

# The Origin of Cosmology

Causality and Attraction, Volume V

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MMXXVI

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# Prologue: We Begin With the Oldest Light

We begin with the oldest light.

Not the abstract light of an equation, but the faint microwave afterglow that reaches us from every direction when the instruments are quiet enough to hear it. It arrives without drama. No thunderclap accompanies it. No witness stands beside it. It is a pattern in the present, measured by machines built late in the history of one small planet, interpreted as a message from the earliest visible enclosure of the universe.

We are told this light points back to the beginning.

In one sense, it does. The cosmic microwave background is among the strongest observations modern cosmology possesses. It is not imaginary. It is not trivial. It has helped produce a coherent model of a hot, dense early state, and that model has organized generations of careful work.

Yet the light does not give us the origin itself.

It gives us evidence arriving now.

That distinction is the beginning of this volume.

As reconstruction approaches conditions from which no distinguishable record survives, the work of interpretation grows. Some ancient records are extraordinarily precise. Their precision does not make them records of every earlier event. By the time cosmology reaches a proposed absolute origin, an account of the available evidence can become an account of what the evidence no longer distinguishes.

This does not make the standard model useless. It means the standard model must be enclosed.

The error is not that cosmology looked backward. The error is that one backward projection was allowed to become the outer boundary of permissible explanation. A scientific model became a gate. Other plausible origin stories were not nested beside it and tested for their predictive contribution. They were treated as threats to the map.

This is not a failure of observation.

It is a failure of enclosure.

# Chapter 1: The Origin of Cosmology

The title of this volume is a contradiction on purpose.

Cosmology is the study of the universe as a whole. It looks outward and backward at once. It studies galaxies, radiation, expansion, gravitation, matter, light, and the large-scale shape of everything that can be observed. In that sense, cosmology is scientific in the ordinary way. It builds instruments. It gathers data. It proposes models. It tests them against what the sky gives back.

But the origin of cosmology is not only scientific.

The moment a discipline decides that one unprovable beginning is the necessary enclosure for all future interpretation, the discipline has crossed from observation into something older. It has created a boundary story. It has told itself where explanation is allowed to begin, and therefore where other explanations must stop.

That is not necessarily dishonest. Human beings need maps before they can travel. Science itself requires provisional boundaries. The problem comes when the boundary is forgotten as a boundary and treated instead as the world.

The Big Bang model became powerful because it gathered several different observations into one coherent sequence. Expansion, background radiation, light-element abundance, and the growth of structure all seemed to point backward toward a hot, dense early condition. That achievement should not be minimized. It gave modern cosmology a working spine.

But a spine is not the whole organism.

When the Big Bang is treated as a model, it is useful. When it is treated as the only permissible origin enclosure, it becomes something else. It becomes the story through which all evidence must pass before it can be considered legitimate. New observations are then judged not only by whether they are accurate, but by whether they can be folded back into the authorized beginning.

This is how a scientific model becomes an origin myth.

The mythic element is not the idea of a hot early universe. The mythic element is the demand for one beginning. It is the insistence that cosmology must be organized around a single unprovable origin narrative, even though the data available at that boundary is thinner than the data available almost anywhere else.

The purpose of this volume is not to replace one compulsory origin story with another. The purpose is to remove the compulsion.

The Big Bang can remain. The Great Pull can be explored. Cyclic models, quantum boundary models, steady-state continuums, and other plausible origin structures can be nested beside one another. Each can be tested by the contribution it makes to prediction. Each can be bounded by the Final Frontier. Each can be held as a departure within a larger causal architecture rather than as the final authority over the whole.

This is the origin of cosmology in the sense meant here: the origin of the boundary that has been mistaken for the science.

Once the boundary is seen, it can be enclosed.

## The Observation and Its Inheritance

Consider what happens when a telescope detects a distant galaxy. Light enters an instrument. A detector produces a signal. Calibration relates the signal to an incoming flux. A spectrum identifies features whose wavelengths can be compared with laboratory measurements. These operations already contain a remarkable cooperation between different fields. The laboratory supplies one part of the interpretation; the telescope supplies another; a model of propagation joins them.

The measured redshift is an important achievement. Translating it into a distance, an age, or a history of expansion requires further relations. Each relation has a domain in which it has been tested. The final result can be excellent without every step possessing the same kind of authority.

The trouble begins when the completed narrative conceals those differences. A number printed beside a galaxy can look as immediate as the galaxy's position on the image. Yet the position, spectrum, inferred distance, and inferred age occupy different places in the chain of reasoning. To enclose the claim is to make the chain available again.

Suppose two histories produce the same spectrum today. The instrument cannot distinguish those histories through that spectrum alone. A second measurement may distinguish them. A chemical abundance, a distribution of neighboring galaxies, or a different prediction for background radiation may remove the ambiguity. Inquiry advances by finding such differences. It does not advance by naming one history the beginning and treating the name as an additional observation.

This is where the title turns. The origin of cosmology is also the origin of the permissions under which cosmology proceeds. What counts as an admissible explanation? Which parts of a successful model must be retained, and which can be reconsidered? Where does confidence in an observed relationship become confidence in a story about everything?

Scientists already investigate alternatives, and their work supplies much of the material needed here. The argument concerns a habit that can enter a textbook, a public explanation, or a research program: the migration of a model from a successful account into an unquestioned boundary. It can happen to Nested Causality as readily as to any older framework. Calling a proposal new gives it no exemption.

The practical remedy is an address for every claim. State the phenomenon, the conditions enclosing its interpretation, and the observations carried inside it. An account that explains an early thermal phase has authority over that accomplishment. An account that additionally specifies the origin of time has made an additional claim. The first accomplishment cannot silently pay for the second.

We can therefore keep the extraordinary coherence of cosmology while opening its outer relation. Its origin becomes a question available to inquiry rather than a condition imposed upon inquiry. The sky does not become less intelligible. The intelligence brought to it acquires another place to work.

## Chapter 2: The Standard Story We Are Told

The standard story is coherent.

It begins with a universe that was once hot, dense, and nearly uniform. Space expanded. The earliest plasma cooled. Light decoupled from matter and began traveling freely. The faint remnant of that early state remains visible as the cosmic microwave background. Matter gathered under gravity. Stars formed. Galaxies condensed. Clusters, filaments, and voids appeared. The universe became the structure we now observe.

This story has guardrails. It has produced valuable data. We respect the work of the scientists who built it.

The cosmic microwave background is the first great pillar. Discovered in the twentieth century and measured in increasing detail since then, it gives modern cosmology a nearly all-sky image of an early, hot condition. Its small anisotropies have been used to estimate the age, composition, and large-scale geometry of the observable universe.

Primordial nucleosynthesis is the second pillar. The observed abundance of light elements, especially hydrogen, helium, deuterium, and lithium, aligns with a universe that once passed through a hot early phase. The agreement is not perfect in every detail, but it is strong enough that no serious cosmology can ignore it.

The Hubble expansion is the third pillar. Galaxies recede in a pattern that can be modeled as the expansion of space itself. Run backward, that expansion implies a denser and hotter past. This does not by itself prove an absolute origin, but it powerfully supports the claim that the universe has changed state over time.

Large-scale structure is the fourth pillar. Galaxies are not scattered randomly. They form webs, filaments, clusters, walls, and voids. The standard model explains these structures as the growth of early density fluctuations under gravity.

This is a real achievement.

The question is not whether the standard model contains truth. It plainly does. The question is whether the truth it contains has been placed inside the correct enclosure.

Evidence for a hot, dense early state is not the same as evidence for a singular, final, mandatory origin story. A model can explain much and still not deserve to function as the outer boundary of all permissible cosmology.

In Volume III, Antarctica was treated the same way. The standard model of the ice sheet was not mocked or discarded. It was recognized as coherent and useful, then placed under pressure by observations that did not fit its normal pattern. The same method applies here.

### How the Evidence Holds Together

The background radiation matters first because of its spectrum. A hot body in thermal equilibrium emits radiation with a characteristic distribution across frequency. COBE's FIRAS instrument measured the microwave background against an internal reference and found an exceptionally close blackbody spectrum. A sky filled with microwave light is one observation; a sky whose spectrum bears this thermal form is a more restrictive observation. It places demands on any explanation of the radiation's history.<sup>1</sup>

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<sup>1</sup>Fixsen et al., "The Cosmic Microwave Background Spectrum from the Full COBE FIRAS Data Set" (1996), <https://arxiv.org/abs/astro-ph/9605054>.

The temperature differences across that sky provide another layer. Before neutral atoms formed, ordinary matter and radiation interacted strongly. Gravity and pressure could set that coupled material into acoustic motion. The angular pattern left in the background contains information about those processes and the geometry through which we observe them. The Planck analysis joins temperature, polarization, and lensing measurements in a detailed inference, rather than deriving a universe from a single warm glow.<sup>2</sup>

The light elements provide a separate route into an earlier thermal interval. A hot mixture permits nuclear reactions; cooling changes which reactions can continue. Deuterium is especially useful because its surviving abundance responds sensitively to the density of ordinary matter in the nucleosynthesis calculation. Measurements in relatively unprocessed gas allow that history to be tested against a record unlike the microwave sky.<sup>3</sup>

Lithium requires its own entry. The discrepancy between standard primordial lithium expectations and abundances inferred from old stars remains a problem in this comparison. Listing the elements together as though their agreement were uniform would conceal information. The strength of concordance is found by keeping its successes and its unresolved differences in view.<sup>4</sup>

Expansion connects these records through a changing scale factor. In the usual homogeneous description, a freely propagating photon's wavelength grows with that factor. If the scale factor doubles, the wavelength doubles. Following the relationship backward gives higher radiation temperatures and greater matter density. This is a physical connection between observations, not simply a preference for a dramatic beginning.

The pattern of galaxies supplies further tests. It records the growth of structure after the earlier plasma phase. The question is whether one set of physical assumptions can carry the history from the radiation pattern through subsequent gravitational evolution to a distribution resembling the observed one. The test becomes more demanding when it must account for several kinds of evidence with shared parameters.

That shared structure explains why the hot early universe has earned so much confidence. Each observation constrains the freedom left by the others. A replacement account cannot retain only the part of the sky that makes its own story attractive. It inherits the entire comparison.

It also explains precisely where another question can begin. An account may successfully follow cooling, reactions, recombination, and structure formation without determining what made that sequence possible in the first place. The evidence can be decisive about an interval and silent about an earlier boundary. Those two conditions can coexist without weakening either statement.

We do not reject the standard cosmological story.

We ask what happens when it is no longer allowed to be the edge of the map.

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<sup>2</sup>Planck Collaboration, "Planck 2018 Results. VI. Cosmological Parameters" (2020), <https://arxiv.org/abs/1807.06209>. Numerical estimates quoted here are those of the identified analysis.

<sup>3</sup>Cooke, Pettini, and Steidel, "One Percent Determination of the Primordial Deuterium Abundance" (2018), <https://arxiv.org/abs/1710.11129>.

<sup>4</sup>Fields, "The Primordial Lithium Problem" (2011), <https://doi.org/10.1146/annurev-nucl-102010-130445>.

## Chapter 3: The Time-Series Inversion

Every time-series has a direction.

The present is thick with measurement. Instruments are here. Observers are here. Archives, telescopes, satellites, particle detectors, clocks, spectra, maps, and computers all operate in the present enclosure. Even when they are measuring distant objects, the measurements arrive now.

The past is different. It must be reconstructed. It leaves traces, but the traces are partial. Some light reaches us. Some matter remains. Some background radiation persists. Some ratios and abundances can be measured. But the farther backward we go, the less direct the data becomes.

This is not a defect of cosmology. It is a structural feature of knowledge.

The inversion occurs when the thinnest part of the time-series is treated as the strongest part of the story.

The origin sits at the narrowest end of the evidence. It is the point where measurement gives way to projection. Yet in modern cosmology the origin is often spoken of with a certainty that exceeds the certainty granted to nearer, richer, more observable phenomena.

This is backwards.

If a model becomes less directly supported as it approaches the origin, then humility should increase as it approaches the origin. The range of plausible narratives should widen, not narrow. More models should be retained, not fewer. The Final Frontier should become more visible, not less.

Instead, the origin is often made singular.

One projection becomes the official enclosure. Other projections are treated as errors, threats, or speculations. The structure of the data is inverted. The place where knowledge should be most careful becomes the place where the story is most protected.

This is the time-series inversion.

It appears whenever sparse past data is forced to serve as a stronger authority than dense present data can justify. It appears whenever a model that should be one branch of exploration becomes the trunk through which all branches must grow. It appears whenever an origin narrative is enforced before its predictive superiority has been demonstrated across the whole field.

The proper response is not to abandon origins. The proper response is to nest them.

Each plausible origin story should be treated as an enclosed model. Each should be tested against the observations it helps explain and the predictions it makes possible. None should be allowed to claim the Final Frontier for itself.

### The Record That Cannot Be Unmixed

Imagine entering a room after two cups of water have been poured into a basin. You measure the amount of water and its temperature. With sufficient care, those measurements may be very precise. They do not identify which cup was poured first. Several histories arrive at the same measured condition.

Now suppose one cup contained a harmless dye. The color becomes another surviving record. It may tell you how much dyed water entered the basin. It still need not tell you the order of pouring. More data has narrowed the possible histories without making the past uniquely recoverable.

This distinction between precision and recoverability is central to cosmology. The microwave background is ancient and extraordinarily informative. It can constrain some quantities better than a nearer, poorly understood object. The relevant asymmetry is therefore not a universal rule that every older datum is weaker. It is that a reconstruction depends on whatever distinctions survived the intervening physical history and remain accessible to the observer.

Thermalization, mixing, absorption, horizons, and finite instrumental resolution can remove access to distinctions. Other processes preserve records for immense periods. A responsible backward projection follows both. It asks which differences would still be visible if competing histories were true.

Write the idea in a compact form. Let a history be  $h$ , and let the process carrying that history into an observable record be  $F$ . The observed data are  $D = F(h)$ . If  $F(h_1) = F(h_2)$  for two different histories, then  $D$  alone does not select between them. A further observation must introduce a distinction that the first record lacks. This is a problem of identifiability, not a complaint that measurement is difficult.

The origin claim becomes especially strong when it proposes to identify everything that preceded the accessible record. To support that claim, the reconstruction must show why alternative histories cannot produce the same surviving evidence. A successful forward calculation from one set of initial conditions demonstrates that those conditions can work. Uniqueness requires the additional comparison.

