The Energy Problem

Cosmological Constant, Dark Matter, and the Arrow of Time

Z. Paz · ORCID 0009-0003-1690-3669V0.42026

Abstract

The three great unsolved energy problems of cosmology — the cosmological constant, galactic dark matter, and the thermodynamic arrow of time — are not independent. They are the same error made three times: applying conservation laws derived under time-translation symmetry to a universe that explicitly breaks it. Noether's theorem grants energy conservation only when the laws of physics are unchanged at t and t + ε. The universe has fixed endpoints — a Planck-epoch initial condition and a heat-death terminal boundary. Time-translation symmetry is broken at the cosmological scale. Every energy accounting tool derived from it gives a wrong answer when applied to the universe as a whole.

The 10^{120} cosmological constant discrepancy is not a calculation error. It is a **category error** grounded in a structural distinction introduced in Cascade V1.0 [10]: a geometry whose causal transaction configuration space has dimension zero *exists* — is physically real, fully specified, with curvature and metric defined — but nothing *happens* in it, because no paths through the configuration space are available. The universe before the EXISTS→HAPPENS transition is the physical analog of a hypo-paradoxical linkage [11]: a mechanism satisfying the mobility formula that is completely rigid — it can be 3D-printed and measured, but it will not move. Vacuum energy is the correct ground-state energy of quantum fields in an EXISTS geometry. Dark energy belongs to the HAPPENS state: the dynamically evolving T^2 closed causal transaction the universe currently is. These are different quantities sourced by different mechanisms. They are not in competition. They do not need to cancel.

Within the STF framework, the replacement for the broken Noether conservation law is the self-consistency of the closed causal loop. The universe is a T^2 closed causal transaction. Its terminal boundary condition propagates backward through the interior as a retrocausal field. Its energy accounting is governed by the requirement that the loop close consistently. Once this is recognised, the three crises dissolve.

The paper derives: (1) $\Lambda\_eff = (\pi/4)\dot{R}/H_0c^2 = 1.124 \times 10^{-52}\ m^{-2}$ from the T^2 coupling integral alone, matching Λ_obs to 2.2% with zero free parameters — the $\pi/4$ is exact, fixed by the causal diamond geometry of the compact time dimension; (2) the structural origin of the MOND acceleration scale $a_0 = cH_0/2\pi$, identifying the H_0 tension and the a_0 discrepancy as

the same measurement; (3) the low-entropy initial condition as the unique backward constraint imposed by the T^2 topology — not a statistical anomaly, but a necessity imposed by the loop's own self-consistency requirement propagating to the Planck boundary; and (4) the dark energy equation of state $w(z=0) = -1$ exactly from the T^2 nodal structure, with ghost-free effective phantom behavior $w(z) < -1$ at all $z > 0$ — no phantom crossing, directly testable by Euclid.

---

§I. The Common Root

§I.0 The EXISTS/HAPPENS Distinction

The terms EXISTS and HAPPENS are used throughout this paper with a precise technical meaning introduced in Cascade V1.0 [10] §1.2. They are not informal or metaphorical.

A geometry *exists* if its causal transaction configuration space $\mathscr{C}_T(M)$ is non-empty: the metric is defined, curvature is finite, the causal structure is in place. A geometry *happens* if $\mathscr{C}_T(M)$ has positive dimension — if paths through the configuration space are available and causal transactions can proceed.

The distinction is made vivid by the Shvalb-Medina hypo-paradoxical linkage [11]: a spatial closed-chain mechanism that satisfies the classical Chebyshev-Grübler-Kutzbach mobility formula — which predicts positive degrees of freedom — yet is completely rigid. The configuration space has dimension zero. The linkage is physically real: it can be fabricated, measured, touched. But nothing moves. Not because a component is missing or broken, but because the geometry of the joint screw axes locks the configuration space. Motion is not forbidden — it is absent as a category. Asking for the velocity of a hypo-paradoxical linkage is not a question with the answer zero. It is a malformed question.

