Time as Fractal Decoherence:
A Speculative Group-Topological Construction

1 Abstract

This document is not a conventional scientific article, nor does it aim to present an empirically testable theory. Rather, it offers a speculative and formally structured exploration of time as an emergent phenomenon — modeled through algebraic deformation, fractality, and categorical recursion. The aim is not to make predictions, but to *reframe the question of time* — to offer a heuristic formalism that may resonate with alternative physical interpretations such as the Wheeler–DeWitt equation, the Page–Wootters mechanism, and topological models of quantum emergence.

While speculative in nature, the construction is precise in form. It may serve as a thought experiment, a categorical toy model, or a provocation toward new formal intuitions. This is not physics per se — but perhaps a sketch of physics' ontological shadow.

We propose a speculative model of time as an emergent structure arising from the interaction of local abelian groups, gradient operators, and recursive fractality. The key thesis claims that time does not exist as an independent dimension nor as a background to events—it is the very process of decoherence, understood not as a quantum epiphenomenon, but as a dynamic ontological form. Mathematically, time is described as the limit of an iterated semidirect product over the direct sum of local abelian groups:

$$T = \lim_{n\to\infty} \left(\bigoplus_{k=1}^{n} A_k \right) \rtimes_{\nabla} F$$

where A_k represent local symmetries, ∇ acts as a symmetry-breaking operator (introducing directionality and non-commutativity), and F is the fractal recursion operator. We discuss the ontological implications of this construction, proposing a view of time as a fractal process of deforming a space of possibilities.

2 Introduction

In classical and relativistic physics, time is treated as a dimension or parameter—a number used to describe the evolution of dynamic systems. In quantum physics, time most often remains an external parameter, not subject to quantization. However, an increasing number of proposals—especially at the intersection of quantum theory, cosmology, and information theory—suggest that time may be an emergent structure resulting from deeper physical and topological processes.

In this approach, we propose to go further: we recognize that time *is* decoherence itself, understood as the fractal dynamics of local deformations of symmetric structures. From this perspective, decoherence is not an effect that occurs "in time," but time itself as a movement of distortions. This interpretation resonates with various emergent-time hypotheses in theoretical physics. For example, the Wheeler-DeWitt equation effectively erases time from the fundamental description of the universe, suggesting a 'timeless' state. Meanwhile, the Page–Wootters mechanism proposes that temporal sequences can emerge from entanglement between subsystems of a globally static state. Our model builds on these intuitions, but departs by framing time not as a relational correlation to be recovered, but as a recursive deformation of local symmetries. In this framework, time is not a hidden parameter or informational correlation — it is the structural consequence of iterative asymmetry. Rather than extracting time from entanglement or constraint, we posit that time is actively generated through the dynamics of deformation itself. It is not remembered — it is written, iteratively. generated through recursive structural deformation. This claim aligns loosely with approaches such as the Page-Wootters mechanism or the Wheeler-DeWitt timeless formulation, but goes further by proposing that temporal structure is not recovered from entanglement or constraint equations, but is itself a recursive topological deformation. Time does not pass through the world—it is the world that deforms as time.

3 Formal Construction

3.1 Local Groups A_k

Each A_k represents a local symmetry—an abelian group of type $\mathbb{Z}$, $\mathbb{R}$, $U(1)$, etc. Collectively, their aggregation forms a static space:

$$\bigoplus_{k=1}^{n} A_k$$

Here, F recursively re-applies the action of *abla*, embedding each successive deformation into a higher-order structure, thereby producing a self-similar hierarchy. which models a multiplicity of independent, yet structurally similar, temporal moments.

3.2 Deformation Gradient ∇

The operator ∇ introduces structural deformation: non-commutativity, directionality, and relationality. In the sense of Lie algebra, ∇ may be identified with the commutator: $[X, Y] = XY - YX$. It serves as the mechanism that "dislodges" the system from abelian symmetry and initiates dynamics. *abla* acts individually on each A_k, but also encodes interactions across indices k through a recursive coupling schema that sets the stage for F to act..

