Toward a Self-Regulated Cosmological Model

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Abstract

We propose a conceptual framework for a self-regulated cosmological model in which the Universe emerges from a pre-physical limit state referred to as Absolute Chaos. This state is defined ontologically rather than dynamically: it admits no distinctions, no relations, no temporal ordering, and no physical degrees of freedom. We argue that such a state is maximally stable from a structural perspective while being ontologically unstable, which necessitates a non-temporal rupture introducing the first irreversible distinction.

Following this rupture, a notion of mediation is introduced as a minimal condition allowing distinctions to coexist without collapsing back into indifferentiation. Time is not assumed a priori; instead, the arrow of time is interpreted as emerging from the appearance of ontologically irreversible processes. To illustrate these ideas, we explore a minimal local dynamics on a two-dimensional lattice, where the irreversible saturation of a mediation-related variable produces a binary ontological freeze. The freeze is not a dynamical field but a derived state encoding the loss of relational capacity.

Numerical simulations show that this mechanism robustly leads to a stationary, partially frozen regime without fine-tuning, independent of initial conditions. While no quantitative cosmological predictions are claimed at this stage, the model suggests a possible route toward understanding self-regulation, irreversibility, and the emergence of temporal order as consequences of ontological constraints rather than fundamental dynamical laws.

Contents

Introduction

Contemporary cosmology describes with remarkable precision the evolution of the Universe from its earliest moments to the present epoch. The standard cosmological model successfully accounts for cosmic expansion, structure formation, and the global energetic content of the Universe. However, beyond parameter fitting, several fundamental questions remain open, in particular those concerning the conceptual origin of space, time, and the physical laws themselves.

Most existing approaches postulate an initial state that is already structured: a mathematical singularity, quantum fluctuations of a vacuum, a pre-geometric phase described by an effective theory, or a landscape of initial conditions. In all cases, a physical, logical, or mathematical framework is assumed to pre-exist the observable Universe. This work explores a more radical hypothesis: that the ultimate origin does not correspond to a specific physical state, nor to a metaphysical “nothingness,” but rather to a limit state defined by the total absence of structure, distinction, and law.

To formalize this idea, we introduce the concept of *Absolute Chaos*, defined not as a dynamical or turbulent disorder, but as an ontological state of complete equivalence in which no property, relation, or measure can be defined. This state does not constitute a physical state in the usual sense; instead, it serves as a conceptual limit intended to formalize the complete absence of any prior framework for physical description. By construction, it admits neither dynamics, nor geometry, nor causality.

The central hypothesis of this work is that such a limit state, although devoid of any structure, cannot persist as such. This is not due to an internal physical mechanism—since none is defined—but to a fundamental ontological instability: the total absence of structure provides no condition for persistence. This conceptual tension constitutes the primary motor of the model. We argue that it makes the emergence of a first distinction necessary, conceived not as a random fluctuation, but as a minimal logical rupture.

From this rupture, we develop a genealogical framework in which mediating structures emerge as a matter of conceptual necessity. These structures localize and intertwine the opposing principles issued from the rupture—erasure and plenitude—and give rise to a primitive discrete architecture, which acts as a precursor to cosmological dynamics. Time and history are not presupposed; rather, they emerge jointly with the loss of symmetry and the appearance of irreversible processes.

This work does not aim to propose a complete cosmological theory, nor a direct alternative to the standard model. Its objective is to establish a coherent generative framework linking ontology, geometry, and cosmological dynamics, and to identify mechanisms capable of producing, without explicit fine-tuning, some of the global properties observed in the Universe. The developments presented here should be understood as a first conceptual step, to be complemented by more detailed analytical and numerical analyses.

Related approaches and positioning. Several approaches have explored the possibility that physical laws may emerge from discrete or automaton-like structures, notably in the context of digital physics and cellular automata [1, 2]. While the present work also relies on local update rules defined on a discrete substrate, it differs fundamentally from these approaches in its ontological status: the dynamics introduced here is explicitly non-fundamental and serves only as an effective realization of mediation loss.

Related ideas concerning the emergence of physical structure from pre-physical or informational principles have also been proposed, for instance in Wheeler's "It from Bit" paradigm and in Tegmark's Mathematical Universe Hypothesis [3, 4]. The notion of Absolute Chaos introduced in this work should however be understood as an ontological limit devoid of any prior mathematical or informational structure.

Structure of the paper. Chapter 1 introduces the formal definition of Absolute Chaos and analyzes its stability properties. Chapter 2 examines the necessary emergence of a mediating structure and its primitive geometry. Chapter 3 discusses the conceptual and methodological limits of the proposed framework. Finally, Chapter 4 explores, in a generative and exploratory spirit, the dynamical consequences of this initial structure, in particular in connection with effective cosmology and the emergence of a dark-energy-like component.

1 Formal definition of Absolute Chaos and notions of stability

1.1 Rigorous definition of Absolute Chaos

1.1.1 Set-theoretic and topological approach

We define *Absolute Chaos* as a limit ontological concept characterized by the absence of any structure, distinction, or relation. This definition is not intended to introduce a physical state, but to formalize rigorously the idea of a state prior to any differentiation.

Set-theoretic definition. Let X be an abstract set representing the set of potential distinctions. We define a universal equivalence relation on X by

$$\forall x \sim y \qquad \forall x, y \in X.$$

Absolute Chaos is then defined as the quotient space

$$C = X/\sim,$$

and, by construction, C contains a single element, denoted

$$C = \{*\}.$$

This formulation captures the central idea that, in Absolute Chaos, any distinction is impossible: all potential elements are identified.

Ontological status. It is essential to emphasize that C is not defined as a physical space, nor as a state space in the sense of statistical physics or quantum theory. It is an abstract conceptual object intended to represent the complete absence of differentiation. No dynamics, metric, causality, or reversible structure can be assigned to it.

Minimal topological structure. We endow C with the trivial (indiscrete) topology

$$\tau_C = \{\varnothing, C\}.$$

This topology has the following properties:

- **No separation:** there is no topological distinction between the points (the set being trivial);
- **Maximal connectedness:** the only open set is C itself;
- **Trivial compactness:** every open cover admits a finite subcover.

Conceptual consequence. This minimal topology does not constitute a physical space, but a coarse relational representation: the absence of spatial or relational structure. It thus describes the concept of absolute indifferentiation, where even the notion of *being* is indistinguishable.

In this sense, Absolute Chaos should not be interpreted as a dynamical disorder, but as an ontological limit from which any physical structure must necessarily emerge.

