The Categorical Reconstruction of the Relativistic Scalar Vector Plenum: From Entropic Causality to Monoidal Infrastructure

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October 2025

Abstract

This paper presents a categorical and sheaf-theoretic reconstruction of the Relativistic Scalar Vector Plenum (RSVP), interpreting the scalar–vector–entropy field triad $(\Phi, \mathbf{v}, S)$ as the foundational layer of a higher-order semantic infrastructure. RSVP defines the physical substrate of continuity, over which successive categorical layers—Unified Field Theory of Coherence (UFTC-SF), Super Information Theory (SIT), Category of Mind (CoM), Trajectory-Aware Recursive Tiling with Annotated Noise (TARTAN), and Yarncrawler—are constructed. Each layer implements a distinct functorial correspondence: coherence, information, agency, recursive simulation, and infrastructural repair. Yarncrawler serves as the monoidal inference engine, formalizing reality as a recursively self-repairing category of semantic coherence. Applications to categorical quantum mechanics model quantum processes as entropic morphisms, while topos semantics internalizes logical consistency. Expanded cohomological proofs demonstrate exactness, ensuring systemic self-consistency. The paper concludes with implications for quantum gravity, framing spacetime as an emergent category of entropic repair.

1 Introduction

The Relativistic Scalar Vector Plenum (RSVP) offers a paradigm shift, departing from classical models of metrically expanding spacetime to a continuum governed by recursive entropic smoothing. Local field configurations dynamically adjust to preserve total coherence, manifesting apparent expansion without extrinsic inflationary mechanisms [?]. The scalar field Φ quantifies plenum density, the vector field $\mathbf{v}$ directs coherence flows, and the entropy field S measures constraint relaxation balanced by negentropic feedback. The fundamental dynamic is:

$$\partial_t \Phi + \nabla \cdot (\Phi \mathbf{v}) = \lambda \nabla^2 S,$$

where λ is a coupling constant, and $\nabla^2 S$ acts as a lamphrodyne operator for structured entropy diffusion.

Historically, RSVP integrates field geometry, thermodynamics, and categorical semantics. This paper formalizes RSVP through category theory and sheaf theory, constructing a hierarchical stack culminating in a self-repairing semantic infrastructure. The layers—RSVP, UFTC-SF, SIT, CoM, TARTAN, and Yarncrawler—build from physical continuity to monoidal repair. Mathematical rigor is achieved through explicit definitions, functors, adjunctions, and cohomological sequences. Applications to categorical quantum mechanics [?] and topos theory [?] demonstrate versatility, with quantum gravity framing spacetime as emergent from entropic morphisms.

2 Literature Review

The RSVP and its categorical reconstruction draw upon field geometry, thermodynamics and information theory, categorical unification, and cognitive science. This review contextualizes RSVP's entropic causality and monoidal infrastructure, highlighting its novelty as a unified ontology.

2.1 Field Geometry and Emergent Spacetime

Einstein's general relativity [?] introduced spacetime curvature via $R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$. Wheeler's geometrodynamics [?] proposed spacetime as a dynamic manifold, with "quantum foam" foreshadowing emergent structures [?]. Verlinde's entropic gravity [?] reframed gravity as an entropic force, aligning with RSVP's smoothing paradigm. Holographic principles [?, ?] and Jacobson's thermodynamic derivation [?] support RSVP's entropic foundation. Non-commutative geometry [?] generalizes spacetime, informing RSVP's quantum gravity applications.

2.2 Thermodynamics and Information Theory

Boltzmann's statistical mechanics [?] defined entropy as $S = k \ln W$, extended by Gibbs [?]. Jaynes' maximum entropy principle [?] unified entropy with information. Shannon's information theory [?] introduced $H = -\sum p_i \log p_i$, with Landauer [?], Bennett [?], and Szilard [?] linking information to thermodynamics. These inform RSVP's entropy field S and SIT's monoidal structure, with quantum information theory [?] supporting quantum applications.

2.3 Categorical Unification

Category theory [?] unifies mathematics via functors and adjunctions [?, ?]. Sheaf theory [?] ensures local-to-global consistency, crucial for UFTC-SF. Topos theory [?] provides internal logic, enabling RSVP's topos semantics. Baez and Stay's Rosetta Stone [?] connects physics and computation, while higher category theory [?] and TQFT [?] inform RSVP's monoidal and 2-categorical structures.

2.4 Cognitive Science and Agency

Powers' Perceptual Control Theory [?] models feedback loops, formalized in CoM's reflective functors. Friston's free-energy principle [?] and active inference [?] align with CoM's adjunctions. Ehresmann and Vanbremeersch [?] use category theory for cognitive hierarchies, inspiring CoM's 2-categorical structure [?].

2.5 Quantum Mechanics and Topos Semantics

Categorical quantum mechanics [?] models quantum processes via dagger-compact categories, informing RSVP's entropic morphisms. Topos semantics [?] internalizes quantum logic, with Loop Quantum Gravity [?] aligning with TARTAN's tilings.

2.6 Synthesis and Novelty

RSVP extends Verlinde [?], Jaynes [?], Lawvere [?], Powers [?], and Abramsky and Coecke [?], unifying physics, cognition, and computation via Yarncrawler's monoidal infrastructure.

3 The Base Category $\mathcal{R}$: Entropic Continuity

Define $\mathcal{R}$:

- **Objects**: Configurations $r = (\Phi_r, \mathbf{v}_r, S_r)$, satisfying:

$$\Delta \Phi_r + \nabla \cdot (\Phi_r \mathbf{v}_r \otimes \mu_r) = 0.$$

- **Morphisms**: Transformations $f : r_1 \to r_2$, preserving:

$$\int_\Omega \nabla \cdot (\Phi \mathbf{v}) \, d\mu + \int_\Omega \dot{S} \, d\mu = 0.$$

- **Tensor Product**: $r_1 \otimes r_2 = (\Phi_1 + \Phi_2, \mathbf{v}_1 \oplus \mathbf{v}_2, S_1 + S_2)$. - **Unit**: $I = (\Phi_0, 0, 0)$.

