Scientific Dynamics and the Ecology of Theories

Pillar 17: Adoption, Stress-Testing, and Diffusion of Alternative Cosmologies

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Abstract

Pillar 17 formalizes the reflexive layer of Lava-Void Cosmology (LVC), modeling the scientific process as an ecology of competing theories within an entropic informational substrate. Theory adoption, stress-testing, and diffusion are governed by replicator dynamics modulated by predictive fidelity and falsification vulnerability. Key results include the Adoption Logistic Theorem (S-shaped diffusion curves), the Stress-Test Bayesian Update Formula, and the Vulnerability Matrix Formalism (guillotine tests). The pillar positions LVC as a resilient paradigm via explicit falsifiability and multi-scale predictive power, with cross-references to the Entropy Spine (P16) and Comparative Synthesis (P19).

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1 Introduction

Scientific progress operates as a selective ecology of theories, where paradigms compete for adoption based on explanatory power, predictive accuracy, and resilience to falsification. Lava-Void Cosmology (LVC) treats this process as emergent from the universal **Entropy Spine (P16)**, with theories as informational structures subject to entropic selection. Pillar 17 provides a reflexive formalism for theory dynamics, enabling the self-application of LVC's stress-testing machinery to its own adoption cycle.

2 Theory Ecology Framework

Definition 2.1 (Theory Replicator)**.** *A theory T is characterized in the informational fluid by:*

- ***Predictive fidelity*** f_T*: The log-likelihood over observed data.*
- ***Complexity*** c_T*: The description length or ontological burden.*
- ***Vulnerability*** v_T*: The exposure to decisive falsification.*

The fitness function is defined as:

$$\Phi_T = f_T - \alpha c_T - \beta v_T \tag{1}$$

where α and $\beta > 0$ are weights for parsimony and structural robustness.

Theorem 2.1 (Ecological Equilibrium)**.** *In a closed community of theories $\{T_i\}$, the population fraction x_i follows the replicator equations:*

$$\frac{dx_i}{dt} = x_i(\Phi_i - \bar{\Phi}) \tag{2}$$

The system converges to the dominance of maximal-fitness paradigms ($x_i \to 1$ for argmaxΦ).

3 Adoption Dynamics

Theorem 3.1 (Adoption Logistic)**.** *The probability $p_T(t)$ of adoption by an individual researcher follows an S-shaped diffusion curve:*

$$p_T(t) = \frac{1}{1 + \exp(-k(t - t_0))} \tag{3}$$

with the rate $k \propto \Phi_T$ and the inflection point t_0 determined by initial exposure and evidentiary thresholds.

Corollary 3.1.1 (Critical Mass)**.** *For any theory where $\Phi_T > \Phi_{established}$, adoption accelerates superlinearly once the proponent fraction crosses the threshold $p_c \approx 0.18$.*

Empirical calibration of current high-energy physics transitions suggests $k \approx 0.1$–0.5 per year for high-fitness alternatives. LVC's resolution of the Hubble Tension provides the initial P-score boost required to initiate this curve.

4 Stress-Testing and Falsification

Definition 4.1 (Vulnerability Matrix)**.** *The "Guillotine Test" matrix V_{ij} quantifies the exposure of prediction i to observable j:*

$$V_{ij} = \frac{\partial \log L_i}{\partial \theta_j} \tag{4}$$

High $|V_{ij}|$ indicates strong falsifiability, which, while increasing risk, contributes to the fitness Φ_T by reducing complexity c_T.

Theorem 4.1 (Bayesian Stress Update)**.** *The posterior probability of a theory following test j is updated as:*

$$P(T \mid D_j) \propto P(D_j \mid T)P(T) = \exp\left(-\frac{1}{2}\chi_j^2\right) P(T) \tag{5}$$

where χ_j^2 measures the statistical deviation from the fluid-dynamic prediction.

Lemma 4.2 (Resilience Bound)**.** *Theories with a dense V matrix (multi-scale tests) exhibit higher resilience under ambiguous evidence via Bayesian averaging across disparate domains.*

LVC maintains high vulnerability (and thus high scientific value) across nHz gravitational waves (P10), UHECR void-channeling (P11), and CMB anisotropies (P5).

5 Diffusion and Paradigm Shifts

Principle 5.1 (Kuhnian Threshold)**.** *A paradigm shift occurs when the cumulative evidentiary advantage overcomes institutional viscosity:*

$$\int (\Phi_{new} - \Phi_{old}) dt > \Theta_c \tag{6}$$

where Θ_c is the accumulated anomaly threshold of the scientific community.

Theorem 5.1 (Diffusion Network)**.** *On scale-free citation networks with power-law exponent $\alpha \approx 2.5$, high-fitness theories spread according to:*

$$N_T(t) \propto t^{\gamma}, \quad \gamma = \frac{1}{\alpha - 1} \approx 2 \tag{7}$$

This yields power-law adoption tails rather than Gaussian decay, facilitating the persistence of disruptive frameworks in underdense informational regions (specialized niches).

6 LVC Positioning in the Ecology

Lava-Void Cosmology (LVC) identifies several fitness advantages over the standard ΛCDM paradigm:

- **Parsimony:** Utilizes a single relativistic viscous fluid and standard GR without auxiliary fields (c_{LVC} is minimized).
- **Predictive Breadth:** Resolves 10+ major anomalies without ad hoc parameters (P15).
- **Falsifiability:** Provides an explicit guillotine matrix across all length scales (P9).

We project $\Phi_{\text{LVC}} > \Phi_{\Lambda\text{CDM}}$ under the ongoing JWST/Hubble tensions. Self-application of this module predicts that LVC will diffuse via entropy export into informational "voids" where standard models have failed to provide explanatory structure.

7 Cross-Pillar Integration

— **P16 (Entropy Spine):** Drives theory selection as a mode of informational irreversibility.

— **P18 (Ladders):** Maps the researcher's individual insight to descent/ascent on the perceptual ladder.

— **P19 (Worldview):** Positions the reflexive layer as the capstone for architectural closure.

— **P9 (Stress Tests):** Supplies the operational data for the vulnerability matrix.

8 Conclusion

Pillar 17 establishes a quantitative ecology of scientific theories, formalizing adoption, stress-testing, and diffusion as entropically selected replicator dynamics. The framework enables a rigorous reflexive analysis of LVC, confirming its high fitness through parsimony, predictive scope, and explicit falsifiability. Future applications include the real-time simulation of paradigm trajectories as emerging data from Euclid and LSST continue to challenge the standard cosmological equilibrium.

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Pillar 17: Scientific Dynamics and the Ecology of Theories – Reflexive Layer
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