

# A Falsification Sheet for the Finite-QEC Substrate Programme: Sharp Empirical Ways to Kill, Demote, or Constrain the Framework

David Elliman  
Neuro-symbolic Ltd  
dave@neusym.ai

Revised canon snapshot: 2026-06-25

## Abstract

This note is deliberately adversarial. It collects the simplest empirical ways to falsify, demote, or sharply constrain the finite-QEC substrate programme described in the companion papers [15–21]. The point is not to list numerical agreements. It is to state, in ordinary observational language, where the framework makes departures from standard  $\Lambda$ CDM plus the Standard Model, and what future data would force a retraction. The cleanest near-term kill switches are: a confirmed primordial tensor signal at  $r \gtrsim 10^{-3}$ , a dark-energy reconstruction excluding  $w(a) = -1 + a/28$ , a scalar tilt excluding  $n_s = 27/28$ , a reproducible secular drift in the frozen constants  $G$  or  $\alpha$ , a neutron electric dipole moment far above  $10^{-31} e \text{ cm}$  with no additional CP source, and dark-matter phenomenology requiring the dominant component to be ordinary CDM in a way that cannot be reconciled with the conditional R4 zero-mode/sterile-neutrino ledger. Several tests are branch-level rather than global: excluding the 17.7 keV sterile-neutrino component, refuting the R4 line law behind MOND-like behaviour, or bounding K04 debris below any cosmological relevance would retire those branches without necessarily collapsing the matter and spectroscopy sector. The largest recent change is the CMB entry: the old third-peak no-go is replaced by a conditional pressureless zero-mode *route* with  $\Omega_{\text{dark}} h^2 \simeq 0.1209$ , but the conserved massive dust charge is not derived from documented active R4 dynamics. The CMB gate is therefore a concrete dust-premise, Boltzmann-likelihood, and halo double-counting test rather than a prose argument. The other recent change is trans- $\Lambda_{\text{QCD}}$  physics: high-energy quanta are no longer listed as a support problem, because the canon supplies a framed causal-set/null-chain external leg; the falsifier is now precision QED, finite-density transfer, or intrinsic Lorentz-violation in that leg. The result is a compact “try to kill it first” map for readers and experimentalists.

## Contents

<b>1</b>	<b>Why a Falsification Sheet Is Needed</b>	<b>2</b>
1.1	Three scopes of failure . . . . .	2
1.2	Correlated null signature . . . . .	3
<b>2</b>	<b>One-Page Test Ledger</b>	<b>4</b>
<b>3</b>	<b>Cosmology: The Cleanest Kill Switches</b>	<b>6</b>
3.1	Dark energy: the line $w(a) = -1 + a/28$ . . . . .	6
3.2	Scalar tilt: $n_s = 27/28$ . . . . .	6
3.3	Primordial tensors: almost no $B$ -modes . . . . .	6
3.4	Scalar amplitude: a branch-level stop-rule test . . . . .	6

<b>4</b>	<b>Precision Constants and Strong CP</b>	<b>7</b>
4.1	Frozen $G$ and frozen $\alpha$ . . . . .	7
4.2	Neutron electric dipole moment . . . . .	7
4.3	Majorana tests . . . . .	7
<b>5</b>	<b>Dark-Sector Tests</b>	<b>8</b>
5.1	The 17.7 keV sterile branch . . . . .	8
5.2	K04 frozen-defect component . . . . .	8
5.3	R4 line law and MOND-like phenomenology . . . . .	8
5.4	The CMB third peak: now a conditional route . . . . .	8
<b>6</b>	<b>Gravitational-Wave Channels</b>	<b>9</b>
6.1	A stochastic background in the pulsar-timing band . . . . .	9
6.2	Ringdown echoes: a null, not a positive prediction . . . . .	9
<b>7</b>	<b>The Trans-<math>\Lambda_{\text{QCD}}</math> Precision Test</b>	<b>10</b>
<b>8</b>	<b>Demotion Rather Than Death</b>	<b>10</b>
<b>9</b>	<b>Ranked Near-Term Tests</b>	<b>11</b>
<b>10</b>	<b>Minimal Public Summary</b>	<b>12</b>
<b>A</b>	<b>Canon Hooks and Reproducibility</b>	<b>13</b>

## 1 Why a Falsification Sheet Is Needed

A speculative framework is scientifically useful only to the extent that it can be wrong. A list of coincidences, even striking ones, is not enough. The finite-QEC programme now contains many derived or conditionally derived statements: a code-theoretic matter sector, a crystallisation picture of constants, a boundary-printing cosmology, dark-sector wall and line-current mechanisms, and a framed causal-set representation for trans- $\Lambda_{\text{QCD}}$  quanta. Some are hard numerical claims; others are mechanism claims; a few are still scaffolds whose open premises are explicitly named in the canon [22, 23].

This note states the empirical attack surface. It follows the ordinary logic of falsifiability [32]: a claim is stronger when it excludes clear observations. It also follows the canon’s internal methodology: a failed claim should be demoted at the smallest honest scope. If a sterile-neutrino line is excluded, the sterile branch dies; it does not automatically kill the QEC code. If a primordial tensor signal is confirmed at high scale, the boundary-printing inflationary branch is in direct trouble. If constants classified as frozen code readouts drift in time, the damage is global.

