BOX ONTOLOGY

A channel-permeability framework for persistent boundaries across physics, biology, logic, and simulation

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Abstract

This manuscript formalizes a simple but ambitious idea: a box is not primarily a shape, container, or shell, but a persistent boundary with channel-specific permeability. The same formal object can then be used to discuss causal patches in cosmology, membranes in protocell models, epistemic or logical boundaries, and synthetic agent-based simulations. The core state of a box is represented by a boundary, a permeability vector, a persistence timescale, and a distinction strength between inside and outside. From these quantities we derive box depth, directional asymmetry, nesting relations, and simple birth, merge, split, and collapse rules. The paper then maps the framework to known boundary concepts in inflationary cosmology and origins-of-life discussions, while making clear that those mappings are interpretive rather than established physical law. Finally, a sequence of increasingly rich toy simulations is presented: a static channel model, a nested directional model, a corrected spatial ecology, a quiet suppression regime, and a resilience regime with repeated splits and merges. The strongest claims in the paper are definitional and internal to the formalism. The simulation results demonstrate internal coherence and generative power, not empirical confirmation.

Absolute as far as possible

The paper separates five levels of claim. Level A: definitions fixed by stipulation inside the formalism. Level B: propositions that follow directly from those definitions. Level C: interpretive mappings to known scientific boundaries. Level D: behaviors observed in the toy simulations. Level E: external empirical claims, which are not established here. Only Levels A and B are treated as near-absolute inside the manuscript.

1. Scope and motivation

The motivating intuition is that many systems generate an inside-outside distinction before they generate a hard wall. An inflationary causal patch, a protocell membrane, a semantic filter, and a social boundary all differ in mechanism, yet each can be analyzed by asking the same question: what crosses, in which direction, and for how long?

The point of Box Ontology is not to erase scientific differences. The point is to create a minimal vocabulary that can describe boundary formation without assuming from the outset that every boundary is geometric, material, or perfectly closed.

Once a box is described by channels, persistence, and asymmetry, the same algebra can be used in toy cosmology, toy origins-of-life models, and synthetic adversarial ecologies.

1.1 Claim classification

Class	Status in this paper	Meaning
A	Strongest	Definitions fixed by stipulation.
B	Strong	Direct consequences of the definitions and metrics.
C	Interpretive	Mappings to physics, biology, and logic.
D	Internal model evidence	Behaviors obtained in the simulations.
E	Not claimed	External confirmation, prediction, or measurement.

2. Formal definitions

Let a box B be represented by the tuple B = (∂B, Pi, tau, Sigma), where ∂B is a boundary, Pi is a channel-permeability state, tau is a persistence timescale, and Sigma is a distinction-strength parameter measuring the operational difference between inside and outside.

The permeability state is channel-wise rather than scalar. In the base version of the framework we use six channels: matter (m), radiation (r), signal or causal influence (s), gravity (g), quantum correlation (q), and topology or structural transfer (t).

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Pi(B) = (P_m, P_r, P_s, P_g, P_q, P_t), with each P_i in [0, 1].

D(B) = sum_i w_i (1 - P_i).

A(B) = sum_i a_i |P_i(out) - P_i(in)|.
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A box is called true, in the internal language of the framework, when Sigma > 0 and tau exceeds a minimal threshold tau_c. This does not mean metaphysical truth; it only means that the distinction is persistent enough to matter.

2.1 Channel semantics

Channel	Symbol	Interpretation
Matter	m	Transport of material carriers or conserved entities.
Radiation	r	Propagation of radiative or visibly transmissible content.
Signal / causal	s	Ability of influence to cross in operational time.
Gravity	g	Residual geometric or field coupling.
Quantum	q	Nonclassical correlation or entanglement-like linkage.
Topology / structure	t	Transfer of connectivity, shape, or structural memory.

2.2 Derived propositions

Proposition 1. If all P_i = 1 and Sigma = 0, the object is a no-box state rather than a meaningful boundary.

Proposition 2. If at least one channel satisfies P_i < 1 and the distinction persists, the inside-outside separation is operational.

Proposition 3. Box depth and directional asymmetry are logically independent: a box can be deep but nearly symmetric, or shallow but strongly one-way.

