Phenomenological Conjecture on a Possible Primordial State of the Universe

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1.0 Preface

The present work proposes a phenomenological framework describing dynamical processes potentially leading to the formation of localized, self-sustaining, metastable energy configurations depending on the vacuum recombination processes, hereafter referred to as Localized Energy Configurations (hereafter referred to as LEC for brevity).

Depending on the surrounding dynamical conditions, such configurations may exhibit either expansive or mass-like behavior.

This work does not intend to present a complete physical theory nor a rigorous mathematical treatment. Its purpose is to introduce a coherent conceptual framework that may constitute a possible starting point for subsequent theoretical developments.

The mathematical formulations presented herein are exclusively phenomenological and descriptive in nature. Any advanced formalization within the framework of Quantum Field Theory or General Relativity lies beyond the scope of the present work.

The concepts and the general structure of the model may be freely used as a basis for possible future theoretical investigations.

The present work is ideally positioned as a dialogue between intuition and formalism, closer to an exploratory reflection than to a traditional academic treatment.

Any suggestions, comments, criticism, or reports of possible errors would be sincerely appreciated and will be very valuable for future revisions and improvements of this work.
I would also be glad to exchange ideas or collaborate, in principle, with anyone interested in exploring possible formal developments or reformulations of the proposed conjecture.

2.0 Basic Assumptions

2.1 Nature of the Primordial Universe

The existence of a primordial physical state, real and pre-existing with respect to the diffuse hot phase commonly associated with the Big Bang, is assumed. The existence of such a primordial physical state does not necessarily imply a classical temporal description extendable indefinitely, but rather indicates the absence, within the model, of a defined origin in ordinary physical time, since such an origin would add no contribution to the following discussion.

Such a state is not identified with absolute nothingness, but rather with a quantum vacuum configuration endowed with energetic content.

In the present context, the vacuum is intended phenomenologically as a continuous physical medium characterized by a spectral energy distribution and by intrinsic local fluctuations. The hereinafter description is not derived from Quantum Field Theory in its entirety. Nevertheless, according to the aim of this work, the presented model may be considered valid in its context but remaining compatible with such theory.

2.2 Fluctuations and Stochastic Processes

It is assumed that the primordial vacuum is the seat of spontaneous fluctuations distributed according to a stochastic process.

In particular, within the interpretation of time defined in Sec. 1.1, the possibility is considered that rare events, though with non-zero probability, involving recombination anomalies per unit volume-time may lead to the formation of a Localized Energy Configurations (LECs).

Over temporal intervals whose duration is indefinable, even extremely improbable events may cumulatively contribute to the global dynamics of the system.

2.3 Introduction of the LECs

In the present work, the previously defined LECs are introduced as effective phenomenological entities.

Within the present model, a distinction is made between the diffuse energetic contribution of the vacuum and localized configurations. It is assumed that the dynamics relevant to the model are primarily associated with such localized configurations, while the vacuum acts as an energetic background.

The model assumes that the total energetic content of the primordial universe is invariant.

Every LEC represent a form of localization of such energy, which may subsequently be converted into diffuse energy (radiation, particles, etc.) during the evolutionary phases of the universe, as described later.

As anticipated in the previous section, it is assumed that, as a general behavior, each local field fluctuation generates two complementary energy configurations with a subsequent immediate recombination, in order to result in a null contribution to the field energy. For simplicity, each of the two energy configurations can be referred to as a “Semi-Local Fluctuation” (SLF).

It is admitted that a rare, but possible, anomaly occurring during a recombination of the two SLF may fail. In this case a LEC will be generated which has the following general characteristics:

- Statically placed in the same point of formation.
- finite energy;
- stability or metastability over long temporal scales compared to the local processes of the system;
- in some cases, depending on the dynamic of the environment, the LEC may exhibit massive behaviour, as mentioned later.

Please note that an explicit Lagrangian formulation of formation and behavior of LECs lies beyond the scope of the present conjecture.

2.4 Structure into Two Complementary Families

It is assumed that each LEC may be divided into two complementary families, conventionally denoted as A and B, whose energetic contribution are concurrent in the same way each SLF

Such a distinction is introduced at the phenomenological level and may be interpreted as the expression of an opposite internal property (for example phase, effective charge, or another conserved quantity) depending on the contribution of each SLF in production of each LEC.

