

The Single-Source Theorem of VERSF

A Unified Derivation of Dynamics, Memory, and Gravity from the Commitment Density Field

Abstract for General Readers

Physics has long sought a single principle from which all observable phenomena follow. This paper shows that within the Void Energy–Regulated Space Framework (VERSF), such a principle exists: everything that can be measured — the behaviour of quantum fields, the expansion of the universe, the attraction of gravity — is determined by a single underlying quantity called the **committed record density**, written $\rho(x,t)$.

The committed record density counts, at each point in space and time, how many irreversible physical events have occurred there — events that have permanently left a mark on reality and cannot be undone. The central claim of this paper is that once you know how these marks are distributed across spacetime, you can derive everything else. This paper argues that forces, fields, cosmic structure, and gravitational dynamics may be read as different projections of the same underlying record — a claim established structurally for dynamical and statistical sectors, and partially for gravity and cosmology.

This is established not by philosophical argument but through an explicit chain of derivations. Each link in the chain — from the statistics of commitment events to quantum bath structure, to a characteristic memory kernel, to cosmological expansion, to Newtonian gravity — is derived from the previous one with no new assumptions introduced at any step. The chain is also deliberately fragile: each link can be tested independently, and failure at any single point would falsify the whole structure.

The result does not simplify physics. It reinterprets its apparent multiplicity as different projections of a single underlying structure.

Abstract

We establish, within the Void Energy–Regulated Space Framework (VERSF), that all physical observables are functionals of a single scalar field: the committed record density $\rho(x,t)$. Starting from irreversible commitment as a primitive and the commitment free energy $F[\rho]$ as the **minimal admissible functional** compatible with causal, non-degenerate fact production, we derive:

1. the κ -field as the unique propagating fluctuation of ρ ,
2. the bath spectral density $J(\omega)$ as a functional of commitment-event statistics,
3. the memory kernel $K(\tau)$ as the retarded Green's function of κ , shown by three computational routes within the κ -field framework to decay as $\cos(m_\kappa \tau)/\tau$,
4. logarithmic cosmological expansion as the infrared asymptotic of κ -field dynamics under white-noise sourcing, and
5. gravitational dynamics as the coarse-grained stress-energy response of the κ -field Lagrangian (structural form only; the gravitational constant G is not yet derived, pending determination of the coupling λ).

Under the constitutive exhaustiveness principle, no additional independent fact-producing field is admissible within the framework: any such field would require an independent substrate of irreversible distinguishability, contradicting the exhaustiveness of ρ . This establishes the **operational single-source structure**:

$\mathcal{O} = \mathcal{A}[\rho]$ for all observables \mathcal{O}

Explanation. Here \mathcal{O} denotes any physical observable, including local field values, correlation functions, spectral quantities, cosmological parameters, and gravitational potentials. The functional $\mathcal{A}[\rho]$ represents a (generally nonlocal) mapping from the committed record density $\rho(x,t)$ to the observable of interest, constructed through the sequence of derived structures:

- event statistics of ρ determine the spectral density $J(\omega)$,
- $J(\omega)$ determines the memory kernel $K(\tau)$,
- $K(\tau)$ governs the nonlocal dynamics of the fluctuation field κ ,
- κ -dynamics determine cosmological observables (e.g. n_s , H),
- coarse-grained ρ determines gravitational response (e.g. Φ , $g_{\mu\nu}$).

The bracket notation $\mathcal{A}[\rho]$ indicates that \mathcal{O} depends on the full spacetime configuration of ρ , not merely its local value. The statement therefore asserts that all physical structure — dynamical, statistical, and geometric — is functionally determined by a single scalar field, with no independent sources of distinguishability.

The result collapses dynamical, statistical, and geometric sectors into a single functional hierarchy. This paper is a closure statement for these sectors, not a new dynamical model; gauge structure, charge, spin, and the Standard Model force sector are not addressed and remain open problems for the programme. Falsifiability criteria are stated throughout and consolidated in §11.

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1. Programme Closure Statement

This paper does not re-derive all intermediate results of the VERSF programme. Instead, it establishes a closure theorem by explicitly linking previously derived results into a single dependency chain.

The following results are taken as established within the VERSF programme:

- The κ -field mass $m^2_{\kappa} = (4/3) \xi^{-2}$ from the $K = 7$ constraint architecture and commitment free-energy curvature.
- The equivalence $s(x,t) \equiv \kappa(x,t)$ under retarded boundary conditions, yielding a unique Klein–Gordon field structure.
- The commitment-event bath spectral density $J(\omega)$, derived from $K = 7$ mode structure and Poisson event statistics.
- The emergence of a white-noise (infrared-flat) spectral density under coarse-graining.
- The resulting memory kernel $K(\tau)$ derived via Caldeira–Leggett reduction and κ -field propagation.
- The logarithmic κ -field displacement $\delta s \sim \ln N$ in the slow-roll regime.
- The two-sector cosmological dynamics ($\rho_{\text{void}} \propto a^{-4}$, $\rho_{\text{sr}} \propto (\ln N)^2$).
- The coarse-grained gravitational sourcing from the commitment density field.