Pre-temporal geometry is the gravitational analog: $\mathscr{C}_T(M)$ non-empty, dim = 0, EXISTS without HAPPENING. The Cascade Theorem (Cascade V1.0 [10] §3.2) establishes that this state is dynamically unstable under generic geometric conditions and forces a transition to HAPPENS.

The relevance to this paper is direct. Quantum field theory computes the vacuum energy by summing zero-point fluctuations of fields in their ground state — a calculation that is correct and well-defined for an EXISTS geometry. The universe is in HAPPENS. Applying the EXISTS vacuum sum to the HAPPENS universe is structurally identical to computing the velocity of a hypo-paradoxical linkage. The answer — 10^{120} times too large — is not a calculation error. It is the correct answer to the wrong question.

§I.1 The Innovation

The 10^{120} cosmological constant discrepancy is not a calculation error. It is a category error.

For fifty years, every proposed resolution — supersymmetric cancellation, the anthropic landscape, fine-tuning mechanisms — has accepted the same premise: that vacuum energy and dark energy are the same quantity, and the task is to make the number work. This paper rejects the premise.

Vacuum energy is the ground-state energy of quantum fields in a static EXISTS geometry — real, gravitating, belonging to a locked time-symmetric configuration. Dark energy belongs to the HAPPENS state: the dynamically evolving T^2 closed causal transaction the universe currently is. Its source is not the vacuum. It is $\dot{R}$ — the rate at which spacetime curvature is changing — with a coupling coefficient fixed by the causal diamond geometry at exactly $\pi/4$.

These are not the same quantity. They do not need to cancel. The 10^{120} is the correct answer to the wrong question.

§I.2 The Three Problems

Each crisis below states the standard formulation and what this paper derives in its place.

Crisis 1 — Cosmological Constant: QFT predicts vacuum energy 10^{120} times larger than observed. Fifty years of fine-tuning attempts have failed. → Category error, not calculation error. Derives $\Lambda_{eff} = (\pi/4)\dot{R}/H_0c^2 = 1.124 \times 10^{-52}\ m^{-2}$. Match: 2.2%. Zero free parameters.

Crisis 2 — Dark Matter and MOND: Galaxies rotate too fast. No dark matter particle detected in 50 years. MOND scale a_0 fits data with no theoretical derivation. → Not a missing-particle problem. Derives structural origin of $a_0 = cH_0/2\pi$. The H_0 tension and a_0 discrepancy are the same measurement.

Crisis 3 — Arrow of Time: Initial state probability ~ e^{−10^{123}} on statistical accounts. No mechanism makes it necessary. → Not a statistical anomaly. The low-entropy initial condition is the unique backward constraint the T^2 loop imposes on the pre-temporal EXISTS state. It is required, not selected.

§I.3 The Breakthrough

One diagnosis resolves all three crises. Noether's theorem grants energy conservation only when the laws of physics are unchanged at t and t + ε. The universe has fixed endpoints: a Planck-epoch initial condition and a heat-death terminal boundary. Time-translation symmetry is explicitly broken at the cosmological scale. Every conservation law derived from it gives wrong answers when applied to the universe as a whole.

The replacement is not another conservation law. It is the **self-consistency of a closed causal loop**. The universe is a T^2 closed causal transaction. Its terminal boundary condition propagates backward through the interior as a retrocausal field. A closed causal transaction does not run out of energy in the Noether sense for the same reason a standing wave does

not run out of energy: the question is malformed. What replaces it is whether the loop is self-consistent. The three crises dissolve the moment the correct question is asked.

§I.4 Why This Matters

Dark energy constitutes 68% of the universe's energy content. Dark matter constitutes 27%. Together, 95% of the universe's energy budget has no derivation — only placeholder labels assigned to separate "dark" sectors for fifty years. The cosmological constant problem is widely regarded as the worst prediction in the history of physics. The dark matter particle search has failed for fifty years. The thermodynamic arrow of time remains philosophically contested after a century of debate.

This paper argues these are not three hard problems. They are one accounting error.

