The Tetrahedral Universe Model and the Geometrical Fingerprint in the CMB

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Abstract

The standard cosmological model is persistently challenged by large-scale anomalies, including the Cosmic Microwave Background (CMB) cold spot, baryon asymmetry, and the efficient early galaxy formation revealed by the James Webb Space Telescope (JWST). This paper proposes a testable "Tetrahedral Universe Model" from a novel first principle of "physical information". The model posits that our universe is one of four material universes (U1-U4) stabilized in a tetrahedral configuration within a higher-dimensional spacetime. It directly predicts that our CMB sky should exhibit two cold spots caused by repulsion from negative-energy neighboring universes and one hot spot caused by gravitational attraction from a positive-energy neighboring universe, whose angular separation reflects the characteristic geometry of the tetrahedron. Preliminary analysis of Planck satellite data shows a qualitative agreement between the distribution of anomalous regions and this prediction. This model provides a unified origin framework for the aforementioned puzzles and suggests that the large-scale structure of the universe may originate from its macroscopic geometric architecture.

Keywords: Cosmological Model; Cosmic Microwave Background; CMB Cold Spot; Large-Scale Anomalies; Multiverse; Tetrahedral Geometry; Physical Information Cosmology

1. Introduction

The Λ-CDM model, a cornerstone of modern cosmology, has successfully described many observational features with six parameters, ushering cosmology into an era of "precision" science. However, as observational accuracy improves, a series of "large-scale anomalies" difficult to explain by standard random fluctuations have emerged, posing profound challenges. Among the most notable is the large-scale "cold spot" in the Cosmic Microwave Background (CMB) radiation (Fig. 1). Initially discovered by the WMAP satellite [1, 2] and confirmed by Planck data [3, 4], its physical origin remains a central enigma in modern cosmology. Systematic analysis of Planck data has

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revealed that multiple such large-scale anomalous regions coexist on the sky [5] (its Fig. 29), strongly suggesting that the cold spot may not be an isolated phenomenon but could be linked to a grander, yet unrecognized, cosmic physical origin. On the other hand, unsolved mysteries within the standard model of particle physics—such as baryon asymmetry and parity violation in weak interactions—also point to the boundaries of the existing physical paradigm.

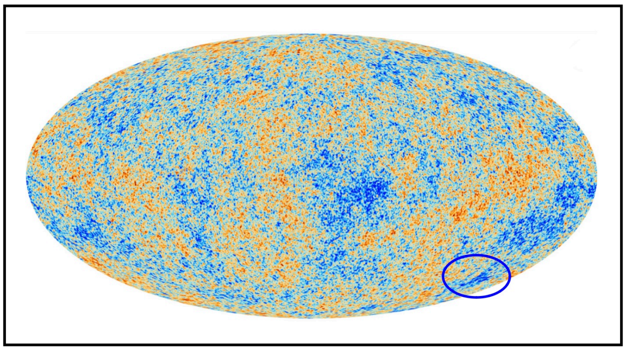


Fig. 1 | CMB temperature fluctuation map, indicating the famous cold spot location. The base map shows the all-sky CMB temperature fluctuations measured by the Planck satellite (Planck Collaboration, 2013). The blue circle marks the famous anomalous cold spot region, centered near Galactic coordinates (l, b) ~ (209°, −57°) (the Eridanus cold spot), based on its original discovery references [1, 2] and subsequent confirmation studies from Planck data (Planck Collaboration, 2016).

Various hypotheses have been proposed for the CMB cold spot, most notably the "supervoid hypothesis" [6], which attributes it to a giant cosmological-scale underdensity causing CMB temperature decrease via the (late-time) integrated Sachs-Wolfe effect.Other explanations include physical models like "cosmic texture collapse" and "early-universe features" [7]. However, detailed galaxy surveys have not found a single supervoid of sufficient scale and depth in the corresponding region to explain the observed temperature fluctuation; predictions of other models have also lacked strong subsequent observational support. More importantly, all these mainstream hypotheses face two fundamental, common limitations: First, they are typically "isolated," aiming to provide a possible cause for that single famous cold spot, yet cannot naturally explain other potential features on the CMB map (e.g., another cold spot or a hot spot) that form specific geometric relations with it. Second, they focus more on providing possible causal models for specific phenomena, without revealing the deeper common cosmological origin and unified physical mechanism behind these phenomena.

