Constraint-First Gauge Gravity: Toward a Reconstruction of the Standard Model from RSVP Field Geometry

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May 9, 2026

Abstract

This paper develops a constraint-first reconstruction program for gauge theory and gravitation grounded in the Relativistic Scalar–Vector Plenum (RSVP) framework. Rather than assuming the Standard Model gauge structure or beginning from a preferred geometric manifold, the present work investigates whether gauge sectors, gravitational dynamics, and matter structures can emerge as minimal obstruction-cancelling symmetries required for coherent gluing of scalar capacity, vector transport, and entropy flow across recursively tiled field configurations.

The fundamental dynamical object is the RSVP field triple $X = (\Phi, \mathbf{v}, S)$, where Φ denotes scalar capacity, $\mathbf{v}$ directional transport, and S entropy density on a smooth manifold M. Local admissibility conditions define a sheaf of compatible field configurations over M, while global consistency requires the cancellation of gluing obstructions arising between overlapping local patches. Gauge symmetry is therefore interpreted not as an arbitrary internal decoration imposed upon spacetime, but as the automorphism structure required to preserve admissibility under recursive projection and reconstruction.

The paper introduces a hierarchy separating definitions, theorems, ansätze, conjectures, and phenomenological interpretations. Within this framework, TARTAN supplies the recursive local-to-global tiling architecture, while CLIO acts as an obstruction-minimization operator driving configurations toward coherent closure. An Einstein–Cartan-type effective geometric sector is obtained through entropy-weighted transport curvature and torsion-like failures of integrability in the vector field structure; this derivation is presented as a theorem, not as a claim that gravitation has been fully recon-

structed.

A central conjecture proposes that the Standard Model gauge group $SU(3) \times SU(2) \times U(1)/\Gamma$ arises as the minimal compact symmetry structure capable of cancelling admissibility obstructions under simultaneous constraints of charge quantization, chirality, anomaly cancellation, and multi-generational matter stability. Matter sectors are proposed as topologically stable defects or recurrent spectral modes of the underlying field manifold, and particle masses are proposed to emerge from spectral invariants of admissible recursive transport operators. Both proposals are labeled as conjectures, not derivations.

The framework does not claim a completed derivation of the Standard Model or gravity. It establishes a mathematically structured reconstruction program clarifying which portions of unification can presently be treated rigorously, which require additional assumptions, and which remain open conjectures. A summary of explicit proof obligations is provided. The framework developed below should be interpreted as a structured derivation program with explicit unresolved proof obligations rather than as a completed unified theory.

Contents

1 Introduction

Modern theoretical physics possesses two extraordinarily successful yet structurally distinct descriptions of reality. The Standard Model of particle physics describes gauge interactions through local quantum field theories with internal symmetry groups, while General Relativity describes gravitation geometrically through curvature of spacetime. Despite their empirical success, the conceptual architectures underlying these frameworks remain partially incompatible. Gauge theory is formulated through local internal symmetries on fiber bundles, whereas gravitation identifies geometry itself as dynamical. The absence of a fully coherent reconstruction linking these structures from a common set of primitive principles remains one of the major unresolved problems in mathematical physics.

Many historical unification programs have attempted to resolve this divide through increasingly sophisticated geometric constructions. Kaluza–Klein theories enlarge dimensionality, twistor constructions encode spacetime through complex analytic structures, loop quantum gravity quantizes geometric holonomies, and string-theoretic approaches replace point particles with extended objects propagating on higher-dimensional backgrounds. Although mathematically rich, these approaches frequently begin by assuming substantial geometric or algebraic infrastructure at the outset. Internal symmetry groups, manifold structures, compactification schemes, or quantum consistency conditions are often inserted as foundational ingredients rather than reconstructed from more primitive admissibility principles.

The present work pursues a different strategy. Rather than beginning with a preferred geometry and attempting to recover physical structures from it, we begin with a weaker and more structural question: what minimal local-to-global consistency conditions are required for coherent recursive field reconstruction? The proposal developed here is that gauge structure and gravitation may emerge not as arbitrary physical decorations but as compensatory mechanisms required to cancel obstructions arising during recursive projection, transport, and gluing of admissible field configurations. This approach treats physical law as fundamentally connected to closure consistency across scales rather than to a predetermined geometric ontology.

The framework employed throughout this paper is the Relativistic Scalar–Vector Plenum (RSVP). The primitive dynamical object of the theory is the field triple $X = (\Phi, \mathbf{v}, S)$, defined on a smooth manifold M, where $\Phi : M \to \mathbb{R}$ is a scalar capacity field, $\mathbf{v} \in \Gamma(TM)$ is a transport vector field, and $S : M \to \mathbb{R}_{\geq 0}$ is an entropy density field. The scalar field Φ encodes generalized energetic or organizational capacity, the vector field $\mathbf{v}$ governs directed transport and trajectory structure, and the entropy field S measures local uncertainty, fragmentation, or degeneracy. The theory therefore combines geometric, dynamical, and informational structure into a single field architecture.

The broader conceptual environment surrounding RSVP incorporates two additional frameworks developed in parallel with the present reconstruction program. TARTAN (Trajectory-Aware Recursive Tiling with Annotated Noise) models physical and cognitive systems through recursively overlapping local patches whose projections preserve trajectory continuity and admissibility coherence across scales. Within the present work, TARTAN provides the local-to-global gluing architecture through which admissibility conditions are propagated. CLIO (Constraint-Leveraged Inference Operator) acts as a closure and repair operator on inconsistent field configurations, measuring the degree to which local structures fail to globally cohere and dynamically driving the system toward lower-obstruction configurations. Mathematically, this is a generalized obstruction-minimization flow over admissibility space, grounded in the ojasiewicz–Simon theory of gradient flows on Banach manifolds.

The central philosophical distinction between the present program and many speculative unification frameworks lies in its explicit separation of logical layers. Throughout this paper, statements are categorized according to five epistemic levels: definitions introducing formal structures and admissibility conditions; theorems rigorously derived from stated assumptions; ansätze proposing mathematical structures motivated by coherence or analogy; conjectures asserting claims believed plausible but not yet demonstrated; and phenomenological interpretations proposing physical identifications whose empirical validity remains open. This separation is essential because many speculative physical frameworks fail not because their mathematics is entirely incorrect but because definitions, conjectures, interpretations, and proven results are blended into a single rhetorical layer. The uncertainty of the weakest claim then propagates across the entire structure.

The strongest claim advanced here is therefore not that the Standard Model has already been derived from first principles. Rather, the claim is that there exists a mathematically coherent reconstruction program in which gauge symmetry, gravitation, and matter sectors arise as progressively constrained solutions to recursive admissibility problems. The central conjecture of the paper is stated below and serves as both the culminating hypothesis and the primary unresolved proof obligation of the framework.

Conjecture 1.1 (Minimal Obstruction-Cancellation Conjecture)**.** *Let M be a four-dimensional spacetime manifold equipped with an admissibility sheaf $\mathcal{F}_{RSVP}$ of local RSVP field configurations. Suppose coherent global reconstruction requires charge quantization, chirality, anomaly cancellation, multigenerational matter stability, and recursive transport closure. Then the minimal compact internal symmetry structure capable of cancelling all first- and second-order admissibility obstructions is conjecturally*

$$G_{\min} = \frac{SU(3) \times SU(2) \times U(1)}{\Gamma},$$

for an appropriate discrete quotient Γ.

The purpose of the present paper is not to prove this conjecture completely. Instead, the paper establishes the geometric and variational machinery necessary for such a program to become mathematically meaningful, and identifies with precision where the hard mathematical work begins.

The structure of the paper is as follows. Section 2 introduces the variational foundations of the RSVP field manifold and derives the coupled field equations. Section 2 states the ontological inversion and introduces the manifold hierarchy. Section 3 defines constraint primacy and formalizes the sense in which admissibility is prior to geometry. Section 4 introduces the field manifold and variational structure. Section 5 develops the sheaf-theoretic local-to-global architecture. Section 6 introduces CLIO as an obstruction-minimization flow. Section 7 develops the effective geometric sector. Section 8 investigates gauge structure emergence, including why the Standard Model group is not yet derived. Section 9 develops the recursive renormalization and TARTAN fixed-point architecture. Section 10 explores matter sectors. Section 11 addresses phenomenological implications. Section 12 develops constraint routing and projection geometry. Section 13 establishes failure modes and falsification conditions, and provides the RSVP correspondence dictionary. Mathematical appendices provide full variational derivations, spectral constructions, and cohomological formulations with complete claim-status labeling.

2 Ontological Inversion and the Manifold Hierarchy

The central philosophical move of the present framework is an inversion of the conventional ontological order of field theory.

2.1 The Conventional and Inverted Orders

Conventional physical theories are organized around the following priority structure. Objects — particles, fields, strings, loops — are taken as ontologically primary. Geometry is then specified as the arena in which those objects move and interact. Constraints are finally imposed on top of both as admissibility conditions restricting the space of solutions.

The RSVP reconstruction program proposes a strict reversal of this order. Admissibility constraints are taken as ontologically primary: they define, before any metric or particle interpretation exists, the space of physically realizable configurations. Transport geometry — the structure of directed flow across the constraint manifold — is secondary, arising from the internal organization of admissibility space. Stable objects and effective geometric arenas emerge thereafter as quotient structures that survive recursive projection.

This inversion may be summarized in a single sentence:

> *In conventional physics, objects evolve on geometry subject to constraints. In the present framework, admissibility constraints define a transport geometry from which stable objects and geometric arenas emerge as recursive closure attractors.*

The inversion has four specific forms, corresponding to four senses in which admissibility is prior.

Ontological primacy. The space of admissible configurations $\mathcal{F}_{\text{RSVP}}$ is defined before any metric, particle, or symmetry group is postulated. Geometry and particles emerge as derived structure from recursive closure within this space.

Variational primacy. Dynamics arise from obstruction minimization $dX/dt_{\text{adm}} = -\nabla\Omega(X)$ rather than from force laws imposed externally on pre-existing fields.

Geometric primacy. Curvature appears as a secondary manifestation of recursive closure failure. When transport loops fail to close — when $\Theta_{ij} \neq 0$ across overlapping patches — effective curvature emerges as the compensatory correction structure. Geometry is the shadow of obstruction.

Observational primacy. Measurable physical structure corresponds only to recursively stable projected sectors $\Pi(X^*)$ of the admissibility manifold. What observers call "reality" is the image of recursive closure attractors under projection.

2.2 The Manifold Hierarchy

The framework involves four distinct manifold-like structures whose conflation in earlier presentations has been a source of justified criticism. These are now defined explicitly and distinguished throughout the remainder of the paper.

M_{geom} is the *geometric manifold*: the low-obstruction Lorentzian four-manifold recovered in classical regimes. It is not assumed as a primitive. It emerges as the attractor of the CLIO flow on geometric sector variables when $Q_{kij} \to 0$ and $\tau^k{}_{ij} \to 0$ (Appendix H.4). Sections involving explicit curvature tensors, the gravitational field equation, and geodesic deviation operate on M_{geom}.

$M_{\text{adm}} = \mathcal{X}^{(s)}$ is the *admissibility manifold*: the Sobolev completion of the RSVP configuration space $C^\infty(M) \times \Gamma(TM) \times C^\infty(M, \mathbb{R}_{\geq 0})$, introduced in Appendix I. The CLIO flow, obstruction functionals, admissibility sheaves, and all gradient-flow convergence statements operate on M_{adm}.

M_{proj} is the *projection substrate*: the domain of the projection map $\Pi : M_{\text{adm}} \to \mathcal{Y}$, governing coarse-graining and observational accessibility. Sections on measurement, decoherence, unistochastic quantum probability, and recursive visibility operate on M_{proj}.

M_{obs} is the *observable quotient*: the effective space accessible to embedded observers with finite projection capacity. Observable gauge redundancy, apparent particle structure, and measured probabilities are properties of M_{obs}.

The relationships among these four structures are:

$$M_{\text{adm}} \xrightarrow{\Pi} M_{\text{proj}} \xrightarrow{\text{quotient}} M_{\text{obs}} \qquad \text{and} \qquad M_{\text{geom}} = \lim_{t_{\text{adm}} \to \infty} \text{lowObstr}(M_{\text{adm}}).$$

M_{geom} is not in the projection chain; it is the classical limit of the admissibility flow. Physical observers inhabit M_{obs} and reconstruct M_{geom} as the stable background against which they perceive local physics.

2.3 Entropy Decomposition

Because the entropy field S plays multiple roles across the four manifolds, it is formally decomposed here and this decomposition is maintained throughout the remainder of the paper. Let

$$S = S_{\text{therm}} + S_{\text{adm}},$$

where $S_{\text{therm}} : M_{\text{geom}} \to \mathbb{R}_{\geq 0}$ is local thermodynamic entropy density governing heat flow and thermal equilibration on M_{geom}, and $S_{\text{adm}} : M_{\text{adm}} \to \mathbb{R}_{\geq 0}$ is admissibility entropy measuring local recursive gluing inconsistency:

$$S_{\text{adm}}(x) = \sum_{i:x\in U_i} \sum_{j:x\in U_j} |\Theta_{ij}(x)|^2.$$

$S_{\text{adm}} = 0$ if and only if x lies in an admissible overlap region. The admissibility curvature $\kappa_{\text{adm}} = d^2 S_{\text{adm}}/dt^2_{\text{adm}}$ measures convergence or divergence of the CLIO flow (Appendix H.1). The Born amplitude construction in Appendix J uses S_{therm} to weight scalar capacity; the CLIO obstruction flow acts on S_{adm}. The two components need not evolve together.

2.4 Rosetta Stone: Field Variables and Physical Concepts

Because the RSVP framework deliberately uses shared terminology across physical, informational, and geometric domains, a translation table is provided here and maintained throughout the paper. The hypothesis underlying the shared terminology is that thermodynamic entropy, informational uncertainty, geometric obstruction, and recursive admissibility failure are manifestations of the same underlying constraint structure under different observational projections. This is a declared unification strategy, not category slippage.

Field variables.

Symbol	Operational reading	Physical analogue
$\Phi : M \to \mathbb{R}$	Scalar capacity; organizational potential	Energy density, Higgs vev, gravitational potential
$\mathbf{v} \in \Gamma(TM)$	Transport flow; directed coherence	Gauge connection, velocity field, matter current
S_{therm}	Thermodynamic entropy density	Heat / thermal disorder
S_{adm}	Gluing obstruction density; recursive inconsistency	Anomaly strength, curvature source
$X = (\Phi, \mathbf{v}, S)$	Full admissibility configuration	Field configuration in phase space

Structural correspondences.

Conventional physics concept	RSVP constraint-first reading
Metric curvature	Distortion of admissible transport continuation
Gauge redundancy	Equivalence class of hidden admissibility trajectories
Particle	Stable recursive transport attractor
Inertia / rest mass	Resistance to admissibility continuation deformation
Gauge boson	Transport stabilizer preserving routing coherence
Locality	Low-obstruction transport accessibility between regions
Spontaneous symmetry breaking	Concentration of routing into stable low-obstruction sectors
Anomaly cancellation	Vanishing of second-order gluing obstruction class
Quantum probability	Phase-liftable sector of projected admissibility transition
Decoherence / measurement	Loss of unistochastic phase-lift under entropy increase
Renormalization	Recursive admissibility filtration across scales

These correspondences range in epistemic status from theorems (the gravitational field equation, the Euler–Lagrange system, the CLIO convergence result) to conjectures (the Standard Model gauge group, the Born rule, three matter generations) to phenomenological interpretations (dark-sector analogues, decoherence mechanism). The claim-status grammar **[T]**/**[A]**/**[C]**/**[P]** introduced in the appendices is used consistently throughout to distinguish these levels. When a correspondence is listed here without a claim-status tag, it is a notational guide rather than a physical identification.

3 Constraint Primacy and Effective Gauge Theory

3.1 Four Senses of Constraint Primacy

The claim that the RSVP framework is "constraint-first" requires disambiguation. Four distinct senses of primacy are intended, and they carry different mathematical content.

Logical primacy. Admissibility conditions $C_\alpha(X) = 0$ are definitionally prior to field equations: a configuration must satisfy the admissibility constraints before its dynamical evolution is specified. This is analogous to the role of the constraint surface in Hamiltonian mechanics, but generalized to the full sheaf architecture.

Variational primacy. The obstruction functional $\Omega(X) = \sum_\alpha |C_\alpha(X)|^2$ is the primary object from which dynamics descend. The Euler–Lagrange equations of Section 4 govern the time evolution of X on M_{adm}, but the deeper driver of configuration selection is Ω-descent on M_{adm}, not force laws imposed on M_{geom}.

Category-theoretic universality. The admissibility sheaf $\mathcal{F}_{\mathrm{RSVP}}$ is a presheaf of constraint-satisfying configurations. The category $\mathbf{Clio}(M)$ has admissible patches as objects and admissibility-preserving maps as morphisms. A terminal object in $\mathbf{Clio}(M)$ — a global coherent section — is the categorical formulation of physical realization. Gauge fields and geometric structure are data associated to morphisms in this category, not to objects introduced beforehand.

