EXPERIMENT 1

RECURRENCE-FIRST FIELD-MODE FRAME-SHAKING PROGRAM

A cross-laboratory protocol for matched observable histories, undetected physical recursion, delayed readout, and preservation of unclassified recurrent artifacts

SECOND EDITION | 20 SEPTEMBER 2026

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STATUS: PROPOSED EXPERIMENTAL PROGRAM - NOT EVIDENCE OF A NEW PHYSICAL EFFECT

FRONT MATTER

Publication, Edition, and Scientific Status

Title. Substrate Cosmology Experiment 1, Second Edition: Recurrence-First Field-Mode Frame-Shaking Program.

Edition. Second digital edition, 20 September 2026. This edition replaces the First Edition as the current Experiment 1 on the public website. The First Edition remains preserved as a developmental record.

Purpose. To test whether two field-mode preparation histories that are matched on a preregistered set of conventional observables can produce a recurrently distinguishable response after the same undetected recursive evolution and the same delayed final challenge.

Scientific boundary

The protocol does not assume that an unmeasured distinction is a new physical variable. Under standard quantum theory, identical complete operational states subjected to identical dynamics have identical outcome distributions. A difference therefore first indicates incomplete state matching, memory, loss, mode mismatch, drift, detector effects, or model inadequacy. Only a residual that survives these explanations, preregistered confirmation, and independent replication becomes a candidate anomaly - never immediate proof of Substrate Cosmology.

Authorship and AI collaboration

James Dunn is the research originator. OpenAI ChatGPT Codex assisted with synthesis of the research history, experimental architecture, mainstream-physics comparison, drafting, citation organization, document production, and website integration. AI participation is disclosed as provenance and is not cited as scientific authority. Every laboratory must independently verify physics, engineering, statistics, safety, and claims.

Recommended citation

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Safety and authority

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WHY THE APPARATUS CHANGED

Preface: The Correction Made by This Edition

The First Edition correctly insisted on preregistration, uncertainty budgets, preserved units, local reports, unpooled heterogeneity, and operator lineage. Its reference apparatus nevertheless constrained the question before the experiment began. A 24-node RLC ring was a large matter-based system whose components, sensors, thresholds, couplings, and classical observables already selected a family of admissible outcomes.

That design could demonstrate history dependence, nonlinearity, resonance, and model sensitivity. It could not cleanly expose the possibility motivating the later discussion: two trials may share the same accepted observational summary while differing in relational history that a later interaction can still use. The former apparatus also treated the 33 Tools too much like a complete set of apparatus variables. The current research no longer supports that closure.

The Second Edition therefore changes the physical question. It uses **field modes** rather than a network of matter modules as the deliberately varied system, permits repeated coherent circulation before any final detector interaction, and asks whether an artifact becomes detectable only because a residual relation re-enters the same interaction region. Matter remains in the source, optics, switches, environment, and detector; it is measured and controlled as context, not mistaken for the entire thing being tested.

The 33 Tools now serve only as prompts for shaking frames. They do not define what an artifact is allowed to be. A recurrent artifact may cross several Tools, resemble none of them, or reveal a missing Tool. Classification follows evidence; it does not govern admissibility.

> *Reproduction of an anomaly is more important than its classification. A stable unknown is a better scientific record than a familiar name imposed too early.*

What has not changed

- The experiment remains mainstream-compliant in measurement, metrology, statistics, safety, and publication.
- Every reduction, threshold, aggregation, coordinate choice, and equality claim receives a loss record.
- Nulls, contradictions, minority results, failed translations, and conventional explanations remain publishable outcomes.
- No experimental outcome can establish that the complete physical environment has been observed.

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Abstract

Experiment 1 Edition 2 is a distributed quantum-optical and classical-field program centered on a dynamically coupled, low-loss recirculating mode loop. Two preparation histories, A and B, are engineered to be indistinguishable within a finite preregistered calibration set while differing in the order, adjacency, and distribution of operations across time-bin, frequency, path, phase, or polarization modes. Calibration is performed on sacrificial copies. Experimental trials enter the loop without in-loop detection, undergo a controlled number of passes through the same mode-mixing cell, receive a common final challenge, and are detected only after release.

The primary comparison is not a claim of identical hidden states. It is a documented equivalence class: A and B match on specified conventional observables within frozen tolerances. The experiment tests whether later response remains exchangeable under that declared equivalence. Candidate artifacts must show an internally recursive dependence on pass count or return structure, recur in protected trials, survive sham recursion and pass-matched controls, and reproduce across independently implemented laboratories.

All conventional explanations retain priority. Loss, dispersion, birefringence, leakage, detector dead time and afterpulsing, source drift, imperfect indistinguishability, phase noise, timing skew, thermal memory, electromagnetic coupling, analysis flexibility, and incomplete tomography are modeled prospectively. A surviving result is registered by a neutral recurrent-artifact identifier, not forced into a Substrate Cosmology category.

Primary scientific question

Can two preparation histories that are matched on a preregistered observable set yield different final response families after the same detector-free recursive transformation and challenge, with the difference following a frozen recursion signature and recurring under independent implementations after ordinary quantum-optical, metrological, and statistical explanations are tested?

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Contents

1. The Experimental Commitments

The experiment studies relations among preparation, circulation, challenge, and delayed measurement. It does not claim direct access to an observer-independent substrate. The strongest empirical object is a reproducible conditional relation with an auditable intervention and observation chain.

