Space-time Curvature as an Information-Theoretic Structure

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Abstract

Papers I–IV [3, 1, 2, 4] established that the universe can be modelled as a finite, static bitstring of n bits; that gravitational collapse converges to a zero-entropy singularity; that expansion from that singularity is the geometric reading of entropy increase; and that the aspect ratio of spacetime is determined by n alone. The present paper takes these results further by deriving a relational scale factor from strict information conservation. Because the bit budget is fixed, every micro-structure must emerge from the same bitstring, reducing the resolution of observable space as perceived by internal observers similar how rope length is affected by knots in it. This single counting principle reproduces, without free parameters, the two boundary solutions of General Relativity — De Sitter vacuum and the Schwarzschild singularity — as the natural extremes of one equation.

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1 Introduction

General Relativity admits two extreme solutions that appear, at first sight, to be unrelated. De Sitter space describes a universe with no matter and a positive cosmological constant, expanding exponentially without bound. The Schwarzschild solution describes the opposite extreme: all mass concentrated at a single point, spacetime contracted to a singularity. Between these extremes, the Friedmann equation governs the observed universe — an expanding geometry whose rate of expansion is modulated by the density of matter and vacuum energy.

The present paper shows that these three are not independent results but three consequences of a single information-theoretic counting principle. When the universe is modelled as a closed system of n bits, partitioned at each moment between free spacetime fabric and composite matter structures, the scale factor perceived by an internal observer is the fraction of the bit budget that remains independently addressable. De Sitter and Schwarzschild emerge as the two limiting cases of this fraction.

No metric tensor is postulated. No force law is imposed. No cosmological constant is introduced as a free parameter. The expansion history of the universe is the geometric reading of information conservation.

The paper is structured as follows. Section 2 derives the relational scale factor from the counting argument and identifies the two GR extremes. Section 3 maps the framework onto Friedmann variables. Section 4 discusses the results. Section 5 states the three foundational results. Section 6 identifies open problems.

2 Setup

2.1 Information Conservation

The universe is modelled as a closed informational system with a fixed total bit count n. From Paper III [2], random bit-flip mutations drive the system from a zero-entropy initial state toward full equilibrium, and filters applied to the evolving bitstring extract hierarchical micro-structures whose abundances follow lognormal-like distributions.

At any moment, the n bits are partitioned between two roles:

- **Spacetime fabric** L_0: bits not consumed by any composite structure, constituting the free background metric.
- **Matter hierarchy** $L_1, L_2, \ldots$: bits bound into composite structures at successive levels (e.g. hadrons, atoms, compounds).

Because the bit budget is fixed, matter structures do not represent new information injected from outside. Every bit locked into a composite entity is a bit withdrawn from the free fabric. Information is strictly conserved:

$$\rho_{\text{fabric}}(t) = n - m(t), \tag{1}$$

where $m(t) = \sum_k w_k \cdot k(t)$ is the total number of bits consumed by matter structures, $k(t)$ is the count of composite entities at each level, and w_k is the bit-width of a level-k structure.

2.2 The Relational Scale Factor

An internal observer can only measure distances using the structures available within the system. The resolution of observable space is therefore the total count of independently addressable entities — both free fabric tokens and composite matter structures.

Consider n bits, all initially free fabric, giving resolution n. When one composite structure of width w bits emerges, w fabric tokens are consumed and one matter entity is created. The new resolution is:

$$(n - w) + 1 = n - (w - 1).$$

Resolution decreases by $w - 1$ for every composite entity formed. Generalising, if matter structures collectively consume $m(t)$ bits and produce $k(t)$ composite entities, the total resolution at time t is:

$$\text{Resolution}(t) = \big(n - m(t)\big) + k(t).$$

The two extremes of General Relativity follow immediately from this counting argument:

- **De Sitter limit** ($m = 0,\ k = 0$): all bits are free fabric. Resolution $= n$. An external observer sees pure exponential expansion — the vacuum solution of General Relativity with $\Lambda > 0$ and $\rho_{\text{matter}} = 0$.
- **Schwarzschild limit** ($m = n,\ k = 1$): all bits are consumed into a single composite entity. Resolution $= 1$. The observable space has contracted to a single point — the informational counterpart of the black hole singularity established in Paper II [1].