Proposition 4. Nesting is admissible when the state of a child box is constrained by a parent box along one or more channels.

3. Mapping to known boundary concepts

The framework is easiest to understand when mapped to pre-existing scientific boundary types. These mappings are interpretive; they do not imply that standard cosmology or origins-of-life work already uses the Box Ontology notation.

In inflationary cosmology, the Hubble radius is a useful operational scale but is not itself a strict horizon. Particle, visual, and event horizons must be distinguished carefully [1]. In de Sitter space, a single observer is enclosed by a finite cosmological horizon that limits the classically accessible region [2].

In origin-of-life work, LUCA is not treated as the first boundary-like living system. Current work places LUCA as an already complex, ecologically embedded stage of evolution, while membrane-bounded protocell models and fatty-acid vesicles are studied as plausible earlier compartmental forms [3, 4].

Example boundary	Best box reading	Status
Coordinate window	Purely symbolic box	Definitional
Hubble patch	Weak operational box	Interpretive
Particle horizon	True causal box	Interpretive
Visual horizon	Photon-opacity box	Interpretive
de Sitter/event horizon	One-way classical box	Interpretive
Bubble/domain wall	Shell-like wall box	Model-dependent
Fatty-acid vesicle / protocell	Compartmental box	Interpretive

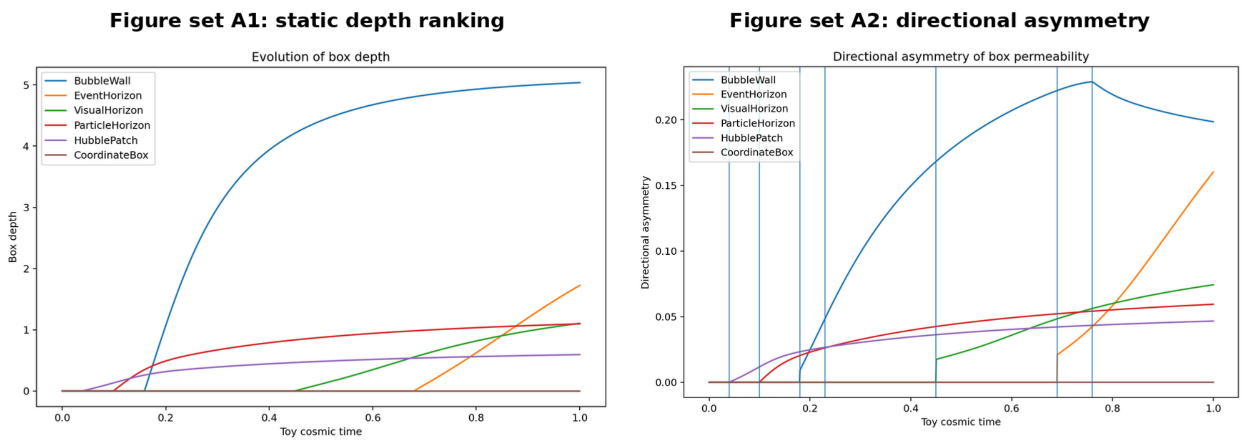

Figure 1. Static depth ranking (left) and directional asymmetry (right) from the first two simulation stages. The pair shows that depth and asymmetry are distinct axes of box behavior.

4. Simulation program

To test whether the formalism can generate nontrivial dynamics, a progression of toy models was built. Each model increases the number of state variables or interaction rules while keeping the interpretation stable.

Stage v1 treats named boxes as static types with time-evolving channel permeability. Stage v2 introduces nesting and inward versus outward permeability. Stage v3c moves to a corrected spatial agent-based ecology. Stage v4 adds visibility-targeted suppression. Stage v4c adds stronger fragmentation and merge behavior.

Stage	Main addition	Key event counts	Final survivors	Interpretation
v1	Static channel model	no event logic	-	Depth ranking
v2	Nested directional model	no event logic	-	Asymmetry and parent constraints
v3c	Corrected spatial ecology	5 nucleations, 21 collisions, 1 merge	4	Stable multi-box ecology
v4	Visibility-targeted suppression	5 nucleations, 2 collapses	3	Quiet adversarial regime
v4c	Resilience regime	7 splits, 7 child births, 7 merges	5	Persistent lineages under pressure

4.1 Method notes

All simulations are toy models. Time is compressed into a dimensionless interval rather than calibrated to a physical clock. The weights in the depth metric are chosen by design for readability and do not correspond to measured couplings.

