The “It from Bit” Metaphor:
A Graduate Introduction to the Finite QEC Substrate

David Elliman
Neuro-symbolic Ltd
`dave@neusym.ai`

Working draft, clearer graduate-introduction version, 2026-06-27

Abstract

This article is the intuition layer for the finite quantum-error-correction (QEC) substrate programme. It is written for a reader who knows some quantum mechanics, special relativity, and the Standard Model vocabulary, but who is new to this framework. The aim is not to replace the equations of quantum theory, quantum field theory, or general relativity. The aim is to supply a coherent picture: physical objects are read as stable quantum records; particles are protected patterns in a finite code; interactions are operations on those records; and the classical world is the part of the quantum world that has become robust enough to remember itself.

The paper deliberately separates three levels. First, there is standard physics which this framework uses rather than challenges: Hilbert space, amplitudes, decoherence, gauge fields, and relativistic propagation. Second, there are coding-theoretic and combinatorial claims, especially the emergence of the minimal balanced $[8, 4, 4]$ record cell. Third, there are speculative or conditional bridges to particle spectra, dark-sector physics, gravity, and cosmology. The closing appendix is a field guide to hard questions: for each one it states what the Standard Model says, why that answer is conceptually incomplete or technically hard, and what this framework offers instead.

1 Why this paper exists

Physics has two kinds of understanding. One is calculational: write the Hamiltonian, compute the amplitude, compare with experiment. The other is structural: know what sort of thing the calculation is about. Quantum physics is extraordinarily successful in the first sense. It is less satisfying in the second. Students quickly learn the formal rules, but the pictures are unstable: particles spread like waves but arrive as point events; measurement seems to alter what it measures; entanglement is stronger than any classical correlation; and the vacuum is not empty.

The usual professional answer is that the formalism is primary. That answer is correct as a matter of practice. But it leaves a genuine explanatory gap. A good picture need not replace the formalism. It can do what the Bohr atom did for early atomic physics: give the mind a ladder, while admitting that the ladder is not the final theory.

The ladder explored here is Wheeler’s slogan “it from bit” [17] taken literally but quantum mechanically. The primitive objects are not hard little beads. They are records. Because the observed world is quantum, the records cannot be ordinary classical bits. They must be qubits. Because qubits are fragile and cannot be copied, a persistent world of qubits must be self-correcting. That leads naturally to quantum error correction. The framework then asks a sharp question:

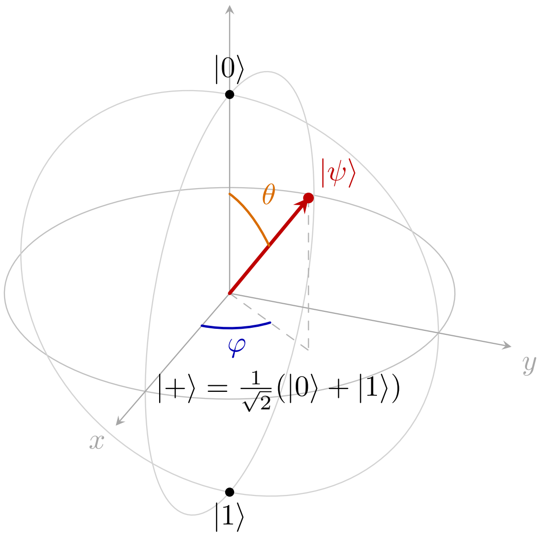


Figure 1: **One qubit.** A classical bit has only two allowed states. A qubit has the whole Bloch sphere. The poles are $|0\rangle$ and $|1\rangle$; the rest of the sphere contains superpositions with relative phase.

> What is the smallest finite quantum record cell that can be read, written, protected, and reused without destroying the information it carries?

The answer proposed by the programme is the self-dual doubly-even $[8, 4, 4]$ code, pictured geometrically as an eight-qubit cell. The rest of the framework is an attempt to read particle labels, charges, forces, and some large-scale cosmology from the geometry and service dynamics of that record cell [5, 8].

This paper is not the technical proof of those claims. It is the map of the claims. It tells the reader what the picture is, what the Standard Model already settles, where the framework adds structure, and where the open problems still live.

2 From bits to quantum records

A classical bit is a robust yes-or-no record. It can be copied, read, and checked many times. A qubit is different. In a chosen basis it is written

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle, \qquad |\alpha|^2 + |\beta|^2 = 1, \tag{1}$$

with complex amplitudes α and β. The probabilities seen in a measurement are the squared moduli $|\alpha|^2$ and $|\beta|^2$. For one qubit, after removing an overall phase, the pure states form the Bloch sphere,

$$|\psi\rangle = \cos\frac{\theta}{2}|0\rangle + e^{i\varphi}\sin\frac{\theta}{2}|1\rangle. \tag{2}$$

The important point is not the notation but the information budget. An unknown quantum state cannot be copied [4, 18]. It also cannot be read without disturbance. These are not two unrelated mysteries. A measurement creates a classical record correlated with the system; for an unknown state that is already a kind of copying operation. Quantum theory therefore forbids the effortless redundancy which makes classical records stable.

