### Graviton-Mediated Detection of Negative-Mass Dark Matter: A New Paradigm Based on Resonant Amplification of Repulsive Force and Quantum Squeezing Enhancement

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**Abstract:** Based on Li Zhijun’s ABC (Electromagnetic-Color-Higgs) vortex field theory, this paper proposes a revolutionary scheme for the direct detection of negative-mass dark matter particles. The core innovation lies in utilizing the repulsive interaction mediated by gravitons between negative-mass dark matter and ordinary matter, rather than the traditionally sought electromagnetic interactions. We have designed a triple-pronged detection scheme: 1) Sensing the micro-Newton scale repulsive force from a dark matter flow using a large-scale quantum resonator array; 2) Measuring the resulting picometer-scale displacement with a Michelson interferometer enhanced by a squeezed light cavity; 3) Capturing the scattering signals between dark matter particles and nucleons via quantum phonon detection in superfluid helium. This paper constructs a complete mathematical model: deriving the differential cross-section of the repulsive force and the flow conservation equation; establishing a collective response model for the resonator array; designing a noise suppression scheme based on quantum squeezing; and predicting observable signal characteristics. The expected sensitivity of this scheme is six orders of magnitude higher than existing experiments, opening a completely new path for the direct detection of dark matter.  
**Keywords:** Negative-mass dark matter; Graviton-mediated; Repulsive interaction; Quantum resonator; Squeezed-light interferometry; Superfluid helium; ABC theory  
**1. Introduction: The Dilemma and Paradigm Shift in Dark Matter Detection**  
Existing dark matter detection experiments (such as LUX-ZEPLIN, XENONnT, etc.) are all based on the electromagnetic or weak interactions between dark matter and ordinary nucleons. However, according to Li Zhijun’s theory, negative-mass dark matter () and positive-mass matter are electromagnetically invisible (due to coupling prohibition caused by mass sign asymmetry), but interact repulsively via gravitons:  
  
where is the graviton field. This provides a completely new approach for detection.  
**2. Theoretical Framework: Graviton-Mediated Repulsive Interaction**  
**2.1 Effective Potential and Equation of Motion**  
The interaction between negative-mass dark matter and a nucleon is described by the effective potential:  
  
where the repulsive potential term is:  
  
The scattering amplitude is calculated via the graviton propagator:  
  
In the non-relativistic limit ():  
  
**2.2 Differential Cross-Section Calculation**  
The differential cross-section is given by the squared modulus of the scattering amplitude:  
  
where , and is the relative velocity.  
The total scattering cross-section requires integration up to the maximum momentum transfer :  
  
**2.3 Repulsive Force Rate Equation**  
The flux of dark matter particles passing through a unit area per unit time is:  
  
where is the local dark matter density.  
The interaction rate (energy deposition per unit time per unit mass) is:  
  
Substituting the cross-section expression:  
  
**3. Detection Scheme I: Large-Scale Quantum Resonator Array**  
**3.1 Mechanical Response Model**  
Consider a resonator with mass and resonance frequency . Its equation of motion is:  
  
The time-dependent component of the repulsive force is:  
  
where is the momentum transfer in the x-direction.  
**3.2 Noise Analysis and Signal Extraction**  
Main noise sources:  
\* Thermal noise:   
\* Quantum noise:   
Signal power spectral density:  
  
**3.3 Array Optimization Design**  
Optimal mass (in the quantum-noise-dominated regime):  
  
Taking typical values: , , , , , we get .  
Array scale: 1000 resonators, arranged in a spherical array covering solid angle, with a total mass of 10 kg.  
**4. Detection Scheme II: Squeezed-Light Enhanced Interferometer**  
**4.1 Interferometer Response Function**  
The output light field of a Michelson interferometer is:  
  
The length change is caused by the repulsive force:  
  
**4.2 Quantum Squeezing Enhancement**  
Squeezing operation:  
  
Noise spectrum after squeezing:  
  
where the Standard Quantum Limit is:  
  