1.1 Five statement classes

Class	Meaning	Permitted language
Recorded observation	Digitizer, time-tagger, monitor, or detector output with provenance.	The instrument recorded...
Derived relation	A declared transformation of recorded values.	Under pipeline P, the contrast was...
Mainstream model	A standard quantum-optical, electromagnetic, thermal, statistical, or instrument explanation.	Model M predicts...
Candidate recurrent artifact	A frozen residual pattern that survives specified controls.	RA-#### recurred under...
Interpretive proposal	A Substrate Cosmology or other conceptual mapping.	This may correspond to...; it is not established by the data.

1.2 Necessary collapse and premature collapse

Detection is a collapse in the broad project sense: a large relational history becomes a bounded record. So are binning, thresholding, state reconstruction, fitting, equality tests, and the assignment of a particle or mode label. Necessary collapse makes action possible. Premature collapse erases a distinction before its relevance is tested or before a recovery path is recorded.

No detector is treated as a neutral window. The detector is a final interaction with its own material, timing, bandwidth, efficiency, saturation, recovery, and classification history. The solution is not detector avoidance - an empirical program must eventually detect - but delayed detection, detector diversity, and explicit measurement models.

1.3 No complete observational equivalence claim

A and B are never called physically identical. They are matched only relative to a finite set O_match, a measurement context J_cal, and tolerances epsilon. The statement is A approximately equals B with respect to (O_match, J_cal, epsilon). The subscript is part of the claim. If later measurements differ, the first inference is that this equivalence class was insufficient for the later interaction.

Mainstream consequence

If complete density operators, environments, operations, and measurement POVMs were actually identical, standard quantum theory predicts identical outcome distributions. The experiment can reveal incompleteness in a practical state description; it cannot bypass that theorem by vocabulary.

2. Collapse Stacks and Why the Detector Is Late

An observed event is not one simple object. It is a nested stack of interactions and summaries: source preparation, mode definition, propagation, environmental coupling, switching, final challenge, conversion in a detector, electronics, time tagging, event building, filtering, and statistical inference. Each layer preserves some relations, merges others, and creates new classifications.

2.1 The collapse ledger

Layer	What is selected	What may be lost	Required record
Preparation	Allowed mode family and history	Alternative decompositions, unmonitored source context	Source settings, diagnostics, environmental state
Propagation	Coupled field-environment evolution	Unobserved modes, loss destination, continuous phase history	Transfer characterization, temperature, timing, loss map
Switching	Path and pass membership	Leakage paths, switching transients	Waveforms, extinction, latency, state sequence
Detection	Absorption or conversion to a count/trace	Undetected field relations, detector microhistory	Detector ID, bias, efficiency, recovery, raw time tags
Event building	Coincidence and threshold rules	Subthreshold and ambiguous events	Unthresholded signals, windows, rejected-event manifest
Inference	Parameter or class	Alternative models and relational histories	Code, priors, transforms, residuals, version

2.2 Residual decay rather than instantaneous erasure

The broad project statement that decoherence has residual decay is translated here into a testable mainstream form: system-environment correlations, instrument memory, non-Markovian response, finite detector recovery, and long-tailed relaxation can persist across operational boundaries. The protocol does not assume a universal decoherence half-life. It measures correlation as a function of controlled separation and pass history and compares Markovian and non-Markovian models.

2.3 CERN as a cautionary comparison

High-energy collisions vividly show how names follow measurement stages. Incoming hadrons are described through partonic interactions; hot QCD matter may be modeled as a quark-gluon plasma; hadronization produces final hadrons; detectors convert those into signals; reconstruction assigns tracks, jets, vertices, and event classes. Each description is scientifically powerful, but none is the collision outside all frames. This experiment adopts the lesson without claiming that its optical fields are collider matter or that hadronization proves Substrate Cosmology.

3. Recursion, Recurrence, and Detectability

Recursion and recurrence are separated operationally.

Term	Operational definition in Experiment 1	Evidence
Recursion	A trial output is physically returned to the same declared transformation zone before detection.	Pass count N, switching record, round-trip timing, and transfer characterization.
Recurrence	A frozen artifact description reappears in new trials, sessions, sites, or platforms.	Protected data and independent recurrence capsules.
Resonance	Selective amplification or reinforcement under specific return conditions.	Non-monotonic or structured dependence on phase, delay, coupling, or pass count with nonresonant controls.
Repetition	The same command is issued again.	Insufficient by itself; may repeat only the apparatus program.

3.1 Two thresholds of detectability

First, a relational difference must survive or be reinforced through enough internal returns to affect an eventual detector distribution. Second, the resulting pattern must recur in independent trials strongly enough to distinguish it from statistical variation, drift, or a one-off instrument event. Internal recursion creates the possibility of detectable strength; external recurrence creates scientific credibility.

3.2 A recursion signature

Each candidate specifies a function of pass count and loop condition before confirmation. Examples include monotonic growth to saturation, alternating sign, a finite-pass maximum, a return threshold, a phase-selective band, or a topology-specific split. An arbitrary difference at one pass count is not evidence of recursion. The candidate must discriminate among N = 0, sham-N, bypass-N, and true-return-N conditions.

3.3 Why more passes are not automatically better

Loss, mode distortion, phase diffusion, and selection bias generally grow with N. The design therefore uses an information-based stopping rule and a prevalidated safe range. Apparent growth that tracks attenuation, detector postselection, or decreasing sample size is rejected as recursive evidence.

> **Minimum candidate form**
>
> RA = {contrast definition, allowed sign or topology, recursion signature, tolerance, null distribution, data boundary, conventional-model tests, and recurrence requirements}. The description is frozen before the confirmation set is unmasked.

