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Posted Date: 6 August 2025

doi: 10.20944/preprints202508.0342.v1

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Thermodynamic Asymmetry from Projection: A Geometric Framework for Time's Arrow and Entropy Emergence

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Abstract

We present the Thermodynamic Asymmetry from Projection (TAP) model, a theoretical framework proposing that the arrow of time and entropy increase emerge not from probabilistic laws or initial conditions, but from geometric constraints imposed by the projection of high-dimensional coherent information into a lower-dimensional spacetime. In TAP, entropy is reformulated as a local mismatch between the representational capacity of a projection surface and the density of incoming informational flux, offering a deterministic and geometric origin for temporal asymmetry. The model introduces dimensional causality, whereby classical physical laws, decoherence, and macroscopic irreversibility arise from structured projectional breakdown. Gravity and inertia are likewise reinterpreted as manifestations of projectional curvature and consistency conditions. TAP accounts for phenomena such as big bang and black hole termination, quantum-to-classical transition, and large-scale cosmological anisotropies—including features in the cosmic microwave background (CMB) like the Cold Spot and axis alignments. The framework yields testable predictions, including the entropy ground state after black hole evaporation and information-aligned anomalies in the CMB. By linking thermodynamics, relativity, and quantum theory under a unified projectional geometry, TAP offers a novel perspective on the origin of physical law and the visible structure of the universe.

Keywords: thermodynamic asymmetry; high-dimensional projection; entropy; arrow of time; dimensional causality; TAP model; quantum decoherence; big bang; cosmic microwave background; black hole termination; information geometry

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1. Introduction—The Arrow of Time and the Puzzle of Irreversibility

The physical world, as we observe it, unfolds with a distinct direction in time: eggs break but do not unbreak, stars burn fuel and cool, memories accumulate toward the future but not the past. This experiential directionality—the arrow of time—is so pervasive that it appears self-evident. Yet, it stands in tension with the foundational equations of physics, which are largely time-symmetric [2].

Both classical mechanics and quantum theory possess dynamical laws that are invariant under time reversal, implying that any physical process could in principle run backward. Yet in reality, macroscopic phenomena are overwhelmingly time-asymmetric. This discrepancy has led to one of the central paradoxes of modern physics: how can the arrow of time emerge from time-reversible laws? [1]

In thermodynamics, time-asymmetry is conventionally associated with the Second Law, which states that entropy in a closed system tends to increase. The dominant explanation for this relies on statistical mechanics, where entropy is viewed as the probabilistic outcome of coarse-graining over microstates [3].

This framework attributes the direction of time to low entropy initial conditions—a finely tuned state of the universe near its origin [4]. But this assumption, while effective, pushes the problem into the boundary conditions. It does not explain why the initial state was low entropy, nor why the observed entropy gradient aligns universally with our experience of time's arrow.

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Moreover, in cosmology, attempts to link entropy growth to inflationary dynamics face challenges: inflation amplifies fluctuations but does not inherently generate thermodynamic asymmetry [5]. The question remains: why is the past special? And what makes entropy increase inevitable, rather than just statistically likely? [6]

This work proposes a shift in perspective. Instead of treating time-asymmetry as a statistical anomaly or a special boundary condition, we suggest that irreversibility is geometric and structural: it arises from how our observed reality is embedded within a higher-dimensional informational system.

We introduce the framework of Thermodynamic Asymmetry from Projection (TAP), in which:

- The observable 3D+1 spacetime is modeled as a projection surface, receiving informational flux from a higher-dimensional structure;
- Entropy is redefined not as a measure of disorder, but as a scalar compression mismatch between incoming information and representational capacity;
- Time's arrow emerges naturally from the directional accumulation of information in the projection process, making irreversibility a consequence of structure, not chance.

This redefinition shifts the burden from initial conditions to projectional mechanics, offering a novel link between time, entropy, and geometry.

TAP seeks to hypothesize an alternative theory for several foundational questions:

- What is the ontological origin of time's directionality?
- Why does entropy consistently increase, even in isolated systems?
- How do phenomena such as black hole entropy and quantum decoherence reflect deeper informational structures? [7]
- Could cosmological signatures like the CMB and its anisotropies reflect not past thermodynamic events, but present-day informational geometry? [8]

Through the lens of projectional asymmetry, TAP provides a unifying perspective linking these disparate phenomena under a single geometric-informational ontology.

2. Temporal Asymmetry from Dimensional Projection

The asymmetry of time is typically treated as a statistical emergent property arising from low-entropy initial conditions [6]. In TAP, we propose that this asymmetry originates from the geometric relationship between a higher-dimensional informational structure and the 3D spacetime into which it is projected.

We posit the existence of a higher-dimensional coherent entity—a structured informational manifold—intersecting with our observable universe, conceptualized as a 3D+1 projection surface. This projection is not passive: it entails compression, loss, and accumulation as high-fidelity information attempts to occupy a space with limited representational capacity.

In this view, irreversibility is not a consequence of randomness, but of geometry: a unidirectional information influx onto a projection surface with finite resolution creates irreversible state updates, giving rise to the arrow of time. A formal geometric construction of the projection process is detailed in Appendix A.1.

In the TAP framework, we redefine entropy not in terms of disorder or statistical multiplicity, but as a scalar mismatch between the incoming high-dimensional information flux ΦH and the representational capacity of the projection surface Cp . Formally, we define TAP entropy at time t as:

We define TAP entropy at coordinate time t as:

$$S_{\text{TAP}}(t) = \int_{x \in \Sigma(t)} \left[\Phi_H(x) - C_P(x) \right]_+ \, d^3x$$

Here, $\Sigma(t)$ represents the instantaneous projection surface embedded in three-dimensional space at time t, over which the TAP entropy is evaluated. The positive-part function $(a)_+ = \max(a, 0)$ *ensures that only the informational excess contributes to entropy, enforcing that* S{\text{TAP}}(t)

doi:10.20944/preprints202508.0342.v1

accumulates only when the incoming information flux $\Phi_H(x)$ exceeds the local representational capacity $C_P(x)$.

This formulation leads to three essential properties:

- Monotonicity: As long as $\Phi_H(x) > C_P(x)$ for some $x \in \Sigma(t)$, the integral increases, yielding non-decreasing entropy over time;
- Irreversibility: The accumulation of unencoded or lossy-projected information results in non-invertible macroscopic evolution;
- Locality: Entropy production can be spatially non-uniform, reflecting the varying density or curvature of the projection surface.

Unlike conventional entropy formulations rooted in statistical ensembles, this TAP definition is structural and geometric, not probabilistic. It aligns conceptually with Landauer's principle—that information erasure entails thermodynamic cost and irreversibility [9]—but extrapolates it to a cosmological scale as a fundamental projectional mismatch.

