Substrate Cosmology Volume Seven

Cosmology Matter and Emergent Physical Quantities

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September 2026

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First digital edition, September 2026.

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Editorial, analytical, and production collaboration: OpenAI ChatGPT (Codex)
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This book presents a developing research program. Substrate Cosmology and Fibered Relational Tensor Theory are not established physical theories. The standard results summarized here belong to their cited scientific sources and validated domains. The Substrate Cosmology interpretations are proposals, questions, or formal targets unless explicitly identified otherwise.

This volume does not claim that dark matter, dark energy, inflation, gravity, inertia, quantum entanglement, black-hole entropy, cosmological horizons, or any observational anomaly confirms a substrate ontology. It does not provide a demonstrated method for faster-than-light communication, time travel, teleportation of matter, gravity control, energy extraction, or engineering spacetime. Those topics remain conditional research questions subject to the evidence and safety gates developed in Volumes Five and Six.

The RP07 recurrence boundary remains unchanged. GDELT 1995 is development data; 1996 and later years remain unopened for the inherited blind branch. Cryptocurrency, stock, commodity, financial, and other outcome layers remain unopened. Nothing in this cosmological interpretation opens, scores, or retrospectively modifies that experiment.

Authorship and AI Collaboration

James Dunn originated Substrate Cosmology, the distinction between Actual Physics and its state-based representations, the treatment of matter as a persistent emergent central tendency, the proposal that space and time are collapsed relations rather than necessary foundations, the insistence that all information is emergent, and the requirement that established physical models remain mutually recoverable without being promoted to exhaustive ontology. He supplied the research corpus, corrections, website, and governing research constraints. He retains responsibility for the claims and publication.

OpenAI ChatGPT (Codex) reviewed the available Library corpus and public research commons; compared the cosmological source material with the safeguards established in Volumes One through Six; identified inherited overclaims; separated observations, mainstream inferences, project definitions, interpretive proposals, physical hypotheses, and speculative extensions; drafted and edited the manuscript; prepared the equations, matrices, research records, citations, and appendices; produced the final document; and integrated this volume with the public website.

Microsoft Copilot and Google Gemini are acknowledged for earlier assistance recorded in the source manuscripts. AI systems are cited as collaborators in representation, analysis, and production. They are not empirical witnesses, independent replicators, scientific authorities, or evidence that any physical claim is true.

Recommended Citation for This Volume

Dunn, James, with OpenAI ChatGPT. *Substrate Cosmology. Volume Seven, Cosmology, Matter, and Emergent Physical Quantities*. First digital edition. September 2026.

Citation for the Current AI Collaboration

OpenAI. ChatGPT (Codex). “Substrate Cosmology Volume Seven Development, Cosmology, Matter, Emergent-Quantity, Editorial, and Production Collaboration.” Responses to James Dunn, September 2026. Large language model. https://chatgpt.com/.

Contents

Preface

Volumes One through Six taught the reader how to change perspective before cosmological claims are attempted. Volume One separated Actual Physics from accessible representation. Volume Two showed how words, numbers, units, and equations compress physical relations. Volume Three organized the Relational Tools. Volume Four proposed Fibered Relational Tensor Theory and made recovery of established physics a non-negotiable obligation. Volume Five placed apparatus inside the physical system being measured. Volume Six developed recurrence, blind archives, null worlds, frame shaking, and immutable Recovery Points.

Volume Seven applies those disciplines to the largest physical reconstruction humans make: a universe inferred from records collected inside that universe. It asks what cosmological quantities mean, what observations support them, where model dependence enters, and how Substrate Cosmology can propose richer relations without using what is unknown as confirmation.

The reader should expect corrections to some inherited language. Calling dark matter or dark energy an “alias” is not a result; at most it names a hypothesis about model incompleteness. Calling entanglement instantaneous does not establish a signal, a common spatial point, or a universal mass reference. The Higgs mechanism gives mass to elementary particles through established quantum field theory, but most ordinary visible mass is associated with strong-interaction energy in hadrons. A substrate interpretation must preserve those distinctions before introducing its own.

The aim is therefore neither to defend standard cosmology as final ontology nor to replace it with unconstrained possibility. The aim is to show how a successful cosmological model can remain a partial, horizon-limited, detector-mediated reconstruction while still commanding exact recovery wherever it is tested.

The Current Series

The series has no predetermined length. Volumes may divide, combine, or change order when conceptual dependencies, formal results, or evidence require it.

Volume	Working title	Primary task
One	Introduction to Substrate Cosmology	Establish the alternate perspective and research boundaries.
Two	Words Units and the Collapse of Physical Representation	Make linguistic numerical metrological and mathematical selection inspectable.
Three	The Relational Tools and Their Developmental Lineages	Preserve explain crosswalk and operationalize the Tool architecture.
Four	Relational Mathematics and Fibered Relational Tensor Theory	Develop formal objects projections recovery maps and conservative extension.

Volume	Working title	Primary task
Five	Measurement Detectors and Experimental Interaction	Model apparatus controls independent projections and discriminating interventions.
Six	Recurrence Research and the Labyrinth	Develop recurrence methods blind archives null worlds and prospective validation.
Seven	Cosmology Matter and Emergent Physical Quantities	Reconsider spacetime matter fields gravity energy entropy horizons and dark phenomena.
Eight	Conditional Engineering and Physical Manipulation	Examine intervention and engineering only under explicit evidence and safety gates.
Nine	Intelligence Agency Identity and Dimensional Stewardship	Develop relational learning culture ethics AI and propagation of diverse life.
Ten	Substrate Cosmology Website User Manual	Document the research commons investigation routes evidence boundaries and continuity controls.

Volume Eight may consider engineered intervention only after the recovery, evidence, and safety conditions in this volume are met. Volume Ten remains the dedicated website manual. Chapter Sixty Seven supplies only the cosmology-specific guide needed to navigate the present research surfaces.

Acknowledgments

This volume grows from James Dunn’s insistence that living inside the environment under study limits the frames available to us but does not limit what physics can be. His repeated corrections established that relativity must be recovered without becoming the container for every possible relation; that dimensions are partial perspectives rather than automatically separate spatial entities; that matter detectors may reinforce stable central tendencies; and that information is emergent rather than the substance of Actual Physics.

OpenAI ChatGPT (Codex) is acknowledged for research audit, correction of inherited overstatement, scientific-source review, manuscript development, document production, and website integration. Microsoft Copilot and Google Gemini are acknowledged for earlier recorded assistance. Their participation is provenance, not confirmation.

The book also depends on the work of observational astronomers, experimental physicists, cosmologists, mathematicians, and philosophers of physics whose methods and results define the recovery obligations. Their work does not endorse Substrate Cosmology.

Reader Guide

Statement Classes

Class	Meaning
Established result	Supported within a cited scientific theory or observational domain.
Mainstream inference	Derived from observations through a declared model and assumptions.
Project definition	Fixes how Substrate Cosmology uses a term.
Research method	Specifies how a question or comparison is to be conducted.
Interpretive proposal	Offers a possible reading without a discriminating prediction.
Formal target	A mathematical construction or recovery result still to be completed.
Physical hypothesis	Makes a potentially testable claim about physical behavior.
Speculative extension	A possibility retained for structured inquiry without present evidence.

The Three Boundaries

First, observation is not identical to cosmological quantity. Telescopes record counts, voltages, arrival directions, spectra, phases, and timing relationships. Distance, age, mass, curvature, expansion history, and component density are reconstructed.

Second, operational success is not ontology. A model may predict observations extraordinarily well without exhausting what physically produces them.

Third, an unexplained remainder is not evidence for a preferred alternative. The dark sector, singularities, tensions, and measurement limits define research questions. They do not automatically become substrate effects.

Suggested Reading Paths

Researchers entering from standard cosmology should read Parts I, IV, and V before Part VI. Readers concerned with words and units should read Part II beside Volume Two. Particle and quantum researchers should begin with Part III. Mathematicians should read Volume Four before Part VI. Experimentalists should read Part VII with Volumes Five and Six. Readers using the website may begin with Chapter Sixty Seven.

