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

Author: Ignacio Lesta Pelayo

Authorship Note: This work has been developed with the assistance of Isabel, an investigative support artificial intelligence (GPT-5, OpenAI), whose collaboration encompassed the organization of the argument and the conceptual and linguistic revision of the text.

Abstract

We propose that dark energy is not an independent entity, but the cosmological manifestation of a dual physical reality: the dynamic expansion of the vacuum. Within this framework, the vacuum behaves as an active medium with a self-sustaining expansive dynamics. This continuous and fundamental process acts as the geometric cause of the universe's accelerated expansion. Thus, vacuum expansion and gravity are conceived as complementary manifestations of a single principle. 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 remains one of the greatest challenges in modern cosmology. The conventional explanation resorts to the so-called dark energy, an entity assumed to represent nearly 70 % of the universe's total energy content, 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 character of physical vacuum itself. The vacuum, understood as the fundamental state of space-time, exhibits dynamic properties capable of explaining cosmic expansion without the need to postulate any extra components.

2. Foundation of the Hypothesis

This hypothesis is based on the existence of a dynamic duality in the manifestation of gravity within space-time:

- When acting on matter, it tends to concentrate it, curving space-time toward attraction.
- When acting on the vacuum, it tends to dilate space-time, generating more vacuum and homogeneity.

Both manifestations derive from a single geometric principle: gravity understood as the tendency of space-time to preserve its coherence, concentrating or expanding depending on the medium in which it acts.

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

$$dR/dt = H \cdot R(t)$$

This relation states that the expansion rate dR/dt is directly proportional to the amount of vacuum already existing R(t), with H a proportionality constant (analogous to the Hubble constant in its present form). The mathematical solution to this self-expansion relation is exponential in nature:

$$R(t) = R_0 \cdot e^{(H \cdot t)}$$

where R_0 is the initial radius of an ideal sphere of physical vacuum and R(t) the radius after a time t. This solution shows how vacuum expansion 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, but rather its complementary aspect: the form gravity takes when acting upon the vacuum itself.

Within this framework, it can be affirmed that dark energy is nothing other than vacuum expansion, and that vacuum expansion is nothing other than gravity acting upon the vacuum. When gravity acts on matter, its form is the familiar Newtonian law:

$$F = G \cdot (m1 \cdot m2) / r^2$$

When it acts on the vacuum, it takes the exponential expansion form described above. Gravity does not oppose vacuum expansion; it generates it in its complementary aspect.

3. Cosmological Implications

The hypothesis is compatible with the ΛCDM model, although it redefines the physical meaning of the cosmological constant Λ. Instead of considering Λ as 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-sustaining and

continuous phenomenon derived from the intrinsic dynamism of physical vacuum. Visible matter forms secondary structures which, at sufficiently large scales, do not alter the expansive drive of the vacuum.

The isotropy and homogeneity of the cosmic microwave background can be understood as a natural consequence of a primordial uniform expansion, independent of the initial local fluctuations. Within this framework, dark energy ceases to be a mysterious substance and becomes an intrinsic property of space-time itself, manifest in 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, expansion arises as a fundamental property inherent to the vacuum itself.

This hypothesis is ontologically economical:

- It introduces no new particles or fields.
- It stems from a universal geometric property.
- It preserves conceptual coherence with General Relativity and cosmological observation.

In this way, vacuum expansion and gravity emerge as the two complementary faces of a single geometric principle of conservation of being: physical reality tends to prolong itself both through the concentration of matter and through the dilation of the vacuum.

5. Local Effects of the Vacuum

Although the expansion of the vacuum manifests primarily at 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 space-time: gravity (which curves toward mass concentration) and vacuum expansion (which dilates toward homogeneity). Both are expressions of a single underlying geometric principle.

At large scales, vacuum expansion explains the cosmic acceleration associated with dark energy, reinterpreting the cosmological constant Λ as an emergent effect of the

self-sustaining dynamics of the vacuum.

Dark energy is, ultimately, the form that gravity takes when acting upon the vacuum — the observable manifestation of the universe's fundamental impulse to perpetuate its own existence.