

The Expansion of the Vacuum as a Complement to Gravity and the Origin of Dark Energy

Author: Ignacio Lesta Pelayo

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Abstract

We propose that dark energy is not an independent entity but rather the cosmological manifestation of a dual physical reality: the dynamic expansion of the vacuum. Within the framework of this hypothesis, the vacuum behaves as an active medium with self-sustaining expansive dynamics. This continuous and fundamental process constitutes the geometric cause of the accelerated expansion of the universe. Thus, vacuum expansion and gravity are conceived as complementary manifestations derived from a single physical principle of spacetime. Their dual interaction explains the structure and evolution of the cosmos with ontological economy, without the need to postulate new particles or additional fields beyond General Relativity.

1 Introduction

The accelerated expansion of the universe is one of the greatest challenges of modern cosmology. The conventional explanation relies on the so-called dark energy, an entity that would represent about 70% of the total energy content of the cosmos, yet whose physical nature remains unknown. In this work, we propose a reinterpretation: dark energy is not an additional force but rather the expression of the expansive nature of the physical vacuum. The vacuum, understood as the fundamental state of spacetime, possesses dynamic properties that can explain cosmic expansion without the need to postulate additional components.

2 Foundation of the Hypothesis

This hypothesis is based on the existence of a fundamental duality in the nature of spacetime:

Gravity: tends to concentrate mass, curving spacetime toward attraction.

Vacuum expansion: tends to dilate spacetime, generating more vacuum and homogeneity.

Dark energy would therefore be the current macroscopic manifestation of this second tendency. Unlike matter or radiation, the physical vacuum possesses the ability to expand in a self-sustaining, homogeneous, and isotropic manner, without requiring external causes to begin or persist. This continuous expansion constitutes the geometric impulse responsible for the observed cosmic acceleration. To model mathematically this principle of geometric autocatalysis, this behavior can be represented by the *Vacuum Proportionality Postulate*:

$$\frac{dR}{dt} = H R(t)$$

This relation expresses that the expansion rate $\frac{dR}{dt}$ is directly proportional to the already existing volume of vacuum $R(t)$, with H a proportionality constant (analogous to the Hubble constant in its current form). The mathematical solution of this self-expansion relation is exponential in nature:

$$R(t) = R_0 e^{Ht}$$

where R_0 is the initial radius of an ideal sphere of physical vacuum, and $R(t)$ the radius of the sphere after a time t . This solution shows how the expansion of the vacuum accelerates over time, reproducing the general form of the observed cosmic expansion. The expansion of the vacuum does not constitute a fifth force nor an interaction independent of gravity. Rather, it represents its complementary aspect: while gravity acts on mass by concentrating it,

the same geometric principle acts on the vacuum by dilating it. Both effects arise from a single spacetime reality that simultaneously tends to form mass and to form vacuum. Thus, the expansion of the vacuum is not added to gravity: it is gravity acting upon the vacuum itself.

3 Cosmological Implications

The hypothesis is compatible with the Λ CDM model, although it redefines the physical meaning of the cosmological constant Λ . Instead of being considered an arbitrary constant added to the field equations, it is interpreted as a geometric effect emerging from the natural expansion of the vacuum. The observed acceleration of cosmic expansion is thus explained as a self-sustained and continuous phenomenon, derived from the intrinsic dynamism of the physical vacuum. Visible matter forms secondary structures which, on sufficiently large scales, do not alter the expansive impulse of the vacuum. The isotropy and homogeneity of the cosmic microwave background can be understood as a natural consequence of a uniform primordial expansion, independent of the initial local fluctuations. Within this framework, dark energy ceases to be a mysterious substance and becomes an intrinsic property of spacetime, revealed through its spontaneous tendency to expand.

4 Conceptual Discussion

The present model shifts the explanatory focus from hypothetical entities to a more elementary principle: the vacuum as a dynamic and self-sufficient agent. From this perspective, the universe does not require an external cause to initiate its expansion; rather, it arises as a fundamental property of the vacuum itself. This hypothesis is ontologically economical:

- It introduces no new particles or fields.
- It is based on a universal geometric property.
- It maintains conceptual coherence with General Relativity and with cosmological observation.

If the vacuum naturally tends to expand, the emergence and evolution of the universe can be understood as continuous manifestations of that dynamic. The role of gravity, consequently, is reinterpreted as the necessary complement of vacuum expansion: two opposing expressions of a single spacetime reality. The empirical verification of this hypothesis will depend on the comparison between the observed expansion patterns and the predictions derived from the self-sustained dynamics of the vacuum.

5 Local Effects of the Vacuum

Although the expansion of the vacuum manifests primarily on cosmological scales, it is possible that its local gradients play a subtle role in the gravitational dynamics of structures. This aspect, still speculative, could be explored in future research without implying a direct equivalence with dark matter.

6 Conclusion

This hypothesis proposes that the structure and evolution of the universe arise from the complementary duality of spacetime: gravity (which curves toward the concentration of mass) and vacuum expansion (which dilates toward homogeneity). Both are expressions of a single underlying geometric principle. On large scales, the expansion of the vacuum explains the cosmic acceleration associated with dark energy, reinterpreting the cosmological constant Λ as an emergent effect of the self-sustained dynamics of the vacuum. This framework offers a coherent and parsimonious way to reinterpret acceleration phenomena without resorting to additional hypothetical entities.