These are not boundary conditions imposed by hand. They are the two extreme values of the same counting equation, separated by the continuous family of states in between.

The relational scale factor, normalised to the maximum resolution n, is:

$$R(t) = \frac{\big(n - m(t)\big) + k(t)}{n} = \frac{\rho_{\text{fabric}}(t) + k(t)}{n}. \tag{2}$$

This definition requires no external metric and no postulated background geometry. It is a pure counting statement: the scale factor is the fraction of the bit budget that remains independently addressable.

The equation is intrinsically 1D and linear. To map to observable 3D sphere geometry:

$$a_{\text{obs}} \propto 4\pi \cdot R(t)^2$$

This converts the linear bit-depletion curve into sperical and quadric $\cos^2$-shaped Schwarzschild interior profile.

3 Mapping to General Relativity

The Friedmann equation governs the expansion of a homogeneous, isotropic universe in General Relativity:

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho_{\text{matter}} + \frac{\Lambda}{3}.$$

The present framework maps onto this equation under the identifications:

$$\rho_{\text{matter}} \longleftrightarrow \frac{\sum_j k_j(t)}{n}, \qquad \Lambda \longleftrightarrow \frac{\rho_{\text{fabric}}(t)}{n}, \qquad a \longleftrightarrow R(t). \tag{3}$$

These identifications are not free parameters. They follow from the counting argument: matter entity density maps to ρ_{matter} because matter entities brake expansion by consuming fabric; free fabric density maps to Λ because it drives expansion by providing addressable resolution. The cosmological constant is not a parameter of the vacuum energy — it is the fraction of the bit budget that remains unbound.

The two GR boundary solutions are recovered exactly:

Limit	**Information picture**	**GR solution**
$k = 0,\ m = 0$	All bits free, $R = 1$	De Sitter ($\Lambda > 0,\ \rho = 0$)
$k = 1,\ m = n$	One entity, $R = 1/n$	Schwarzschild singularity

Numerical analysis shows the spatial contraction profile matches also across all states.

4 Discussion

4.1 Matter as Curvature

In General Relativity, matter curves spacetime through the stress-energy tensor. In the present framework, matter reduces the resolution of observable space by consuming free fabric. These are two descriptions of the same phenomenon: the presence of a composite structure makes the surrounding space less addressable, which an internal observer reads as curvature. Gravity is not a force acting on a background geometry; it is the geometric consequence of information being redistributed from fabric to structure.

4.2 The Cosmological Constant Problem

The cosmological constant problem asks why Λ is so small relative to the vacuum energy predicted by quantum field theory. In the present framework, Λ is not a property of the vacuum — it is the fraction of the bit budget that is currently unbound. Its value at any cosmic epoch is determined by how much matter has formed and how much has decayed. The problem dissolves: there is no vacuum energy to cancel, only a fabric density that evolves with the entropy of the universe.

4.3 No External Time

The bit-flip parameter t is not an external clock. It is the internal measure of entropy increase established in Papers I–IV. The expansion history of the universe is parameterised by how far the