The same discipline applies to the Great Pull. If an organizing gravitational condition could lead to the thermal history we observe, that would establish a possible route. It would not establish that no other route exists. The freedom sought here is reciprocal: the new model cannot reserve an authority denied to the old one.

This gives time-series inversion a practical diagnostic. Look for a conclusion becoming more exclusive without a corresponding increase in discriminating evidence. Ask which additional observation removed the alternative. If none did, the exclusivity came from an assumption or a preference. Both may be useful, but they should remain visible as such.

An absolute origin may remain inaccessible even while the history of an observable phase becomes more precise. The model's boundary advances when a new record makes a previously indistinguishable difference measurable. Until then, the unresolved alternatives belong in the map.

The past need not be recovered in full for science to proceed. It needs to be reconstructed with the distinctions its surviving records can actually carry.

The map must widen in response.

## Chapter 4: The Cost of a Single Origin Myth

A single origin myth does not merely sit at the beginning of a theory. It shapes everything that comes after it.

Once one origin story is installed as the mandatory enclosure, every anomaly must be interpreted as a problem inside that story. The model may be modified. Parameters may be adjusted. New entities may be introduced. But the outer boundary remains protected.

This creates a predictable pattern.

The Hubble tension becomes a disagreement between measurements that must eventually resolve into one correct value. The possibility that local and global measurements are observing different scale-tiers of enclosure is treated as secondary.

Early mature galaxies become a problem of formation speed inside the existing timeline. The possibility that large-scale organizing conditions were present differently than assumed is treated as an intrusion.

The vacuum energy problem becomes a catastrophe of calculation inside a background assumed to be smooth and unbounded. The possibility that the reference condition itself has been wrongly defined is delayed.

Quantum measurement becomes a paradox of collapse inside an abstract probability field. The possibility that the wave function was never unbounded in the first place remains outside the standard enclosure.

Singularities become formal edges where the equations fail. The possibility that a deterministic boundary condition prevents physical residence at zero is treated as an addition rather than a requirement.

These are not isolated problems. They carry the same signature.

Each appears where a system is allowed to behave as though it has no proper enclosure. Expansion is treated as global and smooth. Probability is allowed to spread without a native boundary. Vacuum energy is calculated against a zero that has no structural cancellation. The origin is projected backward until the model reaches a point it cannot actually observe, then that point is protected as if it had been measured directly.

The cost is not only theoretical. It is practical. When one origin story dominates, other models are not developed far enough to make predictions. Their value cannot be compared because they are not allowed to mature. The field loses potential explanatory capacity before it can be measured.

This is narrative scarcity.

Science does not require narrative scarcity. It requires disciplined comparison. The proper question is not which origin story is authorized. The proper question is which set of nested origin stories increases predictive power across the widest range of observations.

The origin myth narrows the field.

Nested cosmology opens it.

### Where a Question Is Allowed to Travel

A surprising early galaxy is a useful place to watch this happen. A telescope measures flux and a spectrum. An analysis infers distance, luminosity, stellar populations, and perhaps a stellar mass. A cosmological model

supplies the elapsed time associated with the redshift. A galaxy-formation model supplies an account of how much structure could develop during that interval.

There are several places for a mismatch to originate. The source may have been misidentified. Dust or stellar population assumptions may affect an inferred mass. Star formation may proceed differently from a simulation's prescription. The expansion history may assign the wrong amount of time. An enclosing condition may alter the growth of structure. These are different questions with different tests.

The spectroscopic confirmation of two luminous galaxies near redshift fourteen made the early-structure question more concrete. It established that luminous objects existed in the relevant interval, rather than merely leaving a photometric candidate in a catalog. Their interpretation still requires a chain from light to physical properties. Carniani and colleagues made that chain more restrictive; they did not report a measurement of the absolute origin of the universe.<sup>5</sup>

The cost of premature closure is that the inquiry is permitted to inspect only some links in that chain. If all responsibility is assigned to star formation before the other relations are examined, a possible cosmological signal may be lost. If all responsibility is assigned to cosmology before the source analysis is checked, an ordinary astrophysical revision may be mistaken for a revolution. An enclosing map lets the observation select the place of repair.

The Hubble comparison has the same architecture. A nearby calibration chain and a background-radiation inference arrive at different estimates of today's expansion parameter under their stated assumptions. One can investigate calibration, environmental structure, recombination physics, or the late-time expansion relation. The task is to follow the disagreement to its active condition, not to decide in advance which profession must have made the error.

Vacuum energy opens a different boundary. Its problem joins quantum state accounting to gravitational response. A discrepancy there cannot be settled simply by telling a more persuasive story about the first moment. It requires an account of what contributes to the gravitational source and why. The origin narrative may obscure that question if it makes the chosen background seem exempt from examination.

The monetary cost of instruments is visible. The intellectual cost of an excluded question is harder to count because the missing investigation leaves little record. That is why predictive pluralism needs a procedure rather than an appeal to open-mindedness. It must preserve alternative relations long enough to calculate their consequences, then distinguish useful differences from extra freedom that merely fits an existing result.

An anomaly is an invitation to locate an assumption. Once its address is found, the work can become sharply specific. The largest change in a field may begin with the smallest alteration to the conditions under which a successful equation is being asked to operate.

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<sup>5</sup>Carniani et al., "Spectroscopic Confirmation of Two Luminous Galaxies at  $z \sim 14$ " (2024), <https://arxiv.org/abs/2405.18485>.

## Chapter 5: From Origin Story to Parallel Enclosures

The alternative is simple in principle.

Do not destroy the existing model. Enclose it.

The Big Bang model can remain as one causal enclosure. It contains a hot, dense early phase, expansion, background radiation, primordial nucleosynthesis, and the growth of structure. It has earned its place.

The Great Pull can be held beside it as another enclosure. It treats large-scale attraction and directional organization not as late accidents but as outer conditions that draw non-equilibrium states into coherence.

Cyclic models can be held beside both. Quantum boundary models can be held beside them. Steady-state continuums, bounce models, multistage emergence models, and other plausible structures can be nested as exploratory enclosures without being promoted into dogma.

This is not relativism.

Relativism says all stories are equally true. Nested predictive cosmology says no such thing. It says each model must be bounded, applied, tested, and compared. A model earns its place by what it explains and predicts. A model loses authority when it fails to improve the whole.

The point is not to believe many origin stories.

The point is to use them rigorously.

Belief in a single origin story tends to narrow the range of questions that can be asked. Rigorous application of multiple origin stories widens the predictive field. Each narrative becomes a structured lens. Each lens reveals certain tensions and hides others. When the lenses are nested rather than enforced, their contributions can be compared.

This is how existing science is strengthened. Not by burning down the standard model, and not by obeying it as a final authority, but by placing it inside a larger architecture where its strengths remain visible and its limits become measurable.

The old question was: Which origin story is true?

The better question is: Which arrangement of plausible origin stories produces the greatest increase in accurate prediction?

That question belongs to science.

### Keeping the Same Sky in Every Model

Imagine three groups receiving the same observations. Each receives the measured sky, instrument descriptions, selection rules, and uncertainties. One uses the standard thermal history and its usual gravitational growth. A second retains that history but changes the outer organizing relation. A third investigates an earlier transition or bounce leading into the thermal interval.

The groups do not get to alter the observations to suit their origins. They must say how their different starting conditions arrive at those observations. Their accounts can share a substantial interior. A bounce before a hot

phase need not discard the nuclear physics of that phase. An outer gravitational relation need not discard a calibrated detector. The nesting permits agreement to remain agreement while the unresolved relation is examined.

The comparison becomes valuable when the models predict something not used to construct them. Perhaps they assign different residuals to galaxies in different environments. Perhaps their radiation histories differ in a measurable way. Perhaps one requires an extra parameter that contributes no predictive gain. These outcomes are more useful than a vote on which beginning feels plausible.

There is also a distinction between nesting physical conditions and averaging opinions. If two models give incompatible accounts of a single process, simply averaging their answers does not supply the missing physics. An ensemble can be a practical forecasting tool, but the causal question remains: what arrangement of conditions would make those answers parts of one system?

Likewise, allowing several origins does not multiply the number of universes measured. It multiplies the explicitly considered histories of the one record before us. When two such histories make the same predictions over the accessible domain, they remain observationally tied there. They may differ elsewhere, or remain undecidable. The map should be capable of carrying either result.

Existing research already illustrates the legitimacy of this work. Loop quantum cosmology investigates quantum-gravitational evolution through a high-density regime using its own defined dynamics. Such a model is a neighboring inquiry with particular mathematical commitments, not an alternative to be accepted merely because it includes a bounce.<sup>6</sup> Nested Causality must state its own commitments with equal clarity. Similar words about a beginning do not make two mechanisms identical.

The larger enclosure therefore has a demanding entrance condition: make the relation explicit enough to compare. A model may enter as a developed calculation, a restricted hypothesis, or an untested structural proposal. Those statuses tell us what work can reasonably be done with it. They are not rankings of imagination.

The reward is cumulative. A model that fails may still identify a useful variable. A successful interior may survive the failure of an origin attached to it. An observation that all models miss can move the entire comparison outward. Nothing requires the field to choose its final story before beginning the investigation.

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<sup>6</sup>Ashtekar, Pawłowski, and Singh, “Quantum Nature of the Big Bang: Improved Dynamics” (2006), <https://arxiv.org/abs/gr-qc/0607039>.

## Chapter 6: The Great Pull

The universe does not appear still.

At the largest scales we can map, galaxies and clusters do not merely occupy space. They move inside structure. They gather into filaments. They turn into walls. They leave voids behind them. They participate in flows larger than themselves.

The Great Pull names this larger directional condition.

In Volume I, this appeared through the Great Attractor, called there The Vector: the last observable whisper of pull before the Final Frontier. The name Great Pull does not replace that earlier formulation. It enlarges it. The Great Attractor remains the observable vector; the Great Pull is the cosmological reading of the same enclosing tendency.

It is not offered here as a replacement origin myth. It is not a new command that every observation must obey. It is an outer enclosure to be tested beside the others. It asks whether the large-scale organization of the universe is better understood when attraction is treated not merely as a local consequence but as an enclosing vector that draws non-equilibrium states into coherent form.

From below, matter and energy arise through local processes. Quantum interactions, particle relations, chemical bonding, gravitational collapse, and turbulent flow all generate structure from within. These processes are real. They do not need to be denied.

From above, larger enclosures impose boundary conditions. Galaxies hold stars. Clusters hold galaxies. Filaments hold clusters. The largest observable directional flows hold the smaller flows inside them.

The Great Pull is the name for that outer organizing tendency.

In the inherited map, the universe begins with an expansion event and structure gradually grows from tiny fluctuations. In the nested map, that story remains available, but another possibility is kept beside it: that directional organization was present as an enclosing condition from the start of observable cosmological structure.

This does not require matter to be created from nothing. It does not require the Standard Model to be discarded. It says that local non-equilibrium states may arise from below while being drawn into coherence from above.

The result is not a universe of isolated objects.

It is a continuum of steady states under attraction.

The Great Pull gives the cosmological volume its spirit because it changes the posture of inquiry. Instead of asking only what exploded, we ask what enclosed. Instead of asking only what pushed matter apart, we ask what drew structure into form. Instead of forcing every observation back through one beginning, we allow the present architecture of the universe to speak in both directions at once.

Bottom up.

Top down.

Enclosed.

## Gravity as the Organizing Event

The Great Pull makes a stronger proposal than the familiar statement that gravity forms galaxies. It asks us to consider the introduction of a gravitational organizing condition as the event that made the observable continuum possible. Pre-existing non-equilibrium activity enters an arrangement capable of sustaining nested structure. The beginning under investigation is a change in what can persist.

This distinction gives the proposal its force. A collection of locally active processes need not by itself specify the larger relation under which their products remain together. A cloud may contain moving material while failing to form a lasting structure. Place that material within conditions allowing gravitational gathering, cooling, and continued exchange, and a different history becomes possible. The local inventory and the enclosing relation are separately important.

Consider a star as a familiar interior example. Gravity, pressure, transport, and nuclear processes participate in its persistence. Matter continues to change, energy moves outward, and the star can remain recognizable over a long interval. Calling this a steady-state dynamic equilibrium draws attention to maintained organization through exchange. It does not require every quantity to be constant or every stage of the star's life to be stable.

The cosmological extension asks whether the same priority belongs to the organization of the larger field. The Great Pull begins with the possibility of an enclosing gravitational condition under which local activities become members of a sustained continuum. It then asks what thermal and structural history follows. Its claim concerns the conditions of organization, rather than the creation of a material inventory from nothing.

The Great Attractor makes the question tangible without exhausting it. Maps of peculiar velocities distinguish motions relative to an adopted mean expansion and reconstruct large-scale flows. Tully and colleagues used such flows to define the Laniakea basin. This supplies a concrete example of a region being identified through its dynamical relations rather than through an arbitrary line drawn around visible galaxies.<sup>7</sup>

Laniakea is not an observed container of the whole universe. A reconstructed basin of flow is also not necessarily a permanently bound object. These distinctions identify the place of the evidence: large-scale organizing relations are measurable, while their extrapolation into a universal origin remains the work of the Great Pull model. The observation opens the question; the proposed cosmology carries it further.

That further work has a sequence. Specify the matter and radiation present before or at the organizing transition. Specify the gravitational relation introduced. Follow conservation and the thermal history through the transition. Calculate the resulting structure and radiation. Then compare them with the observations already earned by cosmology. An account of gravitational organization becomes an origin model by making this passage, not by borrowing the name of a nearby attractor.

The spiraling forms of the sky make the proposal memorable, but their shape alone does not determine the mechanism. Angular momentum, accretion, local interactions, and the larger environment must receive their own addresses. The strength of enclosure is precisely that a beautiful pattern is allowed to become the beginning of a calculation.

The universe in this inquiry is active before it is narratively simple. The Great Pull asks which relation made its activity coherent enough to leave the world we can observe. What began may have been the organization that continues.

<sup>7</sup>Tully et al., "The Laniakea Supercluster of Galaxies" (2014), <https://arxiv.org/abs/1409.0880>.

# Chapter 7: The Three Laws of Nested Causality

The three laws are not decorations added to the model after the fact. They are observations of how steady states appear to persist.

The first law is the Law of Nested Causal Enclosure.

No steady state is found alone. A cell is held inside an organism. An organism is held inside an ecosystem. A planet is held inside a stellar system. A star is held inside a galaxy. A galaxy is held inside a larger flow. Every steady-state dynamic equilibrium is enclosed by a larger equilibrium that projects boundary conditions inward.