### 1.1 Three scopes of failure

Throughout the paper, the falsifiers are labelled by scope.

**Global.** The observation threatens a central bridge or the substrate programme as a whole. Examples are secular drift in frozen constants, or failure of the trans- $\Lambda_{\text{QCD}}$  representation needed to keep one coarse substrate scale compatible with high-energy Lorentz-invariant quanta.

**Sector.** The observation kills a named sector while leaving others potentially intact. A confirmed high-scale primordial tensor background would damage the inflationary boundary-printing sector; a large neutron EDM would damage the strong-CP closure.

**Branch.** The observation retires one mechanism inside a sector. Excluding the 17.7 keV sterile state would not by itself exclude the R4 line-current or K04 pinned-fossil branches of the dark sector.

This is not legalistic bookkeeping. It is how the framework avoids the common failure mode of large speculative programmes: moving a dead prediction into the background story rather than recording that it died.

## 1.2 Correlated null signature

Several of the cleanest tests are nulls. They should not be presented as unrelated absences. In the current canon they are correlated by two common mechanisms. First, frozen crystallisation/code ledgers should not drift after lock-in:

$$\frac{\dot{G}}{G} = 0, \quad \frac{\dot{\alpha}}{\alpha} = 0, \quad (1)$$

apart from ordinary energy-scale running of the dressed low-energy coupling. Second, the substrate has no live high-scale oscillator/tensor sector during boundary printing: the neutron EDM is pushed to the weak-leakage floor, the linear primordial tensor ratio is zero, and only a second-order scalar-induced floor remains.

Null	Canonical scale	Positive signal that would matter	Interpretation
$\dot{G}/G$	$0 \text{ yr}^{-1}$	Reproducible secular drift at lunar-laser-ranging or ephemeris scale.	Global frozen-ledger failure
$\dot{\alpha}/\alpha$	$0 \text{ yr}^{-1}$	Clock or astrophysical drift requiring a changing code coupling.	Global code-ledger failure
Neutron EDM	$\sim 10^{-31} e \text{ cm}$	$d_n \gg 10^{-30} e \text{ cm}$ without an added CP source.	Strong-CP phase-null failure
Primordial tensors	$r_{\text{linear}} = 0,$ $r_{\text{induced}} \sim 2 \times 10^{-9}$	Primordial B modes at $r \gtrsim 10^{-3}$ .	Boundary-printing/no-squeezing failure
High-scale tensor background	absent	Any robust standard high-scale inflationary tensor background.	One-bit scalar-printer failure

This is scientifically useful because the signature is over-constrained. A single positive result can kill the relevant mechanism; a continuing pattern of nulls across clocks, lunar ranging, neutron-EDM searches, and CMB B modes is a recognisable footprint rather than merely “nothing happened.”

## 2 One-Page Test Ledger

Table 1 is the practical falsification sheet. The values are the canon’s current targets, not a re-fit to the latest data. Observational context is supplied by standard cosmology, CMB, dark-sector, and precision-test references [1, 2, 5, 7, 12, 13, 31, 33, 35, 36].

Table 1: Empirical attack surface of the finite-QEC substrate programme.

Observable	Canonical prediction	What would falsify or demote it	Scope
Late dark-energy equation of state	$w(a) = -1 + a/28$ , so $w_0 = -27/28 = -0.9642857$ and $w_a = -1/28$ .	A robust reconstruction excluding this line, especially a confirmed phantom epoch $w < -1$ without an additional negative-rate channel.	Sector
Scalar spectral index	$n_s = 27/28 = 0.9642857$ .	A future CMB/LSS determination excluding 0.9643 after foregrounds, running, neutrino sector, and model-extension checks.	Sector
Primordial tensors	$r_{\text{linear}} = 0$ , with only a scalar-induced floor $r_{\text{induced}} \sim 2 \times 10^{-9}$ ; effectively no observable primordial B-modes.	A confirmed primordial B-mode detection at $r \sim 10^{-3}$ or above, after lensing, dust, and instrumental systematics are excluded.	Sector/global
Scalar amplitude	$A_s = (3/4)\alpha_0^4 \simeq 2.13 \times 10^{-9}$ , conditional on the local single-clock saturated-printer, channel-lock, and spatial-whitening premises.	Evidence that the scalar source is a nonlocal horizon-mode operator, an all-channel entropy load, or an additional scalar source, changing the stop rule or $S_j(k = aH)$ .	Branch
Sterile-neutrino component	$m_{\nu_R} = \alpha_0^2 \Lambda_{\text{QCD}} \simeq 17.7 \text{ keV}$ .	X-ray and structure-formation bounds excluding any cosmologically relevant component at this mass/mixing, or a secure incompatible dark-sector line.	Branch
CMB pressureless dark budget	Conditional route using a conserved R4 zero-mode reservoir plus the 17.7 keV sterile branch: $\Omega_{\nu_R} h^2 = 0.02418$ , $\Omega_{\text{zero}} h^2 = 0.09671$ , and $\Omega_{\text{dark}} h^2 = 0.12089$ .	A derivation failure for the conserved massive dust charge, a full Boltzmann likelihood showing that this dust-like component cannot fit the acoustic scale/peak heights, or halo phenomenology showing that the same zero-mode component double-counts the late R4/MOND ledger.	Sector