This observation is the bridge to error correction. If the world is made from quantum records, it cannot protect them by keeping ordinary spare copies. It must protect them by checking relations among parts of the record without reading the protected information itself. That is exactly what quantum error correction does. Stabilizer checks measure parity-like constraints. They reveal an error syndrome while preserving the encoded state [11, 15].

The philosophical starting point is therefore not merely "information exists". It is more specific:

> Stable physics requires repeatable records; repeatable quantum records require error-corrected structure.

That is the basic reason the framework begins with a code rather than with particles.

3 The minimal balanced record cell

The framework's central reconstruction claim is that the smallest suitable local record cell is not arbitrary. A stable cell must satisfy several requirements:

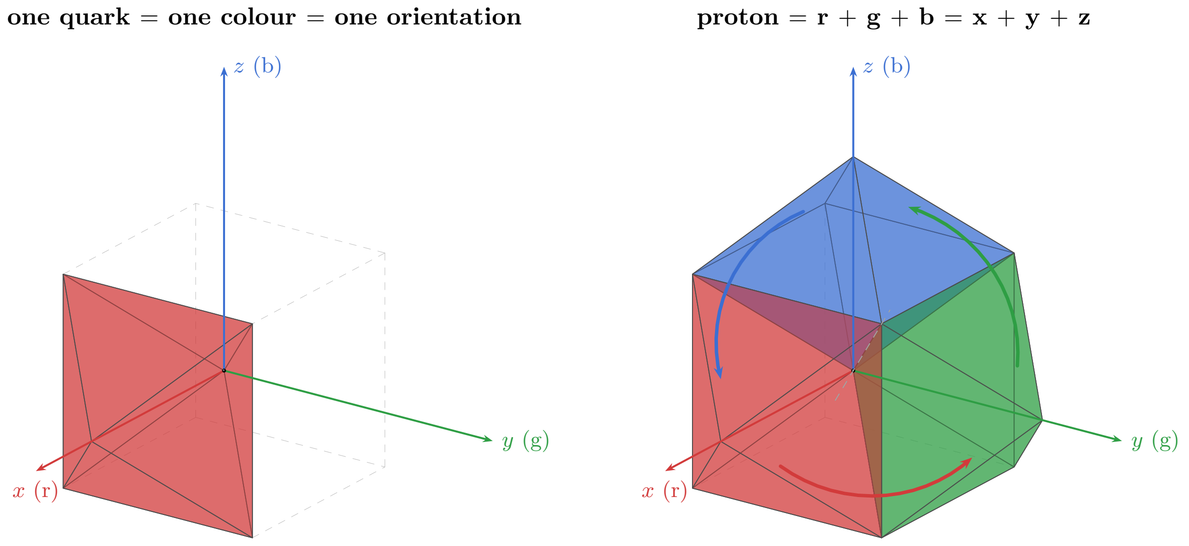
- its checks must commute, so that records can be re-read without changing one another;
- it must protect both bit-type and phase-type errors, suggesting a CSS structure;
- the read and write structures must be balanced, giving self-duality;
- the qubit phase structure must be respected, giving the doubly-even condition familiar from Type-II binary codes;
- the code must protect against the finite local noise budget, with distance four as the first nontrivial erasure-protection threshold.

Coding theory then becomes surprisingly restrictive. Doubly-even self-dual binary codes exist only at lengths divisible by eight, and the smallest example is unique: the $[8,4,4]$ extended Hamming code, also equivalent to $\mathrm{RM}(1,3)$ and to the affine geometry of the cube [12, 14]. In plain language:

> The smallest balanced protected quantum record is a byte: eight qubits.

This is the framework's strongest foundational move. It does not simply assume that nature starts with eight bits. It argues that once stable local quantum records, balanced read/write checks, and distance-four erasure protection are requested, the eight-qubit cell is the unique minimal answer.

The programme then gives that code a geometric reading. The eight record positions are pictured as the eight faces of a small cell related to the three-cube Q_3. The three independent spatial directions of the cube become the three colour orientations. This is the first place where the framework tries to turn an abstract Standard Model label into a spatial record property: colour is no longer merely a name for an $SU(3)$ charge; it is read as orientation in the local record geometry.


one quark = one colour = one orientation

proton = r + g + b = x + y + z

one orientation (x / red)
→ anisotropic → **confined**

three orientations meet at the vertex (C_3: r→g→b)
→ isotropic → **colour-neutral**

Figure 2: **Colour as orientation.** A single quark-cell selects one orientation and is not colour-neutral. A baryon combines the three orthogonal colour orientations at a shared vertex. The figure is a geometric reading of the record-cell structure; it is not a proof of confinement.