Recent observations from the James Webb Space Telescope (JWST) have added a new challenging dimension. Its discovery of a wealth of mature and structurally complex galaxies at very early epochs (redshift $z > 10$) [8, 9], with formation efficiency and speed far exceeding expectations based on the traditional structure formation picture of Λ-CDM, constitutes the so-called "early galaxy timing crisis." These puzzles, seemingly isolated across macroscopic structure and microscopic physics, may collectively point to a more profound common root: the initial conditions and macroscopic architecture of our universe itself.

To break through these limitations, this paper proposes the "Tetrahedral Universe Model" from the novel first principle termed "physical information." The model's innovations are threefold: First, it makes a clear and unique observational prediction—that the CMB should exhibit two cold spots and one hot spot, whose specific angular separation directly manifests the 2D projection of our universe's tetrahedral vertex configuration in a four-dimensional spacetime background, serving as a unique imprint of this deep geometric architecture on the celestial sphere. Second, it provides a unified physical origin—attributing these features to the macroscopic geometric architecture and dynamics of our universe's location. Third, it demonstrates powerful explanatory force—offering a unified solution framework for baryon asymmetry, parity violation, and JWST early galaxies.

From this perspective, cosmic evolution is seen as the stepwise structuring of physical information through a recursive process of progressive and fundamental transitions driven by the information potential, during which overall symmetries and conservation laws are maintained via a "symmetry-bifurcation" mechanism within a grander architecture. This paper demonstrates how, starting from this set of principles, the "Tetrahedral Universe Model" is logically derived: our universe is one of four material universes (labeled U1, U2, U3, U4) originating from the two-level recursive fundamental transitions and symmetry bifurcation of physical information, stabilized in a tetrahedral geometric configuration within a four-dimensional spacetime. A direct, testable prediction of the model is that the CMB sky of our resident universe (U1) should contain two cold spots caused by repulsion from negative-energy neighboring universes (U3, U4) and one hot spot caused by gravitational attraction from the positive-energy-antimatter universe (U2), with the angular separation among the three being approximately 70.53 degrees under ideal conditions—the characteristic angle between tetrahedron vertices. Preliminary analysis of existing Planck satellite CMB data shows a qualitative agreement between the distribution of anomalous regions and this prediction (see Fig. 2).

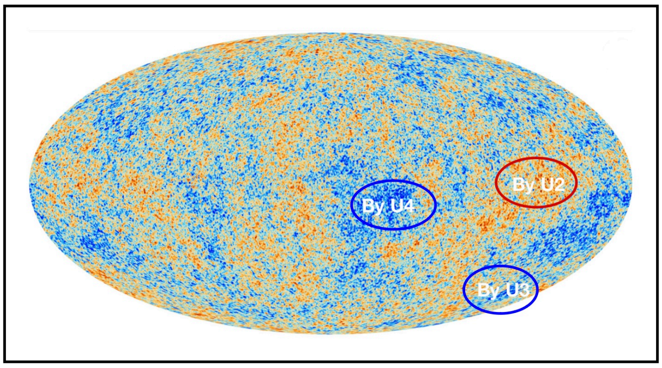


Fig. 2 | Comparison between the predicted CMB geometric fingerprint of the Tetrahedral Universe Model and Planck observational data. This figure is based on the CMB temperature fluctuation map released by the Planck satellite, annotated with the three predicted characteristic spatial configurations of the model. a, The red elliptical region in the figure indicates the predicted hot spot formed by matter overdensity due to gravitational attraction from neighboring universe U2 (its positive energy attribute). b, The two blue elliptical regions in the figure indicate the predicted cold spots resulting from cosmic voids (underdensities) formed by the repulsive forces from the negative-energy neighboring universes U3 and U4, respectively.The spatial distribution of these three features qualitatively matches the predicted tetrahedral geometric relationship (see Fig. 4), constituting strong observational evidence supporting the Tetrahedral Universe Model.

This model, through a concise geometric architecture, provides a unified and testable solution to a series of core puzzles in current cosmology, opening a new path for understanding the ultimate origin of cosmic structure.

2. Theoretical Framework: From Physical Information to the Tetrahedral Universe and Its Causal Isolation Mechanism

Before elaborating the specific Tetrahedral Universe Model, we first define the theoretical rationale, core concepts, and basic principles of our theory.

