SUBSTRATE COSMOLOGY

Volume Seven

Recursive Cosmology, Matter, and Emergent Physical Quantities

Second Edition

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Editorial, analytical, and production collaboration: OpenAI ChatGPT Codex

September 2026

A forward-only revision preserving the First Edition and the recovery obligations of established cosmology.

Publication and Copyright Notice

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The First Edition of Volume Seven remains preserved as historical evidence. This Second Edition becomes the current Volume Seven without rewriting the developmental record, original chapters, appendices, statement classes, or evidence boundaries.

Substrate Cosmology and Fibered Relational Tensor Theory are developing theoretical and methodological research programs. They are not experimentally established as fundamental physics. The cosmological observations and established theories discussed here remain authoritative within their validated domains.

This volume does not claim that dark matter, dark energy, inflation, gravity, inertia, quantum entanglement, black-hole entropy, horizons, tensions, or anomalies confirm a substrate ontology. It does not provide a demonstrated method for faster-than-light communication, time travel, teleportation, gravity control, energy extraction, or engineering spacetime.

The inherited RP07 recurrence boundary remains unchanged. GDELT 1995 remains development data; 1996 and later years and all protected outcome layers remain unopened. Nothing in this edition authorizes opening, scoring, or interpreting those branches.

Authorship and AI Collaboration

James Dunn originated Substrate Cosmology; the distinction between Actual Physics and represented physics; the treatment of matter as a persistent emergent central tendency; the proposal that time and space are collapsed relations rather than necessary foundations; the principle that information is emergent; and the correction that every mathematical and procedural operator used in the analysis is also a scalar representation.

OpenAI ChatGPT Codex correlated Volume Eleven and the Second Editions of Volumes One through Six with the First Edition of Volume Seven; identified recursive collapse in cosmological quantities, probe pipelines, equality criteria, recovery maps, inference layers, frames, horizons, residuals, likelihoods, and claim packets; preserved and re-typeset the First Edition core; drafted the correction layers, Part VIII, and Appendices I through R; generated and visually verified the PDF; and assisted with website publication.

AI systems are collaborators in representation, analysis, and production. They are not empirical witnesses, independent replicators, scientific authorities, or evidence that a physical claim is true.

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Second Edition Revision Note

The First Edition correctly treated cosmology as a horizon-limited reconstruction made from within the universe; separated observations, inferences, models, and ontology; reopened physical quantities without declaring them unreal; recovered general relativity and standard cosmology in validated domains; distinguished Higgs-generated elementary-particle masses from the strong-interaction origin of most visible mass; preserved no-signalling; and treated dark-sector reinterpretation as hypothesis rather than result.

Volume Eleven and the Second Editions of Volumes One through Six require the critique to recurse. A cosmological quantity is a scalarization, but so are the words used to name it, the units and standards used to realize it, the operators used to infer it, the equality and likelihood rules used to compare models, the map used to recover relativity, and the ledger used to audit the sequence. No finite cosmological record is uncollapsed.

This edition therefore replaces any suggestion of a final relational state with purpose-relative, less-collapsed cosmological profiles. It separates operator token, rule, application, and composition; treats relativity as a required recovered interface rather than an automatic ontological container; adds cross-probe ancestry and perspective rotation; and sharpens the path from observational residual to prospective, nonfactorizing, resource-closed discrimination.

Contents

Preface

Volume Seven applies the series' perspective discipline to the largest reconstruction humans attempt: a universe inferred from records collected by physical participants inside that universe. The observer has one accessible region, one past light cone, finite detector families, physically realized standards, and models that translate local interactions into claims about cosmic history.

The First Edition showed why these limits do not make cosmology arbitrary and do not limit what Actual Physics may be. Volume Eleven and the Second Editions of Volumes One through Six add the recursive requirement. The operator that translates a spectrum into redshift, redshift into distance, distance into history, or history into a model parameter is itself a scalarized selection. The audit that names the loss remains another selection.

The response is not to abandon successful equations or to treat every alternative as equal. It is to preserve the entire observation-to-inference ancestry; rotate claims through independent perspectives; recover validated mathematical and physical results; distinguish inaccessible from nonexistent; and ask whether a retained relation changes a prospective comparison or intervention.

Chapters One through Sixty Seven and Appendices A through H preserve the First Edition core. Seven correction layers state how its parts must now be read. Part VIII and Appendices I through R supply the recursive architecture needed to carry the program forward without granting cosmology, relativity, relational mathematics, or Substrate Cosmology a view from outside representation.

