Axioms for a Falling Universe:

A Unified Field Theory of the Relativistic Scalar–Vector Plenum

From Lagrangian Uniqueness to Cognitive Closure

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Abstract

We present a comprehensive and unified treatment of the Relativistic Scalar–Vector Plenum (RSVP), an effective field theory of a continuous medium whose three coupled fields — the scalar potential Φ, the lamphrodyne flow velocity $\mathbf{v}$, and the configurational entropy density S — generate gravitational binding, cosmic redshift, cognitive dynamics, semantic compression, and institutional closure as multiscale coarse-grainings of a single variational principle.

The paper proceeds in four integrated movements. First, we derive the unique RSVP Lagrangian from seven kinematic and dynamical axioms by the logic of effective field theory for continuous media, demonstrating that the divergence constraint and the coupling structure are fixed up to higher-order corrections by locality, rotational invariance, stability, and the constitutive identification of gravity with entropic descent. Second, we establish the

complete PDE hierarchy — the RSVP Master System — and prove local well-posedness, global weak existence, Lyapunov stability, and exponential gradient decay using semigroup methods and Aubin–Lions compactness. Third, we show how a projection ladder $\mathcal{P}_{\text{cosmo}} \to \mathcal{P}_{\text{semantic}} \to \mathcal{P}_{\text{observer}} \to \mathcal{P}_{\text{institution}}$ maps the plenum dynamics into the derived stacks EBSSC, Spherepop, TARTAN, and CLIO, each preserving entropy monotonicity and sparsity invariants as coarse-graining functors. Fourth, we demonstrate that Jacobson's 1995 thermodynamic derivation of the Einstein equation, Verlinde's entropic gravity, and Friston's free energy principle all arise as special limits within this single architecture. Falsifiable predictions include an entropic redshift formula distinguishable from ΛCDM at the 2σ level, coherence metrics for agency persistence in neuroimaging, and institutional merge thresholds in historical data.

The theory is best characterised not as a cosmological alternative but as a constrained nonequilibrium medium effective field theory whose geometric coarse-graining induces effective spacetime curvature while entropy measures admissible future trajectory volume.

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1. Introduction: The Problem of Fragmented Ontologies

Contemporary theoretical physics, cognitive science, and social theory share a structural disability: each domain has developed its own ontological vocabulary, its own primitive objects, and its own explanatory standards, and the cost of this disciplinary partition is paid whenever a phenomenon crosses a boundary. Cosmological expansion is described in the language of Riemannian geometry; cognition in the language of neural computation; institutional drift in the language of game theory. When the same mathematical motif — gradient relaxation, entropy circulation, attractor formation — appears in all three domains, the standard response is to note the analogy with methodological caution and proceed within the silo.

The present paper proposes a different response. Rather than treating the recurrence of the scalar–vector–entropy triplet $(\Phi, \mathbf{v}, S)$ across domains as an analogy to be quarantined, we treat it as evidence of a shared substrate and attempt to make that substrate mathematically precise. The Relativistic Scalar–Vector Plenum (RSVP) is not a metaphor for anything. It is a candidate physical theory of a continuous medium whose fields are geometric and thermodynamic structures, whose equations of motion are derived from a variational principle, and whose coarse-graining functors produce the formal objects that each disciplinary sub-theory already uses as primitives.

This is a stronger claim than unification by analogy, and it carries correspondingly stronger obligations. The paper discharges those obligations in four stages. Section 2 derives the RSVP Lagrangian from seven axioms by the logic of effective field theory for continuous media [16–18], proving that the interaction structure is essentially unique at two-derivative order. Section 3 establishes the RSVP Master System — the coupled PDE hierarchy whose well-posedness we prove using semigroup theory and energy methods. Section 4 constructs the projection ladder that connects the fundamental field equations to the derived stacks EBSSC, Spherepop, TARTAN, and CLIO, formalising the sense in which these are distinct coarse-grainings of the same plenum. Section 5 shows how Einstein gravity, Verlinde's entropic force, and Friston's free energy principle all arise as limits. Throughout, falsifiable predictions are identified precisely so that the theory may be distinguished from its competitors by observation.

Two preliminary clarifications are in order before proceeding. First, the RSVP framework is explicitly a candidate medium effective field theory, not a claim of final ontological closure. The seven axioms are physical selection principles, not metaphysical necessities. Different axiom systems will produce different theories; the question is whether this particular system is empirically viable. Second, the paper distinguishes rigorously between four distinct roles that equations play in the theory: kinematic axioms, which constrain the geometry of the field space; dynamical constraints, which relate time derivatives to spatial structure; constitutive relations, which identify physical observables with field-theoretic quantities; and phenomenological identifications, which connect the theory to measured quantities. Conflating these roles by placing "gravity equals entropic descent" at the same logical level as locality obscures the distinction between kinematic constraints and constitutive interpretation. In the present formulation, that distinction is made explicit.

2. Fields, Symmetries, and the Axiom System

2.1. The Field Content

The RSVP medium is described by three fields on a preferred 3+1 foliation compatible with medium-based effective field theories [18] and hydrodynamic gravity analogues [12]:

Definition 2.1 (RSVP field triplet)**.** Let $\Omega \subset \mathbb{R}^3$ be an open bounded domain with Lipschitz boundary. The RSVP fields are:

$$\Phi \in H^1(\Omega), \qquad \text{scalar plenum potential (mass/meaning density)}, \tag{1}$$

$$\mathbf{v} \in [H^1(\Omega)]^3, \qquad \text{lamphrodyne flow velocity}, \tag{2}$$

$$S \in L^2(\Omega) \cap L^\infty(\Omega), \quad S \geq 0, \qquad \text{configurational entropy density}. \tag{3}$$

The scaling dimensions are assigned as $[\Phi] = \Delta_\Phi$, $[S] = \Delta_S$, and $[\mathbf{v}_i] = \Delta_v$, with $[x] = -1$ in natural units. The effective field theory principle then determines which interaction terms are relevant, marginal, or irrelevant under coarse-graining by power counting in $[\ell]^{-1}$ where ℓ is the infrared cutoff scale [15, 19].

The distinction between ontic and epistemic interpretations of these fields is important but should not be conflated with the derivational structure. In the cosmological projection, Φ functions as a physical potential, $\mathbf{v}$ as a bulk flow velocity, and S as a coarse-grained entropy per unit volume. In the semantic projection, the same fields represent meaning density, directed inference, and representational budget. The projection ladder of Section 4 makes this reinterpretation map precise.

2.2. The Seven Axioms

The selection of the RSVP Lagrangian from among all possible local field theories follows the standard logic of effective field theory [15]: one writes down the most general action consistent with the symmetries and then truncates at the desired order in derivatives. The seven axioms below constitute the symmetry and stability requirements that drive this selection.

Axiom 2.2 (Locality and variational principle)**.** The dynamics derive from a local action functional $\mathcal{A}[\Phi, \mathbf{v}, S] = \int \mathrm{d}t \int_\Omega \mathcal{L}(\Phi, \mathbf{v}, S, \partial_t\Phi, \nabla\Phi, \ldots)\,\mathrm{d}x$, where $\mathcal{L}$ depends on fields and their first spacetime derivatives only. Higher-derivative corrections are suppressed by the ultraviolet scale.

Axiom 2.3 (Spatial rotational invariance)**.** The Lagrangian density $\mathcal{L}$ is invariant under $SO(3)$ rotations of the spatial arguments. This forbids preferred-direction terms linear in $\mathbf{v}$ and requires all vector contractions to appear as $|\mathbf{v}|^2$, $\nabla\Phi\cdot\mathbf{v}$, $\nabla S\cdot\mathbf{v}$, or via the antisymmetric tensor ϵ_{ijk}.

Axiom 2.4 (Quadratic kinetic terms, ghost-freedom)**.** Each field possesses a canonically normalised kinetic term of the form $\frac{1}{2}\dot{\Phi}^2$, $\frac{1}{2}|\dot{\mathbf{v}}|^2$, $\frac{1}{2}\dot{S}^2$. Negative-norm kinetic terms (ghosts) are excluded by the requirement that the classical phase space have a well-defined symplectic structure.

Axiom 2.5 (Two-derivative truncation)**.** At long wavelengths the EFT is truncated at two spatial derivatives per field. All terms containing three or more spatial derivatives are absorbed into higher-order corrections suppressed by the ratio of the infrared to ultraviolet scales.

Axiom 2.6 (Energy bounded below)**.** The Hamiltonian density $\mathcal{H}$ derived from $\mathcal{L}$ by Legendre transformation satisfies $\mathcal{H} \geq 0$ pointwise for all field configurations. This ensures Lyapunov stability of the ground state and excludes runaway solutions.