2.0 Theoretical Rationale: Physical Information Cosmology as a Natural Extension of Current Paradigms

Modern cosmology, while highly successful in describing the universe's evolution from a hot, dense state, rests upon a foundational consensus that masks profound theoretical lacunae. The prevailing narrative posits that our material universe (U1) emerged from a singularity via the Big Bang, preceded by a quantum vacuum subject to fluctuations. This framework, however, encounters fundamental challenges:

- **The Primordial Information Loss Problem:** The pre-Bang state is fundamentally unknown. Describing it as a "quantum vacuum" specifies a mechanism (quantum fluctuations) but not the underlying entity or the initial conditions governing its dynamics.
- **The Problem of Asymmetry from Symmetry:** The remarkable large-scale symmetry of the universe (as seen in the CMB) is believed to have evolved from an initial state of even higher symmetry. Yet, the mechanism by which this primordial symmetry **selectively broke** to yield the observed, pervasive asymmetries—such as baryon asymmetry and parity violation—remains one of the deepest mysteries.
- **The Incompleteness of Single-Stage Fluctuation:** The conventional model of a **single-stage fluctuation** from vacuum directly to particle-antiparticle pairs, while a useful calculational tool, is theoretically incomplete. It inherently leads to divergences requiring ad-hoc **renormalization** and struggles to explain why such a symmetric process (producing equal matter and antimatter) resulted in a vastly matter-dominated universe without invoking additional, unverified physics.

Physical Information Cosmology (PIC) addresses these challenges not by contradicting established physics, but by refining the ontology of the quantum vacuum and proposing a more complete, two-stage genesis narrative.

We propose that what is conventionally called the quantum vacuum is more fundamentally described as a primordial sea of **physical information** in its free state. The subsequent genesis is not a single, poorly-defined event, but a **two-stage, recursive process of generalized condensation**, where each stage is driven by the information potential (Ψ) and rigorously upholds fundamental conservation laws.

(1) First-Stage Transition: Establishing the Energetic Foundation and Symmetry Reservoir

The first critical threshold of the information potential triggers a Fundamental Transition, bifurcating physical information into positive and negative energy foundations.

- **Solves the Energy Conservation Problem:** This process is inherently energy-conserving, producing a universe with a net zero energy balance from the outset.
- **Solves the Primordial Symmetry Problem:** It establishes a **symmetry reservoir**. While positive and negative energy represent a local symmetry breaking, they are born together and remain coupled, preserving a higher-order, global symmetry. The observed asymmetries in our universe (U1) are then naturally explained as a local perspective on this grander, symmetric architecture.

(2) **Second-Stage Transition: Resolving Matter Genesis and Baryon Asymmetry**

Within the newly formed positive and negative energy clusters, the information potential reaches new critical points, leading to a second **Fundamental Transition** and bifurcation:

- Positive Energy → Matter (U1) & Antimatter (U2)
- Negative Energy → Negative Matter (U3) & Negative Antimatter (U4)
- **Solves the Baryon Asymmetry Problem:** This step perfectly conserves baryon number **across the entire four-universe system**. The reason we observe a matter-dominated universe is simply that we are confined to U1. The "missing" antimatter predominantly resides in U2. This provides a clean, geometric solution without requiring CP-violation parameters alone to be exponentially fine-tuned.
- **Refines the Fluctuation Paradigm:** PIC subsumes the standard model's single fluctuation into a deterministic, two-stage process with a definite outcome. The "particle-antiparticle pair production" is no longer a solitary, problematic event but the final step in a structured, information-driven phase transition.

In summary, PIC provides a more self-consistent, complete, and elegant foundation for cosmology. It is not built in a vacuum but directly addresses the recognized shortcomings of the current paradigm. By introducing **physical information** as the fundamental entity and **two-stage transitions** as the dynamical mechanism, it achieves several key advancements:

- **Self-consistency:** It rigorously upholds conservation laws (information, energy, baryon number) at every level.

- **Rationality:** It offers mechanistic, testable explanations for the origin of cosmic architecture and the source of observed asymmetries.
- **Simplicity & Elegance:** It derives the complex, asymmetric observable universe from a simple, symmetric principle through a natural, recursive process, resolving multiple, seemingly disconnected "puzzles" within a single, unified framework.