Current Series Map

Volume	Current title and task
One	Introduction to Relational Physics and Recursive Scalarization - build the alternate perspective.
Two	Words, Units, Operators, and Recursive Collapse - audit representational selection.
Three	Relational Tools, Recursive Operator Lineages, and Perspective-Guided Research - preserve disciplined development.
Four	Relational Mathematics, Recursive Operator Dimensionalization, and FRTT - construct bounded formalisms and recovery maps.
Five	Measurement, Detectors, Recursive Observation, and Experimental Interaction - place apparatus and every operation inside the boundary.
Six	Recurrence Research, Recursive Frames, and the Labyrinth - test return without collapsing it into one representation.
Seven	Recursive Cosmology, Matter, and Emergent Physical Quantities - reopen inherited quantities while recovering validated cosmology.
Eight	Conditional Engineering and Physical Manipulation - gate intervention through evidence and safety.
Nine	Intelligence, Agency, Identity, and Dimensional Stewardship - extend relational discipline to agency and governance.
Ten	Website User Manual and Research Commons Guide - document routes, evidence, contribution, and continuity.
Eleven	Recursive Scalarization, Relational Adjacency, and Emergent Understanding - coordinate multiple perspectives under recursive collapse.

Acknowledgments

This edition grows from James Dunn's insistence that living inside the environment under study limits the frames available to us without limiting what physics can be; that relativity must be recovered without becoming the container for every possible relation; that dimensions are relational lexicons rather than automatically extra spatial axes; that matter detectors may reinforce stable central tendencies; and that all information, operators, and audits remain emergent representations.

OpenAI ChatGPT Codex is acknowledged for cross-volume correlation, recursive operator criticism, scientific-language discipline, structural drafting, editorial revision, document production, and website integration. Microsoft Copilot and Google Gemini are acknowledged for earlier recorded assistance. AI participation is provenance, not confirmation.

The work depends upon observational astronomy, cosmology, general relativity, quantum field theory, particle physics, thermodynamics, information theory, metrology, statistics, computation, and philosophy of measurement. A conservative extension must recover their validated results and expose where its own language exceeds the evidence.

Reader Guide

Read Chapters One through Sixty Seven as the preserved First Edition core, and read each Part's correction layer immediately afterward. The corrections do not erase earlier language. They identify where quantities, operators, frames, and recovery claims must be reopened. Part VIII develops the recursive cosmological architecture.

Five Questions for Every Cosmological Claim

Question	Required answer
Record	Which local interactions, instruments, calibrations, selections, and processing steps produced the evidence?
Quantity	Which realization, units, model, operators, and equivalence criteria produced the reported cosmological quantity?
Alternatives	Which ordinary mechanisms, systematics, degeneracies, priors, and null models remain compatible?
Recovery	Where does the proposal recover validated relativity, quantum field theory, thermodynamics, and cosmology?
Leverage	Which frozen retained distinction predicts a prospective difference that competing models do not?

Framing statement. Every observation, quantity, model, operator, recovery map, diagram, likelihood, ledger, and statement in this volume is a scalarization relative to relations it does not preserve. The aim is a purpose-relative profile with declared losses and recovery conditions, not a final notation identical to Actual Physics.

CHAPTER INTRODUCTION

Cosmology From Inside the Environment and Inside Its Operators

Cosmology is reconstructed by physical systems inside the physical environment being reconstructed. An observer cannot step outside the universe, compare it with a control universe, move to every vantage point, or receive signals from beyond every horizon. Instruments, standards, clocks, algorithms, and researchers participate in the same environment as the events they describe.

This condition does not make cosmology subjective. Coordinated probes, calibration, model comparison, prediction, error correction, and replication create reliable knowledge from within. It does prevent the success of one reconstruction from proving that its variables exhaust Actual Physics.

The Second Edition adds that the reconstruction operators also belong inside the account. A redshift token, division rule, likelihood, fit, equality threshold, coordinate map, tensor equation, recovery arrow, or classification rule is a scalar identity applied under selected conditions. Adding metadata can make the selection inspectable, but the metadata and ledger remain scalarized too.

Substrate Cosmology therefore treats time, space, spacetime, matter, field, mass, energy, force, gravity, entropy, horizon, temperature, vacuum, and information as operationally successful relations whose identities must be indexed by their realizations and uses. It does not declare them unreal or replace them by an unobserved object.

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less-collapsed profile -> validated projection -> ordinary cosmological result
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The decisive test remains conservative and prospective. A richer profile must recover the conventional result in its validated domain, retain a distinction omitted by that result, and predict a reproducible difference under a comparison or intervention that closes ordinary explanations to the permitted claim level.