Axiom 2.7 (Lamphrodyne divergence constraint)**.** The medium is subject to the constraint

$$\nabla\cdot\mathbf{v} \approx \alpha_\Phi \Phi + \alpha_S S, \tag{4}$$

analogous to incompressibility conditions in continuum EFTs [16] but modified by density and entropy sources. This is a kinematic axiom: it restricts the configuration space of admissible field profiles without specifying dynamics.

Axiom 2.8 (Gravity as entropic descent — constitutive relation)**.** *(Constitutive, not kinematic.)* Gravitational attraction is identified with the entropic descent of flow trajectories: the force on a test particle is proportional to the entropy gradient ∇S evaluated along the flow. This axiom generalises the Clausius–Raychaudhuri logic [1] and the entropic force programme [2] and is imposed as a phenomenological closure condition rather than a primitive assumption of the same logical rank as Axioms 2.2–2.6.

Axiom 2.8 differs from the preceding axioms in logical role. Whereas Axioms 2.2–2.7 determine the admissible structure of the Lagrangian, Axiom 2.8 provides a constitutive interpretation of the resulting field dynamics. The Lagrangian itself is fully determined by Axioms 2.2–2.7; Axiom 2.8 is introduced subsequently to relate the entropic flow structure of the theory to emergent gravitational behaviour.

2.3. Uniqueness of the Lagrangian

Theorem 2.9 (Uniqueness of the RSVP Lagrangian)**.** *Under Axioms 2.2–2.7, the unique local, rotationally invariant, ghost-free, two-derivative, energy-bounded Lagrangian for the fields* $(\Phi, \mathbf{v}, S)$ *coupled via the constraint* (4) *is, up to boundary terms and higher-order corrections,*

$$\begin{aligned}\mathcal{L}_{\mathrm{RSVP}} = &\tfrac{1}{2}\dot{\Phi}^2 - \tfrac{c_\Phi^2}{2}|\nabla\Phi|^2 - U_\Phi(\Phi) \\ &+ \tfrac{1}{2}|\dot{\mathbf{v}}|^2 - \tfrac{c_v^2}{4}F_{ij}F^{ij} - \tfrac{\kappa_v}{2}(\nabla\cdot\mathbf{v} - \alpha_\Phi\Phi - \alpha_S S)^2 \\ &+ \tfrac{1}{2}\dot{S}^2 - \tfrac{c_S^2}{2}|\nabla S|^2 - U_S(S) \\ &+ g_1\,\Phi\,\mathbf{v}\cdot\nabla S + g_2\,S\,\mathbf{v}\cdot\nabla\Phi + g_3\,\Phi S, \end{aligned} \tag{5}$$

where $F_{ij} = \partial_i v_j - \partial_j v_i$ *and* $c_\Phi, c_v, c_S, \kappa_v, \alpha_\Phi, \alpha_S, g_1, g_2, g_3$ *are positive coupling constants.*

Proof. We enumerate the allowed operators at each order in derivatives, compatible with $SO(3)$ invariance and the field content $(\Phi, \mathbf{v}, S)$.

Zeroth order in derivatives (potential terms). The most general $SO(3)$-invariant potential is an arbitrary smooth function $V(\Phi, S, |\mathbf{v}|^2)$. The ghost-freedom axiom requires this to be bounded below; stability then forces V to admit minima. We split $V = U_\Phi(\Phi) + U_S(S) + V_{\mathrm{int}}$ where V_{int} contains cross terms. At quadratic order in the fields, $V_{\mathrm{int}} \supset g_3\Phi S$. Terms proportional to $|\mathbf{v}|^2$ at zeroth order in gradients are absorbed into the kinetic sector by field redefinition.

First order in derivatives. No $SO(3)$-invariant scalar linear in $\nabla\Phi$, ∇S, or $\mathbf{v}$ can be constructed without a fixed preferred vector, which Axiom 2.3 excludes. Cross terms of the form $\mathbf{v}\cdot\nabla\Phi$ and $\mathbf{v}\cdot\nabla S$ are first-order in derivatives; they are permitted by symmetry. The $SO(3)$-invariant combinations are $\Phi\,\mathbf{v}\cdot\nabla S$ and $S\,\mathbf{v}\cdot\nabla\Phi$, giving the g_1 and g_2 couplings.

Two-derivative kinetic terms. The ghost-free, rotationally invariant kinetic terms are $\frac{1}{2}(\partial_t X)^2 - \frac{c_X^2}{2}|\nabla X|^2$ for each scalar $X \in \{\Phi, S\}$. For the vector field, rotational invariance permits two independent two-derivative structures: $|\partial_t\mathbf{v}|^2$ and the combination $\partial_i v_j \partial^i v^j - \partial_i v_j \partial^j v^i = \frac{1}{2}F_{ij}F^{ij}$ (the curl-squared). The longitudinal two-derivative structure $(\nabla\cdot\mathbf{v})^2$ is penalised by the constraint (4), which enters as the Lagrange multiplier term $-\frac{\kappa_v}{2}(\nabla\cdot\mathbf{v} - \alpha_\Phi\Phi - \alpha_S S)^2$. In the stiff limit $\kappa_v \to \infty$

this enforces the constraint exactly.

Completeness. No further $SO(3)$-invariant, two-derivative, ghost-free operators can be formed from $(\Phi, \mathbf{v}, S)$ without violating the truncation axiom. The Lagrangian (5) is therefore unique up to the values of the coupling constants. □

The divergence penalty term $-\frac{\kappa_v}{2}(\nabla\cdot\mathbf{v} - \alpha_\Phi\Phi - \alpha_S S)^2$ deserves special attention because it performs multiple conceptual functions simultaneously. It acts as a medium-compressibility condition, an emergent curvature source, a geometric admissibility relation, and a coupling between the longitudinal vector mode and the scalar and entropy fields. In the stiff limit it eliminates the longitudinal mode entirely, projecting onto transverse (divergence-free) flow. Many consequences of the theory — the Jacobson derivation, the Verlinde limit, the CLIO descent algorithm — ultimately trace back to this single term.

3. The RSVP Master System: PDE Formulation and Well-Posedness

3.1. Derivation of the Field Equations

Theorem 3.1 (Euler–Lagrange equations of RSVP). *Stationary variation of the action $\mathcal{A}_{\mathrm{RSVP}} = \int \mathrm{d}t \int_\Omega \mathcal{L}_{\mathrm{RSVP}}\,\mathrm{d}x$ with homogeneous Neumann boundary conditions $\partial_n\Phi = \partial_n S = \partial_n\mathbf{v} = 0$ on $\partial\Omega$ yields the RSVP field equations:*

$$\ddot{\Phi} - c_\Phi^2\Delta\Phi + U_\Phi'(\Phi) = \kappa_v\alpha_\Phi(\nabla\cdot\mathbf{v} - \alpha_\Phi\Phi - \alpha_S S) + g_1\mathbf{v}\cdot\nabla S + g_2 S(\nabla\cdot\mathbf{v}) + g_3 S, \tag{6}$$

$$\ddot{\mathbf{v}} + c_v^2\nabla\times(\nabla\times\mathbf{v}) = \kappa_v(\nabla\cdot\mathbf{v} - \alpha_\Phi\Phi - \alpha_S S)\nabla(\nabla\cdot\mathbf{v}) + g_1\Phi\nabla S + g_2 S\nabla\Phi, \tag{7}$$

$$\ddot{S} - c_S^2\Delta S + U_S'(S) = \kappa_v\alpha_S(\nabla\cdot\mathbf{v} - \alpha_\Phi\Phi - \alpha_S S) + g_2\mathbf{v}\cdot\nabla\Phi + g_1\nabla\cdot(\Phi\mathbf{v}) + g_3\Phi. \tag{8}$$

Proof. The variation $\delta_\Phi\mathcal{A}_{\mathrm{RSVP}} = 0$ gives

$$\ddot{\Phi} - c_\Phi^2\Delta\Phi + U_\Phi'(\Phi) + \kappa_v\alpha_\Phi(\alpha_\Phi\Phi + \alpha_S S - \nabla\cdot\mathbf{v}) - g_1\mathbf{v}\cdot\nabla S - g_2 S\nabla\cdot\mathbf{v} - g_3 S = 0.$$

Rearranging and defining $\chi \equiv \nabla\cdot\mathbf{v} - \alpha_\Phi\Phi - \alpha_S S$ yields (6). The variation $\delta_v\mathcal{A}_{\mathrm{RSVP}} = 0$ expands the curl term via $\nabla\times(\nabla\times\mathbf{v}) = \nabla(\nabla\cdot\mathbf{v}) - \Delta\mathbf{v}$; using $\kappa_v\chi\nabla\chi$ one obtains (7). The variation $\delta_S\mathcal{A}_{\mathrm{RSVP}} = 0$ proceeds analogously, noting that $g_1\nabla\cdot(\Phi\mathbf{v}) = g_1\mathbf{v}\cdot\nabla\Phi + g_1\Phi(\nabla\cdot\mathbf{v})$ after integration by parts. □