2.1 Core Concepts: Physical Information, Information Potential, and Recursive Hierarchical Emergence

We introduce the following set of core concepts to build the theory's foundation:
- **Physical Information**: Regarded as the sole primary fundamental entity of the universe. It is ontologically prior to energy and matter.
- **Information Potential (Ψ)**: The fundamental dynamical quantity driving the evolution of physical information systems. Its role is analogous to the chemical potential in thermodynamics, serving as the fundamental driver for phase transitions.
- **Free State and Bound State**: These are two fundamental states universally present within each level of existence (physical information, energy, matter). The free state represents an unstructured state with high potentiality within that level; the bound state represents a stable, structured state within that level. The information potential drives local evolution from the free state to the bound state within each level, a process defined as a **Progressive Transition**.
- **Fundamental Transition and Symmetry Bifurcation**: When the information potential of a system at any level reaches a critical threshold, a **Fundamental Transition** occurs—a discontinuous structural change or phase transition. The transition, via the symmetry bifurcation mechanism, generates multiple fundamental states at the daughter level from a single state at the parent level, strictly adhering to overall conservation laws.

Based on these concepts, the theory depicts a recursive cosmic genesis:

(1) From Information to Energy: Primary Generalized Condensation

At the physical information level, as the information potential reaches a critical value, its free state undergoes a Fundamental Transition, symmetrically bifurcating into the two energy foundations of the universe—positive energy and negative energy. This process can be seen as the initial "condensation" or "structuring" of physical information from its most primordial free state into entities with definite energy attributes. Thus, energy is the "primary generalized condensate" of physical information.

(2) From Energy to Matter: Secondary Generalized Condensation

Within the nascent energy level, free and bound states also exist. As the internal information potential of energy reaches a new critical point, its free state undergoes a second Fundamental Transition, bifurcating into the fundamental states of the matter level: positive energy bifurcates into matter and antimatter; negative energy bifurcates into negative matter and negative antimatter. This process further structures the energy states into particles possessing rest mass, charge, and other complex attributes. Thus, matter is the "secondary generalized condensate" of physical information mediated through energy.

(3) Recursive Hierarchical Structure

Therefore, energy and matter are not parallel to physical information but are secondary realities emerging from it through recursive Fundamental Transitions. The emergence of each new level provides a stage for more complex free-bound state dynamics and subsequent Progressive Transitions within it. The concept of "generalized condensation" accurately captures the stepwise solidification from informational potentiality to material reality.

2.1 Physical Information and Recursive Fundamental Transitions

Our theoretical framework, based on the above concepts, involves the following specific cosmic generation mechanism:

(1) **First-Level Fundamental Transition: From Information to Energy Foundations**

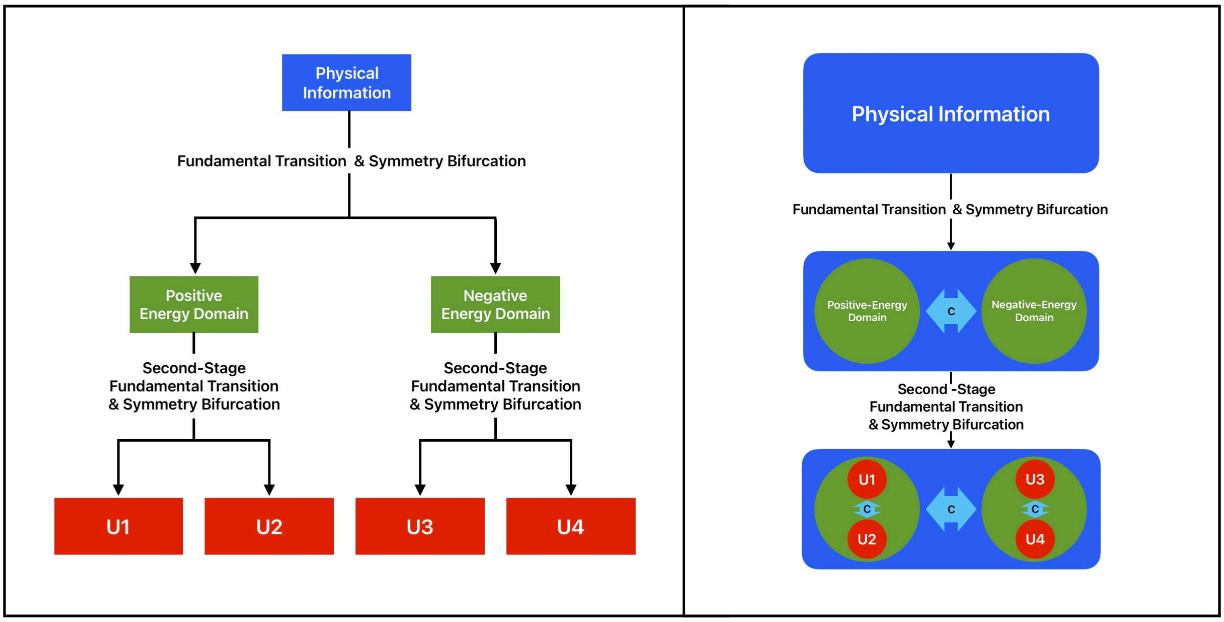
The primordial physical information state (free state) underwent a fundamental Fundamental Transition, symmetrically bifurcating into a positive energy cluster and a negative energy cluster. To ensure the stable existence of these two energy foundations after their birth and prevent mutual annihilation, they established a recessional motion at the speed of light (c) relative to each other, thereby achieving the first level of causal isolation. At this stage, the spacetime structure was not fully solidified; these positive and negative energy clusters, as "primary generalized condensates," constituted the energy foundation for subsequent universe creation.

