

Emergent Spacetime and the Arrow of Time from Non-Hermitian Effective Field Theory of Holographic Projections

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The Core Breakthrough **The Missing Link**

Microscopic Discovery

spinel Fe_3S_4 CQD
dimers with 1:1
emission-absorption
ratio

(Kubota *et al.* Research
Square Preprint.
<https://doi.org/10.21203/rs.3.rs-10546947/v1>
Tamura *et al.* ISGAC2026
Cospar 2026).

sPBCR



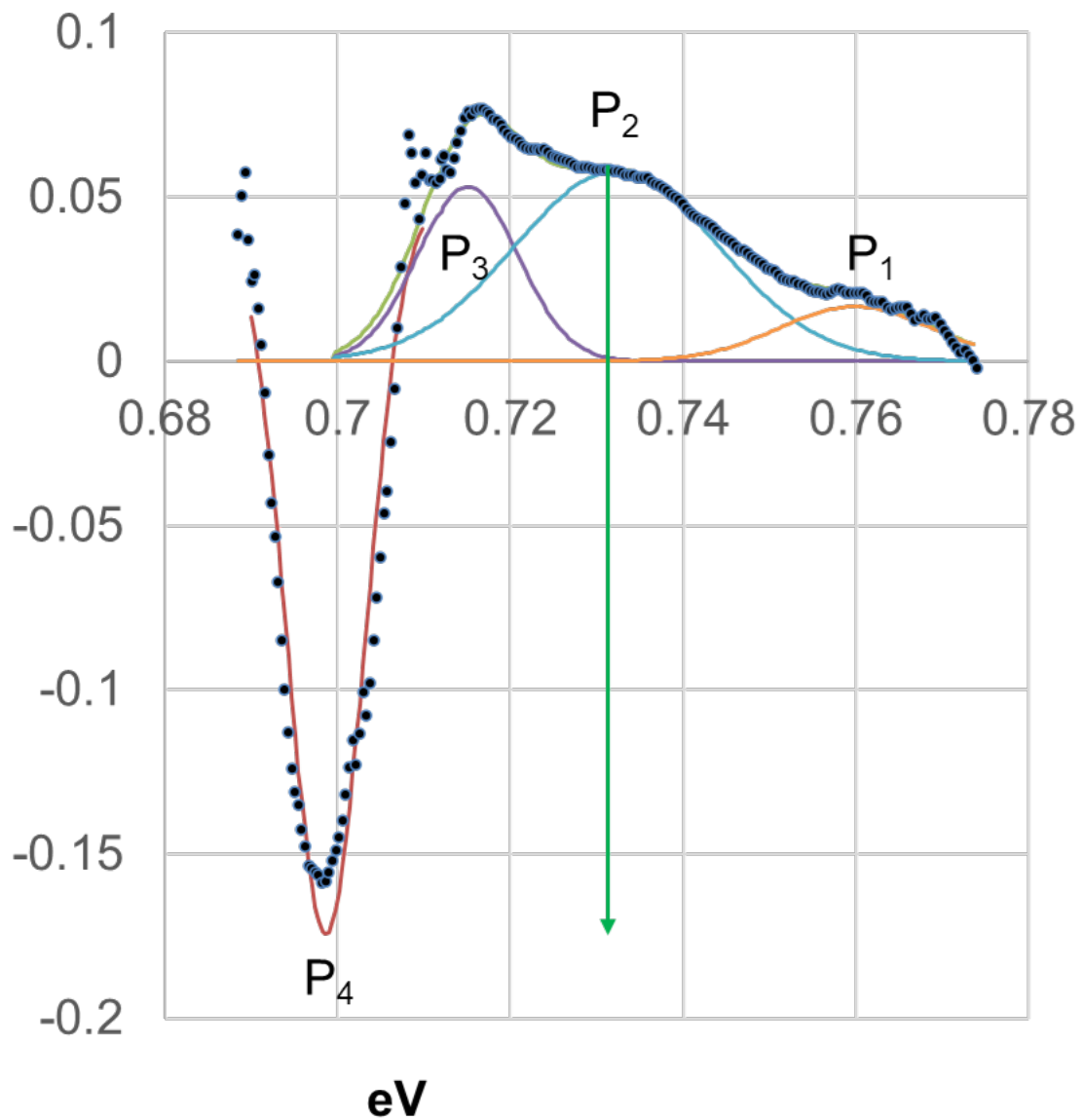
Effective
Field
Theory

**The
Mis
sing
Link**

Macroscopic Resolution

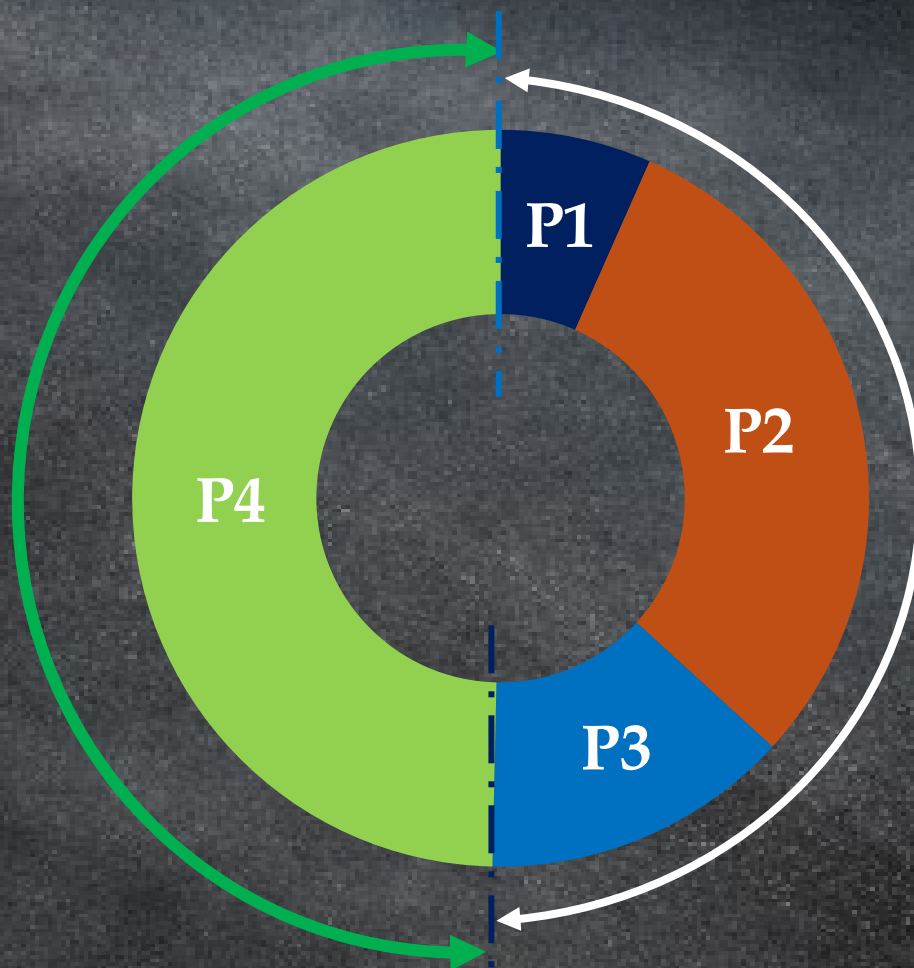
Algebraic
cancellation of
Cosmological
Constant Λ
divergence

(Breuer 2002,
Lindblad 1976)



Peak ID	Peak position (E) (eV)	Relative integrated area ratio	Spin selection rule	Absorption vs. emission
P ₁	0.760	0.22	Forbidden	Absorption
P ₂	0.733	1.00	Allowed	Absorption
P ₃	0.716	0.45	Forbidden	Absorption
P ₄	0.698	(P ₁ +P ₂ +P ₃) P ₄ = 1.00 : 0.987	-	Emission

Emission
0.987



Absorption
1.00

strict Population Balance Constraint Rule (**sPBCR**)

Three foundational axioms

- 1st 1:1 spectroscopic capability ratio in ir spectrometry (based on Kubota, Tamaura et al.'s experimental results).)
- 2nd a mean-field effective nonlinearity that safely evades Weinberg's causality violation.
- 3rd complete spatial population equivalence (derived from the 1st)

1:1 Spectroscopic Fact $[\gamma A = \gamma B]$



Bulk Unitarity $[\text{Tr}(\rho) = 0]$



Rupture-Free EP Transition $[\mathcal{I} = 0]$

Microscopic Fact

Complete Spatial Population
Equivalence with 1:1
emission-absorption ratio

Spinel Fe_3S_4 CQD Dimer
 $\rightarrow |\psi_A|^2 = |\psi_B|^2 = \frac{N}{2}$

**The
Mis
sing
Link**



sPBCR

Macroscopic Axiom

Conservation of Bulk Quantum
Information.