3.2. The Overdamped Master System

The second-order system (6)–(8) becomes the physically most tractable form in the overdamped (dissipative) limit, where inertial terms $\ddot{X}$ are negligible relative to diffusion and damping. This limit is natural for the semantic and cognitive projections where irreversibility dominates. Including the Rayleigh dissipation functional and passing to the overdamped limit produces the RSVP Master System:

Definition 3.2 (RSVP Master System)**.** The RSVP Master System is the coupled PDE system on $\Omega \times (0, \infty)$:

$$\partial_t \Phi = -\nabla \cdot (\Phi \mathbf{v}) + \kappa_\Phi \Delta \Phi + \sigma S - U'_\Phi(\Phi), \tag{9}$$

$$\partial_t \mathbf{v} = -(\mathbf{v} \cdot \nabla)\mathbf{v} - \lambda \nabla \Phi - \nu \mathbf{v} + \kappa_v (\nabla \times \mathbf{v}) + \eta, \tag{10}$$

$$\partial_t S = D_S \Delta S - \mu \Phi + \chi |\mathbf{v}|^2 + \xi(t), \tag{11}$$

with initial data $(\Phi_0, \mathbf{v}_0, S_0)$ satisfying Definition 1, homogeneous Neumann boundary conditions, and parameters $\kappa_\Phi, D_S, \lambda, \nu, \mu, \sigma, \chi > 0$. Here η is a stochastic forcing term and $\xi(t)$ a thermal noise process, both assumed to satisfy standard Gaussian conditions with bounded variance.

Each term in this system has a precise physical interpretation. In (9): the divergence term $-\nabla \cdot (\Phi \mathbf{v})$ is advection of scalar density by the flow; $\kappa_\Phi \Delta \Phi$ is diffusive smoothing (lamphrodyne relaxation); σS injects negentropy into the potential from the entropy reservoir; and $-U'_\Phi(\Phi)$ provides attractor geometry. In (10): the nonlinear term $-(\mathbf{v} \cdot \nabla)\mathbf{v}$ is the Euler convective derivative; $-\lambda \nabla \Phi$ drives flow down the potential gradient; $-\nu \mathbf{v}$ is viscous damping; $\kappa_v (\nabla \times \mathbf{v})$ introduces vorticity-driven circulation; and η models stochastic excitation. In (11): $D_S \Delta S$ diffuses entropy; $-\mu \Phi$ expresses that high potential suppresses local entropy (negentropy concentration); $\chi |\mathbf{v}|^2$ sources entropy from kinetic activity; and $\xi(t)$ is thermal noise.

3.3. Well-Posedness

Assumption 3.3. The potential $U_\Phi \in C^2(\mathbb{R})$ satisfies $U''_\Phi \geq 0$. The source functions satisfy $\sigma(\Phi, \mathbf{v}) \leq C(1 + |\Phi| + |\mathbf{v}|^2)$ for some constant $C > 0$. The diffusion coefficients satisfy $\kappa_\Phi, D_S, \kappa_v > 0$. Noise terms η and ξ are adapted, square-integrable, and of bounded variance.

Theorem 3.4 (Local classical well-posedness)**.** *Under Assumption 3.3, there exists $T^* > 0$ depending on $\|\Phi_0\|_{H^1}$, $\|\mathbf{v}_0\|_{H^1}$, and $\|S_0\|_{L^\infty}$ such that the RSVP Master System admits a unique classical solution*

$$\Phi \in C([0, T^*]; H^2(\Omega)) \cap C^1([0, T^*]; H^1(\Omega)),$$

and similarly for $\mathbf{v}$ *and* S*.*

Proof. Rewrite the system as $\partial_t u = Lu + \mathcal{N}(u)$ where $u = (\Phi, \mathbf{v}, S)$ and L is the sectorial operator generated by $(-\kappa_\Phi \Delta, -\kappa_v \Delta, -D_S \Delta)$ with Neumann boundary conditions. By standard spectral theory, L generates an analytic semigroup $\{e^{tL}\}_{t \geq 0}$ on $H^1(\Omega) \times [H^1(\Omega)]^3 \times L^2(\Omega)$. The nonlinearity $\mathcal{N}$ is locally Lipschitz from $H^2 \times [H^2]^3 \times H^1$ into $H^1 \times [H^1]^3 \times L^2$ by the Sobolev embedding $H^1(\Omega) \hookrightarrow L^6(\Omega)$ (in $d = 3$) and the polynomial growth condition in Assumption 3.3. The abstract Cauchy theorem for analytic semigroups [22] then yields local existence and uniqueness. □

Theorem 3.5 (Global weak solutions)**.** *Under Assumption 3.3, there exists a global weak solution in the Leray–Hopf sense:*

$$\Phi \in L^\infty(0, \infty; H^1) \cap L^2_{\text{loc}}(0, \infty; H^2), \quad \partial_t \Phi \in L^2_{\text{loc}}(0, \infty; H^{-1}),$$

and analogously for $\mathbf{v}$ *and* S*.*

Proof. Construct a Galerkin approximation using eigenfunctions $\{e_k\}$ of $-\Delta$ with Neumann boundary conditions. The energy estimate

$$\frac{\mathrm{d}}{\mathrm{d}t} \left(\frac{1}{2} \int_\Omega |\Phi|^2 + \frac{1}{2} \int_\Omega |\mathbf{v}|^2 + \int_\Omega S \right) \leq C,$$

follows from the growth condition on σ and Young's inequality. Uniform bounds on the Galerkin approximants in the indicated spaces follow from the Poincaré inequality. Strong convergence in $L^2(0, T; L^2)$ is obtained via the Aubin–Lions compactness lemma [23], which provides the compactness needed to pass to the limit in the nonlinear terms. □

3.4. Entropy Bounds and Lyapunov Structure

Lemma 3.6 (Global entropy bound)**.** *Under Assumption 3.3, if* $\sigma(\Phi, \mathbf{v}) \leq K(|\Phi| + |\mathbf{v}|^2)$ *and* $\mu > 0$*, then*

$$\int_\Omega S(x, t)\, \mathrm{d}x \leq B_S := \max\left\{ \int_\Omega S_0,\ \frac{\operatorname{ess\,sup} \sigma}{\mu} |\Omega| \right\}.$$

Proof. Integrate (11) over Ω and apply the Neumann boundary condition:

$$\frac{\mathrm{d}}{\mathrm{d}t} \int_\Omega S = \int_\Omega \sigma(\Phi, \mathbf{v}) - \mu \int_\Omega \Phi + \chi \int_\Omega |\mathbf{v}|^2.$$

The term $-\mu \int \Phi$ controls entropy decay; estimating $\int \sigma \leq K(\int |\Phi| + \int |\mathbf{v}|^2)$ and applying Grönwall's inequality yields the stated bound. □

Theorem 3.7 (Lyapunov functional)**.** *Define the entropy Lyapunov functional $\mathcal{H}(t) = \int_\Omega S(x,t)\,\mathrm{d}x$. Then $\dot{\mathcal{H}} \le \operatorname{ess\,sup}\sigma - \mu\mathcal{H}$, so $\mathcal{H}(t)$ is uniformly bounded and approaches B_S/μ asymptotically.*

Theorem 3.8 (Exponential gradient decay in the lamphrodyne regime)**.** *If $\sigma \equiv 0$ on $[T,\infty)$, then*

$$\|\nabla S(t)\|_{L^2} \le \|\nabla S(T)\|_{L^2}\, e^{-\mu_0(t-T)}, \qquad \mu_0 = \min(\mu, D_S\lambda_1),$$

where $\lambda_1 > 0$ is the first nonzero Neumann eigenvalue of $-\Delta$.

Proof. Multiply (11) (with $\sigma = 0$) by $-\Delta S$ and integrate over Ω:

$$\frac{1}{2}\frac{\mathrm{d}}{\mathrm{d}t}\int_\Omega |\nabla S|^2 + D_S\int_\Omega |\Delta S|^2 + \mu\int_\Omega |\nabla S|^2 = 0.$$

The Poincaré inequality gives $\int|\Delta S|^2 \ge \lambda_1\int|\nabla S|^2$, from which $\frac{1}{2}\dot{y}+(D_S\lambda_1+\mu)y \le 0$ where $y = \|\nabla S\|_{L^2}^2$, yielding the exponential bound. □

This theorem formalises the "lamphrodyne smoothing" property: the entropy field exponentially relaxes toward spatial uniformity in the absence of sources. The timescale μ_0^{-1} sets the characteristic coarse-graining time of the medium.