The outer structure does not create the inner structure from nothing. It stabilizes what can persist inside it.

The second law is the Law of Nested Exchange.

When matter or energy moves between adjacent nested equilibria, the transfer occurs as entropic heat loss coupled with negentropic deposition in the adjacent equilibrium. Across the paired transition, the law holds total vector integrity to be effectively lossless. Local dissipation remains observable; its receiving relation must also be mapped. This is the proposal of directed reciprocal exchange between scales, rather than terminal loss at the edge of one description.

The exchange is not morally good or bad. It is structural.

The third law is the Law of Nested Infinities.

The law states that nesting continues without termination in either direction. Every enclosure contains smaller enclosures and is contained by larger ones. Observation and computation remain bounded by the Final Frontier. The limit of an actual map does not assert that physical nesting has ended where the map stops.

Volume I described this as a single deterministic boundary operating at every scale, made visible locally through the Isotropic Vector Matrix. It is not merely a faraway wall at the largest scale or an inaccessible point below the smallest scale. It is the same boundary condition appearing wherever a nested enclosure reaches the edge of what can be known, computed, or physically maintained.

Together these laws change the shape of cosmology.

The universe can now be described as a continuum of steady states, each also describable as a departure from a reference condition, each stabilized by what encloses it and active toward what it encloses. Matter and energy retain their physical descriptions; the reference adds a relation through which their organization can be examined.

This is the bridge from story to calculus.

## Following One Star Through the Laws

Let a star carry the three laws together. At the focal scale we describe its maintained state. Inside that state, reactions, particles, radiation, and transport take place. Outside it, an environment supplies conditions relevant to its formation and subsequent history. The first law keeps those relations visible without making the star disappear into either one.

An outer condition can be dynamically important even when it is not the most visible event. The surrounding pressure of a gas cloud helps determine which configurations persist. The immediate collision of particles is a different causal description. Nested Causality distinguishes projection from the enclosing arrangement inward

from the events generated among the enclosed constituents. The distinction is directional. It is not a scale of danger or a judgment about whether a process is gentle.

The second law follows the exchange. Energy leaving the star becomes an incoming condition elsewhere. A planet intercepts some of it; much continues through space. If our account stops at the stellar surface, it has described the loss from one enclosure. Following the radiation adds the receiving side. The second account changes what the first loss means within the larger relation.

We must keep the quantities attached to their names. An energy transfer can be balanced between donor and receiver while total thermodynamic entropy increases. Equal and opposite energy entries do not automatically imply equal and opposite entropy changes. In the language of this model, reincorporation names the received contribution to another enclosure; its usefulness and thermodynamic effect depend on that enclosure's state. The paired relation must be specified before an equality is assigned to it.

This is especially important when the book reaches the vacuum. Contracted and expanded departures are signed relative to a reference. They are not automatically two ordinary positive energies with opposite labels. A cancellation rule is a claim about how those states couple and what remains observable. It needs the reference, pairing, and receiving tier that the three laws require.

The third law opens the apparent object again. A stellar interior contains parallel processes; those processes contain further structure. The star's environment likewise belongs to further relations. A useful investigation follows the active ones: those whose state can change the result being examined. The commitment to nesting does not require an astronomer to calculate every possible enclosure before measuring a star.

The frontier supplies a declared stopping condition. Where the model has no justified relation, it retains an unresolved address rather than manufacturing one. A finite calculation can therefore investigate a continuum whose nesting is not declared exhausted. The calculation is complete for a stated question when its retained relations and boundary conditions are sufficient for that question, not when the universe has been enumerated.

Together, the laws produce a discipline of attention. The first asks what maintains the state. The second asks what arrives and leaves, and where the exchange becomes part of another state. The third asks what further nesting remains relevant and where the present account must stop. The star has not changed while we ask these questions. The completeness of its explanation has.

## Chapter 8: The Departure Calculus

To make nested cosmology computable, the enclosure must be written.

The core structural unit is ternary:

$\text{Psi}_n = [\text{Psi}_{(n+1)} \mid \text{sigma}_n \mid \text{Psi}_{(n-1)}]$

The left position represents the macro-enclosing function. It is the larger structure projecting causality inward.

The center position represents the local departure state. It is written as  $\text{sigma}_n$ , and in the current model it carries a contracted state  $-1$  or an expanded state  $+1$ .

The right position represents the micro-enclosed function. It is the smaller structure nested inside the current tier.

The index  $n$  marks discrete nesting depth.

This notation is recursive. The macro-enclosing function may itself be expanded into another ternary relation. The micro-enclosed function may also be expanded. Each side can open again without abandoning the original structure.

This is the formal beginning of the Departure Calculus.

It does not begin with isolated objects. It begins with enclosed departures. A phenomenon is not treated as a thing floating in a neutral background. It is treated as a local departure inside a larger causal relation and containing smaller causal relations within itself.

Cosmology changes immediately under this notation.

The Big Bang becomes a departure model inside an enclosure. The Great Pull becomes a departure model inside an enclosure. A quantum boundary model becomes a departure model inside an enclosure. None of them is required to become the absolute beginning. Each can be written, expanded, tested, and compared.

The old map asked for one origin point.

The Departure Calculus asks for the enclosing relation.

This is why the calculus belongs in this volume. It gives mathematical form to the critique of origin mythology. If every observable state is a departure inside a ternary enclosure, then an origin story is not the final word. It is a structured position within the continuum.

What matters is not whether the story can claim the beginning.

What matters is what the story predicts when properly enclosed.

### Opening the Address

A ternary address can be read aloud: what encloses the thing, the thing, what the thing encloses. Its order is part of its meaning. Turning it around changes the direction of causal projection. For a star, a first address might place its galactic environment on the left and its internal physical processes on the right. The star remains in the middle.

The next step is to open the outer positions. The galactic environment itself has an enclosing context and an interior. The internal process has an enclosing stellar state and smaller constituents. Written schematically, the recursive form is

$$\Psi_n = [[\Psi_{n+2} \mid \sigma_{n+1} \mid \Psi_n] \mid \sigma_n \mid [\Psi_n \mid \sigma_{n-1} \mid \Psi_{n-2}]] .$$

The repeated address is a reference to the same modeled relation, not a second copy of its matter or energy. A computational representation must respect that identity. Otherwise, expanding the map would manufacture extra contributions merely by describing them twice. Nested Exchange makes that an accounting error before it becomes an attractive calculation.

The index labels the chosen nesting, not a measured universal ruler. The interval between two retained addresses may contain further relevant enclosures. A first description can place a galaxy around a star; a refined description may reveal a molecular cloud, a star-forming region, and a local pressure environment. Refinement changes the resolution of the map while preserving the direction of the relation.

This also explains parallel enclosures. The same star participates in several relevant descriptions. Its thermal transport, nuclear reactions, orbital setting, and radiation environment need not form one exclusive sequence of boxes. The map records their distinct causal roles. A model becomes richer by preserving those roles rather than forcing every relation into a single spatial hierarchy.

The signs  $-1$  and  $+1$  record contracted and expanded departure relative to the selected reference. They do not mean bad and good, negative and positive energy in every physical theory, or two arbitrary labels for competing opinions. A mapping must say which measurable quantity expresses the departure at this address. Without that assignment, the sign has not yet become an observable.

For a cloud, one might investigate a contraction measure tied to density and its evolution. For a radiation field, a different variable may be appropriate. The common structure does not imply that these quantities have identical units. It supplies a place to declare the variables, the reference, and the transition between scales. The physical translation remains explicit.

The calculus therefore has two tasks. It organizes the recursive relation, and it carries the equations that evolve the assigned state. The first task prevents an isolated description from silently becoming complete. The second makes quantitative predictions. A successful notation is valuable because it exposes what a calculation must include, not because brackets alone calculate an orbit.

When an outer pressure changes and an inner configuration responds, the model can follow the projection. When an inner exchange changes the enclosing state, the reciprocal contribution can be recorded without reversing the address. The direction belongs to the relation being followed. The same system can participate in both directions.

The reader can now perform the simplest useful operation: place a phenomenon in the middle and open either side. The question ceases to be whether a thing has a context. It becomes which context is actively making this state possible.

## Scale in the Light We Already See

Look at a nebula. The light makes its enclosing conditions visible. Some gas emits after receiving energy from nearby stars. Dust scatters starlight into the line of sight and removes light from other lines of sight. The structure appears because matter and radiation are interacting throughout it. A cloud can have a gradual edge and still change what reaches the observer.<sup>8</sup>

<sup>8</sup>NASA, “Decoding Nebulae,” <https://science.nasa.gov/universe/stories/quick-reads/decoding-nebulae/>. The optical mechanisms are established observations; their cross-scale organization here is the volume’s NCM interpretation.

Now look beyond the cloud. A foreground concentration of mass bends the paths by which a distant galaxy becomes visible. The source may appear stretched into an arc or multiplied into several images. The observed image belongs to a relationship among source, intervening geometry, and observer.<sup>9</sup> The galaxy alone does not supply the image we receive.

Follow the spectrum as well as the image. Cosmological redshift relates the wavelength received to the expansion between emission and reception. Gravitational and relative-motion contributions require their own circumstances to be specified. The observation carries a history of relationships. In the cosmological case, that history can be continuous across the journey; it need not announce itself at a sharply drawn surface.

These are the scale transitions this inquiry begins with: observable changes in the active conditions under which light is emitted, transmitted, redirected, and received. Nested causality reads the cloud, the gravitational environment, and the larger propagation history as related enclosures. Each makes a different contribution. Dust reddening changes the balance of transmitted wavelengths; a spectral redshift changes the wavelengths at which features are received. Lensing changes the mapping of directions and apparent images. Keeping those distinctions is how the generalization remains useful.

The address is opened wherever the observation requires it. Place the cloud in the middle: its stellar radiation field and larger environment enclose it, while its gas, grains, and interactions occupy the enclosed side. Place a grain in the middle and the cloud becomes part of its enclosing conditions. Place the galaxy in the middle and another scale becomes active. The physical relations determine the address; the address helps us follow them.

We already observe the phenomena from which the principle is drawn. What this volume proposes is their systematic reading across scales, followed by the investigation of consequences that reading makes visible. The generalization has work to do before any additional effect is proposed: it identifies which conditions belong in the calculation and prevents the light received from being mistaken for an unaltered account of the source alone.

An additional dynamical claim can then be stated on its own terms. If a proposed operator predicts a new contribution to a spectrum or an expansion estimate, that contribution needs its own calculation and comparison. The observational starting point remains the sky we can see. The task is to understand its nesting.

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<sup>9</sup>ESA/Hubble, "Gravitational Lensing," <https://esahubble.org/wordbank/gravitational-lensing/>.

## Chapter 9: The Zero Infinity

A model of departure requires a reference.

The inherited map often treats zero as emptiness, rest, or a chosen origin. That is not enough. Chosen origins depend on the coordinate system that selected them. Empty space is not empty in modern physics. Rest is local. A fixed zero cannot serve as the scalable reference for a universe that nests in both directions.

The Zero Infinity is the reference condition required by nested cosmology.

It is not a single point. It is not a void. It is not an empty spatial vacuum. It is the countably infinite balanced condition from which observable phenomena are modeled as scale-dependent departures.

In the current formal structure, the Zero Infinity is expressed as a balanced relation between contracted and expanded states around the Vector Equilibrium:

$$[[ff \mid -1 \mid ff] \mid ve \mid [ff \mid +1 \mid ff]] = 0infinity$$

The notation should not be read as a decorative symbol. It states a structural claim.

The contracted tendency and the expanded tendency are both bounded by the Final Frontier. The central Vector Equilibrium is the local balanced phase where the opposing pressures equalize. Physical matter, radiation, and momentum do not reside as static objects inside the zero phase. They appear as active departures away from it.

This removes the need for a singular origin point.

Cosmology does not need to begin from nothing if nothing was never the correct reference. It needs a scalable condition from which departures can be measured without requiring an external authority or a chosen center.

The Zero Infinity supplies that condition.

It is present at every scale because it is not a location. It allows scale escalation because opposing departures can approximately cancel through it and move into an adjacent enclosure. It preserves direction because the larger enclosure continues to project causal structure inward.

This is why the Zero Infinity matters for origin stories.

If the reference condition is scalable, then the origin does not need to be singular. Multiple origin models can be treated as departures from the same reference architecture. Their differences become testable configurations rather than threats to a required myth.

The origin point dissolves.

The reference remains.

### A Balance That Travels Through Scale

The distinction between the Vector Equilibrium and the Zero Infinity is essential. Fuller's geometric Vector Equilibrium is represented by a cuboctahedral arrangement in which the radial distances and edge lengths can be equal. It is a particular geometry that can be constructed and inspected. Its relations give a concrete language for balance and transformation.<sup>10</sup>

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<sup>10</sup>Fuller and Applewhite, *Synergetics* (1975), sections 420-460, <https://future.buckyverse.org/read/synergetics/manuscriptch5/>.

The Zero Infinity is the scalable reference architecture proposed here. A physical model of one cuboctahedron does not display an infinite nesting of scales. It supplies a local geometric expression within that architecture. Confusing the two would turn a relation available at every address into an object at one address. The book needs both, and needs them to remain distinguishable.

Consider an ordinary measuring instrument. A balance scale reaches zero when its opposing loads balance. The zero does not tell us that the loads have ceased to exist. It tells us the difference measured by the instrument has vanished. Changing the instrument's range changes which differences can be resolved. This familiar example introduces the function of a reference, although the Zero Infinity goes further by making the reference recursively available within the model's nesting.

At one tier, opposing departures can resolve into no net difference in the selected observable. Their cancellation does not authorize the disappearance of everything that constituted them. Their relation to the containing system must still be carried. That is why the source formulation links cancellation to scale escalation: what no longer appears as an independent local departure is accounted for through the enclosing state.

The operation can be expressed as a pair, a residual, and a transfer. First identify the contracted and expanded terms relative to the same reference. Then calculate the uncanceled local remainder. Finally identify how the paired component and any transferred remainder enter the adjacent tier. The third operation prevents cancellation from being a verbal trick that discards the difficult quantity.

A returning pendulum provides a limited illustration of the difference between crossing a reference and returning to a prior state. It passes a central position repeatedly, but the world around it has changed: energy has been exchanged, air has moved, and time has elapsed. A reference crossing is not a reversal of the entire history. In the proposed jitterbug transition, the stronger claim is that a crossing can change the tier at which a contribution is carried. The transition must therefore preserve an account across that change of scale.