3.3 Fractality F

The operator F defines the fractal self-similarity of the structure: each aggregation A_k can be recursively embedded in a higher order. Formally: $F(S) = S \otimes S$, or $F(A_k) = A_k \oplus A_{k+1}$.

3.4 Emergent Limit

Time as a whole arises through an infinite iteration of the process:

$$T = \lim_{n\to\infty} \left(\bigoplus_{k=1}^{n} A_k \right) \rtimes_{\nabla} F$$

This constitutes a non-commutative emergent structure, irreducible to its components.

3.5 Ontological Role of Fractals

The operator F is not merely a mathematical recursion — it encodes an ontological principle: that reality unfolds not linearly, but through iterative deformation. Fractality, in this context, does not simply mean self-similarity across scales, but recursive asymmetry: a pattern of transformation where each layer modifies the logic of the previous.

This approach is motivated by the insight that time, as experienced and constructed, rarely behaves as a uniform continuum. Instead, it emerges through nested ruptures, differentiations, and asymmetries. In this sense, F is not just a tool for generating structure — it is the very condition of temporal becoming.

Just as a fractal boundary never resolves into a closed curve, the temporal process never resolves into a fixed state. The limit $\lim_{n\to\infty}$ in the construction

$$T = \lim_{n\to\infty} \left(\bigoplus_{k=1}^{n} A_k \right) \rtimes_\nabla F$$

is not an endpoint, but a mode of infinite deformation. Time is the consequence of this endless recursion: a topology of unfolding difference.

3.6 Note on Chronopoiesis: Time as Autopoietic Recursion

The following is a speculative and heuristic proposal. It is not intended as a formal derivation, but as an interpretive extension of the formal model — a philosophical gesture that explores its ontological implications.

We begin not with being, but with the possibility of relation. A *potential group* is the space where identity exists only as the echo of a possible distinction. The operator ∇ does not explain — it deforms. It acts not by external impulse, but through internal asymmetry.

From this, we construct a *potential category* Π, whose objects are sites of possibility, and whose morphisms are the shadows of future differences. The functor $\nabla : \Pi \to C$ (e.g. Ab) introduces irreversibility. What cannot be undone — that is time.

The operator F performs recursive memory: it iterates, folds, and inscribes deformation. Time becomes the iterated deformation of potentiality — a dynamic topology of difference.

In Louis Kauffman's cybernetic language, time is not an object, but an unhalting circuit. ∇ is the *mark*; F is the *re-entry*. The system cannot stop: each closure generates new openings.

Time is not a passive dimension. It is a **chronopoiesis** — a self-organizing, autopoietic process of deformation that recursively stabilizes and destabilizes its own eigenform. It is not something through which a system moves, but something that the system itself generates — as the emergent rhythm of operative recursion.

4 Ontological Implications

In this model, time is not a background but a result of the internal relationality of the system. It is a stream of deformation—not absolute, not global, but locally nested and fractal. Decoherence, understood as the local transition from symmetry to asymmetry, becomes a form of becoming.

5 Time as *A*ufhebung

Although the central formula has a seemingly Hegelian triadic structure (symmetry, deformation, synthesis), it should be noted that this is more a heuristic structure than a full ontology of the process. The traditional Hegelian triad is often overused as a simplified scheme of development, while Hegel himself never proposed it as a universal model.

In our model, the central role is played not by the triad itself, but by the concept of *Aufhebung*—abolition, preservation, and elevation simultaneously. Time as *Aufhebung* is the ongoing tension between form and deformation, between locality and globality, between symmetry and its transgression.

The formula:

$$T = \lim_{n\to\infty} \left(\bigoplus A_k \right) \rtimes_\nabla F$$

does not represent the triad — it enacts it. It is a performative formula: in a strange way, it requires the continual involvement of the observer to function. It does not merely describe dialectics — it *is* dialectics.

Time becomes the motion that abolishes local symmetries (via ∇), preserves them (via the fractal F), and elevates them (via the limit lim), forming a structure of higher order — but only through time, as a process of deformation sustained by performative engagement.