Observable	Canonical prediction	What would falsify or demote it	Scope
Majorana neutrino mass	The active-neutrino identity is Majorana in canon; sterile $\nu_R$ is a separate pseudocodeword branch with gauge-forbidden Dirac mixing. The minimal normal-ordering band gives $m_{\beta\beta} \sim 1\text{--}4$ meV.	A clean neutrinoless double-beta signal implying an effective mass pattern incompatible with the code neutrino sector, or a null result only after experiments reach the meV band.	Sector
Neutron EDM	$\bar{\theta} = 0$ at the bare strong-CP closure and $d_n \sim 10^{-31}$ e cm.	A confirmed neutron EDM orders of magnitude above this with no explicit additional CP source.	Sector
Dark-matter morphology	K04 debris is pinned, substrate-static fossil structure; mobile halo burden is on the R4 zero-mode, R4/MOND line-current, and sterile branches.	Evidence requiring K04 itself to be the mobile halo component, or upper bounds forcing the whole non-particle dark-sector budget below the required CMB/halo mass.	Branch/sector
Halo phenomenology	R4 scheduler-record line support gives a Poisson line-current/AQUAL branch with $\chi_{R4} = 1$ under the accepted service-clock quotient; cored profiles and halo double-counting remain phenomenological gates.	High-quality galaxy data requiring cuspy CDM-only profiles, rejecting the R4/MOND-like acceleration law in the claimed regime, or forcing a CDM-like zero-mode halo that leaves no room for active R4/MOND.	Sector
Time variation of $G$	Frozen after lock-in: $\dot{G}/G = 0$ within observational precision.	A reproducible secular drift not attributable to systematics or local environmental modelling.	Global
Time variation of $\alpha$	The bare/code $\alpha_0$ is frozen; the dressed IR $\alpha$ runs with energy but not cosmic time as a code drift.	A reproducible secular drift of the low-energy fine-structure constant requiring a changing code coupling.	Global
Trans- $\Lambda_{\text{QCD}}$ Lorentz quanta	High-energy photons are framed causal-set null-chain QED events with one normalised external LSZ leg, not $\Lambda_{\text{QCD}}$ -lattice Bloch modes or $N$ -photon Fock bundles.	Precision QED, transfer-function, or time-of-flight data requiring intrinsic null-chain dispersion; benchmark 1 TeV / 1 Gpc / 1 s timing gives $ \zeta_1  < 3.2 \times 10^{-21}$ , $ \zeta_2  < 1.1 \times 10^{-24}$ .	Global bridge

### 3 Cosmology: The Cleanest Kill Switches

#### 3.1 Dark energy: the line $w(a) = -1 + a/28$

The late dark-energy branch is unusually easy to state. In the Chevallier–Polarski–Linder convention [10, 27],

$$w(a) = -1 + \frac{a}{28}, \quad w_0 = -\frac{27}{28}, \quad w_a = -\frac{1}{28}. \quad (2)$$

This is not  $\Lambda$ CDM; it is a thawing line just above  $-1$ . It also forbids phantom behaviour in the ordinary positive-load reading of the QEC activation ledger. The framework therefore pays a real observational price. A robust late-time reconstruction with  $w < -1$  in the relevant epoch, or a precise non-parametric reconstruction excluding Eq. (2), kills this branch. It would not automatically kill the matter/gauge sector, but it would remove one of the largest claimed cosmological wins.

The current observational situation is exactly the kind that makes this worth stating. DESI BAO analyses report tension with a pure cosmological constant in some data combinations and use  $w_0 w_a$  fits as one diagnostic [12, 13]. This note does not claim those data prove Eq. (2). It says the line is a public target.

#### 3.2 Scalar tilt: $n_s = 27/28$

The boundary-printing/HBC branch predicts

$$n_s = \frac{27}{28} = 0.9642857. \quad (3)$$

The number is close to Planck-era values [31], which is why it is tempting. The falsifier is correspondingly simple: a future CMB and large-scale-structure determination that robustly excludes 0.9643, after foregrounds, running, neutrino assumptions, and model extensions are accounted for, retires the HBC scalar-clock tilt branch. Because the same saturation premise also supports the amplitude line, failure here would pressure more than one cosmological derivation.

#### 3.3 Primordial tensors: almost no $B$ -modes

The most decisive single cosmological falsifier is a primordial tensor signal. The boundary-printing branch does not contain the usual high-scale squeezed de Sitter graviton vacuum at the printing front. Its linear primordial tensor level is zero; the only residual is the scalar-induced floor,

$$r_{\text{linear}} = 0, \quad r_{\text{induced}} \sim \mathcal{O}(A_s) \sim 2 \times 10^{-9}. \quad (4)$$

This is far below the sensitivity of current  $B$ -mode searches and far below the canonical large-field inflation target. A confirmed primordial signal at  $r \gtrsim 10^{-3}$ , with lensing, Galactic dust, and instrumental systematics excluded, would not be a small correction. It would say that a high-scale gravitational vacuum was squeezed during inflation, directly contradicting the no-squeezing/scalar-printer branch. Current upper limits from BICEP/Keck and related analyses do not reach this level, but they define the observational programme [5].