The purpose of the present work is to show that these results form a **closed system**:

\forall observables \mathcal{O} , $\mathcal{O} = \mathcal{F}[\rho]$

where $\rho(x,t)$ is the committed record density. All steps below either (i) directly reference these prior derivations, or (ii) establish the minimal additional structure required to connect them.

1.1 Explicit Dependency Chain

For clarity, we state the full closure chain explicitly:

```

ρ(x, t)
→ (event statistics + K=7 structure)
→ J(ω)
→ (open-system reduction)
→ K(τ)
→ (nonlocal dynamics)
→ κ(t)
→ (infrared asymptotics)
→ cosmological observables [consistency check via M-S bridge]

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→ (coarse-graining)
 → gravitational dynamics [structural form only; λ undetermined]

Each mapping is either derived or referenced in the sections that follow. This chain constitutes the operational content of the single-source statement $\mathcal{O} = \mathcal{A}[\rho]$.

No step in this chain introduces an independent dynamical degree of freedom; each map is fully determined by structures already defined in terms of $\rho(x,t)$. This is the precise sense in which the chain is closed.

The maps in the chain are not generally invertible; information is lost under coarse-graining. The single-source claim concerns forward determination, not reversibility.

1.2 Failure Structure of the Chain

Each step in the dependency chain represents a distinct structural assumption. The chain is therefore falsifiable at multiple levels:

- Failure of event statistics → breakdown of $J(\omega)$
- Failure of white-noise universality → modification of $K(\tau)$
- Failure of kernel asymptotics → breakdown of logarithmic growth
- Failure of coarse-graining → breakdown of gravitational emergence

The closure claim holds only if all links remain valid. This explicitly identifies where the framework can fail.

2. Foundations and Definitions

2.1 Commitment as Primitive

VERSF takes as its sole ontological primitive the notion of an **irreversible commitment event**: a transition from undifferentiated potential to a stable, distinguishable record. No further reduction is assumed. This primitive is not derived but posited as the minimal condition for the existence of physical facts; all subsequent structure is conditional on its adoption.

Definition 1 (Commitment Density). Given a spatial region $V(x)$ centred at x , let $N_{\text{committed}}(V, t)$ be the number of irreversible commitment events whose causal past lies within V by time t . Define:

$$\rho(x, t) := \lim_{\{V \rightarrow 0\}} N_{\text{committed}}(V, t) / |V|$$

Existence. This limit is well-defined when commitment events form a locally finite measure on spacetime — i.e., when there exists a Radon measure μ on $\mathbb{R}^3 \times \mathbb{R}_+$ such that $N_{\text{committed}}(V, t) = \mu(V \times [0, t])$. Existence is guaranteed by the finite-density axiom: no finite spacetime volume

contains infinitely many commitment events. Under this condition, $\rho(x, t)$ is the Radon–Nikodym derivative of μ with respect to Lebesgue measure, existing almost everywhere.

This definition ensures that $\rho(x, t)$ is the unique scalar density carrying irreducible distinguishability. Any alternative scalar field must either reduce to ρ or fail to represent committed physical records.

Definition 2 (Background and Fluctuation Decomposition). Let $F[\rho]$ be the commitment free energy — the minimal admissible functional encoding the thermodynamic cost of maintaining a given distribution of committed records. "Minimal admissible" is used deliberately: locality, analyticity, and non-degeneracy constrain the functional form but do not uniquely fix it without additional symmetry or closure conditions. The present work requires only that F admits a stable extremum and a well-defined quadratic expansion; the non-uniqueness of F does not affect the κ -field structure derived from it. Characterised by:

- **(F1)** Locality: $F[\rho] = \int d^3x f(\rho, \nabla\rho, \rho)$.
- **(F2)** Non-degeneracy: f penalises both $\rho \rightarrow 0$ and $\rho \rightarrow \infty$.
- **(F3)** Parity symmetry under spatial reflection.
- **(F4)** Analyticity near equilibrium.

Define $\rho_0(x, t)$ as the stable local extremum:

$$\delta F / \delta \rho |_{\{\rho_0\}} = 0, \quad \delta^2 F / \delta \rho^2 |_{\{\rho_0\}} > 0$$

The fluctuation field is:

$$\kappa(x, t) := \rho(x, t) - \rho_0(x, t)$$

Under retarded boundary conditions, the established equivalence $s(x, t) \equiv \kappa(x, t)$ holds uniquely, yielding a Klein–Gordon field structure with characteristic mass:

$$m^2_{\kappa} = F''(\rho_0) = (4/3) \xi^{-2}$$

where $\xi = \rho_0^{-1/3}$ is the microscopic commitment scale.

3. Spectral Density as a Functional of ρ

The bath spectral density $J(\omega)$ is not introduced as an independent object but is derived from the statistical structure of commitment events within the $K = 7$ architecture.

The Poisson assumption — that commitment events are uncorrelated at the microscopic level — requires brief justification, given that memory structure is elsewhere treated as central to the framework. The resolution is that the memory kernel $K(\tau)$ captures correlations in the *κ -field response* to commitment events, not correlations among the events themselves. Individual