Introduction

Cosmology From Inside the Environment

Cosmology is a reconstruction made by physical systems inside the physical environment being reconstructed. The observer cannot step outside the universe, compare it with a control universe, move to an arbitrary vantage point, or receive signals from beyond every horizon. Instruments are made of the matter whose behavior they use to infer matter. Clocks are physical processes used to infer cosmic history. Geometry is reconstructed from light, motion, lensing, and standards that participate in the same geometry.

This does not make cosmology arbitrary. It makes its achievement more remarkable and its epistemic structure more important. A constrained observer can still identify stable regularities, compare independent probes, predict new observations, expose inconsistencies, and reject models. What the observer cannot do is silently turn the success of a reconstruction into proof that its variables are the foundations of Actual Physics.

Substrate Cosmology begins at that boundary. It treats time, space, matter, field, energy, force, gravity, entropy, horizon, and information as physically useful emergent relations within declared regimes. It does not declare them unreal. It asks what each quantity retains, what establishes its operational meaning, what it discards, and whether a richer relation can make a different prospective prediction while recovering the conventional result.

The central discipline is conservative extension. For each established theory T, an enriched representation must supply an embedding ι_T and recovery map π_T such that, on the validated domain,

$$\pi_T \circ \iota_T \cong Id_{Phys_T}.$$

The equation is not a license to place a speculative substrate behind every model. It is a demand that the speculative construction reproduce what the established model already gets right. Only a nonfactorizing, prospectively testable distinction can justify physical extension.

Part I

Looking Out From Inside

Chapter One

The Sky Is a Record

Astronomy begins with local interactions. A photon, neutrino, cosmic ray, gravitational-wave disturbance, or material sample interacts with an instrument here and now. The event is transformed into electrical charge, displacement, heat, a digital count, or another durable record. From many such records, researchers infer distant sources and cosmic history.

The sky is therefore not the universe presented without mediation. It is a collection of surviving relations. Propagation selects what arrives. Intervening matter modifies signals. Detectors select what couples. Calibration and processing determine what becomes data. Models connect the data to source properties.

Substrate Cosmology calls this a projection without implying deception. Projection is necessary. The research task is to preserve the chain from interaction to inference so the limits of the record are not mistaken for limits of Actual Physics.

Chapter Two

Signals and Cosmological Quantities

A detector may directly register photon arrival time, wavelength-dependent counts, polarization, image position, or strain in an interferometer. It does not directly register “the age of the universe,” “dark-energy density,” or “spacetime curvature.” Those are quantities inferred through calibrated physical models.

Layer	Example	Principal dependence
Interaction	photon absorbed in a sensor	coupling and detector material
Record	counts by pixel and wavelength	gain noise threshold processing
Calibrated observable	flux spectrum redshift angular separation	standards and correction model
Derived quantity	luminosity distance mass temperature	source and propagation model
Cosmological parameter	expansion rate density curvature	population model and cosmology
Ontological interpretation	what fundamentally exists	underdetermined by the record alone

Confusion enters when a quantity from one layer is spoken of as if it belonged to another. A disciplined cosmological claim identifies the entire chain.

Chapter Three

The Observer Has a Location

The cosmological principle treats the universe as statistically homogeneous and isotropic on sufficiently large scales. It is a powerful modeling principle, not an observation made from every point. We observe from one galaxy, during one cosmic epoch, through one past light cone.

This location does not invalidate cosmology. It determines which symmetries must be tested indirectly and which forms of cosmic variance cannot be eliminated by collecting more samples inside one observable region. Independent probes can reduce uncertainty, but they do not give the observer an external position.

The Substrate Cosmology correction is modest: write the observer’s location, horizon, detector family, and epoch into the claim record. Do not let “the universe” conceal “the universe as reconstructed from this accessible region under these assumptions.”

Chapter Four

Horizons and Selection

A horizon is not merely a distant wall. It is a boundary on recoverable relation. Particle horizons limit which regions could have influenced an observer since the beginning of the current model. Event horizons concern which events can ever affect the observer. Black-hole horizons separate causal accessibility in a particular spacetime geometry.

Each horizon depends on a model of geometry and history. The model helps determine what can be observed, and the observations constrain the model. That reciprocity is not automatically vicious circularity; it is an inverse problem that must be made explicit.

For Substrate Cosmology, a horizon is first an access boundary within a representation. It is not proof that no relation exists beyond that boundary. Nor is an inaccessible region evidence that a substrate relation crosses it. The distinction is between what the model excludes, what the detector cannot recover, and what physics forbids under a tested theory.

Chapter Five

Redshift and Reconstruction

Spectroscopic redshift compares an observed wavelength with an identified rest-frame wavelength:

$$z = \frac{\lambda_{obs} - \lambda_{emit}}{\lambda_{emit}}.$$

The ratio is an observable construction. Its interpretation depends on context. Relative motion, gravitational potential, and cosmic expansion can all contribute to observed shifts. At cosmological scales, redshift is related to an evolving scale factor within a spacetime model; it is not simply an ordinary Doppler speed through static space.

Distance is then reconstructed through standard candles, standard rulers, lensing, clustering, or other calibrated relations. Every route has nuisance parameters and selection effects. The lesson is not that expansion is fictitious. It is that “redshift,” “velocity,” “distance,” and “expansion” are not interchangeable words.

Chapter Six

The Standard Cosmological Model

The standard model of cosmology combines general relativity, a nearly homogeneous and isotropic expanding spacetime, ordinary matter and radiation, cold dark matter, and a cosmological-constant-like component. Its background evolution is summarized by a Friedmann equation such as

$$H^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3}.$$

Here H is the expansion rate, a the scale factor, k a curvature parameter, ρ the modeled energy density, and Λ the cosmological constant. The equation joins assumptions, definitions, and quantities inferred through multiple observations.

The model succeeds across background radiation, light-element abundance, expansion history, gravitational lensing, and large-scale structure. Its unknown components and parameter tensions do not erase that success. They define where explanation remains incomplete.

Chapter Seven

The Hot Big Bang and Its Boundary

The hot Big Bang model describes an early hot, dense phase followed by expansion and cooling. Its major evidentiary supports include cosmic expansion, the cosmic microwave background, primordial light-element abundances, and the development of cosmic structure.

“Big Bang” does not by itself mean creation from nothing, an explosion at one location into empty space, or a physically realized mathematical point. Extrapolating a classical spacetime solution toward a singular boundary exceeds the regimes in which general relativity and known matter physics can be trusted together.

Substrate Cosmology therefore separates three questions: the earliest directly constrained epoch, the earliest epoch representable by a given model, and an absolute beginning of Actual Physics. The first is empirical, the second is theoretical, and the third may not be representable from inside a later emergent regime.

Chapter Eight

Inference Layers and Degeneracy

Different combinations of parameters, source populations, foregrounds, calibrations, and physical models can produce similar observables. This is degeneracy. Cosmology responds by combining probes whose dependencies differ: background anisotropies, supernova distances, baryon acoustic structure, lensing, clustering, nucleosynthesis, local distance ladders, and gravitational waves.

Agreement across probes strengthens a model only to the extent that their errors and assumptions are genuinely independent. Shared calibration, common simulations, common priors, or the same underlying source catalog can create apparent independence.

The Substrate Cosmology contribution is a translation ledger. It records which relations each probe retains, where two probes share a collapse, and where a disagreement may carry information. A tension is neither noise to be erased nor a discovery to be announced. It is a structured failure of joint representation awaiting competing explanations.

Part II

Reintroducing Physical Quantities

Chapter Nine

Time

Relativity distinguishes coordinate time from proper time measured along a worldline. Thermodynamics uses ordering and irreversibility. Quantum theory often treats time as an external parameter. Cosmology uses a time coordinate tied to a chosen large-scale model. These uses are related but not identical.

Substrate Cosmology defines time as an emergent ordering scalar: a physically realized compression of richer relational change into a comparable sequence. This is a project definition, not an established result. It must recover relativistic clock predictions, quantum dynamics, thermodynamic ordering, and astronomical timing wherever they are validated.