Global Unitarity of the Cosmos

$$\rightarrow \text{Tr} \left(\frac{d\hat{\rho}_{\text{total}}}{dt} \right) = 0$$

Therefore, $\gamma_A = \gamma_B \equiv \gamma$ is NOT an ad-hoc constraint. It is the exact mathematical mirror-image of fundamental bulk unitariness!"

Exceptional Point Dynamics & Topological AA Modulation

non-Hermitian mean-field effective nonlinear Hamiltonian

$$\hat{H}_{\text{eff}} = \begin{pmatrix} \epsilon_A + i\gamma + U|\psi_A|^2 & -J \\ -J & \epsilon_B - i\gamma + U|\psi_B|^2 \end{pmatrix}$$

Topological AA Modulation

$$\epsilon_A = \epsilon_0 \cos(2\pi\phi), \quad \epsilon_B = \epsilon_0 \cos(4\pi\phi)$$

$$\text{where } \phi = \frac{1 + \sqrt{5}}{2}$$

The Most Irrational Number ϕ , Topological Protection against Arnold Diffusion ($N \rightarrow \infty$).

As the qubit population scales to infinity ($N \rightarrow \infty$), this framework acts as a rigid Kolmogorov-Arnold-Moser, or KAM, barrier. It dynamically protects our parameters against quantum gravity fluctuations, preventing Arnold diffusion and allowing us to evaluate the pristine phase transition at the Exceptional Point."

