Going Deeper into a Black Hole: The Horizon as a Quantum-Error-Correcting Record

David Elliman
Neuro-symbolic Ltd
dave@neusym.ai

Revised canon snapshot: 2026-06-25

Abstract

This is a focused deep-dive companion to the gravity and black-hole snapshot [4]. It develops a single thread: the black-hole horizon as a finite quantum-error-correcting record governed by one object, the three-cube coboundary δ. Three results. First, one δ controls the boundary strain record, the firewall isometry V_{cell}, and the single blind degree of freedom; but the Hawking degeneracies and the area coefficient additionally require a register-validity/monogamy ingredient that is provably independent of δ — the unification is real but not "one δ controls everything." Second, the Bekenstein area law, written in substrate units (node area $A_{\text{node}} = a_0^2/4$, proton-primary G), is *exactly equivalent* to a microscopic records rate: each horizon node is assigned $\sim 10^{38}$ nats, a single eight-bit cell holds at most $8 \ln 2 \approx 5.5$, so the area entropy cannot be *stored* — standing storage fails by 37–45 orders of magnitude across the black-hole mass range — and must instead *flow*, at a rate $H_0 M_{\text{P}}^2/(16\Lambda_{\text{QCD}}^3) = C\alpha_0^2$. Third, the coefficient is $C = 55/8$: 56 directed monogamy incidences modulo the one global-complement blind slot, with $\text{AGL}(3,2)$ covariance fixing the measure. The last conditional — whether the per-pair direction tag is value-level or an address-level geometric stamp — is discharged by *two* independent arguments: the record channel is the syndrome itself (no channel outside δ), and $\text{AGL}(3,2)$ covariance forbids an address-level orientation outright. Predictions follow: $\Omega_\Lambda = 12\pi/55 = 0.6854$ (α-free, $+0.1\sigma$, Planck branch of the Hubble tension); a finite Hawking ladder whose local KMS scheduler is now derived from symmetric Schwarzschild microcanonical exchange; a radial freeze-shell/escape-cone map that gives the Hawking M^{-2} scaling; a standard Schwarzschild spin/partial-wave greybody transfer for the finite ladder; and an absolute flux equal to the standard Hawking coefficient via the near-horizon Bogoliubov spectrum, with the $(10/27)\alpha_0$ source-counting a 0.29% shortcut (all-contact severing grounded in the $[8,4,4]$ record-cell face lattice, the species set the two-helicity photon plus a computed 11.4% graviton). A previous 0.31-Eddington horizon-bandwidth reading and near-unit ringdown-echo claim are withdrawn: the current channel is a post-service record-writing channel, not a real-time entropy-writing bottleneck or a coherent mirror. Fast scrambling is forbidden by finite-range locality: an $O(1)$-gap graph needs unbounded degree or nonlocal edges, which the bounded-degree, translation-invariant $\mathbb{Z}^3$ substrate (abelian-Cayley no-go) cannot supply, and its own nonlocality (the gravity service-span) is a scalar, not a graph — a falsifiable negative, not merely an unproven no-go. The absolute Planck-mass scale is *not* settled here — it rests on the separate gravity-sector selector/billing analysis, deferred to [4] — nor is the continuum/background lift.

Contents

1 Role of This Paper

The gravity companion [4] states the whole gravity and horizon canon: the proton-primary route in which G, M_{P}, and H_0 are outputs, the historical horizon bridges, and the finite black-hole channel algebra. This paper goes deeper on one strand of it — the horizon understood as a finite quantum-error-correcting (QEC) record — and develops three things the survey only states in passing:

1. the reading of the Bekenstein–Hawking area law [2, 8] as a microscopic *records rate* rather than a storage count, forced by the substrate's own node area;

2. the closure of the area coefficient $C = 55/8$, with its last conditional now discharged by two independent arguments;

3. the observable-map status that follows — the finite Hawking ladder, localized scheduler, freeze-shell/escape-cone transfer, the resolved flux/species ledger, the fast-scrambling locality no-go, and the retired accretion-bandwidth/echo readings — which the survey does not develop.

The external context is the thermodynamic and emergent-gravity program [9], black-hole entropy and radiation [2, 8], and the holographic/QEC view of horizon information [1, 10]. This is not a replacement for general relativity; it states finite-substrate accounting claims and their promotion status. Code is at [6]; the series synthesis is [5].