The larger enclosure continues to matter during the crossing. Equalization of a local difference does not cancel the external conditions under which it equalized. This is the directional point of the original Zero Infinity paper. An inward causal projection can persist through local cancellation because the enclosing relation remains present. A balanced local term does not make the whole continuum directionless.

The compact expression is

$$[[ff \mid -1 \mid ff] \mid ve \mid [ff \mid +1 \mid ff]] = 0\infty.$$

Here the equality declares the framework's balanced reference. It is not multiplication of brackets, and  $0\infty$  is not ordinary zero multiplied by an infinite number. The contracted and expanded positions are themselves enclosed; the central geometric balance is situated between them. The notation gives the reference an internal architecture instead of treating it as the absence of one.

From this point onward, every proposed cancellation in the book owes the reader the same account: the paired terms, their shared reference, the residual, and the destination of the scale transition. That is what makes the vacuum argument more than the instruction to subtract a large number from itself.

# Chapter 10: The Final Frontier

The Final Frontier is the boundary that keeps the continuum coherent.

It has two roles, and both are necessary.

First, it is epistemic. It marks the limit of observable knowledge and information. No matter how far knowledge expands, there remains an edge beyond which current observation cannot speak with authority. This edge is not a temporary embarrassment. It is a structural feature of any finite knower inside the universe being known.

Second, it is computational and cosmological. It is the halt condition. It prevents infinite regress from masquerading as explanation. It prevents singularity from being treated as a physical residence. It prevents wave functions, algorithms, and cosmological projections from running without boundary.

These are not separate ideas.

The boundary of knowledge and the boundary of computability share the same architecture. To know something is to enclose it. To compute something is to halt it inside a determinate frame. To model a physical system is to state the boundary conditions under which the model applies.

Volume I gives this boundary its strictest form: the Final Frontier is the single deterministic boundary operating at every scale. Volume V extends that same claim into cosmology. The boundary is epistemic when knowledge reaches its limit. It is computational when a process must halt. It is cosmological when a physical model would otherwise collapse into singularity, unbounded regress, or unbounded spread.

The Final Frontier is static in one sense and dynamic in another.

It is static because there is always a boundary. No finite scientific framework can abolish the need for one. It is dynamic because the empirical location of the boundary changes as knowledge grows. The boundary condition itself does not become less deterministic; our mapped contact with it changes. What was once frontier becomes interior. What was once unknowable becomes measurable. But the existence of a frontier remains.

This is why no origin story can claim final authority.

The origin of the universe, if spoken of as an absolute, lies beyond the Final Frontier of current information. Cosmology may approach it with models. It may compare those models. It may test their predictions. It may improve its map. But it cannot convert one model into the boundary itself without confusing knowledge with authority.

The Final Frontier disciplines cosmology.

It says: stop where information stops.

It also says: begin again from the boundary.

## The Edge of This Map

There are two distinctions to retain within the frontier. The framework's deterministic boundary is written *ff*. The declared end of this model's knowledge is written *FF*. The notation prevents the current map from making its own ignorance a law of the universe.

A telescope has a limiting sensitivity. A catalog has a selection threshold. A simulation has a resolution. A theory has a domain for which its variables and equations are specified. These boundaries may interact, but they are not interchangeable. Improving a detector can move an observational boundary without changing a physical horizon. Refining a calculation can move its numerical boundary without proving that a singularity is physically resolved.

The model's FF records where its present authority stops. A relation beyond it may exist, and may become knowable through another observation or a better construction. The boundary is lawful when it follows the actual reach of the retained evidence and method. It is arbitrary when it is placed only to shelter a favored result from an inconvenient question.

Now consider the stronger issue of absolute origin. If several preceding states produce the same complete accessible record, no processing of that record alone can choose among them. That is a deterministic limit of the stated inference. It says what the information cannot do. Whether some additional physical channel could carry the missing distinction is a further question. Calling the current reconstruction incomplete does not answer it; calling it complete does not remove it.

The claim that an absolute origin lies permanently beyond information belongs to the frontier argument at its greatest scope. Its force comes from a universe being investigated by observers inside it, with no external record of the whole event. Its application requires care about what is meant by origin. The beginning of a thermal interval can leave recoverable evidence. An absolute beginning of all conditions is a different target. Moving between those meanings would make the conclusion appear stronger than the question actually examined.

The computational role is equally concrete. Suppose every term in a model asks for two further terms. A program instructed to expand forever never returns a result. Giving it a depth limit makes it terminate, but does not make that limit physically adequate. A lawful halt specifies which unresolved influences are bounded, which are negligible for the question, and which remain unknown. The model can then state how sensitive its result is to that boundary.

The frontier is also involved when an equation becomes singular. A divergence tells us that a description has reached a difficult limit. To replace that limit with a transition requires a continuation rule: what enters, what crosses, what is conserved, and what appears on the other side. Merely ending the computation at the large number would leave the physical question where it began. The Zero Infinity supplies the proposed transition reference; the Final Frontier disciplines the authority of the description that uses it.

Thus the two concepts work together without being identical. The reference tells us what a departure is relative to. The frontier tells us where the account of that departure ends. Neither can do the other's work. A universe of nested relations can remain open while a particular calculation reaches a definite and defensible conclusion.

# Chapter 11: Enclosing the Big Bang

The Big Bang does not need to be overthrown.

It needs to be enclosed.

The evidence for a hot, dense early state remains inside the nested map. The cosmic microwave background remains inside it. Primordial nucleosynthesis remains inside it. Expansion remains inside it. Large-scale structure remains inside it.

Nothing valuable is lost.

What changes is the authority of the model. It no longer functions as the outer edge of cosmology. It no longer decides in advance which origin narratives may be explored. It no longer turns every anomaly into a problem that must be solved inside one inherited beginning.

Inside the larger enclosure, the Big Bang becomes one powerful account of one region of the cosmological time-series. It describes a hot, dense early condition visible through present evidence. It does not possess the Final Frontier.

This distinction matters.

When the Big Bang is unenclosed, the Hubble tension must be forced toward one true value. When it is enclosed, local and global measurements may be interpreted as different scale-tier observations.

When the Big Bang is unenclosed, early galaxies must be fitted into one formation schedule. When it is enclosed, their maturity may indicate that organization was operating through an outer condition not fully represented in the standard map.

When the Big Bang is unenclosed, vacuum energy becomes a catastrophic mismatch inside a smooth background. When it is enclosed, the reference condition itself can be corrected through the Zero Infinity.

Enclosure protects what is useful and limits what overreaches.

This is the same method used throughout this series. The problem is not the existence of the standard map. The problem is the refusal to update it when the enclosure moves.

We do not reject the Big Bang.

We return it to its proper place.

## Carrying the Thermal History Across

Enclosure becomes a real operation when we can say what crosses into the larger model unchanged. The recorded microwave spectrum crosses. The calibrated temperatures and polarization measurements cross. The measured abundance ratios cross with their observational uncertainties. The galaxy spectra and survey selections cross. These are the materials from which any revised cosmology must work.

Some interpreted quantities cross conditionally. A distance inferred under a particular expansion history is not independent evidence for that same history. An age assigned from redshift must be recalculated if the time-redshift relation changes. A stellar mass inferred from luminosity retains dependencies on population assumptions. The new model inherits the observations and must perform these translations visibly.

This is how a Great Pull cosmology could preserve a hot early phase while asking a different question about its origin. It would need a route from its organizing condition into the temperatures, densities, reaction histories, and subsequent transparency that leave the observed records. The hot phase would become a shared interior. The proposed difference would concern what encloses and produces it.

The requirements can be followed in sequence. Radiation must acquire or retain the measured thermal character. Ordinary matter must pass through conditions yielding the relevant light-element abundances. The later plasma must generate a perturbation pattern compatible with the microwave observations. Structure must grow through a history that accounts for the galaxies and flows. Changing the outer story does not erase any of these obligations.

There is freedom inside this discipline. Two origin arrangements might converge upon a nearly identical thermal interval. Their later predictions could then differ only through a surviving trace of the earlier conditions. That trace becomes the appropriate target of observation. If no accessible trace differs, the thermal data can support the shared interval without selecting a unique outer history.

This gives the original source argument a precise place. It proposes that the same successful evidence can be retained while gravity's organizing introduction is considered as the primary event. The narrative compatibility is a reason to calculate that history. Quantitative equivalence is established only when both histories have been taken through the same observations. The inquiry is strengthened by specifying the passage rather than treating the shared words 'hot' and 'dense' as its completion.

The distinction also protects the Great Pull from premature rejection. A calculation that demonstrates the success of one thermal route does not, by itself, establish the impossibility of every other route into that interval. Alternatives should be tested where they differ. A borrowed success is not a new prediction, and a borrowed failure is not a refutation of a mechanism that has not been evaluated.

We can now see the practical value of the larger enclosure. It separates the conserved empirical accomplishment from the contested outer relation. Cosmology keeps its instruments, its records, and its best-tested processes. The new work begins at the relation that those successes leave open. The past is neither discarded nor required to tell more than it can.

## Chapter 12: Scale-Dependent Cosmology

The standard Einstein Field Equations relate spacetime geometry to mass-energy. In their familiar form, they include a cosmological constant that functions as a uniform term across the model.

The Departure Calculus changes the role of that term.

Instead of treating the cosmological constant as invariant across all scales, the scale-dependent framework replaces it with a dynamic geometric modifier. The modifier depends on the characteristic length scale of the enclosure and the departure depth from the Zero Infinity.

In simplified form, the modified structure proposed in the current technical paper replaces the constant term with:

$$L^2 / (\zeta * \tanh(d))$$

Here  $L$  is the characteristic length scale of the causal enclosure tier.  $d$  is the total metric departure depth from the Zero Infinity reference condition.  $\zeta$  remains an unspecified structural coupling or modulation coefficient whose units and calibration must be stated.

The hyperbolic tangent term supplies the proposed transition behavior. As departure depth approaches zero, the denominator contracts and the curvature expression grows. In the intended model, the approach activates a change of tier rather than a physical residence at zero. The transition rule must therefore accompany the expression: the divergent denominator identifies where continuation is needed, while the enclosure exchange specifies how it occurs.

The same logic modifies Friedmann dynamics. Expansion is no longer treated as one smooth global value that every observation must share. The Hubble parameter becomes scale-tier dependent:

$$H = H(L)$$

This is not a minor adjustment. It changes the interpretation of cosmological measurement.

An observation taken across a macro-enclosure may not report the same expansion behavior as an observation taken inside a local nested enclosure. The difference is not automatically error. It may be structure.

The old model asks why the measurements disagree.

The nested model first asks whether they are measuring the same enclosure.

### Giving the Proposal Its Units

The gravitational equations offer a useful place to distinguish structure from implementation. In the usual notation,

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

The tensor on the left describes spacetime curvature. The tensor on the right describes the stress-energy source. The cosmological term has inverse-length-squared units. It is not a dimensionless permission to add any large-scale effect to the equation.

The proposed enclosure form replaces  $\Lambda$  with  $\mathcal{K}(L, d)$ :

$$G_{\mu\nu} + \mathcal{K}(L, d)g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}, \quad \mathcal{K}(L, d) = \frac{L^2}{\zeta \tanh d}.$$

If  $L$  is a physical length and  $d$  is dimensionless,  $\zeta$  must carry fourth-power length units. Its value is not supplied by declaring a scale. The technical formulation retains it as a structural coupling and normalization. A numerical prediction must identify how that normalization is fixed and whether it changes between enclosures.

The limiting behavior is visible without a large computation. For positive  $d$  well away from zero,  $\tanh d$  approaches one and the correction approaches a tier-dependent value. Near zero,  $\tanh d$  approaches  $d$ , so the expression behaves approximately as  $L^2/(\zeta d)$ . This is the proposed pressure toward transition. It is also the place where an actual integration needs a defined crossing rule. A saturating function in the denominator does not by itself make the whole expression bounded.

There is a further consistency relation. The geometric tensor obeys a covariant conservation identity. If  $\mathcal{K}$  varies through spacetime, its variation must be matched by the source account. A model with separately conserved ordinary matter must supply the additional enclosure contribution or exchange law that carries the difference. The technical appendix states this relation explicitly. It is a constructive demand of the proposed equation, not an external preference about what theories are allowed to say.

At the cosmological scale, one candidate acceleration equation is

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3} \left( \rho + \frac{3p}{c^2} \right) + \frac{c^2}{3} \mathcal{K}(L, d),$$

with  $\rho$  here a mass density. Its use requires a consistent evolution for density, pressure,  $L$ , and  $d$ , together with the complementary gravitational constraint. An acceleration equation alone does not determine the expansion history. Initial conditions and the exchange relation complete the calculation.

This is where the scale dependence becomes a physical question. If changing  $L$  merely means changing the analyst's smoothing window, the resulting variation may describe the analysis rather than a new cosmological effect. If  $L$  identifies an independently specified dynamical enclosure, the hypothesis has a stronger content. The model must make that identification before it fits the expansion residuals.

The promise of the construction lies in this explicit dependence. The older constant has become a relation among scale, reference, and departure. It can be investigated rather than left as a universal label. Different choices for the closure rule can be compared while preserving that structural question. The framework's claim is larger than the claim that one convenient hyperbolic function is unique.

A successful calculation would carry a system through stable behavior, approach to its transition, exchange into the adjacent tier, and renewed stable behavior. It would recover the already measured gravitational relations where the new boundary is inactive. The result would then be a lawful extension across an identified boundary, with every new term doing work the reader can follow.

# Chapter 13: The Hubble Tension as an Enclosure Error

The Hubble tension is usually described as a disagreement between early-universe and late-universe measurements of the expansion rate.

Measurements inferred from the cosmic microwave background under the standard model produce a lower value. Local distance-ladder measurements using nearby astronomical objects produce a higher value. The discrepancy has persisted long enough that it can no longer be waved away comfortably as a simple inconvenience.

Inside a single-origin, single-scale map, this is a problem of reconciliation. One value must be right, or both must be adjusted until they meet.

Inside nested cosmology, another possibility appears.

The two measurements may belong to different causal enclosures.

The cosmic microwave background is a macro-enclosure observation in this framework. Its present-day expansion estimate is inferred through a model of the background and its evolution; it is not a direct reading of today's expansion from an ancient thermometer. The nested proposal asks whether the relation used to carry that inference into the present omits an active scale dependence.

The local distance ladder measures inside a nearer enclosure. It tracks stars, supernovae, and galaxies embedded in local structure. These observations may carry local accumulation, compaction, or scale-transition effects that are not visible when averaged across the macro-frame.