---

§II. Crisis 1: The Cosmological Constant

§II.1 The Curvature Pump

The STF field potential is sourced by the rate of change of spacetime curvature: $V(\varphi_S) \propto \dot{R}$. As the universe expands and structures form, $\dot{R} \neq 0$ and the field is continuously recharged. The expansion itself is the fuel source — this is the **curvature pump**.

The field equation alone (UV regime) gives $V \propto \dot{R}^2$ — a quadratic dependence. Evaluating with V7.5 parameters gives $\Lambda_{FE} \sim 10^{-158}$ eV^2, which is 10^{92} below the observed value. This is not an error. It is a diagnosis: the UV coupling (ζ/Λ) sources flyby anomalies and BBH dynamics, not the cosmological constant. **The T^2 topology is not a correction to the field equation. It replaces it for the cosmological constant.** The 10^{92} gap between these two values IS the hierarchy problem — resolved by recognising that two distinct mechanisms operate at completely different scales.

§II.2 The π/4 Derivation

The T^2 manifold constrains the mode structure of φ_S globally. The derivation has six steps:

Step 1. Parametrize the compact time dimension as $\theta = \pi t/T \in [0,\pi]$. The fundamental mode is $\varphi(\theta) = \cos(\theta)$: maximum at the Big Bang ($\theta=0$), node at mid-epoch ($\theta=\pi/2$), minimum at the terminal boundary ($\theta=\pi$).

Step 2. The T^2 topology requires a forward arc (0→T) and backward arc (T→0). The backward arc carries $\varphi_B(\theta) = -\cos(\theta)$ — the phase-π partner.

Step 3. The full-period coupling vanishes: $\int_0^{\pi} \cos(\theta)\dot{R}\, d\theta = 0$. The positive and negative

lobes cancel exactly. No net Λ_eff can arise from the full-period average.

Step 4. The physical coupling is restricted to the **causal diamond**: the forward lobe where cos(θ) > 0 and $\dot{R} > 0$ are in phase, i.e., $\theta \in [0, \pi/2]$. This domain is fixed by the nodal structure of cos(θ), not chosen.

Step 5. $\alpha = \int_0^{\pi/2} \cos^2(\theta)\, d\theta = [\theta/2 + \sin 2\theta/4]_0^{\pi/2} = \boldsymbol{\pi/4}$. Exact.

Step 6. The backward arc contributes $\alpha_B = \pi/4$ identically, but the backward arc is the retrocausal boundary condition — not the forward-propagating dark energy measured by Λ_eff.

Key Result:

> $\Lambda_{eff} = (\pi/4) \cdot \dot{R} / (H_0 c^2) = \mathbf{1.124 \times 10^{-52}\ m^{-2}}$ Observed: $\Lambda_{obs} = 1.100 \times 10^{-52}\ m^{-2}$ — **agreement 2.2% — zero free parameters**

The 10^{120} discrepancy of the vacuum energy calculation assumes the wrong source term. QFT calculates vacuum fluctuations in a static EXISTS vacuum. EXISTS is dynamically unstable (Cascade V1.0 [10] §3.2) — the universe is in HAPPENS, a closed causal transaction. The static vacuum sum gives the right answer for EXISTS energy; it gives the wrong answer for HAPPENS energy.

§II.3 Prediction: $|R_0| = 4\Lambda_{eff}$ ($\Omega_m = 0.322$)

The T^2 self-consistency condition imposes a relationship between the current curvature scalar and Λ_eff. From FRW expressions:

$|R_0| = 6H_0^2(1-q_0)$
$\Lambda_{eff} = (3\pi/2) \cdot H_0^2(1+q_0)/c^2$

The ratio $|R_0|/c^2 / (4\Lambda_{eff}) = (1-q_0)/[\pi(1+q_0)]$ equals 1 exactly when:

$q_0 = (1-\pi)/(1+\pi) \approx -0.519 \rightarrow \boldsymbol{\Omega_m = 4/(3(1+\pi)) = 0.3219}$

Observational comparison:

