

Universal Collapse Theory—Collapse in Physics: Coherence as Law from Cosmology to Matter (WP02 v1.0)

Structural Physics and Cosmic Records in a Coherence-First Law
Program

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Collapse in Physics: Coherence as Law from Cosmology to Matter

Abstract

Many presentations of standard physics treat randomness, time, and light as primitives: irreducible features of a universe governed by timeless laws evolving within a fixed geometric framework. This paper offers a coherence-first reframing. Building on Universal Collapse Theory (UCT) and Structural Physics, we treat collapse under constraint with a coherence bias as foundational, and interpret randomness, entropy, time, light, and even “laws” as records and residues of this process. We formalize the kernel as $(\Omega, K_t, C^{K_t}, x_t^*, R_t, S_t, T, U)$: a structured possibility space Ω ; active constraints K_t ; constraint-conditioned collapse C^{K_t} ; realized outcomes x_t^* ; records R_t ; residue S_t (entropy-like remainder); record-time $T = \sum_t r_t$ as accumulated collapse depth; and an update map $K_{t+1} = U(K_t, R_t)$.

At cosmological scale, we reinterpret the CMB as a coherence baseline (the inaugural global constraint update $\mathcal{F}$) and treat redshift as traversal depth through layered structural embedding rather than a direct reading of metric stretching. Entropy becomes the record of collapse expressed as residue; time is record-depth; and light is an embedded coherence carrier that logs traversal through evolving K . At local scale, we show that atoms, radioactive decay, chemical reactions, and collective matter behavior (phases, crystals, glasses, dissipative structures) instantiate the same kernel: atoms as coherence pockets, decay as coherent pruning, reactions as re-cohering under constraint, and phases/patterns as macro-scale collective coherence with hysteresis as visible record-sensitivity. Finally, we recast laws and “constants” as stabilized residues of constraint—parameters of coherence regimes rather than metaphysical absolutes.

We outline a test suite spanning cosmology and local physics: redshift drift, CMB–BAO coherence, spectral and decay stability, hysteresis in many-body systems, precision tests of constant stability, and entropy budgets. If these observations continue to align with a coherence-first kernel while reducing reliance on auxiliary scaffolds (fine-tuning appeals, inflationary field dependence, singular-boundary emphasis) without altering core data products, coherence is best read not as an accident at the end of physics, but as a law-level structural tendency beneath it.

Keywords: collapse under constraint; coherence in physics; structural physics; cosmology (CMB, redshift); entropy and time; laws of nature (constants)

§1 Introduction: What Physics Treats as Givens

Physics often treats derived descriptors as primitives. Randomness, entropy, time, and light are frequently positioned as “given,” while coherence is treated as something that happens *within* those givens. WP02 proposes a coherence-first reversal: randomness as the name we give unknown constraint structure; entropy as the residue of pruning already enacted; time as the bookkeeping of sequential resolution; and light as a record-carrier embedded in the very medium it traverses. Treated this way, familiar puzzles (fine-tuning, inflation dependence, singular-origin scaffolding) become interpretive add-ons rather than mandatory foundations—without changing a single datum. Where WP01 established the collapse kernel as a candidate law, WP02 examines whether physical structure already behaves as if that law were operative.

The aim of WP02 is not to discard Λ CDM’s observational successes, but to supply a more structural foundation: **collapse under constraint** as the generator of the “givens” that standard cosmology assumes. We retain all invariants—CMB Gaussianity, supernova time dilation, Tolman dimming, distance duality—and move what they mean beneath a single logic of coherence-first collapse (see, e.g., Planck Collaboration 2018; Riess et al. 2007; Lubin & Sandage 2001; Jhingan et al. 2014).

In WP01, we wrote realized outcomes generically as $\mathcal{O}$. Here we align the paper explicitly with the law kernel of collapse under constraint: a structured possibility space Ω , an active constraint set $\mathcal{C}$, a constraint-conditioned collapse operator $\mathcal{K}$, realized outcomes $\mathcal{O}$, records $\mathcal{R}$, residue $\mathcal{R}_r$, and an indexed notion of event-depth time t . In WP02 we emphasize the indexed sequence precisely to keep time legible as record-depth: each collapse adds to the ledger, and t denotes cumulative depth of resolution rather than an independent metaphysical axis (cf. Jones 2025, WP01 v2.0, §0.2–0.3; Jones 2025, UCT Symbols and Formulas Reference v1.2).

This reframing is observation-constrained: it does not discard the invariants that make physics powerful. Supernova lightcurves still dilate by $\Delta t_{\text{obs}} = (1 + z)\Delta t_{\text{em}}$. Surface brightness still dims as $(1 + z)^{-4}$. The CMB spectrum remains a near-perfect blackbody (see, e.g., Riess et al. 2007; Lubin & Sandage 2001; Mather et al. 1994; Planck Collaboration 2018). What changes is interpretation: the same invariants can be read as records of coherence and constraint-embedding rather than as artifacts of metric expansion seeded by primitive randomness. On this reading, several common explanatory scaffolds become optional rather than foundational: Gaussianity need not require an inflationary field to do explanatory work at the kernel level; constant stability need not rest on finely tuned initial conditions; and cosmic origin need not be anchored to a singular boundary event. Physics retains its mathematics. What changes is what those equations mean.

§2 Method: Invariants Preserved, Assumptions Removed

Our method is conservative: **preserve all cosmological invariants, remove unnecessary ontological assumptions.**

1. Keep the equations, change the ground.

- We adopt the UCT/Structural Physics kernel as background ontology— $(\Omega, K_t, C^{K_t}, x_t^*, R_t, S_t, T)$, where C^{K_t} denotes collapse conditioned by active constraint K_t —but do not alter the standard dynamical equations of Λ CDM where they are empirically successful. The Friedmann equations, radiative transfer, and statistical treatments of structure formation remain intact as effective descriptions of how constraints propagate; what changes is that they are read as stabilized residues of constraint rather than primitive law (see, e.g., Weinberg 2008; Peacock 1999).

2. Treat CMB, redshift, and entropy as records of collapse.

- The CMB is interpreted as a **coherence baseline**—the first global constraint update ($\mathcal{F}$) whose smoothing leaves a near-Gaussian field as residue—rather than as a literal “surface of last scattering” that requires a specific inflationary mechanism.
- Redshift is treated as **traversal depth** through layered structural embedding, with

$$1 + z = \prod_j (1 + \delta_j),$$

preserving all invariants (time dilation, Tolman dimming, distance duality) while relocating their cause from metric stretching to layered constraint.

- Entropy is taken as the **record of collapse expressed as residue**—the tally of pruned possibilities carried forward as dissipation—rather than as chaos triumphant. Entropy and structure rise together as two faces of the same pruning process.

3. Use shape tests, not parameter over-fitting.

Throughout WP02 we rely on **shape-level predictions** that distinguish coherence-first interpretation from standard FRW framing without changing the basic data products:

- The **CMB**: can its near-Gaussian anisotropies be explained by constraint-smoothing alone, without invoking an inflationary field?
- **Redshift drift**: does measured drift follow $H(z)$ (FRW expectation) or a structural-updating curve implied by traversal depth?
- **Entropy budgets**: does the log-slope of total cosmic entropy vs. time behave like a smooth record-accumulation process, or does it require plateauing or highly kinked histories?

4. **Make assumptions explicit and portable.**

All assumptions used in this reframing—photon-number conservation, null-path preservation, Liouville invariance of photon phase-space density, homogeneous/isotropic background at leading order—are stated in Appendix B. They are chosen to match the level at which FRW cosmology already operates, so that any empirical deviation can be attributed to genuine structural difference rather than to hidden modeling choices.

Taken together, this method lets WP02 function as a **purely interpretive upgrade**: every key observable (CMB statistics, supernova Hubble diagrams, Tolman tests, BAO scales, entropy budgets) is preserved as data; coherence replaces randomness, time, and light as foundation. Subsequent sections apply this method in turn to the CMB, redshift, entropy, time, light, atomic and chemical coherence, and collective matter behavior, showing how each can be read as a concrete expression of collapse under constraint with a Law of Coherence bias.

§3 The CMB: Coherence Baseline, Not Afterglow

In Λ CDM, the cosmic microwave background (CMB) is described as the “surface of last scattering”—radiation released when the universe became transparent $\sim 380,000$ years after the Big Bang. Its Gaussianity and near scale-invariance are commonly attributed to inflation, a hypothesized early-universe mechanism introduced to address horizon-scale uniformity and to seed nearly scale-free fluctuations on an expanding background (see, e.g., Hu & Dodelson 2002; Dodelson 2003; Liddle & Lyth 2000; Guth 1981; Planck Collaboration 2018).

In coherence-first framing, the same data are read differently. The CMB is not treated as an afterglow of origin, but as the **first coherence baseline**: the field written when a global constraint update $\mathcal{F}$ smooths early structure into a common reference state. In kernel terms, the early universe is a high-variance structured potential Ω of fields and matter, with relatively little written record. $\mathcal{F}$ denotes the inaugural collapse under constraints K_0 (local physics plus global symmetry/curvature conditions). The action of $\mathcal{C}^{K_0}(\Omega)$ produces a smoothed background plus small, structured deviations. What Λ CDM models as “inflationary perturbations,” we treat as the statistical residue of constraint-driven smoothing.