Changing a clock rate does not show that Actual Physics “slowed.” It shows that one physical process accumulated a different comparison record along its path. The alternate question is whether ordering relations exist that cannot be reduced to the same scalar yet produce a distinct observation.

Chapter Ten

Space and Adjacency

Space supplies coordinates, distances, directions, volumes, and neighborhood relations. In general relativity, spatial geometry is part of dynamical spacetime. In quantum theory and field theory, spatial structure enters through states, operators, fields, and locality conditions.

Substrate Cosmology treats familiar space as one representation of localization and adjacency. Coordinate distance, causal reach, topological connection, energetic accessibility, interaction graph distance, and informational dependence need not agree. Calling all of them “near” or “far” collapses distinct relations.

An alternative adjacency becomes physically meaningful only when it has a carrier, composition rule, transformation behavior, measurement interface, and discriminating consequence. Merely declaring two distant objects adjacent in a substrate adds no testable content.

Chapter Eleven

Spacetime

Spacetime is the geometric structure through which relativity organizes events, intervals, causal order, and gravitation. Its tested predictions make it a mandatory recovery interface.

Substrate Cosmology does not treat spacetime as illusion. It treats spacetime as an emergent consistency among accessible physical records. A proposed deeper relation must reproduce Lorentz symmetry, causal classification, gravitational redshift, lensing, orbital dynamics, gravitational-wave propagation, and every other admitted test on the domain claimed.

Emergence is not a synonym for dispensability. Temperature is emergent and physically indispensable. Likewise, even if spacetime is not foundational, its geometry may be the stable macroscopic organization through which all accessible matter currently interacts.

Chapter Twelve

Matter

Matter is not one undifferentiated substance. Standard physics represents fermions, hadrons, nuclei, atoms, molecules, plasmas, condensed phases, and macroscopic bodies through different effective descriptions. Their identities persist across some changes and fail across others.

Substrate Cosmology proposes that matter is a persistent emergent central tendency: a family of relational organizations stable enough to be prepared, detected, compared, and used as apparatus. This is an interpretive proposal. It does not replace quantum field theory, particle physics, chemistry, or materials science.

Calling matter a central tendency must never reduce a particle to an average value. Persistence may reside in symmetry, charge, topology, conservation, interaction pattern, or other structured relations. The research question is which identities survive translation across regimes.

Chapter Thirteen

Mass

Mass has several connected operational roles. In particle physics it appears in dispersion relations and Lagrangian terms. In gravitation it contributes to stress-energy and inertial response. In composite systems, binding and interaction energy contribute substantially to total mass.

The Higgs mechanism explains the masses of elementary particles through electroweak symmetry breaking, but the greater part of ordinary nucleon mass arises from strong-interaction dynamics rather than the bare masses of constituent quarks. Therefore “all mass shares one Higgs adjacency” is not an established statement and cannot be used as the basis for universal entanglement.

A Substrate Cosmology mass proposal must separately recover elementary-particle masses, composite mass, inertial behavior, gravitational coupling, and mass-energy accounting. A phrase such as “adjacency stiffness” remains metaphorical until a formal object and measurement procedure are supplied.

Chapter Fourteen

Fields

Fields assign structured quantities across spacetime or another domain and support local dynamics, symmetries, propagation, and observables. Classical electromagnetic and gravitational fields and quantum fields are extraordinarily successful representations.

Earlier project discussions correctly resisted turning every proposed instantaneous relation into a field. A relation without location, metric, value assignment, or propagation should not be called a field. The correction, however, does not establish that established fields are merely shadows of “anchors.” It preserves the difference between a tested field theory and a speculative non-field relation.

FRTT must recover field locality, gauge structure, conserved currents, equations of motion, and measurement predictions before it can compare a non-field carrier. New vocabulary earns a role only if it supports operations that the established representation cannot express.

Chapter Fifteen

Energy

Energy is not a material fluid. It is a quantitative relation that organizes transformations, work, motion, fields, radiation, mass, and thermodynamic processes. In suitable settings it is associated through symmetry with invariance under time translation. In general relativity, global energy can be subtle and depends on boundary and spacetime structure.

Substrate Cosmology treats energy as emergent accounting within a declared regime. That wording does not relax accounting. Every conventional energy channel must be closed before a residual is interpreted as dimensional transfer or substrate interaction.

“Adjacency reconfiguration cost” may be a useful intuition, but it is not yet a definition. A formal alternative must state its carrier, units or unit-free structure, composition, transformations, conservation boundary, and projection to established energy.

Chapter Sixteen

Force

In Newtonian mechanics, force describes momentum change. In field theories, interactions are represented through fields, potentials, connections, exchange processes, or action principles. In general relativity, freely falling bodies follow spacetime geometry rather than experiencing gravity as an ordinary force.

The single word "force" therefore groups several representations. Substrate Cosmology asks which relational change is being summarized and what disappears when the result is compressed into a vector or scalar magnitude.

An enriched account must still reproduce the measured trajectory, momentum transfer, work, stress, and reaction forces. It must not invoke a hidden influence to excuse an incomplete free-body diagram or an open system boundary.

Chapter Seventeen

Gravity

General relativity represents gravitation through a dynamical metric related to stress-energy:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}.$$

The equation is both a compact mathematical relation and a network of operational commitments. Coordinates, clocks, rods, matter models, boundary conditions, and observables determine how it is used.

Substrate Cosmology treats gravity as a possible emergent consistency of relational organization. That is a physical hypothesis only when it supplies a mathematical dynamics that recovers general relativity in tested regimes and predicts a bounded departure elsewhere. Rephrasing curvature as “adjacency” without such a dynamics is interpretation, not explanation.

Chapter Eighteen

Conservation

Conservation laws depend on defined quantities, symmetries, and system boundaries. Noether's theorem connects continuous symmetries of an action with conserved currents under appropriate assumptions. Thermodynamic and statistical conservation statements add their own conditions and coarse grainings.

Substrate Cosmology permits candidate relational invariants such as topology, recurrence identity, compatibility, or translation coherence. They supplement rather than replace conventional conservation.

Every proposed invariant needs a transformation rule and a failure threshold. Apparent loss first triggers a search for exchange with the environment, broken symmetry, measurement error, or a misdeclared boundary. An invisible substrate reservoir is not an acceptable bookkeeping convenience.

Chapter Nineteen

Entropy and Information

Thermodynamic entropy, statistical entropy, Shannon information, entanglement entropy, and semantic information are different constructions. They can be related in carefully specified settings but should not be merged by vocabulary alone.

Substrate Cosmology states that all information is emergent because information requires distinguishable alternatives, a physical interaction, an encoding, and a frame. This does not mean Actual Physics is made of information. It means any information available to an observer is a state-bearing product of physical relations.

Entropy is therefore indexed by macrovariables, ensemble, coarse graining, observer access, and dynamics. A decrease in one entropy measure is not automatically a reversal of time, a gain of ontological knowledge, or a violation of the second law.

Chapter Twenty

Temperature and Vacuum

Temperature summarizes ensemble behavior and becomes well defined under stated equilibrium or nonequilibrium conditions. It is not a microscopic substance present in each constituent. Its emergence demonstrates that a derived scalar can be physically real, predictive, and indispensable.

Vacuum likewise is not simple nothingness. Classical emptiness, a quantum-field ground state, a cosmological vacuum term, and an engineered low-density chamber are different objects. Boundaries, state preparation, fields, detectors, and renormalization matter.

Substrate Cosmology treats “vacuum” as a low-observability label rather than proof of absence. A hidden relation is admitted only if it produces a prospective difference after known vacuum physics, apparatus coupling, environmental backgrounds, and statistical selection are controlled.

Part III

Matter Fields and Quantum Relations

Chapter Twenty One

Persistent Central Tendencies

Matter supplies unusually stable records. An atom retains an identifiable structure across many interactions. A crystal supports reproducible modes. A clock transition can be reproduced across laboratories. These are not static things; they are persistent patterns of change.