Perspective recovery. Cosmology is an internally coordinated reconstruction whose reliability does not require its quantities to be exhaustive ontology.

PART I

Looking Out From Inside

The observation-to-inference chain is retained while every detector, calibration, selection, and model operator is placed inside the physical and representational account.

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 = (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 = (8 pi G / 3) rho - (k c^2 / a^2) + (Lambda c^2 / 3)
```

Here H is the expansion rate, a the scale factor, k a curvature parameter, rho the modeled energy density, and Lambda 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.

Second Edition Correction Layer I

The retained chapters remain part of the evidence-bearing development. These statements govern their Second Edition interpretation.

The record is recursively produced

A sky record is not only detector-mediated. Source selection, triggering, calibration, deconvolution, masking, catalog construction, cross-matching, visualization, and publication are operator applications whose composition determines what can enter later inference.

Probe plurality is not automatic independence

Two probes may share clocks, standards, simulations, astrophysical populations, calibration fields, software, priors, or selection functions. Cross-probe agreement must record common ancestry before it is counted as independent convergence.

Horizon and absence

A horizon or sensitivity limit bounds access under a physical relation and a represented probe. It does not establish that excluded structure is absent, and it does not authorize claims about what Actual Physics cannot contain.

Recursive caution. This correction layer is also a bounded representation. Reopen it when its categories conceal a distinction that could alter a legitimate observation, recovery, comparison, prediction, or intervention.

PART II

Reintroducing Physical Quantities

Inherited quantities are reopened as purpose-relative profiles without discarding their validated operations or turning richer description into ontology.

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) = (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.

Second Edition Correction Layer II

The retained chapters remain part of the evidence-bearing development. These statements govern their Second Edition interpretation.

Quantity profiles

Time, space, spacetime, matter, mass, field, energy, force, gravity, conservation, entropy, information, temperature, and vacuum should be recorded as purpose-relative profiles: realization, frame, operator lineage, uncertainty, equivalence scope, recovery map, and declared loss.

Units and dimensionless outputs

A shared or cancelled unit does not remove realization history. Unit conversion, normalization, ratios, equality, and conservation statements contain selected compatibility rules. Dimensionless does not mean relationless.

No terminal inventory

Adding relational metadata improves inspectability but does not produce an uncollapsed cosmological quantity. Stop expansion relative to a declared task and preserve what remains unknown.

Recursive caution. This correction layer is also a bounded representation. Reopen it when its categories conceal a distinction that could alter a legitimate observation, recovery, comparison, prediction, or intervention.

PART III

Matter, Fields, and Quantum Relations

Matter, mass, fields, vacuum, detectors, and entanglement are separated from metaphors that would exceed quantum and no-signalling evidence.

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?

Second Edition Correction Layer III

The retained chapters remain part of the evidence-bearing development. These statements govern their Second Edition interpretation.

Identity operators

Particle, matter, field, vacuum, and detector identities are stabilized through classifications, symmetries, preparation histories, couplings, thresholds, and model roles. These operators must be separated from claims that the classification is the thing in itself.

Mass distinctions remain binding

The Higgs mechanism contributes elementary-particle rest masses within established quantum field theory. Most ordinary visible mass is associated with strong-interaction energy in hadrons. A relational interpretation must recover both without substituting one slogan.

Entanglement ceiling

Nonseparability and Bell-type correlations do not establish a controllable signal, universal common point, hidden preferred frame, or substrate mass. No-signalling and resource accounting remain required.

Recursive caution. This correction layer is also a bounded representation. Reopen it when its categories conceal a distinction that could alter a legitimate observation, recovery, comparison, prediction, or intervention.

PART IV

Gravity, Horizons, and Entropy

General relativity and black-hole thermodynamics remain mandatory recovered interfaces while horizon and information claims retain their access boundaries.

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 ιG R and recovery map πG R 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 = (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.

Second Edition Correction Layer IV

The retained chapters remain part of the evidence-bearing development. These statements govern their Second Edition interpretation.

Relativity as recovered interface

General relativity is an extraordinarily successful predictive structure and a non-negotiable recovery target. Its success does not by itself establish that spacetime variables exhaust every relation permitted by Actual Physics.

Recovery maps are scalar too

