Incompleteness, Null Signals, and the Cosmological Plenum

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Abstract

This paper explores incompleteness as a unifying principle across logic, computation, cognition, thermodynamics, and cosmology. Beginning with Gödel's incompleteness theorems, it examines how formal systems are inherently limited by their inability to encompass their embedding supersets. Karl Fant's null convention logic (NCL) operationalizes this in hardware, using null states to signal incompletion, with parallels in everyday life such as learner's permits and amber traffic lights. Monica Anderson's critiques of Good Old-Fashioned Artificial Intelligence (GOFAI) highlight similar limitations in symbolic systems, advocating for subsymbolic adaptability. Functional programming's monadic deferral of side-effects mirrors Ilya Prigogine's dissipative structures, which export entropy to maintain order. The Relativistic Scalar-Vector-Potential (RSVP) model reframes cosmic expansion as an entropic "falling outward," constrained by Cosmic Microwave Background (CMB) dipole observations to disfavor multiverse scenarios with varying Friedmann-Robertson-Walker-Lemaître (FRW) parameters. A categorical framework, the Law of Superset Entropy, unifies these domains: order requires exporting incompleteness to a superset or internalizing it via structural reorganisation. The synthesis posits that the cosmos, like logic and computation, is a plenum of null signals, perpetually incomplete yet coherent within a greater whole.

1 Introduction

Kurt Gödel's incompleteness theorems revealed a profound limitation: any formal system sufficiently expressive to encode arithmetic contains true propositions that cannot be proven within its axioms [Gödel, 1931]. This structural feature of categoricity—defining a domain excludes its embedding metalevel—extends beyond mathematics to computation, cognition, thermodynamics, and cosmology. This paper traces the theme of incompleteness across these domains, linking Gödel's logical insights, Karl Fant's null convention logic (NCL), Monica Anderson's critiques of Good Old-Fashioned Artificial Intelligence (GOFAI), functional programming's monadic structures, Ilya Prigogine's dissipative structures, and the Relativistic Scalar-Vector-Potential (RSVP) cosmological model.

The paper is structured to build progressively from foundational logic to cosmic scales, emphasizing the interplay of incompleteness and order. Section 2 delves into Gödelian incompleteness, exploring self-reference, semantic boundaries, and their implications for formal systems. Section 3 provides a comprehensive introduction to NCL, including prerequisites on synchronous and asynchronous logic, detailed mechanics, everyday analogues, and connections to cognitive theories. Section 4 expands on functional programming's handling of side-effects, Prigogine's thermodynamic principles, and their economic and computational parallels, introducing the Law of Superset Entropy. Section 5 details RSVP's fields, dynamics, and "falling outward" analogy, incorporating historical context and inflationary extensions. Section 6 analyzes CMB dipole constraints, arguing against multiverse variability through observational and cognitive parallels. Section 7 synthesizes these under the Law of Superset Entropy, with philosophical and scriptural reflections. Two appendices provide technical details on RSVP's CMB dipole constraints and the "falling outward" mechanism.

This interdisciplinary approach reveals incompleteness as an architectural necessity, with null signals and entropy export ensuring continuity across domains, as exemplified by the scriptural metaphor of Matthew 26:29, where a deferred act signals a greater fulfillment.

2 Gödelian Incompleteness and the Limits of Categories

Gödel's incompleteness theorems (1931) are foundational to understanding systemic limits [Gödel, 1931]. The first theorem states that in any consistent formal system capable of expressing basic arithmetic, there exist propositions that cannot be proved or disproved within the system. The second theorem shows that such a system cannot prove its own consistency. These results arise from self-reference: Gödel constructs a sentence that asserts "I am unprovable," which is true if and only if it is unprovable, creating a paradox analogous to the liar sentence.