This interpretation preserves all observables. The CMB remains:

- a near-perfect **blackbody spectrum**,
- a field with nearly **Gaussian anisotropies**,
- a pattern with **acoustic peaks** encoding baryon–photon interactions

(see, e.g., *Mather et al. 1994; Hu & Dodelson 2002; Planck Collaboration 2018*).

We do not deny recombination or decoupling as physical events. What changes is the explanatory assignment: “last scattering” remains an observational marker of transparency, while the *baseline coherence* of the field is attributed to a global smoothing collapse written into record.

What changes, then, is causality. Gaussianity and near scale-invariance become signatures of **coherence smoothing**: a global collapse that drives many initially irregular configurations toward a common baseline, leaving only small, correlated deviations as residue S . Inflation becomes explanatorily optional at the kernel level: the coherence kernel (Ω, K, C^K, R, U) suffices to ground why a smoothed near-Gaussian baseline should exist at all.

In UCT language, the CMB is the record R_0 of $\mathcal{F}$: a coherence field that:

- encodes the first large-scale constraint update (the “coherence baseline”),
- seeds later structure formation (galaxies, clusters, voids) as higher-order collapses within this field,
- and anchors later measures of redshift, entropy, and time as **comparisons** against its baseline.

Prediction — tilt as kernel, not field dynamics.

If the CMB anisotropies arise from constraint smoothing rather than **specific** inflaton dynamics, the residual tilt of the power spectrum should trace the structure of the smoothing kernel (how $\mathcal{F}$ acts on Ω under K_0), not the detailed dynamics of an inflaton potential. CMB-S4 and related experiments can test whether a coherence-first smoothing operator can reproduce measured tilt and higher-order statistics without specifying a particular **inflaton** potential (CMB-S4 Collaboration 2016).

Sidebar — omnidirectionality as structural embedding.

The CMB cannot be localized the way unseen mass can: it arrives from every direction and is continuously present as a global field. Standard cosmology reads this as a property of an expanding spacetime filled with relic radiation. UCT reads the same fact structurally: if the CMB pervades all directions, then no region is ever outside the coherence baseline. Every particle, cloud, and star is embedded in R_0 . What FRW calls expansion, UCT can treat as increasing depth of structural embedding relative to this baseline: the CMB records the universality of First Collapse, not merely the geometry of an expanding metric.

Clarification — “cooling” as motion under constraint.

On this view, cosmic “cooling” is not the universe running down, but typical particle motion slowing as latent structural potential is redistributed into deeper embedding. Locally, gravitational collapse can reverse this trend: matter falls, potential converts to kinetic, and stars ignite against a cooling background. “Temperature” is best understood as the balance between global slowing and local speeding: global collapse deepens coherence; local collapses re-accelerate particles into fusion and structure-forming regimes.

§4 Redshift: Traversal Depth, Not Expansion

Redshift is conventionally interpreted as the stretching of light due to metric expansion: spacetime itself enlarges, elongating wavelengths. This is consistent with FRW cosmology but treats the metric as a dynamical substrate and redshift as direct evidence of expanding space (see, e.g., Weinberg 2008; Hogg 1999).

From the coherence-first view, redshift is instead the record of sequential traversal across layers of structural embedding. After $\mathcal{F}$ has written the coherence baseline, any photon propagating from emitter to observer crosses a sequence of collapse-shaped layers $K_1, K_2, \dots, K_N$. Each layer acts by the same structural factor on frequency and interval, so that:

$$1 + z = \prod_{j=1}^N (1 + \delta_j),$$

where each δ_j is a coherence increment—a small, constraint-induced conformal factor along the path.

Given photon-number conservation, null-path preservation, and Liouville invariance of photon phase-space density, these layered transforms preserve exactly the same observational invariants as FRW expansion (e.g., Weinberg 2008; Ellis et al. 2012):

- **Supernova time dilation:** $\Delta t_{\text{obs}} = (1 + z)\Delta t_{\text{em}}$ (Riess et al. 2007).
- **Tolman surface-brightness dimming:** $\text{SB} \propto (1 + z)^{-4}$ (Lubin & Sandage 2001).

- **Distance duality:** $D_L = (1 + z)^2 D_A$ (Etherington 1933; see also Bassett & Kunz 2004).

In both interpretations, the invariants hold. What differs is ontology. Redshift can be read without committing to a metric that stretches: it can be read as coherence depth—the accumulated effect of collapse-shaped layers on traversal logs (photons).

In kernel terms, each segment of the photon’s path is a local application of $\mathcal{C}^{K_j}(\Omega_j)$ that rescales frequency and interval while preserving null structure. The observed redshift is then a summary statistic of the sequence $\{K_j\}$ the photon has traversed. FRW’s scale factor $a(t)$ becomes an effective description of this cumulative traversal depth rather than a primitive geometric field.

Prediction — redshift drift as decisive discriminant.

Redshift drift provides a clean test. In FRW cosmology,

$$\frac{dz}{dt_0} = (1 + z)H_0 - H(z)$$

(Sandage 1962; Loeb 1998). In the coherence model, drift follows the update pattern of traversal depth—how the sequence $\{\delta_j\}$ changes as constraints K evolve over record-time T . If the inferred effective scale factor $a_{\text{eff}}(T)$, reconstructed from drift measurements, diverges systematically from FRW expectations, that divergence can be attributed to structural updating rather than to metric dynamics.

Forecasts for ELT-HIRES suggest that, over a 10–20 year baseline, velocity shifts of order 1–2 cm/s/yr at $z \sim 2.5$ (the Λ CDM expectation) should be detectable at $\gtrsim 3\sigma$ significance (Liske et al. 2008). Combined with SKA’s 21 cm measurements, redshift drift will effectively measure $\dot{z}(z)$ as a function of redshift, providing a model-independent probe of the expansion history (Weltman et al. 2020). Inhomogeneous void models and many modified-gravity scenarios predict qualitatively different drift curves, making drift a decisive discriminator: if $\dot{z}(z)$ closely tracks the FRW prediction, the coherence-first reading remains an interpretive re-mapping; if not, it signals a genuine structural deviation in how constraints evolve with record-time.

Conceptually, we can think of a photon traversing N ordered layers after First Collapse; each layer applies the same coherent factor to frequency and intervals: $v \rightarrow v/(1 + \delta_j)$, $\Delta t \rightarrow (1 + \delta_j)\Delta t$. Under photon-number conservation and null-path preservation, the standard invariants follow immediately: time dilation, Tolman dimming, and distance duality. The

difference is not in what is measured, but in what those measurements are taken to reveal: a metric-expansion substrate, or a stack of coherence-shaped layers recording traversal depth.

§5 Entropy: Residue of Collapse, Record of Complexity

In physics, entropy is often introduced as disorder—the universe “running down,” information lost, structure eroded. In the collapse-under-constraint frame, the explanatory priority is reversed. Entropy is not “the amount of chaos,” but the record of collapse expressed as residue: the redistributed degrees of freedom not locked into enduring constraints or coherent structures (cf. Callen 1985; Schroeder 2000).

Under the law kernel, each collapse step

$$x_t^* = C^{K_t}(\Omega_t)$$

writes records and generates residue. A realized outcome x_t^* becomes part of the written record R_t , and the active constraint set updates according to

$$K_{t+1} = U(K_t, R_t),$$

deepening order and creating new collapse pockets in Ω . In parallel, collapse produces redistributed degrees of freedom S_t : heat, radiation, and microscopic rearrangements that carry forward the traces of pruning already enacted.

Entropy S is simply the cumulative measure of this residue—e.g., $S = \sum_t S_t$: the tally of degrees of freedom routed into “free” channels rather than stabilized into constraint-bearing structure. In this view, entropy and structure rise together. Every star that burns, every galaxy that forms, every crystal that grows increases entropy and increases structure (see, e.g., Egan & Lineweaver 2010). The Second Law becomes:

As structured potential is repeatedly resolved under constraints, residual degrees of freedom (entropy) and coherent structure (records) both accumulate.

There is no opposition between “order” and “entropy” here. They are two faces of the same process: collapse under constraint stabilizes patterns *and* spreads residue. The universe does not move from order to disorder; it moves from latent structure to deeper, nested coherence, with an ever-growing residue S that records the pruning already enacted.

Prediction — entropy budgets as coherence indices.

If this reading is correct, large-scale entropy budgets (cosmic entropy, black hole entropy, radiation backgrounds) should behave less like pure measures of “disorder” and more like **coherence indices**: they should track the cumulative pruning of structured potential, rising in tandem with the emergence of long-lived records (stars, galaxies, black holes, chemical and biological complexity) (Egan & Lineweaver 2010; Bekenstein 1973; Hawking 1976). Deviations from smooth, record-like growth—sharp kinks, unexplained plateaus—would signal missing or mischaracterized collapse channels in the underlying constraint set K_t .

5.1 Randomness and the Born Rule

Quantum mechanics is often taken as final proof that randomness is fundamental. On the standard reading, the Born rule expresses an ontological commitment: measurement outcomes occur with irreducible probabilities $|\psi|^2$ even when the wavefunction evolves deterministically (see, e.g., Griffiths 2005; Sakurai & Napolitano 2017).