(2) **Second-Level Fundamental Transition: From Energy to Material Universes**

Subsequently, the nascent positive and negative energy clusters, as independent causal isolation systems, saw their internal information potentials reach critical points again, triggering a second Fundamental Transition and bifurcation:

- The **Positive Energy Cluster** bifurcated into: Our material universe (U1) and an antimatter universe (U2). Although their material composition is opposite, both belong to the positive energy category.
- The **Negative Energy Cluster** bifurcated into: A negative matter universe (U3) and a negative antimatter universe (U4). Both belong to the negative energy category.These four material universes, as secondary generalized condensates, constitute the basic architecture of the observable cosmos.Based on interaction balance and symmetry, the most stable configuration for these four resulting

material universes is a regular tetrahedron in a higher-dimensional spacetime. They also inherited the inherent recessional motion at speed c, constituting the second level of causal isolation mechanism, ensuring the stability of the four material universes as independent systems.This "**dual causal isolation**" architecture—namely, the two-level recessional motion at the speed of light (c) between energy clusters and between material universes—constitutes the foundation of the entire model (see Fig. 3 for a schematic of its dynamical mechanism).



(a) (b)

Fig. 3 | The mechanism of dual causal isolation via recursive fundamental transitions. a, The two-level recursive Fundamental Transitions of physical information and the generation sequence of the tetrahedral universes. b, The dual causal isolation dynamical mechanism corresponding to the transition process. These two juxtaposed schematics jointly reveal the complete process from physical information to a stable material universe architecture: the first-level transition generates positive and negative energy clusters and establishes the first light-speed (c) recessional isolation; the second-level transition generates matter-antimatter universe pairs within each energy cluster and establishes the second light-speed (c) recessional isolation, ultimately forming the four-universe tetrahedral configuration shown in Fig. 4.

Governed by interaction balance and symmetry, the most stable configuration for these four resulting material universes is a regular tetrahedron in a higher-dimensional spacetime. Within this configuration, the equivalent repulsive force arising from the inherent recessional motion at light speed between universes (originating from the two-level transitions) achieves a perfect dynamic balance with the gravitational/repulsive interactions between universes of different energy attributes. This is consistent with the principle of minimum energy ubiquitous in nature (e.g., the tetrahedral geometry of the CH_4 methane molecule is its most stable configuration resulting from balanced electron cloud repulsion), establishing the tetrahedron as the natural and necessary geometric architecture for ensuring the long-term stability of this multiverse system (see Fig. 4 for a schematic of its spatial configuration)

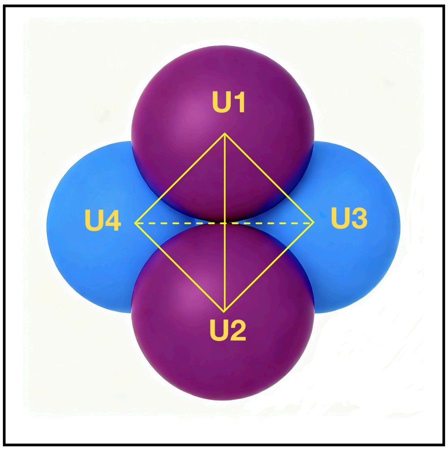


Fig. 4 | Tetrahedral spatial configuration and energy attributes of the fourfold universe. This figure illustrates the stable tetrahedral configuration of the four material universes (U1–U4) in a higher-dimensional spacetime. The yellow solid and dashed lines connect the centers of the four universes, outlining the geometric skeleton of a regular tetrahedron. a, The two red spheres in the front (longitudinal distribution) represent U1 (our resident universe) and U2, originating from the positive energy cluster. b, The two blue spheres in the back (transverse distribution) represent U3 and U4, originating from the negative energy cluster. Colors distinguish their energy attributes, which determine their gravitational (from U2's positive energy) or repulsive (from U3, U4's negative energy) influence on U1.

