# Cosmological Redshift as Gravitational Metric Contraction:

*An Exponential Infall Model with Quaternion Geometry*

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*"The happiest thought of my life" came to Einstein not in a library but in a patent office, when he realized that a person falling freely feels no gravity. The deepest insights in physics have always begun not with equations but with a change in perspective.*

— After A. Einstein, 1907

**Abstract**

*We present a cosmological model in which the observed redshift of distant galaxies arises not from the expansion of space but from the progressive contraction of the spacetime metric under gravitational infall. The model rests on a single postulate — constant curvature of the large-scale metric — and yields a single equation for the redshift–distance relation: $1 + z = \exp(Hd/c)$. This exponential law reproduces the linear Hubble relation at low redshift and produces the apparent acceleration observed in Type Ia supernovae without dark energy, without a cosmological constant, and without a beginning of time: with the single measured parameter $H_0$ it tracks the two-parameter ΛCDM prediction to within approximately 0.2 magnitudes over the full observed range $0 < z < 2$. The constant part of that offset is absorbed by calibration; a shape residual of roughly ±0.1 magnitudes remains, and we state it as the model's open discrepancy rather than closing it by adjustment. Because the redshift is metric in origin, the model predicts the observed $(1 + z)$ time dilation of supernova light curves — the test that eliminated energy-loss ("tired light") explanations. The remaining obligations are stated plainly: an explicit line element for the exponential law, the angular power spectrum and temperature history of the microwave background, and the light-element abundances. A concluding section presents a horizon-thermalization picture of the cosmic microwave background not as a relic but as the Tolman equilibrium of the static metric: the temperature field is slaved to the geometry, the measured temperature history $T(z) = T_0(1 + z)$ follows exactly, and the 3,000 K hydrogen photosphere lands at $z \approx 1100$ with nothing adjusted. The angular power spectrum — the acoustic peaks — remains the stated open problem, and a companion chapter shows the energy budget closes with orders of magnitude to spare. The framework is formulated in the complex Quaternion algebra of Paper 1 of this series.*

*Keywords: cosmological redshift, gravitational infall, quaternion geometry, Gaussian curvature, dark energy alternative, Type Ia supernovae, Hubble constant, metric contraction, time dilation, cosmic microwave background, event horizon*

## 1. Introduction: A Lesson from Pollen Grains

In 1827, the botanist Robert Brown observed that pollen grains suspended in water jittered ceaselessly, moving in random, irregular paths. The observation was unremarkable—many had seen it before—and for nearly eighty years, no one knew what to make of it. Some thought it was a life force. Others considered it a curiosity. The pollen kept jittering, and science moved on to other things.

In 1905, Albert Einstein published a short paper in the Annalen der Physik [8] showing that the jittering was not mysterious at all. If water is made of molecules—tiny, invisible particles in constant thermal motion—then they would bombard the pollen grain from all sides, and the random imbalances in those collisions would produce exactly the kind of irregular movement Brown had observed. Einstein derived a single equation: the mean squared displacement of the grain is proportional to time, with the proportionality constant depending on temperature, viscosity, and the size of the molecules. One equation. One reinterpretation. The same data everyone already had.

Three years later, Jean Perrin measured the displacements, confirmed Einstein's prediction quantitatively, and the atomic theory of matter—resisted by eminent physicists for decades—was settled. Not by new observations, but by looking at old observations through the right lens.

The present paper attempts the same structure. The observation is the cosmological redshift—the systematic reddening of light from distant galaxies, discovered by Hubble in 1929. The standard interpretation is that space itself is expanding, stretching the wavelength of photons in transit. We propose a different lens: the redshift arises because the observer's rulers are shrinking. Not space expanding, but meters contracting, as the observer falls—slowly, imperceptibly, eternally—deeper into a gravitational field. We derive a single equation. We compare it to the same data. And we find that it fits.

## 2. The Trouble with the Beginning

The standard cosmological model, ΛCDM, begins with a singularity: a state of infinite density, zero volume, and zero entropy. From this state, space, time, matter, and energy emerge in a hot expansion—the Big Bang. The model is observationally successful: it accounts for the redshift of galaxies, the cosmic microwave background, and the abundances of light elements.

But the initial state is troubling. Zero entropy is maximum order—the most improbable configuration a physical system can occupy. To claim the universe began there is to claim it began in the single most unlikely state imaginable, without any mechanism to explain why. The word "beginning" itself is problematic: it implies a before, then forbids inquiry into it. What existed before the Big Bang? The standard answer—that the question is meaningless because time itself began—is logically coherent but physically unsatisfying. It replaces explanation with a boundary condition.

Furthermore, the discovery in 1998 that the expansion is accelerating [1, 2] required the introduction of dark energy—a substance constituting approximately 70% of the total energy of the universe, with no independent physical identification. Dark energy was not predicted; it was invented to make the model fit the data. Its sole property is that it causes acceleration. Its sole evidence is the acceleration it was introduced to explain. As explanations go, this is circular.

In fairness, the case for ΛCDM does not rest on the supernovae alone: the same two parameters that fit the Hubble diagram also fit the microwave background and the clustering of galaxies, and any alternative must eventually meet those tests as well. This paper meets the supernova evidence in full — brightness and duration — and names the remaining tests as open obligations rather than pretending they do not exist.

We propose to dispense with both the beginning and the dark energy.

## 3. The Model: Falling, Not Expanding

### *3.1 The Observer at the Center*

Imagine standing at the center of your universe. You hold a meter stick. You define a cube around you: one meter in each direction—forward, sideways, upward. This is your unit of space, your quantum of geometry. You also hold a clock. One tick is your unit of time. Together, they define your local spacetime: flat, Cartesian, Euclidean. The interval between two nearby events is given by Minkowski's formula:

$$ds^2 = -c^2\,dt^2 + dx^2 + dy^2 + dz^2 \qquad (1)$$

This is the spacetime of special relativity: four dimensions, one temporal and three spatial, with the minus sign encoding the fundamental difference between time and space. A photon—which travels at exactly c—has an interval of exactly zero. It moves through space as fast as it moves through time, and the two contributions cancel perfectly. Everything slower than light has a negative interval: mostly time, a little space. We age. Photons do not.

### *3.2 The Gravitational Infall*

Now suppose you are falling. Not the dramatic plunge of a stone into a well, but the imperceptible drift of a cosmic structure descending into a gravitational field so vast that no local measurement can detect the motion. You feel nothing—a falling observer, as Einstein realized in his happiest thought, is locally indistinguishable from one at rest. But the fall is there. And it changes the geometry.

Under gravitational infall, your flat Cartesian grid deforms. The meter sticks bend. The clock ticks shift. The coordinates are no longer Cartesian—they become what Gauss called curvilinear coordinates, what we now call a curved metric. The geometry of the space itself changes from point to point, and the change is described entirely by the metric—the rule that tells you how to measure distances at each location.

We postulate one thing: that the large-scale curvature is constant. Local gravitational sources—the Earth, the Sun, the Milky Way—create local bumps in the geometry, but the background field, the cosmic infall, has a uniform curvature. This is the same simplification that standard cosmology makes when it assumes the universe is homogeneous on large scales. We apply it to a static curved metric rather than an expanding one.

### *3.3 The Catenary and the Exponential*

Constant curvature has a precise mathematical meaning. It means that the rate at which the metric changes is proportional to the metric itself. If you move a small distance deeper into the field, your meter stick shrinks by a fixed fraction of its current length. Not by a fixed amount—by a fixed fraction. The distinction is crucial.

