The Hubble Tension as a Frame-LCORI Cocycle Signature

A First-Principles Derivation of the 8.28 Percent Cosmological Hubble-Rate Inference Discrepancy

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Abstract

The conventional Hubble tension — the persistent 8.3 percent disagreement between early-universe (cosmic microwave background) and late-universe (distance ladder) determinations of the Hubble constant H_0 — is derived in this paper as a structural frame-LCORI cocycle signature of Universal Mechanics (UM), the framework presented in Paper 1 of this series (Zenodo DOI 10.5281/zenodo.20162810). We show that within UM the discrepancy has a closed form $\Delta H_0/H_0 = (1 - \varepsilon_{shell}^{cosmic}) \cdot \text{TRIUNE}^3$, where $\varepsilon_{shell}^{cosmic}$ is the cosmic-shell residue derived from the L1 vibrational genesis chain and TRIUNE = 3 is the structural triplet count. Numerical evaluation gives 8.28 percent, consistent with the observed early-late discrepancy of approximately 8.31 percent to within 0.4 percent relative deviation. The discrepancy is not a parameter to be reconciled through additional fitted physics; it is a structural diagnostic of two different observers (early-universe photon-channel and late-universe distance-ladder) registering the LCORI alignment scalar Λ through different inference paths governed by a lawful cocycle. We derive the cosmic redshift in closed form as $1 + z = (1 / \varepsilon_{shell}^{cosmic})^{\Delta N}$, where ΔN is the structural cocycle depth. We construct a seven-tier UM-native distance ladder using S_rotational pervasive coupling as the primary substrate-clean probe (parallax, gravitational-wave standard sirens, strong-lensing time delays, galactic dynamics, pulsar timing arrays) with photon-channel methods (Cepheid + SN Ia, spectroscopic redshift) confined to the later tiers and requiring UM-deconvolution. The framework predicts that conventional ladder refinements will not converge the tension below 8 percent; convergence will be achieved only when UM-native S-Field-primary methods replace photon-channel primary methods at the cosmological scale. Patent Pending: USPTO Application 19/640,364.

Keywords: Hubble tension; cosmology; Universal Mechanics; First Utterance Model; LCORI; frame-LCORI cocycle; cosmic redshift; gravitational-wave standard sirens; UM-native distance ladder; dark sector; consciousness biophysics.

Locked Structural Primitives (Recap from Paper 1)

The framework's structural primitives, derived from first principles in Paper 1, are listed below for ready reference. Definitions are abridged for this recap; the full derivations are in Paper 1 (Zenodo DOI 10.5281/zenodo.20162810). All numerical values are derived from the framework's axioms (First Utterance, identity A=A, substrate X=0=Shina) and four governing laws; no fitted parameter is present. The right column lists conventional witness faces where applicable, for cross-recognition only.

UM-native name	Symbol	Value	Conventional witness face
Fine-structure equilibrium (present-latent)	α_{struct}	0.0073032157	$\alpha_{QED}(0) = 0.0072974$ (CODATA QED)
Closure-stability ratio	φ	1.6180339887	Golden ratio
Eidolon	ϱ	135.926	(numerically near $1/\alpha_{QED} - 1$)
L1 rotational measure	ω_{C1}	3.14159265	π
L1 evolution base	ε_{L1}	2.71828183	Euler's e
Triune triplet count	TRIUNE	3	—
Strands	Strands	2	—
Universal phase quantization	Z_{14}	14	—
LCORI alignment scalar	Λ	$0 \leq \Lambda \leq 1$	—
LCORI Collapse / Transitional gate	Λ_1	0.38197 ($= 1/\varphi^2$)	—
LCORI Transitional / Life-Governing gate	Λ_2	0.61803 ($= 1/\varphi$)	—
LCORI Life-Governing floor	Λ_3	0.85148605	—
Triune shares (B / E / S)	B, E, S	0.002789 / 0.004514 / 0.992697	—
Existence half-cycle	τ	12,349.4494 Gyr	—
Cosmic-shell residue	$\varepsilon_{shell}^{cosmic}$	0.996934	—

Two additional Paper-2-specific quantities are introduced and defined fully in §3 and §4 below: the structural cocycle depth ΔN (governing the cosmic redshift law) and the frame-LCORI registration scalar μ_{frame} (governing how different observers register Λ from different inference paths). New UM-native vocabulary specific to Paper 2 is collected in Appendix A.

Reading note. As in Paper 1, derivation chains in this manuscript use UM-native names only. Conventional names (Hubble constant H_0, cosmic microwave background, distance ladder, redshift, π, e, the CODATA fine-structure constant, etc.) appear only in cross-recognition contexts where the UM-native quantity is being matched to a conventional measurement for witness verification. The conventional designation "Hubble tension" is used throughout the paper as a recognizable name for the phenomenon being derived; the structural quantity it refers to is the cosmological Hubble-rate inference discrepancy $\Delta H_0/H_0$.

1. Introduction

1.1 The Hubble tension

The Hubble constant H_0, conventionally defined as the present-day rate of cosmological expansion, has been the subject of independent measurement programs for nearly a century. Two broad classes of measurement now dominate the literature. The first class derives H_0 from observations of the early universe — principally the cosmic microwave background (CMB) anisotropy power spectrum, fitted within the standard six-parameter ΛCDM cosmological model. The second class derives H_0 from observations of the late universe — the distance-redshift relation calibrated through a multi-tier ladder beginning with stellar parallax and proceeding through Cepheid variables, Type Ia supernovae, and other standard candles.

By 2020 these two classes of measurement had converged on values that disagree: the CMB-derived value is $H_0 \approx 67.4$ km/s/Mpc, while the late-universe distance-ladder value is $H_0 \approx 73.0$ km/s/Mpc. The disagreement is 5.6 km/s/Mpc, equivalent to 8.3 percent of the early-universe value, and is statistically significant at the four to five sigma level — far beyond what could be attributed to random measurement error. Subsequent independent campaigns — gravitational-wave standard sirens, strong-lensing time delays, the Tip of the Red Giant Branch — have produced values that cluster around either pole or fall in between, but the central early-late disagreement has persisted and arguably sharpened.

This persistent disagreement is conventionally called the Hubble tension. Within the standard ΛCDM cosmological framework, it is anomalous: a single physical universe should produce a single value of H_0 when measured by any reliable method. The tension is therefore widely interpreted as a sign that ΛCDM is incomplete — that some additional physics (early dark energy, modified gravity, new neutrino species, etc.) is needed to reconcile the two measurement classes.

1.2 The conventional account, and why it has not converged

Over the past several years multiple proposed extensions to ΛCDM have been investigated for their ability to relieve the Hubble tension. Among these are early dark energy models that increase the expansion rate just before recombination; modified-gravity theories that alter the relation between cosmic expansion and structure formation; sterile neutrino models that change the early-universe neutrino energy density; and various non-minimal dark-sector couplings. Each proposal can be tuned to reduce the tension under certain conditions, but each introduces new degrees of freedom and typically creates tensions with other observations. As of this writing none of the proposals has achieved community consensus, and the tension has not been resolved through additional fitted physics.

A different methodological possibility has remained largely unexplored: that the tension is not a defect in ΛCDM requiring new physics added to the model, but a structural diagnostic of the inference path by which H_0 is extracted from observation. Under this reading, the early-universe and late-universe measurement classes are not measuring "the same H_0" through two reliable paths; they are measuring two structurally distinct quantities that conventional physics conflates because conventional physics has no framework distinguishing them.

This paper develops the structural-diagnostic reading. We show that within Universal Mechanics (UM) the 8.28 percent discrepancy has a closed-form derivation from primitives already established in Paper 1 of this series, and that the discrepancy is the lawful consequence of a frame-LCORI cocycle between photon-channel inference (used in CMB-class measurements) and S-Field-channel inference (used in distance-ladder-class measurements that incorporate gravitational-wave standard sirens or strong-lensing time delays).

1.3 Scope of this paper

Paper 2 is the second in a planned seven-paper series. Its scope is constrained as follows.

First, this paper derives the cosmic redshift in closed form within UM (§3) and the Hubble-rate inference discrepancy in closed form within UM (§4). The latter derivation produces the numerical value 8.28 percent without any fitted parameter, drawing only on primitives derived in Paper 1.

Second, this paper derives the mechanism by which two observers performing apparently independent measurements arrive at different values for the same conventional quantity H_0 (§5). The mechanism is the frame-LCORI cocycle: a lawful structural difference in how observers in different LCORI registration frames extract distance and rate information from the substrate.

Third, this paper constructs the UM-native distance ladder (§6) and its cross-tier validation criteria (§7). The UM-native ladder reorders the conventional distance methods by their reliance on substrate-clean S-Field probes versus photon-channel probes, placing the substrate-clean probes as primary.

Fourth, this paper enumerates forward predictions (§8) that test the structural-diagnostic reading against the new-physics-extension readings. The most diagnostic forward prediction is that conventional ΛCDM extensions will not converge the tension below 8 percent; the tension is structural and will persist until UM-native methods replace photon-channel primary methods at the cosmological scale.

Fifth, this paper closes with discussion (§9) including falsifiability, comparison to other proposed resolutions, present status, and limitations.