4 Reading particles from the cell

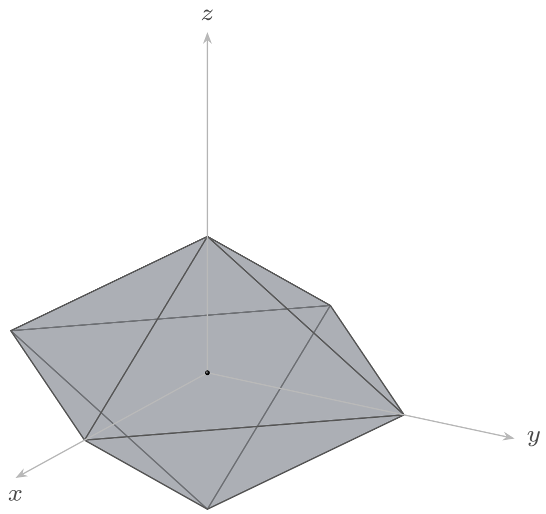
The Standard Model contains a striking pattern: three generations of fermions, each containing quarks and leptons, with chiral weak couplings and colour triplets for the quarks. In orthodox particle physics this pattern is encoded in representations of gauge groups. The framework asks whether the pattern is also visible as a codeword catalogue.

At the intuitive level, the eight record bits serve as labels for generation, lepton/quark type, colour, weak isospin, chirality, and weak-doublet structure. The full technical map is in the matter-sector paper [7]. For this introduction the important readings are:

- a lepton is colourless, so it does not select a spatial colour orientation and can propagate freely;
- a quark carries one colour orientation and is not a free isotropic object;
- a colour-neutral baryon combines three orthogonal colour orientations;
- weak interactions act as controlled flips of internal record bits, especially weak isospin and chirality.

The electron is the simplest colourless cell. It can be pictured as the ground record, with all the relevant labels off. Its neutrino partner is obtained by flipping weak isospin; its right-handed version by changing chirality. This is not intended as a new replacement for quantum field theory. It is a proposed explanation of why the field-theoretic labels have the pattern they do.

The sharp distinction is this. The Standard Model gives the correct algebra of particle labels and interactions. The framework does not dispute that algebra. It tries to explain why that algebra is the one nature uses by deriving it from a finite protected record.



eight faces = eight bits:

G_0	G_1	LQ	C_0	C_1	I_3	χ	W
0	**0**	**0**	**0**	**0**	**0**	**0**	**0**

colour bits = 00
(colourless)

Figure 3: **The electron as the colourless ground cell.** In the record picture the electron is not a small hard object. It is the simplest stable colourless record pattern.

5 Wave, particle, and record

The phrase "particle" is misleading if it suggests a tiny billiard ball. Quantum field theory already teaches that particles are excitations of fields. The record picture adds a complementary statement:

> A particle is a stable quantum pattern that can be recorded as one indivisible event.

An electron therefore has two aspects. It is a persistent pattern with a rest clock, and it is also a wave packet which propagates. The rest clock follows from $E = mc^2$ and $E = hf$: a mass has a Compton frequency. When the particle moves, the phase of that clock appears as the de Broglie wave with

$$\lambda = \frac{h}{p}. \tag{3}$$

In a bound system the wave forms a standing pattern; in a detector it is recorded as one event.

A photon is different because it has no rest clock. It is a travelling electromagnetic phase pattern with no rest frame, carrying energy $E = hf$. It spreads like a wave, interferes like a wave, and is absorbed as one event. Thus wave-particle duality is not two incompatible natures. It is the difference between propagation and recording. The wave is how the possibility travels; the particle is how a stable record is written.

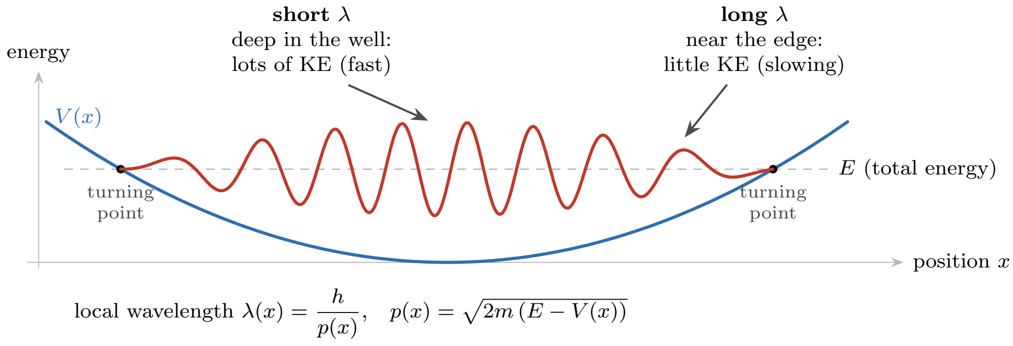


Figure 4: **The electron as a wave packet.** The local wavelength is shorter where kinetic energy is high and longer near the turning points. A bound electron is a standing wave pattern, not a small planet orbiting a nucleus.

