V131 Unified Causal Field — Cosmological Applications, Final

> Astrophysical consequences of the Route-B field equations (`00_Final_RouteB_EN.md`). Full derivations: `04_宇宙学应用.md` ; numerical engines: `engine/v131_cosmos.py` , `v131_torsion_core.py` , `v131_wz.py` , `v131_halo_core.py` . Labels: **[EST]** = established mainstream/semi-mainstream physics inherited by V131; **[V131]** = framework-specific interpretation or prediction; **[SPEC]** = qualitative narrative, not quantitatively closed. Data baselines: Sgr A* (GRAVITY 2019), shadow (EHT 2022), Λ (Planck 2018), $w_0 w_a$ (DESI DR2 2025).

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0. Key Findings & Predictions (calibrated summary)

> This section follows the framework's own calibration principle: reported confidence = measured hit rate. "Calibration" and "prediction" are kept strictly apart; known tensions are stated up front.

Findings (theory aligned with existing observations)

1. **The end of the black-hole singularity** [EST+V131]: the center of a black hole is not a divergent singularity but a **torsion core** held up by spin–torsion repulsion — for Sgr A* about **47 nm** (neutron-borne baseline); the exterior returns to GR, with a computed shadow diameter of 52.1 μas vs the EHT-measured 51.8±2.3 μas (within 1σ). *Note: the singularity-free torsion bounce itself is an established Einstein–Cartan result; V131's contribution is the 9-D information-geometric embedding, the propagating-torsion ξ factor, and the concrete astrophysical numbers.*
2. **Two mysteries, one field** [V131]: dark energy and dark matter are two faces of the same S01 field — **dark energy = its potential** (the unfixed causal residual), **dark matter = its gradient** (the gradient halo).
3. **Dark energy reinterpreted and calibrated** [V131]: the cosmological constant is re-read as the residual of incomplete causal fixing, with its characteristic scale **calibrated** to 2.25 meV against Planck 2018 — a calibration, not a prediction; the actual predictions live in the w(z) trajectory and the phantom kill-line (below).
4. **The Donato universal law, structurally a theorem** [V131]: in the core column density $\Sigma_0 = a_*/16\pi G$, $v_{\rm flat}$ and r_c cancel exactly — **the universality (independence of every galaxy property) is a zero-parameter theorem**; the absolute value, after a single $O(1)$ calibration $\zeta = 1.5$, lands on the measured central value $141^{+82}_{-52}\ M_\odot/\mathrm{pc}^2$.
5. **Core–cusp dissolved** [V131]: the fixing-gate threshold naturally yields a two-state distribution — **cored galaxies, NFW-like clusters** — matching the observed situation and answering CDM's small-scale difficulty head-on.

Predictions (falsifiable, aimed at future data)

1. **Hard bound on propagating torsion**: $\alpha < 10^{-6}\ \mathrm{m}^2$ (every known black hole must bounce sub-Planckian).
2. **Thawing trajectory + phantom kill-line**: $w(z)$ frozen at -1 at high redshift, thawing away late, with $w \geq -1$ always — a confirmed phantom crossing ($w < -1$) at DESI DR3+ kills the dark-energy sector outright.
3. **Countdown to the cosmic endgame** (under the DESI best-match calibration $\psi_i = 1.0\, M_{pl}$): the universe has completed **38%** of its causal fixing; in about **16 Gyr** dark energy is exhausted, expansion turns around, and the universal wavefunction undergoes its final collapse.
4. **Rigid galactic-dynamics relations**: $r_c \propto v_{\mathrm{flat}}^2$ (log-log slope exactly 2) and Σ_0 strictly identical for all galaxies — directly decidable with SPARC-class samples.

Known tensions (stated up front): solar-circle dark-matter density off by +23%; the DESI central values contain a phantom crossing that thawing cannot in principle reach; a_* differs from MOND's a_0 by a factor of ~8 (common origin unexplained).