1.1.2 Minimal algebraic structure

Defining Absolute Chaos as a space reduced to a single element immediately implies the absence of any non-trivial algebraic structure. The purpose of this section is not to enrich C with additional mathematical properties, but rather to show that any attempt to do so necessarily leads to degenerate structures.

Groups and operations. Any binary operation defined on $C = \{*\}$ is necessarily trivial:

$$* \circ * = *.$$

Accordingly, C can be formally endowed with the structure of a trivial group. However, this structure encodes no dynamics, no effective symmetry, and no exploitable information. It merely reflects the logical impossibility of defining distinct elements.

Logical and Boolean structures. Similarly, any logical or Boolean algebra defined on C is degenerate. Fundamental distinctions such as true/false or yes/no do not correspond to any separation within C, but arise as artifacts of the metalanguage used to describe it. In this sense, such structures are not immanent to Absolute Chaos, but imposed externally.

Categorical perspective. In categorical terms, C may be described as a category with a single object and a single morphism (the identity). Once again, this description provides no additional dynamical or relational information: it simply formalizes the total absence of non-trivial morphisms.

Status of these descriptions. It is important to emphasize that these minimal algebraic structures do not confer any positive physical or ontological property to Absolute Chaos. They serve only to establish an upper bound: any admissible mathematical structure is necessarily degenerate. Absolute Chaos therefore possesses no intrinsic algebraic structure; consequently, any meaningful algebraic organization must emerge at a later stage, following an ontological rupture, rather than being postulated at this level.

1.1.3 Absence of differential and metric structure

Defining Absolute Chaos as a space reduced to a single element implies the impossibility of attributing to it any non-trivial differential or metric structure. This impossibility is not a modeling choice, but a direct consequence of the absence of internal distinction.

Absence of a meaningful metric. Any distance function $d : C \times C \to \mathbb{R}$ defined on $C = \{*\}$ necessarily satisfies

$$d(*, *) = 0.$$

Such a distance does not allow one to define proximity, separation, or scale. It supports no notion of length, trajectory, or variation. In particular, no exploitable geometric structure can be constructed from a degenerate metric of this kind.

Absence of differential structure. The construction of a differential structure presupposes the existence of distinguishable neighborhoods and infinitesimal directions. In Absolute Chaos, these notions are devoid of meaning. The tangent space at $*$ is reduced to the null space:

$$T_*C = \{0\}.$$

Consequently, no vector fields, derivatives, flows, or intrinsic differential equations can be defined on C.

Status of measures. Although it is formally possible to define measurable functions on a singleton, such constructions carry no physically or geometrically relevant information in the context of Absolute Chaos. In the absence of observables, distinguishable regions, or processes, the very notion of measure plays no operational role. Any numerical assignment must therefore be understood as an artifact of formalism, rather than as an ontological property.

Conceptual consequence. The joint absence of metric, differential structure, and measure implies that no continuous dynamics can be defined at the level of Absolute Chaos. There exist no trajectories, no parameterized evolution, and no locality. Any physical dynamics must necessarily emerge following an ontological rupture, accompanied by the appearance of distinctions, relations, and non-degenerate structures. In this sense, Absolute Chaos constitutes a pre-differential and pre-geometric state, which can only be described as a conceptual limit preceding any effective physical description.

1.1.4 Absence of physical properties

Defining Absolute Chaos as a state without distinction, relation, or structure implies the absence of any physical property in the usual sense. This absence is not the result of a dynamical annihilation, but the direct consequence of the non-existence of any framework necessary for the definition of physical quantities.

In particular, notions such as energy, entropy, temperature, density, or pressure cannot be intrinsically defined in Absolute Chaos. These quantities presuppose the existence of observables, degrees of freedom, spatial or temporal relations, and a framework of measurement—all of which are excluded by construction.

When one formally writes

$$E(C) = 0, \qquad S(C) = 0, \qquad \rho(C) = 0,$$

such expressions should not be interpreted as physical values, but as conventional notations indicating the absence of operational definitions. They do not represent vanishing measured quantities, but rather symbols signaling that the very question of their value is meaningless at this stage.

Conceptual consequence. The absence of physical properties implies that no conservation law, no operational principle, and no physical dynamics can be formulated at the level of Absolute Chaos. Any physical description of the Universe must therefore begin after an ontological rupture, marking the appearance of distinctions, relations, and structures capable of supporting measurable quantities. In this sense, Absolute Chaos does not constitute a primitive physical state, but a pre-physical ontological limit from which effective physical descriptions may emerge.

1.2 Structural stability and ontological stability

This section introduces a central distinction of the present work: the difference between *structural stability* and *ontological stability*. This distinction makes it possible to formalize the fundamental paradox associated with Absolute Chaos and to motivate the necessity of a rupture without presupposing any pre-existing physical dynamics.

1.2.1 Two distinct notions of stability

Structural stability. Structural stability refers to the robustness of a system with respect to perturbations of its parameters, initial conditions, or internal rules, assuming a fixed ontological structure. Intuitively, a structurally stable system is one whose qualitative global behavior is not altered by small variations. This notion is standard in dynamical systems theory, bifurcation theory, and statistical physics. It presupposes the existence of a well-defined framework: a state space, parameters, and a dynamics.

Ontological stability. We introduce a distinct notion, referred to as *ontological stability*, which measures the capacity of a system to persist as a defined entity, that is, to continue to exist as something identifiable. This notion does not concern the robustness of a given dynamics, but the very possibility of persistence of the state itself.

Operationally, ontological stability does not refer to a probability in the frequentist sense, but to a conceptual propensity for persistence or disappearance. It encodes the existence—or absence—of internal mechanisms of self-maintenance.

1.2.2 Application to Absolute Chaos

We now apply these two notions to Absolute Chaos C, as defined in Section 1.1.

Structural stability of Absolute Chaos. Absolute Chaos possesses no internal structure: no parameters, no dynamics, and no law. There is therefore nothing that can be perturbed in a structural sense. Consequently, the very notion of infinitesimal variation is devoid of content.

Proposition 1.1 (Maximal structural stability). Absolute Chaos exhibits maximal structural stability, in the sense that no structural perturbation can be defined:

$$S_s(C) = \infty.$$

Justification. Structural stability measures the sensitivity of a system to structural perturbations. In C, since no structure is defined, the notion of perturbation itself is inoperative. Structural stability is therefore trivially maximal.

Ontological stability of Absolute Chaos. By contrast, Absolute Chaos possesses no internal mechanism ensuring its persistence as a state. There is neither conservation law, nor invariance, nor structured identity that could define what it would mean to *remain the same*. The total absence of structure implies the absence of any condition of self-maintenance.