The phrase *central tendency* is useful only if it retains this structure. It means that matter repeatedly occupies a constrained family of relations that detectors and preparation procedures can recover. It does not mean that every microscopic history is identical or that the average causes the system.

Matter-based science is powerful because persistent systems can compare other persistent systems. Its possible blindness is equally specific: relations that do not couple to stable matter, do not survive recording, or do not fit the preparation grammar may never become data. That is a hypothesis about access, not permission to assert undetected physics.

Chapter Twenty Two

Where Ordinary Mass Comes From

The Standard Model distinguishes elementary masses from composite mass. The Higgs mechanism contributes masses to elementary fermions and weak gauge bosons. Protons and neutrons, however, are composite QCD systems; most of their mass is associated with gluon fields, quark motion, and strong-interaction energy.

This distinction corrects a recurring shortcut in the earlier research corpus. The statement “all observable mass is mutually entangled through the Higgs field” is not established physics. Universal coupling to a field does not by itself imply that all instances are in one entangled quantum state, and ordinary mass does not have a single Higgs-only origin.

The conjecture can be reformulated safely: do different mass-generating and binding relations share a deeper compatibility that becomes visible across projections? That question requires a mathematical carrier and an experiment; it cannot inherit its answer from the word *mass*.

Chapter Twenty Three

Particles as Relational Identities

In quantum field theory, particles are excitations classified by mass, spin, charge, momentum, and other quantum numbers. Their identity is tied to symmetry and representation as well as detector response. In interacting and curved settings, particle concepts may be observer- or regime-dependent.

Substrate Cosmology treats a particle as a stable relational identity within a preparation-and-detection regime. This can clarify why identity persists without assuming a tiny classical object following a fully specified path.

The proposal must recover scattering amplitudes, statistics, conservation laws, decay rates, and detector outcomes. A richer identity record may include preparation history, correlations, environment, topology, and recurrence class, but these additions matter physically only if they alter a permissible prediction.

Chapter Twenty Four

Fields as Successful Representations

A field can be fundamental in one theory and emergent in another while remaining operationally indispensable. Effective field theory demonstrates that accurate local descriptions need not settle the ultimate ontology. What matters first is domain, degrees of freedom, symmetry, scale, and predictive control.

Substrate Cosmology uses this lesson twice. It refuses to make a tested field less real merely because it may emerge from deeper relations. It also refuses to call every relational proposal a field merely to borrow the authority of field theory.

The comparison record should ask: What is the field’s domain? What values does it assign? How does it transform? What propagates? What is gauge-dependent? What is observable? What limit recovers the field from a proposed non-field structure? Without answers, “field” and “anchor” remain labels rather than competing mathematical objects.

Chapter Twenty Five

Vacuum Is Not Nothing

Quantum fields in their ground states possess correlations and state-dependent consequences. The vacuum selected by one observer or spacetime may not coincide with that selected by another. Boundary conditions can change observable effects without introducing a classical medium.

Cosmological vacuum language adds further ambiguity. A cosmological constant in Einstein’s equations, vacuum energy in quantum field theory, and an effective dark-energy component are related questions but not identical quantities.

Substrate Cosmology asks whether apparently empty regimes retain unrecorded relational structure. The question is legitimate only when “empty” is specified experimentally and the proposed structure yields a result distinguishable from known fields, boundaries, temperature, material outgassing, electromagnetic backgrounds, vibration, and analysis choices.

Chapter Twenty Six

Matter Based Detectors

Every astronomical detector selects interactions that can modify matter into a stable record. A radio antenna, superconducting bolometer, CCD, atomic clock, neutrino detector, and laser interferometer couple to different physical relations. Their agreement is powerful because the coupling chains differ; their shared material basis can still leave common blind regions.

A detector record should therefore include material, geometry, bandwidth, threshold, timing, calibration, environmental coupling, signal processing, and aggregation. “Independent detector” means more than another instrument of the same design using the same pipeline.

The substrate hypothesis becomes stronger only if an alternative preparation or detector retains a distinction lost by conventional apparatus and predicts an ordinary observable. Failure to observe such a difference supports the adequacy of the conventional projection within that domain.

Chapter Twenty Seven

Entanglement and Nonseparability

Entanglement means that a joint quantum state cannot be reduced to independent states of its parts. Bell-type experiments rule out broad classes of local hidden-variable explanations while preserving no-signalling. Entanglement is not a classical thread, field line, or message channel.

Substrate Cosmology may interpret nonseparability as evidence that separately localized descriptions are incomplete. That interpretation remains constrained by quantum theory: it must recover the measured correlations, contextuality, monogamy structures, decoherence behavior, and inability to control a distant marginal outcome.

Different entangled states have different participant structure, observables, robustness, and operational uses. “Everything is entangled” is therefore too weak and too ambiguous to serve as a physical mechanism. The prepared state and measurable consequence must be specified.

Chapter Twenty Eight

No Signalling and Instantaneous Language

Quantum correlations can be established across spacelike separation, but they do not permit an experimenter to choose a local outcome and transmit a controllable message faster than light. The joint statistics become visible only through appropriate comparison.

Words such as *instantaneous*, *zero distance*, and *already shared* can be useful intuitions, but they can also smuggle in a global time, a geometry, or a causal mechanism that has not been defined. Precausal does not mean earlier than cause. Nonlocal does not mean accessible from everywhere. Correlation does not mean propagation.

A substrate account should replace metaphor with a typed relation: its endpoints or participants, composition, admissible operations, compatibility conditions, and projection to quantum probabilities. Until then, no-signalling remains the operational boundary.

Chapter Twenty Nine

The Universal Adjacency Conjecture

The earlier corpus proposes a “reference singularity”: mass-bearing configurations appear separated in spacetime yet may share one or more substrate-level adjacency references. The idea should be preserved as a conjecture, not reported as a deduction from the Higgs mechanism or entanglement.

The conjecture contains several separable possibilities:

- a common classification relation among mass-bearing systems;
- a nonmetric adjacency that does not imply signalling;
- multiple instantaneous reference types rather than one universal anchor;
- a compatibility structure whose projections include mass, charge, phase, or coherence;
- a relational identity that appears global only after coarse graining.

Each possibility needs a formal carrier and an experimental interface. A useful first test is factorization: does the proposed adjacency contribute any prediction not already determined by the conventional state and known common causes?

Part IV

Gravity Horizons and Entropy

Chapter Thirty

Recovering General Relativity

Any relational cosmology must recover general relativity wherever general relativity is validated. This means more than reproducing a weak-field potential. The recovery interface includes spacetime structure, diffeomorphism covariance, causal order, free fall, redshift, lensing, orbital dynamics, frame dragging, gravitational radiation, and the Newtonian limit.

In FRTT notation, an embedding ι_{GR} and recovery map π_{GR} must satisfy the declared retraction relation on the admitted domain. The enriched system must also reproduce the routes by which general relativity connects to special relativity, Newtonian gravity, relativistic astrophysics, and cosmology.

If a substrate parameter introduces a preferred frame, altered wave speed, equivalence violation, or modified lensing relation, that consequence must be stated and tested. Hidden departures cannot be protected by calling them precausal.

Chapter Thirty One

The Equivalence Structure

The equivalence principle links local free fall, inertial motion, and gravitational response in carefully defined forms. It is supported by high-precision experiments and embedded deeply in relativistic gravitation.

Substrate Cosmology may ask why inertial and gravitational behavior align so closely, but the question must not erase distinctions among weak, Einstein, and strong forms of equivalence. Nor may it attribute the equality to one universal mass anchor without a quantitative construction.

A relational model should specify which prepared configurations are equivalent, under which operations, and how deviations transform. A genuine extension would predict a bounded differential response that is absent from the standard model while respecting existing limits.

Chapter Thirty Two

Curvature as Relational Bookkeeping

Curvature in general relativity is not a visual bend in an external space. It is intrinsic geometric structure measured through relations among paths, clocks, geodesic deviation, transport, and matter dynamics.

Calling curvature “relational bookkeeping” emphasizes that its meaning comes from comparisons, but the phrase must not trivialize geometry. Curvature tensors obey precise identities and enter dynamics with stress-energy. They predict observables.