**4.3 Sensitivity Curve**  
Sensitivity after squeezing enhancement:  
  
Taking (15 dB squeezing), , , :  
  
Detectable displacement:  
  
**5. Detection Scheme III: Quantum Phonon Detection in Superfluid Helium**  
**5.1 Phonon Excitation Equation**  
Dark matter collisions with superfluid helium atoms produce phonons:  
  
Interaction matrix element:  
  
Phonon production rate:  
  
**5.2 Resonant Enhancement Mechanism**  
A phonon cavity is used to enhance the signal, with a quality factor:  
  
Effective mass:  
  
where is the number of resonant atoms ( is the helium-4 atomic mass).  
**5.3 Low-Temperature Detection Technology**  
Operating temperature:   
Thermal phonon number:  
  
At and , .  
**6. Signal Processing and Data Analysis**  
**6.1 Characteristic Signal Recognition**  
\* **Time signature:** Pulsed signal, duration   
\* **Energy spectrum:** Recoil energy   
\* **Directional signature:** Anisotropic distribution,   
**6.2 Statistical Significance Analysis**  
Using a likelihood ratio test:  
  
Test statistic:  
  
For a 90% confidence level exclusion, is required.  
**6.3 Background Suppression Strategy**  
\* **Active shielding:**  
\* Electromagnetic shielding: -metal,   
\* Radiation shielding: Pb + Cu, 10 cm  
\* **Passive suppression:**  
\* Cryogenic environment:   
\* Vibration isolation: Six-stage isolation system  
**7. Expected Sensitivity and Discovery Potential**  
**7.1 Exclusion Curve Calculation**  
90% confidence level exclusion limit:  
  
Taking (1 ton of material) and :  
  
**7.2 Parameter Space Scan**

Parameter space of dark matter mass vs. cross-section :

| **Mass Range** | **Cross-Section Sensitivity** |
| --- | --- |
| 1 eV - 1 keV |  |
| 1 keV - 1 MeV |  |
| 1 MeV - 1 GeV |  |
| 1 GeV - 1 TeV |  |

**7.3 Comparison with Other Experiments**

Complementarity with existing experiments:

| **Experiment** | **Mass Range** | **Interaction Type** | **Sensitivity (cm²)** |
| --- | --- | --- | --- |
| LZ | 10 GeV - 10 TeV | Weak Interaction |  |
| ADMX | 1 eV - 100 eV | Axion | (g GeV) |
| This Proposal | 1 eV - 100 TeV | Gravitational Repulsion |  |

| **8. Technical Challenges and Solutions** **8.1 Thermal Noise Suppression** \* **Cryogenic technology:** \* Dilution refrigerator:  \* Adiabatic demagnetization:  \* **Material selection:** \* Low-loss materials: Si, SiO₂ \* High-Q resonators:  **8.2 Quantum Noise Suppression** \* **Squeezed light source:** \* Squeezing level: 15 dB \* Bandwidth: 100 MHz \* **Quantum non-demolition measurement:** \*  **8.3 Vibration Isolation** \* **Multi-stage isolation system:** \* Active isolation:  \* Passive isolation:  \* **Inertial sensors:** \* Resolution:  \* Bandwidth: 0.1 - 100 Hz |
| --- |
| **9. Conclusion and Outlook** This paper proposes a triple-pronged scheme for detecting negative-mass dark matter: \* **Theoretical innovation:** Utilizing the graviton-mediated repulsive interaction. \* **Technological breakthrough:** High-sensitivity detection enhanced by quantum technologies. \* **Scientific value:** A key experiment to validate the ABC theory. **Expected outcomes:** \* **Within 5 years:** Build a prototype, achieving . \* **Within 10 years:** Full-scale experiment, detecting the first signal. \* **Within 15 years:** Precise measurement of dark matter properties. This scheme will usher in a new era of dark matter detection and provide an experimental platform for quantum gravity research. |

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