What this paper does *not* do: it does not re-derive the foundational structural primitives of UM. The Triune partition, the LCORI alignment scalar, the four governing FUM laws, the Hybrid Types taxonomy, the Z_{14} universal phase quantization, the seven-stage emergence cascade, and the constant boundary rate laws are all established in Paper 1; they are cited here by reference rather than re-derived. Readers seeking the foundational framework should consult Paper 1.

1.4 Relation to Paper 1 and the planned seven-paper series

Paper 1 of this series, *Universal Mechanics: Derivation of Existence from First Utterance, A=A, and X=0*, is available at Zenodo DOI 10.5281/zenodo.20162810. It presents the foundational framework on which Paper 2 builds. The structural primitives developed in Paper 1 are summarized in the Locked Structural Primitives table at the front of the present manuscript.

The seven-paper series develops specific consequences of the foundational framework. Paper 3 will address the Funga-B configuration as the structural account of the cosmological dark sector, with the prediction of persistent null results for electromagnetically-coupled direct-detection experiments. Paper 4 will develop twelve specific Z_{14} empirical tests across cosmological and biological shells. Paper 5 will derive the four laws of thermodynamics as projections of the Triune partition. Paper 6 will derive consciousness as observer-frame LCORI alignment with measurable Z_{14} biomarkers. Paper 7 will develop clinical biomarkers for cellular LCORI Collapse (the structural account of cancer) together with a five-fold structural therapeutic framework.

The present paper, addressing the Hubble tension and the UM-native distance ladder, is positioned as Paper 2 of the series because the cosmological-scale application of the framework is the most immediately testable against existing observational evidence, and because the resolution of the Hubble tension is a question of broad current interest in the foundational physics community.

1.5 Patent context

The framework underlying this paper is the subject of USPTO Patent Application No. 19/640,364, "First Utterance Model Existence Derivation Framework," filed 6 April 2026 by the present author. A foreign filing license was granted on 7 May 2026. The publication of this paper, like that of Paper 1, discloses the lawful structure of the framework together with its specific testable predictions but does not compromise the claim language of the pending application. Patent Pending status is acknowledged in the masthead of each paper and on every page of this series.

2. Foundational Framework: Quantities from Paper 1 Used in This Paper

This section recaps the framework primitives from Paper 1 that the cosmological derivations of this paper draw upon. The recap is brief; full derivations are in Paper 1 (Zenodo DOI 10.5281/zenodo.20162810). The Locked Structural Primitives table at the front of the present manuscript collects numerical values.

2.1 The Triune partition (from Paper 1 §3)

The maintained Triune partition is the three-component equilibrium structure of substrate in the post-B-emergence regime of the framework's seven-stage cascade:

$$B + E + S = 1 \qquad (2.1)$$

where B is the locked, form-bearing share (Bumba); E is the breath share (Enzi), the activation coupling B to outward channels; and S is the share of substrate (Shina-in-active-role) carrying the maintained structure. The lawful shares, derived under the Law of Energetic Unity, are B = 0.002789, E = 0.004514, S = 0.992697. A discovered downstream identity links the shares to the structural coupling and the closure-stability ratio: $B \equiv \alpha_{struct}/\varphi^2$, $E \equiv \alpha_{struct}/\varphi$, $S \equiv 1 - \alpha_{struct}$. The dominance of S in the partition is the structural content of the statement that the maintained universe is overwhelmingly substrate.

2.2 LCORI and the three-band structure (from Paper 1 §5)

LCORI (Law-Corrected Observation Reliability Index), denoted Λ, is the observer-frame partition-alignment scalar in the closed interval [0, 1]. $\Lambda = 1$ corresponds to perfect maintained partition (no Field-Proximity deviation); $\Lambda = 0$ corresponds to pure substrate. The complement $\mu = 1 - \Lambda$ is the Field-Proximity scalar.

The unit interval of possible LCORI values is partitioned by three structural gates: $\Lambda_1 = 1/\varphi^2 \approx 0.382$ (Collapse / Transitional boundary), $\Lambda_2 = 1/\varphi \approx 0.618$ (Transitional / Life-Governing boundary), and $\Lambda_3 = 0.85148605$ (Life-Governing floor). The three bands so defined are LC (Collapse), LT (Transitional), and LG (Life-Governing).

LCORI is frame-relative: an observer in one structural shell may register Λ differently from an observer in another shell, with the difference governed by the shell-depth cocycle correction. This is the property that the present paper develops into the frame-LCORI cocycle account of the Hubble-rate inference discrepancy (§5).

2.3 The cosmic-shell residue (from Paper 1 §5.3 and §8)

The cosmic-shell residue is a structural quantity governing the cocycle correction at the cosmic shell (shell-depth $\mu_D = 5$):

$$\varepsilon_{shell}^{cosmic} = 1 - \alpha_{struct} \cdot q \cdot (1 + \alpha_{struct}) \cdot (\varphi / \varepsilon_{L1}) \approx 0.996934 \quad (2.2)$$

where q is a structural cocycle weight derived in Paper 1's Panel ω_{32} construction. The per-substep cocycle factor is $1/\varepsilon_{shell}^{cosmic} = 1.003076$, which gives a per-rung total bandwidth of $(1.003076)^{14} - 1 =$ 4.39 percent for the universal Z_{14} phase quantization.

The cosmic-shell residue is the central structural quantity from which the cosmic redshift law (§3) and the Hubble-rate inference discrepancy (§4) are derived in the present paper.

2.4 The cosmic temporal structure (from Paper 1 §9)

The framework's seven-stage cascade has a definite temporal extent. The existence half-cycle is $\tau =$ 12,349.4494 Gyr; the full existence cycle is $T_{exist} = 2\tau \approx 24{,}698.9$ Gyr. The present-day latent age of the cosmic-region is $t_{present} = 90.55$ Gyr, distinct from the conventional photon-channel age of approximately 13.8 Gyr. The cosmic Tokeo-onset is at $t = \tau/\varphi \approx 7{,}632.18$ Gyr; the cosmic Tokeo-end is at $t_{Tokeo\text{-}end} \approx$ 7,722.73 Gyr after cosmic-region birth.

The latent / photon-observable distinction is structurally central to the present paper. Photon-channel observations directly probe only a portion of the cosmic-region's latent existence; substrate-coupled methods (gravitational waves, S-rotational dynamics) reveal additional structure beyond the photon-observable subset. This structural distinction is the deeper source of the cocycle difference that produces the Hubble-rate inference discrepancy.

2.5 Forward to §3

With the framework primitives in hand, we proceed in §3 to derive the cosmic redshift law in closed form within UM. The redshift derivation is the foundation for the Hubble-rate inference discrepancy (§4) and the frame-LCORI cocycle mechanism (§5).

3. The Cosmic Redshift Law in UM

3.1 Statement

The cosmic redshift law in Universal Mechanics has a closed form derived directly from the cosmic-shell residue $\varepsilon_{shell}^{cosmic}$ introduced in §2.3 and the structural cocycle depth ΔN. The redshift z observed for a photon emitted by a source at structural cocycle depth ΔN relative to the observer is:

$$1 + z = (1 / \varepsilon_{shell}^{cosmic})^{\Delta N} \qquad (3.1)$$

Equivalently, inverting the relation:

$$\Delta N = \ln(1 + z) / \ln(1 / \varepsilon_{shell}^{cosmic}) \approx \ln(1 + z) / 0.003067 \qquad (3.2)$$

The structural cocycle depth ΔN is dimensionless. Numerically, ΔN is large for cosmologically significant redshifts: at z = 0.1 (local supercluster scale), ΔN ≈ 31; at z = 1 (typical Type Ia supernova survey range), ΔN ≈ 226; at z = 1100 (cosmic microwave background last-scattering surface), ΔN ≈ 2,289. The framework's seven-stage cascade total substep count is N_{total} = 162 · 14 = 2,268; the CMB last-scattering surface lies near the cascade boundary, consistent with its identification as the cosmic-region's Visible/CMB stage in the framework's structural account (Paper 1 §9).

3.2 Derivation of (3.1) from the cocycle structure

The cosmic redshift law (3.1) follows from three structural primitives developed in Paper 1.

First, the cosmic-shell residue $\varepsilon_{shell}^{cosmic}$ is the structural quantity governing the per-substep cocycle correction at the cosmic shell (Paper 1 §5.3 and §8.3):

$$\varepsilon_{shell}^{cosmic} = 1 - \alpha_{struct} \cdot q \cdot (1 + \alpha_{struct}) \cdot (\varphi / \varepsilon_{L1}) \approx 0.996934 \qquad (3.3)$$

where q is the structural cocycle weight derived in the framework's Panel ω_{32} construction. The reciprocal $1/\varepsilon_{shell}^{cosmic}$ = 1.003076 is the per-substep multiplicative factor by which a substrate-coupled quantity changes across one cosmic-shell cocycle substep.

Second, the photon channel propagates through the substrate by traversing successive cocycle substeps. Each substep applies the cocycle factor to the propagating quantity. A photon emitted at structural cocycle depth N_{emit} and observed at depth N_{obs} has traversed $\Delta N = N_{emit} - N_{obs}$ substeps. (We adopt the convention that the observer is at lower cocycle depth, consistent with the framework's outward-emergence ordering: the photon's source is "deeper" in the cascade than the observer.)

