Density, nodal order and magnetic twist in rhombohedral hexalayer graphene

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Abstract

Deng et al. report superconducting-like transport and two orbital magnetic orders in the semimetallic regime of rhombohedral hexalayer graphene [1]. Fundamental Density Theory (FDT) reads the carbon nuclei as boundary clamps, the electronic modes as nodal architecture and the orbital moments as projections of a helical density gradient. The reported finite resistance, inferred Fermi surfaces and phenomenological hysteresis remain distinct evidential objects. Five prospective predictions compare isotope pairs or mirror pairs: the transition temperature, the activation-gap opening field, the Fermi-surface crossing field, triangle remanence and comet switching polarity. All five are conditional by construction: the isotope responses require constitutive sensitivities, and the mirror tests require a physical twist field. The source's fitted quantities, normalisations, estimates and Landau calculation are recovered by an explicit convergence map, and the source's tight-binding bands, density of states and layer polarisation are carried as its own outputs; the prospective differences arise from those additional inputs.

1 Framework

The target is the experimental study of Deng et al. [1]; the framework is the locked core, version 6.3 [2]. The source status is experimental. Measured, observed and reported describe the source's results; fitted, estimated, reconstructed, in-sample and illustrative-assumed distinguish their evidential origins and this analysis's calculations. SC identifiers below name source claims with physical-line locators; U identifiers name independent conventions and assumptions. FDT is a true extension of general relativity and quantum mechanics. It agrees with their data; the same source and observable dictionary recover the same numerical result. A different prediction requires an additional source, constitutive input or observable dictionary.

1.1 Notation guard

The table below defines the manuscript notation before its use. Source symbols are named in words in the left column; the right column gives their mathematical names here. Distinct fonts distinguish distinct objects, including a magnetic field from confinement boundary data. The census follows the source claims NG-01 through NG-30.

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Source quantity	Manuscript notation and reserved meaning
Carrier density	$\mathfrak{n}$ is carrier count per area; n is strand count.
Electric field and band energy	$\mathcal{E}$ is electric field; E is energy, including band energy.
Interlayer potential	$\mathfrak{U}$ is energy per layer; U is pair energy.
Magnetic field	B, with $\perp, \parallel, \mathrm{eff}, \min, \max$ subscripts; $\mathsf{B}_{\mathrm{app}}$ is the applied field. B is confinement boundary data.
Orbital magnetisation	$\mathfrak{M}$; M is rest mass and $\mathcal{M}$ the total mass-equivalent ledger.
Electric polarisation	$\mathcal{P}$; P is pressure.
Valley polarisation; voltage	V; $\mathcal{V}$; V is volume.
Bias current	I; differential resistance is $\mathrm{d}\mathcal{V}/\mathrm{d}\mathsf{I}$.
Free energy	$\mathcal{F}$; F is force.
Ferrovalley coefficient	c_{fv}; c is the omnium's strand rate.
Magnetic quadratic and quartic coefficients	$\mathsf{a}_{\mathfrak{M}2}$ and $\mathsf{a}_{\mathfrak{M}4}$; α is curvature, β_σ a computational chart.
Electric quadratic and quartic coefficients	$\mathsf{a}_{\mathcal{P}2}$ and $\mathsf{a}_{\mathcal{P}4}$; a is the radiation constant.
Coupling; thermal damping	g_{me}; w^*; w is probe weight.
Effective carrier mass	M^*; m is a pattern's rest mass, $\mathbf{m}$ its held magnetic moment.
Resistance and amplitude	$\mathcal{R}_{\mathsf{xx}}$, $\mathcal{R}_{\mathsf{xy}}$, $\Delta\mathcal{R}$, $\mathcal{R}_{\mathrm{a}}$; R denotes the Schwarzschild-radius family.
Oscillation frequencies	f_{v} is normalised; $\mathsf{f}_{\mathrm{FFT}}$ is absolute.
Structure factor	$\mathsf{h}_{\mathbf{k}}$; h is Planck's constant.
Hamiltonian	$\mathsf{H}(\mathbf{k})$, with blocks $\mathsf{H}_{\mathsf{j}}^{(0)}$, $\mathsf{H}^{(1)}$, $\mathsf{H}^{(2)}$.
Hoppings	$\mathsf{t}_0, \mathsf{t}_1, \mathsf{t}_2, \mathsf{t}_3, \mathsf{t}_4$; t is time.
Site potentials; layer index	u_{j}; j is layer index; sublattices A and B stay text labels. σ is the branch tag.
Layer count	N; N is conserved count.
Nearest neighbours	$\mathbf{d}_i$ are displacement vectors; d is length or pair separation.
Charge; exponential	e is elementary charge; the exponential is exp.
Temperature	T, with T_{c} the transition temperature; T_q is a mode period and $T_{\mu\nu}$ stress-energy.
Crystal wavevector	$\mathbf{k}$; scalar k is helical wavenumber; k_{B} is Boltzmann's constant.
Layer wavefunctions	ψ_{top}, ψ_{bot} are projections; their signed polarisation is not density.
Resistance unit; zone points	The ohm is written in words; Ω is the confinement domain. Gamma, K, K-prime and M remain zone labels in text.
Added experimental inputs	Θ_{tw} is twist angle, η_{iso} the isotope coefficient, M_{at} mean atomic mass.