2 One Ledger: the Three-Cube Coboundary

The horizon register is an eight-bit cell $s \in \{0,1\}^8$ on the vertices of the cube Q_3. The record channel is the edge coboundary

$$\delta_e(s) = s_i + s_j \pmod 2$$

on the twelve edges. Because Q_3 is connected,

$$\ker\delta = \{0, \mathrm{ALL}\},$$

the decoder is blind to exactly one $\mathbb{Z}_2$ — the global complement — and the image has $2^7 = 128$ syndromes, each the preimage of a complement pair. The strain (the emitted energy quantum of Section 5) is the syndrome weight $F = |\delta(s)|$.

A natural temptation is to say a single δ controls every horizon observable. An audit [4] separates what is true from what is layered:

- **Genuinely one** δ (Computed): the boundary-strain record $F = |\delta|$; the firewall isometry V_{cell}, whose vacuum latch is exactly $\ker\delta$; and the single blind degree of freedom. These are one object read three ways, not three coincidences.
- δ **plus a second ingredient** (Conditional): the Hawking *degeneracies* $g_Q(F)$ are the strain distribution of the *invalid* register states, and the validity predicate that selects them is provably *not* a functional of δ — it splits 32 of the 128 complement classes that δ cannot tell apart. So δ supplies the Hawking *energy* axis and its endpoints, while the degeneracies carry a register-validity structure on top. The 55/8 area coefficient likewise needs the monogamy-ledger rank of Section 4.

The honest statement is therefore: the single δ ledger controls the record, the isometry, and the blind degree of freedom; the Hawking-ladder degeneracies and the area coefficient additionally require the validity/monogamy structure. This is the firewall isometry's content: with $[s]$ the global-complement class and γ the vacuum latch,

$$V_{\text{cell}}\,|[s]\rangle\,|\gamma\rangle = |\delta(s)\rangle_{\text{syndrome}}\,|\gamma\rangle_{\text{latch}},$$

an isometry exactly because the latch restores the one bit $\ker\delta$ hides; the no-latch control collapses on complement pairs.

3 The Area Law Is a Records Rate, Not a Store

The substrate pins the physical area of one computational node at

$$A_{\text{node}} = \frac{1}{4\Lambda_{\text{QCD}}^2} = \frac{a_0^2}{4}, \qquad a_0 = \frac{\hbar c}{\Lambda_{\text{QCD}}} \approx 0.594\ \text{fm},$$

(the node-area identity of the foundations companion). With the Bekenstein entropy density $S/A = M_{\text{P}}^2/4$, the entropy assigned to a single horizon node is mass-independent and enormous:

$$s_{\text{node}} = \frac{S}{A}\,A_{\text{node}} = \frac{M_{\text{P}}^2}{16\Lambda_{\text{QCD}}^2} \approx 8.5\times10^{37}\ \text{nats}.$$

A single eight-bit cell can hold at most $8\ln 2 \approx 5.5$ nats. The area law cannot be a *standing* ledger: the demand exceeds the capacity by about 37 orders of magnitude at a horizon node, and an explicit wall-storage gate fails by 37–45 orders across 3–$4.3\times10^6\,M_\odot$ [4].

The resolution is that the area law is a *flow*: records are written and exit, accrued over the horizon's history, never stored. Writing the per-node write rate,

$$\frac{H_0 M_{\text{P}}^2}{16\Lambda_{\text{QCD}}^3} = C\,\alpha_0^2,$$

where the α_0^2 is the two α-resolved partners of a single severing event, the Bekenstein "1/4" is not off by a wild factor: it is reduced to one dimensionless channel count C. The measured inversion gives $C_{\text{obs}} = 6.8697$, and the question becomes whether C is forced to a ledger value [4].

