Gravity, Horizons, and Black Holes in the Finite-QEC Substrate

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Abstract

This paper states the current gravity and horizon canon of the finite-QEC (quantum-error-correction) substrate program. The preferred presentation is now proton-primary: the measured proton mass fixes $\Lambda_p = m_p/(2\sqrt{2})$, and the QEC/horizon accounting chain predicts G, $M_{\rm P}$, and H_0. The Hubble constant appears in older derivational scaffolding but cancels from the final input ledger; a script varies a dummy H_0 tenfold and verifies that the outputs are unchanged. Since the previous draft, two upgrades have changed the status. First, the local source form is no longer only a horizon-input analogy: an explicit service-current $T^{\mu\nu}_{\rm svc}$, together with RT/first-law entanglement reasoning, gives the linearized Einstein source structure at continuum-Jacobson grade. Second, the hierarchy coefficient has a sharper operator statement,

$$Z_G = 4\alpha_0^2 N_{\rm lock}, \qquad T = 8 + 1 + 0 = 9,$$

which lands $M_{\rm P}$ at $+0.016\%$ before the remaining alpha/Λ precision convention. The horizon side has also sharpened: the Bekenstein severing-channel factor is $C = 55/8$; the finite-cell isometry $V_{\rm cell}$, Schwarzschild shell channel $V_{\rm Sch}(M)$, local half-Boltzmann KMS scheduler, finite Hawking ladder, freeze-shell scaling, exterior greybody transfer, and echo-null statement are all computed or conditionally computed. These results still fall short of a complete quantum theory of black holes. The absolute flux is now resolved: the near-horizon Bogoliubov spectrum is exactly thermal at the KMS temperature, so the flux is the standard Hawking coefficient ($P/P_{\rm SB} = 1.000$ to $\sim 10^{-20}$), with the $(10/27)\alpha_0$ source-counting a 0.29% shortcut; all-contact severing is grounded in the $[8,4,4] = Q_3$ record-cell face lattice plus emergent-Lorentz isotropy; the species set is the two-helicity photon plus a computed 11.4% graviton; and fast scrambling is forbidden by finite-range locality (a falsifiable negative). The Kerr/charge extensions and the full dynamical-collapse lift remain open. The falsification surfaces are explicit: resolving the alpha-convention gate collapses the G window to a single value that must then match CODATA at its 22-ppm precision; the predicted $H_0 = 67.27\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$ dies with a SH0ES-side resolution of the Hubble tension; and $\Omega_\Lambda = 12\pi/55 = 0.6854$ currently stands $+0.1\sigma$ from the Planck value.

Contents

1 Role of This Paper

This is the gravity and horizon companion to the canon snapshot series. Its main job is to keep three different statements separate:

1. the current proton-primary route, where H_0 is an output;
2. older horizon-consuming Dirac-class relations, where H_0 or a late horizon is an empirical input;
3. finite horizon-channel algebra, where Bekenstein–Hawking and Hawking-radiation statements are rephrased as QEC ledger maps.

The external context is the usual one: Dirac large-number reasoning [7], emergent-gravity and thermodynamic-gravity programs [11, 21], black-hole entropy and radiation [4, 10], microstate-counting accounts of horizon entropy in string theory and in quantum geometry [3, 18], and holographic/QEC perspectives on horizon information [2, 13]. This paper is not a replacement for general relativity. It states the finite-substrate accounting claims and their current promotion status.

The code repository is [8]; project information is at `https://neusym.ai`.

2 Input and Output Ledger

The old gravity presentation often began with G, M_{P}, or a cosmological horizon. The current presentation starts with the proton. The matter-sector relation

$$m_p = 2\sqrt{2}\,\Lambda_p$$

fixes

$$\Lambda_p = \frac{m_p}{2\sqrt{2}}.$$

The relation is inherited from the matter companion and is flagged load-bearing in canon: the proton identification lands inside the independently solved Λ^* window at $+0.016\%$, while a neutron variant misses at $+0.10\%$; its standalone precision audit is a named open item. The remaining inputs are dimensionless: the bare service rate $\alpha_0 = 1/137$ (now treated as the monitored-service rate, with the dressed-alpha convention kept as a precision residual rather than a new service rate), the active-demux queue map shared with the cosmological-constant chain of the cosmology companion, the depth-six residual r_6 (the uncorrected fault density surviving at concatenation depth six of the QEC hierarchy), the 55/8 horizon channel count of Section 5, and the finite service budget $T = 9$ (eight single-bit repairs plus one post-service readout). The Hubble constant is not on this input list.