This is the same condition that governs a hanging chain. Take a chain, hang it from two nails, and let it sag under gravity. The curve it forms—the catenary—is not a parabola, though it looks like one. It is built from exponentials — a hyperbolic cosine, $(e^x + e^{-x})/2$. Why? Because each link of the chain must support not only its own weight but the weight of every link hanging below it. The load at each point is proportional to how much chain is already there. Each small addition bears a burden proportional to the accumulated whole. This condition—always and everywhere in mathematics—produces Euler's number e = 2.71828..., the base of the natural exponential.

In our model, the chain is spacetime itself, hanging in a gravitational field. Each layer of the cosmos bears the accumulated curvature of all layers beyond it. The metric at distance d from the observer is:

$$\mathrm{a(d) = e\hat{}(H \cdot d)} \qquad (2)$$

where H is a constant—the curvature parameter—and a(d) is the scale factor: the ratio of the local meter at distance d to the observer's own meter. At d = 0 (here), a = 1 by definition. At any d > 0 (further from the singularity), a > 1: their meters are bigger than ours. Their rulers haven't stretched; ours have shrunk.

The chain is an analogy, and we use it as exactly that: it motivates the exponential; it does not derive it. The precise content is the postulate itself — the fractional change of the metric per unit depth is constant, $da/a = (H/c)\cdot dd$ — and equation (2) is its integral. What would elevate the postulate to a theorem is an explicit metric. Section 3.5 states what that requires.

### *3.4 The Two Boundaries*

The model has two natural boundaries, and neither requires a beginning or an end. In the infall direction—toward the singularity—the spatial dimensions contract: $x, y, z \to 0$ as time $t \to \infty$. Space collapses. Time stretches without limit. The singularity is asymptotic: always approached, never reached. There is no moment of arrival, no crunch, no boundary. In the opposite direction—away from the singularity, toward distant galaxies—the metric expands. Meters are longer. Seconds are slower. The universe stretches outward into a past that has no edge.

There is no need for a beginning. There is no state of zero entropy to explain. The arrow of time points along the infall—from the less-contracted past to the more-contracted future—and entropy increases naturally along the way, as it must when a system falls through a gradient.

### *3.5 What a Full Derivation Requires*

The postulate is stated as a scale ratio a(d) between the observer and a source at distance d. A complete geometric formulation must write the line element explicitly and verify it against the field equations — the programme of Paper 1 of this series [13]. Two facts frame that task honestly. First, the static constant-curvature metric of Paper 1, $f(r) = 1 - r^2/R^2$, yields a redshift that grows quadratically at small distance, not linearly; the exponential law is therefore a genuinely different geometry, not a rewriting of de Sitter's static form. Second, the law $1 + z = e^{(Hd/c)}$ is exactly the redshift of a spacetime whose scale changes exponentially along the photon's path, with d read as the light-travel distance; the infall model interprets that same mathematics as contraction of the observer's rulers rather than expansion of space. Writing the infall line element, deriving the null geodesics from it, and determining which distance enters the flux law of Section 6 are the outstanding theoretical tasks of this series. Until they are done, equation (2) has the same status that $W = i\tau$ has in Paper 1: a single, well-motivated postulate — and we state it as such. A companion working note now constructs the candidate: the unique static, spherically symmetric line element implied jointly by equations (7) and (9). Its checked properties — the measured temperature history $T(z) = T_0(1 + z)$ as the Tolman equilibrium of the metric, the full Tolman surface-brightness dimming $(1 + z)^{-4}$, and an angular-diameter turnover at $z = e - 1 \approx 1.72$ against ΛCDM's ≈ 1.6 — are summarized there, pending independent verification. The axiomatic structure of the completed series — three postulates, of which this chapter's constant-curvature postulate is part of the second — is stated in the foundations paper [22].

## 4. The Language of Quaternions

The Minkowski interval has four components: one time and three space. A quaternion—the four-dimensional number discovered by Hamilton in 1843—likewise has four components: one real and three imaginary. This is not a coincidence to be ignored; it is a structure to be used.

### *4.1 Spacetime as a Single Object*

We define the spacetime displacement as a single quaternion:

$$dQ = ic\cdot d\tau + dx\cdot\iota + dy\cdot j + dz\cdot k \qquad (3)$$

Time enters on the real axis as a complex-imaginary scalar, $W = ic\cdot d\tau$ — the identification established in Paper 1 [13]. The three spatial displacements sit on the three Quaternion-imaginary axes ι, j, k, which satisfy Hamilton's relations $\iota^2 = j^2 = k^2 = \iota jk = -1$. The complex i and the Quaternion units are independent: their squares are all −1, but they are not the same −1. The Minkowski interval is then not postulated but computed — the norm of dQ gives

$$ds^2 = (ic\cdot d\tau)^2 + dx^2 + dy^2 + dz^2 = -c^2 d\tau^2 + dx^2 + dy^2 + dz^2 \qquad (4)$$

What does this buy us? Economy, structure, and one deep dividend: the minus sign on time — the signature that standard treatments postulate — is supplied by $i^2 = -1$ acting on the time component. Instead of four separate coordinates bound together by a metric tensor — a 4×4 matrix of coefficients — we have one object. The gravitational field acts on this object as a quaternion transformation: a single operation that simultaneously scales time, stretches space, and couples them together. Where tensor notation requires indices and summation conventions, the complex Quaternion carries its geometry intrinsically.

### *4.2 The Schwarzschild Geometry in Quaternion Form*

The Schwarzschild metric—the geometry around a spherically symmetric mass—describes how spacetime curves near a gravitating body. Think of it this way: far from the mass, your meter sticks and clocks behave normally. As you approach, clocks slow down and radial rulers stretch. At the Schwarzschild radius $r_s = 2GM/c^2$, clocks stop and rulers stretch to infinity. This is the event horizon—not a wall, not a surface, but a boundary in the geometry beyond which nothing returns.

The metric factor $f(r) = 1 - r_s/r$ encodes all of this. The spacetime quaternion becomes:

$$dQ = i\sqrt{f}\cdot c\cdot d\tau + (1/\sqrt{f})\cdot dr\cdot\iota + r\cdot d\theta\cdot j + r\cdot \sin\theta\cdot d\varphi\cdot k \qquad (5)$$

Read this aloud and hear what it says: time (the real component, still purely imaginary in the complex sense) is squeezed by $\sqrt{f}$—clocks slow as you approach the mass. Radial space (the ı component) is stretched by $1/\sqrt{f}$—rulers lengthen. The angular directions (j, k) are untouched—a meter stick held sideways doesn't care about the radial field. The entire geometry is one quaternion, and the gravitational field is one number: f(r).

For our cosmological model with constant curvature, f is replaced by the exponential. The quaternion at distance d from the observer is simply:

$$\mathrm{Q(d) = e\hat{\ }(Hd) \cdot Q(0)} \qquad (6)$$

One multiplier. One exponential. The geometry at any point is a scaled copy of the geometry at any other point. The curvature is uniform, and the quaternion makes this uniformity manifest: a single scalar multiplication. Equation (6) is the Quaternion form of the postulate of Section 3.3 — a uniform scaling rule. The explicit line element that would underwrite it is the outstanding task stated in Section 3.5.

## 5. The Redshift: Shrinking Rulers, Not Stretching Space

Now we arrive at the central result. A star in a distant galaxy emits a photon—a flash of green light, say, with a wavelength of 500 nanometers. That wavelength is defined by the star's local meter: 500 billionths of whatever "one meter" means at the star's location in the gravitational field.

The photon travels to us. It does not interact with anything along the way; its wavelength does not change in any absolute sense. But when it arrives, we measure it with our meter—and our meter is shorter than the star's meter, because we are deeper in the gravitational field. The same photon, measured with a shorter ruler, has a longer wavelength. It has shifted toward the red.