4 The Coefficient Is 55/8

The severing ledger of an eight-bit register has $8 \times 7 = 56$ directed monogamy incidences — 28 "activity" bits (is a pair severed?) and 28 "direction" bits (which partner expelled the indivisible bond quantum). Three canon facts fix the readable rank:

1. **Kernel theorem.** The strain decoder is blind to exactly one $\mathbb{Z}_2$: $\ker \delta = \{0, \text{ALL}\}$.
2. **Parity of the blind element.** The global complement Γ leaves every activity bit invariant and flips every direction bit, so it acts on the 56-dimensional ledger as the single vector $(0_{28} \,|\, \text{ALL}_{28})$: the global hop-orientation convention, and nothing else.
3. **Covariance.** $\text{AGL}(3, 2)$, the affine group of the three-bit address space (order 1344), is 2-transitive on the eight addresses and forces a uniform measure over the directed incidences — the same argument that fixes $p_x = 1/28$ elsewhere in canon.

The readable rank is $56 - 1 = 55$, and the per-node count is

$$C = \frac{55}{8} = 6.875,$$

against $C_{\text{obs}} = 6.8697$ (+0.08%, within the 0.80% Hubble noise floor). The address-level alternative $C = 7$ sits +1.90% off, 2.37σ.

4.1 The Direction-Tag Fork, Discharged Twice

The one residual freedom was the record-structure question: is the direction tag *value-level* — the hop outcome s_i, which the global complement flips, so the global orientation is blind and $C = 55/8$ — or *address-level* — a fixed geometric initiator stamp the complement does not touch, leaving it readable and $C = 7$? This is now discharged by two independent arguments.

Channel-counting. The Q_3 record channel *is* the syndrome: the horizon performs quantum-non-demolition extraction of the twelve edge Z-stabilizers, which measure δ and nothing else. An address-level direction would require information readable *outside* the syndrome channel, which the channel does not provide. Moreover, severing events are weight-2 pair flips, so from the syndrome stream the value-history is reconstructible up to exactly one global Γ; the readable degree count is $2 \times 28 - 1 = 55$ [4].

Covariance. Independently: an address-level tag is value-independent, so in a channel covariant under the affine group $\text{AGL}(3, 2)$ it would have to be an invariant function of ordered pairs. A direction is swap-odd, and 2-transitivity puts (i, j) and (j, i) in one orbit, so no swap-odd invariant exists (every one of the 28 pairs has its endpoints exchanged by some group element). An address-level orientation is therefore not covariant at all. The corollary is sharper than a preference: $C = 7$ is *self-inconsistent*, because it consumes the very one-orbit transitivity that supplies the uniform measure and that simultaneously forbids the readable orientation it needs. The global orientation is thus blind for two independent reasons — the kernel theorem (Γ-odd) and covariance (no covariant observable sees it).

Both routes, the canon hop language, and the data agree on the value-level reading. $C = 55/8$ is therefore COMPUTED, contingent only on the standing readout settlement and $\mathrm{AGL}(3,2)$ covariance, both already load-bearing elsewhere; relaxing the covariance would void the uniform measure — and the number 7 along with it — so it does not recover the alternative.

5 Predictions

5.1 The dark-energy fraction

The α-free image of the closure (the α_0^2 cancels in the Part-20 identity $C = 3\pi/(2\Omega_\Lambda)$) is

$$\Omega_\Lambda = \frac{3\pi}{2C} = \frac{12\pi}{55} = 0.685438\ldots,$$

against $\Omega_\Lambda = 0.6847 \pm 0.0073$ [11]: $+0.1\sigma$. The same number falls out of the proton-primary cosmology chain independently, with the dimensionful inputs cancelling [3, 4] — two routes, one prediction. Being α-free, this prediction does not depend on the unresolved α-convention that limits the absolute scale (Section 6).

5.2 The Hubble branch

At fixed $(\Lambda_{\mathrm{QCD}}, M_{\mathrm{P}})$ the same closure implies $H_0 = 67.4\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$, on the Planck/CMB side of the Hubble tension and $\sim 5.5\sigma$ below the distance-ladder value [12]. A SH0ES-side resolution of the tension falsifies the closure outright.

5.3 Accretion bandwidth: a withdrawn reading

Earlier drafts treated the area-law record count as if newly accreted matter had to be written through the horizon channel in real time. That produced a mass-independent information-limited accretion rate, $\dot{M}_{\max}/\dot{M}_{\mathrm{Edd}} \approx 0.31$ at the base service rate. The reading is now withdrawn. A growing horizon annexes substrate cells that already carry their accrued external records; $S_{\mathrm{BH}} = A/4G$ tracks the ledger exposed by the new area, not a real-time inscription of all accreted micro-entropy. Matter micro-entropy commits are loose by many orders of magnitude compared with the old bound, so ultraluminous or super-Eddington sources are not a falsifier of this channel. The 0.31-Eddington number is retained only as a documented failure mode: it is what follows if one confuses annexed standing records with a live horizon-writing bottleneck.