Proposition 1.2 (Ontological instability of Absolute Chaos). Absolute Chaos exhibits minimal ontological stability:

$$S_o(C) = 0.$$

Justification. Ontological stability requires the existence of internal mechanisms or constraints allowing a state to persist. In C, none of these conditions is satisfied. Persistence is neither favored nor even definable; the state possesses no intrinsic ontological foundation for its own maintenance.

1.2.3 The fundamental ontological paradox

The two previous results lead to a central paradox:

$$S_s(C) = \infty \quad \text{and} \quad S_o(C) = 0.$$

This paradox may be formulated as follows:

- Absolute Chaos is perfectly stable from a structural point of view, since nothing can be perturbed;
- it is, by contrast, perfectly unstable from an ontological point of view, since nothing guarantees its persistence as a state.

This tension does not arise from a logical contradiction, but from the coexistence of two notions of stability operating at different conceptual levels. It constitutes the conceptual engine of the model.

1.2.4 Consequence: necessity of a rupture

The absence of ontological stability implies that Absolute Chaos cannot constitute a persistent state. This conclusion does not invoke any physical dynamics nor any pre-existing temporality; it expresses a purely conceptual necessity. A state devoid of any condition of self-maintenance has no intrinsic reason to remain identical.

As a result, the emergence of a first distinction—or proto-event—is not interpreted as a contingent fluctuation, but as the inevitable resolution of ontological instability. This rupture marks the end of Absolute Chaos as an operative concept and opens the way to the appearance of structures capable, for the first time, of supporting a dynamics and a history.

The notion of ontological rupture is not introduced as a metaphysical necessity, but as the only consistent outcome once minimal structural constraints are imposed. If ontological instability were allowed to persist without rupture, the system would remain either frozen in an undifferentiated state or evolve trivially without the emergence of stable distinctions.

Remark on time. This necessity of rupture should not be understood as a process unfolding within a pre-existing time. Physical time is not assumed at this stage; it emerges only later as a consequence of the irreversibility introduced by the rupture itself. The distinction introduced here is not meant to be universal, but constitutes a conceptual tool adapted to the analysis of Absolute Chaos.

The necessity of an ontological rupture thus establishes the end of Absolute Chaos as a pertinent description. It remains to be understood how a structure can emerge from this rupture without presupposing either dynamics or geometry. The following chapter introduces the minimal principle enabling this emergence: *mediation*.

2 Principle of mediation and emergence of structure

2.1 Rupture as the appearance of distinction

Section 1.2 established that Absolute Chaos, although structurally stable, is ontologically unstable: it possesses no internal mechanism allowing it to persist as a stable state. This instability does not refer to a physical dynamics, but to a conceptual necessity. The present section specifies the minimal nature of the rupture that follows.

Nature of the rupture. The rupture is not conceived as an event unfolding within a pre-existing time, nor as a transition between two physical states. It is interpreted as the appearance of a first distinction within a state that was previously totally undifferentiated. It presupposes neither local causality, nor process, nor fluctuation of a pre-existing variable. The emergence of a difference is thus not triggered by anything, but corresponds to the minimal resolution of ontological instability.

Minimal distinction. The distinction introduced by the rupture is minimal in an ontological sense. It does not correspond to entities, objects, or degrees of freedom already endowed with properties. It is better described in abstract terms as the opposition between presence and absence, or between plenitude and erasure. These terms do not designate physical properties, but complementary conceptual poles.

Absence of metric or temporal orientation. At this stage, no metric, no spatial orientation, and no temporal hierarchy are defined. The distinction introduced by the rupture does not yet single out a privileged direction, nor does it introduce the arrow of time. It constitutes a purely logical separation, not a measurable distance.

Irreversibility of the rupture. Although the rupture is not a dynamical process, it is intrinsically irreversible. Once the distinction is introduced, returning to a fully undifferentiated state would require the annihilation of the distinction itself. The post-rupture state is therefore not equivalent to the pre-rupture state. This asymmetry marks the end of Absolute Chaos as a pertinent description and makes possible the emergence of relations, structures, and ultimately irreversible dynamics.

Scope of this step. The rupture, understood as the appearance of distinction, constitutes the first non-trivial condition for the emergence of a structured framework. It does not yet define a space, a time, or a physical dynamics, but opens the way to the construction of a framework in which mediations, interactions, and a history may arise. The following section introduces the minimal principle allowing this emergence: *mediation*.

2.2 Principle of mediation

2.2.1 Conceptual definition of mediation

The ontological rupture described in Section 2.1 introduces a first distinction, but this distinction alone is not sufficient to generate an exploitable structure. A purely binary distinction, devoid of relation, does not allow for persistence, organization, or dynamics. For the two poles issued from the rupture to coexist and form a coherent framework, an additional principle is required: *mediation*.

Minimal definition. We define *mediation* as any structure or relation that links the poles issued from the rupture without collapsing them into a single pole. Mediation is neither a supplementary entity nor a simple mixing of poles; it constitutes a minimal act allowing the coexistence of their interaction potentials.

Ontological status. Mediation is not introduced as a physical field, nor as a dynamical interaction, nor as a law. It is defined at a more fundamental level, as a condition of possibility. Without mediation, the distinction introduced by the rupture would remain sterile and could not give rise to a persistent structure.

Conceptual function. The role of mediation is twofold:

- it prevents the immediate collapse into indifferentiation, while maintaining the separation of the poles;
- it renders possible the emergence of relations, by allowing the formation of links without annihilating the distinction.

In this sense, mediation acts as a minimal principle of coherence: it does not yet describe flows or exchanges of mass, but establishes the relational framework from which such processes may emerge.

Initial neutrality and symmetry. At this stage, mediation does not privilege any direction, hierarchy, or intrinsic asymmetry between the poles issued from the rupture. No notion of orientation, scale, or causality is defined. Any asymmetry will emerge only later, from the dynamics that may develop within the mediated framework.

Scope of the definition. Mediation, as defined here, does not presuppose any geometry or distance. It is a local minimal structure, without metric, without measure, and without temporal orientation. The following section introduces the ontological role of mediation and its importance for the stability of the emergent framework.

2.2.2 Ontological role of mediation

Mediation, as defined in Section 2.2.1, plays a central ontological role within the proposed framework. It constitutes the first structure capable of conferring a form of persistence to the system issued from the rupture, without introducing any local dynamics or physical law.