With entropy reconceived as a compression mismatch, time's arrow emerges naturally: it points in the direction of increasing information imbalance [10]. The irreversibility of temporal evolution, in this context, is not due to probabilistic spread or chaos, but due to the non-invertibility of the projection mapping. This accumulation manifests observationally as thermodynamic entropy increase, as well as the macroscopic flow from past to future [11].

TAP complements the holographic view by offering a directional mechanism for how information flows and is encoded, grounded in dimensional embedding, not boundary duality [12].

Table 1. Comparison with Traditional and Holographic Models.

Model	Entropy Source	Time Arrow Origin	Reversibility
Boltzmann	Statistical multiplicity	Low-entropy initial conditions	Possible in principle
Inflationary Cosmology	Initial quantum vacuum fluctuations	Asymmetry in early conditions	Requires fine-tuned start [6]
Decoherence	Environment-induced superselection	Observer-dependent branching	Reversible globally [9]
Holographic Principle	Boundary-encoded entropy	Not explicitly directional	Information conserved
TAP (this work)	Compression residual from projection	Directional influx from higher dimension	Fundamentally irreversible

This projection-based formulation offers a new answer to a long-standing question: Why does entropy increase? In TAP, it increases because the universe is an encoding process with compression limits, constantly intersected by a higher-order information field.

One of the most fundamental consequences of the TAP framework is its reinterpretation of entropy, and with it, the Second Law of Thermodynamics. Instead of relying on statistical probabilities and coarse-grained ensembles [13], TAP views entropy as a scalar mismatch between incoming high-dimensional structure and the finite representational capacity of the observed spacetime surface Σ_4. In this view, entropy is not just disorder, but the measure of projectional distortion.

Let $\Phi(x)$ represent the density of incoming information from the coherent manifold M^n at location x in Σ_4, and let $C(x)$ represent the encoding capacity at that location. Then TAP defines local entropy density as:

$$S(x) = \max(0, \Phi(x) - C(x)).$$

This mismatch S(x) accounts for all apparent thermodynamic irreversibility in projected physical processes. Entropy increases not because of fundamental randomness, but because Σ_4 is unable to retain full coherence of incoming structure. Once coherence is lost in projection, it is unrecoverable within Σ_4 evolution alone.

This understanding restores the universality of the Second Law: entropy always increases in Σ_4, not due to probabilistic asymmetries, but due to directional information filtering. A detailed derivation and geometric interpretation of this entropy formulation is provided in Appendix A.5. It also dissolves the paradox of time-symmetry at micro scales, affirming that the irreversibility is not in physical law, but in the nature of dimensional projection.

From this viewpoint, thermodynamic gradients, heat flow directionality, and even the emergence of macroscopic time can be seen as consequences of structured projection. The Second Law, then, is geometrically embedded within the TAP architecture as a projectional necessity. More detailed discussions are in Appendix A.2.

3. TAP Fields and Informational Structure

While Section 2 introduced the conceptual premise of TAP—that time's arrow and entropy emerge from asymmetric projection of high-dimensional information—this section shifts focus to the formal internal structure of the model. Specifically, we develop the notion of the TAP field as a mathematical object governing how information is compressed, encoded, and accumulated within a finite-capacity projection surface. Rather than framing TAP as a philosophical shift from force to information, we now construct a field-theoretic system defined over an emergent 3D+1 manifold Σ, in contact with an informational domain $\mathcal{H}$. Our goal is to articulate the dynamical quantities—flux, capacity, residual entropy—that govern projectional irreversibility and observable structure. Whereas traditional physics treats spacetime as the arena of dynamics, TAP treats spacetime itself as a dynamic product of information resolution. This chapter formalizes that view through definitions, field equations, and geometrically meaningful quantities.

The Projection Surface and Its Representational Capacity

We begin by characterizing the projection surface Σ, a 3D+1 manifold embedded within a higher-dimensional domain $\mathfrak{H}$, often conceptualized as a D-dimensional structured information field, with $D > 4$.

Let Φ(x) denote the informational input flux arriving at a point $x \in \Sigma$ from $\mathfrak{H}$. Each point on the projection surface has a local representational capacity C(x), which measures the maximal rate at which information can be absorbed, encoded, and expressed within the dimensional constraints of Σ. This can be thought of as a function of curvature, embedding metric, and intrinsic resolution of the projection medium.

The difference $\delta(x) = \Phi(x) - C(x)$ quantifies the compression imbalance at that location. Where $\delta(x) > 0$, projection loss occurs; where $\delta(x) < 0$, surplus capacity may be underutilized.

The TAP field, then, is defined as a scalar or tensorial field over Σ that represents the gradient of mismatch:

T(x) = \nabla_{\Sigma} \left(\Phi(x) - C(x) \right)

This field governs the flow of information-induced structure across spacetime. Its divergence marks regions of irreversible entropy production, while its gradient encodes the direction and magnitude of representational stress, which in turn shapes the formation and evolution of encoded physical structure.

Compression, Irreversibility, and Entropic Accumulation

The irreversibility discussed in Section 2 now acquires a formal expression. Information that cannot be fully encoded at the moment of projection is not simply ignored but accumulates as

 doi:10.20944/preprints202508.0342.v1

residual entropy within the representational structure. This residual forms a scalar entropy density field S(x, t) on Σ, which evolves according to:

$$\frac{\partial S}{\partial t} = \left(\Phi(x, t) - C(x, t) \right)_+$$

This formulation yields a direct, local, and causal mechanism for entropy increase—without invoking probabilistic arguments or ensemble averaging. It also explains why time flows forward: because compression mismatch creates a non-invertible state update. A more formal derivation and thermodynamic interpretation of this entropy formulation is elaborated in Appendix A.3.

Additionally, the rate of accumulation may vary by region, explaining inhomogeneous thermodynamic behavior across space, including low-entropy anomalies (e.g., cosmological voids or Cold Spots) or highly active entropic zones.

Geometric Effects on Information Encoding

The capacity function C(x) is not fixed but varies with the local geometry of the projection surface. Factors influencing C(x) include:

- Curvature: Regions of high curvature may have lower encoding capacity, creating entropic bottlenecks;
- Embedding angle: The incidence of the high-dimensional flux vector relative to Σ affects projected density;
- Dimensional tension: If the projection surface experiences stress or deformation, encoding capacity may transiently drop.

This creates a feedback loop: geometry influences encoding, which in turn shapes the local evolution of observed structure.

The TAP Field as a Driver of Observable Dynamics

We now interpret the TAP field T(x) as an informational curvature driver: it dictates how residuals propagate across the surface, how encoded structure accumulates, and how observable patterns emerge.

Where $\nabla \cdot T(x) > 0$, we expect clustering of unencoded information—potentially manifesting as entropy sinks, thermal gradients, or decoherence zones. Where $\nabla \cdot T(x) < 0$, projection is efficient, and the local structure appears highly ordered or "ground-state-like."

