SymC: A Phenomenological Boundary Postulate for Quantum–Classical Convergence

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Abstract

The dimensionless ratio $\chi \equiv \gamma/(2|\omega|)$, comparing damping rate to characteristic frequency, is proposed as a universal boundary condition governing adaptive stability in open systems. The value $\chi = 1$ marks a critical boundary: a second–order exceptional point where propagator poles coalesce, information efficiency reaches a local maximum, and monotone relaxation is fastest. Systems operating in the adaptive window $0.8 \lesssim \chi \lesssim 1.0$ exhibit stable, responsive behavior; departures toward $\chi < 0.8$ (underdamped) or $\chi > 1.2$ (overdamped) correlate with instability or rigidity. This same structure appears across quantum platforms, cosmological perturbations, biological regulation, seismic fault dynamics, financial market microstructure, and strong–gravity boundary layers—spanning more than fifteen orders of magnitude. This recurrence is not coincidental: any system linearizable near a stationary point inherits a χ–structure by necessity, and only near–critical substrates can support higher–level adaptive behavior. The postulate therefore functions as a boundary constraint on admissible physical theories.

1 The SymC Ratio

The linearized dynamics of open systems reduce to

$$\ddot{x} + \gamma \dot{x} + \omega^2 x = 0, \tag{1}$$

where ω is a characteristic frequency and γ a damping rate. Equation (1) is not a model choice; it is the universal normal form obtained by linearizing any dynamical system near equilibrium and retaining the dominant complex conjugate eigenpair [1,18]. The qualitative behavior is determined entirely by

$$\chi \equiv \frac{\gamma}{2|\omega|}. \tag{2}$$

For $\chi < 1$, trajectories are underdamped and oscillatory. For $\chi > 1$, they are overdamped and monotone. At $\chi = 1$, the system is critically damped—the boundary between oscillation and exponential decay.

2 Why $\chi = 1$ Is Special

Three independent arguments identify $\chi = 1$ as structurally distinguished:

1. **Exceptional point.** The characteristic exponents $\lambda_\pm = -\gamma/2 \pm \sqrt{(\gamma/2)^2 - \omega^2}$ coalesce at $\chi = 1$. The $\chi = 1$ condition generically produces a second–order exceptional point (EP_2), where eigenvectors coalesce and the generator becomes non–diagonalizable [2,3]. The propagator kernel transitions from oscillatory ($e^{-\gamma t/2} \cos \omega' t$) to the critical form $te^{-|\omega|t}$, then to pure exponential decay.

2. **Information efficiency.** An information–efficiency functional $\eta(\chi)$, measuring signal transmission per unit dissipation, reaches a strict local maximum at $\chi = 1$ under broad conditions [19,20]. The adaptive window $0.8 \lesssim \chi \lesssim 1.0$ is not fundamental; it arises from finite bandwidth, noise, and delay, broadening the exact $\chi = 1$ condition into the operational range observed across real systems.

3. **Fastest monotone relaxation.** Among all monotone (non–oscillatory) responses, critical damping returns to equilibrium fastest [18]. This is the optimal trade–off between speed and stability.

Under one–loop renormalization–group flow in weakly coupled theories, $d\chi/d\ell \propto O(\lambda)$, making $\chi = 1$ an approximate fixed line that persists across energy scales [19].

3 Substrate Inheritance

A universal boundary requires a mechanism for its recurrence across scales. Substrate inheritance provides this: stable systems at organizational level L cannot be constructed from persistently unstable components at level $L - 1$. If substrates exhibit $\chi_{L-1} < 0.8$, their oscillatory instabilities propagate upward; if $\chi_{L-1} \gg 1$, sluggishness propagates. Only near–critical substrates ($\chi \approx 1$) permit stable, adaptive higher–level dynamics.

Given inter–level couplings, stability propagates upward via adiabatic mixing: the effective χ of an emergent mode is a weighted average of substrate χ values [20]. The specific couplings are theory–dependent inputs; the structural constraint that they must preserve $\chi \approx 1$ is universal. The dominant eigenvalues of hierarchical Jacobians are smooth functions of substrate eigenvalues, so systems at multiple scales converge toward the same near–critical band because their substrates already occupy it.

4 Cross–Domain Evidence

The same χ structure appears across independent domains. Table 1 summarizes the mapping.

Table 1: Cross–domain manifestations of the SymC boundary condition.