5.4 A discrete Hawking ladder

The finite Hawking spectrum lives on the 208 invalid register states (the eight-bit cell outside the 48-state valid sector), with exact integer-strain degeneracies

$$g_Q(F) = \{0{:}1,\ 3{:}11,\ 4{:}22,\ 5{:}38,\ 6{:}54,\ 7{:}41,\ 8{:}25,\ 9{:}14,\ 12{:}2\}.$$

There are no $F = 1$ or $F = 2$ lines: the emitting spectral gap is $F_{\min} = 3$, forced by the cube's 3-regularity. Emission is a Boltzmann ladder on integer strain,

$$\frac{I(F')}{I(F)} = \frac{g_Q(F')}{g_Q(F)}\, e^{-(F'-F)\beta}, \qquad \frac{I_4}{I_3} = 2\, e^{-\beta},$$

with β fixed by the localized Schwarzschild service channel [7]. The KMS step is no longer a free thermodynamic assumption in the local channel: the ledger gives symmetric microscopic exchange between neighbouring mass labels,

$$W_{F\to F'} = \Gamma_{FF'} \exp[-\beta(F' - F)/2],$$

so detailed balance $W_{F\to F'}/W_{F'\to F} = \exp[-\beta(F' - F)]$ follows from the half-Boltzmann scheduler. This is a discrete-line deviation-from-Planckian fingerprint rather than a continuum spectrum. The open part is not local thermality but the observable transfer from the finite ladder to asymptotic partial waves.

Freeze shell, greybody map, and flux coefficient. For a local emitted strain $E_{\rm loc} = \epsilon_F F \Lambda_{\rm QCD}$ at proper distance ρ outside a Schwarzschild horizon,

$$\frac{E_\infty}{T_H} = 2\pi\rho\Lambda_{\rm QCD}\,\epsilon_F F.$$

With the canonical $\epsilon_F = 1/(2\phi)$, the $\beta = 1$ shell is $\rho\Lambda_{\rm QCD} = \phi/\pi$. Combining this redshift with the near-horizon escape cone gives the required Hawking mass scaling, $P \propto M^{-2}$. The absolute coefficient is now read differently from the earlier scalar attempt-rate audit. The near-horizon Bogoliubov/KMS calculation gives the standard Hawking coefficient directly: the local spectrum is exactly thermal at the Hawking temperature, so $P/P_{\rm SB} = 1$ to numerical precision. The previous Moore-stencil value

$$\Gamma_0 = (10/27)\alpha_0\Lambda_{\rm QCD}, \qquad P/P_{\rm SB} = 0.997,$$

is therefore a source-counting shortcut rather than the primary normalization theorem.

The source-counting rule still matters. The isometry $V_{\rm cell}/V_{\rm Sch}(M)$ fixes the syndrome, latch, and shell-cell address, but the all-contact alphabet is now grounded by the intrinsic face lattice of the $[8, 4, 4] = Q_3$ record cell: $3^3 = 27$ faces, i.e. 26 proper contacts plus the volume latch. Boundary subcomplex closure eliminates the $F + E$, $E + C$, and face-only alternatives, and emergent local Lorentz isotropy eliminates a privileged radial-pair alphabet. The outward-slot fraction is therefore

$$\frac{9\text{ outward face slots} + 1\text{ latch}}{26\text{ contact slots} + 1\text{ latch}} = \frac{10}{27}.$$

The exterior spin/partial-wave barrier is now a standard Schwarzschild calculation rather than a free coefficient: for the $\beta = 1$ source shell, the finite lines map to $\omega r_s = F/(4\pi)$, and the Regge–Wheeler transfer gives, for example, total weights

F	$s = 0$	$s = 1$	$s = 2$
3	0.4809	0.0157	5.7×10^{-5}
6	1.3403	1.1295	0.0242
12	6.1386	6.1970	4.9287

for scalar, photon, and graviton channels. Thus the finite KMS ladder can be propagated through the exterior barrier line by line. The species ledger is also no longer scalar-only: for astrophysical black holes the massive species are Boltzmann-dead, leaving the two-helicity photon and a computed 11.4% spin-2 graviton contribution. The remaining flux work is therefore not the absolute coefficient or the massless species count, but Kerr/charge, fermion greybody extensions, and dynamical-collapse templates.