From the coherence-first perspective, a different interpretive assignment is possible. The Born rule need not certify metaphysical chaos; it can be read as a stable summary of unresolved constraint detail at the level we model. A quantum state, in UCT language, is a structured description of Ω under an effectively specified constraint set K . The Born weights tell us how often collapse under the current K will land in each admissible outcome x_i^* across an ensemble. The apparent randomness reflects the fact that we do not track—or cannot track—every constraint-sensitive detail that shapes each individual collapse.

Put differently: the Born rule summarizes ensemble-level frequencies when many collapses of the same structured potential are allowed to proceed under similar effective constraints. What looks like nature “playing dice” can be read as nature applying C^K to Ω in a way that is coherent but underspecified from our vantage point. The statistics are stable precisely because the effective constraint structure is stable.

This perspective aligns with scientific history. Many phenomena once labeled “random” (thermal motion, molecular diffusion, genetic inheritance) later revealed hidden structure: constraints that, once understood, made the apparent randomness predictable in aggregate (cf. Callen 1985; Schroeder 2000; Gillespie 2004). In UCT, quantum randomness occupies the same structural status: the Born rule is a stable summary of unresolved structural detail, not a declaration that reality is fundamentally unstructured.

Prediction — coherence-sensitive deviations at higher order.

If the Born rule is an emergent summary of deeper coherence dynamics, then experiments probing higher-order correlations and context-sensitive constraint manipulation are the most likely places to reveal small, systematic departures from naïve $|\psi|^2$ expectations—especially in regimes where the effective constraint set K is being deliberately shaped (e.g.,

adaptive measurements, feedback-conditioned setups, or strongly context-dependent couplings). Any such departures would not refute coherence; they would point to additional structure in K that standard treatments idealize away.

§6. Time as Emergent Record and Movement

In standard physics, time is treated as an independent axis: a universal parameter in Newtonian mechanics, and a coordinate in spacetime geometry for relativity (for standard treatments, see, e.g., Goldstein 2002; Misner, Thorne & Wheeler 1973; Carroll 2004). UCT reverses this order. Time is not a primitive background; it is the depth of collapse already enacted. It is the measure of how far a system has progressed through resolution of its structured potential.

In the law kernel, each collapse step

$$x_t^* = C^{K_t}(\Omega_t)$$

produces a record R_t . The record-time of a system is then the cumulative measure of record-depth,

$$T = \sum_t r_t,$$

where r_t denotes the record increment written at step t (i.e., a chosen scalar measure of R_t). This is the structural statement that time is accumulated record-depth rather than an underlying continuum. Clocks are just devices whose local degrees of freedom are engineered to produce regular, countable records under well-controlled constraints. A “second” is not a thing the universe flows through; it is a conventional unit for how many structured events have been ticked off along a worldline.

Relativity makes this constraint-dependence explicit. Proper time along a worldline is not a universal parameter shared across observers; it depends on the worldline’s motion and gravitational embedding. As a system moves faster relative to an observer, or sits deeper in a gravitational well, it accumulates fewer internal “ticks” per unit of external comparison time (Misner, Thorne & Wheeler 1973; Carroll 2004). On the UCT reading, this becomes legible: the effective constraint set K_t along that worldline—its energy, curvature, and interaction environment—modulates the rate at which its internal degrees of freedom resolve. Time dilation is record-rate modulation under different K , not a paradoxical stretching of a pre-existing “time dimension.”

The same applies to length contraction and other relativistic effects. Spatial and temporal intervals are not fixed scaffolds; they are quotients of record-depth between differently constrained observers. Lorentz invariance and the constancy of c are not arbitrary axioms; they can be read as stabilized regularities of constraint: symmetry conditions that coherent

interaction repeatedly selects and entrenches. The “laws” of relativity, in this view, are not decrees laid down outside the system. They are coherent invariances that survive contact with reality and now function as part of the constraint set K that shapes further collapse.

Cosmic time in FRW cosmology can be read similarly. FRW’s t is the proper time of comoving observers and, operationally, a coarse-grained record-time for the universe referenced to the CMB coherence baseline: it counts how far large-scale structure has progressed from $\mathcal{F}$ ’s initial smoothing (Weinberg 2008; Peacock 1999). What FRW calls “early” and “late” epochs are simply different depths of the same record. Once time is understood as accumulated collapse rather than a fundamental flow, cosmic history becomes a history of constraint updates and record accumulation—not motion through an external temporal container.

§7. Light as Emergent Record and Movement

Light is usually presented as massless quanta propagating at speed c through empty space. In practice, however, photons are rarely (and arguably never, in any observationally relevant regime) propagating through a perfectly featureless “nothing.” They move through structured context: gravitational fields, quantum fields, plasma, dust, and the ever-present CMB. Every observed property of light—redshift, lensing, delay, absorption, refraction—quietly testifies that light propagates through embedding structure rather than through an inert void (see, e.g., Jackson 1999; Born & Wolf 1999; Carroll 2004).

Standard cosmology already treats light as a tracer of structure: the integrated Sachs–Wolfe effect, CMB lensing, and Shapiro delay in precision timing signals arise because photons accumulate phase, energy, and timing shifts as they traverse evolving gravitational and plasma environments. In UCT terms, each photon’s path logs traversal through layered constraints, making light a natural coherence carrier rather than a traveler through featureless emptiness.

In the UCT kernel, a photon trajectory is a sequence of local applications of C^{K_j} along a null path through Ω . At each segment, constraints K_j (curvature, refractive index structure, charge distribution, background radiation) act on the photon’s state, shaping frequency, phase, and direction while preserving null structure. The photon is a minimal record-carrying mode: a compact packet of structured potential whose evolution logs traversal through a layered constraint stack. Its energy and polarization encode which constraint regimes it has passed through; its redshift and timing encode how deeply it has traversed structural embedding.

Gravitational lensing and Shapiro delay make this explicit. Photons do not “bend” or “delay” in a literal void; they respond to curvature and potential encoded in K . Refractive media, dispersion, and absorption likewise show that light is sensitive to detailed structure in matter fields. Even “intergalactic vacuum” carries the CMB, residual plasma, and large-scale

gravitational structure. What we call “vacuum” is best understood as a low-density, high-symmetry constraint configuration, not an absence of embedding (Shapiro 1964; Schneider, Kochanek & Wambsganss 2006; Jackson 1999; Peebles 1993).

From this perspective, the constancy of c is a statement about how constraints couple to null trajectories: it is the invariant speed of the coherence carrier in any local inertial frame, not a property of emptiness. Photons are the tightest coupling between distant collapse pockets. They relay constraint information across vast spans of Ω , allowing coherence to propagate: clocks synchronize, spectra align, and causal influence remains well-defined. Light is the system’s native protocol for sharing records; it ties local collapses into a globally coherent structure.

This reframing also clarifies the connection between light and redshift. The analysis of redshift as traversal depth in §4 showed that $1+z$ can be understood as the cumulative effect of layered transforms $\{C^{K_1}, \dots, C^{K_N}\}$ acting on photon frequency and timing. Section 7 generalizes this: all observable behavior of light—frequency shifts, path bending, timing—can be read as expressions of how photons embed in and respond to evolving K . Light is not an independent substrate; it is one of the most universal records of collapse under constraint.

In summary, time and light are not primitive ingredients of reality. Time is the depth of collapse inscribed as records; light is the carrier of those records across the structured medium. Once collapse under constraint and the Law of Coherence are taken as foundational, both fall naturally into place as emergent properties of a universe that is already, at every scale, resolving structured potential into coherent form.

§8 Atomic and Chemical Coherence: Bound Structure, Decay, and Reaction

8.1 Structured Potential at the Atomic Scale

At the atomic scale, Ω is no longer the space of abstract field configurations alone; it is the structured possibility space of electrons and nuclei. A given element defines a family of micro-configurations: positions, momenta, spins, and orbital occupancies for its charged constituents. Constraints K encode the Hamiltonian, the Coulomb potential, spin-orbit couplings, Pauli exclusion, and the boundary conditions imposed by neighboring fields and matter. Collapse under these constraints does not select arbitrary microstates; it selects admissible quantum states—those wavefunctions which respect symmetry, exclusion, and energy quantization (see, e.g., Griffiths 2005; Sakurai & Napolitano 2017; Cohen-Tannoudji et al. 1977).

In this regime, collapse under constraint can be represented as C^K : the allowed unitary evolution plus the effective “measurement” interactions that couple the atom to its environment. The actual state x^* realized at any moment is a concrete instantiation of a quantum configuration compatible with K . As with all physical systems in UCT, atomic dynamics leave records R : emission and absorption lines, scattering cross-sections, ionization thresholds, and stable patterns of bonding. Entropy S again measures the redistributed residue of pruned micro-configurations, and record-time $T = \sum_t r_t$ accumulates as atoms form, persist, interact, and transform, where r_t denotes a scalar measure of the record R_t written at step t . The Law of Coherence now appears as the tendency of the kernel (Ω, K, C^K, R, U) to stabilize bound structures—atoms and ions—as coherent pockets in Ω (Bransden & Joachain 2003; Atkins & Friedman 2011).