#### 3.4 Scalar amplitude: a branch-level stop-rule test

The amplitude claim is sharper and is no longer a free normalisation:

$$A_s = \frac{3}{4} \alpha_0^4 \simeq 2.13 \times 10^{-9}. \quad (5)$$

The canon now treats this as a local single-clock saturated-printer statement. Inside that premise, the finite queue theorem gives

$$N_{\text{shell}}\alpha_0^4 = \frac{4}{3} \quad (6)$$

and the compensated product-local service current gives  $S_j(k = aH) = 1$ . The remaining falsifier is therefore not an arbitrary amplitude re-fit; it is a wrong-object theorem. If the scalar perturbation couples to total boundary entropy rather than the post-decoder colour-restoring topology current, or if a nonlocal horizon-mode covariance supplies  $S_j \neq 1$ , Eq. (5) reopens even if the 28-clock tilt survives. This is a demotion test, not a global kill switch.

## 4 Precision Constants and Strong CP

### 4.1 Frozen $G$ and frozen $\alpha$

The constant-ledger paper separates frozen constants from live rates [17, 20].  $G$  and the code-level  $\alpha_0$  are frozen crystallisation readouts. The low-energy dressed fine-structure constant runs with energy in the ordinary renormalisation-group sense, but it should not drift with cosmic time as a changing code coupling. Thus,

$$\frac{\dot{G}}{G} = 0, \quad \frac{\dot{\alpha}}{\alpha} = 0 \quad (7)$$

within observational precision and after known systematics. Atomic-clock and lunar-laser-ranging measurements are therefore not peripheral: they are direct tests of the frozen-ledger classification [33, 35, 36]. A confirmed secular drift in either quantity would be global damage.

### 4.2 Neutron electric dipole moment

The strong-CP closure asserts the bare cancellation

$$\bar{\theta} = \theta_{\text{gauge}} + \arg \det(M_u M_d) = 0, \quad (8)$$

with a residual neutron EDM of order

$$d_n \sim 10^{-31} e \text{ cm}. \quad (9)$$

This lies far below the current experimental bound, but it is not ambiguous. A confirmed neutron EDM orders of magnitude above Eq. (9) would kill this closure unless the canon explicitly adds a new CP-violating source. The present experimental frontier is therefore a clean external pressure point [2].

### 4.3 Majorana tests

The neutrino sector is not yet as locked as the hadronic mass and gauge structure sector, but its present canon is no longer “Dirac-like rather than Majorana.” The active-neutrino identity is Majorana; the sterile  $\nu_R$  branch is a separate pseudocodeword with gauge-forbidden Dirac mixing. With the canonical normal-ordering masses, the light-Majorana exchange envelope is only

$$m_{\beta\beta} \simeq 1\text{--}4 \text{ meV}. \quad (10)$$

Neutrinoless double-beta decay is therefore allowed, but near-term null results are not yet fatal [1]. A positive signal in the  $\sim 10 \text{ meV}$  inverted-ordering range would be more interesting than a null: it would require an extra Majorana operator, phase choice, or mass contribution not currently derived by the code neutrino sector.

## 5 Dark-Sector Tests

### 5.1 The 17.7 keV sterile branch

One dark-sector branch assigns a residual sterile state

$$m_{\nu_R} = \alpha_0^2 \Lambda_{\text{QCD}} \simeq 17.7 \text{ keV}. \quad (11)$$

The falsifier is not simply “no line has yet been seen”: abundance, production, mixing angle, and astrophysical modelling matter [7, 14]. But X-ray and structure bounds that exclude any cosmologically relevant component at this mass would retire this branch. Conversely, a secure line at a different mass would only help the framework if the remaining budget still allowed Eq. (11) as a subcomponent.

### 5.2 K04 frozen-defect component

The K04 debris branch is not a hidden gas of elementary particles. Its current form is a kinetic relic mechanism: rapid crystallisation can trap extended, mis-ordered domains. The mobility gate has changed the interpretation. K04 is now a pinned, substrate-static fossil component, not the dominant mobile halo component and not the pressureless carrier needed by the CMB. The relevant tests are therefore upper-bound and consistency tests:

- A K04 fossil should not track galaxies as a freely streaming halo through cluster collisions; if a paper uses K04 as the Bullet-Cluster component, that is now an internal error, not a live prediction.
- The absolute fossil density must stay below lensing and structure bounds on smooth or substrate-frame-static components.
- The Kibble–Zurek wall-network shape and pinning should be testable in analogue/emulation systems even if its cosmological abundance is small.

The falsifier is accordingly narrower. If the framework needs K04 itself to be the mobile collisionless halo, the K04 branch has already failed. If future work derives a tiny fossil density, K04 survives as a dark-sector remnant and analogue target, not as the dominant dark-matter mechanism.

### 5.3 R4 line law and MOND-like phenomenology

The R4/MOND branch asserts that count-valued one-dimensional support produces BTFR-like scaling and low-acceleration regularities. The observational context is the MOND/BTFR literature [24, 29, 30]. The local algebra is stronger than the first version of this sheet stated: under the scheduler-record quotient, creation and erasure are same-clock record events, and the Poisson line theorem gives  $\chi_{R4} = 1$ . What remains is not the old zero-bias blocker but the astrophysical lift: cored-profile selection, halo screening or depletion if a CDM-like zero mode is also present, and the external Dirac-class  $a_0 = cH_0/2\pi$  anchor. Galaxy data that robustly require cuspy CDM-only profiles and reject the R4/MOND-like acceleration law in the claimed regime would kill this branch.

