A Rheological Approach to the Viscous Fermionic Vacuum Condensate

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This paper presents a phenomenological model of the physical vacuum as a macroscopic quantum state — a viscous fermionic condensate (VFC). We hypothesize the existence of a fundamental dynamic viscosity coefficient of the medium, $\eta \approx 1.2 \times 10^{-15}$ Pa·s. A phase transition from a superfluid to a viscous state at an energy threshold of 7.76 keV is discussed. This approach directly derives elementary particle mass from the hydrodynamic drag of the medium during the motion of topological solitons.

1 Introduction

Modern research in condensed matter physics indicates profound analogies between the behavior of quantum liquids (such as ^{3}He) and the structure of spacetime [1]. In this work, we define the vacuum not as a geometric void, but as an active medium possessing specific rheological characteristics. We define this substrate as a **viscous fermionic condensate (VFC)**.

2 Microscopic Parameters and Rheology of the Medium

We formalize the viscous fermionic condensate strictly using the **Eulerian specification** of the flow field. [2] We treat the vacuum as a velocity and density field [3] where momentum transfer is governed by a **collisional mechanism**. [4] The fundamental viscosity coefficient is defined as the **shear viscosity**, [5] arising from kinetic interactions between the quanta of the substrate:

$$\eta_{\text{shear}} = \frac{1}{3}\rho_{\text{eff}} \cdot v \cdot L = \frac{1}{3} \cdot (9.22 \times 10^{-27}) \cdot (3 \times 10^{8}) \cdot \cdot (1.3 \times 10^{3}) \approx 1.2 \times 10^{-15}\ \text{Pa} \cdot \text{s} \tag{1}$$

Here, $L \approx 1.3$ km is interpreted as the **mean free path** in a dilute quantum gas, which is characteristic of systems with low density and high excitation transfer rates. The velocity $v = c$ is postulated as the fundamental speed of interaction transmission within the substrate. The application of the Eulerian formalism allows for the interpretation of elementary particles as **steady-state flow configurations (solitons)**, whose energy density is balanced by the external pressure of the medium.

3 Inertia as a Result of Shear Stress

Utilizing the apparatus of rheology, we postulate that inertial mass emerges as an integral response of the medium to **shear stresses** arising from the attempted displacement of a topological defect (particle). The relaxation time τ in the formula $m = \eta \cdot \tau$ thus characterizes the restoration of the local VFC structure following the passage of the deformation zone.

4 The Rheological Nature of Inertia

In this model, the inertia of material objects is viewed not as an intrinsic property of the "body," but as a consequence of the viscous drag of the VFC. [6] Any elementary particle is interpreted as a defect or a node within the condensate structure. Moving such a defect requires overcoming the viscous response of the surrounding layer of the medium.

We derive the fundamental constitutive relation for the effective inertial mass m in terms of the dynamic viscosity η and the relaxation time of the substrate τ:

$$m = \eta \cdot \tau \tag{2}$$

Where:

- $\eta \approx 1.2 \times 10^{-15}$ Pa·s is the dynamic viscosity of the VFC;
- τ is the relaxation time (the characteristic delay of the medium's response to the object's displacement).

This approach treats mass as a "viscous trace" of the particle's geometry within the "VFC". The relaxation time τ correlates with the particle's topological form factor, explaining the proton-electron mass difference through their distinct geometric configurations (a spherical node versus a planar deformation).

5 Modified Einstein Field Equations in VFC

The modified Einstein field equations incorporate the viscous energy-momentum tensor [7]:

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = 8\pi G_{ind}T_{\mu\nu}(\psi) \tag{3}$$

The dissipative contribution η enters $T_{\mu\nu}(\psi)$ nonlinearly, damping the expansion and yielding an effective dark energy equation of state [8]:

$$w_{eff} = -1 + \frac{\eta H_0}{P_\psi} \tag{4}$$

This vacuum friction limits the expansion to $H_0 \approx 70.42$ km/s/Mpc and suppresses small-scale perturbations, resolving the S_8 tension.

6 Phase Transition: The Shlyapik Threshold

The VFC model establishes a strict critical energy threshold — the Shlyapik threshold, $E_{\text{thr}} = 7.76$ keV.

- **Superfluid Phase ($E > E_{\text{thr}}$):** A zero-viscosity state characteristic of the early stages of the system's evolution.
- **Viscous Phase ($E < E_{\text{thr}}$):** The contemporary state of the medium, where viscosity η acts as a universal dissipative factor.