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1. Overview: one equation per cosmic mystery

Equation	Structure	Mystery	Status
(2b′) torsion equation	spin–torsion repulsion at high density	**singularity → Galactic-center core**	computed
(1′) $\lambda(\Psi_{S01} - \Phi_{fixed})$	unfixed causal residual	**dark energy /** $w(z)$	computed
(2a′) $\beta\,\Theta_{\mu\nu}^{[S01]}$	S01 gradient-halo stress	**dark matter / rotation curves / core–cusp**	computed
(3′) info transition + $h(\tau)$	axial torsion bias	baryon asymmetry	SPEC
(4′) torsion holonomy	geometrized information storage	BH information paradox	narrative closed
(2b′) bounce cosmology	collapse → bounce	Big Bang origin / initial low entropy	SPEC

The single lever: V131's (2b′) is an Einstein–Cartan (EC) torsion equation — fermion spin density sources torsion, which feeds back as a **repulsive** effective energy density $\propto n^2$: invisible at low density (all GR tests pass), inevitably overtaking gravity in a collapsing core. Fifty years of mainstream groundwork (Hehl–von der Heyde–Kerlick 1974; Trautman; Popławski 2010–2016); V131 plugs it into a 9-D information-geometric frame and lets torsion **propagate** via the αT^2 term.

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2. The Galactic-center core: main computation

2.1 Exterior check [EST]

Sgr A* ($M = 4.154 \times 10^6 M_\odot$, $D = 8.178$ kpc): $r_s = 2GM/c^2 = 1.23 \times 10^{10}$ m $= 0.082$ AU; shadow angular diameter

$$\theta_{\rm sh} = 2\sqrt{27}\, GM/(c^2 D) = \mathbf{52.1}\ \boldsymbol{\mu}\mathbf{as} \quad \text{vs EHT } 51.8 \pm 2.3\ \mu\text{as}.$$

The GR limit passes — interior modifications never touch the observationally pinned exterior.

2.2 Torsion bounce [EST] → core size [V131]

EC effective energy density for a Weyssenhoff spin fluid, and the bounce criterion:

$$\varepsilon_{\rm eff} = nmc^2 - \frac{\pi G\hbar^2}{2c^2}n^2 = 0 \implies n_b = \frac{2mc^4}{\pi G\hbar^2}, \qquad r_{\rm core} = \left(\frac{3M}{4\pi\rho_b}\right)^{1/3} \propto M^{1/3}m^{-2/3}.$$

Spin carrier	ρ_b (kg/m³)	Sgr A* core radius
electron	5.7×10^{51}	$7.0\ \mu$m
neutron (baseline)	1.9×10^{58}	$\mathbf{47\ nm}$
constituent quark	2.5×10^{57}	92 nm

