From Propagation to Admissibility

Toward a QCG Transition Kernel for Spectral Structure

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Abstract

We propose a transition-kernel formulation within Quantum Collapse Geometry (QCG) motivated by near-threshold mesic nuclear experiments. In standard quantum and field-theoretic descriptions, Green's functions and propagators encode transition amplitudes between configurations and generate observable spectral structure. Within QCG, these objects are reinterpreted as coarse-grained kernels over admissible relational configurations shaped by collapse-selection dynamics.

We construct a minimal QCG transition kernel defined over admissible configuration classes and show how spectral peaks emerge as metastable, collapse-stable sectors under constraint. The real and imaginary components of the standard optical potential are reinterpreted respectively as admissibility basin depth and collapse leakage rate. This formulation provides a bridge between experimental spectral observables and QCG's generative ontology, without modifying the standard formal machinery.

1 Introduction

In mesic nuclear experiments, spectral structure is reconstructed through Green's-function methods applied to an effective optical potential. Observable peaks in excitation spectra correspond to metastable or bound configurations of the system, as explored in near-threshold η'-nucleus searches [1].

From the perspective of Quantum Collapse Geometry (QCG), such structures suggest an alternative interpretation: rather than representing propagation of entities through a pre-existing spacetime, these spectral features may be understood as arising from the persistence of admissible relational configurations under collapse-selection dynamics.

The goal of this work is to define a transition kernel within QCG that plays an analogous role to the propagator, while remaining consistent with the generative ontology of collapse, admissibility, and finite invariance.

2 Configuration Space and Admissible Sectors

Let $\mathcal{C} = \{C_\alpha\}$ denote the set of admissible relational configuration classes.

For the experimental system under consideration, relevant configuration classes include:

- quasifree background configurations,
- near-threshold η'-nucleus configurations,
- metastable bound-like sectors (e.g., $1s$, $2p$),
- absorption and decay channels.

In QCG, these are not treated as states of objects, but as admissible sectors of relational structure.

3 Admissibility and Collapse Functionals

We introduce two fundamental quantities:

3.1 Admissibility Functional

$$\Phi_\alpha(E)$$

This measures the stability or persistence of configuration class C_α at excitation energy E. Higher values correspond to deeper admissibility basins.

3.2 Collapse/Loss Functional

$$\Gamma_\alpha(E)$$

This measures the rate at which configurations lose distinguishability and collapse out of the admissible sector.

These correspond structurally to the real and imaginary components of the optical potential:

- real part $\to$ admissibility depth,
- imaginary part $\to$ collapse leakage.

4 Transition Weights Between Configurations

Define transition weights between configuration classes:

$$T_{\alpha\beta}(E) = A_{\alpha\beta}(E) \exp[-\Gamma_{\alpha\beta}(E)] \exp\left(i\Theta_{\alpha\beta}(E)\right)$$

where:

- $A_{\alpha\beta}$: structural accessibility,
- $\Gamma_{\alpha\beta}$: collapse-loss rate,
- $\Theta_{\alpha\beta}$: relational phase accumulation.

5 QCG Transition Kernel

We define the transition kernel:

$$K_{\mathrm{QCG}}(C_f, C_i; E) = \sum_{\gamma \in \mathcal{P}(C_i \to C_f)} \prod_k T_{\alpha_{k+1},\alpha_k}(E)$$

where γ runs over admissible transition chains.

This kernel plays a role analogous to the propagator but is defined over admissible relational transitions rather than trajectories in spacetime.

6 Spectral Response

The observable spectral response is given by:

$$S_{\mathrm{QCG}}(E) = \sum_{f \in \mathcal{F}_{\mathrm{tag}}} |K_{\mathrm{QCG}}(C_f, C_i; E)|^2 + B(E)$$

where:

- $\mathcal{F}_{\mathrm{tag}}$: tagged final configurations,
- $B(E)$: smooth background.

Spectral peaks correspond to configuration classes satisfying:

- high accessibility,
- low collapse leakage,
- constructive phase reinforcement.

