

Cosmology, Dark Energy, and Inflation in the Finite-QEC Substrate

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Abstract

This paper states the current cosmology-side canon of the finite-QEC substrate program. The sector is deliberately presented with stricter labels than its historical papers used, because dark energy, horizon thermodynamics, and inflation were the main source of earlier overclaims. The late dark energy equation of state is now closed inside the current service instrument: the finite R4 support is a one-chain, its homogeneous FRW lift gives $w(a) = -1 + a/28$, and positive activation excludes phantom behaviour unless new negative-rate physics is added. Structure-formation corrections are no longer free CPL deformations; paired ledgers show that the linear fixed-total-matter correction vanishes and that the first allowed term is a variance susceptibility. The HBC inflationary tilt and amplitude now share one premise: local single-clock saturated boundary printing. Under that premise $n_s = 27/28$, $S_j(k = aH) = 1$, and $A_\nu = (3/4)\alpha_0^4$; without the channel-lock/critical-latch and spatial-whitening identities the tilt can survive while the amplitude remains conditional. The CMB third-peak problem has likewise changed: a pressureless R4 zero-mode reservoir gives the right phenomenological slot, $\omega_{\text{dark}} = 0.12089$, and a CAMB forward run matches TT peak heights at the percent level. But the conserved massive dust charge is an added conditional/AeST-class premise relative to the documented dissipative R4 dynamics, not a derived consequence of the active line ledger. The acoustic scale is closed at continuum service-current grade if the photon-baryon phase clock is the QND service-lapse readout: then the active depth-six busy projector has normalized trace 63/64. The residual is the exact finite substrate lift to the Boltzmann-Keldysh action and the halo branch discipline: the current non-double-counted branch uses the zero-mode as the CDM-like mobile halo component, while independent active R4/MOND requires a new galaxy-screening theorem. The cosmological constant sector is split into the historical $\Lambda_{\text{QCD}}^3 H_0$ horizon/Dirac relation and the active-demux generation-vertex computation, which gives $\rho_\Lambda \simeq 1.0019 \rho_{\text{obs}}$; its residual is below current observational definition and is now an internal operator-algebra convention, not an observationally meaningful fit target. The result is a sharper cosmology program with three live gates: the saturated-printer lift, the zero-mode dust/source premise, and the exact CMB microscopic-lift plus full likelihood/halo-phenomenology branch.

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1 Role of This Paper

This is the companion paper for cosmology, dark energy, and inflation. It does not cover debris dark matter or MOND in detail; those are assigned to the dark-sector paper. It also does not make the proton-primary gravity route the main topic; that belongs to the gravity and horizons paper. The boundary is nevertheless important: the current canon says that the proton route predicts H_0 rather than consuming it, while older large-scale relations using H_0 remain part of the Dirac-class audit trail.

The paper uses the claim labels defined in the overview and foundations papers. In this sector they are not decorative. They prevent three common mistakes:

1. treating an entropy or Landauer story as a coefficient theorem;
2. confusing a finite code identity with a cosmological lift; and
3. presenting a horizon-input large-number relation as an intrinsic prediction.

The code repository [8] contains the audits cited below. Observational comparisons in this draft are used as status checks against the canon, not as fitted inputs unless explicitly stated. The main external cosmology reference point is the Planck 2018 parameter set [15]; BAO/dark-energy motivation is represented by DESI's 2024 release [6].

2 Cosmological Ledgers

The cosmology sector reads several distinct ledgers. Keeping them separate is the core discipline of the paper.

Ledger	Observable family	Risk if conflated
R4 late line ledger	$w(a)$, structure-coupled $w(z)$	Confuse homogeneous activation with halo activity or dark matter.
R4 zero-mode reservoir	CMB equality, third peak, mobile halo budget	Double-count pressureless dust and active MOND/RAR as two independent galaxy explanations.
HBC scalar-current ledger	n_s, A_ν, H_*	Read angular degeneracy, raw entropy, or channel labels as scalar amplitude.
Residual-fault ledger	ρ_Λ , boot residuals	Use observed H_0 or ρ_Λ as hidden inputs without disclosure.
Sky-reading ledger	η , photon entropy, comoving anchors	Import a heat-record unit into a normalized scalar fluctuation where it cancels.
Proton-primary ledger	G, H_0, M_P	Mistake scaffolding H_0 for a consumed measurement when it cancels.

The historical dark-sector retractions mostly failed in this table. They used compelling language about QEC exhaust or horizon entropy while leaving unclear which current was being counted, which event unit was billed, or which observable map turned that count into $T_{\mu\nu}$, $w(a)$, or $\Delta_{\mathcal{R}}^2$.

3 Late Dark Energy

The late dark-energy branch is now one of the cleaner cosmology results. It uses the 28-channel service instrument and a one-dimensional R4 support lemma; here R4 denotes the framework's fourth repair class, whose Landauer exhaust is the dark-energy source ledger. Let

$$\Delta_1 = \frac{1}{28}.$$

The finite service-clock and support audits give the homogeneous late branch

$$f(a) = a, \quad w(a) = -1 + \Delta_1 a.$$

Thus

$$w_0 = w(1) = -\frac{27}{28} \simeq -0.9643.$$

In the common Chevallier–Polarski–Linder convention [5, 12]

$$w(a) = w_0 + w_a(1 - a),$$

the local slope is

$$w_a = -\Delta_1 = -\frac{1}{28}.$$

The associated continuity equation gives

$$\frac{d \ln \rho_{\text{DE}}}{d \ln a} = -3(1 + w) = -3\Delta_1 a, \quad \rho_{\text{DE}}(a) = \rho_{\text{DE}}(1) \exp[3\Delta_1(1 - a)].$$

This is close to a cosmological constant, but it is not exactly Λ CDM.