Nagel and Newman [1958] explain that Gödel uses arithmetisation (Gödel numbering) to encode statements about the system within the system itself, turning meta-mathematical questions into arithmetic ones. For example, a statement like "This sentence is not provable in system S" is encoded as an arithmetic proposition about numbers representing proofs. If the statement is provable, it contradicts itself; if not, it is true but unprovable, exposing the system's limits. This self-referential folding is akin to Russell's paradox in set theory, where the set of all sets that do not contain themselves leads to contradiction if it contains itself [Tarski, 1956].

Tarski's work on semantics further shows that truth in a formal language requires a metalanguage, reinforcing that systems are blind to their supersets [Tarski, 1956]. For instance, the truth of arithmetic statements in Peano Arithmetic cannot be fully defined within Peano Arithmetic itself but requires a higher-order language. Extending the system with new axioms resolves some undecidables but introduces others, leading to a pluralism of consistent frameworks. The Continuum Hypothesis, which concerns the cardinality of the continuum, is independent of Zermelo-Fraenkel set theory with the axiom of choice (ZFC), meaning it can be neither proved nor disproved from standard axioms [Gödel, 1931].

This pluralism has profound implications: no single system exhausts mathematical truth. Each system is locally coherent but globally incomplete, requiring mechanisms to signal boundaries, such as unprovable propositions or external coordinators. For example, the consistency of ZFC relies on assumptions in a meta-system, which may itself be incomplete [Nagel and Newman, 1958]. This insight extends to other domains: computational systems rely on external timing or coordination, cognitive systems on environmental feedback, thermodynamic systems on entropy sinks, and cosmological systems on boundary conditions. Incompleteness is not a flaw but a feature of categoricity, setting the stage for examining its manifestations in computation and beyond.

3 Null Convention Logic as Embodied Incompleteness

Karl Fant's *Computer Science Reconsidered* (2005) operationalises Gödelian incompleteness in hardware through null convention logic (NCL), a paradigm for delay-insensitive circuits [Fant, 2005]. Unlike synchronous logic, which relies on an external clock to enforce timing [Seitz, 1980], NCL introduces a null state to signal incompletion, enabling circuits to self-coordinate. This section provides a comprehensive introduction to NCL, including prerequisites for readers unfamiliar with computation, detailed mechanics, everyday analogues, cognitive parallels, and philosophical connections to incompleteness.

3.1 Prerequisites: Synchronous vs. Asynchronous Logic

Digital circuits process binary signals (0 or 1) through gates like AND, OR, and NOT. Synchronous circuits operate under a global clock, where each gate processes inputs assuming they are valid at clock ticks. However, varying propagation delays—the time for signals to travel through wires or gates—can cause glitches or hazards: temporary erroneous outputs that propagate through the system [Seitz, 1980]. For example, in a Boolean AND gate with inputs A and B, if A arrives before B due to delay, the gate may output 0 transiently before correcting to 1 if both are true. Synchronous systems externalise coordination to the clock, akin to a mathematician managing data flow [Fant, 2005], but this external dependence assumes perfect timing, which is impractical in complex or distributed systems.

Asynchronous circuits eliminate the clock, relying on local handshaking to ensure correct operation. This eliminates timing assumptions but requires explicit mechanisms to signal data validity. Early asynchronous designs, such as those by Seitz [1980], used completion signals, but

Fant's NCL generalises this by integrating null as a fundamental value, making circuits delay-insensitive and robust to propagation variations. This shift mirrors Gödel's move from external proof to internal self-reference [Gödel, 1931].

3.2 NCL Fundamentals

NCL extends Boolean logic by incorporating a null state, creating a three-value (True, False, Null) or four-value (True, False, Null, Intermediate) system [Fant, 2005]. The key principle is the completeness criterion: a gate outputs a valid data value (True or False) only when all inputs are valid data values; otherwise, it outputs Null. This ensures no premature computation, eliminating hazards.