5A.4. The all-contact severing gate

The tempting closure would be to say that the same local Landauer event responsible for the item-120 Moore alphabet is automatically the horizon severing event. That is too quick. The black-hole maps currently prove a radial/shell record channel:

$$V_{\rm Sch}(M):\ |x\rangle_{\Sigma_M}|[s]\rangle_B|\gamma\rangle_{\rm vac} \longmapsto |x\rangle_R|\delta(s)\rangle_{\rm syndrome}|\gamma\rangle_{\rm latch},$$

with the 12-edge strain syndrome and the complement latch carried isometrically over orthogonal shell-cell labels. This fixes the record and the radial location of the event. It does not, by itself, attach a spatial face/edge/corner contact alphabet to the event.

The audit is finite and mechanical. The Chebyshev-nearest shell of a cubic cell splits under O_h into face, edge, and corner orbits

$$F + E + C = 6 + 12 + 8 = 26.$$

Locality, cubic symmetry, and monitored connectedness do not uniquely select the full $F+E+C$ alphabet: $F+E$ and $E+C$ are also connected local alphabets. Since $V_{\rm cell}$ has only syndrome/latch labels, and $V_{\rm Sch}(M)$ only radial shell-cell labels, any of these orthogonal contact alphabets can be tensored onto the isometry without spoiling $V^\dagger V = I$. Therefore $V_{\rm cell}/V_{\rm Sch}(M)$ alone cannot prove the 26-slot Moore shell.

The all-contact rule is now grounded — not from $V_{\rm cell}/V_{\rm Sch}(M)$, but from the intrinsic geometry of the record cell. The $[8,4,4] = Q_3$ cell's face lattice has exactly $3^3 = 27$ faces (26 proper faces + the volume latch), in bijection with the Moore stencil; a service alphabet must be a boundary-closed subcomplex, which eliminates the $F+E$ and $E+C$ alternatives (they omit the bounding vertices of their own faces); and the local isotropy that forbids a codimension-one radial-pair alphabet is derived from emergent Lorentz — the horizon is a bulk metric surface in an unbroken O_h lattice ($r_s/a_0 \sim 10^{20}$), so any preferred local axis is suppressed by $\sim a_0/r_s$. Hence the emitted fraction is

$$\frac{9 \text{ outward face slots} + 1 \text{ latch}}{26 \text{ contact slots} + 1 \text{ latch}} = \frac{10}{27}.$$

This is, however, a *source-counting* number: the near-horizon Bogoliubov calculation gives the exact standard Hawking coefficient, so $(10/27)\alpha_0$ is a 0.29% shortcut to that inherited value rather than an independent coefficient of the horizon map alone.

Ringdown echoes. The current QEC horizon channel is one-way record writing, not a coherent reflecting mirror. The finite $V_{\rm cell}$ and its Schwarzschild shell lift are injective syndrome-and-latch maps; after the record is traced, no delayed identity channel remains to return a phase-coherent gravitational wave. The canonical prediction is therefore a large-echo null. Near-unit reflectivity at the a_0 cutoff would require an additional reflective-memory or rigid-core primitive not present in the present ledger, so echo searches are retained as upper-bound tests on extra horizon structure rather than as a positive prediction.

Scrambling. The same separation between local stencil and global graph matters for horizon scrambling. The documented $V_{\rm Sch}(M)$ channel is a direct sum over shell-cell labels with local one-bit service. On a local two-dimensional horizon-cell graph, both torus-shell and triangulated-sphere tests give a Laplacian gap $\lambda_2 \sim 1/N_H$, not an $O(1)$ expander gap; the mixing time is therefore power-law in the horizon entropy rather than logarithmic. A random bounded-degree expander control keeps $\lambda_2 = O(1)$, so the failure is not a degree artifact but a locality statement.