3.1 What Is Closed

The current finite result is narrower than a full cosmology theorem but stronger than the older prose. The closed pieces are:

- a serial absorbing service clock with first gap $1/28$;
- a finite $8 \rightarrow 112 \rightarrow 28$ instrument bridge whose incidence normalization gives uniform channel weights;
- a one-dimensional R4 support complex; and
- the homogeneous FRW lift of that support: a comoving one-chain has physical measure proportional to a , so $f(a) = a$;
- the first-hitting completion endpoint $N_{\text{physical}} = N_{\text{lock}} = 9\alpha_0/r_6$, with $a = 1$ the scale-factor convention at this completed-support slice; and
- a positive activation reading in which pre-lock strain and post-lock records are not double counted.

The last point is what removes the phantom branch [3]. With one ledger entry per source event, the carrier changes at service completion rather than adding a second gravitating record. Positive absorbing-QEC activation therefore gives $w(a) > -1$. A measured robust phantom epoch would require an additional negative-rate or non-R4 channel not present in the current instrument.

3.2 What Remains Conditional

The former homogeneous-lift blocker is closed inside the present R1–R4 service instrument. The remaining caveat is outside-sector completeness: a hidden register, invalid-state cosmological channel, non-R4 coupling, or negative phantom-rate branch would be new physics rather than an ambiguity in the R4 lift. This is why the paper labels the late branch **CONDITIONAL**, not **LOCKED**.

4 Structure-Formation Corrections

The structure-formation correction is no longer an unconstrained “more clumping gives more dark energy” story. The paired-ledger audit asks a sharper question: at fixed scale factor and fixed total matter, does clumping change the R4 load?

Let $r_i = \rho_i/\bar{\rho}$, with $\langle r \rangle = 1$. If the local load law is linear,

$$\ell(r) = r,$$

then the paired ratio is exactly

$$D_{R4} = \langle r \rangle = 1.$$

There is no structure correction at fixed total matter. The leading allowed scalar correction is quadratic:

$$\ell(r) = r + \chi(r - 1)^2 + \dots, \quad D_{R4}(a) = 1 + \chi \text{Var}[r(a)].$$

In a linear-growth approximation [14],

$$\text{Var}[r(a)] = \sigma_0^2 D(a)^2,$$

so with $\kappa_0 = \chi\sigma_0^2$,

$$\delta w_{\text{sf}}(a) = \Delta_1 a \kappa_0 D(a)^2.$$

If the canonical present value $w_0 = -27/28$ is imposed by normalizing out today's load, the shape becomes

$$f_\epsilon(a) = a [(1 - \epsilon) + \epsilon U(a)], \quad U(a) = D(a)^2, \quad \epsilon = \frac{\kappa_0}{1 + \kappa_0}.$$

This is a useful state of affairs. The form is canon-grounded; the coefficient is not. The open problem is the microscopic R4/matter Kraus susceptibility χ , or equivalently ϵ , together with the nonlinear halo activity kernel replacing $D(a)^2$.

5 CMB Completion and the Zero-Mode Reservoir

The CMB third-peak issue used to be the most dangerous empirical objection to the dark-sector ledger. The sterile relic alone supplies only $\omega_{\nu_R} = \Omega_{\nu_R} h^2 \simeq 0.024$, so without another pressureless component matter–radiation equality lands near recombination and the third acoustic peak is too low. A diagnostic CAMB run [11] makes the target explicit: a component with

$$\omega_x \simeq 0.096, \quad w_x \simeq 0, \quad c_s^2 \ll 1$$

restores $z_{\text{eq}} \simeq 3409$ and the third-to-second peak scale.

The current canon identifies the required phenomenological slot with a minimal R4 zero-mode reservoir, but that identification is conditional. The documented active R4 immigration–death process has no conserved local particle number at homogeneous recombination; a non-dissipative massive dust charge must be admitted as a separate zero-mode/AeST-class premise. If that premise is admitted, the finite lift is a closed exchange

$$N_{\text{zero}} + N_{\text{active}} = N_{\text{tot}},$$

where N_{active} is the late/halo exchange excitation and N_{zero} is the homogeneous conserved reservoir. Its admitted Hamiltonian is only a local rest count plus same-cell exchange. No reservoir hopping, density-gradient stiffness, phase stiffness, or elastic shear is in the operator inventory. Consequently, at fixed comoving count,

$$\rho_{\text{zero}} \propto a^{-3}, \quad p_{\text{zero}} = 0, \quad c_s^2 = 0,$$

the finite analogue of constrained Brown–Kuchar dust [2].

The absolute density is therefore not merely set to the observed cold-dark matter value, but it is not unconditional either. The boot-source candidate is

$$\frac{n_{\nu_R}}{n_\gamma} = \frac{\alpha_0}{208},$$

where $208 = 256 - 48$ is the connected service-complement alphabet, not the old dead $205 = 208 - 3$ gravity count. The admitted source algebra is generation-blind, so the three sterile source corners couple through one S_3 -singlet release port rather than three independent generation ports. Together with the directed R4 incidence $\omega_{\text{zero}} = 4\omega_{\nu_R}$, this gives

$$\omega_{\nu_R} = 0.02418, \quad \omega_{\text{zero}} = 0.09671, \quad \omega_{\text{dark}} = 0.12089, \quad z_{\text{eq}} \simeq 3430.$$

The numerical hit is conditional on the microscopic $\alpha_0/208$ sterile release theorem and on the existence of the conserved massive zero-mode dust charge. Nearby denominators also land at the percent level, so the count alone is not evidence.