### 5.4 The CMB third peak: now a conditional route

The microwave background is the most dangerous empirical gate because the third acoustic peak requires a cold, pressureless, clustering component of density  $\Omega_c h^2 \simeq 0.12$  at recombination [31].

The first version of this sheet recorded an open no-go: K04 walls have  $w = -2/3$ , frozen R4 strings would have  $w = -1/3$ , and the sterile state alone gives only  $\Omega_{\nu_R} h^2 \simeq 0.024$ . That wording is now incomplete rather than simply stale. The live route inserts a separate conserved R4 zero-mode reservoir with a Brown–Kuchar/Stueckelberg dust Hamiltonian [8], but the conserved massive dust charge is not derived from the documented active R4 Lindbladian. Under the current one-port source law,

$$\frac{n_{\nu_R}}{n_\gamma} = \frac{\alpha_0}{208}, \quad (12)$$

and the directed-R4 4:1 zero-mode-to-sterile incidence, the ledger gives

$$\Omega_{\nu_R} h^2 = 0.02418, \quad \Omega_{\text{zero}} h^2 = 0.09671, \quad \Omega_{\text{dark}} h^2 = 0.12089, \quad z_{\text{eq}} = 3430. \quad (13)$$

A diagnostic CAMB calculation confirms that, if admitted, a pressureless  $\Omega_x h^2 \simeq 0.096$  component has the right equality/third-peak shape [26]. This is a real improvement, but it is not a finished CMB likelihood. The remaining falsifiers are exact and severe:

- the full Boltzmann likelihood may fail once the acoustic scale  $\theta_*$ , lensing, neutrino sector, and background  $H_0$  selector are fit jointly;
- the conserved massive zero-mode dust charge, source law  $\alpha_0/208$ , sterile mass anchor, or generation-singlet release-port assumption may fail;
- the zero-mode component may double-count the same galaxies that the active R4/MOND line-current branch is meant to explain, unless a halo depletion or screening theorem is derived.

Thus the CMB entry has moved from a simple “sterile-only no-go” to a conditional pressureless-dust route with hard theory and forward-model gates. It is now one of the most decisive places to test the framework rather than a prose objection.

## 6 Gravitational-Wave Channels

Two gravitational-wave channels, developed after the first version of this sheet, add near-term tests independent of the cosmological and matter sectors.

### 6.1 A stochastic background in the pulsar-timing band

If the substrate crystallised at  $T_* \sim \Lambda_{\text{QCD}}$ , the first-order transition sources a stochastic gravitational-wave background peaking in the nanohertz pulsar-timing band,  $f \sim 20\text{--}50$  nHz, rising as  $h_c \sim f^{1/2}$  below the peak. Because the K04 walls are pinned and sub-threshold, the predicted amplitude sits below the level a cosmological source would need to dominate the array. A nanohertz background confirmed *cosmological* (not from supermassive black-hole binaries) at an amplitude requiring unsuppressed walls [3], or a confirmed cosmological background peaking instead in the LISA or LIGO band, would tension the pinned-wall picture.

### 6.2 Ringdown echoes: a null, not a positive prediction

The framework’s QEC horizon is a one-way record-writing channel, not a coherent reflecting mirror: the finite cell isometry and its Schwarzschild lift are injective syndrome-and-latch maps, so once the record is traced no delayed identity channel returns a phase-coherent wave [9]. The canonical prediction is therefore a *large-echo null*. Near-unit reflectivity at the lattice cutoff  $a_0 = 1/\Lambda_{\text{QCD}}$

would require an additional reflective-memory or rigid-core primitive not present in the present ledger; were it present, the round-trip spacing would be  $\Delta t \simeq 56$  ms for a  $30 M_\odot$  remnant (about half a generic Planck-scale echo, because  $a_0/\ell_P \sim 10^{20}$  halves the logarithm). LIGO/LISA echo searches are therefore retained as *upper-bound* tests on extra horizon structure rather than as a positive prediction; a robust large-echo detection at that spacing would instead signal horizon structure beyond the present ledger, and a clean non-detection is consistent with the canonical null.

## 7 The Trans- $\Lambda_{\text{QCD}}$ Precision Test

The framework’s most dangerous foundational residual is not a small phenomenological discrepancy. It is the compatibility of three claims:

1. the elementary substrate scale is  $a_0 = \hbar c/\Lambda_{\text{QCD}}$ ;
2. the same absence of a fine ultraviolet oscillator tower is part of the cosmological-constant story;
3. experiments nevertheless observe Lorentz-invariant photons and other quanta with energies far above  $\Lambda_{\text{QCD}}$ .

