

# $\Lambda$ : Ground Mode of the Cosmic Boundary

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## Abstract

The cosmological constant  $\Lambda$  is the largest unexplained hierarchy in physics:  $\Lambda \cdot \ell_P^2 \approx 10^{-122}$ . We derive the coefficient that determines this value from a single topological postulate: a Möbius surface embedded in  $S^3$  ( $\partial S^3 = \emptyset$ ) selects anti-periodic boundary conditions; the ground-mode eigenvalue on this surface, sampled at the antinode, yields  $\Lambda_{\text{top}} \cdot \ell_P^2 = 2\Omega_\Lambda^{-1}$ , where  $\Omega_\Lambda = (R_\Lambda/\ell_P)^2 \approx 10^{122}$  is the de Sitter-to-Planck hierarchy. The Gauss–Codazzi equations convert intrinsic 2D curvature to observed 3D spatial curvature under minimal embedding and isotropy, producing a factor of 3/2. The topology locks the coefficient:  $\Lambda_{\text{obs}} = 3/R^2$ , where the 3 is antinode intensity (2) times the Gauss–Codazzi interface (3/2).

**Claim types used in this paper:** AXIOM (assumed), DERIVED (shown step-by-step), MOTIVATED (single bridge assumption, identified explicitly), IMPORTED (observational input).

**Parameter accounting.** This paper uses three physical inputs: the speed of light  $c$ , the reduced Planck constant  $\hbar$ , and the Planck length  $\ell_P$ . One geometric scale is imported from observation: the curvature radius  $R$  of the ambient  $S^3$ . Every numerical factor in the result is derived from the topology.

## 1 The Problem

In general relativity, the cosmological constant  $\Lambda$  appears in Einstein’s field equations:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = 8\pi G T_{\mu\nu} \quad (1)$$

Einstein added  $\Lambda$  by hand [1]. It multiplies the metric itself: pure geometry. General relativity does not explain why it has any particular value. Moving  $\Lambda$  to the right-hand side reinterprets it as vacuum energy density:

$$\rho_\Lambda = \frac{\Lambda c^4}{8\pi G} \quad (2)$$

Quantum field theory estimates vacuum energy from zero-point fluctuations. The result exceeds observation by  $\sim 122$  orders of magnitude. This is the cosmological constant problem [2]: the largest discrepancy between theory and observation in physics. Observation gives:

$$\Lambda \approx 1.11 \times 10^{-52} \text{ m}^{-2} \quad (3)$$

In Planck units ( $\ell_P^2 = \hbar G/c^3$ ):

$$\Lambda \cdot \ell_P^2 \approx 2.84 \times 10^{-122} \quad (4)$$

No mechanism in standard physics explains this value [3].

## 2 The Topology

**[AXIOM]** Eigenvalues arise from differential equations on a domain; the shape determines the spectrum. To derive  $\Lambda$ , we specify the shape:

$$S^1 = \partial(\text{Möbius}) \hookrightarrow S^3, \quad \partial S^3 = \emptyset \quad (5)$$

This topology independently predicts three CMB anomalies from geometry alone [4]; the observed parity asymmetry, quadrupole-octupole alignment, and large-angle power deficit are natural consequences of non-orientable geometry [5].

Manifold	Dim	Role
$S^1$	1D	Boundary of Möbius surface
Möbius	2D	Non-orientable surface; carries eigenproblem
$S^3$	3D	Space; $\partial S^3 = \emptyset$

This is the minimal topology:  $S^3$  is the unique simply connected closed 3-manifold (Poincaré [6]); Möbius is the simplest non-orientable surface with boundary.

### 2.1 The Eigenproblem

A bounded domain permits only certain modes. The eigenvalue problem identifies them: spatial patterns that the differential operator returns unchanged except for a scale factor.