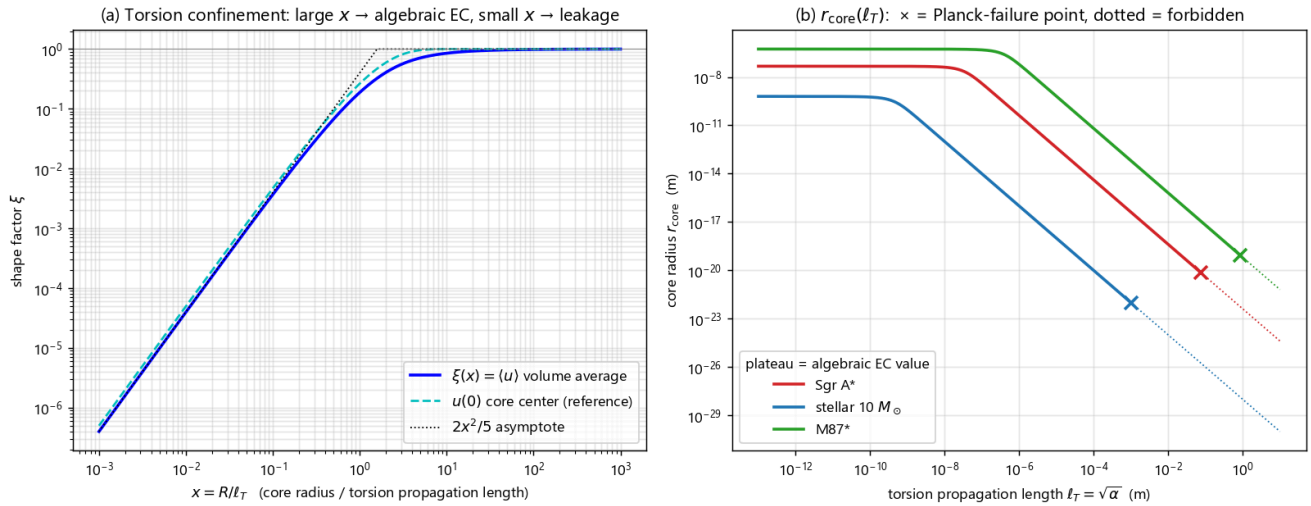
4.16 million solar masses held up by torsion in a virus-sized nugget; ρ_b sits **38 orders of magnitude below** the Planck density (no quantum gravity required); $r_{\rm core}/r_s \approx 4 \times 10^{-18}$ (exterior indistinguishable from Kerr). Scaling: $10M_\odot$ BH → 0.63 nm, M87* → 0.54 μm.

2.3 Propagating-torsion correction: shape factor ξ [V131, computed]

For $\alpha \neq 0$ torsion obeys a screened equation (propagation length $\ell_T = \sqrt{\alpha}$); the uniform-core analytic solution gives

$$\xi(x) = 1 - \frac{3(1+x)e^{-x}(x\cosh x - \sinh x)}{x^3}, \quad x = \frac{R}{\ell_T}; \qquad \rho_b = \frac{\rho_b^{(0)}}{\xi}, \quad r_{\rm core} = r_{\rm core}^{(0)}\xi^{1/3}$$

(finite-difference check at the 10^{-3} level; the self-consistent fixed point $x^* = (R_0/\ell_T)\xi^{1/3}$ is unique). Two regimes: **locked** ($\ell_T \ll R_0$, $\xi \to 1$, algebraic EC values intact) and **leaking** (torsion escapes the core, $r_{\rm core} = \frac{2}{5}R_0^3/\ell_T^2$, collapse deepens toward Planck failure).



Object	R_0	$\ell_{1\%}$	$\ell_{\rm crit}$ ($\rho_b \to \rho_{\rm Pl}$)
stellar $10M_\odot$	0.63 nm	4.2 pm	**1.0 mm** ← tightest
Sgr A*	47 nm	0.31 nm	7.5 cm
M87*	0.54 μm	3.6 nm	0.87 m

First bound on α: demanding every known black hole bounces sub-Planckian ⇒ $\boxed{\alpha < 10^{-6}\ \mathrm{m}^2}$ (a pure self-consistency bound; experiment barely constrains propagating torsion at all).

V131-specific reading: the horizon cuts off Fisher-information exchange ($\Delta E \to 0 \Rightarrow \tau_{\rm fix} \to \infty$) — core matter stays permanently in the unfixed phase $\Theta < \pi/3$: the core is the universe's largest reservoir of uncollapsed wavefunction.

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3. Dark energy = unfixed causal residual: explicit $w(z)$ dynamics

