**The Gravitational Dance of Parallel Universes: Structured Dark Matter Explains the Boötes Void and Cosmological Puzzles**

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Abstract:  
Based on Li Zhijun’s ABC theory, this paper proposes a cosmological model in which dark matter possesses its own complex structures (dark galaxies, dark stars, dark planets). The core thesis is: the 26.8% of negative mass dark matter is not a uniformly distributed “particle soup” but forms a hierarchical structure similar to the visible universe through its dark color charge strong interaction (dark QCD). These dark structures interact with the matter structures of the visible universe via repulsive gravity, leading to large-scale cosmic voids (e.g., the Boötes Void) and the historical suppression of galaxy formation. We construct the fluid dynamics equations for dark matter structure formation, introduce a matter-dark matter gravitational repulsion term, and successfully numerically reproduce the characteristic distribution of the large-scale structure of the universe. Furthermore, this model provides a unified, dynamically originated explanation for the missing satellites problem and the diversity of galaxy rotation curves, avoiding the “fine-tuning” of dark matter parameters.

Keywords: Structured dark matter; Boötes Void; Repulsive gravity; Galaxy formation; Small-scale problem; ABC theory

1. **Introduction: From a Uniform Soup to a Structured Dark Universe**

The cold dark matter (CDM) in the standard cosmological model assumes that dark matter is collisionless and structureless. However, this model faces severe challenges on small scales and cannot explain the origin of giant voids. If dark matter consists of complex particles made of dark quarks and can form dark galaxies, then its gravitational repulsion with matter galaxies would fundamentally alter the evolutionary picture of cosmic structure.

1. **Theoretical Framework: Gravitational Repulsion and Structure Formation Between Matter and Dark Matter**

**2.1 Modified Cosmological Perturbation Equations**

In comoving coordinates, the evolution equations for the density perturbations of matter and dark matter, and are:

Key modification (red terms): Due to the negative mass of dark matter its gravitational source term has a positive sign indicating self-attraction; while the cross terms and have a positive sign, indicating mutual repulsion.

**2.2 Linear Evolution and Mode Separation**

The solution to the above coupled equations shows two eigenmodes exist:

1. Growing mode: (matter and dark matter density perturbations are out of phase)
2. Decaying mode: (matter and dark matter density perturbations are in phase)

The evolution of cosmic structure is dominated by the out-of-phase mode: where matter aggregates, dark matter is repelled away, and vice versa.

1. Explanation of Astronomical Phenomena

**3.1 Origin of the Boötes Void and Large-Scale Voids**

Phenomenon: The Boötes Void is a vast region approximately 330 million light-years in diameter, containing very few galaxies, yet its cosmic microwave background (CMB) temperature shows no significant anomaly.

Traditional explanation dilemma: It is difficult to explain why such a large and “empty” region would form under the standard cosmological model.

Explanation by this model:

1. In the early universe, a region of accidental matter overdensity began to form.
2. According to the out-of-phase mode, this region exerted repulsive gravity on dark matter, expelling it.
3. After dark matter was expelled, the total gravitational potential source in this region significantly decreased, and matter further lost its gravitational source for aggregation.
4. A positive feedback loop formed: more matter aggregation -> more dark matter repelled -> weaker gravity -> matter will be harder to pull away -> region becomes emptier.
5. Ultimately, a giant, true void with almost no matter and no dark matter formed. Since the densities of both matter and dark matter are extremely low, their gravitational potential well is very shallow, resulting in a minimal Sachs-Wolfe effect on CMB photons; hence, the temperature anomaly is not obvious. This perfectly matches observations.

**3.2 The Missing Satellites Problem**

Phenomenon: The CDM model predicts that hundreds of dark matter subhalos, corresponding to dwarf galaxies, should exist around the Milky Way, but the observed number is an order of magnitude smaller.

Explanation by this model:

1. Dark matter itself forms structures through dark QCD, producing dark galaxies and dark subhalos.
2. However, during the formation of a matter galaxy (e.g., the Milky Way), its powerful repulsive force field strips and disperses most of the nearby dark matter subhalos.
3. Only those dark matter subhalos initially located in regions of extremely low matter density survive and may capture small amounts of gas to form dwarf galaxies.
4. This naturally results in the observed number of dwarf galaxies being much smaller than the theoretical prediction for dark matter subhalos, and these dwarf galaxies tend to be distributed in the outer halo of the Milky Way.

**3.3 Diversity of Galaxy Rotation Curves**

Phenomenon: The shapes of rotation curves vary among different galaxies; some are flat, some decline. The CDM model requires “fine-tuning” the distribution of the dark matter halo for each galaxy to explain this.

Explanation by this model:

1. A galaxy’s rotation curve is determined by the distribution of matter and the distribution of repelled dark matter.
2. The initial conditions for a galaxy’s formation (angular momentum, initial ratio and distribution of matter and dark matter) vary.
3. Under repulsive gravity, each galaxy evolves a unique dark matter halo distribution: some dark matter is completely expelled to the far periphery, while some may form a compressed dark matter shell.
4. Therefore, without adjusting dark matter properties, diverse rotation curves naturally arise solely from different formation histories.

**3.4 Galaxy Cluster Collisions (Bullet Cluster)**

Phenomenon: Observations of the Bullet Cluster show that the gravitational center of the galaxies separates from the center of the X-ray gas after the collision, interpreted as evidence for collisionless dark matter.

Explanation by this model:

1. When two dark matter-dominated clusters collide, their dark matter structures (dark galaxies) may also experience inelastic collisions due to their own dark strong interactions, thus lagging behind the collisionless galaxies.
2. Simultaneously, the material gas undergoes violent collisions and is left behind.
3. Therefore, the gravitational center (dominated by the largely collisionless matter stars and dark matter structures at the leading edge) separates from the X-ray center (the lagging material gas).
4. This model also agrees with observations but presents a drastically different physical picture: dark matter is not collisionless but has complex internal interactions.

**4. Implications for Particle Physics Phenomena**

1. The “Null Result” Dilemma in Indirect Dark Matter Detection: If dark matter forms complex dark atoms and dark molecules, its annihilation cross-section and the energy spectrum of its final products become extremely complex, vastly different from the predictions of simple WIMP models. This could be why many indirect detection experiments fail to obtain clear signals.

2. Challenges for Direct Detection: The repulsive gravity between negative mass dark matter and detectors makes it difficult to accumulate within laboratories, explaining why direct detection experiments are also exceptionally challenging.

3. New Avenues for Collider Detection: If portals like kinetic mixing exist, colliders might produce dark hadrons or dark mesons rather than single dark matter particles, with completely different signal characteristics.

1. **Conclusion and Outlook**

The structured dark matter model proposed in this paper, based on ABC theory, provides a unified and self-consistent explanation for several cosmological puzzles:

1. The Boötes Void is a giant out-of-phase structure produced by gravitational repulsion between matter and dark matter.
2. The small-scale problem stems from the expulsion effect of dark matter subhalos during the formation of matter galaxies.
3. The diversity of rotation curves originates from the unique formation and repulsion history of each galaxy.

The model predicts the existence of dark galaxies and dark stars. Although invisible, they could be indirectly detected through their gravitational lensing effects (producing negative convergence and shear) and specific modulations of the large-scale structure of the universe.

Future work will focus on developing cosmological numerical simulation codes that incorporate the fluid dynamics of both matter and structured dark matter to quantitatively test the model’s predictions for the power spectrum, bispectrum, void size distribution, etc.

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