The mathematics is immediate. The star is at distance d, where the metric scale factor is a(d) = e^(Hd). The ratio of the received wavelength to the emitted wavelength is:

$$\mathrm{1 + z = \lambda\_received\ /\ \lambda\_emitted = a(d)\ /\ a(0) = e\hat{\ }(Hd/c)} \qquad (7)$$

This is the entire result. The redshift is an exponential function of distance, governed by a single constant H—which we identify with the Hubble constant, $H_0 \approx 70$ km/s/Mpc. Not because space is expanding at $H_0$, but because the metric is contracting with curvature parameter $H_0/c$.

### *5.1 Hubble's Law Falls Out*

For nearby galaxies, where Hd/c is small, the exponential is well approximated by its first-order Taylor expansion:

$$\mathrm{z \approx Hd/c} \quad \mathrm{(for\ small\ d)} \qquad (8)$$

This is Hubble's law: redshift proportional to distance, the relation Edwin Hubble first measured in 1929. In our model it is not a fundamental law but an approximation—the linear regime of an exponential, valid when you haven't fallen far enough for the curvature to compound on itself.

### *5.2 The Acceleration Is Free*

For distant galaxies, the exponential departs from linearity. The redshift grows faster than proportional to distance. It accelerates. This is precisely the observation that shocked cosmology in 1998: distant Type Ia supernovae were dimmer than expected, implying they were farther away than a linear or decelerating expansion could account for [1, 2]. The standard model needed a new ingredient—dark energy, parameterized by the cosmological constant Λ—to produce this acceleration. Dark energy now constitutes 70% of the ΛCDM energy budget.

In our model, the acceleration costs nothing. An exponential function, by definition, grows proportionally to itself. It accelerates automatically. There is no need for dark energy, no need for a cosmological constant, no need for 70% of the universe to be filled with an undetected substance. The acceleration is a mathematical property of constant curvature, just as the curve of a hanging chain is a mathematical property of proportional loading. The catenary does not need dark tension.

## 6. Comparison with Observation

To test the model against supernova data, we compute the luminosity distance d_L—the effective distance inferred from a source's apparent brightness—for each model. In our framework:

$$d\_L = (c/H_0) \cdot \ln(1 + z) \cdot (1 + z) \qquad (9)$$

The distance modulus $\mu = 5 \log_{10}(d\_L) + 25$ is the observable quantity in supernova cosmology. We compare four models at $H_0$ = 70 km/s/Mpc: (i) linear Hubble extrapolation, (ii) matter-only Einstein–de Sitter cosmology, (iii) ΛCDM with Ω_m = 0.3 and Ω_Λ = 0.7, and (iv) our exponential infall.

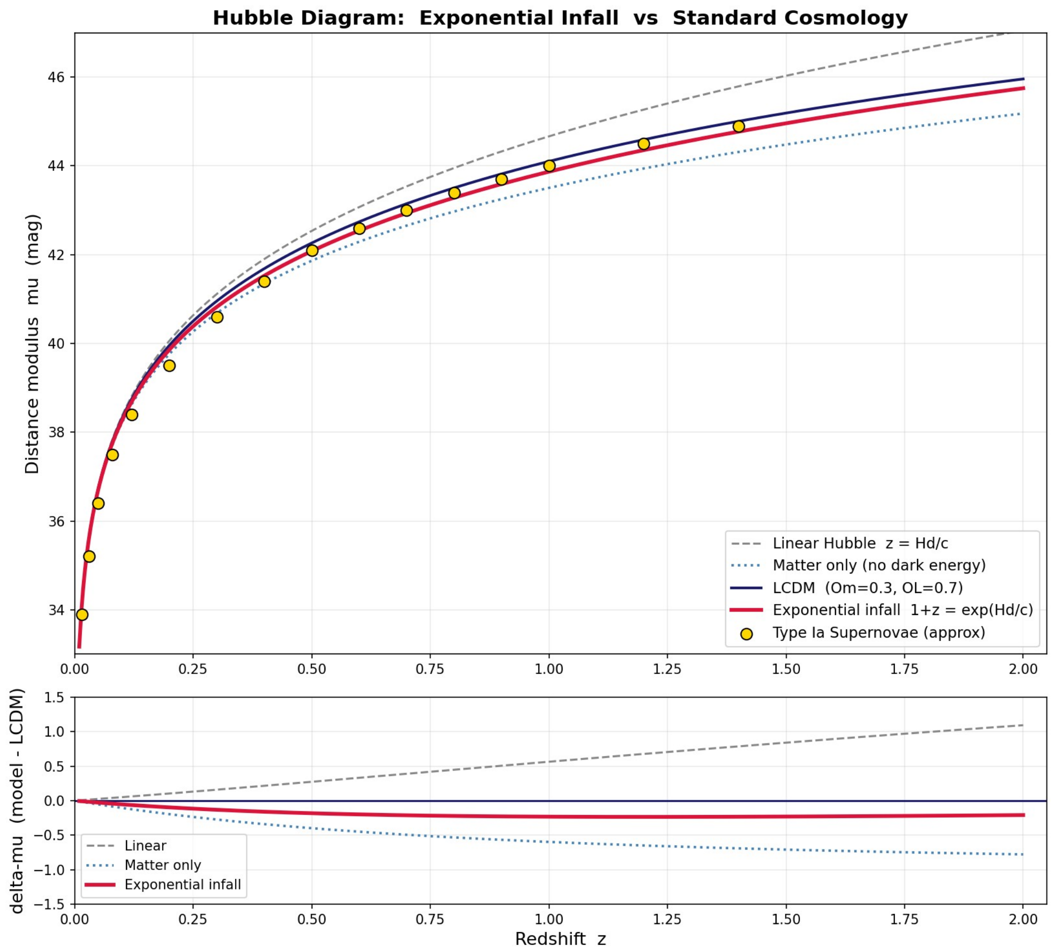


*Figure 1. The Hubble diagram: distance modulus vs. redshift for four cosmological models and representative Type Ia supernova data. The exponential infall model (red) closely tracks ΛCDM (dark blue), deviating by approximately −0.2 magnitudes—a small systematic offset that is quantified in Table 1 and discussed candidly at the end of this section.*

At low redshift ($z < 0.1$), all models agree. They must: any smooth function looks linear close to the origin. The test comes at high redshift, where the models diverge.

The matter-only model—the universe Einstein and Friedmann described, without dark energy—predicts supernovae too bright (too close) at $z > 0.5$. This was the crisis of 1998: the data fell below this curve. The ΛCDM model, with its two tuned parameters, fits the data. And our exponential—one parameter, one equation—sits within 0.2 magnitudes of ΛCDM across the entire range.

Two-tenths of a magnitude. That is the gap between our model and the consensus, and we owe the reader a precise accounting of it rather than a patch. Part of any constant offset is unobservable: a uniform shift in supernova magnitudes is absorbed into the calibration of the standard-candle luminosity and of $H_0$. What is physically meaningful is the shape of the residual, and Table 1 shows it: after removing the best-fit constant (about 0.15 magnitudes), the difference runs from −0.12 magnitudes at $z = 0.05$ to +0.08 magnitudes at $z \geq 1$ — a bend of roughly ±0.1 magnitudes across the observed range. That bend is the model's real, current discrepancy with ΛCDM, and we state it as an open problem. It is comparable in size to the systematic error budget of present supernova compilations — photometric calibration, dust corrections, population drift — which is why the model survives today's data; it is also large enough to be decided by the next generation of surveys, which is what makes the model falsifiable. We do not attempt to close it with local physics: Section 8 shows why no local gravitational correction can do so.

