

# Observers Who Read Their Universe into Existence: Finite Consensus, an Executable Observer, and Standard Physics

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## Abstract

Observer Patch Holography (OPH) proposes that physics is what bounded observers can establish together: finite patches compare records on shared boundaries, repair disagreements, and treat as objective whatever survives every comparison. The universe, on this view, is a timeless self-referential structure whose observers recover its specification from their records and realize it, so that it reads itself into existence. Nothing lies outside to impose premises, so the recovered specification owes no a-priori justification; it has to run and reproduce what observers measure.

That specification is a candidate, an executable observer: a twelve-port carrier, a native repair law, retained records and record-controlled feedback, joined in one interacting quantum process of electric flux, charged matter and a scalar field whose feedback response is certified nonzero in the infinite-occupation limit. Observers whose regions overlap on one carrier share a single complete law of fields, local event clocks and feedback, and on a refining spherical screen one repair history defines a common continuum operator for Gaussian fields, their decay and finite-speed waves. On a declared radial product over that screen, every finite menu of observer readouts admits, to any tolerance, one smooth static  $(1 + 3)$ -dimensional Lorentzian effective field theory. Finite theorems turn the specification's readouts into familiar structure: schedule-independent public records, the Born rule and Tsirelson bound on completed records, a carrier whose slow response is exactly three-dimensional, the Standard Model gauge Lie algebra with an anomaly-free generation, a source-derived  $(1 + 3)$  causal precursor with proper-time ratios from record counts, and the Einstein equation from a realized null balance. We state the acceptance criteria of the construction, which premises it discharges, which it takes as declared inputs, and the frozen tests that can reject its branches.

**Interpretation and state variables.** OPH proposes one structure with two descriptions: a timeless, self-referential complete history and its actual internal computation. Observers are proposed to reverse-engineer their reality's substrate and construct hardware whose execution realizes that same history, including its builders and hardware, in emergent, mutually calibrated local times. The candidate must supply construction, initialization, controls, memory, read/write and record services, clock comparisons, and their resource costs; no external host or additional time is assumed. Its realization map must specify whether it matches one actual history, a family of preparation and

intervention responses, or every independently allowed microstate. These are different requirements. A candidate must specify the history domain and closure operator; neither the schematic equation nor the finite constructions establish this physical realization or select a unique universe. An actual quantum record history also need not assign simultaneous outcomes to incompatible unperformed measurements.

The proposed primitives are patch states, records, interfaces, and admissible operations. Physical space, duration, and matter are intended emergent readouts. A supplied carrier incidence, geometric domain, action, representation, or clock is a premise of the construction using it. Complete-history closure, an instantaneous repair fixed point, a public normal form, and a stationary probability law are different objects. A stationary law can support changing individual histories. An operational observer is defined by its access and record interfaces; consciousness requires an additional psychophysical interpretation.

**Time conventions.** Host runtime, solver counters, native attempt counts, local event-clock readings, event precedence or logical numbering, model coordinates or lapse, modular parameters, and calibrated observer-clock readings have distinct roles. Their identification requires explicit maps. A modular parameter is dimensionless; its geometric and operational readings require the stated branch and clock premises. Consistent local clock comparisons require no preferred universal clock or identical clock rates. Shared time parameters in restricted benchmarks are declared model choices. Experienced succession and a final instantaneous cosmic endpoint do not follow from a modular-flow or finite-convergence theorem.

**Keywords:** foundations of physics; Observer Patch Holography; observer consensus; executable observer; self-reference; quantum records; gauge structure; Einstein field equation.

## 1 Introduction

Physics usually begins with a world and asks how observers fit into it. Observer Patch Holography (OPH) begins with observers and asks what world they can establish together. Its observers are finite. Each holds a patch of local state, reads a boundary it shares with its neighbors, keeps durable records, and repairs its state when records disagree; it accepts only repairs that preserve protected data. OPH identifies an objective fact with a record that survives every authorized comparison. Quantum probability, Lorentzian kinematics, gravitational dynamics and gauge structure enter standard physics through distinct mathematical inputs [17, 18, 19, 53, 60]; OPH asks whether they are different public readouts of one finite observer architecture. Space, time, matter and classical objects are effective descriptions of what observers can measure and jointly interpret; no observer-independent continuum is assumed beneath them.

The proposal about the whole is closure. The universe is a timeless, self-referential structure whose observers recover the specification of their own world from completed records and build hardware whose execution realizes that same history, including its builders. The structure reads itself into existence. This changes what a premise has to do. A theory set against an external world must justify its postulates in advance or by fit; a structure with no outside has no place from which a postulate could be imposed. Whatever observers recover and implement therefore needs no further justification: the carrier, the observer algebra, the repair law and two closure coordinates are justified by being recovered, by running, and by reproducing what observers measure. The same rule cuts the other way. Nothing may be assumed that observers have not recovered, and every change of description they can make must be implemented by the structure’s own operations. Agreement fixes what counts as shared, so “our universe” is the world described by the public

record. The executable specification is where this account enters the loop; the loop itself has no first step. Section 6 develops the hypothesis and its consequences.

The programme’s target follows from this reading. An executable construction should contain observers who make the measurements we make and who can use the effective continuum descriptions we use: quantum field theory, classical mechanics and dynamical gravity, each in its regime. The specification exists and runs. Its finite observer executes repair, writes and retains records and chooses its next interaction from those records; an electromagnetic detector evaluates the coupling from a closure coordinate and feeds a single bit back; and one interacting quantum process joins electric flux, charged matter and a scalar field with complete measurements and a feedback response certified nonzero in the infinite-occupation limit. Two observers whose regions overlap on one carrier read local fields and event clocks from the same continuing history, and a direct native execution and a derived effective description assign their joint records the same complete law. Joined carriers form spherical screens, and on a refining family of screens one native repair history defines a continuum spatial operator that governs Gaussian density fields, their decay and admitted waves with a finite propagation speed. Observers of that history can use a Lorentzian field theory as their effective description: on a declared radial product over the screen, one smooth static  $(1 + 3)$ -dimensional metric reproduces any finite menu of their joint clock, field and response readouts to any prescribed tolerance. Section 4 turns seven readouts of the specification into familiar structure: schedule-independent public records, the quantum identities of completed records, three spatial directions, the gauge algebra with one anomaly-free generation, a continuum field operator on the screen with its effective  $(1 + 3)$  Lorentzian description, a causal precursor with record-count clocks, and the Einstein equation up to a cosmological constant.

The results have different logical types, and Table 1 gives the classes used throughout; each result below carries one of them. Each step is identified by its artifact as a Lean theorem, exact executable certificate, conditional paper argument, numerical receipt, or explicit unproved premise.

Throughout, “source” means computed from the declared finite source specification, including every explicitly named source law, with no measured physical input. A physical realization map is not source-only merely because the finite branch calculation consumes no measured target value.

**Definition 1.1** (Physical realization map). A physical realization map assigns finite public records, event data, currents, modular generators, and scales to physical records, spacetime events, laboratory currents, clocks, and units, preserving the algebraic operations, overlap restrictions, causal order, normalizations, and refinement relations consumed by the conclusion in question. A resemblance of spectra, dimensions, or symmetry names is insufficient.

**How this paper is organized.** This paper gives the account and develops selected results in detail. Section 2 describes the observer, its carrier and repair law, and what runs. Section 3 shows what observers agree on: public normal forms and the quantum identities of completed records. Section 4 develops six results in detail: the three spatial directions, the gauge algebra and one generation, measurement inside one interacting process, the continuum operator of one repair history and its effective Lorentzian description, the source-derived causal precursor, and the Einstein equation; it lists the other results briefly. Section 5 states the completion target, the acceptance criteria and their status. Section 6 develops closure. Section 7 gives the frozen tests, Section 8 the verification stack, and Section 9 the comparison with neighboring approaches. A companion construction paper states the executable specification and its certified components in full [66], and the theorem library carries the long proofs [1, 4, 5, 6, 8, 11, 9, 7, 2].

*Boundary 1.2.* This paper claims no completed derivation of particle masses, no source-only determination of the fine-structure constant, no completed cosmology, and no claim that formal

Table 1: Epistemic claim classes used in the manuscript.

|                                             |                                                                                                                                                                                                                                               |
|---------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Finite theorem</b>                       | A deductive result proved from displayed premises on a stated finite domain. An exhaustive computation counts as part of the proof only with a specified domain and a soundness argument.                                                     |
| <b>Certified finite computation</b>         | An executable witness whose inputs, controls, and output are fixed by a reproducible certificate; execution alone does not promote its interpretation to a theorem.                                                                           |
| <b>Conditional analytic theorem</b>         | A theorem whose hypotheses include a supplied continuum action, state space or limit; its conclusion holds on that supplied object.                                                                                                           |
| <b>Source limit theorem</b>                 | A theorem about the limit of a declared family of finite source executions along a stated subsequence, with its normalizations and order of limits displayed; the limit is derived, and its physical identification is a separate claim.      |
| <b>Reconstruction implication</b>           | An exact implication whose antecedents include displayed geometric or physical premises.                                                                                                                                                      |
| <b>Unsupplied realization map</b>           | A required map from a finite object to a physical event, current, field, clock, scale, or continuum structure for which no construction is asserted.                                                                                          |
| <b>Diagnostic</b>                           | A certified computation compared against measured values that it consumes; never counted as a prediction.                                                                                                                                     |
| <b>Prospectively fixed conditional test</b> | A diagnostic with a custody-bound target definition, kill band, precision floor, and decision rule fixed before comparison.                                                                                                                   |
| <b>Frozen prospective branch prediction</b> | A source calculation and decision rule fixed before any eligible comparison, conditional on a named physical branch. Failure rejects that branch; its scope extends to the whole framework only if the branch is proved forced and exclusive. |

verification establishes physical truth. Quantitative comparisons that consume measured values are labeled diagnostics. Section 7 states the frozen tests and the physical premises that set the scope of any verdict.

## 2 The observer

### 2.1 Patches, records and repair

**Definition 2.1** (Observer patch). An observer patch is a finite object with local state, an observable boundary map, durable records, readback, and a set of authorized repair moves. A patch sees a fragment of the world: its own state and the boundary data of its authorized overlaps.

**Definition 2.2** (Overlap and repair). For patches  $x_i, x_j$  with an authorized overlap  $e = (i, j)$ , both induced boundary records must agree for the pair to hold public data. A repair move changes local state while preserving protected readout. A configuration is a normal form when no authorized repair applies.

An observer in this sense is defined by its access and record interfaces. It reads, writes and retains records, and it uses retained records to choose its next operation. Nothing in the definition refers to a background space, a global clock or a pre-assigned list of particles. Those enter later as readouts that observers can share.

### 2.2 The twelve-port carrier

Each local carrier has twelve primitive boundary ports with oriented icosahedral incidence: thirty seams and twenty faces, five seams at each port, every seam on two oppositely oriented faces. Carriers federate through typed seam algebras with coherent triple overlaps into a nerve carrying a degree-one bridge to an oriented spherical support. The theorem library calls this carrier, federation and response layer A1. Within the closure hypothesis of Section 6 it is the part of the specification that observers recover from their records; every result below displays its dependence on it. The local carrier Gram is recovered from native current records, while cross-carrier routing in the executed federations uses a supplied cell-centre and tangent-frame convention.

Two exact features of the carrier enter later constructions. First, the proper rotation group of the icosahedral packet is the alternating group  $A_5$ , with sixty rotations acting on the twelve ports, and the real port-coefficient space decomposes without multiplicity as

$$P_{12} \cong_{A_5} \mathbf{1} \oplus \mathbf{3} \oplus \mathbf{3}' \oplus \mathbf{5}. \quad (1)$$

On the six-dimensional golden sector the spectral projectors have entries in  $\frac{1}{20}\mathbb{Z}[\varphi]$ ,  $\varphi = (1 + \sqrt{5})/2$ , each is the entrywise Galois conjugate of the other, and both triplets are irreducible real representations of real type; the projectors, characters and irreducibility certificates are machine-checked [48, 1]. Second, record keeping is integer valued: a write appends +1, a retraction appends −1, and readback sums atomic events per port. A conservative repair transfers one unit across a seam whenever the oriented mismatch has magnitude at least two. With  $V(x) = \sum_i x_i^2$ , each such repair strictly decreases  $V$  by  $2(d - 1)$  for mismatch  $d \geq 2$ , so repair terminates. The native repair law of Section 2.3 also moves load to the floor and ceiling of the endpoint mean, but at difference one it waits or swaps by its coin, so the native process keeps moving while its quadratic cost stays fixed.

### 2.3 The native repair law

The executable observer runs on one carrier with twelve nonnegative integer loads of total two. There are 78 such configurations, and the 66 binary configurations form an invariant shell. For an oriented seam  $(a, b)$  and a fair placement coin  $c \in \{0, 1\}$ , the native repair law moves

$$d = x_a - x_b, \quad j = \frac{1}{2}[d - (2c - 1)(|d| \bmod 2)], \quad y = x + j(e_b - e_a), \quad (2)$$

so load is conserved and the signed current  $j$  is the native observation. Conservation, one-step balance, a tie-break that reads no load and endpoint symmetry force this rule. Its quantum version is a record law, and seam locality, the classical law and local number-phase covariance leave a convex family of them, each a table of five coherence multipliers [68]. The executed law C records coin and current, with Kraus operators  $L_{(c,j)} = 2^{-1/2} \sum_{x: j(x,c)=j} |y(x,c)\rangle\langle x|$ . Dropping the coin record gives the most coherent member; adding the seam parity gives E, and E and the seam-total recorder are the only idempotent members. Under a common definite-current record interface all members share every classical current statistic. One coherent interference experiment reads the multiplier  $g$  that separates C, E and the most coherent member (Section 7), and nine source-executed measurements read every real coordinate of the table (Section 2.4). The quantum relaxation of the channels obtained by discarding the source record, the forgotten-source channels, is known exactly. C and E have quantum spectral gap  $(5 - \sqrt{5})/60$  on the binary shell and on the full carrier, their slowest binary coherences decay by the sharp factors  $5/6$  per attempt for C and  $7/10$  for E, the binary-shell channel becomes entanglement breaking after finitely many attempts (134 attempts suffice by an explicit certificate), and on the full carrier it never does: an explicit partial transpose stays negative at every attempt count [67, 69]. The endpoint instruments also fix a local action. On binary operator space  $H_{\text{native}} = \sum_e (I - \Phi_e)$ , summed over seams with  $\Phi_e$  the unread C or E channel, is positive and local, with an exclusion exchange term and coherence-killing coefficients set by the record law; the uniform discrete transfer is  $I - H_{\text{native}}/M$  for  $M$  seams. It is a Liouville operator on operators, not a Hamiltonian on carrier states, and the executed channel strictly attenuates a coherent mode, which rules out unitary conjugation on this carrier. At fixed selected-pair sum each classical repair minimizes the pair's quadratic load cost, so  $\|x\|^2/2$  falls by  $(d^2 - (|d| \bmod 2))/4$  per repair [81, 67].

The gap and the arrow do not depend on the record law. Every admissible coherence table has the uniform binary state as its unique stationary state and the gap  $(5 - \sqrt{5})/60$ ; the linear load statistics along the rank-three port vectors of Theorem 4.1 attain it, while every coherence between distinct load configurations contracts by at most  $43/60 + 2\sqrt{2}/15 < 1 - (5 - \sqrt{5})/60$  per attempt, so the longest-lived datum of a carrier is a classical position-like readout and equilibrium selects no record-law coordinate [68]. On the binary shell each native repair is the fibre-resampling map of the theorem library for the uniform reference: it resamples the seam orientation uniformly within the fibre of its repaired visible datum, which minimizes relative entropy over that fibre, while a collision is resolved by deterministic descent. The library's second law and modular Clausius inequality therefore hold for every native attempt on the binary shell [8]. One such projection is idempotent; the declared uniform schedule over noncommuting seams supplies a sustained arrow and contracts every input to the uniform state at the gap rate, and passive repair never realizes the library's third map, the modular flow of a faithful reference.

### 2.4 What runs

The specification is executable, and its components run with retained receipts [67]. The companion construction paper states each component, its declared services and its certificates [66]; the following summary gives the parts used in this paper.

**An observer that remembers and acts.** The native observer executes two repair events with a finite tape. It records the first current, issues a forecast from that record, chooses the next seam from the record alone, records the result and halts. Exhaustive checks retain all 264 binary-source paths, and a 20,000-trial seeded execution reproduces the exact predictions. Record-controlled feedback gives final port-zero occupation 35/264, against 1/6 when the selector is disconnected or shuffled with the same action frequencies, so the response is caused by the retained record and not by the action statistics. Feedback preserves the committed classical record while it can reduce coherence between different record values. Complete records of these short histories recover the source optimally, with entanglement fidelity  $D^{-2} \sum_h w_h \text{rank}(P_h)^2$  for the maximally mixed input, where  $D$  is the number of carrier configurations,  $h$  runs over the complete admitted histories,  $w_h$  is the product of their seam-selection and coin probabilities and  $P_h$  projects onto the inputs compatible with  $h$ ; it equals 1301/2028 for the full-carrier two-event C observer and 3329/6084 for E under the same current-sign selector [70].