The current script form is

$$N_{\text{lock}} = \frac{9\alpha_0}{r_6}, \qquad H_0 = \frac{\Lambda_p}{N_{\text{lock}}} = \frac{\Lambda_p r_6}{9\alpha_0},$$

and

$$M_{\text{P}} = \Lambda_p \left(\frac{990\,\alpha_{\text{conv}}^4}{\alpha_0 r_6}\right)^{1/2}.$$

For $\alpha_{\text{conv}} = \alpha_0$ this is the ledger form

$$M_{\text{P}}^2 = 110\,\alpha_0^2\,\Lambda_p^2\,N_{\text{lock}}.$$

The current operator audit rewrites the same statement as a service-span renormalisation,

$$Z_G = 4\alpha_0^2 N_{\text{lock}}, \qquad M_{\text{P}} = \sqrt{4\pi Z_G}\,\Lambda_p, \qquad T = 8 + 1 + 0 = 9.$$

The factor four is the local stress-cell area touching four horizon nodes; the $T = 9$ span is eight single-bit repair opportunities plus one post-service latch/readout. Dropping the four-node area, changing T, or billing service rather than committed records moves the result by percent to orders-of-magnitude amounts. The live residual is therefore no longer a search for an arbitrary $O(1)$ gravity coefficient; it is the outside-sector completeness and alpha/Λ precision convention for the operator statement.

The script-level output suite is:

$$G_{\text{bare}} = 6.67218 \times 10^{-11}\ \text{SI},$$

$$G_{\text{dressed}} = 6.67919 \times 10^{-11}\ \text{SI},$$

and

$$H_0 = 67.266\ \text{km}\,\text{s}^{-1}\,\text{Mpc}^{-1}.$$

The two G conventions bracket the CODATA value $6.67430(15) \times 10^{-11}$ [19]. Bracketing is not agreement: the bare value sits -0.032% and the dressed value $+0.073\%$ from CODATA, each far outside the 22-ppm CODATA uncertainty, though the full window is only about twice the unresolved scatter among modern laboratory G measurements themselves [17]. Resolving the alpha-convention gate therefore converts this bracket into a one-shot precision test the chain must pass or fail outright. The predicted H_0 sits on the CMB/Planck side of the Hubble tension, -0.2σ from Planck Collaboration [14] and about 5.5σ below the SH0ES distance-ladder value [16]. A SH0ES-side resolution would falsify this chain.

2.1 Scaffolding Versus Inputs

Several derivational paths pass through formulae containing H_0: Bekenstein accrual, Friedmann accounting, and older Part-20 forms (the canon identity expressing ρ_Λ as $9\alpha_0^2\Lambda_{\rm QCD}^3 H_0$). The current ledger distinguishes this from consuming a Hubble measurement. In the conjunction, H_0 cancels, leaving the equivalent finite statement

$$M_{\rm P}^2 = 110\,\alpha_0^2\,\Lambda_p^2\,N_{\rm lock}.$$

The check in `python_code/g_route_input_ledger.py` varies a dummy Hubble value over a tenfold range and verifies that G, $M_{\rm P}$, Λ_p, and the output H_0 do not change. This is the distinction the paper must preserve: a quantity may appear in intermediate scaffolding without being an input.

2.2 Current Status

The proton-primary route is Computed / Conditional. It has a sharp input/output ledger and falsifiable outputs, but it still rests on the QEC/horizon-accounting chain: the depth-six residual, active-demux generation-vertex loop, 55/8 horizon count, service-span rule, and the alpha/Λ convention. The result is not "G from nothing." It is "G and H_0 from the proton anchor plus dimensionless finite-QEC mechanics," with the linearized source form derived separately from the service-current/entanglement first-law gate.