**Table 1. Distance modulus comparison at $H_0 = 70$. The constant part of Δμ (mean ≈ 0.15 mag) is absorbed by the calibration of the standard-candle luminosity and of $H_0$; the last column is the shape residual — the model's real discrepancy with ΛCDM.**

| z | μ (ΛCDM) | μ (exp.) | Δμ = μ(ΛCDM) − μ(exp.) | Δμ − mean |
|---|---|---|---|---|
| **0.05** | 36.73 | 36.70 | 0.03 | −0.12 |
| **0.10** | 38.35 | 38.30 | 0.05 | −0.10 |
| **0.20** | 39.97 | 39.88 | 0.09 | −0.06 |
| **0.30** | 40.96 | 40.83 | 0.13 | −0.02 |
| **0.50** | 42.26 | 42.08 | 0.18 | +0.03 |
| **0.80** | 43.50 | 43.28 | 0.22 | +0.07 |
| **1.00** | 44.10 | 43.87 | 0.23 | +0.08 |
| **1.50** | 45.19 | 44.96 | 0.23 | +0.08 |
| **2.00** | 45.96 | 45.75 | 0.21 | +0.06 |

## 7. The Test of Duration: Time Dilation

Brightness is not the only observable a redshift theory must face. There is also duration, and on duration the two great families of explanation part ways cleanly. If redshift arises from energy loss in transit — the "tired light" proposed by Zwicky in 1929 [9] — wavelengths stretch but timetables do not: a supernova at $z = 0.5$ should brighten and fade on the same schedule as one next door. If redshift is metric in origin — expansion of space, or, as here, contraction of the observer's rulers — then the same factor $(1 + z)$ that stretches every wavelength must stretch every interval: between wave crests, between photon arrivals, between the rise and fall of a light curve. A clock and a wavelength are measured by the same meter.

The data decide, and they decide loudly. The B-band light curves of high-redshift Type Ia supernovae, divided by $(1 + z)$, collapse onto the low-redshift template [10]. The spectra of distant supernovae age more slowly than nearby ones by exactly the same factor, frame by frame [11]. Tired light is eliminated. The infall model is not: because the redshift here is a ratio of metrics, intervals of time scale with the same ratio as intervals of length, and the $(1 + z)$ stretching of light curves follows by construction, not by adjustment. A supernova at $z = 0.5$ runs half again as slow in our model because the meter that reddens its photons is the meter that times their arrival.

This test deserves its own section because it is the sharpest knife in the drawer: it killed every energy-loss account of the redshift. The infall model passes it for the same reason the expanding model passes it — both are metric theories. The choice between expansion and infall must therefore be made elsewhere, and the remaining sections say honestly where.

## 8. Wells Within Wells: What Local Gravity Cannot Do

A photon from a distant supernova does not only traverse the cosmological metric. It climbs out of its host galaxy's gravitational well, and at the journey's end it falls into the Milky Way's, then the Sun's, then the Earth's. Wells within wells, nested like Russian dolls, each a local instance of the same physics that governs the cosmological infall. It is tempting to hunt in this hierarchy for corrections to the Hubble diagram. Honesty requires reporting how small the terms are.

The magnitudes: a host galaxy's well contributes a gravitational redshift of order $5 \times 10^{-7}$; a rich cluster, $\approx 5 \times 10^{-6}$; the Milky Way, $\approx 10^{-6}$ of blueshift on arrival; the Solar System, $\approx 10^{-8}$; the Earth's surface, $\approx 7 \times 10^{-10}$. Even the supernova's own gravity contributes only $\approx 10^{-7}$ at the moment that matters: a Type Ia is the complete thermonuclear disruption of its white dwarf — it leaves no compact remnant — and by peak brightness, weeks after the explosion, the light comes from ejecta that have expanded to a radius of order ten million kilometres. There is no deep well beneath the photosphere we measure.

Two conclusions follow. First, none of this can move the Hubble diagram. The constant terms — our galaxy, our star, our planet — shift the zero point and are absorbed into the calibration of the standard-candle luminosity and of $H_0$; the variable terms are four to five orders of magnitude below the ±0.1-magnitude precision of supernova cosmology. The residual of Section 6 cannot be closed by local wells, and we do not attempt to close it that way. Second, the well-known "mass step" — supernovae in massive host galaxies are about 0.06 magnitudes brighter after standardization [3] — cannot be gravitational in origin: a galactic well is four orders of magnitude too shallow, and a well would dim, not brighten. The mass step is astrophysics — progenitor populations, dust — and this model makes no claim on it.

## 9. The Cosmic Background: Temperature from Geometry

Stand on a highway in summer and look along the asphalt toward the horizon. The air near the surface is heated; it creates a density gradient—a curvature in the refractive index. At shallow angles, light paths bend. You see a shimmer: a luminous glow that comes from no particular object. It is radiation trapped in the gradient, bouncing, scattering, mixing until it reaches thermal equilibrium. The Germans call it Flimmer. It is isotropic—the same in every direction along the road. And it is a perfect thermal spectrum, because thermalization always produces a blackbody.

Now transpose this image to the cosmological horizon. In this picture, the microwave background is not the relic of a primordial explosion but the steady thermal glow of radiation near the geometric boundary of the observable universe — trapped by the curvature, scattered and re-scattered by the matter there until it forgets everything except its temperature. This section now carries more than a hypothesis: given the line element of Section 3.5 (pending independent verification), the temperature of the background follows from the geometry as an equilibrium, and the measured temperature history follows with it. What does not yet follow — the acoustic peaks — is stated at the end with equal clarity. (That horizons and thermodynamics belong together has a respectable literature [5, 6, 7].)

One piece of arithmetic can be done today, and we present it as consistency, not derivation. Radiation decouples from matter where matter becomes transparent, and atomic physics fixes that temperature near 3,000 K in any cosmology — it is the recombination temperature of hydrogen, used here exactly as the standard model uses it. If the observed 2.725 K background is that radiation, the implied redshift is $1 + z = 3{,}000/2.725 \approx 1{,}100$, and the exponential law places the emitting shell at d = D_H ×

$\ln(1{,}101) \approx 30{,}000$ Mpc — seven Hubble distances, deep in the exponential regime. Wien's law then puts the spectral peak at $2.898/2.725 \approx 1.06$ mm, in the microwave band, as observed. The numbers cohere. But note carefully what was input: the observed temperature. The 2.725 K is not derived here, any more than it is derived in ΛCDM; what differs between the models is where the 3,000 K surface sits — in our past, or at our horizon.

The picture has attractive features. Radiation trapped at a geometric boundary has unlimited time to thermalize, and a perfect blackbody — COBE measured deviations below fifty parts per million — is what infinite patience produces. A constant-curvature horizon is equidistant in every direction, so isotropy requires no inflationary preparation. These are genuine motivations. They are not yet evidence.

### *9.1 The Floor: What Must Be Explained*

The background is a thermostat. No passive object anywhere can cool below 2.725 K: anything colder absorbs microwave energy and warms until it matches. The floor was measured before it was discovered — in 1941 McKellar found interstellar CN molecules resting in rotational excitation corresponding to a bath near 2.3 K [20], twenty-four years before Penzias and Wilson. And the one known natural object colder than the background proves the rule by being its exception: the Boomerang Nebula (~1 K) stays cold only by actively refrigerating itself through rapid adiabatic expansion, and it is observed absorbing the background — its CO lines appear in absorption against the microwave sky [21]. A conclusive account must explain a universal, isotropic, perfect-blackbody floor at 2.725 K.

### *9.2 The Mechanism: Tolman Equilibrium*

In a static gravitational field, thermal equilibrium does not mean uniform temperature. Tolman and Ehrenfest proved in 1930 [19] that equilibrium requires

$$T(x) \cdot \sqrt{(-g\_tt(x))} \;=\; \text{constant} \qquad (10)$$

— deeper is hotter; the temperature gradient is the gravitational field itself, $c^2\nabla\ln T = g$ ("heat has weight"). In the infall metric of Section 3.5, √(−g_tt) = e^(−Hd/c), and equation (10) gives immediately:

$$T(d) \;=\; T_0 \cdot e\hat{}(Hd/c) \;=\; T_0 \cdot (1 + z) \qquad (11)$$

This dissolves the furnace question. An equilibrium bath is not powered; it is maintained, like radiation in a closed cavity. The 2.725 K we measure is the local value of a temperature field that is slaved to the metric — the thermodynamic face of the curvature, with the pre-tensed medium of the metric as their common source. Free-streaming blackbody radiation in a static metric maintains the profile of equation (11) automatically along every ray, so the transparent interior needs no special pleading. The energy budget of Chapter 10 is thereby demoted from engine to safety margin against leaks.