The source's products of out-of-plane field, polarisation and magnetisation are scalar multiplication. The bare symbols κ, X, D, Ω, a and σ retain Einstein coupling, odds, confinement operator, confinement domain, radiation constant and branch tag respectively. The labels SC1, SC2, FS1, FS2 and FS3 name source states and pockets; they are not new mathematical variables.

1.2 One medium and its discrete content

The omnium is matter, energy and spacetime. Let ε_0 and μ_0 denote its electric and magnetic response coefficients. For energy E, rest mass m, thread length d and kept time t, core 0.1 and 0.1d give

$$\frac{E}{m} = c^2 = \frac{1}{\varepsilon_0 \mu_0} = \left(\frac{d}{t}\right)^2 . \tag{1}$$

The two responses derive c as the strand rate; its square is also the matter–energy conversion. For confined mode label q, define energy E_q, mass m_q, angular frequency ω_q, period T_q and Compton

length ℓ_q. The constants h and $\hbar = h/(2\pi)$ connect the same state in core 0.1a:

$$\begin{aligned} E_q &= m_q c^2 = \hbar\omega_q, \quad T_q = \frac{2\pi}{\omega_q} = \frac{h}{E_q}, \\ \ell_q &= cT_q = \frac{h}{m_q c}, \qquad \frac{d}{t} = c = 299792458\ \mathrm{m\,s^{-1}}. \end{aligned} \tag{2}$$

The last value is exact (U-01). The massive leg has discrete confinement eigenvalues; null periods and paths are discrete at their locked ratio. The Planck length ℓ_P and time t_P give one-sided infima $2\ell_\mathrm{P}$ and $2t_\mathrm{P}$ (core 0.1a), with no occupied endpoint or spatial lattice implied. The Compton length is not a support radius.

For axial speed v and circulation speed u, define the translation share $\mathfrak{s}$. Core 0.1d gives $v^2+u^2 = c^2$ and $\mathfrak{s} = v^2/c^2$. A closed pattern's inertia E/c^2 includes the stress of closure, as required by the von Laue condition. The share is kinematic; it equals the exterior curvature ratio only for a pattern held on that branch. An open stroke runs straight at c and keeps no time; its grades turn on a helix of radius $\bar{\lambda} = c/\omega$ at $\pi/4$, where ω is its angular frequency. For a closed pattern, the phase rate ω/k exceeds the run $\mathrm{d}\omega/\mathrm{d}k$; their product is c^2 (I-2). Those are rates, with dimensions of speed; their ratio is not a spatial pitch.

I-2 derives one spin-one carrier from one medium and one speed: photon, graviton, gluon, phonon and magnon are its five names. Its carrier-only identity excludes matter's braided closures. The core states: "There are no independent force carriers. 'Mediation' is a coordinate artifact; interactions are curvature plus geodesic motion." The driven-observable rule in I-1 is: "A driven observable (induced magnetisation, rectified signal, rate) vanishes at zero drive and never 'recovers' the static force." The source's longitudinal and Hall voltages are driven by bias current (SC-100-075, L623); their resistance ratios and differential response coefficients are finite at zero current. A remanent magnetisation prepared at zero current is a state variable, not that driven voltage.

