L0–L3 Regime Architecture in Entropy-Bounded Empiricism

A Foundational Framework for Energy-Flow Cosmology

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Abstract

This document defines the L0–L3 regime architecture underlying Entropy-Bounded Empiricism (EBE) in Energy-Flow Cosmology (EFC). The framework distinguishes four operational regimes: L0 (latent potential), L1–L2 (active/life phase), and L3 (residual structure), connected by phase-extended transitions. This architecture prevents *regime leakage*—the misapplication of inference rules across incompatible dynamical phases. While developed for cosmological modeling, the framework applies to any system governed by energy flow, entropy gradients, and informational constraints. The regime structure clarifies when empirical inference remains valid and when it breaks down due to phase boundaries or deactivation. This is a foundational concept document intended as a reference for EBE/EFC research and as a supplement to full publications.

Keywords

Entropy-bounded empiricism • Regime architecture • Energy-flow cosmology • Phase transitions • L0–L3 framework • Entropy gradients • Dynamical inference • System boundaries • Cosmological epistemology

Categories

Theoretical Physics • Cosmology and Nongalactic Astrophysics • Complex Systems • Philosophy of Science • Systems Theory

Funding Statement

Competing Interests

1. Introduction

To make the logic of Entropy-Bounded Empiricism (EBE) explicit, it is necessary to define the regime structure that underlies inference in Energy-Flow Cosmology (EFC). This structure describes how systems transition from latent potential through active phases and into residual structure. The architecture is not limited to cosmology and applies to any system governed by energy flow, entropy gradients, and informational constraints.

The framework consists of four regimes (L0, L1, L2, L3) with phase-extended transitions rather than instantaneous boundaries. Each regime represents a distinct operational mode, and transitions between regimes are governed by thresholds in energy flow, structural stability, and entropy production.

2. Regime Definitions

2.1. L0 — Latent Regime

L0 represents latent potential. Structure exists, but it is not activated as a self-sustaining process. There is no active dynamics, no historical path, and no life-phase behaviour. The regime defines a space of possibility rather than an operating system.

Key characteristics of L0:

• Potential structure without active energy flow

• No self-maintenance or operational dynamics

• Configuration space rather than trajectory space

• May serve as initial conditions for activation

2.2. Transition L0 $\rightarrow$ L1 — Activation

The transition from L0 to L1 is a phase-extended activation, not a discrete jump. Energy flow, structural coupling, and information exchange gradually exceed critical thresholds. The system moves from latent configuration to active operation as boundary conditions permit sustained dynamics.

This transition is characterized by:

• Gradual increase in energy throughput

• Emergence of feedback mechanisms

• Formation of stable operational modes

• Crossing of critical coupling thresholds

2.3. L1–L2 — Active (Life) Regime

This is the operational phase of the system. L1 corresponds to stable, low-entropy operation with predictable dynamics. L2 introduces non-linear interactions, local sensitivity, and structural formation. The distinction between L1 and L2 is functional rather than categorical—both represent active phases with different complexity levels.

L1 characteristics:

• Stable energy flow and low entropy production

• Predictable dynamics with minimal sensitivity

• Efficient operation near equilibrium

• Clear boundary conditions and conserved quantities

L2 characteristics:

• Non-linear dynamics and structural complexity

• Local sensitivity and emergent patterns

• Higher entropy production than L1

• Formation of hierarchical organization

2.4. Transition L2 $\rightarrow$ L3 — Deactivation

As energy flow and structural stability decline, active dynamics can no longer be sustained. This transition closes the active phase without implying abrupt collapse. The system enters a phase where operational dynamics cease but structural residues remain.

Deactivation occurs when:

• Energy throughput falls below maintenance thresholds

• Feedback mechanisms no longer sustain coherence

• Structural coupling weakens or breaks down

• System transitions from process to residue

2.5. L3 — Residual Structure / Memory Regime

L3 consists of structured residues rather than active processes. It includes information without ongoing dynamics, history without self-maintenance, and structure without operational flow. L3 may act as potential input for future L0 conditions, completing the regime cycle. **The L0–L3 architecture is cyclical rather than linear**: residual structure from one system's L3 phase can serve as latent configuration (L0) for subsequent activation cycles.

L3 is characterized by:

• Persistence of structure without active maintenance

• Information encoded in configuration but not in process

• No operational energy flow or entropy production

• Potential substrate for future activation (new L0 state)

3. The Entropy-Bounded Empiricism Principle

EBE is based on a foundational principle: **inference is valid only within the regime where data and dynamics remain consistent**. Making the L0–L3 architecture explicit prevents three critical errors:

• **Regime leakage:** Applying L1 inference rules to L2 dynamics or vice versa

• **Invalid extrapolation:** Projecting active-phase models into L0 or L3 regimes

• **Residue misinterpretation:** Treating L3 structure as if it represents active dynamics

The regime architecture ensures that:

• Observational data is interpreted within the correct dynamical context

• Phase transitions are recognized as boundaries of inference validity

• Residual structure (L3) is not confused with operational dynamics (L1-L2)

• Latent potential (L0) is not treated as if it has a causal history

4. Applications Beyond Cosmology

While developed in the context of Energy-Flow Cosmology, the L0–L3 framework applies to any system with:

• Bounded energy flow and entropy gradients

• Phase transitions between operational regimes

• Structural formation and decay processes

• Informational constraints on dynamics

Example domains include:

• Biological systems (development, metabolism, aging, death)

• Ecological dynamics (community formation, succession, collapse)

• Economic systems (growth, stability, recession, restructuring)

• Cognitive processes (learning, operation, memory consolidation)

• Technological systems (design, operation, obsolescence)

5. Theoretical Implications

The L0–L3 regime architecture has several important implications for scientific inference:

5.1. Boundary Recognition

Scientific models must explicitly recognize when they cross regime boundaries. A model valid in L1 cannot be automatically extended to L2 without verifying that the underlying assumptions remain consistent with the new dynamical regime.

5.2. Historical vs. Structural Inference

In L3, structure persists but process does not. This means that L3 residues can provide information about *what happened* (structural traces) but not about *what is happening* (active dynamics). Inference about historical events from L3 structure requires different methods than inference about ongoing L1-L2 processes.

5.3. Predictive Limits

Prediction is only reliable within the regime where the model was validated. Crossing into a new regime—particularly the L2→L3 transition—introduces fundamental uncertainties that cannot be resolved by adding more data within the original regime.

6. Usage Notes

This document serves multiple purposes:

• **Conceptual reference:** Defines the core architecture of EBE for research contexts

• **Methodological foundation:** Provides structure for regime-based inference methods

• **Educational resource:** Introduces entropy-bounded reasoning to new researchers

• **Publication supplement:** Can accompany full EFC research papers as foundational material

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7. Related Work

This document is part of the Energy-Flow Cosmology (EFC) research program. Related publications and resources:

• Full EFC framework papers (forthcoming)

• Applications to cosmological structure formation

• EBE methodology and validation studies

• Comparative analysis with standard cosmological models

For updates and additional resources, see the author's ORCID profile: https://orcid.org/0009-0002-4860-5095

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