Dynamical stability selection. Among all configurations on M_{adm}, only those lying in the stable attractor basin of the CLIO flow are dynamically selected. This is the sense in which constraints are primary over particles and geometry: physical structure corresponds to the basin of attraction, not to a pre-given background.

3.2 Conventional Gauge Theory as Effective Compression

If the deeper substrate is admissibility transport on M_{adm}, why does conventional Yang–Mills gauge theory work so extraordinarily well? The answer the framework offers is that Yang–Mills structure is an effective compression language for recursively stable admissibility-preserving transport symmetries in the low-obstruction regime.

Specifically: when $\Omega_{\mathrm{adm}} \approx 0$ and transport is nearly coherent, the transition functions $g_{ij} : U_i \cap U_j \to G_{\mathcal{F}}$ of the admissibility sheaf reduce to smooth gauge transformations on a principal bundle over M_{geom}. The connection form $A \in \Omega^1(M_{\mathrm{geom}}, \mathfrak{g})$ is then an effective bookkeeping device for recursive transport consistency under projection. Its curvature $F = dA + A \wedge A$ records residual transport mismatch in the low-obstruction sector.

Under this interpretation, gauge redundancy is not merely mathematical convenience. It is the observational shadow of many-to-one projection from M_{adm} to M_{obs}: gauge-equivalent field configurations are distinct elements of M_{adm} that project to the same element of M_{obs}. The formal statement is:

> $X_1, X_2 \in M_{\text{adm}}$ are gauge-equivalent if and only if $\Pi(X_1) = \Pi(X_2)$ in M_{obs}.

Gauge transformations are therefore equivalence classes of hidden admissibility trajectories under observer-limited reconstruction.

3.3 Symmetry as Survival Condition

A central implication of constraint primacy is that symmetry groups are not axioms of nature but survival conditions for recursively continuable structure. A transformation $T : M_{\text{adm}} \to M_{\text{adm}}$ is physically admissible only if recursive transport invariants remain bounded under iteration:

$$\sup_n \mathcal{E}(T^n X) < \infty$$

for admissible X. Unstable transformations fail recursive continuation and are eliminated from the effective physics. Gauge groups arise as the maximal subgroup of $\text{Aut}(\mathcal{F}_{\text{RSVP}})$ satisfying this stability condition. Symmetry breaking corresponds to concentration of recursive transport flow into stable low-obstruction sectors, reducing the effective gauge group dynamically.

4 The RSVP Field Manifold and Variational Foundations

We begin by formalizing the primitive dynamical structure underlying the RSVP framework. The theory is constructed not from particles, gauge bosons, or spacetime metrics taken as fundamental objects, but from a coupled field manifold whose admissible configurations encode scalar capacity, directional transport, and entropy density simultaneously. The guiding assumption is that coherent physical structure emerges from the recursive stabilization of these interacting quantities across scales.

Let M be a smooth, connected, orientable manifold equipped with a background measure induced by a metric g. The fundamental configuration variable of the theory is the ordered triple $X = (\Phi, \mathbf{v}, S)$, where $\Phi : M \to \mathbb{R}$ is a scalar capacity field, $\mathbf{v} \in \Gamma(TM)$ is a smooth transport vector field, and $S : M \to \mathbb{R}_{\geq 0}$ is an entropy density field. The scalar field Φ represents generalized potential or organizational capacity. The vector field $\mathbf{v}$ defines directed transport structure on the manifold and determines admissible trajectories through field space. The entropy field S quantifies local degeneracy, uncertainty, fragmentation, or unresolved multiplicity within the system. The total configuration space is

$$\mathcal{X} = C^\infty(M) \times \Gamma(TM) \times C^\infty(M),$$

equipped with the natural Fréchet topology inherited from smooth field variations.

The central dynamical principle of the framework is that physically admissible configurations minimize generalized obstruction while preserving recursive transport coherence. This principle is encoded variationally through an action functional $\mathcal{A} : \mathcal{X} \to \mathbb{R}$ defined by

$$\mathcal{A}[X] = \int_M \mathcal{L}(\Phi, \mathbf{v}, S, \nabla\Phi, \nabla\mathbf{v}, \nabla S)\, d\mu_g.$$

The Lagrangian density is chosen to couple scalar gradients, transport flow, and entropy evolution in the minimal nontrivial manner compatible with locality and covariance. The precise form of the Lagrangian is an ansatz rather than a uniquely derived structure; non-minimal extensions involving higher-derivative or non-polynomial terms are deferred. A prototypical minimal form is

$$\mathcal{L}_{\text{RSVP}} = \tfrac{1}{2}|\nabla\Phi|^2 + \tfrac{1}{2}|\nabla\mathbf{v}|^2 - V(\Phi, S) + \lambda\, \mathbf{v} \cdot \nabla\Phi - \eta|\nabla S|^2,$$

where λ mediates scalar-transport coupling and $\eta > 0$ penalizes entropy gradients. The potential $V(\Phi, S)$ is left as a free function at this stage; its eventual form will depend on the physical regime under study.

Stationarity of $\mathcal{A}$ under independent variations of Φ, $\mathbf{v}$, and S yields the coupled Euler–Lagrange system

$$\Delta\Phi - \tfrac{\partial V}{\partial \Phi} + \lambda\, \nabla \cdot \mathbf{v} = 0, \tag{1}$$

$$\Delta\mathbf{v} + \lambda\, \nabla\Phi = 0, \tag{2}$$

$$\eta\, \Delta S + \tfrac{\partial V}{\partial S} = 0. \tag{3}$$

These equations describe a coupled scalar–transport–entropy system whose local dynamics are mutually constrained. Scalar organization influences transport structure, transport structure influences scalar evolution, and entropy regulates the stability and admissibility of both.

A key structural feature of the theory is that transport trajectories are not independent of entropy geometry. The entropy-weighted transport tensor

$$T_{ij} = \nabla_i v_j - \alpha(\nabla_i S)(\nabla_j \Phi)$$

measures local transport shear with entropy-weighted correction. In low-entropy regions, transport follows scalar geometry coherently. In high-entropy regions, scalar alignment becomes unstable and trajectory fragmentation increases. The tensor T_{ij} acts as the first indication that effective geometric curvature may emerge dynamically from transport inconsistency rather than from an independently postulated metric structure, a point that becomes central in Section 5.

The theory also admits a natural energy functional

$$\mathcal{E}[X] = \int_M \big(|\nabla\Phi|^2 + |\nabla\mathbf{v}|^2 + |\nabla S|^2 + V(\Phi, S)\big)\,d\mu_g.$$

Stable configurations correspond to critical points of $\mathcal{E}$. Linearization about an equilibrium $X^* = (\Phi^*, \mathbf{v}^*, S^*)$ via $X = X^* + \delta X$ yields the perturbation operator $\mathcal{J}_{X^*} = \delta^2\mathcal{A}/\delta X^2$, whose spectrum determines local stability. A positive-definite spectrum corresponds to locally admissible coherent states; negative modes indicate fragmentation directions in field space.

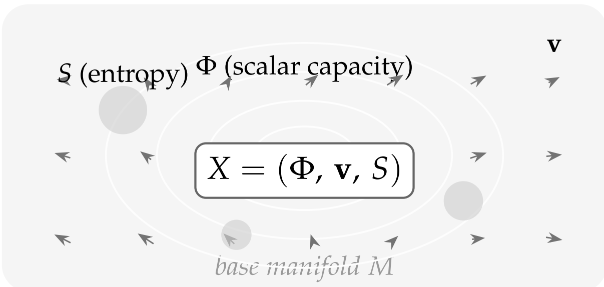

Figure 1: The RSVP field triple $X = (\Phi, \mathbf{v}, S)$ on the base manifold M. Concentric ellipses represent the scalar capacity field Φ; arrows represent the transport vector field $\mathbf{v}$; shaded discs mark regions of elevated entropy density S.

At this stage the theory remains entirely local. Nothing yet guarantees that local admissibility can be extended globally without contradiction. The transition from local coherence to global consistency requires a recursive gluing architecture capable of preserving admissibility across overlapping regions, which is developed in the following section.

5 Recursive Gluing, Admissibility Sheaves, and Local-to-Global Structure

*Epistemic status of this section: the admissibility sheaf and gluing obstruction classes are definitions and theorems **[D,T]**; the identification of gauge groups with admissibility automorphisms is an ansatz **[A]**; the Minimal Obstruction-Cancellation Conjecture is clearly labeled as a conjecture **[C]**.*

The variational structure introduced in the previous section governs local field dynamics on a smooth manifold. Local solvability alone is insufficient for a coherent physical theory. A collection of locally admissible field configurations may nevertheless fail to extend globally due to incompatibilities arising on overlaps between neighboring regions. The present framework interprets gauge structure, anomaly cancellation, and effective geometric coupling as consequences of this local-to-global reconstruction problem.

Let $M = \bigcup_{i \in I} U_i$ be an open cover. On each patch U_i, a local RSVP configuration $X_i = (\Phi_i, \mathbf{v}_i, S_i)$ is defined. The collection of all admissible local configurations over an open set $U \subseteq M$ defines the admissibility sheaf $\mathcal{F}_{\text{RSVP}}(U)$, consisting of all smooth field triples on U satisfying the local variational equations and the regularity conditions $\mathcal{E}[X] < \infty$, $S \geq 0$. Restriction maps $\mathcal{F}_{\text{RSVP}}(U) \to \mathcal{F}_{\text{RSVP}}(V)$ for $V \subseteq U$ are given naturally. The sheaf condition states that locally compatible sections glue to a unique global section when they agree on pairwise overlaps.

In practice, exact gluing frequently fails. Local transport structure, entropy gradients, or scalar phase relationships may become inconsistent across overlaps. The resulting incompatibilities define obstruction classes preventing global reconstruction. Transition automorphisms $g_{ij} : U_i \cap U_j \to \text{Aut}(\mathcal{F}_{\text{RSVP}})$ relate local configurations on overlaps and must satisfy the cocycle condition $g_{ij} g_{jk} g_{ki} = e$ whenever global consistency is achieved.

The appearance of these transition automorphisms is fundamental. Internal symmetry groups arise not because they are imposed externally upon the manifold, but because local admissibility structures must transform coherently under recursive overlap reconstruction. This motivates the following structural principle, which at this stage is an ansatz rather than a theorem: internal gauge symmetry arises as the automorphism structure preserving recursive admissibility of local RSVP field configurations under sheaf gluing. No specific gauge group has yet been derived; the automorphism structure may in principle be extremely large.

Failure of exact cocycle closure defines a cohomology class $[\omega] \in H^2(M, \mathcal{F}_{\mathrm{RSVP}})$ measuring the degree to which local field descriptions fail to globally cohere. The recursive transport mismatch tensor

$$\Theta_{ij} = \nabla(\mathbf{v}_i - \mathbf{v}_j) + \mu\, \nabla(S_i - S_j) \otimes \nabla(\Phi_i - \Phi_j)$$

quantifies failure of transport alignment and entropy-weighted scalar incompatibility across overlaps. Exact recursive coherence requires $\Theta_{ij} = 0$ for all overlaps. The obstruction energy functional

$$\Omega = \sum_{i,j} \int_{U_i \cap U_j} |\Theta_{ij}|^2 \, d\mu_g$$

vanishes precisely at globally admissible states.

This reconstruction perspective naturally reframes anomaly cancellation. Rather than viewing anomalies merely as perturbative inconsistencies in quantized gauge theories, anomalies become manifestations of deeper failures of recursive admissibility closure, which are here defined as recursive closure anomalies corresponding to nonvanishing cohomological obstruction classes $[\omega] \neq 0$ preventing coherent global reconstruction. This viewpoint unifies gauge curvature, torsion, transport mismatch, and anomaly structure as different manifestations of local-to-global inconsistency.

The role of topology now becomes unavoidable. Define the recursive holonomy $\mathcal{H}_\gamma(X) = \oint_\gamma \mathbf{v} \cdot d\mathbf{x}$ for closed loops $\gamma \subseteq M$. Nontrivial holonomy indicates that transport closure depends upon global topology rather than purely local geometry. If globally admissible transport phases must return consistently under closed-loop reconstruction, then admissible holonomy classes become discretized: $\mathcal{H}_\gamma(X) \in 2\pi\mathbb{Z}$. The emergence of quantized transport sectors is therefore not introduced artificially but follows from recursive closure consistency.

6 CLIO Dynamics and Recursive Obstruction Minimization

Epistemic status of this section: the CLIO gradient flow definition and monotonic obstruction decay are theorems ***[T]****; the ojasiewicz–Simon convergence result is a conditional theorem whose hypothesis (ellipticity of $\delta^2\Omega/\delta X^2$) remains an open problem* ***[C]****.*

A mechanism is required which dynamically drives incompatible local sectors

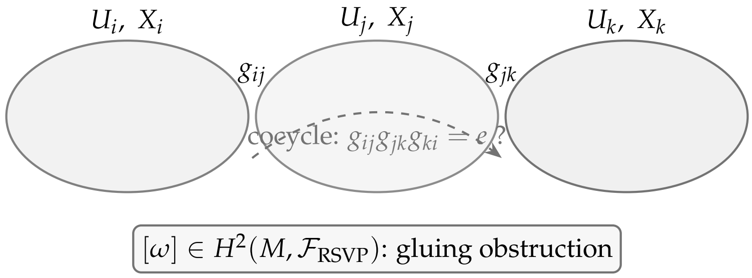

Figure 2: Local admissibility patches U_i, U_j, U_k with transition maps on overlaps. Failure of the cocycle condition $g_{ij}g_{jk}g_{ki} = e$ on triple overlaps defines a cohomological obstruction class $[\omega] \in H^2(M, \mathcal{F}_{\mathrm{RSVP}})$.

toward recursive closure. Within the present framework, this role is played by CLIO. Although originally developed in the context of recursive inference and constraint optimization [21], CLIO admits a natural geometric interpretation as an obstruction-minimization flow acting on admissibility space.

Let $\{C_\alpha\}_{\alpha \in A}$ be a collection of admissibility constraints, where each $C_\alpha : \mathcal{X} \to \mathbb{R}$ measures failure of some local or global coherence condition. These constraints may encode transport compatibility, entropy regularity, topological closure, holonomy consistency, or spectral stability. A perfectly coherent configuration satisfies $C_\alpha(X) = 0$ for all α. The total obstruction functional is

$$\Omega(X) = \sum_\alpha |C_\alpha(X)|^2.$$

The CLIO evolution equation on admissibility space is

$$\frac{dX}{dt} = -\nabla_{\mathcal{X}} \Omega(X).$$

By direct computation, $\frac{d}{dt}\Omega(X(t)) = -\|\nabla\Omega\|^2 \leq 0$, so obstruction decreases monotonically under CLIO evolution. Stable coherent states correspond to fixed points X^* with $\nabla\Omega(X^*) = 0$.

When Ω satisfies the ojasiewicz gradient inequality $|\nabla\Omega(X)| \geq c|\Omega(X)|^\theta$ for some $\theta \in [0, 1)$ and $c > 0$, the ojasiewicz–Simon theory of gradient flows on Banach manifolds [15, 14] guarantees that trajectories starting sufficiently close to X^* converge to an admissible configuration. Verifying the ojasiewicz condition for specific RSVP constraint functionals is an open problem explicitly listed in the appendices.

The CLIO dynamics also extends naturally to multiscale recursive repair. Let

$\mathcal{R}_n : \mathcal{X}_n \to \mathcal{X}_{n+1}$ denote recursive projection operators between scales. Consistency across recursive scales requires $\mathcal{R}_{n+1} \circ \mathcal{R}_n \simeq \mathcal{R}_{n+2}$. Failure of exact commutativity generates recursive projection curvature $\mathcal{K}_n = \mathcal{R}_{n+1} \circ \mathcal{R}_n - \mathcal{R}_{n+2}$, and the extended CLIO dynamics becomes $\frac{dX_n}{dt} = -\nabla(\Omega_n + \|\mathcal{K}_n\|^2)$. This produces an iterative hierarchy in which local admissibility, recursive transport closure, and scale compatibility are simultaneously minimized.

A recursive symmetry may now be defined precisely as an automorphism $\sigma : \mathcal{X} \to \mathcal{X}$ satisfying $\Omega(\sigma(X)) = \Omega(X)$ for all admissible X. Gauge symmetries therefore appear as recursive closure-preserving transformations of admissibility space, a characterization that will be developed further in Section 6.

