Dark Energy from $R^3 \oplus I^3$ Planck-Patch Geometry

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We model space as R^3 coupled to an evanescent adjoint sector I^3 across Planck-area "Planck patches" on a common interface Σ. By the Bekenstein–Hawking area law each patch has capacity 1 nat, and we postulate a per-patch area $A_{\text{patch}} = 4L_P^2$. A local, capacity-limited exchange along Σ conserves the total (normalized) ledger load and equilibrates to an absorbing state where the saturated fraction equals the initial per-patch load, $f_{\text{sat}} = x$. Identifying this homogeneous ledger with vacuum energy gives $\Omega_\Lambda = f_{\text{sat}}$. With the one-bit initial condition ($x = \ln 2$), the mechanism yields $\Omega_\Lambda = \ln 2$, consistent with Planck 2015 (0.692 ± 0.012) and within $\sim 1.2\%$ of Planck 2018 (0.685 ± 0.007). After equilibration the model predicts $df_{\text{sat}}/d\ln a = 0$ and $w = -1$. We state assumptions explicitly and emphasize falsifiability; on-shell R^3 physics remains unchanged while I^3 supports only evanescent modes.

*T*his is a clarified two-page exposition aligned with a PRD Letters submission; it adds explicit assumptions, compact equations that fit two columns, and a short conclusion.

Notation and units. We use $\hbar = c = 1$. R^3 is the on-shell (real) spatial sector; I^3 is an adjoint, evanescent sector sharing the same time; Σ is their common interface tiled by Planck patches.[1] The Planck length is $L_P = \sqrt{\hbar G/c^3}$. We postulate a *Planck patch area*

$$A_{\text{patch}} = 4L_P^2. \tag{1}$$

By the Bekenstein–Hawking law $S/A = 1/(4L_P^2)$, the *per-patch capacity* is

$$C_{\text{patch}} = 1 \text{ nat} = \frac{1}{\ln 2} \text{ bits}. \tag{2}$$

We normalize loads by C_{patch} so $q_i \in [0,1]$ and $x \equiv \langle q_i \rangle \in [0,1]$ are *dimensionless.* The Hubble rate is $H(t) = \dot{a}/a$ ($a = 1/(1+z)$); the reduced Planck mass obeys $M_P^2 = 1/(8\pi G)$; the critical density is $\rho_c = 3M_P^2 H^2$.

Assumptions and scope. (i) *Capacity postulate:* Eqs. (1)–(2). (ii) *Initial condition:* the uniform ledger (not matter) has mean per-patch load x (kept free unless stated). (iii) *Cosmology mapping:* $\rho_\Lambda = \alpha f_{\text{sat}} M_P^2 H^2$ with $\alpha = 3$, hence $\Omega_\Lambda = f_{\text{sat}}$. Thus the mechanism implies $\Omega_\Lambda = x$; data determine x. A motivated special case is the *one-bit initial load* $x = \ln 2$.

Interface capacity and initial load. Tiling Σ by N patches, the conserved total (normalized) ledger load is

$$\sum_{i=1}^{N} q_i = Nx. \tag{3}$$

As a natural, least-biased preparation, we may take an initial per-patch load of one bit,

Why $x = \ln 2$ (symmetry/indifference). Let each patch carry a binary ledger flag $b \in \{0,1\}$ with no prior bias. The per–patch Shannon entropy in nats is

$$S(p) = -p\ln p - (1-p)\ln(1-p),$$

maximized by symmetry at $p = \frac{1}{2}$, giving $S_{\max} = \ln 2$ nats. With per–patch capacity normalized to 1 nat, the mean initial load equals the maximized entropy,

$$x = \frac{S_{\max}}{1 \text{ nat}} = \ln 2.$$

Thus the "one-bit per patch" preparation follows from maximum ignorance for a binary degree of freedom, not from the dynamics.

$$x = \ln 2. \tag{4}$$

Local exchange along Σ (bucket–brigade). Only *adjacent* patches (sharing an edge on Σ) exchange load; the through-interface normal component into I^3 is evanescent, so the time-averaged Poynting flux into I^3 vanishes. One update step:

$$q_{\text{hi}} = \max(q_i, q_j), \quad q_{\text{lo}} = \min(q_i, q_j),$$
$$\Delta = \min\{\, q_{\text{hi}} - q_{\text{lo}},\ 1 - q_{\text{lo}} \,\}, \tag{5}$$
$$q_{\text{hi}} \to q_{\text{hi}} - \Delta, \quad q_{\text{lo}} \to q_{\text{lo}} + \Delta. \tag{6}$$

This is local, capacity-limited ($q \le 1$), and preserves Eq. (3). It halts when no adjacent pair can transfer without violating the cap.