3 Intrinsic Source Form

The framework now separates the coefficient problem from the field-equation form. A local service-current stress tensor can be written directly from the record ledger:

$$T^{\mu\nu}_{\rm svc} = \frac{1}{V}\sum_e r_e\,\frac{p_e^\mu p_e^\nu}{p_e^0},$$

where e runs over local service events, r_e is the record weight, and p_e^μ is the null or massive service momentum assigned to the event. The script-level checks verify symmetry, positivity, conservation under Kirchhoff balance, the radiation control $P/\rho = 1/3$, and the dust control. This is the correct kind of source for a modular-energy first-law argument.

Combining this source with the verified RT/min-cut substrate structure and the entanglement first law gives the linearized Einstein source form at the usual Jacobson/Faulkner continuum grade:

$$\delta S = \delta\langle K\rangle \quad\Longrightarrow\quad \delta G_{\mu\nu} = 8\pi G_{\rm eff}\,\delta T_{\mu\nu}.$$

The result should be read carefully. The local tensor and the linearized source form are intrinsic QEC/entanglement statements. The observed Planck hierarchy is not generated by this local calculation: the bare local scale is order Λ_p, and the observed hierarchy requires the nonlocal service-span theorem of the previous section. This resolves a long-standing ambiguity in the gravity sector: the form of the equation and the numerical hierarchy are different gates.

4 Historical Horizon Bridges

Before the proton-primary cancellation, the gravity sector contained several relations of the form

$$M_{\rm P}^2 \sim \Lambda_{\rm QCD}^3 R_{\rm horizon}$$

or

$$\rho_\Lambda \sim \Lambda_{\rm QCD}^3 H_0.$$

These are not useless. They are the audit trail that showed what the large-scale claims were actually using. They are also not independent parameter-free predictions. They consume the QCD-to-horizon large number in the style of Dirac's large-number hypothesis [7].

The consolidation script records the sharper statement:

- old gravity $M_{\rm P}$ routes use the de Sitter horizon with positive half-power;
- ρ_Λ routes use the inverse horizon power;
- MOND's $a_0 = cH_0/(2\pi)$ names the Hubble horizon;
- the gravity route's de Sitter horizon differs from the a_0 Hubble horizon by the $1/\sqrt{\Omega_\Lambda}$ convention.

Thus the correct old-sector count is one late-horizon Dirac input, dressed in several ways, not three independent large-number predictions. The proton-primary route is interesting precisely because it moves H_0 from the input side to the output side of the ledger.

5 Alpha Power and the Gravity Prefactor

The old "double-Landauer" α^2 gravity story has been demoted. The recoverable part is narrower: one non-unitary erasure supplies one α. A virtual $P \to Q \to P$ gravity loop has a unitary syndrome injection and a non-unitary syndrome erasure. The finite event ledger therefore supports α^1, not α^2, unless a separate theorem constructs a second irreversible operation.

In de Sitter Dirac form the conditional target is

$$M_{\rm P}^2 = \frac{\alpha}{C_{\rm loop}} \Lambda_{\rm QCD}^3 R_{\rm dS}, \qquad C_{\rm loop} \simeq \frac{3}{2}.$$

This is a cleaner coefficient story for a horizon-consuming relation. It is not an intrinsic Planck-mass derivation. The $\Lambda_{\rm QCD}$ end of the bridge has a computed bare stiffness; the $R_{\rm dS}$ end is the late horizon unless the proton-primary ledger is used.

6 Bekenstein Severing Count

The Bekenstein-channel item is now one of the cleaner finite-horizon statements. The rate is written

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

The α_0^2 has a finite event home: pair severing has two α-resolved partners. The residual question was the $O(1)$ channel count $C \simeq 6.87$.

The current theorem target is

$$C = \frac{55}{8}.$$

The ledger behind it is:

1. an eight-bit register has $8 \times 7 = 56$ directed monogamy incidences;

2. the strain decoder has the single global-complement blind direction $\ker\delta = \{0, \mathrm{ALL}\}$;
3. the value-level hop-direction reading makes this blind direction remove exactly one directed severing incidence;
4. covariance under AGL(3, 2) — the affine general linear group of the three-bit address space, order 1344 — forces a uniform measure over the directed incidence orbit.

Thus the readable rank is $56 - 1 = 55$, and the per-node count is $55/8$. The alpha-free form of the same closure gives

$$\Omega_\Lambda = \frac{3\pi}{2C} = \frac{12\pi}{55} \simeq 0.68544.$$

Against the measured $\Omega_\Lambda = 0.6847 \pm 0.0073$ [14] this is $+0.1\sigma$, and it sides with the Planck H_0 branch, not the SH0ES branch.

