Temperature as a Proxy for the Decoherence Rate: Superconductivity in ODTOE Coherence Metrics and Four Channels of Condensate Protection

(Температура как прокси скорости декогеренции: сверхпроводимость
в метриках когерентности ODTOE и четыре канала защиты конденсата)

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ABSTRACT

In the proposed model, the governing axis of superconductivity is the decoherence rate of the electronic condensate. Temperature sets the dominant, thermal channel of this decoherence: quasiparticle population and phase fluctuations grow with heating, and cooling suppresses precisely these. The third law of thermodynamics renders absolute zero an asymptotic limit for closing the thermal channel alone, while the superconductor–insulator transition at $T \to 0$ demonstrates the action of non-thermal decoherence channels. Direct superfluid-stiffness measurements of 2025 have shown that the quantum geometry of wave functions can carry phase coherence where kinetic energy vanishes. The ODTOE metrics (coherence S, contraction modulus $q(B, S)$, lifetime law $T = T_0/(1 - S)^n$, the $S_{\text{true}}/S_{\text{phantom}}$ pair) organize four channels of coherence protection (energy gap, phase stiffness, quantum geometry, protected subspaces) into a single control model with two tiers of falsifiable predictions and a measurement protocol. The core of the model is the balance inequality $\Gamma_{\text{rest}} \geq \Gamma_{\text{dec}}$ between the guaranteed coherence-restoration rate and the total decoherence rate, the critical modulus $q_c(T) = \exp(-\tau_0 \, \Gamma_{\text{dec}}(T))$, and the (B, S) map with the anchor-lever inversion line $S = 1/\sqrt{2}$ and the ridge of worst guaranteed restoration; a second tier of predictions P-A–P-D, conditional on the model's central hypothesis, is added to the first tier P1–P4. Within this model the cuprate pseudogap reads as phantom coherence, and the engineering road toward superconductivity at arbitrary temperature takes the form of coherence engineering along four roads R1–R4. Every claim of the article is stratified into epistemic layers: external physics, corpus invariant, model postulate, dictionary hypothesis, prediction. All numerical invariants are recomputed to fifty decimal places. The work unfolds within the ODTOE programme (Observer-Dependent Theory of Everything), in which all of mathematics, physics, and the phenomenology of consciousness are projections of a single primary act of distinction.

Keywords: superconductivity, decoherence, coherence, superfluid stiffness, quantum geometry, pseudogap, phantom coherence, superconductor–insulator transition, balance inequality, coherence engineering, ODTOE

АННОТАЦИЯ

Управляющая ось сверхпроводимости в предлагаемой модели есть скорость декогеренции электронного конденсата. Температура задаёт главный, тепловой канал этой декогеренции: заселение квазичастиц и фазовые флуктуации растут с нагревом, и охлаждение подавляет именно их. Третье начало термодинамики делает абсолютный нуль асимптотическим пределом закрытия одного лишь теплового канала, а переход сверхпроводник–изолятор при $T \to 0$ демонстрирует работу нетепловых каналов разрушения когерентности. Прямые измерения сверхтекучей жёсткости 2025 года показали, что квантовая геометрия волновых функций способна нести фазовую когерентность при исчезающей кинетической энергии. Метрики ODTOE (когерентность S, модуль сжатия $q(B, S)$, закон времени жизни $T = T_0/(1 - S)^n$, пара $S_{\text{true}}/S_{\text{phantom}}$) организуют четыре канала защиты когерентности (энергетическую щель, жёсткость фазы, квантовую геометрию, защищённые подпространства) в единую управляющую модель с фальсифицируемыми предсказаниями двух ярусов и измерительным протоколом. Ядро модели — балансное неравенство $\Gamma_{\text{rest}} \geq \Gamma_{\text{dec}}$ между гарантированным темпом восстановления когерентности и суммарной скоростью декогеренции, критический модуль $q_c(T) = \exp(-\tau_0\,\Gamma_{\text{dec}}(T))$ и карта (B, S) с линией инверсии якорного рычага $S = 1/\sqrt{2}$ и хребтом наихудшего гарантированного восстановления; к предсказаниям первого яруса P1--P4 добавлен второй ярус P-A--P-D, условный на центральную гипотезу модели. Псевдощель купратов читается в этой модели как фантомная когерентность, а инженерная дорога к сверхпроводимости при произвольной температуре получает вид инженерии когерентности по четырём дорогам R1--R4. Каждое утверждение статьи разнесено по эпистемическим уровням: внешняя физика, корпусный инвариант, модельный постулат, словарная гипотеза, предсказание. Все числовые инварианты пересчитаны с точностью до пятидесяти десятичных знаков. Работа разворачивается внутри программы ODTOE (Observer-Dependent Theory of Everything; наблюдатель-зависимая теория всего), в которой вся математика, физика и феноменология сознания суть проекции единого первичного акта различения.

Ключевые слова: сверхпроводимость, декогеренция, когерентность, сверхтекучая жёсткость, квантовая геометрия, псевдощель, фантомная когерентность, переход сверхпроводник–изолятор, балансное неравенство, инженерия когерентности, ODTOE

I. INTRODUCTION AND POSITIONING

Why does superconductivity require cooling? The standard answer points to an energy scale: thermal excitations break Cooper pairs, and the condensate survives only below the critical temperature T_c. The present article proposes a change of the working axis. The quantity that the experimenter actually controls by cooling is the decoherence rate of the electronic condensate, and temperature serves as a convenient proxy for one channel of that rate, the thermal channel. This reframing immediately opens an engineering question: which further channels destroy the coherence of the condensate, which architectural means close each of them, and how far T_c can climb when they are closed simultaneously.

Within the ODTOE corpus the question is stated explicitly. The interpretive base of electricity and superconductivity is built in [1]: the Cooper pair is described there as a two-operator coherent bundle, the stability of a configuration grows by the lifetime law as $S \to 1$, and the Meissner effect together with magnetic-flux quantization is discussed. The same source records a gap: "The mechanism of high-temperature superconductivity is left unexamined" [1]. The engineering programme of devices and candidate materials is developed in [2]; the base formalism with the coherence metric, the lifetime law, and collective amplification is set in the primary source [3]. The present article closes the declared gap at the theoretical level: it builds a correspondence dictionary between the ODTOE coherence apparatus and the physics of the superconducting condensate, reads the question of absolute zero through this dictionary, and formulates a falsifiable verification programme.

The demarcation is drawn at once. The article refrains from deriving the equations of the microscopic theory, from repeating the device constructions and candidate materials of [2], and from any numerical predictions of T_c. The entire layer of external physics is invoked in survey mode, with references to primary sources; the entire corpus layer is cited without re-derivation. The novelty is concentrated in the correspondence dictionary, in the control model with the balance inequality and the (B, S) map, in the organization of the four roads of coherence engineering, and in the two tiers of predictions with explicit falsifiers.

The exposition proceeds as follows. Section II fixes the epistemic levels of the claims. Section III collects the canonical layer of physics in survey mode: pairing, the order parameter, the rigorous definition of macroscopic coherence, and the two independent ceilings of the critical temperature. Section IV summarizes the ODTOE apparatus in use. Section V builds the correspondence dictionary. Section VI builds the control model: the balance inequality, the critical modulus $q_c(T)$, and the (B, S) map. Section VII answers the question of absolute zero. Section VIII examines the pseudogap as phantom coherence and draws the lessons of the retractions of 2020–2023. Section IX describes the four engineering roads R1–R4. Section X formulates the two tiers of predictions and the measurement protocol M1. Section XI collects the honest limitations, and Section XII gives a brief summary. The Appendix contains a reproducible script of fifty-decimal verification of all numerical invariants.

II. EPISTEMIC STATUS AND THE STRATIFICATION OF CLAIMS

A cross-domain bridge between an operator apparatus and condensed-matter physics carries an elevated risk of mixing levels of reliability. Every substantive claim of the article therefore carries one of five tags.

L1-PHYSICS. An external experimental or theoretical fact with a bibliographic reference to a peer-reviewed primary source. The layer is invoked in survey mode; derivation of formulas from first principles is excluded from the article by construction.

L2-ODTOE. A corpus invariant: a formula or structural result already published in the ODTOE corpus and cited without re-derivation. All numerical values of this layer are recomputed in the Appendix to fifty decimal places (mpmath, `dps = 50`).

L3-DICTIONARY (HYPOTHESIS). A correspondence row between a physical object and an ODTOE object. Every row carries the status of a hypothesis and comes with its own falsification condition; the summary table is given in Section V.

MODEL-POSTULATE. A phenomenological kinetic postulate introduced in the present article (the structure of Γ_{dec}, the balance inequality) and its rigorous consequences; conditional on the central hypothesis H of Section VI. The model contains no microscopic derivation at the level of BCS or Eliashberg theory and replaces neither; it sets the control layer.

PREDICTION. An empirically testable consequence of the model with an explicit falsifier (P1–P4 and P-A–P-D, protocol M1 in Section X).

The article inherits the caveat of the primary source on energy extraction [4]: the identification of coherence S in the ODTOE sense with the physical phase coherence of the condensate is a substantive analogy, and the formal equivalence of the two notions remains unproven. Everything built below is read within this caveat. The template of level stratification is set in the corpus by the doubt–reality-transition model [5], where every claim is assigned to the layers of structural invariant, prediction, and hypothesis; the present article reproduces this discipline for a new domain.