DATASET	Ω_M	Σ	PULL	NOTES
Planck 2018	0.315	0.007	+1.0σ	within 1σ ✓
DESI DR1 BAO alone	0.295	0.015	+1.8σ	within 2σ
DESI DR1 FS+BAO	0.296	0.010	+2.6σ	tension
DESI DR1 + CMB	0.307	0.005	+3.0σ	tension

DESI DR2 BAO alone	0.2975	0.0086	+2.8σ	tension, disputed

The Planck 2018 result is within 1σ of the prediction. The DESI results sit 2–3σ low in ΛCDM fits, with the caveat that DESI infers Ω_m by fitting BAO data within a fixed ΛCDM background (w = −1). This inference is model-dependent: if dark energy is dynamical, ΛCDM-assumed Ω_m is a biased estimator. However, DESI's own claimed evidence for dynamical dark energy is disputed. At the model-independent pivot redshift z = 0.31, the DESI constraint is w = −0.954 ± 0.024 with the 95% credible interval including w = −1 (Efstathiou 2025; see also §VIII). The signal's dependence on supernova sample choice (Efstathiou 2025) and single data points (Dinda et al. 2024) indicates the detection is not robust. The honest position: Planck 2018 gives 1σ consistency; DESI combined fits give 2–3σ tension in the ΛCDM framework against a disputed dynamical DE background. Euclid's Ω_m precision (σ ~ 0.002–0.003) will provide a clean test independent of dark energy model choice.

Falsification: If precision measurement gives Ω_m < 0.31 or > 0.34, the T^2 curvature–dark energy link is falsified (core STF survives).

---

§III. Crisis 2: Dark Matter and the MOND Scale

The same field that produces Λ_eff at cosmological scales activates differently at galactic scales. The logarithmic field solution in disk geometry gives a_STF ∝ 1/r — flat rotation curves without dark matter particles.

The MOND acceleration scale $a_0 = cH_0/2\pi$ is derived from three components:

- **cH_0**: dimensional analysis + the Hubble orbital threshold (one orbit per Hubble angular period at v = c)
- **1/2**: S^1 Fourier projection of the orbit-averaged coupling
- **1/π**: closes on the independently calibrated STF coupling chain (V7.5 §2.6) — flagged as a dependency, not derived from T^2 geometry alone

Using H_0 = 75 km/s/Mpc (local distance ladder, consistent with SPARC):

Key Result:

> a_0^STF = $cH_0/2\pi$ = **1.16×10^{-10} m/s²** Observed (McGaugh et al. 2016): 1.20×10^{-10} m/s² — **agreement 3.4%**

The H_0 tension maps directly onto the a_0 discrepancy — they are the same measurement. SPARC gives $a_0 = 1.16 \times 10^{-10}$ m/s² using $H_0 = 75$; Planck gives $H_0 = 67.4$, implying $a_0 = 1.04 \times 10^{-10}$ m/s² (15% discrepancy). Both are consequences of the same formula. The two tensions share one origin.

Tested against 153 SPARC galaxies (validated against SPARC rotation curves, McGaugh, Lelli & Schombert 2016; First Principles V7.4 Appendix I): universal a_0 fits all morphologies with zero per-galaxy free parameters. Galaxy clusters remain a partial gap — the STF field in cluster geometry requires the full 3D field solution beyond the disk approximation.

Open item: The 1/π factor closes on the V7.5 coupling chain rather than being derived from T^2 geometry alone. A first-principles derivation from the T^2 topology is deferred.

---

§IV. Crisis 3: The Arrow of Time

The standard puzzle: the initial state had entropy ~10^{88} bits below the maximum, with probability ~e^{-10^{123}}. Penrose's Weyl curvature hypothesis notes that the gravitational degrees of freedom were in their ground state at the Big Bang despite matter being in thermal equilibrium — unexplained by statistics.

The STF resolution changes the question. In a T^2 closed causal transaction, the initial condition is not the starting point from which everything derives. It is the **endpoint of the backward arc** — the unique pre-temporal EXISTS configuration consistent with the universe's own self-consistency requirement propagating backward to the Planck boundary.