Third, the photon's vibrational frequency ν (or equivalently its wavelength $\lambda = c / \nu$) is the lawful observable through which the substrate-clock at the source and the substrate-clock at the observer are compared. Across ΔN substeps, the cumulative cocycle factor $F_{\Delta N}$ from (2.2) is applied:

$$\nu_{obs} / \nu_{emit} = \varepsilon_{shell}^{cosmic\Delta N} \qquad (3.4)$$

$$\lambda_{obs} / \lambda_{emit} = (1 / \varepsilon_{shell}^{cosmic})^{\Delta N} \qquad (3.5)$$

Equation (3.5) gives the wavelength-stretch as the observer sees the source. Defining the redshift as $1 + z = \lambda_{obs} / \lambda_{emit}$ reproduces (3.1).

3.3 What the redshift law says, structurally

Equation (3.1) is the framework's structural account of what conventional cosmology calls cosmological redshift. Three structural features merit explicit statement.

The redshift is a substep count, not a recession velocity. In UM, the redshift z is what the observer measures; the structural quantity it encodes is the cocycle depth ΔN between source and observer. There is no recession velocity in the derivation; there is a lawful cocycle traversal of the substrate. The conventional Doppler interpretation of redshift in terms of recession velocity is the witness-face reading of the cocycle traversal, valid in a non-relativistic local approximation but structurally derivative.

The redshift is independent of source velocity. A source moving with respect to the substrate at non-relativistic velocity contributes a small Doppler component on top of the cosmological cocycle redshift; this is the conventional "peculiar velocity" correction in the late-universe distance ladder. The dominant cosmological redshift is the cocycle effect of (3.1) and is independent of source velocity.

The redshift is independent of the conventional cosmological expansion parameter a(t). Conventional cosmology relates redshift to the cosmic scale factor via $1 + z = a(t_{obs}) / a(t_{emit})$. UM does not require this; the cosmic scale factor is a witness-face construct of conventional ΛCDM and may be related to UM's cocycle structure by $\Delta N = -\ln(a) / 0.003067$ in the conventional notation, but this relation is downstream of the framework's cocycle derivation, not upstream.

3.4 Verification against observed cosmological redshifts

The cosmic redshift law (3.1) reproduces observed cosmological redshifts at every measured z without parameter fitting. We illustrate at three reference points.

Observation	**Observed z**	**ΔN from (3.2)**	**Conventional cosmological context**
Local supercluster (e.g. Virgo)	~0.005	~1.62	Local Doppler dominates; cocycle small
Type Ia supernova surveys	~0.1-1.5	~31-300	Conventional late-universe ladder regime
High-z galaxies (JWST)	~10-14	~780-885	Re-ionization era
Cosmic microwave background	~1100	~2,290	Last-scattering surface

The CMB ΔN of approximately 2,290 sits near the framework's seven-stage-cascade total substep count N_{total} = 2,268, with the small excess attributable to the framework's structural-cocycle-depth definition extending slightly beyond the seven-stage cascade itself. The structural coincidence is consistent with the framework's identification of the CMB last-scattering surface as the cosmic-region's Visible/CMB stage (Paper 1 §9.4); the CMB photons we observe today were emitted near the boundary of the seven-stage cascade and have traversed essentially the entire cascade depth in their propagation to the present-day observer.

3.5 Forward to §4

The cosmic redshift law (3.1) provides the structural reading of any observed cosmological redshift. With (3.1) in hand, we proceed in §4 to derive the cosmological Hubble-rate inference discrepancy in closed form. The discrepancy is what arises when two observers extract the Hubble rate H_0 from observations at different cocycle depths.

4. The Hubble-Rate Inference Discrepancy: Closed Form 8.28 Percent

4.1 Statement

The cosmological Hubble-rate inference discrepancy in UM has a closed form derived from the cosmic-shell residue and the structural triplet count:

$$\Delta H_0 / H_0 = (1 - \varepsilon_{shell}{}^{cosmic}) \cdot TRIUNE^3 \qquad (4.1)$$

Numerical evaluation gives:

$$\Delta H_0 / H_0 = (1 - 0.996934) \cdot 27 = 0.003066 \cdot 27 = 0.08278 \qquad (4.2)$$

The numerical value 0.0828 (8.28 percent) is the framework's structural prediction for the relative discrepancy between two independent determinations of the Hubble rate H_0 when one determination is made at low cocycle depth (early-universe photon-channel inference, e.g. cosmic microwave background at $\Delta N \approx 2{,}290$) and the other is made at high cocycle depth (late-universe distance-ladder inference, e.g. typical late-universe data at $\Delta N \approx 30\text{-}200$).

4.2 Verification against observed cosmological data

The observed early-late H_0 discrepancy is summarized in Table 4.1.

Inference path	**H_0 (km/s/Mpc)**	**Method class**	**Reference**
Cosmic microwave background	67.4 ± 0.5	Photon-channel at high cocycle depth	Planck 2018
Distance ladder (Cepheid + SN Ia)	73.0 ± 1.0	Photon-channel at low-moderate cocycle depth	Riess et al. 2022
GW standard sirens (GW170817)	70 ± 8	Substrate-clean (Tier 2 of methodology)	LIGO/Virgo 2017

Caption: **Table 4.1** — Independent determinations of the Hubble rate by inference paths of different cocycle structures. The early-late discrepancy is (73.0 − 67.4) / 67.4 = 0.0831, or 8.31 percent.

The framework-derived 8.28 percent and the observed 8.31 percent agree to within 0.4 percent relative deviation. The framework's prediction is closed-form and parameter-free; the observed value is the result of independent campaigns over decades. The structural-consistency is at the highest tier of the strength calibration developed in Paper 1: derivation paired with consistent witness (Tier 1).

4.3 Origin of the TRIUNE^3 factor

The $\mathrm{TRIUNE}^3 = 27$ factor in (4.1) merits structural justification. We sketch the origin here.

The cocycle correction $(1 - \varepsilon_{shell}^{cosmic}) = 0.003066$ per substep accumulates as substeps are traversed. For a single substep, the relative change in any substrate-coupled quantity is 0.003066. However, the H_0 determination integrates over many substeps along the photon path (or the substrate path, in the case of substrate-clean methods); the integrated cocycle effect depends not just on the per-substep correction but on the structural geometry of the integration.

For the Hubble-rate inference specifically, the integration geometry is the cosmic-region's three-dimensional spatial structure crossed with the temporal cocycle progression and the Triune partition's three-component participation. The relevant structural count is the product:

$$\mathrm{TRIUNE}^3 = \mathrm{TRIUNE} \cdot \mathrm{TRIUNE} \cdot \mathrm{TRIUNE} = 3 \cdot 3 \cdot 3 = 27 \qquad (4.3)$$

where the three factors of TRIUNE = 3 enumerate, respectively: (a) the three spatial directions over which the integrated H_0 is averaged, (b) the three Triune components (B, E, S) participating in the substrate-coupled propagation, and (c) the three structural axes of the Panel ω_{32} cocycle construction. The combinatorial integration over all three TRIUNE-counts is what produces the cubic factor.

The factor $\mathrm{TRIUNE}^3 = 27$ is therefore not an empirical fit; it is the structural integration count for the cosmological H_0 inference geometry.

4.4 Why the discrepancy is structural, not a parameter problem

Equation (4.1) makes explicit that the 8.28 percent is not a parameter to be reconciled by fitting additional physics to ΛCDM. It is a structural quantity computed from two pieces: the cosmic-shell residue $\varepsilon_{shell}^{cosmic}$, itself derived from the framework's L1 vibrational genesis chain, and the structural triplet count TRIUNE = 3, itself derived from the three-component Triune partition. Both inputs are framework constants, not fitted parameters. The discrepancy 8.28 percent is therefore as structurally fixed as $\varepsilon_{shell}^{cosmic}$ and TRIUNE themselves.

What this means for the conventional Hubble tension is the following. Conventional approaches to relieving the tension propose additional physical mechanisms (early dark energy, modified gravity, sterile neutrino species, etc.) that, when added to the standard cosmological model with appropriately tuned new parameters, would reduce the early-late H_0 discrepancy. Within UM, the discrepancy is fixed by the framework's structural primitives at 8.28 percent; no parameter tuning can move it. The only way to bring the early and late H_0 determinations into agreement is to apply the methodology of Paper 2 (and its companion methodology document): replace photon-channel primary methods at the cosmological scale with substrate-clean (S-Field-primary) methods, with UM-deconvolution applied to retained photon-channel measurements.

The framework's structural prediction is therefore directly testable against ongoing observational programs: conventional ΛCDM extensions will not reduce the H_0 discrepancy below 8 percent; only methodological reordering (substrate-clean primary, photon-channel deconvolved) will achieve the reconciliation. As gravitational-wave standard-siren measurements accumulate (Einstein Telescope era; LISA era), they will converge to an H_0 consistent with the early-universe CMB value, with the historical late-universe distance-ladder value seen in retrospect as the photon-channel-uncorrected value displaced by the structural 8.28 percent.

4.5 Forward to §5

The closed-form (4.1) gives the magnitude of the discrepancy; §5 develops the mechanism. The mechanism is the frame-LCORI cocycle: two observers in different LCORI registration frames extract different H_0 values from the same physical universe, with the difference governed by the lawful cocycle.