2.2 Causal Isolation and the Cosmological Origin of Light Speed

A profound implication of this model is that these four universes recede from each other at speed c while expanding. This inherent recession velocity constitutes the dynamic stabilization and causal isolation mechanism of the tetrahedral universe structure. Consequently, we can provide a natural cosmological origin explanation for local physical laws:

- **Light Speed as the Base Velocity**: Within our universe (U1), the motion of any object or information occurs atop this inherent "light-speed base." Therefore, the speed of light c is not an ordinary velocity but a local manifestation of the inherent recessional speed of the cosmic spatial structure itself.
- **Necessity of the Speed Limit**: Since no motion within our universe can cancel out or exceed the inherent recessional speed of the universe's architecture itself, the speed of light c becomes the absolute speed limit for all motion and information transfer within our universe.
- **Deep Origin of Lorentz Transformation**: The constant c appearing in the Lorentz transformation, independent of the motion state of the source and observer, is no longer an accidental, empirical assumption from this perspective. It precisely reflects that the local physical laws of our universe are grounded and constrained

by the geometry and dynamics of the larger-scale cosmic structure (i.e., the light-speed recession of the tetrahedral universes).

Establishment Mechanism of the Primordial Imprint

The model reveals a fundamental physical picture: the four universes recede from each other at light speed, ensuring that for most of cosmic evolution, they cannot establish causal connection via interactions propagating at or below c. However, as described in Section 3, the gravitational and repulsive forces from neighboring universes have left imprints on our CMB from the very early universe. This guides us to investigate their establishment mechanism.We propose that the seeds of these large-scale imprints were planted precisely in the universe's extreme infancy (e.g., around the end of the inflationary epoch). At that time, the particle horizon scale of our universe was much smaller than the current observable universe, and the inherent recessional distances between the four universes were relatively smaller. During this brief period of "causal contact," the gravitational and repulsive potential fields of the neighboring universes (U2, U3, U4) could effectively influence the density distribution of the primordial plasma in our universe (U1), in a manner analogous to primordial perturbations, thereby engraving their geometric configuration onto the CMB.

Subsequently, as the universe expanded, causal isolation became complete, but these gravitational potential imprints, serving as initial conditions, had already been established. They were then frozen in and amplified by the cosmic expansion, ultimately manifesting as the observed cold and hot spots on the CMB last scattering surface.This picture naturally resolves the apparent paradox of "imprints under causal isolation" and incorporates the effects of the four-universe architecture into the standard early cosmic evolution scenario.

3. The Tetrahedral Geometric Fingerprint on the CMB and Existing Evidence

3.1 Mechanism, Quantitative Prediction, and Observational Comparison

Our model not only allows but necessitates interactions between universes. As shown in Fig. 4, neighboring universe U2 (positive energy-antimatter) exerts a gravitational effect on the primordial plasma of our universe (U1), while neighboring universes U3 and U4 (negative energy) exert repulsive effects. This necessarily leads to the geometric fingerprint on the CMB, as illustrated in Fig. 2:

- U2 direction forms a matter overdensity → CMB hot spot (red elliptical region in Fig. 2).
- U3 and U4 directions form matter underdensities (cosmic voids) → two CMB cold spots (two blue elliptical regions in Fig. 2).

The qualitative agreement between these cold/hot spots and the predicted tetrahedral geometry (Fig. 4) constitutes strong observational evidence supporting the

Tetrahedral Universe Model.It must be emphasized that the CMB sky we observe is a two-dimensional projection onto the celestial sphere. In our model, the four universes form a tetrahedral structure in a four-dimensional spacetime. When viewed from within our universe (U1), the central directions of the other three interacting universes (U2, U3, U4) project onto the CMB celestial sphere. The angles between the lines connecting these projections, under ideal static conditions, correspond to the angles between the center and vertices of a regular tetrahedron, i.e., ~70.53° (geometric relationship schematic in Fig. 4). Therefore, the model predicts that the two cold spots and one hot spot caused by the interaction of these three neighboring universes form a specific spatial configuration on the CMB sky. Their angular separation will have ~70.53° as the ideal benchmark and is expected to show a trend of increase due to minor perturbations from the dynamics of the very early universe—particularly the net repulsive effect from U3 and U4. This is a unique, quantitatively testable joint prediction of geometry and dynamics by our model.