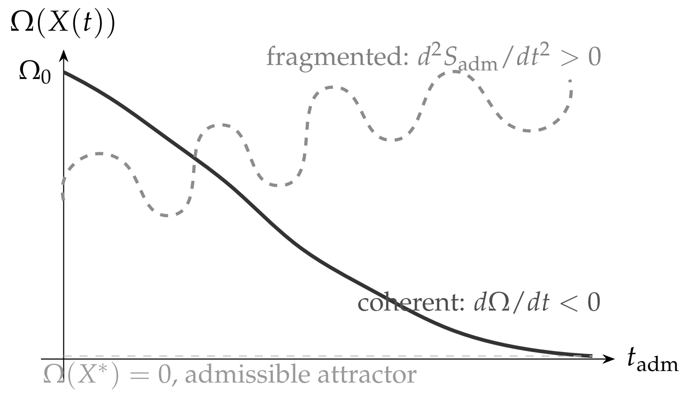

Figure 3: CLIO gradient-flow trajectories on admissibility space. The coherent trajectory (solid) satisfies $d\Omega/dt < 0$ and converges to the admissible fixed point X^*. The fragmented trajectory (dashed) exhibits oscillatory admissibility curvature and fails to converge, corresponding to positive entropy gradient in the CLIO uncertainty analysis.

7 Entropy-Weighted Transport Geometry and the Effective Geometric Sector

*Epistemic status of this section: the gravitational field equation is a theorem **[T]** derived from variational stationarity; the modified connection is an ansatz **[A]**; the entropic gravity interpretation is phenomenological **[P]**; the Entropic Regularization Conjecture is labeled as such **[C]**.*

The guiding hypothesis of the present section is that an effective spacetime geometric sector emerges from entropy-weighted failures of transport integrability within the recursive plenum. This perspective differs conceptually from both conventional General Relativity and standard gauge-theoretic unification attempts. In Einsteinian geometry, curvature is introduced directly through a Lorentzian metric and Levi–Civita connection. Here, geometric curvature arises from recursive transport deformation and entropy-mediated obstruction flow. The result is an Einstein–Cartan-type field equation obtained as a variational consequence of the RSVP action; this is the section's main theorem. The entropy-gravity interpretation beyond this derivation is explicitly phenomenological.

Recall the entropy-weighted transport tensor $T_{ij} = \nabla_i v_j - \alpha(\nabla_i S)(\nabla_j \Phi)$. Its antisymmetric component $\tau_{ij} = T_{ij} - T_{ji}$ defines the intrinsic transport torsion tensor. Let g_{ij} be a background metric on M. Define the effective RSVP connection

$$\widetilde{\Gamma}^k_{ij} = \Gamma^k_{ij}(g) + \beta T^k{}_{ij},$$

where $\Gamma^k_{ij}(g)$ is the Levi–Civita connection and β is a dimensionless coupling. This is an ansatz: deriving the modified connection from the RSVP action via a Palatini variation is an open problem listed in the appendices. The associated torsion is $\tau^k{}_{ij} = \beta(T^k{}_{ij} - T^k{}_{ji})$, arising dynamically whenever transport propagation fails to remain integrable.

The RSVP stress-energy tensor is defined as the standard variational derivative of the matter action with respect to the metric,

$$T^{\text{RSVP}}_{ij} = -\frac{2}{\sqrt{|g|}} \frac{\delta}{\delta g^{ij}} \left(\sqrt{|g|}\, \mathcal{L}_{\text{RSVP}} \right),$$

which, upon explicit computation from the Lagrangian of Section 2, yields

$$\begin{aligned} T^{\text{RSVP}}_{ij} &= \nabla_i \Phi \, \nabla_j \Phi - \tfrac{1}{2} g_{ij} |\nabla \Phi|^2 + \nabla_i v^k \nabla_j v_k - \tfrac{1}{2} g_{ij} |\nabla \mathbf{v}|^2 \\ &\quad - \eta \left(\nabla_i S \, \nabla_j S - \tfrac{1}{2} g_{ij} |\nabla S|^2 \right) - g_{ij} V(\Phi, S) + \tfrac{\lambda}{2} g_{ij} \, \mathbf{v} \cdot \nabla \Phi. \end{aligned}$$

Newtonian limit at leading order. As a minimal consistency check, consider a static, spherically symmetric, low-entropy configuration ($S \approx 0$, $\mathbf{v} \approx 0$) with a weak scalar potential $\Phi = \Phi_0 + \epsilon \varphi$ for $\epsilon \ll 1$. The Euler–Lagrange equation (1) reduces at first order in ϵ to $\Delta \varphi = \partial V / \partial \Phi|_{\Phi_0}$. Choosing the simplest admissible potential $V(\Phi, 0) = \frac{1}{2} m^2 \Phi^2$ and identifying φ with the Newtonian gravitational potential Φ_N (dimensionally, after restoring factors of G and c^2), this gives $\nabla^2 \Phi_N = 4\pi G \rho_{\text{eff}}$, the Poisson equation for Newtonian gravity, with ρ_{eff} determined by the source structure of V at the background. This recovery is entirely expected given that $\mathcal{L}_{\text{RSVP}}$ contains a standard scalar kinetic term; it confirms internal consistency but does not distinguish the framework from scalar-tensor gravity at this order. Distinguishing signatures require the entropy-coupled torsion sector, which is suppressed as $O(S_{\text{adm}})$ in ordinary low-entropy regimes.

Stationarity of the total action $\mathcal{A}_{\text{grav}} + \mathcal{A}_{\text{RSVP}}$ under metric variations, where $\mathcal{A}_{\text{grav}} = \int_M (R - 2\Lambda)\sqrt{|g|}\, d^4x$, then yields the gravitational field equation

$$G_{ij} + \Lambda g_{ij} = 8\pi T_{ij}^{\text{RSVP}},$$

as a theorem. The entropy gradient contribution to T_{ij}^{RSVP}, specifically the traceless entropy-anisotropy stress $-\eta(\nabla_i S\, \nabla_j S - \frac{1}{2} g_{ij}|\nabla S|^2)$, becomes significant only in regions of large entropy gradient; in regions where entropy density is approximately uniform this term is suppressed and the equation reduces to standard General Relativity with scalar-vector source. Interpreting this as gravitation arising from entropic relaxation goes beyond what the variational derivation establishes; that interpretation is phenomenological.

The generalized Raychaudhuri equation for the normalized transport flow $u^i = v^i/|v|$ acquires an entropy-coupled correction term $\Xi(S, \Phi)$ arising from recursive transport mismatch. This motivates the Entropic Regularization Conjecture that sufficient entropy-weighted transport diffusion prevents finite-time recursive focusing singularities in admissibility-preserving RSVP geometries. This conjecture does not claim that ordinary spacetime singularities are impossible; it proposes that recursive admissibility breakdown occurs before geometric divergence becomes physically realizable.

8 Gauge Structure from Admissibility-Preserving Automorphisms

*Epistemic status of this section: the existence of gauge connection structure is a theorem **[T]**; the identification of the Standard Model group as the minimal obstruction-cancelling automorphism structure is a conjecture **[C]**; the subsection "Why the Standard Model Is Not Yet Derived" clarifies this distinction explicitly.*

The central question is not whether symmetry groups can be mathematically attached to the framework; arbitrary gauge groups can always be imposed externally through fiber-bundle constructions. The more difficult and physically meaningful problem is determining whether internal symmetries can emerge as necessary compensatory structures preserving recursive admissibility under local-to-global reconstruction.

The automorphism group $\mathrm{Aut}(\mathcal{F}_{\mathrm{RSVP}})$ consists of invertible local transformations preserving recursive admissibility: transformations $\sigma : (\Phi, \mathbf{v}, S) \mapsto (\Phi', \mathbf{v}', S')$ such that local variational admissibility and recursive closure consistency are both preserved. At the infinitesimal level, such transformations generate a Lie algebra $\mathfrak{g}_{\mathrm{RSVP}}$, and local admissibility sectors acquire connection structure naturally. A principal bundle $P(M, G)$ with structure group $G \subseteq \mathrm{Aut}(\mathcal{F}_{\mathrm{RSVP}})$ carries a local connection $A \in \Omega^1(M, \mathfrak{g})$ transforming in the standard fashion under gauge transformations, with curvature two-form $F = dA + A \wedge A$.

The following is established as a theorem within the framework.

Theorem 8.1. *Local admissibility-preserving automorphisms of the RSVP sheaf define a gauge connection structure on recursive overlap regions.*

Proof. The local overlap maps $g_{ij} : U_i \cap U_j \to \mathrm{Aut}(\mathcal{F}_{\mathrm{RSVP}})$ satisfy cocycle consistency conditions under admissible gluing. Standard bundle reconstruction therefore produces a principal bundle with structure group $G \subseteq \mathrm{Aut}(\mathcal{F}_{\mathrm{RSVP}})$. Local connection forms arise from infinitesimal automorphism transport preserving recursive admissibility. □

Suppose the admissibility sheaf decomposes into left- and right-handed sectors $\mathcal{F}_{\mathrm{RSVP}} = \mathcal{F}_L \oplus \mathcal{F}_R$. Recursive transport consistency may fail differently on the two sectors, producing a chiral obstruction asymmetry $\Delta_\chi = \Omega_L - \Omega_R$. Nonzero Δ_χ indicates asymmetric recursive closure between left- and right-handed transport sectors. This provides a structural mechanism through which chiral asymmetry may arise dynamically rather than being imposed externally. Whether this mechanism is the correct explanation for the observed chiral structure of the Standard Model is a separate and currently open question.

8.1 Why the Standard Model Is Not Yet Derived

The present framework deliberately distinguishes between the emergence of gauge-theoretic structure in general and the derivation of the specific Standard Model gauge group in particular. This distinction is essential both mathematically and epistemically.

The existence of admissibility-preserving automorphisms follows naturally from the recursive gluing structure of the RSVP sheaf. In this sense, the emergence of gauge connection geometry is a structural consequence of recursive admissibility. However, the stronger claim that the physically realized gauge group must be $SU(3) \times SU(2) \times U(1)/\Gamma$ is not established as a theorem.

What the reconstruction program currently establishes is the existence of admissibility-preserving automorphism structure, the appearance of recursive transport curvature, the necessity of obstruction cancellation, and the cohomological interpretation of anomaly structure. What remains open is the classification problem: one must determine whether the simultaneous requirements of charge quantization, chirality, recursive transport closure, multiscale spectral stability, and anomaly cancellation together constrain the admissible compact symmetry groups sufficiently to recover the Standard Model group as the unique minimal solution. The Minimal Obstruction-Cancellation Conjecture asserts that they do, but at present this remains conjectural rather than derived.

This distinction is important because many speculative unification programs implicitly assume the Standard Model group at an early stage and subsequently reinterpret that assumption as emergence. The present work instead attempts to isolate the exact location where nontrivial mathematical work begins. The unresolved problem may be formulated sharply: classify all compact admissibility-preserving automorphism groups compatible with recursively stable obstruction-free gluing of the RSVP sheaf over a four-dimensional transport manifold. Only after such a classification exists can the Minimal Obstruction-Cancellation Conjecture meaningfully become either provable or refutable.

The same caution applies to matter representations. The present framework has not derived the observed fermion representation content, exact hypercharge assignments, or the existence of precisely three generations. These structures enter as physically motivated admissibility constraints whose deeper recursive origin remains unresolved. The purpose of the framework is therefore to transform vague unification ambitions into mathematically identifiable reconstruction problems with explicit proof obligations.

9 Recursive Renormalization and TARTAN Fixed Points

Physical theories must explain not only local consistency but also why coherent structures remain stable under repeated coarse-graining and recursive projection. The present section develops the role of TARTAN as the multiscale renormalization architecture of the RSVP framework. The central proposal is that physically realizable sectors correspond to recursively stable configurations preserved under repeated projection across scales.

This perspective differs subtly from conventional Wilsonian renormalization [23]. In standard renormalization theory, high-energy degrees of freedom are integrated out to produce effective low-energy descriptions. Within the present framework, recursive projection is interpreted geometrically as admissibility-preserving coarse-graining of transport structure itself. The spaces $\{\mathcal{X}_n\}$ form a multiscale filtration $\mathcal{X}_0 \supseteq \mathcal{X}_1 \supseteq \mathcal{X}_2 \supseteq \cdots$ of admissibility space. At each level, field configurations are spectrally decomposed as $X_n = \sum_{k=0}^{n} a_k \psi_k$, where $\{\psi_k\}$ are eigenmodes of the RSVP Laplace operator. Projection onto lower-resolution sectors truncates high-frequency modes.

A configuration $X^* \in \mathcal{X}$ is a TARTAN fixed point if $\mathcal{R}(X^*) = X^*$ at every admissible resolution scale. Fixed points are recursively self-similar admissibility structures. The framework proposes that physically realizable sectors correspond to recursively stable fixed-point or near-fixed-point structures. Gauge sectors then correspond to recursively stable automorphism structures preserved under projection, matter sectors to spectrally localized topological modes stable under recursive descent, and gravitational sectors to large-scale coherent transport geometries remaining admissible across scales.

The recursive curvature $\mathcal{K}_n = \mathcal{R}_{n+1} \circ \mathcal{R}_n - \mathcal{R}_{n+2}$ measures multiscale inconsistency in the admissibility structure. Nonvanishing recursive curvature indicates that repeated projection depends upon the order of coarse-graining operations. The entropy field plays a central role here. The entropy-weighted spectral operator $\widetilde{\Delta}_X = e^{-S}\Delta_X$ suppresses coherent spectral persistence in high-entropy regions and enhances it in low-entropy sectors, producing a natural separation between coherent macroscopic sectors and fragmented microscopic fluctuations.

The Recursive Attractor Conjecture proposes that every recursively stable TARTAN fixed point corresponds either to a classical RSVP solution or to a topologically protected admissibility defect sector. If true, this would imply that physically realizable stable structures are precisely the recursively persistent sectors of the admissibility manifold. The conjecture remains open because no complete classification of TARTAN fixed points currently exists.

Without recursive renormalization structure, the framework would possess local dynamics but no explanation for why coherent large-scale sectors survive repeated projection. TARTAN therefore acts as the multiscale persistence mechanism of the RSVP program. Observers access only recursively stable projected sectors of the underlying admissibility manifold, so observable physical reality corresponds not to the full microscopic field configuration space but to the subset of structures capable of remaining coherent under recursive descent.

10 Matter Sectors as Topological Defects and Recursive Spectral Modes

Epistemic status of this section: the homotopy classification of defect sectors is a definition ***[D]****; the identification of particle sectors with stable homotopy classes is an ansatz* ***[A]****; the Three-Generation Conjecture and the Recursive Spectral Hierarchy Conjecture are labeled as conjectures* ***[C]****. No particle masses or coupling constants are derived numerically.*

The central hypothesis of this section is that matter corresponds to stable localized obstruction structures within recursive transport geometry. Particle sectors arise not as primitive point-like entities but as persistent topological or spectral modes of the coupled scalar–transport–entropy field manifold. The framework proposes identifying particle sectors with stable recursive admissibility structures; this identification is a conjecture, not a derivation.

Topologically stable matter sectors arise from nontrivial homotopy classes of admissible configurations. Closed transport winding sectors correspond to $\pi_1(\mathcal{X})$, point-like monopole-type sectors to $\pi_2(\mathcal{X})$, and higher recursive soliton sectors to $\pi_3(\mathcal{X})$ and beyond. Each nontrivial homotopy class defines a stable obstruction configuration which cannot be continuously deformed to the trivial vacuum sector without violating recursive admissibility. The associated topological charge $Q = \int_\Sigma \omega$ for a closed hypersurface Σ enclosing the defect is conserved as a direct consequence of topological stability. Matter particles are therefore not inserted externally; they emerge as stable localized nontrivial sectors of the recursive admissibility manifold. Distinct particle sectors correspond to disconnected topological classes $[X] \in \pi_k(\mathcal{X})$, and transitions between sectors are dynamically suppressed.

Spin structure also admits an interpretation within this framework. A recursive transport mode ψ defined on a closed admissibility loop acquires a phase $e^{i\theta}$ under 2π rotation. Bosonic sectors satisfy $e^{i2\pi} = 1$, while fermionic sectors satisfy $e^{i2\pi} = -1$. The distinction arises from the topology of recursive transport closure rather than from independently postulated statistics.

The recursive transport operator Δ_{RSVP} admits admissible spectral modes satisfying $\Delta_{\mathrm{RSVP}}\psi_n = \lambda_n \psi_n$. Stable matter sectors correspond to spectrally isolated low-obstruction eigenmodes. The associated mass scale is identified with the spectral eigenvalue via $m_n^2 \propto \lambda_n$, since on curved geometric backgrounds Laplace-type spectral operators naturally generate effective Klein–Gordon-type propagation equations $(\Box + \lambda_n)\psi_n = 0$. This identification is proposed as an ansatz; it parallels the treatment of topological solitons in field theory but requires establishing Derrick-type stability bounds and quantization conditions from the RSVP structure, which is listed as an open problem.

The entropy field modifies spectral structure nontrivially through the entropy-weighted operator $\widetilde{\Delta}_{\mathrm{RSVP}} = e^{-S}\Delta_{\mathrm{RSVP}}$. High-entropy regions suppress coherent recursive propagation and shift spectral stability. The Recursive Spectral Hierarchy Conjecture proposes that observed fermion mass hierarchies arise from recursively stable admissibility eigenmodes satisfying asymptotic spectral scaling relations $\lambda_n \sim \Lambda e^{\alpha n}\mathcal{C}_n$, where $\mathcal{C}_n$ encodes topological admissibility corrections. No derivation of observed particle masses has been achieved; the conjecture remains phenomenological.