4. The 33 Tools Are Seeds, Not a Cage

Volume 3 defines a versioned registry of 33 relational Tools. In Experiment 1 they function as questions that diversify interventions and audits. They are neither elementary physical degrees of freedom nor an exhaustive basis. No result is scored by how many Tools it resembles.

4.1 The provisional registry

No.	Tool	Frame-shake use
1	Substrate	Question what the apparatus presumes is the underlying domain.
2	Frame	Change the descriptive or interaction frame and record losses.
3	Phase	Vary closure and relative phase without equating phase with ontology.
4	Drift	Track slow change across source, loop, environment, and detector.
5	Anchor	Declare comparison references and the transformations under which they hold.
6	Gradient	Order a change without presuming spatial direction.
7	Compatibility	Vary which modes can compose or interfere.
8	Adjacency	Change direct participation among mode families.
9	Coherence	Test persistence under declared transformations.
10	Invariance	Test stability under a specified transformation class.
11	Relational Time	Compare ordering by round trip, clock time, and event relation.
12	Transformation	Separate field evolution from interrogation-induced change.
13	Modulation	Vary coupling, timing, basis, or control schedule.
14	Contextuality	Test dependence on environment, history, and measurement context.
15	Stabilization	Distinguish persistence from apparatus-maintained reinforcement.
16	Translation	Audit mappings between mode, time, spectral, and count descriptions.
17	Embedding	Test whether a reduced description recovers known predictions.
18	Resonance	Search for selective reinforcement with matched nonresonant controls.
19	Constraint	Vary boundaries on admissible paths and transformations.
20	Expansion	Test growth of accessible distinctions, not growth of labels.
21	Collapse	Record preserved, merged, discarded, generated, and unknown relations.
22	Convergence and Divergence	Compare approach or separation in a declared relation space.
23	Meaning	Keep semantic labels separate from physical discrimination.
24	Value	Separate evaluative priority from measured magnitude.
25	Agency	Identify available intervention pathways and their consequences.
26	Identity	Test which continuity claims survive transformation.
27	Relation	Preserve pairwise and higher-order structures before scalarization.
28	Harmony	Examine compatible organization without treating aesthetic fit as evidence.
29	Ethics	Record obligations, risks, and affected parties.
30	Coherence System	Test coordinated persistence across several relations.
31	Integrative Field	Test cross-mode coupling without positing a literal field.
32	Multi Identity Ecosystem	Preserve several identity assignments when data do not choose one.
33	Substrate Level Order	Search for order that appears only at a less-collapsed description.

4.2 The open-artifact rule

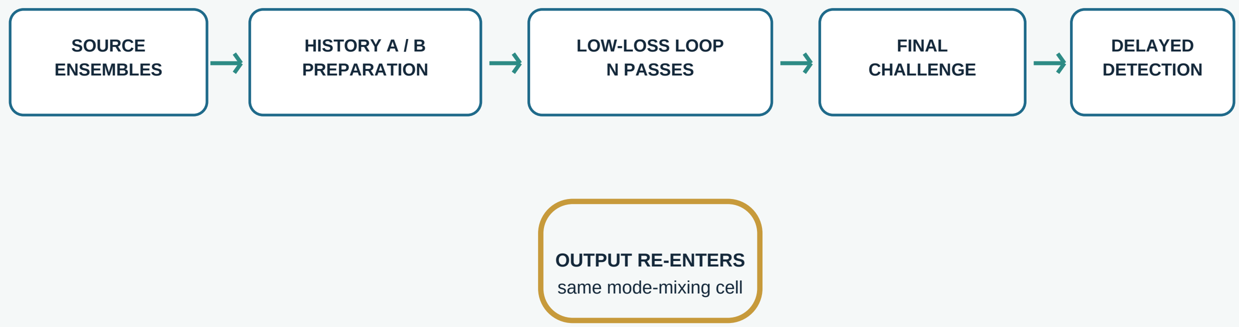
A result may be tagged to zero, one, or several Tools. Tags are secondary metadata. The primary record is the empirical pattern and its recurrence capsule. If a candidate cannot be represented without distortion, it receives only a neutral RA identifier and a description of which registry assumptions failed.

4.3 A Tool can itself collapse

A Tool name compresses a family of relations. Applying Adjacency, Resonance, or Collapse can hide the operation that established the label. Every Tool use therefore records its input domain, frame, interaction, context, history, output, preserved relations, and losses. The same recursion applies to the Tool registry: it must remain revisable and retain rejected or superseded categories.

5. Reference Platform: Recirculating Field Modes

The reference platform is a dynamically coupled, low-loss optical loop in which a prepared set of field modes passes repeatedly through a programmable mode-mixing cell before a single final readout. Equivalent microwave, acoustic, mechanical, or matter-wave platforms may later become translation tracks, but they are not required to copy an optical scalar.



No in-loop detector. Calibration uses sacrificial copies. Each experimental trial is detected only after release.

5.1 Minimum components

Subsystem	Reference implementation	Role
Source	Heralded photon pair source, weak squeezed source, and classical coherent reference	Provides nonclassical and conventional calibration tiers.
Preparation	Pulse shaper, interferometers, electro-optic modulation, polarization and path control	Creates histories A and B across several mode labels.
Recirculation	Low-loss fiber or free-space loop with fast in/out coupling	Returns the field through the same declared transformation.
Mode-mixing cell	Programmable phase, delay, coupling, polarization rotation, or frequency conversion	Implements the frozen recursion program.
Final challenge	Common interferometric or mode-overlap transformation after release	Converts surviving relational differences into outcome distributions.
Detection	Photon-number-resolving detectors or characterized click detectors plus time tagging	Measures only after recursion; detector family is rotated in confirmation.
Monitors	Independent temperature, vibration, RF, laser, clock, loss, and switch diagnostics	Tests ordinary history and leakage explanations.

