Addendum: A Bridge Model Connecting Geometric Entropy (FPISBS) and First-Passage Dynamics (EDFPM)

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Abstract

This document outlines a minimalist theoretical model designed to bridge two novel, independently developed frameworks for the quantum to classical transition: the Finite Path Integrals on Stochastic Branched Structures (FPISBS) model and the Event Driven First Passage Model (EDFPM). The former provides a geometric and entropic basis for why collapse occurs, while the latter offers a statistical and operational description of how and when it manifests. We demonstrate that the core statistical functions of the EDFPM can be derived as emergent properties of the foundational entropic principles of the FPISBS, suggesting a deep and compelling synthesis between the two approaches.

1 Conceptual Frameworks

The proposed bridge connects two distinct but complementary models, situated within a broader effort to formulate physical, falsifiable theories of measurement [5, 9].

1.1 The FPISBS Framework

This model replaces the continuous path integral with a finite, simplicial decomposition of configuration space [1]. Quantum evolution occurs on a "branched manifold," where each branch σ_i carries a weight w_i. Wavefunction collapse is not a postulate, as in standard interpretations, but an emergent phenomenon driven by the maximization of an associated Shannon entropy, which forces branches to coalesce into a stable, classical state.

1.2 The EDFPM Framework

This model treats the quantum to classical transition as a first passage process in proper time, τ [2]. A quantum system "survives" in superposition until a random temporal threshold T_0 is met. This is described by a survival probability $S(\tau)$ and an instantaneous hazard rate $\lambda_{\text{hit}}(\tau)$. The model makes concrete, falsifiable predictions, such as a strict early time plateau in interferometric visibility ($S(\tau) = 1$ for $\tau < T_0$) followed by exponential like decay. This approach builds on the tradition of dynamical collapse theories like GRW [4], but posits a different physical mechanism.

The convergence of these ideas with related concepts, such as the critical transition mechanism of the Tlalpan Interpretation (QTI) [3], suggests a robust underlying principle.

2 The Bridge Model

We construct a toy model to demonstrate how the EDFPM's dynamics can emerge from the FPISBS's principles, offering a potential solution to the measurement problem distinct from explanations based solely on environmental decoherence [6, 7]. Importantly, we emphasize that the bridge equation introduced below is an *ansatz* rather than a postulate imported wholesale from FPISBS.

2.1 Step 1: The SPS Arena

We begin with the core components of the FPISBS framework:

- A system is described by a superposition of N distinct branches, $\{\sigma_i\}$, each with a time-dependent weight $w_i(\tau) \geq 0$.
- A single, stable "classical" state, C, represents the collapsed outcome.
- The total probability is conserved. We define the survival probability $S(\tau)$ as the total weight of the uncollapsed branches:

$$S(\tau) = \sum_{i=1}^{N} w_i(\tau). \tag{1}$$

  The weight of the collapsed state is $W_C(\tau)$, such that $S(\tau)+W_C(\tau) = 1$.

- The complexity of the superposition is quantified by the Shannon entropy of the uncollapsed branches:

$$H(\tau) = -\sum_{i=1}^{N} \frac{w_i(\tau)}{S(\tau)} \ln \frac{w_i(\tau)}{S(\tau)}. \tag{2}$$

  The normalization by $S(\tau)$ ensures the argument of the logarithm is a probability distribution.

2.2 Step 2: The Bridge Rule with a Two Phase Dynamic

We now introduce a dynamical rule that links the entropy of the manifold to the collapse process, gated by a temporal threshold T_0 motivated by the EDFPM:

1. **Geometric Caging ($\tau < T_0$):** Before the threshold, the branches evolve but are not yet dense enough to trigger a large scale coalescence. No probability flows to the classical state:

$$\frac{dW_C}{d\tau} = 0 \quad (\tau < T_0). \tag{3}$$

2. **Entropy Driven Coalescence ($\tau \geq T_0$):** At and after the threshold, the manifold reaches a critical complexity. We *postulate* that the rate of collapse is directly proportional to the total entropic content of the uncollapsed state, which is $S(\tau)H(\tau)$:

$$\frac{dW_C}{d\tau} = k\, S(\tau)H(\tau) \quad (\tau \geq T_0), \tag{4}$$

where k is a coupling constant. This is the central "bridge equation" of the model.

2.3 Step 3: Deriving the EDFPM Functions

From this setup, the core functions of the EDFPM emerge naturally. Although decoherence is acknowledged as a necessary part of the quantum to classical transition, this model provides a mechanism for the final selection of a single outcome [8].

Survival Probability. Since $S'(\tau) = -W_C'(\tau)$, we have:

$$S'(\tau) = -k\, S(\tau)H(\tau) \quad (\tau \geq T_0), \tag{5}$$

and for $\tau < T_0$, $S'(\tau) = 0$ with $S(\tau) = 1$, reproducing the EDFPM's strict plateau.

Hazard Function. The hazard rate is defined as $\lambda_{\text{hit}}(\tau) = -S'(\tau)/S(\tau)$:

$$\lambda_{\text{hit}}(\tau) = \begin{cases} 0, & \tau < T_0, \\ k\, H(\tau), & \tau \geq T_0. \end{cases} \tag{6}$$

Thus the phenomenological hazard rate of the EDFPM is identified with the physical entropy of the branched manifold in the FPISBS.

3 Analytic Solution for the Equal Weights Case

To see the model in action, consider the simple case where all branches are initially equal, $w_i(0) = 1/N$. The entropy is constant at its maximum value, $H(\tau) = \ln N$. The differential equation for the survival probability for $\tau \geq T_0$ becomes:

$$S'(\tau) = -k(\ln N)S(\tau), \tag{7}$$

with the initial condition $S(T_0) = 1$. The solution is a simple exponential decay:

$$S(\tau) = \exp\left[-k(\ln N)(\tau - T_0)\right] \quad (\tau \geq T_0). \tag{8}$$

This corresponds to a constant hazard rate $\lambda_{\text{hit}} = k \ln N$, matching the “OR” gate or Poissonian limit of the EDFPM. More generally, if we do not assume the weights renormalize to stay equal, the entropy $H(\tau)$ itself evolves. The differential equation $S' = -kS\,H(S)$ yields a non-constant hazard rate, corresponding to the “ageing” cases (e.g., “AND” gates) in the full EDFPM. This testability distinguishes such models from nonlinear modifications of quantum mechanics that may not produce unique experimental signatures [10].

4 Conclusion

This minimalist bridge model provides a proof of concept for a deep unification between the geometric entropic principles of the FPISBS framework and the statistical, first passage dynamics of the EDFPM. It successfully recovers the characteristic features of the EDFPM.The strict temporal plateau and the subsequent decay governed by a hazard function. From an explicitly entropy driven collapse ansatz. This suggests that the two frameworks are not merely analogous but may be describing complementary aspects of the same underlying physical reality, paving the way for a more complete, falsifiable theory of the quantum to classical transition. Such a theory must ultimately be assessed by experiment, using measures of macroscopicity to quantify the regime being tested [11].

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