- *Three-Value Logic*: A gate's truth table is extended to include Null. For an AND gate, if inputs are (True, True), (True, False), (False, True), or (False, False), it outputs the Boolean result; if either input is Null, it outputs Null [Fant, 2005]. This enforces input completeness, preventing partial states from propagating.

- *Four-Value Logic*: Adding an Intermediate value ensures both data-to-null and null-to-data transitions are complete. A gate outputs Null only when all inputs are Null, and data only when all inputs are data, with Intermediate for mixed states [Fant, 2005]. This provides robust symbolic determinacy, ignoring intermediates during monitoring.

- *Two-Value Implementation*: For hardware practicality, NCL uses dual-rail encoding: two wires represent one logical signal (e.g., (1,0) for True, (0,1) for False, (0,0) for Null, (1,1) illegal). Mutually exclusive assertion groups ensure only one wire in a group carries data [Fant, 2005]. Gates become threshold-based: a threshold-N gate outputs data if at least N inputs are data.

The data resolution wavefront propagates when all inputs are valid, and a null wavefront resets the system, forming a self-synchronising cycle. For example, in a combinational circuit, if one input remains Null, at least one output remains Null, ensuring the system waits for complete data before proceeding [Fant, 2005]. The null-data cycle ensures circuits return to all-Null before the next dataset, preventing state overlap.

In the "shaking bag" analogy, Fant describes symbols interacting spontaneously, resolving only when conditions are complete, akin to biological self-organisation without external control [Fant, 2005, Schneider and Sagan, 2005]. This analogy highlights NCL's ability to internalise coordination, a key parallel to Gödelian incompleteness.

3.3 Null-Data Cycle and Wavefront

The null-data cycle is central to NCL's operation. Circuits start in an all-Null state, transition to all-data when inputs are valid, and return to all-Null before the next cycle [Fant, 2005]. This cycle is analogous to a handshake: the system signals its readiness (Null) and completion (data). The wavefront of validity propagates symbolically, not temporally, eliminating the need for a clock.

In the four-value system, the Intermediate state ensures robust transitions. For instance, a gate with mixed inputs (some Null, some data) outputs Intermediate, which is ignored by downstream gates until full data or Null states are reached. The feedback solution uses hysteresis: gates "remember" their previous state, transitioning only when inputs are fully consistent, making NCL effectively delay-insensitive [Fant, 2005].

This cycle mirrors biological or social systems where partial states are deferred until complete, such as a committee awaiting all votes before deciding. The null-data cycle thus operationalises incompleteness, ensuring systems wait for full information, akin to Gödel's unprovable statements awaiting meta-level resolution [Nagel and Newman, 1958].

3.4 Everyday Analogues

NCL's null state mirrors everyday control signals, illustrating its intuitive grounding:

- Do Not Disturb Sign: Signals suspension of action, akin to Null preventing premature gate output. It informs others not to interpret the current state as actionable [Fant, 2005].

- Learner's Permit: Marks an incomplete state, allowing limited driving under supervision, like Null awaiting full data validity. It signals partial readiness, deferring full authorisation [Fant, 2005].
- Amber Traffic Light: Indicates a transitional state, neither go nor stop, akin to NCL's Intermediate value signalling partial readiness before a full state change [Fant, 2005].
- Matthew 26:29: Jesus' refusal to drink wine until the kingdom signifies a null state, a suspension awaiting fulfillment, with the future act signalling completion.

These analogues highlight null as a meta-signal of incompleteness, preventing misinterpretation, much like Gödel's unprovable statements expose systemic limits.

3.5 GOFAI Critiques

Monica Anderson's critiques of Good Old-Fashioned Artificial Intelligence (GOFAI) align with NCL's philosophy [Anderson, 2006]. GOFAI relies on explicit, programmer-defined rules, exporting semantic burden to human designers, rendering systems brittle in ambiguous contexts. For example, a rule-based chess program fails in novel scenarios without preprogrammed responses. Sub-symbolic approaches, such as neural networks, embrace partial states, learning from data without predefined ontologies [Clark, 2013, Hohwy, 2013]. This mirrors NCL's null, which allows circuits to defer action until inputs are complete, internalising coordination.