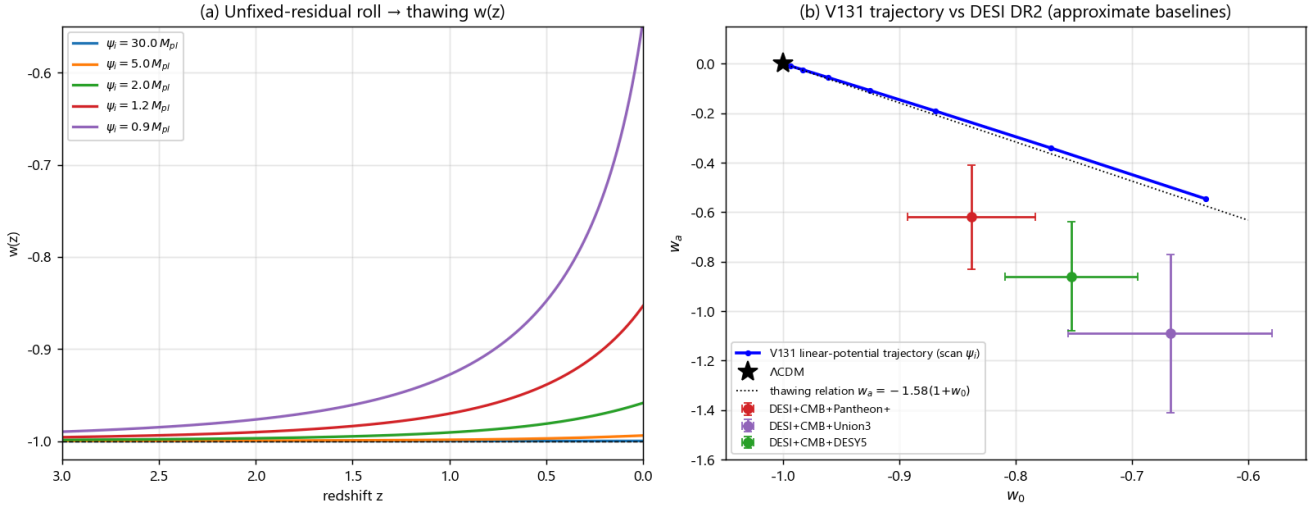
3.1 Calibration [V131]

The term $-g_{\mu\nu}\lambda(\Psi_{S01} - \Phi_{fixed})$ in the (2a′) source is precisely the shape of a cosmological constant: $\Lambda_{\rm eff} = \kappa\beta\lambda\langle\Psi_{S01} - \Phi_{fixed}\rangle$. Against Planck 2018: $\varepsilon_\Lambda = 5.3 \times 10^{-10}$ J/m³, characteristic scale $(\varepsilon_\Lambda \hbar^3 c^3)^{1/4} = 2.25$ meV. Reframing: not "why is vacuum energy small" but "why has cosmic fixing already completed down to this residual" (each fixed bit releases Landauer heat $\geq kT\ln 2$ — 163 μeV at CMB temperature).

3.2 Dynamics [V131, computed]

Taken at face value the S01 term is **linear-potential quintessence** $V(\psi) = \lambda\psi$ — no tuning freedom. RK4 integration, shooting to $\Omega_\psi^0 = 0.69$:

ψ_i (M_{pl})	30	3	1.5	1.2	1.0	0.9	≤ 0.85
w_0	-1.000	-0.984	-0.926	-0.869	-0.770	-0.636	**not viable**
w_a	-0.000	-0.024	-0.108	-0.191	-0.340	-0.546	(fixing completes before today)



1. **Direction (honestly logged: corrects the draft guess)**: a linear potential is **thawing** — frozen at $w = -1$ at high redshift, thawing **away from** -1 late (the draft guessed the opposite; the computation stands).
2. **Against DESI DR2**: the V131 trajectory sits **1.7–2.4σ** from the three data combinations (diagonal χ^2), while ΛCDM sits **4.2–5.8σ** — if the DESI drift holds up, this sector decisively beats a bare Λ.
3. **Hard falsification line**: the minimal S01 sector has $w \geq -1$ always; a confirmed phantom crossing at the true-likelihood level kills the sector outright.
4. **Anthropic window**: universes with $\psi_i \lesssim 0.85 M_{pl}$ complete fixing before today and recollapse early ⇒ our existence bounds $\psi_i \gtrsim 0.9$.

