaxation in quantum gravity is generally an emergent phenomenon arising when microscopic quantum geometry (spin networks, spin foams, or holographic degrees of freedom) is coarse-grained to macroscopic scales [4, 11]. In SFIT, it acquires a specific, testable meaning: the compressed exponential with $\beta = K = 1.060$ is a direct signature of the 1.20134 mHz information-carrying gravitational flux acting on quantum probes [7, 10].

This makes SFIT one of the few quantum-gravity-inspired models with a clear, laboratory-accessible KWW signature [12]. Future high-precision GRANIT experiments have the potential to confirm or refine this connection, providing rare empirical insight into quantum gravity at accessible energies [13].

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