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The Evolution of Cosmic Structures from a Superdense Primordial State

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Abstract

This paper proposes a qualitative framework in which condensates of a superdense, non-baryonic, electromagnetically inconspicuous substance or physical phase, provisionally termed *primordial invisible matter* (PIM), could contribute to cosmic structure formation. Through fragmentation, expansion, and phase transitions, these condensates might generate different configurations, suggesting evolutionary connections among compact objects, Little Red Dots, quasars, and galaxies. The hypothesis considers an alternative evolutionary direction, from initially superdense configurations toward more diffuse and complex structures, rather than the conventional growth of primordial density perturbations. Possible connections with dark matter and dark energy are also discussed. This remains a hypothetical concept requiring a quantitative physical description and observational tests.

Keywords: *Primordial invisible matter; primordial condensates; cosmic structure formation; Little Red Dots; quasars; galaxies; dark matter; dark energy.*

1. Introduction

The ΛCDM cosmological model successfully describes the large-scale evolution of the Universe, although the fundamental nature of dark matter and dark energy remains unresolved (Planck Collaboration 2020). Questions concerning black hole (BH) interiors, classical singularities, and the information paradox also remain open.

Recent James Webb Space Telescope (JWST) observations have revealed unexpectedly massive and luminous objects in the early Universe, including compact sources known as Little Red Dots (LRDs), whose physical nature and relationships with early BHs and active galactic nuclei (AGN) remain under investigation (Inayoshi & Ho 2026; Mathee et al. 2024). These discoveries, together with theoretical challenges concerning the formation of early massive BHs (Bogdán et al. 2024; Latif et al. 2026), motivate reconsideration of the origins of compact cosmic structures.

This paper explores whether different cosmic structures could originate from a common, initially superdense physical state, evolving through fragmentation, expansion, and phase transitions. This conceptual framework is provisionally termed the *primordial invisible matter (PIM) hypothesis*.

2. The PIM Hypothesis and Possible Evolutionary Connections

2.1. Primordial Invisible Matter

PIM is proposed as a hypothetical, superdense, non-baryonic substance or physical phase characterized by weak or negligible electromagnetic emission. Its physical nature might involve an unknown matter phase, a quantum condensate, or another form of matter-energy, possibilities that require further theoretical definition.

The central hypothesis is that PIM condensates could undergo fragmentation, expansion, and phase transitions under changing physical conditions, potentially producing different physical configurations. Any

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conversion into ordinary matter, radiation, or energetic outflows would have to satisfy energy-momentum conservation.

Historical investigations of superdense matter by Ambartsumian and Saakyan (1960, 1962a, 1962b) provide conceptual background, although they do not establish the existence of PIM as proposed here.

Unlike conventional structure-formation scenarios, which emphasize the gravitational growth of primordial density perturbations, the PIM hypothesis considers whether initially compact, superdense condensates could provide an alternative set of initial conditions for cosmic structure formation.

2.2. Connections with LRDs, Quasars, and Galaxies

Within this scenario, unstable PIM condensates might release energy and mass through fragmentation and energetic ejection. The released material could potentially convert into ordinary baryonic matter, forming gravitationally bound structures around surviving central condensates, such as dense envelopes, obscured cocoons, or disk-like configurations. Depending on their masses and evolutionary histories, these systems might exhibit characteristics resembling LRDs or quasars. Such an interpretation remains hypothetical and would need to reproduce their observed luminosities, spectra, and other physical properties.

Gravitationally bound fragments surrounding central condensates might undergo further fragmentation, mass ejection, and conversion into baryonic matter on smaller scales, potentially contributing to star formation, stellar systems, angular-momentum redistribution, and ultimately galaxy formation. Surviving central condensates might also contribute to phenomena currently classified as AGN.

The proposed evolutionary connections can be summarized as: **PIM condensates → compact structures, including LRD-like sources and quasars → AGN and galaxies.**

This is not intended as a universal chronological sequence but as a conceptual framework encompassing potentially overlapping or distinct evolutionary stages.

Observations by the Event Horizon Telescope (EHT Collaboration 2019, 2022) provide important constraints on alternative interpretations of BH-like objects. A PIM-based model would need to reproduce their observed properties and/or predict measurable deviations from conventional BH models.

2.3. Possible Connections with Dark Matter and Dark Energy

Some PIM condensates might remain relatively inactive and electromagnetically undetectable, potentially contributing to gravitational effects currently attributed to dark matter. Such a proposal would need to reproduce galaxy rotation curves, gravitational lensing, galaxy-cluster dynamics, and large-scale structure.

More speculatively, certain PIM phases might contribute to accelerated cosmic expansion. This would require a consistent description of their effective stress-energy tensor and equation of state, including the negative pressure necessary for accelerated expansion, while remaining compatible with cosmological observations (Planck Collaboration 2020).

2.4. Observational Tests and Theoretical Requirements

The viability of the PIM hypothesis depends on establishing its physical properties and identifying predictions that distinguish it from existing models. Key requirements include:

- **Gravitational waves:** Predicting possible signals from condensate fragmentation and energetic mass ejection.
- **Compact objects:** Reproducing the imaging and gravitational properties of systems such as M87* and Sagittarius A*.
- **LRDs and early quasars:** Explaining their luminosities, masses, spectra, outflows, and formation timescales, while identifying distinctive predictions testable through JWST and other observations.
- **Galaxy dynamics and lensing:** Reproducing observed gravitational effects if PIM is proposed as a dark-matter component.
- **Cosmic expansion:** Establishing a consistent equation of state if PIM is proposed as a contributor to dark-energy-like behavior.

3. Conclusions

This paper introduces primordial invisible matter (PIM) as a hypothetical superdense, electromagnetically inconspicuous physical phase and explores its possible role in cosmic structure formation.

The proposed framework considers whether fragmentation, expansion, and phase transitions of PIM condensates could contribute to the emergence of compact structures, LRD-like sources, quasars, AGN, and galaxies, potentially through successive fragmentation and matter-conversion processes. Possible connections with dark matter and, more speculatively, dark energy are also considered.

The hypothesis does not yet constitute an established alternative to ΛCDM cosmology or conventional BH models. Its development requires a defined microscopic description, mathematical consistency, and quantitative, observationally testable predictions.

The central question is whether apparently distinct astrophysical phenomena could represent different manifestations or evolutionary outcomes of a common primordial physical state, evolving from initially superdense configurations toward increasingly complex cosmic structures.

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