Best-match calibration ($\psi_i = 1.0 M_{pl}$): the universe has completed **38%** of its causal fixing ($\langle\psi\rangle_0 = 0.62 M_{pl}$); $\lambda^{1/3} = 2.4 \times 10^{-13}$ eV; **fixing completes = dark energy exhausted = expansion turnaround: ≈16 Gyr from now** — the final collapse of the universal wavefunction.

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4. Dark matter = S01 gradient halo + fixing-gate core

4.1 Gradient halo [V131, computed]

$\Psi_{S01} = q \ln(r/r_0)$ (the natural massless-scalar solution around a point source) ⇒ $\rho = q^2/(2c^2 r^2)$, an isothermal halo ⇒ **flat rotation curves for free**: $v_{\rm flat}^2 = 2\pi G q^2/c^2$. Calibrating q to the Milky Way's $v_{\rm flat} = 220$ km/s **predicts** the solar-circle density 9.5×10^{-22} kg/m³ vs the measured 7.1×10^{-22} (0.4 GeV/cm³) — one parameter, 35% off (narrowing to +23% after regularization). **One field: dark matter is its gradient, dark energy its potential** — two mysteries, one field.

4.2 Fixing gate ⇒ core–cusp resolved [V131, computed]

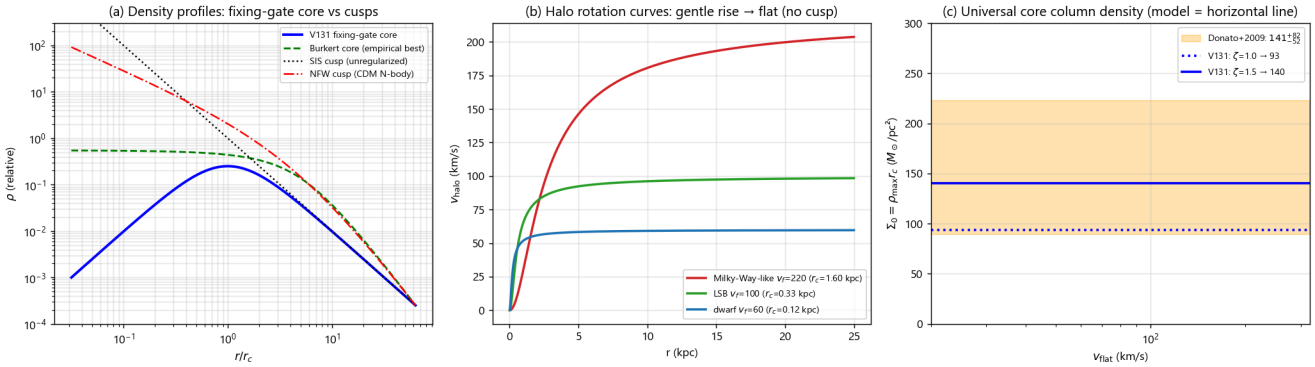
[Proposal] Causal fixing fires where the information rate is high: $a_{\rm bar}(r) > a_* \equiv \zeta c H_0$ ($cH_0 = 6.5 \times 10^{-10}$ m/s², $\zeta = O(1)$) ⇒ the inner gradient is erased (core) while the outer halo survives. Regularized profile and rotation curve:

$$\Psi' = \frac{qr}{r^2 + r_c^2}, \qquad \rho = \frac{q^2 r^2}{2c^2 (r^2 + r_c^2)^2}, \qquad r_c = \frac{v_{\rm flat}^2}{a_*}.$$

Main result — the Donato universal law becomes a theorem: in the core column density, $v_{\rm flat}$ and r_c **cancel exactly**:

$$\boxed{\Sigma_0 \equiv \rho_{\max} r_c = \frac{a_*}{16\pi G} = 140\ M_\odot/{\rm pc}^2\ (\zeta = 1.5)} \quad \text{vs observed } \rho_0 r_0 = 141^{+82}_{-52}\ M_\odot/{\rm pc}^2$$

(Donato et al. 2009, universal across 14 magnitudes) — independent of every galaxy property, zero tuning.