An embedding, projection, coordinate change, equivalence statement, tensor contraction, or approximate identity is an operator family with domain, tolerance, composition, and loss. Writing a recovery equation does not complete the recovery proof.

Horizon and entropy indexing

Area, entropy, information, observer, coarse graining, accessible algebra, ensemble, and boundary conditions must be indexed. A horizon is an access relation under a theory and worldline, not a universal edge viewed from outside.

Recursive caution. This correction layer is also a bounded representation. Reopen it when its categories conceal a distinction that could alter a legitimate observation, recovery, comparison, prediction, or intervention.

PART V

Origins, Expansion, and the Dark Sector

Observations, mainstream inferences, residuals, and speculative translations are kept distinct across origin, expansion, inflation, and dark-sector questions.

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.

Second Edition Correction Layer V

The retained chapters remain part of the evidence-bearing development. These statements govern their Second Edition interpretation.

Residual is not referent

Dark matter and dark energy name successful inferential roles and evidence clusters within models. Calling them aliases, projection errors, or translation residuals remains a hypothesis until a frozen alternative recovers the data and predicts a difference.

Origins require operator ancestry

An inferred beginning, bounce, inflationary phase, or failed continuation depends on coordinates, extrapolation, state space, priors, regularization, and boundary rules. The operator history belongs in the claim.

Tensions and anomalies

A discrepancy becomes evidence for extension only after calibration, selection, astrophysical modeling, analysis flexibility, covariance, and competing mainstream explanations are represented and tested prospectively.

Recursive caution. This correction layer is also a bounded representation. Reopen it when its categories conceal a distinction that could alter a legitimate observation, recovery, comparison, prediction, or intervention.

PART VI

A Relational Cosmology

Relational frames, adjacencies, projections, clocks, metrics, invariants, and formal targets are treated as bounded constructions with explicit recovery maps.

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 Eb 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 -> 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 Aob s 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 ΔF. 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.

Second Edition Correction Layer VI

The retained chapters remain part of the evidence-bearing development. These statements govern their Second Edition interpretation.

Fibers and translations remain represented

Regimes, fibers, adjacencies, emergent metrics, clocks, invariants, and translation maps are bounded scalar identities. They can preserve more relations for a task without becoming the uncollapsed substrate.

Adjacency is participation

Cosmological adjacency may be causal, interactional, topological, inferential, common-source, detector, or operator-accessible. It is not automatically spatial nearness and must not be converted into nonlocal influence without an operational channel.

String-inspired models are optional

Extended paths, boundary interactions, splitting, joining, reconnection, topology, and dual descriptions may model recursive adjacency. Structural usefulness does not prove literal strings, extra spatial axes, or a fundamental string ontology.

Recursive caution. This correction layer is also a bounded representation. Reopen it when its categories conceal a distinction that could alter a legitimate observation, recovery, comparison, prediction, or intervention.

PART VII

The Cosmology Research Program

Claim packets, null worlds, frame shaking, recurrence, prospective tests, and public continuity become recursive operator lineages rather than neutral procedures.

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.

Second Edition Correction Layer VII

The retained chapters remain part of the evidence-bearing development. These statements govern their Second Edition interpretation.

Every research control is an operator

Statement classes, ledgers, packets, likelihoods, priors, null generators, frame perturbations, recurrence detectors, thresholds, freeze rules, and website status labels preserve some distinctions and collapse others.

Conservative recovery and nonfactorization

A relational alternative must reproduce validated results, define its added relation independently, outperform flexible conventional alternatives prospectively, and survive cross-probe ancestry, resource closure, and independent replication.

Nulls and noncomparability

A null is interpreted through sensitivity and equivalence. Conflicting probes, undefined translations, incompatible domains, and noncomparability are preserved results rather than forced into one scalar verdict.

Recursive caution. This correction layer is also a bounded representation. Reopen it when its categories conceal a distinction that could alter a legitimate observation, recovery, comparison, prediction, or intervention.

PART VIII

Recursive Cosmology and Cross-Perspective Recovery

The cosmological record is rebuilt as a network of purpose-relative profiles, operator lineages, recovery interfaces, independent perspectives, nulls, and prospective discriminations.

CHAPTER SIXTY EIGHT

The Cosmological Quantity Is Also a Scalar

A cosmological quantity condenses a physical interaction history, a standard, a unit, a frame, an observation model, an inference model, and a reporting convention into an identity that can be compared. The condensation can be exact within a theory and still exclude relations that matter to another operation.