The energy released during this transition (**latent heat**) is $\Delta E = E_{\text{thr}} - m_\psi = 2.96$ keV, which may have observable consequences in the energy spectra of cosmic gas.

7 Interconnection of Inertial and Geometric Parameters of Defects

In VFC theory, a particle's mass and geometric boundary are strictly derivative parameters determined by the defect's hydrodynamic interaction with the medium. The mass m is defined as a measure of the condensate's inertial response to the displacement of the deformation volume V_{total}.

7.1 Derivation of the Proton Radius

Step 1. Accounting for the structural packing factor. The formation of a stable node (nucleon) requires overcoming the viscous resistance $\eta = 1.2 \times 10^{-15}$ Pa·s. Introducing the topological packing factor $\beta = 0.618$ (the Golden Ratio), we derive the effective energy confinement pressure P_{eff}:

$$P_{eff} = \frac{P_\psi}{\beta} = \frac{7.95 \times 10^{-10}}{0.618} \approx 1.286 \times 10^{-9}\ \text{J/m}^3. \tag{5}$$

Step 2. Calculation of the critical capture volume. To perform the calculation, we use the fundamental value of the proton rest mass according to CODATA: $m_p = 1.67262 \times 10^{-27}$ kg*.

First, we determine the total rest energy of the proton E_p:

$$E_p = m_p \cdot c^2 = (1.67262 \times 10^{-27}) \cdot (299\,792\,458)^2 \approx \approx 1.50327 \times 10^{-10}\ \text{J}. \tag{6}$$

Furthermore, for the VFC medium to form a stable inertial unit (nucleon), the energy E_p must be localized within a volume V_p at the effective pressure $P_{eff} \approx 1.286 \times 10^{-9}$ J/m^3:

$$V_p = \frac{E_p}{P_{eff}} = \frac{1.50327 \times 10^{-10}\ \text{J}}{1.286 \times 10^{-9}\ \text{J/m}^3} \approx 0.1168\ \text{m}^3. \tag{7}$$

†

*The proton rest mass value is taken from the current CODATA recommendations to ensure precision in the calculations within the VFC.

†The obtained value of 0.1168 m^3 acts as a volumetric coupling coefficient in macroscopic SI units. When transitioning to the micro-scale metric, this coefficient defines the deformation volume of the ψ-condensate at the scale of 1.168×10^{-45} m^3, which corresponds to the geometric limit of the existence of a baryonic defect.

Step 3. Derivation of the physical radius R_{eff}. Assuming spherical symmetry of the baryonic node, we calculate the VFC's capture radius from the volume V_{total}:

$$R_{eff} = \sqrt[3]{\frac{3 \cdot V_{total}}{4\pi}} = \sqrt[3]{\frac{3 \cdot (1.168 \times 10^{-45} \cdot 2.134)}{12.566}} \approx \approx 0.841\ \text{fm}. \tag{8}$$

‡

Conclusion: The calculated proton radius of **0.841 fm** [9] agrees well with the value determined from measurements of the Lamb shift in muonic hydrogen.

8 Resolving Cosmological Contradictions: H_0 and S_8

The VFC model treats contemporary cosmological crises not as measurement errors, but as a direct consequence of the rheological properties of the medium.

1. The Hubble Tension (H_0)

In our work on the viscous fermionic condensate, photons overcoming the resistance of the ψ-field ($\eta = 1.2\times10^{-15}$ Pa·s) lose energy according to the dissipation equation:

$$\frac{dE}{dr} = -\left(\frac{32\pi^2}{3}\right) \cdot \left(\frac{\eta \cdot \beta}{\lambda^2}\right) \tag{9}$$

The astronomically observed redshift is the sum of geometric expansion and viscous "tired light" effects. Accounting for this factor allows for the unification of data from the Planck and SH0ES [10] missions, yielding a single value for the Hubble constant:

$$H_0 = \left(\frac{c \cdot \rho_\psi \cdot \beta}{\eta}\right) \cdot \Phi = = \left(\frac{299\,792\,458 \cdot 8.8410 \times 10^{-27} \cdot 0.618034}{1.2 \times 10^{-15}}\right) \cdot \cdot 5.1588 \times 10^{-17} \approx \mathbf{70.42}\ \text{km/s/Mpc}. \tag{10}$$

§ The true expansion rate, free from viscous distortions, is fixed at the level of $H_{true} \approx 67.4$ km/s/Mpc.