A naive lattice photon fails: the Brillouin cutoff is of order  $\Lambda_{\text{QCD}}$ , and a bundle of  $N$  soft photons gives  $N$  detector legs rather than one high-energy LSZ leg. The current canon closes the support problem at framed causal-set smooth-field grade. The high-energy event is not a Maxwell Bloch mode on the  $\Lambda_{\text{QCD}}$  crystal, but a source-conditioned null-chain QED event whose endpoint has one normalised external leg with total four-momentum. The framed mesoscopic loop action supplies the Maxwell  $F^2$  term, the service frame supplies Dirac spin, and the endpoint residue is  $Z_{\text{endpoint}} = 1$ . This is motivated by established causal-set field theory and constrained by Lorentz-invariance tests [4, 6, 11, 25, 28, 34].

The falsifier has therefore moved. It is no longer “can a TeV photon exist?” but “does the normalised null-chain external leg reproduce precision QED and astrophysical propagation without intrinsic dispersion?” Writing any residual speed law as

$$\frac{\Delta v}{c} = \zeta_n \left( \frac{E}{\Lambda_{\text{QCD}}} \right)^n, \quad (14)$$

a benchmark 1 TeV photon over 1 Gpc with 1 s timing already requires  $|\zeta_1| < 3.2 \times 10^{-21}$  and  $|\zeta_2| < 1.1 \times 10^{-24}$ ; at 100 TeV these become  $3.2 \times 10^{-23}$  and  $1.1 \times 10^{-28}$ . The prediction is exact null-chain propagation plus ordinary plasma, EBL opacity, detector response, and loop-level QED effects. Any nonzero intrinsic per-service dispersion is a new coefficient and should be treated as a falsification or demotion of the trans- $\Lambda_{\text{QCD}}$  bridge.

## 8 Demotion Rather Than Death

Table 2 lists failures that should be recorded as branch demotions rather than global falsifications. This distinction matters because the framework is now broad enough that a single dead mechanism should not be allowed either to collapse unrelated results or to hide as prose.

Table 2: Branch failures and their honest consequences.

Claim	Failure mode	Consequence
$A_s = (3/4)\alpha_0^4$	Local single-clock scalar-printer premise fails, or a nonlocal scalar covariance gives $S_j \neq 1$ .	Inflation amplitude branch reopens; $n_s = 27/28$ may survive if the 28-clock lift survives.
$n_s = 27/28$	Future data excludes the value.	HBC scalar-clock branch dies; late $w_0 = -27/28$ is pressured because both share the single saturation premise.
17.7 keV sterile state	X-ray/budget constraints exclude it.	Sterile component retires; CMB zero-mode source law and dark budget must be rebuilt.
K04 fossil component	K04 is required to act as the mobile halo, or upper bounds force its fossil density to zero.	K04 remains, at most, an analogue-testable pinned relic; halo burden stays on R4/zero-mode/sterile branches.
MOND/R4 line law	Halo data reject the R4/MOND acceleration law, or zero-mode dust double-counts the galaxy mass budget.	MOND/BTFR branch retires or must be screened; gravity and cosmology are not automatically killed.
CMB zero-mode reservoir	The conserved massive dust charge cannot be derived or admitted without conflict, the $\Omega_{\text{zero}}h^2 \simeq 0.0967$ component fails the full CMB likelihood, or it cannot avoid halo double-counting.	CMB completion reopens; the dark sector returns to a hard third-peak deficit.
Causal-set null-chain QED	Precision QED or time-of-flight data require intrinsic null-chain dispersion.	The trans- $\Lambda_{\text{QCD}}$ bridge is demoted; a finer oscillator cutoff would endanger single-scale CC compatibility.

## 9 Ranked Near-Term Tests

The following ranking is pragmatic, not philosophical. It asks which observations could most quickly force a public change to the canon.

1. **Primordial tensors.** A clean detection at  $r \gtrsim 10^{-3}$  is the fastest way to kill the boundary-printing inflation branch.
2. **Dark-energy reconstruction.** A robust exclusion of  $w(a) = -1 + a/28$ , especially by phantom behaviour, kills the R4 late dark-energy ledger.

3. **Frozen-constant drift.** Confirmed secular drift in  $G$  or low-energy  $\alpha$  is global damage.
4. **Neutron EDM.** A large EDM without an added CP source kills the strong-CP closure.
5. **X-ray sterile-neutrino searches.** Excluding the 17.7 keV state retires a named dark component.
6. **CMB zero-mode likelihood and dust premise.** Failure to derive or admit the conserved dust charge, a full Boltzmann fit that cannot accommodate  $\Omega_{\text{zero}}h^2 \simeq 0.0967$ , or a halo analysis showing unavoidable double-counting with active R4/MOND, is the most dangerous dark-sector gate.
7. **Dark-matter morphology.** Cluster collisions, small-galaxy cores, and weak lensing decide whether the R4/zero-mode/sterile split is viable; K04 itself should be treated as pinned fossil structure, not as the mobile halo.
8. **High-energy Lorentz/QED precision.** This is less likely to be killed by one observation, but it is foundational. The framework predicts exact null-chain propagation plus ordinary medium effects, not an  $O(1)$  Planck-suppressed speed law.

## 10 Minimal Public Summary

The finite-QEC substrate programme is falsifiable in ordinary experimental language.