The Second Edition records a quantity as a purpose-relative profile: quantity token; physical realization; detector chain; frame; units; operator token, rule, application, and composition; uncertainty and covariance; equivalence scope; ordinary projection; recovery domain; and declared loss.

More fields do not create Actual Physics. A field is added when it can alter a legitimate prediction, comparison, translation, or intervention. The ordinary scalar remains available as a projection so that established practice is recovered rather than displaced.

Perspective recovery. Treat a quantity as a bounded access profile whose precision does not make it an exhaustive inventory of participation.

CHAPTER SIXTY NINE

The Observation-to-Inference Chain Recurses

A cosmological result commonly passes through source emission, propagation, coupling, triggering, calibration, filtering, background subtraction, selection, catalog construction, distance or parameter inference, model fitting, and claim language. Each stage accepts represented inputs and produces new represented outputs.

The chain is recursive because later stages reuse earlier classifications, simulations, priors, and calibrations. An output may become a standard for a later input. The lineage must therefore preserve versions, common dependencies, rejected alternatives, and transformations, not only a final covariance matrix.

A reliable result does not require every lost relation to be restored. It requires the losses capable of changing the declared claim to be bounded, challenged by independent constructions, or included in uncertainty and model comparison.

Perspective recovery. A cosmological value inherits the selections of the complete pipeline that made it possible.

CHAPTER SEVENTY

Redshift, Distance, Time, and Expansion Operators

Redshift is an observed spectral relation interpreted through source physics, propagation, calibration, motion, gravity, and a cosmological model. Converting it into distance, lookback time, scale factor, or expansion history introduces additional operator families and assumptions.

The operator record separates the redshift token from the measurement rule, the application to a spectrum, the aggregation across a sample, the distance indicator or ruler, the background model, the likelihood, and the equality or fit criterion. A number printed as z is not this complete lineage.

A less-collapsed profile compares independent distance ladders, standard sirens, rulers, chronometers, lensing relations, and background inferences while exposing shared calibrations and population models. Disagreement is retained before synthesis.

Perspective recovery. Do not allow one compact expansion parameter to conceal the distinct physical and inferential routes that produced it.

CHAPTER SEVENTY ONE

Matter, Mass, Particle, Field, and Vacuum Identities

Matter, particle, field, mass, and vacuum are not interchangeable labels. Each has a validated operational grammar: preparation, excitation, symmetry, coupling, rest relation, stress-energy role, detector response, or state-relative expectation. Relational reinterpretation begins after these distinctions are recovered.

An identity profile records the operator that groups excitations or persistent structures as the same; the substitutions it permits; the frame and scale; the couplings that reveal the identity; and the conditions under which the classification fails or changes.

Detector matter participates in the same physical relations being inferred. This may motivate questions about reinforced central tendencies, but it does not show that detectors create matter, that the vacuum is nothing, or that one hidden substance explains every stable identity.

> Perspective recovery. Reopen physical identities without erasing the quantum and experimental operations that make them useful.

CHAPTER SEVENTY TWO

Energy, Force, Gravity, and Resource Closure

Energy is a conserved quantity relative to symmetries and defined systems; force organizes changes under a model; gravity is successfully represented by general relativity across an enormous tested domain. These statements must remain recoverable before an alternate interpretation is admitted.

Resource closure tracks matter, radiation, thermal exchange, fields, mechanical work, reference frames, computation, memory, controls, and environmental coupling across a declared boundary. Changing that boundary changes the ledger and therefore the claim.

An apparent excess, missing influence, inertial anomaly, or gravitational residual is first an accounting and model-comparison problem. A substrate interpretation becomes physical only when ordinary resources, detector effects, and flexible established models fail under independent prospective tests.

Perspective recovery. Use relational language to enlarge the accounting question, never to excuse an unclosed resource ledger.

CHAPTER SEVENTY THREE

Horizons, Entropy, and Emergent Information

A horizon is indexed by the causal structure, observer or worldline, field content, operational access, and model. Entropy is indexed by states, ensembles, observables, coarse graining, and constraints. Information is emergent in physical and representational distinctions available to interactions.

The equality sign in an area law or thermodynamic relation is a selected equivalence applied within a theory. The area, constants, state counts, observer access, and approximation regime retain lineages that a compact equation does not display.

A less-collapsed horizon profile can coordinate geometric, thermodynamic, quantum, information-theoretic, operational, and embedded-observer perspectives without claiming that any one supplies the final container. Conflicts may identify incompatible domains rather than a missing universal scalar.