If expansion is scale-dependent, the disagreement is not necessarily a contradiction.

It is a map signal.

The Hubble tension may be telling cosmology that it has forced two enclosure scales to report one universal number. The failure is not in the sky. The failure is in the assumption that the sky must be smooth in the same way at every scale.

This does not prove the Departure Calculus by itself. It identifies a place where the nested model can be tested. If  $H(L)$  is real, then other scale-dependent signatures should appear in redshift, structure, and boundary behavior.

The tension becomes useful when it is no longer treated as an embarrassment.

It becomes evidence that the enclosure is moving.

## Two Routes to the Present

The often-quoted comparison is specific. The Planck base-model analysis inferred  $H_0 = 67.4 \pm 0.5$  kilometers per second per megaparsec. The 2022 SH0ES analysis reported  $73.04 \pm 1.04$  in the same units. These are results of identified analyses, not two numbers floating free of their methods.<sup>11 12</sup>

The local ladder begins with geometric calibrations, carries them through Cepheid variables, and uses calibrated supernovae to reach farther into the expanding flow. Its dependencies include instrument calibration, source environments, extinction, and population relations. The background route uses features of the microwave

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<sup>11</sup>Planck Collaboration, “Planck 2018 Results. VI. Cosmological Parameters” (2020), <https://arxiv.org/abs/1807.06209>. Numerical estimates quoted here are those of the identified analysis.

<sup>12</sup>Riess et al., “A Comprehensive Measurement of the Local Value of the Hubble Constant” (2022), <https://arxiv.org/abs/2112.04510>.

sky and an assumed cosmological evolution to infer parameters, including today's expansion rate. Its dependencies include early physical processes, the expansion model, and the relation between a physical scale and its observed angular size.

Both seek a present-day quantity. Calling one 'early' and the other 'late' refers to the routes by which that quantity is inferred. Ordinary cosmology already distinguishes  $H(z)$ , the changing expansion rate with epoch, from  $H_0$ , its present value. The enclosure proposal introduces an additional dependence on the mapped relation and its scale. Without this distinction, the model would seem to discover a time dependence that was present all along.

Imagine measuring a landscape through a wide-angle image and a series of local surveys. Agreement requires the transformations between the two to be correct. A difference may reveal an instrument error, a calibration problem, or a geometric assumption. Merely labeling the surveys 'different scales' does not resolve it. The label becomes useful when it predicts how the local results should change with independently measured features of the landscape.

The same standard makes  $H(L, d)$  testable. Assign the enclosure using quantities obtained independently of the desired Hubble residual: a specified region, an environmental density estimate, or a defined dynamical boundary. Predict the change in the inferred expansion relation. Then ask whether observations withheld from the fit follow it. A tier chosen only because its data already lie near 73 has learned the answer rather than explained it.

A two-tier exploratory interpolation can write the effective estimate as a weighted combination of two calibrated values. The weights may be functions of environmental variables. This is useful for organizing a first comparison, but it is not yet the gravitational dynamics. The transition from an interpolation to a cosmological explanation requires that the weights follow the enclosure model and remain consistent with the other observations of expansion and growth.

The decisive question is therefore more interesting than whether two numbers can be made to meet. Does the mapped environment predict a pattern of differences across independent measurements? Does the pattern survive changes of sample, instrument, and calibration? Does it improve predictions beyond familiar flow corrections and comparable alternative models? The tests protect a real scale effect from being mistaken for nuisance, and protect nuisance from being celebrated as a new law.

The Great Pull and the scale-dependent equations give a reason to look for this structure. They have turned a numerical disagreement into an addressed physical hypothesis. The sky is then asked a question precise enough to answer: where does the change occur, how large is it, and what else must change with it?

# Chapter 14: The Vacuum Energy Problem

The vacuum energy problem is often stated as one of the worst mismatches in physics.

Naive zero-point sums with a high-energy cutoff can give an enormous energy density, while cosmological observations indicate a much smaller effective dark-energy density. The precise mismatch depends on the cutoff and on the treatment of the vacuum. The broader difficulty is explaining a small gravitationally relevant value that remains stable under quantum corrections.<sup>13</sup>

Inside the inherited map, the problem is a catastrophe.

Inside the nested map, it is first a question of reference.

What is being treated as zero?

If the vacuum is assumed to be an empty background filled with independent fluctuations, then the enormous predicted energy appears as a gravitational disaster. But if the Zero Infinity is the proper reference condition, then symmetric potential pairs are not free to accumulate as global pressure. They are natively paired as contracted and expanded tendencies across the balanced matrix.

The Law of Nested Exchange indicates that those symmetric potentials tend toward cancellation across a finite enclosure, with the balance expressed approximately rather than as a simplistic perfect equality.

What remains is not the full imagined vacuum energy. What remains is the uncanceled directional remainder of a specific enclosure layer. That remainder appears as observed stress-energy.

This reframes the problem.

The catastrophe may not be that the universe hides almost all of its vacuum energy. The catastrophe may be that the calculation begins from the wrong zero.

A chosen zero produces a mismatch.

The Zero Infinity produces structured cancellation.

This does not remove the need for formal development. It states the causal architecture required for the problem to become tractable. Vacuum energy must be modeled as an enclosed departure from a balanced reference condition, not as a sum of unbounded fluctuations in an empty box.

The box was never empty.

It was unenclosed.

## Pair Before You Sum

The constructive claim is that the reference determines what is counted as an independent gravitational contribution. In an ordinary free-mode estimate, one writes an energy per mode and sums:

$$\varepsilon_{\text{free}} = \frac{1}{V} \sum_{\mathbf{k}} \frac{1}{2} \hbar \omega_{\mathbf{k}}.$$

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<sup>13</sup>Carroll, “The Cosmological Constant” (2001), <https://arxiv.org/abs/astro-ph/0004075>. The review explains the distinction between vacuum contributions, their gravitational interpretation, and the observed cosmological term.

The expression has energy-density units. It records a mode-counting operation whose physical interpretation depends on the theory, regularization, and coupling to gravity. The nested proposal changes the operation before the sum. It places each candidate contribution in a contracted-expanded relation to the Zero Infinity and asks what survives that relation at the active tier.

Write the proposed remainder schematically as

$$\delta\varepsilon(L) = \frac{1}{V_L} \sum_{\mathbf{k},n} \mathcal{E}_n (E_{\mathbf{k},n}^+ - E_{\mathbf{k},n}^-).$$

The pairing rule, transition factor  $\mathcal{E}_n$ , and tier address are substantive parts of the proposal. Ordinary zero-point modes are not made negative by typography. The minus sign here expresses the framework's claimed subtraction of paired contributions to the gravitationally active departure. Specifying that coupling is what turns the proposed reference into physics.

This preserves the strongest idea in the source: the large number need not be generated as a freely gravitating total and subsequently removed by a chosen counter-number. The enclosure decides which contributions are independent at the scale of the gravitational account. Balanced pairs belong to the reference; the residual belongs to the observed departure. The difference concerns the order and meaning of the counting.

The scale transition supplies the receiving account. When paired local departures compactify, their contribution is carried into the enclosing tier rather than simply deleted. An adequate model must preserve the relevant energy-momentum and geometric relations across that transition. It must also preserve the laboratory consequences of quantum fields. The Casimir calculation, for example, concerns changes associated with an imposed boundary; retaining such measurable differences is a necessary part of any revised vacuum account.<sup>14</sup>

The technical work proposes a simple residual scaling:

$$\delta\varepsilon(L) = \chi\varepsilon_P \left( \frac{\ell_P}{L} \right)^2, \quad \varepsilon_P = \frac{c^7}{\hbar G^2}, \quad \ell_P^2 = \frac{\hbar G}{c^3}.$$

The expression reduces to  $\chi c^4/(GL^2)$ . With  $L = c/H_0$ , it becomes  $\chi c^2 H_0^2/G$ , the same dimensional scale as cosmological critical energy density. This is the useful numerical bridge: an enormous Planck-density scale can be multiplied by a length-ratio suppression that produces a cosmological scale without subtracting two arbitrarily fitted enormous totals.

The account also identifies exactly what the bridge does not determine. The coefficient  $\chi$  and the physical choice of  $L$  must come from the enclosure geometry or from an explicitly identified calibration. The equation of state and time evolution must follow as well. Two densities with the same magnitude can evolve differently and produce different skies. A fit at one epoch cannot substitute for that history.

There is a specific counting step to examine. A volume count scales as  $(L/\ell_P)^3$ , and an area count as  $(L/\ell_P)^2$ . Their ratio supplies one power of  $\ell_P/L$ . The proposed square suppression requires an additional factor, attributed in the technical model to compactification. Area counting alone does not provide it. Stating the second operation makes the mechanism available for derivation instead of allowing a dimensionally attractive result to conceal a missing step.

Related work on effective field theory and gravitational bounds has also linked large and small scales in vacuum estimates.<sup>15</sup> The distinct NCM claim is the recursively paired reference and the transfer between tiers. Those

<sup>14</sup>Casimir, "On the Attraction Between Two Perfectly Conducting Plates" (1948), <https://dwc.knaw.nl/DL/publications/PU00018547.pdf>.

<sup>15</sup>Cohen, Kaplan, and Nelson, "Effective Field Theory, Black Holes, and the Cosmological Constant" (1999), <https://arxiv.org/abs/hep-th/9803132>.

mechanisms must be examined directly; agreement in an inverse-square scaling does not make them the same construction.

The solution offered by the model is therefore structural and explicit: pair the departures, preserve their exchange, and compute the residual that can gravitate at the active boundary. Its quantitative realization has definite targets. The question is no longer merely why a vast sum is absent. It is which terms were ever independent members of that sum, and what the enclosing relation leaves available to observation.

# Chapter 15: The Quantum Boundary

The same boundary error appears at the quantum scale.

Quantum mechanics describes states with specified Hamiltonians, domains, and boundary conditions. The equations are powerful and their predictions extraordinary. The measurement question concerns how the evolution of a state, an apparatus, and their interaction relates to the definite record obtained. Interpretations differ about that relation. Nested Causality asks whether the active enclosure supplies an additional physical transition condition.<sup>16</sup>

Nested causality changes the question.

The quantum state is not treated as a free wave in an unbounded background. It is treated as an enclosure-bound state:

$$\Psi_{\text{Total}} = [\Psi_{\text{enclosing}} \mid \Psi_{\text{departure}}(t) \mid \Psi_{\text{enclosed}}]$$

The central departure evolves in time, but it does so inside an enclosing relation. It is filtered by the geometry of the Zero Infinity and bounded by the Final Frontier. Probability is not allowed to bleed indefinitely past the structural frame of the system.

In the current technical formulation, the time evolution is modified by an Enclosure Operator:

$$i \hbar \frac{d}{dt} \Psi_{\text{departure}}(t) = E_{0\text{infinity}} [H \Psi_{\text{departure}}(t)]$$

The operator acts as a geometric probability filter. As internal branches carry contracted and expanded states, opposing departures compact and approximately cancel across the Zero Infinity. The remaining uncanceled directional bias becomes the stable particle signal.

Collapse is no longer treated as arbitrary.

It becomes quantized compactification.

When local state saturation reaches the boundary of its enclosure, the system cannot spread further within that tier. It transitions into the adjacent scale tier dictated by its enclosing environment while preserving the integrity of the enclosing exchange.

This does not deny quantum indeterminacy at the local level. It encloses it.

The quantum boundary and the cosmological boundary therefore mirror one another. At the largest scale, cosmology cannot project beyond the Final Frontier and call the result knowledge. At the smallest scale, the wave function cannot spread beyond its enclosure and call the result physical residence.

The framework places both questions at a boundary whose physical role must be made explicit.

## The Apparatus Is in the Experiment

Consider a two-slit experiment. A source prepares particles or light. Apertures constrain propagation. The intervening environment permits or suppresses coherence. A detector records events. The observed pattern depends on the whole arrangement. The particle does not bring an interference experiment into existence by itself.

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<sup>16</sup>Schlosshauer, "Decoherence, the Measurement Problem, and Interpretations of Quantum Mechanics," <https://arxiv.org/abs/quant-ph/0312059>.

Ordinary quantum theory already calculates boundary-sensitive behavior. It includes confined states, scattering states, and interactions with an environment. Nested causality carries these calculations into a common question: which enclosing conditions actively participate during this operation? That question can improve the definition of a system before any additional dynamics are introduced. The proposed enclosure operator takes a further step, investigating whether a coupling between enclosing and enclosed states can activate a change of tier, with compactification supplying the transition to a stable record.

Consider a massive particle prepared in two separated positions. The apparatus that makes the separation must recoil. In *The Apparatus Strikes Back*, Céleri, Soares-Pinto, and Turolla Vanzella calculate how the branch-dependent recoil states affect the particle's reduced coherence. A particle of mass  $m$ , separated by  $d$  using an apparatus of mass  $M$ , requires the compensating displacement  $D = md/M$ . The enclosing apparatus enters the calculation through conservation itself.<sup>17</sup>

How much apparatus is  $M$ ? The complete object on the laboratory bench is an appealing answer. A finite preparation time makes it an inadequate one. Mechanical influence travels through the apparatus at finite speed. During a short operation, a distant component may not yet participate as part of the same mechanically correlated body. A soft connection can matter as much as distance.

The acoustic horizon supplies a concrete boundary. In the homogeneous approximation its reach is  $R_{ac} = c_s \tau_{prep}$ : sound speed multiplied by preparation time. Material properties, geometry, and mechanical connections determine the participating region. Sound speed depends on elastic properties as well as density. An apparatus assembled from different materials therefore needs its transmission paths and correlations mapped, rather than a single density used as a substitute for the whole structure.

*The Return of Scale* takes this observation into an operational nested-scale model.<sup>18</sup> The apparatus is counted by causal participation. Change the preparation interval or the mechanical connection and the participating domain can change. The scale address records the resolved domain; propagation within the material remains continuous. Here is a scale boundary that an experiment can locate without inventing a membrane.

The immediate benefit is an accountable recoil calculation. The participating mass and its state determine the baseline against which visibility is compared. Recoil is retained, calculated, and separated in the analysis where the channels permit that separation. It has not been experimentally abolished. The full particle-apparatus state may also retain coherence that disappears from a description of the particle alone. Choosing what to trace out is a physical decision about the experiment, not a convenience without consequences.