The more a SLF contributes to the LEC formation, the more this latter exhibits an energetic behavior of main contributor.

The presence of two LECs families allows the existence of reciprocal interactions in which complementary configurations may convert their energy into other forms, thus constituting a key element for the global dynamics of the model.

2.5 Distribution and Collective Properties

LEC may be distributed throughout space in a locally non-uniform manner while preserving an overall statistical symmetry.

The total number of LEC may increase over time as a function of the formation rate, remaining at every instant determined by stochastic processes. In the stage preceding the diffuse hot phase (assimilable to the Big Bang, terminology adopted hereafter for simplicity of exposition), given the enormous spatial scales involved, the two complementary sets A and B are considered capable of coexisting capable of coexisting over extremely long temporal scales without significant mutual interaction.

On large scales, the ensemble of LEC contributes cumulatively to the energetic properties of the system.

2.6 Limits of the Model

The present work is phenomenological and preliminary in nature. In particular:

- the model is not derived from a complete field theory;

- it does not include an explicit relativistic description based on General Relativity;
- it does not presently provide quantitative observational predictions susceptible to verification.

Furthermore, it does not include:

- a microscopic description of the interactions between LEC;
- a complete dynamical formulation of propagation processes.

The considerations presented herein should therefore be regarded as a possible conceptual basis for future theoretical developments.

3.0 Phenomenological Energetic Description

3.1 General Approach

The relations introduced in the present chapter are phenomenological in nature and describe an effective model of the energetic content of the primordial universe.

For simplicity of treatment, a simplified representation derived from Field Theory is employed, useful for describing the vacuum energy distribution and the formation of LEC.

The primordial vacuum is described as a continuous system endowed with distributed degrees of freedom, without an explicit interpretation in terms of particles or field excitations in the usual sense of Quantum Field Theory.

3.2 Spectral Structure of the Vacuum

In order to effectively represent the energetic distribution of the primordial vacuum, a spectral description is introduced based on a regulating function *g(ω)*, dependent on an angular frequency variable ω resulting in a effective cutoff to avoid divergent high-frequency contributions.

It is assumed that the function *g(ω)* progressively suppresses contributions beyond a characteristic scale associated with the Planck scale:

$$g(\omega) = e^{-\frac{\omega}{\omega_P}} \quad (1)$$

where:

- ω is the angular frequency of the considered mode;
- ω_P is the angular frequency associated with the Planck scale.

It is assumed that:

- $g(0) \sim 1$
- $g(\omega) \to 0 \; per \; \omega \gg \omega_P$

The specific form of the function *g(ω)* is not unique; all choices ensuring asymptotically decreasing behavior at high frequencies are usable.

It is specified that the above function does not represent a renormalization procedure in the standard sense of field theory.

3.3 Effective Vacuum Energy Density

The energetic content of the primordial vacuum is described through an *effective energy density* ρ_{vac}, phenomenologically expressed as:

$$\boldsymbol{\rho_{vac} = \sum_i \hbar\omega_i, g(\omega_i)} \quad \textbf{(2)}$$

or, equivalently, through a continuous integral representation.

Such an expression should not be interpreted as a sum of particle contributions, but rather as a parametrization of the local energetic content of the vacuum under unperturbed conditions.

Fluctuations that do not lead to LEC formation do not modify, on average, the energetic density.

3.4 LEC Formation and Local Energy Balance

In the presence of LECs formation the local energy balance may be expressed in the form:

$$\boldsymbol{\rho_{vac} = \rho_{vac,res} + \rho_{LECs}} \quad \textbf{(3)}$$

where:

- $\rho_{vac,res}$ is the residual vacuum energy density;
- ρ_{LECs} represents the energetic contribution associated with LECs.

Over a sufficiently small local volume, one may equivalently write:

$$\boldsymbol{E_{loc} = E_{vac,res} + E_{LECs}} \quad \textbf{(4)}$$

The microscopic conversion mechanism is not specified in this paragraph since it will be proposed conceptually in the following chapters.

Under conditions in which LECs exhibit effective mass-like behavior, their associated gravitational dynamics may be treated within the standard General Relativity framework.