Anderson argues that GOFAI's modular, rule-based models fail to capture the interactive, reuse-driven nature of cognition, much like synchronous logic fails in asynchronous environments [Anderson, 2006]. Predictive processing models, where brains minimise error via feedback loops, parallel NCL's self-coordination [Clark, 2013, Hohwy, 2013]. For instance, predictive coding treats perception as hypothesis testing, deferring interpretation until sensory data aligns, akin to NCL's completeness criterion.

3.6 Philosophical Resonance

NCL embodies Gödelian incompleteness: synchronous logic hides timing in a superset (clock), while NCL internalises coordination via null states. Fant's critique parallels Gödel: conventional computer science assumes an external "mathematician" (clock or engineer) to ensure correctness, but NCL embeds this awareness in the system, akin to Gödel's self-referential statements [Fant, 2005, Nagel and Newman, 1958]. This shift from external to internal coordination is a computational solution to incompleteness, setting the stage for broader applications in programming, thermodynamics, and cosmology.

4 Functional Programming and Deferred Entropy

Functional programming, particularly in pure languages like Haskell, manages incompleteness by deferring side-effects through monads, preserving referential transparency until interaction with the external world [Wadler, 1992, Turner, 1979]. This section explores this parallel, extends it to thermodynamic systems, and introduces the Law of Superset Entropy as a unifying framework, with detailed examples from computation and economics.

4.1 Monads in Functional Programming

In imperative programming, side-effects (e.g., I/O, state changes) contaminate composition, requiring external coordination (e.g., runtime systems). For example, a C program modifying global variables loses predictability. Pure functional languages encapsulate side-effects in monads, such as the IO monad, which describes computations without executing them until runtime [Wadler, 1992]. A function $f : X \to \text{IO } Y$ delays printing until the monad is evaluated, ensuring composition remains pure.

The monad's bind operator ($\gg=$) sequences effects, analogous to NCL's wavefront propagation, ensuring deterministic behaviour without external timing [Turner, 1979]. For instance, in Haskell, the computation:

$$\text{putStrLn "Hello"} \gg \text{putStrLn "World"}$$

sequences outputs in a pure context, deferring execution to the runtime. This internalises the coordination that synchronous systems externalise to a runtime, mirroring NCL's shift from external clocks to null states [Fant, 2005].

Monads thus defer incompleteness: designers work with pure functions while the runtime handles "dirty" effects, similar to Gödel's meta-level extensions

4.2 Dissipative Structures and Entropy Export

Ilya Prigogine's dissipative structures provide a thermodynamic analogue [Prigogine and Stengers, 1984, Nicolis and Prigogine, 1977]. Systems like hurricanes, organisms, or economies maintain internal order by exporting entropy to their environment. The second law of thermodynamics states that total entropy increases ($\Delta S_{\text{universe}} \geq 0$), but locally, dissipative structures reduce entropy ($\Delta S_{\text{system}} < 0$) by increasing it externally ($\Delta S_{\text{environment}} > 0$) [Nicolis and Prigogine, 1977].

For instance, a hurricane organises itself by dissipating heat into the atmosphere, increasing global entropy. The entropy change is:

$$\Delta S_{\text{universe}} = \Delta S_{\text{hurricane}} + \Delta S_{\text{environment}} \geq 0,$$

where $\Delta S_{\text{hurricane}} < 0$ reflects the storm's internal order [Nicolis and Prigogine, 1977]. Biological systems, such as cells, sustain complexity by expelling disorder, as detailed in Schneider and Sagan [2005]. In computation, garbage collection externalises memory cleanup to a runtime process, freeing programmers from manual deallocation. In economics, platforms like Uber offload labor and maintenance costs to drivers, maintaining corporate efficiency by exporting economic entropy.