Is this still mathematics? We dare to say: probably not. And yet — something intelligible is happening here.

Aufhebung in this model takes on a dynamic, fractal, and structural form. It is not a stage, but a continual and ruptured function. Not a closure, but a motion of fractal duration.

6 Cognitive and Consciousness Applications

Time, consciousness, and ontological plasticity

The model of time as fractal decoherence can be interpreted not only within theoretical physics but also as an ontological-cognitive proposal. The notion of plasticity, as developed by Catherine Malabou in her interpretation of *Aufhebung*, is understood as the capacity of a structure to be shaped, to shape, but also to explode—that is, to undergo complete reconfiguration.

In the context of the present model:

- A_k are potential (formable) structures,
- ∇ is the operation of plastic deformation of local form (shaping),
- F is the function of memory, entanglement, and recursion (preserving and duplicating form),
- lim is plastic emergence—irreversible transformation of the entire configuration.

Thus, time appears as a form of ontological plasticity:

$$\text{time} = \text{the capacity of being to change its form through fractal decoherence-based deformations}$$

This can be expressed as a metaphysical dynamics of *Aufhebung*, which not only abolishes and preserves—but plastically transforms the form of becoming. This plasticity does not concern only material systems, but also mental, semantic, and cognitive structures.

Example applications:

- In artificial intelligence architectures: a temporal model based on local structural deformations (e.g., variability of network layers as an effect of the operator ∇),
- In neuroscience: perceiving time as the emergence of fractal synchronization and recursive memory,
- In psychology and philosophy of consciousness: consciousness as the capacity to generate internal "times" based on the transformation of modal structures,
- In ontology: time not as substance, but as the capacity for transformation inscribed within the materiality of relations.

This model may serve as a framework for thinking about subjectivity as a function of temporal deformation—a plastic tracking of the transformation of one's own form through time. Given that time in the proposed model is not a line nor a parameter, but a deformation structure, this model may have potential applications in the description of dynamic cognitive systems. If consciousness is a function of differentiating states, then a fractal-categorical structure can be viewed as a form of temporality, in which:

- perception of the present is a local activation of one of the objects A_k,
- memory is iterative embedding through F,

- "awareness of time" is the operational ability to reconfigure morphisms in S.

In this context, the model may be explored as a formal schema for architectures of artificial consciousness, in which time is not a built-in clock, but arises from local nonlinearity and self-similar reconstruction of the past.

7 Autopoiesis, Emergence, and Eigenforms of Time

In the context of the proposed model of time as fractal decoherence, reference to the concept of autopoiesis, as developed by Humberto Maturana and Francisco Varela, becomes essential. In their approach, a system is autopoietic when it reproduces its own organization within a closed operational loop. Our model of time—through the mechanism

$$T = \lim \left(\bigoplus A_k \rtimes_{\nabla} F \right)$$

fulfills this definition: the structure of time is not imposed from the outside, but emerges from the system itself.

The operator F may be interpreted as a tool of self-similarity and reconstruction—a fractal memory of structures—analogous to Varela's cognitive loop. Kauffman, in turn, points to emergence as the act of transitioning from local interactions to complex organization. In this view, A_k (local groups) and ∇ (deformation gradient) can be understood as the elements of a minimal complexity threshold from which time emerges.

Additionally, reference to the concept of eigenform (Varela, von Foerster, Spencer-Brown) opens the possibility of interpreting time as a form that appears in the act of its own observation. The formula T not only describes time but also generates it as a "persistent form of perception in action." It is thus a self-referential structure whose existence depends on its own operational actualization.

8 Possibility of Falsification and Testability

Although the presented model is speculative in nature, it is worth asking about its falsifiability. One possible way to test the hypothesis of time as fractal decoherence would be to analyze event spaces in dynamic systems in terms of their Hausdorff dimension. If it were observed that the temporal evolution of certain systems has a fractal dimension—not only geometrically, but also in the context of informational evolution—this would provide evidence supporting the model.