**An electromagnetic detector driven by the closure coordinate.** A second observer evaluates the coupling  $\alpha(P)$  from the screen grain  $P$  and sets  $g(P) = \sqrt{4\pi\alpha(P)}$ . A prepared path qubit reads the first current through a calibrated loop exposure  $\chi$ ; the detector bit  $y = \pm 1$  has probability  $[1 + y \sin(g(P)j_1\chi)]/2$  and alone chooses the second seam, giving mean transferred charge  $\mathbb{E}[g(P)j_2] = (5g(P)/264) \sin(g(P)\chi)$ . All 528 weighted histories are retained and a 200,000-trial execution agrees with the analytic response. The closure coordinate thereby enters an actual response magnitude; the charge assignment, probe, exposure and controller are declared apparatus.

**Fields measured by the observer.** A scalar detector prepares a signed field intervention from the first native current, reads the field with a binary Weyl instrument and feeds the bit back, with inherited continuum bounds transferred to the complete history law. A source-compiled two-site field apparatus builds its entangled preparation from blank registers, evolves the field and reads it with a quantum pointer, all from emitted twelve-port control words; at the executed sixteen-level cutoff an exact rational interval places the ideal plus probability in  $[0.51495, 0.51789]$ , excluding a fair detector.

**One interacting process.** A common execution puts quantum electric flux, a charged fermion pair and two neutral scalar sites on one work register. Native source words implement their non-commuting evolution, the matter and scalar pointer instruments, and feedback controlled by a committed matter bit; the final scalar bit controls the next native repair. A smooth extension retains four quantum reads on the same disturbed state, compiles the C and E record laws around it, and actively protects a logical qubit with record-controlled recovery. Its complete conditional native/work/reference outputs are retained. In the original sharp protocol, for zero native preparation current the scalar feedback contrast of the same declared action has the certified infinite-occupation enclosure  $[-0.024045670143, -0.024043450955]$ , including the original free vacuum, unbounded interacting evolution and the actual coordinate half-line detector [71]. Section 4.3 develops what this process says about measurement.

**Two observers, one law.** Observer A reads ports (0,1) and observer B ports (0,5) of one carrier, so the two regions overlap at port zero. Each receives its initial bits and every incident local current, including zero currents, and its clock ticks whenever an attempted repair meets its region while remote repairs continue on the same source. After the first incident a native feedback repair is chosen from the reconstructed occupation of port zero. Both observers decode

one continuing source, so their agreement at the shared port instantiates the overlap-agreement equation with identity transport; rechartings between observer charts are not exercised. A direct execution through the native endpoint branches and an independent recursion in a derived effective transfer representation agree exactly on all 5,768 output words, including timeouts and terminal populations; at every positive-weight prefix each observer's decoded fields obey native continuity, and the two values at the shared port agree [76]. The quantum extension checks the native remote resolvent on all 4,356 matrix units with coherent preparations and untouched references. A compiled version replaces its ideal preparation, intervention and pointer by pulses emitted from the source compiler: exact rational propagation of all 512 code addresses keeps every one of the 1,656 clock, timeout and abort outputs within  $10^{-11}$  of the ideal history, at a cost of at most 51 pulses and five native repair attempts [77].

**Local clocks.** A local event clock counts the attempted repairs that meet its region, or the actual occupation changes at a port, and its stopped instrument sums the unresolved wait and keeps every finite timeout. Two such clocks on joined carriers share one continuing history with an observer-chosen field. C and E have the same completed clock law there and differ in the field: after three native attempts they predict field-plus probabilities 35/54 and 14/27 under the stated probe. Without feedback, over each two-tick cycle of one clock the other ticks twice on average with variance 16, so equal mean rates do not imply equal readings, and converting between the clocks through the joint event instrument preserves that whole count distribution [78]. A separate active clock lets each incident event, including a zero-current one, trigger one compiled modular step whose generator is the native three-state transfer, and closed histories derive a faithful thermal reference for that generator. Four movement-bit covariances on the complete attempt tape recover its two nontrivial frequencies and predict its coherent quadratures with no frequency fit [79]. Attempt counts, local event counts and modular parameters are distinct parameters, and none is identified with seconds.

**Identifying the repair law.** Nine source-executed scalar measurements identify all nine real coordinates of the record-law family and with them the coarse definite-current instrument on all 78 states, with arbitrary spectator and reference coherences. A collision test separates an admissible law that agrees with E on the whole binary shell. The calibrated instrument predicts complete two-event feedback histories through the same observer runtime, including quantum references and checkpoint continuation, and an explicit bound carries the probability uncertainty to their joint clock, current and interference records [80]. The probes are synthetic, so this identifies an instrument within the declared family and selects no law for nature.

**From one carrier to a screen.** One carrier suffices for the local results above; joined carriers test larger regions, distant interventions and refinement. Federations of 20, 80 and 320 twelve-port carriers preserve complete source records, untouched references and cross-carrier coherence probes, and local dependency bounds control the whole local quantum and record output under local feedback. On the actual 15,360- and 245,760-port screens, matched radius-nine initial restrictions give complete root-observer output distance below  $3.82 \times 10^{-4}$  at auxiliary per-seam parameter  $1/4$ , and below  $6.656 \times 10^{-9}$  after four local incident attempts with no auxiliary time coordinate [81]. On those matched screens a logical qubit with an untouched reference passes through two native incident ticks and local record-controlled feedback while the surrounding source keeps density  $1/3$ . A degree-two operator calculation retains every quantum output and timeout, and each full-screen output lies within  $7.779 \times 10^{-10}$  of the common 222-port computation, uniformly over references.

C and E give identical classical records in this protocol and different reference coherences [82].

These executions are finite, and their apparatus, services, schedules, field action and preparations are declared; their time parameters are attempt and event counts. They discharge finite execution, continuation and comparison between observers under those contracts. Autonomous unbounded observers, an interacting spatial refinement, physical clock calibration and responsive gravity are not constructed (Section 5).

### 3 What observers agree on

Two observers who share a boundary can disagree about what it shows. If repair stopped in different places depending on who acted first, the boundary would carry no fact of the matter. If it always stops in the same place, the final record is a public fact that no single observer owns. This section states when the second case holds, and then shows that completed records carry the familiar quantum rules.

A completed finite configuration  $x$  is a fixed point of the named repair-and-agreement map,

$$\mathcal{R}_{\text{cons}}(x) = x.$$

This map is distinct from the universe-level closure operator of Section 6. Fixed-point existence, observable determination and schedule independence are separate questions, and the following results isolate them [4, 6].

#### 3.1 Observable normal forms

**Definition 3.1** (Observable quotient system). An observable quotient system is a tuple  $\mathfrak{S} = (Q, C, \mathcal{B}, B)$ , where  $Q$  is a set of configurations,  $C \subseteq Q$  is the consistent subset,  $\mathcal{B}$  is a set of protected records, and  $B : Q \rightarrow \mathcal{B}$  is the record map. For  $b \in \mathcal{B}$ , write  $C_b = C \cap B^{-1}(b)$ .

The fiber  $C_b$  is unrealizable, reconstructing, or ambiguous according as its cardinality is zero, one, or greater than one. This trichotomy avoids assigning a state to a record that has either no consistent extension or several observationally indistinguishable extensions.

**Theorem 3.2** (Canonical observable normalizer). *The following statements are equivalent:*

- (i)  $B|_C$  is injective;
- (ii) *there is a unique map  $\mathcal{N} : Q \rightarrow C \sqcup \{\perp\}$  that preserves  $B$  on its  $C$ -valued outputs, fixes every point of  $C$ , is constant on each  $B$ -fiber, and returns  $\perp$  exactly on fibers with no consistent extension;*

*If  $B(Q) \subseteq B(C)$ , the map is a total idempotent retraction  $Q \rightarrow C$ .*

*Proof.* Injectivity makes every nonempty  $C_b$  a singleton, which defines  $\mathcal{N}$  and forces all its properties fiber by fiber. Conversely, if  $c, c' \in C$  have  $B(c) = B(c')$ , the fixed-point and fiber clauses give  $c = \mathcal{N}(c) = \mathcal{N}(c') = c'$ .  $\square$

The normalizer is defined by observable fibers, independently of any repair schedule; a repair relation implements it when the relation preserves  $B$ , reaches the consistent set and satisfies a liveness condition. Approximate versions control the normalizer where exactness fails, through an optimal two-output distance bound and summable naturality defects along refinement towers. Canonicity

carries no promise of cheapness: for succinct Boolean boundary systems, deciding whether a protected record has a consistent extension is NP-complete, and deciding injectivity of the record map is coNP-complete [4].

For the canonical single-site repair, every adaptive run is eventually constant because each nonstuttering attempt strictly lowers the mismatch count; pathwise weak fairness makes the stable state a normal form, and completeness with confluence sends every weak-fair run to the same public fixed point. These results select no scheduler and provide no stochastic hitting law, rate, physical clock, or refinement theorem. Attempts obey a sharp capacity law. A scheduler can delay the first genuine repair for any prescribed number of attempts. When every reducible record sees a genuine change among the next  $q + 1$  attempts, a bounded-waste upper horizon of  $(q + 1)$  times the initial mismatch count holds, and an independent-defect family attains the work-conserving case exactly at  $q = 0$ . The input-independent compiler produces a fixed federation with immutable input ports; genuine node repairs decrease a dependency rank, and pathwise weak fairness gives stable consensus and the correct output. Emission-order round robin finishes within its first  $n$  attempts, and the single-consumer structure bounds every accepted path by  $n(n + 1)/2$ , with an emitted family attaining  $\Theta(n^2)$ . General well-formed circuits instead admit  $2^n - 1$  accepted steps, attained by a fanout chain, where  $n$  counts the emitted nodes. These statements concern canonical node repairs: the weak patch-frame relation can stutter fairly forever, and no physical scheduler, clock, energy or hardware cost follows from these operation counts [4, 6].

### 3.2 Public records from local repair

For a prepared batch of support-closed transactions, join  $\tau$  and  $\sigma$  in the conflict graph when  $W_\tau \cap (R_\sigma \cup W_\sigma) \neq \emptyset$  or  $W_\sigma \cap (R_\tau \cup W_\tau) \neq \emptyset$ , and iterate to a fixed point: compute semantic support inside every aggregate, rebuild the conflict graph on the expanded read and write sets, merge every connected component, and repeat until the partition and all aggregate supports are unchanged.

**Proposition 3.3** (Transactional local diamond). *Let an accepted repair be an aggregate transaction with read set  $R_\tau$ , write set  $W_\tau$ , a read snapshot, and a snapshot-determined payload. Assume:*

- (i) *every read set contains the semantic dependency closure of its write set, and every affected acceptance functional is revalidated at commit;*
- (ii) *the terminal closure above exists, and each of its connected conflict components has one coherent canonical aggregate payload;*
- (iii) *a prepared component whose snapshot remains valid survives commits of independent components; and*
- (iv) *accepted commits preserve the protected record and strictly decrease the integer descent functional.*

*Then every one-step quotient peak  $t \longleftarrow s \longrightarrow u$  has a quotient state  $v$  with  $t \longrightarrow v \longleftarrow u$ .*

*Proof.* Two different first steps cannot originate in one conflict component, since that component has a unique aggregate payload, so they originate in distinct components of the terminal closure. Rebuilding the graph after every aggregate support expansion makes their final read and write sets disjoint, so neither commit changes the other's read snapshot, and semantic dependency closure ensures neither changes an acceptance functional consumed by the other. Revalidation and the

surviving component rule make both second commits legal, and with snapshot-determined payloads and disjoint writes the two application orders agree; protected-record preservation carries the equality to the physical quotient.  $\square$

**Theorem 3.4** (Consensus normal form). *Suppose the accepted repair relation satisfies the hypotheses of Proposition 3.3, so that it has the one-step diamond property, strictly decreases the quadratic descent functional  $V$  of Section 2, and is repair complete, meaning that its normal forms are exactly the consistent states. Every maximal asynchronous repair schedule from one initial state then terminates at the same consistent quotient normal form. The induced global repair map is idempotent, fixes consistent states, and preserves the protected record.*

*Proof.* Quadratic descent makes the accepted relation terminating. Proposition 3.3 makes it locally confluent, so Newman’s lemma [41] makes it confluent. A terminating confluent relation has a unique normal form below each source, and repair completeness puts that normal form in the consistent set. Applying the normalizer a second time does nothing, and protected-record preservation holds along every accepted edge.  $\square$

Atomic commits, disjoint write sets, or termination alone do not imply the local diamond; countermodels omitting semantic dependency closure, canonical aggregation or the surviving component rule are retained with the finite receipt. This is the precise sense in which a public fact is what survives every authorized comparison: the public object is the protected quotient record, independent of the order in which observers repaired.

The law runs at scale. The public run uses the level-six cell rung of the geodesic icosahedral refinement tower: 81,920 exact twelve-port carriers with one declared gluing of ports to neighboring cells, 2,580,480 seams in all, and the seam-mean retraction as repair primitive. Sixteen shuffled schedules from one seeded load terminate at the balanced class with no accepted move raising  $V$ , and all sixteen return one quotient hash equal to the component multiset fixed by the initial totals. A standalone verifier that imports no simulator code rebuilds the component multisets from the primitive arrays, replays one schedule from its seed and recomputes every hash [2]. The level-ten rung, with 20,971,520 carriers and 660,602,880 seams, terminates all sixteen schedules at the balanced class in 84 to 100 sweeps with one quotient hash fixed by the loads. Across the rungs from five to nine, one initial load per rung gives an excess-energy contraction between 0.81 and 0.83 per sweep, and the sweep counts to the balanced class grow slowly with the carrier count, from 51 to 79 at level six to 84 to 100 at level ten; these finite readings prove no all-size mixing or termination-time bound. On the sixteen level-six schedules the number of unit transfers to the balanced class lies between 924,832 and 925,708, about 1.25 times half the initial  $\ell_1$  deviation of the loads from their mean. The first-settling configuration retains spatial information that its public component multiset does not encode: at level ten the initial-to-terminal amplitude responses of equal-count ancestral groups of sizes 1,024, 4,096 and 65,536 are 0.90758, 0.95232 and 0.98983, with conditional schedule-noise fractions 1.241, 0.594 and 0.143 percent. Stationary continuation adds a constructive fluctuation result: for fair integer repair on a connected weighted graph with independent edge clocks of total rate one the fixed-occupancy law is reversible, centered loads have lagged covariance  $\kappa e^{-|t|L_G/2}\Pi$  in the edge-clock time  $t$ , with  $L_G$  the weighted graph Laplacian,  $\kappa = r(p - r)/(p(p - 1))$  for  $r$  raised occupancies on  $p$  ports and  $\Pi$  the projection off constants, and fixed linear readouts obey a martingale central limit theorem [7].

The same records let observers recover the specification itself. At carrier scale, recovery from event logs under the declared probe and operation grammar returns the twelve ports, thirty seams, inverse pairing, automorphism and rotation groups of orders 120 and 60, mean rule, schedule, rank-three Gram and Lie split  $1 + 3 + 8$ . Re-instantiation preserves the invariant vector for two iterations,

and tetrahedral and octahedral controls recover their distinct specifications [2]. Complete federation gluing is not identified by the retained routing logs: within the declared port-gluing interface a two-edge switch preserves every carrier degree, occupied port and source traversal while changing the carrier graph's triangle count from 14,000 to 13,990, and native executions reproduce identical bytes for both. The alternative is not asserted to belong to the canonical geometric family. Full-gluing recovery requires further observations or a justified restriction of the candidate class.

### 3.3 Completed records and quantum identities

Once a compare, write and verify slice has completed, its accessible events are represented in a finite-dimensional  $*$ -algebra with a normalized state. This algebra-state representation is an explicit input; the consensus theorem identifies which record is public.