7 One-Pole Approximation

For a metastable sector C_*, define:

$$K_*(E) = \frac{g_{f*} g_{*i}}{E - E_* + i\Gamma_*/2}$$

with:

- E_*: location of admissible invariant sector,
- Γ_*: collapse-loss rate,
- g: overlap factors.

Multiple sectors yield:

$$K(E) = \sum_* K_*(E) + K_{\mathrm{bg}}(E)$$

To make the transition-kernel proposal concrete, we now examine a minimal numerical toy model that isolates the roles of sector accessibility, collapse leakage, and relational phase in the emergence of spectral structure.

8 Numerical Toy Model

To illustrate the QCG transition-kernel framework in a minimal setting, we consider a toy spectral model built from a small set of admissible intermediate sectors. The goal is not to reproduce the full mesic-nucleus calculation, but to demonstrate that a QCG-style transition kernel can generate propagator-like spectral structure under controlled assumptions. In the present toy model, we work in a reduced one-pole approximation, in which the full transition kernel is approximated by a sum over dominant intermediate sectors.

We define the total transition kernel as

$$K(E) = \sum_{\alpha \in \{1s, 2p\}} \frac{A_\alpha e^{i\phi_\alpha}}{E - E_\alpha + i\Gamma_\alpha/2} + K_{\mathrm{bg}}(E), \tag{1}$$

where E denotes excitation energy, E_α is the center of the admissible sector α, Γ_α is its collapse-loss rate, A_α is an effective accessibility amplitude, and ϕ_α is a relational phase. The background term is taken to be a smooth linear function,

$$K_{\mathrm{bg}}(E) = a_0 + a_1 E. \tag{2}$$

The observable spectral response is defined by

$$S(E) = |K(E)|^2. \tag{3}$$

To mimic finite experimental resolution, the raw response is convolved with a Gaussian of width σ,

$$S_\sigma(E) = \int dE' \, S(E') \, G_\sigma(E - E'). \tag{4}$$

For the simulations shown below, we use an excitation-energy range $E \in [-60, 40]$ MeV and place two candidate sectors at

$$E_{1s} = -30 \text{ MeV}, \qquad E_{2p} = -6 \text{ MeV}, \tag{5}$$

chosen to mirror the qualitative structure observed in the motivating near-threshold mesic-nucleus experiment. These values are chosen to mirror the qualitative structure observed in experimental spectra near the η' production threshold [1]. The default accessibility amplitudes are

$$A_{1s} = 1.00, \qquad A_{2p} = 0.72, \tag{6}$$

and the background is taken as

$$a_0 = 0.35, \qquad a_1 = 0.002, \tag{7}$$

with Gaussian resolution $\sigma = 1.6$ MeV.

Three collapse-loss regimes are explored:

1. high loss / weak persistence,
2. intermediate loss / metastable sectors,
3. low loss / collapse-stable sectors.

These are implemented by varying Γ_{1s} and Γ_{2p} while keeping the sector locations fixed. In a second diagnostic plot, the peak heights are tracked continuously as a function of the common collapse-loss rate Γ. Finally, a phase-sensitive comparison is produced by varying the relative phase between the two sectors while keeping all other parameters fixed.

Within the QCG interpretation, E_α labels the location of an admissible invariant sector, Γ_α measures collapse leakage from that sector, A_α measures structural accessibility, and ϕ_α encodes relational phase. The simulation therefore serves as a minimal demonstration that collapse-stable sectors can produce observable spectral peaks in a coarse-grained transition-kernel description.

9 Interpretation

Within QCG:

- Within this perspective, propagators may be viewed as effective kernels over admissible transitions, rather than fundamental transport mechanisms.
- they are effective kernels over admissible transitions,

- spectral peaks reflect collapse-stable invariant sectors,
- background reflects rapidly collapsing configurations.