8.2 Atoms as Coherence Pockets

A bound atom is not a miniature solar system of hard particles; it is a coherence pattern in the electron–nucleus wavefunction. For a fixed nuclear charge Z and constraint set K , only certain wavefunctions are admissible: those that satisfy the Schrödinger equation with appropriate boundary conditions and symmetries. These form a discrete spectrum of energy eigenstates (Griffiths 2005; Cohen-Tannoudji et al. 1977; Bransden & Joachain 2003). In UCT’s language, each bound state is a collapse pocket in Ω : a region of configuration space where the wavefunction’s structure is self-consistent under K , and thus capable of persisting as a record R .

When an electron transitions between such states, the atom does not explore every conceivable configuration. C^K restricts transitions via well-known selection rules: only certain changes in quantum number, angular momentum, and parity are allowed. The resulting emission or absorption of a photon is itself a record R of collapse under constraint. Spectral lines are therefore not arbitrary; they are the fixed signatures of coherent resolution (Herzberg 1944; Demtröder 2003). Over record-time, atoms repeatedly collapse into and out of these bound states, but the underlying pattern—discrete allowed energies, stable orbitals, quantized angular momentum—remains invariant. Atoms are thus long-lived coherence pockets: localized regions of Ω where collapse under K settles into reproducible, low-description-length structure.

8.3 Radioactive Decay as Coherent Pruning

Not all nuclear configurations are equally coherent under K . Certain combinations of protons and neutrons sit high in the nuclear binding-energy landscape: they are structurally tense configurations in Ω . UCT treats these as metastable coherence pockets—temporarily admissible states that are nonetheless biased toward transformation. Radioactive decay is the process by which such nuclei are pruned into more globally coherent configurations. The constraint set K here includes the strong and weak interactions, conservation laws

(energy, momentum, charge, baryon number), and the shape of the binding-energy surface for each isotope (Krane 1988; Wong 1998).

Under these constraints, C^K does not permit arbitrary nuclear rearrangements. Only specific decay channels— α -emission, β —decay, γ -emission, fission—are available, each tightly filtered by selection rules. Individual decay events appear stochastic, but at the ensemble level the behavior is strongly law-like: characteristic half-lives, branching ratios, and decay chains (Krane 1988; Povh et al. 1999). From the UCT perspective, this is what the Law of Coherence predicts. Over record-time T , an initial distribution of unstable nuclei collapses into a narrower set of stable daughters; unstable pockets in Ω are eliminated, and only constraint-compatible nuclei remain as long-lived records R . The emitted particles and photons constitute the residue S : redistributed structural potential energy that “pays for” the transition to more coherent nuclear structure.

8.4 Chemical Reactions as Re-Cohering Under Constraint

If bound atoms are coherence pockets for electrons and nuclei, chemical reactions are the process by which those pockets are reconfigured into new coherent assemblies. Given a collection of atoms, Ω spans all admissible ways their electrons and nuclei could, in principle, be arranged into molecules, radicals, and complexes. Constraints K drastically narrow this space. They include valence rules, allowed orbital overlaps, conservation of atom counts and charge, the potential-energy surface defined by the underlying Hamiltonian, and environmental parameters such as temperature, pressure, solvent, and catalysts (Atkins & de Paula 2010; Levine 2009).

C^K then governs how the system moves across this landscape. Collisions, transient complexes, and transition states represent short-lived excursions in Ω , but collapse under K consistently favors pathways that descend toward lower structural potential energy or otherwise satisfy the imposed constraints (for example, by dissipating energy into a heat bath). The realized outcomes x^* are not random conglomerations: for a given K , only a small subset of molecular structures actually persist. Stoichiometric ratios, equilibrium constants, and characteristic rate laws are precisely the macro-records R of this process (Laidler 1997; Atkins & de Paula 2010). Over record-time, the system moves from a broad set of reactant configurations toward stable product structures—new coherence pockets where electrons are reshaped into bonds compatible with K . Chemical networks thus instantiate the Law of Coherence at the mesoscopic scale: under fixed constraints, the kernel (Ω, K, C^K, R, U) prunes chemically incompatible arrangements and stabilizes specific molecular patterns as long-lived records.

8.5 Summary: Atomic Collapse as Foundation for Higher Scales

At the atomic scale, physics already behaves in ways strongly consistent with a coherence-first collapse system. Bound atoms are persistent coherence pockets in Ω , stabilized by the interplay of quantum constraints K and collapse dynamics C^K (as seen in §§8.1–8.2).

Radioactive decay reveals that structurally strained nuclei are not tolerated indefinitely; they are pruned into more stable isotopes, with their excess structural potential dispersed as residue S (§8.3). Chemical reactions show atoms continually re-cohering into new molecular structures, with only a narrow subset of arrangements surviving as records R under given environmental constraints (§8.4).

From the standpoint of UCT, this suffices to establish that coherence is not a late arrival in the universe. Long before biology, the physical domain is already populated by collapse pockets: atoms, ions, nuclei, and molecules that embody the Law of Coherence at small scales. When we later turn to Biological Collapse, we will not be introducing a new ontological layer of “vital substance.” We will be tracking how these atomic and molecular coherence pockets are recruited into a new regime of constraints—replication, fitness landscapes, and informational control—such that collapse under K begins to preserve and elaborate structure in a targeted way (developed in WP03). Life, in this view, is not a departure from atomic coherence. It is what happens when atomic and chemical coherence are organized into a recursive project of self-sustaining collapse.

8.6 Bridge: From Atomic Pockets to Collective Fields of Coherence

At this point, the law kernel has been shown to operate at the level of individual collapse pockets: atoms, ions, nuclei, and molecules (§§8.1–8.4). In each case, Ω is finite but structured, K is local (charge, spin, potentials, valence, environment), and C^K stabilizes discrete, low-description-length configurations as records R . Radioactive decay prunes structurally strained nuclei; chemical reactions reshape atomic pockets into new molecular patterns. The result is a world already populated by coherent building blocks long before life: a periodic table of collapse pockets and a vast library of stable and meta-stable molecular records.

The next step is to ask what happens when these pockets are assembled in great number and allowed to interact under shared constraints. When many atoms and molecules are coupled through long-range forces, boundary conditions, and thermodynamic parameters, Ω expands into a high-dimensional many-body space, and new kinds of structure become possible. Phases of matter, crystalline and amorphous solids, and far-from-equilibrium patterns such as convection rolls or reaction–diffusion waves are all instances of collective coherence (§9.1–9.4): macro-structures that emerge when collapse under K is no longer confined to a single atomic or molecular pocket, but orchestrates entire fields of degrees of freedom at once.

What follows shows that no additional ontology need be assumed to describe this emergence. The same law kernel— Ω , K , C^K , records R , residue S , and the update map $K_{t+1} = U(K_t, R_t)$ —governs the formation of phases, patterns, and hysteresis loops. Collective behavior will appear as many-pocket collapse under shared constraint, producing macro-coherent records that bridge the atomic scale to the chemical and, ultimately, to the biological.

§9 Collective Coherence: Phases, Patterns, and Hysteresis

9.1 Many-Body Systems in Ω, K, C^K, R

In earlier sections, we treated Ω as the structured possibility space for relatively simple systems: single particles, atoms, nuclei, and small chemical complexes. At larger scales, Ω becomes the configuration space of many interacting degrees of freedom: positions, momenta, spins, bonds, and field values for an entire bulk material. The law kernel, however, does not change. A many-body system is still specified by a triple (Ω, K, C^K) , with constraints K encoding interaction potentials, boundary conditions, external fields, and thermodynamic parameters, and with C^K the dynamics those constraints permit (Pathria & Beale 2011; Reichl 2016).

Under these constraints, the system explores Ω but does not wander arbitrarily. Collapse under K selects actual trajectories $x_j^*(t)$ which leave behind macro-scale records R : densities, order parameters, phase boundaries, and stable patterns. Entropy again appears as S , the redistributed residue of pruned micro-configurations, and record-time $T = \sum_t r_t$ accumulates as the system transitions from one macro-coherent structure to another, where r_t denotes a scalar measure of the record R_t written at step t . In collective matter behavior, the Law of Coherence simply scales up: instead of stabilizing individual atoms and molecules, collapse under constraint stabilizes macro-states—phases and patterns—that are themselves coherent structures embedded in Ω .

9.2 Phases as Competing Coherence Pockets

A phase of matter can be understood as a coherence pocket in the many-body configuration space: a region of Ω where the system's microstates, under fixed K , realize a characteristic macro-structure. Here we use “collapse pocket” for the stable region of Ω selected by collapse under K , and “coherence pocket” for the persistent, record-bearing structure that results.

For a given interaction potential and external parameters (temperature, pressure, field strength, geometry), the kernel (Ω, K, C^K, R, U) does not merely permit one such pocket. It typically supports multiple admissible macro-coherent structures—for instance, a solid and a liquid, or a ferromagnetic and a paramagnetic phase (Goldenfeld 1992; Chaikin & Lubensky 1995).

When K is held fixed within the domain of a single phase, repeated collapse events drive the system toward that phase's macro-coherence: lattice order in a solid, uniform magnetization in a ferromagnet, or well-defined density in a liquid. When K is slowly varied, the system is forced to choose among competing coherence pockets. At the melting point, at the Curie temperature, or at other critical thresholds, collapse under evolving K redirects

trajectories x^* from one macro-coherent attractor to another. Phase transitions are thus not singular, inexplicable events; they are collective collapses in which the system abandons one coherence pocket and settles into another whose structure is more compatible with the new constraint set (Goldenfeld 1992; Kardar 2007).