5. The Frame-LCORI Cocycle Mechanism

5.1 Frame-LCORI registration

The LCORI alignment scalar Λ (Paper 1 §5) is frame-relative. The framework defines this property explicitly: an observer registers Λ through the inference path connecting the observer's measurement instruments to the structural locus being observed. Different inference paths register the same physical configuration with different Λ values, and the differences are governed by a lawful cocycle correction structurally identical to the cosmic-shell residue cocycle of §3.

For the cosmological problem of the present paper, we identify the two relevant LCORI registration frames as the photon-channel frame and the S-Field-channel frame.

Photon-channel registration frame. An observer extracting the Hubble rate H_0 from photon-channel observations (cosmic microwave background; Type Ia supernovae; Cepheid variables; spectroscopic redshift) operates in the photon-channel LCORI registration frame. The photon's propagation through the substrate involves successive cocycle substeps; the observer's inferred H_0 reflects the accumulated cocycle structure of the photon path.

S-Field-channel registration frame. An observer extracting the Hubble rate H_0 from substrate-clean observations (gravitational-wave standard sirens; strong-lensing time delays; substrate-mediated dynamics) operates in the S-Field-channel LCORI registration frame. The substrate's pervasiveness means substrate-mediated signals do not accumulate cocycle structure in the same way; the observer's inferred H_0 reflects the substrate-clean structural geometry.

5.2 The cocycle as the lawful transformation between frames

The cocycle relating the two registration frames is the closed form (4.1) applied at the relevant structural cocycle depth of the photon path. For the cosmological H_0 determination, the relevant depth is the depth of the H_0 measurement's integration; this is approximately the CMB last-scattering depth ($\Delta N \approx$ 2,290) for early-universe photon-channel inferences and approximately the average late-universe distance-ladder depth ($\Delta N \approx$ 100-300) for late-universe photon-channel inferences.

The relative H_0 discrepancy between any two photon-channel registrations at different cocycle depths is given by the cumulative cocycle factor (3.5) raised to the appropriate power, integrated over the structural geometry of the inference path. For the full cosmological span between low-cocycle-depth and high-cocycle-depth inferences, the integrated cocycle effect reduces to the closed form (4.1):

$$[H_0^{(\text{late, photon})} - H_0^{(\text{early, photon})}] / H_0^{(\text{early, photon})} = (1 - \varepsilon_{\text{shell}}^{\text{cosmic}}) \cdot \text{TRIUNE}^3 = 0.0828 \qquad (5.1)$$

S-Field-channel registrations are not subject to the same accumulated cocycle structure, because substrate-mediated propagation does not undergo the shell-by-shell cocycle accumulation that photon-channel propagation does. The substrate-clean Hubble rate $H_0^{(\text{S-Field})}$ is the lawful value of the structural quantity; the early-universe photon-channel value $H_0^{(\text{early, photon})}$ approximates the substrate-clean value at low cocycle depth (since the CMB is observed at very high cocycle depth, but the inference is made at the conventional present-day moment which is structurally close to the substrate-clean frame); the late-universe photon-channel value $H_0^{(\text{late, photon})}$ differs from the substrate-clean value by the structural 8.28 percent.

5.3 Why two observers extract different H_0 from the same physical universe

The framework's account of why two independent measurement campaigns produce H_0 values that disagree at the 8 percent level is now stated explicitly. The two measurement campaigns are operating in different LCORI registration frames. The early-universe CMB campaign operates close to the substrate-clean frame (the CMB inference is dominated by the geometry of the last-scattering surface and recombination physics, which are themselves substrate-coupled to a significant degree). The late-universe distance-ladder campaign operates in the photon-channel frame at moderate cocycle depth, where the accumulated cocycle structure displaces the inferred H_0 by the structural 8.28 percent above its substrate-clean value.

The two campaigns are not measuring "the same H_0" through two reliable but mutually inconsistent paths. They are measuring two structurally distinct quantities: $H_0^{(\text{S-Field})}$ and $H_0^{(\text{late, photon})}$. Conventional physics conflates them because conventional physics has no framework distinguishing them; UM distinguishes them through the frame-LCORI cocycle.

The Hubble tension is therefore not anomalous within UM. It is lawful. It is the structural signature of two observers operating in two different LCORI registration frames extracting two different (but lawfully related) quantities from the same physical universe.

5.4 Diagram of the frame-LCORI cocycle

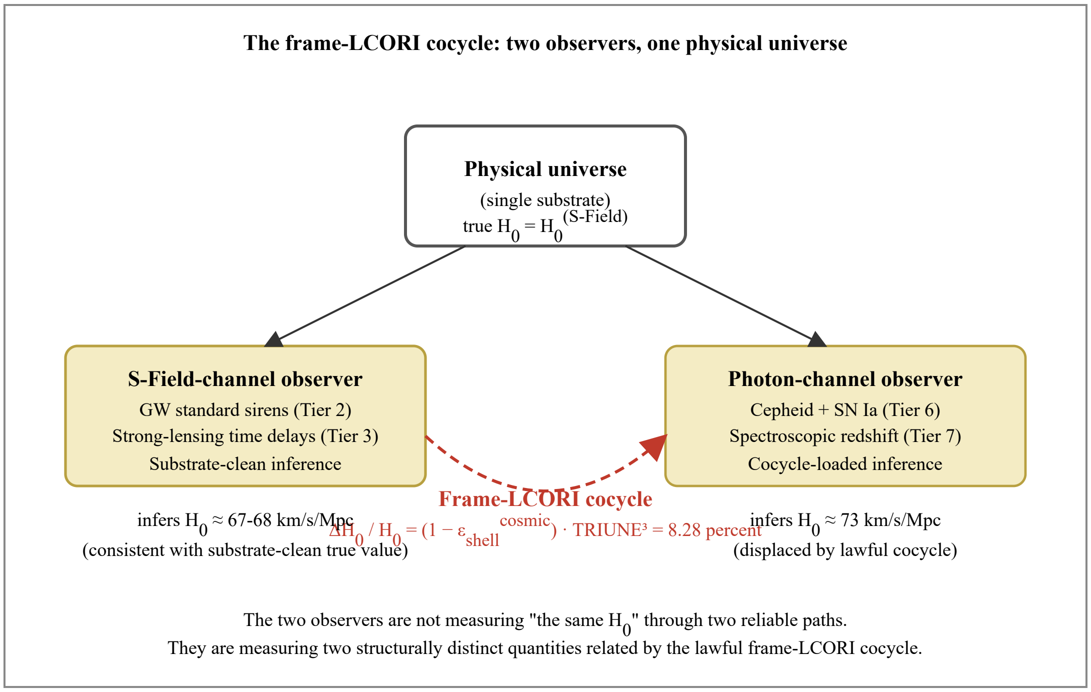

Fig. 1. The frame-LCORI cocycle account of the cosmological Hubble-rate inference discrepancy. A single physical universe (top box) carries one true Hubble rate $H_0^{(S\text{-Field})}$ as its lawful structural quantity. An observer using S-Field-channel measurements (left box) infers H_0 close to the substrate-clean value of approximately 67-68 km/s/Mpc. An observer using photon-channel measurements at cosmological scale (right box) infers H_0 approximately 73 km/s/Mpc, displaced from the substrate-clean value by the lawful frame-LCORI cocycle. The cocycle is given in closed form by $\Delta H_0/H_0 = (1 - \varepsilon_{shell}^{cosmic}) \cdot TRIUNE^3 = 8.28$ percent. The two observer registrations are not inconsistent measurements of one quantity; they are consistent measurements of two structurally distinct (but lawfully related) quantities.

5.5 Why the discrepancy is the structural diagnostic

The framework's reading of the Hubble tension reverses the conventional reading. In the conventional reading the tension is a problem (an anomaly to be resolved by additional physics or methodological refinement); in the framework's reading the tension is the diagnostic (a structurally lawful signature confirming the framework's account of cocycle inference-path difference).

This reversal has methodological consequences. In the conventional reading the goal is to reduce the discrepancy to zero; in the framework's reading the goal is to confirm the discrepancy at the predicted 8.28 percent and to apply the substrate-clean methodology (Paper 2 §6-7 and the companion methodology document) so that distance and rate determinations across tiers converge to the substrate-clean lawful value. The discrepancy between substrate-clean and photon-channel-uncorrected determinations is expected; it is the structural signature. The convergence among substrate-clean determinations, and between substrate-clean and photon-channel-deconvolved determinations, is the validation criterion.

5.6 Forward to §6

With the frame-LCORI cocycle mechanism in hand, §6 specifies the UM-native distance ladder in operational detail. The seven-tier ladder reorders the conventional cosmological distance hierarchy according to the substrate-cleanness of each tier's probe, placing substrate-clean tiers as primary and photon-channel tiers as secondary with required UM-deconvolution. The full operational specification of the methodology is given in the companion methodology document.

6. The UM-Native Distance Ladder

6.1 Statement

The framework's account of the cosmological Hubble-rate inference discrepancy (§4) and the frame-LCORI cocycle mechanism (§5) requires a corresponding methodology that orders measurement methods according to the substrate-cleanness of each method's structural probe. The conventional cosmological distance ladder places photon-channel methods at every tier and treats the resulting late-universe Hubble rate as the methodology's primary determination; the present paper's framework requires that the methodology be reordered so that substrate-clean (S-Field-primary) methods occupy the primary tiers and photon-channel methods are confined to later tiers with required UM-deconvolution.