These systems defer incompleteness, exporting entropy to a superset, much like Gödelian systems rely on metalevels for truth [Tarski, 1956]. Prigogine's framework generalises incompleteness to physics: order is provisional, dependent on environmental sinks, paralleling the computational and logical domains.

4.3 Law of Superset Entropy

The parallels suggest a unifying principle, the Law of Superset Entropy: any ordered system maintains coherence by exporting incompleteness or entropy to a superset, or internalising it through structural reorganisation. In functional programming, monads internalise side-effects; in NCL, null states internalise timing; in dissipative structures, internal organisation absorbs some entropy, reducing external export

This law extends to social and economic systems. For example, a corporation maintains internal order by outsourcing inefficiencies (e.g., labor costs, waste management) to external entities. Similarly, cognitive systems, as discussed below, export uncertainty to the environment via predictive processing [Clark, 2013, Hohwy, 2013]. The Law of Superset Entropy frames incompleteness as a trade-off between external dependence and internal complexity, unifying logical, computational, and physical domains.

5 RSVP and the Cosmological Extension

The Relativistic Scalar-Vector-Potential (RSVP) model reinterprets cosmic redshift as an entropic relaxation process, "falling outward," rather than metric expansion [Whittle, 2015]. This section details RSVP's fields, dynamics, historical context, and inflationary extensions, connecting them to the incompleteness theme.

5.1 RSVP Fields and Dynamics

RSVP posits three interacting fields:

- Scalar $\Phi(x, \eta)$: Drives entropic smoothing, analogous to NCL's null state, deferring structural relaxation by encoding spatial incompleteness.
- Vector $\mathbf{v}(x, \eta)$: Represents bulk flows and local deviations, facilitating transport of matter and energy.
- Entropy $S(x, \eta)$: Quantifies disorder, redistributed during structure formation, aligning with Prigogine's entropy export [Prigogine and Stengers, 1984].

The entropic redshift potential is defined as:

$$\Upsilon = \delta\Phi - \beta(\eta)\varphi_m, \quad \varphi_m(k, \eta) = \frac{4\pi G a^2(\eta)\bar{\rho}_m(\eta)}{k^2}\mathcal{T}_m(k, \eta)\delta_m(k, \eta). \tag{1}$$

Here, $\delta\Phi$ is the scalar perturbation, φ_m the dimensionless matter potential, and $\beta(\eta)$ a time-dependent coupling [Dodelson, 2003]. Φ mediates void expansion, explaining acceleration without invoking exotic vacuum energy [Einstein, 1917, de Sitter, 1917, Peebles and Ratra, 2003]. The effective potential governing outward/inward acceleration is:

$$\mathbf{a}_{\text{eff}} = -\nabla\Phi_{\text{eff}}, \quad \Phi_{\text{eff}} = \Phi - \gamma(\eta)\varphi_m. \tag{2}$$

This balances scalar capacity (outward fall) and matter density (inward pull), with $\gamma(\eta)$ a coupling function.

5.2 Falling Outward

Mark Whittle's "falling outward" analogy describes vacuum energy driving expansion by reducing gravitational potential [Whittle, 2015, 2006]. In a matter-dominated sphere, the potential energy $U = -\frac{GMm}{r}$ becomes less negative as radius r increases, favouring collapse. In a vacuum-dominated sphere, mass scales as $M \propto r^3$, making $U \propto -r^2$, so expansion is energetically favourable. RSVP reframes this: Φ drives voids to "smooth outward," generating entropy to fill expanded volumes, a self-sustaining process akin to Prigogine's dissipative structures [Prigogine and Stengers, 1984, Whittle, 2015].