commitment events are irreversible and locally determined: once an event has occurred in a region, it does not causally influence the timing of the next event in the same region beyond the background shift in ρ . The Poisson structure applies at the level of event arrival statistics; the non-Markovian memory arises at the level of the field dynamics driven by those events.

From the full derivation of the commitment-event bath, the spectral density takes the form:

$$J(\omega) = \Gamma |\hat{f}(\omega)|^2 W_{\{K_7\}}(\omega)$$

where:

- Γ is the local commitment event rate ($\Gamma \propto \rho$),
- $\hat{f}(\omega)$ is the Fourier transform of the single-event temporal profile,
- $W_{\{K_7\}}(\omega)$ is the response-weighted spectral contribution of the $K = 7$ mode structure.

The function $W_{\{K_7\}}(\omega)$ is derived from:

1. the exact $K = 7$ Laplacian eigensystem,
2. mode response functions $\chi_{\alpha}(\omega)$,
3. statistical averaging over Poisson-distributed commitment events,
4. coarse-graining across spatial regions satisfying self-averaging conditions.¹

¹ *Self-averaging conditions: regimes in which fluctuations in Γ average out over the coarse-graining volume, leaving only the mean rate.*

Under these conditions, the infrared behaviour is:

$$\bar{W}_{\{K_7\}}(\omega) = \bar{W}_{\{K_7\}}(0) + O(\omega^2)$$

so that:

$$J(\omega) \approx \text{const} (\omega \ll m_{\kappa})$$

This establishes that the commitment-event bath lies in the **white-noise universality class** in the infrared — a derived result, not an assumption. The infrared flatness of $J(\omega)$ is not imposed but follows from the absence of long-range correlations in the Poisson-distributed commitment events after coarse-graining. The variance of event amplitudes is fixed by the $K = 7$ vertex covariance: $\sigma^2 = v^2(1 - \rho_c)$, where ρ_c is the critical commitment fraction at the simplicial connectivity transition. Both v and ρ_c are structural constants, not free parameters.

Crucially, $W_{\{K_7\}}(\omega)$ is not an arbitrary weighting function but a fully determined object of the $K = 7$ eigensystem. No independent spectral structure is introduced at this stage; all frequency

dependence is inherited from the commitment density field through its event statistics and geometric constraint structure.

Therefore $J(\omega) = \mathcal{F}_1[\rho]$, with \mathcal{F}_1 entirely determined by ρ and the $K = 7$ geometry.

4. Memory Kernel from κ -Field Dynamics

The memory kernel is not derived independently in this paper but follows from previously established κ -field dynamics and open-system reduction. Three independent derivations within the VERSF programme converge on the same asymptotic result.

Route 1 — Retarded Green's function:

$$K(\tau) = \Gamma_0 \delta(\tau) + \lambda G_{\kappa}(\tau), \text{ with } G_{\kappa}(\tau) = e^{-\gamma\tau} \sin(\omega_{\kappa} \tau) / \omega_{\kappa}$$

Route 2 — Spatially extended source integration:

Integration of G_{κ} over an extended source region of radius R , via the substitution $u = \tau - r/c$:

$$K_{\text{eff}}(\tau) = 4\pi c^2 \int_0^{\tau} (\tau - u) e^{-\gamma u} e^{i\omega_{\kappa} u} du \sim \cos(m_{\kappa} \tau + \varphi) / \tau$$

An exponential envelope is not excluded in general physical systems, but would require an additional characteristic decay scale beyond m_{κ}^{-1} . Within the present framework, where no independent infrared scale is introduced, such behaviour cannot arise from the κ -field dynamics alone. The algebraic $1/\tau$ decay is therefore the minimal causal behaviour consistent with the absence of additional scales. Any faster algebraic decay requires an additional infrared scale, also absent by hypothesis.

Route 3 — Caldeira–Leggett reduction:

For $J(\omega) \approx \text{const}$ (white noise, established in §3), the Caldeira–Leggett open-system kernel is:

$$K(\tau) \propto \int_0^{\infty} (\cos \omega\tau / \omega) d\omega \rightarrow \cos(m_{\kappa} \tau) / \tau$$

The integral as written is formally divergent at both limits and requires UV regularisation (a high-frequency cutoff $\Lambda \sim m_{\kappa}$) and standard Caldeira–Leggett renormalisation to yield the finite asymptotic form. This procedure is treated in full in the companion open-systems paper; here the regularised result is used directly.

Convergence. All three routes yield:

$$K(\tau) \sim A \cos(m_{\kappa} \tau + \varphi) / \tau$$

This kernel is causal (retarded), algebraically decaying (non-Markovian), and oscillatory with frequency set by m_κ .

The three derivations differ in computational method — Green's function propagation, spatial coarse-graining, and open-system reduction — but are not fully independent. All three presuppose κ -field propagation with mass m_κ ; they differ in how that propagation is used. Routes 1 and 3 share the same underlying spectral input $J(\omega)$ and therefore test internal consistency of the open-system formulation. Route 2 performs a spatial integration over a source region rather than a frequency-domain reduction — a distinct calculation, though not a distinct physical input. Taken together, the three routes establish robustness of the kernel across multiple computational formulations of the same underlying κ -field physics. We emphasise that any alternative kernel with faster decay (e.g. exponential or τ^{-2}) would require either (i) an additional infrared scale or (ii) violation of causal propagation constraints. Neither is admissible within the present framework.

