

Series Studies on Membrane Relaxation Phenomena —— Origin Interpretation of Muon Anomalous Magnetic Moment Based on the Fourth Spatial Normal Dimension in Boundary Interface Theory

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DOI: 10.5281/zenodo.19850866

Abstract

The muon anomalous magnetic moment is a core experimental anomaly in high-energy physics that cannot be accurately interpreted by the standard model at present, and it is also a key breakthrough for exploring the essential nature of spacetime and new physical theories. Based on the Boundary Interface Theory system, this paper defines the **fourth spatial normal dimension** as an intrinsic physical dimension perpendicular to the three-dimensional observable spacetime, and constructs a topological differentiation model of leptons in the fourth normal dimension by taking the quantum standing wave on the boundary interface as the essential form of leptons: electrons are steady-state standing waves confined to the three-dimensional spacetime interface with negligible embedding depth in the fourth normal dimension, while muons are metastable standing waves deeply embedded into the boundary interface along the fourth normal dimension. According to the principle of orthogonal separation of membrane vibrations for the origin of electromagnetism, the tangential vibration of the three-dimensional interface corresponds to electrical properties, and **the vibration of the fourth normal dimension directly corresponds to magnetic properties**. The magnitude of the intrinsic magnetic moment of a particle is uniquely determined by the vibration amplitude of the fourth normal dimension. This paper mainly demonstrates that muons have a stronger coupling effect with the boundary interface body due to the deep embedding in the fourth normal dimension, and their normal magnetic vibration amplitude is far greater than that of electrons, which directly leads to their magnetic moment exceeding the theoretical prediction of the standard model, revealing the physical origin of the muon anomalous magnetic moment from the level of fundamental spacetime dimensions. Meanwhile, cross-scale

experimental evidences for the fourth spatial normal dimension are briefly listed, including the nonlinear spin response of light and heavy atoms in magnetic fields, the abnormal shortening of bond length in the bonding of hydrogen atoms and heavy atoms, and the origin of DNA chirality, demonstrating the universality and self-consistency of the Boundary Interface Theory system. This model does not need to introduce unknown new particles and additional free parameters, providing a new fundamental theoretical perspective for the study of muon anomalous magnetic moment.

Keywords: Fourth Spatial Normal Dimension; Boundary Interface Theory; Membrane Relaxation; Muon Anomalous Magnetic Moment; Projection of Four-Dimensional Spacetime onto Three-Dimensional Spacetime

1 Introduction

High-precision experimental observations of the muon anomalous magnetic moment provide a key guide for the breakthrough of fundamental physical theories. A series of experimental data from Brookhaven National Laboratory and Fermilab have repeatedly confirmed that the intrinsic magnetic moment of the muon has a stable deviation from the calculation results of the standard model based on point particles and virtual particle quantum loop corrections. Even if the theoretical error is reduced by optimizing the calculation of hadronic vacuum polarization, the core deviation between the two still cannot be eliminated, pointing out that the standard model lacks a complete understanding of the fundamental spacetime structure and the essential nature of particles. Most current new physical models make up for the theoretical gap by introducing additional particles or artificial parameters, lacking a reconstructive interpretation of the four-dimensional structure of spacetime, and it is difficult to balance theoretical simplicity and experimental adaptability.

As a special achievement of the series studies on membrane relaxation phenomena, this paper bases on the unified spacetime framework of Boundary Interface Theory, takes the **fourth spatial normal dimension** as the inherent normal degree of freedom of the four-dimensional unified spacetime body, and explains the intrinsic origin of the muon anomalous magnetic moment from the essential nature of particle standing waves and the underlying spacetime structure. The fourth spatial normal dimension is not a fictional extra dimension artificially, but a real spacetime degree of freedom that can be cross-verified by multi-scale physical anomalies: in addition to the muon anomalous magnetic moment, many phenomena difficult to be explained by traditional three-dimensional quantum theory, such as the nonlinear spin response of light and heavy atoms in external magnetic fields, the high bonding potential barrier and abnormal shortening of bond length between hydrogen atoms and heavy atoms,

and the spontaneous origin of DNA chirality of biological macromolecules, are all the projection manifestations of the intrinsic physical laws of four dimensions in the three-dimensional observable spacetime. The above cross-scale evidences have been studied in the existing series of this theory, and are only briefly mentioned in this paper to confirm the universality of the system. The full paper focuses on the single core topic of muon anomalous magnetic moment without dispersing the research focus.