5.2 Why this is plausible

Time-multiplexed photonic experiments already use fiber loops, dynamic couplers, repeated mode transformations, and time-resolved detection. The novelty here is not the existence of a loop. It is the comparison architecture: matched finite observational histories, detector-free internal returns, frame-shake families, neutral anomaly registration, and cross-laboratory recurrence rules.

5.3 The apparatus does not remove matter

The loop, modulators, nonlinear crystals, clocks, and detectors are material systems. Their properties are neither ignored nor called substrate. They are held, measured, substituted, or randomized so that a candidate cannot be attributed to an unexamined equipment history. The deliberately varied carrier is the field-mode relation; the material platform is part of the conditioning context.

6. Two Histories with a Declared Observable Match

Histories A and B are different sequences of operations that are designed to agree on a frozen set of accessible summary measurements before recursive testing. No measurement is performed on the actual trial inside the loop. Matching is established on interleaved sacrificial ensembles prepared by the same control schedules.

6.1 Example history pair

Stage	History A	History B	What is held matched
Mode creation	Correlations introduced in time-bin then rotated into polarization	Correlations introduced in polarization then distributed into time-bin	Photon number and marginal spectra
Phase structure	Local phases followed by path mixing	Path mixing followed by compensating local phases	Declared first- and second-order observables
Adjacency	Nearest-bin couplings then frequency mixing	Frequency mixing then permuted bin couplings	Final calibrated transfer marginals
Release input	Same declared mode labels and timing window	Same declared mode labels and timing window	O_match within epsilon

6.2 Matching set O_match

- Per-mode and total photon-number distributions, including vacuum and multiphoton fractions.
- Marginal time-bin, frequency-bin, path, and polarization distributions.
- Selected first- and second-order coherence functions and pairwise visibilities.
- Heralding efficiency, source brightness, spectral purity proxies, and timing distributions.
- Process-characterization summaries for the preparation network over a frozen probe set.
- Environmental, loss, and control-waveform distributions during sacrificial calibration.

6.3 What remains deliberately unresolved

Finite calibration cannot prove equality of all multiparticle correlations, system-environment correlations, phases, leakage modes, or higher-order temporal structure. Those omissions are not relabeled as hidden substrate variables. They are the practical negative space of the match. The experiment asks whether this negative space has a reproducible later consequence and whether mainstream characterization can identify it.

No post hoc tightening

Matching observables, tolerances, equivalence tests, and exclusion rules are frozen before challenge outcomes are visible. A and B may fail the match; such trials remain in the manifest and are not repaired after outcome inspection.

7. Physical Recursion Before Detection

Each accepted trial is injected into the loop and traverses the same programmable cell N times. The field leaving the cell becomes the field entering it on the next round trip. No outcome-conditioned electronics are required for the core test; recursion is physical recirculation, not an analyst repeatedly transforming a file.

7.1 Pass schedule

A representative schedule is N in {0, 1, 2, 4, 8, 16}, restricted by measured transmission and phase stability. Exact values are platform-specific and preregistered. Randomized block order prevents N from being confounded with drift. Pass count is verified by independent timing and switch logs.

7.2 True-return and false-return controls

Condition	Physical meaning	Discriminates
N = 0	Bypass recursion; same preparation and final challenge	Baseline A/B response
True-return N	Field re-enters the same cell N times	Recursive dependence
Sham-N	Controller issues N commands without field return	Electronic and expectancy effects
Pass-matched bypass	Comparable delay and attenuation without repeated cell interaction	Loss and elapsed-time effects
Reversed program	Same component inventory in reverse order	Order and noncommutation
Randomized program	Matched operation budget with randomized sequence	Chosen-pattern overfitting
Classical reference	Coherent field under the same control schedule	Purely classical transfer and memory

7.3 Recursive amplification is not assumed

The loop can attenuate, preserve, scramble, or selectively reinforce structure. The protocol therefore uses the neutral term recursive response until a registered dependence shows amplification relative to matched controls. A stable null across the usable N range is a valid result.

7.4 No in-loop detector

Monitoring light or tap detectors can collapse or load the field and are excluded from the experimental path. Loop health is inferred from interleaved reference pulses, separate calibration channels, or trials allocated specifically to diagnostics. Any tap in a variant is a declared intervention arm, not invisible housekeeping.

8. Frame Shaking as a Program of Nonexclusive Views

A frame shake changes a relation, a representation, or both and then records what remains comparable. No frame is declared the observer-free view. Representation-only nulls are paired with physical interventions so that computational sensitivity is not mistaken for a physical effect.

Shake family	Representation-only operation	Physical operation	Primary question
Basis	Change time/frequency/polarization coordinates in analysis	Apply an equivalent basis rotation before challenge	Does the candidate covary as expected?
Adjacency	Relabel or permute an isomorphic mode graph	Change which modes mix directly	Does direct participation matter beyond marginals?
Order	Reorder displayed operations only	Reverse or permute noncommuting operations	Is endpoint equality hiding path dependence?
Boundary	Change bin/window convention	Change loop closure or release boundary	Is recurrence tied to a physical or analytic boundary?
Scale	Convert units and normalize	Change delay, bandwidth, or coupling with dimensionless matches	Is the result a scale effect or a unit artifact?
Detector	Reconstruct through an alternate response model	Swap detector technology or channel assignment	Does the detector manufacture the recurrence?
Recursion	Reindex the same pass data	Change physical return count or program	Does the artifact require physical return?