Consider a spherical region in the RSVP plenum with a test particle at its boundary. For matter-rich regions, the effective energy is $E \sim -\frac{GMm}{r}$, driving inward collapse. For void-like regions dominated by Φ, $M(r) \propto r^3$, yielding $E \sim -r^2$, driving outward relaxation. The entropy generated by the fall sustains the new capacity, mirroring Whittle's self-generating expansion [Whittle, 2015].

5.3 Inflationary Extension

In the early universe, a high-density Φ triggers a rapid "lamphron-lamphrodyne flash," an explosive entropic smoothing akin to inflation [Whittle, 2015]. The effective energy scales steeply, leading to exponential outward relaxation:

$$\frac{d^2 r}{dt^2} \propto \rho_\Phi r. \tag{3}$$

This resolves horizon and flatness issues by smoothing entropic gradients, establishing causal uniformity. Post-flash, residual potentials drive observed void expansion, linking early smoothing to late-time acceleration [de Sitter, 1917].

5.4 Historical and Observational Context

Einstein introduced the cosmological constant Λ for a static universe [Einstein, 1917], but de Sitter showed it yields exponential expansion without matter [de Sitter, 1917]. Observations by Riess et al. [1998] and Perlmutter et al. [1999] confirmed acceleration, interpreted as dark energy [Peebles and Ratra, 2003]. RSVP aligns with these but frames acceleration as entropic, consistent with Dodelson [2003]'s modern cosmology. The model's emphasis on Φ as a smoothing capacity parallels NCL's null state, deferring relaxation until conditions align.

This extension to cosmology shows incompleteness at universal scales: the plenum's Φ field encodes entropic boundaries, deferring relaxation until conditions align, much like NCL's null states and monadic deferral in programming.

6 Dipole Constraints and the Absence of Multiverses

RSVP imposes stringent constraints on beyond-horizon inhomogeneities through CMB dipole observations (Appendix A). A significant density or entropic gradient would produce a residual dipole misaligned with local gravitational flows (e.g., Great Attractor) [Riess et al., 1998, Perlmutter et al., 1999]. The observed dipole ($\varepsilon_{\mathrm{kin}} \sim 10^{-3}$) aligns with reconstructions, and the intrinsic dipole is bounded by:

$$\Delta\Upsilon_* = \|\nabla\Upsilon_*\| R_* \lesssim \text{few} \times 10^{-5}. \tag{4}$$

This implies isotropy and homogeneity extend at least one horizon length beyond the observable, disfavoring bubble universes with varying FRW parameters [Dodelson, 2003]. The universe is constrained by inherent conditions, not sampling arbitrary parameters, resonating with predictive processing models in cognition that minimise environmental uncertainty [Clark, 2013, Hohwy, 2013].

The alignment test reinforces this: RSVP bulk-flow estimators converge to the CMB dipole, indicating no super-horizon tilt. Long-mode consistency further tightens bounds, tying residuals to the small quadrupole ($\sim 10^{-5}$) [Whittle, 2006]. This section expands the cosmological implications, showing how RSVP's entropic framework naturally rejects multiverse variability, aligning with the essay's theme of constrained incompleteness.

7 Synthesis

Incompleteness is an architectural necessity across domains. Gödel's theorems reveal logical limits; NCL's null signals enable self-coordinating circuits; GOFAI critiques advocate adaptive systems; monads defer side-effects; dissipative structures export entropy; and RSVP's Φ drives cosmic relaxation. The Law of Superset Entropy unifies these: order requires exporting incompleteness to a superset or internalising it through reorganisation.

In Matthew 26:29, Jesus' refusal to drink wine until the kingdom signifies a null state, fulfilled by future action, opening a larger incompleteness. The cosmos, as a plenum of null signals, falls outward within a greater whole, never fully complete yet coherent. This synthesis extends to cognitive science, where predictive processing minimises uncertainty by exporting it to the environment [Clark, 2013, Hohwy, 2013], and to social systems, where institutions maintain order by delegating complexity. Incompleteness, far from a limitation, is the mechanism that ensures continuity and adaptability across scales.