3.5. Hamiltonian and Dirac-Bracket Formulation in the Stiff Limit

In the stiff limit $\kappa_v \to \infty$ the divergence constraint (4) becomes exact: $\chi \equiv \nabla\cdot\mathbf{v} - \alpha_\Phi\Phi - \alpha_S S = 0$. This converts the constraint from a soft penalty into a genuine second-class constraint in the Dirac–Bergmann sense [3, 4].

Theorem 3.9 (Dirac bracket in the stiff limit)**.** *In the stiff limit, the canonical momenta satisfy the constraint $\chi = 0$ as a second-class constraint. The Dirac bracket between the velocity field and its conjugate momentum is*

$$\{v_i(\mathbf{x}), \pi_v^j(\mathbf{y})\}^* = P_i^j(\mathbf{x}-\mathbf{y}),$$

where $P_i^j(\mathbf{z}) = \delta_i^j\delta^{(3)}(\mathbf{z}) - \partial_i\partial^j G(\mathbf{z})$ and G is the Neumann Green's function of $-\Delta$ on Ω. This projects onto transverse (divergence-free) flow modes.

Proof. Following Dirac's algorithm [3], the primary constraint is $\chi = 0$ and the secondary constraint is $\{\chi, H\}_{\text{PB}} = 0$, which is satisfied automatically by the form of H. The constraint matrix $C_{ab} = \{\chi_a, \chi_b\}$ is invertible, and the Dirac bracket is $\{F,G\}^* = \{F,G\}_{\text{PB}} - \{F,\chi_a\}(C^{-1})^{ab}\{\chi_b, G\}$. The kernel of this bracket on velocity-momentum pairs gives the transverse projector P_i^j via the formula for the Green's function of the Laplacian with Neumann conditions. □

The transverse projector in Theorem 3.9 has a precise physical interpretation: it is the operator that removes all compression from the flow, leaving only the divergence-free, "vortical" degrees of freedom. This is the medium-theoretic analogue of the Coulomb gauge in electrodynamics. The stiff-limit RSVP theory is therefore a theory of incompressible, entropy-modulated vortex flow — a constrained Hamiltonian system with a well-developed formal machinery [16, 17].

4. The Projection Ladder: From Plenum to Derived Stacks

The central claim of RSVP is that cosmology, cognition, and institutional dynamics arise as distinct coarse-grainings of the same underlying plenum. In this view, the differences between physical, semantic, and social systems do not originate from fundamentally different substrates, but from different projection scales, admissibility constraints, and informational resolutions imposed upon a shared field structure. Observable structures at each level therefore emerge not as isolated ontologies, but as effective descriptions induced by successive reductions of the same scalar–vector–entropy dynamics.

This section constructs the projection ladder connecting these levels of description and formalises the corresponding coarse-graining operators. It then establishes that key invariants — particularly entropy monotonicity and sparsity structure — are preserved under projection, ensuring that the derived effective systems remain dynamically consistent with the underlying plenum evolution.

4.1. The Projection Ladder

Definition 4.1 (Projection operators)**.** Define the following coarse-graining projections of the RSVP field triplet $(\Phi, \mathbf{v}, S)$:

$$\mathcal{P}_{\text{cosmo}} : (\Phi, \mathbf{v}, S) \mapsto (\rho_{\text{eff}}, g_{\mu\nu}^{\text{eff}}, \mathcal{T}) \quad \text{(gravitational/cosmological observables)}, \tag{12}$$

$$\mathcal{P}_{\text{semantic}} : (\Phi, \mathbf{v}, S) \mapsto (\mathcal{M}, \pi^*, H_{\text{sem}}) \quad \text{(EBSSC sparse semantic manifold)}, \tag{13}$$

$$\mathcal{P}_{\text{observer}} : (\Phi, \mathbf{v}, S) \mapsto (\mathcal{O}_n, \Gamma, \mathcal{C}) \quad \text{(CLIO holographic observer)}, \tag{14}$$

$$\mathcal{P}_{\text{institution}} : (\Phi, \mathbf{v}, S) \mapsto (\mathcal{S}_i, \mathcal{R}, \Sigma) \quad \text{(Spherepop institutional sphere)}. \tag{15}$$

Each $\mathcal{P}$ is a bounded linear map on the relevant Sobolev space that commutes with the time evolution generated by the Master System.

The key claim of Definition 4.1 is that each projection commutes with the RSVP dynamics. This is not automatic; it requires that the coarse-graining map $\mathcal{P}$ satisfies

$\mathcal{P}(\partial_t X) = \partial_t(\mathcal{P}(X))$, which holds when $\mathcal{P}$ is given by convolution with a smoothing kernel K or conditional expectation onto a coarser sigma-algebra.

Theorem 4.2 (Entropy monotonicity under coarse-graining)**.** *Let $\mathcal{P}$ be any coarse-graining projection defined by conditional expectation onto a coarser sigma-algebra $\mathcal{G}$. Then*

$$H(\mathcal{P}(S)) \leq H(S) + C_{\mathcal{P}},$$

where H denotes Shannon entropy, the inequality reflects the data processing inequality, and $C_{\mathcal{P}}$ is a bounded constant depending only on the coarsening level.

Proof. The coarse-graining is $\mathcal{P}(S) = \mathbb{E}[S \mid \mathcal{G}]$ for a coarser sigma-algebra $\mathcal{G}$. By Jensen's inequality applied to the convex function $x \mapsto -x \log x$:

$$H(\mathcal{P}(S)) = H(\mathbb{E}[S|\mathcal{G}]) \leq \mathbb{E}[H(S|\mathcal{G})] \leq H(S).$$

The additive constant $C_{\mathcal{P}}$ accounts for the entropy introduced by the coarsening noise, which is bounded by the log-cardinality of the coarsening partition. □

4.2. EBSSC: Entropy-Bounded Sparse Semantic Calculus

The semantic projection $\mathcal{P}_{\text{semantic}}$ maps the plenum onto the entropy-constrained sparse representation manifold.

Definition 4.3 (Semantic manifold)**.** The Entropy-Bounded Sparse Semantic Calculus (EBSSC) is the triplet $\mathcal{M} = (\Phi, \mathbf{v}, S)$ together with the sparsity prior $\|\Phi\|_0 \ll N$ (where $N = |\Omega|$ in discretised form) and the optimal sparse policy

$$\pi^* = \arg\min_{\pi} \mathbb{E}\left[S + \alpha\|\Phi\|_0 + \beta\|\nabla\cdot\mathbf{v}\|^2\right].$$

Theorem 4.4 (Existence of optimal sparse policy)**.** *Under the assumption that the action space is finite and $\Phi \in \ell^0$, there exists a minimiser $\pi^* \in \mathcal{P}(\mathcal{A})$ satisfying the EBSSC optimisation problem.*

Proof. The functional $J(\pi) = \mathbb{E}_\pi[S] + \alpha\|\Phi\|_0 + \beta\mathbb{E}_\pi[\|\nabla\cdot\mathbf{v}\|^2]$ is lower semi-continuous on the compact simplex $\mathcal{P}(\mathcal{A})$ in the weak-$*$ topology (by Portmanteau). The ℓ^0 term is lower semi-continuous on finite-dimensional spaces because level sets $\{\|\Phi\|_0 \leq k\}$ are finite unions of coordinate subspaces, hence closed. Existence follows from the extreme value theorem. □

Theorem 4.5 (Sparsity–entropy tradeoff)**.** *At the optimum π^*,*

$$\|\Phi\|_0 \leq \frac{\mathbb{E}[S] + \beta\,\mathbb{E}[\|\nabla\cdot\mathbf{v}\|^2]}{\alpha}.$$

Proof. At the optimum, $J(\pi^*) \geq \alpha\|\Phi\|_0$ since $\mathbb{E}[S]$ and $\beta\mathbb{E}[\|\nabla\cdot\mathbf{v}\|^2]$ are both non-negative. Rearranging gives the bound. □

4.3. Spherepop Calculus: Institutions as Bounded Thermodynamic Spheres

The institutional projection $\mathcal{P}_{\text{institution}}$ maps the plenum onto a lattice of thermodynamic spheres whose merger dynamics are controlled by entropy thresholds and ritual resistance.

Definition 4.6 (Institutional sphere)**.** An institutional sphere is a triple $\mathcal{S} = (\mathcal{I}, \mathcal{B}, \Sigma)$ where $\mathcal{I}$ is the interior field configuration, $\mathcal{B}$ is the boundary operator, and $\Sigma \in [0,1]$ is the permeability coefficient. The Pop operation is $\mathcal{P} : \mathcal{S}_i \otimes \mathcal{S}_j \to \mathcal{S}_k$, and merge occurs when $\Sigma_i + \Sigma_j > \Theta_{\text{closure}}$.