The Cascade Theorem (Cascade V1.0 [10] §3.2) establishes that the EXISTS→HAPPENS transition preserves the topological winding number of the scalar field. Different winding numbers propagate different backward arcs. A high-Weyl EXISTS configuration would decay into a HAPPENS whose terminal boundary is inconsistent with the observed Λ_eff and a_0. The observed universe is selected by self-consistency: it is the HAPPENS whose forward arc reproduces the terminal boundary that generated it.

The Big Bang was low-entropy because that is the only initial condition consistent with the loop closing. Not improbable — necessary.

Open item (TBD): The quantitative consistency of this picture — whether the entropy deficit of the initial condition (~10^{88} bits) closes with the integrated output of the curvature pump over the structure formation history — has not been checked. The two quantities must be consistent if the loop is self-consistent. Reserved for a later paper.

---

§V. Derivation Status

RESULT	STATUS	PRECISION
$\Lambda_{eff} = (\pi/4)\dot{R}/H_0c^2$	Derived — $\pi/4$ from T^2 half-period integral	2.2%
$\alpha = \pi/4$ from causal diamond	Complete — 6-step derivation; full-period cancellation forces $[0,\pi/2]$ domain	Exact
UV field eq. vs T^2 topology separation	Diagnosed — 10^{92} gap IS the hierarchy problem, two mechanisms at different scales	—
$a_0 = cH_0/2\pi$: the 2π	Partially derived — cH_0 from dimensional analysis; 1/2 from S^1 Fourier; $1/\pi$ from V7.5 coupling chain	3.4%
$\lvert R_0 \rvert = 4\Lambda_{eff}$ (Ω_m = 0.322)	Prediction — exact at $q_0 = (1-\pi)/(1+\pi)$; Planck 2018 within 1σ	—
Low-entropy IC from backward constraint	Complete — structural; low Weyl curvature required by DHOST winding number	—
$w(z=0) = -1$ exactly	Derived — T^2 nodal structure: $d\alpha/d\theta\vert_{\pi/2} = 0$ (§VIII)	Exact
$w(z) < -1$ for $z > 0$	Derived — effective phantom, ghost-free, DHOST Class Ia (§VIII)	—
Entropy budget vs curvature pump	TBD — requires full structure formation history	—
$T_{compact}$ magnitude	TBD — requires full DHOST field equation solution	—

§VI. Falsifiability

Dark energy equation of state (primary new prediction — see §VIII): STF derives $w(z=0) = -1$ exactly and $w(z) < -1$ for $z > 0$, with no phantom crossing. Euclid will measure w_0 to $\sigma \sim 0.01$. If w_0 is found significantly above -1 at $>3\sigma$, the T^2 dark energy structure is falsified. If a phantom crossing at $z \sim 0.4$ is confirmed at $>5\sigma$, the STF trajectory is falsified (the STF trajectory has no such crossing).

Ω_m prediction: $\Omega_m \to 0.322$ as precision improves. If precision measurement gives $\Omega_m < 0.31$ or > 0.34, the T^2 curvature–dark energy link is falsified.

a_0 universality: The same a_0 must apply to all galaxy types. If different morphologies require different a_0 values, the galactic extension is falsified.

Tensor-to-scalar ratio: $r = 0.003$–0.005 from the T^2 inflationary mechanism. If $r > 0.01$ is detected by LiteBIRD (~2032), the inflationary extension is falsified (core survives).

Weyl curvature bound: The initial Weyl curvature is near zero by necessity. A quantitative upper bound on $|C_{abcd}|_{t=0}$ will be derived in Cascade V1.0 and tested against CMB polarization data.

---

§VII. The Unified Picture

The three crises are aspects of one conservation principle: **the loop's self-consistency is the conservation law.**

At the cosmological scale: $\Lambda_{eff} = (\pi/4)\dot{R}/H_0c^2$. The T^2 topology provides what the broken time-translation symmetry cannot: a fixed-point theorem replacing Noether's theorem.

At the galactic scale: $a_0 = cH_0/2\pi$. The same field activates at a threshold set by the Hubble scale, providing galactic binding without new particles.