6 Antimatter and the role of complex phase

Antimatter is often introduced as matter with signs reversed. That is partly right but incomplete. A mirror reflection changes handedness; charge conjugation changes charges; time reversal changes the direction of propagation. The robust symmetry of relativistic quantum theory is the combined CPT operation, not a simple mirror image.

In the record picture, a bit flip is an ordinary unitary operation. It can exchange two poles of a qubit's Bloch sphere. Antimatter is not just such a single-bit operation. It is tied to the time-reversed solution of the underlying walk, and therefore to an anti-unitary transformation. This is closely related to the universal-NOT obstruction: inverting an unknown qubit state is not a physical gate [1].

This matters because the matter-antimatter imbalance of the universe must come from a process which distinguishes a process from its time-reversed or charge-conjugated partner. In standard cosmology this is the baryogenesis problem: Sakharov conditions require baryon-number violation, departure from equilibrium, and CP violation. The framework's current baryogenesis route reads the surviving matter fraction as a small QEC residual,

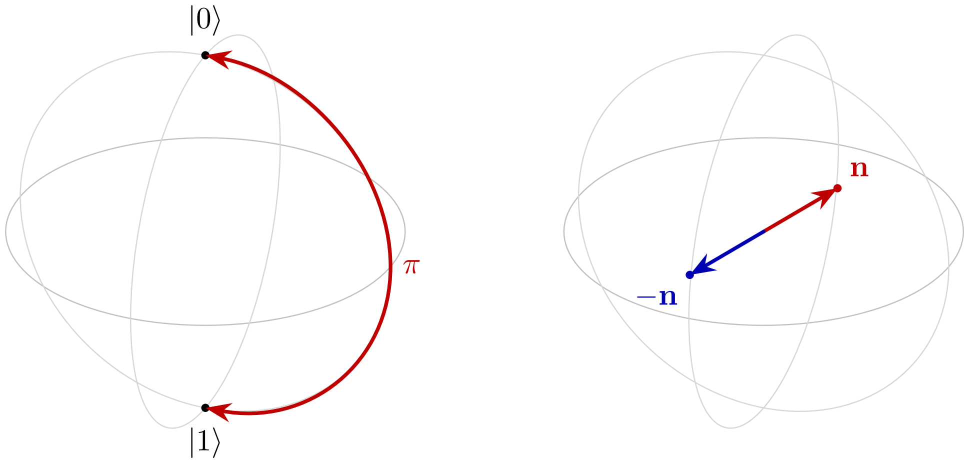
$$\eta \sim \frac{3}{14}\alpha_0^4, \tag{4}$$

where $\alpha_0 \approx 1/137$ is the bare service rate. This is a compact and testable idea, but its CP-holonomy sector remains one of the places where the framework is still genuinely under construction [10].

7 Forces as operations on records

The Standard Model represents interactions through gauge fields. The record picture translates that language into operations on record labels and phases.

Electromagnetism. Electromagnetism is the coupling to a $U(1)$ phase. A charged cell can emit or absorb a photon, i.e. a travelling phase disturbance. The coupling is measured by the fine-structure constant. The framework derives a bare integer $\alpha_0^{-1} = 137$ from the record-counting structure, while the small physical dressing to $137.036\ldots$ remains a separate QED-response problem.



(a) bit flip $|0\rangle \leftrightarrow |1\rangle$
unitary (a real gate)

(b) inversion $\mathbf{n} \to -\mathbf{n}$
anti-unitary (no real gate)

Figure 5: **Bit flip versus antiparticle.** A bit flip swaps two poles of a Bloch sphere and is unitary. The particle-antiparticle relation is tied to a full anti-unitary inversion and time reversal.

The weak force. The weak interaction changes particle type. In the record picture it is read as a controlled flip of weak-isospin, conditioned on chirality. This gives a natural picture of why the weak force is left-handed: the operation is permitted only on the appropriate chirality bit. The framework does not replace the standard electroweak theory; it supplies a record-level picture for its chiral selection rule.

The strong force. The strong force is tied to colour orientation. A single colour orientation is anisotropic and confined; colour-neutral combinations restore the full set of orientations. This gives a useful geometric picture of confinement, but not a rigorous proof of the Yang-Mills mass gap. That remains hard in the standard theory and hard here.

Thus the phrase “force” does not mean one thing in the framework. Some forces shift phase, some flip bits, some enforce orientation completeness, and gravity responds to energy and record geometry. The common theme is that interactions are legal changes of a protected record.

8 The vacuum, screening, and the fine-structure constant

The vacuum of quantum field theory is not empty. It fluctuates. Virtual excitations screen charges, shift atomic energy levels, and correct magnetic moments. These effects are standard QED: vacuum polarization, the Lamb shift, and the anomalous magnetic moment.