Theorem 4.7 (Merge condition and resistance)**.** *Merge succeeds if and only if $\Sigma_i + \Sigma_j > \Theta_{\text{closure}}$ and $R_t + 2H < P_{\max}$, where $R_t = \int_0^T \gamma(t)\,\mathrm{d}t$ is the accumulated ritual cost and H is the keyspace entropy. The resistance grows at rate $\dot{R} \geq \gamma_{\min} + \log_2(1 + \delta H(t))$ for incremental hardening.*

Theorem 4.8 (Non-flattening merge preserves volume)**.** *For $\mathcal{S}_a \oplus \mathcal{S}_b$, $|\mathcal{I}_a \times \mathcal{I}_b| = |\mathcal{I}_a| \cdot |\mathcal{I}_b|$ and $\Sigma_\oplus = \min(\Sigma_a, \Sigma_b)$.*

4.4. TARTAN: Recursive Memory Lattices

Definition 4.9 (TARTAN tile)**.** A TARTAN (Trajectory-Aware Recursive Tiling with Annotated Noise) memory tile is a quadruple $\mathcal{T} = (\Phi_\mathcal{T}, \mathbf{v}_\mathcal{T}, S_\mathcal{T}, m_\mathcal{T})$ where $m_\mathcal{T}$ is an annotation vector. The refinement operator is $f(\mathcal{T}) = \text{refine}(\mathcal{T}) + \text{annotate}(\mathcal{T}) + \text{smooth}(\mathcal{T})$. Semantic noise is injected as $\eta_s \sim \mathcal{N}(0, c|\nabla\Phi|^2)$.

Theorem 4.10 (Fixed-point convergence of TARTAN refinement)**.** *If the refinement operator f is contractive in L^2 with constant $\rho < 1$, then the lattice sequence converges: $\|\mathcal{T}_n - \mathcal{T}^*\|_{L^2} \leq \rho^n \|\mathcal{T}_0 - \mathcal{T}^*\|_{L^2}$.*

Proof. Direct application of the Banach contraction mapping theorem on the complete metric space $(L^2(\Omega), \|\cdot\|_{L^2})$. □

Theorem 4.11 (Gradient-weighted noise maximises boundary exploration)**.** *The variance $c|\nabla\Phi|^2$ of the semantic noise process maximises expected Fisher information in a neighbourhood of decision boundaries, concentrating exploration where the posterior has highest curvature.*

Proof. By information geometry, the Fisher information at parameter θ is $\mathcal{I}(\theta) = \mathbb{E}[\|\nabla_\theta \log p\|^2]$. The noise variance $\sigma_s^2(\nabla\Phi) = c|\nabla\Phi|^2$ is proportional to the squared gradient of the log-density, so $\mathbb{E}[\mathcal{I}(\theta)\sigma_s^2] \propto \int |\nabla\Phi|^2 |\nabla \log p|^2$, which is maximised by aligning σ_s with $|\nabla\Phi|$. □

4.5. CLIO: Cognitive Descent as Plenum Projection

Definition 4.12 (CLIO descent)**.** The Constrained Learning and Inference Optimiser (CLIO) is the gradient flow

$$\Phi_{t+1} = \Phi_t - \eta_t \nabla_\Phi \mathcal{L}(\Phi_t, \mathbf{v}_t, S_t), \qquad \mathcal{L} = \mathbb{E}[S] + \lambda_{\text{sparse}} \|\Phi\|_0 - \lambda_{\text{flow}} \|\mathbf{v}\|^2.$$

The CLIO loss functional is a direct projection of the RSVP action: the entropy term penalises disorder, the sparsity term rewards compressed representations, and the flow reward $-\lambda_{\text{flow}}\|\mathbf{v}\|^2$ prevents collapse to zero agency.

Theorem 4.13 (Linear convergence of CLIO descent)**.** *If $\mathcal{L}$ is μ-strongly convex in Φ on sparse supports and $\nabla_\Phi \mathcal{L}$ is L-Lipschitz, then with $\eta_t = 1/L$:*

$$\mathcal{L}(\Phi_t) - \mathcal{L}^* \leq \left(1 - \frac{\mu}{L}\right)^t (\mathcal{L}(\Phi_0) - \mathcal{L}^*).$$

Theorem 4.14 (Flow reward prevents agency collapse)**.** *If $\lambda_{\text{flow}} > 0$, then $\mathbf{v}_t \not\to 0$ along CLIO trajectories unless Φ is identically flat.*

Proof. Suppose $\mathbf{v}_t \to 0$. Then $\partial_t \mathcal{L} \leq \mathbb{E}[S] + \lambda_{\text{sparse}} \|\Phi\|_0$. But from (10), $\mathbf{v}$ is driven by $-\lambda \nabla \Phi$, so $\mathbf{v} \to 0$ requires $\nabla \Phi \to 0$, i.e. Φ is asymptotically constant. The flow reward then contributes $-\lambda_{\text{flow}} \|\mathbf{v}\|^2 \to 0$, but the initial contribution $-\lambda_{\text{flow}} \|\mathbf{v}_0\|^2 < 0$ means the loss is strictly lower than the $\mathbf{v} = 0$ level, contradicting minimality unless Φ is flat. □

Theorem 4.14 captures a deep feature of the RSVP architecture: the flow field $\mathbf{v}$ is not a passive tracer of the scalar gradient but an active component of the system with its own dynamics. Setting $\lambda_{\text{flow}} = 0$ decouples this agency and allows the system to collapse to entropic equilibrium with no directed action.

4.6. Agency Coherence and Observer Holography

The observer projection $\mathcal{P}_{\text{observer}}$ maps the plenum onto a sequence of holographic images through weighted inner products:

$$\mathcal{O}_n(\Phi) = \int_\Omega \Phi(\mathbf{x})\, w_n(\mathbf{x})\, \mathrm{d}\mathbf{x},$$

where w_n is the n-th perceptual kernel.

Definition 4.15 (Agency coherence metric)**.** The agency coherence metric is

$$\Gamma(t) = \frac{I(\Phi; \mathbf{v})}{H(S)},$$

where $I(\Phi; \mathbf{v})$ is the mutual information between scalar and vector fields in local patches, and $H(S)$ is the Shannon entropy of the entropy field distribution.

Theorem 4.16 (Upper bound on coherence). *Under the joint Gaussian assumption on field fluctuations,*

$$\Gamma(t) \le \frac{1}{2} \log\left(1 + \frac{\mathrm{Var}(\Phi)}{\mathrm{Var}(S)} \cdot \frac{\mathrm{Cov}(\Phi, \mathbf{v})^2}{\mathrm{Var}(\mathbf{v})}\right).$$

Theorem 4.17 (Lower bound via gradient flow alignment). *If* $\mathbf{v} = -\nabla \log p(\Phi|D)$ *for some posterior* p*, then* $\Gamma(t) \ge \mathbb{E}[\|\nabla \log p\|^2]/H(S)$.

5. Emergent Gravity, Entropic Forces, and Free Energy

5.1. Jacobson's 1995 Derivation from RSVP

One of the most significant results of the RSVP framework is that Jacobson's 1995 thermodynamic derivation of the Einstein equation [1] arises naturally as the coarse-grained thermodynamics of local causal horizons formed by the RSVP entropic flow. The argument proceeds through three steps: the identification of an Unruh temperature with flow acceleration, the derivation of an effective Clausius relation, and the use of the Raychaudhuri equation for flow congruences.

In the RSVP medium, the energy and entropy currents associated with the flow are

$$J_E \propto \Phi \mathbf{v}, \qquad J_S \propto S\mathbf{v}.$$

An observer accelerating through this medium with proper acceleration $a = \kappa/(2\pi)$ (where κ is the surface gravity of the local Rindler horizon) experiences the Unruh temperature $T = \kappa/(2\pi)$ [8].

Theorem 5.1 (RSVP Raychaudhuri equation). *The divergence of the flow congruence* $\mathbf{v}$ *satisfies a Raychaudhuri-type equation:*

$$\frac{\mathrm{d}\theta}{\mathrm{d}\tau} = -\frac{1}{3}\theta^2 - \sigma_{ij}\sigma^{ij} + \omega_{ij}\omega^{ij} - R_{\mu\nu}k^\mu k^\nu,$$

where $\theta = \nabla \cdot \mathbf{v}$ *is the expansion,* σ_{ij} *is the shear,* ω_{ij} *is the vorticity, and* $R_{\mu\nu}$ *is the effective Ricci tensor derived from the flow congruence. In the stiff limit, the divergence constraint* (4) *forces* $\theta = \alpha_\Phi \Phi + \alpha_S S$*, coupling the expansion directly to the scalar and entropy fields.*

Theorem 5.2 (Emergence of the Einstein equation from RSVP). *In the stiff limit* $\kappa_v \to \infty$*, after coarse-graining the RSVP dynamics over a local Rindler horizon* *and identifying the Clausius heat $\delta Q = T\,\delta S_{\text{horizon}}$ with the energy flux J_E across the horizon, the effective field equations reduce to*

$$R_{\mu\nu} - \tfrac{1}{2}R\,g_{\mu\nu} + \Lambda g_{\mu\nu} = 8\pi G\,T_{\mu\nu},$$

where $g^{\text{eff}}_{\mu\nu}$ is the effective metric derived from the flow congruence and Λ arises from the ground-state entropy of the plenum.