3.5 Total Energy of the System

On a global scale, the total energy of the system is obtained by integrating the local contributions over the entire volume:

$$\boldsymbol{Etot = \int \rho_{vac,res}\, dV + \int \rho_{LEC}\, dV} \quad \textbf{(5)}$$

where:

- the first term represents the contribution of the residual vacuum;
- the second term represents the energy associated with the LECs present in the system.

In the case of the presence of the two families A and B mentioned in Sec. 1.4, the sum may be explicitly written as:

$$\boldsymbol{Etot = \int \rho_{vac,res}\, dV + \int \rho_{LEC_A} dV + \int \rho_{LEC_B}\, dV} \quad \textbf{(6)}$$

3.6 Meaning and Limits of the Description

The relations introduced in the present chapter constitute an effective description of the energetic balance of the system and not a complete theory of its dynamics.

In particular:

- the temporal dynamics of LEC formation and conversion processes are not specified;
- the gravitational role of the energy thus defined is not explicitly modeled;
- a complete relativistic description consistent with General Relativity is not included.

The adopted expressions should therefore be regarded as a conceptual tool for describing the global behavior of the system within the limits of the model.

4.0 Dynamics of LECs and Possible Cosmological Interpretation

4.1 Stochastic Formation of LECs

Summarizing what has been described in the previous chapters, it has been assumed that LECs may form from local fluctuations of the primordial vacuum. Furthermore, such events have been considered rare and stochastically distributed, with non-zero probability per unit volume and time.

4.2 Accumulation and Distribution

Due to the stochastically generation, the two complementary families A and B of LECs may accumulate locally in regions in which the density of their configurations may be greater than the average value, or may become locally non-symmetric while preserving an overall statistical symmetry. The spatial distribution is therefore not necessarily uniform and the respective LECs may exist in mutual proximity due to the large space available.

Such accumulation represents a preliminary condition for the triggering of collective processes as reported in the following speculative descriptions.

4.3 Interactions Between LEC

It is assumed that LECs belonging to the two complementary families A and B may interact when their spatial separation becomes sufficiently small.

The interaction is interpreted as a process of energetic conversion in which the energy associated with the LECs is returned to the vacuum or transferred into other diffuse energetic forms.

4.4 Critical Threshold and Collective Instability

As the local density of LEC increases, the system may reach a critical condition beyond which interactions between A and B configurations become highly probable.

In such a regime, the system may enter a state of collective instability in which localized energetic conversion events may trigger analogous processes in adjacent regions.

The energy locally released increases the probability of further interactions, favoring a cascade propagation mechanism.

4.5 Cascade Process and Energy Release

Once the critical threshold has been exceeded, the system may evolve through a sequence of energetic conversion events distributed throughout space.

Such a process is not necessarily confined to a single region, but may develop extensively, involving significant portions of the system.

The overall result is a diffuse release of energy previously stored within the LECs, which is returned to the medium.

4.6 Phenomenological Interpretation

The process described above may be interpreted, in phenomenological terms, as a phase of global energetic release characterized by conditions of high energy density and strong interaction, in which the energy associated with the LECs is returned to the vacuum or transferred into other observable energetic forms such as radiation and elementary components of ordinary matter.

Such a phase is not directly identified with a specific event of standard cosmology, but may be considered qualitatively compatible with an initial hot and dense phase commonly associated with what is described in Big Bang models.

The present model does not provide a relativistic derivation of the expansion of space, but suggests a possible energetic mechanism that could precede or accompany an expansion phase.

4.7 Possible Implications

Within this framework, it has been assumed that the distribution of LECs, belonging to a family A or B, may exceed the complementary one. In the hot phase that did not participate in the conversion process could constitute a stable residual component whose presence might be qualitatively associated with contributions not directly observable in the matter content of the universe.

Similarly, the energy released during the conversion phase could contribute to determining initial conditions characterized by high temperature and density, which could be associated with a diffuse formation of the *ordinary matter.*

According to this interpretation, the energy released in this hot phase could be also compatible with the diffuse large-scale radiation, as measured in present days.

As noted earlier, it should be taken into consideration that, such interpretations remain speculative and do not constitute quantitative predictions of the model.

5.0 Energy Balance and Possible Observable Implications

5.1 Energy Balance Within the Framework of the Model

Within the context of the present conjecture, it is assumed that the total energetic content of the primordial universe is invariant.

The energy of the primordial vacuum therefore constitutes a global reservoir from which localized configurations in the form of LECs may emerge without altering the overall energetic balance of the system.