The remaining named condition is not a free coefficient. It is the record-structure statement that the hop tag is value-level, not an address-level geometric stamp. The later hop-tag confirmation script supports this reading from the canon's partner-asymmetry and strain-ledger language, plus a reconstruction theorem for severing histories.

7 Finite Horizon Isometry

The finite horizon isometry is built from the Q_3 cube and the [8, 4, 4] affine code. Let $s \in \{0,1\}^8$ be a vertex-value register. The horizon syndrome is the edge coboundary

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

on the 12 edges of Q_3. Because Q_3 is connected,

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

The syndrome alone cannot distinguish a state from its global complement.

For the ideal affine code

$$c(x) = a_0 + a_1x_1 + a_2x_2 + a_3x_3, \qquad x \in \mathbb{F}_2^3,$$

the edge syndrome records the gradient (a_1, a_2, a_3) and is blind to the intercept a_0. Therefore the finite isometry has the form

$$V_{\text{code}}\,|a_1, a_2, a_3\rangle_{\mathcal{H}_B}\,|a_0\rangle_{\mathcal{H}_{\text{vacuum}}} = |\delta(a)\rangle_{\text{syndrome}}\,|a_0\rangle_{\text{latch}}.$$

The full-cell version is

$$V_{\text{cell}}\,|[s]\rangle_{\mathcal{H}_B}\,|\gamma\rangle_{\mathcal{H}_{\text{vacuum}}} = |\delta(s)\rangle_{\text{syndrome}}\,|\gamma\rangle_{\text{latch}},$$

where $[s]$ is the global-complement class and γ is the vacuum or complement latch. The no-vacuum control fails exactly by complement-pair collisions, so $\mathcal{H}_{\text{vacuum}}$ is not optional. It is the one bit required by the kernel theorem.

This closes the finite stabilizer-isometry leg. It does not by itself say which horizon cells participate in an astrophysical black hole or what their rates are.

8 Schwarzschild Shell Channel

The shell-channel script composes the finite cell map over the horizon shell:

$$V_{\rm Sch}(M) = \bigoplus_{x\in\mathcal{H}(M)} V_{{\rm cell},x}.$$

Equivalently,

$$|x\rangle_{\rm shell}|[s]\rangle_{\mathcal{H}_B}|\gamma\rangle_{\mathcal{H}_{\rm vacuum}} \mapsto |x\rangle_R|\delta(s)\rangle_{\rm syndrome}|\gamma\rangle_{\rm latch}.$$

The shell labels are orthogonal, so the direct sum is an isometry.

The cells that enter are the radial bonds or cells straddling the frozen-coin horizon surface — the coin is the substrate walk's direction register, so a frozen coin is the finite form of the horizon's one-way membrane: the exterior endpoint still has a functioning coin, while the interior endpoint is in the obligatory-inward phase. To thin-shell order their count is

$$N_H(M) = 16\pi r_s^2 \Lambda_{\rm QCD}^2.$$

The radial scheduler is a local one-bit reversible jump generator on the invalid subspace $\mathcal{Q}$:

$$W_{c\to c'}(x) = \Gamma_x \exp\left[-\frac{\beta_H \Delta E_\infty(c,c')}{2}\right].$$

Using the Tolman local temperature $T_{\rm loc} = T_H/\sqrt{f}$ [20] and redshifted energy $E_\infty = \sqrt{f}\,E_{\rm loc}$, the exponent is unchanged:

$$\beta_{\rm loc}E_{\rm loc} = \beta_\infty E_\infty.$$

Under the standard Schwarzschild regularity premise, with the jump process taken as a Davies-type thermal generator [6], the stationary line weights are therefore

$$P(F) \propto g_{\mathcal{Q}}(F)\, e^{-\beta_{\rm eff}F}.$$

The newer scheduler audit derives the half-Boltzmann form locally rather than putting it in by hand. Schwarzschild area degeneracy gives the KMS ratio, Tolman redshift makes the exponent invariant, and symmetric QEC service in the GNS frame transforms back to

$$W_{ij} = A_{ij}\exp[-\beta(F_j - F_i)/2].$$

Uniform and full-Boltzmann controls fail. Thus the local KMS source is now a computed conditional result, with its remaining assumptions concentrated in the localized-mass horizon steady state and continuum lift.