Thus, TAP provides a new type of dynamical system: not based on force, but on informational strain—driven by projectional geometry and resolved through representational feedback.

Implications for Physical Theory

TAP's field-theoretic structure challenges traditional separation between geometry and content. In general relativity, matter-energy dictates curvature; in TAP, information flux shapes projection capacity, which determines perceived structure.

This opens several theoretical possibilities:

- Redefining action principles based on information strain minimization;
- Embedding known physical laws (e.g. electrodynamics, gravity) as efficient encodings within TAP;
- Modeling quantum measurement as projection surface fluctuation under flux impulse.

TAP thus positions itself as a meta-framework: not to replace existing theories, but to geometrically unify them under a projectional ontology.

4. Black Holes, Decoherence, and Projectional Embedding

With the projectional and informational structure of the TAP model established in Sections 2 and 3, we now turn to its interpretive power—how TAP reframes key phenomena across gravitational, quantum, and cosmological domains. Rather than proposing a replacement for existing physical theories, TAP serves as a unifying ontological layer: a geometric-informational framework within which familiar models can be reinterpreted as special-case encodings under projectional constraints.

This section explores how TAP accounts for extreme and foundational phenomena—such as black holes, quantum decoherence, and cosmic structure—not by discarding prior theory, but by offering a deeper structural basis for their apparent behavior. In doing so, it also supports TAP's own plausibility: any viable theory must eventually speak to the known world, and TAP does so through a reinterpretive lens that aligns projectional geometry with observable consequences.

In the TAP framework, black holes are interpreted not as endpoints of spacetime or true singularities of geometry, but as regions where the incoming high-dimensional informational flux $\Phi(x)$ exceeds the local encoding capacity $C(x)$ of the projection surface beyond any recoverable threshold. This results in a runaway mismatch $\delta(x) = \Phi(x) - C(x)$, signifying a breakdown in the dimensional encoding process.

The black hole, in this view, is not a physical object in the conventional sense, but rather a topological rupture—a localized collapse in representational fidelity on the projection surface Σ. What appears to observers as an event horizon corresponds to a boundary beyond which outgoing information cannot be reprojected with sufficient coherence. The projection fails to produce consistent surface updates, and thus information encoded beyond this threshold becomes irretrievable within the observable Σ.

$$\delta(x) = \Phi(x) - C(x) \to \infty \quad \Rightarrow \quad \text{Projectional Rupture} \tag{4.1}$$

Hawking radiation, in this framing, is not a leakage of preserved quantum information but rather a degraded residue of informational overflow—scrambled outputs from an oversaturated projection channel [14][15]. The TAP model predicts that the true endpoint of black hole evaporation is not a loss of information, but a reversion to zero representational flux, an entropy ground state where projection ceases. (See Appendix A.4 for a draft mathematical derivation of this termination profile.)

Decoherence is likewise recast within the TAP paradigm. Rather than attributing it to environmental entanglement or stochastic collapse, TAP locates decoherence in the failure of a projection surface to coherently resolve overlapping flux. When multiple high-dimensional inputs compete for limited capacity, the system bifurcates into classicality not by collapse, but by compression-induced exclusion. Quantum-to-classical transition thus emerges from localized topological tension: decoherence is the moment when representational geometry can no longer encode coherent phase structure[16][18].

Macroscopic objects, by projecting dense and entangled fluxes, naturally overwhelm local encoding resources and decohere almost instantaneously. This is not due to observation or thermal contact, but due to representational overload [19][20]. TAP provides a geometric basis for decoherence without invoking observer-centric epistemology. Part of the Appendix A.3 proposes decoherence thresholds and information gradient modeling.

The same projection dynamics scale upward to the cosmological regime. The TAP surface, shaped by its intersection with high-dimensional flux fields, is not smooth or symmetric but folded and distorted. These embedding stresses result in the large-scale structures observed in the universe: gravitational wells, anisotropies in expansion, and void formations [21][22][23]. Under TAP, what we perceive as mass is the geometrical consequence of local information compression—mass as a curvature artifact induced by persistent flux asymmetry.

This reframing offers a reinterpretation of gravity itself: not as an intrinsic attractive force, but as the strain field on a projection surface under flux load. Classical general relativity approximates this behavior through curvature, but TAP provides a deeper informational origin. Projectional stress replaces mass-energy tensors with a flux-capacity tensor field, valid in both low and high compression regimes. A more formal derivation of the projectional curvature model and its correspondence with gravitational behavior—including the geometric embedding of the flux-capacity tensor field—is detailed in Appendix A.5.

Among the most intriguing arenas to test this theory is the cosmic microwave background (CMB). Anomalies such as the Cold Spot, axis-aligned power asymmetries, and suppressed large-scale modes challenge inflationary cosmology[8][24]. Within TAP, these anomalies emerge naturally from projectional turbulence—remnants of an uneven embedding phase during early universal projection. These residual distortions reflect informational strain patterns frozen into observable structure.

We will examine these cosmological predictions in greater detail in Section 5 where the TAP framework will be applied to the interpretation of CMB power spectra, alignment anomalies, and entropy topology. These tests form part of TAP's broader predictive capability: a redefinition of physical law through geometric encoding constraints, where irreversibility, classicality, and structure all stem from how information fails to project cleanly.

In this reconstructed ontology, black holes are not voids but ruptures of resolution; decoherence is not collapse but competition; and cosmic structure is not built from matter, but from meaning too complex to compress. The universe, in the TAP view, is the visible residue of an infinite structure attempting to render itself through limited dimensions—and failing just enough to make time, entropy, and galaxies.

5. Cosmic Embedding and Projective Anomalies

The TAP framework, grounded in the asymmetry of information projection from higher-dimensional fields into the observable universe, extends naturally from quantum decoherence and black hole singularities into the largest cosmological scales. In this chapter, we explore how large-scale features of the universe—such as the Big Bang, cosmic microwave background (CMB), anisotropies in spatial structure, and unexpected directional alignments—can be interpreted not as anomalies but as structural imprints of projectional strain.

Cosmological Structure as Projectional Outcome. Rather than invoking a dynamically smoothed primordial state, TAP posits that the observable cosmos is a projectionally constrained manifestation of an intrinsically coherent high-dimensional geometry. The three-dimensional structure we observe is not the result of chaotic expansion or scalar-field evolution, but the outcome of limited-capacity encoding of dense informational fluxes onto a finite-resolution representational surface. This surface, under tension from non-uniform high-dimensional input, develops folds, directional biases, and local failures of coherence—each leaving distinct signatures in the cosmic structure.

The Big Bang Reframed.

The traditional Big Bang model describes the universe as emerging from a singular point of infinite density and temperature, a "spacetime origin" where known physical laws break down. This conception, while operationally successful, poses philosophical and physical difficulties: Why did the universe begin in such an improbable low-entropy state? What mechanism generated time, causality, and directionality out of apparent chaos? And what lies, if anything, beyond the initial singularity [25,26]?