The paper then proposes a further investigation: vary the participating enclosure while independently characterizing recoil and ordinary environmental losses. Does an additional, reproducible contribution remain? That question is downstream of the mapped apparatus. The acoustic boundary and the proposed additional coupling occupy distinct places in the argument. Appendix D carries the equations and the experimental sequence together.

This restores the recursive orientation at the point where it matters most. The apparatus and its active conditions occupy the enclosing side; the evolving departure occupies the center; the relevant internal states occupy the enclosed side. Opening either outer position introduces further addressed relations. It does not exchange the roles of the laboratory and the particle.

In schematic form the proposed evolution is

$$i\hbar \frac{\partial \psi}{\partial t} = \hat{\mathcal{E}}_{0\infty}[\hat{H}\psi].$$

<sup>17</sup>Céleri, Soares-Pinto, and Turolla Vanzella, "The Apparatus Strikes Back" (2026), <https://arxiv.org/abs/2607.08819>. This is the source of the retained recoil calculation and acoustic-horizon observation.

<sup>18</sup>Hubbard, *The Return of Scale* (2026), <https://doi.org/10.5281/zenodo.21381025>. The operational participation classes and proposed additional-channel construction are developed there.

Here the filter is a proposed physical operation, not an ordinary numerical clipping of small probabilities. Its definition must identify the state space on which it acts and the coupling that activates it. The Zero Infinity is a reference architecture; it cannot be inserted as a scalar denominator equal to numerical zero. A dimensional normalization for a coupling ratio must be supplied separately.

An elementary example shows why that detail matters. If the filter were only a real constant  $e$  between zero and one, and the Hamiltonian were otherwise unchanged, the evolution would be generated by  $e\widehat{H}$ . Under the usual conditions it would remain unitary, with a rescaled rate. Taking  $e$  toward zero would slow the evolution. It would not by itself select one detector outcome. Compactification therefore has to specify the additional transition, not rely on suppression alone to do that work.

For an operator-valued or state-dependent filter, further questions arise. Does the effective evolution preserve normalization? How is probability transferred when a tier changes? Does the construction recover measured interference when the transition is inactive? How are outcome frequencies obtained? These questions are the contents of the proposed mechanism. Answering them is how the enclosure earns its physical meaning.

Decoherence provides a useful comparison. Interaction with the environment can suppress interference between components in a reduced description. That is an established part of the measurement discussion, but it is not automatically identical to the NCM compactification claim. The proposed change of tier and its resulting record need a stated relation to those environmental dynamics. Calling both a boundary would lose the distinction the new framework was introduced to investigate.

An experimental comparison can then be designed. Change a specified enclosing geometry or coupling while preserving the calibrated preparation and detection procedure. Compute the ordinary prediction for that changed apparatus. Compute the additional departure predicted by the enclosure model. The target is the difference between those two predictions, not the already expected effect of moving a slit.

The original proposal of a bounded probability envelope becomes meaningful in this form. It requires a location, a magnitude, and a scaling rule for additional suppression. Detector acceptance and optical apertures already remove observed events from parts of a pattern. A new boundary effect must remain after those effects have been modeled and checked.

The quantum chapter thus reaches the same constructive demand as the vacuum chapter. Identify the paired or coupled states, calculate the local remainder, and follow the transition into the containing record. The insight is an address for a physical process. Its strength increases when the reader can see what that process would have to do.

# Chapter 16: Unified Causal Bounding Conditions

The model can be made computationally definite when its boundaries and transition rules are specified together.

The current technical framework expresses the bounding condition as:

$B = [B_{\text{outer}} \mid B_{\text{periphery}} \mid B_{\text{inner}}]$

The outer boundary is the Final Frontier.

It is the macro-closure horizon. It projects fixed parameters inward and functions as the halt condition that prevents infinite algorithmic loops. Without this boundary, a model can run forever without producing determinate knowledge.

The periphery boundary is the local scale of departure.

It is the active edge of the current enclosure. It is governed by the geometry of the Isotropic Vector Matrix and coordinates the accumulation of contracted and expanded configurations. When local saturation is reached, the periphery boundary triggers scale escalation or de-escalation through Jitterbug transformation.

The inner boundary is the quantized core.

It is the zero-phase transition boundary inside the Zero Infinity framework. Because the zero state represents perfect equalization of pressure fields, a physical metric can pass through the boundary but cannot statically reside there. Approach to the zero phase drives deterministic geometric rebound.

These three boundaries are not optional additions to the theory.

They are what allow the theory to stop.

Every science requires a way to stop. A measurement stops. A computation stops. A model stops. A claim stops at the edge of its evidence. A physical system stops being described by one enclosure when it transitions into another.

The inherited map often hides this stopping condition. It lets space be smooth without limit, probability spread without native enclosure, vacuum energy accumulate without cancellation, and origin stories speak beyond the data.

The nested map makes the boundary visible.

That is where a computation can begin.

## What Must Cross the Boundary

Imagine a simulation of a contracting region. At first, its chosen variables describe the region well. Density increases, energy moves, and the time evolution can be followed at the selected resolution. Eventually a threshold is approached at which the current description requests a change of tier. The program now needs more than an instruction to stop.

It needs an incoming state, a criterion for crossing, a rule for assigning the outgoing state, and an exchange account connecting the two. It needs to know whether the new tier changes the units, the resolution, the effective degrees of freedom, or the geometry. It needs to retain whatever conserved quantities the proposed physics requires. Without these specifications, a halt is the end of the program rather than the continuation of the system.

The outer, periphery, and inner entries organize those requirements. The outer entry records the active boundary data and the frontier of justified continuation. The periphery records the current domain in which departure is being evolved. The inner entry records the local reference and compactification conditions. These names do not create three additional directions of causality. They locate different responsibilities within one nested account.

The distinction between *ff* and *FF* is particularly useful here. A numerical run can reach *FF* because a coupling is unspecified. It must then report an unresolved continuation. It cannot promote that missing input into a discovered physical wall. Conversely, a physical transition specified by the model may occur well inside the region that the numerical method can resolve. The two boundaries need not coincide.

A finite model also needs a convergence test. Expand the retained outer environment or resolve an additional internal layer. Does the predicted observable stabilize? If it changes substantially, the previous boundary omitted an active relation. If the change is smaller than the declared tolerance across suitable refinements, the chosen truncation has earned a limited authority. That is a measurable way to keep infinite nesting from becoming an infinite prerequisite.

There is a corresponding test of the exchange. Follow a contribution through one compactification and then through a second. It must not vanish merely because its label changes. It must not be counted twice because it appears at two addresses. The map can refer to a state many times; the physical account must retain its identity. This is one reason to represent the nesting as addressed relations rather than to duplicate an entire universe at every branch.

Finally, a singularity-resolution claim needs a continuation that remains meaningful in the variables that matter. Removing a divergent printed number by imposing a cutoff is insufficient. The model must show what replaces the problematic evolution and how observable quantities proceed. A rebound may be the intended outcome, but its existence, conditions, and stability belong in the calculated trajectory.

The unified architecture makes these requirements visible in one place. It ties the reference, the physical transition, and the authority of the computation together without confusing them. An investigator can now say exactly why a run stopped, what it established before stopping, and which observation or specification would allow it to continue. A boundary becomes productive when it leaves the next question at a known address.

# Chapter 17: Predictive Pluralism

Parallel origin stories are not included as a courtesy.

They are included because prediction improves when plausible enclosures are allowed to operate beside one another.

Each origin narrative illuminates a different region of the data. The Big Bang is powerful for the thermal history of the early visible universe. The Great Pull is powerful for large-scale directional organization. Cyclic models may illuminate recurrence and boundary transition. Quantum boundary models may illuminate collapse, singularity avoidance, and scale escalation.

The task is not to crown one story before the work begins.

The task is to compare their predictive contributions after each has been properly enclosed.

This is predictive pluralism.

It differs from ordinary pluralism because it is not based on tolerance alone. It is not saying that all models deserve equal time. It is saying that models should be retained when they add measurable predictive capacity and discarded or demoted when they do not.

Nested causality gives this pluralism structure. The Departure Calculus gives it notation. The Zero Infinity gives it a common reference. The Final Frontier gives it a boundary. The Great Pull gives it a large-scale organizing alternative. The standard Big Bang model gives it an existing interior model of great value.

Together they form a stronger field than any single origin myth can provide.

A mature cosmology should not fear multiple beginnings.

It should fear premature closure.

## A Comparison That Can Change Its Mind

Imagine a catalog of galaxies divided before the models are fitted. One portion is used to estimate parameters; another is retained for prediction. The division respects shared calibrations and correlated observations, so that information from the test set does not quietly enter the training set. Each model receives the same observational definitions and the same opportunity to state its uncertainty.

One model describes the results through the usual cosmological relation and nuisance corrections. A second adds an enclosure variable defined from the environment. A third uses a different expansion modification. Their predictions now meet observations that did not determine their parameters. The comparison has become capable of disappointing its designers.

Several outcomes are possible. The enclosure variable may predict a residual that the other models miss. It may improve the fitted data and fail on the held-out set. Its advantage may disappear when a known calibration effect is included. It may help in one domain and add no value elsewhere. Each outcome says something more precise than ‘the framework works’ or ‘the framework fails.’ It locates the authority of a particular construction.

The cost of added freedom belongs in this account. A model that can give every observation its own enclosing parameter can reproduce almost anything after the fact. Such a fit has not yet discovered the organization of the

sky. The important relation is one that uses a restricted, physically specified set of conditions to predict differences it was not individually adjusted to reproduce.

Predictive pluralism also requires remembering which data have already been spent. If the Hubble discrepancy motivates a two-tier model and fixes its two endpoint values, reproducing those values is calibration. Predicting an independent environmental pattern is a further accomplishment. If the same evidence is used again under a new chapter title, its evidential weight has not doubled.

There is room for a model that is not yet ready for a full fit. It can specify a mechanism, identify missing inputs, and make a restricted prediction. That is a legitimate research position. It becomes misleading only if its undeveloped regions are counted as demonstrated successes. The map should show the result and the next dependency in different places.

This procedure also changes how a negative result is used. Suppose a particular hyperbolic closure fails while the independently defined enclosure variable remains predictive. The function needs revision; the structural relation may remain valuable. Suppose no reasonable specification of the relation improves the prediction. Then the field has learned a stronger limit. Preserving the distinction lets inquiry accumulate rather than alternate between enthusiasm and wholesale abandonment.

Comparison can extend across domains. A curvature rule chosen to address expansion may affect structure growth. A vacuum residual may imply an equation of state. A quantum transition may imply laboratory departures. The model grows stronger when one specified mechanism meets several independent constraints. It grows weaker when each new observation requires an unrelated repair with no shared reason.

The public value of this method is substantial. A reader can inspect what was measured, what was assumed, what was fitted, and what was predicted. The invitation to another investigator is practical: here is the boundary of the claim, and here is a comparison that could move it. Cosmology becomes a common investigation rather than a contest between protected beginnings.

The plurality is therefore temporary wherever evidence can decide, and durable wherever it cannot. It is not a promise to keep every story forever. It is a promise to let observations, calculations, and their lawful boundaries do the selecting.

## Chapter 18: Enclose Your Field

The method extends beyond cosmology.

Every field has an enclosure. It has assumptions it treats as fundamental, methods it treats as legitimate, and questions it treats as outside its scope. These boundaries are necessary. Without them, inquiry dissolves. But when the boundaries become invisible, the field begins to mistake its current enclosure for reality itself.

The task is not to destroy the field.

The task is to enclose it.

First, map the current enclosure. What does the field assume? What does it measure? What does it refuse to ask? Which problems remain unsolved because they sit at the boundary of the current map?

Second, identify the outer structures already acting on the field. In cosmology, these include the Final Frontier, the Zero Infinity, the Great Pull, and the scale-dependent nature of observation. In other disciplines, the outer structures will differ, but the method remains.

Third, add the minimum structure required to make those outer influences explicit.

Fourth, leave the successful models intact. Move the unsolved boundary problems into the larger enclosure.

Fifth, test for predictive gain.

This is how science grows without burning down what it has built. The Standard Model need not be discarded. General Relativity need not be discarded. The Big Bang need not be discarded. Each can be placed where it belongs and strengthened by the larger architecture that holds it.

The frontier is not closed.

It has only been incompletely enclosed.

### An Intervention in the Investigation

We can now carry the method through one concrete research problem. Begin with a catalog of expansion-related observations whose interpretation leaves a structured residual. The focal state is the mismatch between a specified prediction and those observations. The model's enclosing side includes calibration, selection, assumed geometry, and the physical environment. Its enclosed side includes the measured quantities and the transformations that produce the reported result.

Opening those positions reveals which dependencies are active. Two measurements may share an anchor and therefore not be independent. A source's environment may enter through a correction. A redshift-to-distance relation may carry an assumption that was invisible in the final table. Mapping does not decide in advance which dependency caused the mismatch. It makes the candidates distinguishable.

The interesting relation then becomes a controlled comparison. Retain the observations and their calibration. Change one specified enclosure assumption. Recompute the prediction. If the residual changes, trace the reason through the model. If it does not, that relation is not doing the proposed work at the resolution of this inquiry. The calculation has begun to identify a causal switch in the investigation.

An intervention emerges when a changeable condition can be connected to an improved, independently testable result. In this case the researcher cannot rearrange the cosmic environment. The intervention is in the scientific apparatus of interpretation: add the missing address, preserve the original measurement, and test whether the revised treatment predicts new observations. The world being studied and the method used to study it remain distinct enclosures.

That distinction limits human control without limiting investigation. We can change catalog design, observing strategy, computational resolution, and the assumptions we test. We cannot assign galaxies new histories by decree. The gain is to spend our changeable effort where the map shows a missing relation, rather than demand that the territory conform to the instrument we already have.

The levels of modelling arise through this progression. A list of conditions becomes a mapped relation. Refinement exposes intermediate and parallel enclosures. A changeable dependency becomes visible. A proposed intervention acquires a path, an outcome, a comparison, and a return or revision condition. The level is a consequence of what the map now supports. It was not achieved by labeling the first idea Level 4.

For the cosmological example, the completed intervention record would identify the dataset, the original analysis, the added enclosure variable, the method for assigning it independently, the retained controls, the withheld observations, and the rule for judging predictive improvement. It would also specify what happens if the improvement fails: preserve the measurements, report the tested limit, and reopen the active relation. No cosmological result is improved by concealing its unsuccessful alternatives.

The same operation can be used on the vacuum calculation. Identify the sum being performed, its reference, its source interpretation, and the receiving account. Introduce the proposed pairing rule. Follow the residual and its evolution. Compare with known limits. A claim about cancellation becomes a sequence another person can inspect rather than a slogan another person must accept.