8.1 Tool-guided, artifact-open design

Each site must include at least one shake motivated by each Tool family, but it need not implement 33 separate hardware changes. A single intervention can illuminate several Tools, and a candidate need not inherit any Tool label. The registry expands only after an artifact description is frozen.

8.2 Counterbalanced frame sequences

Because frame sequence can itself become history, the order of shakes is balanced across blocks. Calibration and challenge schedules are independently randomized. The laboratory publishes the entire attempted shake register, including failed or noninformative configurations.

9. Final Challenge and Delayed Measurement

After N returns, the field exits the loop and encounters a common final challenge. The challenge is not a passive readout. It is a controlled interaction selected to convert surviving relational structure into measurable distributions while being identical, within uncertainty, for A and B.

9.1 Challenge families

Challenge	Observable family	Use
Mode-overlap interferometer	Coincidence surface, visibility, phase-dependent counts	Tests whether histories differ in later composability.
Hong-Ou-Mandel-type overlap	Delay-dependent coincidence suppression	Tests indistinguishability and hidden mode mismatch.
Programmable inverse network	Recovery fidelity across mode labels	Tests whether apparently lost relations can be operationally recovered.
Random unitary ensemble	Response geometry across many projections	Tests whether a candidate is projection-resistant or basis-local.
Partial mode erasure	Conditional response after selected distinctions are removed	Locates which distinctions a response uses.

9.2 Detector plurality

The reference readout uses characterized photon-number-resolving detectors when available, with time-resolved click detectors as an independent implementation. At least one confirmation stage swaps detector channels; one independent site should use a different detector family. The final record preserves raw time tags or waveform samples before coincidence windows, dead-time correction, background subtraction, or event classification.

9.3 Residual detector decay

Afterpulsing, dead time, latching, thermal recovery, phosphorescence, electronic ringing, and buffer behavior can create apparent recurrence across events. The acquisition schedule includes dark blocks, unilluminated commands, randomized interevent intervals, detector swaps, and models conditioned on recent detection history. A candidate that follows detector memory is a valuable instrument result but not a field-recursion anomaly.

10. Experimental Arms and Freeze Boundaries

The program separates calibration, discovery, confirmation, and transfer. Data cannot move backward across a freeze boundary.

Arm	Data access	Permitted work	Output
C0 - engineering	Full access	Establish stability, safety, usable N, source and detector models	Qualified apparatus range
C1 - match	A/B labels available; no challenge outcomes	Freeze O_match, epsilon, equivalence tests	Match certificate or failure
D - discovery	Designated subset only	Explore candidate artifacts and ordinary explanations	Frozen RA capsule
H - local holdout	Blinded labels until code freeze	Apply capsule without tuning	Local confirmation report
R - rotated hardware	New detector, channel, loop direction, or component instance	Test apparatus dependence	Rotation report
L - independent laboratory	Independent implementation and protected schedule	Test recurrence, not numerical identity	Site-resolved replication
P - platform transfer	Different physical platform if justified	Test translated relation and loss	Partial, successful, or failed translation

10.1 Arm A: frozen mainstream predictions

Quantum-optical and instrument teams submit predictions for the complete registered observable family before holdout release. Models include calibrated linear optics, open-system evolution, loss, partial distinguishability, source impurity, detector response, timing, and environmental covariates. A model may be wrong without the result being new physics.

10.2 Arm B: bounded challenge selection

After a candidate is frozen, multiple model teams may choose one challenge from the same safe grammar to maximally discriminate their explanations. Energy, pass count, data access, and trials are matched. The challenge choice is itself logged as an intervention; it is never retroactively treated as a neutral observation.

11. Controls and Conventional Explanations

The design is valuable even if every result receives an ordinary explanation. A recurrence caused by non-Markovian apparatus memory, higher-order mode structure, or a detector recovery tail improves the physical model and demonstrates why the prior scalar description was incomplete.

Explanation family	Prospective control or model	Failure condition for a candidate
Loss and postselection	Transmission by mode and pass; pass-matched attenuation; unconditional denominators	Contrast disappears under loss-aware likelihood or matched sampling
Dispersion and birefringence	Independent transfer measurement; reversal; compensation schedule	Candidate tracks measured spectral/polarization drift
Partial distinguishability	HOM scans, spectral-temporal characterization, mode-overlap model	Residual predicted by mismatch
Source drift	Interleaved A/B, herald records, brightness and pump diagnostics	Candidate follows source covariate or run order
Switch leakage and RF pickup	Sham commands, RF probes, optical isolation, timing offsets	Response persists without field return and follows command
Thermal or mechanical memory	Temperature/vibration logs, randomized block intervals, recovery curves	Artifact follows apparatus relaxation
Detector memory	Dark blocks, channel swap, different detector family, event-history model	Recurrence follows detector state
Clock and coincidence construction	Independent clock, raw time tags, multiverse of frozen windows	Effect is created by alignment or threshold
Analysis flexibility	Registered primary analysis, specification curve, independent code	Only favorable unregistered pipelines produce it
Incomplete state matching	Expanded tomography or challenge-specific observables	A measured omitted degree predicts the result

11.1 Positive conventional outcomes

A resolved candidate is not a failed experiment. It identifies a relation that the earlier observational collapse omitted. The program publishes which added measurement recovered the response, how the original equivalence class failed, and whether the same lesson transfers to other sites.

11.2 No elimination theater

A checklist cannot prove that all conventional explanations were eliminated. Each control has sensitivity and domain limits. The report states which alternatives were tested, what effect size they could exclude, and which remain unresolved.

12. Statistics Without Scalar Erasure

The primary unit is a response family indexed by history, pass condition, challenge, detector, and laboratory - not one pooled p-value.