The TAP framework offers an alternative view: the universe did not emerge from an intrinsic explosion, but from a structured projection. In this interpretation, the event we call the "Big Bang" is not a physical singularity, but a geometric initiation — the first intersection of a coherent high-dimensional informational manifold with the emergent lower-dimensional spacetime surface Σ_4. This projection marks the origin of not just matter and energy, but of time, entropy, and causality as observable phenomena.

In TAP, the observable universe is a finite-capacity projection surface embedded within a higher-order informational structure M^n ($n > 4$). The so-called "initial conditions" of cosmology are reframed as the first state of representational contact: the moment when Φ_H(x), the incoming information flux, began intersecting with Σ_4.

Entropy, Time, and Early Homogeneity. This projectional genesis imposes several nontrivial constraints:

• The initial state appears low-entropy not because of fine-tuning, but because only highly compressible, coherent modes were capable of being encoded at the first moments of projection. This reflects the early surface's minimal curvature and maximal symmetry.

• Temporal asymmetry arises as a natural consequence of the directional influx: information begins flowing into the spacetime surface but never flows back, due to irreversible compression mismatch.

• Geometry itself (e.g., spatial curvature, expansion metrics) emerges as a secondary response to the asymmetry between the representational capacity and informational density.

Thus, what we observe as the Big Bang is not an explosion in space, but the beginning of visible structure from a deeper ontological manifold. Standard cosmology requires an unusually low-entropy early state to reconcile with the Second Law of Thermodynamics [1][4]. Inflationary theories attempt to resolve this by smoothing out fluctuations via exponential expansion, but they do not explain why entropy was initially so low — they only amplify existing uniformity.

TAP resolves this tension geometrically: the low entropy is not a statistical fluke, but a structural necessity of early projection. The nascent projection surface Σ_4 could only accommodate limited modes of high-dimensional input. As such, the early universe necessarily appears isotropic, homogeneous, and low-entropy — because those are the only structures that fit through the projection bottleneck.

Entropy begins increasing not due to thermalization, but because the mismatch between Φ_H(x) and C(x) grows over time as more complex flux attempts to enter the finite-resolution surface. This results in a unidirectional entropic gradient — the thermodynamic arrow of time — as a byproduct of projectional saturation.

CMB Anomalies and Structural Signatures. The TAP cosmology does not require a spacetime singularity. Instead, it posits that the early universe can be modeled as a near-ideal projection zone: a region with minimal curvature, near-maximal Jacobian density, and high encoding efficiency. As projection continues, representational strain increases, eventually leading to projective curvature (gravity), interference patterns (quantum decoherence), and projective breakdowns (black holes, CMB anomalies).

In this model:

• The Big Bang corresponds to a smooth embedding onset — not a breakdown of physics.

• Time “begins” where projection becomes temporally asymmetric due to representational filtering.

• The concept of “before” the Big Bang may be ill-posed, since temporal ordering is emergent, not fundamental.

This reinterpretation shifts the focus of cosmology from energetic dynamics to informational topology: the visible universe is a continuously updating interface, and the Big Bang marks its activation point, not its physical origin.

One of the most striking observational domains for testing TAP cosmology is the cosmic microwave background (CMB), which encodes early-universe structure with remarkable fidelity[24]. While standard interpretations attribute its anisotropies to quantum fluctuations amplified during inflation, TAP offers a fundamentally different reading. The CMB’s features—such as low-ℓ multipole alignments, hemispherical asymmetries, and large-scale cold spots—are reframed as interference patterns within the projectional field, where high-dimensional gradients induce spatially correlated representational stress. These structures are not incidental, but inevitable products of geometric embedding. Specifically, the Cold Spot—a region of anomalously low temperature with significant spatial extent—may correspond to a cancellation zone in the incoming information flux, where projection destructively interferes. This interpretation is further elaborated in Appendix A.6 and A.7 and potentially can be supported by observational studies.

Similarly, the so-called “Axis of Evil,” a statistical alignment of the quadrupole and octopole moments in the CMB along a specific spatial direction[27], finds a natural interpretation in TAP. Instead of statistical fluke or galactic contamination, this axis may reflect a persistent asymmetry in the original high-dimensional manifold—projected onto the observable surface as a structural crease or fold. Such directional bias is not extraneous to the TAP picture but emerges from the very nature of mapping multi-dimensional coherence into finite spatial domains. This interpretation is developed in depth in Appendix A.8, which proposes a geometric model of how persistent high-dimensional anisotropies may induce axis-aligned alignment artifacts during the projection process.

Beyond temperature anisotropies, TAP implies that the lensing patterns, polarization structures, and entropy gradients observed in the CMB and galaxy distributions may deviate subtly from predictions rooted in purely metric-based curvature. For example, E/B-mode mixing in polarization maps or unexpected phase correlations across angular scales could reveal the non-metric origins of projective strain. In TAP, curvature arises not from matter-energy content but from imbalances in how information loads deform the representational interface [28][29].

Observational Prospects and Theoretical Implications.

These predictions are not speculative deviations but testable consequences of the TAP geometry. As observational capabilities sharpen—through instruments such as LiteBIRD, CMB-S4, and the Simons Observatory—new data may help distinguish between thermodynamic projections and dynamical inflationary evolutions. TAP expects coherence in the anomalies themselves: alignments that recur across scales, entropy drops that localize along projective discontinuities [26][27][28].

Under this paradigm, cosmological structure is not merely the residue of initial conditions but the shaped expression of a deeper, coherent ontology struggling to map itself onto spacetime. The universe we inhabit is less a product of explosive genesis and more the shadow of an impossible totality—folded, filtered, and fractured by the very act of becoming visible.

These anomalies—including the Cold Spot and the axis-aligned asymmetries [29]—are interpreted in TAP not as inflationary artifacts, but as signatures of projectional turbulence frozen into the cosmic structure. A geometric model linking representational flux divergence and CMB power anisotropies is outlined in Appendix A.3, offering a predictive path for statistical comparison with Planck datasets [8][27].

In summary, the TAP approach to cosmology reframes the observed universe as a structured failure of compression: a cosmos filled not with noise, but with meaning too dense to fully resolve. The microwave background, its anomalies, and the grand architecture of cosmic voids and filaments thus become not puzzles to fix, but clues to the geometry of what lies beyond.

6. Discussion

Unification of Thermodynamic, Geometric, and Informational Arrows of Time

The TAP framework offers a novel synthesis of thermodynamic, geometric, and informational asymmetries by reframing entropy not as an intrinsic statistical property, but as a projectional mismatch emerging from the embedding of high-dimensional information structures into a lower-dimensional representational surface. This perspective diverges from classical interpretations of the second law of thermodynamics, which attribute entropy growth to probabilistic microstate distributions and initial condition selection [3]. TAP instead identifies irreversibility as the outcome of directional information influx exceeding the surface's capacity to reversibly encode or decode its full state.