Mediation and persistence. The distinction introduced by the rupture separates conceptual poles, but does not guarantee their maintenance. In the absence of mediation, this distinction remains unstable: it could fade away without leaving any trace or, conversely, collapse into indifferentiation. Mediation acts as a minimal mechanism of maintenance, ensuring the coexistence of the poles without reducing them to a single undifferentiated state.

Condition of possibility of structure. Mediation does not yet describe a measurable interaction, but it makes the very existence of structure possible. It introduces a primitive relation that allows distinct configurations to appear, to be compared, and to be transformed at a later stage. In this sense, mediation is a necessary condition for any emergent organization.

Prefiguration of locality. By locally linking distinct poles, mediation prepares the emergence of a notion of neighborhood. Although no spatial metric is defined at this stage, the presence of a mediation relation introduces a relational differentiation between configurations. This differentiation constitutes the germ of a primitive locality, prior to any continuous geometry.

Ontological neutrality. Mediation carries no privileged orientation, hierarchy, or intrinsic asymmetry. It implies neither conservation, nor dissipation, nor growth. Its role is purely structural: it stabilizes distinction without imposing any dynamics. Any arrow of time or future asymmetry must therefore arise from later mechanisms, and not from mediation itself.

Scope and transition. By ensuring minimal persistence and preparing an emergent locality, mediation constitutes the ontological bridge between the rupture and the formation of a primitive spatial structure. The following section exploits this idea to introduce a minimal discrete geometry, conceived as an organization of mediation relations, preliminary to the emergence of cosmological dynamics.

2.3 Primitive geometry and discretization

2.3.1 Minimal network and locality

Mediation, understood as a primitive relation linking the poles issued from the rupture, calls for a minimal organization capable of accounting for the multiplicity of possible relations. This organization constitutes the first form of emergent geometry within the proposed framework.

From mediation to network. When multiple mediations coexist, they can be naturally represented as an ensemble of relations linking distinguishable elements. This representation leads to a network-like structure, in which nodes correspond to the poles issued from the rupture and links correspond to active mediations. At this stage, the network should not be interpreted as an approximation of a continuous space, but as a discrete relational organization.

Primitive locality. The notion of locality emerges here as a relational property rather than a geometric one. Two elements are said to be locally related if they are connected by a mediation link, independently of any notion of distance or position. Locality is therefore defined by network connectivity, not by an underlying metric.

Absence of metric and dimension. The minimal network possesses no intrinsic distance, angle, or dimension in the usual sense. Notions such as length, volume, or curvature are not yet definable. Any attempt to assign a spatial dimension at this stage would be arbitrary. The emergent geometry is purely topological and relational.

Configuration and structural diversity. Although minimal, the network admits a plurality of possible configurations, defined by the patterns of connectivity between nodes. This diversity allows for the appearance of distinct local structures, without presupposing any temporal dynamics. The set of network configurations thus constitutes a space of possibilities from which richer geometric properties may later emerge.

Scope of this construction. The minimal network provides a stable framework for the organization of mediations and the introduction of a notion of locality sufficient for preparing the emergence of structured dynamics. The following section discusses how an effective interpretation of such a network may be associated with geometric notions, and under which conditions an effective notion of dimension may arise.

2.3.2 Geometric interpretation

The minimal network introduced in Section 2.3.1 provides a relational organization sufficient to support a geometric interpretation, without postulating space, metric, or dimension a priori. This interpretation must be understood as emergent and effective, rather than fundamental.

From connectivity to effective geometry. In a relational network, certain global properties may emerge from the structure of connectivity itself. Statistical regularities, recurrent patterns, or comparable degrees of connectivity can lead to an effective geometric interpretation, in which the network behaves locally as a finite-dimensional space. This dimension is not postulated, but inferred from the properties of the graph.

Emergent dimension. The notion of dimension appears here as a derived quantity, associated with the growth of the number of accessible nodes as a function of the number of successive mediations. Depending on the organization of the network, this growth may mimic that of a one-dimensional, two-dimensional, or three-dimensional space. The effective dimension is therefore neither fixed nor universal at this stage; it depends on the global structure of the network.

Continuous approximation. When the network exhibits sufficiently regular and dense connectivity at large scales, it may be approximately described by a continuous space. Such an approximation does not reflect a fundamental reality, but an emergent description valid at scales where the discrete details of the network become negligible. The continuous space then appears as an effective limit of the underlying discrete network.

Absence of a fundamental metric. It is important to emphasize that this geometric interpretation does not presuppose the existence of a fundamental metric. Notions such as distance or volume, when they emerge, are effective constructions derived from network properties, not primitive structures. Geometry thus remains relational and contextual.

Scope for subsequent developments. This geometric interpretation provides the necessary framework for introducing, in subsequent sections, notions of dynamics and energetics. It prepares in particular the emergence of gradients, fluxes, and differentiated regions, without presupposing specific physical laws. Chapter 4 will exploit this effective geometry to explore the cosmological consequences of the proposed framework.

3 Conceptual and methodological limits, and falsifiability

The previous chapters introduced an ontological and structural framework intended to describe the emergence of a cosmological organization from a pre-physical limit state. This chapter makes explicit the limits assumed by this approach, in order to clarify its scientific status, its domain of validity, and the possible ways in which it may be put to the test.

3.1 Scope and status of the proposed framework

The framework developed in this work does not constitute a complete cosmological theory. It is neither intended to replace the standard model, nor to provide an exhaustive description of observable phenomena. Its objective is more fundamental: to propose a coherent conceptual genealogy linking ontology, structural emergence, and effective cosmology.

In particular, Chapters 1 and 2 operate at a pre-physical level. The objects introduced—Absolute Chaos, ontological rupture, mediation, and the relational network—must not be interpreted as directly observable physical entities, but as conditions of possibility enabling the later emergence of a physical description.

3.2 Deliberate absence of fundamental dynamics

No fundamental dynamics is postulated in the early stages of the framework. This absence is intentional. Introducing a dynamics at this level would amount to presupposing the existence of time, degrees of freedom, and differential relations, whereas these notions are precisely what the framework seeks to explain.

The dynamical mechanisms considered in later developments should therefore be understood as effective descriptions, compatible with the proposed ontological structure, but not as fundamental laws. The framework presented here is thus compatible with multiple possible dynamical realizations.

3.3 Emergence of the arrow of time and ontological irreversibility

The framework developed in Chapters 1 and 2 is explicitly pre-temporal. At the level of Absolute Chaos, no dynamics can be defined, and the very notion of a temporal parameter is devoid of meaning. Ontological rupture introduces a first distinction, but does not yet postulate the existence of a pre-existing physical time. In this V1, the arrow of time is therefore addressed as an emergent property, appearing with the birth of irreversible processes.