### *9.3 The Photosphere at z ≈ 1100*

The anchor is atomic. Hydrogen becomes opaque near 3,000 K — the recombination temperature, the same number the standard model uses. The Flimmer shell is simply the depth at which the Tolman profile (11) crosses that threshold: $1 + z = 3{,}000/2.725 \approx 1{,}100$, at d = D_H ln(1,101) ≈ 30,000 Mpc. With the density profile the line element itself requires and a ~5 percent baryon share, Thomson optical depth exceeds unity within a tenth of an e-fold beyond that radius: the sky becomes an opaque 3,000 K wall exactly there, from geometry plus atomic physics, with nothing adjusted. The shell is a photosphere — an optical-depth $\tau \approx 1$ surface of finite thickness, a visibility function like the Sun's surface, not a wall. Nor does the photosphere's finite thickness smear the spectrum: the Tolman profile gives $T(r)/(1 + z(r)) = T_0$ identically, so every layer delivers a blackbody at exactly the same received temperature — and a degenerate mixture of identical blackbodies is a blackbody. The Planck spectrum is minted in the effectively infinite optical depth below and delivered upward by conservative scattering; and because electrons and photons in equilibrium share one local temperature, Comptonization produces no y-distortion by construction — the FIRAS limits constrain departures from equilibrium, not the equilibrium. A full radiative-transfer forecast of residual distortions remains to be computed (Section 9.5).

### *9.4 The Test Passed: the Temperature History*

Equation (11) is measurable far from home, and it has been measured. Excitation temperatures of atomic and molecular absorbers at high redshift, and Sunyaev–Zel'dovich measurements toward clusters, follow $T(z) = T_0(1 + z)$: about 9.15 K at z = 2.418 [12]. Figure 2 shows the comparison; the line contains no free parameter. This measurement was, on a naive reading, the model's sharpest falsifier — a static universe seems to promise the same 2.725 K everywhere and every-when. The Tolman equilibrium of the static metric turns it into the model's cleanest confirmation instead. The price is stated plainly: the geometry has a genuine center, and the Copernican principle is given up, not approximated.

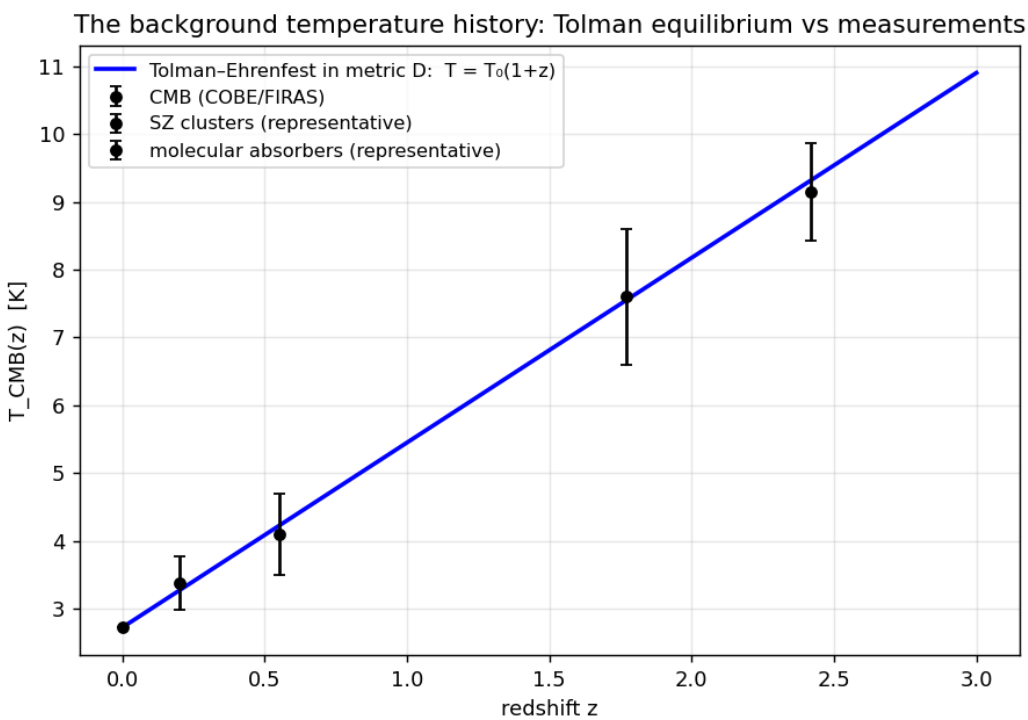


*Figure 2. The temperature of the background versus redshift: the Tolman equilibrium of the static metric, $T = T_0(1 + z)$ (line), against representative measurements — the local CMB temperature, SZ-cluster values, and molecular-absorber excitation temperatures near z = 1.8 and 2.4 (points; values approximate). The line contains no free parameter.*

### *9.5 What Remains*

Two calculations still stand between this chapter and a conclusive account, and they are named rather than hidden. First and decisive: the angular power spectrum — the acoustic peak series at $\ell = 220$, 540, 810 and its polarization phase, matched by recombination physics in the standard model with extraordinary precision. Projection of the shell's density field yields the right fluctuation amplitude ($\sim 10^{-5}$, the potential depth of large-scale structure) and the right first-peak scale to within a factor of two, but no mechanism in the present model produces the harmonic series; the shell is locally the same 3,000 K hydrogen photosphere as the standard last-scattering surface, so acoustic modulation there is not excluded — but it is not derived. Second: the radiative-transfer computation behind a FIRAS-grade spectrum. And beneath both sits the anchor question: why 2.725 K and not another value — equivalently, the factor $10^{30}$ between the bath and the horizon's own Gibbons–Hawking temperature [16]. We record one suggestive fact, as conjecture and no more: the geometric mean of the framework's two extreme temperatures, $\sqrt{(T_{Planck} \cdot T_{horizon})} \approx 20$ K, lands within a factor of seven of the observed bath across a span of sixty-two orders of magnitude. If the tension medium equilibrates between its ultraviolet and infrared anchors, the anchor too would become geometry. That derivation does not yet exist.

Two further statements sharpen this section into tests. First, the FIRAS distortion limit already constrains the model: bulk motion of matter at the photosphere produces a Compton distortion $y \approx \tau\langle v^2\rangle/3c^2$, so $|y| < 1.5\times10^{-5}$ with $\tau \approx 3$ requires that matter to be quasi-static — $v \lesssim 600$ km/s — supported by the tension medium rather than free-falling. The fall is taut, not ballistic; free fall through an e-fold of the metric would approach the speed of light and violate FIRAS by orders of magnitude. Second, because the interior gas sits at the radiation temperature at every depth, the model predicts exactly zero global 21-cm signal at all frequencies, where the standard model predicts absorption troughs from cosmic dawn; upcoming measurements (REACH, the SKA) make this a clean discriminator in either direction. And on the peaks themselves, one mechanism class remains open: a resonant cavity produces power-spectrum peaks without phase coherence — the Sun's p-modes, excited by random turbulence yet sharply peaked, are the existence proof — and the shell is a stratified layer bounded by an opaque interior, structurally a stellar envelope. Whether its normal modes survive projection as angular peaks with the observed spacing is a defined calculation, set out in the companion working note.