Absorbing states and saturated fraction. Any absorbing configuration has $q_i \in \{0,1\}$ for all but at most one patch. Let N_{sat} be the number with $q = 1$ and $q_* \in [0,1)$ (optional single partial). Conservation gives

$$N_{\text{sat}} + q_* = Nx \;\Rightarrow\; f_{\text{sat}} \equiv \frac{N_{\text{sat}}}{N} = x - \frac{q_*}{N} = x \pm O\Big(\frac{1}{N}\Big). \tag{7}$$

Thus $f_{\text{sat}} = x$ (up to $1/N$), independent of microscopic details of the rule.

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[1] A full interface construction with Dirac/EM boundary conditions appears in Ref. [7].

Cosmological mapping and predictions. We use

$$\rho_\Lambda = \alpha \, f_{\rm sat} \, M_P^2 H^2, \tag{8}$$

$$\rho_c = 3 \, M_P^2 H^2, \qquad \alpha = 3. \tag{9}$$

Then

$$\Omega_\Lambda \equiv \frac{\rho_\Lambda}{\rho_c} = f_{\rm sat} = x, \qquad \Omega_m = 1 - f_{\rm sat}. \tag{10}$$

With Eq. (4),

$$f_{\rm sat} = \ln 2 \simeq 0.693. \tag{11}$$

Each saturated patch then carries $1/\ln 2 \simeq 1.443$ bits.

Key test. After equilibration (late times) the saturated fraction is constant:

$$\frac{df_{\rm sat}}{d\ln a} = 0. \tag{12}$$

Equivalently, $df_{\rm sat}/dz = 0$ since $a = 1/(1+z)$. Moreover,

$$w \equiv \frac{p_\Lambda}{\rho_\Lambda} = -1. \tag{13}$$

Information budget and matter channels. The ledger variable q_i tracks only the *homogeneous vacuum ledger* on Σ; it does *not* encode non-uniform, dynamical matter information. Hence Eq. (10) splits the cosmic energy budget without double counting: "empty" ($q = 0$) means empty with respect to the uniform ledger, while $\Omega_m = 1 - f_{\rm sat}$ denotes non-uniform sectors (localized R^3 excitations, bound/composite interface states with $E_{\rm tot} = 0$, compact objects).

Observational status. For flat ΛCDM, Planck 2015 reports $\Omega_m = 0.308 \pm 0.012$ (so $\Omega_\Lambda = 0.692 \pm 0.012$); Planck 2018 finds $\Omega_m = 0.315 \pm 0.007$ (so $\Omega_\Lambda = 0.685 \pm 0.007$). The 2015 central value lies within 0.1σ of $\ln 2$, and 2018 remains within $\sim 1.2\%$.

Evolving DE tests. DESI Y1 cosmology (BAO) is consistent with a constant equation of state within uncertainties ($w = -0.99^{+0.15}_{-0.13}$) while also permitting mild dynamics; DESI DR2 strengthens hints that $w(z)$ may evolve.[8–11] Our constant–x (equilibrated) model predicts $w = -1$ and $df_{\rm sat}/d\ln a = 0$ at late times; persistence of significant evolution in $w(z)$ across data combinations and systematics would rule out this simplest version. A non-equilibrated extension with slowly varying $x(a)$ is possible but lies beyond this Letter.

CONCLUSION

This model derives the dark energy fraction $\Omega_\Lambda = \ln 2$ from a minimal set of information-theoretic postulates applied to the Planck-scale structure of spacetime, offering a fundamental explanation for a key parameter of the Standard Model of cosmology.

DATA AVAILABILITY

No datasets were generated or analyzed. The only numerical values used for comparison are published Planck cosmological parameters (2015/2018) cited below.

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