III. THE CANONICAL LAYER: SUPERCONDUCTIVITY AS MACROSCOPIC QUANTUM COHERENCE

All material of this section belongs to layer L1 and is presented in survey mode.

III.1. Pairing and the energy gap

The microscopic theory [6] describes the transition of a metal into the superconducting state as a condensation of electron pairs accompanied by the opening of an energy gap Δ in the excitation spectrum. In the weak-coupling limit the theory yields the dimensionless invariant

$$\frac{\Delta(0)}{k_B T_c} \approx 1.764, \tag{1}$$

which ties the zero-temperature gap to the critical temperature [6]. The gap sets the depairing cost: the larger the gap, the higher the thermal threshold for pair destruction. The ratio (1) is recomputed in the Appendix as the control constant of layer L1 (**L1-PHYSICS**).

III.2. The order parameter and the observability of the phase

The phenomenological theory [7] introduces the complex order parameter $\psi = |\psi|e^{i\varphi}$ with two characteristic lengths: the coherence length ξ and the penetration depth λ. The amplitude $|\psi|$ measures the density of the condensate, and the phase φ carries its coherence. The phase is observable operationally: the tunnel current between two superconductors obeys the relation

$$I = I_c \sin(\Delta\varphi), \tag{2}$$

where $\Delta\varphi$ is the phase difference of the order parameters on the two banks of the junction [8]. Equation (2) turns the macroscopic phase from a computational abstraction into a directly measurable quantity (**L1-PHYSICS**).

III.3. The rigorous definition: off-diagonal long-range order

The rigorous criterion of macroscopic quantum coherence was given by Yang [9]: superconductivity is equivalent to off-diagonal long-range order (ODLRO) in the two-particle density matrix. The largest eigenvalue of this matrix grows in proportion to the number of particles, and the phase correlation survives over macroscopic distances. The property of being a superconductor thereby receives an exact formulation as a coherence property, applicable to any pairing mechanism (**L1-PHYSICS**).

III.4. Two independent ceilings of the critical temperature

The classical analysis of Emery and Kivelson [10] separated two scales. The first, T_{pair}, is set by the gap: above it the pairs break apart. The second, T_θ, is set by the phase stiffness ρ_s (the superfluid density): above it phase fluctuations destroy long-range order even while the pairs stay alive. The critical temperature is bounded by the lower of the two ceilings:

$$T_c \approx \min\left(T_{\text{pair}},\, T_\theta\right). \tag{3}$$

In ordinary metallic superconductors $T_\theta \gg T_{\text{pair}}$, and formula (3) degenerates into the familiar rule that the gap decides everything. In cuprates with a small superfluid density the two ceilings approach each other, and phase ordering becomes the bottleneck [10]. The Uemura band establishes the empirical proportionality $T_c \propto n_s/m^*$ for a wide class of underdoped materials [11]; the Homes law ties the superfluid density to the normal-state conductivity, $\rho_s \propto \sigma_{dc}(T_c)\, T_c$, along a single scale across families [12]. The two laws independently confirm the status of phase stiffness as a ceiling in its own right (**L1-PHYSICS**).

III.5. Empirical splittings of amplitude and phase

Two classes of observations separate amplitude and phase experimentally. First: in underdoped cuprates above T_c, pair correlations survive without phase coherence, as recorded by the Nernst signal and by fluctuation diamagnetism [13]; the interpretation of these signals remains a subject of debate between the preformed-pair scenario and the competing-order scenario [14]. Second: in ultrathin films at $T \to 0$ a superconductor–insulator transition is observed under the control of disorder and thickness [15]. The second class of observations is fundamental for the entire article: coherence is destroyed where the thermal channel is almost fully closed, and the destruction is carried out by non-thermal mechanisms (**L1-PHYSICS**).

IV. THE ODTOE APPARATUS: COHERENCE METRICS

This section collects the corpus invariants of layer L2; the derivations are cited without repetition.

The base formalism [3] defines the coherence of a configuration of N elements through pairwise mismatches of belief anchors:

$$S = 1 - \frac{2}{N(N-1)} \sum_{i<j} |B_i - B_j| \, . \tag{4}$$

The sum in formula (4) runs over pairwise mismatches of the belief anchors B_i; the quantity N counts the elements of the configuration. The canonical status of the quantity B is fixed by the primary source: B is a property of the observer–configuration pair (O, C), and in the present article the anchor factors are never mapped onto electronic degrees of freedom; electrons and pairs enter the dictionary below exclusively as elements of a coherent configuration. The lifetime law ties the stability of a configuration to its coherence:

$$T = \frac{T_0}{(1-S)^n}, \qquad n \geq 1, \tag{5}$$

with the lifetime diverging as $S \to 1$ [3]. Dissipation decreases linearly with coherence:

$$D(\eta) = D_0 \, (1 - S). \tag{6}$$

The notation of formulas (5) and (6) is inherited from the primary source; the exponent n in (5) remains an open parameter of the corpus.

The doubt–reality-transition model [5] introduces the contraction modulus of the self-observation operator

$$q(B, S) = B\,S + (1 - B)\sqrt{1 - S^2}. \tag{7}$$

The modulus (7) satisfies $q < 1$ at all interior points of the square $(B, S) \in (0, 1)^2$ (a Banach contraction). The derivative

$$\frac{\partial q}{\partial B} = S - \sqrt{1 - S^2} \tag{8}$$

changes sign at $S = 1/\sqrt{2} = 0.70710678$: below this threshold, growth of the anchor B decreases q (deepening the contraction); above it, the same growth increases q (weakening the contraction) [5]; the entire vertical $S = 1/\sqrt{2}$ is a level line of $q = 1/\sqrt{2}$ (Section VI). Coherence is bounded from above by the dimensionless ceiling

$$S \leq S_{\text{max}} = 1 - (\pi - 3)^2 = 0.97995152045, \tag{9}$$

so that an irremovable mismatch residue on the order of two percent persists under any architecture (**L2-ODTOE**) [5]. The same source splits coherence into a pair: the lifetime law (5) uses the true coherence S_{true}, whereas the declared, phantom coherence $S_{\text{phantom}} \gg S_{\text{true}}$ merely postpones the collapse [5]. The multi-agent detector of phantomness defines the adjusted coherence

$$S_{\text{adjusted}} = S_{\text{team}} \times \bar{B}, \tag{10}$$

which exposes states of the type "agreed around an error" [16].

The golden-ratio framing is fixed verbatim from the corpus [5]. The point $\varphi^{-1} = 0.61803398875$ on the diagonal $B = S$ is non-stationary: the derivative of the diagonal restriction $g(v) = q(v, v)$ at this point equals $g'(\varphi^{-1}) = +0.14963349$. The true minimizer of the diagonal is $v^* = 0.56228513453$ with the value $q^* = 0.67813000236$, whereas at the golden-section point $q(\varphi^{-1}, \varphi^{-1}) = 0.68224911725$. The selection of φ^{-1} rests on an external KAM argument about the survival of the worst-Diophantine torus and is carried in the corpus with the status of a **HYPOTHESIS** [5]. All six numerical values of this paragraph are reproduced in the Appendix.

The corpus interpretive base of superconductivity [1] describes the Cooper pair as a two-operator coherent bundle and reads the Meissner effect together with flux quantization $\Phi_B = nh/(2e)$ as macroscopic signatures of high S. The engineering programme [2] formulates the principle of two roads: the standard road lowers D_0 by cooling, the alternative road raises S by material architecture; formula (6) joins the two roads in a single expression.

V. THE CORRESPONDENCE DICTIONARY (LAYER L3)

Table 1 collects the correspondence dictionary. Every row carries the status of a **HYPOTHESIS** and comes with its own falsifier; the rows are consistent with the caveat of Section II.

Several rows of Table 1 call for unpacking. The correspondence of S to normalized phase coherence is operationalized through the ratio of superfluid stiffnesses $\rho_s(T)/\rho_s(0)$ and through the amplitude of off-diagonal order; protocol M1 in Section X adds an independent noise proxy of the same quantity. Temperature enters the dictionary as a proxy for the rate of one channel, since the quasiparticle population scales as $\exp(-\Delta/k_B T)$ while phase fluctuations grow with the ratio T/ρ_s [10]; the total decoherence rate is set by all channels together. Finally, the ceiling (9) is invoked below only as a qualitative parallel to residual violators of coherence. A numerical identification of the residue $1 - S_{\text{max}}$ with any measured quantity of a superconductor is excluded from the article (Section XI).

Table 1: The correspondence dictionary between the physics of superconductivity and the ODTOE metrics. Every row holds the status of an L3 hypothesis with its own falsifier.

