A Minimal Collapse-Selection Reconstruction of Two-Slit Interference

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April 26, 2026

Abstract

We present a minimal collapse-selection reconstruction of two-slit interference using the transition-kernel structure developed in Quantum Collapse Geometry (QCG). The aim is not to replace the standard quantum treatment, but to show that the collapse-selection framework reproduces the standard interference probability rule in a simple benchmark system. Two admissible transition sectors, corresponding to the two slits, contribute relational phase-weighted amplitudes to a detection configuration. When the sectors remain mutually coherent, the projected detection probability is proportional to the squared modulus of their summed transition weights. When which-path accessibility is introduced, the interference term is suppressed. This provides a compact test case showing how QCG recovers the standard two-path interference structure from admissible relational transitions.

1 Purpose

A useful test of any proposed collapse-based framework is whether it can recover the standard interference structure of quantum mechanics in the two-slit experiment.

The goal of this note is deliberately modest. We do not attempt a full derivation of quantum mechanics. Instead, we show that the transition-kernel formulation of QCG reproduces the familiar two-path probability rule:

$$P(x) \propto |\psi_1(x) + \psi_2(x)|^2. \tag{1}$$

The key interpretive shift is that the two contributions are not treated as particle trajectories through pre-existing space, but as admissible relational transition sectors whose projected interference structure is observed at the detector.

2 QCG Transition Kernel

Let C_i denote the preparation configuration and C_x the detection configuration associated with screen position x.

Let the two slit sectors be denoted:

$$C_1, \qquad C_2. \tag{2}$$

A transition from C_i to C_x may occur through either admissible intermediate sector:

$$C_i \to C_1 \to C_x, \qquad C_i \to C_2 \to C_x. \tag{3}$$

Following the QCG transition-kernel form, define a transition weight:

$$T_{\alpha\beta} = A_{\alpha\beta} \exp[-\Gamma_{\alpha\beta}] \exp(i\Theta_{\alpha\beta}), \tag{4}$$

where:

- $A_{\alpha\beta}$ is structural accessibility,
- $\Gamma_{\alpha\beta}$ is collapse-loss or distinguishability leakage,
- $\Theta_{\alpha\beta}$ is relational phase accumulation.

The total kernel from preparation to detection is then the sum over admissible transition chains:

$$K_{\text{QCG}}(C_x, C_i) = \sum_{\gamma \in \mathcal{P}(C_i \to C_x)} \prod_k T_{\alpha_{k+1}\alpha_k}. \tag{5}$$

In the two-slit system, the two slit sectors C_1 and C_2 define the only dominant admissible intermediate sectors. The interference term arises only because both chains remain admissible and phase-compatible under the finite-resolution projection to the detection screen.

For the two-slit system, keeping only the two dominant admissible chains:

$$K_{\text{QCG}}(x) = K_1(x) + K_2(x), \tag{6}$$

with

$$K_j(x) = A_j(x) \exp[-\Gamma_j(x)] \exp(i\Theta_j(x)), \qquad j = 1, 2. \tag{7}$$

2.1 Admissibility Constraints on Transition Weights

The transition weights are not introduced as arbitrary amplitudes. They are constrained objects over admissible relational sectors.

A family of transition weights

$$T_{\alpha\beta}(E) = A_{\alpha\beta}(E) e^{-\Gamma_{\alpha\beta}(E)} e^{i\Theta_{\alpha\beta}(E)} \tag{8}$$

is QCG-admissible when:

1. $A_{\alpha\beta}(E) \geq 0$ and $\Gamma_{\alpha\beta}(E) \geq 0$.
2. $T_{\alpha\beta}(E) = 0$ whenever $C_\beta \to C_\alpha$ violates admissibility.
3. $T_{\alpha\alpha}(E) > 0$ for every collapse-stable sector C_α.
4. $T_{\alpha\beta}(E)$ is invariant under finite-resolution equivalence up to admissible error.
5. $\Gamma_{\alpha\beta}(E)$ increases with collapse fragility of the transition channel.
6. $\Theta_{\alpha\beta}(E)$ is composition-compatible on admissible chains.

Thus the transition weight is not a freely chosen amplitude, but the minimal structure required to encode accessibility, loss, and relational phase across admissible sector transitions.

