A Minimal Collapse-Selection Model for Quantum Measurement

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Abstract

Collapse-based approaches to quantum foundations require explicit treatment of measurement in order to be physically meaningful. In this note, we construct a minimal two-state model in which a collapse-selection operator acts on relational configurations to produce definite outcomes. The model reproduces the transition from an initial superposed configuration to a single outcome corresponding to a fixed-point sector of the collapse dynamics. This provides a simple example of how measurement-like behavior can emerge from collapse-driven selection without taking projection as a primitive postulate.

1 Introduction

Measurement remains a central problem in quantum foundations, requiring an account of how definite outcomes arise from superposed configurations. Collapse-based frameworks must demonstrate that they can reproduce this behavior in concrete systems.

The aim of this note is to construct the simplest possible collapse-based model that reproduces:

- the emergence of a definite outcome from an initial configuration,
- the reduction of a multi-state configuration to a single stable state.

The approach taken here treats collapse as a selection process acting on relational configurations prior to any coarse-graining. Observable outcomes are then interpreted as configurations that remain stable under this selection.

2 Standard Benchmark: Two-State Measurement

In the standard formulation, a quantum state is expressed as:

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle \tag{1}$$

A measurement yields either outcome $|0\rangle$ or $|1\rangle$, with probabilities $|\alpha|^2$ and $|\beta|^2$, respectively. The process is typically modeled using projection operators onto eigenstates.

3 Minimal Collapse-Selection Construction

3.1 State Space

We define a minimal two-state relational configuration:

$$\Sigma = \{(w_0, w_1)\}, \quad w_0, w_1 \geq 0, \quad w_0 + w_1 = 1 \tag{2}$$

The variables w_0 and w_1 represent the relative support for each outcome.

3.2 Collapse Operator

We define a collapse-selection operator $\Phi : \Sigma \to \Sigma$:

$$w_i' = \frac{w_i^\gamma}{w_0^\gamma + w_1^\gamma}, \quad \gamma > 1 \tag{3}$$

This operator amplifies dominant components and suppresses subdominant ones.

3.3 Fixed Points

The system has two fixed points:

$$(1, 0), \quad (0, 1) \tag{4}$$

These correspond to definite outcomes of the measurement.

Repeated application of Φ converges to one of these fixed points. In this sense, the collapse operator maps configurations to a fixed-point sector, effectively acting as a projection onto a definite outcome.

4 Behavior Under Collapse

4.1 Initial Configuration

We take an initial configuration:

$$(w_0, w_1) = (|\alpha|^2, |\beta|^2) \tag{5}$$

4.2 Collapse Dynamics

Under repeated application of Φ:

$$(w_0, w_1) \xrightarrow{\Phi} (1, 0) \quad \text{or} \quad (0, 1) \tag{6}$$

depending on which component, w_0 or w_1, is initially dominant.

In this minimal model, outcome selection is deterministic given the initial configuration. The incorporation of probabilistic outcome selection is deferred to future work.

4.3 Outcome Selection

The collapse operator maps the configuration to a fixed-point sector corresponding to a definite outcome. This reproduces the key feature of measurement: the emergence of a single observed result.

5 Interpretation

In this construction, measurement is not taken as a primitive projection process. Instead:

- Measurement corresponds to selection of a collapse-stable fixed-point configuration.
- Definite outcomes arise from fixed-point structure of the collapse operator.

Thus, state reduction is interpreted as convergence to a stable sector rather than an externally imposed projection.

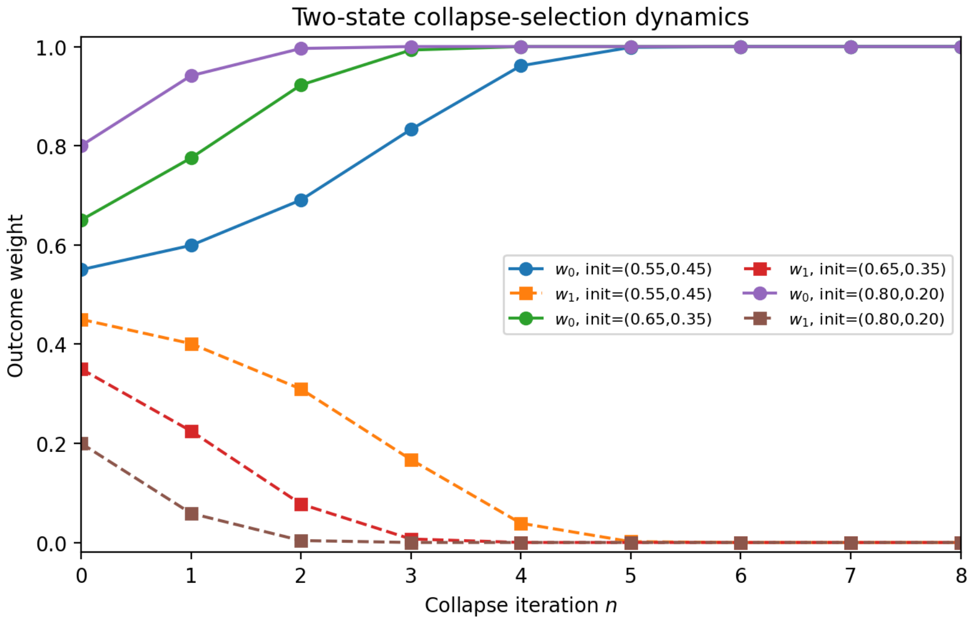

Figure 1: Two-state collapse-selection dynamics under repeated application of the operator defined in Eq. (3). For several initial configurations (w_0, w_1), the collapse operator amplifies the dominant component and suppresses the subdominant one, driving the system toward a fixed-point sector corresponding to a definite outcome. The figure was generated by direct iteration of the collapse map.

6 Relation to Standard Measurement Theory

In standard quantum mechanics:

- projection operators select eigenstates,
- measurement outcomes correspond to eigenvalues.

In the present construction:

- the collapse operator Φ selects fixed-point sectors,
- outcomes correspond to stable configurations.

This establishes a structural correspondence between collapse-selection dynamics and standard measurement theory.

7 Limitations and Next Steps

This model is intentionally minimal. It does not yet provide:

- a derivation of the Born rule,
- a treatment of continuous spectra,
- an explicit role for environmental interaction.

Future work will extend this framework to:

- multi-state systems,
- continuous measurement models,
- connections to decoherence and environment-induced selection.

8 Conclusion

We have presented a minimal collapse-selection model for measurement in a two-state system. The model reproduces the emergence of definite outcomes as fixed points of collapse dynamics, providing a simple example of how measurement-like behavior can arise from collapse-driven selection.