Physics	**ODTOE**	**Row falsifier**
Condensate of Cooper pairs	cluster of high S built of elements of a coherent configuration [3]	mismatch of S-proxies between independent probes (P2)
Normalized phase coherence, $\rho_s(T)/\rho_s(0)$, ODLRO amplitude [9]	coherence S, formula (4)	the same (P2)
Temperature	proxy for the rate of the thermal decoherence channel	P1
Critical temperature T_c	the point where $S_{\text{true}}(T)$ crosses the stability threshold of law (5)	P1, P2
Coherence length ξ [7]	overlap radius of configuration elements	mismatch between overlap scales and ξ in M1
Flux pinning and quantization [1]	inertia of the held configuration	depinning statistics diverging from law (5)
Dissipation of the normal phase	$D(\eta) = D_0(1 - S)$, formula (6)	nonlinearity of $D(S)$ incompatible with (6)
Pseudogap	phantom coherence $S_{\text{phantom}} \gg S_{\text{true}}$ [5]	P2; competing order in full (Section VIII)
Materials engineering	four channels of coherence protection (Section IX)	P3, P4

VI. THE CONTROL MODEL: THE BALANCE INEQUALITY AND THE (B, S) MAP

This section builds a quantitative control layer on top of the dictionary of Section V. All the mathematics of subsections VI.2 and VI.5 consists of exact consequences of the corpus formula (7), recomputed in the Appendix (**L2-ODTOE**); the kinetic part of subsections VI.3–VI.4 is a postulate at the level of the present article (**MODEL-POSTULATE**); the physical content is conditional on hypothesis H of subsection VI.1.

VI.1. The central hypothesis H

Hypothesis H: the corpus contraction modulus $q(B, S)$ of the Banach coherence-restoration iteration [5] is identified with the dimensionless restoration rate of the superconducting condensate after a perturbation. Hypothesis H is the single gluing point between the corpus apparatus and condensate physics: upon its falsification, subsections VI.3–VI.8 lose their physical status, while the mathematics of subsections VI.2 and VI.5 survives as layer L2. The first-tier predictions P1–P4 (Section X) are independent of H; the second tier P-A–P-D is conditional on H (**L3-DICTIONARY (HYPOTHESIS)**).

VI.2. The guaranteed restoration rate

A corpus fact: the coherence-restoration iteration is a contraction with modulus q, that is, $\|\Psi_k - \Psi^*\| \le q^k \|\Psi_0 - \Psi^*\|$ [5]. The error envelope in time

$$\varepsilon(t) = \varepsilon_0 \, q^{t/\tau_0} \tag{11}$$

decays geometrically, and its exponent reads as the guaranteed minimal restoration rate:

$$\Gamma_{\text{rest}}(B,S) = \frac{-\ln q(B,S)}{\tau_0}. \tag{12}$$

The Banach estimate bounds the error from above, so the envelope (11) and formula (12) give a lower bound on the rate: the actual asymptotic rate is set by the spectrum of the linearization and can be higher. Here τ_0 is the microscopic tick of one iteration, an empirical parameter and the only carrier of dimension in the entire model. The rate $\Gamma_{\text{rest}} = 0$ is reached only at the corners $(0,0)$ and $(1,1)$: perfect coherence is marginal, with a critical slowing-down of restoration. The corner $(1,1)$ is asymptotic and lies outside the admissible band $S \le S_{\text{max}}$; the corner $(1,0)$ with $q = 0$ formally gives $\Gamma_{\text{rest}} = \infty$ and is unphysical (**L2-ODTOE** + **MODEL-POSTULATE**).

Table 2 collects reference values of $-\ln q$ at characteristic points of the (B,S) map; all values are recomputed in the Appendix. The point of almost-perfect coherence $(0.9,\ 0.95)$ restores, by the guaranteed estimate, 4.58 times slower than the point $(0.3,\ 0.9)$: the control relief is counterintuitive (**L2-ODTOE**).

Table 2: Reference values of the guaranteed restoration rate: $-\ln q$ at characteristic points of the (B,S) map (recomputation in the Appendix, mpmath `dps = 50`).

Point (B,S)	$-\ln q$
saddle pass $(1/2,\ 1/\sqrt{2})$	$\ln 2/2 = 0.34657359028$
$(v^*,\ v^*)$	0.38841626552
$(\varphi^{-1},\ \varphi^{-1})$	0.38236041327
$(0.3,\ 0.9)$	0.55317147660
$(0.9,\ 0.95)$	0.12078442157
$(0.3,\ S_{\text{max}})$	0.83597717864
$(0.9,\ S_{\text{max}})$	0.10327383107

VI.3. The decoherence channels

The total destruction rate of condensate coherence is postulated as a sum of channels:

$$\Gamma_{\text{dec}}(T) = \nu_A \, e^{-\Delta/k_B T} + \frac{k_B T}{\hbar} \, g_{\text{ph}}(S) + \Gamma_{\text{dis}} + \Gamma_{\text{qf}}. \tag{13}$$

The activation term describes the quasiparticle population above the gap (1); the phase term describes fluctuations that decrease with growing phase stiffness (structurally $\sim T/\rho_s$, cf. (3), [10]); the terms Γ_{dis} (disorder) and Γ_{qf} (quantum fluctuations) are independent of temperature, and their sum $\Gamma_0 = \Gamma_{\text{dis}} + \Gamma_{\text{qf}} = \Gamma_{\text{dec}}(0) > 0$ governs the superconductor–insulator transition at $T = 0$ [15], a structural correspondence. All coefficients are phenomenological; Γ_{dec} grows strictly monotonically in T for $g_{\text{ph}} > 0$ (**MODEL-POSTULATE**; the channel structure is **L1-PHYSICS** in survey mode).

VI.4. The balance inequality, the critical modulus, the temperature ceiling

The balance weighs the guaranteed restoration rate (12) against the sum of the destruction channels (13):

$$\Gamma_{\text{rest}}(B,S) \geq \Gamma_{\text{dec}}(T) \quad \Longleftrightarrow \quad q(B,S) \leq q_c(T), \tag{14}$$

where the critical modulus

$$q_c(T) = \exp\bigl(-\tau_0\,\Gamma_{\text{dec}}(T)\bigr) \tag{15}$$

strictly decreases in T, and $q_c(0) = \exp(-\tau_0\Gamma_0) < 1$. The balance (14) is a sufficient condition for holding the condensate: guaranteed restoration outruns destruction. An honesty caveat: through $g_{\text{ph}}(S)$ the right-hand side itself depends on S, and the boundary is set by an implicit equation; for phase-stiff materials the dependence is weak (**MODEL-POSTULATE**).

The temperature ceiling T_{max} is defined by the balance (14) solved as an equality and is a lower bound on the maximal holding temperature. The solution exists and is unique when

$$\tau_0\Gamma_0 < -\ln q(B,S) < \tau_0 \sup_T \Gamma_{\text{dec}}(T); \tag{16}$$

for $g_{\text{ph}} > 0$ the upper bound is infinite, and the left inequality suffices. Violation of the left inequality means the insulating side of the superconductor–insulator transition: superconductivity is absent at every temperature (**MODEL-POSTULATE**).

Two limiting regimes of the lever:

$$T_{\text{max}} = \frac{\Delta/k_B}{\ln\bigl[\nu_A\tau_0/(-\ln q - \tau_0\Gamma_0)\bigr]}, \qquad 0 < -\ln q - \tau_0\Gamma_0 < \nu_A\tau_0, \tag{17}$$

$$T_{\text{max}} = \frac{\hbar}{k_B}\,\frac{-\ln q - \tau_0\Gamma_0}{\tau_0\,g_{\text{ph}}(S)}. \tag{18}$$

In the activation regime (17) the (B,S) lever enters under the logarithm: its influence is weak, and the main knobs here are Δ and $\nu_A\tau_0$; the validity region of the formula is stated explicitly beside it. In the phase-limited regime (18) the lever is linear in $-\ln q$ and inverse in $g_{\text{ph}} \sim 1/\rho_s$: a structural correspondence to the Uemura band [11] without identification of the quantities. Both T_{max} expressions are lower bounds (**MODEL-POSTULATE**).

The dimensionless lever is rigidly bounded on the entire phase-limited sector $S \in [1/\sqrt{2},\, S_{\text{max}}]$: for such S we have $\partial q/\partial B = S - \sqrt{1-S^2} \geq 0$ (8), so $q(B,S)$ is non-decreasing in B and is minimized at $B = 0$, where $q(0,S) = \sqrt{1-S^2}$ is a function decreasing in S; hence the minimum over the entire sector is attained at the corner point $(B,S)=(0,S_{\max})$, whence

$$\sup_{B\in[0,1],\ 1/\sqrt{2}\le S\le S_{\max}} \big(-\ln q(B,S)\big) = -\ln\sqrt{1-S_{\max}^2} = -\ln\big[(\pi-3)\sqrt{2-(\pi-3)^2}\big] = 1.6132648006, \tag{19}$$

so that for working points in this sector $\tau_0\,\Gamma_{\rm dec}(T_{\max}) \le 1.6132648006$ and $T_{\max} \le \Gamma_{\rm dec}^{-1}\big(1.6132648006/\tau_0\big)$; for $B \ge B_{\min} > 0$ the bound is strictly smaller. The words "arbitrary temperature" mean precisely the following: no universal dimensionless limit on $T_{\max}$ exists, and the arbitrariness is transferred entirely to the empirical freedom of τ_0 and to the suppression of $\Gamma_{\rm dec}$ (**L2-ODTOE** for the constant; the reading is **MODEL-POSTULATE**).

VI.5. The (B,S) map: the inversion line, the ridge, iso-contours, the region $\Omega(T)$

The trigonometric form of the modulus

$$q = R(B)\sin(\theta+\psi), \qquad S=\sin\theta,\quad R(B)=\sqrt{B^2+(1-B)^2},\quad \tan\psi=\frac{1-B}{B} \tag{20}$$

gives an independent proof of contraction inside the band: by form (20), $q \le R(B) < 1$ for $B\in(0,1)$; the equality $q=1$ requires $R=1$ and $\sin(\theta+\psi)=1$ simultaneously, which happens only at the corners $(0,0)$ and $(1,1)$ (**L2-ODTOE**).