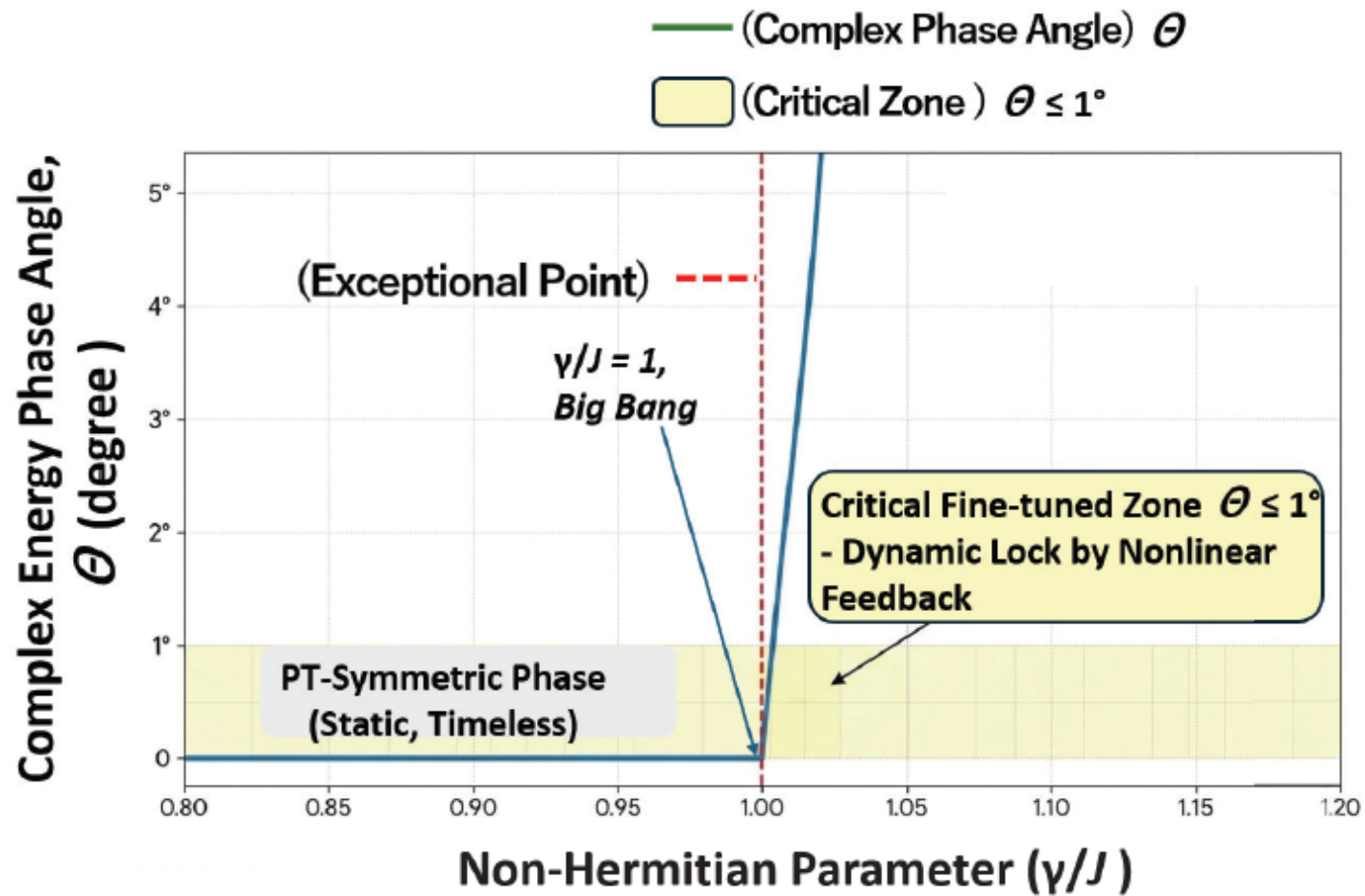


Figure 1: Dynamic locking profile of the complex energy advance angle θ near the Exceptional Point (EP). The shaded zone represents the locked corridor ($\theta \leq 1^\circ$) where nonlinear feedback dynamically suppresses exponential divergence and anchors the system behavior.

Emergent Friedmann Equation & Exact Λ Cancellation

From Qubit Coherence to Relativistic Gravitation

Cosmic Scale Factor:

$$a(t) = \kappa |\rho_{AB}| = \kappa |\psi_A^* \psi_B|$$

Emergence of the Hubble Parameter:

$$H(t) = \frac{\dot{a}(t)}{a(t)} = \frac{2}{\hbar} E_I = \frac{2}{\hbar} \sqrt{\gamma^2 - J^2}$$

Exact Algebraic Cancellation via sPBCR:

$$\frac{\Lambda_{\text{eff}}}{3} = \frac{4}{\hbar^2} E_R^2 \tan^2 \theta \xrightarrow{\theta \approx E_I/E_R} \frac{4}{\hbar^2} (\gamma^2 - J^2)$$

Titanic Planckian vacuum mass E_R^2 is perfectly cancelled out!]