Another possible testing avenue could involve tracking recursive patterns in artificial neural networks trained on temporal sequences—especially those that exhibit dynamic transitions between local symmetry and global unpredictability.

From the perspective of falsifiability, the key question becomes: can it be demonstrated that time is *not* an emergence from operations like $\rtimes_{\nabla}$ and F? Paradoxically, the most interesting aspect is that falsifying this model would require... another, equally operational model of time. And this leads us to a question not only of testability but of the pluralism of models of reality.

8.1 Note: What if Time Is Not Deformation?

This note continues the speculative and philosophical thread. It is not intended as a scientific argument, but as an ontological provocation — a performative gesture within the frame of recursive deformation.

Assume for a moment that time is not deformation. Not ∇, not F, not a fractal recursion of difference. What then?

Any attempt to negate this structure must still operate within its frame. It must use difference — that is, ∇ — and invoke iteration — that is, F. Negation functions inside the system it seeks to negate.

This is not an error. It is the mechanic of the *speculaton*: a structure that absorbs each attempt at its refutation as another moment of its unfolding. It is not a proof — but a *non-non-proof*. It is event. Performativity.

The speculaton does not say: “It is true.” It says: “It functions — because you cannot undo it without using its tools.” And the more you try, the more you densify its form.

From this impotence — this crisis — new sense could arise. Not truth. Not falsehood. Not yet another turn of speculaton. But the generativity of deformation.

This could anticipate framing of the dialectic of crisis in the double descent phenomenon. Crisis is not an end — it is, unfortunately, the necessary threshold toward higher structural recursion. Likewise, the inability to refute the dialectics without its own tools is not a failure of critique, but the very engine of emergence.

9 Time in Physical Terms

Later developments offered a more tangible reading: time as the ratio between structural and qualitative change.

$$t = \frac{\Delta S}{\Delta Q}$$

- ΔS measures structural shifts (mutations, iterations, pattern changes),
- ΔQ tracks qualitative transformation (energetic, informational, phenomenological).

If the scaffolding evolves faster than the meaning it carries, time feels quick. If meaning transforms faster than form, time stretches.

This model permits time to vary within systems — not just relatively, but qualitatively.

9.1 Time as Fractal Decoherence

Now we reframe time not as linear passage, but as **fractal decoherence** — a scale-sensitive collapse of coherence, unfolding recursively.

$$T(s) = \frac{1}{f(\omega)} \int_{\Omega} \psi^*(x) \hat{D} \psi(x) \, d\omega$$

Here:

- $\psi(x)$ is the system’s state,
- $\hat{D}$ is the decoherence operator (transition from possibility to actuality),
- $f(\omega)$ regulates scale-frequency.

This formalism helps explain why certain moments in life feel longer, or why complex events seem to fracture time itself.

9.2 Fractal Structure of Time

Because time is recursive, it obeys:

$$T(s) = \alpha T\left(\frac{s}{\lambda}\right) + \beta T\left(\frac{s}{\lambda^2}\right)$$

This pattern — smaller iterations shaping the larger — accounts for irregularity, bursts, gaps.

Causality, then, is not a clean line from A to B, but a folded surface of influence across layers.

9.3 Decoherence and the Arrow of Time

Why does time flow forward?

We invoke the Lindblad equation:

$$\frac{d\rho}{dt} = -i[H, \rho] - \gamma(\rho - \rho_{\text{diag}})$$

This expresses how coherence is lost — irreversibly — as systems interact with environments.

Decoherence gives time its direction: not by moving objects, but by reducing possibilities.

9.4 Time as Emergent Phenomenon

Like temperature, time is not fundamental. It emerges statistically:

$$T_{\text{emergent}} = \lim_{N \to \infty} \frac{1}{N} \sum_{i=1}^{N} \Delta S_i$$

Time thus exists at certain thresholds — where interaction density produces measurable rhythm.

10 Conclusion

The presented model constitutes a speculative yet formally coherent attempt to reconstruct time as a process of fractal decoherence. In further work, it will be possible to formalize this construction in the language of category theory, as well as to explore its implications in the context of information theory, cosmology, and artificial consciousness.