With this pressureless reservoir inserted as an effective dust species, the full TT forward run using $H_0 \simeq 67.3$, $n_s = 27/28$, $A_s = (3/4)\alpha_0^4$, and $w(a) = -1 + a/28$ matches the Planck-2018 Λ CDM peak heights and damping tail at about one percent: first, second, and third peak residuals are approximately +1.2%, +1.1%, +1.3%, and the RMS fractional difference over $30 \leq \ell \leq 2000$ is about 1.2%. The old “third peak no-go” is therefore not a shape argument once the imported dust slot is allowed; the live failure point is whether the framework can justify that slot and its halo bookkeeping.

The live CMB gate is the acoustic scale. At the selector-locked H_0 , the forward run gives

$$100\theta_* = 1.04420,$$

about +0.31% above the Planck/LCDM reference. A CAMB root wants

$$H_0 = 66.218 \text{ km s}^{-1} \text{ Mpc}^{-1} \simeq \frac{63}{64} H_0^{\text{selector}}.$$

The 63/64 form is suggestive because the service selector is depth six, and the substrate-service side now has the right operator. The active-address completion demultiplexer gives the busy projector

$$P_{\text{busy}} = I - |111111\rangle\langle 111111|, \quad \text{Tr}(P_{\text{busy}})/64 = 63/64,$$

because every incomplete selector state exposes exactly one native service channel per tick, while the complete state exposes none. The QND acoustic-clock audit closes the continuum side of the sector coupling. In the photon–baryon action the acoustic ruler is a phase clock, $d\phi = kc_s d\eta$, so it reads the conformal lapse. The relativity and service-current gates identify that scalar lapse with the A_{1g} service-clock covariance sourced by the conserved service-current stress tensor. Hence the long-wavelength acoustic mode phase-modulates the native service lapse; it does not execute a completion jump, count internal backlog labels, or read the endpoint flux. Symmetry, finite bandwidth, and no internal backlog resolution then force

$$P_{\text{acoustic}} = P_{\text{busy}}, \quad H_{\text{CMB}} = (\text{Tr } P_{\text{busy}}/64) H_{\text{selector}} = \frac{63}{64} H_{\text{selector}}.$$

The competing readings are excluded: a blind depth-label draw or a normalized additive hazard gives 1/2, independent local hazards count the backlog, a completion Lindblad/Peierls jump is not QND, and the completed endpoint gives 1/64. This is a continuum service-current/EFT-grade closure, not yet an exact finite substrate lift to the Boltzmann–Keldysh action or a replacement for a full Planck TT/TE/EE/lensing likelihood.

The halo bookkeeping is separate. The non-double-counted CMB-compatible branch is to let the zero-mode reservoir be the CDM-like mobile halo mass, with active R4/MOND not also fitted as an independent galaxy force. If the active baryonic MOND/RAR branch is retained, the fair-sample zero-mode must be galaxy-depleted or screened by more than 95%. Existing halo-model and operator-inventory audits sharpen this from a qualitative caveat to a branch verdict. Fair-sampling N_{zero} is 4.317 baryon masses; a 0.07 dex RAR-scatter proxy leaves only 0.175 fractional acceleration room. Hence an independent MOND branch would need the zero-mode reduced to $\leq 4.1\%$ of its fair-sample value, i.e. at least 95.9% depletion. The admitted same-cell exchange cannot do this while preserving the Poisson line ledger: $f = 0.959$ would require $x/N_{\text{tot}} = 23.7$, the opposite of the $N_{\text{tot}} \gg x$ reservoir limit. Otherwise the halo model double counts the same dark budget. The present live branch is therefore zero-mode CDM-like halos plus, at most, subleading active-R4 polarisation. A separate MOND branch is not forbidden forever, but it requires a new local depletion/screening operator. There is, however, a sharper non-double-counted theorem target. If N_{active}

is not a second mass component but the baryon-coupled constitutive response $\delta N_{\text{active}}[N_{\text{zero}}, \rho_b]$ of the same zero-mode reservoir, then the stress ledger remains $T_{00} = \epsilon(N_{\text{zero}} + N_{\text{active}})$. The cored R4 profile fixes a finite reservoir edge rather than a depletion factor:

$$\frac{M_z(R_t)}{M_b} = \frac{\Omega_z}{\Omega_b f_{\text{ret}}}, \quad \frac{M_z(y r_M)}{M_b} = y - \frac{1}{3} \arctan(3y).$$