The suppression models contain a latent truth tag only as an internal marker. The suppressor does not use that tag as an input. In the model, attack is keyed to visibility, size, asymmetry, and location, not to correctness.

5. Results

5.1 Corrected spatial ecology

The corrected spatial ecology (v3c) produced 5 nucleations, 21 collisions, 1 merge, and 4 surviving boxes at the final frame.

The main qualitative point is that a multi-box ecology can remain stable without collapsing into one giant region. Distinct boxes drift, interact, and occupy separate domains while maintaining appreciable depth.

Figure set B1: corrected spatial population

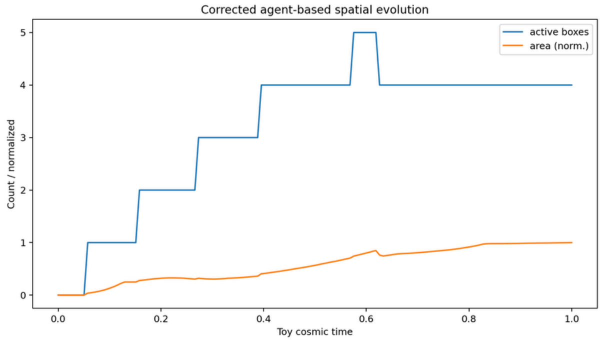

Figure set B2: final owner regions

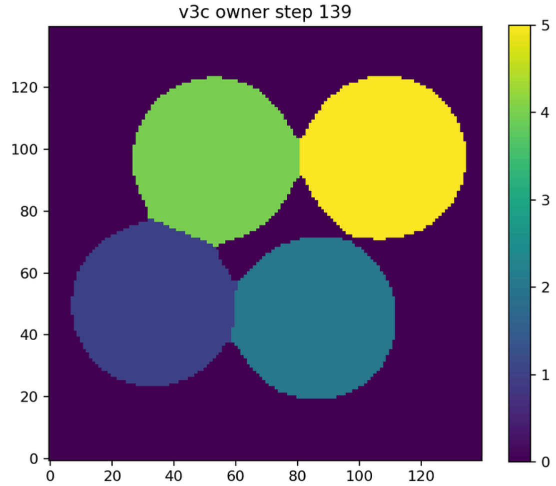

Figure 2. Corrected spatial ecology. Left: the number of active boxes rises and then stabilizes. Right: the final ownership map shows four large surviving regions rather than universal merger.

5.2 Suppression and resilience

In the quiet suppression regime (v4), the model generated 5 nucleations and 2 collapses, finishing with 3 surviving boxes. This regime demonstrates attrition without large-scale fragmentation.

In the resilience regime (v4c), the model generated 5 nucleations, 11 collisions, 7 splits, 7 child births, and 7 merges, while retaining 5 active boxes at the end.

Taken together, the two regimes show that visibility-based pressure does not have a single universal effect. Depending on thresholds, it can either thin the ecology quietly or force a lineage-rich cycle of splitting and recombination.