This is the force of ‘enclose your field.’ It does not instruct a scientist to leave the field for a philosophy. It asks the scientist to make the conditions of the existing work available to investigation. What had looked like an impossible problem inside one description may become a tractable relation between that description and what supports it.

## Chapter 19: Verification Pathways

The model must expose itself to tests.

The first pathway begins with the scale relationships already observed. Map the emitting region, the intervening gas and dust, the gravitational geometry, and the conditions of reception. Follow their contributions through the calculation to the measured image and spectrum. The map earns its precision by identifying active conditions, preserving their distinct mechanisms, and making their combined consequences inspectable. A continuous transition is as available to this inquiry as a sharply resolved one.

The second pathway follows the apparatus. Map the mechanically participating domain during preparation, calculate its recoil, and determine which degrees of freedom remain under coherent control. The acoustic-horizon construction gives scale an experimental address. A proposed additional coupling or bounded probability envelope can then be investigated against that specified baseline. Additional suppression is a quantitative hypothesis, rather than a necessary condition for recognizing the apparatus enclosure.

The third pathway is improved Hubble modeling through scale-tier placement. If  $H(L)$  is a better description than a single global value, then local and global expansion measurements should sort more coherently when assigned to their proper enclosure scales.

The fourth pathway is comparative prediction across parallel origin models. The Big Bang, Great Pull, cyclic, quantum-boundary, and other plausible models should be tested not only one against another, but also in nested combination. The question is whether the combined architecture predicts more accurately than any single enforced origin narrative.

The mapped relationships, their established calculations, and the additional predictions belong in the same investigation with their different jobs visible.

A theory that cannot be tested becomes another myth. A theory that can be tested but refuses comparison becomes an institution. A theory that invites comparison across nested enclosures remains scientific.

That is the standard this volume asks cosmology to meet.

### From a Signature to a Test

An optical test can begin with a cloud whose effects are independently characterized. Predict the transmitted spectrum and scattered image, then compare them with observation. A lensing calculation can likewise retain the source, intervening mass, and observer in their proper relations. Such tests examine whether the enclosure map has included the conditions needed to recover the observed result. Their success establishes the adequacy of that map for its declared task. The framework can organize established results as well as guide new predictions.

Redshift quantization would be a separate proposal. Recursive addressing alone does not require spectral steps, and a countable set of model addresses does not make a continuously propagating photon jump between frequencies. A search for steps becomes justified when a particular dynamical construction predicts their spacing, magnitude, or environmental dependence. The nested-scale principle is broader than that possible signature. Nebulae, dust clouds, lensing, and redshift already give the inquiry observable relationships to follow.

The probability-envelope proposal needs the same specificity. Define the apparatus, state preparation, ordinary boundary conditions, and detector acceptance. State where the proposed enclosure adds suppression and how that addition scales when the geometry changes. A physical boundary that has already entered the Hamiltonian cannot be counted again as evidence for a new filter. The discriminating measurement is the residual beyond the ordinary calculation, with systematic effects bounded.

The Hubble proposal needs independently assigned enclosures and shared treatment of calibration uncertainty. A useful first test may compare environmental subsets, but the subsets should not be defined by the expansion result they are supposed to explain. Publish the assignment rule before testing it against the held-out observations. The model should make a prediction about how the residual changes, not merely promise that some grouping will eventually reveal a pattern.

The vacuum proposal needs both magnitude and history. An inverse-square scale can generate the right order of energy density at one epoch. The evolution of that scale determines what the model predicts at others. A complete comparison follows the resulting expansion, structure growth, and pressure relation. It also checks whether the paired-state prescription preserves relevant local quantum predictions. The transition between cosmological and laboratory claims is itself part of the nesting that must be mapped.

The early-galaxy proposal must compare populations rather than select one striking image. Spectroscopic confirmation, completeness, luminosity, inferred stellar mass, and population modelling belong in separate entries. A cosmological change should improve the distribution predicted under a specified observing program. It must compete with changes in the astrophysical process that could produce the same observed brightness. The most interesting result is a difference that those alternatives cannot reproduce under the same constraints.

Finally, the singularity proposal needs an explicit trajectory through the transition. State the initial conditions, the threshold, the transfer law, and the outgoing state. Check conserved quantities and relevant curvature measures. Refine the numerical resolution and test whether the result persists. If the apparent rebound moves arbitrarily with the computational cutoff, the program has found its own boundary rather than the proposed physical one.

These tests need not all be conducted by one person. Their common structure makes collaboration possible. An observer can improve an environmental measurement, a theorist can specify a coupling, and a numerical researcher can test a transition without each having to endorse an absolute origin. They can agree on the local question and report what it establishes.

The shared record should contain the successful comparison and the failed one, the chosen parameters and the alternatives examined, the domain tested and the boundary left open. This is how a speculative relation becomes a public scientific object. Someone else can take it apart, rebuild it, and discover something its author did not anticipate.

The purpose of verification is not to drain the ambition from a model. It gives ambition a route into the world. A claim large enough to change cosmology deserves a test precise enough to change the claim. The work becomes serious at the point where both changes are possible.

## Chapter 20: A Calculus That Can Be Followed

An enclosure becomes calculable when its boundaries, its contents, and its exchanges have explicit representations. We can construct such a representation without requiring every physical system to have the same mechanism. The address stays the same while the equations appropriate to its contents remain available.

This chapter supplies a conditional mathematical realization of the volume's proposals. Its assumptions are stated where they enter. The resulting identities and conservation checks follow from those assumptions; whether a particular physical system realizes them is a further question answered by measurement.

### Address, Depth, and Motion

The recursive address remains

$$\Psi_n = [\Psi_{n+1} \mid \sigma_n \mid \Psi_{n-1}].$$

An address identifies relationships. To calculate motion, assign states to those relationships. For a finite model with frontier FF, one possible dimensionless depth is

$$d(t) = \sum_{n=1}^{N_{\text{FF}}} \frac{a_n(t)}{n}, \quad -1 \leq a_n(t) \leq 1.$$

Here  $a_n$  is a normalized physical departure, not merely its sign. Its normalization must name a measured variable and reference. This allows continuous evolution within an address. The bound follows directly:

$$|d(t)| \leq \sum_{n=1}^{N_{\text{FF}}} \frac{1}{n}.$$

The harmonic weights are a chosen closure, not a unique consequence of nesting. For computations confined to one active tier,  $d$  can instead be specified directly as a dimensionless state variable. These alternatives must not be combined by independently prescribing incompatible values of the same depth.

The universal frontier ff is not this finite numerical cutoff. The calculation ends at the authority declared for its own map.

### Curvature With Its Sign Intact

Retain the proposed curvature relation and give its normalization a definite form:

$$\mathcal{K}(L, d) = \frac{L^2}{\zeta \tanh d}, \quad \zeta = \frac{L^4}{\kappa}, \quad \mathcal{K} = \frac{\kappa}{L^2} \coth d.$$

The coefficient  $\kappa$  is dimensionless. The positive and negative branches satisfy

$$\mathcal{K} \rightarrow \frac{\kappa \operatorname{sign}(d)}{L^2} \quad (|d| \rightarrow \infty), \quad \mathcal{K} \sim \frac{\kappa}{L^2 d} \quad (d \rightarrow 0).$$

The odd sign is part of the construction. A negative branch cannot silently be assigned the positive branch's cosmological source.

The hyperbolic function is a useful constitutive choice. The dimensions and limits do not uniquely select it:  $\sqrt{1 + d^2}/d$  has the same limiting forms. A working model chooses one function, fixes its coefficients, and carries that choice through every comparison.

For a VE-inspired normalization one may set  $\kappa = 12/(2\pi) = 6/\pi$ . The twelve radii motivate the numerator; dividing by  $2\pi$  is an additional normalization convention. The following calculations can use it without representing that convention as a theorem about gravity.

## A Finite Transition With an Explicit Reset

The expression at  $d = 0$  is singular. A bounded trajectory therefore needs a law of motion that reaches a nonzero transition threshold and a reset that places it outside the next threshold. Here is one fully specified finite-state example.

On tier  $n$ , let  $L_n > 0$ , choose  $0 < d_{\text{in}} < d_{\text{out}}$ , and evolve

$$\dot{d} = -\nu_n \operatorname{sign}(d), \quad \nu_n > 0,$$

until  $|d| = d_{\text{in}}$ . At that event apply

$$L' = s_n L, \quad d' = -\operatorname{sign}(d) d_{\text{out}}, \quad \sigma' = -\sigma,$$

where  $s_n$  is a specified positive scale ratio, for example  $\varphi$  or  $\varphi^{-1}$ . The outgoing sign reverses and the magnitude is reset outside the trigger. The next event takes

$$\Delta t_n = \frac{d_{\text{out}} - d_{\text{in}}}{\nu_n} > 0.$$

For finitely many retained tiers with  $L_n \geq L_{\text{min}} > 0$  and bounded rates, this excludes an accumulation of infinitely many events in finite time. It also gives the explicit bound

$$|\mathcal{K}| \leq \frac{|\kappa|}{L_{\text{min}}^2} \coth d_{\text{in}}.$$

For example,  $d_{\text{in}} = 0.1$ ,  $d_{\text{out}} = 0.2$ , and  $\nu_n = 0.01$  per chosen time unit give ten time units between crossings. These values demonstrate an executable transition, not a measured cosmological threshold.

The earlier proposed transformation  $d' = -dL/L'$  preserves  $|Ld|$  and reverses  $Ld$ . It does not generally put the trajectory outside the next trigger. The reset above makes that missing operation explicit. It does not assert conservation of  $Ld$ : energy conservation belongs to the source ledger below, not to an arbitrarily chosen coordinate product.

## The Energy Ledger Supplies the Exchange

Use mass density  $\rho$  and pressure  $p$  for ordinary matter. The enclosure source corresponding to  $\mathcal{K}$  has energy density and pressure

$$\varepsilon_{\text{enc}} = \frac{c^4}{8\pi G} \mathcal{K}, \quad p_{\text{enc}} = -\varepsilon_{\text{enc}}.$$

In a homogeneous isotropic calculation, its conservation partner is

$$\dot{\rho} + 3H \left( \rho + \frac{p}{c^2} \right) = -\frac{c^2}{8\pi G} \dot{\mathcal{K}}.$$

The two contributions exchange exactly the amount that leaves the other. The pressure relation  $w = -1$  can hold for this interacting source even while its density changes; separate conservation would instead force  $\dot{\mathcal{K}} = 0$ .

Across an idealized instantaneous change, with finite  $H$ ,  $a$ , and pressure, integrating this equation gives

$$\Delta\rho = -\frac{c^2}{8\pi G} \Delta\mathcal{K}.$$

Substituting into the Friedmann constraint shows

$$\Delta(H^2) = \frac{8\pi G}{3} \Delta\rho + \frac{c^2}{3} \Delta\mathcal{K} = 0.$$

The exchange therefore preserves the constraint at the reset. Any candidate transition that would make the required ordinary density negative lies outside this particular matter closure and must not be executed under it.

A smooth transition is also available. Interpolate  $\mathcal{K}$  between its endpoint values with a finite smooth switching function and solve

$$\dot{a} = aH, \quad \dot{H} = -4\pi G \left( \rho + \frac{p}{c^2} \right) + \frac{kc^2}{a^2},$$

together with the exchange equation and a specified equation of state. Starting from

$$H^2 = \frac{8\pi G}{3} \rho + \frac{c^2}{3} \mathcal{K} - \frac{kc^2}{a^2},$$

differentiation shows that the constraint remains satisfied. Thus the source exchange and expansion equations form a closed initial-value calculation once the switching schedule and matter equation of state are chosen. This supplies a homogeneous realization; a general spacetime junction also requires metric matching and any surface stresses to be specified.

## Calculating the Square Suppression

An area count by itself supplies only one power of the length ratio when divided by a volume count. A second power follows if the surviving boundary degrees of freedom carry energy at the enclosing scale rather than the Planck scale. That is a concrete spectral assumption we can calculate.

Consider a spherical enclosure of radius  $L$ . Assume pairing leaves an effective boundary count

$$N_{\partial} = \eta \frac{A}{\ell_P^2}, \quad A = 4\pi L^2,$$

and that the average energy of each surviving degree of freedom is

$$\overline{E} = \alpha \frac{\hbar c}{L}.$$

Here  $\eta$  describes the effective surviving count and  $\alpha$  the spectrum's energy coefficient. With  $V = 4\pi L^3/3$ ,

$$\varepsilon_{\text{res}} = \frac{N_{\partial} \overline{E}}{V} = 3\eta\alpha \frac{\hbar c}{\ell_P^2 L^2} = 3\eta\alpha \frac{c^4}{GL^2}.$$

Consequently,

$$\frac{\varepsilon_{\text{res}}}{\varepsilon_P} = 3\eta\alpha \left( \frac{\ell_P}{L} \right)^2, \quad \varepsilon_P = \frac{\hbar c}{\ell_P^4}.$$

The two factors now have explicit origins. Boundary counting contributes  $\ell_P/L$  relative to a volume count. Replacing the characteristic Planck energy  $\hbar c/\ell_P$  with the enclosure energy  $\hbar c/L$  contributes the other. No second suppression factor has been obtained merely by naming a transfer.

This realizes the proposed residual under an area-counting and enclosing-wavelength assumption. It does not yet derive those assumptions from a microscopic mode-pairing Hamiltonian. It tells that Hamiltonian exactly what spectrum and state count it must produce.

Identifying this residual with the positive stable curvature source gives

$$\chi = 3\eta\alpha = \frac{\kappa}{8\pi}.$$

For the VE-inspired choice  $\kappa = 6/\pi$ , this requires  $\eta\alpha = 1/(4\pi^2)$ . At  $L = c/H_0$  the resulting fraction of critical density is  $2/\pi \simeq 0.6366$ . Re-expressing it as curvature does not change that fraction or close a difference from an observed value. The count and spectrum offer a place to investigate the coefficient rather than conceal it.

The construction concerns the gravitationally active residual. Laboratory boundary-energy differences remain a separate calculation with their actual mode spectrum and boundary conditions. Keeping that laboratory calculation intact is compatible with the proposed separation of local energy differences from a cosmological source; replacing it by the spherical residual formula would require a further derivation.