On a flat surface, that operator is the Laplacian  $\nabla^2$ ; however, the cosmic (Möbius) surface is curved, and the metric  $g$  stretches and bends the coordinates. The Laplacian generalizes to the Laplace–Beltrami operator:

$$\Delta_g = \frac{1}{\sqrt{|g|}} \partial_\mu \left( \sqrt{|g|} g^{\mu\nu} \partial_\nu \right) \quad (6)$$

For the ground-mode calculation, we treat the Möbius surface as a flat strip with twisted identification; curvature corrections enter at subleading order. The flat-strip model fixes the boundary-condition spectrum and  $1/L^2$  scaling; the curvature-eigenvalue correspondence in §IV uses a constant-curvature identification at the same scale.

**[DERIVED]** The eigenvalue problem:

$$-\Delta_{\text{Möbius}} \psi = \lambda \psi \quad (7)$$

The field  $\psi$  is the modal amplitude on the surface; its intensity  $|\psi|^2$  determines observable strength. The Möbius surface has coordinates  $(y, w)$ :

Coord	Range	Description
$y$	$[0, L]$	Longitudinal (along the strip)
$w$	(drops out)	Transverse (across the width)

The Möbius identification twists the strip:

$$(y + L, w) \sim (y, -w) \quad (8)$$

The longitudinal period  $L$  is set by the embedding. Let  $R$  denote the curvature radius of the ambient  $S^3$ . The boundary  $S^1$  is a single closed loop traversing the strip twice; its total length is  $2L$ . This boundary is a great circle of  $S^3$  with circumference  $2\pi R$ :

$$2L = 2\pi R \Rightarrow L = \pi R \quad (9)$$

Matter is fermionic. Fermions require a  $4\pi$  rotation to return to their original state (spinor behavior). On a non-orientable surface, this maps to the anti-periodic sector:

$$\psi(y + L, w) = -\psi(y, -w) \quad (10)$$

Transverse edges are free boundaries (Neumann condition). One lap ( $L$ ) brings you to the flip side. Two laps ( $2L$ ) bring you home.

## 2.2 The Spectrum

**[DERIVED]** With boundary conditions set, we solve for the eigenvalues.

For the lowest transverse mode, we select even parity in  $w$ :  $\psi(y, -w) = \psi(y, w)$ . This is the simplest mode with no transverse nodes. Even parity means the field is symmetric across the strip width, so the  $w$ -flip in the Möbius identification has no effect. Only the sign flip survives:

$$\psi(y + L) = -\psi(y) \quad (11)$$

Applying this anti-periodic boundary condition to the general solution  $\psi \propto e^{iky}$ :

$$e^{ikL} = -1 \quad (12)$$

This is satisfied when  $kL = (2m + 1)\pi$  for integer  $m$ . The constant mode ( $k = 0$ ) is forbidden; anti-periodicity requires at least one sign flip.

The solutions  $kL = (2m + 1)\pi$  give a half-integer spectrum. The ground mode is  $m = 0$ . The eigenproblem reduces to one dimension:

$$-\frac{d^2\psi}{dy^2} = \lambda \psi \quad (13)$$

with boundary condition  $\psi(y + L) = -\psi(y)$ .

For  $m = 0$ , we have  $k = \pi/L$ . The ground mode wavefunction:

$$\psi_0(y) = \sin(\pi y/L) \quad (14)$$

Substitution confirms this satisfies both the eigenequation and the boundary condition; the eigenvalue is:

$$\lambda_0 = \left(\frac{\pi}{L}\right)^2 = \frac{1}{R^2} \quad (15)$$

The second equality follows from  $L = \pi R$ . The eigenvalue carries the geometric scale directly.

### 3 The Ground Mode

The cosmological background selects the ground mode:

Argument	Mechanism
Isotropy	Higher modes ( $m > 0$ ) have internal nodes, creating $O(1)$ anisotropy. CMB is isotropic to $10^{-5}$ .
Orthogonality	Cosmological measurements integrate over Gpc volumes. Oscillating cross-terms cancel.

#### 3.1 The Intensity Profile

**[DERIVED]** The eigenvalue  $\lambda_0 = (\pi/L)^2$  sets the mode structure. The observable intensity depends on where that mode is sampled. Different positions on a standing wave carry different intensity; the intensity profile encodes this variation.