Within this interpretation, spectral peaks correspond to metastable admissible sectors whose persistence is sufficient to produce observable structure, consistent with the interpretation of bound or quasi-bound states in mesic nuclear experiments [1]. In this sense, the distinction between the real and imaginary components of the optical potential is not merely formal, but reflects a structural separation between persistence (admissibility) and loss (collapse), which together determine whether a configuration contributes observable spectral weight.

10 Discussion

This formulation does not modify the standard Green's-function machinery but reinterprets its role within a generative ontology.

It provides:

- a bridge between experimental spectral data and QCG,
- a candidate transition object analogous to propagators,
- a framework for understanding persistence and decay in terms of admissibility and collapse.

Future work will aim to formalize conditions under which this kernel reduces to standard propagator structure.

11 Predicted Deviations from Effective Optical-Potential Descriptions

The optical-potential framework provides a successful effective description of near-threshold mesic nuclear systems, capturing spectral structure through a complex potential and Green's-function formalism. Within Quantum Collapse Geometry (QCG), this description is interpreted as a coarse-grained representation of deeper admissibility structure arising from collapse-selection dynamics.

From this perspective, the optical potential is not fundamental, but an effective compression of a more structured landscape of admissible relational configurations. As such, QCG does not predict the breakdown of optical-potential modeling at the level of gross spectral features (e.g., the existence of near-threshold peaks), but rather anticipates systematic deviations in how spectral weight is organized.

11.1 Non-Universality of Effective Potential Parameters

In the optical-potential framework, the system is characterized by a small number of global parameters (e.g., V_0 and W_0) assumed to be independent of the observational channel. In QCG, these parameters are interpreted as effective summaries of sector-dependent admissibility and collapse leakage.

As a consequence, QCG predicts that the extracted effective potential parameters may exhibit systematic variation depending on:

- the decay channel or tagging condition,
- the spectral window used in fitting,

- the background model assumed.

Such variations would reflect the compression of multiple admissibility sectors into a single effective description rather than true physical changes in a uniform medium.

11.2 Structure of Collapse-Loss Beyond a Single Width Parameter

The imaginary component of the optical potential is typically interpreted as a single absorption or decay width. In QCG, this term corresponds to collapse leakage, i.e., the rate at which configurations lose distinguishability and fail to persist as admissible sectors.

QCG predicts that this leakage may not be fully captured by a single smooth parameter. Instead, collapse-loss may be:

- sector-dependent,
- energy-dependent near threshold,
- sensitive to decay pathways.

Observable consequences may include deviations from simple Lorentzian peak shapes, asymmetric broadening, or channel-dependent effective widths.

11.3 Residual Structure in the Spectral Background

In standard analyses, the non-peak component of the spectrum is treated as a smooth pedestal, often modeled with a low-order polynomial. Within QCG, this component is interpreted as the contribution of rapidly collapsing or unresolved admissible sectors.

If this interpretation is correct, the background need not be strictly smooth. QCG therefore predicts that:

- weak structure may be present within the pedestal,
- the apparent background shape may depend on tagging conditions,
- subtle correlations may appear near threshold regions.

Such effects would indicate that the pedestal is not purely incoherent background, but a compressed representation of unresolved sector structure.

11.4 Limits of Single-Kernel Propagation Descriptions

The Green's-function method assumes that spectral structure can be reconstructed from a single effective propagator associated with the optical potential. In QCG, this propagator is interpreted as an effective transition kernel over admissible sectors.

QCG predicts that this description may become insufficient in regimes where:

- multiple admissible sectors overlap strongly,
- collapse-loss mechanisms vary across sectors,
- intermediate configurations are not well described by a single coherent propagation channel.

In such cases, deviations may appear in the relative weighting of spectral features, the shape of spectral tails, or inconsistencies across different observables.

11.5 Metastable Sectors versus Static Eigenstates

Within the optical-potential framework, spectral peaks are commonly interpreted as bound or quasi-bound eigenstates of the effective Hamiltonian. In QCG, these features are instead interpreted as metastable admissible sectors.

While these interpretations coincide at the level of observable peaks, QCG predicts that:

- sector identities may exhibit mixing beyond simple orbital classification,
- peak prominence may depend on preparation and decay pathways,
- interference-like effects may modify spectral structure.