For $f_{\text{ret}} = 1$ this gives $R_t = 4.8179 r_M$; for a Milky-Way-like $6 \times 10^{10} M_\odot$ baryonic galaxy with $f_{\text{ret}} = 0.25$ it gives $R_t \simeq 159$ kpc. The constitutive law has also been reduced one layer. The R4 $p = 3$ susceptibility fixes the asymptotic mass-per-radius demand $dM_z/dr = 4\pi A$, regular geodesic shell capture requires $dM_z/dr \sim r^2$ at the origin, and the minimal saturating latch

$$F(x) = \frac{x^2}{1 + x^2}, \quad x = r/r_c,$$

therefore gives $dM_z/dr = 4\pi A r^2/(r^2 + r_c^2)$, i.e. $\rho_z = A/(r^2 + r_c^2)$. The one- a_0 central-cell latch then fixes $r_c = r_M/3$. The scheduler step has now been reduced to a same-service class theorem: a bounded two-state shell-capture record with rates $U \rightarrow L : \Gamma_0 x^2$ and $L \rightarrow U : \Gamma_0$ has stationary fraction $F = x^2/(1 + x^2)$, and the line ledger itself is Poisson because creation and recycling share the same monitored Γ_0 clock. Thus the depletion contradiction is removed on the polarised-zero-mode branch up to one remaining local coefficient: the primitive one- a_0 phase-return latch that fixes $r_c = r_M/3$. The AeST literature [16] is a useful comparison point because it shows the kind of relativistic pressureless mode a MOND-like cosmology needs, but the present claim is internal: the reservoir exists only if the above record-number and source-map gates hold.

6 HBC Inflation

The inflationary branch is structurally narrowed but not closed. Unlike slow-roll inflation [10], where the tilt and amplitude descend from a potential and its derivatives [13], here the finite code supplies the same $\Delta_1 = 1/28$ clock. The cosmological lift asserts that early holographic-boundary-crystallisation (HBC) printing supplies a radial log-shell clock and a mode-local scalar-current readout. Under that premise,

$$\frac{d \ln \Delta_{\mathcal{R}}^2}{d \ln k} = -\frac{1}{28}, \quad n_s = 1 - \frac{1}{28} = \frac{27}{28} = 0.96429,$$

against the measured $n_s = 0.9649 \pm 0.0042$ [15]: a -0.15σ agreement. The result is a conditional scalar-clock/log-shell theorem. The finite 28-clock is solid; the bridge from finite service action to cosmological radial horizon shells remains load-bearing.

6.1 Scalar Projector

The scalar readout is no longer arbitrary. Homogeneity and translation covariance force a Fourier-character readout; compensation removes the homogeneous $k = 0$ mode; the horizon crossing condition selects $|k| = aH$. The admissible scalar projector has the schematic form

$$\Pi_k \delta j = V_H^{-1/2} \int_{V_H} e^{-i\mathbf{k}\cdot\mathbf{x}} \left[\frac{j(\mathbf{x}, N)}{\bar{j}(N)} - 1 \right] d^3x.$$

This rules out several tempting but wrong amplitude readings. A CMB scalar mode is not one of the 28 service labels, not one of the 112 incidence flags, not raw horizon entropy, and not angular degeneracy. It also leaves a genuine nonzero-mode question: the scalar amplitude samples channel utilisation and the compensated horizon-mode covariance, not only the homogeneous entropy ledger.

6.2 Amplitude

For the normalized scalar current

$$\nu_{\text{HBC}}(\mathbf{x}, N) = \int^N \left[\frac{j(\mathbf{x}, N')}{\bar{j}(N')} - 1 \right] dN',$$

the amplitude has the current-covariance form

$$A_\nu = \frac{F_{\text{eff}} S_j(k = aH)}{N_{\text{shell}}}.$$

The finite audits close several pieces but not the whole amplitude:

- $F_{\text{eff}} = 1$ for the continuous-time Markov-chain (CTMC) service-count ledger;
- the scalar projector form Π_k is fixed;
- the scalar observable is the colour-restoring topology current, not all-channel entropy; and
- $S_j(k = aH) = 1$ follows only if the horizon printer has the serial-clock/fixed-total and de Sitter-homogeneous local covariance structure, so that no independent horizon-mode service covariance is present.

A direct observable audit constructs the clean escape hatch: a nonlocal Fourier-pair horizon current $\sum_x \cos(k \cdot x) J_x, \sum_x \sin(k \cdot x) J_x$ changes $S_j(k = aH)$ while leaving the homogeneous shell count unchanged. A positive Lindblad source raises the amplitude; lowering the central value requires a nonlocal feedback/quota suppressor. Neither operator is generated by the current local HBC/QEC service algebra, so either would be a new scalar source. If the channel-lock/critical-latch and spatial-whitening identities hold, the local single-clock scalar-printer algebra fixes the shell count:

$$N_{\text{shell}} = \frac{4}{3} \alpha_0^{-4}, \quad A_\nu = \frac{3}{4} \alpha_0^4 \simeq 2.13 \times 10^{-9},$$

which sits $+1.0\sigma$ from the measured $A_s = (2.10 \pm 0.03) \times 10^{-9}$ [15]. The reason is finite: define $\lambda_{\text{shell}} = N_{\text{shell}} \alpha_0^4$. Coherent constant- H printing requires $\lambda_{\text{shell}} \leq C_F$, while saturated no-idle scalar printing requires $\lambda_{\text{shell}} \geq C_F$. Thus $\lambda_{\text{shell}} = C_F = 4/3$. The latest amplitude audit keeps this as the sharp candidate but not as an unconditional theorem: all-channel entropy loading can preserve total printed entropy while changing the colour-load projection, and an allowed horizon-mode covariance can preserve the homogeneous clock while changing $S_j(k = aH)$.