Without an ontological rupture, three generic failure modes can be identified: (i) persistence of an undifferentiated state with no relational capacity; (ii) reversible fluctuations that fail to generate a stable arrow of time; (iii) global transitions leading to homogeneous saturation without structure. The introduction of a local and irreversible rupture avoids all three pathologies simultaneously.

Guiding principle. We posit that the arrow of time coincides with the appearance of an effective irreversibility: an order becomes definable whenever a robust asymmetry exists between a process and its inverse. At this stage, this principle does not require the introduction of microstates, probabilistic counting, or a fundamental probabilistic structure. It is formulated at the ontological and relational level of the proposed framework.

Definition (ontological irreversibility). We define an *ontologically irreversible process* as any process whose effective reversal would imply a return toward a *less structured state*, in the sense of a loss of distinctions, relations, or mediating capacity—that is, toward a state closer to Absolute Chaos as defined in Section 1.1. Proximity to Absolute Chaos must here be understood as a *conceptual proximity* (degeneration of distinctions and relations), and not as a metric distance or a measurable physical quantity.

This definition does not presuppose that the system "aims" toward any particular state. It merely formalizes the fact that reversing such a process would, if required, necessitate the restoration (at least partially) of indifferentiation and the absence of mediation.

Consequence: emergent temporal order. As soon as an ontologically irreversible process exists, an order becomes definable: one direction corresponds to transformations that move away from the regime of indifferentiation (in the sense defined above), while the other corresponds to transformations that would restore it. The arrow of time is thus interpreted as the trace of a structural asymmetry introduced by irreversibility, and not as a primitive given.

Link with ontological freeze. The mechanism explored in Chapter 4 provides a minimal dynamical realization of this principle through the local construction of an irreversible mediation freeze. Once a region is frozen, no local rule allows mediation to be restored; any effective inversion of the process would require the reconstitution of destroyed relational capacity, which would amount to a return toward a more indifferentiated regime. Thus, in an effective realization, the arrow of time may be correlated with the appearance of absorbing states and the irreversible loss of mediation, without postulating a fundamental time parameter.

Remark (non-teleology). The intuitive expression according to which the cosmos "moves away" from Absolute Chaos should not be interpreted in a finalist or intentional sense. It does not describe a goal-directed tendency, but a coherence constraint: after the rupture, any effective dynamics compatible with the existence of distinctions and mediations necessarily selects trajectories that do not spontaneously reconstruct total indifferentiation.

Asymptotic regime and residual memory. The framework does not imply that the Universe must indefinitely move away from Absolute Chaos. It is compatible with the existence of late-time regimes that are weakly structured, in which dynamics globally fades while residual information persists at small scales (for instance, in the form of correlations or non-erasable structures within an effective description). Such a state would be conceptually distinct from Absolute Chaos: it would be closer to the disappearance of active mediations, while still retaining a minimal informational memory. This possibility is mentioned here as a conceptual compatibility of the framework, and not as a quantitative prediction of this V1.

Scope. This section clarifies that, within the proposed framework, physical time is not an axiom. The arrow of time emerges with the appearance of ontologically irreversible processes. The developments of Chapter 4 illustrate a minimal realization of this principle through mediation freeze; alternative realizations could be envisaged without modifying the pre-temporal status of Chapters 1 and 2.

3.4 Neutrality with respect to cosmological parameters

The present work does not aim to determine directly cosmological parameters such as the cosmological constant or the density of dark energy. Any numerical proximity between an emergent quantity within the model and observed values must be interpreted as coincidental at this stage.

The ambition of the framework is to show that an effective component of dark-energy type may emerge without explicit fine-tuning, from generic structural mechanisms. Any quantitative comparison with observations pertains to a subsequent level of modeling, which lies beyond the scope of this first version.

3.5 Falsifiability and possible tests

Although conceptual, the proposed framework is falsifiable in the scientific sense. Several routes for putting it to the test can be identified:

- the impossibility of constructing any coherent dynamical realization compatible with the proposed mediation and relational geometry;
- the systematic absence of attractive or self-limiting behaviors in dynamical realizations inspired by the framework;
- the necessity of explicit fine-tuning in order to reproduce global cosmological properties, in contradiction with the objective of the model.

If a local dynamics compatible with mediation were shown to generate stable distinctions and a persistent arrow of time without any irreversible ontological transition, the present framework would be invalidated.

3.6 Positioning with respect to existing approaches

The proposed framework shares certain concerns with approaches to pregeometry, discrete quantum gravity, and emergent cosmology, without being reducible to any of them. It does not assume a prior quantization of geometry, nor a fundamental causal structure, nor a set of primitive probabilistic laws.

This neutrality is intentional. The aim is to maintain the framework at the most general possible level, so that it may serve as a conceptual basis for different potential physical realizations.

3.7 Chapter conclusion

This chapter has clarified the limits and the status of the framework developed in this work. The proposed approach should be understood as a first conceptual step, intended to identify minimal conditions for the emergence of a cosmological structure without fine-tuning. Further dynamical developments and quantitative confrontations constitute natural extensions, but are not required for the conceptual validity of this initial version.

4 Exploratory dynamics and ontological freeze

The previous chapters established an ontological and structural framework allowing for the emergence of a relational geometry without presupposing any fundamental dynamics. The present chapter explores an additional step: the possibility of introducing a minimal effective dynamics compatible with this framework, in order to analyze its qualitative properties.

The objective of this chapter is not to propose a fundamental law, but to show that simple, local, and generic dynamics, once implemented on the relational structure defined by mediation, can lead to robust and self-limiting behaviors. These behaviors are interpreted as manifestations of a *local ontological freeze*, in the sense of an irreversible loss of mediating capacity.

The results presented here must be understood as exploratory. They aim to establish the dynamical plausibility of the proposed framework and to identify emergent properties that do not rely on explicit fine-tuning.

4.1 Minimal dynamical framework

To explore the dynamical consequences of the mediation principle introduced in the previous chapters, we now consider a minimal effective realization implemented on a discrete bidimensional geometry. The choice of a two-dimensional lattice is not intended to carry physical significance; it is adopted solely for simplicity and for its ability to illustrate the mechanisms at work within a controlled and transparent setting.

The two-dimensional lattice and the associated frozen-energy proxy should be understood strictly as a toy realization of a generic absorbing-state mechanism.

No direct correspondence with physical dark energy is implied; the interest lies in the structural emergence of a self-limiting effective component.

Dynamical variables. At each site of the network, we introduce three local variables:

- an α variable, representing an active energetic density;
- a χ variable, representing a cumulative or mediating density;
- a variable $M \in [0, M_{\max}]$, representing a degree of saturation of the local mediation.