With normalized coordinate  $\Theta = y/L$ :

$$\psi_0(\Theta) = \sin(\pi\Theta) \quad (16)$$

Observable intensity is  $|\psi|^2$ . The mean of  $\sin^2(\pi\Theta)$  over  $[0, 1]$  is  $1/2$ ; normalizing to unit mean multiplies by 2:

$$C(\Theta) = 2 \sin^2(\pi\Theta) \quad (17)$$

The Möbius identification seam fixes the origin:  $\Theta = 0$  is the twist line, where the wavefunction vanishes. The antinode sits at the geometric midpoint ( $\Theta = 60/120$ ), as far from the seam as the domain permits:

$$C(60/120) = 2 \sin^2(\pi/2) = 2 \quad (18)$$

#### 3.2 The Scale

**[DERIVED]** The eigenvalue  $\lambda_0 = (\pi/L)^2$  establishes dimensional structure:  $\Lambda$  scales as the inverse square of a length. Which length?

The curvature radius  $R$  is the single geometric input. The topological eigenvalue is the product of mode intensity and geometric scale:

$$\Lambda_{\text{top}} = C(\Theta) \cdot \lambda_0 \quad (19)$$

At the antinode,  $C(60/120) = 2$  and  $\lambda_0 = 1/R^2$ :

$$\Lambda_{\text{top}} = \frac{2}{R^2} \quad (20)$$

The topology determines the coefficient. The scale  $R$  is geometry.

For comparison with observation, let  $\Lambda_{\text{obs}}$  denote the observed cosmological constant. The de Sitter parameterization gives (in units where  $c = 1$ ):

$$R_\Lambda = \sqrt{3/\Lambda_{\text{obs}}} \quad (21)$$

In Planck units:

$$\Omega_\Lambda \equiv \left( \frac{R_\Lambda}{\ell_P} \right)^2 \approx 10^{122} \quad (22)$$

The curvature radius of  $S^3$  is the de Sitter radius; they are the same object. Setting  $R = R_\Lambda$  and expressing in Planck units:

$$\Lambda_{\text{top}} \cdot \ell_P^2 = 2\Omega_\Lambda^{-1} \approx 2.0 \times 10^{-122} \quad (23)$$

### 3.3 Topological Protection

**[DERIVED]**  $\Lambda$  sits at the antinode. The antinode is the only position on the mode spectrum where no environmental shift can move the observable.

The sensitivity of  $C(\Theta)$  to small shifts is measured by the logarithmic slope:

$$\frac{d \ln C}{d \Theta} = 2\pi \cot(\pi\Theta) \quad (24)$$

The cotangent diverges near the boundary ( $\Theta \rightarrow 0$ ) and vanishes at the midpoint. At  $\Theta = 60/120$ :

$$\left. \frac{d \ln C}{d \Theta} \right|_{60/120} = 2\pi \cot(\pi/2) = 0 \quad (25)$$

The slope is exactly zero. The cosmological constant is topologically protected because it occupies the unique position where the intensity profile has vanishing derivative. Any other position on the mode spectrum has finite slope and can be shifted by environmental perturbations. The antinode cannot.

This is the reason  $\Lambda$  is constant. The topology does not permit it to evolve.

## 4 The Conversion

The topological eigenvalue  $\Lambda_{\text{top}}$  lives on a 2D surface. The observed  $\Lambda_{\text{obs}}$  is inferred from 3D spatial dynamics. The Gauss–Codazzi equations relate them.

### 4.1 Gauss–Codazzi Equation

**[DERIVED]** The Gauss–Codazzi equation [7] relates intrinsic curvature of an embedded surface to ambient curvature:

$$R_\Sigma = R_{\text{spatial}} - 2 \text{Ric}(n, n) + K^2 - K_{ij}K^{ij} \quad (26)$$

Symbol	Meaning
$R_\Sigma$	Intrinsic scalar curvature of surface
$R_{\text{spatial}}$	Scalar curvature of ambient space
$K_{ij}$	Extrinsic curvature
$K$	Trace of extrinsic curvature ( $g^{ij}K_{ij}$ )
$n$	Unit normal to surface

## 4.2 Minimal Embedding

For a minimally embedded surface ( $K_{ij} = 0$ ), the equation simplifies:

$$R_\Sigma = R_{\text{spatial}} - 2 \text{Ric}(n, n) \quad (27)$$

We take minimal embedding as the geometric correspondent of the ground mode ( $m = 0$ ): higher modes have nodes and oscillations that would require bending (extrinsic curvature) to be embedded; the ground mode lies flat.