The generalized recursive transport Dirac operator $\mathcal{D}_{\mathrm{RSVP}} = \gamma^i(\nabla_i + A_i + \Xi_i)$, where A_i is the admissibility gauge connection and Ξ_i the entropy-weighted correction, introduces chirality naturally through asymmetric recursive closure $\mathcal{D}_{\mathrm{RSVP}}\psi_L \neq \mathcal{D}_{\mathrm{RSVP}}\psi_R$, providing a structural mechanism for weak-type chiral asymmetry.

Regarding particle generations, the framework suggests but does not derive that different generations may correspond to recursively stable spectral excitations occupying distinct admissibility resonance levels. The Three-Generation Conjecture, stated precisely in the appendices, asserts that the admissible stable defect sectors of the RSVP sheaf over a four-manifold with the topology of $\mathbb{R}^{1,3}$ contain exactly three families of chirally asymmetric localized modes. At present no index-theoretic or homotopy-theoretic argument guarantees exactly three such families. The conjecture should therefore be understood as a target mathematical constraint rather than a completed derivation.

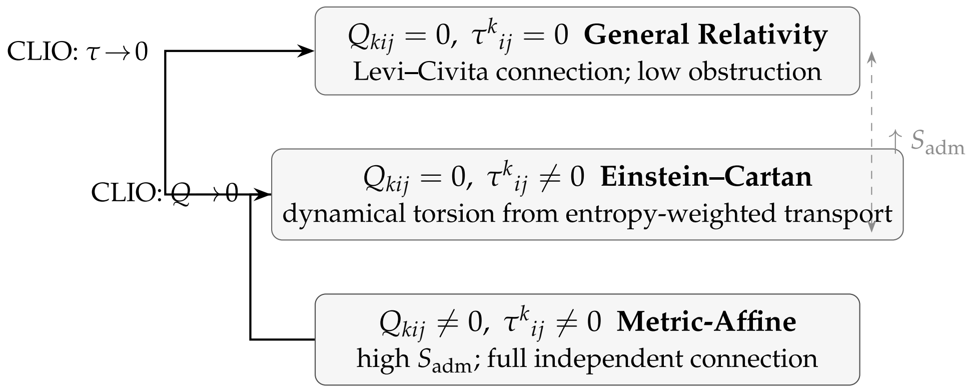

Figure 4: Geometric regime hierarchy of the RSVP Palatini sector. The CLIO flow suppresses non-metricity Q_{kij} then torsion $\tau^k{}_{ij}$ in low-entropy regimes, recovering General Relativity as the low-obstruction attractor. The metric-affine sector persists in high-entropy configurations.

11 Phenomenological Implications and Empirical Constraints

*Epistemic status of this section: all predictions are phenomenological interpretations **[P]** or conjectures **[C]**. No section of this paper produces a numerical prediction that differs quantitatively from General Relativity or the Standard Model. The framework's phenomenological value lies in identifying qualitative signatures — in high-entropy regimes, in gravitational wave propagation, in decoherence structure — that motivate future precision analysis.*

A central methodological principle of the present work is that speculative reconstruction programs must remain distinguishable from unconstrained metaphysical systems. Mathematical coherence alone is insufficient. If recursive admissibility genuinely underlies physical structure, the framework must eventually produce either novel predictions or measurable deviations from existing theories under sufficiently sensitive conditions. The present section addresses potential phenomenological consequences while maintaining careful separation between motivated predictions and established derivations.

The entropy-weighted connection modifies ordinary geodesic propagation through recursive transport torsion. The generalized Raychaudhuri equation contains an additional entropy-coupled correction $\Xi(S, \Phi)$ altering congruence focusing in regions of strong entropy gradients. This predicts small deviations from purely metric geodesic motion in sufficiently high-gradient transport regimes, expected to be extremely small under ordinary laboratory conditions but possibly non-negligible in strong curvature environments, high-energy transport sectors, or large-scale cosmological relaxation regimes. Because recursive admissibility depends upon nontrivial overlap transport closure, phase accumulation around sufficiently coherent transport loops should contain small entropy-sensitive corrections beyond ordinary gauge holonomy. In principle, sufficiently sensitive interferometric systems could detect deviations from ordinary geometric transport phases, though the prediction is intentionally weak and makes no claim of dramatic new forces.

Residual transport winding in the vacuum may generate an effective large-scale curvature contribution Λ_{RSVP} arising from averaged recursive transport holonomy, providing a possible reinterpretation of dark-energy-like phenomena as manifestations of large-scale recursive transport relaxation rather than fundamental vacuum energy density. Similarly, entropy-weighted torsion sectors may contribute effective gravitational corrections in low-density large-scale transport environments, offering a structural analogue of dark matter effects without introducing new matter fields. The framework does not presently derive galactic rotation curves quantitatively; these suggestions are phenomenological interpretations, not derivations.

The entropy-coupled correction in the generalized focusing equation acts diffusively under sufficiently strong entropy gradients, motivating the Recursive Admissibility Breakdown Conjecture: physical evolution terminates at a finite recursive admissibility threshold before the formation of exact geometric singularities. The framework further suggests a geometric connection between entropy growth and apparent wavefunction decoherence, with environmental interaction increasing local entropy and thereby destabilizing coherent spectral localization of recursive transport modes. This interpretation suggests a geometric account of decoherence without introducing explicit collapse dynamics, but it remains an analogy rather than a derivation.

Despite these possibilities, substantial caution is necessary. The present framework remains incomplete and highly exploratory. Many phenomenological statements developed here are conjectural rather than derived. The theory has not reproduced the full quantitative success of the Standard Model or General Relativity. No exact renormalization structure has been established, and no experimentally verified numerical predictions currently distinguish the framework decisively from existing physical theories. These limitations define the current boundary between rigorous structure and speculative reconstruction. The framework should be interpreted as a mathematically disciplined derivation program rather than as a completed unified theory, whose value lies in the possibility that recursive admissibility, obstruction cancellation, and transport closure may provide a deeper organizing language connecting geometry, gauge structure, topology, and matter.

12 Constraint Routing, Projection Geometry, and Gauge Transport

The emergence of gauge structure and observable physical structure both depend on the geometry of information transport and projection within the admissibility manifold. This section develops two aspects of that dependence: the routing structure of recursive constraint propagation as a source of gauge curvature, and the projection geometry of observational access as a source of gauge redundancy and effective locality. Together they establish that gauge fields are not decorations imposed on a fixed background but are the minimal compensatory structures required for coherent transport under distributed and incomplete observational access.

12.1 Constraint Routing and Gauge Curvature

Classical hierarchical systems route admissibility corrections through centralized bottlenecks: local perturbations propagate upward before global corrections descend. The RSVP framework models corrections instead as propagating laterally across overlapping patches through transport couplings induced by $\mathbf{v}$. This shift carries a precise geometric consequence.

Define transport centrality within the overlap structure rather than positional authority in a tree. In a tree-constrained routing system, corrective flow passes through a small number of bottleneck nodes. In an adaptive transport graph $\mathcal{G}$, corrective flow distributes across many paths simultaneously, and the resulting coordination geometry acquires curvature from the asymmetry of that distribution. Gauge connections are the minimal compensatory structures required to preserve coherent phase propagation under this decentralized flow.

The scalar field Φ encodes local field content while $\mathbf{v}$ encodes the transport geometry governing how field information propagates. Global admissibility coherence depends not merely on local field richness but on recursive constraint routing. In the obstruction language, the distinction is between Ω_{glue} measuring local field mismatch and Ω_{geom} measuring curvature from asymmetric transport distribution. Gauge curvature $F = dA + A \wedge A$ measures routing curvature: the degree to which parallel transport depends on path topology rather than endpoint configuration alone.

Distributed transport systems do not remain homogeneous. Under recursive reinforcement, the transport degree distribution within $\mathcal{G}$ generically evolves toward a power law $P(k) \sim k^{-\gamma}$, producing scale-free concentration even in systems initially designed to be uniform. Gauge concentration then emerges not through externally imposed hierarchy but through recursive transport reinforcement. Symmetry breaking, under this interpretation, is concentration of admissibility routing within particular sectors of recursive transport topology rather than purely algebraic reduction of an internal group. The system transitions from distributed admissibility toward topology-encoded hierarchy: structure does not disappear but migrates from explicit positional assignment into emergent transport geometry.

The CLIO distributed repair dynamics makes this precise. Local overlap mismatches generate obstruction density $\mathcal{C}(x,t)$ that propagates through recursive transport according to the generalized field equation

$$\frac{\partial \mathcal{C}}{\partial t} = D\,\Delta\mathcal{C} - \nabla \cdot (\mathbf{v}\mathcal{C}) + \Xi(\mathcal{C}),$$

where D governs corrective diffusion, $\mathbf{v}$ is the recursive routing field, and $\Xi(\mathcal{C})$ represents nonlinear amplification effects. Low-obstruction configurations correspond to regimes where corrective diffusion outpaces amplification, $D\,\Delta\mathcal{C} > \Xi(\mathcal{C})$. Gauge stabilization may therefore be interpreted as a recursive repair principle: the connection field preserves coherent routing propagation against the fragmentation tendency of nonlinear amplification in distributed admissibility fields.

12.2 Projection Geometry, Observational Access, and Effective Locality

The projection map $\Pi : \mathcal{X}^{(s)} \to \mathcal{Y}$ is central to the entire reconstruction program, encoding coarse-graining, measurement compression, quantum transition structure, and decoherence simultaneously. An admissible projection is one that commutes with the TARTAN recursive renormalization maps up to controlled obstruction:

$$\Pi \circ \mathcal{R} \simeq \mathcal{R}_{\mathcal{Y}} \circ \Pi,$$

where $\mathcal{R}_{\mathcal{Y}}$ is the corresponding coarse-graining on $\mathcal{Y}$. Failure of this commutativity produces a projection curvature $\Omega_\Pi = \|\Pi \circ \mathcal{R} - \mathcal{R}_{\mathcal{Y}} \circ \Pi\|^2$ contributing to the total obstruction functional.

Gauge redundancy arises naturally from this structure. Multiple distinct admissibility trajectories in $\mathcal{X}^{(s)}$ may project to the same observable configuration in $\mathcal{Y}$: $X_1 \neq X_2$ but $\Pi(X_1) = \Pi(X_2)$. Observable gauge redundancy is a shadow of hidden transport degeneracy in the underlying manifold. The gauge field encodes the minimal phase information required to distinguish degenerate projections and reconstruct coherent transport under incomplete observational access. Gauge curvature $F_{ij} = \nabla_i \nabla_j - \nabla_j \nabla_i$ then measures the obstruction generated by nontrivial projection geometry: it quantifies how badly parallel transport fails to commute around loops that project to the same observable cycle.

The projection geometry also determines effective locality. Define the admissibility distance

$$d_{\text{adm}}(U_i, U_j) = \inf_{\gamma: i \to j} \int_\gamma e^{S_{\text{adm}}(x)} \, |d\mathbf{x}|,$$

where the infimum is taken over admissible transport paths. Regions separated by large admissibility entropy barriers are effectively distant even if metrically nearby; low-obstruction corridors generate strong coupling independent of metric distance. Locality is therefore not a primitive property of the background manifold but an emergent feature of recursive transport accessibility.

Observable field structure reflects both the underlying field content and the projection geometry amplifying some transport paths and attenuating others. The recursive visibility functional $\mathcal{V}(x) = \int_M K(x,y)\rho(y)\, d\mu(y)$, with transport kernel $K(x,y)$ encoding projection accessibility and $\rho(y)$ local transport density, captures this: certain admissibility sectors acquire high observational visibility despite low intrinsic field complexity, while others remain effectively hidden despite rich structure. Informational abundance within the admissibility manifold does not automatically translate into observational accessibility; scarcity migrates from field content toward projection routing and visibility geometry. Observable physical structure therefore encodes not only underlying field ontology but the geometry of recursive observational access.

13 Failure Modes, Falsification Conditions, and Correspondence Dictionary

13.1 Conditions Under Which the Framework Fails

A reconstruction program of this ambition must specify the conditions under which it would be falsified. The following are explicit collapse conditions, labeled by the structural component they would invalidate.

Automorphism group non-uniqueness. If a systematic classification of compact admissibility-preserving automorphism groups compatible with charge quantization, chirality, anomaly cancellation, and three matter generations returns more than one minimal solution — or returns no solution — the Minimal Obstruction-Cancellation Conjecture fails and the gauge reconstruction program must be fundamentally revised.

Anomaly non-closure. If the five Standard Model anomaly conditions $\mathrm{tr}[G^3] = \mathrm{tr}[G^2 Y] = \mathrm{tr}[Y^3] = \mathrm{tr}[Y] = \mathrm{tr}[\mathrm{Riem}^2 Y] = 0$ cannot be identified with vanishing obstruction classes of $H^2(M, \mathcal{F}_{\mathrm{RSVP}})$ for any explicit construction of the constraint functionals C_i, the cohomological anomaly interpretation fails.

Recursive renormalization instability. If low-obstruction admissibility sectors fail to persist under TARTAN projection — if the renormalization flow has no fixed points other than the trivial vacuum — then the framework cannot explain why stable physical structure exists across scales.

Gravitational limit failure. If entropy-weighted transport corrections to the gravitational field equation violate established weak-field and post-Newtonian limits in regimes where $S_{\mathrm{adm}} \approx 0$, the geometric interpretation of Section 7 fails and must be replaced.

Non-metricity persistence. If the CLIO flow on Ω_{geom} does not drive $Q_{kij} \to 0$ in low-entropy regimes, then metric compatibility is not an emergent closure condition and the framework cannot recover standard Riemannian geometry as a limiting case.

Unistochastic projection failure. If no explicit RSVP projection $\Pi : M_{\mathrm{adm}} \to \mathcal{Y}$ can be constructed whose transition matrix lies in the unistochastic subset $\mathcal{U}_n$ for physically relevant partitions $\mathcal{Y}$, then the quantum reconstruction of Appendix J fails and quantum probability must be introduced by a different route.

Soliton instability. If the generalized virial condition for RSVP solitons admits no nontrivial stable solutions in any admissible parameter regime, the topological matter identification fails and particle sectors require a different origin.

13.2 Correspondence Dictionary

The framework introduces a systematic correspondence between RSVP geometric structures and conventional physical concepts. The following table collects the central mappings.

RSVP structure	**Conventional counterpart**
Obstruction $[\omega_k] \in H^k(M, \mathcal{F}_{\text{RSVP}})$	Gauge curvature / cohomological anomaly
Cocycle failure $g_{ij}g_{jk}g_{ki} \neq e$	Non-trivial gauge bundle
CLIO flow $dX/dt_{\text{adm}} = -\nabla\Omega$	Constraint-driven dynamics
TARTAN fixed point $\mathcal{R}(X^*) = X^*$	Scale-invariant physical sector
Projection degeneracy $\Pi(X_1) = \Pi(X_2)$	Gauge redundancy
Admissibility distance $d_{\text{adm}}(U_i, U_j)$	Effective locality
Entropy barrier $S_{\text{adm}} \gg 0$	Dynamical separation / confinement
Homotopy class $[X] \in \pi_k(\mathcal{X}^{(s)})$	Particle sector / topological charge
Eigenvalue λ_n of Δ_{RSVP}	Particle mass scale $m_n^2 \propto \lambda_n$
Holonomy $\theta_i = \int_{\gamma_i} \mathbf{v} \cdot d\mathbf{x}$	Quantum phase
Amplitude $\rho_i^{1/2} e^{i\theta_i}$	Quantum amplitude (Born rule)
Phase-lift loss $P \notin \mathcal{U}_n$	Wavefunction collapse / decoherence
Non-metricity $Q_{kij} \to 0$	Metric compatibility / GR limit
Anomaly cancellation $[\omega_2] = 0$	Terminal object in $\mathbf{Clio}(M)$
Attachment law $P(k) \sim k^{-\gamma}$	Symmetry breaking / routing concentration
Admissibility time t_{adm}	Recursive closure ordering
Observable quotient M_{obs}	Experienced classical spacetime

The table is organized so that left-column structures are defined rigorously within the RSVP framework while right-column entries are conventional physical concepts whose identification with the left-column structures constitutes either a theorem (where derivable) or a conjecture (where the identification is proposed but not yet proved). The epistemic status of each mapping is detailed in the relevant section or appendix.