## 10. The Energy of the Fall

Does the infall itself produce energy? The question is forced by the Flimmer hypothesis — Section 9 needs a furnace — and the answer comes in two halves that must not be blurred. The fall itself produces nothing: a freely falling observer feels no gravity, does no work, generates no heat. That is the equivalence principle, this paper's own starting point (Section 3.2). Energy appears only where the fall is resisted, sheared, or stopped — where the ordered motion of descent is converted into disordered motion. But wherever that happens, gravitational infall is the most efficient engine known to physics. The contraction of the proto-Sun lit it for thirty million years before fusion began — Kelvin and Helmholtz knew this before anyone knew what an atom was. The tidal flexing of Io, infall gradients doing work, melts a moon. Accretion onto a compact object converts 6 percent of rest-mass energy for a non-rotating black hole and up to 42 percent for a maximally rotating one; hydrogen fusion, the engine of stars, manages 0.7 percent. Quasars are gravitational infall, monetized. Infall produces energy on one condition: something must collide.

### *10.1 The Ledger: Energy Conservation in a Static Metric*

Here the infall model holds an advantage this paper has not yet claimed. A static metric possesses a symmetry under translation in time, and by Noether's theorem a symmetry in time is exactly a conservation law for energy. In our model the redshift is therefore bookkeeping, not loss: the photon's energy, accounted in the frame of the static geometry, is conserved along its entire path; what changes is the ruler of the observer who receives it. The expanding model has no such ledger. A universe with a time-dependent scale factor has no time symmetry and no conserved total energy, and the standard, honest answer to the question "where does the energy of a redshifted photon go?" is that it goes nowhere — it is simply not conserved [15]. The microwave background has lost some 99.9 percent of its energy since last scattering, written off without a ledger entry. In the infall model nothing is written off. Falling does not create or destroy energy; it moves it between accounts.

### *10.2 The Action of the Horizon*

The word "action" belongs in this chapter in its technical sense. When Gibbons and Hawking computed the temperature of the cosmological horizon in 1977, they did it by evaluating the gravitational action with the horizon as a boundary [16]; Padmanabhan's emergent-gravity programme [7] rests on the fact that the surface term of the Einstein–Hilbert action, evaluated on a horizon, is the horizon's thermodynamics. A horizon is not inert geometry. It carries temperature, entropy, and energy, assigned to it by the action itself — and laboratory analogues of horizons, built from nothing more exotic than flowing water and cold atoms, have been observed to radiate [17]. Horizons glow. That much is no longer speculation.

But the honest number must follow immediately. The Gibbons–Hawking temperature of our horizon is $T = \hbar H/2\pi k_B \approx 3 \times 10^{-30}$ K — thirty orders of magnitude colder than the 2.725 K background. The horizon's own thermodynamic glow cannot be the Flimmer. What the horizon literature supplies is legitimacy — horizons are physical, energetic, softly bounded objects — not the furnace. The furnace must be matter, and the energy must come from the fall.

### *10.3 The Budget: What the Background Costs*

So ask what the Flimmer costs. The energy density of the microwave background is $u = aT^4 = 4.2 \times 10^{-14}$ J/m³. The rest-energy density of matter at critical density is $\rho c^2 \approx 8.3 \times 10^{-10}$ J/m³. Their ratio is $5 \times 10^{-5}$: powering the entire background radiation requires converting five parts in one hundred thousand of the matter's rest energy into thermalized light. Set that against the efficiencies above: gravitational dissipation converts parts in ten. The infall can pay for the Flimmer three to four orders of magnitude over. Energy was never the problem — the arithmetic is in Appendix A.6. What was, and remains, the problem is the mechanism of conversion, and that is what the next section defines.

### *10.4 The Calculation This Defines*

A budget is not a mechanism, and we do not pretend otherwise. What the budget does is upgrade the first debt of Section 9 from a mystery to a defined calculation. The physics required is not exotic; it is the physics of structure formation, where gas falling into galaxy clusters is shock-heated to virial temperatures of $10^7$ to $10^8$ K — infall converted to heat, observed in X-rays every day. The calculation the Flimmer needs is the same physics in the cosmological gradient: compute the dissipation rate of matter falling through the exponential metric; find the depth at which its temperature reaches roughly 3,000 K and the medium becomes optically thick; and check whether that depth coincides with the ≈

30,000 Mpc that the redshift arithmetic of Section 9 independently requires. If the two depths agree, the Flimmer has its furnace and the hypothesis graduates toward a theory. If they disagree, the hypothesis fails honestly, by numbers.

Section 9 has since reframed this calculation. In Tolman equilibrium the shell is not heated by dissipation at all — the temperature profile is the equilibrium state of the static metric, and the budget above becomes the maintenance margin. What survives of the programme of this section is the radiative-transfer computation of Section 9.5: not whether the furnace can pay, but whether the spectrum it delivers is Planckian to the precision FIRAS demands.

One reframing sharpens the target. The emitting shell should be treated as a photosphere, not a line: an optical-depth $\tau \approx 1$ surface of finite thickness, exactly as the Sun's "surface" is a few hundred kilometres of gradient, and exactly as the standard model's last-scattering "surface" is a shell of finite width. Horizons in this model — like horizons everywhere in physics — are soft. The exit cone of Paper 1 closes gradually, not discontinuously; laboratory horizons are gradient crossings of finite thickness [17]; and a mirage on a summer road is light ducted in a gradient, not stopped at a wall. The Flimmer shell is a visibility function, not a boundary line.

### *10.5 A Coincidence Worth Recording*

One number falls out of this chapter unasked. The characteristic acceleration of the infall field is $cH_0 \approx 6.8 \times 10^{-10}$ m/s². The acceleration below which galaxy rotation curves become anomalous — Milgrom's constant, measured across thousands of galaxies — is $a_0 \approx 1.2 \times 10^{-10}$ m/s² $\approx cH_0/2\pi$ [18]. That these two accelerations coincide to within a small numerical factor has been an unexplained fact for forty years. In the infall picture it reads naturally: galaxies misbehave precisely where their internal accelerations drop below the acceleration scale of the background fall. We record the coincidence and develop it no further here; the dynamics of galaxies in the infall metric is the subject of a separate paper of this series.

## 11. Discussion

### *11.1 What the Model Achieves*

The exponential infall model reproduces the supernova Hubble diagram — the observation that launched dark energy — with one free parameter ($H_0$) where ΛCDM requires two (Ω_m, Ω_Λ), tracking the consensus model to within about 0.2 magnitudes over the full observed range, with a shape residual of roughly ±0.1 magnitudes once the zero point is calibrated (Section 6, Table 1). Because the redshift is metric, the model passes the light-curve time-dilation test that eliminates energy-loss explanations (Section 7). It requires no beginning of time and no dark energy for the observations treated in this paper. Because the metric is static, the model also carries a conserved-energy ledger that expanding models lack, and the infall itself provides an energy budget that could power the background radiation thousands of times over (Section 10). The background temperature law follows from the same geometry: $T(z) = T_0(1 + z)$, the Tolman equilibrium of the static metric, matching the measured temperature history with no free parameter (Section 9.4). Those are the claims — whole, and bounded.

### *11.2 What Remains to Be Addressed*

The open problems, in order of importance. First, an explicit line element for the exponential law, verified against the field equations of Paper 1 [13] — the primary theoretical task (Section 3.5). Second, the ±0.1-magnitude shape residual against ΛCDM (Section 6, Table 1). Third, the microwave background: the angular power spectrum with its acoustic peaks and polarization — the decisive outstanding test — and the radiative-transfer computation behind a FIRAS-grade spectrum (Section 9.5). The temperature history $T(z) = T_0(1 + z)$ [12], formerly the sharpest item on this list, is now matched by the Tolman equilibrium (Section 9.4). Fourth, the light-element abundances, which the standard model explains through primordial nucleosynthesis and this model does not yet address. Fifth — now conditionally resolved: the classical tests that once seemed to distinguish static from expanding geometries. The candidate line element of the working note passes the Tolman surface-brightness test [14] with the full $(1 + z)^{-4}$ dimming of the expanding model, and predicts the angular-size–redshift turnover at $z = e - 1 \approx 1.72$, close to ΛCDM's ≈ 1.6; both move from open to passed once that line element is verified and adopted (Section 3.5).