This suggests that observed peaks may reflect families of collapse-stable configurations rather than purely static eigenmodes.

11.6 Summary of Expected Deviations

In summary, QCG does not predict a breakdown of effective optical-potential descriptions at the level of gross spectral features. Instead, it predicts that deviations should appear in the detailed organization of spectral weight, including:

- channel-dependent variation in effective parameters,
- non-universal collapse-loss behavior,
- structured contributions within the spectral background,
- limitations of single-kernel propagation models,
- metastable sector behavior beyond simple eigenstate interpretation.

These deviations provide potential avenues for distinguishing between a purely effective optical-potential description and a deeper collapse-selection-based ontology.

12 Conclusion

We have constructed a minimal QCG transition kernel motivated by mesic nuclear experiments. This kernel reinterprets propagation as a coarse-grained summary of admissible relational transitions under collapse-selection dynamics. This suggests that QCG-style admissibility structures may provide a useful interpretive layer for organizing spectral phenomena across a broader class of near-threshold systems.

This provides a concrete bridge between QCG and experimentally accessible spectral observables, and establishes a foundation for further formal development.

References

[1] R. Sekiya et al. "Excitation Spectra of the $^{12}\mathrm{C}(p,d)$ Reaction near the η'-Meson Emission Threshold Measured in Coincidence with High-Momentum Protons". In: *Phys. Rev. Lett.* 136 (14 Apr. 2026), p. 142501. DOI: 10.1103/6vsl-ng7x. URL: https://link.aps.org/doi/10.1103/6vsl-ng7x.