Appendix A: CMB Dipole Constraints in RSVP (Entropic Redshift Form)

A.1 Fields, Potential, and Normalisation

We model the plenum with scalar capacity Φ, vector flow $\mathbf{v}$, and matter density ρ_m. Perturbations define an *entropic redshift potential* Υ that controls photon redshift analogously to the Newtonian potential $\Phi_{\rm N}$ in ΛCDM.

Convention (normalisation). We normalise Υ so that the instantaneous Sachs–Wolfe (SW) contribution at last scattering is:

$$\left(\frac{\Delta T}{T}\right)_{\rm SW} = \frac{1}{3}\Upsilon_*. \tag{5}$$

To make contact with ΛCDM when desired, one can adopt the dictionary:

$$\Upsilon = \delta\Phi - \alpha_m(\eta,k)\delta\rho_m, \quad \alpha_m(\eta,k) = \frac{4\pi G a^2(\eta)\bar{\rho}_m(\eta)}{k^2}\mathcal{T}_m(\eta,k), \tag{6}$$

where $\mathcal{T}_m$ is the RSVP transfer from $\delta\rho_m$ into the potential sector. Setting $\alpha_\Phi \equiv 1$ recovers $\Upsilon \to \Phi_{\rm N}$ in the ΛCDM limit.

A.2 Large-angle Anisotropy Decomposition

For line-of-sight $\hat{\mathbf{n}}$:

$$\frac{\Delta T}{T}(\hat{\mathbf{n}}) = \hat{\mathbf{n}}\cdot\frac{\mathbf{v}_0}{c} + \frac{1}{3}\Upsilon_*(\hat{\mathbf{n}}) + 2\int_{\eta_*}^{\eta_0}\dot{\Upsilon}\,d\eta, \tag{7}$$

where the terms represent:

- $\hat{\mathbf{n}}\cdot\frac{\mathbf{v}_0}{c}$: Kinematic dipole from local bulk velocity ($\varepsilon_{\rm kin}\sim 10^{-3}$).
- $\frac{1}{3}\Upsilon_*(\hat{\mathbf{n}})$: Entropic Sachs–Wolfe effect at last scattering.
- $2\int_{\eta_*}^{\eta_0}\dot{\Upsilon}\,d\eta$: Entropic Integrated Sachs–Wolfe (ISW) effect.

The intrinsic dipole amplitude is:

$$D_{\rm int} = \left|\left(\frac{\Delta T}{T}\right)^{\rm int}_{\ell=1}\right| \lesssim \varepsilon_{\rm dip}, \quad \varepsilon_{\rm dip}\sim 10^{-5}. \tag{8}$$

A.3 Super-horizon Gradient Bound (Intrinsic Dipole)

Assume a nearly uniform super-horizon gradient across our patch:

$$\Upsilon(\mathbf{x},\eta) = \Upsilon_0(\eta) + \mathbf{G}(\eta)\cdot\mathbf{x}, \quad \|\mathbf{G}\|R_* \ll 1, \tag{9}$$

with R_* the comoving radius to last scattering. The intrinsic dipole amplitude obeys:

$$D_{\rm int} = \frac{1}{3}\|\mathbf{G}_*\|R_* + \mathcal{O}\left(\int \dot{\Upsilon}\,d\eta\right). \tag{10}$$

Imposing $D_{\rm int}\lesssim\varepsilon_{\rm dip}$ yields the dimensionless gradient bound:

$$\boxed{\|\nabla\Upsilon_*\|R_* \lesssim 3\varepsilon_{\rm dip}}. \tag{11}$$

A.4 Linking to "Falling Outward" (Effective Potential Form)

