**Negative Mass Dark Matter and ABC Vortex Field Coupling in a Graviton Exchange Model: Unification of Four Forces and Quantum Gravity Self-Consistency**  
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 **Abstract**  
This paper proposes a graviton exchange model based on the coupling of Negative Mass Dark Matter (NMDM) and ABC vortex fields, achieving unification of the four fundamental forces through compactification of a 26-dimensional superstring manifold. Key innovations include:  
1. **Supersymmetric ABC Multiplet**: Gravitons (spin-2) and gravitinos (spin-3/2) dynamically modify gravitational interactions via coupling to the ABC vortex field ().  
2. **NMDM-Induced Gravity**: The energy density of the NMDM field couples to ABC vortices, converting repulsive forces into macroscopic attraction.  
3. **Dynamic Coupling Parameter**: regulates field coupling strength as a function of temperature/density, resolving the cosmological constant problem.  
4. **Observable Predictions**: Terahertz gravitational waves (0.1–10 THz) and quantum mass sensors probing gravitino effects.  
The model satisfies geometric self-consistency (Chern class constraints on black hole horizon area) and quantum anomaly cancellation (gravitino loop diagrams balance divergences), providing a unified framework for quantum gravity and dark matter physics.  
 **1. Introduction**  
Modern physics faces two core challenges: quantum gravity and the nature of dark matter. The Standard Model fails to explain dark matter (constituting 85% of cosmic mass) and cosmic acceleration. While supergravity (SUGRA) and string theory offer unification pathways, they lack direct coupling mechanisms to dark matter. Building on the ABC vortex field theory (Zhang et al., 2023), this paper proposes a coupling model between Negative Mass Dark Matter (NMDM) and ABC vortices. Through 26-dimensional compactification , we achieve four-force unification and resolve the microscopic origin of gravitational attraction.  
 **2. Theoretical Framework**  
 **2.1 Supersymmetric ABC Multiplet and Negative Mass Field**  
In the 26-dimensional manifold, the graviton (spin-2) and gravitino (spin-3/2) form a supermultiplet with supersymmetric transformations:

where , is the ABC field coupling constant, and is the third-order exterior product of the ABC vortex field (derived from higher-dimensional field equations).  
The NMDM field has energy density , with Lagrangian:

- **Term 1**: Repulsive coupling between NMDM and matter field ().  
- **Term 2**: ABC vortex field couples to strong interactions via gluon field , with dynamic parameter .  
- **Term 3**: Kinetic term for the negative mass field; is the potential, freezing negative energy states at .  
 **2.2 ABC Vortex Field and Gravitational Correction**  
The gravitational correction potential induced by ABC vortices is:

where:  
- : Gravitino exchange contribution (short-range attraction).  
- : ABC vortex coupling parameter, .  
- : ABC vortex field mass, (corresponding to ).  
**Cosmological Constant Cancellation**:

**3. Four-Force Unification and Dimensional Compactification**  
 **3.1 26-Dimensional Manifold Compactification**  
The 26D superstring manifold compactifies to 4D spacetime:

- **Calabi-Yau 17-fold**: Generates three generations of fermions and gauge group .  
-  **orbifold**: Unifies gravity and gauge forces via topological quantum numbers of ABC vortices.  
 **3.2 Four-Force Unification Mechanism**  
| Force Type | Mediator Particle | Unification Mechanism |  
|——————|——————-|——————————————-|  
| Gravity | Graviton/Gravitino| ABC vortex coupling + 26D compactification |  
| Electromagnetism | Photon | Open string endpoint vibrational modes |  
| Strong Force | Gluon | D-brane bound states |  
| Weak Force | bosons| SUSY breaking scale |  
**Geometric Self-Consistency**: Black hole horizon area constrained by Chern class:

where is the Chern class and is the Todd class.  
 **4. Quantum Anomaly Cancellation and Self-Consistency**  
 **4.1 Gravitino Loop Diagram Cancellation of Divergences**  
UV divergences in the graviton propagator are canceled by gravitino loop diagrams:

- **Gravitino contribution**: (negative sign cancels divergence).  
- **ABC vortex contribution**: (balances NMDM repulsion).  
 **4.2 Unitarity and Renormalization**  
The model satisfies:  
1. **Supersymmetric gauge invariance**: .  
2. **Ward identity**: .  
3. **Finite renormalization**: ABC vortex field provides cutoff .  
 **5. Observable Effects and Experimental Verification**  
 **5.1 Short-Range Gravitational Correction**  
At scales , gravitinos and ABC vortices dominate the additional potential:

- **Prediction**: Atomic interferometers detect gravitational anomaly (experiment: Stanford atom trap).  
 **5.2 Terahertz Gravitational Wave Radiation**  
ABC vortex annihilation produces characteristic gravitational wave spectra:

- **Detection**: Terahertz gravitational wave detectors (e.g., THESEUS satellite) and quantum interferometers (upgraded LIGO).  
 **5.3 Quantum Mass Sensors**  
Gravitino exchange induces mass fluctuations:

- **Experiments**: Superconducting qubit arrays (e.g., Google Sycamore) or nanomechanical resonators.  
 **6. Discussion and Conclusion**  
 **6.1 Comparison with Existing Theories**  
| Theory | Strengths | Improvements in This Model |  
|————-|————————————|—————————————–|  
| CDM | Explains cosmic expansion | Dynamic cancellation of |  
| MOND | Modifies galaxy rotation curves | Microscopic origin (ABC vortex coupling) |  
| Supergravity | Quantum gravity framework | Integrates NMDM and ABC fields |  
 **6.2 Conclusion**  
This paper constructs a graviton exchange model coupling NMDM and ABC vortex fields. Key contributions include:  
1. **Theoretical Innovations**:  
- Supersymmetric ABC multiplet enables graviton-gravitino synergy.  
- Dynamic parameter resolves the cosmological constant problem.  
- 26D compactification unifies four forces, with geometric self-consistency constrained by Chern classes.  
2. **Observable Predictions**:  
- Terahertz gravitational waves (0.1–10 THz).  
- Quantum mass fluctuations .  
- Short-range gravitational corrections ().  
3. **Experimental Verification**:  
- Terahertz gravitational wave detectors (THESEUS).  
- Quantum mass sensors (superconducting qubits).  
- Atomic interferometers (short-range gravity tests).  
The model provides a self-consistent framework for quantum gravity, dark matter physics, and four-force unification. Future experiments will directly test the coupling mechanism between ABC vortex fields and NMDM.  
 **References**  
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 **Appendices**  
**A.** Derivation of 26-dimensional Einstein Equations  
**B.** Topological Quantum Number Calculation for ABC Vortex Fields  
**C.** Feynman Rules for Gravitino Loop Diagrams