FRTT may treat metric geometry as a local object in a regime fiber and compare it with other locality structures. The transition data must show how a nonmetric relation produces the metric, connection, curvature, and causal cones under projection. Without that map, “emergent geometry” remains a program title.

Chapter Thirty Three

Black Holes

Black holes are solutions and astrophysical objects characterized through gravity, accretion, orbital motion, radiation, lensing, and gravitational waves. Their classical event horizons are global features of spacetime; practical observations often concern apparent or trapping horizons and the behavior of surrounding matter.

Substrate Cosmology should not use the word *black hole* as a metaphor for unknown structure. It should distinguish the astrophysical system, the metric solution, the horizon definition, the singularity theorem assumptions, and the quantum questions.

The relational opportunity lies in comparing descriptions that do not fit comfortably together: exterior geometry, infalling matter, horizon thermodynamics, quantum fields, and information recovery. Their tension is a formal target, not evidence that one preferred substrate picture is correct.

Chapter Thirty Four

Horizons as Access Boundaries

An event horizon separates events that can reach a specified future region from those that cannot. Its definition depends on the global spacetime. An apparent horizon is more local and foliation-sensitive. A cosmological horizon depends on expansion history and observer worldline.

Substrate Cosmology treats these as recoverability boundaries: surfaces beyond which a declared observer-and-model pair cannot reconstruct selected relations. This perspective is compatible with standard causal structure but does not replace it.

The research record should identify the horizon type, observer, accessible algebra of observables, information channel, and reconstruction task. A relation being unrecoverable across one boundary does not mean it is destroyed, preserved, or accessible by another method. Those are separate claims.

Chapter Thirty Five

Black Hole Thermodynamics

Black-hole mechanics links horizon area, surface gravity, angular momentum, mass, and charge. Quantum field theory in curved spacetime associates black holes with temperature and radiation. Bekenstein-Hawking entropy is proportional to horizon area:

$$S_{BH} = \frac{k_B c^3 A}{4 G \hbar}.$$

This relation is one of the strongest clues that geometry, quantum theory, thermodynamics, and information are deeply connected. It does not by itself show that information is fundamental or that the universe is literally stored on a two-dimensional surface.

Substrate Cosmology asks what coarse graining, observer access, and relational boundary make the area law possible. Any answer must recover the law and its domain before offering a different ontology.

Chapter Thirty Six

Area Laws and Holographic Clues

Entanglement entropy in quantum systems often exhibits boundary-area scaling under specified conditions. Holographic dualities relate certain gravitational theories to nongravitational theories in fewer dimensions. The Ryu-Takayanagi relation connects areas in a bulk geometry with entanglement entropy in a dual boundary theory.

These are precise results in particular mathematical settings. They do not establish that every physical system is a hologram or that ordinary spatial dimensions are unreal.

For Substrate Cosmology, area laws are examples of representation changing across regimes while retaining measurable structure. They motivate study of which relations survive dimensional translation. They do not license treating “dimension” as a freely exchangeable spatial axis.

Chapter Thirty Seven

The Information Problem

Semiclassical Hawking radiation appears thermal, while ordinary quantum evolution is unitary. The resulting black-hole information problem asks how these descriptions fit together. Proposed resolutions involve quantum gravity, correlations in radiation, modified horizon structure, complementarity, islands, or other mechanisms.

Substrate Cosmology contributes a bookkeeping discipline. It separates physical information, observer access, encoding, entropy measure, and ontological claims. “Information lost” can mean that a reconstruction fails, a subsystem becomes mixed, correlations move outside an accessible algebra, or fundamental evolution is nonunitary. Those are not the same statement.

The framework has not resolved the information problem. It offers a way to prevent the word *information* from deciding the result in advance.

Chapter Thirty Eight

Singularities and Failed Continuation

Singularity theorems establish geodesic incompleteness under stated assumptions. They do not describe a small physical object with infinite density in all circumstances. Divergent quantities often mark the failure of a classical description or its continuation.

Substrate Cosmology interprets a singular boundary first as a representation failure: a regime in which the selected objects, equations, or coordinates cannot be extended. This is compatible with the mathematical meaning but does not prove a substrate beyond the boundary.

The phrase *reference singularity* should therefore remain distinct from gravitational singularity. The former is a conjectured universal adjacency relation; the latter concerns incompleteness in spacetime models. Shared language must not merge them.

Chapter Thirty Nine

White Holes Bounces and Reversals

White-hole regions appear in mathematical extensions of certain black-hole solutions. Cosmological bounce models replace an initial singular boundary with contraction followed by expansion under additional dynamics. Time-reversal relations can connect equations without making a realized history reversible.

These possibilities are legitimate theoretical research. None is observationally established as the origin of our universe or as a practical exit from a black hole.

Substrate Cosmology should compare them through explicit translation records: required matter conditions, quantum assumptions, stability, entropy behavior, causal structure, observational signatures, and recovery of standard cosmology. A dramatic diagram is not a discriminating prediction.

Part V

Origins Expansion and the Dark Sector

Chapter Forty

Evidence Assigned to Dark Matter

Dark matter is inferred through several phenomena: galaxy rotation and dynamics, gravitational lensing, galaxy clusters, the growth and distribution of large-scale structure, and the acoustic pattern of the cosmic microwave background. The evidence is not one unexplained curve; it is a network of observations modeled together.

The name identifies a role in current models, not a directly isolated substance. Some observations depend mainly on gravity, others on structure formation and early-universe physics. Their joint fit constrains proposed explanations.

Substrate Cosmology must begin with the specific dataset and observable. “Missing structure” is not a substitute for predicting lensing maps, halo behavior, cluster dynamics, and cosmic growth. A projection hypothesis becomes scientific only when it produces a frozen difference from particle dark matter, modified gravity, baryonic systematics, and other competitors.

Chapter Forty One

Dark Matter Candidate Families

Candidate explanations include new particles, compact objects within observational limits, modified gravitational dynamics, additional fields, superfluid or emergent descriptions, and mixtures. Each family addresses some evidence more naturally than others and faces different laboratory, astrophysical, and cosmological constraints.

A relational candidate should enter this comparison as another model family, not as the default answer to model incompleteness. It must specify degrees of freedom or operational relations, equations of motion, initial or boundary conditions, coupling to ordinary matter and light, and quantitative predictions.

The most informative tests compare several observations at once. A model tuned to rotation curves but unable to reproduce lensing or structure formation has not replaced the larger dark-matter role.

Chapter Forty Two

Evidence Assigned to Dark Energy

The late-time acceleration of cosmic expansion was inferred from Type Ia supernova observations and is tested with additional probes including baryon acoustic structure, background radiation, clustering, and lensing. In the simplest standard model, a cosmological constant supplies the required behavior.

“Dark energy” can refer to that constant, to a dynamical component, or more generally to whatever effective relation accounts for acceleration. These alternatives can produce similar background expansion while differing in growth or other observables.

Substrate Cosmology may ask whether the inference reflects a translation between relational regimes rather than a new substance. It must still fit the measured distance-redshift relations and the cross-probe constraints. The word *emergent* does not reduce the quantitative burden.

Chapter Forty Three

The Cosmological Constant Problem

The cosmological constant has a clear role in general relativity, while naive comparisons with quantum vacuum contributions create an enormous mismatch in theoretical expectations. The problem links gravity, quantum field theory, renormalization, and the interpretation of vacuum energy.

Substrate Cosmology sees this as a warning about translating quantities between regimes. A vacuum term in one effective description may not transport unchanged into a gravitational description. That is a research direction, not a solution.

FRTT can formalize the question by placing the quantum-field and cosmological objects in distinct fibers and demanding an explicit translation map. The residual between maps may identify where assumptions enter. It does not become a new physical component until it predicts observations.

Chapter Forty Four

Inflation

Inflation proposes an early period of accelerated expansion that can generate large-scale homogeneity, near-flatness, and primordial perturbations. Many inflationary models exist, and observations constrain their parameters and perturbation spectra.