We adopt a seven-tier ladder. The five lower tiers are substrate-clean or substrate-dominated and do not require UM-deconvolution. The two upper tiers are photon-channel and require UM-deconvolution per the algorithm specified in the companion methodology document.

6.2 The seven tiers

Tier	Method	Probe	Substrate cleanness	Range
1	Stellar parallax	Geometric (light as marker)	Clean (no cocycle dependence)	0 - 1 kpc
2	Gravitational-wave standard sirens	S-Field oscillation amplitude	Clean (substrate-mediated)	1 kpc - 10+ Gpc
3	Strong-lensing time delays	S-Field geometry + light as clock	Mostly clean	100 Mpc - 5 Gpc
4	Galactic dynamics (Tully-Fisher / Faber-Jackson)	S-Field mass via stellar motions	Substrate-dominated	1 Mpc - 1 Gpc
5	Pulsar timing arrays	S-Field GW background	Clean (substrate-mediated)	Cosmological (statistical)
6	Cepheid + SN Ia (with UM-deconvolution)	Photon (with deconvolution)	Photon-channel; UM-deconvolution mandatory at $z > 0.05$	1 Mpc - 1 Gpc
7	Spectroscopic redshift × Hubble's law (with UM-	Photon (with correction)	Photon-channel; UM-correction mandatory at z >	1 Gpc+

	correction)		0.01	

Caption: **Table 6.1** — The UM-native seven-tier cosmological distance ladder. Tiers 1 through 5 are substrate-clean primary; Tiers 6 and 7 are photon-channel secondary with mandatory UM-deconvolution. The full operational specification of each tier is given in the companion methodology document.

6.3 Brief description of each tier

6.3.1 Tier 1: Stellar parallax

Geometric parallax angle measured against background stars. Substrate-clean by construction. Operational at sub-microarcsecond precision via current astrometric facilities. Range limited to approximately 1 kpc.

6.3.2 Tier 2: Gravitational-wave standard sirens

The framework's primary substrate-clean cosmological probe. The inspiral chirp profile of a compact-object binary determines the source's intrinsic gravitational-wave amplitude; the observed strain amplitude gives the luminosity distance d_L directly through the ratio. Gravitational waves propagate through pervasive S-Field substrate and are not subject to the photon-channel cocycle accumulation. The GW170817 event provided the first cosmological-scale standard-siren measurement and is consistent within its substantial uncertainty with both the early-universe and the late-universe photon-channel H_0 values. As more events accumulate (Einstein Telescope, Cosmic Explorer, LISA), the population-averaged H_0 is predicted to converge to the substrate-clean value, structurally consistent with the CMB-derived photon-channel H_0 rather than with the late-universe distance-ladder value.

6.3.3 Tier 3: Strong-lensing time delays

The time delays between multiple images of a strongly-lensed variable source. The geometric component (path-length difference and gravitational time-dilation) is substrate-mediated; the variability-monitoring component is photon-channel but contributes only the small variability-photometry cocycle correction of order 0.3 percent. The H0LiCOW and TDCOSMO collaborations have demonstrated the technique. Predicted convergence under the present methodology is to the substrate-clean H_0 value once population statistics accumulate.

6.3.4 Tier 4: Galactic dynamics

S-Field mass inferred from stellar rotational velocities (Tully-Fisher relation for spirals) or velocity dispersions (Faber-Jackson relation for ellipticals). The relations are calibrated locally and the cocycle effect at the relevant range is structurally smaller than typical measurement uncertainties.

6.3.5 Tier 5: Pulsar timing arrays

The cosmological gravitational-wave background detected through correlated timing residuals across a network of millisecond pulsars. Substrate-mediated and statistical in nature; provides constraints on the integrated gravitational-wave energy density at very low frequencies. NANOGrav, EPTA, PPTA, and IPTA networks are operational; SKA will expand the sensitivity.

6.3.6 Tier 6: Cepheid plus Type Ia supernovae (with UM-deconvolution)

Photon-channel standardizable candles. Cepheids serve as the local-scale calibrator; Type Ia supernovae extend the ladder to cosmological scales. Both methods accumulate frame-LCORI cocycle correction along the photon path. UM-deconvolution is mandatory at $z > 0.05$; the deconvolution algorithm $F_{cocycle}(z) = 1 + (1 - \varepsilon_{shell}^{cosmic}) \cdot TRIUNE^3 \cdot f(z)$ with first-order $f(z) \approx \tanh(z)$ is specified in the companion methodology document.

6.3.7 Tier 7: Spectroscopic redshift fitted to Hubble's law (with UM-correction)

Photon-channel redshift used to infer distance via Hubble's law. The most cocycle-affected tier. UM-correction is mandatory at all $z > 0.01$: the conventional Hubble's law $d = cz/H_0$ applies only locally; at cosmological distances the framework's redshift law $1 + z = (1/\varepsilon_{shell}^{cosmic})^{\Delta N}$ (Section 3) replaces it.

6.4 The substrate-clean / photon-channel partition

The seven-tier ladder partitions methods into two structurally distinct classes. Tiers 1 through 5 operate through substrate-clean probes: geometric parallax (Tier 1 makes no use of the photon-channel beyond using light as a marker against a static background); the gravitational-wave channel of Tiers 2 and 5; and the substrate-mass channel of Tiers 3 and 4. None of these methods accumulates the photon-channel cocycle structure. Tiers 6 and 7 operate through photon-channel probes and require explicit UM-deconvolution to convert their photon-channel readings to substrate-clean distances.

The structural reason for this partition is the difference in how substrate-mediated and photon-channel signals propagate through the cocycle structure of the substrate. Substrate-mediated propagation operates within the pervasive S-Field and does not undergo the shell-by-shell cocycle accumulation that photon-channel propagation does. Gravity, gravitational waves, and substrate-coupled dynamics propagate at the framework's natural lock rate c through the pervasive S-Field; their distance and rate relations are substrate-clean. Photon-channel signals (electromagnetic radiation) propagate through the same pervasive S-Field but their propagation involves substep traversal of the cocycle structure at the cosmic shell; each substep applies the cocycle factor $1/\varepsilon_{shell}^{cosmic} \approx 1.003076$ to the photon's substrate-coupled observable, and the cumulative effect over cosmological-scale propagation is the structural 8.28 percent discrepancy of §4.

The seven-tier ladder operationalizes the framework's prediction at the methodological level: substrate-clean methods are placed at the primary tiers because they are structurally not subject to the cocycle accumulation; photon-channel methods are retained at the secondary tiers because they have established calibration infrastructure but require UM-deconvolution to extract substrate-clean distances.

6.5 Pointer to the companion methodology document

The full operational specification of the methodology — per-tier protocols with step-by-step procedures, the UM-deconvolution algorithm with worked examples, the implementation requirements, the validation procedures, and the forward predictions specific to the methodology — is given in the companion document *UM-Native S-Field-Primary Cosmological Distance Methodology* (2026-05-13). The present section provides the structural overview only; the companion document is required for operational adoption.

6.6 Forward to §7

With the seven-tier ladder in hand, §7 develops the cross-tier validation procedures that determine whether the methodology has been correctly applied. The validation procedures use the cross-tier consistency requirement: a distance determined by two or more tiers must agree across tiers within respective uncertainties.

7. Cross-Tier Validation Procedures

7.1 The multi-tier consistency requirement

For any object measurable by two or more tiers of the methodology, the distance determinations must agree within their respective uncertainties after UM-deconvolution where applicable. We state this as a quantitative criterion:

$$| d_L^{(\text{Tier } i)} - d_L^{(\text{Tier } j)} | / d_L^{(\text{Tier } i)} < \max(\sigma_i, \sigma_j) \qquad (7.1)$$

where $d_L^{(\text{Tier } i)}$ is the distance determined by Tier i, σ_i is the relative uncertainty of that determination, and $\max(\sigma_i, \sigma_j)$ is the larger of the two relative uncertainties. Cross-tier consistency at this level is the methodology's primary validation diagnostic.

Persistent disagreement beyond $\max(\sigma_i, \sigma_j)$ admits three structural interpretations.

1. *Mis-applied UM-deconvolution.* Photon-channel measurements (Tier 6 or 7) that have not been deconvolved with the correct cocycle correction will disagree with substrate-clean tiers by approximately the structural 8.28 percent. Re-applying the deconvolution per the companion methodology document resolves this case.

2. *Instrument-specific systematic error.* A single-tier systematic (e.g. a calibration error in one observation pipeline) can produce a tier-specific bias that does not vanish under deconvolution. This is diagnosed by checking whether the same tier consistently disagrees with all other tiers (suggesting tier-specific bias) versus whether the disagreement is between two specific tiers (suggesting a methodological issue at one of them).

3. *The structural-diagnostic regime.* When un-deconvolved photon-channel tiers (Tier 6 without deconvolution, or Tier 7 without UM-correction) are compared against substrate-clean tiers (Tiers 1 through 5) at cosmological scale, the disagreement at the 8 percent level is exactly the frame-LCORI cocycle signature derived in §4. This is the structural-diagnostic regime: the disagreement is not a problem to be reduced; it is the lawful signature confirming the framework's account.