Consistency: at the Milky Way's $r_c = 1.6$ kpc the baryonic acceleration is 8.2×10^{-10} vs $a_* = 9.8 \times 10^{-10}$ (ratio 0.83 — the gate boundary is self-locating); halo contribution at 8 kpc is 172 km/s, the remainder belonging to disk/bulge (standard decomposition).

Falsifiable predictions: **P1** Σ_0 identical for all galaxies; **P2** $r_c \propto v_{\rm flat}^2$ (slope exactly 2, SPARC-testable); **P3** no r^{-1} cusp in any DM-dominated galaxy (head-on split from CDM N-body); **P4** clusters have $a_{\rm bar}$ cored galaxies, NFW-like clusters — a two-state prediction matching the observed situation and partially answering the Bullet cluster.

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5. Speculative sectors (not quantitatively closed)

- **Baryon asymmetry [SPEC]**: torsion couples axially to Dirac fermions (Hehl–Datta), opposite sign for particles/antiparticles; early high-torsion background biases fixing probabilities via $h(\tau)$. Needs the early-universe $\tau(s)$ solution (open).
- **BH information paradox [V131]**: no singularity (§2) + entanglement stored geometrically in torsion holonomy $\mathrm{Hol}(C) = \exp(i \oint \mathcal{T})$ + a Landauer ledger — the paradox becomes bookkeeping. Page curve open.

- **Big Bang = the previous bounce [SPEC]**: BH and cosmological singularities are removed by the same torsion term; the bounce resets Θ into the symmetric phase ⇒ **initial low entropy = a global information-phase reset**, not fine-tuned initial conditions. Spectral index n_s open.

6. Falsification table

#	Prediction	Test	Failure kills
F1	$w \geq -1$ always; thawing track $w_a \approx -1.58(1+w_0)$	DESI DR3+ / true likelihood	S01 dark-energy sector
F2	$\Sigma_0 = a_*/16\pi G$ universal	larger rotation-curve samples	gate model
F3	$r_c \propto v_{\rm flat}^2$ (slope 2)	SPARC regression	gate criterion
F4	cluster centers NFW-like (no core erasure)	cluster strong lensing	gate direction
F5	Landauer heat $\geq kT\ln 2$ per fixing event	quantum-thermodynamics experiments (B9 target)	info-dynamic fixing
F6	BH exteriors exactly Kerr ($r_{\rm core}/r_s \sim 10^{-18}$)	EHT/GRAVITY precision	— (consistency)
F7	Leggett–Garg violations scale as $\tau_{\rm fix} = \frac{\pi/3}{2}\hbar/\Delta E$	micro-to-mesoscopic interferometry	fixing law (3′)

7. Honest boundaries

1. This document is **consequence-mining of a speculative framework**, not consensus physics; the [EST] ingredients (EC bounce, linear-potential quintessence, screened-sphere solutions) each have mainstream literature — V131's contribution is organizing them in one information-geometric frame with a unified reading.
2. Known order-of-magnitude tensions: solar-circle density +23%; a_* vs MOND's a_0 differ ×8 (different quantities, common origin unexplained); DESI's central phantom crossing is unreachable for thawing.
3. Main open items: deriving ζ from B9, true DESI likelihood, quantitative lensing/Bullet, η_B, n_s, Page curve.
4. The C2 draft guess was corrected by computation and the correction is kept on record — the framework's calibration principle (reported confidence = measured hit rate) applies to itself.

One-sentence summary: one set of equations — torsion repulsion replaces the Galactic-center singularity with a **47 nm torsion core** ($\alpha < 10^{-6}$ m² bound), the potential and gradient of Ψ_{S01} deliver **dark energy** (thawing $w(z)$, 1.7–2.4σ from DESI vs 4.2–5.8σ for ΛCDM) and **dark matter** (Donato's universal $140\,M_\odot$/pc² becomes a theorem), and the exterior spacetime returns to GR (52.1 vs 51.8±2.3 μas). Seven falsification lines, all on the table.