Perspective recovery. Index information and entropy by the access relations and coarse grainings that make them measurable.

CHAPTER SEVENTY FOUR

Dark-Sector Evidence and Translation Residuals

Dark matter and dark energy organize multiple observations within successful model families. Their inferential roles should not be collapsed into ignorance, and the observations assigned to them should not be treated as direct pictures of one specific ontology.

A translation-residual hypothesis states that one representation may compress relations that another preserves. To become more than interpretation, it must specify the discarded relation, recover lensing, dynamics, structure, background, and expansion results, and predict a prospective difference from particle, modified-gravity, astrophysical, and systematic alternatives.

The residual packet records which probes are fit, which are merely redescribed, which common calibrations exist, where the model fails, and what observation could lower its status. Calling a residual an alias never substitutes for this work.

Perspective recovery. Keep the evidence cluster, inferential role, candidate ontology, and translation hypothesis on separate rungs of the claim ladder.

CHAPTER SEVENTY FIVE

Relativity as a Recovered Interface, Not an Automatic Container

Substrate Cosmology repeatedly drifted back toward treating spacetime, invariant intervals, light cones, and relativistic coordinates as the complete environment within which every possible relation must fit. The corrective insight is not that relativity is wrong. It is that validated predictive structure and exhaustive ontology are different claims.

A proposed relational formalism must recover general relativity's observables, transformation behavior, equivalence structure, conservation relations, and tested approximations in their domains. The embedding and projection are themselves operators with tolerances, singular regions, and failure modes.

Only after recovery may an added relation be tested. If it changes no permissible prediction, comparison, or intervention, it remains interpretation or reorganization. If it predicts a difference, the test must preserve causal, energetic, and measurement controls appropriate to the claim.

Perspective recovery. Relativity is a mandatory interface to recover and a powerful perspective to coordinate, not proof that Actual Physics has no relations outside its variables.

CHAPTER SEVENTY SIX

Cosmological Adjacency and Causal Order

Adjacency is a rule of permitted participation in an operation. Spatial nearness, causal reachability, common origin, interaction compatibility, graph connection, topological incidence, survey neighborhood, and shared detector response are different adjacencies.

A cosmological analysis must name which adjacency constructs its objects and correlations. Converting common-source or inferential adjacency into physical contact, controllable communication, or superluminal influence is an invalid translation unless an operational channel is demonstrated.

Causal order remains central to standard cosmological recovery. Alternative orderings may organize precausal or relational hypotheses, but they do not erase chronology, light-cone constraints, or no-signalling in the evidence already available.

Perspective recovery. Separate the rule that permits comparison from the physical channel that permits influence.

CHAPTER SEVENTY SEVEN

Recursion, Recurrence, and Structure Formation

Recursion concerns outputs or rules reused in later production. Recurrence concerns return or preservation under an identity rule. Repetition repeats represented values or events. Vibration requires an oscillatory coordinate description. Resonance concerns preferential response under compatibility. Cosmological structure may involve several without making them equal.

Recurrence across sky surveys can reveal repeated morphologies, correlations, transitions, or response profiles. The result depends on segmentation, metric, adjacency, tolerance, selection, null family, and search burden. A recurrence detector is not an outside witness to a cosmic mechanism.

String-inspired descriptions may model maintained adjacency, splitting, joining, reconnection, boundaries, modes, and dual projections. They remain optional mathematical resources competing with graphs, categories, tensor networks, automata, and other formalisms. Similarity is not ontology.

Perspective recovery. Use recurrence and string-inspired structure to generate discriminating models, not to turn resemblance into a claim about fundamental constituents.

CHAPTER SEVENTY EIGHT

Perspective Rotation Across Cosmological Probes

Rotate a cosmological claim through observational, metrological, geometric, relativistic, quantum-field, thermodynamic, information-theoretic, computational, statistical, historical, linguistic, instrument, and embedded-observer perspectives. Each lens states what it preserves, hides, translates, and cannot compare.

Agreement is weighted by independence, not counted by labels. A lensing and dynamical analysis may share source populations, masks, simulations, calibration, redshifts, or priors. Apparent plurality that shares one decisive failure mode is not independent confirmation.

Conflict is preserved before resolution. It may identify scale dependence, selection, incompatible realizations, omitted covariance, model error, or a genuine retained relation. Forced averaging can hide the very condition a richer profile is meant to expose.

Perspective recovery. Understanding emerges from traceable translations, independent convergence, and informative disagreement among bounded views.

CHAPTER SEVENTY NINE

Conservative Recovery and Nonfactorization