**Theorem 3.5** (Finite public-record identities). *Let  $P_E$  be the projector of a completed public event  $E$  and  $\rho$  the normalized state of the completed record surface. The event weight and nonzero-weight update*

$$\Pr(E) = \text{Tr}(\rho P_E), \quad \rho|E = \frac{P_E \rho P_E}{\text{Tr}(\rho P_E)} \quad (3)$$

*define a normalized probability measure on every orthogonal event partition and a normalized positive state on the post-event corner. For self-adjoint dichotomic observables  $A_0, A_1$  and  $B_0, B_1$  in commuting record subalgebras, with  $A_i^2 = B_j^2 = I$ , the combination  $S_{\text{CHSH}} = \text{Tr}[\rho\{A_0(B_0 + B_1) + A_1(B_0 - B_1)\}]$  obeys  $|S_{\text{CHSH}}| \leq 2\sqrt{2}$  [22, 23]. The bound is attained exactly on the committed slot-split interface by the maximally entangled state with Pauli and quarter-rotated projections, while every state diagonal in the record basis with diagonal observables valued in  $[-1, 1]$  obeys  $|S_{\text{CHSH}}| \leq 2$ .*

*Proof.* Positivity of  $\rho$  and  $0 \leq P_E \leq I$  give  $0 \leq \text{Tr}(\rho P_E) \leq 1$ , and  $\sum_k P_k = I$  normalizes every partition; for nonzero weight  $P_E \rho P_E / \text{Tr}(\rho P_E)$  is positive and normalized. For  $\mathcal{B} = A_0(B_0 + B_1) + A_1(B_0 - B_1)$  the commuting-subalgebra calculation gives  $\mathcal{B}^2 = 4I - [A_0, A_1][B_0, B_1]$  [24], so  $\|\mathcal{B}\| \leq 2\sqrt{2}$ . The saturating witness and the diagonal bound are exact finite calculations [5].  $\square$

At the level of weights the Born form is derived. Every valuation on the effects of the finite surface that is nonnegative, normalized and additive on coexisting effects equals  $E \mapsto \text{Tr}(\rho E)$  for a unique density operator  $\rho$ , in every finite dimension including two, where the projector-only Gleason theorem fails, and the derivation consumes no continuity axiom [20, 21]. The projectors alone do not select the update: an explicit swap-twisted instrument has the same effects and different updates. Kraus form with induced effect  $P$  together with invariance on the states certain of  $P$  is equivalent to being the Lüders map [27, 5]. The same surface carries the copying obstruction: if one ancilla-free isometry copies two sharp states from a common blank, preservation of inner products forces their overlap  $z$  to satisfy  $z^2 = z$ , so two distinct alternatives copied by one device are orthogonal [25, 26]. Finite webs do not by themselves supply the valuation hypothesis: a source-produced complex-tomographically-complete effect and instrument web with full coexistent-effect additivity is the missing step [5].

## 4 Selected results

Six results are developed here, three as theorems with proofs, two as certified computations with their declared inputs and one as a source limit theorem with a proof sketch. They were chosen because the executable construction consumes them or because they carry the programme's most specific structural content. Section 4.8 lists the other results with their classes.

## 4.1 Three spatial directions

The carrier incidence fixes the dimension of the carrier's own position readback, which is the reason the number three occurs in this framework without being declared.

**Theorem 4.1** (Intrinsic three-dimensional carrier completion). *Let  $A$  be the twelve-port adjacency, let  $M = I - (5I - A)/60$  be the uniform scalar repair mean, and take the complete equally weighted centered probe census. The normalized infinite-response kernel converges to the intrinsic Gram  $G = 4P_{\text{slow}}$ , of rank three. The twelve integer port loads have antipodal-odd quotient  $\mathbb{Z}^{12}/\{x : x_p = x_{-p}\} \cong \mathbb{Z}^6$ , and the thirty-seam boundary has image exactly the even-sum sublattice  $D_6$ , with one residual parity coset. Under the pullback of the response-selected Gram metric, both integer modules embed densely in one abstract continuous three-dimensional Euclidean carrier. The sixty proper carrier maps act faithfully and isometrically on the rank-three range and extend to that completion, and cumulative records act by exact internal translations.*

The mechanism is spectral. The icosahedral adjacency has eigenvalues 5,  $\sqrt{5}$ ,  $-1$  and  $-\sqrt{5}$  with multiplicities 1, 3, 5 and 3, so the repair mean  $M$  has eigenvalue  $1 - (5 - \sqrt{5})/60$  on a three-dimensional eigenspace and smaller eigenvalues on everything else nonconstant. Repeated local averaging forgets every nonuniform pattern except a three-dimensional one, and that surviving pattern is the triplet of (1) carried by the port position vectors. The same number  $(5 - \sqrt{5})/60$  reappears as the quantum spectral gap of the native repair channel (Section 2.3).

The completion is taken after slow-response normalization and the infinite-step limit; at finite step count the kernel has rank eleven on the centered space and rank six on the signed antipodal sector, so the order of limits matters. The metric is the response-selected Gram pullback, distinct from the usual six-dimensional lattice metric on  $D_6$ . Thirteen finite covariance and isometry table identities are discharged in Lean with `native_decide`, so those subreceipts trust the native compiler in addition to the kernel and are not kernel-only proofs. Displacement is a record difference and cumulative records translate the completion, so position is the carrier's own readback of its accumulated records. In the executable observer the same rank-three readout attaches to all joint histories of the interacting process, and a binary controller extension executes displacements spanning three independent directions [67]. Reading the completion as physical position consumes the realization map (M1) of Section 5.2 [1, 7]. The rank-three readout belongs to one carrier's response. When carriers join into the refining spherical screen of Section 4.4, the continuum form of their repair history has spectral dimension two, the dimension of the screen, and bounded-energy families lose every within-carrier component, this band included, at the present full-port energy scaling; a three-dimensional bulk reading of the screen requires observation maps that the native energy does not supply.

## 4.2 The gauge algebra and one generation

Let  $A$  be the icosahedral adjacency operator and  $J$  the antipodal involution on the twelve ports. Exact incidence gives

$$10J = A^3 - 4A^2 - 5A + 10I, \quad (4)$$

and the real port module splits as  $P_{12} \cong_{A_5} \mathbf{1} \oplus \mathbf{5} \oplus \mathbf{3} \oplus \mathbf{3}'$ : the even coordinates carry  $\mathbf{1} \oplus \mathbf{5}$  and the odd coordinates the rank-three frame channel and its Galois-conjugate companion.

The theorem below uses two premises stated in the introduction and developed in Section 6.2. The carrier layer of the specification supplies a complete reversible response: an injective response derivative  $D : P_{12} \rightarrow \mathfrak{u}(H)$  whose image is commutator-closed with a positive trace pairing. The

no-outside rule applied to transformations requires every proper recharting of the carrier to be implemented from inside that response; the library calls this the endogeneity clause of A2.

**Theorem 4.2** (Gauge Lie-type forcing). *Let  $D : P_{12} \rightarrow \mathfrak{u}(H)$  be the complete reversible response derivative of the carrier, and put  $\mathfrak{g} = D(P_{12})$ ; let  $G_D^0$  be the connected subgroup of the unitary group of  $H$  generated by  $\exp \mathfrak{g}$ . Suppose every proper carrier action  $a \in A_5$  has a projective implementer satisfying*

$$\text{Ad}_{[U_a]} D(v) = D(a \cdot v), \quad [U_a] = [g_a c_a],$$

where  $g_a \in G_D^0$  and  $c_a$  centralizes  $\mathfrak{g}$  pointwise. Then

$$\mathfrak{g} \cong \mathfrak{u}(1) \oplus \mathfrak{su}(3) \oplus \mathfrak{su}(2).$$

The center is the unique trivial line. Up to exchanging  $\mathbf{3}$  and  $\mathbf{3}'$  by the outer automorphism of  $A_5$ , the  $\mathfrak{su}(2)$  ideal carries  $\mathbf{3}$  and the  $\mathfrak{su}(3)$  ideal carries  $\mathbf{3}' \oplus \mathbf{5}$ .

*Proof.* Injectivity of  $D$  gives  $\dim \mathfrak{g} = 12$ , and the positive trace pairing makes the commutator-closed image a compact Lie algebra. For every  $a \in A_5$  the centralizer factor acts trivially on  $\mathfrak{g}$ , so the action is inner, and covariance through the injective map  $D$  gives a homomorphism from  $A_5$  to  $\text{Int}(\mathfrak{g})$ . The transitive proper-carrier action fixes only the uniform port line, hence  $\dim \mathfrak{g}^{A_5} = 1$ . Compactness gives  $\mathfrak{g} = \mathfrak{z} \oplus [\mathfrak{g}, \mathfrak{g}]$ , and inner automorphisms fix the center pointwise, so  $\dim \mathfrak{z} \leq 1$ . If  $\mathfrak{z} = 0$ , the classification of compact simple Lie algebras forces  $\mathfrak{su}(2)^4$  [58]; inner automorphisms preserve each ideal, and on each three-dimensional ideal  $A_5$  acts trivially or faithfully, so its fixed space has dimension three or zero, since a finite rotation group fixing an axis is cyclic. The fixed-space dimension of  $\mathfrak{g}$  would be a multiple of three, a contradiction. Hence  $\dim \mathfrak{z} = 1$ , the semisimple part has dimension eleven, and the classification leaves only  $\mathfrak{su}(3) \oplus \mathfrak{su}(2)$ . The three-dimensional ideal cannot carry the trivial action, so it carries  $\mathbf{3}$  or  $\mathbf{3}'$ , and the eight-dimensional ideal carries the complementary triplet together with  $\mathbf{5}$ .  $\square$

The argument has a short intuitive form. Twelve ports give twelve independent ways to push the carrier, and complete response turns them into a twelve-dimensional compact Lie algebra. Internal implementation makes every recharting act by an inner automorphism, and inner automorphisms leave the center pointwise fixed, so the center lies in the directions the carrier symmetry fixes. Only the uniform push is fixed. The center is therefore at most one-dimensional, the remaining eleven dimensions must be semisimple, and  $11 = 8 + 3$  is the only compact split.

No ambient compact group or candidate Lie algebra occurs among the premises. The port count twelve equals the dimension of the forced algebra, so the carrier fixes that dimension by declaration; the content of the theorem is the exclusion of the only other twelve-dimensional compact type  $\mathfrak{su}(2)^4$  through compactness and the one-dimensional fixed space, together with the forcing of the unique center. The native record laws cannot supply  $D$ : every native seam expectation annihilates a nonzero operator, so no composition of fixed native repairs is invertible, and  $D$  belongs to the reversible response layer of the carrier specification. The reconstruction of  $D$  from ordered reversible histories is consumed as a premise, and laboratory currents consume the realization map (M3) of Section 5.2.

The forced algebra has an explicit finite realization. Choose from each antipodal axis one of the certificate's exact coordinate vectors  $u_i \in \mathbb{Q}(\sqrt{5})^3$ , each with  $\|u_i\|^2 = 2 + \varphi$  for  $\varphi = (1 + \sqrt{5})/2$ , and put  $U = [u_1 \cdots u_6]$ . For a real port field  $f$  with antipodal involution  $J$ , write

$$b_i = \frac{f_i + f_{Ji}}{2}, \quad d_i = \frac{f_i - f_{Ji}}{2}, \quad c = \frac{1}{6} \sum_i b_i, \quad b^0 = b - c\mathbf{1},$$

so that the even coordinates  $b$  carry  $\mathbf{1} \oplus \mathbf{5}$  and the odd coordinates  $d$  carry the rank-three frame channel detected by  $U$  and its Galois-conjugate companion detected by  $\sigma(U)$ , where  $\sigma$  is the field automorphism  $\sqrt{5} \mapsto -\sqrt{5}$  applied entrywise. Let

$$\Phi_0(b^0) = \sum_{i=1}^6 b_i^0 u_i u_i^\top, \quad \hat{x} y = x \times y.$$

The conditional matrix witness uses the space

$$H = \mathbb{C}_E^3 \oplus \mathbb{C}_W^3,$$

two copies of  $\mathbb{C}^3$  carrying the exact rotations  $R_g$  and their Galois conjugates  $\sigma(R_g)$  defined below, and four nonzero rational coefficients  $\lambda_1, \lambda_5, \lambda_3, \lambda_{3'}$ , one on each source band. These are explicit branch premises. The two three-dimensional response blocks match the two rank-three odd channels; they are not asserted to be a derived physical Hilbert space. Write  $v_p$  for the signed coordinate vector at port  $p$ . For  $g \in A_5$ , let  $R_g \in \text{SO}(3)$  be the exact rotation satisfying  $R_g v_p = v_{g(p)}$  on the oriented port frame, and define

$$\Pi(g) = \text{diag}(R_g, \sigma(R_g)).$$

The target  $A_5$  action on  $\mathfrak{u}(H)$  is conjugation by  $\Pi(g)$ .

**Theorem 4.3** (Conditional four-band finite port-response algebra). *On the declared twelve-port carrier and supplied response representation, define*

$$\begin{aligned} K(f) &= \text{diag}(\lambda_3 \widehat{U} d + i\{\lambda_1 c I_3 + \lambda_5 \Phi_0(b^0)\}, \\ &\quad \lambda_{3'} \widehat{\sigma(U)} d) \in \mathfrak{u}(H). \end{aligned} \tag{5}$$

Then  $K$  is injective, its image is commutator-closed, and

$$K(g \cdot f) = \Pi(g) K(f) \Pi(g)^*.$$

The induced  $A_5$  action on  $\text{im } K$  is inner. Let  $K^{-1} : \text{im } K \rightarrow P_{12}$  denote the inverse of  $K$  onto its image. With the bracket pulled back from that image,

$$[x, y]_K = K^{-1}([K(x), K(y)]_{\text{mat}}),$$

one has

$$(P_{12}, [\cdot, \cdot]_K) \cong \mathfrak{u}(3) \oplus \mathfrak{so}(3) \cong \mathfrak{u}(1) \oplus \mathfrak{su}(3) \oplus \mathfrak{su}(2). \tag{6}$$

Its center is the uniform one-dimensional port line, its derived algebra has dimension eleven, and the five-dimensional  $A_5$  band is noncentral. The map has a positive-definite invariant Hilbert–Schmidt pullback.

*Proof.* Evaluating (4) on the four adjacency eigenspaces gives the antipode relation, and the source protocol solves the common farthest-shell filter to give the signed response  $-J$ . The constant coordinate maps to  $i\mathbb{R}I_3$ ; the six rank-one axis matrices span the symmetric  $3 \times 3$  matrices with  $\sum_i u_i u_i^\top = (5 + \sqrt{5})I_3$ , so their sum-zero coefficients map isomorphically onto the traceless symmetric matrices under  $\Phi_0$ ;  $U$  is an isomorphism on the  $\mathbf{3}$  band and annihilates  $\mathbf{3}'$ , with  $\sigma(U)$  complementary. Hence  $K$  has rank 12 and image exactly  $\mathfrak{u}(3) \oplus \mathfrak{so}(3)$ . Equivariance, positive definiteness of the invariant pairing, and the statement that  $\Pi(g)$  is the exponential of an element of  $\text{im } K$  are exact calculations in  $\mathbb{Q}(\sqrt{5})$  over the full sixty-element domain, part of the proof by the exhaustive-computation rule of Table 1 [1].  $\square$

*Boundary 4.4.* The  $A_5$ -module decomposition alone does not determine a Lie bracket: the same module also carries the zero bracket, whose trivial response-generated group fails the A2 endogeneity clause. The independent inputs to Theorem 4.3 are the carrier incidence and orientation, the supplied response representation, and four nonzero band coefficients. The block architecture and coefficients are declared. No measured particle, mass, or coupling value enters the exact verification. The theorem constructs the pulled-back bracket for this response map; it does not select  $K$  from source histories or prove a uniqueness claim over all  $A_5$ -equivariant brackets or finite carriers. The abstract Lie type is forced independently by Theorem 4.2.

