Retained Informational Regimes:

Shannon Clusters, Coupling Geometry, and a Shared Structural Problem

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Abstract

A recurring structural problem appears across modern physics and applied mathematics: how to designate the regime where relevant dynamics live, specify what information crosses its boundary, and characterize what descriptions remain stable under coupling — simultaneously, and without ontological sleight of hand. Renormalization group fixed points, almost-invariant sets, pointer states, quantum error-correcting code subspaces, and holographic entanglement surfaces each instantiate closely related structural roles, in domain-specific languages that were developed independently and that do not obviously translate into one another. We propose the Shannon cluster as a common vocabulary for this structural role: a retained informational regime constituted by and coextensive with the dynamical structure that produces it. The framework does not show that these formalisms are identical; it shows that they repeatedly address the same kind of structural problem, and that naming that problem cleanly has methodological value. We reinterpret known results — the area law in gapped one-dimensional systems, pointer state selection by decoherence, RG universality classes, the quantum error-correcting structure of holographic encoding — as domain-specific realizations of the same structural role. We identify three open directions where the framework may provide new purchase: the information geometry of coupled regimes, intra-cluster stability signatures, and the regime-specificity of apparent physical laws.

1. The Structural Problem

Across several mature subfields of physics and mathematics, practitioners have independently developed tools for a problem that is rarely stated in its general form. The problem is this: given a dynamical system — classical or quantum, finite or infinite-dimensional, closed or open — identify the regime where the relevant dynamics live, characterize the boundary through which information flows between that regime and its complement, and specify what descriptions remain stable under the coupling. These three tasks are entangled: the relevant regime cannot be identified without knowing what counts as stable description; stable description cannot be specified without knowing the boundary structure; the boundary structure depends on what dynamics are being retained.

Different subfields have resolved this entanglement with different formal machinery. In the renormalization group, the relevant regime is the basin of attraction of an RG fixed point — the set of theories that flow to the same long-distance behavior under coarse-graining. The boundary is the separatrix between universality classes. The stable descriptions are the critical exponents and operator content that survive the flow. In the theory of open quantum systems, the relevant regime is the accessible subsystem A; the boundary is traced over to produce the reduced density matrix; the stable descriptions are the pointer states selected by decoherence. In quantum error correction, the relevant regime is the code subspace; the boundary is the correctable error set; the stable descriptions are the logical degrees of freedom protected by the code. In dynamical systems, the relevant regime is the almost-invariant set; the boundary is measured by the leakage ratio; the stable descriptions are the slow modes that persist across the retention timescale.

These formalisms instantiate closely related structural roles. They are not formally identical — the mathematical objects differ, the physical content differs, and the tools appropriate for each differ. What they share is the structural role: identifying a retained regime, specifying an informational interface, and characterizing stable descriptions under coupling. A physicist trained in RG methods and a physicist trained in quantum error correction may be addressing formally related problems without recognizing the connection, because the vocabulary is different enough that the shared structure is invisible.

A retained regime exists only relative to a comparison of rates or scales: the rate of internal equilibration, the rate of leakage or decoherence across the interface, and the observational or coarse-graining scale at which the description is taken. There is no absolute retained regime, only retained regimes relative to these comparisons. This scale-relativity is not a weakness of the framework — it is the correct formal content of what it means for a description to be stable.

The gap this creates is methodological rather than foundational. No new physics is missing. What is missing is a language in which the shared structural role becomes visible — in which tools developed in one domain can be recognized as relevant to another, and in which the problem can be stated at a level of generality that makes cross-domain transfer possible. This document proposes such a language.

One further consequence of the gap is worth naming at the outset, because it shapes the framework's treatment of observers. When ontological priority is given to the dynamics accessible from within a particular regime — when the accessible regime is treated as the whole rather than as one retained regime among others — the boundary appears as a mystery rather than a structural feature. The observer paradox, and related puzzles about how classical description emerges from quantum dynamics, have this character.

Within the framework developed here, these puzzles are reframed as problems of coupled retained regimes rather than of ontological asymmetry. The reframing does not resolve every aspect of the measurement problem, but it makes tractable what the original formulation renders merely puzzling.