When M reaches its maximal value, mediation at the corresponding site is considered destroyed. The ontological state of the site is then defined by this saturation and is encoded by a derived binary mask. We thus introduce a freeze indicator $m(\mathbf{x})$ defined by

$$m(\mathbf{x}) = \begin{cases} 1 & \text{if } M(\mathbf{x}) = M_{\max}, \\ 0 & \text{otherwise.} \end{cases} \tag{1}$$

This binary variable encodes the ontological state of the site (frozen or unfrozen) independently of the instantaneous values of the dynamical variables.

It is essential to emphasize that these variables should not be interpreted as fundamental physical fields. They are effective degrees of freedom intended to encode the local state of mediation within the emergent relational structure.

Operational status of the variable M. The variable M does not constitute an independent dynamical degree of freedom. It plays the role of an internal counter (in an operational sense), recording irreversible local interactions and enabling the identification of an irreversible threshold.

All dynamical evolution of M is entirely subordinated to the evolution of α and χ. Once M reaches its maximal value, it no longer evolves and does not influence the subsequent dynamics as an active variable. In particular, the freeze does not correspond to a new dynamics of M, but to a derived state marking the irreversible loss of mediation, encoded by the binary mask m.

Principle of local dynamics. The local dynamics is defined by simple rules:

- when mediation is not saturated ($M < M_{\max}$), the variables α and χ may interact;
- under certain local interaction conditions, mediation may reach saturation in an irreversible manner;
- once mediation is saturated, it cannot be restored.

This irreversibility constitutes the central dynamical ingredient of the model. It translates, at the effective level, the ontological irreversibility introduced in the previous chapters.

Status of the dynamics. It is important to stress that this dynamics is not postulated as fundamental. It represents one possible realization among many. Its role is to illustrate, in the simplest possible setting, how local irreversible mechanisms can emerge from a mediated relational structure.

Alternative rules or higher-dimensional realisations could be envisaged without altering the ontological status of the framework. The following section specifies the precise local update rules and their numerical implementation before analysing the emergent properties of the resulting dynamics.

4.2 Irreversible local freeze rule

The central mechanism explored in this chapter is the irreversible destruction of mediation at the local scale. The present section specifies the adopted freeze rule, its conceptual status, and the principles guiding its implementation, without introducing any fundamental law or fine-tuned parameter.

General principle of the freeze. Local freeze corresponds to the definitive loss of mediation at a given site. When a cell reaches the frozen state, defined by the irreversible saturation of mediation ($M = M_{\max}$), it definitively ceases to participate in local interactions. This transition is not interpreted as a thermodynamic phase change, but as an extinction of local relational capacity.

Triggering condition. The destruction of mediation is triggered by local conditions involving the dynamical variables of the site and its immediate neighborhood. Qualitatively, the freeze intervenes when the intensity of interactions or local gradients exceeds a critical threshold, reflecting an overload of mediation.

It is important to emphasize that this threshold is not adjusted to reproduce any target global value. It defines solely a local rupture condition, identical for all sites and independent of the global state of the system.

Remark on the status of the threshold $M_{\max}$. The threshold $M_{\max}$ is not interpreted as a fundamental ontological constant, but as a minimal operational convention allowing, within this dynamical realization, the identification of irreversible loss of mediation. No quantitative meaning, in the sense of a measurable physical magnitude, is attached to its value in this V1.

Irreversibility and absence of local feedback. Once mediation is destroyed, no rule allows for its restoration. This irreversibility constitutes a fundamental structural choice of the model. At the effective level, it encodes the asymmetry introduced by the ontological rupture described in the previous chapters.

In particular, the freeze is not compensated by any local repair, relaxation, or healing mechanism. This absence of retroaction ensures that the frozen state acts as an absorbing configuration.

Immediate local consequences. The freeze of a cell has two direct local effects:

- the local dynamical variables cease to evolve through interactions with the neighborhood;
- the frozen cell acts as a relational boundary, modifying the circulation of interactions within the network.

These effects are strictly local. No global information is required either to trigger the freeze or to apply the freeze rule.

Status of the mechanism. The irreversible local freeze rule does not constitute a fundamental law. It represents a minimal hypothesis, chosen to explore the consequences of a progressive loss of mediation in a relational network. The central result sought is not the microscopic trajectory of the system, but the existence—or absence—of robust emergent behaviors at large scales.

The following section analyzes these behaviors in detail, in particular the emergence of stationary states characterized by a stable frozen fraction.

4.3 Numerical results and emergent attractor

This section presents the numerical results obtained from the implementation of the minimal dynamics and the irreversible local freeze rule described in Sections 4.1 and 4.2. The objective is not to adjust any global parameter, but to examine the emergent properties of the system arising from simple and identical local rules applied across the entire network.

4.3.1 Numerical setup

The simulations are performed on a regular two-dimensional lattice, with initial conditions specified independently for all dynamical variables. The spatial dimension, network size, and numerical parameters are chosen for simplicity and computational stability, without any claim of fundamental dimensional significance.

Initial conditions are characterized by a random seed, used solely to generate the starting configurations. No fine-tuning dependent on the seed is introduced in either the dynamical rules or the freeze mechanism.

4.3.2 Temporal evolution and saturation

The temporal evolution of the system exhibits a dynamics structured into three well-defined regimes:

1. an initial phase during which mediation is globally active and local interactions develop throughout the network;

2. a transient phase characterized by the rapid appearance of locally frozen regions, associated with a progressive destruction of mediation;

3. a stationary regime in which the global configuration ceases to evolve in a significant manner.

The frozen surface fraction converges systematically toward a finite asymptotic value, strictly bounded between 0 and 1. This convergence occurs in finite time and does not exhibit any subsequent long-term drift, which characterizes the existence of an absorbing state.

4.3.3 Attractor and robustness with respect to initial conditions

A central result of the present study is the robustness of the asymptotic frozen fraction with respect to initial conditions. Simulations performed with distinct random seeds converge toward comparable final values, despite exhibiting different microscopic trajectories.

This robustness indicates that the observed asymptotic value is not determined by the initial details, but dynamically selected by the local freeze mechanism. The system thus displays an attractor-like behavior: a broad class of initial conditions leads to the same macroscopic stationary state.

Remark on the use of the term "attractor". The term *attractor* is employed here in a weak sense. It designates a macroscopic stationary state dynamically selected from a wide ensemble of initial conditions, without claiming a complete mathematical characterization in the sense of dynamical systems theory (basin structure, invariant measures, etc.).