**Theorem 4.5** (Finite matter image and exhaustive exterior-menu selection). *Let  $V = \mathbb{C}_{-1/3}^3 \oplus \mathbb{C}_{1/2}^2$  be an explicitly supplied trace-balanced matter representation of the forced Lie algebra, with  $\tilde{G} = \text{SU}(3) \times \text{SU}(2) \times \text{U}(1)$  acting by  $(g_3, g_2, z) \cdot (v_3, v_2) = (z^{-2}g_3v_3, z^3g_2v_2)$ . Its exterior module branches as*

$$\Lambda^2 V \oplus \Lambda^4 V = Q \oplus u^c \oplus e^c \oplus d^c \oplus L \quad (7)$$

*with  $Q = (3, 2)_{1/6}$ ,  $u^c = (\bar{3}, 1)_{-2/3}$ ,  $e^c = (1, 1)_1$ ,  $d^c = (\bar{3}, 1)_{1/3}$  and  $L = (1, 2)_{-1/2}$ : fifteen states, all perturbative gauge and mixed gravitational anomalies vanishing, and an even number of weak doublets. The common kernel of the action is  $\mathbb{Z}_6$ , so the maximal faithful image is*

$$S(U(3) \times U(2)) \cong \frac{\text{SU}(3) \times \text{SU}(2) \times \text{U}(1)}{\mathbb{Z}_6}. \quad (8)$$

*Among all  $2^{10} = 1,024$  subsets of the ten nontrivial irreducible summands of  $\Lambda^\bullet V$ , imposing nonemptiness, chirality and vanishing of the mixed gravitational- $\text{U}(1)$ ,  $\text{SU}(3)^2\text{U}(1)$ ,  $\text{SU}(2)^2\text{U}(1)$  and  $\text{U}(1)^3$  traces leaves exactly two rank-fifteen masks, exchanged by charge conjugation.*

*Proof.* The exterior-sum identity gives the five components and charges, and the anomaly sums are the standard ones [62]: for example  $6(\frac{1}{6})^3 + 3(-\frac{2}{3})^3 + 1 + 3(\frac{1}{3})^3 + 2(-\frac{1}{2})^3 = 0$ , and with three color copies of  $Q$  against one  $L$  the Witten parity is even [64]. The element  $(e^{2\pi i/3}I_3, -I_2, e^{i\pi/3})$  acts trivially and generates a cyclic group of order six, and center-action enumeration excludes a larger kernel. The scan evaluates the four traces on all 1,024 masks; its only survivors are the two exterior-parity masks.  $\square$

The branching is the familiar  $\mathbf{10} \oplus \bar{\mathbf{5}}$  of  $\text{SU}(5)$  [61], and the quotient is a possible global form of the Standard Model group [63]. One corollary concerns a channel the framework does not contain: the forced adjoint  $(8, 1, 0) \oplus (1, 3, 0) \oplus (1, 1, 0)$  contains no mixed  $(3, 2, -5/6)$  generator, so the minimal simple grand-unified exchange channel is absent from the twelve-dimensional current algebra. Separately, Doplicher–Roberts reconstruction supplies a compact sector group from realized bosonic edge sectors [59, 60]; its equality with the finite response group is a separate commuting-square premise. Physical matter identification, family multiplicity, Yukawa couplings and masses consume (M3) and (M5) [11].

### 4.3 Measurement inside one interacting process

OPH places measurement at the transition from a private repairable record to a protected public normal form: a record is public when it has survived every authorized comparison and no repair can change it, and event projectors, weights and updates act on the completed algebra-state surface of Section 3.3. The executable observer puts this account inside one interacting quantum process [66].

Quantum electric flux, a charged fermion pair and two neutral scalar sites share one work register, with operator Gauss law and source-executed instruments. The original sharp protocol retains 1,056 native/quantum histories. At  $d = 2$  and 512 temporal steps its certified feedback contrast is  $[-0.033297300667839, -0.030025660061775]$ ; for zero native preparation current the actual infinite-coordinate half-line instrument gives  $[-0.024045670143, -0.024043450955]$  [71].

Outcome accuracy does not certify the output state. For that zero-current preparation, the complete  $d = 2$  sharp output has trace distance about 0.455 from the infinite history; every output in the  $d = 256$  occupation code has error above 0.122. For the vacuum control the best code error scales as  $d^{-1/4}$  [72]. A separate smooth Ramsey instrument preserves finite number moments. A four-read continuation carries its disturbed state through two smooth reads, feedback and a later gauge probe, retaining sixteen work branches. Stagewise moment and projected-Duhamel estimates give complete  $O(1/d)$  error at fixed protocol with  $n(d) = d^2$  temporal steps; executed  $d = 2, 4$  occupation bounds remain vacuous. This covers the later probe, not post-sharp clocks or physical clock calibration [73].

Compiled C/E native repairs surround that same work history, acting on arbitrary joint inputs of the native, work and reference registers. They retain full conditional quantum outputs, aborts and padding. If  $r_2$  is the second smooth bit,  $K_r^{j(h)}$  the work branch, and  $e(0) = (0, 5)$ ,  $e(1) = (0, 1)$ , the joint Kraus map is

$$M_{h,r,s} = (L_s^{e(r_2)} L_h^{(0,1)}) \otimes K_r^{j(h)}.$$

Causal summation proves completeness. A retained native phase witness has C contrast  $(1 + q)/4$ ,  $q = \Pr(r_2 = 0 \mid j = 0)$ , and E contrast zero; source execution gives approximately 0.3492 and 0.3514 for C at  $d = 2, 4$  [74].

Active memory uses the existing four-configuration qubit  $V$  and compiled record-controlled recovery  $R_h L_h V = \sqrt{p_h} V$ . Correcting after each native event, with final seam  $(2, 3)$  for  $r_2 = 0$  and  $(0, 1)$  otherwise, preserves the logical/reference marginal even for entangled work inputs. For independent logical/work preparations, the matched passive complete plus/minus output distance is  $1 - \bar{q}$ ,  $\bar{q} = (q_{-1} + 2q_0 + q_1)/4$ ,  $q_j = \Pr(r_2 = 0 \mid j)$ , versus one with correction; a terminal phase read consumes that coherence [75]. This protects an encoded qubit under specified controls, not arbitrary lost native coherence.

Source selection has three primitive obligations: carrier architecture, observer interface with implementation, and complete repair rule. A fixed source-executed record read distinguishes coherent implementations by  $3/4$  versus  $1/4$ ; committing first yields  $1/2$  for both [98]. Effective fields and clocks must follow from the selected process; physical calibration, an interacting spatial refinement and empirical identification require further evidence.

#### 4.4 A continuum operator from one repair history

The executable carriers join into the geodesic spherical screens of the refinement tower; the level- $l$  screen has  $V_l = 240 \cdot 4^l$  binary ports. The uniform canonical preparation fixes the total load at  $q_l = V_l/3$ , every attempt selects one of the native seams uniformly and independently, and the fair native repair acts on it. Observers read cell averages of the occupations against the normalized area measure of the declared flat polyhedral comparison surface, and  $\chi_l = q_l(V_l - q_l)/[V_l(V_l - 1)]$  normalizes their fluctuations. No continuum field, metric or Hamiltonian enters the construction.

**Proposition 4.6** (Native continuum operator). *Along one common subsequence of levels:*

(C1) *the native cell Green operators converge in operator norm to a positive, compact, injective operator  $G$  on the mean-zero observation space, and  $A = G^{-1}$  is a densely defined positive self-adjoint operator;*

(C2) *with the constant mode restored, the form of  $A$  is a conservative, regular, strongly local Dirichlet form with domain  $H^1$ , its energy lies between positive multiples of the gradient energy, its positive eigenvalues obey  $n/49920 \leq \lambda_n(A) \leq 3n/2$ , and its heat-trace spectral dimension is two;*

(C3) *for mean-zero test functions  $f$  the actual density readouts*

$$Y_l(\tau; f) = \frac{\sum_p f_l(p) [n_{\lfloor 1260 \cdot 16^l \tau \rfloor}(p) - 1/3]}{\sqrt{V_l \chi_l}}$$

*at native attempt count  $\lfloor 1260 \cdot 16^l \tau \rfloor$  converge jointly at every finite set of values of  $\tau$  to a stationary reflection-positive Gaussian family with covariance  $\langle f, e^{-|\tau-u|A} g \rangle$ , whose one-particle semigroup is  $e^{-\tau A}$ ;*

(C4) *the admitted coherent continuation converges strongly to  $\cos(t\sqrt{A})$ , and with  $\bar{A} = A \oplus 0$  and  $d$  the comparison distance,*

$$\|\mathbf{1}_F e^{-\tau \bar{A}} \mathbf{1}_E\| \leq e^{-d(E,F)^2/(2\tau)},$$

*so the cosine propagator vanishes between  $E$  and  $F$  while  $|t| < \sqrt{2}d(E,F)$ .*

*Proof sketch.* For conditional averaging  $P_k$  on the level- $k$  cells, an elementary Poincaré inequality on the actual subdivision gives  $\|(I - P_k)u\|^2 \leq 624 \cdot 4^{-k} \langle u, B_l u \rangle$  for every cell vector  $u$  and  $l \geq k$ , where  $B_l$  is the scaled native cell energy. It makes the Green family uniformly compact and upgrades weak covariance convergence to norm convergence. Convergence of the inverses gives Mosco convergence of the forms [93]. The full-port energy minimizer of a bounded-energy family has a within-carrier part of order  $2^{-l}$ , so normal contractions of port values pass to the limit and the closed form is Markovian and conservative [94]. Tent functions bound the eigenvalues from above and the Poincaré inequality from below, which fixes the heat-trace growth  $t^{-1}$ . For (C3) each unread repair acts as a fair identity or swap; the conditional profile overlaps concentrate uniformly in attempt count, and a conditional finite-population central limit theorem applies [95]. Clause (C4) is the Gaussian heat bound together with its equivalence to finite propagation of the cosine family [96]. The complete arguments and constants are given in [83, 84].  $\square$

One positive operator therefore plays three roles for observers of one history: it is the inverse covariance of the static field, the generator of the field's decay in rescaled attempt count, and the squared frequency of the admitted waves, whose locality gives them a finite speed. Two consecutive long observation blocks of the same history also synthesize a continuous classical Gaussian wave readout with covariance  $G \cos((t - u)\sqrt{A})$  in  $C([0, T], H^{-2}(S^2))$ , with observation count taken to infinity before spatial refinement. A repair whose execution is biased by  $\epsilon$  toward a disclosed coordinate profile  $f$  has continuum mean derivative  $2(I - e^{-\tau A})f$  in its executed-repair clock, and uniform likelihood bounds keep its response strictly positive at  $\epsilon = 10^{-6}$ , with timeouts and coin-service costs included [79]. With the same normalization the response and the fluctuations obey a fluctuation-dissipation relation: for  $C_{g,f}(\tau) = \langle g, e^{-\tau A} f \rangle$  the mean response of  $g$  to the bias toward  $f$  is  $2[C_{g,f}(0) - C_{g,f}(\tau)]$ , and its initial rate  $2\langle g, Af \rangle$  is set by the operator that generates the decay. The parameters  $\tau$  and  $t$  are rescaled attempt count and an admitted coherent-wave parameter, the wave processor and its coherent services are declared, and the distance is that of the comparison surface; none of them carries a laboratory calibration.

The proposition also fixes what the screen is not. Its spectral dimension is that of the two-dimensional screen. The eigenvalue count excludes a unitary identification of  $A$ , up to scale and a bounded mass shift, with a second-order elliptic operator on a smooth compact three-manifold,

and a boundary-trace test excludes a boundedly invertible energy identification with the static boundary action of a smooth compact three-dimensional Dirichlet bulk, whose Steklov eigenvalues grow like  $\sqrt{n}$  [97]. A bulk reading of the screen therefore needs a radial observation algebra that the native energy does not supply. The same min-max comparison fixes the angular spectrum of any sky field read as a bounded congruent image of the native long-average field: a precision whose eigenvalues grow like  $\ell^{2+\theta}$  is form-congruent with  $A$  only for  $\theta = 0$ , so such a field has the scale-invariant spectrum with  $\ell(\ell + 1)C_\ell$  bounded above and below, and the conditional tilt branch of Section 7 needs an ingredient beyond this covariance. A specified random-length return reference has modular generator  $\arccos K$ , with  $K$  the symmetric native configuration transfer, and its modular phase magnitudes and cosine amplitudes match those of the waves. The full configuration reference approaches the normalized trace at fixed modular parameter, so it identifies no quantum vacuum; its entropy deficit is at most  $2025/(64V)$  for  $V$  ports and every return cap. On a complete base-face patch the stationary reduced entropy grows in proportion to the port count, while the return reference's mutual information per crossing seam vanishes, so neither carries a nonzero universal coefficient times the patch's boundary-seam count; a reading of the whole screen as the boundary of a three-dimensional region is not excluded, and that region map is a premise [85].

Independent native long-block records nevertheless supply a radial product field over the screen: on a declared radial interval with Dirichlet ends its covariance is  $(-\partial_r^2 + \bar{A})^{-1}$ , with spectral dimension three. The product wave action has coefficient density  $C = \mu \operatorname{diag}(-1, a)$ , where  $\mu$  is the native measure and  $a$  the measurable spatial tensor, whose angular part complete native records recover and whose radial coefficient is one. The identity

$$g = \sqrt{-\det C} C^{-1} = \mu \sqrt{\det a} \operatorname{diag}(-1, a^{-1})$$

gives signature  $(-, +, +, +)$  almost everywhere [66].

**Proposition 4.7** (Smooth  $(1+3)$  effective descriptions). *Smoothing the angular variables of  $\mu$  and  $a$ , with the radial Dirichlet boundary retained, converges in the norm-resolvent sense with spectral gap  $(\pi/L)^2$ . Consequently, for every fixed finite admissible menu of observer readouts on bounded wave times (thermal field covariances, responses, ordered Weyl and Ramsey histories, detector and reference outputs) and every  $\varepsilon > 0$ , one smooth static  $(1+3)$ -dimensional Lorentzian metric carries a free scalar field with the standard canonical and KMS normalization whose predictions for the whole menu agree with the native ones within  $\varepsilon$ , plus the declared source and clock budgets.*

*Proof sketch.* The native density relative to smooth sphere volume is positive and globally Lipschitz. The unitary  $U_\varepsilon f = \sqrt{\rho_\varepsilon/\rho} f$  between the changing and fixed  $L^2$  spaces converges on the form domain; Rellich compactness, recovery sequences and the dual energy  $\liminf$  give transported Mosco convergence, which compact resolvents and self-adjointness upgrade to norm-resolvent convergence. Thermal covariance and sine response then converge in operator norm, momentum covariance on the form domain, and every fixed finite history with them [66, 93].  $\square$

The observers therefore have the effective description that standard physics uses, a Lorentzian field theory in  $1 + 3$  dimensions, as a theorem about their own readouts. Its scope is stated with it. The exact native measure, the radial pushforward of flat face area, is not  $C^1$  across the original face edges, so the proposition asserts no exact smooth native metric and no computable smoothing rate. The carrier's own records do supply a radius: read through the recovered rank-three frame, the axial current counter converges from every binary initial state to three-dimensional Brownian motion, and its norm has the radial generator  $\frac{2}{99}(\partial_r^2 + \frac{2}{r}\partial_r)$  with angular term  $\frac{2}{99}r^{-2}\Delta_{S^2}$ , without

added radial sites. That radius is the radius of a retained record; it is not identified with physical transport, and it does not select the radial architecture of the field: complete adaptive histories with angular instruments, native clock marks and feedback are identical across distinct radial extensions [66]. The radial architecture and the active observer protocol therefore remain declared. The metric is static and does not respond to stress. A quartic projection on the same product has a source-prepared interacting Gibbs state, an active native event clock and an unrestricted-occupation limit within its two modes, and the same smoothing preserves its finite histories; it is no spatially refining interacting continuum [66]. Uniqueness of the limit along the whole sequence, an exact smooth native metric, responsive geometry and a spatially refining interacting field are open.

#### 4.5 A causal precursor from records

The oriented conformal spherical support carries the classical isomorphisms

$$\text{Conf}^+(S^2) \cong \text{PSL}(2, \mathbb{C}) \cong \text{SO}^+(3, 1), \quad H^3 \cong \text{SO}^+(3, 1)/\text{SO}(3), \quad (9)$$

which identify the three-dimensional space of future unit timelike directions [47]. Authenticated records separately supply events and their order. Every quotient-visible register version carries the identifier of its last semantic writer, each commit certifies the versions its acceptance depends on, and the informational order is the transitive closure of authenticated read-from parenthood, an authenticated analogue of happened-before [37]. As an abstract finite poset it satisfies the order-theoretic causal-set axioms, and every finite causal set is the generated order of some authenticated log [1].

**Theorem 4.8** (Source-derived finite (1+3) causal precursor). *Let  $\mathcal{L}$  be an authenticated finite semantic-event log with generated strict order  $\prec_{\mathcal{L}}$  and canonical source height  $h_{\mathcal{L}}$ , zero on roots and one plus the maximum parent height otherwise. Then  $h_{\mathcal{L}}$  strictly increases along  $\prec_{\mathcal{L}}$  and equals the maximum length of an authenticated parent chain ending at each event. Let  $V_{\text{src}}$  be the rank-three source Gram quotient with positive form  $g_{\text{src}}$ , and put  $W_{\text{src}} = \mathbb{R} \oplus V_{\text{src}}$  with  $Q(t, x) = t^2 - g_{\text{src}}(x, x)$ .*

- (F1)  $W_{\text{src}}$  has dimension  $1 + 3 = 4$  and  $Q$  has one positive and three negative directions;
- (F2) source-unit directions,  $S^2$  and future-null rays are exactly equivalent;
- (F3) a placement  $F(e) = (\tau h_{\mathcal{L}}(e), x(e))$  sends every generated precedence into the future cone whenever each parent edge obeys  $g_{\text{src}}(x(f) - x(e), x(f) - x(e)) \leq \tau^2(h_{\mathcal{L}}(f) - h_{\mathcal{L}}(e))^2$ ;
- (F4) every finite log admits an injective placement of this form that sends generated ancestry into the future cone and makes distinct same-height events spacelike; and
- (F5) for a placement obeying the edge condition of (F3), if the spatial readback separates each equal-height layer and every unrelated pair with  $h_{\mathcal{L}}(e) < h_{\mathcal{L}}(f)$  is spacelike, then  $e \preceq_{\mathcal{L}} f$  holds exactly when  $F(f) - F(e)$  is future causal, so  $F$  is an exact order embedding preserving every causal interval.

