The Universal Replication Principle as a Unified Framework for the Expansion of Physical Vacuum and the Origin of Life

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Authorship Note
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Abstract

This work proposes the Universal Replication Principle (URP) as a unified conceptual framework for interpreting the persistence, reproduction, and evolution of physical configurations in the universe. According to this principle, configurations that reach a certain degree of stability and coherence tend to persist and, under favorable dynamical conditions, to generate new configurations with similar structural properties.

From this perspective, apparently diverse phenomena—such as the formation of gravitational structures, the accelerated expansion of the universe, and the emergence of living systems capable of replication—can be understood as manifestations of a common underlying dynamic of coherence replication.

In the cosmological domain, dark energy is interpreted as the observable manifestation of the expansion of the physical vacuum, understood as a dynamical state of spacetime capable of extending its own structure. In the biological domain, the URP situates the origin of life within a natural continuity of physical and chemical organization processes, as a transition toward advanced forms of structural and informational replication.

This approach does not introduce new physical interactions but rather provides a unifying reinterpretation of known phenomena, linking cosmology, fundamental physics, and biology under a common dynamical principle. Although further theoretical development and empirical validation are required, the proposed framework suggests that the evolution of the universe can be understood as a process in which coherence is not only preserved but, under certain conditions, replicated and transformed across different levels of organization.

1. Introduction

One of the most remarkable features of nature is the recurrent emergence of processes of persistence, replication, and self-organization across different levels of the universe. From the formation of large-scale cosmological structures to the emergence of living systems capable of self-replication, many phenomena exhibit a common tendency to generate configurations that preserve fundamental properties of previous states.

In cosmology, one of the most significant open problems is the nature of dark energy, responsible for the accelerated expansion of the universe. Despite the descriptive success of the standard cosmological model, the physical interpretation of this phenomenon remains uncertain.

In parallel, biology faces another fundamental question: the origin of life, understood as the emergence of systems capable of reproducing information and maintaining organization against entropy. Although various physicochemical scenarios have been proposed, there is no clear consensus on the principles that enabled this transition.

Although these problems belong to different domains, they may be related to more general properties of the dynamics of the universe.

This work proposes the Universal Replication Principle (URP) as a conceptual principle describing the tendency of certain stable physical configurations to persist and, under favorable dynamical conditions, to generate analogous configurations. From this perspective, phenomena such as the expansion of the physical vacuum associated with dark energy and the emergence of self-replicating living systems can be interpreted as manifestations of a common underlying dynamic.

2. The Universal Replication Principle (URP)

The Universal Replication Principle (URP) is proposed as a general conceptual principle describing a recurrent property in natural systems: the tendency of certain stable physical configurations to persist and, under favorable dynamical conditions, to generate new configurations with similar structural properties.

This principle does not introduce a new physical interaction nor replace existing laws. Its function is descriptive: it identifies a regularity in the dynamics of nature that manifests across different levels of organization, from fundamental physical structures to complex systems.

In general terms, the URP can be formulated as:

Physical states that reach a certain degree of stability tend to maintain their coherence and, under certain conditions, generate analogous configurations.

The URP does not imply that every coherent configuration replicates, but rather that this capacity depends on the dynamics of the system in which the configuration exists. Coherence is a necessary condition for persistence, but not sufficient for replication. Replication requires the existence of a dynamical process capable of generating new configurations from previous states. In systems that exhibit such replicative capacity, coherence is not only preserved but can propagate or reproduce under favorable conditions, whereas in systems lacking such dynamics, coherence remains local without leading to replication processes.

To describe this tendency conceptually, we introduce the notion of structural coherence C, understood as the ability of a system to maintain its organization against disordering processes.

Schematically, this dynamic can be expressed as a proportional relationship between the temporal variation of coherence and the level of coherence present in the system:

$$dC/dt \propto C$$

This expression does not constitute a fundamental law but rather a simplified representation of the tendency of certain systems to preserve and amplify coherence under favorable conditions.

