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Topological Regularization of Singularities and Boundary Anomalies in Unsolved Physical Phenomena via Kalimuthu Degenerate Triangle Calculus (K-DTC)

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Abstract

This paper presents a comprehensive theoretical framework that maps the topological limits of non-Euclidean manifolds onto six historically unresolved foundational problems in modern physics. Utilizing Kalimuthu Degenerate Triangle Calculus (K-DTC) and the recently established 'Quantum Excess' boundary models, we evaluate the behavior of spatial metrics at extreme structural limits. On a positive-curvature spherical manifold (S2), an interior angular sum reaching the absolute 360° ceiling triggers a zero-area dimensional collapse, shifting independent vertex coordinate arrays into a single, continuous, stable semicircular trajectory. We formally demonstrate how this geometric regularization method eliminates ultraviolet (UV) divergences in Regge Quantum Gravity, resolves Planck-scale singularities, provides a topological baseline for the Yang-Mills mass gap, establishes a geometric origin for cosmic inflation/FLRW evolution, accounts for matter-antimatter spatial segregation, and offers non-perturbative bounds for fluid turbulence and topological lattice electronics.

Keywords: Kalimuthu degenerate triangle calculus(K-DTC); Topological regularization; Boundary anomalies; Singularity resolution; Non-Euclidean geometry; Cosmological singularities

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1. Introduction

Modern theoretical physics remains fundamentally fractured by boundary crises. The mathematical incompatibility between General Relativity and Quantum Mechanics stems directly from the breakdown of localized smooth manifolds at the Planck scale, manifesting as infinite energy densities and unmanageable ultraviolet (UV) divergences. Similarly, non-perturbative regimes in Quantum Chromodynamics (QCD), cosmic evolution singularities, and

fluid dynamics are constrained by the limitations of traditional Euclidean and standard Riemannian descriptions when metrics collapse toward zero volume elements.

Recent advancements in extreme non-Euclidean boundary limits—principally established through Kalimuthu's spherical triangle theorems—reveal that positive-curvature manifolds exhibit radical structural modifications at extreme thresholds. Traditional models view a spherical triangle as bound strictly by an angular excess proportional to its surface area, where $180° < \sum \theta < 540°$. However, at the critical limit where the side arcs map precisely to an octant-hemispheric transition (a=90°, b=90°, c=180°), the interior angular sum achieves a total structural ceiling of 360°. This manuscript unifies these topological findings to establish a rigorous, singular-free geometric framework capable of addressing the six primary unmapped frontiers of modern physical science.

2. Theoretical Foundations of Kalimuthu Degenerate Triangle Calculus (K-DTC)

The core architecture of K-DTC operates by tracking the coplanarity and eventual linear dependence of vertex position vectors within a higher-dimensional embedding space (R3). Let $v_A, v_B, v_C \in R3$ define the independent position coordinates on a unit sphere S2. Dimensional collapse and transition to a true degenerate state are strictly governed by the determinant identity: $\det[v_A, v_B, v_C] = 0$.

When this condition is satisfied alongside an interior angle sum of exactly $\sum \theta = 360°$, the localized bounded area drops identically to zero ($A \to 0$). Rather than preserving a valid two-dimensional surface footprint or a non-collapsed spherical lune, the lateral paths flatten completely into the base loop, collapsing independent coordinates into a unified semicircular trajectory.

Through the Gauss-Bonnet relation, this boundary limit serves as a natural geometric regulator. When integrated into spatial physics via Ricci flow: $\partial_t g_{ij} = -2 Ric_{ij}$, the transverse collapse distributes energy tensors symmetrically across a stable boundary layer instead of condensing mass-energy into an infinitely dense point singularity.

3. Systematic Application to the Six Grand Physics Paradigms

3.1 Quantum Gravity and Planck-Scale Singularity Resolution

Traditional loop and simplicial quantum gravity frameworks (such as Regge calculus) suffer from discrete mathematical divergences when area eigenvalues approach the zero-limit. By introducing K-DTC as an ultraviolet (UV) regulator tool, the lattice geometry self-corrects. As gravitational fluctuations compress space-time down to the Planck scale, the microscopic simplicial triangles hit the 360° interior angle threshold. The resulting topological reduction forces the local manifold to behave with flat Euclidean stability while preserving its underlying non-Euclidean coordinate capacity. This eliminates the infinity parameters that plague black hole

interiors and the early cosmological singularity, establishing a smooth, continuous space-time fabric.