The associated HBC scale can be written

$$N_{\text{shell}} = \frac{S_{\text{dS}}(H_*)}{u_{\text{event}}}, \quad S_{\text{dS}} = \frac{8\pi^2 \bar{M}_{\text{P}}^2}{H_*^2},$$

with \bar{M}_{P} the reduced Planck mass and S_{dS} the Gibbons–Hawking horizon entropy [9]. If the scalar event is one newly printed boundary cell, then $u_{\text{event}} = \ln 2$ and

$$H_* = \sqrt{\frac{6\pi^2}{\ln 2}} \alpha_0^2 \bar{M}_{\text{P}} \simeq 1.2 \times 10^{15} \text{ GeV}.$$

In ordinary slow-roll inflation this H_* would imply primordial tensors far above the current bound $r < 0.036$ [1]. HBC printing is not a smoothly stretching inflaton background. The printer perturbation is scalar shot noise, so at linear order the scalar/vector/tensor decomposition produces no

transverse-traceless graviton mode; the residual tensor expectation is second-order, $r \sim O(A_s) \sim 2 \times 10^{-9}$. Thus the branch predicts essentially no observable primordial B-modes. A robust detection at $r \gtrsim 10^{-3}$ would falsify the no-squeezing HBC reading.

The honest tier is therefore: $A_\nu = (3/4)\alpha_0^4$ is a sharp **CONDITIONAL** candidate, not a fully discharged amplitude theorem. The remaining HBC theorem is exactly channel-lock/critical-latch plus spatial-whitening, with constant- H and exit compatibility. A failure of those identities changes the amplitude while the 28-clock tilt can remain intact.

7 Cosmological Constant

The cosmological constant is the sector’s most delicate object [4, 17]. The current canon contains two routes with different status.

7.1 Historical Horizon/Dirac Route

The older route expresses the observed scale through a relation of the form

$$\rho_\Lambda \sim \text{coefficient} \times \Lambda_{\text{QCD}}^3 H_0.$$

This is a useful scale fact but not an intrinsic prediction. It consumes the late-horizon scale. Together with historical gravity and MOND large-number relations, it belongs to one Dirac-class family: the same $\Lambda_{\text{QCD}} \leftrightarrow H_0$ large number appears with different powers and different code or α prefactors. This is precisely the kind of relation Dirac’s large-number hypothesis warns us to audit carefully [7].

The canon therefore keeps the horizon route as an accounting and consistency result, not as the final cosmological-constant derivation.

7.2 Boot Residual-Fault Scale

The boot residual-fault route — “boot” denoting the crystallisation epoch at which the register-bearing phase forms — is a non-horizon scale theorem at conditional grade. The structure is

$$q_{\ell+1} = \frac{q_\ell^2}{p_{\text{th}}}, \quad q_\ell = p_{\text{th}} r^{2^\ell},$$

with a local pair probability

$$r = \frac{1}{2} \left(\frac{2}{3} \right)^2 = \frac{2}{9}$$

and candidate depth $\ell = 6$. This gives a value within a factor $\simeq 1.65$ of the observed ρ_Λ scale, without inserting H_0 on the prediction side. The coefficient is still not closed: the finite-depth/boundary corrections tested so far do not license the needed adjustment.

7.3 Active-Demux Generation-Vertex Route

The strongest current route is the active-address demux chain. The finite handoff analysis selects the stationary one-jump post-service branch:

- no scheduler is catastrophically high;
- pre-service readout is the wrong observable map;

- established full-reset slaving undershoots;
- active-address demux with post-service residual is the live branch.

At the raw register-thermodynamics generation rate (canon §5.2) this branch gives

$$\rho_\Lambda \simeq 1.616 \rho_{\text{obs}}.$$

The generation-vertex correction is then computed using the chirality/Weyl vacuum-polarisation loop machine of canon item 115. The loop gives

$$\Delta(-\ln \gamma) = \alpha_0 C_{\text{loop}}, \quad C_{\text{loop}} = \frac{1}{3} \left\langle \frac{1}{|\sin k|} \right\rangle,$$

and the evaluated branch lands at

$$\rho_\Lambda \simeq 1.0019 \rho_{\text{obs}}.$$

This is the strongest cosmological-constant result in the current canon. At the raw coefficient level the residual is real:

$$C_{\text{target}} - C_{\text{loop}} \simeq 0.0011875, \quad \frac{C_{\text{loop}}}{C_{\text{target}}} - 1 \simeq -0.3897\%.$$

Finite source shapes, alpha-scheme substitutions, and simple determinant or resummation forms have not produced a canon-derived next-order object. A later audit changes the interpretation: because C_{target} is defined by matching the observed ρ_Λ , it inherits the Planck-era uncertainties of H_0 and Ω_Λ . The propagated floor is roughly $\pm 4\%$ of C , an order of magnitude above the 0.39% gap; the residual is only $\sim 0.1\sigma$ against the sky. Observation therefore does not define the third digit of this coefficient. The remaining question is internal and algebraic: which exponentiation or normal-ordering convention the monitored billing formalism forces. The status is COMPUTED at observational precision, not LOCKED as a microscopic operator theorem.

8 Sky-Reading Normalisations

Some cosmological numbers are ratios of ledger counts and are almost convention-free. Others require a reading convention. The sky-reading audit separates them into classes:

- Class 1: ratios of ledger counts in one era, such as $w_0 = -27/28$ and $F_{\text{eff}} = 1$.
- Class 2: count-to-photon or count-to-entropy readings, such as the baryogenesis entropy-per-event unit s_1 .
- Class 3: comoving-anchor or absolute-scale readings, such as H_* , N_{shell} , and absolute ρ_Λ .