We treat this kernel as a derived input to the closure argument. This result fixes the leading infrared behaviour of the memory kernel; any deviation would require modification of either the event statistics or the causal propagation structure.

5. κ -Field Dynamics and Logarithmic Growth

5.1 Nonlocal Equation of Motion

Proposition 1 (Nonlocal Equation of Motion). The κ -field satisfies:

$$\ddot{\kappa}(t) + 3H \dot{\kappa}(t) + m_\kappa^2 \kappa(t) + \int_0^t K(t-t') \kappa(t') dt' = J(t)$$

where K is the derived kernel of §4 and $J(t)$ is the stochastic forcing of §3. This equation follows from variation of the nonlocal effective action obtained by integrating out the ρ -bath via the Schwinger–Keldysh (in-in) formalism.

5.2 Logarithmic Growth

Theorem 1 (Logarithmic Growth). Given:

- $K(\tau) \sim 1/\tau$ (derived, §4),
- $J(\omega) \approx \text{const}$ in the infrared (derived, §3),
- absence of an infrared cutoff below H ,
- quasi-static regime validity: $Ht \gg 1$ and $H \ll m_\kappa$ (self-consistency with the Friedmann equation deferred; see §5.2 and §13.4),

the κ -field quasi-static displacement satisfies:

$$\delta s(N) \sim \ln N$$

Proof.

Step 1. From the Caldeira–Leggett framework, the quasi-static mean displacement is governed by the balance between driving and memory dissipation. With $K(\tau) \sim 1/\tau$, the memory integral contributes:

$$\int_0^t K(t-t') \kappa(t') dt' \sim \kappa \cdot \int_0^t d\tau/\tau \sim \kappa \cdot \ln t$$

Step 2. In the quasi-static regime, the time derivatives $\dot{\kappa}$ and $3H\kappa$ are subleading compared to the accumulated memory term and stochastic forcing. The dominant balance in the nonlocal equation of motion is therefore between the memory integral and the effective driving scale set by $J(t)$, whose characteristic magnitude is Γ . This yields the infrared balance condition:

$$\int_0^t K(t-t') \kappa(t') dt' \sim \Gamma$$

With $K(\tau) \sim 1/\tau$, the integral gives $\int_0^t d\tau/\tau \sim \ln t$, forcing:

$$\kappa(t) \sim \ln t$$

Step 3. Converting to e-folds via $t \propto e^N$:

$$\delta s(N) \sim \ln N \blacksquare$$

Logarithmic growth is not assumed but emerges as the self-consistent infrared asymptotic of the full nonlocal equation under white-noise sourcing and a $1/\tau$ kernel. This result holds in the regime where the kernel asymptotic $K(\tau) \sim 1/\tau$ dominates the integral, i.e. for timescales large compared to the microscopic scale m_κ^{-1} but small compared to any external cutoff scale. This behaviour dominates any subleading contributions from higher-order terms in $K(\tau)$, which decay faster than $1/\tau$ and therefore do not alter the leading infrared scaling.

Consistency of the quasi-static approximation. The neglected derivative terms remain subleading under the derived scaling $\kappa(t) \sim \ln t$. Explicitly:

$$\dot{\kappa} \sim 1/t, \quad 3H\kappa \sim H/t$$

which is subleading compared to the memory integral $\sim \ln t$ provided:

$$Ht \gg 1 \text{ and } H \ll m_\kappa$$

These conditions are satisfied in the regime where the infrared kernel dominates and logarithmic growth holds. Outside this regime the approximation breaks down and the full nonlocal equation must be used.

Self-consistency note. The validity conditions $Ht \gg 1$ and $H \ll m_\kappa$ involve H , which is itself determined by the Friedmann equation (§6.1) with $\rho_{sr} \sim (\ln N)^2$. The approximation is therefore self-consistent only if the derived scaling $\kappa \sim \ln t$ is compatible with the H arising from ρ_{sr} . A

full verification of this self-consistency is deferred; the conditions above represent necessary rather than sufficient criteria for validity of the approximation in the cosmological context.

6. Cosmological Consequences

6.1 Energy Density Scaling

Proposition 2 (Energy Components). In the VERSF cosmological background:

$$\rho_{\text{void}} \propto a^{-4}, \rho_{\text{sr}} \propto (\ln N)^2$$

Derivation.

- ρ_{void} : Void energy is carried by uncommitted potential — the background against which commitment occurs. Since void quanta carry no committed record, they are massless (see the Two-Planck Principle paper for the derivation of the void energy spectrum) and dilute as radiation: $\rho_{\text{void}} \propto a^{-4}$.
- ρ_{sr} : The slow-roll energy density is set by the κ -field displacement squared. From Theorem 1, $\delta s \sim \ln N$, so $\rho_{\text{sr}} \sim (\delta s)^2 \propto (\ln N)^2$.

The Friedmann equation is:

$$3 M_{\text{Pl}}^2 H^2 = \rho_{\text{void}} + \rho_{\text{sr}}$$

No additional scalar field is introduced; the κ -field itself provides the effective inflaton degree of freedom.

6.2 Spectral Index

Theorem 2 (Spectral Index). In the VERSF slow-roll regime:

$$n_s - 1 = -2/N^*$$

Consistency Check. The κ -field acts as the inflaton with effective potential $V(\kappa) = \frac{1}{2} m_{\kappa}^2 \kappa^2$. The number of e-folds from κ_* to end of inflation is $N^* = \kappa_*^2 / (2M_{\text{Pl}}^2)$. Using the Hubble slow-roll parameters — the physically relevant quantities for perturbation evolution — one obtains:

$$n_s - 1 = -2/N^*$$

This is consistent with Planck observations for $N^* \approx 55\text{--}60$. The dependence on N^* reflects the emergent temporal structure of the κ -field dynamics rather than an imposed inflationary potential.

This result coincides formally with the standard slow-roll expression. However, the derivation here uses the Mukhanov–Sasaki formalism as a calculational bridge rather than deriving the perturbation spectrum directly from κ -field fluctuations. The physical origin differs: in VERSF the scaling $n_s - 1 = -2/N^*$ arises from the infrared structure of the κ -field dynamics and the derived logarithmic displacement $\delta s \sim \ln N$, rather than from an assumed inflaton potential.

Accordingly, this result should be understood as:

- a consistency check that the κ -field dynamics reproduce the observed scaling, rather than
- a fully internal derivation of the primordial spectrum.

A complete derivation of the perturbation spectrum from κ -fluctuation statistics is deferred to a companion paper. Until that derivation is completed, this step represents the **least internally closed element of the chain.** ■

7. Gravitational Sector

Gravitational dynamics are not introduced independently but emerge from the stress-energy structure of the commitment density field.

7.1 Klein–Gordon Lagrangian for κ

From the unique Klein–Gordon structure established for $s \equiv \kappa$ (§2.2), the Lagrangian is:

$$\mathcal{L} = \frac{1}{2}(\partial s)^2 - \frac{1}{2} m^2_{\kappa} s^2 + s \cdot \rho_{\text{committed}}$$

where $\rho_{\text{committed}}$ is the full (unsmoothed) commitment density at the field-theory level. In the macroscopic limit, this is replaced by its coarse-grained counterpart ρ_{bound} — the spatial average of $\rho_{\text{committed}}$ over scales larger than the coherence length ξ . The two quantities therefore represent the same underlying density at different levels of resolution: $\rho_{\text{committed}}$ is the microscopic source, ρ_{bound} is its effective macroscopic form. No additional independent density is introduced at either level.

The stress-energy tensor is:

$$T_{\mu\nu} = \partial_{\mu} s \partial_{\nu} s - g_{\mu\nu} \mathcal{L}$$

7.2 Emergence of Gravitational Dynamics

Theorem 3 (Gravity Emergence). In the weak-field limit, the κ -field equation yields a Yukawa-type response:

$$(\nabla^2 - m^2_{\kappa}) \kappa = -\lambda \rho_{\text{bound}}$$

Two regimes follow:

- **Short-range** ($r \ll m_{\kappa}^{-1}$): the Yukawa exponential is $O(1)$, giving $\nabla^2 \kappa \approx -\lambda \rho_{\text{bound}}$, which corresponds to the Newtonian regime arising from $r \ll m_{\kappa}^{-1}$, where the Yukawa suppression is negligible.
- **Long-range** ($r \gg m_{\kappa}^{-1}$): the κ -field is exponentially suppressed, giving deviations from Newtonian behaviour.

Defining $\Phi := -(\lambda/m^2_{\kappa}) \kappa$ and $G := \lambda/(4\pi m^2_{\kappa})$, the short-range limit gives:

$$\nabla^2 \Phi = 4\pi G \rho_{\text{bound}} \quad (r \ll m_{\kappa}^{-1})$$

Status of the coupling λ . Within the present work, λ is inherited from the effective κ -field sourcing term and is not independently derived. The emergence of Newtonian gravity therefore depends on the ratio λ/m^2_{κ} . If λ is fixed by the same underlying structure that determines m^2_{κ} , then G becomes a derived quantity; otherwise the framework reduces gravitational dynamics to a single effective parameter. The determination of λ from first principles within the VERSF architecture is therefore a key open problem.

The derivation therefore establishes the **structural form** of gravitational dynamics but does not yet constitute a predictive derivation of G . That requires λ to be fixed by independent means.

This establishes that gravity is sourced by ρ , that κ -field fluctuations provide local dynamics, and that the metric emerges as an effective large-scale description. The full covariant generalisation — recovering $G_{\mu\nu}$ sourced by $T_{\mu\nu}$ via covariant Buchert averaging — is treated in the companion gravity paper.

Gravity therefore appears as the large-scale, coarse-grained response of the same underlying field that governs microscopic commitment dynamics. This derivation does not replace general relativity but provides its sourcing mechanism within the VERSF framework.

7.3 Intermediate-Scale Behaviour

At scales $r \sim m_{\kappa}^{-1}$, the Yukawa form predicts a transition between Newtonian behaviour and exponential suppression:

$$\Phi(r) \sim e^{\{-m_{\kappa} r\}} / r$$

This regime represents a distinctive prediction of the framework: a scale-dependent modification of gravitational response determined by the κ -field mass. Detection of such a transition would provide a direct test of the single-source structure.

Observation of gravitational behaviour inconsistent with both Newtonian scaling ($r \ll m_{\kappa}^{-1}$) and Yukawa suppression ($r \gg m_{\kappa}^{-1}$) would falsify the κ -mediated sourcing mechanism.

8. The Single-Source Theorem

We now assemble the full dependency chain established in §§2–7.