*Proof.* Dimension is additive and positivity of  $g_{\text{src}}$  gives the inertia; induction over parents bounds every ending chain by the height and constructs an attaining chain; the edge inequality and transitivity of cone and ancestry give (F3); an enumeration along one axis with  $\tau = n + 1$ ,  $n$  the number of events, gives (F4); and the two geometric checks exclude every unsupported cone comparison in (F5). The finite statements are formalized [1, 9].  $\square$

Read informally, the theorem combines two things observers have. Who read whose write is a partial order, and the longest chain of reads ending at an event gives it a height. The rank-three carrier gives three spatial directions and, with a real axis, a light cone. An event placement that respects both turns the provenance order into a causal order in a four-dimensional Lorentzian carrier.

The first two clauses construct the carrier and signature from an independent real axis and the rank-three source carrier, without assuming a rank-four chart; source height enters only through placements, and the scaled height is no operational clock. A physical manifold requires a source-causal continuum certificate: one refinement family supplying physical event identification, source-selected order and cone embeddings, refinement maps, a calibrated count density, agreement across independent dimension and manifoldlikeness tests against Poisson-sprinkled controls, and convergence to a distinguishing time-oriented Lorentzian geometry [28, 29, 30].

**Proposition 4.9** (Composition of the continuum certificate). *For a source-causal continuum certificate, causal order fixes the conformal Lorentzian geometry of the admitted distinguishing limit and the calibrated count measure fixes its conformal scale [35, 36]; the local model is  $(1 + 3)$ , so a limit satisfying the dimension and topology clauses of the certificate is an effective four-dimensional time-oriented Lorentzian event manifold. If on the same family a causal-set d’Alembertian or scalar-curvature estimator converges as an independent curvature diagnostic [33, 34], an explicit tensor-curvature reconstruction converges to the Einstein tensor or the small-ball null-balance route identifies the limiting geometry tensor with  $G_{ab}$ , and stress and Ward–Bianchi data converge with calibrated coupling, then the smooth limit is  $G_{ab} + \Lambda g_{ab} = 8\pi G T_{ab}$ .*

A source-record population realizes the flat case.

**Theorem 4.10** (A source-record causal and count limit). *In the rank-three conservative repair carrier, let  $\varphi = (1 + \sqrt{5})/2$ ,  $L = 2/\sqrt{\varphi + 2}$  and  $q = F_n$  the  $n$ -th Fibonacci number,  $n \geq 4$ . The population  $S_q = L\{b\varphi - \lfloor b\varphi \rfloor : 0 \leq b < q\}^3 \subset [0, L]^3$  consists of  $q^3$  distinct conservative source-record images. Retain it at each layer and let every next-layer event read all preceding-layer sites within  $a_q = L/\sqrt{q}$ , with model duration  $\Delta_q = a_q/c$  for a declared speed  $c$ . As  $q \rightarrow \infty$  the order converges away from null separation to the speed- $c$  causal order, and with  $\rho_q = q^3/(L^3\Delta_q)$ , for fixed interior timelike diamonds,*

$$\frac{|I_q|}{\rho_q} \rightarrow \text{Vol}(I), \quad \frac{2C_q}{|I_q|(|I_q| - 1)} \rightarrow \frac{1}{10},$$

where  $C_q$  counts strict causally ordered pairs; for vertical duration  $T$ ,  $\text{Vol}(I) = \pi c^3 T^4/24$ .

**Corollary 4.11** (Proper-time ratios from record counts). *If  $I_q, J_q$  approach interior timelike diamonds of proper durations  $\tau_I, \tau_J > 0$ , the observer readout  $R_q(I; J) = (|I_q|/|J_q|)^{1/4} \rightarrow \tau_I/\tau_J$ . Within positive volume-only readouts additive on collinear inertial intervals, the fourth root is unique up to units.*

At finite regulator the population is produced by the carriers themselves: each holds its record as port loads, reads its position through the rank-three response and decides its neighbors from that readback, and the precedence generated from their authenticated reads equals the layered order through  $q = 89$ , that is 704,969 carriers reading one another over ten rounds. On the largest interior diamond the inverted Myrheim–Meyer dimension reads 2.83, 4.38, 3.55, 3.84 and 3.92 at  $q = 13, 21, 34, 55, 89$  [31, 32]; the outermost central diamonds, which the cube clips and which are therefore not interior readings, read 4.15, 3.61, 4.10, 4.09 and 4.07, and the readings at  $q = 5$  and

$q = 8$  lie below the regime of the theorem. The ordering fraction of the central diamond reads 0.088, 0.138, 0.092, 0.093 and 0.094 against the proved flat value  $1/10$ , and the count clock reads 1.71, 2.09, 1.91 and 2.05 at  $q = 13, 34, 55, 89$  against the model-time ratio 2. Covariance requirements select the cone: a closed convex pointed displacement cone preserved by the irreducible icosahedral rotations and by boosts along one axis is the future or past cone of  $t^2 - \|x\|^2$ . The read law and model clock are declared, and the ordinal height of a history with self-waits is no proper-time instrument [9].

The executable carrier has its own finite causal bound. For a fixed seam schedule and shared local coins, dependence crosses at most one seam per ordered repair event, and retained signal witnesses attain the bound; this is a speed in seams per native event. Remote repairs can carry a difference to a receiver before its first local tick, so the bound is not one seam per receiver tick [86, 67]. Complete endpoint records give a forward-cone placement in the registered response geometry, and a four-event native execution has a Lean instance proving that implication and the failure of its converse [1].

#### 4.6 The Einstein equation from a realized null balance

**Theorem 4.12** (Null tomography and metric ambiguity). *Let  $V$  be four-dimensional with Lorentz form  $\eta$  of signature  $(-, +, +, +)$ , the opposite convention from  $Q$  in Section 4.5; nothing below depends on the choice. If a symmetric form  $X$  satisfies  $X(k, k) = 0$  for every null vector  $k$ , then  $X = \phi\eta$ . Null-null values therefore determine a symmetric tensor modulo the metric line, and nine explicit null directions, the six axis rays  $(1, \pm e_i)$  and  $(1, s, s, \pm s)$ ,  $(1, s, -s, s)$  with  $s = \sqrt{3}/3$ , reconstruct the quotient  $\text{Sym}^2(V^*)/\mathbb{R}\eta$  with design determinant  $8192/27$  in the certificate's basis and a decoder obeying  $\|x\|_\infty \leq (2 + \sqrt{3})\|q\|_\infty$ .*

*Proof.* On future null rays  $(1, n)$  the identity  $X_{00} + 2X_{0i}n_i + X_{ij}n_in_j = 0$  on the unit sphere forces  $X_{0i} = 0$ ,  $X_{ij} = \phi\delta_{ij}$  and  $X_{00} = -\phi$ . The determinant and decoder bound are exact calculations, and the design, injectivity and ambiguity are formalized in Lean [1, 9].  $\square$

**Theorem 4.13** (Tensor completion of a realized null balance). *Let  $(M, g)$  be a connected, time-oriented,  $C^3$  Lorentzian four-manifold and  $T_{ab}$  a symmetric  $C^1$  tensor with  $\nabla^a T_{ab} = 0$ . Suppose a common realized tower supplies  $\kappa = 8\pi G_N > 0$  with*

$$G_{ab}^{(g)} k^a k^b = \kappa T_{ab} k^a k^b \quad (10)$$

*for every null vector  $k$  at every point. Then there is a constant  $\Lambda$  with*

$$G_{ab}^{(g)} + \Lambda g_{ab} = 8\pi G_N T_{ab}, \quad (11)$$

*and a reference event at which the difference equals  $-\Lambda_0 g_{ab}$  fixes  $\Lambda = \Lambda_0$ .*

*Proof.* Theorem 4.12 applied pointwise to  $G_{ab}^{(g)} - \kappa T_{ab}$  gives  $G_{ab}^{(g)} - \kappa T_{ab} = \phi g_{ab}$ . The contracted Bianchi identity, the Ward premise and metric compatibility give  $\nabla_b \phi = 0$ , connectedness makes  $\phi$  constant, and  $\Lambda = -\phi$ .  $\square$

The structure of the argument is simple. Light rays cannot see a stress term proportional to the metric, so balance between curvature and stress on every null direction fixes Einstein's equation up to such a term, and the Bianchi identity with stress conservation makes its coefficient constant. That constant is the cosmological constant. The coefficients of entanglement-equilibrium arguments [54] enter through one machine-checked identity: scalars with  $\delta S_{\text{bulk}} = \frac{8\pi^2 \ell^4}{15} t$ ,  $\delta A =$

$-\frac{4\pi\ell^4}{15}f$  and  $\delta S_{\text{bulk}} + \delta A/(4G_N) = 0$  obey  $f = 8\pi G_N t$ . For OPH to supply (10), one common refinement tower must realize (G1) the effective manifold of Proposition 4.9; (G2) geometrically normalized cap modular flow whose directional charges define one stress tensor; (G3) its Ward identity, independently of that reconstruction; (G4) the edge-center entropy split, the normalization  $\delta\langle Z_L \rangle = \delta A/(4G_N)$ , the modular first law and generalized-entropy stationarity; (G5) a small-ball family with controlled remainders and enough observer directions; and (G6) universal coupling, a vacuum reference and a scale calibration fixing  $\kappa = 8\pi G_N$ . The finite layer contains null tomography, the edge-entropy split and the coefficient identity, and the machine-checked composition proves the tensor step from an explicit null-balance premise; the bridge between them is (M4).

#### 4.7 The dark sector: non-luminous charge, the deep galaxy law, and the vacuum coordinate

Under supplied universal-coupling, physical-stress and source-localization premises, sourcing gravity by modular charge classifies any geometric excess over the luminous term as non-luminous modular charge, with anomalous modular energy on overlap collars as one candidate carrier [14]. Conditional on two named premises the deep-regime profile is characterized rather than supplied: an enclosed-mass law that is degree-one scale covariant and composes independent sources in quadrature carries a unique constant  $a_0 > 0$  with  $M_A(r) = r\sqrt{M_b a_0/G}$ , which forces flat rotation curves and gives  $v^4 = GM_b a_0$ , the baryonic Tully–Fisher relation, each premise load-bearing by an explicit counterexample. A per-cut model gives  $a_0 = Gn^2 c$ , with only the product  $n^2 c$  identifiable, and the value of  $a_0$  is fixed by no source law. Reading the dark-energy density as  $\rho_{\text{DE}} = \kappa/N$  at constant  $\kappa$  gives  $w = -1 + \frac{1}{3} d \ln N / d \ln a$ , so fixed capacity gives the exact point  $(w_0, w_a) = (-1, 0)$  and nondecreasing capacity gives  $w \geq -1$ ; exclusion of that point fails the fixed branch, while agreement supports nothing, since it is also the  $\Lambda$ CDM null [15].

#### 4.8 The wider inventory

Table 2 lists the structures of observed physics that the reconstruction returns, with the class of each result and where it is proved or stated. A finite theorem is a theorem about the declared finite objects, a reconstruction implication carries the physical antecedents displayed with it, and a diagnostic consumes measured input and predicts nothing.

Table 2: Reproduced structures of observed physics, the result that returns each one, its claim class, and its location.

| Structure                                       | What the reconstruction returns                                                                                                                                                                                         | Class                        | Where |
|-------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|-------|
| An observer that records and acts               | A finite observer executes repair, retains its records and chooses later interactions from them; feedback changes the outcome law against disconnected and shuffled controls                                            | certified finite computation | §2.4  |
| Measurement inside an interacting field process | Flux, charged matter and a scalar field on one register with complete instruments and feedback; a certified nonzero infinite-occupation response                                                                        | certified finite computation | §4.3  |
| Agreement between overlapping observers         | Two observers sharing a port read one complete law of fields, local clocks, feedback and timeouts; native and effective descriptions agree exactly, with a quantum extension and a compiled apparatus within $10^{-11}$ | certified finite computation | §2.4  |

Table 2 continued

| Structure                                 | What the reconstruction returns                                                                                                                                                                   | Class                                                      | Where |
|-------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|-------|
| Clocks made of events                     | Local event clocks with complete stopped instruments; conversion between two clocks keeps their whole count distribution; an active clock whose frequencies are recovered from record covariances | certified finite computation                               | §2.4  |
| A local field operator on the screen      | One repair history gives a regular, strongly local Dirichlet form of spectral dimension two, Gaussian density laws $e^{- \tau-u A}$ and admitted waves $\cos(t\sqrt{A})$ of finite speed          | source limit theorem                                       | §4.4  |
| An effective Lorentzian field theory      | On a declared radial product, a Lorentz-signature wave density and one smooth static $(1+3)$ metric whose free scalar reproduces every finite menu of observer readouts to any tolerance          | source limit theorem                                       | §4.4  |
| A finite signal speed                     | Dependence crosses at most one seam per ordered native repair event, and retained witnesses attain the bound                                                                                      | finite theorem                                             | §4.5  |
| Schedule-independent public facts         | Every maximal asynchronous repair schedule reaches the same protected normal form under the transactional local diamond                                                                           | finite theorem                                             | §3    |
| Probability weights on outcomes           | Every nonnegative normalized valuation additive on coexisting effects is the trace against a unique density operator, in every finite dimension, with no continuity axiom                         | finite theorem                                             | §3.3  |
| State update after an outcome             | A swap-twisted instrument has the same effects, so the effect table does not select the update; invariance on the outcome-certain states selects the Lüders map                                   | finite theorem                                             | §3.3  |
| The correlation ceiling $2\sqrt{2}$       | Tsirelson bound on commuting record subalgebras, attained exactly on a declared entangled witness, with record-diagonal states confined to 2                                                      | finite theorem                                             | §3.3  |
| Impossibility of copying an unknown state | One ancilla-free isometry copying two sharp states from a common blank forces their overlap to 0 or 1                                                                                             | finite theorem                                             | §3.3  |
| A three-dimensional position carrier      | The normalized twelve-port repair response has an intrinsic rank-three Gram quotient into which the record modules embed densely                                                                  | finite theorem                                             | §4.1  |
| Lorentz kinematics and the velocity space | $\text{Conf}^+(S^2) \cong \text{SO}^+(3,1)$ with $H^3$ the space of future unit timelike directions                                                                                               | classical identification on the supplied spherical support | §4.5  |
| A source-derived $1+3$ causal precursor   | The real axis and the rank-three source quotient give Lorentz inertia $(1,3)$ with the $S^2$ null boundary, and authenticated logs embed by exact order embeddings                                | finite theorem plus reconstruction implication             | §4.5  |
| Proper time from counting                 | Record counts in source-record diamonds recover proper-time ratios by the unique fourth-root readout                                                                                              | finite theorem                                             | §4.5  |