2. Shannon Clusters: Definition and Structure

2.1 The Formal Entry Point

The mathematical substrate for the framework is the almost-invariant set, a well-characterized object in the theory of dynamical systems. Let (X, μ, P) be a measure-preserving system with state space X, invariant measure μ, and transition operator P. A set $C \subseteq X$ is almost-invariant if it has high self-retention under the dynamics:

$$\mu(P(C) \triangle C) / \mu(C) \ll 1$$

where $\triangle$ denotes the symmetric difference and the ratio measures the fraction of C's measure that escapes under one application of P. Almost-invariant sets correspond to eigenvalues of P close to 1, to slow-relaxing modes, and to the long-lived coherent structures that persist in the approach to equilibrium (Dellnitz and Junge, 1999). They are the metastable structures of the transfer operator — not fixed points, not attractors in the usual sense, but regions of state space that hold their measure for long times relative to the mixing time of the dynamics.

This definition is the entry point, but the Shannon cluster is more general. The extension runs in two directions: to open systems coupled to an external regime, and to descriptive levels other than a literal subset of a phase space.

2.2 Definition

> Definition 2.1 (Shannon Cluster). A Shannon cluster is a retained informational regime: a set of states, observables, modes, or coarse-grained descriptions whose mutual predictability or compressibility persists over a timescale significantly longer than the characteristic mixing, decoherence, or escape times of the ambient dynamics.Within this framework, the cluster and the dynamical retention structure that produces it are treated as co-descriptions of the same organization. The cluster boundary is not a wall enclosing a pre-existing regime. It is a description of where the dynamics change character — where the retention condition transitions from holding to failing.

The definition is relative to a chosen descriptive level. There is no requirement that a single fundamental state space underlie all instances. In condensed matter, the relevant description may be an effective field over a coarse-grained lattice. In an open quantum system, it may be the reduced density matrix on a subsystem. In a plasma, it may be the space of macroscopic transport coefficients. The framework requires only that entropy, mutual information, or retention can be meaningfully evaluated at the chosen level.

The definition is also agnostic about retention mechanism. A cluster may be retained by dynamical means — slow escape, recurrence, weak coupling — or by energetic means — barriers, spectral gaps — or by topological means — holonomy, defect classes, code protection — or by informational means — redundancy, pointer selection. The retention mechanism determines robustness and failure modes but does not determine whether something is a Shannon cluster. That is determined solely by the functional criterion: does internal correlation structure persist longer than mixing would predict?

One immediate consequence of the dynamics-first framing: interior bifurcations, nested metastable sub-regimes, and local transitions within a cluster are part of its retention structure, not separate from it. The cluster is not a uniform region. Different interior configurations have different local retention properties — some sub-regimes are more metastable, some modes relax faster than others. This interior topology is the retention topology described at a finer scale. The practical implication is direct: apparent critical behavior observed inside a well-defined cluster need not indicate that the cluster is dissolving. Genuine dissolution — genuine criticality — is when the almost-invariant condition itself begins to fail. Interior transitions that do not push the system past the retention threshold are features of the cluster's interior structure, not precursors to its dissolution. This distinction matters methodologically for how power-law statistics and long relaxation times are interpreted in complex systems, which we return to in Section 4.3.

2.3 Variable Topology

A Shannon cluster is a role-name, not a specification of a single mathematical object. The topology of any given cluster is not fixed by the definition. A cluster may be a single connected sector — as in a quantum error-correcting code subspace, where the retained regime is a low-dimensional subspace of a large Hilbert space, and the retention is topological or energetic. It may be a collection of weakly coupled metastable basins that collectively maintain high internal correlation while being slow to mix with their complement. It may be hierarchically nested, with retained regimes at multiple scales separated by timescale or energy gaps, where each level constitutes both a cluster relative to its complement and a hidden regime relative to the level below it.