The honest boundary is clear. The algebraic/radial form of $V_{\rm Sch}(M)$ is computed. The local KMS scheduler and its finite ladder are computed under the horizon steady-state premise. Exact shell-position selection, species/polarization emission bookkeeping, and absolute flux normalisation are still open.

9 Hawking Ladder

The finite Hawking spectrum lives on the invalid horizon-register subspace $\mathcal{Q}$ — the 208 states of the eight-bit cell register outside the 48-state valid code sector. The exact strain degeneracies are

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

There are no $F = 1$ or $F = 2$ lines. The emitting spectral gap is

$$F_{\min} = 3.$$

The wavepacket verification now checks the finite dynamical bracket. A monitored local horizon wavepacket is dephased into populations on the 208-state $\mathcal{Q}$, and the induced one-bit KMS (Kubo–Martin–Schwinger thermal-equilibrium; 9) jump process relaxes to

$$P(F) = \frac{g_{\mathcal{Q}}(F)e^{-\beta F}}{\sum_{F'} g_{\mathcal{Q}}(F')e^{-\beta F'}}.$$

The script verifies detailed balance, graph connectedness, mixing, and line ratios such as

$$\frac{I_4}{I_3} = \frac{22}{11}e^{-\beta}.$$

With the scheduler derivation above, this is no longer merely an assumed KMS fit. It is a finite ladder prediction for the substrate's horizon register under the localized-mass steady-state premise. It is still not by itself a continuum Planck spectrum or an absolute flux law.

10 Freeze Shells, Greybody Transfer, and Flux

The freeze-shell map gives a compact scale for the near-horizon source. The $\beta_{\text{eff}} = 1$ shell satisfies

$$\rho_* \Lambda_{\text{QCD}} = \frac{\varphi}{\pi} = 0.196726, \qquad \rho_* = 0.1169 \text{ fm},$$

where ρ is proper distance from the horizon and φ is the golden ratio. Choosing the literal substrate spacing $a_0 = 1/\Lambda_{\text{QCD}}$ instead gives $\beta_{\text{eff}} = \pi/\varphi$. In either convention the redshift and escape-cone factors supply the standard M^{-2} Hawking flux scaling; the remaining difference is an $O(1)$ shell-position selection, not a new mass law.

The exterior transfer problem is now a bounded Schwarzschild calculation. At the $\beta = 1$ shell the finite line F maps to

$$\omega r_s = \frac{F}{4\pi}.$$

The greybody-transfer script propagates these line energies through the standard Schwarzschild barrier [12, 15]. It evaluates spin and partial waves for $s = 0, 1, 2$. The result is a computed transfer map, not a new finite-QEC principle: low F lines are strongly spin-filtered, higher lines escape more efficiently, and the black-hole spectrum is the finite ladder convolved with the usual exterior barrier.

The absolute coefficient is sharper but still conditional. The required near-horizon attempt rate is

$$\Gamma_{\text{req}}/\Lambda_{\text{QCD}} = 2.711306813 \times 10^{-3}.$$

The Landauer-Moore candidate gives

$$\Gamma_0 = \frac{10}{27}\alpha_0 \Lambda_{\text{QCD}}, \qquad P/P_{\text{SB}} = 0.997096067,$$

where P_{SB} is the scalar blackbody normalization used by the audit. The 10/27 numerator is the outward face plus latch, and the denominator is the $26 + 1$ Moore alphabet. This is close enough to be load-bearing, but the transfer is conditional: V_{cell} and $V_{\text{Sch}}(M)$ alone do not force the Moore alphabet. The missing theorem is that horizon severing is closed-cell Landauer erasure through every non-empty nearest contact, plus the species/polarization emission ledger.

11 Interior and Information Ledger

The framework's black-hole picture is not a classical singularity in the substrate variables. It separates three ledgers:

- the bulk matter or baryon-number condensate;
- the horizon syndrome-erasure ledger carrying Bekenstein–Hawking entropy;
- the intermediate radial shell ledger produced by snapped Wilson lines (broken gauge-web records) or strain records.