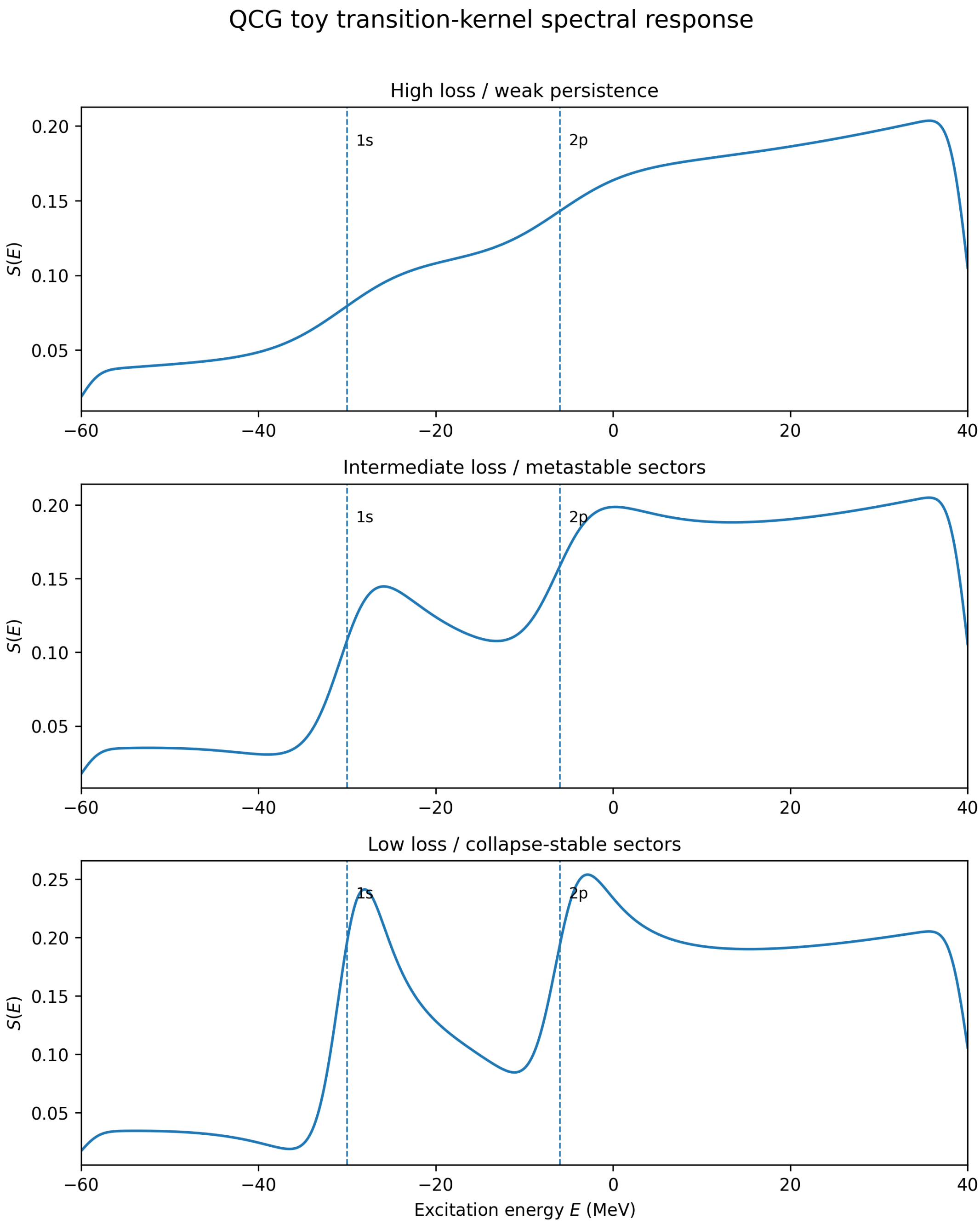

Figure 1: Toy spectral response generated by the QCG transition kernel in three collapse-loss regimes. The two vertical dashed lines mark the centers of the candidate admissible sectors at $E_{1s} = -30$ MeV and $E_{2p} = -6$ MeV. In the high-loss regime, the spectral response is largely smooth and the sectors fail to appear as distinct peaks. In the intermediate regime, metastable structure begins to emerge. In the low-loss regime, both sectors appear as clear spectral peaks. This illustrates the basic QCG principle that observable structure emerges when admissibility is sufficiently strong relative to collapse leakage.