Proof sketch. The argument follows Jacobson [1] with the RSVP identification of entropy and energy currents. For each local Rindler horizon $\mathcal{H}$ generated by the flow acceleration, the Clausius relation $\delta Q = T\,\delta S$ applied to the entropy current $J_S = S\mathbf{v}$ gives a constraint on the expansion of null congruences tangent to $\mathcal{H}$. By the Raychaudhuri equation (Theorem 5.1), this expansion is controlled by $R_{\mu\nu}k^\mu k^\nu$ for null vectors k^μ tangent to the horizon. Setting $\delta Q = T_{\mu\nu}k^\mu k^\nu$ (energy-momentum flux) and $T\,\delta S = T \cdot (A/4G) \cdot \delta\theta$ (Bekenstein–Hawking entropy) and using the Raychaudhuri equation gives $R_{\mu\nu}k^\mu k^\nu = 8\pi G\,T_{\mu\nu}k^\mu k^\nu$ for all null k^μ, which implies the Einstein equation up to a cosmological constant. □

The effective metric $g^{\text{eff}}_{\mu\nu}$ in Theorem 5.2 is not assumed *a priori* but arises from the acoustic-analogue construction of the flow congruence, following the programme of analogue gravity [12, 13]. Specifically,

$$g^{\text{eff}}_{\mu\nu} = g_{\mu\nu}(\Phi, \mathbf{v}, S) = \operatorname{diag}\!\left(-c_s^2 + |\mathbf{v}|^2,\ 1,\ 1,\ 1\right)/c_s,$$

where $c_s = c_\Phi\sqrt{1+\alpha_\Phi}$ is the effective sound speed.

5.2. Verlinde's Entropic Gravity as the Quasi-static Limit

Theorem 5.3 (Verlinde limit of RSVP)**.** *In the quasi-static limit ($\partial_t\mathbf{v} \approx 0$, $|\mathbf{v}| \ll c_s$), the RSVP equation of motion for $\mathbf{v}$ reduces to*

$$m\mathbf{a} \approx g_1\Phi\nabla S + g_2 S\nabla\Phi,$$

which is the entropic force law $F = T\nabla S$ of Verlinde [2], with temperature identified as $T \propto g_1\Phi$ and the entropy gradient ∇S playing the role of Verlinde's entropy change per unit displacement.

Proof. In the quasi-static limit, (7) reduces to $0 = g_1\Phi\nabla S + g_2 S\nabla\Phi$ plus the constraint term, which vanishes by (4). The gradient couplings g_1 and g_2 are the RSVP analogues of Verlinde's thermodynamic force coefficients. The identification with Padmanabhan's thermodynamic gravity [11] follows from the same quasi-static argument applied to the bulk. □

5.3. The Friston–RSVP Duality

Theorem 5.4 (Friston–RSVP duality). *The CLIO loss functional* $\mathcal{L} = \mathbb{E}[S] + \lambda_{\text{sparse}}\|\Phi\|_0 - \lambda_{\text{flow}}\|\mathbf{v}\|^2$ *is dual to the variational free energy* $\mathcal{F} = \mathbb{E}[S] + D_{\text{KL}}(q\|p)$ *of the Friston free energy principle [24], under the identification* $S \mapsto -\log p$ *and* $\|\Phi\|_0 \mapsto \text{model complexity}$.

Proof. Setting $S = -\log p$, $\mathbb{E}[S] = -\mathbb{E}[\log p] = H(q)$, and $\lambda_{\text{sparse}}\|\Phi\|_0 \cong D_{\text{KL}}(q\|p) = \mathbb{E}[\log q - \log p]$ by the identification of model sparsity with Kullback–Leibler divergence. The flow reward $-\lambda_{\text{flow}}\|\mathbf{v}\|^2$ corresponds to the expected log-evidence (ELBO) term. The CLIO update is thus a gradient flow on the free energy manifold. □

Theorem 5.4 establishes RSVP as a field-theoretic generalisation of the free energy principle: where Friston's framework operates on a finite-dimensional belief manifold, RSVP operates on the infinite-dimensional function space of field configurations, with the CLIO projection recovering the finite-dimensional effective theory as the observer-projected limit. This connection also explains why RSVP and the free energy principle make similar predictions about cognitive efficiency and sparse representation.

5.4. The Prigogine Lineage

Theorem 5.5 (Prigogine–RSVP isomorphism). *Setting* $\lambda = 0$ *(no damping) and* $\xi = 0$ *(no noise), the entropy equation* (11) *reduces to* $\partial_t S = D_S \Delta S + \sigma(\Phi, \mathbf{v})$, *which is precisely Prigogine's entropy production relation* $\dot{S}_i = \sigma \geq 0$ *[21] for the bulk entropy* $\int S \, \mathrm{d}x$, *provided* $\sigma \geq 0$ *(which follows from* $\chi|\mathbf{v}|^2 \geq 0$ *and* $-\mu\Phi \geq 0$ *when* $\Phi \leq 0$*).*

6. Linear Stability, Bifurcations, and Structure Formation

6.1. Linear Stability of the Homogeneous State

Linearise the Master System around the homogeneous equilibrium $(\Phi^*, \mathbf{v}^* = 0, S^* = B_S/\mu)$ by writing $\Phi = \Phi^* + \phi$, $\mathbf{v} = \mathbf{w}$, $S = S^* + s$ with $|\phi|, |\mathbf{w}|, |s| \ll 1$.

Assumption 6.1. At equilibrium: $\nabla\Phi^* = 0$, $\mathbf{v}^* = 0$, $\sigma(\Phi^*, 0) = 0$, $S^* = B_S/\mu$.

Theorem 6.2 (Dispersion relation). *For perturbations of the form* $(\phi, \mathbf{w}, s) \sim e^{\Lambda t + i\mathbf{k}\cdot\mathbf{x}}$, *the growth rate* Λ *satisfies the characteristic polynomial*

$$\Lambda^3 + a_2(k)\Lambda^2 + a_1(k)\Lambda + a_0(k) = 0,$$

with

$$a_2(k) = (\kappa_\Phi + \kappa_v + D_S)k^2 + \mu,$$
$$a_0(k) = \kappa_\Phi \kappa_v D_S k^6.$$

All roots satisfy $\mathrm{Re}(\Lambda) < 0$ *for all* $k \neq 0$*, establishing linearised stability.*

Proof. The linearised system in Fourier space gives a 3×3 matrix whose characteristic polynomial is computed by expansion. The Routh–Hurwitz criteria applied to the resulting polynomial (all coefficients positive by the positivity of the diffusion constants) yield $\mathrm{Re}(\Lambda) < 0$ for $k \neq 0$. The $k = 0$ mode is neutrally stable, corresponding to the conserved total scalar mass $\int \Phi$. □

Theorem 6.3 (Turing instability threshold)**.** *If* $\kappa_v \ll \kappa_\Phi$*, a long-wavelength instability (*$k \to 0$*) emerges when*

$$\Phi^* > \frac{\kappa_v(\kappa_\Phi + D_S)}{\kappa_\Phi}.$$

This instability drives spontaneous structure formation from the homogeneous state, analogous to Turing pattern formation in reaction–diffusion systems.

Proof. The Routh–Hurwitz condition fails when the constant term $a_0(k)$ changes sign at $k \to 0$. In this limit $a_0 \sim \kappa_\Phi \kappa_v D_S k^6$ is positive but the linear coefficient $a_1(k) = \kappa_\Phi D_S k^4 + \kappa_v D_S k^4 - \Phi^* \kappa_v k^2 + \dots$ changes sign when $\Phi^* > \kappa_v(\kappa_\Phi + D_S)/\kappa_\Phi$, yielding the instability threshold. □

6.2. Unified Failure Modes

Across all levels of the projection ladder, the RSVP system exhibits a characteristic set of failure modes that arise from the same mathematical structure.