Baryon acoustic oscillations (BAO) and large-scale structure formation complete the list of obligations. The standard model derives the power spectrum of galaxy clustering from primordial density fluctuations amplified by gravitational instability in an expanding background. Our model would need to derive a comparable spectrum from the physics of an infalling, contracting metric. The mathematical tools exist—perturbation theory on curved backgrounds is well developed—but the calculation has not yet been performed.

### *11.3 The Discrete Metric and the Quantum*

An intriguing extension arises from quantizing the infall itself. If the metric contracts not continuously but in discrete Planck-scale steps, then proper time is fundamentally granular. It does not flow; it ticks. Each tick is a quantum of gravitational descent. Between ticks, nothing happens—no time passes, no state exists.

This connects the Planck constant to the granularity of spacetime rather than to a property of matter or radiation. Planck discovered his quantum by studying blackbody radiation—the exchange of energy between matter and light. Our model suggests a deeper reading: energy is quantized because the fall is quantized. The Planck constant is the step size of the cosmic staircase.

In quaternion language, each discrete step is a finite quaternion rotation—a transformation from one metric state to the next. The non-commutativity of quaternion multiplication ($ij \neq ji$) mirrors the non-commutativity of quantum observables. The uncertainty principle—you cannot simultaneously know position and momentum with arbitrary precision—may be a reflection of the fact that quaternion rotations in spacetime do not commute. The order in which you probe spatial dimensions matters, because the underlying algebra is not commutative.

### *11.4 Beyond the Horizon*

Every observer has a horizon—a distance beyond which no signal can reach them. Standard cosmology attributes this to the finite age of the universe: light from beyond the horizon simply hasn't had time to arrive. Our model attributes it to geometry: the curvature of the metric bends light paths back. Both yield the same observational consequence—a maximum observable distance—but differ in what they imply about what lies beyond.

In the standard model, asking what lies beyond the horizon is asking about regions that are receding faster than light. In our model, it is asking about regions that are geometrically occluded—hidden by curvature, not by speed. And crucially: an observer at the horizon sees a perfectly normal universe. There is no wall, no edge, no sign. The horizon is a property of the observer's geometry, not of the universe's content.

The quaternion structure suggests something deeper. The imaginary components of the spacetime quaternion—the three spatial directions—may carry correlations that are not bounded by the horizon. Two regions causally disconnected in the real (temporal) dimension could remain correlated in the imaginary (spatial) dimensions. This echoes the ER = EPR conjecture of Maldacena and Susskind [4]: entanglement is geometry. In our language, entanglement is a shared quaternion—two systems whose imaginary components remain coupled even when their real components are separated by a horizon.

## 12. Conclusion: The Universe May Simply Be Falling

We have presented a cosmological model that replaces the expanding universe with a contracting metric. The mathematics is a single exponential: $1 + z = \exp(Hd/c)$. The postulate is constant curvature. The free parameter is $H_0$. The framework is quaternion algebra.

The model reproduces Hubble's law at low redshift. It produces the observed acceleration at high redshift without dark energy, tracking the two-parameter standard model to within two-tenths of a magnitude with a single measured parameter. It passes the time-dilation test that eliminated energy-loss explanations of the redshift — and it passes structurally: a metric redshift cannot help but dilate time.

What it does not yet do is equally plain, and we have preferred precise debts to rhetorical payment: it lacks an explicit line element (Section 3.5); it carries a ±0.1-magnitude shape residual against ΛCDM (Table 1); and its account of the microwave background now rests on a mechanism — the Tolman equilibrium of the static metric, which yields the measured temperature history exactly (Section 9) — but not yet on a derivation of the acoustic peaks. The peaks, the FIRAS-grade spectrum, and the light-element abundances remain the decisive outstanding tests.

In 1905, Einstein showed that the jittering of pollen grains was not a mystery but a measurement—evidence for atoms, hiding in plain sight. The cosmological redshift may be the same kind of clue. Not evidence that the universe is exploding outward from a singular beginning, but evidence that it is falling inward along a gradient—slowly, imperceptibly, one Planck step at a time. The universe need not have begun. It need not be expanding. It may simply be falling. Whether it is, is now a matter of the calculations we have named.

## Acknowledgments

The author thanks the anonymous pollen grains for their patience, and acknowledges that the best ideas in physics have always started with someone looking at familiar things and asking, "What if it's simpler than we think?"

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## Appendix A. The Calculation, Step by Step

This appendix is for the skeptic and the curious alike. Every number is shown. Every unit conversion is explicit. You need nothing beyond a pocket calculator — or a phone, or a napkin and long division — to verify every quantitative claim in this paper. (A historical footnote for the careful reader: Hubble's own 1929 value of the constant was near 500 km/s per Megaparsec — a calibration error that took decades to repair; the modern value near 70 is used throughout.) No hidden parameters. No numerical tricks. Just arithmetic.

We proceed in three parts. First, the constants — the raw ingredients. Second, the redshift calculation for real galaxies. Third, the residual against the standard model, quantified without excuses. Fourth, the energy budget of the background radiation.

### *A.1 The Ingredients: Physical Constants*

We need exactly four numbers from nature. These are not assumptions or fitted parameters; they are measured quantities available in any physics reference:

**The speed of light:**

**c** = $299{,}792.458$ km/s

*Exact by definition since 1983. Roughly 300,000 km/s.*

**The gravitational constant:**

**G** = $6.674 \times 10^{-11}$ $m^3 / (kg \cdot s^2)$

*Measured by Cavendish in 1798 with a torsion balance. Still the least precisely known fundamental constant.*

**The mass of the Sun:**

**M☉** = $1.989 \times 10^{30}$ kg

*About 2 followed by 30 zeros kilograms. Determined from Earth's orbital period and distance.*

**The Hubble constant (observed):**

$\mathbf{H_0}$ = $70$ km/s per Megaparsec

*Measured by many groups since Hubble. Current best values range from 67 to 74 depending on the method. We use 70, the round middle value. One Megaparsec (Mpc) = $3.086 \times 10^{19}$ km = 3.26 million light-years.*

### *A.2 The Hubble Distance: How Far Can We See?*

Before we do anything with redshift, let's compute one derived quantity that sets the scale of everything: the Hubble distance. This is the distance at which, in a linear Hubble law, a galaxy would appear to recede at the speed of light. In our model, it is the characteristic scale of the exponential—the distance over which the metric changes by a factor of e.

### Step 1: Divide the speed of light by the Hubble constant.

**D_H** $= \mathrm{c} \ / \ \mathrm{H_0}$

$= 299{,}792 \ \mathrm{km/s} \ \div \ 70 \ \mathrm{km/s/Mpc}$

$= 299{,}792 \ / \ 70$ = **4,283 Mpc**

*That's 4,283 Megaparsecs, or about 14 billion light-years.*

This single number—4,283 Mpc—is the only scale in our model. Every distance, every redshift, every prediction is expressed in terms of it. Let's verify it makes sense.