Figure set C1: quiet suppression regime

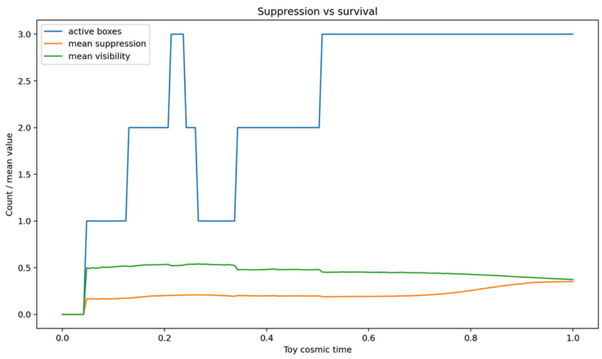

Figure set C2: resilience regime

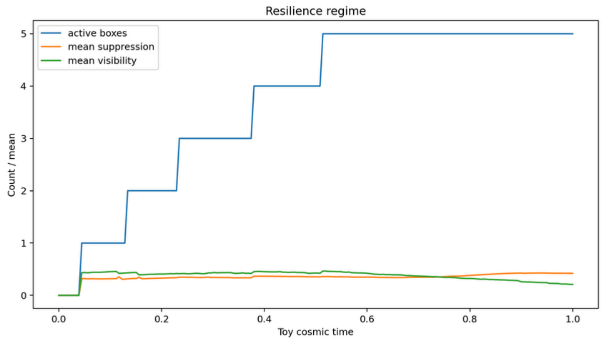

Figure 3. Two adversarial regimes. The quiet regime (left) mainly thins the ecology. The resilience regime (right) supports a larger standing population under comparable mean suppression by allowing repeated fragmentation and recombination.

6. Interpretation

The simulations support three internal conclusions. First, box depth is a useful coarse variable: it orders boundaries in a way that is easy to compare across model stages. Second, directional asymmetry is genuinely separate from depth. Third, lineage and ecology matter: once boxes can move, split, and merge, the population-level behavior cannot be inferred from a single isolated boundary.

The most interesting philosophical result is that a boundary can be real without being absolute. A box may be soft, leaky, one-way, transient, nested, or merely operational, and still matter. That is one reason the framework can bridge between physics and logic: both domains often care less about perfect closure than about constrained access.

The most important scientific caution is that internal coherence is not empirical proof. A toy simulation can show that a vocabulary is fertile and self-consistent without showing that nature uses its exact variables.

7. Limitations and falsifiability

This manuscript does not claim a new law of cosmology, a new origin-of-life theory, or an experimentally validated account of social suppression. It offers a formal language and a family of toy models.

The mapping from Hubble patch to box type is heuristic, because the Hubble radius is not a strict causal horizon in the same sense as a particle horizon [1]. Likewise, the mapping from protocell membranes to box dynamics is suggestive rather than exhaustive [4].

The truth tag in the suppression models is intentionally latent. Because it is not used by the suppressor, the model can illustrate attacks on visibility rather than correctness. However, aggregated observables may still correlate with the truth tag through co-location, survival bias, or lineage composition. The design therefore supports a causal statement about the rule, not a universal statistical statement about every output.

Falsifiability in the narrow sense comes in two layers. The formalism can be falsified internally if its metrics fail to distinguish cases they are supposed to separate. Its scientific usefulness can be falsified externally if the mappings never lead to tractable predictions, discriminating measurements, or tighter explanations than existing boundary vocabularies.

8. Conclusion

Box Ontology starts from a minimal claim: a boundary should be described by what crosses it, in what direction, and for how long. From that starting point, a compact framework emerges that is expressive enough to talk about causal patches, membranes, epistemic filters, and adversarial ecologies.

The strongest outcomes of the paper are definitional and structural. The weaker but still useful outcomes are the simulation behaviors: stable depth rankings, asymmetric boxes, persistent spatial ecologies, quiet suppression, and resilience through fragmentation.

The next decisive step would be to connect the framework to a calibrated field model or observational target. Until then, the paper should be read as a rigorous proposal rather than a confirmed theory.

References

[1] G. F. R. Ellis and J.-P. Uzan, 'Causal structures in inflation', Comptes Rendus Physique 16 (2015) 928-942.

[2] D. Anninos, 'De Sitter Musings', International Journal of Modern Physics A 27 (2012) 1230013.

[3] E. R. R. Moody et al., 'The nature of the last universal common ancestor and its impact on the early Earth system', Nature Ecology & Evolution 8 (2024).

[4] A. Lopez and M. Fiore, 'Investigating prebiotic protocells for a comprehensive understanding of the origins of life: a prebiotic systems chemistry perspective', Life 9 (2019) 49.

Appendix A. Reproducibility inventory

The manuscript is based on the simulation files generated in this session. The principal artifacts are: box_permeability_simulation_summary.csv, box_ontology_v2_summary.csv, box_ontology_v3c_agent_stats.csv, box_ontology_v4_suppression_stats.csv, and box_ontology_v4c_resilience_stats.csv, together with the associated plots reproduced as Figures 1-3.

Because these are toy models, exact outcomes depend on the chosen update rules and random seeds. Reproducibility therefore means replaying the same design choices, not claiming universality across parameter space.