In the record picture the vacuum is the substrate in its corrected ground operation. It is not silent because quantum systems cannot have all conjugate variables perfectly sharp. Local faults flicker and are corrected. Around an electron, the result looks like the usual QED vacuum cloud.

This example is useful because it shows the discipline required. Getting the bare integer 137 is not enough to claim the measured fine-structure constant. Low-energy QED measures a dressed response, not a raw count. The framework must prove the billing map from record-service occu-

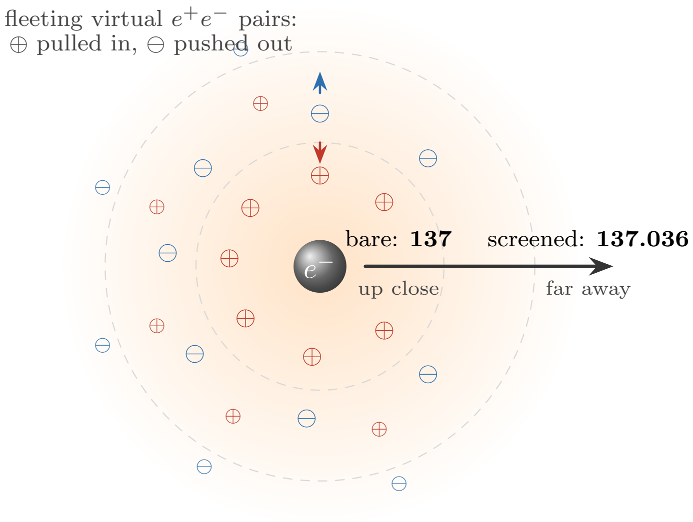


Figure 6: **Vacuum screening.** Virtual charged pairs polarise around an electron and screen the charge seen at long distance. The framework derives the bare 137 count; the precise physical dressing to 137.036 . . . remains an open response-map problem.

pation to the physical Thomson or LSZ charge. At present that map is not fully closed. The right lesson is not that the framework fails, but that the level of claim must match the level of derivation.

9 Dark matter and dark energy

The dark sector is where visual pictures are tempting and dangerous. The framework currently distinguishes several mechanisms rather than treating dark matter as one substance.

K04 crystal debris. During a rapid early crystallisation, differently oriented ordered regions can meet. Their boundaries may freeze as mis-ordered defects. Such defects carry strain energy and therefore gravitate, but they need not carry ordinary gauge charges. This makes them dark in a natural way.

The important recent conclusion is that these defects are likely pinned to the substrate. A pinned fossil cannot by itself be the mobile halo component seen in galaxy mergers. It may be a subdominant relic or bound, but the halo burden must be carried by a mobile component.

Sterile and zero-mode components. The framework also contains sterile neutrino-like states and a pressureless zero-mode reservoir. These are better candidates for mobile dark matter or for the CMB-required pressureless component. The relevant open issue is not whether one can write down something with $w = 0$. It is whether the framework derives the abundance and avoids double-counting late MOND-like R4 responses.

Dark energy. For dark energy, the picture is different. The raw vacuum fluctuation energy of ordinary QFT is far too large. The framework's proposal is that QEC cancels almost all of the local vacuum load, leaving only a residual service cost spread over the cosmic horizon. This is a