The stronger topological audit shows that any bounded-degree genus-controlled horizon graph is separator-limited. The present black-hole channel is therefore not a substrate-native fast scrambler. The current result is stronger than "not supplied": finite-range locality forbids an $O(1)$-gap graph unless the horizon obtains unbounded degree or nonlocal edges. The service-span nonlocality used in the gravity hierarchy is scalar bookkeeping, not such a surface graph. Hence confirmed black-hole fast scrambling would falsify the present local horizon service model.

6 What This Settles and What It Does Not

Settled here. The area law is a records *rate*, forced by the node area and the storage-impossibility gap; the coefficient is $C = 55/8$, with the last record-structure conditional discharged by two independent arguments; $\Omega_\Lambda = 12\pi/55$ follows α-free.

Not settled here. The records rate fixes the *coefficient* and the α-free ratio Ω_Λ; it does not fix the absolute Planck-mass *scale*, which still belongs to the separate gravity-sector selector, billing, and scale-convention analysis — deferred to the gravity companion [4]. The local KMS scheduler, Schwarzschild freeze-shell scaling, standard spin/partial-wave greybody transfer, the inherited Hawking flux coefficient, all-contact severing, and the massless species ledger are now finite-channel/exterior-transfer results. What remains on this side is Kerr/charge, fermion greybody extensions, dynamical-collapse templates, and the continuum/background lift. The no-singularity interior is a finite ledger decomposition — horizon syndrome-exhaust, bulk conserved charges, and a radial shell of snapped records — not yet a derived general- relativistic background.

7 Status Ledger

Claim	Status	Current reading
One δ: record, V_{cell}, blind DOF	COMPUTED	Same coboundary, three readings; latch = $\ker\delta$.
One δ: Hawking degeneracies, 55/8	CONDITIONAL	δ gives the energy axis; degeneracies/count add a validity/monogamy structure independent of δ.
Area law as records rate	COMPUTED	Standing storage fails 37–45 OOM; $H_0 M_{\text{P}}^2/16\Lambda_{\text{QCD}}^3 = C\alpha_0^2$.
$C = 55/8$	COMPUTED	$56 - 1$ readable, uniform measure; direction-tag fork discharged twice (channel + covariance).
$\Omega_\Lambda = 12\pi/55 = 0.6854$	CONDITIONAL output	α-free image of $C = 55/8$; $+0.1\sigma$; also a proton-primary output.
Horizon bandwidth ≈ 0.31 Edd	RETIRED	Withdrawn: area growth annexes existing records; not a live entropy-writing bottleneck.
Discrete Hawking ladder and local KMS	COMPUTED	Exact $g_{\mathcal{Q}}$, gap $F_{\min} = 3$; half-Boltzmann scheduler gives detailed balance.
Freeze shell and exterior greybody transfer	COMPUTED	$\rho\Lambda_{\text{QCD}} = \phi/\pi$ gives $\beta = 1$; escape cone gives M^{-2}; Regge–Wheeler spin/partial-wave transfer now computed.
Absolute Hawking flux coefficient	COMPUTED inherited	Near-horizon Bogoliubov/KMS gives the standard Hawking coefficient; $10\alpha_0/27$ gives $0.997\,P_{\text{SB}}$ as a source-counting shortcut. All-contact severing and the massless photon-plus-graviton species ledger are grounded; Kerr/charge/fermion extensions remain.
Ringdown echoes	COMPUTED null	Current record channel has no coherent delayed identity; large echoes require extra reflective structure.
Fast scrambling	COMPUTED no-go (forbidden)	Finite-range local horizon service cannot supply an $O(1)$-gap graph without unbounded degree or nonlocal edges. Confirmed black-hole fast scrambling would falsify the present local service model.
Absolute M_{P} scale	CONDITIONAL	Not fixed by this horizon-observable map; see the gravity companion for the selector, billing, and scale-convention analysis.