The two-regime rule of the anchor lever: by the derivative (8), below the line $S=1/\sqrt{2}$ growth of B decreases q and raises the guaranteed rate; above the line it increases q and lowers the rate; on the line itself the lever is exactly inert: the entire vertical $S=1/\sqrt{2}$ is a level line of $q=1/\sqrt{2}$ for every B (verified to fifty decimal places, Appendix) (**L2-ODTOE**).

The ridge of the map

$$S_{\rm ridge}(B)=\frac{B}{R(B)}, \qquad q\big(B,S_{\rm ridge}(B)\big)=R(B) \tag{21}$$

is the curve of the worst guaranteed restoration at a given B (the maximum of q over S); the minimum of the ridge height is the saddle pass $(1/2,\ 1/\sqrt{2})$ with the value $q=1/\sqrt{2}$; the saddle character of the pass is confirmed by the sign of the Hessian, $\det\mathrm{Hess}=-4$ (Appendix). An engineering trajectory crosses the ridge near the pass, at the point of minimal barrier height. A diagonal note: the minimizer of the diagonal $B=S$ is an algebraic number of degree three, a root of the equation

$$8v^3+4v^2-3v-1=0, \tag{22}$$

$v^*=0.56228513453$, $q^*=0.67813000236$; the point φ^{-1} loses to v^* in q by $0.607\,\%$ and keeps the status of a KAM hypothesis (the framing of Section IV verbatim) (**L2-ODTOE**).

The iso-contours of the modulus are explicit: for $S\neq 1/\sqrt{2}$

$$B(S;c)=\frac{c-\sqrt{1-S^2}}{S-\sqrt{1-S^2}}, \qquad \min\big(S,\sqrt{1-S^2}\big)\le c\le \max\big(S,\sqrt{1-S^2}\big), \tag{23}$$

where c is the level of q; the condition on c in formula (23) is the existence condition of the contour inside the band $B \in [0, 1]$ (**L2-ODTOE**).

The admissible region of the condensate at temperature T:

$$\Omega(T) = \{(B, S) : \; q(B, S) \le q_c(T), \; B \ge B_{\text{min}}\}; \tag{24}$$

the family $\Omega(T)$ is nested and shrinks monotonically as T grows. In the phase-dominated sector $S > 1/\sqrt{2}$ the boundary in B is explicit:

$$B \le B_c(S, T) = \frac{q_c(T) - \sqrt{1 - S^2}}{S - \sqrt{1 - S^2}}, \qquad S > 1/\sqrt{2}. \tag{25}$$

Here B_{min} is the corpus threshold quantity; its numerical value is an open empirical task. The line $S = 1/\sqrt{2}$ classifies the limitation regimes inside the region (amplitude-limited for $S < 1/\sqrt{2}$, phase-limited for $S > 1/\sqrt{2}$); the existence boundary is set by exactly the two conditions of formula (24) (the geometry is **L2-ODTOE**; membership in Ω is **MODEL-POSTULATE**).

VI.6. The engineering trajectory and a numerical illustration

Under hypothesis H, a material with control knobs p (doping, pressure, disorder, thickness, gate) is a curve $(B(p), S(p))$ on the map. A route into $\Omega(T_{\text{target}})$ is built in three steps. Step 1: for $S < 1/\sqrt{2}$, raise B; below the inversion line this decreases q. Step 2: cross the barrier ridge (21) near the pass ($B \approx 1/2$, $S \approx 1/\sqrt{2}$), where the barrier is minimal. Step 3: beyond the ridge, raise S toward S_{max}, holding B in the window $[B_{\text{min}}, \; B_c(S, T)]$ by formula (25): for $S > S_{\text{ridge}}(B)$ one has $\partial q / \partial S < 0$, and phase stiffness self-amplifies restoration. The objective function of the route is maximization of the balance margin $(-\ln q) - \tau_0 \Gamma_{\text{dec}}(T)$ (**L3-DICTIONARY (HYPOTHESIS)** as a methodology; the geometry of the steps is **L2-ODTOE**).

The numerical illustration is dimensionless; the parameters are declared arbitrary, and kelvins appear only after empirical τ_0, Δ, ν_A, g_{ph}. The balance as an equality in the dimensionless temperature t:

$$a\, e^{-1/t} + b\, t + \tau_0 \Gamma_0 = -\ln q, \qquad t = \frac{k_B T}{\Delta}, \quad a = \nu_A \tau_0, \quad b = \tau_0 \frac{\Delta}{\hbar}\, g_{\text{ph}}. \tag{26}$$

Table 3 collects the roots of equation (26) at $a = 100$, $b = 0.5$, $\tau_0 \Gamma_0 = 0.05$. Moving the working point from the corner $(0.9, \; 0.95)$ into the balanced zone $(0.3, \; 0.9)$ raises t_{max} by 61 % (**L2-ODTOE** for the numbers; the parameters are arbitrary).

VI.7. A structural reading of the T_c dome and the choice of the mapping

The adopted mapping V1: B corresponds to the normalized weight of the amplitude (gap) channel, S to the normalized phase coherence. Status: V1 is the only one of the two candidate mappings that passed retrodictive screening against three external anchors, namely the Emery–Kivelson splitting of the ceilings [10], the Uemura

Table 3: The dimensionless temperature ceiling $t_{\max}$, the root of equation (26) at $a = 100$, $b = 0.5$, $\tau_0\Gamma_0 = 0.05$ (the parameters are declared arbitrary; recomputation in the Appendix).

Working point (B, S)	$-\ln q$	$t_{\max}$
saddle pass $(1/2,\ 1/\sqrt{2})$	0.34657359028	0.16282561354
$(v^*,\ v^*)$	0.38841626552	0.16742498282
$(0.3,\ 0.9)$	0.55317147660	0.18209620279
$(0.9,\ 0.95)$	0.12078442157	0.11296295121
ceiling (19)	1.6132648006	0.2360

band [11] together with the Božović data on overdoped cuprates [17], and the BCS–BEC crossover [18]. The screening is a calibration of the mapping; independent support comes only from prediction P-A (Section X) (**L3-DICTIONARY (HYPOTHESIS)**).

The dome picture is piecewise; the model gives no single smooth formula $T_c(q)$, and this caveat is stated explicitly. The underdoped side is the amplitude basin ($B > 1/2$, $S < 1/\sqrt{2}$, a point under the ridge): the contraction is deep and single-channel; its temperature scale is T^* (the pseudogap, Section VIII); the superconducting T_c is set by the weak phase shoulder, $T_c \propto \rho_s$, in agreement with the Uemura band [11]. The top of the dome is the pass ($B \approx 1/2$, $S = 1/\sqrt{2}$): the intersection of the ridge ($\partial q/\partial S = 0$) and the inversion line ($\partial q/\partial B = 0$), where both levers are simultaneously inert; this matches the condition $T_{\text{pair}} = T_\theta$ of Emery–Kivelson [10]; the convergence of T^* and T_c near optimal doping is the same geometry. The overdoped side is the neighbourhood of the ridge on the descent toward $(0, 0)$; the exact pinning of the trajectory to the ridge (a curve of measure zero) is an additional hypothesis; the joint fall of Δ, ρ_s, and T_c agrees with the Božović data [17]. The BCS–BEC crossover [18] reads as a passage through the pass: the maximum of T_c over the coupling constant (**L3-DICTIONARY (HYPOTHESIS)**).

The rejected mapping V2 (B as carrier coherence, S as pairing amplitude) diverges from at least two anchors: it predicts maximal condensate stability at the underdoped edge and harmfulness of ρ_s growth on the underdoped side, in contradiction with the Uemura band [11]. The falsifier of V1: a statistical decoupling of the fall of T_c from the fall of ρ_s on the overdoped side (a violation of the Božović correlation [17]). The structural content of the dome is the geometry of the pass and the sign change of the marginal return of the anchor lever (**L3-DICTIONARY (HYPOTHESIS)**).

VI.8. Operationalizations: B_{sc}, S_{sc}, τ_0

The proposed operationalization of the anchor:

$$B_{\text{sc}} = \frac{\Delta}{\Delta + \hbar\Gamma_{\text{pair}}} \in (0, 1), \tag{27}$$

where Γ_{pair} is the pair-breaking rate (the Dynes parameter from tunneling spectroscopy); the monotonicity of the form (27) and its limiting values are verified in the Appendix; the choice of the form is a proposal, and alternatives are subject to empirical selection. The operationalization of coherence:

$$S_{\text{sc}} = \frac{\rho_s(T)}{\rho_s^{\text{ideal}}(0)}, \tag{28}$$

measurable through $\lambda^{-2}(T)$. An honesty remark on normalization is mandatory: the variant $\rho_s(T)/\rho_s(0)$ trivially gives unity as $T \to 0$; the substantive content of the ceiling S_{max} requires normalization to the ideal clean limit, and the choice of normalization is a separate empirical task. Candidates for the tick τ_0: the gap time $\hbar/\Delta$ or the inverse attempt frequency; the value is fixed by experiment, by the gap-recovery time in a pump–probe scheme. All the dimensionality of the model enters here and only here. The two-regime threshold is operationalized directly by comparing the scales T_θ and T_{pair}: T_θ is extracted from $\rho_s(0)$, and T_{pair} from the gap ($2\Delta/4.3\,k_B$ for d-wave pairing) or from the onset of the Nernst signal; the threshold corresponds to the equality $T_\theta = T_{\text{pair}}$ (**L3-DICTIONARY (HYPOTHESIS)**, proposal status).