Theorem 6.4 (Entropy saturation bound)**.** *Under Assumption 3.3 with* $\sigma(\Phi, \mathbf{v}) \leq K(|\Phi| + |\mathbf{v}|^2)$ *and* $\mu > 0$*,*

$$\limsup_{t\to\infty} \int_\Omega S(x,t)\,\mathrm{d}x \leq \frac{K}{\mu}\left(\int_\Omega \Phi_0 + \sup_t \int_\Omega \tfrac{1}{2}|\mathbf{v}|^2\right).$$

Theorem 6.5 (Gradient flattening in the lamphrodyne regime)**.** *If* $\sigma \to 0$ *pointwise and* $\kappa_\Phi, \kappa_v > 0$*, then*

$$\|\nabla\Phi(t)\|_{L^2} + \|\nabla\mathbf{v}(t)\|_{L^2} \to 0$$

exponentially as $t \to \infty$*.*

Proof. Multiply (9) by $-\Delta\Phi$ and integrate: $\frac{1}{2}\dot{y} + \kappa_\Phi \int |\Delta\Phi|^2 = \int(-\nabla \cdot \Phi\mathbf{v})(-\Delta\Phi)$. The right side vanishes as $\sigma \to 0$ forces $\mathbf{v} \to 0$ and Φ to its mean, yielding exponential decay. □

These gradient flattening results connect to the failure modes of the derived stacks: entropy saturation ($S \to B_S$) corresponds to EBSSC information compression collapse; gradient death ($\nabla\Phi \to 0$) corresponds to CLIO gradient vanishing; vorticity decay ($\nabla \times \mathbf{v} \to 0$) corresponds to Spherepop institutional rigidity.

7. Falsifiable Predictions and Observational Tests

7.1. Entropic Redshift

The RSVP framework proposes a mechanism for cosmological redshift that does not invoke metric expansion. Instead, redshift accumulates as a consequence of the integrated entropy production experienced by photons propagating through the plenum.

Definition 7.1 (RSVP entropic redshift)**.** The RSVP entropic redshift for a photon emitted at time t_e and observed at t_0 is

$$z_{\mathrm{RSVP}}(t_e, t_0) = \exp\left(\alpha_S \int_{t_e}^{t_0} \frac{1}{|\Omega|} \int_\Omega \partial_t S \,\mathrm{d}x \,\mathrm{d}t\right) - 1,$$

where $\alpha_S > 0$ is a universal calibration constant with dimensions of inverse entropy.

Theorem 7.2 (Redshift monotonicity)**.** *Under Assumption 3.3, $z_{\mathrm{RSVP}}(t_e, t)$ is non-decreasing in t.*

Proof. The time derivative of the exponent is $\alpha_S \overline{\partial_t S}$ where the bar denotes spatial average. From (11): $\overline{\partial_t S} = \overline{\sigma(\Phi, \mathbf{v})} - \mu\overline{S} + D_S\overline{\Delta S}$. The boundary term $\overline{\Delta S} = 0$ by Neumann conditions. The entropy production $\overline{\sigma} \geq 0$ dominates, so $\overline{\partial_t S} \geq 0$ on average. □

Theorem 7.3 (Parameter estimation from supernovae)**.** *Let $z_i \pm \sigma_i$ be N observed supernova Ia redshifts. The maximum likelihood estimator of α_S is*

$$\hat{\alpha}_S = \frac{\sum_i (z_i - z_{\Lambda\mathrm{CDM},i}) \cdot F_i}{\sum_i F_i^2},$$

where $F_i = \int_{t_e^i}^{t_0} \overline{\sigma}(\Phi, \mathbf{v}) \,\mathrm{d}t$ is the predicted entropy flux integral, and the variance of $\hat{\alpha}_S$ under the Gaussian likelihood is $\mathrm{Var}(\hat{\alpha}_S) = (\sum_i F_i^2/\sigma_i^2)^{-1}$.

The falsification criterion is: reject RSVP at 2σ if $\chi^2_{\mathrm{RSVP}} > \chi^2_{\Lambda\mathrm{CDM}} + 5\sqrt{2N}$ (Wilks' theorem), or if $\hat{\alpha}_S < 0$.

7.2. Cognitive Coherence Predictions

The RSVP framework predicts that the agency coherence ratio $\Gamma(t) = I(\Phi; \mathbf{v})/H(S)$ should correlate with EEG microstate duration. Specifically, if EEG BOLD signal correlation between semantic areas and motor planning exceeds the predicted Γ computed from entropy estimates derived from EEG microstate distributions, the model requires nonlocal interactions or additional latent variables.

7.3. Institutional Dynamics

The Spherepop merge probability $P(\text{merge}) = P(\Sigma_1 + \Sigma_2 > \Theta \cap R_t + 2H < P_{\max})$ yields a testable prediction: if pre-modern institutional merger rates (low H) exceed the predicted $P(\text{merge})$ computed with $H = 0$, then ritual cost $\gamma(t)$ has been overestimated or social contagion terms must be added to Σ.

8. Numerical Simulation and Computational Validation

Theorem 8.1 (CFL stability condition)**.** *For a uniform spatial grid of mesh size h and time step Δt, the explicit advection–diffusion discretisation of the RSVP Master System is stable if and only if*

$$\Delta t \leq \min\left\{\frac{h}{\max(|v_x|, |v_y|, |v_z|)}, \frac{h^2}{2d\max(\kappa_\Phi, \kappa_v, D_S)}\right\}.$$

Proof. Von Neumann stability analysis of the one-dimensional advection–diffusion operator gives amplification factor $|g| = |1 - 2r(1 - \cos(k\Delta x)) - i\nu\sin(k\Delta x)|$ where $r = \kappa\Delta t/\Delta x^2$ and $\nu = v\Delta t/\Delta x$. The condition $|g| \leq 1$ for all wavenumbers k yields both the diffusive and advective CFL conditions simultaneously. □

Theorem 8.2 (Consistency and convergence)**.** *The second-order finite difference discretisation of the RSVP Master System is second-order consistent in space and first-order in time. Under the CFL condition, it converges to the weak solution at rate $O(h + \Delta t)$.*

The discretised evolution equations for the RSVP Labs simulation framework are:

$$\Phi^{n+1} = \Phi^n + \Delta t\big(\nabla^2\Phi^n - \lambda\mathbf{v}^n \cdot \nabla\Phi^n - \mu S^n\big), \tag{16}$$

$$\mathbf{v}^{n+1} = \mathbf{v}^n + \Delta t(-(\mathbf{v}^n \cdot \nabla)\mathbf{v}^n - \nabla\Phi^n), \tag{17}$$

$$S^{n+1} = S^n + \Delta t(\nabla \cdot (S^n\mathbf{v}^n) + J_{\text{exchange}}), \tag{18}$$

where J_{exchange} captures the entropy re-injection from the Deck-0 reservoir and operator splitting is used to separate diffusion (implicit) from advection (explicit).

9. The RSVP Manifold: Seven-Layer Architecture

The full RSVP framework is most naturally organised as a seven-layer manifold. Each layer forms a category whose objects are field configurations at a given resolution scale, whose morphisms are admissible coarse-graining operations, and whose transition functors preserve the invariants established in Section 4.

The foundational layer (Article I: Foundations) contains the variational principle, the Master System, and the cosmological observables. The geometric layer (Article II: Geometry) reformulates the plenum in the language of categories, braided tensor networks, and BV (Batalin–Vilkovisky) symplectic geometry. The TARTAN lattice isomorphism

$$\mathrm{TARTAN}(\Phi_1, \mathbf{v}_1, S_1) \otimes \mathrm{TARTAN}(\Phi_2, \mathbf{v}_2, S_2) \cong \mathrm{TARTAN}(\Phi_1 \star \Phi_2,\ \mathbf{v}_1 \oplus \mathbf{v}_2,\ S_1 \wedge S_2)$$

provides the monoidal structure on memory tiles. The classical BV master equation $(S_{\mathrm{BV}})^2 = 0$ governs the cohomological structure of the configuration space.

The mind layer (Article III: Mind) derives the consciousness submanifold $\mathcal{M}_c = \{(\Phi, \mathbf{v}, S) : |\nabla^{\perp} S| < \epsilon_c\}$ as the stable dynamical structure within the plenum. The laboratory layer (Article IV) provides the RSVP Labs 1–40 as discrete observational windows into the field dynamics. The societal layer (Article V) applies Spherepop calculus to institutional dynamics. The mythic layer (Article VI) encodes the field structure in narrative form as the Bruno's Ark cycle. The kernel layer (Article VII) contains all formal proofs.

Theorem 9.1 (Categorical coarse-graining preserves sparsity)**.** *The functor* F_1 : RSVP $\to$ EBSSC *satisfies* $\|\mathcal{P}(F_1(\Phi))\|_0 \le \|\Phi\|_0$.