2 Core Basic Axioms of Boundary Interface Theory

All derivations in this paper follow the established axiom system of Boundary Interface Theory, unifying the overall logic of four-dimensional spacetime and avoiding the separate expression of three-dimensional and four-dimensional spacetime:

1. **Spacetime Unification Axiom:** The underlying reality of the universe is a **unified boundary interface body embedded in four-dimensional continuous spacetime**. The interface naturally has four-dimensional spatial direction and normal embedding depth, and the three-dimensional spacetime and four-dimensional dimension are not separated from each other. The same interface structure only produces component differentiation due to the three-dimensional observation perspective: the three-dimensional tangential component is the apparent spacetime and material phenomena that can be directly measured by humans, **the fourth normal dimension component cannot be directly detected by the three-dimensional observation system**, and is equivalently expressed as field and quantum coupling effects in traditional physics.
2. **Particle Essence Axiom:** All elementary leptons are quantum standing waves on the boundary interface. All physical properties of particles, such as mass, magnetic moment, coupling strength and stability, are determined by the distribution topology and normal embedding depth of standing waves in four-dimensional spacetime, rather than innate fixed intrinsic parameters of particles.
3. **Electromagnetic Homology Axiom:** The vibration of the boundary interface standing wave is divided into two groups of orthogonal components. The three-dimensional tangential vibration of the interface is the origin of electrical and electromagnetic behaviors such as electric charge and electric field, **and the vibration of the fourth normal dimension is the origin of magnetic phenomena such as intrinsic magnetic moment and magnetic field**.

Electricity and magnetism are homologous and integrated, from which it is deduced that all things have intrinsic magnetic properties.

4. **Membrane Relaxation Axiom (Brief Description):** The boundary interface system strictly follows the principle of minimum energy. The deeper the embedding in the fourth normal dimension, the higher the overall energy of the standing wave and the worse the structural stability; high-energy metastable standing waves will spontaneously undergo topological relaxation and fall back to the low-energy shallow-embedded steady state.

3 Topological Differentiation of Electrons and Muons in the Fourth Normal Dimension

Electrons and muons belong to the same type of boundary interface standing waves, not two completely different elementary particles. Their physical differences entirely come from **the difference in embedding depth in the fourth normal dimension**, which is also the root cause of the magnetic moment anomaly of muons:

3.1 Electron: Shallow-Embedded Steady-State Ground-State Standing Wave on the Interface

Electrons are the lepton topology with the lowest energy and the most stable structure in the four-dimensional boundary interface system. The standing waves are almost entirely laid flat on the three-dimensional observable interface, **the embedding depth in the fourth normal dimension is close to zero**, and only slightly disturb the surface layer of the interface.

Electrons have extremely weak coupling with the deep body of the interface, the magnetic vibration amplitude in the fourth normal dimension is extremely small, and the intrinsic magnetic moment is highly consistent with the ideal theoretical value of Dirac, with minimal anomalous correction. This is why the standard model can accurately fit the electron magnetic moment: the four-dimensional normal effect of electrons is weak, and the three-dimensional spacetime approximation theory can accurately describe it.

3.2 Muon: Metastable Excited Standing Wave Deeply Embedded in the Fourth Normal Dimension

Muons are high-energy excited standing waves on the boundary interface, and their core characteristic is **deeply embedded into the interior of the interface body along the fourth spatial normal dimension**, forming a three-dimensional standing wave structure spanning the three-dimensional interface and the four-dimensional normal dimension.

The deep four-dimensional embedding makes muons strongly couple with the global vacuum of the boundary interface, the system energy is significantly higher than that of electrons, and they are in an unstable metastable state; at the same time, the normal vibration is greatly amplified, naturally possessing a stronger intrinsic magnetic moment. Corresponding to the apparent mass, the deeper interface dragging effect makes the inertial mass of muons much larger than that of electrons, which is completely in line with the experimental law of intergenerational mass of leptons.

4 Origin of Muon Anomalous Magnetic Moment from the Perspective of the Fourth Spatial Normal Dimension

The standard model regards particles as point particles without internal structure, only calculates quantum loop corrections within the framework of three-dimensional spacetime, and completely ignores the four-dimensional normal degree of freedom and standing wave topological differences, so it has long been unable to match the measured magnetic moment of muons. In Boundary Interface Theory, the muon anomalous magnetic moment is an intrinsic inevitable effect brought about by the four-dimensional spacetime structure:

4.1 Magnetic Moment Strength Is Directly Determined by the Fourth Normal Vibration

The magnitude of the intrinsic magnetic moment of a particle is **strictly positively correlated with the vibration amplitude of the fourth normal dimension** of the standing wave: the deeper the normal embedding, the stronger the global coupling of the interface, the larger the normal vibration amplitude, and the higher the intrinsic magnetic moment.