VII. WHY ABSOLUTE ZERO: THE GOVERNING AXIS IS THE DECOHERENCE RATE

The answer to the original question can now be assembled in full.

Cooling closes exactly one channel: the thermal one. Lowering the temperature exponentially empties the quasiparticle states above the gap (1) and suppresses the phase fluctuations bounded by the stiffness in (3). The third law of thermodynamics (the Nernst theorem) forbids reaching $T = 0$ in a finite number of operations, so the closure of the thermal channel by cooling is asymptotic by construction: the road through zero is a limiting road whose limit stays out of reach (**L1-PHYSICS**).

The thermal channel, meanwhile, remains one channel among several. The superconductor–insulator transition in ultrathin films [15] unfolds at temperatures where the thermal channel is practically closed; coherence is destroyed by disorder and by quantum fluctuations of the phase. The existence of such a transition means that the governing axis of the problem is wider than temperature: it is the total decoherence rate summed over all channels, thermal and non-thermal (**L1-PHYSICS**; the dictionary row carries the status of an L3 **HYPOTHESIS** with falsifier P1).

The apparatus of Section IV gives this axis a compact expression. Formula (6) splits dissipation into two factors: the scale factor D_0 and the coherence factor $(1 - S)$. The standard road lowers D_0 by cooling. The alternative road raises S by material architecture; the principle of two roads is formulated in the corpus at the level of devices [2], and here it is lifted to the level of theory. Absolute zero in this optic is the asymptote of one of the roads, and the second road carries no such asymptote: the growth of S is bounded by the ceiling (9), and within this ceiling the lifetime law (5) admits arbitrarily long stability times of the condensate at temperatures set by the balance of the channels (**L2-ODTOE** + dictionary **HYPOTHESIS**).

Cooling lowers the decoherence rate along the thermal channel. Coherence engineering lowers it along all the others. The question of why absolute zero is needed becomes the question of which channels remain open and what closes them.

In the terms of the control model of Section VI, cooling is a monotone lowering of $\Gamma_{\text{dec}}(T)$, that is, a raising of the critical modulus $q_c(T)$ by formula (15) and a widening of the region $\Omega(T)$ by formula (24); the superconductor–insulator transition at $T = 0$ reads as a violation of the left edge of the existence condition (16) (**MODEL-POSTULATE**).

VIII. PHANTOM COHERENCE: THE PSEUDOGAP AND THE LESSONS OF THE RETRACTIONS

VIII.1. Phenomenology of the pseudogap

In underdoped cuprates, gap-like features in the spectra survive far above T_c; in the same doping region an anomalous Nernst signal and fluctuation diamagnetism are observed [13]. The field is divided between two living readings. First reading: above T_c there exist preformed pairs deprived of phase coherence. Second reading: the pseudogap reflects a competing order, autonomous with respect to superconductivity. The current review consensus keeps both readings open [14]. The article states this controversy honestly and builds its dictionary row for the first reading only (**L1-PHYSICS** + explicit caveat).

VIII.2. The ODTOE reading: amplitude without phase

In the dictionary of Section V the preformed-pair regime reads directly: the local amplitude $|\psi|$ has formed, phase coherence stays small, and the declared coherence of the system stands far above the true one, $S_{\text{phantom}} \gg S_{\text{true}}$. The lifetime law (5) operates on S_{true}, whence the corpus model predicts a regime of sudden collapse of phantom states [5]. The adjusted metric (10) supplies a theoretical discriminator: a true condensate holds simultaneously a high pairwise agreement and a high quality of every element, while a phantom order holds the first without the second [16]. In the coordinates of the map of Section VI, the preformed-pair regime lies in the amplitude basin (B large, $S < 1/\sqrt{2}$); the screening protocol based on the metric (10) is formalized in Section IX.5. The dictionary row is tied to the phenomenology of preformed pairs; if the cuprate pseudogap turns out to be a competing order in full, the row is falsified for the cuprates. This condition is declared in Table 1 (L3 **HYPOTHESIS**, falsifier P2).

VIII.3. The field-level layer of phantomness: cautionary records

The years 2020–2023 gave the field three cautionary records; the present subsection is the only place in the article where they are cited, and they are cited exclusively as records of an epistemic failure. The claim of room-temperature superconductivity in a carbonaceous sulfur hydride [19] was retracted by the journal's editors. The claim of near-ambient superconductivity in a nitrogen-doped lutetium hydride [20] was retracted after it. The claim about the material LK-99 was refuted by independent replication: the observed resistance jump was explained by a first-order structural transition in the Cu_2S impurity [21]. The pattern of failure in all three records is one and the same. Amplitude-like transport signatures were accepted in the absence of phase-coherent evidence at the level of the Meissner effect or the Josephson response (2). In the language of the present article, the field three times took S_{phantom} for S_{true}. The post-2023 community norm, which requires magnetic and transport evidence jointly, is the experimental analogue of the discriminator (10): confirmation is obliged to be multi-channel (**L1-PHYSICS** as a fact of the records; the dictionary reading carries the status of a **HYPOTHESIS**).

As of mid-2026 the literature contains no credible ambient-condition room-temperature superconductor: every claim of this kind has been either retracted or refuted. The statement records the state of the literature, with no forecast about the future of the field.

IX. COHERENCE ENGINEERING: FOUR ROADS R1–R4

Formula (3) turns the task of raising T_c into the task of lifting the lower of two ceilings; the splittings of Section III.5 add the requirement of closing the non-thermal channels; the control model of Section VI gives the task a quantitative frame. On the line $S = S_{\text{max}}$ the dimensionless lever is bounded by the ceiling (19): no universal dimensionless limit on T_{max} exists, and the arbitrariness of temperature is transferred entirely to the empirical freedom of the tick τ_0 and to the suppression of Γ_{dec}. Table 4 collects the four physical channels of coherence protection; the roads R1–R4 are regime-matched levers on top of the channels: R1 rests on the energy-gap channel; R2 on the channels of phase stiffness and quantum geometry (both are the S-lever); R3 on the protected-subspace channel and the lowering of Γ_{dec}; R4 adds the network level (cluster percolation), absent from the channel table. Table 5 collects the four roads.

IX.1. Road R1 (anchor): the gap scale

The ODTOE derivation of the road is the two-regime rule (8): below the inversion line, growth of B decreases q and raises the guaranteed restoration rate (12). The road passes through the preformed-pair zone “on credit”: raising B without an accompanying growth of S shifts the point toward the unphysical corner $(1, 0)$; this links to the pseudogap (Section VIII) and to the screening protocol of Section IX.5 (the sign part is **L2-ODTOE**; the reading is **L3-DICTIONARY (HYPOTHESIS)** on top of an L1 anchor).

The hydride programme raised the ceiling T_{pair} by a direct increase of the gap. Hydrogen sulfide under a pressure of about 155 GPa showed superconductivity at 203 K with an isotope effect certifying the phonon mechanism [22]; lanthanum hydride LaH_{10} lifted the record to ≈ 250 K at megabar-range pressures [23]. The roadmap of the field formulates the principle of chemical precompression of the hydrogen sublattice as a replacement of part of the external pressure by internal pressure [29]. The price of this road is known: megabars. Reports of magnetic-flux trapping in hydrides [30] are cited here with a mandatory caveat: an author correction has been issued for that work, and

Table 4: Four channels of protection of condensate coherence.

Channel	**Physical carrier**	**Representative systems**	**ODTOE reading**
Energy gap	depairing cost Δ [6]	hydrides under pressure [22,23]	raising the destruction threshold of configuration elements
Phase stiffness	superfluid density ρ_s [10]	cuprates, nickelate films [24]	stability of inter-element agreement
Quantum geometry	geometric contribution to the superfluid weight [25]	flat-band moiré graphene [26,27]	coherence carried by the structure of the wave function
Protected subspaces	topological protection, incommensurability	chirality signatures [28]; φ-tuning (hypothesis)	isolation of the configuration from resonant channels

the interpretation of the measurements remains the subject of an ongoing discussion. In the ODTOE dictionary the amplitude road reads as raising the destruction cost of individual configuration elements: the thermal channel needs more energy for every act of decoherence (**L1-PHYSICS**; the reading carries the status of a **HYPOTHESIS**).

The limit of the road is the inversion line $S = 1/\sqrt{2}$: on it the sign of the lever changes, and the baton passes to road R2; the physical twin of the limit is the lattice instability at an excessive coupling constant λ. Operationalization: the B-proxies are λ, $\omega_{\log}$, $2\Delta/k_B T_c$; the S-proxy is $\rho_s(0)$ from λ_L^{-2}; the detector of the inversion line is the crossover at which T_c stops following the Δ scale and starts following the ρ_s scale. Falsifier of the road: a family in which T_c grows monotonically with the coupling constant deep in the phase-limited branch (**L3-DICTIONARY (HYPOTHESIS)**).

IX.2. Road R2 (stiffness): phase and quantum geometry

The ODTOE derivation of the road: beyond the ridge (21) one has $\partial q/\partial S < 0$, so growth of S decreases q; in the phase-limited regime the $T_{\max}$ lever is linear in $-\ln q$ by formula (18) and inverse in $g_{\text{ph}} \sim 1/\rho_s$. The two-channel structure is exact: the modulus q is affine in B, and the S-channel is controlled independently of the B-channel; the flat-band case (quantum metric at vanishing kinetic energy) is a direct physical analogue of this independence (the affinity is **L2-ODTOE**; the reading is **L3-DICTIONARY (HYPOTHESIS)**).