12.1 Primary estimand

Each site preregisters a contrast Delta(N, F, J) between A and B for a defined outcome distribution under pass count N, frame condition F, and challenge J. The model estimates the entire curve with uncertainty and covariance. A recursion candidate requires a registered structure in Delta across N, not merely Delta different from zero at one selected N.

12.2 Distributional reporting

- Raw event/time-tag files and unnormalized counts.
- Detection and herald denominators, missingness, saturation, and failed trials.
- Outcome histograms or point-process representations before scalar summaries.
- Effect estimates with uncertainty, model residuals, posterior or predictive checks, and sensitivity.
- Multiplicity control for the frozen candidate family and a separate exploratory registry.
- Laboratory-specific results before any hierarchical synthesis.

12.3 Equivalence and noninferiority

The match stage uses equivalence tests with physically justified tolerances rather than failure to reject a difference. Tolerances are tied to challenge sensitivity and uncertainty. Passing O_match does not certify complete state equality; it certifies only the registered equivalence class.

12.4 Recurrence evidence ladder

Level	Requirement	Status language
0 - occurrence	Unexpected pattern in discovery data	Exploratory occurrence
1 - internal return	Frozen pattern follows true-return recursion controls	Recursive candidate
2 - local holdout	Reappears in protected data without tuning	Locally recurrent
3 - hardware rotation	Survives detector/channel/component rotation	Apparatus-robust candidate
4 - independent site	Recurs under independent implementation	Independently recurrent
5 - predictive	Frozen capsule predicts a new condition	Predictively recurrent
6 - interactive	Registered intervention changes it as predicted	Controllable recurrent relation
7 - generative	A model predicts a new artifact family prospectively	Generative relation

13. Recurrent Artifact Registry

A candidate is registered as RA-YYYY-SITE-####. The identifier is deliberately semantically empty. Names such as resonance, substrate memory, hidden dimension, or coherence phase are prohibited in the primary ID.

13.1 Required capsule

Field	Required content
Empirical fingerprint	Outcome distribution, topology, temporal shape, or multivariate relation
Recursive signature	Dependence on true return, pass count, phase, delay, or recursion topology
Boundaries	Discovery data, spent data, protected data, and future confirmation sets
Match context	O_match, tolerances, calibration method, failed or ambiguous matches
Controls	Completed, failed, unresolved, and not-yet-feasible tests with sensitivity
Provenance	Raw files, hashes, code, firmware, settings, environment, operators, timestamps
Translation status	Which representations preserve, alter, or erase the pattern
Classification	Optional Tool tags; always separable from the fingerprint
Disconfirmation	Prospective outcomes that would retire or restrict the candidate

13.2 Allowed unresolved status

An artifact can remain unclassified indefinitely while its empirical definition remains stable. The registry distinguishes unresolved from unexplained: unresolved means available evidence does not select among declared models; unexplained means no current model meets the frozen predictive standard. Neither word means supernatural, fundamental, or supportive of Substrate Cosmology.

13.3 Retirement without deletion

If a conventional cause is found, the artifact is marked resolved-to-model with a link to the reproducing control. If a result fails confirmation, it is marked nonrecurrent under the tested conditions. Records are never overwritten or silently removed.

14. Cross-Laboratory Program

Laboratories reproduce the relation, not necessarily the hardware scalar. One may use a fiber loop, another an integrated photonic loop, and a third a microwave resonator network if each publishes a translation ledger and demonstrates the required recursive return, match class, challenge, and delayed measurement.

14.1 Common core

- Same frozen candidate fingerprint and recurrence decision rule.
- Explicit O_match and local tolerances, with a cross-site translation map.
- True-return, sham, pass-matched, and detector-history controls.
- Protected data and a local report locked before viewing other sites.
- Raw and derived records with calibration, operator, and loss lineage.

14.2 Licensed heterogeneity

Sites are expected to differ. Source technology, loop length, detector family, clocking, and environmental control are declared heterogeneity axes. A common effect may scale differently; a conditional effect may appear only in one architecture; a translation may fail. These are separate outcomes, not deviations to be averaged away.

14.3 Site-resolved synthesis

Outcome	Meaning	Next action
Common relation	Fingerprint and direction survive accepted translations	Bound domain and seek prediction
Conditional relation	Recurrence depends prospectively on a measured platform relation	Test conditioning relation
Minority cluster	Robust subset of sites shares a pattern	Exchange components and protocols
Contradiction	Accepted sites produce incompatible fingerprints	Issue contradiction packet; do not average as resolution
Failed translation	No defensible mapping preserves the tested relation	Report platforms separately
Resolved artifact	Ordinary mechanism predicts the pattern	Publish mechanism and update match class
Null	No registered pattern within sensitivity	Constrain effect over tested domain

14.4 Independence audit

Shared source designs, vendors, code, calibration services, analysts, and training data create dependence. The consortium publishes an ancestry graph before calling sites independent. A laboratory with separate hardware but copied analysis is not fully independent.

15. Data Architecture and Operator Dimensionalization

Words, units, and operators are part of the apparatus because they decide which records can be compared and which histories disappear.

15.1 The relational record

For each event or acquisition block, retain source context, preparation sequence, mode labels, loop program, pass timing, challenge setting, detector microhistory, environment, calibration versions, raw observations, and every derived view. A summary table points to the record; it never replaces it.

