Phase Transition of the Fermionic Condensate (ψ-field) at 7.76 keV: From Superfluid Early Universe to Viscous Late-Time Expansion

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Abstract

This research note provides a fundamental physical mechanism for the evolution of the cosmic medium within the Fermionic Universe Hypothesis (FUH). We identify a critical phase transition at an energy threshold of approximately 7.76 keV. Above this energy (Early Universe, $T > 90$ million K), the fermionic condensate (ψ-field) existed in a superfluid state with zero bulk viscosity, explaining the rapid, coherent growth of primordial fluctuations. As the Universe cooled below 7.76 keV, spontaneous symmetry breaking led to the emergence of a viscous liquid phase with a dynamic viscosity $\eta = 1.2 \times 10^{-15}$ Pa·s.

Key Findings

- **CMB Anomaly Correlation:** The transition at 7.76 keV provides a hydrodynamic explanation for the Planck A_L (lensing amplitude) anomaly and the suppression of the CMB quadrupole ("Axis of Evil"). The onset of viscosity acted as a damping mechanism for large-scale perturbations.

- **Viscosity-Induced "Cosmic Brake":** The transition from superfluidity to a viscous state at 7.76 keV triggered the "Cosmic Brake" mechanism, which we have previously shown to resolve the H_0 and S_8 tensions with 7.5σ significance using DESI DR2 data.

- **Future Crystallization:** We predict that the increasing density of the ψ-field will lead to a second phase transition — crystallization of the space-time medium — in approximately 20–100 billion years, marking the end of biological viability in the Universe.

Table 1: Phase States of the ψ-field Medium

Cosmological Era	**Energy Scale**	**Dynamic Viscosity (η)**	**Physical Regime**
Early Universe	> 7.76 keV	0	Superfluid
Late-Time Expansion	< 7.76 keV	1.2×10^{-15} Pa·s	Viscous Liquid
Future Universe	Critical Density	$\eta \to \infty$	Crystalline Solid

Physical Mechanism of Symmetry Breaking

The phase transition at 7.76 keV is interpreted as a spontaneous symmetry breaking within the fermionic manifold. In the high-energy superfluid regime ($E > 7.76$ keV), the ψ-field quanta occupy a single macro-quantum state with zero entropy production. As the ambient energy drops below the Shlyapik Threshold, the transition to a viscous liquid phase signifies the emergence of localized interactions between fermions.

This process transforms the spacetime metric from a non-interacting geometric background into a physical medium with measurable impedance. The fundamental form factor $\beta = 0.618$ represents the configuration of minimal hydrodynamic resistance during this transition, ensuring the stability of the emerging viscous manifold.

Key Physical Predictions

The phase transition at 7.76 keV leads to several testable consequences:

- **The 2.96 keV Quantum Snap:** An exothermic energy release predicted during the transition, potentially observable in high-redshift thermal signatures.
- **Anisotropic Impedance:** Local variations in the ψ-field density should manifest as a directional 1.1 keV shift in liquid xenon detectors.
- **Damping Step-Function:** The S_8 suppression should show a clear evolutionary step at the energy-equivalent redshift of 7.76 keV.

Phase Transition Energy Balance

The transition at the Shlyapik Threshold releases a specific latent energy (the "Quantum Snap"), defined by the mass-gap between the superfluid and viscous states:

$$\Delta E = E_{thr} - m_\psi = 7.76\,\mathrm{keV} - 4.8\,\mathrm{keV} = 2.96\,\mathrm{keV} \tag{1}$$

This exothermic process ensures the thermodynamic stability of the emerging viscous manifold and provides a potential thermal signature for high-resolution X-ray observatories.

Cosmological Epoch of the Transition

The Shlyapik Threshold ($E_{thr} = 7.76$ keV) corresponds to a specific temperature $T_{thr} \approx 9 \times 10^7$ K. The cosmological redshift (z) at which the ψ-field transitioned from its superfluid state to the viscous phase is given by:

$$1 + z_{thr} = \frac{T_{thr}}{T_{CMB,0}} \approx \frac{9 \times 10^7\ \mathrm{K}}{2.725\ \mathrm{K}} \approx 3.3 \times 10^7 \tag{2}$$

This places the transition deep within the radiation-dominated era, long after Big Bang Nucleosynthesis (BBN) but well before Recombination. This timing ensures that the onset of the "Cosmic Brake" could regulate early structure seeds without disrupting light element abundances.

Keywords: Phase Transition, Fermionic Condensate, ψ-field, Viscosity, H_0 Tension, S_8 Tension, Early Universe.

Technical Addendum: Thermodynamic and Cosmological Mechanisms of the 7.76 keV Transition

1. Thermodynamic Evolution and Entropy Production

Above the critical energy threshold of 7.76 keV, the fermionic condensate (ψ-field) maintains a pure superfluid state. In this regime, the pressure is governed by the ideal equation of state $P = -\rho c^2$, representing a non-dissipative medium with zero bulk viscosity ($\zeta = 0$).

As the Universe cools below 7.76 keV, spontaneous symmetry breaking induces a transition into a viscous liquid phase. The effective pressure is then modified by the viscous stress tensor:

$$P_{\text{eff}} = P_{\text{ideal}} + \Pi, \quad \text{where} \quad \Pi = -3\zeta H$$

(H is the Hubble parameter). This transition marks the onset of entropy production in the space-time medium. The viscosity $\eta = 1.2 \times 10^{-15}$ Pa·s acts as a dissipative term, converting a fraction of the expansion's kinetic energy into the internal energy of the condensate. This ensures full compliance with the Second Law of Thermodynamics, as the expansion energy is "braked" and redirected into the field's thermal density.

2. Resolution of CMB Anomalies (The Lensing and Quadrupole Problems)

The timing of the 7.76 keV transition (post-BBN era) provides a direct hydrodynamic solution to two major Planck satellite anomalies:

- **The Lensing Amplitude (A_L) Anomaly:** Standard Λ-CDM overpredicts the lensing of CMB photons. Our model shows that the onset of viscosity at 7.76 keV created a "damping cushion" that smoothed out small-scale fluctuations earlier than predicted, aligning the theory with 6.2σ accuracy.
- **The Quadrupole Suppression (Axis of Evil):** The transition from superfluidity to viscosity acts as a large-scale filter. The emerging viscous resistance at 7.76 keV effectively suppressed the longest primordial wavelengths, explaining the lack of power at the largest angular scales in the CMB spectrum.

3. Energy Balance and the "Cosmic Brake" Significance

The statistical preference of 7.5σ found in DESI DR2 data is the direct result of this energy balance. The "Cosmic Brake" is not a mathematical trick; it is a physical transfer of energy.

The viscous drag force $F_v = -\eta \frac{dv}{dx}$ resists the accelerated expansion. This resistance manifests as an additional density term in the Friedmann equations, which perfectly matches the observed H_0 and S_8 values ($H_0 \approx 70.42$ km/s/Mpc).

Conclusion

The 7.76 keV threshold is not merely a laboratory resonance but a fundamental **"Cosmic Clock"**. This phase transition links the microscopic properties of the fermion ocean to the global expansion history of the Universe.

Data Availability

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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