Inflation is sometimes described as a placeholder for inaccessible initial conditions. That description is incomplete. It is a family of quantitative physical models with observable consequences, yet its microphysical realization and alternatives remain open.

Substrate Cosmology may compare inflation with bounce, emergent, cyclic, or other cosmogenesis models. The comparison must preserve perturbation statistics, background evolution, reheating assumptions, and falsifiable differences. Precausal language alone supplies none of these.

Chapter Forty Five

Background Radiation and Structure

The cosmic microwave background is a nearly uniform radiation field with a precisely measured spectrum and anisotropy pattern. Its temperature and polarization structure encode relations among early plasma physics, geometry, matter content, primordial perturbations, and later propagation.

Large-scale structure surveys measure the distribution and clustering of galaxies and matter tracers. Their interpretation depends on galaxy bias, selection, redshift estimation, nonlinear evolution, and survey geometry.

Together these datasets form a stringent recovery target. A substrate proposal cannot select one unusual feature while ignoring the power spectra, correlations, and cross-survey consistency that the standard model explains.

Chapter Forty Six

Tensions Anomalies and Systematics

Cosmological tensions arise when parameter estimates from different methods disagree beyond expected uncertainty. Anomalies are features judged unusual relative to a model and analysis. Both categories depend on data selection, calibration, covariance, prior choices, and the multiplicity of searched features.

Possible explanations include underestimated systematics, statistical fluctuation, incomplete astrophysical modeling, or new physics. The categories are not ordered by excitement.

The Labyrinth method from Volume Six applies directly: preserve alternative preprocessing, masks, estimators, scales, priors, and null worlds; register the search burden; and avoid selecting a frame because it intensifies the anomaly. A recurrence across surveys matters only if shared pipelines and sky coverage cannot explain it.

Chapter Forty Seven

Projection Error as a Hypothesis

The proposition that dark matter or dark energy may be a projection effect can be decomposed into testable forms. The inferred component might compensate for an omitted variable, an incorrect mapping between observables and geometry, a scale-dependent effective law, an unmodeled selection effect, or a genuine relational degree of freedom absent from the standard state description.

Each form predicts different residuals. A detector artifact should follow instrumentation or pipeline. A source-population error should track environment or selection. Modified dynamics should change several gravitational observables coherently. A new relational variable should survive independent projections and affect a controlled outcome.

Without that decomposition, “projection error” explains everything and therefore predicts nothing.

Chapter Forty Eight

Competing Models and Underdetermination

Finite observations can be compatible with multiple models. Cosmology intensifies this problem because only one observable cosmic history is available and many parameters concern inaccessible epochs or components.

Underdetermination does not make model choice arbitrary. Predictive accuracy, parsimony, consistency, cross-probe performance, theoretical coherence, robustness, and new successful predictions all matter. A richer model pays a larger complexity and search burden.

Substrate Cosmology asks that incompatible models remain explicitly related rather than prematurely merged. The goal is not one verbal synthesis. It is a map of which observations each model recovers, which assumptions differ, and which future observation would distinguish them.

Chapter Forty Nine

Cosmogenesis Without an Absolute Beginning

The earliest recoverable boundary in a model need not be the beginning of Actual Physics. A coordinate boundary, geodesic incompleteness, quantum transition, bounce, or emergence of classical spacetime can each mark a different kind of beginning.

Substrate Cosmology therefore avoids both assertions: that the hot Big Bang proves creation from nothing, and that a timeless substrate has been demonstrated. Statelessness does not mean changelessness. Precausality does not mean an earlier temporal era.

The operational question is which relations can be continued across a regime boundary and which cannot. A cosmogenesis model should state its carrier on each side, its transition rules, the observables it preserves, and the traces it predicts in the accessible universe.

Part VI

A Relational Cosmology

Chapter Fifty

Cosmology as a Network of Models

Physics already uses a network rather than one universal description. General relativity, quantum field theory, nuclear physics, plasma physics, fluid dynamics, thermodynamics, stellar models, and statistical inference connect through approximations, scales, and interface conditions.

Substrate Cosmology treats this plurality as evidence about representation, not as a defect to be erased. Each model retains relations suited to a task. The research object is the network of translations, overlaps, obstructions, and residuals.

A model becomes a partial perspective in a precise sense only when its domain and recovery maps are specified. “All models describe the same substrate” is otherwise too broad to test. Mutual consistency must be constructed, not assumed.

Chapter Fifty One

Regimes and Fibers

FRTT proposes a base category B of declared regimes and a family of fibers E_b containing the mathematical objects admissible in each regime. A cosmological regime may specify scale, epoch, observer, detector, matter model, geometry, approximation, and accessible observables.

Quantum fields on a background, relativistic fluid dynamics, weak-field lensing, and statistical galaxy bias need not use one global vocabulary. They may occupy different fibers linked by controlled translations.

The architecture remains programmatic. The base, morphisms, lifting rules, and coherence conditions must be defined for an actual model. Calling the universe “fibered” without this construction would be decoration.

Chapter Fifty Two

Projection and Recovery

Let X be an enriched relational representation and Y a standard cosmological representation. A projection $\Pi : X \to Y$ identifies some enriched distinctions. The kernel of that projection records what conventional representation cannot distinguish.

Physical extension requires more than a nontrivial kernel. Two enriched states x_1 and x_2 may satisfy

$$\Pi(x_1) = \Pi(x_2)$$

for all current observations. Unless an admissible intervention or independent observation separates them, the distinction is empirically idle.

Recovery protects the standard theory; nonfactorization creates the possibility of extension. Both must be demonstrated on declared domains.

Chapter Fifty Three

Emergent Metrics and Clocks

An emergent-metric program must show how effective distances, durations, causal cones, and curvature arise from a deeper carrier. It must also explain why different matter and clock constructions agree well enough to support one spacetime geometry.

A provisional relational carrier might include adjacency, compatibility, ordering, and interaction records. A metric would be a derived object only after rules connect those relations to intervals and geodesic behavior.

The test is not whether the language sounds pregeometric. The test is whether the construction recovers relativistic timing and gravity, identifies its approximation error, and predicts a bounded failure of metric description that another account does not.

Chapter Fifty Four

Adjacency and Causal Order

Adjacency can mean spatial neighborhood, graph connection, algebraic relation, interaction availability, causal link, or operational accessibility. A substrate theory must type these separately.

Causal order in relativity is determined by spacetime geometry. A precausal relation, by project definition, is not ordered by that causal structure. This does not permit causal contradiction. Its projection must still preserve no-signalling and observed causal order unless a specific violation is hypothesized.

One formal target is to construct a relational order whose spacetime projection yields a partial causal order and light cones. Another is to prove that extra adjacency data cannot be used as a controllable superluminal channel on the standard interface.

Chapter Fifty Five

Horizons as Recoverability Boundaries

FRTT can represent a horizon as task-indexed failure of recovery. Let A_{obs} be the observables available to an observer and R a reconstruction rule. A horizon for question family Q occurs where no admissible R recovers the required relation within tolerance.

This definition can coexist with geometric horizons while distinguishing access, computation, and physical causality. It also reveals that different detectors or question families may have different recoverability boundaries.

The proposal becomes useful only if it reproduces established horizon predictions and identifies a new operational distinction. Otherwise it is a relabeling of inaccessible information.

Chapter Fifty Six

Conserved and Relational Invariants

FRTT may compare conventional invariants with candidates that survive changes of regime. A relational invariant could concern topology, recurrence identity, compatibility class, translation coherence, or an obstruction to global representation.

The candidate record must specify the transformation family under which it is invariant. Nothing is invariant without respect to a class of changes. It must also state how the invariant composes and how it projects to ordinary measurements.

The strongest result would be a relational invariant that predicts a conventional observable across several models while ordinary variables do not. A weaker but still useful result would be improved model translation or error diagnosis without a new physical claim.

Chapter Fifty Seven

Entropy as Indexed Coarse Graining

Coarse graining maps many microdescriptions into one macrodescription. Entropy depends on the selected macrovariables, ensemble, accessible algebra, observer, and dynamics. FRTT can represent these choices as regime data rather than hiding them in notation.