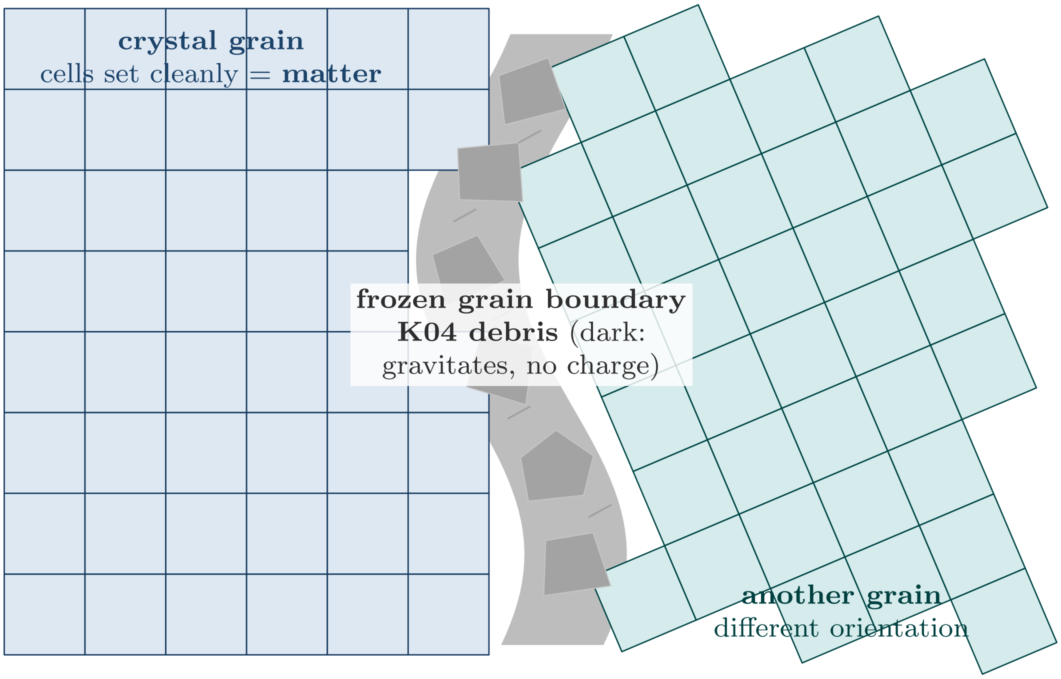


Figure 7: **Crystal defects.** Ordered regions with different orientations can meet badly. The boundary is a defect: gravitationally active but gauge-blind. Current canon treats this K04 debris as pinned and subdominant, not as the main mobile halo component.

promising route to the cosmological constant problem, but it depends on exact microscopic billing theorems. Where those theorems are not closed, the result must remain conditional.

The dark sector therefore illustrates both the strength and the risk of the programme. It provides concrete mechanisms, but it must not promote a mechanism to a prediction until the mobility, abundance, pressure, and observational maps are all derived.

10 Mass, gravity, and clocks

The cleanest sentence about mass is:

> Mass is energy that stays with a system.

For an electron, that energy is its rest-clock. For a proton, much of it is the binding energy of the strong force. For a crystal defect, it is frozen strain. For dark energy, it is an ongoing residual service cost. Gravity responds to all of these because gravity responds to energy.

Special relativity enters through the clock. A particle at rest has a Compton frequency mc^2/h. When it moves, its proper clock dilates. The de Broglie wave can be read as the phase bookkeeping of that moving rest-clock. The framework's discrete walk is required to have the Dirac equation as its continuum limit [9].

General relativity is then pictured as a variation in clock rate across spacetime. Energy changes the local time geometry. A free body follows the path on which its own clock accumulates the greatest proper time. That is the geodesic principle in a clock-first language.

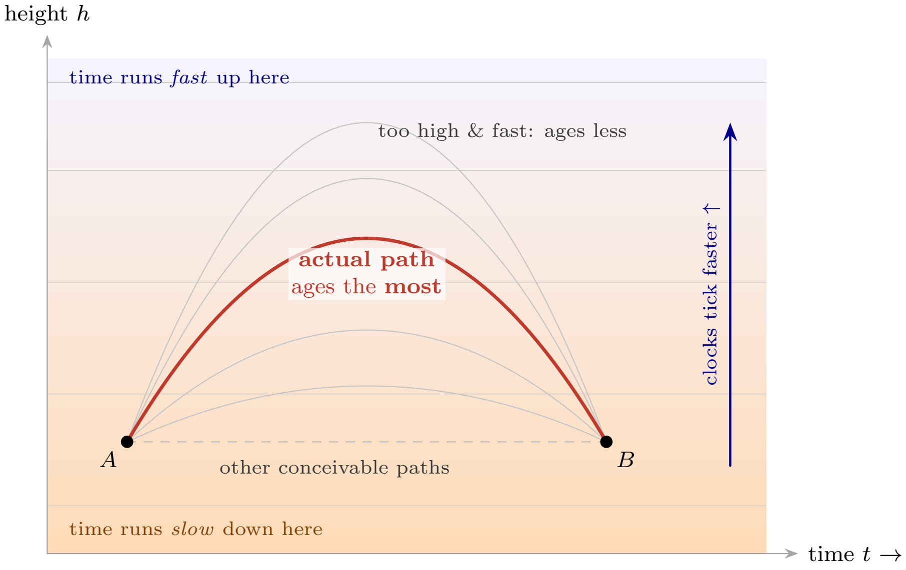


Figure 8: **Gravity as clock geometry.** The useful picture is not a ball rolling into a dent in space. It is a path through regions where clocks tick at different rates.

The strongest unresolved issue is the absolute gravitational scale. The framework has a precise horizon-linked route connecting the QCD scale, cosmic horizon, and Planck mass [6]. That is an impressive consolidation, but it still uses the horizon scale. A fully intrinsic derivation of G or M_P would require deriving the relevant scale selection from the record dynamics itself.

11 What is solid, what is conditional, what is open

It is useful to classify the claims into three groups.

Standard physics used by the framework. Hilbert space, complex amplitudes, entanglement, no-cloning, stabilizer error correction, gauge fields, QED screening, relativistic wave propagation, and geodesic motion are not new claims here. They are the established background.

Strong internal claims. The main internal claim is the reconstruction of the minimal balanced record cell as the unique $[8, 4, 4]$ byte. Closely related are the codeword readings of three generations, colour structure, bare 137, and several finite combinatorial identities. These are where the programme is most distinctive.

Conditional bridges. The bridges to dark energy, dark matter, gravity, CMB phenomenology, the electroweak scale, and detailed QED dressing are harder. They require rates, measures, phases, or dimensionful scales, not just counts. The recent record action and service-billing programme has reduced several of these to sharper questions, but not all are closed.