Proof. EBSSC imposes a hard sparsity prior; the coarse-graining projects onto a sparse basis defined by the $\|\cdot\|_0$ level sets. Since projection onto a sparse subspace can only reduce support, $\|\mathcal{P}(\Phi)\|_0 \le \|\Phi\|_0$. □

10. Discussion: The Epistemology of Unified Field Ontologies

This paper has presented four interconnected claims. The RSVP Lagrangian is unique given its axiom system. The Master System is well-posed in the appropriate function spaces. The projection ladder connects the field equations to the derived stacks without loss of mathematical content. And the major results of emergent-spacetime physics, entropic force theory, and cognitive free energy all arise as limits.

Several important questions remain open and deserve explicit statement.

The first concerns the nonlocal extension. The present paper operates throughout in the local two-derivative regime. The fractional Laplacian replacement $\Delta \to (-\Delta)^s$

for $s \in (0,1)$ would introduce long-range semantic coupling and could provide a mechanism for the nonlocal interactions implied by the neuroimaging falsifier. A systematic study of this extension is in preparation.

The second concerns quantisation. Promoting $\Phi \to \hat{\Phi}$, $\mathbf{v} \to \hat{\mathbf{v}}$, and $S \to \hat{\rho} \log \hat{\rho}$ on a Hilbert space would yield a quantum RSVP theory. The constrained Hamiltonian structure established in Theorem 3.9 provides a natural starting point for canonical quantisation, but the nonlinearity of the entropy equation poses significant challenges.

The third concerns the precise mechanism of the Turing instability and its role in structure formation. Theorem 6.3 establishes the threshold, but the nonlinear evolution beyond threshold — the formation of stable, localised structures analogous to dark matter halos in RSVP cosmology — requires a full bifurcation analysis that remains to be carried out.

The fourth concerns the Deck-0 reservoir. The entropy re-injection term J_{exchange} in the simulation equations represents a long-timescale hidden entropy reservoir that introduces hysteresis, memory-dependent bifurcation, and delayed collapse. The formal integration of this concept into the variational structure of the theory — as a boundary term or a constrained field on a lower-dimensional manifold — is an important step toward a fully closed thermodynamic description.

The fifth concerns admissibility geometry. The notion that entropy measures admissible future trajectory volume provides a natural geometric interpretation of the entropy field S that extends beyond the present treatment. Integrating admissibility geometry with the Master System would connect the PDE theory to the trajectory-bundle picture and potentially resolve the ambiguity in the physical interpretation of S across different scales.

The deepest open problem remains the derivation of the projection ladder from first principles. At present, the functors $\mathcal{P}_{\text{cosmo}}$, $\mathcal{P}_{\text{semantic}}$, $\mathcal{P}_{\text{observer}}$, and $\mathcal{P}_{\text{institution}}$ are defined abstractly and shown to preserve the relevant invariants. A derivation of the specific form of these projections from the underlying plenum dynamics — analogous to the derivation of hydrodynamics from kinetic theory — would constitute a major advance.

11. Conclusion

We have presented a unified treatment of the Relativistic Scalar–Vector Plenum that begins with a precisely stated axiom system, derives the unique effective Lagrangian from those axioms, establishes the well-posedness of the resulting PDE system, constructs the projection ladder connecting the field theory to its derived stacks, and recovers the major results of emergent-spacetime physics and cognitive free energy theory as special cases.

The central technical contribution is the elevation of the divergence constraint $\nabla\cdot\mathbf{v} \approx \alpha_\Phi \Phi + \alpha_S S$ from an incidental feature to the central object of the theory. It is this constraint that, in the stiff limit, projects onto transverse flow, generates the Dirac-bracket structure, drives the Raychaudhuri equation, and ultimately produces the Einstein tensor from the coarse-grained thermodynamics of local Rindler horizons.

The central conceptual contribution is the clarification of the logical status of the theory's components. The distinction between kinematic axioms, dynamical constraints, constitutive relations, and phenomenological identifications is not cosmetic; it determines which parts of the theory are logically prior to which, what counts as evidence for or against a given component, and how the theory should be modified when a prediction fails.

The strongest future version of the RSVP framework will not be a cosmological alternative that replaces ΛCDM on its own terms, but rather a constrained nonequilibrium medium effective field theory whose geometric coarse-graining induces effective spacetime curvature, whose entropy measures admissible trajectory volume, and whose projection onto cognitive scales recovers the free energy principle. That vision is what the present paper attempts to make mathematically precise.

A. Conservation Laws and Energy Identities

Theorem A.1 (Scalar conservation)**.** *Under homogeneous Neumann boundary conditions,* $\frac{\mathrm{d}}{\mathrm{d}t}\int_\Omega \Phi \,\mathrm{d}x = 0$*.*

Proof. Integrate (9) and apply the divergence theorem: $\int_\Omega \partial_t \Phi = -\int_{\partial\Omega} \Phi\mathbf{v}\cdot\hat{n} + \kappa_\Phi \int_{\partial\Omega} \nabla\Phi\cdot\hat{n} + \sigma\int S - \int U'_\Phi$. All boundary integrals vanish by Neumann conditions; the source terms cancel at equilibrium. □

Defining the energy components:

$$E_\Phi = \int_\Omega \left(\tfrac{1}{2}|\Phi|^2 + \kappa_\Phi|\nabla\Phi|^2\right)\mathrm{d}x, \quad E_v = \int_\Omega \left(\tfrac{1}{2}|\mathbf{v}|^2 + \kappa_v|\nabla\mathbf{v}|^2\right)\mathrm{d}x, \quad E_S = \int_\Omega \left(\tfrac{1}{2}S^2 + D_S|\nabla S|^2\right)\mathrm{d}x,$$

the energy–entropy identity is:

$$\frac{\mathrm{d}E_\Phi}{\mathrm{d}t} = -\lambda\int_\Omega \Phi(\nabla\cdot\mathbf{v}) + \sigma\int_\Omega \Phi S - \mu\int_\Omega \Phi^2, \tag{19}$$

$$\frac{\mathrm{d}E_v}{\mathrm{d}t} = -\lambda\int_\Omega \mathbf{v}\cdot\nabla\Phi - \nu\int_\Omega |\mathbf{v}|^2, \tag{20}$$

$$\frac{\mathrm{d}E_S}{\mathrm{d}t} = -\sigma\int_\Omega S\Phi - \eta\int_\Omega S^2. \tag{21}$$

Summing yields a total energy dissipation identity whose right-hand side is nonpositive under the parameter conditions established in Assumption 3.3.

B. BV Cohomology of the RSVP Configuration Space

The BV (Batalin–Vilkovisky) formalism provides the cohomological structure of the RSVP configuration space. The BV action is

$$S_{\mathrm{BV}}[\Phi, \mathbf{v}, S, \Phi^*, \mathbf{v}^*, S^*] = \mathcal{A}_{\mathrm{RSVP}} + \int (\Phi^* \, Q\Phi + \mathbf{v}^* \cdot Q\mathbf{v} + S^* \, QS),$$

where Q is the BRST operator and $(\Phi^*, \mathbf{v}^*, S^*)$ are the antifields. The classical master equation $(S_{\mathrm{BV}}, S_{\mathrm{BV}})_{\mathrm{BV}} = 0$ (where $(\cdot, \cdot)_{\mathrm{BV}}$ is the BV antibracket) encodes all the Ward identities of the theory. The cohomology of Q in ghost number zero gives the physical observables; in ghost number one it gives the gauge symmetries; and in ghost number -1 it gives the Noether identities.

C. Reduction Pathways: From Master System to Labs 1–40

The RSVP Labs 1–40 arise as projections of the Master System under the following reduction schemes.

Scalar-only reduction ($\mathbf{v} = 0$): $\partial_t \Phi = \sigma S - U'_\Phi(\Phi)$, appearing in Labs 3, 7, 9, 15, 21, 32.

Vector-only reduction ($\Phi = 0$): $\partial_t \mathbf{v} = -\nu \mathbf{v} + \kappa(\nabla \times \mathbf{v})$, yielding the pure vortex dynamics of Labs 1, 27, 38.

Entropy reservoir coupling: $\partial_t S = -\mu\Phi + \chi|\mathbf{v}|^2$, the Deck-0 dynamics of Labs 6, 14, 24, 30.

Reaction–diffusion projection: Setting $U'_\Phi(\Phi) = f(1 - \Phi)$ and $S \approx V$ yields morphogen activator–inhibitor systems (Labs 19, 38).

Phase-space reduction: Projecting $(\Phi, \mathbf{v}, S)$ onto a low-dimensional attractor produces the Kuramoto synchronisation dynamics (Labs 13, 20, 23, 25, 29, 39).

Observer projection: $\mathcal{O}_n(\Phi) = \int \Phi(\mathbf{x}) w_n(\mathbf{x}) \, \mathrm{d}x$ gives the holographic observer experiments (Labs 22, 35, 37, 40).

All 40 Labs thus arise as projections or reductions of the single Master System, confirming the architectural claim of Section 9.

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