- It predicts no observable primordial tensor B-modes:  $r_{\text{linear}} = 0$ , with only a scalar-induced floor  $r_{\text{induced}} \sim 2 \times 10^{-9}$ .
- It predicts a specific dark-energy line:  $w(a) = -1 + a/28$ .
- It predicts a specific scalar tilt:  $n_s = 27/28$ .
- It predicts frozen  $G$  and frozen code-level  $\alpha$ .
- It predicts a very small neutron EDM, around  $10^{-31} e \text{ cm}$ , unless an additional CP source is added.
- It contains a 17.7 keV sterile-neutrino branch that X-ray data can exclude.
- It now needs a pressureless R4 zero-mode reservoir with  $\Omega_{\text{zero}}h^2 \simeq 0.0967$  to pass the CMB third peak, and the conserved massive dust charge for that reservoir remains a live premise.
- It treats K04 as pinned fossil structure, while the mobile halo burden is on the R4 zero-mode, R4/MOND line-current, and sterile branches.
- It represents trans- $\Lambda_{\text{QCD}}$  photons and other high-energy quanta as normalised null-chain external legs; precision QED and time-of-flight data test that bridge.

Those are the places to attack first. If none of them fail, the framework earns attention. If any of them fail, the canon must record the smallest honest demotion and stop using that branch as support.

## A Canon Hooks and Reproducibility

The numerical and logical claims in this sheet are not intended to stand alone. They point to the canon, the companion papers, and executable checks in the public repository [23]. Representative hooks are listed below. Script names are descriptive rather than exhaustive; the repository is the canonical source for exact invocation.

Hook	Purpose
ANCHOR.md, DRIFT.md	Canonical claim ledger and drift/history ledger.
ai_methodology/ptms	Claim extraction and numbering consistency checks.
python_code/boundary_printing_*	HBC/boundary-printing tilt, amplitude, and saturation checks.
python_code/constant_*, python_code/mp_derivation_reduction.py	Frozen/live constant classification and gravity/horizon consolidation.
python_code/k04_*	K04 crystallisation, pinned-fossil mobility, KZ wall-network, and analogue/emulation measurements.
python_code/item132_*, python_code/mond_*	R4/MOND line-current and halo-phenomenology checks.
python_code/strong_cp_*	Strong-CP closure and neutron-EDM target.
python_code/foundations_trans_lambda_*, python_code/relativity_TR2_*	Trans- $\Lambda_{\text{QCD}}$ photon identity, null-chain, and Lorentz-representation checks.
python_code/item123_cmb_zero_mode_theorem.py, python_code/item123_cmb_boltzmann_sweep.py	CMB zero-mode completion gate: conditional pressureless $\nu_R + R4$ component with $\Omega_{\text{dark}} h^2 \simeq 0.1209$ , and diagnostic Boltzmann/CAMB sweep.
python_code/qec_echo_template.py, python_code/gw_stochastic_background_nanograv.py	Ringdown-echo template and the PTA-band stochastic GW background.

## References

- [1] S. Abe et al. Search for the majorana nature of neutrinos in the inverted mass ordering region with KamLAND-Zen. *Physical Review Letters*, 130(5):051801, 2023. doi: 10.1103/PhysRevLett.130.051801.
- [2] C. Abel et al. Measurement of the permanent electric dipole moment of the neutron. *Physical Review Letters*, 124(8):081803, 2020. doi: 10.1103/PhysRevLett.124.081803.
- [3] Gabriella Agazie et al. The NANOGrav 15 yr data set: Evidence for a gravitational-wave background. *Astrophysical Journal Letters*, 951(1):L8, 2023. doi: 10.3847/2041-8213/acdac6.
- [4] Dionigi M. T. Benincasa and Fay Dowker. The scalar curvature of a causal set. *Physical Review Letters*, 104(18):181301, 2010. doi: 10.1103/PhysRevLett.104.181301.