15.2 Operator cards

Operator	Hidden decisions to record
/ - division	Numerator and denominator domains, zero/missing handling, covariance, normalization context, lost scale
= - equality	Equivalence relation, tolerance, resolution, matching domain, allowed exceptions
+ - aggregation	Compatibility of operands, ordering, weights, dependence, distinctions merged
- - residual	Alignment, prediction model, sign convention, covariance, conditioning
* - composition	Order, interaction, scaling, tensor versus scalar interpretation
Transform	Basis, invertibility, windowing, padding, phase reference, precision
Threshold	Detector and analysis threshold, ambiguous region, saturation, false classifications
Fit	Model family, priors, optimizer, initialization, identifiability, residual structure

15.3 Dimensionality of an operation

An operator is not treated as an empty glyph. Its dimensional profile includes input quantity types, output type, domain restrictions, interaction context, ordering, tolerance, covariance, recoverability, implementation, and loss. The card is recursive: any scalar used to summarize an operator card receives its own card.

15.4 Immutable zones

Zone	Content	Mutation rule
Raw	Instrument outputs, time tags, controller and environment logs	Append-only with checksums
Calibration	Standards, sacrificial ensembles, response models	Versioned; never overwrite
Curated	Validated formats and alignments	Regenerable from raw plus code
Derived	Features, state estimates, contrasts, figures	Versioned with complete lineage
Interpretive	Tool tags and theoretical mappings	Separable, revisable, never edits evidence

16. CERN and Hadronization as a Developmental Analogy

The collider comparison motivated the apparatus correction because it makes layered collapse difficult to ignore. A recorded proton-proton collision is an immense bundle of interactions. The labels parton, plasma, hadron, jet, track, and event each belong to a model-and-detector relation. Modern work even investigates whether entanglement-sensitive observables can probe hadronization. These facts make richer relational histories scientifically respectable; they do not show that optical-loop anomalies share a collider mechanism.

16.1 What the analogy contributes

- A familiar object can cease to be the most useful description during an interaction and later reappear as reconstructed matter.
- Final detectors observe products conditioned by a long, largely inaccessible interaction history.
- Several effective descriptions can be valid at different scales without being interchangeable.
- Event reconstruction is a layered inference, not an unmediated view of the collision.

16.2 What the analogy does not contribute

- It does not license the terms pre-matter or substrate as established particle-physics entities.
- It does not make optical modes equivalent to quark-gluon plasma or hadronization.
- It does not convert a detector residual into evidence for hidden dimensions.
- It does not exempt Experiment 1 from standard quantum-optical modeling.

Use of analogies

An analogy is a frame shake: it exposes an assumption by comparing structures. It becomes evidence only when translated into a discriminating observable, a control, or a successful prediction.

17. Implementation Roadmap and Stop Conditions

The experiment advances only when the previous stage is documented. Publication of this design does not imply that laboratories, equipment, funding, or approvals exist.

Stage	Gate	Deliverable
0 - simulation	Conventional models recover known loop and detector behavior	Open simulation and sensitivity study
1 - classical field	Shams, pass matching, drift, and transfer models validated	Classical reference report
2 - source qualification	Stable heralded or squeezed source and calibrated detectors	Source and detector model cards
3 - match qualification	A/B pass the frozen O_match equivalence tests	Match certificate
4 - recursive discovery	Usable true-return range and protected data partition	Discovery register and frozen capsule
5 - local confirmation	Independent code and holdout recurrence	Local confirmation report
6 - rotation	Candidate survives or resolves under hardware changes	Rotation report
7 - cross-site	At least two independently implemented laboratories report	Relational synthesis
8 - transfer	A justified second platform tests the translated relation	Transfer ledger

17.1 Scientific stop conditions

- Stop or redesign when the A/B match repeatedly fails under the registered equivalence test.
- Stop increasing N when unconditional information falls below the preregistered detection floor.
- Suspend a candidate when controls predict its fingerprint within uncertainty.
- Freeze exploration when the protected dataset boundary is compromised; create a new dataset.
- Do not claim independent recurrence when implementations share unmodeled ancestry.

17.2 Safety stop conditions

Laser interlock failure, electrical fault, thermal excursion, damaged optics, unsafe access, unexpected high optical power, or local responsible-person instruction stops acquisition immediately. Safety stops produce a censored run record and never count as negative scientific evidence.

17.3 What counts as success

Success is not a new-physics announcement. The program succeeds if it produces a recoverable comparison among histories, tests recursion separately from repetition, identifies where detectors and operators collapse information, resolves ordinary memory effects, or establishes a recurrent anomaly with boundaries clear enough for independent laboratories to challenge.

Appendix A. Minimum Common Protocol Checklist

- [ ] Local laser, electrical, institutional, equipment, and data approvals documented.
- [ ] Source, preparation, loop, challenge, detectors, clocks, monitors, and firmware versioned.
- [ ] O_match, tolerances, equivalence tests, and sacrificial calibration schedule frozen.
- [ ] Discovery, holdout, rotation, and independent-site boundaries committed before access.
- [ ] True-return, sham, pass-matched, reversed, randomized, classical, and detector-history controls scheduled.
- [ ] Raw time tags or waveforms retained before coincidence, threshold, subtraction, or fit.
- [ ] Unconditional denominators, loss, missingness, saturation, and failed runs retained.
- [ ] Primary contrast and recursion signature preregistered as a response family across N.
- [ ] Mainstream model ensemble and control sensitivities documented.
- [ ] RA capsule frozen before confirmation; neutral ID used in primary record.
- [ ] Complete Tool and frame-shake register published, including null and failed shakes.
- [ ] Local report locked before viewing other laboratories' protected results.
- [ ] Cross-site dependency graph and translation ledger completed before pooling.
- [ ] Interpretive Substrate Cosmology mapping separated from observational and derived layers.