The honest statement is therefore neither “the framework explains everything” nor “it is only a metaphor.” It is a structured research programme. Its best-established layer is a record-theoretic reconstruction of a finite QEC substrate. Its frontier is the derivation of the dynamical rates and scale bridges needed to turn that substrate into all of observed physics.

A A field guide to hard questions

This appendix is designed for a new reader entering the field. Each entry has three parts: what standard physics says, why the issue remains hard or conceptually unsatisfying, and what the finite-QEC substrate picture offers.

Why does measurement produce one result?

Standard physics. Textbook quantum mechanics postulates measurement and the Born rule. Modern decoherence explains why macroscopic alternatives stop interfering and why pointer states are stable.

Why it is hard. Decoherence explains why branches do not interfere, but by itself it does not make a single experienced outcome feel inevitable. Nor does it explain why the probability rule has exactly the squared-amplitude form unless extra assumptions are supplied.

Framework picture. Measurement is record-writing. A stable outcome is one that has been redundantly written into the environment. Born weights are then tied to the closed-record-pair measure: once outcomes are orthogonal projectors in a complex Hilbert space, the squared-amplitude rule is forced by standard Gleason-type reasoning. This is one of the better grounded conceptual parts of the programme.

Why quantum theory, and why complex numbers?

Standard physics. Quantum theory is postulated as the theory that works. Informational reconstructions derive much of its form from operational axioms such as local tomography and purification [3, 13].

Why it is hard. Any reconstruction must eventually stop at axioms. The question is whether those axioms are natural and minimal, not whether a theory can prove its own starting point.

Framework picture. The irreducible floor is stable local records and compatible tests. From there the framework follows the reconstruction route: local tomography points to complex Hilbert space; repeatable readout points to projectors; stable noisy records point to QEC. The remaining deep question is not "why quantum?" in the vague sense, but why nature uses this monitored QEC service alphabet and this billing rate.

Why exactly three generations?

Standard physics. The Standard Model simply contains three generations of quarks and leptons. Their repetition is measured, not derived.

Why it is hard. A fourth generation is not forbidden by the idea of a generation alone; it is excluded phenomenologically. The origin of the threefold repetition remains unexplained in the Standard Model.

Framework picture. The finite record catalogue has three allowed generation branches once the forbidden record sector is removed. In this sense "three" is a code-count, not an empirical input. This is one of the cleanest places where the framework claims a structural explanation.

Why three colours and confinement?

Standard physics. Quarks transform under $SU(3)$ colour. Only colour-neutral states are observed. Confinement is supported by lattice QCD, but a complete analytic Yang-Mills mass-gap proof is still a major open problem.

Why it is hard. The Standard Model encodes colour algebraically but does not give a simple spatial picture of what colour is.

Framework picture. Colour is read as one of three spatial record-cell orientations. A quark carries one orientation; a baryon restores all three. This gives a strong visual explanation of colour neutrality, while leaving the fully rigorous confinement theorem in the same hard class as ordinary Yang-Mills confinement.

Why is the fine-structure constant near 1/137?

Standard physics. The low-energy fine-structure constant is measured. Renormalisation explains why it runs with energy, but not why its low-energy value is what it is.

Why it is hard. The measured number is not a bare count. It is a dressed QED response involving vacuum polarisation and the definition of physical charge.

Framework picture. The bare service alphabet gives $\alpha_0^{-1} = 137$. This is a major structural result. The small difference between 137 and 137.036 . . . is not yet fully derived; it requires a sector-billing theorem connecting monitored service occupation to the physical QED charge residue.

Why are there masses?

Standard physics. Fermion masses are Yukawa couplings to the Higgs field. The Higgs mechanism explains how gauge bosons and fermions acquire mass without breaking gauge consistency, but the Yukawa values themselves are inputs.

Why it is hard. The mass spectrum spans many orders of magnitude. The electroweak scale itself is also an input relative to QCD and gravity.

Framework picture. A mass is a rest-clock: a persistent internal frequency of a record pattern. Some mass ratios and special relations are code-structured, but the electroweak/top scale remains a second absolute anchor. This is one of the main remaining walls.

What is dark matter?

Standard physics. Cosmology requires a pressureless gravitating component beyond baryons. Particle models, sterile neutrinos, modified gravity, and other mechanisms remain under investigation.

Why it is hard. The CMB requires something CDM-like at recombination, galaxy phenomenology suggests strong baryonic correlations, and merger systems show that the main dark component must be mobile and weakly collisional.

Framework picture. K04 defects are natural dark relics but are pinned and therefore subdominant. The mobile burden shifts to sterile/zero-mode/R4 components. The decisive remaining work is a full CMB and halo implementation which avoids double-counting MOND-like late responses.

What is dark energy?

Standard physics. Observations are consistent with a small positive cosmological constant. Naive QFT vacuum energy estimates are catastrophically too large [2, 16].