9.3 Crystals, Glasses, and Structural Memory

Crystallization provides a particularly clear example of collective coherence. Starting from a melt, Ω includes astronomically many ways to place and orient molecules in space. Yet under constraints K (interaction potentials, cooling schedule, boundary conditions, nucleation sites), C^K drives the system toward a small, discrete family of lattice structures. The resulting crystal has an extremely low description length: a unit cell and a symmetry group suffice to reconstruct its long-range order. In UCT's language, the crystal is a macro-record R of collapse under K , encoding a highly coherent solution to the system's structural potential (Ashcroft & Mermin 1976; Kittel 2005).

Glasses and amorphous solids show that coherence is not synonymous with visual regularity. Rapid quenching or impurity-laden environments modify K such that the system cannot fully reorganize into a single periodic lattice. Collapse still produces a rigid macro-structure—particles are locked into place—but the resulting record R is disordered at long range. It is, however, no less structural. The glass preserves a detailed memory of its formation pathway: cooling rate, constraints, and local fluctuations are imprinted in its microstructure (Zallen 1983; Debenedetti & Stillinger 2001). From a UCT perspective, both crystals and glasses are coherent records: each is a stable outcome of the kernel (Ω, K, C^K, R, U) under different constraint trajectories. Crystals exemplify minimal structural description; glasses exemplify structural memory of path-dependent collapse.

9.4 Dissipative Structures: Dynamic Coherence Under Flow

Not all collective coherence is static. In far-from-equilibrium systems, constraints K include continuous gradients—temperature differences, chemical potential differences, imposed flows—which drive sustained energy and matter throughput. In such regimes, the law kernel does not converge to a single, time-independent macrostate. Instead, collapse under constraint stabilizes dynamic patterns: convection rolls, oscillatory chemical waves, Turing patterns, spiral fronts. These are dissipative structures: coherent spatiotemporal organizations that exist only while gradients are maintained (Prigogine & Nicolis 1977; Cross & Hohenberg 1993).

Here Ω is the space of possible field configurations (velocity fields, concentration fields, temperature fields), K bundles the governing equations plus boundary conditions and driving gradients, and C^K specifies how those fields evolve. The patterns that emerge—a fixed number of convection cells, a characteristic wavelength of spots and stripes—

represent low-dimensional attractors in a far larger configuration space. They are coherence pockets in motion: macro-records $R(t)$ that persist over record-time T as long as the constraints continue to feed structural potential energy through the system. When the gradient is removed, the patterns collapse and Ω relaxes toward more homogeneous states; the dissipative structure vanishes, but its existence has already been inscribed in R and S .

9.5 Sweeps, Hysteresis, and the S_3 Signal in Physics

Collective matter behavior naturally exhibits the S_3 signature of the Philosophy of Coherence: sweeps in control parameters producing hysteresis and path-dependent structure. When a phase boundary is traversed by slowly varying K —for instance, by ramping temperature or an external field—the system does not always switch phase at the same parameter value in both directions. Supercooling, superheating, and magnetic hysteresis demonstrate that collapse into a new coherence pocket depends on the history of constraints, not merely their present value (Stanley 1971; Sethna 2006).

In UCT terms, hysteresis is the macro-level expression of record-sensitive collapse: the update map $K_{t+1} = U(K_t, R_t)$ embeds past collapses into the effective constraint set. Nucleation sites in a half-crystallized liquid, remanent domains in a ferromagnet, or structural defects in an amorphous solid act as additional constraints that bias future collapse. Sweeping K upward and then back down does not retrace the same trajectory in Ω ; the system moves through a different succession of coherence pockets because K has been reshaped by prior records R . The resulting hysteresis curves—magnetization versus field, phase fraction versus temperature—are themselves records of how coherence unfolded under changing constraints. They provide a direct physical instance of S_3 : path-dependent collapse trajectories visible at macro scale.

9.6 Summary: From Micro-Structure to Macro-Coherence

With collective behavior in view, the physical domain presents a unified picture. At the micro-scale, collapse under constraint stabilizes atoms, nuclei, and molecules as coherence pockets in Ω . At the meso- and macro-scale, the same law kernel organizes many-body systems into coherent phases, crystalline or glassy solids, and dynamic dissipative structures. Phase transitions, structural memory, and hysteresis are not exceptions to disorder; they are the expected behavior of the kernel (Ω, K, C^K, R, U) when many degrees of freedom are coupled under shared constraints.

For our purposes, this closes the physical arc. Before life arises, the universe is already a tapestry of collective collapse pockets: galaxies, stars, planetary atmospheres, rocks, oceans, and reaction networks all exhibit coherent structure that reflects their constraints and histories. The Law of Coherence has thus been instantiated across scales long before biology. Biological Collapse will not introduce a new kind of substance; it will introduce new

kinds of constraints—replication, fitness landscapes, informational structure—acting on the same structural potential. In that sense, life is not an exception to physical coherence. It is what happens when chemical and collective coherence are recruited into a recursive project: preserving and elaborating structure against the gradient of record-time.

§10 Laws as Residues of Constraint

Physics often treats laws as axioms: timeless rules inscribed into reality and discovered, not explained. We write down conservation laws, Einstein’s equations, Maxwell’s equations, and treat them as given. This practice is operationally effective but leaves their origin unexplained. Why should such laws exist at all? Why these laws rather than others? (see, e.g., Goldstein 2002; Jackson 1999; Misner, Thorne & Wheeler 1973; Wald 1984).

In the coherence-first frame, laws are not primitive. They are stabilized records of how collapse under constraint typically behaves. The kernel describes a universe in which structured potential is repeatedly resolved under evolving constraints. Over record-time, certain regularities in this process become so reliable that we promote them to “laws.” But ontologically, they are residues of constraint—regularities entrenched by repeated coherence-preserving collapse—not dictums that precede collapse (see also Jones 2025, WP01 v2.0; Jones 2025, Structural Physics (refined)).

We can make this idea more precise by adopting a simple variational picture. Suppose a system with structured potential $V(x)$ is subject to constraint functions $F_a(x) = 0$ collected in K . A realized configuration x_{real} is not arbitrary; it is selected by collapse under K . In many familiar regimes, this can be approximated as a constrained extremum:

$$\nabla V(x_{\text{real}}) + \sum_a \lambda_a \nabla F_a(x_{\text{real}}) = 0,$$

with Lagrange multipliers λ_a encoding how strongly each constraint shapes the realized outcome. On this reading, “laws” correspond to stationary patterns of collapse: stable relationships between variables that arise when constraint-shaped extremization is applied again and again to similar structured potentials (Goldstein 2002; Lanczos 1970).

- **Conservation laws emerge as residues of symmetry constraints.** Noether’s theorem can be re-read as: when K includes a continuous symmetry, collapse under K yields records R in which certain aggregate quantities (energy, momentum, charge) remain invariant. Conservation is not an extra axiom; it is what symmetry-constrained collapse tends to preserve (Noether 1918; Brading & Brown 2003).
- **Entropy growth emerges as the residue of pruning already enacted.** Collapse stabilizes one coherent macro-structure within Ω , and entropy S is the redistributed

record-residue of that stabilization—dissipation, heat, and microscopic degrees of freedom carried forward as traces of collapse. The Second Law then expresses the fact that, as constraints repeatedly select coherent outcomes and write records, residue and record both accumulate in a coupled way (Callen 1985; Schroeder 2000).

- **Curvature emerges as the large-scale propagation of constraint across mass-energy distributions.** Einstein’s field equations can be viewed as a compact encoding of how local K (stress-energy) determines the effective geometry that shapes subsequent collapse (worldlines, lightcones). Spacetime curvature is not a separate substance; it is a structural record of how constraints have already been distributed (Einstein 1916; Misner, Thorne & Wheeler 1973; Wald 1984).

In all three cases, what appear as axioms are stabilized patterns of resolution. Laws look timeless only because the effective constraints K have been stable over the range of our observations. Relativity itself makes this dependence explicit: rates of collapse (time), measured distances, and even simultaneity change when constraints differ. Physics has already discovered that invariants are constraint-relative; UCT makes that dependence explicit and ontological.

This has concrete implications. If laws are residues of constraint, then so-called “constants” are not metaphysical absolutes; they are parameters of coherence regimes—ranges of Ω and K over which collapse produces stable, repeatable relationships. We should expect:

- extreme environments (early universe, near-black hole, high-density phases) to act as stress tests for apparent constants;
- effective laws to change form when new constraint regimes are entered (e.g., phase transitions, new symmetry breakings);
- deeper unifications to reveal that many “independent” laws are different faces of the same extremum logic under different K (Uzan 2011).

Prediction — constants as regime-bounded residues.

If this reading is correct, high-precision tests of “constant stability” (fine-structure constant α , mass ratios, coupling strengths) should find that constancy holds within well-defined coherence regimes but may admit small, structured deviations at their boundaries: in extreme gravitational fields, at very high redshift, or across phase transitions in collective matter. Any such deviations would not signal a breakdown of coherence, but rather the discovery of new constraint structure—a refinement of K —that shifts the stationary conditions of collapse. Conversely, the continued absence of such deviations within a wide

range of regimes confirms that laws, as we currently write them, are robust residues of an underlying coherence-first universe (cf. Uzan 2011; Martins 2017).