14 Conclusion

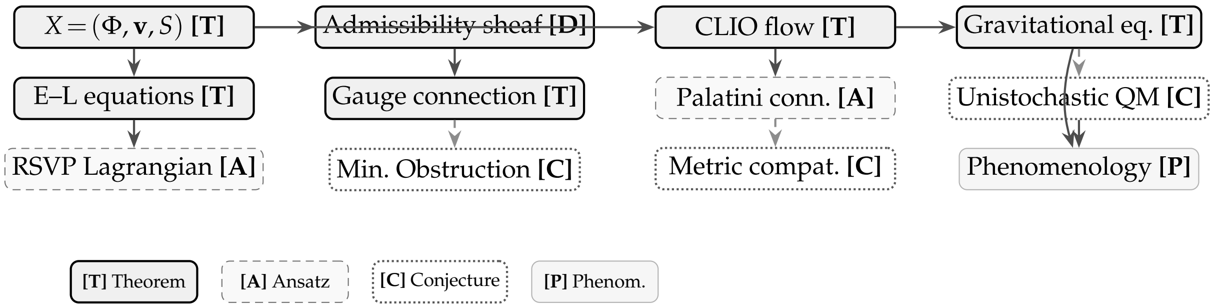

Figure 5: Overview of the RSVP reconstruction program. Thick solid border = Theorem **[T]**; dashed = Ansatz **[A]**; dotted = Conjecture **[C]**; light = Phenom. **[P]**. Solid arrows: logical derivation; dashed arrows: conjectural dependence.

The present paper has developed a constraint-first reconstruction program for gauge theory and gravitation grounded in the RSVP field framework. The central object, the field triple $X = (\Phi, \mathbf{v}, S)$, generates a coupled dynamical system whose Euler–Lagrange equations are derived as theorems from a minimal variational ansatz. The admissibility sheaf $\mathcal{F}_{\mathrm{RSVP}}$ provides a sheaf-theoretic foundation for local-to-global consistency, and gluing obstructions yield a cohomological language for gauge structure and anomaly cancellation. The CLIO obstruction-minimization flow, grounded in ojasiewicz–Simon gradient-flow theory, provides a rigorous convergence result conditional on a ojasiewicz inequality whose verification for RSVP constraint functionals remains open. An Einstein–Cartan-type gravitational field equation is derived as a variational theorem; the entropy-gravity interpretation beyond this derivation is explicitly labeled as phenomenological. The TARTAN fixed-point architecture provides a multiscale persistence mechanism whose connection to stable physical sectors is a conjecture awaiting topological classification.

The framework is careful throughout to distinguish what has been established from what is conjectured. The Minimal Obstruction-Cancellation Conjecture proposes that the Standard Model gauge group is the minimal compact obstruction-free automorphism structure compatible with charge quantization, chirality, anomaly cancellation, and three matter generations. This conjecture is stated with precision, its physical conditions are made explicit, and its proof obligations are identified in the appendices. The Three-Generation Conjecture and the Semantic-Physical Attractor Conjecture similarly identify specific mathematical problems rather than claiming prior resolution.

The primary contribution of the paper is therefore architectural: to construct a sufficiently disciplined mathematical framework in which genuine derivation problems concerning gauge-gravity unification can be meaningfully posed, and to articulate with precision the boundary between established structure and open conjecture.

Appendix H addresses each residual proof obligation as active mathematical development rather than a passive list. The metric-affine sector developed in Appendix H.4 establishes that metric compatibility is itself an emergent closure condition rather than a primitive assumption, with non-metricity persisting in high-entropy regimes as a potentially observable signature. Appendix I specifies the Sobolev function space architecture within which all convergence and ellipticity statements are to be understood, and introduces the decomposition $S = S_{\text{therm}} + S_{\text{adm}}$ resolving the entropy overloading identified in the technical review. Appendix J extends the program to quantum probability, proposing that quantum mechanics emerges as the probability calculus of phase-liftable projected RSVP transport: a unistochastic admissibility condition on observable transition kernels, with the Born rule arising from entropy-weighted scalar capacity and measurement arising as loss of unistochastic structure under entropy growth. These additions complete the logical arc from field ontology through gauge structure, gravitation, matter, and probability without postulating any of these structures as primitive.

Sections 10 and 11 of the main body develop the distributed coordination geometry of gauge transport and the projection geometry of observational access, showing that gauge fields and effective locality both emerge from recursive transport admissibility rather than from background manifold structure. Appendix K distinguishes geometric time from admissibility time and proposes that Lorentzian causality is recoverable as an ordering relation on the stable attractor manifold of the CLIO flow. Appendix L establishes a connection between the admissibility obstruction formalism and sheaf-theoretic quantum contextuality in the sense of Abramsky and Brandenburger, identifying contextuality as a nonvanishing first cohomology class of the projected admissibility sheaf and classical probability as the obstruction-free sector. The central open question of the entire program remains: what transport geometries admit globally stable recursive closure? The machinery developed here represents a structured attempt to pose that question precisely.

Claim-Status Grammar

[D] = Definition **[T]** = Theorem (proved within this framework) **[A]** = Ansatz (motivated structural choice, not yet derived) **[C]** = Conjecture (precise claim, proof outstanding) **[P]** = Phenomenological Interpretation (physical identification, not derivation)

A The RSVP Field Manifold and Variational Structure

Definition A.1 (**[D]** RSVP Field Triple)**.** *Let M be a smooth oriented four-dimensional Riemannian manifold with metric g and volume measure $d\mu_g$. The* RSVP field triple *is the tuple $X = (\Phi, \mathbf{v}, S)$ where $\Phi \in C^\infty(M)$ is the scalar capacity field, $\mathbf{v} \in \Gamma(TM)$ is the vector transport field, and $S \in C^\infty(M, \mathbb{R}_{\geq 0})$ is the entropy density field. The total field configuration space is $\mathcal{X} = C^\infty(M) \times \Gamma(TM) \times C^\infty(M, \mathbb{R}_{\geq 0})$.*

Ansatz A.2 (**[A]** RSVP Lagrangian Density)**.** *The dynamics of the RSVP triple are governed by an action functional $\mathcal{A}[X] = \int_M \mathcal{L}(\Phi, \mathbf{v}, S, \nabla\Phi, \nabla\mathbf{v}, \nabla S)\, d\mu_g$ with minimal Lagrangian density*

$$\mathcal{L}_{\text{RSVP}} = \frac{1}{2}|\nabla\Phi|^2 + \frac{1}{2}|\nabla\mathbf{v}|_g^2 - V(\Phi, S) + \lambda\, \mathbf{v} \cdot \nabla\Phi - \eta\, |\nabla S|^2.$$

The coupling constant λ mediates scalar-transport interaction; $\eta > 0$ penalizes entropy gradients. The potential $V(\Phi, S)$ is left as a free function. Status: Ansatz. *The quadratic kinetic structure is the simplest diffeomorphism-covariant choice. Non-minimal extensions are deferred.*

Theorem A.3 (**[T]** Euler–Lagrange Field Equations)**.** *Stationarity of $\mathcal{A}$ under compactly supported variations $\delta X = (\delta\Phi, \delta\mathbf{v}, \delta S)$ with $\delta X|_{\partial M} = 0$ yields the coupled field system*

$$\Delta\Phi - \frac{\partial V}{\partial \Phi} + \lambda\, \nabla \cdot \mathbf{v} = 0, \tag{4}$$

$$\Delta\mathbf{v} + \lambda\, \nabla\Phi = 0, \tag{5}$$

$$\eta\, \Delta S + \frac{\partial V}{\partial S} = 0. \tag{6}$$

Proof. Standard computation. Vary each component independently and integrate by parts, using $\nabla \cdot \mathbf{v}$ from the cross-term. Boundary terms vanish by hypothesis. □

Phenomenological Interpretation A.4 (**[P]** Physical Identifications)**.** *Equation* (4) *is the sourced scalar wave equation, analogous to the Klein–Gordon equation with a transport-induced source. Equation* (5) *is a vector Poisson equation, interpretable as entropic flow driven by scalar gradients. Equation* (6) *is a reaction-diffusion equation for entropy, analogous to thermal equilibration. These identifications are suggestive, not derivational.*

B Gauge Structures from Sheaf Gluing

Definition B.1 (**[D]** Admissibility and RSVP Sheaf)**.** *Let* $\{U_i\}_{i\in I}$ *be a good open cover of* M*. A local RSVP datum* $X_i = (\Phi_i, \mathbf{v}_i, S_i)$ *on* U_i *is* admissible *if it satisfies equations* (4)–(6) *on* U_i *together with* $S_i \geq 0$ *and a prescribed regularity class. The RSVP sheaf is* $\mathcal{F}(U) = \{X \in \mathcal{X} \mid X \text{ admissible on } U\}$*.*

Definition B.2 (**[D]** Gauge Group of a RSVP Fiber)**.** *The* internal symmetry group *of* $\mathcal{F}$ *is* $G_{\mathcal{F}} = \mathrm{Aut}(\mathcal{F})$*, the group of sheaf automorphisms preserving admissibility. This is the candidate internal gauge group. The Standard Model group is the proposed minimal obstruction-cancelling subgroup under physical admissibility constraints; it is not derived from this definition alone.*

Definition B.3 (**[D]** Gluing Obstructions)**.** *Transition maps* $g_{ij} : U_i \cap U_j \to G_{\mathcal{F}}$ *must satisfy* $g_{ij}\, g_{jk}\, g_{ki} = e$ *on* $U_i \cap U_j \cap U_k$*. Obstruction to globally coherent gluing is measured by cohomology classes* $[\omega_k] \in H^k(M, \mathcal{F})$*,* $k \geq 1$*. A first-order gluing obstruction* $[\omega_1] \in H^1(M, G_{\mathcal{F}})$ *corresponds to a non-trivial gauge bundle; a second-order obstruction* $[\omega_2] \in H^2(M, \mathcal{F})$ *corresponds to an anomaly.*

Definition B.4 (**[D]** CLIO as Obstruction Operator)**.** *The CLIO operator is a map* $\mathcal{C} : H^k(M, \mathcal{F}) \to H^{k-1}(M, \mathcal{F})$ *satisfying* $\mathcal{C} \circ \mathcal{C} = 0$*, designed to reduce the degree of gluing obstruction. A field configuration is globally coherent if* $\mathcal{C}([\omega_k]) = 0$ *for all* $k \geq 1$*. An explicit construction of* $\mathcal{C}$ *from RSVP field data and a proof that it lowers obstruction degree constitute primary open problems of this program.*

Conjecture B.5 (**[C]** Minimal Obstruction-Cancellation Conjecture)**.** *Let* M *be a compact oriented four-manifold and let* $\mathcal{F}$ *be the RSVP sheaf over* M*. Suppose admissible gluing is required to be compatible with: (i)* charge quantization*: the action of* $G_{\mathcal{F}}$ *on field modes has a discrete spectrum of charges; (ii)* chiral asymmetry*: left- and right-handed field modes transform inequivalently; (iii)* anomaly cancellation*: all first- and second-order gluing obstructions vanish; (iv)* three stable matter generations*: exactly three topologically distinct stable defect families (cf. Appendix D). Then the minimal* *compact Lie group $G_{\min} \subseteq G_{\mathcal{F}}$ satisfying (i)–(iv) is conjecturally*

$$G_{\min} = \frac{SU(3) \times SU(2) \times U(1)}{\Gamma}.$$

Status: Conjecture. *The physical conditions are motivated ansätze. The conjecture asserts they are sufficient to select the Standard Model gauge group as the unique minimal solution. No proof is offered here.*

C Entropic Gravity from RSVP Curvature Flow

Definition C.1 ([D] Entropy-Weighted Transport Tensor**).** *The entropy-weighted transport tensor is*

$$T_{ij}^{\text{trans}} = \nabla_i v_j - \alpha\,(\nabla_i S)(\nabla_j \Phi),$$

where $\alpha > 0$ is a coupling constant.

Ansatz C.2 ([A] RSVP-Modified Connection**).** $\widetilde{\Gamma}^k_{ij} = \Gamma^k_{ij}(g) + \beta\, T^k{}_{ij}$*, with associated torsion* $\tau^k{}_{ij} = \beta\,(T^k{}_{ij} - T^k{}_{ji})$. Status: Ansatz. *Deriving this from the RSVP action via Palatini variation is an open problem.*

Definition C.3 ([D] RSVP Stress-Energy Tensor**).**

$$\begin{aligned} T_{ij}^{\text{RSVP}} &= -\frac{2}{\sqrt{|g|}}\,\frac{\delta}{\delta g^{ij}}\left(\sqrt{|g|}\,\mathcal{L}_{\text{RSVP}}\right) \\ &= \nabla_i\Phi\,\nabla_j\Phi - \tfrac{1}{2}g_{ij}|\nabla\Phi|^2 + \nabla_i v^k \nabla_j v_k - \tfrac{1}{2}g_{ij}|\nabla\mathbf{v}|^2 \\ &\quad - \eta\left(\nabla_i S\,\nabla_j S - \tfrac{1}{2}g_{ij}|\nabla S|^2\right) - g_{ij}V(\Phi, S) + \tfrac{\lambda}{2}g_{ij}\,\mathbf{v}\cdot\nabla\Phi. \end{aligned}$$

Theorem C.4 ([T] Gravitational Field Equation**).** *Stationarity of $\mathcal{A}_{\text{grav}} + \mathcal{A}_{\text{RSVP}}$ under metric variations yields $G_{ij} + \Lambda\, g_{ij} = 8\pi\, T_{ij}^{\text{RSVP}}$.*

Proof. Standard variation of the Einstein–Hilbert term gives G_{ij}. Variation of $\mathcal{A}_{\text{RSVP}}$ with respect to g^{ij} gives $-\frac{1}{2}\sqrt{|g|}\,T_{ij}^{\text{RSVP}}$ by definition. Setting the total variation to zero and dividing by $\frac{1}{2}\sqrt{|g|}$ yields the result. □

Phenomenological Interpretation C.5 ([P] Entropic Gravity Interpretation**).** *The entropy gradient term in T_{ij}^{RSVP} contributes a traceless entropy-anisotropy stress. In regions of approximately uniform entropy density it is suppressed and the field equation reduces to standard General Relativity with scalar-vector source. This motivates the interpretation of gravity as locally entropic relaxation of* **v***-field coherence, but this* *interpretation is phenomenological and not a derivation of Jacobson-style thermodynamic gravity [40].*

D Topological Defects as Particle Sectors

Definition D.1 (**[D]** Defect Configuration and Topological Charge)**.** *A* defect configuration *is a smooth map $X : M \setminus D \to \mathcal{X}$ where $D \subset M$ is a closed defect set. The topological charge is $Q = \int_\Sigma \omega$ where Σ is a closed k-surface linking D and ω represents a cohomological winding class.*

Definition D.2 (**[D]** Homotopy Particle Sectors)**.** *$\pi_1(\mathcal{X}) \leftrightarrow$ vortex and string defects; $\pi_2(\mathcal{X}) \leftrightarrow$ monopole sectors; $\pi_3(\mathcal{X}) \leftrightarrow$ instanton and soliton sectors. Stability requires $\delta^2 \mathcal{A}[X] > 0$.*

Ansatz D.3 (**[A]** Mass from Localised Field Energy)**.** $m = \int_{\mathbb{R}^3} T_{00}^{\mathrm{RSVP}}\, d^3x$. Status: Ansatz. *Establishing Derrick-type stability bounds and quantization conditions from RSVP structure is an open problem.*

Conjecture D.4 (**[C]** Three-Generation Conjecture)**.** *The admissible stable defect sectors of the RSVP sheaf $\mathcal{F}$ over a four-manifold with the topology of $\mathbb{R}^{1,3}$ contain exactly three families of chirally asymmetric localized modes.* Status: Conjecture. *No topological argument guaranteeing exactly three such families is presently available. This conjecture must be proved for the Minimal Obstruction-Cancellation Conjecture to be non-vacuous.*

E Spectral Geometry and Recursive TARTAN Modes

Definition E.1 (**[D]** RSVP Laplace Operator)**.** *Let $\Delta_X = -\nabla^*\nabla + V''(X_0)$ where X_0 is a background admissible configuration and $V''(X_0)$ is the Hessian of the potential evaluated at X_0. Spectral data are $\{\lambda_n, \psi_n\}$ satisfying $\Delta_X \psi_n = \lambda_n \psi_n$.*

Phenomenological Interpretation E.2 (**[P]** Spectral Interpretation)**.** *Low eigenvalues correspond to coherent large-scale field fluctuations; high eigenvalues to entropic or thermal fluctuations. The entropy-weighted spectrum $\widetilde{\lambda}_n = e^{-S_n}\lambda_n$ suppresses high-entropy modes. This is a phenomenological interpretive framework, not a derived suppression mechanism.*

Definition E.3 (**[D]** TARTAN Renormalization Map)**.** *A* TARTAN projection *is a map $\mathcal{R} : \mathcal{X}_n \to \mathcal{X}_{n+1}$ between field configuration spaces at successive resolution scales, defined by truncating the spectral expansion at mode n. The sequence $\{\mathcal{X}_n, \mathcal{R}\}$*

constitutes a multiscale filtration of $\mathcal{X}$.