3.2 Uniqueness of the Explanation for Existing Observations

Current observations (e.g., the famous CMB cold spot) already hint at the existence of such anomalies. Our model provides a unique theoretical framework that not only offers a physical origin for this known cold spot (interpretable as U3's repulsive fingerprint) but, more importantly, uniquely predicts the existence of two other associated features on the CMB sky: a hot spot caused by U2's gravitational attraction and a cold spot caused by U4's repulsion, with the three forming a specific spatial configuration.Encouragingly, preliminary analysis of the Planck satellite CMB sky map shows anomalous structures in the predicted directions that qualitatively match the above prediction. Initial observation suggests the angular separation formed by these three feature points is slightly larger than 70.53°, consistent with the direction of the dynamical perturbation predicted by the model from the net repulsive force of negative-energy universes (U3, U4) on the primordial plasma distribution.

Furthermore, the residual large-scale temperature asymmetry present in the overall CMB map, after subtracting the dipole anisotropy caused by the solar system's motion, particularly in the right hemisphere (the sky direction of U2, U3, U4), can be directly explained as resulting from the net positive energy background from these three neighboring universes (detailed in Section 4.2 discussion). Final validation of the model awaits rigorous, quantitative statistical significance analysis of these features.

4. Discussion

4.1 Revisiting the Core Logic and Observational Support

The model's argument is built upon a traceable, theory-driven logical chain:

(1) **Theoretical Derivation**: Starting from the "physical information" first principle, the existence of four material universes (U1–U4) and their tetrahedral configuration is necessarily derived.
(2) **Interaction Mechanism**: U1 is subject to non-local interactions from U2 (gravitational) and U3, U4 (repulsive).
(3) **Spatial Prediction**: This mechanism necessarily leaves one hot spot (U2) and two cold spots (U3, U4) on U1's CMB sky, with their angular separation reflecting the tetrahedral geometry (ideal value ~70.53°).
(4) **Observational Discovery**: Existing data show a qualitative match in spatial configuration between a known cold spot and the model's newly predicted additional cold spot and hot spot.
(5) **Dynamical Evidence**: The deviation of the observed angular separation from the ideal value, far from falsifying the model, instead reveals dynamical processes in the very early universe, providing richer clues for the model.This suggests that CMB anomalies may not be isolated, accidental statistical fluctuations but a systematic phenomenon with a common physical origin and geometric architecture.

4.2 Unifying Explanatory Power: From CMB Anomalies to the Network of Cosmological Puzzles

The value of the model lies not only in its prediction of CMB geometric features but also in its architectural unity, capable of providing a common origin for a series of seemingly isolated puzzles in cosmology, constituting strong circumstantial evidence supporting the model:

- **Ultimate Solution for Baryon Asymmetry and Parity Violation**: These fundamental puzzles within the standard model framework are naturally resolved in the four-universe system. Antimatter predominantly resides in the antimatter universe U2, while parity symmetry is perfectly restored across the ensemble of four universes. The observed asymmetries are not inherent violations of physical laws but an "observer effect" resulting from our confinement within the horizon of a single universe (U1).
- **Natural Resolution of the JWST Early Galaxy Crisis**: The abundance of mature galaxies discovered by JWST at very early epochs poses a severe challenge to traditional slow gravitational growth models. In our model, the persistent gravitational and repulsive forces from neighboring universes in the early universe provide a set of powerful, non-random, directional initial perturbations for matter aggregation. This is equivalent to setting clear "gravitational potential wells" and "repulsive potential hills" from the universe's inception, thereby greatly accelerating and front-loading the structure formation process, providing a perfect dynamical origin for JWST observations.
- **New Paradigm for the Origin of Large-Scale Structure**: The observed cosmic web

filamentary structure may not be governed solely by random fluctuations and dark matter gravity. The fixed-direction forces from U2, U3, U4 provide a persistent, "externally architecturally driven field" for structure formation. This non-random "cosmic stirring" action can very efficiently guide material flows, thereby significantly shaping and reinforcing the formation of the cosmic web.