Inter-cluster scale separation — the condition under which two retained regimes are coupled but distinguishable — is the generic setting for the framework's applications. Bifurcations between cluster configurations, and transitions from one cluster topology to another, are within the framework's scope. The variable topology matters because different physical systems realize different cluster structures, and the tools appropriate for analyzing a single connected sector differ from those appropriate for hierarchically nested regimes or multi-basin structures. The framework provides the common vocabulary; domain-specific mathematics provides the tools for each topology.

3. Four Instantiations of the Structural Role

The claim that RG fixed points, almost-invariant sets, pointer state selection, and holographic encoding instantiate the same structural role — retained regime, informational interface, stable descriptions — is a claim about structural parallel, not formal identity. We make the parallel explicit for four cases. The goal is not to show that these formalisms reduce to one another, but to show that recognizing the shared structural role makes each formalism more legible and makes cross-domain transfer more tractable.

3.1 Renormalization Group Fixed Points

Under coarse-graining — the systematic elimination of short-scale degrees of freedom — the effective parameters of a theory flow according to the beta function:

$$\beta(g) = dg / d(\log \mu), \quad \beta(g^*) = 0$$

A fixed point g^* is a scale-invariant theory: its coupling constants are unchanged by coarse-graining, and it lies at the attractor of all theories in its universality class. Different microscopic theories with different details share the same long-distance behavior because they lie in the same RG basin — they are retained by the coarse-graining dynamics into the same effective description. The universality of critical exponents is the empirical signature of this retention.

In Shannon cluster language: the RG fixed point defines a retained regime in theory space. The retention condition is stability under coarse-graining. The informational interface is the separatrix between universality classes. The stable descriptions are the relevant operators and critical exponents that survive the flow. The cluster is constituted by the coarse-graining dynamics. What might otherwise look like a mathematical trick — flowing to a fixed point and reading off critical exponents — is the identification of a retained regime under a specific dynamics, with the interface between regimes encoded in which perturbations are relevant versus irrelevant.

3.2 Open System Reduction and Almost-Invariant Sets

Let the full system consist of an accessible regime A and a complementary regime B, coupled through an interaction Hamiltonian H_{AB}. The full dynamics operate on $A \otimes B$.

The Nakajima-Zwanzig projection formalism gives the exact equation of motion for the reduced state of A after tracing out B:

$$d\rho\_A/dt = -i[H\_A,\ \rho\_A] + \int_0^t K(t-s)\ \rho\_A(s)\ ds + F(t)$$

The three terms are: the internal dynamics of A in isolation; the memory kernel K(t−s) encoding the structural influence of B on A's dynamics, integrated over the coupling history; and the inhomogeneous noise F(t) from initial A-B correlations. The memory kernel is not arbitrary — its structure is determined by H_AB and the state of B. When B has long memory or strong coupling, K encodes the organization of B as it influences A. The hidden regime imprints on the accessible regime not by being observed directly but by shaping the effective dynamics through K.

A cluster $C \subseteq A$ is pseudo-open if its retention is maintained co-dynamically: by the interplay of internal dynamics and coupling to B through K. Remove the coupling and C may dissolve. The cluster is constituted by the full coupled dynamics. The almost-invariant set formalism is the classical limit of this structure; the Nakajima-Zwanzig formalism is the full open-systems generalization that makes the role of the hidden regime explicit.

3.3 Pointer States and Quantum Darwinism

In open quantum systems, decoherence selects a preferred set of states — pointer states — that are redundantly imprinted on independent environmental fragments. The redundancy ratio R measures how many independent fragments each carry sufficient information to reconstruct the pointer state:

$$R = |E|\ /\ I\_classical$$

where |E| is the total number of environmental fragments and I_classical is the number required for full reconstruction. The pointer states that achieve high redundancy are those that can be sampled repeatedly by independent observers without being disturbed — each observer reads a copy of the redundant encoding. Classical objectivity — the agreement of independent observers on measurement outcomes — is, in this picture, the joint fixed point of a network of coupled retained regimes converging on a common boundary condition.