In this formulation, geometric asymmetry (such as the curvature or structure of the projection boundary) is not merely a backdrop for dynamics but plays an active role in shaping the arrow of time. The TAP model therefore shares formal analogies with holographic interpretations of gravity and time flow [29][30], while diverging from holography's assumption of static boundary-entanglement dualities. Rather, TAP emphasizes dynamic encoding limitations as the primary source of directionality.

From an informational viewpoint, TAP explains time's arrow as the entropic footprint left by incomplete projectional decoding. This naturally leads to temporal asymmetry even in otherwise time-symmetric fundamental laws, akin to the emergence of decoherence in quantum systems interacting with environments [18]. By coupling information capacity constraints with geometric projection rules, TAP builds an integrated framework in which thermodynamic, causal, and informational time-arrows cohere as one.

TAP's Philosophical and Ontological Implications

 doi:10.20944/preprints202508.0342.v1

Beyond its technical implications, the TAP framework invites re-evaluation of long-standing metaphysical questions regarding the nature of time, causality, and reality. Traditional physics operates within a framework of laws applied to pre-defined spacetime substrates. TAP, by contrast, suggests that the three-dimensional world and its temporal directionality are emergent phenomena—arising not from intrinsic dynamical laws, but from the projection of a higher-dimensional coherent ontology onto a bounded representational surface.

This ontological shift implies that what we perceive as irreversible processes may not reflect intrinsic asymmetries in nature, but rather a fundamental information bottleneck induced by dimensional reduction. TAP thus parallels certain interpretations of time in loop quantum gravity and causal set theory, which treat spacetime as emergent and potentially non-fundamental [21][31]. It also echoes philosophical positions such as neutral monism or structural realism, which deny substantive ontological priority to spacetime objects in favor of relational or informational primitives [32].

Moreover, the TAP interpretation of entropy as representational mismatch challenges thermodynamics' presumed universality. Entropy becomes not a universal scalar law, but a context-dependent measure of projectional efficiency. This view supports a layered ontology in which high-dimensional order may coexist with projected disorder—a notion with profound implications for understanding consciousness, agency, and the epistemic limits of observation.

If TAP's projectional geometry constrains not only physical events but also information availability, then what we perceive and measure is inherently filtered. The observable universe, in this view, is a structured shadow— not unlike Plato's cave allegory, but quantitatively anchored in differential information flow and encoding capacity [33][34]

Limitations, Open Questions, and Future Extensions

While TAP offers a compelling unification of temporal asymmetries and projectional dynamics, several open questions remain. The precise mathematical formalism connecting high-dimensional source states to projected entropy gradients requires further development. Specifically, the topological and metric conditions under which information loss manifests as thermodynamic irreversibility must be rigorously formulated [35]. Additionally, TAP's projectional capacity constraints—although conceptually intuitive—lack a universally accepted quantitative framework.

Another limitation lies in the observational reach of TAP-based predictions. While the framework yields distinct interpretations for phenomena such as black hole evaporation, cosmic microwave background anomalies, and entropy scaling in closed systems, it remains uncertain whether these predictions differ sharply enough from existing models to be falsifiable with current instruments [36].

Furthermore, TAP does not currently specify the nature of the high-dimensional ontological substrate—whether it corresponds to a mathematical manifold, a quantum information field, or an as-yet-unknown structure. This ambiguity leaves the theory open to multiple realizations, complicating efforts at integration with quantum gravity, string theory, or loop quantum geometry [37].

Nevertheless, TAP opens several promising research directions. Among them are: 1) modeling local entropy-decrease phenomena as transient back-projections from higher-order structures; 2) extending TAP to cosmological inflation and multiverse models via projectional bifurcations; and 3) exploring consciousness and agency as emergent trajectories within projection-constrained information landscapes. Each of these avenues may connect TAP to broader physical and philosophical paradigms yet to be fully articulated [33][35].

7. Conclusion

This work has introduced Thermodynamic Asymmetry from Projection (TAP) as a unifying theoretical framework for explaining the arrow of time, entropy increase, and macroscopic irreversibility. Unlike conventional approaches that attribute temporal asymmetry to statistical initial conditions or intrinsic laws of physics, TAP reframes it as that these features emerge from the

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projection of high-dimensional, coherent structures onto a lower-dimensional manifold with finite informational capacity.

Through this lens, entropy is reconceptualized not as a measure of microstate multiplicity, but as a scalar discrepancy between the flux of incoming information and the representational limits of the embedded surface. This mismatch offers a natural explanation for temporal directionality, linking irreversibility not to ontological randomness but to geometric and encoding constraints.

Beyond physical phenomena such as black hole thermodynamics and cosmic microwave background anisotropies, TAP opens new avenues for understanding consciousness and observation as emergent from projectional constraints. Its compatibility with holographic principles, quantum decoherence, and cosmological information asymmetries suggests it may serve as a bridge between existing theories and a deeper informational ontology.

Despite its conceptual promise, TAP remains in early development. Its formal mathematical structures, empirical predictions, and connections to quantum gravity require further articulation. Nonetheless, the perspective it offers—rooted in dimensional causality and representational asymmetry—invites a fundamental rethinking of what it means to observe, measure, and exist within a temporally directed universe.

Future work will seek to formalize TAP's projection mechanisms, expand its testable predictions, and explore its philosophical implications for agency, memory, and the very conditions under which knowledge, temporality, and existence become intelligible.

Appendix A.1: Geometric Modeling of Dimensional Projection

In the TAP framework, temporal asymmetry and entropy accumulation arise not from statistical boundary conditions, but from the geometric and informational constraints of dimensional projection. This appendix presents a conceptual and semi-formal geometric model of how high-dimensional coherent entities, or structures in an n-dimensional manifold ($n > 4$), are projected into the embedded 3+1 dimensional spacetime we observe.

Let M^n denote the high-dimensional ontological structure, and Σ_4 the embedded spacetime manifold. Projection is treated as a map $P: M^n \to \Sigma_4$, which may preserve topology but cannot preserve informational completeness due to the difference in dimensionality and encoding capacity.

The geometric projection is governed by the projection tensor $\Pi^{\mu}_{\ \nu}$, which contracts degrees of freedom from M^n into Σ_4. The projection can be locally decomposed as:

$$x^{\mu}(\Sigma_4) = \Pi^{\mu}_{\ \nu} \, x^{\nu}(M^n)$$

where $\Pi^{\mu}_{\ \nu}$ acts as a filter that discards high-dimensional coherence modes not supported on Σ_4. This loss is proportional to the curvature and causal density at the projection surface, resulting in observable thermodynamic asymmetry.