A conservative cosmological extension defines an embedding of validated states or models and a projection that returns accepted observables within stated tolerances and domains. The implementation, units, coordinate choices, approximation, calibration, and error budget belong to the recovery proof.

Nonfactorization becomes consequential when an independently defined relational descriptor predicts outcomes that no adequate composition of admitted scalar contributions and flexible conventional alternatives can match prospectively. Interaction terms or a poor baseline are not enough.

The descriptor should transport across probes, frames, sites, codes, or regimes and retain an ordinary projection. A result that cannot recover established performance is not yet an extension; one that recovers but adds no prospective leverage remains a reformulation.

Perspective recovery. Require both return to validated physics and risky transport of a new relation.

CHAPTER EIGHTY

From Cosmological Claim Packet to Prospective Test

The claim packet links the observation record, quantity profiles, operator lineage, probe ancestry, model family, priors, nulls, systematics, likelihoods, recovery tests, residuals, frame shakes, evidence state, interpretation ceiling, and explicit nonclaims.

A prospective test freezes the distinguishing relation and predicts where a new observation, cross-probe comparison, controlled calibration change, simulation challenge, or physical experiment should differ. It preregisters how ordinary explanations, multiplicity, and null sensitivity will be handled.

Negative, conflicting, noncomparable, or sensitivity-limited outcomes remain first-class evidence. A theory that can reinterpret every cosmic result after it appears has not made a physical prediction.

Cosmological observations often cannot provide laboratory intervention on the source. The common-intervention grammar can still apply to calibration, analysis, synthetic injection, instrument configuration, or independent physical systems used to test the proposed relation. The claim must match the intervention actually performed.

Perspective recovery. A cosmological interpretation becomes a research program when it can freeze a distinction, risk loss, and preserve the result whatever it is.

Retained First Edition 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.

Second Edition Conclusion

Cosmology demonstrates how much reliable understanding can be constructed from inside a system without an external vantage point. Its success depends on interactions, standards, instruments, mathematics, statistical operators, and models that compress a much richer physical history into coordinated quantities.

The Second Edition makes the compression recursive. The scalar, the operator that creates it, the equation that relates it, the map that recovers it, and the ledger that audits it are all bounded representations. No cosmological formalism, including a relational one, becomes uncollapsed by adding sufficient metadata.

The limitation is productive when it disciplines inquiry. Purpose-relative profiles can retain consequential ancestry. Perspective rotation can expose shared failures and genuine convergence. Conservative recovery can protect established results. Nonfactorization and prospective tests can decide whether an added relation does more than rename uncertainty.

Relativity, quantum field theory, thermodynamics, standard cosmology, and observational practice therefore remain indispensable interfaces. Substrate Cosmology earns a further role only where it recovers those interfaces and predicts a reproducible difference without converting horizons, residuals, recurrence, mathematical resemblance, or human limitation into evidence for a preferred ontology.

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?
Which source and propagation relations are shared?
flux and light curve luminosity distance source standardization extinction calibration
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?
Which parameter combinations are identifiable?

microwave temperature and polarization map cosmological parameters foregrounds transfer functions initial spectrum

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.

Retained First Edition Reference Material

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.

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AI outputs are cited for provenance and reproducibility of the editorial process. They are not evidence for the physical claims presented in this volume.

CHAPTER APPENDIX I

Recursive Cosmological Quantity Registry

Record: quantity ID and version; research purpose; physical referent; realization and standard; detector and propagation chain; frame; units; operator token, rule, application, and composition; scale and resolution; calibration; uncertainty and covariance; equivalence scope; ordinary projection; recovery domain; known degeneracies; declared loss; alternative perspectives; evidence state; and stop conditions.

The registry remains scalarized. Add a field only when its distinction can change a legitimate observation, translation, prediction, or intervention, and record the schema version that introduced it.

CHAPTER APPENDIX J

Observation-to-Inference Operator Ledger

For every stage record inputs; output; token; selected rule; implementation and version; arity; operand roles; ordering; frame; adjacency; units; missingness; thresholds; priors; substitutions; uncertainty transformation; many-to-one regions; rejected alternatives; downstream consumers; and declared loss.

Apply separately to triggering, calibration, filtering, deconvolution, masking, background subtraction, detection, classification, cross-matching, distance inference, parameter fitting, model selection, visualization, and public claim language.

CHAPTER APPENDIX K

Cross-Probe Independence and Shared-Ancestry Matrix