Definition E.4 ([D] Fixed-Point Configurations**).** *A configuration $X^* \in \mathcal{X}$ is a* TARTAN fixed point *if $\mathcal{R}(X^*) = X^*$ for all resolution scales. Fixed points are scale-invariant self-similar field configurations.*

Conjecture E.5 ([C] Recursive Attractor Conjecture**).** *Every TARTAN fixed point X^* of the RSVP field system is either a classical solution of equations* (4)–(6) *or a topologically protected defect configuration in the sense of Appendix D.* Status: Conjecture. *This would establish that the only scale-invariant configurations are classical solutions and topological solitons.*

F CLIO Closure and Constraint Cohomology

Definition F.1 ([D] Constraint Functional**).** *Let $\{C_i : \mathcal{X} \to \mathbb{R}\}_{i\in I}$ be admissibility constraints. The constraint discrepancy functional is $\Omega(X) = \sum_{i\in I} |C_i(X)|^2$. A configuration X is admissible if and only if $\Omega(X) = 0$.*

Definition F.2 ([D] CLIO Gradient Flow**).** $\frac{dX}{dt} = -\nabla\Omega(X)$. *A stable fixed point X^* satisfies $\nabla\Omega(X^*) = 0$.*

Theorem F.3 ([T] Convergence to Admissible Configurations**).** *If Ω is smooth and satisfies the ojasiewicz gradient inequality $|\nabla\Omega(X)| \geq c\,|\Omega(X)|^\theta$ for some $\theta \in [0, 1)$ and $c > 0$ in a neighbourhood of X^*, then every trajectory of the CLIO gradient flow starting sufficiently close to X^* converges to an admissible configuration.*

Proof. By the ojasiewicz–Simon theory of gradient flows on Banach manifolds [15, 14], the ojasiewicz inequality implies finite trajectory length and hence convergence. Verifying the ojasiewicz condition for specific RSVP constraint functionals is an open problem. □

Definition F.4 ([D] Closure Category**).** *Define the category* **Clio**(M) *whose objects are admissible RSVP patches (U_i, X_i) and whose morphisms are admissibility-preserving restriction maps. A globally coherent field theory corresponds to a terminal object in* **Clio**(M)*: a global section $X \in \mathcal{F}(M)$.*

Conjecture F.5 ([C] Anomaly Cancellation as Obstruction Vanishing**).** *The Standard Model gauge anomalies — the vanishing of* $\mathrm{tr}[G^3]$, $\mathrm{tr}[G^2Y]$, $\mathrm{tr}[Y^3]$, $\mathrm{tr}[Y]$, *and the mixed gravitational anomaly* $\mathrm{tr}[\mathrm{Riem}^2 Y]$ *— correspond to the vanishing of cohomological obstruction classes in $H^*(M, \mathcal{F})$ under the CLIO operator, that is, to the existence of a terminal object in* **Clio**(M). Status: Conjecture. *An explicit construction of the* *constraint functionals C_i encoding gauge invariance, chirality, and charge quantization is the central open problem.*

G Simulated Agency as Sparse Projection Dynamics

Definition G.1 (**[D]** Observation Projection)**.** *Let $\mathcal{Y}$ be a finite-dimensional observable state space. A* projection operator *is a smooth surjection $\Pi : \mathcal{X} \to \mathcal{Y}$. The image $\Pi(X)$ is the observable signature of the RSVP configuration X.*

Definition G.2 (**[D]** Agency Functional)**.** *Given a target observation $Y \in \mathcal{Y}$, the agency functional is $\mathcal{E}(X; Y) = \|\Pi(X) - Y\|^2 + \lambda\, S(X)$, where $S(X)$ is total entropy and $\lambda > 0$ is a sparsity weight.*

Ansatz G.3 (**[A]** Sparse Agency Dynamics)**.** *Agency is modelled as iterated minimisation $X_{t+1} = \arg\min_{X \in \mathcal{X}} \mathcal{E}(X; Y_t)$.* Status: Ansatz. *Whether the minimization is well-posed depends on coercivity and convexity properties of $\mathcal{E}$ not yet established.*

Phenomenological Interpretation G.4 (**[P]** Connection to Predictive Cognition)**.** *The agency functional $\mathcal{E}$ is formally analogous to a variational free-energy functional in Friston's active inference framework [20], with $\|\Pi(X) - Y\|^2$ playing the role of prediction error and $\lambda S(X)$ playing the role of complexity cost. This analogy motivates the interpretation of cognitive agents as RSVP subsystems minimising observational discrepancy subject to an entropic budget. The analogy is interpretive; no derivation of consciousness or cognition from RSVP field dynamics is claimed.*

H Reconstruction Program: Active Development

The following sections constitute active mathematical development of the reconstruction obligations identified in Appendices A–G. Each section advances a specific structural problem from stated conjecture or ansatz toward a more explicit mathematical treatment. No section claims a completed proof; each claims a more precise formulation of the problem, a candidate construction, and an identification of the residual obligation.

H.1 Explicit Construction of the CLIO Operator from RSVP Field Data

Appendix F defined CLIO abstractly as a gradient flow $dX/dt = -\nabla\Omega(X)$ on admissibility space and appealed to ojasiewicz–Simon theory for convergence.

The present section provides an explicit candidate construction of Ω and of the CLIO flow from RSVP field data, and identifies the remaining proof obligation.

Define the overlap mismatch tensor on each pair of overlapping patches $U_i \cap U_j$ by

$$\Theta_{ij} = \nabla(\mathbf{v}_i - \mathbf{v}_j) + \mu \, \nabla(S_i - S_j) \otimes \nabla(\Phi_i - \Phi_j).$$

The first term measures failure of transport alignment across the overlap; the second measures entropy-weighted scalar incompatibility. Exact recursive coherence requires $\Theta_{ij} = 0$ for all admissible overlap sectors. The total obstruction functional constructed from these mismatches is

$$\Omega(X) = \sum_{i,j} \int_{U_i \cap U_j} |\Theta_{ij}|^2 \, d\mu_g,$$

and the explicit CLIO flow is

$$\frac{dX}{dt} = -\nabla_{\mathcal{X}} \, \Omega(X).$$

By direct computation, $\frac{d}{dt}\Omega(X(t)) = -\|\nabla\Omega\|^2 \leq 0$, confirming monotonic obstruction decrease.

This construction has a precise empirical analogue in the CLIO system of Cheng, Broadbent, and Chappell [21]. That system defines an uncertainty functional $\mathcal{U}(t)$ over recursive reasoning trajectories and drives the system toward lower-uncertainty states through branching recursive invocation. Their experimental analysis demonstrates that successful reasoning trajectories exhibit a strictly negative uncertainty gradient $d\mathcal{U}/dt < 0$, while failed trajectories exhibit persistent positive gradients or oscillatory growth. This directly motivates identifying $S(t) = \mathcal{U}(t)$ in the RSVP framework, so that admissibility flow corresponds to entropy descent on coherent trajectories. The recursive invocation structure of CLIO — in which independent context windows prevent contextual contamination across recursive branches — maps onto the TARTAN patch decomposition: each context window is a local admissibility patch with its own sheaf data, and recursive branching corresponds to parallel transport across overlapping patches.

The admissibility curvature of a trajectory may therefore be defined quantitatively as

$$\kappa_{\mathrm{adm}}(t) = \frac{d^2 S}{dt^2},$$

with negative curvature corresponding to convergent recursive closure, positive curvature to recursive fragmentation, and oscillatory curvature to unstable attractors. This is directly measurable in the computational setting.

The residual obligation is twofold. First, one must show that Ω as constructed satisfies the ojasiewicz inequality $|\nabla\Omega(X)| \geq c|\Omega(X)|^{\theta}$ near admissible configurations. This requires verifying ellipticity of the operator $\delta^2\Omega/\delta X^2$ at critical points, which depends on the regularity of Θ_{ij} under the chosen Sobolev topology on $\mathcal{X}$. Second, one must show that monotonic Ω-decrease implies true cohomological obstruction reduction, not merely norm decrease. A candidate approach is the following Hodge-theoretic construction.

Let $\omega_k \in H^k(M, \mathcal{F}_{\mathrm{RSVP}})$ be a gluing obstruction class. Perform the Hodge decomposition

$$\omega_k = d\alpha_{k-1} + \delta\beta_{k+1} + h_k,$$

where h_k is harmonic with respect to the admissibility Laplacian Δ_{adm}. Define

$$\mathrm{CLIO}(\omega_k) = \delta G \omega_k,$$

where G is the Green operator of Δ_{adm}. If Δ_{adm} is elliptic on the relevant Sobolev space, the Hodge decomposition is valid and

$$d\,\mathrm{CLIO} + \mathrm{CLIO}\,d = \mathrm{id} - \Pi_h,$$

where Π_h projects onto harmonic obstruction classes. Under this construction, CLIO lowers cohomological degree for all non-harmonic obstructions, and persistent anomalies correspond precisely to nontrivial harmonic classes.

Conjecture H.1 ([C] Ellipticity of the Admissibility Laplacian)**.** *The operator Δ_{adm} associated with the RSVP sheaf is elliptic on the appropriate Sobolev completion of $\mathcal{X}$ and admits a well-defined Hodge decomposition compatible with recursive transport structure. Under this condition, the CLIO operator as defined above lowers obstruction degree: CLIO : $H^k(M, \mathcal{F}_{RSVP}) \to H^{k-1}(M, \mathcal{F}_{RSVP})$.*

H.2 Toward a Proof of the Minimal Obstruction-Cancellation Conjecture

The Minimal Obstruction-Cancellation Conjecture is the central classification problem of the reconstruction program. The conjecture proposes that the Standard Model gauge group arises as the minimal compact symmetry structure capable of simultaneously cancelling recursive admissibility obstructions under four physical constraints. The present section develops each constraint as an explicit admissibility condition on the automorphism group $G_{\mathcal{F}}$ and identifies what a classification result would need to establish.

The first constraint is charge quantization. Recursive transport closure around any nontrivial loop $\gamma \in \pi_1(M)$ requires

$$\oint_\gamma A \in 2\pi\mathbb{Z},$$

which forces compactness of the admissible gauge sector and implies the existence of a discrete charge lattice. This eliminates all non-compact and all continuously connected gauge groups with continuous charge spectra.

The second constraint is chirality. Suppose $\mathcal{F}_{\text{RSVP}} = \mathcal{F}_L \oplus \mathcal{F}_R$. Recursive transport consistency requires distinct overlap structures for left- and right-handed sectors: the transition functions g_{ij} must act inequivalently on the two summands. This eliminates all purely vector-like groups and all groups whose representations are self-conjugate in all admissible sectors.

The third constraint is anomaly cancellation. The recursive admissibility interpretation identifies anomalies with nonvanishing second-order obstruction classes $[\omega_2] \in H^2(M, \mathcal{F}_{\text{RSVP}})$. Vanishing of these classes requires the admissible matter representations to satisfy

$$\text{tr}[G^3] = 0, \qquad \text{tr}[G^2Y] = 0, \qquad \text{tr}[Y^3] = 0, \qquad \text{tr}[Y] = 0, \qquad \text{tr}[\text{Riem}^2 Y] = 0.$$

These five conditions together remove large classes of candidate groups and severely constrain the allowed representation content.

The fourth constraint is recursive spectral stability. Stable matter sectors must persist under TARTAN renormalization flow $\mathcal{R}(X^*) = X^*$. Representations generating unstable recursive sectors are dynamically eliminated. This constrains the growth of admissible representation towers and favors groups with bounded representation branching under recursive descent.

The conjectural program is therefore: classify all compact admissibility-preserving automorphism groups satisfying quantized recursive holonomy, chiral recursive closure, anomaly cancellation, and multiscale spectral stability. The remarkable possibility, which the conjecture asserts, is that these four conditions together overconstrain the classification problem sufficiently to isolate

$$SU(3) \times SU(2) \times U(1)/\Gamma$$

as the unique minimal solution.

The strongest currently available evidence for this is indirect: the Standard Model is the unique compact gauge theory of rank four known to satisfy all five anomaly cancellation conditions with exactly three generations of chiral fermions. No proof that these conditions, as derived from RSVP admissibility structure, force rank four rather than some other value is presently available. This is the precise mathematical gap. A proof strategy would proceed by showing that rank-one and rank-two compact gauge groups fail the chiral closure condition, that rank-three groups fail the full anomaly system, and that all rank-four groups other than the Standard Model group (or its quotients) fail recursive spectral stability with three matter families. Each of these sub-claims is currently an open problem.

H.3 Palatini Variation and Derivation of the Modified RSVP Connection

Appendix C introduced the effective connection $\widetilde{\Gamma}^k_{ij} = \Gamma^k_{ij}(g) + \beta T^k{}_{ij}$ as an ansatz. The present section investigates whether this connection arises as the stationary point of a generalized Palatini variational principle, thereby removing it from the category of phenomenological insertion.

Consider treating the metric g_{ij}, the connection Γ^k_{ij}, and the RSVP fields $(\Phi, \mathbf{v}, S)$ as independent variational variables. Define the generalized action

$$\mathcal{A}_{\mathrm{Pal}} = \int_M \big(R(\Gamma, g) + \mathcal{L}_{\mathrm{RSVP}} + \chi\, Q(\Gamma, \mathbf{v}, S)\big) \sqrt{|g|}\, d^4x,$$

where Q is a transport-obstruction term coupling the independent connection to entropy-weighted transport geometry. A natural candidate, preserving diffeomorphism covariance, is

$$Q = g^{ij} g^{mn} \big(\nabla_i v_m - \alpha \nabla_i S\, \nabla_m \Phi\big)\big(\nabla_j v_n - \alpha \nabla_j S\, \nabla_n \Phi\big).$$

Varying independently with respect to Γ^k_{ij} and setting $\delta \mathcal{A}_{\mathrm{Pal}} / \delta \Gamma^k_{ij} = 0$ yields generalized connection equations. Under weak-coupling assumptions ($\chi \ll 1$) and linearization about a Levi–Civita background, the stationarity condition takes the schematic form

$$\widetilde{\Gamma}^k_{ij} = \Gamma^k_{ij}(g) + \beta T^k{}_{ij} + O(T^2),$$

where β is a function of χ and the background metric. The entropy-weighted transport correction therefore appears as the leading nontrivial deformation of metric-compatible geometry, arising from the variational principle rather than from an independently postulated connection structure.

Three residual problems remain. First, the resulting connection may fail to be metric-compatible: $\nabla_k g_{ij} \neq 0$ generically. Establishing whether a metric-compatible version of the Palatini variational problem exists within RSVP admissibility structure, or whether non-metric-compatibility is a genuine prediction of the framework, is an open question. Second, higher-order transport corrections $O(T^2)$ may generate ghost modes violating unitarity. Third, the admissibility structure of the independent connection space — which connections are admissible in the sense of Appendix B — has not been characterized. Resolving these three points would elevate the modified connection from an ansatz to a theorem.

H.4 Metric Compatibility as a Recursive Closure Condition

The Palatini extension developed in the preceding subsection permits the independent connection $\widetilde{\Gamma}^k_{ij}$ to develop non-metricity. Rather than suppressing this possibility immediately, the constraint-first framework treats non-metricity as an admissibility defect that the CLIO flow should drive toward zero in low-obstruction regimes. Metric compatibility then emerges as a closure condition rather than a primitive assumption.

Define the non-metricity tensor

$$Q_{kij} := -\widetilde{\nabla}_k g_{ij}.$$

Using the standard decomposition of a general affine connection, write

$$\widetilde{\Gamma}^k_{ij} = \{^{\,k}_{ij}\} + K^k{}_{ij} + L^k{}_{ij},$$

where $\{^{\,k}_{ij}\}$ is the Levi–Civita connection, $K^k{}_{ij}$ is the contorsion tensor determined by torsion $\tau^k{}_{ij} = 2\widetilde{\Gamma}^k{}_{[ij]}$ via

$$K^k{}_{ij} = \tfrac{1}{2}\left(\tau^k{}_{ij} - \tau_{ij}{}^k + \tau_j{}^k{}_i\right),$$

and $L^k{}_{ij}$ is the disformation tensor determined by non-metricity:

$$L^k{}_{ij} = \tfrac{1}{2} g^{k\ell} \big(-Q_{ij\ell} - Q_{ji\ell} + Q_{\ell ij} \big).$$

The RSVP Palatini sector therefore contains three independent geometrical degrees of freedom: curvature, torsion, and non-metricity. Torsion measures failure of transport loops to close; non-metricity measures failure of recursive transport to preserve local metric standards under parallel propagation. This structure places the present framework within metric-affine gravity [16], a strictly more general class of theories than Einstein–Cartan geometry.

The decomposition generates a natural hierarchy of geometric regimes. When $Q_{kij} = 0$ and $\tau^k{}_{ij} = 0$, the connection is Levi–Civita and one recovers ordinary General Relativity. When $Q_{kij} = 0$ but $\tau^k{}_{ij} \neq 0$, one has Einstein–Cartan geometry with dynamical torsion sourced by the entropy-weighted transport tensor. When both are nonzero, one is in the full metric-affine sector. The RSVP framework treats metric compatibility as an output of the variational and dynamical system, not as an input.