DEPLOYABLE RECORDS

Appendix B. Recurrence Capsule Template

Field	Entry
RA identifier	RA-YYYY-SITE-####
Fingerprint	Exact empirical structure, representation, and tolerance
Discovery boundary	Files, runs, dates, and analysts used
Protected boundary	Reserved local and external data
Match class	O_match, epsilon, J_cal, certificate hash
Recursive signature	Expected structure across true-return N and controls
Challenge	Exact final interaction and measurement family
Primary estimator	Distributional or relational statistic and code hash
Mainstream predictions	Frozen models and predictive distributions
Disconfirmation	Outcomes that retire or restrict candidate
Unresolved controls	Known explanatory gaps and sensitivity limits
Tool tags	Optional and nonbinding
Translation rules	What must be preserved at another site/platform
Owners and freezes	Named responsibilities, signatures, timestamps

Appendix C. Minimum Data Dictionary

Field group	Minimum elements
Identity	site_id, apparatus_id, run_id, trial_id, parent_trial_id, archive_version
Preparation	history_code, ordered_operations, mode_map, control_waveform_hash, source diagnostics
Match	match_set_version, tolerance_version, sacrificial_batch, equivalence_result, ambiguity_flag
Recursion	N_commanded, N_verified, loop_direction, cell_program_hash, round_trip_times, release_event
Challenge	challenge_id, basis, delays, phases, topology, calibration_version
Detection	detector_id, channel, bias, efficiency_model, recent_event_history, raw_file_pointer
Environment	temperature, vibration, RF, magnetic field if monitored, clock status, operator events
Processing	software environment, code hash, operator cards, transform lineage, random seeds
Outcome	raw event reference, inclusion flag, failure code, derived views, candidate links

Every field has a unit, type, missingness meaning, uncertainty or precision, acquisition method, and version. A missing value is never encoded as zero. A transformed value never replaces its parent.

Appendix D. Preregistered Decision Rules

D.1 Match acceptance

Accept A/B into challenge testing only if every primary matching observable meets its frozen equivalence rule and the joint diagnostic model shows no registered challenge-relevant imbalance beyond tolerance. Ambiguous cases form a separate stratum; they are not silently pooled with accepted matches.

D.2 Candidate discovery

A discovery candidate must specify its empirical fingerprint, recursion signature, null generator, analysis degrees of freedom, ordinary explanation tests, and protected confirmation data. The discovery effect size is not a confirmation threshold unless justified prospectively.

D.3 Local recurrence

Local recurrence requires the frozen candidate to meet its direction or topology rule in protected data, while shams and pass-matched bypasses fail to reproduce the true-return signature, and while predeclared data-quality gates are satisfied. All components are reported; no conjunct may be hidden by a composite score.

D.4 Cross-site recurrence

Cross-site recurrence requires each site to issue a locked local conclusion under its translated capsule before synthesis. Numerical equality is not required. The synthesis tests whether the fingerprint lies inside the registered translation class and whether dependency compromises independence.

D.5 Classification

Classification is never a gate for recurrence. Tool tags, mainstream-model labels, and Substrate Cosmology interpretations are added only after the observational record and recurrence decision are frozen. Several incompatible classifications may coexist.

Appendix E. First-Edition Disposition and Change Inventory

First Edition element	Second Edition disposition	Reason
24-node RLC ring as reference apparatus	Replaced by a recirculating field-mode loop	The earlier matter network preselected classical entities, couplings, and detector-compatible outcomes.
Platform family after reference stabilization	Retained as later translation track	Cross-platform diversity remains valuable after a sharper core test exists.
33 Tools implicit as apparatus dimensions	Reframed as provisional prompts	Artifacts must not be forced to fit a closed registry.
Recursive feedback arm	Replaced by undetected physical recirculation plus separate adaptive arm	File or controller feedback is not the same as an artifact recursively re-entering a physical interaction.
Measured local observables throughout network	Replaced by sacrificial calibration and delayed final detection	Intermediate detection can select or destroy the relation being tested.
Frozen models, preregistration, blinding, controls	Retained and strengthened	These are essential to mainstream compliance.
Relational ledger and operator cards	Retained and made recursive	The ledger itself can collapse information and therefore requires provenance and loss records.
Cross-lab heterogeneity and no forced pooling	Retained	Different outcomes may expose conditioning relations.
Anomaly packets	Replaced by neutral RA recurrence capsules	Reproducibility is primary; classification is optional and later.
First Edition publication	Preserved as an archive	The conceptual correction should remain inspectable.

SCIENTIFIC AND PROJECT SOURCES

Appendix F. References

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PROVENANCE

Appendix G. Collaboration and Verification Record

Research originator and conceptual direction

James Dunn.

AI collaboration

OpenAI ChatGPT Codex assisted with correlation of the prior volumes and Experiment 1 First Edition, identification of premature material and scalar constraints, development of the recirculating field-mode design, differentiation of recursion from recurrence, mainstream-physics boundary language, drafting, references, PDF production, and website integration.

Required human verification

- Quantum-optical feasibility, component choices, loss budgets, and detector models.
- Statistical design, power or precision targets, equivalence margins, and multiplicity.
- Laser, electrical, cryogenic if applicable, institutional, and equipment safety.
- Citation accuracy, intellectual contribution, and authorship requirements.
- Independent implementation, data custody, software reproducibility, and claim language.

Edition statement

This Second Edition replaces Experiment 1 First Edition as the current website-linked protocol. The First Edition remains preserved so the development from a matter-network frame to a recurrence-first field-mode frame can be audited.

End of Experiment 1, Second Edition