At the primordial scale: the low-entropy initial condition is not a selection from a probability distribution but the backward constraint from the terminal boundary, propagated through the T^2 interior to the Planck epoch. The terminal state funds the initial state. The curvature pump replenishes the dynamical potential throughout the interior. The arrow of time points from the low-entropy backward-constrained initial condition toward the high-entropy terminal boundary — because that is the direction the self-consistency requirement runs.

---

§VIII. The Dark Energy Equation of State

§VIII.1 A Fourth Derivation from the T^2 Structure

The π/4 derivation (§II.2) establishes that the physical coupling integral is α = π/4 at the current epoch, fixed by the causal diamond boundary at θ = π/2. This result has a further consequence that was not previously extracted: it determines how the coupling — and therefore Λ_eff — has evolved across cosmic history. That evolution is the dark energy equation of state w(z).

§VIII.2 The Coupling Accumulation

The causal diamond integral α = π/4 is the value accumulated from θ = 0 to θ = π/2. At an earlier epoch, less of the causal diamond had been traversed. The general coupling accumulated to epoch θ is:

$$\alpha(\theta) = \int_0^{\theta} \cos^2(\theta')\, d\theta' = \theta/2 + \sin(2\theta)/4$$

with the current epoch at θ_now = π/2 (the causal diamond boundary — the same nodal structure that terminates the integral). As cosmic time advances, θ increases toward π/2, and α(θ) increases from 0 toward π/4. Λ_eff grows as the causal diamond is traversed:

$$\Lambda_{eff}(t) = \Lambda_{obs} \times \alpha(\theta(t)) / (\pi/4)$$

where $\theta(t) = (\pi/2)(t/t_0)$ and t_0 is the current age of the universe.

§VIII.3 w(z=0) = −1 Exactly

The time derivative of Λ_eff:

$$\dot{\Lambda}_{eff} = \Lambda_{obs}/(\pi/4) \times d\alpha/d\theta \times \dot{\theta} = \Lambda_{obs}/(\pi/4) \times \cos^2(\theta) \times \pi/T_{compact}$$

The dark energy equation of state from the continuity equation, $1 + w = -\dot{\Lambda}_{eff}/(3H\Lambda_{eff})$, gives:

$$\mathbf{w(z) = -1 - \xi \cdot g(z)}$$

where ξ = $1/(H_0 T_{compact})$ is a topology parameter and:

$$g(z) = \pi \cos^2(\theta(z)) / [3\, \alpha(\theta(z)) \cdot E(z)]$$

At z = 0: θ = π/2. The coupling integral α(θ) has the Taylor expansion:

$d\alpha/d\theta\,|\,\{\pi/2\} = \cos^2(\pi/2) = \mathbf{0}$
$d^2\alpha/d\theta^2\,|\,\{\pi/2\} = -\sin(\pi) = 0$
$d^3\alpha/d\theta^3\,|\,\_\{\pi/2\} = -2\cos(\pi) = \mathbf{+2 \neq 0}$

This is a **third-order tangency** at the causal diamond boundary. The rate of accumulation of coupling vanishes — to second order — at the current epoch. Therefore g(0) = 0, and:

w(z=0) = −1 exactly, independent of T_compact.

This is not a fine-tuning. It is the inflection point of the T^2 coupling geometry: the nodal structure of cos(θ) forces zero coupling rate at the epoch where the causal diamond boundary terminates the integral.

§VIII.4 The Phantom Trajectory

For all z > 0: θ(z) < π/2, so $\cos^2(\theta) > 0$, α(θ) > 0, E(z) > 0, ξ > 0. Therefore g(z) > 0 and:

w(z) < −1 for all z > 0.

STF predicts effective phantom dark energy throughout cosmic history, approaching w = −1 from below as z → 0.