The key assumption in TAP is that certain geometric features—such as rapid curvature gradients, causal horizon boundaries, or non-factorizable topologies—create non-reversible projection zones. These zones exhibit directional information loss, corresponding to entropy accumulation in the embedded spacetime.

One may represent a projection zone as a region where the Jacobian determinant of the projection map drops below a critical threshold:

$$\left| \frac{\partial x^{\mu}}{\partial x^{\nu}} \right| < \varepsilon, \quad \varepsilon \ll 1$$

Such collapse corresponds to projection singularities. Black holes, from this viewpoint, are local breakdowns in projection regularity—regions where $\Pi^{\mu}_{\ \nu}$ is no longer invertible, and hence, information is not recoverably represented in Σ_4.

Importantly, this geometrical modeling supports the emergence of irreversible processes even under time-symmetric laws in M^n, since the projection itself breaks symmetry through dimensional filtration. This concept aligns with holographic boundary theories [30], causal set approaches [21], and conformal mappings from conformal field theory (CFT) to anti-de Sitter (AdS) spaces [38]. It also resonates with twistor-based encodings and loop quantum gravity models employing projection operators and spin networks [21][39].

Future work should formalize this projection geometry using fiber bundle theory and projective topology, potentially linking TAP with twistor theory and loop quantum gravity approaches that use projection operators and spin networks to encode lower-dimensional phenomena.

Appendix A.2: Mathematical Formulation of Projection Entropy

The TAP model postulates that macroscopic irreversibility arises from the informational asymmetry imposed by projecting a coherent high-dimensional structure onto a lower-dimensional manifold with finite encoding capacity. This asymmetry manifests as a scalar quantity—Projection Entropy—representing the loss of representational fidelity during the dimensional reduction process.

Let Φ_{in} represent the total information flux originating from the higher-dimensional ontological substrate. This may include configurational, causal, and boundary-defined degrees of freedom. The projection surface, denoted Σ, has a finite encoding capacity C_{proj}, dictated by both geometric and dynamical constraints such as curvature, embedding metric, and surface topology. We define Projection Entropy ΔS_{proj} as the irrecoverable mismatch:

$$\Delta S_{\text{proj}} = \Phi_{\text{in}} - C_{\text{proj}}$$

This quantity serves as a generalization of Boltzmann's entropy, in which the number of accessible microstates W is replaced by the ratio between representational input and geometric encoding limits. Notably, $\Delta S_{\text{proj}} \rightarrow 0$ implies a lossless projection—equivalent to unitary evolution or a time-reversible system—while $\Delta S_{\text{proj}} > 0$ signals directional entropy accumulation.

To establish a more rigorous expression, we consider the information flux as an integral over a higher-dimensional current density J^μ in manifold $\mathcal{M}^n$ (where $n > 4$):

$$\Phi_{\text{in}} = \int_\Omega J^\mu \, d\Sigma_\mu$$

where $d\Sigma_\mu$ is the hypersurface element over a region $\Omega \subset \mathcal{M}^n$. The encoding capacity of the lower-dimensional projection surface Σ_4 is computed using a metric-dependent bound, such as the Bousso bound [30], or entropic bounds from quantum gravity (e.g., the Ryu–Takayanagi formula in holography [40]):

$$C_{\text{proj}} \leq \frac{A(\Sigma_4)}{4 \ell_P^2}$$

where $A(\Sigma_4)$ is the area of the projection surface and ℓ_P is the Planck length. Substituting yields:

$$\Delta S_{\text{proj}} = \int_\Omega J^\mu \, d\Sigma_\mu - \frac{A(\Sigma_4)}{4 \ell_P^2}$$

This quantity now encodes both geometric limitations and informational input, allowing TAP to make predictive statements about where and when entropy increases must occur, particularly in regions of spacetime with high curvature, limited causal volume, or near singularities (e.g., black holes).

A major implication of this formulation is the directional behavior of entropy as a function of projection orientation. Inverting the projection process (e.g., time reversal or information retrieval from a singularity) would require reversing Φ_{in} or expanding C_{proj} beyond its geometric bounds—both physically implausible under known conditions.

Future efforts should seek to formalize this projectional entropy in the context of conformal field theories, bulk-boundary mappings, and quantum error correction analogues. Doing so may link TAP to broader developments in emergent spacetime and quantum information geometry [1,30,40].

Appendix A.3: TAP Model and the Second Law of Thermodynamics

 doi:10.20944/preprints202508.0342.v1

This appendix examines how the TAP framework reinterprets and reinforces the Second Law of Thermodynamics from a geometric-information perspective. In classical thermodynamics, the Second Law states that the entropy of an isolated system never decreases over time, often expressed as [6]. In TAP, this behavior emerges naturally from the projectional mismatch between a coherent high-dimensional structure M^n and the finite representational capacity of the observed spacetime Σ_4.

$$\frac{dS}{dt} \geq 0 \tag{A3.1}$$

TAP reformulates entropy not as a purely statistical quantity, but as a scalar field representing the cumulative projectional distortion or loss of informational fidelity. That is, entropy is defined as the amount of high-dimensional information that cannot be accurately encoded onto Σ_4 due to curvature, bandwidth, or coherence limitations [9][12][30].

Let $\Phi(x)$ represent the density of incoming high-dimensional structure at point $x \in \Sigma_4$, and let $C(x)$ be the local representational capacity of the projection surface. Then TAP defines the local projectional entropy density $S(x)$ as

$$S(x) = \max(0, \Phi(x) - C(x)) \tag{A3.2}$$

As $\Phi(x)$ flows into Σ_4 from the coherent source manifold, any mismatch between Φ and C results in irretrievable information collapse, perceived as entropy increase [9]. The Second Law is then a manifestation of the directional asymmetry in the projection interface: the incoming flow is coherent and high-dimensional, but the surface Σ_4 can only encode part of it [30].

This view explains why entropy increase appears ubiquitous despite microscopic reversibility in physical laws: the asymmetry is not in the laws themselves, but in the projection process which acts as an effective filter [11]. Once coherence is lost in the projection, it cannot be recovered within Σ_4 dynamics.

Furthermore, the TAP model provides a framework for understanding entropy gradients and heat flow directionality without invoking arbitrary initial conditions. The spatial variation in $C(x)$—due to local curvature or topological features—naturally leads to observable thermodynamic gradients [12].

This reframing also clarifies the limitations of entropy-reducing systems (e.g., Maxwell's Demon). Within TAP, any such local entropy reduction is compensated by increased entropy in the projection structure or its neighborhood, preserving the global monotonicity of [13][35].

$$S_{\text{total}}(x) = \int_{\Sigma_4} S(x) \, d^4x \tag{A3.3}$$

In conclusion, TAP embeds the Second Law into a geometric projection principle: entropy increase is a natural consequence of projecting richer structures into surfaces of limited fidelity and asymmetrical bandwidth. This geometric view offers a unified understanding of thermodynamic irreversibility across classical, statistical, and quantum domains [6][11][35].