## 4.3 Isotropic Space

On the spatial slice of FLRW, the Ricci tensor is isotropic:

$$R_{ij} = \frac{R_{\text{spatial}}}{3} g_{ij} \quad (28)$$

Therefore:

$$\text{Ric}(n, n) = \frac{R_{\text{spatial}}}{3} \quad (29)$$

## 4.4 The Gravity of 3/2 Emerges

**[DERIVED]** Substituting into the Gauss–Codazzi equation:

$$R_\Sigma = R_{\text{spatial}} - \frac{2R_{\text{spatial}}}{3} = \frac{R_{\text{spatial}}}{3} \quad (30)$$

and inverting:

$$R_{\text{spatial}} = 3 R_\Sigma \quad (31)$$

## 4.5 Connection to $\Lambda$

On a constant-curvature  $S^3$  spatial section of radius  $R$ , the spatial scalar curvature is:

$$R_{\text{spatial}} = \frac{6}{R^2} = 2\Lambda_{\text{obs}} \quad (32)$$

$R_\Sigma$  is intrinsic geometry;  $\Lambda_{\text{top}}$  is the eigenvalue from §III. Both are scalar curvatures at the same geometric scale  $R$ . We identify them:

**[MOTIVATED]**  $R_\Sigma := \Lambda_{\text{top}}$ .

This is the single bridge assumption, and where the eigenproblem hands the baton to general relativity:

$$2\Lambda_{\text{obs}} = 3 \Lambda_{\text{top}} \quad (33)$$

$$\Lambda_{\text{obs}} = \frac{3}{2} \Lambda_{\text{top}} \quad (34)$$

These are formally different objects:  $\lambda_0$  comes from the spectrum of  $\Delta_g$ , while  $R_\Sigma$  comes from the Riemann tensor. Yet on a constant-curvature surface they coincide in both dimension and scale (both  $\sim 1/R^2$ ). Whether this coincidence is forced by the geometry of the Möbius identification or is a dimensional artifact is an open question in spectral geometry. There is currently no known theorem relating the two; the author has submitted this question for independent mathematical review ([Math StackExchange #5126487](#)).

The bridge has roots in group theory. The same 3/2 ratio arises independently from the discrete symmetry of  $S^3$ . The binary icosahedral group  $2I$ , the largest exceptional discrete subgroup of  $SU(2) \cong S^3$ , acts on the 3-sphere with stabilizer orders determined by the icosahedral geometry: faces carry order 3 (each triangular face has  $\mathbb{Z}_3$  rotational symmetry) and edges carry order 2 (each edge has  $\mathbb{Z}_2$  symmetry). Their ratio is 3/2.

In the  $\Lambda$  derivation, the 3/2 emerges from Gauss–Codazzi under isotropy. In the group-theoretic setting, it emerges from the stabilizer structure of the same manifold [8]. When two branches of mathematics – differential geometry and finite group theory – converge on the same numerical factor on the same manifold, dimensional coincidence is insufficient as an explanation. The bridge remains the least proven link in the chain, but it is structurally motivated from both sides. If the group-theoretic convergence reflects a deeper identity in spectral geometry on quotient spaces of  $S^3$ , the bridge graduates from motivated to derived.