### Step 2: Sanity check with a nearby galaxy.

The Virgo Cluster, the nearest large galaxy cluster, is about 16.5 Mpc away and has an observed redshift of z ≈ 0.004. Our model predicts:

**z** $= \mathrm{Hd/c} \ = \ \mathrm{d} \ / \ \mathrm{D\_H}$

$= 16.5 \ / \ 4{,}283$ = **0.00385**

**Observed:** = **0.004**

**Agreement:** = **∼ 96%**

*The 4% discrepancy is well within the uncertainty caused by the Virgo Cluster's own gravitational pull on us (the "Virgocentric infall"), which adds about 200 km/s to our motion.*

### Step 3: A more distant galaxy.

The Coma Cluster is at about 100 Mpc with z ≈ 0.023.

**z (predicted)** $= 100 \ / \ 4{,}283$ = **0.0234**

**z (observed)** = **0.023**

**Agreement:** = **∼ 98%**

*At this distance, local peculiar velocities are negligible and the agreement tightens.*

## *A.3 Where the Exponential Matters: Distant Supernovae*

For nearby galaxies, the linear approximation z ≈ d/D_H works fine. The exponential and the straight line are indistinguishable. But at cosmological distances—where the supernovae are that triggered the dark energy discovery—the difference appears. Let's compute both and see.

### A supernova at redshift z = 0.5 (about 6 billion light-years)

What distance does our model assign?

**d** $= \mathrm{D\_H} \times \ln(1 + \mathrm{z})$

$= 4{,}283 \times \ln(1.5)$

$= 4{,}283 \times 0.4055$ = **1,737 Mpc**

What does the linear Hubble law give?

**d (linear)** $= \mathrm{D\_H} \times \mathrm{z} \ = \ 4{,}283 \times 0.5$ = **2,141 Mpc**

The linear law says 2,141 Mpc. Our exponential says 1,737 Mpc. That's a 19% difference—the supernova is closer than the linear law predicts. Equivalently, at a given distance, the exponential produces more redshift than the linear law. The curvature is compounding.

### A supernova at redshift z = 1.0 (about 10 billion light-years)

**d (exponential)** $= 4{,}283 \times \ln(2.0) \;=\; 4{,}283 \times 0.6931 = \mathbf{2{,}968\ Mpc}$

**d (linear)** $= 4{,}283 \times 1.0 = \mathbf{4{,}283\ Mpc}$

At z = 1, the linear law overshoots by 44%. The exponential and the straight line have clearly parted ways. This is the regime where dark energy was "discovered"—and where our model naturally produces the same curvature in the Hubble diagram without it.

### The luminosity distance (what we actually measure)

Astronomers don't measure distance directly. They measure brightness. A "standard candle"—a supernova of known intrinsic luminosity—appears dimmer at greater distance. The luminosity distance d_L accounts for this, including the additional dimming from redshift (photons arrive with less energy and at a lower rate):

**d_L** $= \mathrm{d} \times (1 + \mathrm{z})$

At z = 0.5:

**d_L (exponential)** $= 1{,}737 \times 1.5 = \mathbf{2{,}606\ Mpc}$

**d_L (ΛCDM)** $= \approx \mathbf{2{,}838\ Mpc}$ (numerical integration)

The distance modulus—the quantity actually plotted on the Hubble diagram—is:

**μ** $= 5 \times \log_{10}(\mathrm{d\_L}) + 25$

**μ (exponential)** $= 5 \times \log_{10}(2{,}606) + 25 \;=\; 5 \times 3.416 + 25 = \mathbf{42.08}$ mag

**μ (ΛCDM)** $= 5 \times \log_{10}(2{,}838) + 25 \;=\; 5 \times 3.453 + 25 = \mathbf{42.26}$ mag

**Difference:** $= \mathbf{0.18}$ mag

There it is. The gap. Our model gives 42.08; the consensus model gives 42.26. We are 0.18 magnitudes short—the supernova in our model is slightly brighter (closer) than ΛCDM predicts. This is the 0.2-magnitude discrepancy visible in Figure 1. Appendix A.4 quantifies it; Section 6 states what it means — and what it does not.

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### *A.4 The Residual Against ΛCDM, Quantified*

Step 1: at each redshift, compute Δμ = μ(ΛCDM) − μ(exp.). The values are in Table 1: 0.03 mag at z = 0.05, rising to 0.23 at z = 1, settling near 0.21 by z = 2.

Step 2: remove what calibration absorbs. A constant offset in all supernova magnitudes is indistinguishable from a change in the standard-candle luminosity or in $H_0$. The best-fit constant here is about 0.15 mag.

Step 3: what survives is the shape. $\Delta\mu$ minus its mean runs from −0.12 mag at $z = 0.05$, through zero near $z \approx 0.35$, to +0.08 mag at $z \geq 1$. This ±0.1-magnitude bend is the model's true discrepancy with ΛCDM — small enough to survive today's systematic error budget, large enough to be decided by the next generation of surveys. We put it on the table instead of under the rug.

### *A.5 The Time-Dilation Check*

Take a template Type Ia supernova that rises and falls over 40 days in its rest frame. A metric redshift predicts an observed duration of $40 \times (1 + z)$ days: 60 days at $z = 0.5$, 80 days at $z = 1$. This is what is measured [10, 11]. A tired-light model predicts 40 days at every redshift. The measurement has been made. The answer is $(1 + z)$, and the infall model produces it by construction.

### *A.6 The Energy Budget of the Background*

Energy density of the microwave background, from the radiation constant $a = 7.566 \times 10^{-16}$ J m$^{-3}$ K$^{-4}$:

$$u = aT^4 = 7.566 \times 10^{-16} \times (2.725)^4 = 7.566 \times 10^{-16} \times 55.13 = 4.2 \times 10^{-14}\ \text{J/m}^3$$

Rest-energy density of matter at critical density, $\rho_{crit} = 3H_0^2/8\pi G = 9.2 \times 10^{-27}$ kg/m³:

$$\rho c^2 = 9.2 \times 10^{-27} \times (2.998 \times 10^8)^2 = 8.3 \times 10^{-10}\ \text{J/m}^3$$

Required conversion fraction: $4.2 \times 10^{-14} / 8.3 \times 10^{-10} = 5.0 \times 10^{-5}$ — five parts in one hundred thousand.

Available from gravitational dissipation: efficiencies from 0.057 (accretion, non-rotating) to 0.42 (accretion, maximally rotating); fusion, for comparison, 0.007. Headroom: three to four orders of magnitude. For completeness, the horizon's own Gibbons–Hawking temperature, $\hbar H_0/2\pi k_B = 1.055 \times 10^{-34} \times 2.27 \times 10^{-18} / (2\pi \times 1.381 \times 10^{-23}) \approx 2.8 \times 10^{-30}$ K, confirms that the horizon itself cannot supply the glow — the matter must.

### *A.7 The Scorecard*

Let us summarize what each model requires to fit the supernova Hubble diagram:

| | **This Model** | **ΛCDM** |
|---|---|---|
| **Free parameters** | 1 ($H_0$) | 2 ($\Omega_m$, $\Omega_\Lambda$) |
| **Equation** | $1 + z = \exp(Hd/c)$ | Friedmann equations |
| **Acceleration mechanism** | Exponential (intrinsic) | Dark energy (postulated) |
| **Light-curve time dilation** | $(1 + z)$, automatic | $(1 + z)$, automatic |
| **CMB power spectrum** | Open (Section 9) | Explained |
| **CMB temperature history T(z)** | Matched (Tolman, Section 9.4) | Matched (expansion) |
| **Light-element abundances** | Open | Explained (BBN) |

The numbers are on the table — including the rows that read “open.” The model uses one measured constant and one equation, matches the two-parameter standard model to about a tenth of a magnitude in shape, and passes the duration test automatically. The rows where the standard model wins are printed in the same ink. That is the trade on offer.

Since we anticipated that some readers may wish to verify these results independently before formulating a response, we have endeavored to save them the effort. Every number in this appendix can be reproduced with the four physical constants listed in Section A.1 and a calculator. We look forward to the discussion.