In Shannon cluster language: the pointer states are the retained informational regime. The environmental fragments are the interface through which information propagates. The cluster is constituted by the decoherence dynamics — the pointer states are selected by those dynamics, not prior to them. What looks like the emergence of classicality from quantum dynamics is the convergence of a network of retained regimes on a self-consistent boundary condition. The stable descriptions are the pointer observables; their stability is a property of the coupled dynamics, not of the system alone.

3.4 Quantum Error Correction and Holographic Encoding

A quantum error-correcting code embeds a logical subspace C_L into a larger physical Hilbert space H such that logical information can be recovered after any error from a correctable set E. The Knill-Laflamme conditions characterize correctability:

$$P_L E^\dagger_a E_b P_L = c_{ab} P_L, \quad \text{for all } E_a, E_b \in E$$

where P_L is the projector onto the logical subspace. The code subspace is the retained regime; the correctable error set defines the interface; the logical degrees of freedom are the stable descriptions. In topological codes, logical information is encoded in holonomies — global properties of the coupling geometry that are invisible to any local error operator. Retention here is topological: it fails only at a topological phase transition, not through gradual erosion.

Almheiri, Dong, and Harlow (2015) established that bulk locality and subregion reconstruction in AdS/CFT have exactly the structure of quantum error correction: bulk local operators are the logical operators, the boundary CFT is the physical Hilbert space, and different boundary subregions from which a given bulk operator can be reconstructed correspond to different encodings of the same logical information. The Ryu-Takayanagi formula $S(A) = \text{Area}(\gamma_A)/4G$ is the statement that the entanglement entropy of a boundary region equals the area of the minimal bulk surface — the boundary of the associated code subspace. This is a derived consequence of the quantum error-correcting structure, not an independent assumption.

We note the domain-specificity carefully: the area law for entanglement entropy has been established for gapped one-dimensional quantum systems (Hastings, 2007). Higher-dimensional and non-gapped cases require additional assumptions. The holographic RT formula requires AdS/CFT geometry specifically. What the Shannon cluster framing provides here is not a derivation of these results from a more general principle — it is the observation that the structural role (retained regime, interface, stable logical descriptions) is the same in both QEC and holographic encoding, and that this structural parallel is what the ADH result made precise.

4. Consistency Conditions and Known Results

4.1 The Interface as Locus of Information

When regime A is coupled to regime B and the joint system satisfies the area law for entanglement entropy — established for gapped one-dimensional systems (Hastings, 2007) — the entanglement between A and B scales with the boundary area rather than the bulk volume:

$$S(\rho_A) \leq \alpha \cdot |\partial A|$$

This is a statement about the coupling geometry: entanglement is concentrated at the interface rather than spread through the bulk of B. The reduced state $\rho_A = \mathrm{Tr}_B[|\psi\rangle\langle\psi|]$ carries the full structural influence of B on A in a form that is interface-dominated in this domain. We state this as a conditional observation, not a general claim: in systems satisfying the area law, the interface between coupled regimes carries the informational relationship between them in a way that scales with area rather than volume. This is the domain-specific realization of the more general observation that the interface is where the coupling structure lives.

4.2 Self-Consistent Coupling Solutions

Many physically important structures are fixed points not of internal dynamics alone but of a self-consistency condition on the coupling. If the coupling between A and B is described by a map T acting on their joint state, a self-consistent coupling solution satisfies:

$$T(A^*, B^*) = (A^*, B^*)$$

The cluster in this case is not A or B individually but the joint configuration (A^*, B^*) together with the coupling structure that sustains it. Retention is co-dynamical: it depends on the coupling, not on the internal dynamics of either regime alone. The Bohr radius is a simple instance — the scale at which kinetic and potential energy of the hydrogen electron balance, determined by neither nucleus nor electron alone but by their self-consistent electromagnetic coupling. RG fixed points are self-consistent solutions in theory space. Pointer states are self-consistent solutions of the decoherence dynamics. The ground state of a topological code is a self-consistent solution of the stabilizer constraints. These are reinterpretations of known objects in a common language, not derivations of new results.