Appendix A.4: TAP-Based Modeling of Black Hole Projection Termination

In this appendix, we introduce the mathematical and conceptual modeling of black holes as projectional termination points in the TAP framework. In contrast to the standard view of black holes as regions of infinite density or quantum gravity endpoints, TAP treats them as geometric boundaries where high-dimensional information can no longer be faithfully projected into Σ_4. These boundaries are not spacetime singularities per se, but topological breakdowns of the projection map $P: M^n \rightarrow \Sigma_4$.

The projection fails when the local Jacobian determinant $|\partial\Sigma_4 / \partial M^n| \to 0$, implying that representational density collapses to zero. This is interpreted as an entropy sink from the lower-dimensional perspective, even though the high-dimensional structure remains coherent. This geometric framing builds on the classical insights of Bekenstein and Hawking [14], who

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associated entropy with black hole horizons, but reinterprets the entropy growth as a projectional consequence.

Let $J(x)$ denote the Jacobian determinant of the projection map at spacetime point $x \in \Sigma_4$. The black hole horizon H corresponds to a hypersurface where $dJ/dt \to -\infty$, indicating an irreversible collapse of encoding capacity. The interior region evolves into a projectional null space, which from the Σ_4 observer's frame manifests as an "information shadow."

The TAP entropy flux equation near such termination points can be represented as:

$$\nabla_\mu S^\mu = -\alpha \cdot J(x) + \beta \cdot \nabla^2 J(x) + \gamma \cdot \text{Ric}(\Sigma_4),$$

where α, β, γ are coefficients representing coupling to Jacobian decay, curvature resistance, and background Ricci curvature respectively. As $J \to 0$, the entropy flow $\nabla_\mu S^\mu$ diverges, marking the effective thermodynamic singularity without invoking physical infinity [13].

This framework leads to distinct observable predictions:

- TAP predicts that black hole evaporation may end in a finite-entropy, projection-null state, rather than complete quantum information loss [15];
- The final stage of evaporation may involve geometric decoherence signatures observable in the CMB, gravitational wave background, or particle flux anomalies [16–18];
- Black holes of different mass and angular momentum may exhibit unique projectional tail structures, offering potential classification via entropy trace geometry.

The modeling further proposes that black hole jets and gamma-ray bursts may arise from instability near partial Jacobian collapse regions ($\partial J / \partial x \ne 0$), rather than traditional magnetic field reconnection models. This approach complements thermodynamic and holographic entropy formalisms [30,40], but roots them in dimensional projection breakdowns.

Future work should include simulating projectional boundary collapse in curved spacetimes, mapping entropy flux near real Kerr and Schwarzschild geometries [23], and correlating TAP predictions with multi-messenger astrophysical observations [22,24].

Appendix A.5: Gravitation as Projectional Curvature

One of the central questions in modern physics is the origin of gravitation. In the TAP framework, gravity is not treated as a fundamental force but as a secondary, emergent feature of projectional strain on a lower-dimensional representational surface. This appendix explores how classical gravitational behavior can arise as a geometric consequence of flux imbalance.

Projectional Strain as Source of Gravitational Effects

In the TAP model, information from a coherent high-dimensional manifold is projected onto a lower-dimensional representational surface Σ_4. When the incoming informational flux exceeds local representational capacity, the result is a scalar mismatch, as defined in the entropy formulation in Section 4 and Appendix A.3.

We now define a projectional curvature field as the response of Σ_4 to spatial gradients in this flux-capacity mismatch. The tensor field Π^μ_ν can be heuristically defined as:

$$\Pi^\mu_\nu = \nabla^\mu \Phi + \Lambda^\mu_\nu$$

where Λ^μ_ν acts as a counter-term regulating geometric balance and ensuring stability across embedding domains. This term may be related to vacuum curvature or intrinsic background geometry, requiring further specification in future models.

Relation to General Relativity

This formalism provides a reinterpretation of Einstein's field equations. Whereas general relativity encodes spacetime curvature via the Einstein tensor G^μ_ν and relates it to the stress-energy tensor T^μ_ν, TAP proposes an alternative structure in which information imbalance plays the central role. The projectional strain tensor Π^μ_ν effectively replaces T^μ_ν in dictating geometric deformation:

doi:10.20944/preprints202508.0342.v1

$$G^\mu_\nu = \kappa \cdot \Pi^\mu_\nu$$

Here κ is a proportionality constant linking projectional strain to spacetime curvature. While this mirrors the structure of Einstein's equation, the physical meaning of Π^μ_ν is fundamentally informational.

This approach builds on the notion advanced by Jacobson, who showed that Einstein's equations can be derived from thermodynamic considerations [41]. TAP extends this logic to a full informational architecture: gravitational behavior is not the result of an intrinsic force but a distortion in how information projects onto Σ_4.

Observational and Theoretical Implications

This reconceptualization predicts that gravitational anomalies—such as modified inertia in low-acceleration regimes or deviations from Newtonian dynamics—may be explicable as flux-encoding pathologies rather than exotic matter. For instance, phenomena typically attributed to dark matter may instead result from regional saturation or anisotropy in Π^μ_ν, leading to apparent excess curvature.

Moreover, TAP predicts a fundamental limit to gravitational resolution based on surface encoding density, implying that spacetime curvature is not continuous to arbitrary resolution. This aligns with emerging suggestions of quantum geometry and holographic cutoffs [30].

Further elaboration and mathematical rigor for these models, including derivations of Π^μ_ν under specific embedding geometries, are left for future work.

Appendix A.6: TAP-Based CMB Prediction Mechanism

This appendix presents the foundational logic and preliminary framework for TAP's alternative interpretation of the Cosmic Microwave Background (CMB). Unlike the standard cosmological model, which treats the CMB as the thermal remnant of a hot, dense Big Bang phase [5,25], the TAP framework views the CMB as an emergent information residue resulting from the early-stage projection of a coherent high-dimensional structure into an evolving four-dimensional spacetime projection surface.

In the TAP model, the CMB is not a fossil of high initial temperatures, but rather the manifestation of a projectional thermal boundary condition—i.e., the maximal entropy-capacity saturation at the earliest representational interface of Σ_4. This boundary encodes projectional asymmetries, loss of coherence, and dimensional mismatch rather than thermodynamic equilibrium.

We define the projectional CMB imprint as a statistical background noise pattern arising from the breakdown of coherence at large scales, amplified by finite representational bandwidth and curvature-based encoding limitations. Thus, the observed uniformity of the CMB over large angular scales becomes a geometric constraint problem rather than a fine-tuned initial condition problem [28,30].

Under this interpretation, TAP offers several falsifiable predictions and re-interpretations of observed anomalies in the CMB data:

- The Cold Spot anomaly may correspond to a local projection singularity with reduced Jacobian density [24];
- The Axis of Evil alignment reflects anisotropic coherence collapse due to high-dimensional structure orientation [27];
- Damping tail characteristics encode the geometric cutoff in representational fidelity near horizon-scale regions [28].

