Serena Theory as a Pre-Dynamical Foundational Framework

Operational Language, Postulates and Falsification Program

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25 December 2025

Abstract

We present Serena Theory as a pre-dynamical foundational framework aimed at restricting the space of physically admissible dynamics. The framework introduces a minimal operational language—based on the operators of Coherence, Exchange, and Radiative Loss—and a set of restrictive postulates acting as admissibility filters. Quantization and causal geometry are not postulated, but rather formulated as emergent phenomena whose appearance constitutes an explicit falsification criterion for the framework.

1 Motivation and Scope

Serena Theory is neither a closed dynamical theory nor a direct alternative to General Relativity or Quantum Mechanics. Its purpose is prior in nature: to define minimal structural criteria that any physical dynamics must satisfy in order to generate observable persistence, interaction, and stability.

The Serena framework plays a role analogous to that of thermodynamics: it does not fix specific equations of motion, but severely constrains the space of physically admissible theories.

2 Ontological Substrate

Postulate 1 (Single Field). Every physically admissible dynamics is formulated in terms of a single continuous field Ψ defined over a spacetime manifold M.

Postulate 2 (Finite-Order Locality). The dynamics of the field is governed by local operators of finite order, allowing for nonlinear and higher-derivative terms compatible with the stability of bound configurations.

This postulate excludes purely linear models and prevents the trivial collapse of extended configurations (Derrick's theorem).

3 Inner Product and State Space

Definition 1 (Local inner product)**.** *There exists a bilinear form*

$$\langle \cdot, \cdot \rangle_{\mathrm{loc}} : V \times V \to \mathbb{C},$$

defined on the field state space, satisfying:

1. *Positive definiteness.*

2. *Invariance under the internal symmetries of the field.*

3. *Coercivity: control of a local norm of the field.*

4. *Compatibility with a conserved flux density.*

Remark 1. *The inner product does not define the spacetime metric. Lorentzian structure and causality emerge at the effective level from admissible field dynamics.*

4 Operational Language

4.1 Evolution Parameter

Remark 2. *The parameter t used in the following definitions acts as an auxiliary evolution parameter (laboratory time). Causal emergence does not create this parameter, but rather the effective physical causal structure associated with macroscopic dynamics.*

4.2 Coherence

Definition 2 (Coherence Operator)**.** *We define dynamical coherence as*

$$C[\Psi] := \lim_{T \to T_\Psi} \frac{1}{T} \int_0^T \langle \Psi(t), \overline{\partial_t \Psi(t)} \rangle_{\text{loc}} \, dt,$$

when the limit exists.

Postulate 3 (Persistence). Only configurations with $C[\Psi] > 0$ over macroscopic intervals are physically distinguishable.

4.3 Exchange

Definition 3 (Exchange Operator)**.** *The operator I quantifies the transfer of coherence and action between regions, scales, or modes of the field Ψ.*

Postulate 4 (Interaction). Every physical interaction corresponds to a process with $I \neq 0$. Completely sterile sectors are excluded.

4.4 Resolution and Radiative Loss

Definition 4 (Resolution Operator)**.** *Let R_Λ be a nonlinear coarse-graining operator compatible with the topology of coherent field configurations. We denote by $\Psi_\Lambda := R_\Lambda(\Psi)$ the part resolvable at scale Λ.*

Definition 5 (Effective Radiative Loss)**.** *We define*

$$R_\Lambda[\Psi; V, T] := \frac{1}{T} \int_0^T \left(\|\Psi - \Psi_\Lambda\|_V^2 + \|\partial_t \Psi - \partial_t \Psi_\Lambda\|_V^2 \right) dt + \frac{1}{T} \int_0^T \int_{\partial V} \Phi_{\text{rad}}(\Psi_\Lambda) \cdot dS \, dt.$$

Remark 3. *Radiative loss does not represent loss of the single field, but irreversible transfer of coherence toward non-resolvable degrees of freedom.*

Postulate 5 (Radiative Selection). Configurations whose dynamics irreversibly transfers coherence outside the resolvable subspace do not persist as effective states.

5 Causal Emergence

Postulate 6 (Causal Emergence). Any admissible dynamics possessing a stable macroscopic regime must induce an effective causal structure, allowing an emergent geometric description.

Remark 4. *Causality is not postulated at the microscopic level, but emerges as an effective ordering structure associated with stable macroscopic dynamics.*

6 Non-Vacuity of the Framework

Proposition 1. *The Serena framework excludes:*

1. *Purely linear dynamics without a spectral threshold.*

2. *Scale-invariant theories lacking a characteristic length.*

3. *Systems without separation between bound and continuous spectra.*

4. *Completely non-interacting sectors ($I \equiv 0$).*

These exclusions affect broad classes of mathematically consistent theories, demonstrating that the framework is non-trivial.

7 Existence of Admissible Dynamics

Theorem 1 (Existence). *There exists at least one class of nonlinear local dynamics (Skyrme-type or dissipative Ginzburg–Landau models) satisfying the postulates of the Serena framework and exhibiting:*

1. *Bound states with $C > 0$.*

2. *A radiative continuous spectrum.*

3. *Dynamical selection via radiative loss.*

Remark 5. *This result establishes existence, not universality.*

8 Discreteness Conjecture

Conjecture 1 (Serena Conjecture). *Under the postulates of the Serena framework, long-lived configurations organize into discrete families due to radiative stability and topology, without postulating fundamental quantization.*

Falsification of the framework occurs if no admissible dynamics satisfies this conjecture.

9 Locality and Correlations

The Serena framework assumes fundamental dynamical locality. Nevertheless, it does not exclude the emergence of non-factorizable correlations at the effective level as a consequence of extended coherent states and dynamical coarse-graining.

This stance allows structural compatibility with Bell-type phenomena without introducing fundamental non-locality.

10 Falsification Program

The Serena framework is falsified if:

1. No admissible dynamics exhibits stable discrete states.

2. Radiative selection fails to eliminate unstable configurations.

3. No effective causality emerges in any macroscopic regime.

11 Conclusion

Serena Theory defines a restrictive grammar for fundamental physics. It does not postulate gravity or quantization: it demands that any dynamics capable of describing the universe generate them structurally.

The value of the framework lies in its exclusion power, not in the promise of predefined results.