The common bare service rate is no longer a free convention. The R14 record-pair theorem gives

$$\alpha_0^{-1} = \text{Sym}^2(16) + 1 = 136 + 1 = 137,$$

because the billed objects are clonable syndrome records, not Pauli-excluded matter pairs. Downstream cosmology still has to prove the sector billing map: HBC bills four topology commits, the CMB sterile source bills one non-unitary release through the 208-label service complement, and the cosmological constant generation vertex bills one monitored register touch. The physical dressed

shift $1/137 \rightarrow 1/137.036 \dots$ is a separate QED sector-billing residual: the alpha-escape route is now sign/form/near-value sharp, but its service-occupation readout is not yet the Ward/Kubo physical QED billing slot. It is subdominant for the cosmology comparisons made here.

This matters for inflation. The baryogenesis/photon record unit $\ln(8 \times 137)$ is not allowed to enter the normalized scalar amplitude unless a separate theorem says the scalar current samples that record. In $\nu_{\text{HBC}} = j/\bar{j} - 1$, ordinary heat per event cancels. The scalar event unit is instead tied to the HBC printed-cell capacity, with $u_{\text{event}} = \ln 2$ only under the printed-cell scalar-current identification.

9 Input/Output Boundary with Gravity

This paper uses H_0 in two different ways and must distinguish them.

The old horizon/Dirac relations consume H_0 or the late horizon as an empirical input. Those relations are kept as audits and consistency checks. By contrast, the current proton-primary gravity route uses the measured proton mass to set Λ_{QCD} , combines it with dimensionless microphysics, and outputs G , M_{P} , and H_0 . In that route, Hubble quantities appear in derivational scaffolding but cancel from the final input list. The gravity paper will own that derivation; the cosmology paper records only the boundary convention so the two presentations do not contradict each other.

The cosmological selector has also been sharpened. Inside the current homogeneous R4 service instrument the physical span is the first hitting endpoint

$$N_{\text{physical}} = N_{\text{lock}} = \frac{9\alpha_0}{r_6},$$

and $a = 1$ is the scale-factor convention at this completed-support slice. Equivalently, the D2 relic-exhaustion reading consumes a finite burn stock $B_0 = 9\alpha_0$ at rate r_6 . Static K04-stock readings are closed negative. The remaining caveat is again outside-sector completeness, not a free cosmological epoch selector.

10 Status Table

Claim	Status	Current reading
Late $w(a)$	CONDITIONAL	Finite 28-clock, R4 $d = 1$ support, and homogeneous FRW lift close inside the current instrument; only outside-sector completeness remains.
Non-phantom branch	COMPUTED	Positive absorbing-QEC activation excludes $w < -1$ unless an extra negative-rate channel is added.
Structure corrections	CONDITIONAL target	Fixed-total linear correction vanishes; leading term is variance susceptibility $\chi\text{Var}(r)$.
Inflationary tilt	CONDITIONAL	$n_s = 27/28$ follows from finite 28-clock plus HBC radial log-shell scalar clock.
Scalar projector	COMPUTED	Compensated Fourier shell at $k = aH$; angular degeneracy and raw entropy are ruled out as amplitude counts.
Scalar amplitude	CONDITIONAL	$A_\nu = (3/4)\alpha_0^4$ is the sharp saturated-printer candidate; channel-lock/critical-latch and spatial-whitening remain the live operator identities.
ρ_Λ , horizon route	DIRAC-CLASS	$\Lambda_{\text{QCD}}^3 H_0$ scale relation consumes the late horizon; useful audit, not intrinsic prediction.
ρ_Λ , active-demux route	COMPUTED	Generation-vertex loop gives $1.0019\rho_{\text{obs}}$; the 0.39% coefficient residual is below the current observational noise floor and is now an internal billing-convention issue.
Proton-primary H_0	cross-paper boundary	Gravity route outputs H_0 ; this paper avoids mixing it with horizon-input predecessors.
CMB peak heights	CONDITIONAL / imported dust premise	An effective pressureless zero-mode dust slot gives $\omega_{\text{dark}} = 0.12089$, $z_{\text{eq}} = 3430$, and CAMB TT peak heights within about 1%, but documented active R4 dynamics do not derive the conserved massive dust charge.
CMB acoustic scale	CONDITIONAL continuum theorem	Selector-locked H_0 gives $100\theta_*$ high by 0.31%; the QND acoustic-clock audit identifies the continuum photon-baryon phase clock with the service-lapse readout P_{busy} , whose normalized trace is $63/64$. The residual is the exact finite substrate lift to the Boltzmann-Keldysh action and full CMB likelihood.
Halo branch	COMPUTED / CONDITIONAL	Halo-model and operator-inventory audits reject natural $> 95\%$ galaxy depletion for the CDM-like zero-mode. Current non-double-counted branch: zero-mode CDM-like halos plus at most subleading active R4 polarisation. A viable stronger branch is polarised zero mode: active R4 is the response of the same reservoir, with $R_t = 4.8179r_M$ for full baryon retention, $R_t \simeq 159$ kpc for a Milky-Way-like $6 \times 10^{10} M_\odot$, $f_{\text{ret}} = 0.25$ galaxy, and the cored law follows from the same-service shell-capture latch $F = x^2/(1+x^2)$. Remaining caveats are the one- a_0 phase-return operator and full halo phenomenology.