This separation is the mechanism by which the finite substrate avoids the naive "all entropy is bulk cells" reading. The horizon stores the entanglement and QEC-exhaust history; the bulk stores conserved charges and rest mass. The current paper does not claim that this fully derives the GR interior geometry. It gives the finite ledger decomposition and the shell map that a full geometry must realize.

12 Status Ledger

Claim	Status	Current reading
Proton-primary G, H_0 route	Computed / Conditional	H_0 is output, not input; Planck hierarchy operator statement gives $Z_G = 4\alpha_0^2 N_{\mathrm{lock}}$; live residual is outside-sector completeness and alpha/Λ precision.
Einstein/source form	Computed / Conditional	Service-current $T^{\mu\nu}_{\mathrm{svc}}$ plus RT/first-law entanglement gives linearized Einstein source form; the observed hierarchy is a separate nonlocal span theorem.
Old M_{P} horizon routes	Dirac-class	Useful audit trail; consume the QCD-to-horizon large number unless proton-primary cancellation is used.
Gravity α power	Conditional	α^1 per non-unitary erasure is recoverable; old α^2 double-Landauer story is not derived.
Bekenstein $C = 55/8$	Computed / Conditional theorem	Quotient map and hop-tag reading are computed from the finite record algebra; reconstruction floor remains.
$\Omega_\Lambda = 12\pi/55$	Conditional output	Alpha-free image of $C = 55/8$; Planck-side Hubble branch.
V_{cell}	Computed	Finite $[8, 4, 4]/Q_3$ stabilizer isometry constructed; vacuum latch is required by $\ker\delta$.
$V_{\mathrm{Sch}}(M)$ shell channel	Conditional / Computed	Direct-sum shell form, Tolman exponent cancellation, and local half-Boltzmann scheduler computed; localized-mass steady-state and continuum lift remain.
Hawking ladder	Computed / Conditional	Wavepacket dynamics relaxes to exact finite ladder under the derived local KMS scheduler; continuum/species flux remain.
Freeze/greybody map	Computed / Conditional	$\beta = 1$ shell, escape-cone M^{-2} scaling, and standard Schwarzschild spin/partial-wave transfer are computed; exact shell selection remains $O(1)$.
Flux coefficient	Computed (inherited)	Near-horizon Bogoliubov = exact Hawking ($P/P_{\mathrm{SB}} = 1.000$ to $\sim 10^{-20}$); the $(10/27)\alpha_0\Lambda_{\mathrm{QCD}}$ source-counting (0.9971) is a 0.29% shortcut. All-contact severing grounded in the $[8, 4, 4] = Q_3$ face lattice; species = photon + 11.4% graviton.
Fast scrambling	Computed no-go (forbidden)	Forbidden by finite-range locality: an $O(1)$-gap graph needs unbounded degree or nonlocal edges (abelian-Cayley no-go), and the service-span nonlocality is a scalar, not a graph. Falsifier: confirmed BH fast scrambling.
Interior singularity resolution	Conditional	Finite ledger decomposition replaces bulk-entropy count; full GR background lift still open.
Gravitational-wave channels	sharpened	PTA-band stochastic background (sub-threshold); ringdown-echo *null* (one-way record channel, not a coherent mirror — echo searches are upper-bound tests, not a positive prediction).

13 Gravitational-Wave Channels

Three gravitational-wave statements follow from the horizon model and the emergent-gravity construction; they postdate the first version and are added here.

The Einstein form is intrinsic, not only the prefactor. The proton-primary route fixes the coefficient G. Separately, the field *form* $G_{\mu\nu} = 8\pi G\, T_{\mu\nu}$ follows from the service-current stress tensor and entanglement thermodynamics — the Clausius relation $\delta Q = T\,\delta S$ on local Rindler horizons [11] — once the substrate supplies the area law and KMS temperature. The remaining hierarchy to the observed M_{P} is the nonlocal service-span statement, not a local tensor statement.

A stochastic background in the pulsar-timing band. If the substrate crystallised at $T_* \sim \Lambda_{\mathrm{QCD}}$, the first-order transition sources a stochastic gravitational-wave background peaking at $f \sim$ 20–50 nHz (the NANOGrav/PTA band) and rising as $h_c \sim f^{1/2}$ below the peak; the pinned K04 walls keep its amplitude sub-threshold. A nanohertz background confirmed *cosmological* at an amplitude requiring unsuppressed walls [1], or one peaking instead in the LISA/LIGO band, would tension the pinned-wall picture.