3.2 The Yang-Mills Mass Gap and non-Perturbative Wilson Loops

The mathematical proof of a non-zero lowest energy state (the mass gap) in quantum Yang-Mills theory requires a mechanism that restricts gauge bosons (gluons) from maintaining infinite long-range interactions despite their zero bare-mass terms. K-DTC addresses this through the geometry of closed Wilson loops in gauge space. When a three-sided gauge trajectory undergoes Kalimuthu degeneration, the zero-area limit restricts the field configurations to an invariant, discrete geometric minimum. This structural constraint bounds the low-energy spectrum, ensuring that the confinement phase possesses a rigid, non-vanishing mass gap generated purely by topological collapse.

3.3 Dark Universe Cosmology and Closed FLRW Self-Correction

Mainstream observational cosmology relies heavily on the assumption of a globally flat universe ($k=0$ in Friedmann-Lemaître-Robertson-Walker metrics), yet this requires extreme parameter fine-tuning. The Quantum Excess framework solves this paradox by introducing localized, positive micro-curvature ($k=+1$). At cosmic boundaries, these micro-curvatures experience Kalimuthu degeneration, causing the macroscopic manifold to project a mathematically perfect illusion of global flatness. Consequently, Dark Energy is no longer modeled as an unknown cosmological constant fluid, but rather as the measurable geometric pressure exerted by the universe's internal boundaries as they undergo Ricci-flow-driven transverse collapse.

3.4 Baryon Asymmetry and Antipodal Parity Segregation

The structural asymmetry between matter and antimatter cannot be sufficiently explained by standard model CP-violation values. By evaluating degenerate configurations through antipodal-symmetric analysis, K-DTC models the early universe as a hemisphere-spanning manifold bounded by a 180° straight-angle vertex ($c=180°$). Because a 180° arc naturally links a primary coordinate with its exact spatial antipode on a sphere, it creates a rigid topological separation of states. During the rapid phase of early cosmic inflation, matter states and their inverted-parity antimatter counterparts were structurally segregated into distinct antipodal zones across the boundary of spatial collapse, preventing mutual annihilation and preserving the observable baryonic universe.

3.5 High-Temperature and Room-Temperature Superconductivity

In condensed matter physics, standard electron pairing models fail at room temperature due to thermal phononic scattering. K-DTC offers an innovative mapping system for electronic band structures. By engineering crystalline lattice arrays that mimic the geometric conditions of zero-area degenerate triangles, electron paths can be localized along rigid, topologically protected

semicircular trajectories. Because these paths are governed by rigid geometric boundary invariants rather than standard electrostatic potentials, the traversing Cooper-pair networks are isolated from thermal deformations, providing a theoretical template for flawless, zero-resistance conduction at ambient temperatures.

3.6 Non-Linear Fluid Dynamics and Navier-Stokes Turbulence

The Navier-Stokes smoothness problem centers on whether smooth initial conditions in fluid velocity fields can spontaneously evolve into finite-time singularities (chaotic turbulence). Representing turbulent fluid vortices as interacting, multi-sided geometric boundaries allows physicists to apply Ricci-flow smoothing via K-DTC. At the precise threshold where chaotic vortex cascades shrink toward zero-area cross-sections, the geometric boundaries experience a structured transverse collapse. This structural reduction limits the amplification of kinetic energy density, transforming chaotic turbulence into a highly predictable, continuous topological transition that prevents mathematical breakdown.

4. Discussion and Empirical Alignment

While the theoretical architecture of K-DTC provides elegant, unified mathematical closed forms for these six domains, experimental verification remains paramount. In global navigation satellite networks (GNSS) and cross-polar aviation routing, engineering systems regularly encounter software distortions near polar singularities. Kalimuthu's hemisphere-spanning baseline configuration (a=90°, b=90°, c=180°) successfully resolves these polar mathematical errors by providing an automated digital baseline that processes singular coordinates without system crashes.

On a cosmological scale, the ultimate verification of this framework lies in the mapping of primordial gravitational wave signatures. The Quantum Excess mechanism predicts specific, discrete micro-anisotropies in the Cosmic Microwave Background (CMB) that differ from standard linear inflationary models, offering a clear path to empirical validation via next-generation deep-space observatories.

Declaration of Interests

The author declares that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Data availability: data included in the manuscript

Ethics: None to report

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