11 Open Frontiers

1. **Structure susceptibility.** Derive χ , or ϵ , from the microscopic R4/matter Kraus coupling and replace linear $D(a)^2$ with the nonlinear halo event-rate kernel.
2. **HBC amplitude locks.** Derive the channel-lock, critical-latch, and spatial-whitening identities from HBC/QEC mechanics, then derive the saturated constant- H phase and exit. Without those identities $A_\nu = (3/4)\alpha_0^4$ remains a conditional candidate.
3. **CMB acoustic microscopic lift.** Build the exact finite substrate lift to the Boltzmann–Keldysh acoustic action whose long-wavelength limit is the QND service-lapse readout P_{busy} , or find the microphysical observable that replaces it. At continuum service-current grade the 63/64 factor is forced; a backlog, hazard, or endpoint reading would be new structure and would refute the repair.
4. **Zero-mode dust premise and halo branch.** Either derive the non-dissipative conserved massive dust charge that active R4 dynamics do not supply, or treat the pressureless component as an external/AeST-class import. The halo bookkeeping itself is now branch-resolved in current canon: the zero-mode is the CDM-like mobile halo component, and active R4/MOND is not an independent galaxy force unless future canon adds a local depletion/screening operator capable of removing $> 95.9\%$ of fair-sample N_{zero} from galaxies without breaking the Poisson line ledger, or derives the stronger polarised-zero-mode constitutive law in which active R4 is the baryon-coupled response of that same reservoir. The current reduction now derives the minimal regular saturating shell-capture latch $F = x^2/(1 + x^2)$ relative to the same-service theorem; the remaining questions are the one- a_0 phase-return operator and full nonlinear halo phenomenology.
5. **Source-map microscopic clause.** The CMB zero-mode density is conditional on one α_0 -billed sterile release through the 208-label service complement; the denominator, uniform addressing, and generation-singlet port are derived, but the release event remains the boot-source theorem target.
6. **Billing algebra.** The cosmological-constant residual is below the observational noise floor, but the monitored formalism still has to choose its exponentiation/normal-ordering convention internally.
7. **Input/output hygiene.** Keep the proton-primary H_0 -output route, the selector lock, and older horizon-input routes visibly separated.

A Reproducibility Starter Table

Script	Sector	Purpose
<code>python_code/item131_serial_clock_theorem.py</code>	late $w(a)$	Proves the serial absorbing service-clock gap 1/28.
<code>python_code/item131_w_to_28_instrument.py</code>	late $w(a)$	Builds the $8 \rightarrow 112 \rightarrow 28$ service-instrument bridge.
<code>python_code/item131_r4_support_dimension.py</code>	late $w(a)$	Proves one-dimensional R4 support at finite level.
<code>python_code/item131_late_activation.py</code>	late $w(a)$	Derives $f(a) = a$ and $w(a) = -1 + a/28$ under the line-ledger lift.

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Script	Sector	Purpose
python_code/item131_r4_homogeneous_lift_theorem.py	late $w(a)$	Closes the finite-to-homogeneous R4 lift inside the current service instrument.
python_code/cosmological_selector_lock_theorem.py	selector	Identifies $N_{\text{physical}} = N_{\text{lock}} = 9\alpha_0/r_6$ as the R4 completion endpoint.
python_code/a1_completion_d2_lift_audit.py	selector	Converts the $a = 1$ lift into the D2 relic-exhaustion first-hitting law.
python_code/r4_activation_identification_closure.py	activation	Audits the pre-lock strain / post-lock record carrier and non-phantom branch.
python_code/item123_structure_paired_ledgers.py	structure $w(z)$	Runs the fixed-total clumped-vs-homogeneous load test and emits the paired-ledger form.
python_code/item123_structure_wz_corrections.py	structure $w(z)$	Computes the linear-growth ϵ -family for $w(z)$.
python_code/item131_inflation_hbc_status_gate.py	HBC inflation	Consolidates the tilt and amplitude status gates.
python_code/item131_scalar_mode_projector.py	HBC amplitude	Derives the compensated Fourier-shell scalar readout form.
python_code/item131_t5b_correlation_volume_audit.py	HBC amplitude	Reduces the correlation volume to $S_j(k = aH)$ and N_{shell} .
python_code/item131_hbc_channel_whitening_closure.py	HBC amplitude	Tests the local whiteness route; later audits keep spatial-whitening as an explicit amplitude lock.
python_code/item131_hbc_stop_rule_proof.py	HBC amplitude	Gives the local scalar-printer queue-balance candidate $N_{\text{shell}}\alpha_0^4 = C_F = 4/3$.
python_code/item131_hbc_scalar_printer_observable_audit.py	HBC amplitude	Constructs the nonlocal Fourier-pair horizon-current escape and pins the remaining channel/spatial locks.
python_code/item131_saturation_residuals_audit.py	HBC inflation	Consolidates the remaining shared saturated-printer dynamics and amplitude-lock theorem.
python_code/item123_r4_zero_mode_dust_hamiltonian.py	CMB zero-mode	Derives the minimal rest-count Brown–Kuchar dust form if a conserved zero-mode reservoir is admitted.
python_code/item123_zero_mode_source_geodesic_halo_gate.py	CMB/halo	Derives uniform Q -addressing, the geodesic dust lift, and the halo non-double-counting ledger.
python_code/item123_halo_depletion_halomodel_audit.py	CMB/halo	Tests the independent-MOND depletion branch; fair-sample zero-mode halos require $> 95.9\%$ galaxy depletion, and the current operator inventory supplies no such screen.
python_code/item123_halo_non_double_counting_residual.py	CMB/halo	Records the adopted non-double-counted branch: zero-mode CDM-like halo mass plus at most subleading active-R4 polarisation.
python_code/item123_zero_mode_r4_polarisation_branch.py	CMB/halo	Tests the stronger branch $N_{\text{active}} = \delta N_{\text{active}}[N_{\text{zero}}, \rho_b]$: active R4 as response of the same zero-mode reservoir, with a finite cored-profile edge and a remaining constitutive-law gate.
python_code/item123_zero_mode_r4_constitutive_law.py	CMB/halo	Reduces the polarised-zero-mode cored profile to the R4 $p = 3$ shell-demand, regular zero-mode shell capture $F = x^2/(1 + x^2)$, and one- a_0 core latch.
python_code/item123_zero_mode_shell_capture_latch_theorem.py	CMB/halo	Derives $F = x^2/(1 + x^2)$ from the P1 two-state, one-rate shell-capture service latch and records the hidden-rate and wrong-power controls.
python_code/item132_p1_service_class_reduction.py	CMB/halo	Splits P1 into a closed same-service Poisson scheduler leg and a separate a_0 phase-latch scale leg.
python_code/item132_a0_phase_latch_minimality.py	CMB/halo	Reduces the $a_0 = cH_0/(2\pi)$ rule to a primitive KMS phase-return latch and excludes hidden integer cadences under that operator.
python_code/item123_zero_mode_nonlinear_galaxy_bracket.py	CMB/halo	Runs the analytic nonlinear galaxy bracket for zero-mode edges, outer-disk residuals, and scaling with baryonic mass.
python_code/item123_sterile_generation_singlet_source.py	CMB source	Proves the three sterile corners couple through one generation-singlet source port.
python_code/item123_nuR_absolute_density_boot_qec.py	CMB source	Computes the $\alpha_0/208$ source-law density candidate and $\omega_{\text{dark}} = 0.12089$.
python_code/item123_omega_dark_absolute_chain.py	CMB source	Consolidates the one-port sterile source and 4:1 zero-mode incidence into the current absolute $\Omega_{\text{dark}}h^2$ ledger.
python_code/item123_cmb_boltzmann_swEEP.py	CMB peaks	Extracts the pressureless slot target and equality/third-peak restoration with CAMB.