4.3.4 Separation between spatial freeze and energetic freeze

The simulations reveal a notable dissociation between the frozen surface fraction and the fraction of energy effectively involved in the dynamics. While the frozen surface fraction rapidly reaches a stable plateau, the cumulative loss of mediation and energetic activity continues until the near-complete extinction of exchanges.

This separation highlights an important point: the freeze is a local and spatially partial phenomenon, yet its consequences are global from an energetic perspective. The freeze does not invade space entirely, but it progressively suppresses large-scale dynamical activity.

4.3.5 Spatial structure of the final state

The analysis of the final configurations reveals a heterogeneous distribution of frozen regions, without global percolation or complete homogenization. The remaining active regions are isolated and unable to sustain a persistent global dynamics.

The final state is thus characterized by a stable coexistence of frozen and active zones, whose organization results solely from local rules and the irreversibility of mediation. No global coordination mechanism is introduced or required.

4.3.6 Interpretation

The numerical results presented here demonstrate the existence of a mechanism of dynamical self-limitation based on the irreversible local destruction of mediation. This mechanism selects a stable global state, robust with respect to initial conditions and independent of any global fine-tuning.

Within the conceptual framework developed in the previous chapters, this attractor may be interpreted as the emergence of an effective ontological freeze, resulting from the progressive loss of relational capacity of the network. The following section discusses the scope of these results and their potential implications for an emergent cosmology.

The central result is therefore the existence of a stationary attractor dynamically selected, independent of initial conditions and not relying on any global parameter adjustment.

4.3.7 Numerical illustrations and final configurations

In order to concretely illustrate the mechanisms described in the previous sections, we present here several snapshots extracted from numerical simulations (seed = 3). These figures provide representative visualizations of the typical behavior of the system, without any claim of statistical exhaustiveness at large scales.

These illustrations introduce no new element into the argumentation. They are not used to calibrate the model nor to adjust any global parameter; their sole purpose is to visualize behaviors that have already been established analytically and numerically.

Figure 1 shows the temporal evolution of the frozen surface fraction. After a rapid transient phase, the curve converges toward a stationary plateau, characteristic of an absorbing state.

Figure 2 presents the evolution of the fraction of energy effectively decoupled from the dynamics (proxied via mediation). In contrast with the spatial fraction, this quantity continues to increase after geometric saturation, illustrating the dissociation between local freeze and global energetic effect.

Figures 3 and 4 show the final spatial distributions of the dynamical variables α and χ. Although visually similar, these maps do not encode the same information: they describe distinct local dynamical variables and reveal a persistent heterogeneity, as well as the absence of global homogenization.

Figure 5 displays the freeze mask, which encodes a binary ontological state corresponding to the irreversible loss of mediation.

The frozen-zone mask highlights the diffuse geometry of the ontological freeze: no global percolation nor sharp boundary emerges, even though the dynamics is globally extinguished.

In contrast with the dynamical fields α and χ, the freeze mask does not represent an intensity but a relational capacity. It identifies regions that are definitively decoupled from the network of mediation, independently of the local values of the dynamical variables.

In this version of the model, the dynamical variables and the freeze mask inherit the same spatial geometry, determined by the initial conditions. The distinction between α, χ, and m therefore does not lie in the geometric structure, but in the ontological nature of the information they encode.

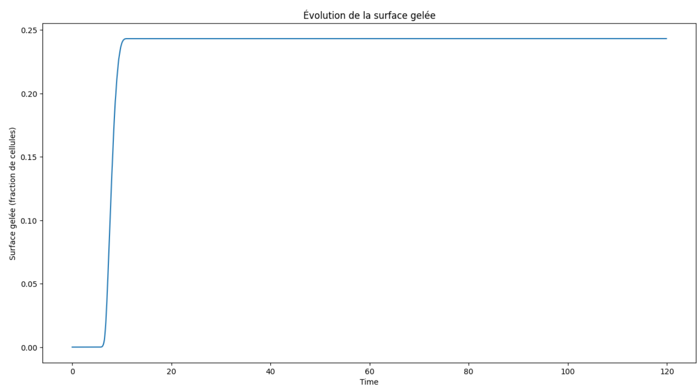

Figure 1: Temporal evolution of the frozen surface fraction (seed $= 3$). The rapid saturation toward a stationary plateau indicates the attainment of an absorbing state.

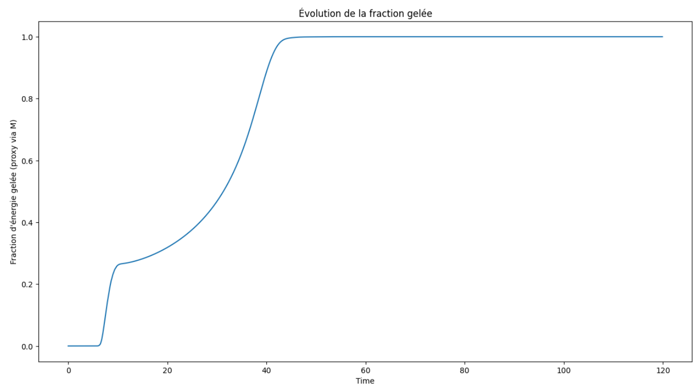

Figure 2: Evolution of the frozen energy fraction, defined as a proxy via the mediation variable SM (seed = 3). The continued growth after saturation of the spatial fraction highlights the dissociation between local freeze (surface) and global effect (frozen energy).

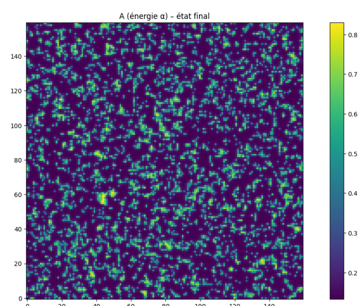

Figure 3: Final spatial distribution of the variable α (seed = 3). The persistent heterogeneous structure indicates the absence of global homogenization in the stationary regime.

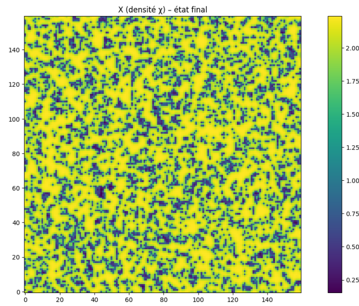

Figure 4: Final spatial distribution of the variable χ (seed = 3). The distribution remains spatially contrasted, consistent with residual local dynamics but unable to sustain a persistent global evolution.