A Reproducibility Starter Table

Script	Purpose
python_code/bh_delta_unification_audit.py	Separates the genuinely-one-δ legs from the validity/monogamy-layered ones.
python_code/bh_isometry_v_construction.py	Constructs the finite $V_{\rm cell}$ from the $[8,4,4]/Q_3$ strain syndrome.
python_code/bh_qec_observables.py	Area-law records rate ($C_{\rm obs} = 6.8697 \sim 55/8$), standing-storage failure, the retired bandwidth reading, and the discrete Hawking lines.
python_code/bekenstein_blind_slot_theorem.py	Derives $C = 55/8$ ($56 \to 55$ quotient, uniform measure), the $\Omega_\Lambda = 12\pi/55$ image, and the covariance discharge of the direction-tag fork.
python_code/bekenstein_hop_tag_confirmation.py	The independent channel-counting / reconstruction-algebra discharge of the same fork.
python_code/bh_hawking_ladder_wavepacket.py	Verifies local wavepacket relaxation to the exact finite Hawking ladder under KMS.
python_code/bh_kms_scheduler_derivation.py	Derives the local half-Boltzmann Schwarzschild service scheduler and detailed balance.
python_code/bh_freeze_surface_greybody_map.py	Computes the freeze-shell relation, $\beta = 1$ shell, escape-cone scaling, and PM^2 constancy.
python_code/bh_flux_hawking_bogoliubov_closure.py	Verifies that the near-horizon Bogoliubov/KMS spectrum gives the standard Hawking flux coefficient; $10\alpha_0/27$ is a source-counting shortcut.
python_code/bh_greybody_transfer.py	Computes the standard Schwarzschild Regge–Wheeler spin/partial-wave transfer for the finite KMS ladder.
python_code/bh_all_contact_severing_facelattice_theorem.py	Grounds all-contact severing in the intrinsic closed face lattice of the $[8,4,4] = Q_3$ record cell.
python_code/bh_flux_species_polarization_ledger.py	Bills the two photon helicities and the spin-2 graviton greybody contribution in the massless horizon flux ledger.
python_code/bh_echo_reflectivity_null.py	Tests the current QEC channel for coherent delayed identity and records the large-echo null.
python_code/bh_fast_scrambling_locality_axiom_verdict.py	Shows that finite-range local horizon service forbids fast scrambling unless new nonlocal topology is added.
python_code/bh_fast_scrambling_topological_obstruction.py	Combines expander bisection with genus/separator bounds to rule out an $O(1)$ gap on bounded-degree local horizon graphs.
python_code/ulx_fork_resolution.py	Retires the 0.31-Eddington accretion-bandwidth reading as annexed-record bookkeeping.
python_code/bh_flux_species_severing_residual_audit.py	Records the remaining frontiers: Kerr/charge, fermion greybody extensions, and dynamical-collapse lift.

References

[1] Ahmed Almheiri, Xi Dong, and Daniel Harlow. Bulk locality and quantum error correction in AdS/CFT. *JHEP*, 04:163, 2015.

[2] Jacob D. Bekenstein. Black holes and entropy. *Phys. Rev. D*, 7:2333–2346, 1973.

[3] D. G. Elliman. Cosmology, dark energy, and inflation in the finite-QEC substrate. Zenodo preprint, `https://doi.org/10.5281/zenodo.20671860`, 2026.

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

[5] 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.

[6] David Elliman. It-for-bit model: Reproducibility repository. `https://github.com/dgedge/itforbit_model.git`, 2026. Code and reproducibility repository for the canon snapshot series.

[7] R. Haag, N. M. Hugenholtz, and M. Winnink. On the equilibrium states in quantum statistical mechanics. *Commun. Math. Phys.*, 5:215–236, 1967.

[8] Stephen W. Hawking. Particle creation by black holes. *Commun. Math. Phys.*, 43:199–220, 1975.

[9] Ted Jacobson. Thermodynamics of spacetime: the Einstein equation of state. *Phys. Rev. Lett.*, 75:1260–1263, 1995.

[10] Fernando Pastawski, Beni Yoshida, Daniel Harlow, and John Preskill. Holographic quantum error-correcting codes: toy models for the bulk/boundary correspondence. *JHEP*, 06:149, 2015.

[11] Planck Collaboration. Planck 2018 results. VI. cosmological parameters. *Astron. Astrophys.*, 641:A6, 2020.

[12] Adam G. Riess et al. A comprehensive measurement of the local value of the Hubble constant with $1\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ uncertainty from the Hubble Space Telescope and the SH0ES team. *Astrophys. J. Lett.*, 934:L7, 2022.