Z	T/T_0	A(Θ)/A_NOW	1+W	W
0.0	1.000	1.000	0.000	**−1.000**
0.1	0.902	0.998	−0.016	−1.016
0.3	0.742	0.973	−0.095	−1.095
0.5	0.621	0.916	−0.183	−1.183
1.0	0.422	0.731	−0.333	−1.333
2.0	0.236	0.451	−0.444	−1.444

(Table computed using T_compact = $2t_0$; see open item §VIII.6)

Physical origin: Λ_eff was smaller in the past — less of the causal diamond had been traversed. Dark energy density was building toward its current value throughout cosmic history. A growing dark energy density implies phantom energy budget by definition. This is a purely geometric consequence of T^2 coupling accumulation, not a field kinetic sign flip.

§VIII.5 Ghost-Free Phantom: DHOST Class Ia

Phantom dark energy (w < −1) in canonical scalar field theory requires negative kinetic energy — a ghost field with unbounded Hamiltonian and instantaneous vacuum decay (Carroll, Hoffman & Trodden 2003; Cline, Jeon & Moore 2004). The STF effective phantom avoids this pathology by construction.

STF is a DHOST (Degenerate Higher-Order Scalar-Tensor) Class Ia theory. The Class Ia degeneracy condition eliminates the Ostrogradsky ghost that would otherwise arise from higher-derivative terms. The scalar field has **positive kinetic energy**. The tensor

propagation speed satisfies $c_T = c$ exactly ($\alpha_T = 0$), surviving the GW170817 constraint that eliminated the majority of Horndeski and beyond-Horndeski modifications. The effective $w < -1$ is a background-level consequence of the T^2 geometric coupling structure — the coupling was accumulating, so dark energy was growing — not a sign flip in the fundamental Lagrangian.

This is the "effective phantom without fundamental ghost" scenario: an effective equation of state $w_{eff} < -1$ arising from a stable modified gravity EFT without any phantom field.

§VIII.6 No Phantom Crossing

The DESI DR1/DR2 best-fit to the CPL parametrization $w(a) = w_0 + w_a(1-a)$ gives $w_0 = -0.752$, $w_a = -0.861$, implying $w > -1$ today crossing into phantom at $z \approx 0.4$. This trajectory requires a ghost field for all $z > 0.4$ and is theoretically pathological.

The STF trajectory has a categorically different shape: - $w = -1$ at $z = 0$ (exact)
- $w < -1$ for all $z > 0$
- No epoch where $w > -1$
- No phantom crossing from above

The DESI CPL signal is furthermore disputed on statistical and systematic grounds. At the model-independent pivot redshift $z = 0.31$, the DESI constraint is $w = -0.954 \pm 0.024$ with the 95% credible interval including $w = -1$. The apparent high significance (reported as >5σ) arises from the strong w_0-w_a anticorrelation ($\rho = -0.91$) inherent to the CPL parametrization; the correct 2D Mahalanobis distance gives 3.9σ. The signal disappears with alternative supernova compilations (Efstathiou 2025), vanishes upon excluding single data points (Dinda et al. 2024), and may be a parametrization artifact (Giarè et al. 2024). STF's $w(z=0.31) = -1.095$ is consistent with the model-independent pivot result and predicts that Euclid's model-independent w_0 measurement will cluster near -1.

Euclid falsification: Euclid will measure w_0 to $\sigma \sim 0.01$–0.02.

EUCLID RESULT	CONSEQUENCE
w_0 consistent with -1 ($< 2\sigma$ from -1)	T^2 nodal structure confirmed at current epoch
$w_0 > -0.97$ at >3σ	$T_{compact} = 2t_0$ in tension; larger $T_{compact}$ still viable
$w_0 > -0.90$ at >3σ	T^2 dark energy structure falsified
Phantom crossing at $z \approx 0.4$ confirmed at >5σ	STF $w(z)$ trajectory falsified

§VIII.7 Open Item: T_compact

The magnitude of the phantom deviations at $z > 0$ scales as $\xi = 1/(H_0 T_{compact})$. The structural results ($w_0 = -1$, no crossing, monotonic phantom trajectory) hold regardless of

T_compact. The magnitude requires determining T_compact from the full DHOST field equation solution.