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Script	Sector	Purpose
<code>python_code/cmb_camb_tt_comparison.py</code>	CMB peaks	Runs the framework TT forward spectrum and checks percent-level peak-height closure.
<code>python_code/item123_cmb_theta_halo_completion_gate.py</code>	CMB scale	Quantifies the $100\theta_*$ selector gate and halo branch alternatives.
<code>python_code/item123_cmb_lock_attempt.py</code>	CMB scale	Finds the 63/64 acoustic target before the later service-lapse closure.
<code>python_code/item123_substrate_busy_lag_law.py</code>	CMB scale	Proves the active-address busy projector $P_{\text{busy}} = I - 111111\rangle\langle 111111 $ with normalized trace 63/64.
<code>python_code/item123_acoustic_readout_map_derivation_attempt.py</code>	CMB scale	Derives $P_{\text{acoustic}} = P_{\text{busy}}$ at substrate-service level and rejects additive hazard/backlog readings.
<code>python_code/item123_acoustic_sector_coupling_theorem.py</code>	CMB scale	Reduces full acoustic closure to the continuum QND service-lapse coupling clause; under that clause $H_{\text{CMB}} = (63/64)H_{\text{selector}}$.
<code>python_code/item123_acoustic_clock_qnd_lapse_readout_audit.py</code>	CMB scale	Proves the continuum photon-baryon acoustic phase is the QND service-lapse readout at service-current/EFT grade, leaving only the exact finite Boltzmann/Keldysh lift.
<code>python_code/item123_boot_residual_fault_theorem.py</code>	ρ_Λ	Computes the conditional boot residual-fault scale route.
<code>python_code/register_handoff_form_selection.py</code>	ρ_Λ	Selects the post-service one-jump handoff branch.
<code>python_code/register_handoff_demux_decision_audit.py</code>	ρ_Λ	Chooses stationary active-demux over the demoted tick-13 transient.
<code>python_code/cc_generation_vertex_item115_loop.py</code>	ρ_Λ	Computes the item-115 generation-vertex loop coefficient.
<code>python_code/cc_next_order_residual_audit.py</code>	ρ_Λ	Confirms the real 0.39% next-order coefficient residual.
<code>python_code/cc_residual_noise_floor.py</code>	ρ_Λ	Propagates Planck uncertainties through the chain sensitivity: the coefficient residual is $\sim 0.1\sigma$ against observation.
<code>python_code/alpha0_record_pair_symmetry_theorem.py</code>	normalization	Derives the bare 1/137 monitored record-pair service rate.
<code>python_code/alpha0_downstream_billing_map_audit.py</code>	normalization	Separates sector billing maps from the dressed- α problem.
<code>python_code/large_scale_dirac_consolidation.py</code>	horizon audit	Consolidates gravity, ρ_Λ , and MOND horizon-input large-number relations.
<code>python_code/g_route_input_ledger.py</code>	cross-paper	Verifies that the proton-primary gravity route outputs H_0 rather than consuming it.

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