Why it is hard. The problem is not merely that the number is small; it is that known local quantum fields appear to contribute enormously unless some cancellation principle exists.

Framework picture. The substrate cancels most local vacuum load by QEC, leaving a residual service cost. Several routes now connect this to the observed scale, but the exact microscopic fault-rate and billing theorem remains load-bearing. The picture is strong; the final coefficient is still a frontier.

Where does gravity come from?

Standard physics. General relativity describes gravity as spacetime curvature sourced by stress-energy. Quantum field theory on curved spacetime works semiclassically, but a complete quantum gravity theory remains open.

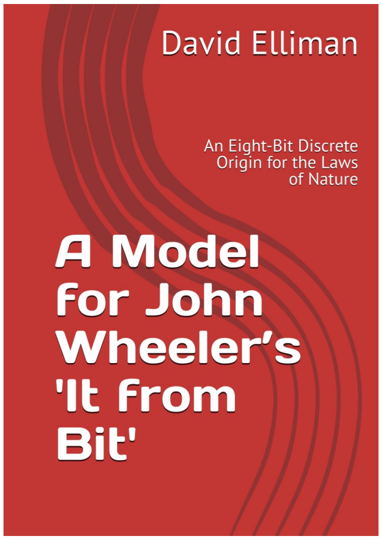
Why it is hard. Gravity is geometrical, universal, and extremely weak. Quantising it as just another force has not produced a settled theory.

Framework picture. Gravity is the response of record geometry and clock rate to energy. The Planck hierarchy is largely consolidated into a QCD-horizon relation, and recent work narrows the service-span route. A fully intrinsic derivation of the absolute Planck scale is still open.

What should make a reader sceptical?

The right scepticism is not “this is unfamiliar.” The right scepticism is: does each claimed number follow from a forced count, a sector-native invariant, or a derived service rate? Wherever a free rate, scale, phase, or probability measure enters, the framework must either derive it or mark the result conditional. The programme is strongest where it turns a particle-physics label into a finite record invariant. It is weakest, and most interesting, where dynamics rather than counting is required.

The book, and where to read more



This paper is an intuition and orientation layer. The technical construction is set out in the companion papers and book.

Book: *A Model for John Wheeler's “It from Bit”* (David Elliman)
`https://www.amazon.co.uk/dp/1919558853`

Papers: `https://neusym.ai`

References

[1] V. Bužek, M. Hillery, and R. F. Werner. Optimal manipulations with qubits: Universal-NOT gate. *Physical Review A*, 60(4):R2626–R2629, 1999. doi: 10.1103/PhysRevA.60.R2626.

[2] Sean M. Carroll. The cosmological constant. *Living Rev. Relativity*, 4:1, 2001.

[3] Giulio Chiribella, Giacomo Mauro D'Ariano, and Paolo Perinotti. Informational derivation of quantum theory. *Phys. Rev. A*, 84:012311, 2011.

[4] D. Dieks. Communication by EPR devices. *Physics Letters A*, 92(6):271–272, 1982. doi: 10.1016/0375-9601(82)90084-6.

[5] 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.

[6] D. G. Elliman. Gravity, horizons, and black holes in the finite-QEC substrate. Zenodo preprint, `https://doi.org/10.5281/zenodo.20671864`, 2026.

[7] D. G. Elliman. Matter, gauge structure, and spectroscopy in the finite-QEC substrate. Zenodo preprint, `https://doi.org/10.5281/zenodo.20671858`, 2026.

[8] 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.

[9] 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.

[10] David Elliman. Baryogenesis as a quantum-error-correction residue. Zenodo preprint, `https://doi.org/10.5281/zenodo.20723972`, 2026.

[11] D. Gottesman. *Stabilizer codes and quantum error correction.* PhD thesis, California Institute of Technology, 1997. arXiv:quant-ph/9705052.

[12] R. W. Hamming. Error detecting and error correcting codes. *Bell Syst. Tech. J.*, 29:147–160, 1950.

[13] Lucien Hardy. Quantum theory from five reasonable axioms. *arXiv preprint quant-ph/0101012*, 2001.

[14] F. Jessie MacWilliams and Neil J. A. Sloane. *The Theory of Error-Correcting Codes.* North-Holland, 1977.

[15] A. M. Steane. Error correcting codes in quantum theory. *Phys. Rev. Lett.*, 77:793–797, 1996.

[16] Steven Weinberg. The cosmological constant problem. *Rev. Mod. Phys.*, 61:1–23, 1989.

[17] John Archibald Wheeler. Information, physics, quantum: the search for links. In Wojciech H. Zurek, editor, *Complexity, Entropy and the Physics of Information.* Addison-Wesley, 1990.

[18] W. K. Wootters and W. H. Zurek. A single quantum cannot be cloned. *Nature*, 299(5886): 802–803, 1982. doi: 10.1038/299802a0.