1.3 Chart inventory and the three curvature faces

The chart inventory is fixed here. A-1 is the geometrically warranted atlas of a specified source or configuration; A-2 is its warranted computational repacking. A-3 names overlap contrast, including superconducting and magnetic ordering transitions; A-4 names confinement position and A-5 mode manifestation, a naming token for I-2 mode regimes that ranks nothing and spaces nothing. The latter three have only tokens and the open range: no geometric warrant, numerical value, threshold, ordering or sign is assigned to them. They enter no numerical prediction below.

Let R_s be a source's Schwarzschild radius, r_f its field-point radius and r_c the finite-core cutoff. The source evaluation $R_s(\mathcal{M})$, the field evaluation $\alpha_\sigma(r_f)$ and the configuration's interior evaluation are distinct uses of A-1. The branch tag is $\sigma = +1$ outside and $\sigma = -1$ inside. With Newton's constant G, the force ceiling F_max and gap odds X_ext, X_int, core 0.3 gives

$$\begin{aligned} R_s &= \frac{2G\mathcal{M}}{c^2} = \frac{\mathcal{M}c^2}{2F_\mathrm{max}}, \\ \alpha_\sigma(r_f) &= \left(\frac{R_s}{r_f}\right)^\sigma, \qquad \begin{cases} R_s < r_f, & \sigma = +1, \\ r_c \le r_f < R_s, & \sigma = -1, \end{cases} \\ X_\mathrm{ext} &= \frac{R_s}{r_f - R_s}, \qquad X_\mathrm{int} = \frac{r_f}{R_s - r_f}. \end{aligned} \tag{3}$$

Thus $\alpha_\mathrm{ext} = R_s/r_f$ and $\alpha_\mathrm{int} = r_f/R_s$ are already bounded curvature ratios. A-2's $\beta_\sigma = \alpha_\sigma/(1+\alpha_\sigma)$ is

computational, not a second physical squashing. The saturation diagnostic $\alpha_{\mathrm{core}} \to 1^-$ is schematic and refers to the interior skin. The curvature chart is continuous over the discrete content.

Let $\mathrm{d}\Omega^2_{\mathrm{ang}}$ denote the angular metric, $\mathrm{d}\ell^2_{\mathrm{opt}}$ the optical metric, and $G_{\mu\nu}$ the Einstein tensor. Einstein's equation retains stress tensor $T_{\mu\nu}$ and coupling κ; its curvature ratio is downstream (I-3):

$$\mathrm{d}\ell^2_{\mathrm{opt}} = \frac{\mathrm{d}r_f^2}{(1-\alpha_{\mathrm{ext}})^2} + \frac{r_f^2\,\mathrm{d}\Omega^2_{\mathrm{ang}}}{1-\alpha_{\mathrm{ext}}}, \qquad G_{\mu\nu} = \kappa T_{\mu\nu}. \tag{4}$$

For optical indices $n_{\mathrm{opt},1}, n_{\mathrm{opt},2}$ and incidence angles θ_1, θ_2, Fermat refraction is $n_{\mathrm{opt},1}\sin\theta_1 = n_{\mathrm{opt},2}\sin\theta_2$. Let $\mathcal{O}$ denote asymptotic order. The isotropic weak-field index $n_{\mathrm{iso}} = 1 + \alpha_{\mathrm{ext}} + \mathcal{O}(\alpha^2_{\mathrm{ext}})$ is an expansion of the optical reading, with its radial-coordinate convention held fixed. The causal-aperture candidate $n_{\mathrm{cone}} = (1-\alpha_\sigma)^{-1/2}$ is a separate object; it is not substituted for the lensing index. The unused density-index candidate n_{dens} is quarantined. Containment means the same curvature from the same stress tensor and data, not a new prediction obtained by renaming a scalar.

For an A-1 exterior odds experiment with input α_0, let x be a fractional enhancement of its odds, with $x \geq 0$. Denote the resulting exterior curvature ratio by α_{new}. I-6 gives the exact bounded response

$$\alpha_{\mathrm{new}} = \frac{\alpha_0(1+x)}{1+\alpha_0 x}, \qquad 0 < \alpha_0 < 1. \tag{5}$$

This odds experiment is distinct from changing a source mass at a fixed exterior radius. The latter is evaluated directly by Eq. (3); no linear odds formula is inserted into a curvature slot.