These relations are illustrative in nature and do not aim to replace the established equations of existing theoretical frameworks. The formal solution of this relation corresponds to exponential behavior:

$$C(t) = C_o\, e^{kt}$$

where C(t) represents the level of coherence at time t, C_o the initial coherence, and k a parameter describing the efficiency with which coherence is preserved or amplified.

From this perspective, the URP can be interpreted as a general organizing principle that does not act as an additional force, but as an emergent property of certain physical systems favoring persistence and the generation of coherent configurations.

If this property constitutes a fundamental feature of the dynamics of the universe, its manifestation should be observable in the most basic physical states. In particular, it is natural to analyze how this tendency is expressed in the two fundamental modes of physical existence: matter and the physical vacuum.

3. Replication of Fundamental Physical States

In the framework of the Universal Replication Principle (URP), the fundamental physical states of the universe can be interpreted as different manifestations of a common tendency toward the preservation and replication of coherence. Among these states, matter and the vacuum stand out—not as completely independent entities, but as complementary modes through which this dynamic is expressed at different scales.

In the case of matter, gravitational interaction favors the concentration of mass. Under the action of gravity, regions of higher density tend to attract surrounding matter, giving rise to increasingly complex and organized structures such as stars, galaxies, and galaxy clusters. This process can be understood as a form of persistence and amplification of mass-dominated configurations.

Similarly, the physical vacuum exhibits its own characteristic dynamics. At cosmological scales, the vacuum shows a tendency to expand, generating new spatial regions with similar properties. This expansion, observed in the evolution of the universe, can be interpreted as a form of vacuum replication, in which space itself extends by generating new regions with analogous structural characteristics.

From the perspective of the URP, these two behaviors represent differentiated manifestations of the same fundamental dynamic: the tendency of the universe to preserve and replicate its own coherence.

Thus, while gravity favors the concentration of matter, cosmological expansion favors the extension of the vacuum. Both processes contribute to the structural evolution of the cosmos and can be understood as complementary expressions of the replicative dynamic described by the URP.

4. Expansion of the Vacuum and Dark Energy

The accelerated expansion of the universe is one of the most significant phenomena in modern cosmology. Observations of distant supernovae and other cosmological data indicate that this expansion not only continues but also accelerates over time. Within the framework of the standard cosmological model, this behavior is attributed to so-called dark energy, a component estimated to account for approximately 70% of the total energy content of the observable universe.

However, the physical nature of dark energy remains largely unknown, opening the possibility of exploring alternative interpretations based on more fundamental properties of spacetime.

Within the framework of the Universal Replication Principle, cosmological expansion can be interpreted from a different perspective. If the vacuum constitutes a physical state capable of preserving and replicating its coherence, then its expansion can be understood as a direct manifestation of this fundamental dynamic.

From this perspective, the vacuum is not considered a simple absence of matter, but a physical state of spacetime with its own dynamical properties. In particular, cosmological expansion can be interpreted as the tendency of the vacuum to extend itself, generating new spatial regions with similar physical properties.

This dynamic can be represented in a simplified way through a proportional relationship between the rate of expansion and the amount of existing vacuum:

$$dR/dt \propto R$$

where R represents a characteristic spatial scale (for example, the radius of an idealized region of vacuum). This relation expresses that the expansion rate is proportional to the size of the system itself.

The solution to this relation leads to an exponential behavior of the spatial scale:

$$R(t) = R_o \, e^{Ht}$$

where R(t) represents a characteristic spatial scale (which can be interpreted, for example, as the radius of an idealized region of physical vacuum) at time t, R_o its initial value at a reference instant, and H a constant describing the rate of expansion.

As in the previous case, this relation is schematic in nature and does not aim to replace the precise description of cosmological expansion provided by standard models.

Within this interpretative framework, the expansion of the vacuum can be understood as a particular manifestation of the dynamics of spacetime. While gravity produces attraction and concentration when acting on matter, its effect in regions dominated by vacuum may be interpreted as a tendency toward the expansion of space itself.