## 4.6 Summary

Factor	Source
3	Spatial Ricci trace (isotropic space)
2	de Sitter relation ( $R_{\text{spatial}} = 2\Lambda_{\text{obs}}$ )
3/2	Gauss–Codazzi interface

Assumption	Status
Minimal embedding	Ground mode ( $m = 0$ )
Isotropic space	CMB verified to $10^{-5}$
de Sitter vacuum	Late-time $\Lambda$ CDM limit
$R_\Sigma = \Lambda_{\text{top}}$	Eigenvalue bridge (identification)

## 5 The Result

[**DERIVED**] The derivation yields:

$$\boxed{\Lambda_{\text{obs}} = \frac{3}{R^2}} \quad (35)$$

The coefficient 3 decomposes as two locked factors. The antinode intensity  $C(60/120) = 2$  ([§III.A](#)): the ground mode sampled at the midpoint of the Möbius strip carries twice the mean intensity. The Gauss–Codazzi conversion  $3/2$  ([§IV.D](#)): intrinsic 2D curvature maps to observed 3D spatial curvature through the embedding interface. Their product:  $2 \times 3/2 = 3$ .

The topology determines what  $\Lambda$  must be, given the geometry of the space it lives in. In Planck units, with  $\Omega_\Lambda = (R/\ell_P)^2 \approx 10^{122}$ :

$$\Lambda_{\text{obs}} \cdot \ell_P^2 = 3 \Omega_\Lambda^{-1} \quad (36)$$

$10^{-122}$  is not a “coincidentally large number,” it is the inverse of the squared ratio of the largest scale in the universe ( $R \approx 10^{26}$  m) to the smallest ( $\ell_P \approx 10^{-35}$  m). The topology contributes the 3. The universe contributes the scale.

The curvature radius of  $S^3$  and the de Sitter radius are the same geometric object. With  $R = 1.64 \times 10^{26}$  m [[3](#)]:

$$\frac{3}{R^2} = \frac{3}{(1.64 \times 10^{26})^2} = 1.12 \times 10^{-52} \text{ m}^{-2} \quad (37)$$

**Observed:**  $\Lambda_{\text{obs}} = 1.11 \times 10^{-52} \text{ m}^{-2}$ . Agreement:  $< 1\%$ .

Equivalently, since  $L = \pi R$  ([§II.A](#)):

$$\Lambda_{\text{obs}} = \frac{3\pi^2}{L^2} \quad (38)$$

where  $L$  is the comoving half-circumference of the Möbius boundary, independently constrainable from CMB and BAO data.

## 5.1 The Derivation Chain

Step	Input	Output
1	Möbius topology	Anti-periodic BC
2	Even transverse mode	1D reduction
3	Anti-periodic BC	Half-integer spectrum
4	Isotropy + orthogonality	Ground mode ( $m = 0$ )
5	$L = \pi R$ , $\lambda_0 = 1/R^2$	Eigenvalue carries geometric scale
6	Intensity at antinode	$C(60/120) = 2$
7	In Planck units	$\Lambda_{\text{top}} \cdot \ell_P^2 = 2\Omega_\Lambda^{-1}$
8	Gauss–Codazzi	$R_{\text{spatial}} = 3R_\Sigma$
9	de Sitter	$R_{\text{spatial}} = 2\Lambda_{\text{obs}}$
10	Bridge: $R_\Sigma = \Lambda_{\text{top}}$	$\Lambda_{\text{obs}} = (3/2)\Lambda_{\text{top}}$
11	Result	$\Lambda_{\text{obs}} = 3/R^2$

## 5.2 Derived vs. Imported

Element	Status	Source
Anti-periodic BC	DERIVED	Möbius topology
$\lambda_0 = 1/R^2$	DERIVED	Spectral geometry on the boundary
$C(60/120) = 2$	DERIVED	Ground mode + unit normalization
Gauss–Codazzi 3/2	DERIVED	Minimal embedding in isotropic $S^3$
Coefficient 3	DERIVED	Product of above: $2 \times 3/2$
Scale $R$	IMPORTED	Curvature radius of $S^3$ (observed)
$R_\Sigma := \Lambda_{\text{top}}$	MOTIVATED	Bridge assumption ( <a href="#">§IV.E</a> )

The coefficient 3 is the content of the derivation. If the eigenvalue chain had produced  $2.7/R^2$  or  $4/R^2$ , the framework would have failed against observation.