Magic-angle twisted bilayer graphene opened the class of flat-band superconductors [26]: the kinetic energy of electrons in a flat band nearly vanishes, and by Fermi-liquid logic the superfluid weight is bound to vanish with it. The theory of quantum geometry predicted the opposite: the superfluid weight receives

Table 5: Four roads of coherence engineering on the (B, S) map.

Road	Regime	Lever	ODTOE derivation	Limit	Falsifier
R1 anchor	$S < 1/\sqrt{2}$	raising B	below the inversion line, growth of B decreases q (8)	inversion line $S = 1/\sqrt{2}$	growth of T_c with the coupling constant deep in the phase branch
R2 stiffness	$S > 1/\sqrt{2}$	raising S	beyond the ridge $\partial q/\partial S < 0$; the lever is linear in $-\ln q$ (18)	ceiling $S_{\max}$ (9)	reducibility of the S-proxy to a function of the B-proxy
R3 channel	any	lowering Γ_{dec}	raising $q_c(T)$ (15), widening $\Omega(T)$ (24)	existence condition (16)	shared with P-D
R4 cluster	island networks	network topology	correction (10); threshold (29)	$\bar{B} \geq 0.72157322728$	onset insensitive to topology

a contribution from the quantum metric of the wave functions that survives at zero group velocity [25]. In 2025 two independent groups measured the superfluid stiffness of magic-angle graphene directly for the first time and found values an order of magnitude above the Fermi-liquid prediction, with a power-law temperature dependence [27,31]. Quantum geometry has thereby moved from a theoretical prediction to a measured carrier of phase coherence (**L1-PHYSICS**).

Nickelates supplied the second front. Bulk $La_3Ni_2O_7$ under pressure showed signs of superconductivity near 80 K [32], then zero resistance with a strange-metal normal phase [33]. Thin films carried the effect to ambient pressure: signatures of superconductivity with a transition onset in the range 26–42 K [34], and then an onset above 40 K with a Berezinskii–Kosterlitz–Thouless phase-ordering temperature near 9 K and a Meissner response below ≈ 8 K [24]. The gap of more than a factor of five between the onset and the phase ordering is the phase bottleneck in its purest observed form: the amplitude is ready at 40 K, and long-range order arrives at 9 K. Moiré WSe_2 added a tunable platform where the ratio of the pairing and ordering scales is regulated by the twist angle and by gating [35]. For protocol M1 these are the reference systems (**L1-PHYSICS**).

The limit of the road is the ceiling $S_{\max}$ (9). Falsifiers: a superfluid weight at the level of the conventional estimate despite a large quantum metric; reducibility of the S-proxy to a function of the B-proxy within families (**L3-DICTIONARY (HYPOTHESIS)**).

IX.3. Road R3 (channel): lowering Γ_{dec}

The ODTOE derivation of the road: by formula (15), every closed non-thermal channel (a decrease of Γ_{dis}, Γ_{qf}) raises $q_c(T)$ and widens the region $\Omega(T)$ (24) at an unchanged working point (B, S); the existence condition (16) shows the insulating side at an excessive Γ_0 (**MODEL-POSTULATE**).

Sub-lever (a): protected subspaces. Signatures of chiral superconductivity in rhombohedral graphene [28] point to a possible class of states with a topologically protected order parameter; the status of the report: signatures from a single group, without independent replication. Pressure in hydrides also works as structural protection, suppressing competing lattice distortions [29] (**L1-PHYSICS**; the reading is **L3-DICTIONARY (HYPOTHESIS)**).

Sub-lever (b): the KAM rule of incommensurability. The corpus line adds a hypothesis of its own: irrational working points of the φ^{-1} type and incommensurate lattice modulations as protection against resonant decoherence channels; working points at Diophantine-distant ratios of dimensionless parameters starve the resonant channels of competing orders. The rule inherits the KAM framing of Section IV verbatim and is carried with the status of a **HYPOTHESIS** (the weakest row of the dictionary; the check is supplied by item (ii) of protocol M1 and by prediction P-D); the discipline is strictly dimensionless and qualitative, with no numerical fitting. Precedents of the structural picture: the $1/8$ anomaly and stripe correlations in cuprates [36]; commensurate lock-in transitions of charge-density waves in kagome metals [37]; the TJ-II stellarator, whose rotational transform deviates from φ by two percent, shows the largest Hurst exponent of fluctuations among the nine facilities of the retrospective analysis [38]. Operationalization: the measure of incommensurability is Diophantine distance, that is, the continued-fraction depth to a pre-registered precision (protection against researcher degrees of freedom); the null model is random placement of the domes. The falsifier is shared with prediction P-D (Section X).

IX.4. Road R4 (cluster): percolation of coherent islands

The ODTOE derivation of the road is the multi-agent correction (10): the effective stiffness of a network is the product of phase agreement and mean node quality. The threshold of the coherent regime in raw units is $S_c^{\mathrm{raw}} = 1/(\sqrt{2}\,\bar{B})$, and reachability of the phase-dominated sector requires

$$\bar{B} \geq \frac{1}{\sqrt{2}\,S_{\max}} = 0.72157322728. \tag{29}$$

A cluster with $\bar{B} = \varphi^{-1}$ has $S_c^{\mathrm{raw}} = 1.14412280564 > 1$: the phase-dominated regime is unreachable for it in principle (**L2-ODTOE**, recomputation in the Appendix). A structural consequence: degradation of $\bar{B}$ from 0.8 to 0.7 at $S = 0.9$ moves S_{adjusted} from 0.72 (above the inversion line) to 0.63 (below it): the granular material crosses the inversion line, and the sign of the usefulness of the anchor lever changes (**MODEL-POSTULATE** on top of L2).

The carriers of the road: granular aluminum with $T_c \approx 3$ K against the bulk 1.2 K [39], Josephson networks, the superconductor–insulator transition [15]. The cluster threshold $n > n_{\text{cr}}$ corresponds to the Anderson criterion $\delta < \Delta$ for the minimal superconducting grain [40]: a correspondence hypothesis, without transfer of the corpus number $n_{\text{cr}} = 5$. The lever of the road is network topology: coordination number, percolation threshold, barrier transparency at fixed island properties. Falsifiers: an onset of global coherence insensitive to topological predictors; the absence of threshold behaviour in the island fraction (**L3-DICTIONARY (HYPOTHESIS)** on top of L1; the threshold n_{cr} is a **HYPOTHESIS**).

IX.5. The S_{adjusted} screening protocol: a detector of phantom coherence

The basis of the protocol is the corpus metric (10) and the two-ceiling structure (3). The protocol: measure independently a B-proxy (the gap: tunneling, ARPES, optics; the Dynes parameter for the operationalization (27)) and an S-proxy (the stiffness ρ_s: λ_L^{-2}, muon spin relaxation, spectral weight; the normalization (28)). A large gap at small stiffness gives a small product: phantom coherence (the pseudogap, Section VIII); the retraction lessons of Section VIII.3 demand multi-channel confirmation. A mandatory part of the protocol is a check of the within-family variation of $B_{\text{sc}}(x)$ from Dynes data: the assumption of saturation of the B-proxy on the underdoped side is subject to verification, and the status of the assumption stays open. The statistical frame is prediction P-B (Section X) (**L3-DICTIONARY (HYPOTHESIS)**; the check is **PREDICTION** P-B).

The unifying thesis of the section: raising T_c is a combined movement across the (B, S) map (roads R1, R2, and R4 move the working point) together with a raising of the critical modulus $q_c(T)$ (road R3 widens the admissible region $\Omega(T)$); the four roads form the complete engineering basis of the model in the proposed dictionary (L3 **HYPOTHESIS**; falsifiers P3, P4, and P-A–P-D).

X. FALSIFIABLE PREDICTIONS AND THE MEASUREMENT PROTOCOL

The predictions of the article form two tiers. Tier one, P1–P4: all four are built on measurable quantities, are free of fitting parameters drawn from π or φ, and are constructed so as to bypass the mapping of $q(B, S)$ onto the condensate; they retain their force upon falsification of the central hypothesis H, and they rest on the lifetime law (5), the pair $S_{\text{true}}/S_{\text{phantom}}$, and the channel composite of Section IX. Tier two, P-A–P-D (subsection X.2): predictions generated by the control model of Section VI and conditional on hypothesis H; each carries an explicit falsifier.

P1 (ordering of families by the phase-stiffness deficit). For every family of superconductors define the ratio $r = T_\theta/T_{\text{pair}}$ following Emery–Kivelson [10] and the width of the fluctuation window $w = (T_{\text{onset}} - T_c)/T_c$. Prediction: w decreases monotonically with growing r across all families, the new platforms included. Hydrides ($r \gg 1$) give $w \approx 0$; underdoped cuprates ($r \lesssim 1$) give a large w; nickelate films with an onset above 40 K and ordering near 9 K [24] are bound to fall at the cuprate end of the scale. Falsifier: a family with $r \gg 1$ and a wide preformed-pair window, or a documented violation of monotonicity (**PREDICTION**).