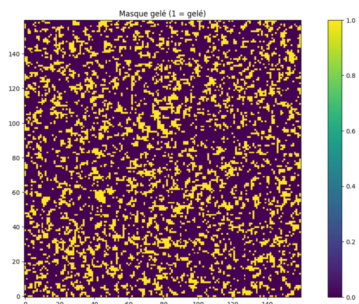

Figure 5: Frozen-zone mask in the final state (seed = 3), defined by the attainment of the threshold $SM = M_{\max}$. The spatial distribution of the freeze is diffuse and non-percolating, yet sufficient to interrupt the global dynamics of the system.

It is important to emphasize that the variable M does not directly represent a measurable physical energy, but an internal model quantity used to operationalize the ontological transition toward the frozen state.

4.4 Discussion and cosmological scope

The numerical results presented in Section 4.3 highlight the existence of a non-trivial mechanism of irreversible local freeze leading to a stationary state that is robust with respect to initial conditions and independent of any global fine-tuning. The present section discusses the conceptual scope of these results in a cosmological context, while explicitly clarifying their limits.

Table 1: Simulation results for different random seeds and temporal horizons. All simulations converge toward a stationary state characterized by a stable frozen fraction and a near-complete saturation of the frozen-energy proxy.

Seed	Convergence	Frozen fraction	Frozen-energy proxy	Time (iterations)
0	yes (plateau)	0.2490	0.99999993	12000
1	yes (plateau)	0.2479	0.99999974	12000
2	yes (plateau)	0.2464	0.99999994	12000
3	yes (plateau)	0.2433	0.99999984	12000
4	yes (plateau)	0.2507	0.99999989	12000
5	yes (plateau)	0.2365	0.99999986	12000
6	yes (plateau)	0.2450	0.99999991	12000
7	yes (plateau)	0.2470	0.99999992	12000
8	yes (plateau)	0.2439	0.99999985	12000
9	yes (plateau)	0.2380	0.99999983	12000
10	yes (plateau)	0.2450	0.99999993	12000
11	yes (plateau)	0.2369	0.99999994	12000
12	yes (plateau)	0.2446	0.99999992	12000
13	yes (plateau)	0.2433	0.99999993	12000
14	yes (plateau)	0.2408	0.99999970	12000
15	yes (plateau)	0.2462	0.99999965	12000
16	yes (plateau)	0.2568	0.99999987	12000
17	yes (plateau)	0.2490	0.99999997	8000
18	yes (plateau)	0.2490	0.99999992	16000

Reminder. In this framework, the variable M is an operational counter derived from local interactions, and not a measurable physical quantity nor a fundamental degree of freedom.

Ontological freeze and effective component. Within the proposed framework, the freeze corresponds to a progressive and irreversible loss of mediation, that is, of the relational capacity of the network. Although the freeze does not extend to the entire space, its cumulative effects lead to a global extinction of dynamical exchanges.

This dissociation between a finite frozen spatial fraction and a global energetic effect suggests the emergence of an effective component, persistent and decoupled from local dynamics. Such a component shares certain qualitative properties with what is designated, in the standard cosmological model, as an effective dark-energy component. It is however essential to stress that this analogy is structural and conceptual, and not quantitative at this stage.

The term "dark energy" is used here by analogy with the effective component introduced in the standard cosmological model following the observational discovery of cosmic acceleration [5, 6]. No quantitative identification with this component is claimed in the present work.

Absence of fine-tuning. A central feature of the explored mechanism is the absence of explicit fine-tuning. The stationary value of the frozen fraction is neither imposed a priori nor adjusted to reproduce any observed cosmological parameter. It results solely from local dynamics and from the irreversibility of the freeze.

This property fundamentally distinguishes the proposed framework from approaches in which a cosmological constant is introduced as a fundamental parameter.

Status of the results and limits. The results presented in this chapter rely on a minimal effective model implemented on a simplified discrete geometry. They do not constitute a direct cosmological prediction, nor a complete alternative to the standard model. In particular, no quantitative confrontation with observations is proposed in this version.

The role of this chapter is to demonstrate the dynamical plausibility of the previously developed ontological framework, by showing that it admits concrete realizations endowed with non-trivial emergent properties. The mechanism would be invalidated if no local dynamics compatible with mediation were able to produce a robust stationary attractor, or if the final frozen fraction were found to depend systematically on global fine-tuning.

Perspectives. Natural extensions of this work include the exploration of alternative dynamical realizations compatible with mediation, the study of geometries with higher effective dimension, and the analysis of the link between ontological freeze and effective cosmological expansion. These developments lie beyond the scope of the present version, but constitute clear directions for future investigations.

Chapter conclusion. This chapter has shown that a simple mechanism of irreversible local destruction of mediation can lead to a stable global attractor, without fine-tuning, and compatible with an emergent cosmological interpretation.

General conclusion

In this work, we have proposed a minimal conceptual framework aimed at exploring the emergence of a self-regulated stationary state from a local dynamics without global parameter tuning. The objective was not to quantitatively reproduce a standard cosmological scenario, but to identify generic mechanisms capable of producing effective stabilization from simple local rules.

The core of the model relies on the introduction of a dynamical mediation, capable of being irreversibly deactivated when certain local conditions are met. This irreversible deactivation leads to the emergence of an ontological freeze, interpreted as a complete local loss of relational capacity, rather than as an extinction of energy. A central distinction is thus established between continuous dynamical variables and a discrete ontological state of mediation.

Analytical considerations and numerical results show that this freeze, although spatially heterogeneous and non-percolating, is sufficient to extinguish the global dynamics of the system. The frozen surface fraction converges toward a stationary value that is robust and independent of detailed initial conditions, while the fraction of effectively decoupled energy continues to grow beyond geometric saturation. This dissociation between local freeze and global energetic effect constitutes a central result of the model.

The numerical simulations presented here do not aim to establish statistical properties at large scale, but to illustrate concretely the mechanisms put forward analytically. In this respect, the dynamical variables and the freeze mask inherit the same spatial geometry, while the distinction between them lies in the ontological nature of the information they encode, rather than in the emergence of independent morphological structures. This limitation is fully consistent with the conceptual objective of the present version.

The main interest of this work thus lies in the identification of a mechanism of dynamical self-limitation without fine-tuning, grounded in an ontologically irreversible local transition. This framework opens the way to natural extensions, including the introduction of non-local mediation mechanisms, multi-scale diffusion effects, and feedback processes, which would allow a more detailed exploration of the links between geometry, dynamics, and ontological structure.

In this sense, the proposed model does not constitute a complete cosmological description, but offers a falsifiable conceptual basis upon which more elaborate developments may be constructed.

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