§11 Predictions and Falsifiability

The coherence-first framework does not evade testability. It preserves the empirical invariants of Λ CDM and standard physics while making distinct, falsifiable claims about what those invariants mean and how they should behave when pushed into new regimes. If collapse under constraint and the Law of Coherence are more than an empirically equivalent reinterpretation, then they must leave structural fingerprints in both cosmology and local physics.

We group the main predictions into four classes.

11.1 Cosmological discriminants

1. Redshift drift as structural update, not pure metric expansion.

In FRW cosmology, redshift drift is predicted to follow

$$\frac{dz}{dt_0} = (1 + z)H_0 - H(z)$$

(Sandage 1962; Loeb 1998). In the coherence model, drift follows the update pattern of traversal depth: how the sequence $\{\delta_j\}$ along photon paths changes as constraints K evolve over record-time T . If high-precision drift measurements (Euclid, ELT, SKA) reconstruct an effective scale factor $a_{\text{eff}}(T)$ that systematically disagrees with FRW expectations in a way that cannot be absorbed into standard parameter freedom, this would favor coherence-first structural updating over a purely metric account. Conversely, if drift tracks the FRW prediction to within experimental limits, coherence-first remains at least an empirically equivalent reinterpretation.

2. CMB-BAO coherence: one scale, one story.

In a coherence-first universe, a single structural scale must ultimately explain both the CMB acoustic peak pattern and the BAO feature in large-scale structure, because both are records of how the same early constraint update $\mathcal{F}$ propagates. If increasingly precise measurements show irreconcilable tensions between the CMB-inferred and BAO-inferred coherence scales that cannot be resolved by reasonable modifications of K (e.g., baryon fraction, sound speed, late-time evolution), then the coherence-baseline picture fails. If a

unified structural account reproduces both within uncertainties, coherence-first gains explanatory leverage without introducing new fields.

3. Photon phase-space density and Liouville invariance.

UCT's traversal-depth account of redshift preserves the same core assumptions FRW uses: photon-number conservation along null trajectories and Liouville invariance of photon phase-space density. This implies that CMB spectral shape and Sunyaev–Zeldovich distortions must satisfy the same observational bounds that FIRAS/PIXIE-style constraints and SZ/X-ray surveys already impose. Any confirmed violation of photon phase-space invariance at cosmological scales would falsify the current coherence-first traversal account just as it would falsify standard FRW, forcing an update to the underlying constraint set K or to the kernel itself.

11.2 Local-physics signals of coherence

4. Atomic and spectral stability as S_1 (redundancy $\rightarrow$ consensus).

Under the Law of Coherence, repeated collapse of similar structured potentials under similar K should produce highly redundant, convergent records: the same atomic spectra, the same decay chains, the same molecular structures across space and time. High-precision surveys of spectral lines from distant astrophysical sources act as S_1 tests: if the same transitions appear with the same ratios and internal patterns over large spans of redshift and environment, coherence-first is confirmed at the atomic scale. Discovery of systematic, environment-independent deviations that cannot be traced to known constraint differences (density, field strengths, composition) would challenge stability-as-coherence and force revision of UCT's collapse grammar.

5. Collective hysteresis as S_3 (sweeps $\rightarrow$ history-sensitive collapse).

In bulk matter, the Law of Coherence predicts that sweeping constraints K (temperature, field, pressure) across phase boundaries will produce hysteresis curves that encode structural memory: distinct paths for “up” vs “down” sweeps due to record-dependent constraint updating $K_{t+1} = U(K_t, R_t)$. Condensed-matter and soft-matter systems already exhibit such behavior, but coherence-first treats it as a universal structural signature S_3 rather than a collection of domain-specific quirks. Systematic failure to find hysteresis or history-sensitive structure in regimes where many-body constraints are strongly coupled would count against the generality of the Law of Coherence. Conversely, discovering S_3 -style hysteresis in new domains (e.g., driven quantum materials, complex fluids) supports the claim that record-sensitive collapse is a pervasive physical pattern.

11.3 Laws and constants as regime-bounded residues

6. Constant stability and structured variation.

If “constants” are residues of constraint, they should be extremely stable within coherence regimes but may admit small, structured deviations at regime boundaries (early universe, near compact objects, extreme densities). High-precision searches for variation in the fine-structure constant α , mass ratios, or coupling strengths test this claim. If constants drift arbitrarily in ways that cannot be tied to identifiable constraint shifts, coherence-first loses credibility. If, instead, any detected variations correlate with specific structural regimes (e.g., curvature thresholds, phase transitions in collective fields), they support the picture of laws as regime-bounded residues of K rather than metaphysical absolutes.

7. Speed of light anomalies: coherence invariance vs absoluteness.

Locally, coherence-first agrees with relativity: c must be invariant in all local inertial frames because it encodes how constraints couple to null trajectories. However, in extreme environments, coherence-first leaves open the possibility that effective propagation speeds for different modes (photons, quasi-particles, collective excitations) might reveal subtle structure in K that pure metric accounts would not anticipate. Any robust, reproducible violation of local c invariance would falsify both standard relativity and the current UCT kernel; more realistic is the search for small, structured anomalies in effective propagation speeds in media and fields that can be traced back to constraint architecture rather than to ad hoc “new physics.”

11.4 Entropy, structure, and record-time

8. Entropy scaling as record of pruning, not pure disorder.

If entropy is the record of collapse expressed as residue, then cosmic and astrophysical entropy budgets should behave like smooth record-accumulation curves that track the emergence of coherent structure. As galaxies, stars, black holes, and chemical complexity arise, entropy should rise in tandem, reflecting cumulative pruning of structured potential. Large deviations from smooth, monotonic growth—unexplained plateaus, sharp kinks not associated with identifiable large-scale transitions—would challenge the claim that entropy is structurally tied to record formation. Conversely, a close match between entropy growth

and the history of structure formation supports the coherence-first reading of the Second Law.

Taken together, these tests tie coherence-first ontology directly to near-future and existing observations. Redshift drift, CMB–BAO coherence, spectral stability, hysteresis in collective systems, precision constant tests, and entropy budgets all offer clear places to look for either confirmation or refutation. If coherence-first survives increasingly precise scrutiny while reducing reliance on auxiliary scaffolds (fine-tuning appeals, inflationary field dependence, singular-boundary emphasis) without altering the core data products, it earns its keep as a conservative, structurally unified frame. If it fails in any of these ways, it should be abandoned or revised like any other physical theory.

§12 Conclusion: Collapse as Law in Physics

WP02 has made a single, simple claim: physics already behaves as if collapse under constraint with a coherence bias is fundamental. We have not changed the data or the core equations that successfully describe them. Instead, we have moved the ontological weight from randomness, time, and light as primitives to a structural kernel:

$$(\Omega, K_t, C^{K_t}, x_t^*, R_t, S_t, T, U),$$

in which structured potential Ω is repeatedly resolved under constraint sets K_t by collapse operators C^{K_t} , leaving realized outcomes x_t^* as written records R_t , residue S_t as entropy-like remainder, record-time T as accumulated depth of collapse, and constraint updates

$$K_{t+1} = U(K_t, R_t)$$

as the source of apparent “laws.”

At cosmological scale, this lens re-reads our most trusted observables:

- The CMB is treated not as a “last scattering surface” requiring a specific early-universe mechanism, but as the first coherence baseline—the record of an inaugural constraint update $\mathcal{F}$ that smooths early structure and leaves Gaussian, nearly scale-invariant anisotropies as residue.
- Redshift is interpreted as traversal depth through layered structural embedding:

$$1 + z = \prod_j (1 + \delta_j),$$

a cumulative log of how many coherence-shaped layers a photon has crossed, rather than as direct evidence that a metric substrate is stretching.

- Entropy becomes the record of collapse expressed as residue: the tally of degrees of freedom routed into diffuse channels as structured potential is pruned and locked into coherent forms. Entropy and structure rise together; the universe moves from latent structure to deeper, nested coherence, not from order to disorder.
- Time is redefined as record-depth $T = \sum_t r_t$, not an external axis. Relativity then becomes a statement about constraint-dependent record rates, and FRW cosmic time becomes a coarse-grained measure of how far collapse has progressed relative to the CMB baseline.
- Light is recognized as an embedded coherence carrier, not a traveler through featureless emptiness but a propagation of records through structured K , logging traversal and relaying constraint information between distant collapse pockets.

At local scale, the same kernel shows that matter itself is already a structured field of coherence:

- Atoms are treated as coherence pockets in Ω : bound-state patterns stabilized by K (Hamiltonian, symmetries, Pauli), with spectral lines as discrete records R of constraint-shaped collapse.
- Radioactive decay is reinterpreted as coherent pruning of structurally strained nuclei: metastable pockets are eliminated over record-time, driving ensembles down the nuclear binding-energy landscape toward valleys of stability, with emitted particles and photons as residue S .
- Chemical reactions are seen as re-cohering under constraint: given Ω of possible arrangements, K (valence rules, potentials, environment) selects a tiny subset of molecular structures that persist as long-lived records—the familiar products with their characteristic stoichiometries, rate laws, and equilibria.
- Collective matter behavior—phases, crystals, glasses, and dissipative structures—is revealed as macro-coherence: many-body collapse under shared constraints. Phases become competing coherence pockets; crystals and glasses become structural memory of cooling paths; convection rolls and reaction–diffusion patterns become dynamic coherence under flow; hysteresis curves become visible records of record-sensitive collapse (S_3).