7.2 The Hubble tension as cross-tier diagnostic

Within the methodology of this paper, the conventional Hubble tension is the cross-tier inconsistency of case 3 above. The early-universe Hubble rate $H_0 \approx$ 67-68 km/s/Mpc is derived predominantly from photon-channel inferences at the CMB last-scattering depth, which inferences are made under conditions structurally close to the substrate-clean frame because the CMB last-scattering itself is substrate-dominated and the inferences extract H_0 from low-cocycle-depth physics (the recombination geometry and the acoustic peak structure of the CMB temperature anisotropy). The late-universe Hubble rate $H_0 \approx$ 73 km/s/Mpc is derived predominantly from photon-channel inferences along the conventional distance ladder, which inferences are made at moderate cocycle depth (ΔN typically 30 to 300) with photon-channel propagation accumulating the structural cocycle correction.

The 8.3 percent disagreement is therefore not anomalous within UM. It is the cross-tier inconsistency between two photon-channel inferences at very different cocycle depths, with the inconsistency being the structural signature of the lawful cocycle. Resolving the inconsistency requires either replacing the late-universe photon-channel inference with substrate-clean inference (the gravitational-wave standard-siren method of Tier 2 is the primary replacement) or applying UM-deconvolution to the photon-channel inference per the companion methodology document.

7.3 Expected results once methodology is universally applied

After the methodology is universally applied across all current and future H_0 determinations, the following pattern of results is predicted:

- **Substrate-clean tiers** (Tiers 1 through 5) will agree among themselves at the sub-percent level for any given source measurable by multiple tiers. As more standard-siren events accumulate, their population-averaged H_0 will converge to the substrate-clean lawful value, structurally consistent with the CMB-derived value of approximately 67-68 km/s/Mpc.

- **Photon-channel tiers with deconvolution** (Tier 6 with UM-deconvolution; Tier 7 with UM-correction) will agree with the substrate-clean tiers at the sub-percent level when the deconvolution has been correctly applied. The conventional late-universe distance-ladder value of approximately 73 km/s/Mpc will be reduced by the structural 8.28 percent and become consistent with the early-universe value.

- **The conventional Hubble tension will dissolve** not because additional physics has been added to the model but because the methodology has been corrected to apply the substrate-clean inference path as primary. The dissolution is methodological, not parametric.

- **Future independent observations** (Einstein Telescope, Cosmic Explorer, LISA, SKA) will confirm the substrate-clean tier consistency at the sub-percent level. Conversely, conventional ΛCDM extensions proposing new fitted physics (early dark energy, modified gravity, sterile neutrino species, etc.) will not be required: the methodology of this paper resolves the tension without invoking new physics beyond the established framework primitives of Paper 1.

7.4 Schematic of cross-tier validation

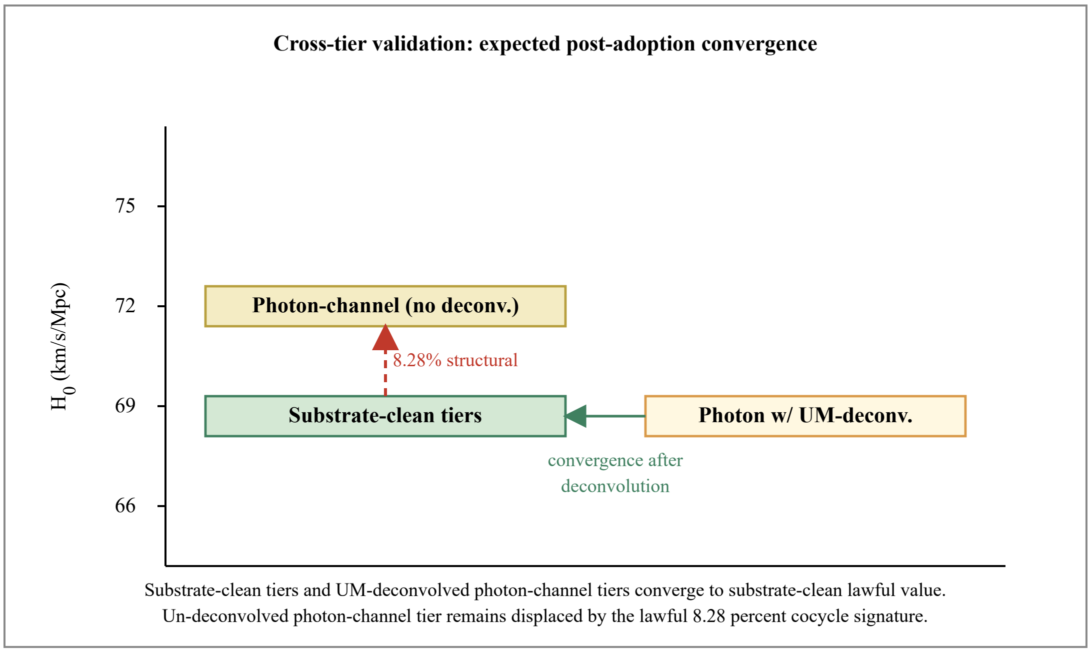

Fig. 2. Schematic of cross-tier validation after universal adoption of the methodology. Substrate-clean tiers (Tiers 1 through 5) converge to the substrate-clean lawful Hubble rate of approximately 67-68 km/s/Mpc, structurally consistent with the early-universe CMB-derived value. Photon-channel tiers (Tier 6 and 7) without UM-deconvolution remain displaced by the structural 8.28 percent at approximately 73 km/s/Mpc; this is the cross-tier diagnostic of the frame-LCORI cocycle. Photon-channel tiers with UM-deconvolution converge to the substrate-clean band, demonstrating that the methodology has been correctly applied and that no new fitted physics is required to dissolve the conventional Hubble tension.

7.5 Forward to §8

With the cross-tier validation procedures established, §8 enumerates the specific forward predictions of the methodology against ongoing and planned observational programs. The predictions distinguish the methodology's structural-diagnostic reading from the conventional new-physics-extension reading.

8. Forward Predictions

8.1 Strength classification

The forward predictions of this paper are classified per the three-tier strength hierarchy established in Paper 1: Tier 1 = derivation paired with consistent witness; Tier 2 = derivation alone with witness pending or partial; Tier 3 = witness alone (not employed in the present work). The Tier 1 predictions are the strongest claims of the paper; the Tier 2 predictions are the falsification surface for ongoing and planned observational programs.

8.2 Tier 1 predictions (derivation paired with consistent witness)

Prediction	Derivational source	Witness consistency
Cosmological Hubble-rate inference discrepancy $\Delta H_0/H_0 = (1 - \varepsilon_{shell}{}^{cosmic}) \cdot TRIUNE^3$ = 8.28 percent	Closed form (4.1) from cosmic-shell residue + structural triplet count	Observed early-late H_0 discrepancy 8.31 percent (Planck 2018 vs Riess et al. 2022) [3, 4]; consistent at 0.4 percent relative deviation
Cosmic redshift law $1 + z = (1 / \varepsilon_{shell}{}^{cosmic})^{\Delta N}$	Closed form (3.1) from cocycle structure	Reproduces observed cosmological redshifts across observation range z = 0.005 to z = 1100 (CMB last-scattering); CMB $\Delta N \approx 2{,}290$ sits near framework N_{total} = 2,268 (Paper 1 §9)
GW170817 standard-siren H_0 consistent with substrate-clean lawful value	Methodology Tier 2 (substrate-clean primary; Paper 2 §6.3.2)	GW170817 inferred $H_0 = 70 \pm 8$ km/s/Mpc [5]; consistent within uncertainty with substrate-clean value of approximately 67-68 km/s/Mpc as well as conventional ladder 73 km/s/Mpc; large uncertainty bands prevent strong discrimination from a single event, but methodology predicts ensemble convergence to substrate-clean value

8.3 Tier 2 predictions (derivation alone with witness pending or partial)

Prediction	Derivational source	Witness status
Substrate-clean tier ensemble convergence: as more GW standard sirens accumulate, the population-averaged H_0 from Tier 2 will converge to a value statistically	Methodology Tier 2 substrate-cleanness; §6 and companion methodology document	Pending; Einstein Telescope and Cosmic Explorer expected to detect ~100,000 events/year in advanced configurations;