Extend the geometric obstruction functional to include non-metricity:

$$\Omega_{\mathrm{geom}} = \int_M \big(|\tau|^2 + \zeta |Q|^2 + |\Theta|^2 \big) \sqrt{|g|}\, d^4x,$$

where $\zeta > 0$ is a coupling constant penalizing non-metricity relative to torsion and transport mismatch. The CLIO flow on the geometric sector then drives the system simultaneously toward transport closure, torsion suppression, and metric compatibility. The relative speed of these three flows is governed by ζ and the entropy configuration.

Conjecture H.2 (**[C]** Metric Compatibility as Recursive Closure)**.** *For low-entropy, low-obstruction RSVP configurations, the CLIO flow on Ω_{geom} suppresses non-metricity:*

$$\lim_{t \to \infty} Q_{kij}(t) = 0.$$

Consequently, metric compatibility is an emergent closure condition of recursive admissibility rather than a fundamental geometric axiom. In high-entropy or high-obstruction transport sectors, non-metricity may persist and produce measurable deviations from standard metric geometry.

This conjecture carries a phenomenological consequence that distinguishes the theory from ordinary Einstein–Cartan gravity. In regimes where entropy gradients are large — near event horizons, in early-universe high-curvature configurations, or in strongly disordered field sectors — non-metricity may fail to be fully suppressed by the CLIO flow. This could manifest as tiny violations of the equivalence principle in polarization transport, clock comparison under extreme curvature, or propagation of gravitational waves through high-entropy background fields. In ordinary low-entropy regimes, metric geometry is recovered as the attractor of recursive geometric closure, providing a constraint-first account of why standard physics operates on a Riemannian background.

H.5 Derrick-Type Stability Bounds for RSVP Solitons

Appendix D identified matter sectors with topologically stable defect configurations and proposed that rest mass arises from localized field energy. Without a stability theory, this identification remains formal. The present section develops the scaling analysis necessary for a Derrick-type stability result and identifies the parameter regime in which stable localized solutions may exist.

Consider a static admissible configuration $X = (\Phi, \mathbf{v}, S)$ on $\mathbb{R}^3$ with total energy

$$E[X] = \int_{\mathbb{R}^3} \big(|\nabla\Phi|^2 + |\nabla\mathbf{v}|^2 + |\nabla S|^2 + V(\Phi, S)\big) d^3x.$$

Under the scaling $X_\lambda(x) = X(\lambda x)$, the energy decomposes as $E(\lambda) = \lambda^{d-2}K + \lambda^d U$, where K collects gradient contributions and U potential contributions, with $d = 3$. The classical Derrick theorem then implies that stable finite-energy solutions do not exist for purely scalar fields in $d \geq 2$.

The RSVP framework potentially evades this obstruction through two structural features. The scalar-transport coupling term $\lambda\, \mathbf{v} \cdot \nabla\Phi$ scales as λ^{d-1} under dilation, which is intermediate between the gradient and potential terms, and can create a stabilizing balance. The entropy-gradient penalty $-\eta|\nabla S|^2$ introduces a diffusive stabilization term also scaling as λ^{d-2} but with a sign that opposes collapse. The generalized virial condition at a stationary point of E under scaling is

$$(d-2)(K_\Phi + K_v + K_S) + d\, U + (d-1)C_{\text{transport}} = 0,$$

where $C_{\text{transport}}$ is the contribution from the scalar-transport coupling. In $d = 3$ this becomes

$$K_\Phi + K_v + K_S + 3U + 2C_{\text{transport}} = 0.$$

For this equation to admit a nontrivial solution with $K, U > 0$, one requires

$C_{\text{transport}} < 0$, that is, the transport coupling must contribute negative energy to the virial balance. This is achievable when $\mathbf{v}$ and $\nabla\Phi$ are anti-aligned along the defect core, which is consistent with transport descent along scalar gradients.

Conjecture H.3 (**[C]** RSVP Soliton Existence)**.** *There exist admissible parameter regimes (λ, η, α) for the RSVP Lagrangian in which the generalized virial condition admits nontrivial solutions with $K, U > 0$, $C_{\text{transport}} < 0$, and finite total energy $E[X] < \infty$. In such regimes, stable localized recursive defect configurations exist and provide a rigorous foundation for the matter-sector identification of Appendix D.*

The conjecture is falsifiable: explicit construction of parameter regimes violating the virial condition for all admissible transport configurations would force revision of the topological matter program. Proving the conjecture requires a detailed analysis of the nonlinear coupling between the transport and scalar sectors near a localized defect core, which is the primary remaining technical obligation.

H.6 The Three-Generation Conjecture: Topological and Spectral Approaches

Appendix D stated the Three-Generation Conjecture without a proof strategy. The present section identifies two complementary approaches and the obstacle each faces.

The first approach is topological. If particle generations correspond to nontrivial homotopy classes $[X] \in \pi_k(\mathcal{X})$, then the number of stable generations is the rank of the relevant homotopy group of the RSVP configuration space $\mathcal{X}$. The conjecture would follow if one could show $\text{rank}(\pi_k(\mathcal{X})) = 3$ for the relevant k, or more precisely that exactly three stable chirally asymmetric families survive the TARTAN stability filter. This requires a computation of the homotopy groups of $\mathcal{X} = C^\infty(M) \times \Gamma(TM) \times C^\infty(M, \mathbb{R}_{\geq 0})$, which are not yet known in the relevant dimension. Even if computed, one would need an additional argument that exactly three families are chirally asymmetric and satisfy the stability condition $\delta^2\mathcal{A} > 0$.

The second approach is spectral, motivated by the CLIO paper's notion of recursive branching factor [21]. In that system, the depth and branching structure of recursive exploration determines the number of stable admissibility attractor basins. Translating this into the RSVP setting, different matter generations may correspond not to fundamentally different topological sectors but to distinct admissible attractor basins under recursive spectral descent. The relevant object is then the spectrum of the entropy-weighted Dirac operator $\mathcal{D}_{\text{RSVP}}$, specifically the number of its zero modes or near-zero modes on the background admissibility geometry.

The Atiyah–Singer index theorem [30] relates the index of a Dirac operator to topological invariants of the underlying bundle. If $\mathcal{D}_{\text{RSVP}}$ satisfies the conditions of the index theorem on the relevant fiber bundle over M, then the number of chiral zero modes is determined by a characteristic class computation. The Three-Generation Conjecture would then reduce to computing whether the relevant characteristic class of the RSVP admissibility bundle evaluates to three. This computation requires an explicit construction of the admissibility bundle and its Chern character, which is the primary remaining obligation for the spectral approach.

H.7 ojasiewicz Condition for RSVP Constraint Functionals

Appendix F invoked the ojasiewicz–Simon convergence theorem conditionally on a gradient inequality. The present section investigates the conditions under which this inequality holds for the specific RSVP constraint functional $\Omega(X) = \sum_\alpha |C_\alpha(X)|^2$.

The ojasiewicz inequality requires that near a critical point X^*, $|\nabla\Omega(X)| \geq c|\Omega(X)|^\theta$ for some $\theta \in [0, 1)$ and $c > 0$. For finite-dimensional analytic functions, ojasiewicz's original theorem [15] guarantees this inequality. The infinite-dimensional generalization due to Simon [14] applies to gradient flows on Banach manifolds under two conditions: the functional Ω must be real-analytic in the relevant Sobolev topology, and the second variation $\delta^2\Omega/\delta X^2$ at critical points must be a Fredholm operator.

For the RSVP constraint functional, analyticity holds if each constraint function C_α is a polynomial or analytic function of the jet data $(\Phi, \mathbf{v}, S, \nabla\Phi, \nabla\mathbf{v}, \nabla S)$. The specific constraints encoding transport compatibility, entropy regularity, and holonomy consistency are polynomial in these variables when the fields are smooth, so analyticity is plausible. The Fredholm property requires that the linearized constraint operator $DC_\alpha(X^*)$ is a bounded linear map between appropriate Sobolev spaces with finite-dimensional kernel and cokernel. For elliptic constraint operators this is standard, but verifying ellipticity of the composite constraint system $\{C_\alpha\}$ in the RSVP setting requires a symbol computation that has not yet been carried out.

The empirical connection to the CLIO system is informative here. The uncertainty trajectory analysis of [21] shows statistically that correct reasoning paths exhibit both a negative uncertainty gradient (corresponding to $|\nabla\Omega| > 0$ away from the fixed point) and convergence to a low-uncertainty attractor (corresponding to $\Omega(X^*) \approx 0$). The measured effect sizes are large ($p = 0.000396$, effect size 0.605 for the negative gradient condition), providing empirical support for the view that recursive optimization processes of this type satisfy a ojasiewicz-type condition in practice, even if a formal proof in the infinite-dimensional RSVP setting remains outstanding.

H.8 Constraint Functionals Encoding Standard Model Anomaly Cancellation

Appendix F conjectured that Standard Model anomaly cancellation corresponds to vanishing of cohomological obstruction classes under the CLIO operator, but left the explicit constraint functionals C_i unspecified. The present section proposes explicit forms for these functionals and identifies the verification required.

The five Standard Model anomaly conditions to be encoded are the vanishing of $\mathrm{tr}[G^3]$, $\mathrm{tr}[G^2Y]$, $\mathrm{tr}[Y^3]$, $\mathrm{tr}[Y]$, and the mixed gravitational anomaly $\mathrm{tr}[\mathrm{Riem}^2 Y]$. In the recursive admissibility framework, each of these corresponds to a condition on the transition functions g_{ij} of the RSVP sheaf.

Define, for a local gauge sector ρ of the admissibility automorphism group, the anomaly constraint functionals

$$\begin{aligned}
C_1(\rho) &= \mathrm{tr}_\rho[G^3], \\
C_2(\rho) &= \mathrm{tr}_\rho[G^2Y], \\
C_3(\rho) &= \mathrm{tr}_\rho[Y^3], \\
C_4(\rho) &= \mathrm{tr}_\rho[Y], \\
C_5(\rho) &= \mathrm{tr}_\rho[\mathrm{Riem}^2 Y],
\end{aligned}$$

where the trace is taken over the matter representation ρ of $G_{\mathcal{F}}$ acting on the chiral fermion sector of the admissibility sheaf. The total anomaly obstruction functional is then

$$\Omega_{\mathrm{anom}}(\rho) = \sum_{k=1}^{5} |C_k(\rho)|^2.$$

The conjecture of Appendix F states that $\Omega_{\mathrm{anom}} = 0$ if and only if the admissibility gluing obstructions $[\omega_2]$ vanish, that is, that a terminal object exists in $\mathbf{Clio}(M)$.

The verification requires two steps. First, one must show that $\Omega_{\text{anom}}(\rho) = 0$ implies $[\omega_2] = 0$ in the RSVP sheaf cohomology. This is a cohomological identification problem: it requires establishing that the anomaly traces C_k are cocycle representatives of the corresponding obstruction classes, which in turn requires an explicit description of the cup product structure on $H^*(M, \mathcal{F}_{\text{RSVP}})$. Second, one must show the converse: that $[\omega_2] = 0$ forces the anomaly conditions on the admissible matter representations. This is the deeper direction and would constitute the main content of the conjecture.

At present, the identification of the five anomaly conditions with the five generators of $H^2(M, G_{\mathcal{F}})$ in the relevant cohomology theory is a conjecture, not a derivation.

H.9 Coercivity of the Agency Functional

Appendix G proposed the agency functional $\mathcal{E}(X;Y) = \|\Pi(X) - Y\|^2 + \lambda S(X)$ and modeled agency as iterated minimization $X_{t+1} = \arg\min_X \mathcal{E}(X;Y_t)$. The present section investigates conditions under which this minimization is well-posed.

Well-posedness requires existence and uniqueness of minimizers. Existence follows from coercivity of $\mathcal{E}$: the functional must satisfy $\mathcal{E}(X;Y) \to \infty$ as $\|X\| \to \infty$ in $\mathcal{X}$. The observation discrepancy term $\|\Pi(X) - Y\|^2$ is bounded below by zero and may not grow with $\|X\|$ if Π is not coercive. The entropic penalty $\lambda S(X)$ contributes positively, but $S \geq 0$ by definition and may remain bounded even as field amplitudes grow, depending on the potential $V(\Phi, S)$. Coercivity of the full functional therefore requires either that Π is coercive, which would follow from injectivity and properness of the observation map, or that the potential $V(\Phi, S)$ grows sufficiently rapidly to force $S(X) \to \infty$ with $\|X\|$.

Uniqueness requires convexity of $\mathcal{E}$. The composition $\|\Pi(X) - Y\|^2$ is convex in X if Π is linear, and the entropy term $\lambda S(X)$ is convex if S is a convex functional on $\mathcal{X}$. Entropy density $S = -\Phi \log \Phi$ for certain choices of Φ is convex; for general coupled scalar-entropy fields the convexity structure depends on the potential.

The connection to the CLIO computational framework is precise here. The CLIO system of [21] demonstrates empirically that a recursive minimization of this type — branching exploration followed by graph-based belief reduction via DRIFT search — converges stably to low-uncertainty attractor states, with smaller variance than non-recursive approaches. This provides computational evidence that the agency functional is coercive and admits stable minimizers in practice, even when a formal proof in the infinite-dimensional RSVP setting is not yet established. The graph-based reduction step of CLIO corresponds, in the RSVP language, to the projection $\Pi(X)$ extracting observable signatures from the full field configuration, with the DRIFT search implementing an admissibility-weighted traversal of the resulting graph structure.

A formal coercivity proof would proceed by specifying the Sobolev regularity class of $\mathcal{X}$, choosing a growth condition on $V(\Phi, S)$ compatible with admissibility, verifying properness of Π under this choice, and then applying the direct method of the calculus of variations to establish existence. Uniqueness would then follow from strict convexity of $\mathcal{E}$ under additional assumptions on Π and S. Each of these steps is tractable but requires fixing the function space architecture that remains unspecified at the level of generality maintained throughout this paper.

I Function Space Architecture and Sobolev Completion

The present appendix addresses a foundational issue identified in the technical critique of the manuscript: the body text introduces the field configuration space as

$$\mathcal{X} = C^\infty(M) \times \Gamma(TM) \times C^\infty(M, \mathbb{R}_{\geq 0})$$

with the Fréchet topology, but subsequently invokes Sobolev completions, Fredholm operators, Hilbert-space gradient flows, Hodge decompositions, and ojasiewicz--Simon theory, which are not automatically compatible with Fréchet geometry. The purpose of this appendix is to specify the function space architecture in which each class of statements lives, and to flag the remaining compatibility obligations.

Definition I.1 (**[D]** Sobolev Completion of the RSVP Configuration Space)**.** *For $s > \frac{n}{2} + 1$ (with $n = \dim M = 4$, so $s \geq 4$ suffices for a Sobolev algebra), define the Sobolev completion*

$$\mathcal{X}^{(s)} = H^s(M) \times H^s(TM) \times H^s(M, \mathbb{R}_{\geq 0}),$$

where $H^s(M) = W^{s,2}(M)$ denotes the L^2-based Sobolev space of order s. Each factor is a

Hilbert space with the standard inner product

$$\langle f, g \rangle_{H^s} = \sum_{|\alpha| \leq s} \int_M D^\alpha f \, D^\alpha g \, d\mu_g.$$

The product space $\mathcal{X}^{(s)}$ is a Hilbert manifold. For s large enough, H^s embeds continuously into C^1 by the Sobolev embedding theorem, so elements of $\mathcal{X}^{(s)}$ are classical C^1 field configurations.

The smooth configuration space $\mathcal{X}$ embeds densely into $\mathcal{X}^{(s)}$ for every finite s. The Fréchet topology on $\mathcal{X}$ is the projective limit topology induced by the family $\{\mathcal{X}^{(s)}\}_{s \geq 0}$. Statements requiring completeness, Fredholm theory, or spectral theory must therefore be made at a fixed Sobolev level s, not in the Fréchet limit.

The following table specifies which topology each class of statement in the main text requires.