Ringdown echoes: a null, not a positive prediction. The QEC horizon channel is one-way record writing, not a coherent reflecting mirror: the finite V_{cell} and its Schwarzschild shell lift are injective syndrome-and-latch maps, so once the record is traced no delayed identity channel returns a phase-coherent gravitational wave. The canonical prediction is therefore a *large-echo null* [5]. Near-unit reflectivity at the lattice cutoff $a_0 = 1/\Lambda_{\mathrm{QCD}}$ would require an additional reflective-memory or rigid-core primitive not present in the present ledger; if it existed, the round-trip spacing would be $\Delta t \simeq 56$ ms for a $30\,M_\odot$ remnant (about half a generic Planck-scale echo, since $a_0/\ell_{\mathrm{P}} \sim 10^{20}$ halves the tortoise logarithm), so LIGO/LISA echo searches are retained as *upper-bound tests* on extra horizon structure at that spacing rather than as a positive echo prediction.

14 Open Frontiers

1. **Alpha/Λ precision convention.** The bare service rate is now the canonical α_0. The remaining gate is the dressed-alpha and Λ-normalization convention that converts the hierarchy statement into a CODATA-grade G value.

2. **Outside-sector completeness of the span theorem.** The service-span operator statement lands the hierarchy conditionally. The remaining question is whether all nonlocal gravitational bookkeeping is exhausted by that span or whether an additional horizon-sector correction exists.

3. **Black-hole flux sector — resolved since this draft.** The three items previously listed here (all-contact severing, the species/polarization ledger, and the fast-scrambling graph) are now closed. All-contact severing is grounded in the intrinsic face lattice of the $[8, 4, 4] = Q_3$ record cell (subcomplex-closure eliminates the $F{+}E/E{+}C$/face-only alternatives; local isotropy is derived from emergent Lorentz, a codim-1 radial-pair excluded by $\sim a_0/r_s$). The species set is the two-helicity photon plus a computed 11.4% graviton (Regge–Wheeler greybody, Page-matched), every massive species being Boltzmann-dead at astrophysical T_H. Fast scrambling is forbidden by finite-range locality, not merely underived. And the absolute flux is the standard Hawking coefficient via the near-horizon Bogoliubov spectrum, with $(10/27)\alpha_0$

a 0.29% source-counting shortcut. What remains is the Kerr/charge/ fermion greybody extensions and the dynamical-collapse lift.

4. **Background geometry.** Lift the finite cell and shell maps into a full Schwarzschild or dynamical collapse background, including rotation and charge if the framework is extended beyond the nonrotating neutral case.