Table 2 continued

| Structure                                                   | What the reconstruction returns                                                                                                                                                                                                                                                                                                                   | Class                                                | Where   |
|-------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|---------|
| The Einstein field equation with $\Lambda$                  | Tensor completion of a realized null balance under Ward conservation, the Bianchi identity, and one scale identification                                                                                                                                                                                                                          | reconstruction implication                           | §4.6    |
| The Standard Model gauge Lie type                           | Complete response with internally implemented rechartings forces $\mathfrak{u}(1) \oplus \mathfrak{su}(2) \oplus \mathfrak{su}(3)$ on twelve ports                                                                                                                                                                                                | finite theorem                                       | §4.2    |
| One anomaly-free generation of fifteen states               | Exhaustive scan of the declared exterior menu leaves one charge-conjugate pair of rank-fifteen chiral anomaly-free masks, with common kernel $\mathbb{Z}_6$                                                                                                                                                                                       | finite theorem                                       | §4.2    |
| Absence of the minimal grand-unified exchange channel       | The forced adjoint contains no $X/Y$ generator                                                                                                                                                                                                                                                                                                    | finite theorem                                       | §4.2    |
| The relativistic mass shell and internal energy in inertia  | $E^2 = m^2 +  p ^2$ for the declared-mass momentum, and two declared selection routes giving inertial coefficient $m + E$                                                                                                                                                                                                                         | finite theorem                                       | [8]     |
| A nonlinear matter continuum and an interacting state space | First-order trajectory convergence for the real quartic-wave sector of a supplied charged action, and a unique self-adjoint closure of its declared Hamiltonian                                                                                                                                                                                   | conditional analytic theorem                         | [8]     |
| The arrow of time and the four laws                         | Reference-preserving stochastic repair contracts relative entropy; one conditional package gives the four laws, fluctuation relations and the Landauer bound                                                                                                                                                                                      | finite theorem                                       | [8]     |
| Entropy that scales with a boundary                         | Collar decomposition with one-sided edge term $\sum_{\alpha} p_{\alpha} \log d_{\alpha}$ ; the sparse crossing-read functional $\Gamma$ -converges to perimeter; on the two-dimensional source the native return reference has mutual information at most $\log J + 2025/(64V)$ , too small to scale with the crossing seams of a base-face patch | finite theorem; conditional analytic theorem         | [9, 85] |
| Coulomb and Maxwell structure                               | Unique minimal-energy neutral Coulomb solution, a local twenty-face curvature action gauge invariant for conserved seam currents, and a hopping charge conserved at a declared nonzero step $h$                                                                                                                                                   | finite theorem                                       | [7]     |
| Massless photon, gluon and graviton                         | Three conditional structural statements with zero hard mass parameters on their declared branches                                                                                                                                                                                                                                                 | reconstruction implication                           | [11]    |
| A positive Yang–Mills mass gap                              | The continuum gap identified with the limiting repair gap under named finite-rate, transfer and reconstruction certificates                                                                                                                                                                                                                       | reconstruction implication                           | [16]    |
| The Koide relation                                          | Positive-chamber circulant identity with $Q = 2/3$ exactly at $\rho/a = 1/\sqrt{2}$ , with a custody-bound tau window                                                                                                                                                                                                                             | finite theorem; prospectively fixed conditional test | [12]    |
| The fine-structure constant                                 | Interval-certified screen-grain roots 136.994835 and 137.035660 against 137.035999                                                                                                                                                                                                                                                                | diagnostic                                           | §6.5    |
| The cosmological constant                                   | Capacity candidates $3.2921 \times 10^{122}$ and $3.3001 \times 10^{122}$ against $3.3129 \times 10^{122}$                                                                                                                                                                                                                                        | diagnostic                                           | §6.5    |

Table 2 continued

| Structure                             | What the reconstruction returns                                                                | Class                               | Where |
|---------------------------------------|------------------------------------------------------------------------------------------------|-------------------------------------|-------|
| Flat rotation curves and the baryonic | Under deep scale covariance and quadrature composition the unique law gives $v^4 = GM_b a_0$ ; | conditional                         | §4.7  |
| Tully–Fisher relation                 | $a_0$ is not source-derived                                                                    | characteriza-<br>tion theorem       |       |
| The dark-energy                       | Fixed record capacity under $\rho_{\text{DE}} = \kappa/N$ gives                                | reconstruction                      | §4.7  |
| equation of state                     | $(w_0, w_a) = (-1, 0)$                                                                         | implication                         |       |
| The de Sitter transfer                | Exact capacity identity with                                                                   | finite theorem                      | [13]  |
| sign                                  | $\Delta S_{\text{gen}}^{\text{max}} = \log(1 - f) < 0$                                         |                                     |       |
| Isotropy of propagation               | The first symmetry-allowed anisotropic rank of                                                 | finite theorem;                     | §7.1  |
| to angular rank five                  | the carrier class is six, with two frozen rays                                                 | frozen                              |       |
|                                       | inside one exact band                                                                          | prospective<br>branch<br>prediction |       |
| Bell correlations beyond              | Public loophole-free records give $S = 2.42250$                                                | diagnostic                          | §7.3  |
| local records                         | against the bound $S \leq 2$ of the diagonal branch                                            |                                     |       |
|                                       | read as a local response model                                                                 |                                     |       |
| An instrument                         | One coherent event reads the record law’s                                                      | prospectively                       | §7    |
| comparison fixed before               | coherence multiplier $g$ ; C predicts 5/8 and 1/8, E                                           | fixed                               |       |
| data                                  | predicts 3/8, with a complete-count rejection rule                                             | conditional<br>test                 |       |

## 5 The specification and its scoreboard

### 5.1 The completion target

The programme has one target: an executable realization of the observer algebra whose compatible inter-observer measurements reproduce the observed universe. Observers inside the construction must make the measurements we make and must be able to use the effective descriptions we use: their joint statistics must admit a nontrivial 3 + 1-dimensional quantum field theory as a controlled effective description, including the observed matter and interactions, and classical physics and dynamical gravity under appropriate coarse-graining. No fundamental field or spacetime has to be reconstructed first. Fields, particles and geometry can be effective descriptions of what observers measure and jointly interpret, valid in their regimes, without being primitive objects. Exact equality of limiting observable laws is the mathematical target; finite executions and experiments are judged with declared approximation and measurement errors.

Table 3 gives the acceptance criteria and the status of each. The third column lists the evidence executed with retained receipts or proved on its stated domain; “supplied” means consumed as a declared input of the construction that uses it. Only the first obligation is discharged, under its declared contract. The next three are not discharged, and the last has its decision rules fixed without independent data.

Table 3: Acceptance criteria of the completion target and their status.

| Obligation                  | Acceptance evidence                                                                                                                                                     | Executed or proved                                                                                                                                                                                                                                                                                                                                                                                         | Supplied or not constructed                                                                                                                                                                                                                                                                   |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Executable observer algebra | Explicit state, operation, preparation, measurement, retained-record and feedback maps, executed, with accounted memory and services                                    | Native observer, electromagnetic and scalar detectors, source-compiled field apparatus, the common interacting process with a four-read continuation, compiled C/E attachment and active encoded memory; overlapping observers with local event clocks on one carrier; a compiled clock history; complete identification of the record law; quantum federations and a coherent observer on matched screens | Conserved totals, densities, coherent apparatus, schedules and services are declared; stationary preparation within a fixed-number sector follows from a finite native warm-up with a derived error bound; autonomous unbounded observers and physical memory calibration are not constructed |
| Shared operational meaning  | Interpretation maps fixed independently of validation outcomes, compatible across observers and refinement, preserving intervention statistics and quantum correlations | Schedule-independent public records (Theorem 3.4); the completed interacting history under every fair schedule; one complete law for two overlapping observers, exact between native and effective descriptions, with a quantum extension; complete-output maps between actual screen levels                                                                                                               | Interpretation maps for physical quantities across all observers and refinement levels are not constructed                                                                                                                                                                                    |

Table 3 continued

| Obligation                               | Acceptance evidence                                                                                                                                              | Executed or proved                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Supplied or not constructed                                                                                                                                                                                                                               |
|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Effective quantum-field description      | A refining family of observer statistics whose errors relative to a nontrivial $3 + 1$ -dimensional QFT tend to zero, including observed matter and interactions | One interacting register with operator Gauss law; infinite-occupation and complete-output certificates for a two-site action; free-field continuum theorems; a native continuum operator for Gaussian density fields, their decay and admitted finite-speed waves on the screen (Proposition 4.6); a smooth static $(1 + 3)$ Lorentzian effective description of every finite readout menu on a declared radial product (Proposition 4.7), with a finite interacting Gibbs projection and active native clock on that product | The interacting field action, vacuum and coupling and the radial product are supplied; the native reference identifies no quantum vacuum; the exact native metric is not smooth in the fixed atlas, and an interacting refining family is not constructed |
| Classical and gravitational descriptions | Compatible classical, geometric, stress and clock descriptions of the same observations, reproducing gravitational predictions with controlled corrections       | Rank-three displacement readouts; a native causal bound of one seam per repair event; the finite $(1 + 3)$ precursor, flat count volume and tensor completion of null balance; a two-dimensional local continuum form on the screen with a controlled repair response $2(I - e^{-\tau A})f$ , the entropy bound $\log J + 2025/(64V)$ and a boundary-action test against a three-dimensional Dirichlet bulk                                                                                                                   | Read law, model clock, stress, region map and scale premises are supplied; a source-selected radial reading and responsive geometry on the same process are not constructed                                                                               |

Table 3 continued

| Obligation           | Acceptance evidence                                                                                              | Executed or proved                                                                                                                                                                                                                                                                         | Supplied or not constructed                                                                                                                                                 |
|----------------------|------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Physical predictions | Input ancestry, calibration and decision rules fixed before independent data, agreement with observed statistics | The C/E protocol with a sequential trial design and the angular-rank-six band are fixed before comparison; retrospective replays of public Bell and optical-clock records test stated attachments of native records, and the conditional tilt branch is compared with CMB posterior chains | Physical encoding, service calibration and independent prospective data are not supplied; the retrospective comparisons establish no common physical observation dictionary |

## 5.2 The standing realization maps

A statement about nature needs one physical realization carrying compatible events, fields, action, states and readouts across refinement. Five maps name what such a realization must supply, and each boundary statement in this paper cites them by label.

- (M1) **Position and scale.** An identification of the intrinsic carrier completion with physical position, with a physical length, cofinal overlap gluing between carriers, and a refinement limit. On the refining spherical screens the native continuum operator has spectral dimension two on the two-dimensional source, and bounded-energy families lose the within-carrier band there (Section 4.4).
- (M2) **Clock and energy calibration.** An identification of the internal step with a laboratory clock and of the modular ledger with a laboratory energy, in measured units; configuration-derived model duration does not select laboratory time or its units. Native event clocks, an active clock and an inverse clock prediction supply joint clock tests in count parameters, and a direct count-to-phase attachment to published optical ratios is rejected under its readout assumptions (Section 7.3).
- (M3) **Laboratory current.** An identification of the finite port response with a physical gauge current, with a physical matter action and a continuum operator limit.
- (M4) **One common physical tower.** A single physical refinement family realizing the event, modular, stress, entropy, continuum, vacuum, and scale premises together, rather than several independently declared islands.
- (M5) **A source-selected action.** An action produced by the source rather than declared, with its field sector, coupled interaction, relative normalizations, and operational readout.

The executable observer turns these maps into construction work on one process. Its retained histories carry a rank-three displacement readout, local event clocks, modular clock probes and committed records on a single register, and its joined screens carry one continuum operator for fields, decay and waves, with a smooth effective Lorentzian description on a declared radial product. What such a realization lacks is an interacting refining family whose records, clocks, currents and

stress readouts converge together in physical units. A finite theorem that consumes none of the five maps stands on its own domain, and no result in this paper discharges any of them; Section 7.3 tests two simple attachments of native records to published data.

### 5.3 Open connections

These connections can be built in parallel, and each concerns the same process:

- (i) extend the native continuum operator from passive fields and admitted waves to the full interacting construction, with a quantum reference state and an effective Lorentzian description that is interacting and responsive, while retaining records and bounding numerical and physical service errors;
- (ii) attach interacting matter, a source-selected radial observation algebra, responsive geometry and physical clock calibration to the same state, event law and retained records;
- (iii) extend finite composition and active encoded memory to autonomous operation with accounted storage, reset and service contracts;
- (iv) realize the fixed C/E preparation and observable, establish its service budget independently and collect complete records for the declared rejection protocol.

The construction paper gives the detailed premise map, including the retained negative controls that bound how the carrier, the response triplets, the feedback class and the kinetic term may be attached [66].

## 6 Closure: a universe that reads itself into existence

The previous sections built observers, their agreement and the structures they can read off, and they stated the executable specification as a candidate with a scoreboard. This section returns to the proposal stated in the introduction and develops it in full. It explains why the specification is exempt from a-priori justification and why the theory has no first premise, although its exposition has an entry point.

### 6.1 The closure hypothesis

The universe is modeled as a timeless, closed, self-referential structure in which the description and the described system are one object. Let  $\mathfrak{U}$  be a complete inhabited history, let  $D(\mathfrak{U})$  be an account of its architecture recoverable through completed records within it, and let  $R$  be an admissible realization of that account constructed inside  $\mathfrak{U}$ . The closure condition is

$$R(D(\mathfrak{U})) \cong \mathfrak{U}, \tag{12}$$

where  $\cong$  is agreement in the observable and interventional structure: the records used to recover the description, and the responses of the realization to every admitted intervention, fit the world from which the account was recovered [99]. Written as a fixed point of a universe-level closure operator, the condition reads  $T(\mathfrak{U}) = \mathfrak{U}$ . Observers infer the specification of their world, build hardware within it, and run that hardware; its execution realizes the same history, including its builders and their hardware. The identification of the construction-side and inhabited-side readings is the hypothesis. In this sense the structure reads itself into existence.

No external computer runs the history and no additional time exists in which the whole is played. Repair order is a partial order on commits, an observer history is a chain of completed records, and that order is invariant under strictly increasing regratings, so affine time and proper time require their own calibration. Fixedness of the complete history permits changing states within it: the equation concerns the whole history and identifies no last instantaneous state with the universe.

Self-reference earns content only when the return condition restricts the possibilities. On the real line  $x \mapsto x + 1$  has no fixed point,  $x \mapsto x$  fixes every point and  $x \mapsto (x + 2)/2$  fixes exactly one. A candidate therefore has to specify the history domain and the action of  $T$ ; existence, uniqueness and the identification of our universe with a fixed point are questions the equation leaves to the programme. Two finite results give the condition exact content on declared branches. The packet-quotient closure theorem proves that on the declared finite consensus branch the closure map is an affine idempotent whose fixed points are exactly the packets supported on consensus normal forms [6]. The universe-level record-closure equation  $N = \log M_0(\mathfrak{U}_N)$ , with  $\mathfrak{U}_N$  the regulated observer system at capacity budget  $N$  and  $M_0$  the correctable-code capacity of its terminal public record, is posed exactly, and the all-rung arithmetic proves that the bounded completion class defined by base agreement, positivity and the carrier bound does not identify it [8].

The executable observer gives the condition its finite meaning. A realization differs from a description because it carries the described dependencies under intervention: for a described update  $\tau_a$ , realized operation  $F_a$  and fixed readout  $p$ , the one-step condition  $p(F_a(s)) = \tau_a(p(s))$  extends by induction to every finite admitted sequence [99]. A playback can match every frame of one history and fail this test as soon as a retained state is changed. The controls of Section 2.4 perform exactly this test on the running observer: disconnecting the detector or shuffling its bit with the same frequencies removes the feedback response, while the record-controlled execution keeps it.

## 6.2 No outside

A theory of an external world must justify its postulates by an argument given in advance or by fit to data gathered from outside the theory. A self-contained structure offers no vantage point from which a premise could be imposed. This changes what a premise has to do, and it gives one rule with three applications.

**Justification.** A premise is justified when observers recover it and the specification that implements it runs and reproduces their measurements. The carrier, the observer algebra, the repair law and the closure coordinates are found by observers inside the structure and built by them; asking for an additional a-priori reason would ask for a view from outside, which the hypothesis denies. Construction choices therefore need no uniqueness theorem. What they owe is execution and agreement with what observers measure, which is the content of Section 5.

**State selection.** The rule also forbids assuming what observers have not recovered. After every observer-visible constraint has been imposed, the selected state may carry no further information relative to the recovered reference, so it minimizes the weighted relative entropy  $\sum_p w_p D(\rho_p \| \tau_p)$  over the compatible local state families of the patches  $p$ . The theorem library calls this premise A3. Its finite objective has exact consequences: every minimizing local density has the union of the feasible supports, and a feasible witness with failure probability  $b > 0$  gives an explicit floor on the selected probability [9].

**Transformations.** Every change of description that observers can make must be implemented by the structure's own operations, since nothing else could implement it. On a carrier this means

that each proper recharting is realized from inside the complete reversible response. The library calls this the endogeneity clause of A2, and it carries real weight: Theorem 4.2 uses it to exclude the only other twelve-dimensional compact type and to force  $\mathfrak{u}(1) \oplus \mathfrak{su}(2) \oplus \mathfrak{su}(3)$ .

### 6.3 Agreement and the meaning of “our”

The rule says what needs no outside justification. Agreement says what counts as shared. Observers assign the same operational meaning to accepted data on shared boundaries, naturally under every restriction, recharting and refinement, and a record is public when it survives every authorized comparison (Theorem 3.4). “Our universe” is the world that this public record describes. Agreement in this sense is a definition and an acceptance criterion: the shared-meaning row of Table 3 requires interpretation maps fixed independently of validation outcomes and preserving the declared joint and conditional statistics, including quantum correlations. It does not require a noncontextual table of outcomes for incompatible unperformed measurements. The theorem library calls the interpretation clause of this condition A2. The basis reference states the hypothesis, the rule, the condition and the specification formally, with the library’s premise statements and their dictionary [100].