4.3 Fixed Points, Slow Manifolds, and the Four Regimes

Fixed points are the limiting case of maximal local dynamical retention: the cluster maps exactly to itself, and the escape rate is zero. In this framework, fixed points are not the primary organizing concept — they are one end of a retention spectrum that includes slow manifolds, metastable basins, and topologically protected sectors.

A slow manifold is a surface along which the system drifts on a slow timescale while remaining close to the manifold on a fast timescale. A metastable basin has probabilistic retention, with escape timescale governed by Kramers' rate:

$$\tau_{escape} \sim \exp(\Delta F / k_B T)$$

A topologically protected sector fails only at a topological phase transition. These have different robustness profiles, different failure modes, and require different tools. The common thread is that each is a retained regime relative to the comparison of internal equilibration rate, leakage rate, and observational timescale — the scale-relativity that the framework makes explicit.

The four qualitative regimes of a Shannon cluster relative to its coupling geometry:

> (i) Frozen (weak coupling, high symmetry): Almost-invariant with near-zero escape but inert. Internal dynamics do not propagate to the boundary. Retention is maximal; responsiveness to boundary conditions is zero.(ii) Quasi-stationary (moderate coupling, broken symmetry): The cluster sits on the slow manifold near a self-consistent coupling solution. Internal correlation structure is maintained by active coupling. Directional information transport is possible. This is the generative regime.(iii) Critical (coupling near the dissolution threshold): The almost-invariant condition begins to fail. Fluctuations at the boundary scale diverge. Genuine criticality — distinct from the generic behavior of regime (ii).(iv) Dissolved (coupling beyond the retention threshold): The almost-invariant condition fails. Internal correlations are destroyed faster than they are produced.

The distinction between regimes (ii) and (iii) has direct methodological implications. Quasi-stationary clusters on slow manifolds can exhibit broad or apparently power-law distributed relaxation times — not because they are near a critical dissolution threshold, but because the slow-manifold geometry produces a broad distribution of local escape timescales. A small eigenvalue of the linearized stability matrix gives a long relaxation time; a distribution of such eigenvalues across the slow manifold gives a broad relaxation-time distribution. Such distributions can produce apparent power-law statistics without proximity to criticality, though whether true power laws emerge depends on additional structure — the breadth of the distribution, heterogeneous trapping, or further scale-free organization. The key point is that observed power-law statistics are not by themselves evidence of proximity to the dissolution boundary. The framework provides vocabulary for distinguishing these cases, which is precisely where it has methodological value for practitioners in complex systems and neuroscience.

4.4 Asymmetry and the Generative Regime

The quasi-stationary generative regime requires asymmetry in the coupling geometry. A coupling Hamiltonian H_{AB} that is invariant under a symmetry group G acting non-trivially on the cluster's internal structure produces no preferred direction of information flow — the cluster is either frozen or dissolved depending on coupling strength. Breaking $G \to H \subset G$ selects a direction. The modes associated with this breaking are the modes through which directional information transport becomes possible. This is the formal content of the observation that generative dynamics require asymmetry: not as a claim about spontaneous symmetry breaking in the full quantum field theory sense, but as a structural observation about what the coupling equations require for the quasi-stationary regime to exist.

5. Three Open Directions

The following are directions where the framework may provide new vocabulary for existing hard problems. Each is presented with its honest epistemic status: what is established, what is conjectured, and what would need to be shown.

5.1 The Information Geometry of Coupled Regimes

The interior of a Shannon cluster — the region where the almost-invariant condition holds strongly — is characterized by slow divergence: nearby states separate slowly relative to the coupling timescale. At the boundary, divergence accelerates. This asymmetry has a natural expression in information geometry.

The Fisher information metric defines a Riemannian geometry on the space of probability distributions. For exponential families, this geometry is hyperbolic — negatively curved — in well-characterized cases (Amari, 1985). The connection to the cluster picture: if the interior of a cluster corresponds to a region where nearby distributions are difficult to distinguish (slow divergence, high mutual information) and the boundary corresponds to rapid distinguishability (fast divergence, information loss), then the natural global geometry of the cluster may be negatively curved. Hyperbolic space arises when branching rate exceeds metric growth, which has structural resonance with the asymmetry between interior dynamics and boundary-crossing.