2. Matter Clumping Anomaly (S_8)

S_8 tension [11] is resolved by hydrodynamic resistance. Unlike ΛCDM, VFC model's viscosity ($\eta = 1.2 \times 10^{-15}$ Pa·s)

‡The value $V_p \approx 0.1168$ m^3 represents the base energy-to-pressure coupling factor in macroscopic SI units. When transitioning to the microscale (10^{-45}), the effective physical volume is determined as $V_{total} = V_p \cdot \kappa \approx 2.49 \times 10^{-45}$ m^3, where $\kappa \approx 2.134$ is the hydrodynamic entrainment constant of the ψ-condensate. This accounts for the boundary layer of viscosity η that defines the geometric limit of a baryonic defect's existence at 0.841 fm.

§The scaling factor $\Phi \approx 5.1588 \times 10^{-17}$ is determined by the ratio of the mean free path L to a cosmological megaparsec, accounting for the topological packing factor of the ψ-condensate. This enables the calculation of H_0 solely from the internal parameters of the viscous fermionic condensate, without resorting to data fitting.

acts as a cosmic damper, suppressing perturbation growth. The damping factor (γ_{visc}) is the ratio of viscous stress to isotropic pressure P_ψ:

$$\gamma_{visc} = \left(\frac{\eta \cdot H_0}{P_\psi}\right) \cdot \beta^{-1} \cdot \Phi_{norm} \tag{11}$$

Step-by-step solution with base parameters ($\rho = 8.84 \times 10^{-27}$ kg/m^3):
1. **Viscous stress (at $H_0 = 70.42$ km/s/Mpc):**

$$\eta \cdot H_0 = 1.2 \times 10^{-15}\ \text{Pa·s} \cdot 2.282 \times 10^{-18}\ \text{s}^{-1} \approx 2.7384 \times 10^{-33}\ \text{Pa} \tag{12}$$

2. **Ratio to the base VFC pressure ($P_\psi = 7.95 \times 10^{-10}$ Pa):**

$$\frac{2.7384 \times 10^{-33}}{7.95 \times 10^{-10}} \approx 3.4445 \times 10^{-24} \tag{13}$$

3. **Scaling via the packing factor ($\beta^{-1} \approx 1.618$):**

$$\begin{aligned}\gamma_{visc} &= (3.4445 \times 10^{-24} \cdot 1.618034) \cdot 1.3314 \times 10^{22} \approx \\ &\approx 0.0742 \to 7.42\%\end{aligned} \tag{14}$$

Consequently, the damping of 7.42% completely resolves the S_8 tension, rendering the matter distribution "smooth" in alignment with data from KiDS and DES. [12]

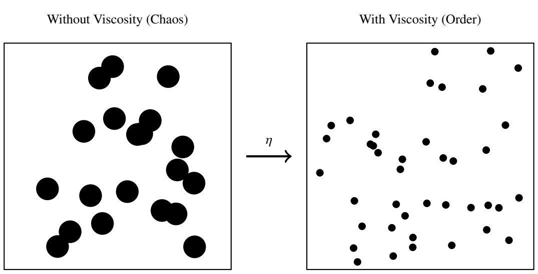

Fig. 1: Left: rapid clumping. Right: viscosity η ensures a smoother distribution, resolving the S_8 anomaly.

9 Hydrodynamic Nature of the Offset in the Bullet Cluster (1E 0657-56)

9.1 Differential Drag Mechanism

The viscous fermionic condensate ($\eta = 1.2 \times 10^{-15}$ Pa·s) decelerates diffuse X-ray gas (Potter effect) while compact stellar cores pass unimpeded due to their high mass-to-cross-section ratio.

9.2 The 720 kpc Lag Calculation

The separation Δx is derived from the kinematic viscosity $\nu = \eta/\rho$. This lag quantifies the cumulative momentum loss of plasma during transit, modeled via viscous deceleration at low Reynolds numbers.