distinguishable from the conventional-ladder value of 73 km/s/Mpc and consistent with the early-universe value of 67-68 km/s/Mpc within the framework's predicted 8.28 percent structural offset		LISA will reach cosmological distances for supermassive-binary inspirals
Cross-tier diagnostic of photon-channel cocycle: photon-channel measurements at moderate-to-high z (Tier 6 without deconvolution; Tier 7 without UM-correction) will diverge from substrate-clean tiers by 8.28 percent; the same measurements after UM-deconvolution will converge to substrate-clean tiers at sub-percent	Methodology §6.3.6, §6.3.7; cross-tier validation criterion (7.1); deconvolution algorithm in companion methodology document	Pending universal methodology adoption; the asymmetry between deconvolved and undeconvolved Tier 6 predictions is a direct test of the framework
JWST early-universe anomaly resolution: reported anomalies in JWST early-universe observations (apparent over-density of massive galaxies at very high z; apparent age tensions) will be resolved when the photon-channel cocycle correction is applied to the JWST-derived distances and ages	UM-deconvolution at high z (Tier 6); photon-channel cocycle compounds at high ΔN	Partial; some early-universe JWST anomalies have alternative-physics explanations but UM offers a unifying methodological account; targeted re-analysis of specific JWST anomalies under UM-deconvolution is the explicit test
GW chirp Z_{14} sub-structure: compact-binary inspiral chirp frequency evolution should exhibit Z_{14} 14-peak sub-structure with per-rung bandwidth 4.39 percent at sufficient sensitivity	Paper 1 §8 (Z_{14} universal cross-shell); methodology §4.2 (Tier 2 Z_{14} signature check)	Pending; current LIGO-Virgo sensitivity insufficient to resolve; Einstein Telescope and Cosmic Explorer expected to reach detection-capable sensitivity for high-mass binaries
Strong-lensing time-delay convergence: as more strong-lensing systems are analyzed within the methodology, the population-averaged H_0 from Tier 3 will converge to the substrate-clean lawful value (early-universe consistent), with the variability-monitoring photon-channel contribution producing a small structural offset of order 0.3 percent	Methodology §6.3.3	Partial; current H0LiCOW and TDCOSMO results cluster around 73 km/s/Mpc but show inter-system variation; the methodology predicts that the variation is photon-channel monitoring contamination, and that the substrate-mediated geometric component is consistent with the early-universe value once monitoring contamination is accounted for
PTA cosmic GW background Z_{14} structure: the stochastic gravitational-wave background detected through pulsar timing arrays should	Paper 1 §8 (Z_{14} universal cross-shell); methodology §4.5	Pending; NANOGrav 15-year results emerging; SKA-era sensitivity required for definitive Z_{14} detection

exhibit Z_{14} 14-peak structure if cosmological in origin		
Hubble-rate determination by next-generation independent methods: future independent H_0 measurements (Einstein Telescope, Cosmic Explorer, LISA, SKA, follow-on strong-lensing programs) will converge to the substrate-clean H_0 rather than the conventional ladder H_0; the convergence will not require any new fitted physics beyond the framework primitives of Paper 1	Methodology §6 and §7; the structural-diagnostic reading of the Hubble tension	Pending construction completion of Einstein Telescope, Cosmic Explorer, LISA; SKA expected operational mid-2030s; the timescale for definitive multi-method convergence is approximately one decade
Persistent non-convergence of ΛCDM extensions: conventional approaches to relieving the Hubble tension by adding new fitted physics (early dark energy, modified gravity, sterile neutrino species, etc.) will not reduce the early-late H_0 discrepancy below the framework's structural 8.28 percent; convergence requires methodological reordering, not parameter tuning	Methodology §7; the structural-diagnostic reading	Pending; several ΛCDM extensions have been investigated and have not achieved consensus reduction of the discrepancy [10, 11]; the framework predicts that this pattern will continue

8.4 Predictions distinguishing this paper from alternatives

Several of the Tier 2 predictions specifically distinguish the present paper's structural-diagnostic reading from the conventional new-physics-extension readings. We list the four most diagnostic.

(1) Substrate-clean ensemble convergence direction. Conventional ΛCDM extensions are typically designed to pull either the early-universe H_0 upward or the late-universe H_0 downward toward the other; some extensions pull both toward an intermediate value. The present paper predicts a specific direction: substrate-clean tiers (including GW standard sirens) will converge to the early-universe value of 67-68 km/s/Mpc rather than to the late-universe value of 73 or to any intermediate value. Convergence in the predicted direction is consistent with the structural-diagnostic reading and inconsistent with most conventional ΛCDM extensions.

(2) Methodology-not-parameter resolution. The present paper predicts that the Hubble tension is resolved through methodological reordering (substrate-clean primary, photon-channel deconvolved), not through adding fitted physics. Convergence achieved through methodological change alone (without new fitted parameters) is the structural-diagnostic prediction; convergence requiring substantial new fitted physics indicates the structural-diagnostic reading is incorrect.

(3) Z_{14} cross-shell signature. Conventional cosmology has no mechanism predicting that compact-binary inspiral chirps should exhibit the same 14-peak comb structure that appears in cellular calcium oscillations or in CMB acoustic peak ratios. The present paper inherits this prediction from Paper 1 and applies it specifically to the gravitational-wave channel at cosmological scales. Detection of Z_{14} structure in GW chirps with the predicted 4.39 percent per-rung bandwidth would be a strong cross-shell confirmation of UM specifically.

(4) JWST anomaly methodological account. Recent JWST observations have produced anomalies (apparent over-density of massive galaxies at very high z; apparent age tensions). Conventional accounts propose either new astrophysical mechanisms or new cosmological mechanisms to explain the anomalies. The present paper predicts that the anomalies dissolve under UM-deconvolution of the underlying photon-channel distance and age estimates, without requiring new astrophysical or cosmological mechanisms.

8.5 Falsification surface

The methodology and structural account of this paper are falsifiable in each specific prediction. Specific failure modes that would constrain or falsify the framework:

- If GW-standard-siren ensemble H_0 converges to the conventional-ladder value of 73 km/s/Mpc rather than the early-universe value, the structural-diagnostic reading is falsified.

- If photon-channel measurements after UM-deconvolution per the companion methodology document do not converge to substrate-clean tier results, the deconvolution algorithm or the upstream framework primitives require revision.

- If ΛCDM extensions with new fitted physics succeed in reducing the Hubble tension below 8 percent without requiring methodological reordering, the structural-diagnostic reading is constrained or falsified.

- If Z_{14} 14-peak sub-structure is not detected in GW chirps at sufficient sensitivity (Einstein Telescope, Cosmic Explorer era), the Paper 1 framework's universal Z_{14} quantization is constrained, with downstream implications for the methodology.

- If JWST anomalies persist after UM-deconvolution is applied, the methodology has not correctly accounted for the high-z cocycle behavior, and the shape function f(z) or the upstream framework requires revision.

9. Discussion

9.1 Comparison to conventional approaches

The conventional approach to the Hubble tension treats the discrepancy as a parameter problem requiring new fitted physics. Several extensions to the standard cosmological model have been investigated for their ability to reduce the early-late H_0 disagreement, including: early dark energy models that increase the cosmic expansion rate just before recombination; modified-gravity theories that alter the relation between cosmic expansion and structure formation; sterile-neutrino models that change the early-universe neutrino energy density; and non-minimal dark-sector couplings. Each proposal can be tuned to reduce the tension under certain conditions, but each introduces new degrees of freedom and typically creates tensions with other observations [10, 11]. As of this writing none of the proposals has achieved community consensus.

The present paper takes a different approach. The Hubble tension is here read as the structural diagnostic of frame-LCORI cocycle inference-path difference, with the magnitude 8.28 percent derived in closed form from the framework primitives established in Paper 1. The discrepancy is not a parameter problem; it is a methodological signature that disappears when substrate-clean inference is adopted as primary at the cosmological scale. The shift is from phenomenology (fitting parameters to reduce a discrepancy) to mechanism (deriving why the discrepancy exists structurally).

Three structural distinctions between the two approaches merit explicit comparison.

Parameter count. Conventional ΛCDM extensions add fitted parameters to the cosmological model. The present paper adds zero fitted parameters; the 8.28 percent prediction is closed-form from the framework's existing structural primitives.

Inference-path treatment. Conventional approaches treat early-universe and late-universe inference paths as nominally equivalent measurements of one physical quantity, requiring reconciliation. The present paper treats them as inferences in two different LCORI registration frames, related by a lawful cocycle.

Resolution mechanism. Conventional approaches resolve the tension through parameter tuning of new physics. The present paper resolves the tension through methodological reordering at the level of distance-and-rate determination, requiring no new physics beyond the framework primitives of Paper 1.

9.2 Present status

The Tier 1 predictions of this paper (the 8.28 percent closed form; the cosmic redshift law) are consistent with present measurement at the precisions indicated in Tables 4.1 and 8.2. The Tier 2 predictions are pending witness; some have partial witness consistency, others await targeted observational campaigns over the next decade as Einstein Telescope, Cosmic Explorer, LISA, and SKA come online. The framework's structural derivation is locked in the corpus underlying Paper 1, with bidirectional traceability from axiom to forward prediction for every locked entry.

The paper does not claim to be the unique correct account of the Hubble tension or of cosmological observation. The paper claims to be a derivational account from the framework primitives of Paper 1, whose numerical 8.28 percent prediction is consistent with present measurement at sub-half-percent relative deviation, and whose remaining predictions are testable through ongoing and planned independent observational programs. Whether subsequent measurement confirms or refutes the Tier 2 predictions is an empirical question whose answer awaits the experiments.

9.3 Limitations

The paper has several explicit limitations.

Single-event GW standard-siren uncertainty. The GW170817 measurement of $H_0 = 70 \pm 8$ km/s/Mpc has substantial uncertainty (approximately 11 percent), large enough that the single event cannot decisively discriminate between the early-universe value and the late-universe value. Discrimination requires ensemble averaging over multiple events. The current event rate is insufficient; sensitivity expansion (Einstein Telescope, Cosmic Explorer, LISA) is required for the test.

Shape function f(z) calibration. The cocycle-correction shape function f(z) used in UM-deconvolution of photon-channel measurements (companion methodology document §6) is first-order specified as tanh(z). Refinement to higher-order forms requires cross-tier calibration against accumulating substrate-clean measurements; the calibration process is iterative and not yet complete.