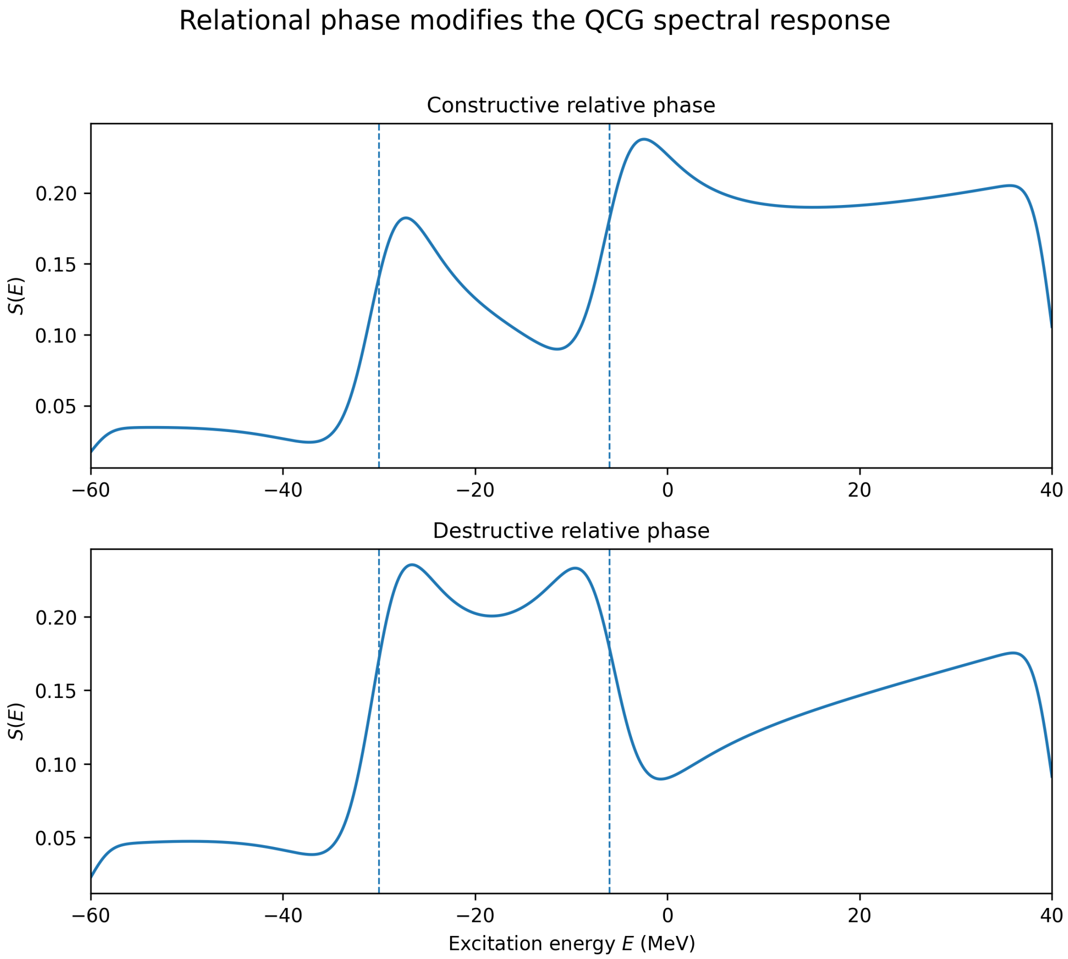

Figure 2: Dependence of the toy spectral response on the relative relational phase between the two admissible sectors. The upper panel shows a constructive relative phase, while the lower panel shows a destructive relative phase. Although the sector locations remain fixed, the spectral response changes due to phase-dependent interference in the transition kernel. This demonstrates that the QCG kernel can encode not only accessibility and loss, but also relational phase structure.

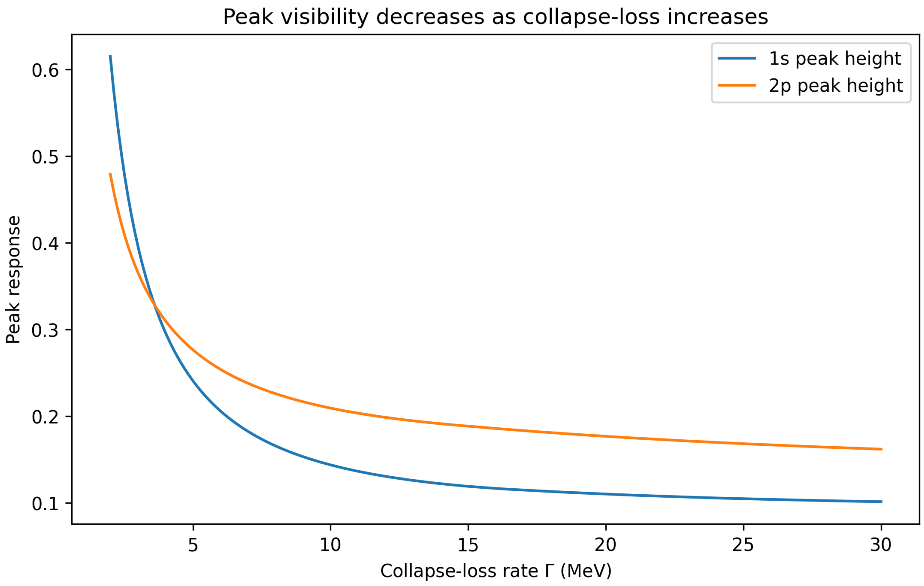

Figure 3: Peak visibility as a function of the collapse-loss rate Γ in the toy model. The plotted quantities are the local peak heights near the $1s$ and $2p$ sectors. As Γ increases, both peaks are progressively washed out. This supports the interpretation of Γ as a collapse-leakage parameter: larger leakage suppresses the persistence of admissible sectors and therefore reduces observable spectral structure.