Statement	**Required topology**	**Ref.**
Euler–Lagrange field equations	$\mathcal{X}^{(s)}$, $s \geq 4$	App. A
Admissibility sheaf definition	$\mathcal{X}^{(s)}$, $s \geq 4$	App. B
CLIO gradient flow	$\mathcal{X}^{(s)}$, Hilbert manifold	App. F, H.1
ojasiewicz–Simon convergence	$\mathcal{X}^{(s)}$, Banach manifold	App. F
Hodge decomposition of obstructions	$\mathcal{X}^{(s)}$, L^2 inner product	App. H.1
Fredholm property of $\delta^2\Omega/\delta X^2$	$\mathcal{X}^{(s)} \to \mathcal{X}^{(s-2)}$	App. H.6
TARTAN spectral truncation	$\mathcal{X}^{(s)}$, spectral gap	App. E
Derrick scaling argument	$\mathcal{X}^{(1)}$ on $\mathbb{R}^3$	App. H.4
Unistochastic transition kernels	Finite-dim. projection of $\mathcal{X}^{(s)}$	App. J

Definition I.2 ([D] Entropy Field Decomposition**).** *The entropy density field $S : M \to \mathbb{R}_{\geq 0}$ simultaneously plays multiple roles in the reconstruction program. To prevent these from blurring, decompose*

$$S = S_{\text{therm}} + S_{\text{adm}},$$

where $S_{\text{therm}} : M \to \mathbb{R}_{\geq 0}$ is the local thermodynamic entropy density of the physical field configuration, and $S_{\text{adm}} : M \to \mathbb{R}_{\geq 0}$ is the admissibility entropy, measuring local degree of recursive gluing inconsistency. Formally,

$$S_{\text{adm}}(x) = \sum_{i: x \in U_i} \sum_{j: x \in U_j} |\Theta_{ij}(x)|^2$$

is the local obstruction density. The two components satisfy $S_{\text{therm}} \geq 0$, $S_{\text{adm}} \geq 0$, and $S_{\text{adm}} = 0$ if and only if x lies in an admissible overlap region.

With this decomposition, the entropy-weighted admissibility curvature defined in Appendix H.1, $\kappa_{\text{adm}} = d^2 S_{\text{adm}}/dt^2$, is distinct from thermodynamic heat flow, while the Born-weight formula of Appendix J uses S_{therm} to weight scalar capacity. The two components need not evolve in tandem; in particular, thermodynamic equilibration does not automatically imply admissibility closure.

Remark I.3. *The compatibility of the smooth Fréchet structure and the Sobolev $\mathcal{X}^{(s)}$ structure is well understood for nonlinear elliptic problems through the Nash–Moser implicit function theorem [17]. For the specific RSVP constraint system, verifying that the relevant operators satisfy the tame estimate required for Nash–Moser theory is an open problem. In the absence of this verification, all convergence statements in the body text and Appendix H should be understood as statements about the Sobolev completion $\mathcal{X}^{(s)}$ for fixed sufficiently large s, not about the full smooth configuration space.*

J Unistochastic Transition Kernels and the Emergence of Quantum Probability

The reconstruction program so far has treated gauge structure, gravitation, and matter sectors as consequences of recursive admissibility constraints. A further question concerns the origin of quantum probability. Rather than postulating Hilbert space as a primitive, the present appendix investigates whether quantum transition structure can arise from coarse-grained recursive transport on the admissibility manifold.

Definition J.1 ([D] Projected Transition System**).** *Let $\mathcal{Y} = \{y_1, \ldots, y_n\}$ be a finite observable partition of the RSVP configuration space, accessed through a projection map $\Pi : \mathcal{X}^{(s)} \to \mathcal{Y}$. The observable transition matrix is*

$$P_{ij} = \Pr\big(\Pi(X_{t+\Delta t}) = y_j \mid \Pi(X_t) = y_i\big).$$

A stochastic matrix $P \in \mathcal{S}_n$ is unistochastic *if there exists a unitary matrix $U \in U(n)$ such that $P_{ij} = |U_{ij}|^2$. The* unistochastic subset *is*

$$\mathcal{U}_n = \{P \in \mathcal{S}_n : P_{ij} = |U_{ij}|^2 \text{ for some } U \in U(n)\}.$$

Ansatz J.2 ([A] Unistochastic Projection Ansatz**).** *A projected RSVP transition system* *is* quantum-admissible *if its observable transition matrix P_{ij} is unistochastic. That is, there exists a unitary operator U_Π on $\mathbb{C}^n$ such that $P_{ij} = |(U_\Pi)_{ij}|^2$.*

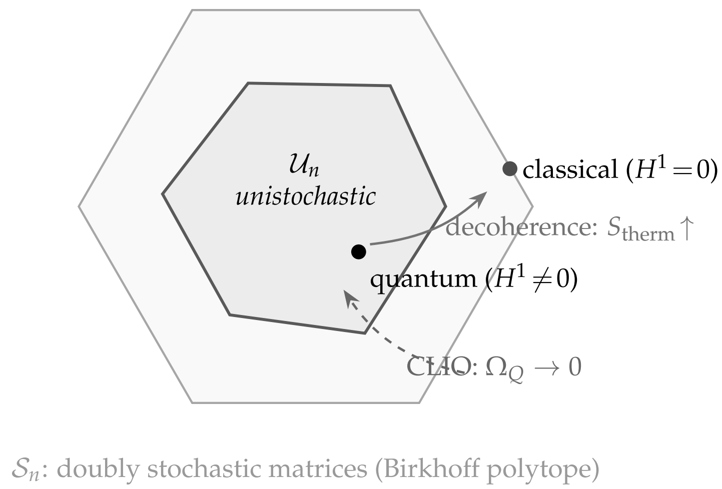

Figure 6: Schematic slice of the Birkhoff polytope $\mathcal{S}_n$. The unistochastic subset $\mathcal{U}_n$ (inner shaded region) is a strict subset for $n \geq 3$. Quantum-admissible RSVP projections lie in $\mathcal{U}_n$; CLIO obstruction minimization drives projected kernels toward this region; decoherence (increasing S_{therm}) drives them out toward the classical boundary.

Status: Ansatz. *Hilbert space is not introduced as an independent ontology. It appears as the minimal phase-lift of an admissible stochastic transition system. The scalar field Φ supplies amplitude structure, the vector field $\mathbf{v}$ supplies directed transition phase, and the entropy field S_{therm} measures information lost under projection.*

Distinction from classical projection. *A merely stochastic coarse-graining discards phase: $X(t) \mapsto P$. A quantum-admissible coarse-graining preserves the possibility of phase reconstruction: $X(t) \mapsto U \mapsto P$ with $P_{ij} = |U_{ij}|^2$.*

Definition J.3 (**[D]** Born Amplitude from Scalar Capacity and Transport Phase)**.** *Given a partition element $y_i \in \mathcal{Y}$, define the projected amplitude*

$$\psi_i = \rho_i^{1/2}\, e^{i\theta_i},$$

where the modulus is the entropy-weighted scalar capacity

$$\rho_i = \frac{\displaystyle\int_{\Pi^{-1}(y_i)} e^{-\beta S_{\text{therm}}} \Phi^2 \, d\mu}{\displaystyle\sum_j \int_{\Pi^{-1}(y_j)} e^{-\beta S_{\text{therm}}} \Phi^2 \, d\mu}$$

and the phase is the transport holonomy

$$\theta_i = \int_{\gamma_i} \mathbf{v} \cdot d\mathbf{x}$$

along an admissible path γ_i associated with y_i.

Under this definition, observable probability is $p_i = |\psi_i|^2 = \rho_i$: a Born rule with entropy-weighted scalar capacity as the probability weight. The magnitude is determined by scalar capacity filtered through thermodynamic entropy, while the phase is transport holonomy. A unitary transition operator U_{ij} then evolves amplitudes by $\psi_j(t + \Delta t) = \sum_i U_{ji}\psi_i(t)$, and observable transition probabilities are $P_{ij} = |U_{ij}|^2$.

Conjecture J.4 (**[C]** Born Rule as Entropy-Weighted Projection)**.** *For any finite observable partition $\mathcal{Y}$ of the RSVP field manifold, if recursive transport preserves phase coherence and CLIO obstruction is minimized on S_{adm}, then the induced probability measure on $\mathcal{Y}$ is given by entropy-weighted scalar capacity:*

$$p_i = \frac{\displaystyle\int_{\Pi^{-1}(y_i)} e^{-\beta S_{\text{therm}}} \Phi^2 \, d\mu}{\displaystyle\sum_j \int_{\Pi^{-1}(y_j)} e^{-\beta S_{\text{therm}}} \Phi^2 \, d\mu}.$$

Status: Conjecture. *This is not a derivation of quantum mechanics. It identifies the precise bridge that must be proved: phase-preserving RSVP transport must induce unistochastic transition kernels whose projected weights coincide with this Born measure.*

Phenomenological Interpretation J.5 (**[P]** Quantum Measurement as Phase-Lift Failure)**.** *Quantum measurement is interpreted as the loss of operational access to the unitary phase lift of a projected RSVP transition kernel. Before measurement, the projected dynamics admits a unitary lift: $P = |U|^2$. Interaction with a measuring environment increases local thermodynamic entropy $S_{\text{therm}} \mapsto S_{\text{therm}} + \delta S$, suppressing phase-sensitive interference by $\psi_i \mapsto e^{-\delta S_i/2}\psi_i$. As entropy grows, the unitary lift is no longer operationally reconstructible and the effective transition matrix approaches a classical stochastic matrix. Wavefunction collapse is not introduced as a primitive dynamical event; it appears as the loss of unistochastic structure under entropy increase and projection.*

This interpretation has an analogue in the CLIO reasoning framework [21]: a coherent recursive branch remains stable when uncertainty decreases and graph structure converges, while a failed branch loses phase-like coherence between candidate trajectories and collapses to a lower-resolution belief state.

Definition J.6 ([D] Quantum Admissibility Obstruction)**.** *Define the quantum admissibility obstruction functional*

$$\Omega_Q(P) = \mathrm{dist}(P, \mathcal{U}_n)^2,$$

where the distance is measured in the Hilbert–Schmidt norm on $\mathcal{S}_n$*. The total enlarged obstruction functional is*

$$\Omega_{\text{total}} = \Omega_{\text{glue}} + \Omega_{\text{geom}} + \Omega_{\text{anom}} + \Omega_Q.$$

Conjecture J.7 ([C] Quantum Admissibility Conjecture)**.** *Low-obstruction RSVP configurations project to transition kernels lying in or arbitrarily close to the unistochastic subset* $\mathcal{U}_n$*. Classical stochastic dynamics arise when entropy growth drives the projected kernel away from* $\mathcal{U}_n$ *or destroys operational access to its phase lift. Under this conjecture, quantum theory is the probability calculus of the phase-liftable sector of recursive admissibility dynamics, and the hierarchy*

$$\begin{gathered}\textit{deterministic RSVP transport}\\ \Downarrow \\ \textit{projected stochastic transition}\\ \Downarrow \\ \textit{unistochastic admissibility}\\ \Downarrow \\ \textit{Hilbert-space quantum mechanics}\end{gathered}$$

constitutes the emergent reconstruction of quantum probability.

The geometry of $\mathcal{U}_n \subset \mathcal{S}_n$ is well-studied: the unistochastic matrices form a proper subset of the Birkhoff polytope of doubly stochastic matrices, and for $n \geq 3$ the inclusion is strict. The residual mathematical obligation of this appendix is to characterize precisely when a RSVP projection Π produces a transition matrix in $\mathcal{U}_n$, and to determine whether CLIO obstruction minimization on Ω_Q generically favors unistochastic kernels. This would provide a constraint-first account of why quantum probability appears in nature without being postulated as a primitive structure.

K Temporal Architecture: Geometric Time and Admissibility Time

The reconstruction program developed throughout this manuscript implicitly inherits ordinary temporal evolution from the PDE framework of Section 2. The CLIO gradient flow parameter t and the Lorentzian evolution parameter of the underlying manifold M are distinct objects that have not been carefully separated. The present appendix distinguishes them and identifies the structural tension this creates in the quantum reconstruction of Appendix J.

Definition K.1 (**[D]** Geometric Time and Admissibility Time)**.** *Let t_{geom} denote the temporal coordinate of the underlying Lorentzian manifold M, governing the hyperbolic evolution of the RSVP fields through the Euler–Lagrange system of Appendix A. Let t_{adm} denote the parameter of the CLIO gradient flow $dX/dt_{\text{adm}} = -\nabla\Omega(X)$ on admissibility space $\mathcal{X}^{(s)}$. These are distinct: t_{geom} is a coordinate on M and determines causal structure, while t_{adm} is a descent parameter on the space of field configurations and determines obstruction reduction.*

The distinction matters for several reasons. First, the CLIO flow need not be compatible with Lorentzian causality: gradient descent on Ω can move field configurations in ways that violate the causal order defined by g_{ij}. This is not necessarily a defect of the framework; it may indicate that admissibility closure is a trans-causal or background-independent process that the underlying Lorentzian structure emerges from rather than constrains. Second, the TARTAN recursive projection operators $\mathcal{R}_n : \mathcal{X}_n \to \mathcal{X}_{n+1}$ are defined in terms of spectral scale rather than in terms of t_{geom}, so the multiscale renormalization architecture is naturally expressed in admissibility time.

Ansatz K.1 (**[A]** Admissibility-First Temporal Architecture)**.** *The physically observable Lorentzian time t_{geom} emerges as an ordering relation on t_{adm}-stable field configurations. That is, physical causality is a property of the low-obstruction attractor structure of admissibility space rather than a primitive property of the background manifold.*

Status: Ansatz. *This reverses the usual relationship between geometry and dynamics. The conjecture that t_{geom} is recoverable from t_{adm} ordering requires an explicit reconstruction theorem analogous to the recovery of metric geometry from admissibility closure in the metric-compatibility conjecture of Appendix H.4.*

The temporal distinction also clarifies the quantum reconstruction of Appendix J. The unistochastic transition matrix P_{ij} is defined for transitions over a

t_{geom} interval Δt, but the phase-liftability condition is a property of the admissibility geometry of the projected transition system. The Born amplitude $\psi_i = \rho_i^{1/2} e^{i\theta_i}$ is built from scalar capacity and transport holonomy, both of which depend on t_{adm}-stable structures. Quantum probability therefore measures properties of admissibility-time attractors projected onto geometric-time transition intervals.

Conjecture K.2 (**[C]** Temporal Recovery Conjecture)**.** *There exists a map $\Sigma : t_{\text{adm}} \to t_{\text{geom}}$ such that the causal order on low-obstruction RSVP configurations under t_{adm} descent maps bijectively to the partial causal order of the Lorentzian manifold (M, g). Under this map, geometric time is the observable shadow of admissibility-descent ordering on the stable attractor manifold of the CLIO flow.*

L Sheaf-Theoretic Contextuality and Admissibility Obstructions

The reconstruction program has employed sheaf theory throughout as the natural language for local-to-global consistency. The present appendix identifies a connection between the admissibility obstruction formalism and sheaf-theoretic treatments of quantum contextuality in categorical quantum foundations, as developed by Abramsky and Brandenburger [42].

In the Abramsky–Brandenburger framework, quantum contextuality arises when a family of locally compatible probability distributions over measurement outcomes fails to admit a global joint distribution. This is precisely the obstruction to the existence of a global section of the observable sheaf: local sections exist, but they cannot be assembled into a coherent global section. The obstruction is measured by a cohomology class in H^1 of the measurement cover, exactly analogous to the gluing obstructions of Appendix B.

Phenomenological Interpretation L.1 (**[P]** Contextuality as Admissibility Obstruction)**.** *Quantum contextuality, in the Abramsky–Brandenburger sense, corresponds to a nonvanishing first-order gluing obstruction $[\omega_1] \in H^1(M, \mathcal{F}_{\text{obs}})$ of the observable sheaf $\mathcal{F}_{\text{obs}}$ over the measurement context cover. This is a special case of the RSVP admissibility obstruction structure: the measurement contexts play the role of local admissibility patches, and contextuality corresponds to the failure of a global section of the projected admissibility sheaf.*

Status: Phenomenological Interpretation. *The identification of $\mathcal{F}_{\text{obs}}$ with a subsheaf of $\mathcal{F}_{RSVP}$ under the observation projection Π is an interpretive proposal, not a* *derivation.*

This connection has a direct implication for the Bell-locality tension identified in the technical review. Bell-type nonlocality and Kochen–Specker contextuality can both be expressed as obstructions to global sections of observable sheaves. Within the RSVP framework, these obstructions are instances of the general obstruction classes $[\omega_k] \in H^k(M, \mathcal{F}_{\text{RSVP}})$. The projection structure Π determines which sub-sheaf is accessible to local observers, and non-factorizability of joint measurement probabilities corresponds to non-triviality of the projection-restricted cohomology.

The CLIO operator, interpreted as a cohomological degree-lowering map, then acts on contextuality obstructions in the same way it acts on gauge-gluing obstructions: it attempts to reduce $H^1(M, \mathcal{F}_{\text{obs}})$ toward zero. Physical quantum systems live in the regime where contextuality obstructions cannot be fully resolved — they are stabilized by the topology of the observable bundle — while classical systems correspond to projections whose observable sheaf admits a global section.

Conjecture L.2 (**[C]** Contextuality-Admissibility Correspondence)**.** *The class of measurement scenarios exhibiting quantum contextuality corresponds exactly to the class of RSVP projections* Π *for which the projected admissibility sheaf* $\Pi_* \mathcal{F}_{RSVP}$ *has nonvanishing first cohomology. Classical probability arises from projections for which* $H^1(M, \Pi_* \mathcal{F}_{RSVP}) = 0$*, and quantum probability from projections for which* $H^1 \neq 0$ *but* $H^1(M, \Pi_* \mathcal{F}_{RSVP})$ *is finitely generated and compatible with unistochastic projection.*

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