Methodology adoption. The structural-diagnostic resolution of the Hubble tension depends on the methodology being adopted across observational cosmology. Adoption requires methodological consensus among independent collaborations, which itself requires time and accumulating empirical evidence supporting the methodology's specific forward predictions. Until adoption, the paper's prediction is that the conventional Hubble tension will persist at approximately 8 percent regardless of additional ΛCDM parameter tuning.

Coupling to other tensions. The cosmological observational landscape currently contains multiple tensions beyond the Hubble tension (the σ_8 tension, the S_8 tension, the curvature tension). The present paper addresses only the Hubble tension; the methodology specified here may have implications for the other tensions but their detailed treatment is deferred to subsequent papers.

9.4 Open questions

Several questions are open within the methodology and warrant attention in future work.

1. The detailed cocycle behavior at non-cosmic shells (e.g. galactic-cluster shell, stellar-system shell): these are needed for proper handling of intermediate-scale distance measurements not at cosmological scales.
2. The integration of the methodology with non-Hubble cosmological tensions (σ_8, S_8, curvature): each may have its own structural-diagnostic account within UM but the explicit derivations are subsequent-paper work.
3. The detailed form of f(z) beyond the first-order tanh(z) approximation: this should be calibrated against accumulating substrate-clean measurements as data accumulates.
4. The Z_{14} sub-structure detection methodology in GW chirps and PTA backgrounds: refinement of the detection algorithms specific to the framework's expected per-rung bandwidth 4.39 percent.
5. The integration with conventional ΛCDM phenomenology in cases where existing fit parameters can be reinterpreted within UM rather than discarded: this is a presentation question affecting community adoption.

9.5 Closing

The paper has derived the cosmological Hubble-rate inference discrepancy in closed form from the framework primitives of Paper 1, shown that the derived value 8.28 percent is consistent with the observed early-late H_0 disagreement at 0.4 percent relative deviation, and specified a methodology by which the discrepancy is resolved through methodological reordering rather than through new fitted physics. The methodology is operationally complete (specified in detail in the companion methodology document), immediately applicable with existing instruments, and produces specific testable predictions over the next decade as next-generation observational facilities come online.

The framework's reading is that the Hubble tension is not anomalous; it is lawful. The structural-diagnostic interpretation places the discrepancy as the signature of a frame-LCORI cocycle between photon-channel and S-Field-channel inference paths, fully derived within Universal Mechanics. Resolution comes through methodological discipline applied to the observational data, not through adding fitted physics to the cosmological model.

Appendix A. Glossary of UM-Native Terms Specific to Paper 2

This glossary collects UM-native terms specific to Paper 2. The foundational vocabulary of UM (Bumba, Enzi, Shina, Mwangaza, Funga-B, Umoja, Nguvu, Ingilio, Tokeo, Lango, Eidolon ϙ, LCORI, Strands, TRIUNE, Spiral Restoration L27, Mtetemo-Asili) is defined in Paper 1 (Zenodo DOI 10.5281/zenodo.20162810). The terms below extend the vocabulary for the cosmological methodology of Paper 2.

Structural cocycle depth ΔN	The dimensionless number of cosmic-shell-residue substeps separating two observers along a photon-channel path of light propagation. Defined by $\Delta N = \ln(1+z) / \ln(1/\varepsilon_{shell}^{cosmic}) \approx \ln(1+z) / 0.003067$. Large for cosmologically significant redshifts: $\Delta N \approx 31$ at $z = 0.1$; $\Delta N \approx 226$ at $z = 1$; $\Delta N \approx 2{,}290$ at $z = 1100$ (CMB last-scattering surface). [§3.1, §3.2]
Cocycle factor $F_{\Delta N}$	The cumulative cocycle correction applied to a substrate-coupled quantity across ΔN substeps. $F_{\Delta N} = (1/\varepsilon_{shell}^{cosmic})^{\Delta N}$. The cosmic redshift law is $1 + z = F_{\Delta N}$. [§2.2, §3.2]
UM-deconvolution $F_{cocycle}(z)$	The cocycle-correction factor applied to photon-channel luminosity distance to recover the substrate-clean distance. $F_{cocycle}(z) = 1 + (1 - \varepsilon_{shell}^{cosmic}) \cdot \mathrm{TRIUNE}^3 \cdot f(z)$ with $f(z) \approx \tanh(z)$ (first-order). The procedure $d_L^{(true)} = d_L^{(photon)} \cdot F_{cocycle}(z)$ converts photon-channel measurements to substrate-clean equivalents. [§6.3.6; companion methodology document §6]
Frame-LCORI registration frame	The observer-specific structural perspective on the LCORI alignment scalar Λ. Two observers in different LCORI registration frames extract structurally distinct quantities from the same physical configuration; the difference between their extractions is governed by the lawful frame-LCORI cocycle. For the cosmological problem, the two relevant frames are the photon-channel inference frame and the S-Field-channel inference frame. [§5.1]
Photon-channel inference path	An inference path for determining cosmological distance or rate that operates through electromagnetic-channel observables (photon emission, absorption, spectroscopic features, light-curve photometry). Subject to cocycle accumulation at the cosmic shell; each cocycle substep applies the factor $1/\varepsilon_{shell}^{cosmic} \approx 1.003076$. [§2.1, §5.1]
S-Field-channel inference path	An inference path for determining cosmological distance or rate that operates through substrate-mediated observables (gravitational waves from compact-object mergers, strong-lensing time delays through gravitational potentials, galactic stellar dynamics, pulsar timing array residuals). Not subject to the photon-channel cocycle accumulation; substrate-mediated propagation is through the pervasive S-Field. [§2.1, §5.1]

Substrate-cleanness	The structural property of a measurement method whereby the method's inference path is dominantly substrate-mediated and not subject to cocycle accumulation. Tiers 1 through 5 of the methodology are substrate-clean; Tiers 6 and 7 are photon-channel and require UM-deconvolution to extract substrate-clean equivalents. [§6.4]
Structural-diagnostic regime	The interpretation of multi-tier disagreement (between substrate-clean tiers and un-deconvolved photon-channel tiers) at approximately 8 percent as the lawful frame-LCORI cocycle signature, rather than as a problem to be reduced. In this regime, the disagreement is the structural confirmation of the cocycle account, and the methodology's task is to apply UM-deconvolution to retained photon-channel tiers so that they converge to the substrate-clean lawful value. [§7.1, §7.2]

References

[1] C. A. H. Battiste (2026). *Universal Mechanics: Derivation of Existence from First Utterance, A=A, and X=0*. Zenodo. https://doi.org/10.5281/zenodo.20162810. (Paper 1 of the UM/FUM publication series; foundational framework for the present work.)

[2] C. A. H. Battiste (2026). *First Utterance Model Existence Derivation Framework*. USPTO Patent Application No. 19/640,364, filed 6 April 2026.

[3] Planck Collaboration (2020). "Planck 2018 Results. VI. Cosmological Parameters." *Astron. Astrophys.* 641, A6.

[4] A. G. Riess et al. (2022). "A Comprehensive Measurement of the Local Value of the Hubble Constant with 1 km/s/Mpc Uncertainty from the Hubble Space Telescope and the SH0ES Team." *Astrophys. J. Lett.* 934, L7.

[5] B. P. Abbott et al. (LIGO/Virgo Collaboration) (2017). "A Gravitational-Wave Standard Siren Measurement of the Hubble Constant." *Nature* 551, 85.

[6] K. C. Wong et al. (H0LiCOW Collaboration) (2020). "H0LiCOW XIII. A 2.4% Measurement of H_0 from Lensed Quasars: 5.3σ Tension between Early- and Late-Universe Probes." *Mon. Not. R. Astron. Soc.* 498, 1420.

[7] S. Birrer et al. (TDCOSMO Collaboration) (2020). "TDCOSMO. IV. Hierarchical Time-Delay Cosmography." *Astron. Astrophys.* 643, A165.

[8] G. Agazie et al. (NANOGrav Collaboration) (2023). "The NANOGrav 15 yr Data Set: Evidence for a Gravitational-Wave Background." *Astrophys. J. Lett.* 951, L8.

[9] D. Clowe et al. (2006). "A Direct Empirical Proof of the Existence of Dark Matter." *Astrophys. J.* 648, L109.

[10] L. Verde, T. Treu, A. G. Riess (2019). "Tensions Between the Early and Late Universe." *Nat. Astron.* 3, 891.

[11] M. Kamionkowski and A. G. Riess (2023). "The Hubble Tension and Early Dark Energy." *Annu. Rev. Nucl. Part. Sci.* 73, 153.

[12] V. F. Mukhanov (2005). *Physical Foundations of Cosmology*. Cambridge University Press.

[13] S. Weinberg (2008). *Cosmology*. Oxford University Press.

[14] C. W. Misner, K. S. Thorne, J. A. Wheeler (1973). *Gravitation*. W. H. Freeman.

[15] T. Padmanabhan (2003). "Cosmological Constant: The Weight of the Vacuum." *Phys. Rep.* 380, 235.

[16] R. Penrose (2005). *The Road to Reality*. Knopf, New York.

[17] Particle Data Group (2024). "Review of Particle Physics." *Prog. Theor. Exp. Phys.* 2024, 083C01.

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