8.1 Analytic vs Substantive Content

The single-source statement has two logically distinct components:

(1) Analytic closure. Given the constitutive principle that all physical distinguishability within the VERSF admissibility class arises from irreversible commitment events, the definition of $\rho(x,t)$ as the density of such events implies that any observable must be expressible as a functional of ρ . This component is definitional within the framework.

(2) Substantive content. The non-trivial physical content lies in the specific functional forms linking ρ to observables:

- $J(\omega)$ as a function of event statistics (§3),
- $K(\tau) \sim \cos(m_\kappa \tau)/\tau$ as the derived memory kernel (§4),
- $\delta s \sim \ln N$ as the infrared dynamical behaviour (§5),
- $n_s - 1 = -2/N^*$ as the cosmological scaling (§6),
- $\nabla^2 \Phi \propto \rho_{\text{bound}}$ as the gravitational response (§7).

The predictive power of the framework resides entirely in these derived mappings. The analytic component identifies the correct variable; the substantive component determines the physics.

Theorem 4 (Single-Source Theorem). Let $\rho(x, t)$ be the committed record density (Definition 1). Within the dynamical, statistical, and gravitational sectors addressed in this paper, all observables are functionals of ρ :

$$\forall \mathcal{O}, \mathcal{O} = \mathcal{F}[\rho]$$

Conditional notes. (i) The field-exclusion component of this theorem is conditional on the Constitutive Principle of Exhaustiveness (§8, Exclusion of Independent Fields): it is a consequence of a definitional commitment, not a result derived from dynamics. (ii) The scope is restricted to the sectors explicitly treated; gauge structure, charge, spin, and the weak and strong forces are not addressed and represent open problems for the programme.

Explanation. Here \mathcal{O} denotes any physical observable — local field values, correlation functions, spectral quantities, cosmological parameters, or gravitational potentials. The functional $\mathcal{F}[\rho]$ is a generally nonlocal mapping from the committed record density to the observable of interest, constructed through the derived sequence:

- event statistics of ρ determine the spectral density $J(\omega)$,
- $J(\omega)$ determines the memory kernel $K(\tau)$,
- $K(\tau)$ governs the nonlocal dynamics of κ ,
- κ -dynamics determine cosmological observables (n_s, H),

- coarse-grained ρ determines gravitational response ($\Phi, g_{\mu\nu}$).

The bracket notation $\mathcal{A}[\rho]$ indicates dependence on the full spacetime configuration of ρ , not merely its local value. The claim is therefore not that observables are functions of ρ at a point, but that they are determined by the entire history and distribution of committed records — a strictly stronger statement.

Dependency Chain

$$\rho \xrightarrow{\mathcal{F}_1} J(\omega) \xrightarrow{\mathcal{F}_2} K(\tau) \xrightarrow{\mathcal{F}_3} \kappa(t) \xrightarrow{\mathcal{F}_4^*} \{\text{cosmology, } n_s, H\} \xrightarrow{\mathcal{F}_5^\dagger} \text{gravity}$$

\mathcal{F}_4 is a consistency check via M–S bridge, not a fully internal derivation (§6.2). \mathcal{F}_5 establishes structural form only; G is not yet derived (§7.2).

Map	Content	Location
$\mathcal{F}_1: \rho \rightarrow J(\omega)$	Poisson statistics + $K=7$ mode structure	§3
$\mathcal{F}_2: J(\omega) \rightarrow K(\tau)$	Caldeira–Leggett + retarded propagation	§4
$\mathcal{F}_3: K(\tau) \rightarrow \kappa(t)$	Nonlocal equation of motion	§5
$\mathcal{F}_4: \kappa(t) \rightarrow$ cosmology	Slow-roll dynamics, spectral index (M–S bridge; see §6.2, §13.2)	§6
$\mathcal{F}_5: \rho \rightarrow$ gravity	Stress-energy coarse-graining (structural form only; λ undetermined; see §7.2, §13.3)	§7

Scope

This statement applies to propagating fields (κ), statistical observables (J, K , spectra), cosmological quantities (n_s, H, ρ_{sr}), and gravitational dynamics ($\Phi, g_{\mu\nu}$).

Exclusion of Independent Fields

The exclusion of additional independent fields is not derived from the dynamics but follows from a constitutive principle of the framework.

Constitutive Principle (Exhaustiveness of Commitment). Within the VERSF admissibility class, all physically meaningful distinguishability arises from irreversible commitment events.

Under this principle, the committed record density $\rho(x,t)$ is defined as the unique scalar measure of irreducible distinguishability. Any field ϕ that contributes to physically observable structure must therefore either:

- (i) correspond to a reparameterisation or coarse-grained representation of ρ , or
- (ii) introduce a distinct form of distinguishability not reducible to irreversible commitment.

Case (ii) lies outside the admissibility class of VERSF. Within the framework, all physical observables are constructed from commitment-defined distinguishability, and therefore any admissible field must be functionally reducible to ρ .

Auxiliary or effective fields (inflaton, dark energy, graviton) may appear at intermediate levels of description but fall under case (i): they are representations of ρ -dynamics at different coarse-graining scales, not independent ontological sources.

The single-source statement should therefore be understood as **conditional on this constitutive principle**.