RSVP kinematics of outward fall are governed by an effective scalar potential:

$$\mathbf{a}_{\rm out} = -\nabla\Phi_{\rm eff}, \quad \Phi_{\rm eff} = \Phi - \gamma(\eta, k)\varphi_m, \tag{12}$$

with φ_m a dimensionless matter potential and γ a model-dependent coupling. For the linear redshift imprint, we identify $\Upsilon = \mathcal{N}(\eta)\Phi_{\rm eff}$ for some normalisation $\mathcal{N}$ compatible with (5). The last-scattering bounds are:

$$|\delta\Phi|_* \lesssim \frac{\varepsilon_{\rm dip}}{\alpha_\Phi}, \quad |\delta\rho_m|_* \lesssim \frac{\varepsilon_{\rm dip}}{\alpha_m}, \tag{13}$$

with $\alpha_\Phi \equiv \partial\Upsilon/\partial(\delta\Phi)$ and α_m as in (6).

A.5 Vector Alignment Test (Entropy-weighted Convergence)

Define the RSVP bulk-flow estimator inside radius R by entropy-weighted redshift fits:

$$\mathbf{v}_0^{\rm RSVP}(R) = \arg\min_{\mathbf{v}} \sum_{i:r_i<R} w_i \left(z_i^{\rm obs} - z_i^{\rm RSVP}(\mathbf{v})\right)^2, \quad w_i \propto \frac{1}{\sigma_{S,i}}, \tag{14}$$

where $\sigma_{S,i}$ are semantic/entropy weights in RSVP. Convergence to the CMB dipole means:

$$\angle\left(\mathbf{v}_0^{\rm RSVP}(R), \mathbf{d}_{\rm CMB}\right) \to 0, \quad \|\mathbf{v}_0^{\rm RSVP}(R)\| \to cD_{\rm kin} \quad \text{as } R \to \infty, \tag{15}$$

with $D_{\rm kin}$ the measured kinematic dipole amplitude.

A.6 Long-mode Consistency (RSVP Gauge)

Super-horizon adiabatic Υ modes correspond to an RSVP *semantic-slicing* gauge redefinition. The leading dipole cancels as a gauge artifact, and any residual is tied to the quadrupole via the transfer of $\dot{\Upsilon}$ at horizon entry. Since the measured quadrupole is small ($\sim 10^{-5}$), this tightens (11).

A.7 Takeaway (RSVP)

The entropic redshift potential $\Upsilon = \Upsilon[\Phi, \rho_m]$ encapsulates how scalar capacity (falling outward) and mass (inward pull) imprint the CMB. The residual dipole forces Υ to be nearly uniform across the last-scattering sphere:

$$\Delta\Upsilon_* \lesssim \text{few} \times 10^{-5}, \tag{16}$$

so RSVP's falling-outward cosmology must satisfy near-homogeneity in Υ at least one horizon scale beyond the visible patch.

Appendix B: Falling Outward in the RSVP Framework

Consider a spherical region in the RSVP plenum with a test particle at its boundary, governed by Φ, $\mathbf{v}$, and S.

Case 1: Matter-Dominated Sphere. For matter-rich regions, the effective energy is:

$$E \sim -\frac{GMm}{r}, \tag{17}$$

driving inward collapse.

Case 2: Entropic Vacuum-Dominated Sphere. In void-like regions dominated by Φ, the "mass" scales as $M(r) \propto r^3$, yielding:

$$E \sim -r^2 \tag{18}$$

This drives outward relaxation, with entropy generated by the fall itself.

Inflationary Extension. In the early plenum, a high-entropy Φ dominates, producing a lamphron-lamphrodyne flash:

$$E \sim -\rho_\Phi r^2, \quad \frac{d^2 r}{dt^2} \propto \rho_\Phi r \tag{19}$$

This rapid smoothing establishes causal uniformity, prefiguring void expansion. The CMB dipole constraint ($\Delta\Upsilon_* \lesssim$ few $\times 10^{-5}$) ensures this coherence persists, ruling out arbitrary parameter variations.

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