*On circularity.* In standard GR,  $\Lambda$  is a free constant inserted into Einstein’s equations, and  $R_\Lambda = \sqrt{3/\Lambda}$  is defined from it. Inverting that definition to write  $\Lambda = 3/R^2$  explains nothing, because  $\Lambda$  was the input. This paper reverses the arrow.  $R$  is the geometric input: the curvature radius of  $S^3$ , imported from observation. The topology forces what  $\Lambda$  must be at that scale. The de Sitter relation  $R_{\text{spatial}} = 2\Lambda_{\text{obs}}$  enters only to convert spatial curvature to the conventional  $\Lambda$  parameterization ([§IV.E](#)). It contributes the factor of 2 in the denominator, not the coefficient 3 in the numerator. The 3 comes from the eigenvalue chain: antinode intensity (2) times Gauss–Codazzi (3/2). No circular path produces that decomposition.

### 5.3 One Step to $\alpha$

The scaling law that produces  $\Lambda$  at the antinode ( $\Theta = 60/120$ ) generalizes to other positions on the mode spectrum. At the Fibonacci well  $\Theta = 13/60$  on the bosonic grid:

$$\alpha = C(13/60) \times \Omega_{\Lambda}^{-1/60} = 0.00733 \quad (39)$$

**Observed:**  $\alpha = 0.007297$ . Agreement: 0.5%.

The fine structure constant occupies a different well on the same mode spectrum, diluted by a different power of the same hierarchy.  $\Lambda$  and  $\alpha$  are two entries in a single topological table [9]. The full particle mass spectrum, derived from McKay spectral geometry on  $S^3/2I$ , reproduces 10 of 12 Standard Model fermion masses within a factor of 3 [10].

These derivations are developed in their respective companion papers; they appear here to illustrate that  $\Lambda$  is one entry in a structure that extends across the full mode spectrum.

## 6 Compatibility with GR

Einstein's field equations are unchanged:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = 8\pi G T_{\mu\nu} \quad (40)$$

This framework provides what the equation leaves undefined: the value of  $\Lambda$ . Einstein wrote  $\Lambda$  into the geometry but left it as a free constant. A century of cosmology measured it; no theory derived it. The topology closes that gap without modifying a single tensor.

The  $\Lambda g_{\mu\nu}$  term multiplies the metric itself. It is pure geometry. This paper identifies which geometry: the ground-mode eigenvalue of the cosmic boundary, converted from surface to space through Gauss–Codazzi. The term Einstein added by hand is the term the topology requires.

In the de Sitter limit, the Friedmann equation reduces to:

$$H^2 = \frac{\Lambda}{3} \quad (41)$$

where  $H$  is the Hubble parameter. The factor of 3 in the denominator is the same 3 in the numerator of  $\Lambda = 3/R^2$ : they cancel, leaving  $H^2 = 1/R^2$ . The expansion rate is the inverse curvature radius. General relativity describes dynamics in space; topology specifies the boundary condition that sets the scale.

## 7 Falsification

Eigenvalues of the Laplacian on fixed topology are constants. If the topology is fixed,  $\Lambda$  is fixed.

### 7.1 The DESI Tension

The Dark Energy Spectroscopic Instrument (DESI) reports evidence for an evolving dark energy equation of state  $w(z)$  [11].

$\Lambda$  is a topological eigenvalue on fixed topology; it cannot evolve. Apparent evolution of  $w(z)$  can arise without evolving vacuum energy: the anti-periodic boundary condition on the Möbius surface produces a standing-wave modulation of the effective scale factor. Near the phase midpoint, the wave derivative changes sign, altering the distance-redshift relation. Fluid-based  $w(z)$  models interpret this geometric structure as phantom crossing ( $w < -1$ ) [12].

The evolution is an inference artifact, not physics.

### 7.2 Falsification Criteria

Prediction	Falsified if . . .	Threshold
$\Lambda$ constant	Best-fit $\Lambda$ varies with $z$	$> 2\sigma$ across probes
$3/2$ conversion	$\Lambda_{\text{obs}}/\Lambda_{\text{top}} \neq 3/2$	$> 3\sigma$

These predictions are pre-registered to the European Space Agency’s Euclid Data Release 1, scheduled for October 2026 [13].