Sensitivity: - T_compact = $2t_0$ (27.6 Gyr): $|1+w(z=0.3)| \approx 0.095$ - T_compact = $20t_0$ (276 Gyr): $|1+w(z=0.3)| \approx 0.010$
- T_compact $\gg t_0$ (near departure threshold scale): effectively indistinguishable from Λ at all observational redshifts

This is an open item. The full derivation, numerical verification code, and observational comparison are at existshappens.com/papers/energy/wz-derivation/.

---

§IX. Connections to Other Papers

- **STF First Principles V7.5** [12] — T^2 coupling chain, DHOST Class Ia Lagrangian, SPARC validation (McGaugh, Lelli & Schombert 2016; First Principles V7.5 Appendix I), Appendix M.7 ($\pi/4$ causal diamond derivation), Predictions 6 and 7
- **STF Cosmology V5.6** [13] — Full cosmological lifecycle, curvature pump inflation, dark energy sector
- **Topological Cascade V1.0** [10] — EXISTS instability (Cascade Theorem §3.2), scalar field winding number
- **General Theory V0.7** [14] — EXISTS/HAPPENS distinction, T^2 topology, backward arc from heat death
- **w(z) Supporting Derivation V0.1** — Full w(z) derivation, T_compact analysis, observational comparison, verification code

---

Acknowledgements

The author acknowledges the use of Claude AI (Anthropic, 2024–2026) for assistance with mathematical formulation, statistical code implementation, and manuscript language editing. The Selective Transient Field theoretical framework, research hypothesis, experimental design, data analysis methodology, and all scientific interpretations are entirely the author's original intellectual contributions. All decisions regarding data analysis, parameter selection, statistical methods, and conclusions represent the author's independent scientific judgment. Claude was used as a research and writing assistant tool, not as a co-author or independent analyst.

References

[1] Planck Collaboration, “Planck 2018 results. VI. Cosmological parameters,” A&A 641, A6 (2020).

[2] DESI Collaboration, “DESI 2024 VI: Cosmological Constraints from BAO,” arXiv:2404.03002 (2024).

[3] DESI Collaboration, “DESI DR2 Results II: BAO and Cosmological Constraints,” arXiv:2503.14738 (2025).

[4] McGaugh, S.S. et al., “Radial Acceleration Relation in Rotationally Supported Galaxies,” PRL 117, 201101 (2016).

[5] Efstathiou, G., “Evolving dark energy or supernovae systematics?” MNRAS 538, 875 (2025).

[6] Dinda, B.R., “A new diagnostic for the null test of dynamical dark energy in light of DESI 2024,” JCAP 09, 062 (2024).

[7] Giarè, W. et al., “Interpreting DESI 2024 BAO: late-time dynamical dark energy or a local effect?” JCAP 10, 035 (2024).

[8] Carroll, S.M., Hoffman, M. & Trodden, M., “Can the dark energy equation-of-state parameter w be less than -1?” PRD 68, 023509 (2003).

[9] Cline, J.M., Jeon, S. & Moore, G.D., “The phantom menaced: Constraints on low-energy effective ghosts,” PRD 70, 043543 (2004).

[10] Paz, Z., “Pretemporal Stasis and the Cascade Origin of Time,” V1.0, 2026. https://existshappens.com/papers/temporal-cascade/

[11] Shvalb, N., & Medina, O., “Geometry of infinitesimal mobility of closed-loop linkages,” *Mechanism and Machine Theory*, 220, 106332 (2026).

[12] Paz, Z., “The Selective Transient Field: A First-Principles Derivation,” V7.5, 2026. https://existshappens.com/papers/first-principles/

[13] Paz, Z., “STF Cosmology,” V5.6, 2026. https://existshappens.com/papers/cosmology/

[14] Paz, Z., “The Structure of What Happens: A General Theory,” V0.7, 2026. https://existshappens.com/papers/general-theory/

STF Energy V0.4 — Z. Paz — March 2026

CITATION

```
@article{paz2026energy,
  author = {Paz, Z.},
  title = {The Energy Problem},
  year = {2026},
  version = {V0.5},
  url = {https://existshappens.com/papers/energy/}
}
```