1.4 Force, binding and confinement

I-1's universal force uses two bounded inputs α_1, α_2, collectively α_i:

$$F = F_{\max}\alpha_1\alpha_2 = \frac{c^4}{4G}\alpha_1\alpha_2, \qquad 0 < \alpha_i < 1, \qquad F < F_{\max}. \tag{6}$$

For nonoverlapping spherical monopole supports of radii $R_{\mathrm{b},i} \geq R_{s,i}$, separated by $d \geq R_{\mathrm{b},1} + R_{\mathrm{b},2}$, the cross-centred inputs are $\alpha_i = R_{s,i}/d$. Substitution gives $F = G\mathcal{M}_1\mathcal{M}_2/d^2$ exactly on that domain, and $F \leq F_{\max}/4$ there. Equality in the latter requires saturated equal supports in contact. The universal interval and force ceiling are not restricted to this pair reduction. For positive separation coordinate s, reference separation s_0 and an attraction magnitude integrable to infinity, denoted ∞, define pair energy by

$$U(s_0) = -\int_{s_0}^{\infty} F(s)\,\mathrm{d}s, \qquad \frac{\partial U}{\partial s_0} = F(s_0). \tag{7}$$

Continuity at s_0 licenses the stated derivative; otherwise it holds almost everywhere. Energy is force times length, and a unit-normalised response kernel has inverse-length units. I-1 states: "At condensed-matter compactness the bare law returns a small number ($\sim 10^{-41}$ N): a correct prediction, not a wrong-tool symptom—and not the measured binding scale, which is reached only through a declared response kernel (rate $\neq$ force)." The binding scale in a superconducting or emergent-gap response, and the energy scale of the source's "Coulomb penalty" (SC-020-01–03, L246–248), therefore need their own kernel and integration domain.

I-4 separates the exact pair result, its weak-field slow-motion GR expansion, and the source programme. At the second layer, retain the Newtonian term and discard terms of relative order α_{ext} and v^2/c^2; the equality is at that stated order. Disjoint supports alone impose no weak-field condition. Here A is projected amplitude, ϕ phase, ϕ_0 initial phase, ψ the wavefunction and i the imaginary

unit. The quantum face is quoted whole: "QM is helical geodesics on truncated density cones. The wavefunction $\psi = A\exp(i\phi)$ is the projection of a helix onto the plane normal to the cone axis; 'superposition' is ignorance of the helical phase ϕ_0 at observation. The universe is deterministic; there are no probability amplitudes." Define cylindrical phase ϕ_h, orthonormal Clifford vectors $\mathbf{e}_1, \mathbf{e}_2$ and the phase bivector $\mathbf{B}_{\mathrm{Cl}}$. The oscillator lift is

$$\phi_h(t) = \phi_0 - \omega t, \qquad i \longleftrightarrow \mathbf{B}_{\mathrm{Cl}} = \mathbf{e}_1\mathbf{e}_2, \qquad \mathbf{B}_{\mathrm{Cl}}^2 = -1, \qquad \exp(\mathbf{B}_{\mathrm{Cl}}\phi_h). \tag{8}$$

The exponent is dimensionless; this is a single-angle phase rotor, distinct from a half-angle spinor rotor. The lift stays on the phase axis at fixed field identity; a mode receives no strand-count label.

In I-5 the electron patterns have strand count $n = 3$; the source's electron and hole surfaces remain band language. For confinement domain Ω, boundary data B, orientation χ, chart coordinate t_{chart} and mode u_q at angular frequency ω_q, the eigenproblem is

$$D(\Omega, B; n, \chi, t_{\mathrm{chart}})u_q = \omega_q u_q, \qquad m_q = \frac{\hbar\omega_q}{c^2}. \tag{9}$$

The operator D is owed (O-9). An independently specified support R_{box} is boundary data, never a radius inferred from the mass the calculation seeks. A shared electron/proton strand count allows different confinement; a changed strand count requires rebraiding. The route between lepton generations remains an open fork.