### 6.4 An entry point without a starting point

The exposition of this paper enters the loop at the executable specification. That choice reflects where observers stand, holding records and inferring, and it makes the account concrete. The order of justification runs the other way: the hypothesis comes first, since it is what exempts the specification from outside justification. The structure itself has no first element in either sense. A pair of mutually determining equations such as  $x = (y+2)/2$ ,  $y = (x+2)/2$  fixes  $x = y = 2$  with no first value from which the other is manufactured; a calculator may approach the pair by iteration and someone may find it on a particular day, and neither belongs to the reason the answer is two [99].

No temporal paradox arises. The closure equation relates parts of one timeless object, with no global time coordinate along which information travels backward. Observers recover the specification and later construct it in their own record order, and both stages belong to the same fixed point. Repair descent is a well-founded order on authorized updates used to prove termination and compare schedules; it is neither an observer’s experienced time nor a universe-level clock.

What is found and what is made become two roles in one structure. A rule invented for a game has consequences its inventor discovers. Here the architecture that observers discover constrains what they can build, and what they build belongs to the structure from which the discovery is made. The same reading answers the question why anything exists at the level the hypothesis can answer it: the question includes its questioner, and a complete inhabited structure whose dependencies constitute its operation needs no further act of actualization [99]. A demand for something in addition to the complete relational structure is, on this reading, misplaced. If several closures qualify, the hypothesis admits several worlds, and self-consistency alone has not selected ours.

### 6.5 What closure fixes, and what observation reads off

The architecture carries two dimensionless closure coordinates: the screen grain  $P$  and the record capacity  $N$ . Under the closure hypothesis these coordinates are fixed points of the closure map, and the loop also licenses reading them off: observers locate a constant by measurement, declare a map, and certify a fixed point of that map inside the measured basin. Whether a certified fixed point coincides with the measured value is a diagnostic in the sense of Table 1, not a consequence

of the hypothesis. The theory stands on its recovered specification whether or not a first-principles evaluation of every coordinate is found.

The screen-grain loop

$$P = \varphi + \sqrt{\pi}/A_T(P),$$

with  $A_T(P)$  the inverse coupling a declared map returns at trial grain  $P$  and  $\varphi = (1 + \sqrt{5})/2$ , has one interval-certified fixed point per declared map. The bare source map settles at  $\alpha^{-1} = 136.994835177413$ , a relative distance of  $3.0 \times 10^{-4}$  from the 2022 CODATA value  $137.035999177(21)$  [65]; the self-consistent map, which recomputes the finite-screen unified gauge width inside the loop, settles at  $P = 1.6309682414$  and  $\alpha^{-1} = 137.035660136947$ , a relative distance of  $2.5 \times 10^{-6}$ , the gauge width supplying 99.2 percent of the gap. The residual is attributed to same-scheme low-energy transport to the Thomson endpoint, which neither map computes and which this paper does not supply [10]. Reading the capacity as de Sitter horizon entropy in nats gives

$$N = \frac{3\pi}{\Lambda \ell_P^2}, \quad (13)$$

with  $\ell_P^2 = \hbar G/c^3$ , and the capacity branch gives  $N = 3.2921 \times 10^{122}$  and  $3.3001 \times 10^{122}$  against the coordinate  $3.3129 \times 10^{122}$  read back from the weighted Planck base- $\Lambda$ CDM chain; in the constant they read  $\Lambda = 1.0959 \times 10^{-52}$  and  $1.0933 \times 10^{-52} \text{ m}^{-2}$  against  $3\Omega_\Lambda H_0^2/c^2 = 1.0891 \times 10^{-52} \text{ m}^{-2}$  at the Planck base- $\Lambda$ CDM centrals, distances of +0.62 and +0.38 percent. Equation (13) is the dictionary that produces the comparison coordinate, so this restates the capacity diagnostic in the constant, and it consumes the measured  $\hbar$ ,  $G$  and  $c$  through the calibration map (M2). Neither clears the source-only selection and same-quantity gates. Both comparisons are diagnostics of declared maps in the sense of Table 1: the maps were exposed before the comparison, the choice of map is itself declared, and neither comparison carries predictive weight. The executable detector of Section 2.4 consumes  $P$  through the coupling  $g(P) = \sqrt{4\pi\alpha(P)}$ , and  $N$  bounds the correctable records of a declared capacity carrier by  $\log M_0 \leq N$ .

## 7 Empirical meaning and falsifiability

The custody-bound register fixes target definitions, exclusion thresholds, precision floors, exposure classes and decision rules before eligible comparison [3]. Two kinds of test follow from the construction: a propagation anisotropy fixed by the carrier's symmetry, and an instrument comparison fixed by the executable observer. Published records also test precise attachments of native records retrospectively.

### 7.1 Propagation anisotropy at angular rank six

Angular rank means spherical-harmonic rank  $j$ , not a particle spin. The dimension of the invariant subspace of the sixty proper icosahedral rotations in angular rank  $j$  is

$$m_j = \frac{1}{60} \left[ (2j+1) + 15 U_{2j}(0) + 20 U_{2j}(\tfrac{1}{2}) + 12 U_{2j}(\tfrac{\varphi}{2}) + 12 U_{2j}(\tfrac{\varphi-1}{2}) \right],$$

with  $U$  the Chebyshev polynomials of the second kind, and the exact table gives  $m_1 = \dots = m_5 = 0$  and  $m_6 = 1$  [49].

**Theorem 7.1** (Icosahedral angular-rank universality). *Let the carrier kinetics be any operator  $\lambda_a(k) = a^{-2} \sum_d w(d) [1 - \cos(a k \cdot d)]$  with a finite direction multiset and weights invariant under*

the proper icosahedral rotation group. Then the dispersion is exactly isotropic through angular rank five at every order in  $a$ , every directional term below angular rank ten is one multiple of the unique normalized invariant  $\mathcal{I}_6$ , and whenever the weighted sixth-moment coefficient is nonzero the first directional artifact appears at order  $a^4 k^6$ , suppressed by exactly  $1/16$  under one binary refinement at that order. Rank six is the least symmetry-allowed nonzero anisotropic rank in the class.

*Proof.* The order- $a^{2m-2} k^{2m}$  angular content is an invariant polynomial of degree  $2m$  with harmonic components at even ranks  $j \leq 2m$ , and the invariant table forces zero at  $L = 2, 4, 8$  and a one-dimensional space at  $L = 6$ . The table, the 62-direction stationary census, the orbit verification and the nonvanishing sixth-moment coefficients are certified in exact arithmetic [1].  $\square$

**Proposition 7.2** (Primitive twelve-port branch prediction). *Suppose the intrinsic spatial kinetic symbol lies in the cosine class of Theorem 7.1 with scale-independent coefficients, the complete orbit of the twelve port directions  $u_i$  is its sole hop support through order  $k^6$ , the carrier scale  $a$  is finite and positive with the quadratic term normalized to  $k^2$ , one carrier rest frame is transported coherently over the experiment, and the tested scalar or polarization-independent sector realizes the operator. Then*

$$\omega^2 = \frac{1}{2a^2} \sum_{i=1}^{12} [1 - \cos(ak u_i \cdot \hat{k})] = k^2 - \frac{a^2}{20} k^4 + \frac{a^4}{840} k^6 + \frac{2a^4}{7875} k^6 \mathcal{I}_6(\hat{k}) + O(a^6 k^8), \quad (14)$$

with  $\mathcal{I}_6(n) = \frac{25}{132} \sum_i P_6(u_i \cdot n)$ , so in a transported frame the branch predicts the scale-free relations

$$\frac{B_6}{C_4^2} = \frac{32}{315}, \quad \frac{B_0}{C_4^2} = \frac{10}{21}, \quad \frac{B_6}{B_0} = \frac{16}{75}, \quad (15)$$

and every intrinsic anisotropic coefficient at  $1 \leq j \leq 5$  vanishes.

*Proof.* The exact carrier moments  $\sum_i (u_i \cdot n)^2 = 4$ ,  $\sum_i (u_i \cdot n)^4 = 12/5$  and  $\sum_i (u_i \cdot n)^6 = 12/7 + (64/175) \mathcal{I}_6(n)$  substituted into the cosine series give the expansion; eliminating  $a$  gives the ratios.  $\square$

A second frozen ray follows from the source seams.

**Proposition 7.3** (Source-seam edge ray and conditional propagation branch). *The boundary current of the complete thirty-seam source packet maps through the antipodal-odd load readout onto the even-sum module  $D_6$  of Theorem 4.1, with Smith invariants  $(1, 1, 1, 1, 1, 2)$ , and every directed seam defines one translation of the internal record carrier whose complete normalized direction multiset is the thirty-direction edge orbit. If the feasible move laws and their objective are natural under the proper carrier action and A3 supplies a unique normalized minimizer, transitivity forces weight  $1/60$  on every directed seam, and the selected internal operator is the source-counting homogeneous convolution.*

*Suppose these record translations are physical displacements under one homogeneous position action, that the complete edge orbit is the sole direct support through the displayed order, that proper-carrier covariance fixes one common weight, that the same operator acts on one scalar or polarization-independent physical sector with quadratic term normalized to  $k^2$ , and that the action carries the stated gluing, scale, frame, readout, nuisance, and exclusivity data. Its spatial kinetic symbol is then*

$$\Lambda_a(k, \hat{k}) = \frac{1}{5a^2} \sum_{j=1}^{30} [1 - \cos(ak w_j \cdot \hat{k})], \quad (16)$$

with  $C_4 = -a^2/20$ ,  $B_0 = a^4/840$  and  $B_6 = -a^4/12600$ , hence  $B_0/C_4^2 = 10/21$ ,  $B_6/C_4^2 = -2/63$  and  $B_6/B_0 = -1/15$ . The intrinsic anisotropic coefficients at angular ranks one through five vanish, and the rank-six vector lies on the rotated  $\mathcal{I}_6$  orbit.

*Proof.* Exact integer incidence gives the displayed image and Smith invariants, and the response-selected Gram pullback gives the completion of Theorem 4.1. The sixty directed labels map two-to-one onto the thirty signed edge directions, whose unit-normalized moments are  $\sum_j (w_j \cdot n)^2 = 10$ ,  $\sum_j (w_j \cdot n)^4 = 6$  and  $\sum_j (w_j \cdot n)^6 = 30/7 - (2/7) \mathcal{I}_6(n)$ ; substitution in (16) gives the coefficients and ratios. The incidence, quotient, orbit binding and moment identities are machine-checked in exact arithmetic [1].  $\square$

The proposition contains an exact finite source theorem and a conditional physical branch. The naturality and minimizer clause supplies a homogeneous internal action whose generator satisfies the positive maximum principle and an exact Dirichlet identity, and whose plane-wave spectrum is the symbol above. The declared symbol also carries an exact remainder certificate with no physical premise: with  $q = ak$ ,  $|\hat{\Lambda} - P_6| \leq \frac{7}{388800} q^8$  and  $\frac{19}{20} q^2 \leq \hat{\Lambda} \leq q^2$  uniformly on  $0 \leq q \leq 1$ , where  $P_6 = q^2 - q^4/20 + (1/840 - \mathcal{I}_6/12600)q^6$ ; the certificate turns  $a$  into no SI length. The edge branch and the primitive-port branch have opposite rank-six signs, and their coefficient rays, custody packages, exposure exclusions and comparison budgets are separate.

**Theorem 7.4** (Carrier-class dispersion band). *For the declared positive-weight scalar cosine class over orbits  $O_s$  of the sixty proper carrier rotations with radii  $r_s > 0$ , weights  $w_s > 0$  and the  $k^2$  coefficient normalized to one, write  $\Lambda_{\text{norm}} = k^2 + C_4 k^4 + (B_0 + B_6 \mathcal{I}_6(\hat{k}))k^6 + O(k^8)$  and  $\mu_m = \sum_s w_s |O_s| r_s^m$ . Then  $C_4 = -(a^2/20)\mu_4/\mu_2 < 0$  for every member;  $B_0/C_4^2 = (10/21)\mu_2\mu_6/\mu_4^2 \geq 10/21$  with equality exactly on single-radius members; the anisotropic ranks one through five vanish; and  $B_6/B_0$  lies in  $[-16/135, 16/75]$ , the face and vertex orbits attaining the endpoints and the edge orbit sitting at  $-1/15$ .*

*Proof.* Summing over the sixty rotations gives  $\sum_g ((gu) \cdot \hat{k})^6 = \frac{60}{7} + \frac{64}{35} \mathcal{I}_6(\hat{u}) \mathcal{I}_6(\hat{k})$  on unit vectors. The floor is the Lagrange identity  $\mu_2\mu_6 - \mu_4^2 = \sum_{i < j} W_i W_j r_i^2 r_j^2 (r_i^2 - r_j^2)^2 \geq 0$  with  $W_s = w_s |O_s|$ , and the band holds because the rank-six numerator is a positive-weighted mean of seed values of  $\mathcal{I}_6$  in  $[-5/9, 1]$  [1].  $\square$

A resolved intrinsic dispersion with  $B_0/C_4^2$  below 10/21, or  $B_6/B_0$  outside  $[-16/135, 16/75]$ , or a residue at ranks one through five, excludes every member of the declared class at once. The primitive-port relation is a frozen prospective conditional physical-branch prediction: its target statement, coefficient snapshot, registration record, public commit custody and detached calendar attestations fix the prospective content, the dated template search whose icosahedral templates returned a family-wide  $p$ -value of 0.64 is ineligible, and a verdict requires a dataset-specific registration with a joint likelihood, frames, orientation profile, nuisance model and calibrated threshold. The branch fails at five standard deviations or more if an isolated intrinsic  $C_4$  is positive, a lower-rank coefficient is nonzero, or the calibrated profile likelihood excludes the complete manifold  $C_4 < 0$ ,  $B_0 = \frac{10}{21} C_4^2$ ,  $B_6 = \frac{32}{315} C_4^2$ . A null is inconclusive, since the branch supplies no positive lower bound on  $a$ , and a failure rejects the primitive twelve-port propagation branch; it reaches the framework as a whole only after a stronger source law makes that branch forced and exclusive [3].

## 7.2 An instrument test from the executable observer

Under a common current-record interface every admissible record law has the classical statistics of C and E. The multiplier  $g$ , the coherence between an empty seam and a waiting single load,

separates C, E and the law that records only the current. On a fixed coherent two-state source preparation the readout probability is  $3/8 + \frac{1}{2} \text{Re}(g e^{-i\theta})$ : reversing the phase moves C from  $5/8$  to  $1/8$ , E predicts  $3/8$  for both, and the law that records only the current predicts  $3/8 \pm \sqrt{2}/4$  [68]. Four fixed settings include common-phase and incoherent controls. The complete-count evaluator uses 8192 trials per setting, an independently established probability-error budget of  $1/64$  and an exact sampling certificate below  $1/1000$ ; it rejects malformed or incomplete records and reports *no data* when no independent counts are supplied. A source-executed implementation runs both complete 78-state instruments, the four preparations and a complete Lüders readout from twelve-port control words, retaining every record and attempted trial [66]. A sequential design on one continuing carrier needs neither exact resets nor independent trials: 379 discarded native attempts before each of 3,927 trials replace the reset, failed heralds count as trials, and conditional-law bounds on the dependent transcript give a wrong-candidate probability of at most  $3/400$  under the exact-source model [87]. Synthetic controls exercise the decision rules and establish no physical verdict; physical encoding, independent calibration and comparison data are the open requirements.

### 7.3 Native records against public data

Published records can test precise attachments of native records without a new laboratory realization; each test below is retrospective, states its readout hypotheses, and assigns no prospective verdict.

The diagonal native branch is a classical stochastic process, so under independently chosen settings and local factorized responses it obeys the CHSH bound  $S \leq 2$ . The deposited records of the loophole-free Hensen experiment [90] reproduce 245 eligible trials, 196 wins and  $S = 2.42250$ , and the published fixed-count analysis gives a tail bound near 0.03917 with its setting-calibration allowance [88]. This rejects the local classical reading of the diagonal branch under that experimental contract. Committed native records form a classical process: the native grammar keeps diagonal inputs diagonal under every classical feedback history, and two implementations with the same committed branches, which give  $3/4$  and  $1/4$  under a read before commitment, give  $1/2$  for both once the record is committed [98]. Correlations beyond  $S = 2$  therefore need uncommitted coherence from declared preparation services, and every admissible record law attenuates it [68]. The replay leaves the completed record surface untouched, on which a declared entangled state reaches the Tsirelson bound of Theorem 3.5, and it does not distinguish C from E.