From this perspective, dark energy can be interpreted as the observable cosmological manifestation of this expansive dynamics of the vacuum. This interpretation is phenomenologically compatible with the standard cosmological model ΛCDM, in which accelerated expansion is described through a cosmological constant. In this sense, the acceleration of the expansion of the universe does not necessarily require the introduction of an independent entity, but can be understood as the expression of the tendency of the vacuum to extend its own structure, in coherence with the Universal Replication Principle.

The dynamics described is not an isolated phenomenon within the evolution of the universe. If the Universal Replication Principle operates as a fundamental property of reality, its manifestation is not limited to the cosmological domain but extends across different levels of organization, contributing to the emergence of increasingly complex structures.

5. Structural Replication and Complexity

The Universal Replication Principle is not limited to describing cosmological processes, but manifests continuously in the progressive organization of matter across different scales.

In many open physical systems, certain configurations reach relatively stable states that allow them to persist over time and, in some cases, to generate new similar structures. This behavior can be observed in a wide range of phenomena, from the formation of gravitational structures to the organization of complex chemical systems.

The evolution of the universe shows a recurrent tendency toward the emergence of increasingly organized structures. From the earliest particles and fundamental fields, atoms are formed, followed by molecules, and later chemical structures of increasing complexity. Each of these levels introduces new forms of stability and organization.

From the perspective of the URP, this progression can be interpreted as a manifestation of the tendency of coherent configurations to persist and reproduce under favorable dynamical conditions. Structures that manage to maintain their coherence against disordering processes tend to endure and generate new related configurations.

In this way, the evolution toward increasing complexity does not depend solely on random processes, but can also be understood as a consequence of the dynamics through which the universe preserves and replicates structurally stable configurations.

This process of structural replication prepares the physical and chemical context in which systems capable of explicit replication—the defining feature of living organisms—can emerge.

As structural complexity increases, the replication of coherence acquires progressively more elaborate forms. In this process, certain configurations not only persist over time, but also actively participate in the generation of new similar structures. This development establishes the framework in which replication ceases to be purely structural or dynamical and begins to incorporate the transmission of information, a fundamental characteristic of living systems.

6. The Origin of Life as a Replicative Process

In this context, the emergence of life can be interpreted as a natural consequence of the progressive development of coherence replication in increasingly complex physical systems. In living organisms, matter acquires the capacity to maintain organized structures, exchange energy with the environment, and reproduce information through replication mechanisms.

In current scientific approaches, the origin of life is typically understood as the result of a series of gradual transitions in increasingly complex chemical systems. From simple molecules, certain systems can develop reaction cycles that favor the formation of structures capable of reproduction or participation in autocatalytic processes.

In this context, the emergence of replicative systems does not necessarily constitute a rupture with prior physical dynamics, but rather an intensification of organizational processes already present at more basic levels of matter.

From the perspective of the Universal Replication Principle, life can be interpreted as a particularly complex manifestation of the tendency of coherent configurations to persist and

reproduce. Unlike simple physical or chemical systems, living organisms introduce a new level of organization: the replication of structured information.

The emergence of molecules capable of storing and transmitting information—such as primitive molecular replicators analogous to RNA or DNA—allows certain configurations not only to persist, but also to reproduce with heritable variations. This process opens the possibility of biological evolution through natural selection.

From this perspective, life does not constitute an exception within the laws of the universe, but rather a continuation of the general dynamics through which stable configurations are preserved and reproduced over time.

Thus, biological replication can be understood as an advanced form of the replicative tendency that manifests across different levels of organization in nature, from fundamental physical structures to living systems capable of evolution.

7. Cosmological and Biological Implications

The hypothesis presented in this work suggests that different phenomena observed in the universe may be interpreted as manifestations of a common underlying dynamic associated with the persistence and replication of coherent configurations.

In the cosmological domain, the Universal Replication Principle provides a conceptual framework for interpreting the accelerated expansion of the universe from the perspective of vacuum dynamics. Rather than considering dark energy as an independent entity, it may be understood as the observable manifestation of the tendency of the vacuum to extend and generate new spatial regions under certain cosmological conditions.

