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### **A Self-Consistent Mathematical Model for the Non-Collapse of Matter Particles into Black Holes during Cosmic Inflation**

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 **Abstract**  
Addressing the core problem of why matter particles (4.9%) failed to collapse into black holes under the equivalent gravitational force induced by negative-mass dark matter (26.7%) during the early cosmic inflation, this paper proposes a triple synergistic suppression mechanism: spacetime stretching effect, repulsive barrier from negative-mass dark matter, and quantum dispersion effect. By constructing a complete mathematical framework incorporating the competition between Hubble timescale and free-fall timescale, a repulsive barrier model, and quantum pressure equations—combined with numerical validation of typical parameters—we demonstrate that the inflation expansion rate () exceeds the gravitational collapse timescale by times. Furthermore, quantum pressure () vastly surpasses gravitational compression work (), constituting the essential reason for black hole suppression. The model’s self-consistency is verified through exponential decay of density perturbations (), offering a novel explanation for matter stability in the early universe.  
**Keywords:** Cosmic inflation; Negative-mass dark matter; Black hole collapse; Quantum dispersion; Repulsive barrier  
 **1. Introduction**  
During cosmic inflation (), matter particle density reached Planck-scale levels (), theoretically prone to gravitational collapse into black holes. However, observations indicate that matter particles (constituting 4.9% of the universe’s total mass-energy) remained stable within the equivalent gravitational field induced by negative-mass dark matter (26.7%). Existing theories struggle to resolve this contradiction. This paper reveals the underlying physical essence by constructing a self-consistent mathematical model of a triple suppression mechanism.  
 **2. Core Physical Mechanisms and Mathematical Model**  
 **2.1 Spacetime Stretching Effect: Expansion Timescale Dominates Collapse**  
The competition between the free-fall timescale (gravitational collapse timescale) and Hubble timescale (cosmic expansion timescale) is defined as:

where:  
- ( is negative-mass dark matter density, is the coupling coefficient);  
- is the positive energy density dominated by inflation.  
**Non-collapse criterion:**

**Conclusion:** Inflation expansion outpaces gravitational collapse by times, preventing collapse.  
 **2.2 Repulsive Barrier Model of Negative-Mass Dark Matter**  
Negative-mass dark matter generates repulsive pressure on matter particles (spherical coordinates):

Integration yields the effective barrier potential:

**Collapse curvature verification:**

The repulsive term dominates curvature, suppressing gravitational collapse.  
 **2.3 Quantum Dispersion Effect Model**  
Heisenberg’s uncertainty principle () induces particle momentum dispersion, generating an effective quantum temperature:

Corresponding quantum pressure:

**Quantum-gravitational pressure ratio:**

Quantum pressure completely suppresses gravitational collapse.  
 **3. Complete Self-Consistent Equations and Numerical Validation**  
 **3.1 Cosmic Evolution Dynamics Equations**

where is the particle generation source function (peaking at ), and is the sound speed with quantum corrections.  
 **3.2 Numerical Validation of Typical Parameters**  
| **Physical Quantity** | **Value** | **Unit** |  
|————————|——————-|———–|  
| Inflation time | | s |  
| Hubble parameter | | s |  
| Matter density | | kg/m |  
| Quantum pressure | | Pa |  
| Gravitational pressure | | Pa |  
**Stability vetification:**

Density perturbations exhibit exponential decay , confirming system stability.  
 **4. Conclusion**  
The mechanism preventing matter particles from collapsing into black holes during inflation is attributed to three synergistic effects:  
1. **Timescale dominance:** Inflation expansion timescale is times shorter than gravitational collapse timescale ;  
2. **Repulsive barrier:** Negative-mass dark matter forms a potential barrier , inhibiting particle aggregation;  
3. **Quantum freezing:** Quantum pressure from the uncertainty principle exceeds gravitational compression by times.  
**Essential mechanism:** The ultra-short inflation timescale () is the direct cause, while the synergy between negative-mass repulsion and quantum dispersion constitutes the fundamental physical basis. This model provides a unified explanation for early universe matter stability through self-consistent equations and numerical validation.  
**References**  
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 **Notes**  
1. **Mathematical self-consistency:** All equations are validated via dimensional analysis and limit conditions (e.g., reducing to the standard Friedmann equation when ).  
2. **Parameter sources:** Negative-mass dark matter ratio is derived from Li’s prior research [1].  
3. **Innovation:** First integration of quantum pressure, repulsive barrier, and spacetime expansion into a unified framework to explain black hole suppression.