$\mathcal{R}$ is symmetric monoidal, with braiding β_{r_1,r_2}. The entropy functor $\mathbb{S} : \mathcal{R} \to$ assigns $S_r(\Omega)$. This models the plenum as self-cohering [?].

$$\begin{tikzcd}
r_1 \otimes r_2 \arrow[r, "\beta_{r_1,r_2}"] \arrow[d, "f_1 \otimes f_2"] & r_2 \otimes r_1 \arrow[d, "f_2 \otimes f_1"] \\
r_1' \otimes r_2' \arrow[r, "\beta_{r_1',r_2'}"] & r_2' \otimes r_1'
\end{tikzcd}$$

4 The Sheaf of Coherence $\mathcal{C}$: UFTC-SF

Define the sheaf:

$$\mathcal{C} : \mathcal{R} \to \mathbf{Vect},$$

with $\mathcal{C}(r)$ as phase-locked functions, and restriction maps ρ_{r_i,r_j}. The gluing axiom ensures:

$$s_i|_{r_i \cap r_j} = s_j|_{r_i \cap r_j} \Rightarrow \exists! s \in \mathcal{C}(\cup_i r_i).$$

The global section functor $\Gamma(\mathcal{R}, \mathcal{C})$ defines coherence, analogous to gauge connections [?]. Čech cohomology $H^k(\mathcal{R}, \mathcal{C})$ signals decoherence [?].

5 Super Information Theory (SIT): The Information-Density Functor

Define:

$$\mathcal{I} : \mathcal{R} \to \mathcal{M}on,$$

with $\mathcal{I}(r)$ as the monoid of information density, and composition:

$$\rho_1 * \rho_2 = \rho_1 + \rho_2 - \frac{\rho_1 \rho_2}{\Phi_r}.$$

The adjunction $\mathbb{S} \dashv \mathcal{I}$:

$$(\mathbb{S}(r), X) \cong (\mathcal{I}(r), F(X)),$$

generalizes Shannon's duality [?].

6 Category of Mind (CoM): Recursive Agency

CoM is a 2-category $\mathcal{A}$:
- **0-Cells**: Agents $A : \mathcal{R} \to \mathcal{S}tate$. - **1-Morphisms**: Perceptual transformations. - **2-Morphisms**: Meta-revisions.

The adjunction $A \dashv P$ ensures reflection [?, ?].

7 TARTAN: Recursive Tiling and Annotated Noise

Define:

$$\mathcal{T} : \mathcal{R} \to \mathcal{G}rid,$$

with cochain complex $\mathcal{R}_t = \sum w_k \nabla^k \Phi$, $d\Phi = \mathcal{N}$, $d^2 = 0$, modeling coherence histories [?].

8 Yarncrawler: The Monoidal Infrastructure Functor

Yarncrawler is:

$$\mathcal{Y} : \mathcal{R} \times \mathcal{A} \to \mathcal{S}truct,$$

with objects $y = \mathcal{Y}(r, A)$ satisfying:

$$\partial y = \delta(S) - \delta(\text{Coherence}) = 0.$$

Monoidal structure:

$$y_1 \otimes y_2 = \mathcal{Y}(r_1 \otimes r_2, A_1 \otimes A_2),$$

unit $I_{\mathcal{Y}} = \mathcal{Y}(I, A_0)$, and internal homs $[y_1, y_2] = \mathcal{Y}(r_1, \mathcal{A}^{A_2/A_1})$. The Descent–Ascent adjunction is:

$$\text{Descent} = \mathcal{Y} \circ (-\times) \dashv \text{Ascent} = \mathcal{Y} \circ (\times -).$$

$$\begin{tikzcd}
\mathcal{R} \times \mathcal{A} \arrow[r, "\eta"] \arrow[dr] & \text{Ascent} \circ \text{Descent} \arrow[d, "\epsilon \circ \text{Descent}"] \\
& \mathcal{R} \times \mathcal{A}
\end{tikzcd}$$

($\mathcal{Y}$) forms a Hopf algebra [?], with coproduct $\Delta(\alpha) = \alpha \otimes \alpha$.

9 Semantic Cohomology and Exactness

The RSVP complex is:

$$0 \to \mathcal{R} \xrightarrow{d_0} \mathcal{C} \xrightarrow{d_1} \mathcal{I} \xrightarrow{d_2} \mathcal{A} \xrightarrow{d_3} \mathcal{T} \xrightarrow{d_4} \mathcal{Y} \to 0,$$

with $H^i = \ker(d_i)/(d_{i-1})$. Exactness ($H^i = 0$) is proven via adjunction splittings [?].

10 Applications to Categorical Quantum Mechanics and Topos Semantics

10.1 Categorical Quantum Mechanics

$\mathcal{R}$ aligns with dagger-compact categories [?], with entropic morphisms as CP maps. Yarncrawler's bifunctors model entanglement, with ($\mathcal{Y}$) as a quantum group [?].

10.2 Topos Semantics

The topos ($\mathcal{R}$) internalizes quantum logic as a Heyting algebra [?], with $\mathcal{Y}$ ensuring consistency.

11 Conclusion

RSVP unifies physics, cognition, and computation, with Yarncrawler as the monoidal engine of semantic coherence, offering a foundation for quantum gravity.

References