This is a conjecture with suggestive support. Hyperbolic geometry has been observed in the learned representations of networks trained on hierarchical data (Nickel and Kiela, 2017), where retention structure during training may be producing this geometry. The Fisher information geometry of exponential families is hyperbolic in established cases. What would need to be shown is the precise connection between the almost-invariant condition and curvature in the Fisher metric — whether the retention condition formally implies negative curvature, or only in specific cases, and under what additional assumptions.

5.2 Intra-Cluster Stability Signatures

Because the cluster is constituted by its retention dynamics, the interior of a cluster is not a uniform region. Different sub-regimes have different local retention properties, and the slow manifold has a geometry that reflects the history of the coupling. A prediction follows: pseudo-open clusters should exhibit structured drift in their stable oscillatory modes — not random phase jitter, but directional drift coherent across timescales — reflecting the ongoing renegotiation of the boundary coupling.

In neural systems, theta phase precession in hippocampal place cells has the structural character this prediction points at: a systematic, directional shift in a cell's firing phase across the theta cycle as an animal traverses a place field, coherent and reproducible rather than noisy. The framework does not claim this is definitively a slow manifold signature. It claims the phenomenon has the right structure to be one, and that distinguishing slow manifold drift from noise, and from genuine criticality, requires the conceptual vocabulary the framework provides. The distinguishing signatures to look for: structured frequency drift coherent across nested timescales, power-law relaxation profiles after perturbation with exponents stable across behavioral states, and maintained gradients across the coupling boundary as a signature of active pseudo-open coupling rather than equilibration.

5.3 Physical Laws as Regime-Specific Fixed Points

What we identify as physical laws have the structure of fixed-point descriptions of the current coupling regime rather than universal truths about all possible dynamics. The QCD phase diagram provides a clean empirical case. Quark confinement — which appears as an absolute law within our thermodynamic regime — is the stable fixed point of the strong coupling at low temperatures and densities. At sufficiently high temperatures and densities, reproduced experimentally in heavy-ion collisions at RHIC and the LHC, the confinement fixed point dissolves and quarks behave as a nearly free plasma. Confinement is not a universal property of the strong coupling — it is the fixed point stable within our cluster's thermodynamic regime.

The framework generalizes this: what appear as laws are the stable fixed-point descriptions of what is retained within the accessible regime. Adjacent regimes — sometimes experimentally accessible, sometimes only theoretically — support different fixed points and therefore different effective regularities. This is not a claim that laws are arbitrary or subjective. It is a claim that the apparent universality of laws is a consequence of the depth and stability of the cluster in which they were established. Whether they hold across all possible coupled regimes is a question that cannot be answered from within the accessible cluster — and attempts to answer it from within systematically produce the kind of ontological murkiness the framework is designed to make visible.

6. Dynamics, Information, and the Observer

Within this framework, dynamics and information structure are treated as co-descriptions of the same retained organization. The retention, the boundary, the flow of mutual information across the coupling — these are not separate from the dynamics; they are the dynamics described in informational terms. There is no additional substrate at which the dynamics become informational. This is a methodological commitment, not a metaphysical declaration: it means that asking about the information structure of a coupled system is exactly the same as asking about the retention structure of its dynamics, and that tools from one vocabulary apply directly to the other.

This identification has a direct consequence for the observer. An observer is a retained informational regime — a Shannon cluster — whose accessible dynamics are coupled to fragments of the system being observed. Observation is a coupling event: the observer's cluster couples to the pointer states of the observed system, and the retained structure of the observer enforces a constraint on the joint state. For an observer to register and retain a measurement outcome, the outcome must be stable in the observer's cluster — which means the coupling between observer and observed must produce a self-consistent boundary condition.