P2 (lifetime scaling of phantom coherence). In the preformed-pair regime the pair-correlation time τ, extracted from the Nernst signal [13], from paraconductivity, and from the terahertz response, obeys the law

$$\tau \propto (1 - s)^{-n}, \qquad n > 1, \tag{30}$$

where s is the normalized proxy of true coherence under protocol M1, and the exponent n agrees between independent probes of the same material. The Gaussian baseline is set by fluctuation theory [41]:

$$\tau_{GL} = \frac{\pi\hbar}{8k_B(T - T_c)}. \tag{31}$$

The baseline (31) in the variable $s \propto 1 - T/T_c$ corresponds to the exponent $n = 1$. The law (30) is structurally parallel to the corpus law (5). Falsifier: a strict exponent $n = 1$ everywhere in the pseudogap regime, or a mismatch of n between probes (**PREDICTION**).

P3 (departure from the Homes law for geometric superconductors). Superconductors with a dominant quantum-geometric contribution to the superfluid weight, measured directly [27,31], depart from the Homes scale $\rho_s \propto \sigma_{dc}(T_c)\, T_c$ [12] toward an excess of ρ_s that grows with the geometric fraction computable from the band structure [25]. Falsifier: flat-band superconductors fall on the Homes line within experimental error (**PREDICTION**).

P4 (the Uemura band as an indicator of coherence limitation). Superconductors limited by phase coherence lie in the Uemura band $T_c/T_F \sim 10^{-2}$–10^{-1} [11]; those limited by pairing lie orders of magnitude below the band. Prediction: any new candidate for superconductivity at arbitrary temperature that operates through the coherence-protection channels of Table 4 will land inside the band. Falsifier: a material with a documented phase-fluctuation limitation of T_c far outside the band (**PREDICTION**).

X.1. Protocol M1: a noise proxy of coherence

The protocol operationalizes the quantity s for prediction P2. Status of the protocol: a measurement programme. The method precedent is given by the corpus verification on plasma turbulence: a retrospective analysis of twenty regimes at nine toroidal facilities extracted coherence from the Hurst exponent H of fluctuation time series [38] via the mapping

$$S = 2H - 1. \tag{32}$$

The transfer to superconductors: extraction of $S(T)$ by formula (32) from the Hurst exponent of voltage and magnetic-flux fluctuations on the passage through T_c. Expectations of the protocol: (i) a discontinuous jump ΔS at T_c, mirroring the jumps $\Delta S \approx 0.3$–1.15 at L→H confinement transitions [38]; (ii) an elevated H-coherence in φ-tuned and incommensurately modulated lattices, the superconducting twin of the TJ-II result; the statistical frame of the test is prediction P-D (subsection X.2). Item (ii) inherits the hypothesis status of the dictionary row on incommensurability (Section IX.3). No new formulas linking S to noise exponents beyond the mapping (32) are introduced in the article; consistency with the corpus precedent is mandatory by the construction of the protocol.

X.2. Second-tier predictions (conditional on hypothesis H)

P-A (two-regime response of the anchor lever). The threshold is operationalized directly by comparing the scales T_θ (from $\rho_s(0)$) and T_{pair} (from the gap), as in subsection VI.8. Weak form: a clean enhancement of the amplitude channel (calibrated uniaxial strain, resonant pumping of the apical phonon) shifts the onset scale of the pair channel (T^*, the Nernst onset, paraconductivity) upward for $T_\theta < T_{\text{pair}}$ and downward for $T_\theta > T_{\text{pair}}$. Strong form: the same lever gives $\Delta T_c > 0$ for $T_\theta < T_{\text{pair}}$ and $\Delta T_c < 0$ for $T_\theta > T_{\text{pair}}$, with zero response at $T_\theta = T_{\text{pair}}$; only the sign of the response is independent of the current B, while the magnitude depends on B through q and through the slope of Γ_{dec} at the balance point. Epistemic status of the strong form: it follows from an additional postulate of global monotonicity of T_{max} in $-\ln q$; the piecewise dome picture (subsection VI.7) is free of this postulate; an experiment on a pair of samples on the two sides of the point $T_\theta = T_{\text{pair}}$ distinguishes the monotonicity postulate from the min-rule (3), since their sign patterns are opposite. Falsifiers: a verified sample with $T_\theta > T_{\text{pair}}$ whose T_c grows under a clean amplitude lever (strong form); a monotone growth of the onset on both sides of the threshold (weak form) (**PREDICTION**, conditional on H; the strong form additionally assumes the monotonicity postulate).

P-B (rank screening of the product). The product of independent proxies $S_{\text{phase}} \times B_{\text{amp}}$ (protocol of Section IX.5) orders superconductor families by T_c better than either factor alone; the null model is the Homes predictor [12]: the product is obliged to add rank power on top of the Homes variables. On the phase-limited branch P-B reduces to the Uemura band [11] under the condition of small within-family variation of B_{sc}; the condition is checked from Dynes data as part of the protocol of Section IX.5. Operationalization: Spearman rank correlation over four or more families (cuprates by doping, iron-based superconductors, hydrides, moiré graphene, granular materials). Falsifiers: a product rank that fails to exceed the maximum of the factor ranks; zero addition on top of the Homes predictor (**PREDICTION**).

P-C (a strengthening of P2: pre-registration and the ceiling). The law (30) is supplemented by three items. (i) Channel universality: the paraconductivity [41], the Nernst signal, and the fluctuation diamagnetism of one material give one exponent n. (ii) The coherence class of a family is pre-registered before the fits by an independent measurable criterion (the Ginzburg number Gi or the family's ratio T_θ/T_{pair}); a drift of n at a fixed pre-registered class means falsification. (iii) The lifetime-amplification ceiling follows from (5) and (9):

$$T_{\text{life}} \leq T_0\,(\pi - 3)^{-2n}, \tag{33}$$

where $T_{\text{life}} \equiv T$ from formula (5) is the configuration lifetime (the notation is decoupled from temperature); the dimensionless ceiling ratios: 49.879 for $n = 1$, 2487.924 for $n = 2$. Falsifiers: absence of a power law; divergence of n between channels; drift of n at a fixed class (**PREDICTION**; an extension of P2 resting directly on (30)).

P-D (statistics of incommensurability). The maxima of superconducting domes statistically avoid values of control parameters at low-order rational numbers; competing locked orders (charge-density waves, stripes, correlated insulators) are statistically attracted to them. The measure is Diophantine distance with a pre-registered continued-fraction precision; the test runs over three or more families against a null model of random placement; in parallel, the distribution of commensurate lock-in points is checked [36,37]. The statistical frame is tied to item (ii) of protocol M1 (subsection X.1). Falsifier: absence of a statistical avoidance signal, which closes P-D and sub-lever (b) of road R3 simultaneously (**PREDICTION**, inheriting the status of the KAM hypothesis).

XI. HONEST LIMITATIONS AND BOUNDARIES OF APPLICABILITY

The caveat of Section II applies to the entire article: the identification of S with physical phase coherence (ODLRO, ρ_s) remains a substantive analogy without a proven formal equivalence [4]. The dictionary of Section V is built so that every row is falsifiable independently of the others. The failure of one row leaves the rest in force.

The dimensionless ceiling (9) is invoked as a qualitative parallel to irremovable residual violators of coherence. A numerical identification of the residue $1 - S_{\text{max}} \approx 0.02$ with any observable of a concrete material (a residual quasiparticle fraction, residual absorption) is absent from the article and excluded by its methodology: dimensional and material-specific quantities are never derived from π and φ in the corpus. For the same reason the article is deliberately free of numerical predictions of critical temperatures. Every quantitative statement either cites external measurements of layer L1 or concerns dimensionless corpus invariants of layer L2.

The controversy of the pseudogap is declared explicitly: both readings are presented in Section VIII.1 [14], the dictionary row is built for the preformed-pair scenario, and its falsification condition for the cuprates is formulated in Table 1 and in Section VIII.2. The most speculative part of the dictionary remains the mapping of the modulus $q(B, S)$ onto condensate physics; predictions P1–P4 are built so as to bypass this mapping and retain their force upon its failure.

The open tasks of the corpus remain the numerical value of the stability threshold for the dictionary row on T_c, the derivation of the exponent n of law (5), the rigorous derivation of the gap $(\pi - 3)^2$ in the ceiling (9), and the formal bridge between S and ODLRO [3,5].

XII. CONCLUSION

The article has closed the gap declared in the corpus interpretive base of electricity [1]: high-temperature superconductivity has received a reading in the ODTOE coherence metrics. The central shift consists in moving the governing axis from temperature to the decoherence rate of the condensate; cooling toward absolute zero occupies, in this optic, the place of an asymptotic closure of one channel out of four. The nearest test of the model lies in prediction P2: the lifetime-scaling exponent of pair correlations in the pseudogap regime, agreed between independent probes, will separate phantom coherence from true coherence on a measurable material.