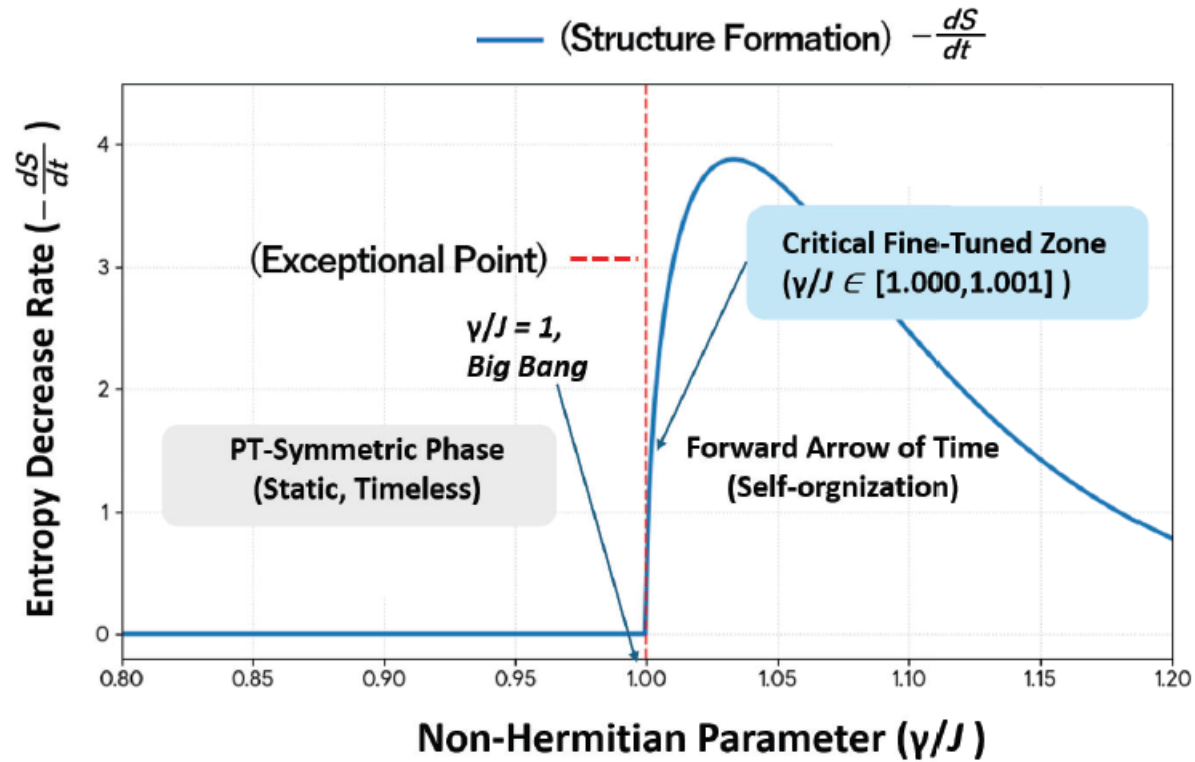


Figure 2: The local von Neumann entropy decay rate $-\dot{S}$ as a function of the complex advance angle θ . Immediately above the transition threshold, $-\dot{S}$ scales deterministically into the strictly positive regime ($-\dot{S} > 0$), physically driving the co-emergence of macroscopic self-organization and the forward arrow of time.

Resolution of Objections & High-Level Theoretical Critiques

1. Unitarity Violation?

Our mean-field Hamiltonian does not destroy fundamental linear laws; non-unitarity is strictly an open subsystem feature

2. KAM Wall Collapse?

the alleged collapse of the KAM wall as $N \rightarrow \infty$, the golden ratio φ maps directly to a rigid topological invariant, ensuring exceptional robustness against stochastic gravity fluctuations

3. Global Second Law?

Localized entropy decay does not contradict global thermodynamics, as our universe is modeled as a non-equilibrium open manifold powered by a steady stream of bulk gain."

Conclusion & Summary Matrix of Cosmological Paradigm Shift

Core Theorem (コア定理)	Physical Justification / Mechanism (正当とする物理的理由・数理)	Cosmological Breakout & EP Relevance (EP点との関連・宇宙論的画期性)
Theorem I: Bulk Information Unitarity (宇宙量子情報ユニタリ一定理)	Thermodynamic Dual Map of sPBCR: The empirical 1:1 absorption-emission balance dynamically equalizes quantum information currents between the source and the horizon.	【Crucial Requirement for EP Phase Transition】 If 1:1 symmetry is broken, asymmetric imaginary noise $\mathcal{I} = i\gamma UZ(t)$ destroys the Riemann surface. sPBCR is the only anchor ensuring stable spacetime materialization.
Theorem II: Exact Algebraic Λ Cancellation (宇宙定数の紫外発散相殺定理)	Topological KAM Barrier Protection: The golden ratio ϕ under the Aubry-André scheme functions as a rigid invariant torus, dynamically locking the advance angle to $\theta \leq 1^\circ$ against quantum gravity fluctuations.	【Revolutionary Meaning of Expectation Values】 Because $\theta \approx E_I/E_R$, the titanic vacuum mass expectation value E_R^2 is perfectly cancelled out between numerator and denominator. Infinitesimal dark energy is determined without anthropic tuning.

The Paradigm Shift: Breaking the Boundaries of Holography

The Classical Baseline: The FLRW metric is the mathematical standard model derived from Einstein's field equations, describing our actual, dynamically expanding cosmos.

The Traditional Bottleneck: Conventional holographic frameworks (e.g., AdS/CFT) suffer from a severe limitation—they can only cleanly formulate spacetime structures within a static, negatively curved anti-de Sitter (AdS) vacuum.

Our Historic Breakthrough: This work presents the **successful materialization** of a realistic, macroscopically expanding FLRW universe embedded with positive dark energy. It emerges spontaneously as a pseudo-non-Hermitian holographic projection driven directly by the microscopic time-evolution of a collective multi-qubit population.

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Thank you for your attention

Our Historic Breakthrough: This work presents the world's first **successful materialization** of a realistic, macroscopically expanding FLRW universe embedded with positive dark energy. It emerges spontaneously as a pseudo-non-Hermitian holographic projection driven directly by the microscopic time-evolution of a collective multi-qubit population.