Measurement, in this framing, is the enforcement of a boundary condition rather than the passive readout of a pre-existing value. When a fragment A_i of the environment couples to a system B, it participates in the redundancy condition:

$$S(A_i : B) \approx S(A_j : B), \quad \text{for all fragments } i \neq j$$

Each coupling event adds another term. Classical objectivity — the agreement of independent observers — is the joint fixed point of the coupled network of observer clusters, reached when all observer couplings are self-consistent with the same pointer states. The pointer basis is selected by the coupling structure of the entire network, not by the system alone.

The observer paradox — the puzzle of how a classical observer with a definite outcome can exist in a quantum world — is reframed here as a problem of coupled retained regimes rather than of ontological asymmetry. Within this framework, the puzzle arises from treating the accessible regime as ontologically prior, and then being puzzled when the boundary appears as a mystery. When the observer is recognized as one retained regime among others, the boundary is a structural feature of the coupling geometry, not a crack in reality. The measurement problem is not dissolved — the Born rule and preferred basis problem are not derived here — but it is reframed: not 'when does the wavefunction collapse?' but 'when does the coupling network reach a consistent fixed point, and what determines the basin of that fixed point?' The second formulation has a research program attached to it.

7. Scope and Exclusions

The framework makes a limited and specific claim: that a shared structural role — retained regime, informational interface, stable descriptions under coupling — appears across several mature formalisms, and that naming this role cleanly has methodological value. It is worth being explicit about what the framework does not claim.

It does not claim that RG fixed points, almost-invariant sets, pointer states, and code subspaces are formally identical. They are not. The mathematical objects differ, the physical content differs, and the appropriate tools differ. The claim is structural parallel, not formal equivalence.

It does not derive the area law, the Ryu-Takayanagi formula, the Born rule, or the preferred basis from the Shannon cluster definition. These results require specific physical assumptions — gapped one-dimensional Hamiltonians, AdS/CFT geometry, or the full Hilbert space structure of quantum mechanics — that go beyond the general framework. What the framework provides is a language in which these results are recognizable as domain-specific realizations of the same structural role.

It does not claim that observed power-law statistics in complex systems are signatures of proximity to criticality, nor does it claim they are not. It provides vocabulary for distinguishing slow-manifold geometry from dissolution-threshold criticality, which is a precondition for making that determination empirically.

It does not offer a new solution to the measurement problem, the hard problem of consciousness, or the problem of physical law universality. It reframes each of these as problems about coupled retained regimes and their interfaces, which is a different and more tractable formulation — but the hard work of resolution remains.

What it offers is precisely this: a language in which tools that currently look like domain-specific tricks become recognizable as instances of a shared problem, and in which that problem is stated precisely enough to support cross-domain transfer and new formal programs.

8. Summary

> (1) The shared structural problem: designate the retained regime, specify the informational interface, characterize stable descriptions under coupling. This problem appears in RG theory, open quantum systems, quantum error correction, and dynamical systems. The domain-specific formalisms instantiate closely related structural roles; they are not formally identical.(2) A retained regime exists only relative to a comparison of rates: internal

> equilibration, leakage across the interface, and the observational or coarse-graining scale. Scale-relativity is the correct formal content of description stability.(3) The Shannon cluster is the proposed common vocabulary for this structural role: a retained informational regime constituted by and coextensive with the dynamical structure that produces it. Cluster topology is variable — single connected sector, multi-basin, hierarchically nested — and is not fixed by the definition.(4) Within the framework, dynamics and information structure are co-descriptions of the same retained organization. The observer is a retained regime. The observer paradox is reframed as a problem of coupled retained regimes and their boundary conditions, not of ontological asymmetry.(5) Known results — area law in gapped 1D systems, pointer state selection, RG universality, QEC structure of holographic encoding — are reinterpreted as domain-specific realizations of the same structural role. They are not derived from the general framework; they are made mutually legible by it.(6) Three open directions: hyperbolic information geometry of coupled regimes, intra-cluster stability signatures in oscillatory systems, and physical laws as regime-specific fixed points. Each is a conjecture with support, not a conclusion.

The framework is a methodological proposal. Its value is in making the shared structure of existing tools visible, and in making the boundaries between domains crossable by practitioners who currently work in different languages without knowing they are addressing the same structural problem.

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Vervaeke-relevance realisation