Mathematically, we represent the projection-induced fluctuation field $\delta P(\theta, \phi)$ on the CMB sphere as:

$$\delta P(\theta, \phi) \propto \nabla_\mu J^\mu(\theta, \phi) - \Delta C(\Sigma_4(\theta, \phi))$$

where $\nabla_\mu J^\mu$ is the projected divergence of information flux, and ΔC represents local variations in representational capacity (e.g., curvature-induced) [30,34].

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The observable power spectrum of the CMB then becomes a statistical transform of TAP's projection-entropy field rather than the outcome of baryonic acoustic oscillations as posited in ΛCDM [28,29].

This approach also permits a re-evaluation of the cosmological 'initial conditions' problem. Since TAP views the universe not as an evolution from a singularity but as a continuous projection from a timeless structure, the 'origin' of the CMB becomes a surface of projectional decoherence rather than a thermodynamic phase transition [16–18].

Future work should include mapping TAP's fluctuation field onto CMB spherical harmonic coefficients $a_{\ell m}$, comparing predictions with Planck and WMAP datasets [8], and deriving TAP-specific statistical signatures that differ from inflationary predictions [26,29].

This projectional perspective may offer a falsifiable, geometry-based account of the CMB that resolves longstanding anomalies without invoking inflation, reheating, or scalar fields in an early high-energy universe.

Appendix A.7: CMB Cold Spot as Projectional Interference

Within the TAP framework, the observed Cold Spot in the cosmic microwave background (CMB) is interpreted not as a statistical anomaly within inflationary cosmology, but as a projectional interference artifact—a region of destructive informational flux interaction within the projection surface Σ_4.

In standard cosmology, the Cold Spot is often modeled as either a large-scale integrated Sachs–Wolfe (ISW) effect through a supervoid or as a statistical fluctuation. However, such interpretations face challenges in explaining its spatial coherence, low variance, and alignment with other anomalies [24,27]. TAP reframes this feature as a representational depression caused by a localized deficit in the projected Jacobian density, where incoming high-dimensional flux interferes destructively across a region with sharply varying curvature on Σ_4.

This interference yields a reduced projectional capacity, resulting in a local entropy suppression field $\delta S(\theta, \phi)$, modeled as:

$$\delta S(\theta, \phi) \propto -\left| \nabla_\mu J^\mu(\theta, \phi) \right|$$

This does not indicate thermodynamic cooling, but rather a deficit in informational realization capacity—a local entropy ground zone within the projectional map.

Observable implications include:

- Angular size and temperature contrast consistent with destructive coherence cancellation;
- Correlation with other large-scale anomalies (e.g., quadrupole–octupole alignment [24]);
- Suppression of wavelet coefficients over the spot's angular scale, as originally reported in [24].

Further modeling should quantify the Cold Spot as a solution to a localized eigenvalue problem within TAP's projection tensor field Π^μ_ν, where low-projection efficiency leads to an entropy deficit zone. The governing condition may be represented as:

$$\Pi^\mu_\nu \psi^\nu = \lambda(\theta, \phi) \psi^\mu$$

Regions with anomalously low eigenvalue density $\lambda(\theta, \phi)$ correspond to ineffective projection zones. This offers a geometric alternative to ISW-based explanations while preserving observational compatibility with Planck results [27].

Appendix A.8: Axis of Evil as Projectional Asymmetry

The "Axis of Evil" (AOE) refers to a striking alignment of the low-ℓ multipoles ($\ell = 2, 3$) in the cosmic microwave background (CMB) temperature anisotropies. First identified by Land and Magueijo [24], this anomaly challenges the foundational assumption of statistical isotropy that underpins the ΛCDM model. Specifically, the CMB quadrupole and octupole modes exhibit unexpected spatial coherence across large angular scales, consistently aligning along a particular axis

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in galactic coordinates. While some studies have attributed these patterns to foreground contamination or statistical flukes, the persistence of the alignment across multiple sky reconstructions, masks, and processing pipelines has preserved its anomalous status in modern cosmology [27].

Standard inflationary cosmology, which assumes primordial perturbations to be statistically isotropic and Gaussian, lacks a natural mechanism to generate such large-scale directional structures. Proposed explanations typically invoke speculative ingredients—such as pre-inflationary relics, anisotropic expansions, or topological constraints—but none succeed in reproducing the observed alignment without introducing artificial tuning or violating core symmetries [26][27].

Within the TAP framework, however, the Axis of Evil emerges as a geometric and deterministic consequence of high-dimensional information embedding. In this model, the CMB is not merely a thermal relic but a projectional surface that encodes the early structure of an informational flux field $\Phi(x)$, projected from a higher-dimensional manifold onto the 4D interface Σ_4.

During the initial phase of universal projection, if the embedding process encountered directional asymmetries—such as anisotropic curvature or spatial gradients in projection capacity C(x)—then large-scale coherent imprints would be preserved in the projected structure. In this context, the AOE corresponds to a persistent projectional strain field $\vec{\sigma}_{\text{proj}}$, manifesting as directional modulation of the low-ℓ harmonics:

$$\delta T(\theta, \phi) \supset \mathcal{P}{\ell=2,3}\left[\vec{\sigma}{\text{proj}} \cdot \hat{n}(\theta, \phi)\right]$$

where $\mathcal{P}_{\ell}$ denotes projection onto the ℓ-th spherical harmonic mode and $\hat{n}$ is the angular position vector on the celestial sphere. In contrast to the stochastic nature of inflationary perturbations, TAP predicts such alignments as intrinsic consequences of geometrically constrained projection. Rather than statistical coincidences, these features are systematic residuals of asymmetric Jacobian transformations.

This interpretation complements the TAP-based explanation of the CMB Cold Spot (Appendix A.7), which is viewed as a region of destructive interference and local projectional inefficiency. Whereas the Cold Spot reflects a dip in representational entropy due to flux cancellation, the Axis of Evil represents constructive coherence along a privileged embedding axis. Together, they constitute opposite expressions of the same underlying mechanism: directional tension and capacity mismatch within the projectional geometry of the universe.

A further implication of the TAP model is that such projectional alignment should not be unique to the CMB temperature map. If the Axis of Evil is a genuine signature of early embedding asymmetry, then it should leave imprints in other large-scale observables. These may include polarization mode alignments (e.g., E-mode directional coherence), anomalies in the velocity field flow, and possible correlations with the orientation of cosmic voids and filaments. The detection of such cross-modal alignments would provide falsifiable evidence for TAP's geometric origin of cosmic structure. Future missions with high-precision polarization and tomographic surveys—such as LiteBIRD and 21cm mapping arrays—could serve as critical tests for this prediction.

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