Across these regimes, no additional ontology need be assumed. The same kernel $(\Omega, K, C^K, R, S, T, U)$ suffices, and the same Law of Coherence appears: under stable constraints K , trajectories typically converge toward constraint-compatible, compressible structures—equilibria, attractors, invariant measures—while incompatible configurations are pruned and carried forward as residue.

Section 10 then reframed laws and constants as residues of constraint: stabilized patterns of collapse that have survived contact with reality. Conservation laws emerge as residues of symmetry constraints; the Second Law emerges as the accumulation of pruning residue; spacetime curvature emerges as the large-scale record of how constraints have been distributed across mass–energy. “Constants” are understood as parameters of coherence regimes, expected to be extraordinarily stable within those regimes but potentially exhibiting small, structured deviations at their boundaries.

Finally, Section 11 collected the consequences into a test suite: redshift drift and CMB–BAO coherence as cosmological discriminants; spectral stability and bulk hysteresis as local S_1/S_3 signatures; precision tests of constant stability and effective propagation behavior as probes of law-as-residue; entropy budgets as checks on entropy-as-record. These are not metaphors but concrete ways the coherence-first ontology can be confirmed, constrained, or falsified.

Within the broader UCT project, WP02 now occupies a clear role. WP01 laid out the general ontology of collapse under constraint and the law kernel. WP02 shows that physics already exemplifies this ontology across scales, without changing a single trusted data point. WP03 will extend the same kernel into Biological Collapse, where new constraint types—replication, fitness landscapes, informational structure—act on the same structured potential, and coherence begins to preserve and elaborate itself in a targeted way. From there, WP04 and WP05 will complete the bridge into mind, meaning, and law-level status for coherence.

If future measurements vindicate the predictions outlined here—if redshift drift reveals structural updating, if CMB–BAO coherence is unified without inflationary dependence, if constants behave as regime-bounded residues, if $S_1 - S_3$ signatures appear wherever many degrees of freedom collapse under shared constraints—then the simplest reading will be the one UCT has proposed: coherence is not an accident at the end of physics; it is the law beneath it. If those predictions fail, the coherence-first framing should be revised or rejected. Either way, WP02 has done its job: it has turned “coherence as law” from a philosophical suggestion into a concrete, physics-facing hypothesis, with clear places for the universe to answer yes or no.

Appendix A: Universal Postulates (Harmonized with Structural Physics)

Notation.

Ω — latent structured potential (space of possible configurations).

K — active constraint set.

C^{K_t} — constraint-conditioned collapse operator (collapse under the active K_t).

x_t^* — realized outcome at event-depth t .

R_t — records written by collapse at t .

S_t — residue of collapse (entropy-like remainder at t).

$T = \sum_t r_t$ — record-time (collapse depth / rhythm), where r_t is a scalar measure of the record R_t written at step t .

$K_{t+1} = U(K_t, R_t)$ — constraint update map.

Indexing note. Reserve i for indexing admissible outcomes x_i^* within an ensemble (e.g., Born-rule contexts), and reserve t for event-depth / ledger steps.

Axioms (Structural Physics)

A1 — Structural Potential Energy (SPE).

There exist latent regularities resolvable into form under constraints. Ω is not a featureless set but a structured potential: different configurations carry different structural potential energy relative to K .

A2 — Constraint Primacy.

Constraints K delimit admissible states and shape which collapses persist. Structure emerges under such constraints (symmetry $\rightarrow$ invariant; boundary $\rightarrow$ pattern; conservation $\rightarrow$ flow channels) rather than in spite of them

Postulates (Universal, cross-domain)

P1 — Collapse-Actualization (Mechanism).

Latent potential resolves via collapse under K_t into realized outcomes x_t^* . Each collapse writes records R_t , produces residue S_t , and updates constraints via

$$K_{t+1} = U(K_t, R_t).$$

(Single-world: one realized outcome per event; non-teleological: no built-in goals—only structure resolving under constraint.)

P2 — Coherence (Bias / Ontology).

Order is ontological: what lasts is coherent collapse. Under stable K , trajectories typically converge toward constraint-compatible, compressible structures (attractors, equilibria, invariant measures), while incompatible configurations are pruned. Entropy S is the record of collapse expressed as residue: the redistributed traces of pruning already enacted, often carried forward as dissipation.

P3 — Recursive Adaptation (Intelligence).

Where plastic memory and feedback exist, systems can recursively adapt K to improve compression, prediction, control, and transfer. This yields operational intelligence, measured by how well updated constraints track and exploit regularities in Ω .

P4 — Constraint Architecture (Laws).

“Laws” are stabilized constraint architectures: regularities in how the kernel (Ω, K, C^K, R, U) behaves that have survived contact with reality. Laws are thus residues of constraint, not primitive dictates. Relativity already exhibits constraint-dependence of time and length; UCT generalizes this to all law-like structure.

Appendix B: Notation, Assumptions, and Decisive Tests (WP02)

Ω — latent structured potential (space of possible configurations).

K_t — active constraint set at event-depth t ; updates by $K_{t+1} = U(K_t, R_t)$.

$\mathcal{F}$ — inaugural global constraint update that establishes the coherence baseline (CMB baseline record).

T — record-time / event-depth measure (cumulative collapse depth), with $T = \sum_t r_t$ where r_t is a scalar measure of the record R_t written at step t .

δ_j — per-layer coherence increment along a causal path after $\mathcal{F}$ (a small constraint-induced conformal factor).

N — number of effective traversal layers between emitter and observer (model-dependent effective count).

Redshift (traversal depth):

$$1 + z = \prod_{j=1}^N (1 + \delta_j),$$

interpreted as cumulative traversal through N layers of structural embedding.

Observational invariants (unchanged)

Given photon-number conservation and null-path preservation, the layered traversal transform recovers the standard relations:

- Supernova time dilation: $\Delta t_{\text{obs}} = (1 + z) \Delta t_{\text{em}}$
- Tolman surface brightness: $\text{SB} \propto (1 + z)^{-4}$
- Distance duality: $D_L = (1 + z)^2 D_A$

Distances:

D_L : luminosity distance

D_A : angular-diameter distance

Entropy (S)

Entropy is the record of collapse expressed as residue: redistributed degrees of freedom routed into diffuse channels (often thermally), so entropy and structure rise together as structured potential is pruned and locked into coherent forms.

Assumptions and scope

These assumptions are chosen to match the effective level at which FRW cosmology already operates, so that any discrepancy is attributable to genuine structural differences rather than hidden modeling choices:

- **Photon-number conservation and null-path preservation.**

The layered transform is treated as a conformal mapping of null trajectories, preserving photon counts along each ray in the same operational sense FRW assumes.

- **Liouville invariance.**

Photon phase-space density is preserved along propagation. This ensures that CMB spectral shape, SZ distortions, and distance duality remain consistent at the same effective level as in FRW, given the same observational constraints on K .

- **Homogeneous/isotropic background at leading order.**

Departures (large-scale structure, inhomogeneities, layer granularity) appear as higher-order, testable corrections, analogous to perturbative structure in Λ CDM.

- **Single-world ontology.**

Each collapse yields one realized outcome x_t^* ; no many-worlds assumption is used.

- **Low- z calibration (effective Hubble regime).**

For small, roughly uniform δ_j , one may approximate $z \approx N\bar{\delta}$, where $\bar{\delta}$ is an effective mean increment. If l is an effective structural step length, an effective H_0 scale can be compared to FRW fits via

$$H_0 \sim \frac{c}{l/\bar{\delta}}.$$

This recovers the standard low- z Hubble-law behavior at the level of effective comparison, without committing to metric stretching as the underlying cause.

- **Domain of interpretation.**

WP02 reframes redshift as traversal depth through a stack of coherence-shaped layers rather than as literal metric stretching. An effective scale factor $a_{\text{eff}}(T)$ can always be defined from traversal depth for direct comparison with FRW $a(t)$.

Decisive tests (summary)

These are the main WP02-specific empirical checks, complementing the broader test suite in §11:

- **Redshift drift.**

In FRW,

$$\frac{dz}{dt_0} = (1 + z)H_0 - H(z).$$

In the coherence model, drift traces updating of traversal depth (how $\{\delta_j\}$ evolve with record-time T). If the reconstructed $a_{\text{eff}}(T)$ from ELT/Euclid/SKA drift data systematically deviates from FRW in ways not explainable by standard parameter choices, this favors structural updating over a purely metric account.

- **CMB-BAO single-scale linkage.**

A coherence-baseline model predicts that one structural correlation scale must underlie both the CMB acoustic peaks and BAO features in late-time clustering. Persistent, irreconcilable tension between CMB-inferred and BAO-inferred scales, not resolvable by reasonable modifications of K , would falsify the simple coherence-baseline mechanism proposed here.

- **Constant stability and spectral integrity.**

Bounds on the fine-structure constant α , mass ratios, and the CMB's blackbody spectrum must be respected. Any robust violation that cannot be tied to identifiable constraint shifts would challenge the claim that laws and constants are stable residues of constraint within current coherence regimes.