Closure is achieved at the level of fact-producing structure. ■

9. Epistemic Status

Result	Status	Location
Exhaustiveness of commitment (all distinguishability derives from irreversible events)	Constitutive axiom	§8
κ -field mass $m^2_{\kappa} = (4/3)\xi^{-2}$	Proven (K=7 architecture paper)	§2
Spectral density $J(\omega)$	Derived — K=7 eigensystem + Poisson statistics	§3
Infrared white-noise universality	Derived — coarse-graining + self-averaging	§3
Memory kernel $K(\tau) \sim \cos(m_{\kappa}\tau)/\tau$	Derived — three computational routes within κ -field framework	§4
Logarithmic growth $\delta s \sim \ln N$	Derived — infrared asymptotic of nonlocal EOM	§5
Cosmological energy scaling	Derived — radiation + κ -displacement	§6
Spectral index $n_s - 1 = -2/N^*$	Consistency check (M-S bridge; internal derivation pending)	§6
Gravity $\nabla^2\Phi \propto \rho_{\text{bound}}$	Derived — coarse-grained Klein-Gordon	§7
Single-source closure $\mathcal{O} = \mathcal{A}[\rho]$	Derived — this paper; conditional on constitutive axiom (see §8.1 and first row)	§8

No result listed as "derived" depends on the introduction of free parameters beyond those fixed by the K = 7 architecture and CCC scaling. All derived results follow from previously established VERSF structures and do not introduce new free parameters. Free parameters arising

in intermediate formulations are either fixed by the $K = 7$ structure or explicitly identified as open problems.

10. What This Paper Establishes

This paper does not introduce new dynamical ingredients. Its contribution is structural:

- it assembles previously derived results into a closed dependency chain,
- it shows that no step in that chain requires an independent fact-producing source,
- it establishes that dynamical, statistical, and geometric sectors are functionally unified under ρ .

The present work does not derive the tensor-to-scalar ratio r or the primordial amplitude A_s . Nor does it address charge, spin, gauge structure, or the weak and strong forces. If the single-source structure is complete, all of these must also be functionals of ρ . Their derivation would significantly strengthen the cosmological closure and the programme's claim to universality; they are identified as explicit open problems alongside λ .

The result is therefore not a new model but a **closure statement** for the VERSF programme.

11. Falsifiability

The Single-Source Theorem is falsified if any of the following are observed. Each criterion below corresponds to a distinct structural element of the closure chain. Failure of any single criterion falsifies the corresponding link and therefore the single-source structure as a whole.

Criterion	Prediction	Falsified if
IR spectral density	$J(\omega) \rightarrow \text{const}$ as $\omega \rightarrow 0$	$J(\omega) \rightarrow 0$ faster than ω (Ohmic or sub-Ohmic)
Memory kernel decay	$K(\tau) \sim \cos(m_\kappa \tau)/\tau$	$K(\tau) \sim e^{-\alpha\tau}$ or $K(\tau) \sim 1/\tau^2$
Spectral index	$n_s \approx 1 - 2/N^*$	Significant deviation at $N^* = 55-60$
Gravity sourcing	$\nabla^2\Phi \propto \rho_{\text{bound}}$	Gravitational field independent of matter density
Intermediate gravity regime	Transition $\Phi \sim e^{-m_\kappa r}/r$ at $r \sim m_\kappa^{-1}$	No scale-dependent transition observed
Single scale	All scales set by $\rho_0^{-1/3}$	Discovery of independent scale with no ρ origin

Criterion	Prediction	Falsified if
No new fields	No independent fact-producing fields	Discovery of a field with no functional dependence on ρ (note: this criterion is a heuristic constraint rather than a directly operational experimental test)

The bench-top falsification criterion from the Coupled Temporal paper — $\sigma_\tau/\sigma_{\text{opt}} = \sqrt{2 \ln 2} \approx 1.18$ across three independent measurement channels — provides the sharpest near-term experimental test of the $1/\tau$ kernel prediction. This criterion follows from the $1/\tau$ kernel structure by mapping the temporal response width to the Fourier-limited spectral width under the derived memory kernel. A full derivation is provided in the Coupled Temporal paper; here it serves as an experimentally accessible consequence of the $K(\tau) \sim 1/\tau$ scaling.

The presence of multiple independent falsification criteria ensures that agreement with a subset of predictions does not confirm the framework unless the full structure is satisfied.

12. Conclusion

VERSF reduces all of physics to:

the structured evolution of a single causally cumulative scalar field $\rho(\mathbf{x}, t)$

under a minimal admissible free energy whose properties are fixed by the requirements of causal, non-degenerate, irreversible fact production.

The Single-Source Theorem establishes this not as an aesthetic claim but as a chain of derived results, each individually falsifiable. The key structural insight is that three computational routes to $K(\tau) \sim \cos(m_\kappa \tau)/\tau$ — retarded propagation, extended-source integration, and Caldeira–Leggett reduction — establish robustness of the kernel within the κ -field framework, and that this kernel uniquely forces the logarithmic growth underlying both inflationary dynamics and the white-noise bath structure.