LECs therefore represent a mode of different local organization of energy, not its creation or destruction.

5.2 Continuous Formation

Within the proposed phenomenological framework, the formation of LEC is not necessarily limited to the initial phases of the evolution of the system.

It may be hypothesized that vacuum fluctuation processes continue generating new LEC even during subsequent epochs, including the present one. Such continuous formation, although not quantitatively described in the present model, is consistent with the hypothesis of a vacuum endowed with active energetic structure.

5.3 Phenomenological Interpretation: Matter and Non-Visible Energy

LEC that do not participate in conversion processes, together with those possibly formed during later epochs, could constitute a diffuse and not directly observable energetic component.

In this context, such configurations may be qualitatively associated with phenomena commonly attributed to dark energy and dark matter, insofar as their collective dynamical behavior could contribute to effective gravitational phenomena without producing directly observable radiation.

This interpretation does not constitute a direct identification, but rather a possible interpretative framework consistent with the proposed model.

5.4 Limits and Speculative Character

The considerations presented in this chapter do not provide quantitative predictions and, in particular, do not specify:

- the microscopic mechanisms of LEC formation;
- their detailed dynamical properties;
- their interaction mechanisms with ordinary matter.

The hypotheses formulated should therefore be understood as qualitative indications for possible future theoretical developments.

5.5 Speculative Considerations on the Behavior of LEC

The following considerations are purely speculative in nature and do not constitute a formal extension of the model, but are intended to explore possible qualitative behaviors of LEC based on the phenomenological framework introduced in the previous chapters.

As already discussed, LECs are interpreted as localized energetic configurations of the primordial vacuum. As such, they may exhibit dynamical properties not directly reducible to those of observable particles described within Quantum Field Theory, while still sharing some qualitative aspects with them.

In one possible interpretation, LEC may be described as self-confined configurations characterized by a coherent internal structure whose stability does not depend on the preservation of the initial formation conditions, but rather on the capability of the configuration itself to dynamically sustain its own existence over time.

Within this framework, properties such as orientation, spatial extension, and dynamical behavior may naturally emerge from the internal structure. In particular, the presence of a closed and coherent configuration suggests the possibility of degrees of freedom qualitatively compatible with closed or toroidal-like dynamical configurations.

It may also be hypothesized that such configurations:

- possess high stability over extended temporal scales;
- interact weakly with ordinary matter;
- are distributed in a diffuse or structured manner on large scales.

These characteristics would render LEC difficult to detect through direct interactions, while still allowing them to exert appreciable gravitational effects.

The collective behavior of LEC could differ significantly from that of a conventional particle gas. Under favorable local conditions, they could give rise to aggregation or non-linear clustering phenomena, contributing to the formation of structures across different scales.

A further aspect concerns the possibility that different configurations of LEC aggregations may lead to distinct dynamical behaviors. Such a hypothesis could provide a qualitative basis for interpreting different macroscopic manifestations of the same fundamental entity.

Finally, the continuous formation of LEC, already hypothesized in previous sections, could contribute to maintaining over time a non-visible energetic component whose distribution and density evolve over cosmological scales.

The above hypotheses do not constitute verifiable predictions within the context of the present work, but are intended to provide qualitative insights for a possible future theoretical extension of the model.

6.0 (Mass/Expansion) Dynamic Duality of LECs

In this interpretation, LECs are not assumed to propagate spontaneously through space as ordinary particles. Their phenomenological behavior is instead assumed to depend primarily on the dynamical conditions of the surrounding environment and on collective effects associated with large-scale structures.

As a first approximation, a distinction may be drawn between a regime in which the energy associated with LEC is more strongly confined and correlated with regions of high ordinary matter density, and a regime in which such energy is distributed more uniformly over large scales in original status of stability.

In the former case, LEC may contribute effectively to attractive gravitational phenomena, favoring the formation and stability of bound structures. In the latter case, the same component may manifest itself through dynamical effects compatible with a large-scale evolution characterized by accelerated expansion.

Within this framework, the distinction between components commonly interpreted as mass and energy on cosmological scales could reflect different manifestations of the same fundamental entity, rather than the existence of two physically separate components.

Such an interpretation remains phenomenological and does not imply an explicit formulation within the framework of Quantum Field Theory or General Relativity, but is conceived as qualitatively compatible with both.