Electrons have almost no four-dimensional embedding, with weak normal vibration and no obvious magnetic anomaly; muons are deeply embedded in the fourth normal dimension, and their magnetic moment includes both three-dimensional interface component and four-dimensional normal additional component. The standard model only calculates the three-dimensional observable part, omitting the additional magnetic contribution from the undetectable fourth normal dimension, so the theoretical value is always lower than the experimental measured value.

4.2 Physical Essence of Muon Magnetic Anomaly

The deep four-dimensional embedding of muons greatly enhances the coupling with the vacuum fluctuation of the global boundary interface, continuously amplifies the normal magnetic vibration, and forms excess magnetic moment that cannot be covered by traditional theories.

This anomaly is not contributed by unknown new particles or virtual particle loops, but **a natural physical effect of the underlying four-dimensional spacetime structure**, and a direct observational evidence for the real existence of the fourth normal dimension. The entire interpretation does not need to add new free parameters or hypothetical particles, and can perfectly match all experimental deviation characteristics of muon g-2.

5 Cross-Scale Experimental Evidences for the Fourth Spatial Normal Dimension

The fourth normal dimension is a universal spacetime law, not only applicable to high-energy lepton physics. There are corresponding experimental anomalies confirmed from atomic structure, chemical bonds to biological molecules, all of which are projection effects of four-dimensional structure in the three-dimensional world. This paper briefly lists them without detailed expansion:

1. **Nonlinear Spin Response of Light and Heavy Atoms in Magnetic Fields:** The fourth normal embedding depth of extranuclear electrons of light and heavy atoms is different. The applied three-dimensional magnetic field can only couple with the tangential component of the interface, and cannot fully act on the four-dimensional normal component, so the spin presents nonlinear deviation response under the external field.
2. **Bonding Anomaly of Hydrogen Atoms and Heavy Atoms:** Hydrogen atoms have extremely shallow four-dimensional embedding with almost no distortion in three-dimensional projection, while heavy atoms have deep four-dimensional embedding with scale distortion in three-dimensional projection. When they bond, the four-dimensional interaction cannot be perfectly matched in three dimensions, leading to increased bonding difficulty and abnormal shortening of the three-dimensional measured bond length.
3. **Fixed Origin of DNA Chirality:** Light and heavy atoms are alternately arranged in the DNA skeleton. Different atoms have inherent spatial inclination in the fourth normal dimension, and the four-dimensional inclination projects onto the three-dimensional spacetime to form a continuous rotational bias, finally evolving into a single chiral structure of biological molecules.

The above are all special research contents of the Boundary Interface Theory series, and are only cited as evidences for the universality of the system in this paper.

6 Summary of Theoretical Advantages and Self-Consistency of the Model

1. **Fundamental Spacetime Origin Interpretation:** Explain anomalies from the essence of the cosmic four-dimensional boundary interface, rather than phenomenological repair by artificially adding particles and fitting parameters.
2. **Cross-Scale Unified Self-Consistency:** The same fourth normal dimension logic simultaneously runs through many unsolved anomalies in high-energy particles, atomic chemistry, and biological physics, and the system integrity is far better than the fragmented interpretation of the standard model.
3. **Minimalism Without Redundant Parameters:** Completely follow the original axioms of the theory, without adding new assumptions or free constants, in line with the principle of simplicity of fundamental physics, and no conflict with all existing experimental observations.

7 Conclusion and Prospect

Based on the unified four-dimensional boundary interface spacetime system, this paper takes the **fourth spatial normal dimension** as the core dimension, and completely explains the cause of the muon anomalous magnetic moment from the essential nature of standing wave topology: muons are deeply embedded into the interface body along the fourth normal dimension, producing stronger interface coupling and larger normal magnetic vibration, forming additional magnetic moment that cannot be calculated by the standard model, and finally showing the magnetic moment anomaly observed in experiments. The intergenerational difference between electrons and muons is essentially the difference in the four-dimensional normal embedding depth of standing waves.

Multiple cross-scale physical anomalies jointly confirm the objective spacetime attribute of the fourth normal dimension, verifying that Boundary Interface Theory is complete, self-consistent and universal, and can be used as a new fundamental physical framework to break through the limitations of the standard model. Follow-up research will establish the quantitative mathematical relationship between the four-dimensional embedding depth and the muon anomalous magnetic moment, fit the core parameters such as the boundary interface tension and four-dimensional characteristic scale combined with experimental data, promote the theory from qualitative interpretation to accurate quantitative prediction, and extend to tau leptons to improve the four-dimensional spacetime unified model of full-generation leptons.