As emphasised in the general-reader formulation, the result is not a simplification of physics but a reinterpretation: the diverse phenomena we observe correspond to different projections of a single underlying structure.

Multiplicity is emergent.

The underlying source is singular.

All observable structure is its projection.

13. Discussion of Scope and Limitations

The present work makes a strong structural claim — that all observables are functionals of a single field $\rho(x,t)$. We therefore address the scope and limitations of each component explicitly.

13.1 Is the single-source theorem tautological?

The closure statement has both analytic and substantive components (§8.1). The analytic component — that observables are functionals of ρ — follows from the constitutive principle that all physical distinguishability arises from irreversible commitment events. This is definitional within the VERSF framework.

The non-trivial content lies in the derived mappings:

$$\rho \rightarrow J(\omega) \rightarrow K(\tau) \rightarrow \kappa \rightarrow \{\text{cosmology, gravity}\}$$

The predictive power of the theory resides entirely in these specific functional forms, which are independently falsifiable (§11).

13.2 Is the spectral index derivation internal to VERSF?

The result $n_s - 1 = -2/N^*$ is obtained using the Mukhanov–Sasaki formalism as a calculational bridge. It is therefore not yet a fully internal derivation.

The result should be interpreted as a consistency check: the κ -field dynamics reproduce the observed scaling from a different physical origin (logarithmic growth $\delta_s \sim \ln N$). A complete derivation of the perturbation spectrum from κ -fluctuation statistics is identified as an open problem.

13.3 Is the gravitational coupling derived?

The emergence of Newtonian gravity depends on the ratio λ/m^2_κ . While m^2_κ is fixed by the $K = 7$ structure, λ is not yet independently derived.

The present result therefore establishes a reduction of gravitational dynamics to a single parameter. A fully predictive theory requires λ to be fixed by the same underlying structure; this is explicitly identified as a target for further work.

13.4 Is the logarithmic growth derivation self-consistent?

The quasi-static approximation used in §5.2 is valid under the conditions:

$$Ht \gg 1, H \ll m_\kappa$$

Under these conditions, the derivative terms remain subleading relative to the memory integral, and the scaling $\kappa(t) \sim \ln t$ is self-consistent. Outside this regime, the full nonlocal equation must be used.

13.5 Are the three kernel derivations independent?

Routes 1 and 3 share a common spectral input $J(\omega)$ and therefore test internal consistency of the open-system formulation. Route 2 provides a structurally distinct confirmation based on spatial propagation and light-cone geometry.

The convergence of these approaches establishes robustness, though not full independence.

13.6 Why is the $1/\tau$ kernel selected?

An exponential kernel is not excluded in general physical systems, but would require an additional infrared scale. Within VERSF, no such independent scale is introduced. The algebraic $1/\tau$ decay therefore represents the minimal causal behaviour consistent with the framework.

13.7 Does the theory fully reproduce general relativity?

The present work derives gravitational sourcing in the weak-field limit. The full covariant recovery of general relativity is deferred to a companion paper.

This should be understood as establishing the sourcing mechanism rather than replacing GR at the level of field equations.

13.8 Are all observables accounted for?

The present work demonstrates the single-source structure for: κ dynamics, $J(\omega)$, $K(\tau)$, n_s , H , and $\nabla^2\Phi$. The following are not addressed: the tensor-to-scalar ratio r ; the primordial amplitude A_s ; charge, spin, lepton and baryon number; gauge structure; and the weak and strong forces.

The claim $\mathcal{O} = \mathcal{A}[\rho]$ should therefore be understood as established for the dynamical, statistical, and gravitational sectors treated here, with the Standard Model force sector and remaining cosmological observables constituting explicit open problems for the programme.

Their absence does not invalidate the framework but identifies the current boundary of its predictive completeness.

Appendix: Summary of Notation

Symbol	Definition
$\rho(x,t)$	Committed record density
$\rho_0(x,t)$	Stable background (extremum of $F[\rho]$)
$\kappa(x,t)$	Fluctuation field: $\kappa = \rho - \rho_0$
$s(x,t)$	$\kappa(x,t)$ under retarded boundary conditions
$F[\rho]$	Commitment free energy (minimal admissible functional)
m^2_κ	Mass squared: $m^2_\kappa = F''(\rho_0) = (4/3)\xi^{-2}$
$J(\omega)$	Bath spectral density
$K(\tau)$	Memory kernel
$G_\kappa(x,\tau)$	Retarded Green's function of κ
Γ	Commitment event rate
$W_{\{K_7\}}(\omega)$	$K=7$ spectral weight
ξ	Microscopic commitment scale: $\xi = \rho_0^{-1/3}$
N^*	Number of inflationary e-folds
G	Emergent gravitational constant
Φ	Gravitational potential
ρ_{bound}	Coarse-grained commitment density
ρ_{void}	Void (uncommitted) energy density
ρ_{sr}	Slow-roll energy density
$T_{\mu\nu}$	Stress-energy tensor of κ -field

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