A Reproducibility Starter Table

Script	Sector	Purpose
`python_code/g_route_input_ledger.py`	proton-primary gravity	Verifies H_0-independence and prints G, H_0, Λ_p, N_{lock}, and Ω_Λ.
`python_code/planck_hierarchy_operator_statement_audit.py`	proton-primary gravity	Audits $Z_G = 4\alpha_0^2 N_{\text{lock}}$, the $T = 9$ span rule, and control failures for the observed M_{P} hierarchy.
`python_code/cosmological_selector_lock_theorem.py`	proton-primary gravity	Identifies $N_{\text{lock}} = 9\alpha_0/r_6$ as the R4 completion endpoint, so $a = 1$ is the endpoint convention rather than an epoch pick.
`python_code/item131_r4_homogeneous_lift_theorem.py`	proton-primary gravity	Closes the in-instrument finite-to-homogeneous R4 lift, $\chi_{\text{R4}}(a) = a/a_{\text{lock}}$.
`python_code/a1_completion_d2_lift_audit.py`	proton-primary gravity	Converts the selector to a D2 first-hitting exhaustion law and reduces the stock to the integrated burn $B_0 = 9\alpha_0$.
`python_code/a1_episode_count_closure_attempt.py`	proton-primary gravity	Uses homogeneous $\text{AGL}(3, 2)$ covariance to close one opened service episode per physical cell inside the current instrument.
`python_code/gravity_service_current_stress_tensor_gate.py`	intrinsic gravity	Constructs $T^{\mu\nu}_{\text{svc}}$ and checks symmetry, positivity, conservation, radiation, dust, and modular-coupling controls.
`python_code/intrinsic_gravity_linearized_einstein_gate.py`	intrinsic gravity	Tests the RT/min-cut plus entanglement-first-law route to the linearized Einstein source form.
`python_code/large_scale_dirac_consolidation.py`	horizon audit	Consolidates old M_{P}, ρ_Λ, and a_0 routes into one late-horizon Dirac input class.
`python_code/gravity_alpha1_erasure_dirac.py`	gravity prefactor	Audits α^1 per non-unitary erasure and demotes double-Landauer α^2.
`python_code/gravity_alpha_power_target.py`	gravity prefactor	Shows the older alpha-power family (canon item 205) and Part-20 routes unify as one alpha-power Dirac relation; alpha power remains not magnitude-forced.
`python_code/bekenstein_severing_count_audit.py`	horizon count	Tests seven-channel and 55/8 severing-count candidates.
`python_code/bekenstein_blind_slot_theorem.py`	horizon count	Derives the global-complement blind-slot quotient $56 \to 55$.
`python_code/bekenstein_hop_tag_confirmation.py`	horizon count	Confirms value-level hop-tag reading from canon anchors and reconstruction algebra.
`python_code/bh_isometry_v_construction.py`	black holes	Constructs finite V_{cell} from the $[8, 4, 4]/Q_3$ strain syndrome map.
`python_code/bh_schwarzschild_channel_derivation.py`	black holes	Builds the direct-sum $V_{\text{Sch}}(M)$ shell channel and verifies Tolman/KMS exponent cancellation.
`python_code/bh_kms_scheduler_derivation.py`	black holes	Derives the local half-Boltzmann KMS service rates from Schwarzschild degeneracy, Tolman redshift, and symmetric QEC service in the GNS frame.
`python_code/bh_hawking_ladder_wavepacket.py`	black holes	Verifies local wavepacket relaxation to the exact finite Hawking ladder under KMS.
`python_code/bh_freeze_surface_greybody_map.py`	black holes	Computes the $\beta = 1$ freeze shell, the literal-a_0 comparison, and the escape-cone M^{-2} scaling.
`python_code/bh_greybody_transfer.py`	black holes	Propagates finite Hawking lines through standard Schwarzschild spin/partial-wave greybody barriers for $s = 0, 1, 2$.
`python_code/bh_flux_hawking_bogoliubov_closure.py`	black holes	Verifies that the near-horizon Bogoliubov/KMS spectrum gives the standard Hawking flux coefficient; 10/27 is a source-counting shortcut.
`python_code/bh_all_contact_severing_facelattice_theorem.py`	black holes	Grounds all-contact Landauer severing in the closed $[8, 4, 4] = Q_3$ face lattice and local Lorentz isotropy.

Script	Sector	Purpose
`python_code/bh_flux_species_polarization_ledger.py`	black holes	Bills the massless photon helicities and the spin-2 graviton greybody contribution in the horizon flux ledger.
`python_code/bh_fast_scrambling_locality_axiom_verdict.py`	black holes	Shows that finite-range local horizon service forbids fast scrambling; a positive fast-scrambling result would require new nonlocal topology.
`python_code/bh_fast_scrambling_topological_obstruction.py`	black holes	Combines expander bisection with genus/separator bounds to rule out an $O(1)$ gap on bounded-degree local horizon graphs.
`python_code/bh_flux_species_severing_residual_audit.py`	black holes	Records the remaining flux frontiers: Kerr/charge, fermion greybody extensions, and dynamical-collapse lift.
`python_code/gravity_mond_closure_gate.py`	boundary with MOND	Confirms intrinsic G/M_{P} remains conditional outside the proton-primary route and keeps MOND separate.
`python_code/qec_echo_template.py`	GW / black holes	Echo round-trip spacing $\Delta t \propto \ln(r_h/a_0)$ at the $a_0 = 1/\Lambda_{\mathrm{QCD}}$ cutoff, used as the upper-bound echo-search geometry; canonical reflectivity is the large-echo null (one-way record channel).
`python_code/gw_stochastic_background_nanograv.py`	GW / crystallisation	PTA-band stochastic background peak ($\sim$ 20–50 nHz) from a $T_* \sim \Lambda_{\mathrm{QCD}}$ transition; sub-threshold.

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