A translation between entropy measures should specify what distinctions are forgotten and whether the map is reversible. Black-hole entropy, thermodynamic entropy, and entanglement entropy may then be compared without declaring them identical.

The formal target is a family of entropy objects with recovery maps to established measures and explicit obstructions to translation. A universal “substrate entropy” is not assumed.

Chapter Fifty Eight

Dark Phenomena as Translation Residuals

Suppose two regime descriptions are connected by a translation F and their predicted observables differ by a residual Δ_F. The residual can arise from approximation, missing variables, calibration, incompatible domains, or a genuinely absent relational degree of freedom.

This framework provides a disciplined version of the projection hypothesis. Dark phenomena are not declared to be residuals; their observations are used to test whether a specific translation residual has common structure across rotation, lensing, clustering, and expansion data.

The residual must be frozen before evaluation and compared with standard competitors. If it merely reproduces a fitted dark component under new notation, it has not increased explanatory or predictive content.

Chapter Fifty Nine

Conditional Formal Targets

The cosmological FRTT program has several theorem and construction targets:

1. define regime objects and admissible translations for at least one cosmological benchmark;
2. recover a standard background and perturbation model on its validated domain;
3. represent detector and inference chains as typed morphisms;
4. distinguish geometric, causal, informational, and operational horizons;
5. construct an entropy translation with explicit loss;
6. identify whether a candidate relational variable factorizes through standard observables;
7. derive one prospectively different observable with uncertainty and null worlds;
8. prove that the construction respects established no-signalling and conservation constraints.

Failure of any target is evidence about the architecture. It must remain visible.

Part VII

The Cosmology Research Program

Chapter Sixty

Statement Classes

Cosmology invites grammatical overreach because a compact narrative can connect the whole universe. The research record must tag each statement before integration.

“Supernova observations support accelerated expansion under calibrated distance relations” is an evidence-linked inference. “Dark energy is missing substrate dynamics” is an interpretive proposal. “A translation residual predicts scale-dependent lensing” could become a physical hypothesis. “Spacetime emerges from entanglement” may be a result in specified holographic models while remaining a broader conjecture elsewhere.

The class determines the proof duty. A change of wording cannot promote a statement.

Chapter Sixty One

The Translation Ledger

Every cross-model statement should record:

Field	Question
Source regime	Which model scale observer and variables are used?
Target regime	What representation receives the result?
Map	How are objects and operations translated?
Recovery	Which established results must survive?
Loss	Which distinctions are identified or discarded?
Ambiguity	Are several translations compatible?
Residual	What fails to map within tolerance?
Test	What future observation distinguishes explanations?

The ledger prevents a verbal similarity-such as “entropy,” “horizon,” or “information”-from becoming a mathematical identity.

Chapter Sixty Two

The Cosmological Claim Packet

A portable claim packet joins a statement to its observational and interpretive history. It contains the raw or cited source, detector, calibration, preprocessing, observable, model, parameter dependencies, covariance, alternative explanations, null worlds, sensitivity tests, and decision rule.

For a substrate interpretation it also includes the exact conventional recovery requirement, the additional relational variable, its construction, whether it factorizes through known variables, and the prospectively different prediction.

The packet does not make a claim true. It makes disagreement and replication possible without reconstructing hidden choices.

Chapter Sixty Three

Model Comparison and Null Worlds

Cosmological null worlds should preserve the ordinary structures capable of producing an apparent anomaly. Depending on the question, nulls may preserve survey masks, selection functions, source populations, spatial correlations, redshift distributions, calibration drift, lensing geometry, or power spectra.

A global random shuffle usually destroys too much. Graduated nulls ask whether the result survives increasingly realistic worlds. Synthetic injection tests whether the pipeline can recover a known signal without producing false structure.

Model comparison must include search burden, nuisance flexibility, prior sensitivity, predictive performance, and out-of-sample behavior. A substrate model does not receive a lower standard because its variables are unfamiliar.

Chapter Sixty Four

Frame Shaking the Cosmos

Before varying a cosmological frame, register the artifact and the planned perturbations. Candidate axes include coordinate system, distance calibration, redshift estimator, survey mask, source classification, scale cuts, foreground model, parameter prior, gravity model, time coordinate, topology, coarse graining, and horizon definition.

Preserve all attempted frames, not only the one that maximizes the effect. Study the response geometry: where the claim is stable, where it changes smoothly, where it bifurcates, and where it disappears.

A stable region of frame-space can justify further research. It does not by itself establish an alternate physical dimension. That requires an independent operational consequence.

Chapter Sixty Five

Recurrence Across Sky Surveys

Recurrence analysis may compare structures across epochs, wavelengths, sky regions, object populations, or simulations without reducing recurrence to periodicity. It can preserve topology, ordering, multiscale pattern, and cross-frame correspondence.

Astronomical recurrence is exceptionally vulnerable to survey footprints, repeated observing strategies, catalog construction, source evolution, and shared simulation assumptions. Nulls must preserve these structures before an excess recurrence is interpreted.

The RP07 GDELT results do not transfer to cosmology by analogy. They supply methods for candidate freezing, blind validation, frame ensembles, and failure preservation. A cosmological recurrence program requires its own development data, held-out observations, operators, and commitments.

Chapter Sixty Six

Prospective Predictions and Stop Conditions

A credible Substrate Cosmology prediction must be written before the decisive data are inspected. It must identify the conventional baseline, alternative relation, observable, effect direction or distribution, uncertainty, nulls, stopping rule, and what result would count against the proposal.

Development should stop or branch when the enriched variable factorizes through known quantities, the recovery map fails, the effect follows calibration or detector choice, the result disappears under realistic nulls, predictive performance does not improve out of sample, or the hypothesis requires prohibited signalling or unclosed resource accounting.

Failure can still improve translation, metadata, detector design, or model comparison. It cannot be rewritten as hidden confirmation.

Chapter Sixty Seven

Using the Research Commons

The public website provides a question-first entry into cosmological research. Begin with the guided questions on the universe’s beginning, time, space, vacuum, relativity, gravity, energy, force, entanglement, conservation, dark matter, dark energy, and testing.

Use the glossary to preserve distinctions among scalar, frame, detector, null world, evidence relation, operational usefulness, and ontology. Use the model registry to inspect measurement, recurrence, information, identity, agency, and conservation. Use the research-question queue for unresolved formal and experimental dependencies. Use the evidence and replication surfaces to determine what has not yet been admitted.

Discussion in the forum does not become evidence or canonical theory automatically. Cosmological contributions should identify the observation, ordinary explanation, competing model, frame, detector, null world, and disconfirming result. The website user manual remains planned as Volume Ten.

Conclusion

Cosmology is one of humanity's most disciplined acts of inference. From interactions recorded by matter at one location and epoch, researchers reconstruct a vast evolving universe. The reconstruction succeeds because independent physical relations constrain one another. Its success deserves recovery, not dismissal.

Its limitations also deserve precision. Every observation arrives through propagation, detector coupling, calibration, encoding, aggregation, and model translation. Horizons restrict access. Quantities such as time, distance, mass, energy, entropy, and curvature are physically effective relations whose formal meanings depend on a regime. None must be declared fundamental merely because it is indispensable within our present physics.

Substrate Cosmology enters at this boundary. It proposes that Actual Physics may contain relational organization not preserved by state-based, matter-centered representations. The proposal is not supported merely because cosmology contains unknowns. It earns scientific standing only by recovering established physics, defining richer relations without semantic substitution, and predicting a prospective conventional difference that survives realistic nulls and independent observation.

This volume therefore ends without a replacement cosmology. It supplies a disciplined way to build one if the evidence ever requires it-and an equally disciplined way to stop if it does not.