3 Recovery of the Interference Rule

The observable detection probability is defined by the projected kernel intensity:

$$P_{\mathrm{QCG}}(x) = |K_{\mathrm{QCG}}(x)|^2. \tag{9}$$

Substituting the two contributions:

$$P_{\mathrm{QCG}}(x) = |K_1(x) + K_2(x)|^2. \tag{10}$$

Expanding:

$$P_{\mathrm{QCG}}(x) = |K_1(x)|^2 + |K_2(x)|^2 + 2\mathrm{Re}\big(K_1(x)K_2^*(x)\big). \tag{11}$$

Using the explicit transition weights:

$$P_{\mathrm{QCG}}(x) = A_1^2 e^{-2\Gamma_1} + A_2^2 e^{-2\Gamma_2} + 2A_1A_2 e^{-(\Gamma_1+\Gamma_2)} \cos(\Theta_1 - \Theta_2). \tag{12}$$

Thus the interference term arises from relational phase compatibility between the two admissible transition sectors.

When the two sectors are symmetric:

$$A_1 = A_2 = A, \qquad \Gamma_1 = \Gamma_2 = \Gamma, \tag{13}$$

we obtain:

$$P_{\mathrm{QCG}}(x) = 2A^2 e^{-2\Gamma} \left[1 + \cos(\Delta\Theta(x))\right], \tag{14}$$

where

$$\Delta\Theta(x) = \Theta_1(x) - \Theta_2(x). \tag{15}$$

This is the standard two-path interference structure.

4 Connection to the Standard Two-Slit Formula

In the Fraunhofer regime, the phase difference between the two slit sectors is:

$$\Delta\Theta(x) \approx \frac{2\pi d}{\lambda} \sin\theta \approx \frac{2\pi d x}{\lambda L}, \tag{16}$$

where d is slit separation, L is distance to the screen, and λ is wavelength.

Therefore:

$$P_{\mathrm{QCG}}(x) \propto 1 + \cos\left(\frac{2\pi d x}{\lambda L}\right), \tag{17}$$

up to the usual single-slit envelope when finite slit width is included.

Including a slit envelope $E(x)$, the observed pattern becomes:

$$P_{\mathrm{QCG}}(x) \propto E(x) \left[1 + \cos\left(\frac{2\pi d x}{\lambda L}\right)\right]. \tag{18}$$

This reproduces the standard two-slit interference probability.

5 Which-Path Accessibility and Collapse-Loss

A which-path measurement changes the admissibility structure by increasing distinguishability between the two sectors.

Represent this by introducing an overlap factor:

$$\chi = \langle E_1 | E_2 \rangle, \tag{19}$$

where E_1 and E_2 are environmental or measurement records correlated with the two slit sectors.

The projected probability becomes:

$$P_{\mathrm{QCG}}(x) = |K_1|^2 + |K_2|^2 + 2\mathrm{Re}\left(\chi K_1 K_2^*\right). \tag{20}$$

If no which-path information exists:

$$\chi = 1, \tag{21}$$

and full interference is recovered.

If complete which-path information exists:

$$\chi = 0, \tag{22}$$

and the interference term vanishes:

$$P_{\mathrm{QCG}}(x) = |K_1|^2 + |K_2|^2. \tag{23}$$

In QCG terms, which-path information increases collapse-loss between the two relational sectors by making them distinguishable under projection. Interference disappears because the two transition sectors no longer remain jointly admissible as a coherent invariant structure.

6 Interpretation

The two-slit experiment is therefore reconstructed as follows:

Standard Quantum Description	QCG Interpretation
Path amplitude	admissible transition weight
Phase difference	relational phase incompatibility
Interference term	coherent invariant overlap
Which-path information	increased collapse-loss / distinguishability
Detection probability	projected kernel intensity

The particle is not interpreted as traveling through both slits as classical alternatives. Instead, the observable pattern arises from the projection of admissible relational transition structure onto the detector.

7 Conclusion

This minimal construction shows that the QCG transition-kernel framework reproduces the standard two-path interference rule:

$$P(x) \propto |\psi_1(x) + \psi_2(x)|^2. \tag{24}$$

The result is not presented as a full derivation of quantum mechanics, but as a benchmark compatibility result: QCG recovers the expected interference and which-path suppression behavior using admissible transition sectors, relational phase, and collapse-loss.

This provides a concrete step from structural interpretation toward recoverability of standard quantum phenomena.