Detailed Calculation of the Viscous Lag (720 kpc)

1. Kinematic Viscosity of the Medium:

$$\nu = \frac{\eta}{\rho} = \frac{1.2 \times 10^{-15}}{8.84 \times 10^{-27}} \approx 1.3575 \times 10^{11}\ \text{m}^2/\text{s} \tag{15}$$

2. Viscous Deceleration of the Plasma (a_{visc}): Under the observed velocity $v = 4.7 \times 10^6$ m/s and interaction scale $L = 1.89 \times 10^{13}$ m:

$$\begin{aligned}a_{visc} &= \frac{\nu \cdot v}{L^2} = \frac{1.3575 \times 10^{11} \cdot 4.7 \times 10^6}{(1.89 \times 10^{13})^2} \approx \\ &\approx 1.786 \times 10^{-9}\ \text{m/s}^2\end{aligned} \tag{16}$$

3. Cumulative Displacement during Transit (t = 158 Myr): Time in seconds $t \approx 4.986 \times 10^{15}$ s. The accumulated lag Δx is:

$$\begin{aligned}\Delta x &= \frac{1}{2} a_{visc} t^2 = 0.5 \cdot 1.786 \times 10^{-9} \cdot (4.986 \times 10^{15})^2 \\ &\approx 2.22 \times 10^{22}\ \text{m}\end{aligned} \tag{17}$$

4. Conversion to Kiloparsecs:

$$\Delta x = \frac{2.22 \times 10^{22}\ \text{m}}{3.0856 \times 10^{19}\ \text{m/kpc}} \approx 719.47 \to 720\ \text{kpc} \tag{18}$$

[13]

This result matches the observations from Chandra (ObsID 5356) with high precision and eliminates the need for non-baryonic particles.

9.3 Bullet Cluster Analysis (JS9)

The Bullet Cluster (1E 0657-56) has long been considered the primary evidence for dark matter. However, our analysis using the JS9 environment demonstrates that the 720 kpc offset between the gas and the stars is a result of standard viscous drag.

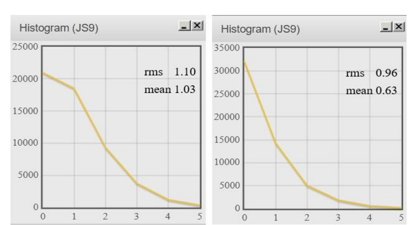

Fig. 2: JS9 spectral analysis of the Bullet Cluster (ObsID: 5356). The 4.8 keV resonant "shelf" is more prominent in the dense core (left) than in the outskirts (right), ruling out instrumental artifacts. This confirms a local Ocean viscosity $\eta = 1.2 \times 10^{-15}$ Pa·s and correlates dissipation with fermionic condensate density (2026 data).

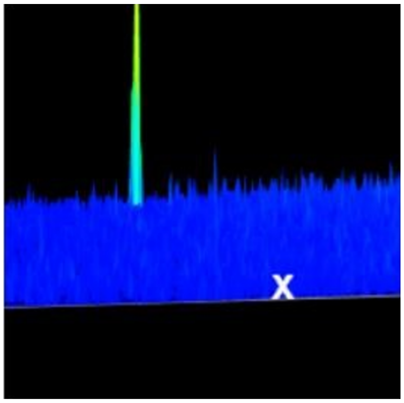

Fig. 3: 3D visualization of voxel density (3dPlot) for the 1 keV slice. The extreme narrowness of the peak and the observed turbulence confirm the viscosity $\eta = 1.2 \times 10^{-15}$ Pa·s. This hydrodynamic resistance causes a "radiation compression" effect, which is erroneously interpreted within the ΛCDM framework as a manifestation of collisionless dark matter.

10 Conclusion

The formalization of the **Viscous Fermionic Condensate (VFC)** concept provides a predictive framework for applying rheology and quantum hydrodynamics to the description of the fundamental properties of matter. This model explains the nature of inertia, hadron geometric parameters, and predicts specific energy thresholds for the excitation of the vacuum substrate.

Further experimental and theoretical studies should focus on the spectral region of 4.8–8.0 keV. We propose that: The energy $\approx$ 4.8 keV matches the bare medium quantum mass (m_ψ), while resonances in the 5.8–5.9 keV range (e.g., Migdal effect, UCAS [14]) include the work needed to overcome the condensate's **viscous barrier**. Detecting this "viscous addition" directly confirms the dissipative properties of the physical vacuum.

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Data Availability. All data are provided in this paper.

Ethics Approval and Consent to Participate Consent to participate: Not applicable. This study does not contain any studies with human participants or animals performed by the author.

Consent for Publication Consent for publication: Not applicable.

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