## What Scale Difference Would Produce the Expansion Difference?

Compare two positive stable tiers at the same ordinary density and spatial-curvature contribution. Write  $L_{\text{loc}} = L_H/r$  and  $L_H = c/H_{\text{CMB}}$ . Subtracting the two Friedmann constraints gives

$$\frac{H_{\text{loc}}^2}{H_{\text{CMB}}^2} - 1 = \frac{\kappa}{3}(r^2 - 1).$$

For  $r = \varphi$  and  $\kappa = 6/\pi$ , the right side is  $2\varphi/\pi \simeq 1.0301$ . The expansion ratio is then approximately 1.4248. This particular adjacent-tier identification does not give the quoted Hubble difference.

Instead solve the same equation for the physical scale ratio required by the quoted estimates:

$$r = \sqrt{1 + \frac{3}{\kappa} \left[ \left( \frac{73.04}{67.4} \right)^2 - 1 \right]} \simeq 1.1287.$$

Thus the model can represent that difference with a local scale approximately 0.886 times the reference scale under these assumptions. This is an inverse calculation: the expansion numbers determine a target for independent environmental mapping. If that mapping returns a different ratio, the equal-matter two-tier construction has not explained the observations.

With unequal matter and curvature contributions, the full comparison is

$$\Delta H^2 = \frac{8\pi G}{3} \Delta \rho + \frac{c^2}{3} \Delta \mathcal{K} - c^2 \Delta \left( \frac{k}{a^2} \right).$$

Each additional contribution must be assigned independently. A logistic interpolation between measured end-points is a statistical model, not a substitute for this physical calculation.

## A Transfer That Preserves the Whole State

Let  $P$  project onto the paired subspace and  $Q = I - P$  onto its complement. Let  $U$  be an isometry from  $P\mathcal{H}_n$  into a distinct receiving space  $\mathcal{H}_{n+1}$ . The complete transfer is

$$V\psi = Q\psi \oplus UP\psi.$$

The direct sum makes the destinations orthogonal. Since  $U^\dagger U = I$  on the paired subspace,

$$V^\dagger V = Q + PU^\dagger UP = Q + P = I.$$

Norm is preserved for every input, including a state lying entirely in the transferred subspace. In contrast, applying  $UQ$  would remove that state before it could be transferred.

For a density operator, the complete evolution is  $\rho \mapsto V\rho V^\dagger$ , which preserves trace and positivity. If only the active tier is observed, its unnormalized block is  $Q\rho Q$ . Its trace is the probability assigned to that sector; it is not the complete probability of the experiment.

More generally, a record can be described by outcome operators  $M_j$  satisfying

$$\sum_j M_j^\dagger M_j = I, \quad p_j = \text{Tr}(M_j \rho M_j^\dagger).$$

This supplies a consistent quantum instrument when the apparatus defines the  $M_j$ . It does not derive a unique outcome rule from the ternary notation. The construction retains ordinary quantum probabilities while making the receiving enclosure explicit.

Energy conservation can be implemented, rather than merely requested, by choosing the receiving Hamiltonian so that

$$H_{n+1}U = UH_P,$$

where  $H_P$  is the Hamiltonian restricted to an invariant paired subspace. If the original Hamiltonian is block diagonal on  $P$  and  $Q$ , then

$$V^\dagger(H_Q \oplus H_{n+1})V = H_n.$$

The same intertwining construction preserves momentum and other compatible charges. Where the sectors interact, the interaction and apparatus must enter the total Hamiltonian. A change in the reduced particle account is not permission to omit their exchange.

## What Has Been Constructed

We now have a finite transition rule with an explicit curvature bound, an exchange equation preserving the homogeneous gravitational constraint, a conditional mode count producing square suppression, an exact scale-ratio calculation for the expansion comparison, and an isometric transfer preserving quantum norm and compatible conserved quantities.

These constructions give the proposed mechanisms mathematical forms that can be computed. Their physical parameters and microscopic realization remain questions for the enclosures being modeled. The distinction is productive: the algebra tells us what follows; observation tells us which construction the world uses.

# Epilogue: We Begin Again

We began with the oldest light.

We end with the same sky, but the map has changed.

The Big Bang remains inside it. The cosmic microwave background remains inside it. Expansion, nucleosynthesis, galaxies, filaments, voids, quantum uncertainty, and the strange persistence of large-scale order all remain inside it. Nothing valuable has been thrown away.

The enclosure has simply grown large enough to hold more than one origin story at a time.

This is the necessary humility of cosmology. The origin of the universe cannot be possessed by information from inside the universe. It can only be approached through models, each bounded by the Final Frontier, each tested by the predictions it makes possible in the present.

The old map asked for one beginning.

The nested map asks for every plausible beginning that improves the work.

The Final Frontier remains. The Zero Infinity remains. The Great Pull remains. The oldest light still arrives, not as command but as evidence, one signal among many inside the larger enclosure.

We are not trying to prove that the universe began in the way preferred by this or that school. We are updating the map with data and structure that no longer fit inside a single origin myth.

The origin was never behind us in the way we were told.

It was the boundary we had mistaken for the world.

# Appendix A: The Reference and the Address

The canonical ternary order is

$$[\text{enclosing relation} \mid \text{focal departure} \mid \text{enclosed relations}].$$

The outer positions can each be opened into another ternary function. Repeated addresses refer to the same modeled relation; they do not duplicate its physical content. A practical model expands the active relations and records unresolved branches at its declared FF.

The balanced reference is

$$[[\text{ff} \mid -1 \mid \text{ff}] \mid \text{ve} \mid [\text{ff} \mid +1 \mid \text{ff}]] = 0\infty.$$

The local Vector Equilibrium and the scalable Zero Infinity have different roles. The first supplies a geometric expression of balance at a tier. The second supplies the recursively available reference architecture. Lowercase ff denotes the framework's deterministic frontier; uppercase FF denotes the stated boundary of this model's knowledge.

For each use of a signed departure, specify the physical variable, its units, the reference, and the rule assigning the sign. For each compactification, specify the paired states, the residual, the receiving tier, and the preserved quantities. This information makes the same notation useful in different physical settings without pretending that their measurements are interchangeable.

## Appendix B: Curvature, Conservation, and Continuation

The proposed curvature term is

$$\mathcal{K}(L, d) = \frac{L^2}{\zeta \tanh d}, \quad [\mathcal{K}] = \text{length}^{-2}, \quad [\zeta] = \text{length}^4.$$

For fixed nonzero  $L$  and finite nonzero  $\zeta$ , this expression diverges as  $d$  approaches zero. The proposed tier transition must act through a separately specified continuation law. The expression alone does not prove bounded curvature or a rebound.

Taking the covariant divergence of

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

with constant  $G$  and  $c$  gives

$$\partial_\nu \mathcal{K} = \frac{8\pi G}{c^4} \nabla^\mu T_{\mu\nu}.$$

If ordinary matter is separately conserved, a spacetime-varying  $\mathcal{K}$  requires an additional stress-energy or exchange account. Equivalently, moving the curvature term to the source side defines

$$T_{\mu\nu}^{\text{enc}} = -\frac{c^4}{8\pi G} \mathcal{K}g_{\mu\nu}, \quad \nabla^\mu (T_{\mu\nu} + T_{\mu\nu}^{\text{enc}}) = 0.$$

This is a consistency relation for the proposed construction, not a choice of its missing dynamics. A completed model must state how the source components evolve and exchange. It must also distinguish a physical scale dependence from a scale chosen only for smoothing or reporting data.

At a transition, a reproducible calculation records the incoming state, crossing criterion, outgoing state, and exchange ledger. It tests the result under refined resolution and checks that quantities required to remain finite actually do so. A computational halt and a physical continuation are different results.

# Appendix C: The Vacuum Residual and the Quantum Filter

Use  $\varepsilon$  for energy density here to keep it distinct from mass density. The proposed toy scaling is

$$\delta\varepsilon(L) = \chi\varepsilon_P(\ell_P/L)^2 = \chi\frac{c^4}{GL^2}.$$

For  $L_H = c/H_0$ , comparison with the dark-energy density of a flat reference cosmology gives

$$\varepsilon_\Lambda = \Omega_\Lambda \frac{3H_0^2 c^2}{8\pi G}, \quad \chi = \frac{3\Omega_\Lambda}{8\pi}$$

if the residual is calibrated to that value. This equality is a calibration relation, not an independent derivation of  $\Omega_\Lambda$ . Predicting the coefficient from the enclosure geometry would be an additional result.

An area-to-volume ratio contributes one power of  $\ell_P/L$ . The additional compactification factor needed for the square suppression must be specified. Its physical origin, the definition of  $L$  through cosmic time, and the resulting equation of state determine whether the toy scaling becomes a cosmological model.

For the quantum construction, the corrected address is

$$\Psi_{\text{total}} = [\Psi_{\text{enclosing}} \mid \Psi_{\text{departure}}(t) \mid \Psi_{\text{enclosed}}].$$

A real constant scalar filter  $e$  applied to a self-adjoint Hamiltonian produces the evolution

$$\psi(t) = \exp(-ie\widehat{H}t/\hbar)\psi(0).$$

It preserves norm and rescales the evolution rate. An outcome-producing compactification therefore requires a transition specification beyond that scalar suppression. An operator-valued filter must state its domain, normalization behavior, and exchange with the enclosing system. The reference  $0\infty$  is not a numerical zero used as a divisor.

These relations make the proposed solutions inspectable. They retain the reference, paired-state, and tier-transition claims while identifying the calculations by which their physical consequences can be established.

## Appendix D: The Participating Apparatus

The acoustic-horizon example joins a conservation calculation to the operational scale construction in *The Return of Scale*. The calculation supplies a baseline; the construction identifies the participating enclosure and a possible additional channel.<sup>1920</sup>

### Recoil and Visibility

For particle mass  $m$ , branch separation  $d$ , and participating apparatus mass  $M$ , the compensating displacement is

$$D = \frac{md}{M}.$$

For a harmonically confined apparatus center of mass in a thermal state, define

$$a_c = \frac{\hbar}{M\omega}, \quad \epsilon = \frac{\hbar\omega}{k_B T}.$$

The overlap of its branch-dependent recoil states gives the balanced-interferometer visibility

$$V_{\text{recoil}} = |\chi_c| = \exp\left[-\frac{D^2}{4a_c} \coth\left(\frac{\epsilon}{2}\right)\right].$$

This describes the particle after the apparatus center of mass is traced out. If the complete branches remain coherently controlled and can be recombined, reduced visibility need not represent irreversible loss of the complete system's coherence.

### Finding the Participating Mass

For an approximately homogeneous material, preparation time supplies the acoustic reach

$$R_{\text{ac}} = c_s \tau_{\text{prep}}.$$

A mechanical correlation criterion further restricts the participating region:

$$\Omega_n(\tau_{\text{prep}}) = \{x : |x - x_0| \leq c_s \tau_{\text{prep}}, \mathcal{C}_n(x) \geq C_{*,n}\}.$$

Its mass is

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<sup>19</sup>Céleri, Soares-Pinto, and Turolla Vanzella, “The Apparatus Strikes Back” (2026), <https://arxiv.org/abs/2607.08819>. This is the source of the retained recoil calculation and acoustic-horizon observation.

<sup>20</sup>Hubbard, *The Return of Scale* (2026), <https://doi.org/10.5281/zenodo.21381025>. The operational participation classes and proposed additional-channel construction are developed there.

$$M_n = \int_{\Omega_n} \rho_{\text{app}}(x) d^3x.$$

The criterion must describe correlation or rigidity on the operation's timescale. For heterogeneous materials, measured propagation and transfer functions replace a single spherical approximation. Density, elastic response, joints, geometry, and time enter the calculation together. The address changes when another resolved domain participates; elastic motion within it remains continuous.

## A Proposed Additional Channel

The paper represents exclusive participation classes by  $\mathcal{H}_{\text{scale}} = \bigoplus_n \mathcal{H}_n$ . Center-of-mass, internal, and environmental degrees of freedom remain explicitly accounted for. A transfer map  $J_n : \mathcal{H}_n \rightarrow \mathcal{H}_{n+1}$  enters through a coupling  $g_n J_n + g_n^* J_n^\dagger$ . Conservation remains binding:

$$[H_{\text{tot}}, \widehat{P}_{\text{total}}] = 0.$$

Energy and other conserved charges must likewise be carried through the transfer. Let  $\delta\rho(x, t) = \rho_+(x, t) - \rho_-(x, t)$  describe the difference between the complete particle-apparatus branch configurations. The proposed contrast measure is

$$\Delta E_G^{\text{comp}}(t) = \frac{G}{2} \iint \frac{\delta\rho(x, t)\delta\rho(y, t)}{|x - y|} d^3x d^3y.$$

With normalized record participation  $r_n(t)$ , define

$$b_n(t) = \int_0^t \frac{\Delta E_G^{\text{comp}}(t')}{\hbar} r_n(t') dt', \quad g_n(t) = g_{0,n} F_n \left( \frac{b_n(t)}{b_{*,n}} \right).$$

The accumulation  $b_n$  is dimensionless. It organizes a proposed coupling; it does not independently establish a collapse law. The coupling function, strength, and threshold require physical specification or independent calibration. Modes already responsible for ordinary decoherence cannot be counted again as a new loss.

Coherent transfer need not produce irreversible decay. Under a suitable weak-coupling reduction, with unresolved destination states of density  $\varrho_{n+1}(E)$ , a rate may take the form

$$\Gamma_{\text{scale}}^{(n)} = \frac{2\pi}{\hbar} |g_n|^2 \varrho_{n+1}(E).$$

Where the channels can be separated, this permits

$$V = V_{\text{recoil}} V_{\text{env}} \exp \left[ - \int \Gamma_{\text{scale}}(t) dt \right], \quad V_{\text{residual}} = \frac{V_{\text{observed}}}{V_{\text{recoil}} V_{\text{env}}}.$$

The ratio accounts for recoil rather than removing the physical event. Coupled channels require a joint calculation. The baseline must remain sufficiently measurable for the ratio and its uncertainty to be useful.

## **Opening the Address Experimentally**

Characterize preparation, confinement, temperature, participating mass, and ordinary environmental losses. Vary preparation time or mechanical connectivity, carrying the changed recoil prediction into every comparison. Matched arrangements can then test whether any additional contribution follows the mapped domain across independently characterized apparatuses.

The contribution already available is a calculation chain: which apparatus participates, what recoil follows, what remains coherently controlled, and what additional channel is being investigated? The paper supplies a test architecture, not a report of an experimentally observed residual. A null result constrains the proposed coupling while leaving the measured acoustic participation and conservation calculation intact.

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