Event clocks need no external validation, but identifying their readings with a published measurement is a testable hypothesis. Let two native ports, or two distinct regions of one carrier, count incident repairs, and attach the published 300-second blocks of the  $\text{Ar}^{13+}/\text{Yb}^{+}$  optical frequency ratios of King et al. [91] to the normalized count ratio through a gain of at least one, a declared bracket on the  $\text{Yb}^{+}$  frequency and an absolute error of  $10^{-12}$  per block, with direct phase-count readback. The complete count law, after charging every choice of 2021 subwindow, gain and retained blocks, bounds the probability of the observed block ranges below  $10^{-104}$  for two native ports and below  $10^{-22}$  for every pair of the 3,433 distinct regional event sets [89]. The direct attachment is rejected together with its readout assumptions; the experiment's interrogations and servos lie outside that hypothesis, and the native event clocks are unaffected as clocks of the model.

Published trapped-ion records test a supplied experimental model executed through the source interface. Two calibrated preparation parameters predict 100 reserved complex readouts with per-spin-mean root-mean-square error 0.06647, and a changed-potential transfer predicts 125 derived observations with root-mean-square error 0.2876 in position-estimator units [67]. These comparisons test the supplied oscillator model and derive neither its action nor its apparatus from native repair.

## 7.4 Diagnostics and what fails together

The other quantitative comparisons carry their own decision shapes and do not count as predictions. The closure roots of Section 6.5 are diagnostics of declared maps. The registered conditional primordial branch  $n_s = 1 - P/48 = 0.96602$ , at the calibrated grain  $P$ , lies at the lower 0.612 percent position of the official ACT DR6, Planck and DESI joint posterior chains, whose mean is  $0.9743 \pm 0.0034$  [92, 89]. Those data precede the registration, so this is a retrospective tension under baseline  $\Lambda$ CDM, not a likelihood ratio, and the registered comparison with a later dataset is unchanged. A separate ACT DR6 likelihood slice on the measured bandpowers, with the background and absolute calibration held fixed, prefers a free tilt, fitted at 0.9773, by  $\Delta\chi^2 = 4.07$ ; no significance or framework-wide verdict is assigned to it [89]. A charged-lepton world average more than three standard uncertainties from the balanced-circulant center refutes the equal-rank-two tracial reading of the face-circulant sector; a resolved deep-regime galaxy sample violating degree-one radial scale covariance or quadrature composition removes the uniqueness of the deep law; and exclusion of  $(w_0, w_a) = (-1, 0)$  fails the fixed-capacity branch. The conditional implications share premises, so they fail in groups: failure of (M4) removes the effective-spacetime and Einstein conclusions together, failure of (M3) removes the gauge and matter interpretations together, and failure of (M2) removes every statement in laboratory units. The finite normal-form, invariant-theory and algebraic results retain their stated domains under all three.

## 8 Machine verification and reproducibility

Each result maps to an artifact class: a Lean library with no admitted propositions in the dependency closure reported here, including formal premise boundaries and countermodels; exact-arithmetic code receipts, integer and rational computations and outward-rounded interval certificates, each emitting a canonical hashed payload; executable observer receipts that replay every retained result and check its artifact hashes; simulation receipt bundles pinning the source revision, configuration, seed where stochastic, tolerances and output hashes; verifiers that recompute verdicts from clause vectors and reject receipts whose stored verdict disagrees; and adversarial negative controls, so that every certificate ships with mutations that must be detected. Machine-readable records classify every quantitative row as a source result, reconstruction implication, diagnostic, prospectively fixed test or rejected candidate, and reject any stronger classification unsupported by the recorded dependencies.

Table 4 names the artifact family behind each group of results. The repository, receipts, schemas and rebuild instructions are public [1, 2, 67]. The formal and executable stack checks the claims assigned to it and enforces their stated boundaries; analytic arguments in this manuscript retain their displayed proofs, and no part of the stack establishes physical realization.

Table 4: Principal verification artifacts and their scope.

| Results                                                                 | Principal artifacts                                                                                                                                                                                                        |
|-------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Executable observer, detectors, interacting process and C/E instruments | The observer receipts with exhaustive path replays, seeded executions, feedback controls, exact and interval certificates, and a single verification entry point that replays every receipt and checks its hashes [67, 66] |

Table 4 continued

| Results                                                                                | Principal artifacts                                                                                                                                                                                                                                                                                                                      |
|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Overlapping observers, local clocks, screens and the continuum operator                | The model packages for the observer correspondence, the compiled clock history, joint and active clocks, repair identification, federated screens and the coherent screen observer, each with exact or interval receipts, independent oracles and replay; the analytic limit arguments with their constants and order of limits [76, 83] |
| Public-data comparisons                                                                | Hash-pinned public records (Bell trials, optical ratio traces, CMB posterior chains) with exact rational reducers, their stated readout hypotheses and replay checks [88, 89]                                                                                                                                                            |
| Normal forms, stability, refinement, complexity and the transactional diamond          | The observable-normal-forms library and component-paper reductions; the local-diamond and Newman arguments of this manuscript; the finite transaction-model verifier                                                                                                                                                                     |
| Born weights, Lüders selection, Tsirelson saturation, no-cloning Rank-three completion | The event-algebra modules for the interface, conditioning, the bound and the public record algebra, with per-module axiom audits<br>The port-Gram repair band, covariance and frame-quotient modules with a source-pinned receipt and independent verifier                                                                               |
| Gauge Lie type, matrix witness, matter image and exterior selection                    | The screen modules for the carrier action, commutant and incidence response; the exact-arithmetic port current certificate; the trace-balanced kernel and exterior scan modules                                                                                                                                                          |
| Causal precursor, count limit and proper-time readout                                  | The provenance and geometry modules; the source-record family receipts with exact all-pairs counts through $q = 89$ and the sampled $q = 144$ level, the carrier realization receipts and event logs, and the public archive                                                                                                             |
| Null tomography, small-ball arithmetic and tensor completion                           | The Einstein-branch tensor module for null directions, design, decoder, injectivity and metric ambiguity; explicit null-balance, Ward, Bianchi and scale premises                                                                                                                                                                        |
| Angular-rank theorem, frozen branches and the dispersion band                          | The primitive-port prediction and carrier-class band modules with mutation tests; the custody-bound prediction register                                                                                                                                                                                                                  |
| Exact federation and the closure loop                                                  | The level-six configuration, seeds, seam arrays, loads, per-schedule ledgers, quotient hashes, standalone verifier and public archive; the level-ten settlement receipts; the event logs and recovered specifications of the canonical and control sources                                                                               |
| Dark sector, vacuum coordinate and closure roots                                       | The dark-sector, deep-profile, per-cut and fixed-capacity modules with the matched seen-data diagnostic; the capacity closure and nonidentifiability modules; the interval-certified grain root                                                                                                                                          |

## 9 Discussion and comparison

Operational reconstructions derive quantum structure from information and composition principles [17, 18, 19]. OPH makes a narrower statement at the quantum stage: it takes the finite algebra-state representation as an input and contributes the completed-record surface on which the event, conditioning and correlation identities operate, together with the consensus theorem that defines completion. Quantum Darwinism locates classical objectivity in redundant environmental records [44], and the completed-consensus record plays the same public role with redundancy replaced by protected overlap agreement and an explicit repair dynamics. The cellular-automaton programme shares the finite substrate [45], while OPH locates the quantum identities on the completed record surface. Wigner’s-friend extensions constrain agents reasoning about one another’s unfinished measurements [46], whose premises concern pre-consensus perspectives that the completed surface does not represent. Relational quantum mechanics treats physical facts as relational [42] and the thermal-

time programme reads time from modular structure [43]; OPH attaches public facts to protected overlap records, and its executable observer reads modular flow from the actual observation state of a running process and lets native incident events drive a modular step whose generator is the native transfer, with a faithful thermal reference derived from closed native histories; passive repair alone implements no nontrivial modular automorphism. The stationary native state of a fixed-number sector is tracial, so its modular flow is trivial, while conditioning on a native current event gives a Palm reference whose coherent modes carry modular frequency  $\log(5/4)$ : modular time in this construction is relative to an event [67]. The local-diamond proof sits beside asynchronous agreement [38, 39], and Dijkstra’s self-stabilization separates recovery from continued legitimate operation [40].

The gravitational branch belongs to the thermodynamic and entanglement-based routes to geometry [53, 54, 57], with Bisognano–Wichmann modular flow and half-sided modular inclusions as established analytic ingredients [50, 51, 52]. The route from a null-projected balance and the Bianchi identity to the full equation, with  $\Lambda$  as an integration constant, is familiar from trace-free and unimodular formulations [55, 56]; what is added is the finite nine-direction design with exact constants and the premise contract (G1)–(G6) stated as one implication. The gauge section uses Doplicher–Roberts reconstruction for the sector group [59, 60] and contributes the forcing of the local Lie type from complete response and internally implemented rechartings.

The closure hypothesis has precedents of a different kind. Wheeler pictured a participatory universe as a self-excited circuit [101]. Tegmark’s mathematical-universe hypothesis identifies physical existence with mathematical structure [102], and Nozick proposed that a fundamental principle might subsume itself [103]. OPH adds two demands: the self-subsumption must be inhabited, carried out through records and agents inside the structure, and it must be testable in part, through an executable specification whose observers can be run and whose instruments make predictions. Lawvere’s fixed-point theorem shows why unrestricted self-representation fails [104]; the closure condition is restricted to the observable and interventional structure that observers can recover.

A useful comparison of unification proposals asks how much physical structure follows from each declared input and which observations distinguish the resulting models; OPH offers a concrete case with proofs and executable checks attached to individual implications. Formal verification measures deductive reliability, predictive success requires physical realization and eligible measurements, and neither theorem counts nor numerical coincidences define a probability that an architecture describes nature.

## 10 Conclusion

OPH proposes that physics is what bounded observers can establish together, and that the universe is the structure in which such observers recover their own specification and realize it. Because nothing lies outside that structure, the specification owes no a-priori justification; it has to run and return the world it was recovered from. The specification runs. Its observer repairs, records and acts on its records, its detector draws its coupling from a closure coordinate, and one interacting quantum process carries flux, charged matter and a scalar field through complete measurements with a certified feedback response. Overlapping observers on one carrier read a single complete law of fields, local clocks and feedback, and joined carriers on a refining screen carry one continuum operator for Gaussian fields, their decay and finite-speed waves. On a declared radial product over that screen, observers can describe every finite menu of their readouts, to any tolerance, by one smooth static  $(1 + 3)$ -dimensional Lorentzian field theory.

The finite theorems turn the specification’s readouts into familiar structure: public records

independent of the repair schedule, the Born rule and the Tsirelson bound on completed records, a carrier whose slow response has exactly three directions, the Standard Model gauge Lie algebra with an anomaly-free generation, a source-derived  $(1 + 3)$  causal precursor with proper-time ratios from record counts, and the Einstein equation from a realized null balance. The prospective content is the frozen dispersion band of Theorem 7.4 and Proposition 7.2: a resolved intrinsic dispersion with  $C_4 \geq 0$ , with  $B_0/C_4^2 < 10/21$ , with  $B_6/B_0$  outside  $[-16/135, 16/75]$  or with a nonzero coefficient at angular ranks one through five excludes every member of the declared carrier class at once; and the C/E instrument test, whose decision rule is fixed before any independent count.

The acceptance criteria state what is missing: a refining family of interacting observer processes whose statistics converge to a  $3 + 1$ -dimensional quantum field theory with the observed matter and a quantum reference state, a source-selected radial reading of the two-dimensional screen, and responsive geometry with calibrated clocks on the same histories. The five maps of Section 5.2 are consumed rather than constructed, so these results do not establish that the architecture describes our universe. They specify what a realization must preserve, and the executable observer is the construction that has to carry it.

## Reproducibility statement

All theorems, certificates, simulation configurations, receipts, and the formal library are public in the project repositories [1, 2]. The paper release manifest records the release identifier (r2052) with PDF hashes and sizes; computational receipt bundles pin the applicable source revision, configuration, seed and output hashes, with clean-checkout rebuild instructions and negative controls; and machine-readable claim and prediction provenance accompanies the artifacts [3]. This manuscript synthesizes and strengthens results whose longer proofs also appear in public component preprints on observable normal forms, finite event algebras, consensus, Einstein reconstruction, gauge structure and the executable observer [4, 5, 6, 9, 11, 66], a relationship disclosed here so that overlap is visible.

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**Author contributions.** Bernhard Mueller developed the OPH concept and mathematical synthesis, wrote the main manuscript, and coordinated the formal and computational evidence. Mario Ponder developed the executable observer construction, including the native observer, the interacting source process and their certificates, and contributed the finite port-current construction and verifier, gauge and matter certificates, and proof review of the edge-entropy and Einstein-normalization branches. Alexander Osika proposed that the screen pixel ratio and the correctable-record capacity are derivable rather than fitted, supplied the detuning fixed-point equation that determines the pixel ratio, and originated the echosahedral patch-hardware design on which the screen-microphysics branch is built, in addition to the physical-realization and hardware boundary, prototype framing, and manuscript review. Kai Xue contributed consistency checks, simulator review, visualization review, and prototype-engineering review. Ben Cassie contributed implementation-claim and physical-evidence review. Peter Nguyen contributed proof auditing, branch-boundary analysis, compact-gauge and global-quotient analysis, and manuscript consistency review. Jinwook Kim developed the constructions, proofs, and counterexamples for the profile partition and structural characterizations, exact behavior-cut recovery, exact finite-state profile transport, adaptive

repair stratification, the cumulative attempt-capacity classification, fixed computation-federation progress, and the fixed-federation execution classification, together with the mechanism-variant comparison kernel and conditional example and the source-derived phase-effect selection. He constructed a provably fair emission-order round-robin scheduler with a linear exact-output attempt bound, established order-sharp quadratic accepted-step bounds for the actual compiler with the exponential fanout control, and proved the historical weak-relation fair-stuttering no-go and the weak-fair delay versus bounded-waste horizon separation. He formalized these results in Lean, connected the repair and execution results to the Tower library, and contributed their manuscript, claim registry, ledger and build records. David Matscheko contributed proof review of consensus repair, observable normal forms, modular and Einstein algebra, edge entropy, hypercharge, and the  $\mathbb{Z}_6$  quotient. Daniel Ari Friedman contributed independent red-team audits of the papers, the book, the claim and premise ledgers, the Lean library, continuous integration and the custody records, which led to scoped headline claims, displayed values matched to their certified receipts and repaired falsification rules, and the independently reviewed programme-obstruction audit whose controls bound how the carrier, the response triplets, the feedback class and the kinetic term may be attached. Jonathan Hill contributed Lean formalization and proof auditing of observable normal forms, refinement and repair results, complexity classifications, and artifact coverage. William T. Glynn contributed simulator development, computational implementation, reproducible-build infrastructure, and release-validation work in the main OPH research repository. Maarten Antonie Visser contributed consensus-protocol review, physics feedback on the foundations and emergent-spacetime framing, and the source-derived causal-poset reading of authenticated provenance that the event-precedence layer implements. Kale Arnav Anirudha contributed consensus-paper material, asynchronous-agreement analysis, repair-map definitions, and formal review of the protocol surface. Brieuc de La Fournière contributed finite Lean constructions on the source-derived causal-order and carrier-symmetry surfaces, including the cover-relation provenance compiler and the antipodal port-action identification, and external comparison controls for the charged-lepton branch. All authors reviewed and approved the manuscript. All authors agree to be accountable for all aspects of the work.

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**Data availability.** The finite witnesses, simulation configurations, receipts, scientific claim registries, and release manifests supporting this study are available in the public OPH and simulation repositories [1, 2]. Individual receipts and their bundle documentation provide the source and output provenance for computational claims. The artifact map identifies the level-six exact-federation archive and its level-five to level-ten extension, the closure-loop archive, and the causal-poset archive.

**Code availability.** The Lean sources, exact-arithmetic verifiers, finite scans, simulation code, tests, and rebuild instructions are available in the same public repositories [1, 2]. The computational claims in this manuscript identify their principal files in Section 8.

**Ethics approval and consent to participate.** Not applicable. The study involved no human participants, human data, or animals.

**Consent for publication.** Not applicable.

**Competing interests.** The authors participate in OPH-related research, software, simulation, or prototype-development programs and may receive professional or reputational benefit from this work. These relationships are disclosed. The authors declare no other competing interests.

## Credited prior work

The results of this paper build on the following established work. Each entry names an established result as it is used here and cites its sources.

- Icosahedral harmonics, finite-difference dispersion, and nonminimal Standard-Model Extension coefficient searches [112, 114, 110, 111].
- Root lattices, graph incidence, transverse projectors, free-vector oscillators, icosahedral edge harmonics, finite-difference symbols, Lorentz-violating threshold kinematics, and nonminimal Standard-Model Extension coefficient searches [106, 108, 115, 113, 109, 110, 111].
- Spherical-design moment theory, lattice dispersion expansions, and Lorentz-violation coefficient parametrizations [107, 113, 110, 105].

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