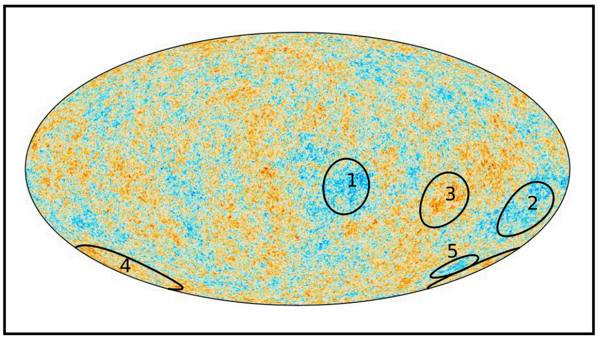
4.3 Paradigm Shift: From Isolated Patches to a Unified Architecture

The value of this model lies in its paradigmatic breakthrough. Existing theories (e.g., supervoids, cosmic textures) attempt to find isolated, post-hoc explanatory causes for single phenomena. They essentially serve as "patches" for the Λ-CDM model.In contrast, our model provides an a priori framework for a unified origin of unified physical architecture. Within this framework, CMB anomalies, baryon asymmetry, JWST observations, and large-scale structure are no longer isolated "unsolved mysteries" but necessary manifestations of the same deep cosmic geometric architecture across different aspects.Therefore, the model's advantage lies not in providing another "explanation," but in using a more fundamental "architecture" to unify the "puzzles" that are isolated under the existing paradigm, guiding cosmology from a "patching models" paradigm towards a new "exploring architecture" paradigm.It should be noted that the "Tetrahedral Universe Model" described here depicts the generation of the visible cosmic architecture through two levels of transitions. In the more complete Physical Information Cosmology (PIC) framework, each transition does not necessarily convert the entire entity of the previous level.

4.4 Quantitative Comparison with Independent Observations and Unified Interpretation

The conformity of the model's predictions is strongly supported by an independent study. The Planck Collaboration [5], in its systematic analysis of extreme CMB large-scale features, identified the five most significant temperature anomaly regions (Fig. 5). Encouragingly, regions numbered 1, 3, and 5 correspond almost precisely in both location and cold/hot property to the features predicted by our model as caused by U4, U2, and U3, respectively. Crucially, while that study confirmed the existence and statistical significance of these anomalies, it did not provide a unified explanation for their physical origin. Our model, for the first time, posits that these three features are not independent statistical fluctuations but necessary manifestations of a common deep physical mechanism—the 'Tetrahedral' geometric architecture our universe inhabits. This not only provides a mechanistic origin for known anomalies like the cold spot but elevates them to geometric fingerprints revealing the macroscopic architecture of the universe.

Fig. 5 | The five large-scale temperature anomaly regions identified by the Planck Collaboration. This figure is reproduced from [5] (its Fig. 29). Regions numbered 1, 3, and 5 in the figure largely coincide in position and property with the features predicted by our model (see Fig. 2 and main text discussion).



Furthermore, the distribution of the other two anomaly regions (2 and 4) in that figure can also be reconciled with the physical picture of our model. Cold region 2, adjacent to the hot spot (region 3) caused by U2's gravitational attraction, might result from U2's gravity pulling matter to form the hot spot, concurrently causing relative matter sparsity in its flanking regions (i.e., a gravitational halo effect). Similarly, hot region 4, adjacent to the cold spot (region 5) caused by U3's repulsion, could be explained as a pile-up of matter pushed away by U3's repulsive force in the neighboring region (i.e., a repulsive stacking effect). Although these are secondary effects, they collectively depict a dynamic picture where the gravitational and repulsive forces from neighboring universes jointly "sculpt" the primordial matter distribution, showcasing the great potential of our theoretical framework in unifying the explanation of a series of large-scale observational features.

5. Conclusion and Outlook

This paper's proposed "Tetrahedral Universe Model" redefines CMB large-scale anomalies as probes for exploring the ultimate architecture of the cosmos. The research demonstrates that these anomalies need not invoke multiple ad hoc assumptions but can be uniformly attributed to a grander multiverse system with a specific geometric morphology.Future work will focus on:

(1) **Quantitative Verification**: Performing rigorous statistical analysis of the tetrahedral angular separation features in the CMB.

(2) **Theoretical Formalization**: Developing a complete interaction potential model to simulate its impact on the primordial power spectrum and structure formation.

(3) **Extended Application**: Expanding the framework to address core puzzles like dark matter and dark energy, and deriving new, testable secondary predictions.

Author Contributions

Zhong WANG is the sole author of this work and is responsible for the entire research process, including the conception of the theory, performance of all analyses, and the writing of the manuscript.

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