APPENDIX. NUMERICAL VERIFICATION SCRIPT (mpmath, dps = 50)

All numerical invariants of the article are reproduced by the script below (Python 3, the mpmath library, precision of fifty decimal places). The script is free of fitting parameters: only the dimensionless corpus invariants of layer L2 and one control constant of layer L1 are computed.

```
# -*- coding: utf-8 -*-
# ODTOE_superconductivity_coherence: numerical falsifier, mpmath dps=50
from mpmath import mp, mpf, sqrt, pi, log, findroot, exp, euler

mp.dps = 50

# --- Dimensionless corpus invariants ---
S_max = 1 - (pi - 3)**2          # coherence ceiling
inv_sqrt2 = 1 / sqrt(2)          # dq/dB sign-change point
phi = (1 + sqrt(5)) / 2
phi_inv = 1 / phi                # KAM-selected point (HYPOTHESIS)

# --- q-modulus machinery (post-f572ef9 framing) ---
def q(B, S):
    return B * S + (1 - B) * sqrt(1 - S**2)

def g(v):                        # diagonal restriction q(v, v)
    return q(v, v)

def gprime(v):                   # g'(v)
    return 2*v - sqrt(1 - v**2) + (1 - v) * (-v / sqrt(1 - v**2))

q_phi  = g(phi_inv)              # q at the KAM point
gp_phi = gprime(phi_inv)         # nonzero => phi^-1 not stationary
v_star = findroot(gprime, mpf("0.56"))   # true diagonal minimizer
q_star = g(v_star)

# --- L1 cross-check (external, cited): BCS weak-coupling ratio ---
bcs_ratio = pi * exp(-euler)     # Delta(0) / (kB * Tc)

# --- Block 2: control-model invariants (Section VI) ---
ln2_half   = -log(q(mpf(1)/2, 1/sqrt(2)))   # saddle -ln q = ln2/2
mlnq_vstar = -log(q_star)
mlnq_phi   = -log(q_phi)
mlnq_0309  = -log(q(mpf("0.3"), mpf("0.9")))
mlnq_0995  = -log(q(mpf("0.9"), mpf("0.95")))
```

```
mlnq_03max = -log(q(mpf("0.3"), S_max))
mlnq_09max = -log(q(mpf("0.9"), S_max))
sqrt_smax  = sqrt(1 - S_max**2)     # = (pi-3)*sqrt(2-(pi-3)^2)
lnq_sup    = -log(sqrt_smax)        # eq:lnqsup, max on S = S_max line
cubic_res  = 8*v_star**3 + 4*v_star**2 - 3*v_star - 1
level_chk  = max(abs(q(b, 1/sqrt(2)) - 1/sqrt(2))
                 for b in [mpf(0), mpf("0.25"), mpf("0.5"),
                           mpf("0.75"), mpf(1)])
q_BS0      = 1 + inv_sqrt2/sqrt(1 - inv_sqrt2**2)   # d2q/dBdS
hess_det   = -q_BS0**2              # det Hess at saddle (d2q/dB2 = 0)
iso_B      = (mpf("0.8") - sqrt(1 - mpf("0.9")**2)) \
             / (mpf("0.9") - sqrt(1 - mpf("0.9")**2))
iso_chk    = q(iso_B, mpf("0.9"))  # must be 0.8
iso_B2     = (mpf("0.6") - sqrt(1 - mpf("0.5")**2)) \
             / (mpf("0.5") - sqrt(1 - mpf("0.5")**2))
iso_chk2   = q(iso_B2, mpf("0.5")) # must be 0.6
b_mean_min = 1 / (sqrt(2) * S_max) # eq:bmeanmin
s_raw_phi  = 1 / (sqrt(2) * phi_inv)   # unreachable: > 1
life_n1    = (pi - 3)**(-2)         # eq:tlifecap ratio, n = 1
life_n2    = (pi - 3)**(-4)         # eq:tlifecap ratio, n = 2
# dimensionless balance, a=100, b=0.5, g0=0.05 (arbitrary)
def tmax(mlnq, a=mpf(100), b=mpf("0.5"), g0=mpf("0.05")):
    return findroot(lambda t: a*exp(-1/t) + b*t + g0 - mlnq,
                    mpf("0.15"))
t_saddle = tmax(ln2_half); t_vstar = tmax(mlnq_vstar)
t_0309 = tmax(mlnq_0309); t_0995 = tmax(mlnq_0995)
t_ceiling = tmax(lnq_sup)

for name, val in [("S_max", S_max), ("1/sqrt(2)", inv_sqrt2),
                  ("phi^-1", phi_inv), ("q(phi^-1,phi^-1)", q_phi),
                  ("g'(phi^-1)", gp_phi), ("v*", v_star),
                  ("q*", q_star), ("BCS ratio", bcs_ratio),
                  ("ln2_half", ln2_half), ("mlnq_vstar", mlnq_vstar),
                  ("mlnq_phi", mlnq_phi), ("mlnq_0309", mlnq_0309),
                  ("mlnq_0995", mlnq_0995), ("mlnq_03max", mlnq_03max),
                  ("mlnq_09max", mlnq_09max), ("sqrt_smax", sqrt_smax),
                  ("lnq_sup", lnq_sup), ("cubic_res", cubic_res),
                  ("level_chk", level_chk), ("hess_det", hess_det),
                  ("iso_B", iso_B), ("iso_chk", iso_chk),
                  ("iso_B2", iso_B2), ("iso_chk2", iso_chk2),
                  ("b_mean_min", b_mean_min), ("s_raw_phi", s_raw_phi),
                  ("life_n1", life_n1), ("life_n2", life_n2),
                  ("t_saddle", t_saddle), ("t_vstar", t_vstar),
                  ("t_0309", t_0309), ("t_0995", t_0995),
                  ("t_ceiling", t_ceiling)]:
    print(name, "=", val)
```

Script output (verbatim):

```
S_max = 0.979951520449400811941369299800866169869316989009 84
1/sqrt(2) = 0.70710678118654752440084436210484903928483593768847
```

```
phi^-1 = 0.61803398874989484820458683436563811772030917980576
q(phi^-1,phi^-1) = 0.68224911725088275968210787558278824961032689402959
g'(phi^-1) = 0.14963349374158880245292037293989093858686022793845
v* = 0.56228513453238733481549563500073880952342840052545
q* = 0.67813000236282321186797140396571544817465503043068
BCS ratio = 1.76387698886204569069266213454333953508602722889667
ln2_half = 0.34657359027997265470861606072908828403775006718013
mlnq_vstar = 0.38841626552428381809488024171016269936590718746552
mlnq_phi = 0.38236041327377469046025782405953178359876750421835
mlnq_0309 = 0.55317147660238317291590750926249057500400847441915
mlnq_0995 = 0.12078442157123711946432440762723765985069281333371
mlnq_03max = 0.83597717863711793487062725440646552452964408226711
mlnq_09max = 0.10327383107126990953959925966807223293020702004 39
sqrt_smax = 0.19923608500697754449358968195166302304276867833 17
lnq_sup = 1.61326480060383141184704228536729713485211388813 49
cubic_res = 2.67276471009219564614053646715148187881519688010 5e-51
level_chk = 1.33638235504609782307026823357574093940759844005 25e-51
hess_det = -4.0
iso_B = 0.78453388800740849109295190348613523130424187217367
iso_chk = 0.8
iso_B2 = 0.72679491924311227064725536584941276330571947461896
iso_chk2 = 0.6
b_mean_min = 0.72157322727788812469723730086260252737888918325253
s_raw_phi = 1.14412280563536859520014556716060415307230675367 55
life_n1 = 49.87909419645306929932097819737569180199253851648 7
life_n2 = 2487.92403785863825893249885248151602491936322195 79
t_saddle = 0.16282561353595576298971682367763639858287463227787
t_vstar = 0.16742498282154395807712132221520254967773209042 41
t_0309 = 0.18209620278911366862262928886367547374025521464351
t_0995 = 0.11296295121114468207813348389301581548008885192785
t_ceiling = 0.23602243349196433023233171171072987210584503980909
```

Cross-check against the text: the ceiling (9) rounds to 0.97995152045; the sign-change point of (8) equals $1/\sqrt{2} = 0.70710678\ldots$; the values $q(\varphi^{-1}, \varphi^{-1}) = 0.68224911725$, $g'(\varphi^{-1}) = +0.14963349$, $v^* = 0.56228513453$, $q^* = 0.67813000236$ agree with Section IV; the ratio (1) is reproduced as $\pi e^{-\gamma_E} = 1.7638769889 \approx 1.764$. The derivative check at the minimizer gives $g'(v^*) = 0$ to the precision of the working arithmetic.

Cross-check of Block 2 against Sections VI, IX, and X: the values `ln2_half`, `mlnq_vstar`, `mlnq_phi`, `mlnq_0309`, `mlnq_0995`, `mlnq_03max`, `mlnq_09max` round to the eleven digits of Table 2; the residual of the cubic equation (22) at the root v^* (`cubic_res`) and the deviation of the level line $q(B, 1/\sqrt{2}) = 1/\sqrt{2}$ over five values of B (`level_chk`) are zeros of the working arithmetic ($\leq 10^{-49}$); the saddle Hessian `hess_det` equals -4 exactly; the lever ceiling (19) is reproduced as 1.6132648006; the iso-contour (23) is verified at two points: $q(\texttt{iso\_B}, 0.9) = 0.8$ and $q(\texttt{iso\_B2}, 0.5) = 0.6$ exactly; the threshold (29) is reproduced as 0.72157322728, and the unreachability of the phase-dominated sector at $\bar{B} = \varphi^{-1}$ as `s_raw_phi` $= 1.14412280564 > 1$ (Section IX.4); the lifetime ceilings (33) give 49.879 for $n = 1$ and 2487.924 for $n = 2$ (Section X); the roots `t_saddle`, `t_vstar`, `t_0309`, `t_0995`, `t_ceiling` of equation (26) agree with Table 3.

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