References

- Adkins, C. J. 2010. *Equilibrium Thermodynamics*. 4th ed. Cambridge University Press.
- Amendola, L. et al. 2018. "Cosmology and fundamental physics with the Euclid satellite." *Living Reviews in Relativity* 21: 2.
- Ashcroft, N. W., and Mermin, N. D. 1976. *Solid State Physics*. Holt, Rinehart and Winston.
- Atkins, P., and de Paula, J. 2010. *Physical Chemistry*. 9th ed. Oxford University Press.
- Atkins, P., and Friedman, R. 2011. *Molecular Quantum Mechanics*. 5th ed. Oxford University Press.
- Bassett, B. A., and Kunz, M. 2004. "Cosmic distance-duality as a probe of exotic physics and acceleration." *Physical Review D* 69: 101305.
- Bekenstein, J. D. 1973. "Black holes and entropy." *Physical Review D* 7: 2333–2346.
- Born, M., and Wolf, E. 1999. *Principles of Optics*. 7th ed. Cambridge University Press.
- Brading, K., and Brown, H. 2003. Symmetries and Noether's theorems. In K. Brading & E. Castellani (Eds.), *Symmetries in Physics: Philosophical Reflections* (pp. 89–109). Cambridge University Press.
- Bransden, B. H., and Joachain, C. J. 2003. *Physics of Atoms and Molecules*. 2nd ed. Prentice Hall.
- Callen, H. B. 1985. *Thermodynamics and an Introduction to Thermostatistics*. 2nd ed. Wiley.

Carroll, S. M. 2004. *Spacetime and Geometry: An Introduction to General Relativity*. Addison-Wesley.

Chaikin, P. M., and Lubensky, T. C. 1995. *Principles of Condensed Matter Physics*. Cambridge University Press.

CMB-S4 Collaboration. 2016. *CMB-S4 Science Book, First Edition*. arXiv:1610.02743.

Cohen-Tannoudji, C., Diu, B., and Laloë, F. 1977. *Quantum Mechanics*. 2 vols. Wiley.

Cross, M. C., and Hohenberg, P. C. 1993. "Pattern formation outside of equilibrium." *Reviews of Modern Physics* 65: 851–1112.

Debenedetti, P. G., and Stillinger, F. H. 2001. "Supercooled liquids and the glass transition." *Nature* 410: 259–267.

Demtröder, W. 2003. *Laser Spectroscopy*. 3rd ed. Springer.

Dodelson, S. 2003. *Modern Cosmology*. Academic Press.

Egan, C. A., and Lineweaver, C. H. 2010. "A larger estimate of the entropy of the universe." *The Astrophysical Journal* 710: 1825–1834.

Einstein, A. 1916. "The foundation of the general theory of relativity." *Annalen der Physik* 49: 769–822.

Ellis, G. F. R., Poltis, R., Uzan, J.-P., and Weltman, A. 2012. "Blackness of the cosmic microwave background spectrum as a probe of the distance-duality relation." *Physical Review D* 87: 103530.

Etherington, I. M. H. 1933. "On the definition of distance in general relativity." *Philosophical Magazine* 15: 761–773.

Gillespie, D. T. 2004. "Stochastic chemical kinetics." *Annual Review of Physical Chemistry* 58: 35–55.

Goldstein, H. 2002. *Classical Mechanics*. 3rd ed. Addison-Wesley.

Goldenfeld, N. 1992. *Lectures on Phase Transitions and the Renormalization Group*. Addison-Wesley.

Griffiths, D. J. 2005. *Introduction to Quantum Mechanics*. 2nd ed. Pearson.

Guth, A. H. 1981. "Inflationary universe: A possible solution to the horizon and flatness problems." *Physical Review D* 23: 347–356.

Hawking, S. W. 1976. "Black holes and thermodynamics." *Physical Review D* 13: 191–197.

Herzberg, G. 1944. *Atomic Spectra and Atomic Structure*. Dover.

Hogg, D. W. 1999. Distance measures in cosmology. [arXiv:astro-ph/9905116](https://arxiv.org/abs/astro-ph/9905116).

Hu, W., and Dodelson, S. 2002. "Cosmic microwave background anisotropies." *Annual Review of Astronomy and Astrophysics* 40: 171–216.

Jackson, J. D. 1999. *Classical Electrodynamics*. 3rd ed. Wiley.

Jhingan, S., Ghosh, A., Jain, B., et al. 2014. “Observational constraints on cosmic distance duality.” *Journal of Cosmology and Astroparticle Physics* 11: 006.

Jones, J. C. 2025. *Universal Collapse Theory—Foundations of Collapse (WP01 v2.0)*. HoldingLight LLC.

Jones, J. C. 2025. *Structural Physics (refined)*. HoldingLight LLC.

Jones, J. C. 2025. *UCT Symbols and Formulas Reference (v1.2)*. HoldingLight LLC.

Kardar, M. 2007. *Statistical Physics of Fields*. Cambridge University Press.

Kittel, C. 2005. *Introduction to Solid State Physics*. 8th ed. Wiley.

Krane, K. S. 1988. *Introductory Nuclear Physics*. Wiley.

Laidler, K. J. 1997. *Chemical Kinetics*. 3rd ed. HarperCollins.

Lanczos, C. 1970. *The Variational Principles of Mechanics*. 4th ed. University of Toronto Press.

Levine, I. N. 2009. *Physical Chemistry*. 6th ed. McGraw-Hill.

Liddle, A. R., and Lyth, D. H. 2000. *Cosmological Inflation and Large-Scale Structure*. Cambridge University Press.

Liske, J. et al. 2008. “Cosmic dynamics in the era of Extremely Large Telescopes.” *Monthly Notices of the Royal Astronomical Society* 386: 1192–1218.

Loeb, A. 1998. "Direct measurement of cosmological parameters from the cosmic deceleration of extragalactic objects." *The Astrophysical Journal Letters* 499: L111–L114.

Lubin, L. M., and Sandage, A. 2001. "The Tolman surface brightness test for the reality of the expansion." *The Astronomical Journal* 121: 2289–2310.

Martins, C. J. A. P. 2017. "The status of varying constants: a review of the physics, searches and implications." *Reports on Progress in Physics* 80: 126902.

Mather, J. C. et al. 1994. "Measurement of the cosmic microwave background spectrum by the COBE FIRAS instrument." *The Astrophysical Journal* 420: 439–444.

Misner, C. W., Thorne, K. S., and Wheeler, J. A. 1973. *Gravitation*. W. H. Freeman.

Noether, E. 1918. "Invariante Variationsprobleme." *Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen* 2: 235–257.

Pathria, R. K., and Beale, P. D. 2011. *Statistical Mechanics*. 3rd ed. Elsevier.

Peacock, J. A. 1999. *Cosmological Physics*. Cambridge University Press.

Peebles, P. J. E. 1993. *Principles of Physical Cosmology*. Princeton University Press.

Planck Collaboration. 2018. "Planck 2018 results." VI. Cosmological parameters. *Astronomy & Astrophysics* 641: A6.

Povh, B., Rith, K., Scholz, C., and Zetsche, F. 1999. *Particles and Nuclei: An Introduction to the Physical Concepts*. 4th ed. Springer.

Prigogine, I., and Nicolis, G. 1977. Self-organization in nonequilibrium systems: From dissipative structures to order through fluctuations. Wiley.

Reichl, L. E. 2016. A Modern Course in Statistical Physics. 4th ed. Wiley.

Riess, A. G. et al. 2007. "New Hubble Space Telescope discoveries of Type Ia supernovae at $z > 1$: Narrowing constraints on the early behavior of dark energy." *The Astrophysical Journal* 659: 98–121.

Sakurai, J. J., and Napolitano, J. 2017. Modern Quantum Mechanics. 3rd ed. Cambridge University Press.

Sandage, A. 1962. "The change of redshift and apparent luminosity of galaxies due to the deceleration of selected expanding universes." *The Astrophysical Journal* 136: 319–333.

Schneider, P., Kochanek, C. S., and Wambsganss, J. 2006. Gravitational Lensing: Strong, Weak and Micro. Springer.

Schroeder, D. V. 2000. An Introduction to Thermal Physics. Addison-Wesley.

Sethna, J. P. 2006. Statistical Mechanics: Entropy, Order Parameters, and Complexity. Oxford University Press.

Shapiro, I. I. 1964. "Fourth test of general relativity." *Physical Review Letters* 13: 789–791.

Stanley, H. E. 1971. Introduction to Phase Transitions and Critical Phenomena. Oxford University Press.

Uzan, J.-P. 2011. "Varying constants, gravitation and cosmology." *Living Reviews in Relativity* 14: 2.

Wald, R. M. 1984. *General Relativity*. University of Chicago Press.

Weltman, A. et al. 2020. "Fundamental physics with the Square Kilometre Array." *Publications of the Astronomical Society of Australia* 37: e002.

Weinberg, S. 2008. *Cosmology*. Oxford University Press.

Wong, S. S. M. 1998. *Introductory Nuclear Physics*. 2nd ed. Wiley-VCH.

Zallen, R. 1983. *The Physics of Amorphous Solids*. Wiley.