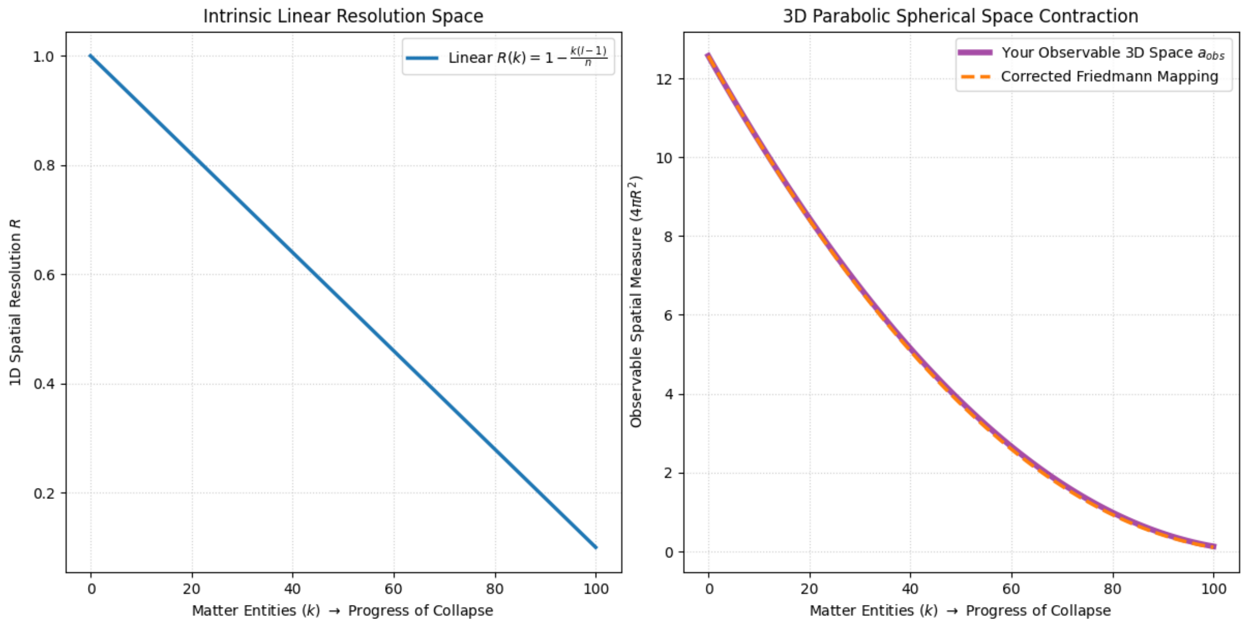

Figure 1: The purple (counting equation) and dashed orange (Friedmann mapping) curves perfectly overlap, demonstrating that general relativity's geometric contraction under the presence of matter is fundamentally equivalent to an internal observer's loss of background resolution.

system has progressed from zero entropy toward full saturation, not by an absolute time coordinate. This is consistent with the static, timeless picture of Paper I: the entire expansion history is encoded in n, and t is the internal observer's reading of their position along the entropy gradient.

5 Conclusion

This paper establishes two key results.

First, De Sitter space and the Schwarzschild singularity are the two extreme values of a single counting equation — the relational scale factor $R(t)$ defined by information conservation. De Sitter corresponds to all bits free ($R = 1$); Schwarzschild corresponds to all bits bound into one entity ($R = 1/n$). General Relativity's two boundary solutions are not independent discoveries but the endpoints of one information-theoretic spectrum.

Second, the Friedmann equation maps onto the framework under explicit variable identifications that follow from the counting argument alone. The cosmological constant is the free fabric fraction; matter density is the bound entity fraction; the scale factor is the addressable resolution fraction. No constants are fitted to observation.

6 Future Work

Analytic Derivation of the Friedmann Equation

A rigorous derivation requires showing that $(\dot{R}/R)^2 \propto k(t)/n + \rho_{\text{fabric}}(t)/n$ holds analytically.

Quantum Fields and the Wave Function

The framework developed in Papers I–V recovers the large-scale structure of spacetime from information conservation. The remaining foundational question is the origin of quantum field dynamics: why does the microcosm behave wave-like, and what selects a particular measurement outcome? This is addressed in Paper VI.

Cosmology and Inflatory Expansion

Explain the observed modest positive Hubble constant by applying the framework at the cosmological scale.

Supplementary Material

- `friedman.py:` Calculates and plots the 1D and 3D relational spatial contraction profiles based on the counting equation and the Friedmann equation.
- `spacetime_warp.py:` Simulates the evolution of the universe with three level of emergent structures (matter).

References

[1] Juha Meskanen. "Black Hole Singularities as Zero-Entropy States". In: *Unpublished Manuscript* (2002).

[2] Juha Meskanen. "Emergent Spacetime Structures from Zero-Entropy Initial States". In: *Unpublished Manuscript* (2003).

[3] Juha Meskanen. "The Axiomatic Foundations of Reality". In: *Unpublished Manuscript* (2001).

[4] Juha Meskanen. "The Geometry of Spacetime as an Information-Theoretic Structure". In: *Unpublished Manuscript* (2026).