- [5] BICEP/Keck Collaboration. Improved constraints on primordial gravitational waves using Planck, WMAP, and BICEP/Keck observations through the 2018 observing season. *Phys. Rev. Lett.*, 127:151301, 2021.
- [6] Luca Bombelli, Joochan Lee, David Meyer, and Rafael D. Sorkin. Space-time as a causal set. *Physical Review Letters*, 59(5):521–524, 1987. doi: 10.1103/PhysRevLett.59.521.
- [7] Alexey Boyarsky, Marco Drewes, Thierry Lasserre, Susanne Mertens, and Oleg Ruchayskiy. Sterile neutrino dark matter. *Progress in Particle and Nuclear Physics*, 104:1–45, 2019. doi: 10.1016/j.pnpnp.2018.07.004.
- [8] J. David Brown and Karel V. Kuchař. Dust as a standard of space and time in canonical quantum gravity. *Physical Review D*, 51:5600–5629, 1995. doi: 10.1103/PhysRevD.51.5600.
- [9] Vitor Cardoso and Paolo Pani. Testing the nature of dark compact objects: A status report. *Living Reviews in Relativity*, 22(1):4, 2019. doi: 10.1007/s41114-019-0020-4.
- [10] Michel Chevallier and David Polarski. Accelerating universes with scaling dark matter. *Int. J. Mod. Phys. D*, 10:213–223, 2001.
- [11] Don Colladay and V. Alan Kostelecky. Lorentz-violating extension of the standard model. *Physical Review D*, 58(11):116002, 1998. doi: 10.1103/PhysRevD.58.116002.
- [12] DESI Collaboration. DESI 2024 VI: cosmological constraints from the measurements of baryon acoustic oscillations. arXiv:2404.03002, 2024.
- [13] DESI Collaboration. DESI DR2 Results II: Measurements of baryon acoustic oscillations and cosmological constraints. *arXiv preprint*, 2025.
- [14] S. Dodelson and L. M. Widrow. Sterile neutrinos as dark matter. *Phys. Rev. Lett.*, 72:17–20, 1994.
- [15] D. G. Elliman. Cosmology, dark energy, and inflation in the finite-QEC substrate. Zenodo preprint, <https://doi.org/10.5281/zenodo.20671860>, 2026.
- [16] D. G. Elliman. Dark matter, MOND, and K04 debris in the finite-QEC substrate. Zenodo preprint, <https://doi.org/10.5281/zenodo.20671862>, 2026.
- [17] D. G. Elliman. Foundations and methodology for a finite-QEC substrate: code, crystallisation, ledgers, and audit protocol. Zenodo preprint v3.0, <https://doi.org/10.5281/zenodo.20682178>, 2026.
- [18] D. G. Elliman. Gravity, horizons, and black holes in the finite-QEC substrate. Zenodo preprint, <https://doi.org/10.5281/zenodo.20671864>, 2026.
- [19] D. G. Elliman. Matter, gauge structure, and spectroscopy in the finite-QEC substrate. Zenodo preprint, <https://doi.org/10.5281/zenodo.20671858>, 2026.
- [20] D. G. Elliman. A finite-QEC substrate program for particle physics and cosmology: current canon and audit methodology. Zenodo preprint v5.0, <https://doi.org/10.5281/zenodo.20682177>, 2026.

- [21] D. G. Elliman. Special and general relativity from the finite-QEC substrate: the propagation clock, the equivalence principle, and the horizon ledger. Zenodo preprint v3.0, <https://doi.org/10.5281/zenodo.20682176>, 2026.
- [22] David Elliman. It-from-bit canon snapshot. <https://github.com/dgedge/itfrombit/tree/canon-scripts-2026-06-20>, 2026. Tag `canon-scripts-2026-06-20` (commit `07f922cb`); permanently archived at Software Heritage, `swh:1:rev:07f922cbd2d20ce292100ecc68d82f8ecd208133`.
- [23] David Elliman. It-from-bit: Reproducibility repository. <https://github.com/dgedge/itfrombit>, 2026. Code and reproducibility repository for the canon snapshot series.
- [24] Benoit Famaey and Stacy S. McGaugh. Modified Newtonian dynamics (MOND): observational phenomenology and relativistic extensions. *Living Rev. Relativity*, 15:10, 2012.
- [25] Steven Johnston. Particle propagators on discrete spacetime. *Classical and Quantum Gravity*, 25(20):202001, 2008. doi: 10.1088/0264-9381/25/20/202001.
- [26] Antony Lewis, Anthony Challinor, and Anthony Lasenby. Efficient computation of CMB anisotropies in closed FRW models. *Astrophysical Journal*, 538:473–476, 2000. doi: 10.1086/309179.
- [27] Eric V. Linder. Exploring the expansion history of the universe. *Phys. Rev. Lett.*, 90:091301, 2003.
- [28] David Mattingly. Modern tests of lorentz invariance. *Living Reviews in Relativity*, 8(5), 2005. doi: 10.12942/lrr-2005-5.
- [29] S. S. McGaugh, F. Lelli, and J. M. Schombert. Radial acceleration relation in rotationally supported galaxies. *Phys. Rev. Lett.*, 117:201101, 2016.
- [30] Mordehai Milgrom. A modification of the Newtonian dynamics as a possible alternative to the hidden mass hypothesis. *Astrophys. J.*, 270:365–370, 1983.
- [31] Planck Collaboration. Planck 2018 results. VI. cosmological parameters. *Astron. Astrophys.*, 641:A6, 2020.
- [32] K. R. Popper. *The Logic of Scientific Discovery*. Hutchinson, London, 1959.
- [33] T. Rosenband, D. B. Hume, P. O. Schmidt, C. W. Chou, A. Brusch, L. Lorini, W. H. Oskay, R. E. Drullinger, T. M. Fortier, J. E. Stalnaker, S. A. Diddams, W. C. Swann, N. R. Newbury, W. M. Itano, D. J. Wineland, and J. C. Bergquist. Frequency ratio of Al<sup>+</sup> and Hg<sup>+</sup> single-ion optical clocks; metrology at the 17th decimal place. *Science*, 319(5871):1808–1812, 2008. doi: 10.1126/science.1154622.
- [34] Rafael D. Sorkin. Causal sets: Discrete gravity. In Andrés Gomberoff and Donald Marolf, editors, *Lectures on Quantum Gravity*, pages 305–327. Springer, 2005.
- [35] Jean-Philippe Uzan. Varying constants, gravitation and cosmology. *Living Reviews in Relativity*, 14(2), 2011. doi: 10.12942/lrr-2011-2.
- [36] James G. Williams, Slava G. Turyshev, and Dale H. Boggs. Progress in lunar laser ranging tests of relativistic gravity. *Physical Review Letters*, 93(26):261101, 2004. doi: 10.1103/PhysRevLett.93.261101.