## 8 Conclusion

Einstein put geometry into his equations and then took it out. A century of physics put it back in and called it energy when it was geometry all along. The blunder was not adding  $\Lambda$ . It was removing it.

The cosmological constant is neither a fitted parameter nor “dark energy.” It is the ground mode of the cosmic boundary, the ground tone of a resonant universe.

Einstein’s constant, resolved.

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## LLM Disclosure

The initial conceptual framework was developed through extended philosophical dialogue with Gemini. The unintended derivation chain, structured exposition, and adversarial testing were later formulated and further conducted with Claude as the manuscript platform. An Epistemic Rigor Protocol (ERP), designed by the author, governed all AI interactions: claims were classified by evidential status (Axiom, Derived, Motivated, Imported), drift toward particle-first ontology was flagged and corrected, and objections were processed through a structured audit before acceptance or rejection.

ChatGPT was used primarily for numerical calculations and independent verification of key results. Venice AI, Gemini, and CoPilot provided editorial review and cross-validation from outside the primary development context. All platforms were accessed via their high-tier subscriptions.

**Adversarial AI Cross-Validation (AACV).** The  $\Lambda$  derivation was independently verified across all five platforms. Specific checks included: dimensional consistency of the scaling law at each step, numerical evaluation of  $C(\Theta)$  at the antinode, the Gauss–Codazzi conversion factor under minimal embedding and isotropy, and the final numerical agreement with observed  $\Lambda$ . The eigenvalue chain (Möbius topology  $\rightarrow$  anti-periodic BC  $\rightarrow$  half-integer spectrum  $\rightarrow \lambda_0 = 1/R^2$ ) was reproduced independently by each model from the boundary conditions alone.

The author originated the physical postulate, directed all derivation paths, designed the claim classification system, and exercised final editorial judgment throughout. No model was treated as an oracle; all outputs were critically evaluated against internal consistency, dimensional analysis, and cross-model agreement.

**About the Author.** The author holds a civil engineering degree with minors in mathematics and physics, graduating *cum laude* as a Tau Beta. Relevant academic coursework included Fourier transforms and quantum probability, with a focus on the three-polarizer experiment.

For the better part of the last decade, the author has practiced as a professional engineer specializing in causation analysis as an expert witness in litigation support, where fact-finding without hedging is paramount in a courtroom setting. The passage of time has lent itself to the outsider hurdles established within the academic realm; otherwise this work would be making its rounds through traditional peer review.

All of the author’s work can be found at the GitHub registry: <https://github.com/dmobius3/mode-identity-theory> if further validation of the framework’s consistency is warranted.

## Originality and Novelty Statement

**What is novel.** The derivation of the cosmological constant as a topological eigenvalue from a single postulate ( $S^1 = \partial(\text{Möbius}) \hookrightarrow S^3, \partial S^3 = \emptyset$ ), with the coefficient 3 locked by the product of antinode intensity and Gauss–Codazzi conversion. The identification of topological protection at the antinode as the mechanism for  $\Lambda$ 's constancy. The claim that  $10^{-122}$  is a geometric ratio with a derived coefficient, requiring no free parameters.

**How it differs from prior work.** Standard approaches treat  $\Lambda$  as vacuum energy and attempt to cancel or suppress quantum contributions. This framework treats  $\Lambda$  as intrinsic curvature of a bounded surface, converting to spatial curvature through established differential geometry. The 122-order hierarchy is the scale ratio  $R/\ell_P$  squared; the topology contributes only the coefficient.

**Limitations.** The identification  $R_\Sigma := \Lambda_{\text{top}}$  (§IV.E) is motivated by group theory, not derived purely from geometry. There is currently no known theorem in spectral geometry connecting the lowest Laplace–Beltrami eigenvalue to the scalar curvature on a surface with anti-periodic boundary conditions. This question is under independent mathematical review ([Math StackExchange #5126487](#)).

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