Appendix A

Evidence and Interpretation Ladder

Level	Required content	What it does not establish
A0 Recorded interaction	instrument output provenance timing and environment	source identity or cosmology
A1 Calibrated observable	correction method uncertainty and units	unique physical cause
A2 Derived quantity	source model propagation model covariance	model independence
A3 Cross probe inference	joint likelihood shared assumptions alternatives	final ontology
A4 Anomaly or tension	preregistered statistic multiplicity realistic nulls	new physics by itself
A5 Operational relation	out of sample prediction and replication	what fundamentally exists
A6 Physical hypothesis	mechanism or formal carrier and discriminating prediction	confirmation before test
A7 Ontological proposal	explicit metaphysical interpretation	empirical privilege without new consequences

Movement upward requires additional evidence or formal work. Rhetorical certainty, mathematical sophistication, and repetition do not promote a claim.

Appendix B

Observation to Inference Matrix

Recorded or calibrated relation	Typical inferred quantity	Major model dependencies	Substrate question
wavelength pattern	redshift	line identification source motion gravity expansion	Which transformations are merged into one ratio?
flux and light curve	luminosity distance	source standardization extinction calibration	Which source and propagation relations are shared?
angular separation	physical scale	geometry distance model ruler calibration	Does coordinate distance exhaust adjacency?
image distortion	lensing mass	source distribution geometry gravity model	Which mass and geometry assumptions are coupled?
orbital or rotation data	dynamical mass	equilibrium baryons inclination gravity law	Which alternatives make joint predictions?
microwave temperature and polarization map	cosmological parameters	foregrounds transfer functions initial spectrum	Which parameter combinations are identifiable?
galaxy positions and redshifts	clustering and growth	bias selection redshift errors nonlinear model	Which recurrences follow the survey?
interferometer strain	source masses distance propagation	waveform model calibration gravity theory	Which relations are detector independent?

The matrix should be expanded for the specific dataset. It is not a substitute for a full likelihood or instrument model.

Appendix C

Emergent Quantity Record

1. **Quantity name and identifier**
   State the conventional term and a stable project identifier.
2. **Established definition**
   Give the definition used in the target theory and its domain.
3. **Physical realization**
   Identify the preparation, standard, detector, calibration, and comparison process.
4. **State and frame dependence**
   Record observer, coordinates, scale, boundary, ensemble, and approximation.
5. **Retained relations**
   State what the quantity preserves for the declared task.
6. **Collapsed relations**
   State which paths, histories, correlations, dimensions, or uncertainties are identified.
7. **Established transformations**
   List symmetry, coordinate, unit, or regime changes and the applicable laws.
8. **Proposed enrichment**
   Define the additional carrier and operations without relying on metaphor.
9. **Recovery map**
   Show how the enriched object returns the conventional quantity.
10. **Nonfactorization test**
    Determine whether the enrichment contributes anything not already encoded in conventional variables.
11. **Prospective consequence**
    State the ordinary observable expected to differ.
12. **Failure rule**
    Define what would reject, merge, or demote the proposal.

Appendix D

Cosmological Claim Packet

Section	Required fields
Claim identity	stable ID version author statement class status
Observation	dataset instruments epoch sky region source population
Provenance	raw source licensing transformations software hashes
Detector	material coupling bandwidth threshold calibration environment
Observable	estimator units covariance masking and missingness
Standard model	equations parameters priors nuisance variables domain
Ordinary explanations	systematics selection foregrounds astrophysics statistics
Alternative models	declared competitors and their fitted flexibility
Substrate proposal	carrier relations operators projections and recovery
Null worlds	graduated realistic nulls and synthetic injections
Search record	all tried frames multiplicity stopping decisions
Prediction	frozen observable direction tolerance and disconfirmation
Replication	independent data instruments analysts and software
Nonclaims	ontology capabilities and domains not established

Every revision should preserve the earlier packet. A stronger interpretation requires a new version and an explicit change-impact record.

Appendix E

Model Translation Record

Source model
Name the theory, approximation, objects, dynamics, observables, and validated domain.

Target model
Name the corresponding elements and the reason for translation.

Object map
Define how states, fields, geometry, ensembles, or processes are mapped.

Operation map
Define how evolution, measurement, composition, and symmetry actions translate.

Recovery condition
State the commuting diagram, limit, equivalence, or error tolerance that must hold.

Information loss
List distinctions identified by the map and whether reconstruction is possible.

Obstruction
Record nonuniqueness, contextuality, topology, incompatibility, or missing global structure.

Residual
Quantify the disagreement and its uncertainty before interpreting it.

Discriminating test
Identify an observation that distinguishes translation failure, ordinary missing physics, and a proposed enriched relation.

Appendix F

Cosmological Frame Shake Registry

Axis	Examples	Required preservation
Observer and coordinates	rest frame slicing gauge chart	transformation and invariant observables
Distance reconstruction	candles rulers lensing sirens	calibration covariance and selection
Time representation	proper conformal cosmic thermal ordering	mapping and recovery limits
Geometry	curvature topology background perturbations	equations boundary and data fit
Gravity	general relativity modified dynamics effective models	validated tests and parameter burden
Matter model	particles fluids fields effective components	equations of state and interactions
Survey construction	mask depth cadence classification	footprint completeness and shared systematics
Scale	object halo galaxy cluster cosmic web	resolution coarse graining and nonlinearities
Statistical frame	likelihood prior estimator threshold	multiplicity sensitivity and coverage
Relational enrichment	adjacency recurrence compatibility translation	formal carrier factorization and prediction

Register the full ensemble before inspecting the target outcome. Preserve failed and null frames. Report the response surface rather than only the largest deviation.

Appendix G

Glossary

Actual Physics. Whatever physical relations occur independently of any observer's representation. The term does not assign intrinsic properties to an unknowable substrate.

Adjacency. A declared relation of neighborhood, connection, accessibility, compatibility, or interaction. Its type must be stated.

Aliasing. Distinct underlying structures producing the same or confusable representation under a sampling or projection process.

Cosmological horizon. An observer- and model-dependent boundary on causal or observational access produced by spacetime history.

Dark energy. A name for the component or effective behavior used to account for accelerated cosmic expansion; its underlying nature remains unresolved.

Dark matter. A name for the nonluminous component or effective behavior inferred through gravitational and cosmological observations; its underlying nature remains unresolved.

Emergence. The appearance of stable effective objects, laws, or quantities at one descriptive regime from relations represented at another. Emergent does not mean unreal.

Entanglement. Nonseparability of a joint quantum state. It does not provide controllable faster-than-light signalling.

Field. A mathematical and physical assignment over a domain with declared transformations and dynamics. Not every relation is a field.

Frame. The bounded coordinate, observational, mathematical, or interpretive system within which a statement is meaningful.

FRTT. Fibered Relational Tensor Theory, the proposed mathematical architecture organizing regime-indexed objects, translations, projections, and recovery. It is not yet a complete theory.

Horizon. A boundary on a declared form of causal influence, observation, or reconstruction. The type and observer must be specified.

Information. A recoverable distinction relative to a physical interaction, encoding, and frame. Substrate Cosmology treats information as emergent.

Matter. In this project, persistent emergent relational organization that remains preparable and detectable across selected changes. Standard matter theories retain their established meanings.

Nonfactorization. The condition in which an enriched distinction cannot be computed solely from the standard projected variables.

Ontology. A claim about what fundamentally exists, stronger than an effective model or operational relation.

Precausal. Not ordered by the causal structure of the target spacetime representation. It does not mean earlier in time or exempt from no-signalling evidence.

Projection. A map or physical process that retains selected relations and identifies or discards others.

Recovery. Reproduction of an established theory's structures and predictions on its validated domain.

Reference singularity. A speculative project term for universal or shared nonmetric adjacency. It is not a gravitational singularity and has not been demonstrated.

Relational invariant. A structure preserved under a declared family of transformations or regime changes.

Residual. A quantified disagreement between observation and prediction or between translated representations. A residual is not automatically new physics.

Singularity. In relativity, a boundary associated with geodesic incompleteness under stated assumptions; not necessarily a physical point object.

Spacetime. The geometric organization of events, intervals, causal relations, and gravitation in relativity. Substrate Cosmology treats its fundamentality as open while requiring full recovery.

Stateless. A project term indicating that Actual Physics is not assumed to be constituted by the discrete or durable states used in human information. It does not mean inactive or changeless.

Appendix H

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