This interpretation remains consistent with the standard cosmological model in terms of the observational description of cosmic expansion, while proposing an alternative reading of its physical meaning. Within this framework, gravity may manifest differently depending on the medium in which it acts. When acting on matter, it favors the concentration of mass and the formation of gravitational structures. When acting in regions dominated by vacuum, its effect may be interpreted as a tendency toward the expansion of space itself. From this perspective, the expansion of the vacuum and gravitational attraction may be interpreted as complementary manifestations within the global dynamics of spacetime.

In the biological domain, the URP suggests a possible continuity between processes of physical organization and the emergence of living systems. Life may be interpreted as a particularly complex form of structural replication, in which matter acquires the capacity to preserve and reproduce information in a stable manner.

Under this interpretation, the origin of life does not appear as an isolated phenomenon within the evolution of the universe, but rather as an advanced manifestation of the same general tendency toward the persistence and reproduction of coherent configurations.

Although this hypothesis requires further theoretical and empirical development, it provides a conceptual framework in which apparently distinct phenomena—such as vacuum expansion, the formation of cosmological structures, and the emergence of life—can be interpreted within a single general dynamic of structural replication.

8. Implications and Possible Paths of Verification

The framework proposed in this work does not introduce new physical interactions but offers a unifying reinterpretation of already observed phenomena. In this context, its scientific value depends in part on its capacity to generate testable implications or, at least, to guide the interpretation of existing data within a coherent perspective.

In the cosmological domain, interpreting dark energy as a manifestation of vacuum expansion suggests that cosmic acceleration may not require the introduction of an independent component, but could instead be understood as an intrinsic property of spacetime. This perspective is compatible with current observations, while opening the possibility of exploring whether certain aspects of expansion—such as its stability, homogeneity, or possible large-scale deviations—can be more naturally described within this framework.

Likewise, the model suggests that the distinction between attractive gravity and vacuum expansion may be interpreted as two manifestations of a common underlying dynamic. This idea opens the possibility of investigating whether intermediate regimes or subtle effects exist in which both tendencies manifest simultaneously, potentially affecting the formation and evolution of large-scale structures.

In the domain of the origin of life, the Universal Replication Principle suggests that the emergence of replicative systems is not an exceptional phenomenon, but a possible consequence of the general dynamics of matter under suitable conditions. From this perspective, research in prebiotic chemistry may be understood as the search for conditions under which structural replication intensifies to the point of producing systems capable of storing and transmitting information.

Beyond specific predictions, the main value of the proposed framework lies in its ability to integrate diverse phenomena under a common conceptual logic. In this sense, its empirical assessment does not depend solely on the emergence of new observations, but also on its capacity to provide more coherent or unified descriptions of already available data.

Although these lines of verification remain preliminary, the approach presented here suggests that vacuum expansion, the stability of physical structures, and the emergence of life can be analyzed as expressions of a single general dynamic, opening new avenues of research at the intersection of cosmology, fundamental physics, and biology.

9. Conclusion

This work has proposed the Universal Replication Principle (URP) as a conceptual framework for describing a general property of the universe: the tendency of stable physical configurations to persist and generate analogous structures over time. From this perspective, apparently diverse processes—such as the formation of gravitational structures, the expansion of the vacuum associated with dark energy, and the emergence of living systems capable of replication—can be interpreted as manifestations of a single underlying dynamic.

In the cosmological domain, this approach allows the accelerated expansion of the universe to be reinterpreted as an expression of the dynamics of the physical vacuum, understood as a state with active properties capable of extending its own structure. Within this framework, dark energy may be interpreted as the observable manifestation of this process.

In the biological domain, the URP suggests a continuity between physical organization, chemical complexity, and the emergence of systems capable of informational replication. Life may thus be understood as an advanced expression of the same dynamic of preservation and reproduction of coherent structures.

Although this framework requires further theoretical and empirical development, it offers a way to interpret, in a unified manner, phenomena that have traditionally been studied independently. From this perspective, the evolution of the universe may be understood as a process in which structures not only persist, but also give rise to new forms of organization over time.