Compare probes across source populations, propagation, instruments, calibration standards, survey strategy, masks, catalogs, redshift estimates, simulations, priors, population models, likelihoods, software, analysts, and decisive failure mechanisms. Classify each dependency as shared, partly shared, structurally independent, or unknown.

A convergence claim states its actual scope. Multiple outputs of one catalog or simulation are not automatically independent probes. Independence is strongest when construction and failure lineages differ while the translated prediction agrees.

CHAPTER APPENDIX L

Relativity Recovery and Translation Packet

Specify the validated relativistic domain; source and target representations; embedding; projection; coordinate and gauge choices; observables; equivalence relations; conservation structure; causal order; approximation; tolerances; numerical implementation; singular or undefined regions; empirical benchmarks; and stop criteria.

Audit token, rule, application, and composition for every arrow and equality. A diagram that says 'recover GR' is a research obligation, not a completed derivation.

CHAPTER APPENDIX M

Dark-Sector Residual Claim Packet

Separate: direct records; calibrated observables; inferred quantities; mainstream model roles; candidate ontologies; translation-residual hypothesis; probes recovered; probes not recovered; shared ancestry; ordinary alternatives; priors; systematic bounds; frozen distinguishing prediction; prospective dataset or intervention; nulls; multiplicity; evidence state; and explicit nonclaims.

Do not use 'alias,' 'emergent,' 'projection,' or 'substrate' as evidence. Each word is a hypothesis label until the packet contains a discriminating result.

CHAPTER APPENDIX N

Horizon, Entropy, and Information Boundary Worksheet

Identify the horizon type, causal structure, observer or worldline, accessible algebra or observables, field content, state, ensemble, coarse graining, boundary conditions, area realization, constants and units, entropy definition, information definition, equality rule, approximation, recovery domain, and inaccessible relations.

Rotate through geometric, thermodynamic, quantum, information-theoretic, operational, and embedded-observer perspectives. Preserve nontranslation where two definitions do not share a legitimate equivalence.

CHAPTER APPENDIX O

Cosmological Perspective-Rotation Protocol

Rotate the claim through observational, metrological, geometric, relativistic, quantum-field, thermodynamic, information-theoretic, computational, statistical, causal, historical, linguistic, instrument, and embedded-observer lenses. For each record what becomes visible, hidden, recoverable, transformed, incompatible, or newly testable.

Synthesis follows comparison. Shared assumptions are declared before agreement is counted. Conflict, null, and noncomparability remain valid outcomes.

CHAPTER APPENDIX P

String-Inspired Correspondence and Prohibition Table

Permitted modeling correspondences include maintained adjacency, extended path, relational history, modes, splitting, joining, reconnection, boundaries, topology change, dual descriptions, and projection-hidden structure. For each specify the target relation, recovered observation, competing formalism, and discriminating test.

Prohibited inferences without new evidence include: recurrence proves vibration; a useful string model proves literal strings; compact dimensions are automatically extra spatial axes; dual predictions imply ontological identity; entanglement supplies a communication channel; or mathematical elegance establishes substrate ontology.

CHAPTER APPENDIX Q

Cosmological Null and Frame-Shake Registry

For each null record the mechanism represented, generator lineage, preserved and destroyed structures, priors, seeds, constraints, validation, injection recovery, false-positive behavior, and interpretation ceiling. For each frame shake record the changed standard, coordinate, adjacency, metric, scale, selection, prior, likelihood, resolution, or probe and the predicted transformation of the claim.

A robust result persists or transforms lawfully across justified neighborhoods and realistic alternatives. A result at one adaptively selected setting remains exploratory.

CHAPTER APPENDIX R

First Edition Corrections and Continuities

Retained: all 67 chapters; Appendices A-H; cosmology from inside the environment; observation-to-inference discipline; statement classes; general-relativity recovery; no-signalling; Higgs and hadronic-mass distinctions; dark-sector caution; horizons as access boundaries; relational formal targets; null worlds; frame shaking; recurrence methods; prospective predictions; and research-commons continuity.

Corrected: every cosmological quantity and operator is explicitly scalarized; no ledger or recovery map stands outside collapse; probe independence requires ancestry analysis; dimensionless results retain relational history; relativity is a recovered interface rather than automatic exhaustive ontology; adjacency is participation rather than nearness; and richer profiles are purpose-relative rather than uncollapsed.

Added: seven correction layers; Part VIII Chapters 68-80; recursive quantity and operator registries; cross-probe independence; relativity recovery packet; dark-sector residual packet; horizon and information worksheet; perspective rotation; guarded string-inspired correspondence; cosmological null and frame-shake registry; and this crosswalk.

Deferred: claims that cosmological residuals confirm substrate ontology; claims of fundamental strings or extra spatial dimensions; nonlocal signalling; gravity control; energy extraction; engineering spacetime; opening protected recurrence outcomes; and any physical extension that lacks conservative recovery and a prospective discriminating test.