Domain	**χ Expression**	**Observable Consequence**
Quantum systems [1,2,19]	$\chi = \gamma/(2\|\omega\|)$ via Lindblad dynamics	Spectral merger at exceptional point; coherence–to–decoherence transition at $\chi = 1$
Cosmology [11,12,21]	$\chi_\delta = \Gamma/(2\omega_\delta)$ for density perturbations	$\chi_\delta = 1 \Leftrightarrow q = 0$ identity; growth–to–decay transition at deceleration boundary
Biological regulation [24]	$\chi(t)$ from eigenvalues of linearized control dynamics	Healthy regulation clusters in $0.8 \lesssim \chi \lesssim 1.0$; departures correlate with pathology
Neurodynamics [15,23]	$\chi = \gamma/(2\omega)$ from oscillatory envelope decay	Tremor ($\chi < 0.8$), rigidity ($\chi > 1.2$), healthy motor control ($\chi \approx 0.9$)
Seismology [13,14,22]	χ_{fault} from GPS/strain time series	Precursor transitions toward $\chi = 1$ before rupture; χ indicates capacity, stress orientation determines slip direction
Market microstructure [16,17,26]	γ = liquidity replenishment, ω = order arrival frequency	Efficient markets cluster at $\chi \approx 0.9$; $\chi < 0.8$ precedes directional breaks; χ indicates move capacity, order flow determines direction
Strong gravity [5–10,25]	$\gamma = 2\|\omega\|$ as membrane boundary condition	Echo delays $\Delta t \approx 4M \ln(1/\varepsilon)$; nonzero tidal Love numbers $k_2 \sim \kappa/\|\ln \varepsilon\|$; QNM shifts

A structural parallel emerges between seismology and market microstructure: in both systems, χ governs the *capacity* for large moves while an external forcing variable (stress orientation, net order flow) determines *direction*. This separation of susceptibility from forcing is a signature of the universal role χ plays as a stability index.

5 Falsification Pathways

The framework stands or falls on domain–specific predictions:

1. **Quantum (Circuit QED) [19]:** Spectral merger at $\chi = 1$ with precision $\Delta\chi \sim 0.02$. Falsified if merger occurs at $\chi < 0.7$ or $\chi > 1.3$.

2. **Cosmology (DESI) [21]:** The identity $\chi_\delta = 1 \Leftrightarrow q = 0$ to percent–level precision. Falsified if scale–factor offset exceeds $\Delta a > 0.09$.

3. **Biology/Oncology [24]:** Protocols constrained to $0.8 \leq \chi \leq 1.0$ show systematic advantage. Falsified if no improvement in relapse/toxicity outcomes.

4. **Neurodynamics [23]:** Correlations between $\chi(t)$ deviations and symptom severity. Falsified if no statistical relationship.

5. **Seismology [22]:** Systematic $\chi_{\text{fault}} \to 1$ transitions before large earthquakes. Falsified if no precursor pattern in corrected catalogs.

6. **Markets [26]:** $\chi < 0.8$ precedes major directional moves. Falsified if crashes/breakouts occur without prior χ departure from adaptive window.
7. **Strong gravity (LIGO/LISA) [25]:** Echo timing and Love number signatures. Falsified if absent at predicted levels.

Failure in any mature domain falsifies the universality claim. Convergence across domains establishes $\chi = 1$ as a fundamental boundary principle.

6 Conclusion

The SymC postulate identifies $\chi = 1$ as a universal boundary organizing the dynamics of open systems. The mathematical structure (exceptional point, information extremum, fastest monotone relaxation) is domain–independent; substrate inheritance explains its recurrence across scales. Seven independent domains—quantum, cosmological, biological, neural, seismic, financial, and gravitational—exhibit the same boundary and the same adaptive window. Each provides falsifiable predictions testable within the coming decade. SymC is a boundary postulate rather than a bulk law: it specifies the stability condition that any deeper microscopic theory must reproduce.

A Critique and Rebuttal

Table 2: Anticipated critiques and responses.

Critique	**Rebuttal**
Lack of first–principles derivation	Intentional: SymC is a boundary postulate, not a bulk law. It constrains the correct limit any complete theory must approach. Derivation follows identification of the boundary.
Coefficients are model–dependent	The robust predictions are the scalings and the boundary location $\chi = 1$. Order–unity coefficients will be fixed by future theories.
Abstract ω and γ	Deliberate structural agnosticism enables universality. Each domain maps these to specific observables; the postulate concerns the ratio, not the constituents.
Nonstandard terminology	Typical for new frameworks. "SymC" (Symmetrical Convergence) is concise and descriptive. Adoption follows demonstrated utility.
Speculative / unverified	Acknowledged. Critically, it is falsifiable across seven independent domains with predictions testable within the decade.
Inheritance is asserted, not derived	The adiabatic mixing mechanism is derived [20]; specific inter–level couplings are theory–dependent inputs. The postulate concerns the structural constraint, not the microscopic details.

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