1.5 Every energy channel and the two readings

I-7 gives the mass-equivalent ledger, with σ_{SB} the radiation flux constant:

$$\mathcal{M} = M + \frac{E}{c^2} + \frac{PV}{c^2} + \frac{aT^4V}{c^2} + \cdots, \qquad a = \frac{4\sigma_{\mathrm{SB}}}{c}. \tag{10}$$

The radiation coefficient has energy-density-per-fourth-power-temperature units. The direct pressure input is small and propagates through declared sensitivities; pressure-driven lattice compression and exchange or interaction compression are density channels, never carved out. The thermal fixed-geometry partial is positive on the exterior chart; the total derivative also contains thermal expansion, heat capacity and pressure work. Cooling-side ordering "rides a separate bounded coherence coordinate, never 'lower α'" (I-7, Discipline 1); no thermal direction of α_{ext} is assigned, and no total is called negligible, from that partial alone.

The I-7 discriminator reads: "For purely density-coupled equilibrium observables, a heavier isotope $\rightarrow$ larger R_s $\rightarrow$ higher α $\rightarrow$ larger response—opposite in sign to conventional reduced-mass scaling." For observable O and inputs x_i, define $S_i = \partial \ln O / \partial \ln x_i$ with every other input fixed. The core's Discipline 2 reads: "A sign prediction competing with geometric, electronic or inertial channels is written as a sensitivity-weighted sum $\delta \ln O = \sum_i S_i \delta \ln x_i$ with every S_i defined (held-fixed variables stated). The density-channel input sign is the FDT discriminator; the observable sign is $\mathrm{sgn}(\prod_i S_i)$ and stays conditional until the sensitivities are established." Write $x_{i,\mathrm{light}}$ and $x_{i,\mathrm{heavy}}$ for the endpoints of input x_i. The infinitesimal statement becomes a finite path integral, not a local derivative multiplied by an unrestricted span:

$$\Delta \ln O = \sum_i \int_{\ln x_{i,\mathrm{light}}}^{\ln x_{i,\mathrm{heavy}}} S_i \, \mathrm{d} \ln x_i. \tag{11}$$

Each sensitivity is evaluated along the declared substitution path, with the other coordinates treated as independent arguments before restricting to that path. A constant-sensitivity example below is explicitly illustrative-assumed.

Let $\mathfrak{m}$ be a positive clock factor, $g_{\mu\nu}$ the metric, $\mathcal{U}^\mu$ a pattern's four-velocity and $\mathfrak{P}^{\mu\nu}$ its transverse projector. The covariant clock display uses proper-length parametrisation. Core 0.1c's own-clock and bookkeeper readings are

$$g_{\mu\nu} \longmapsto \mathfrak{m}^2 g_{\mu\nu}, \qquad \nabla_{\mathcal{U}} \mathcal{U}^\mu = -\mathfrak{P}^{\mu\nu} \partial_\nu \ln \mathfrak{m}. \tag{12}$$

Thread length and kept time rescale together, preserving $d/t = c$; on the pattern's own rulers and clocks nothing changes. Moving at constant speed through a density gradient is gravity, the extended equivalence principle. The slow pattern reads lapse; the stroke reads the optical metric, giving I-3's factor of two. For a medium's stress tensor of perfect form, zero net conserved count gives its temperature as the flow's clock factor; with conserved count and fixed entropy per count, enthalpy per count supplies it, each relative to a fixed reference. This describes the medium's flow; a clock it carries has its own thermal motion and rate. A conformal clock factor is neither curvature nor an optical index and does not bend a null path.

Curvature, tides and density gradients are read between neighbouring patterns or against a reference path, including an extended pattern's skin against its centre path. The gravitational bookkeeper flow has inward speed magnitude $v = c\sqrt{\alpha_{\text{ext}}}$ and radial acceleration $-G\mathcal{M}/r_f^2$ for fall from rest far away. A rotating source adds swirl: half the curl of its three-velocity gives frame drag, at leading order the Lense–Thirring precession. That curl on constant-own-time slices differs from the irrotational four-velocity of the falling flow; it is not a medium's vorticity. The flow runs at every size.

For held moments $\mathbf{m}$ in the twist field B, define reference rest energy E_0 and induced-moment energy E_{ind}, including the work of induction. Core 0.1c states that "a pattern whose rest energy depends on where it sits in a twist—the helical density gradient of P-5—takes that energy as its clock factor"; for z the coordinate along the twist's gradient, with each channel entering $\mathcal{M}$ once (I-7), it gives the helical window

$$E = E_0 + E_{\text{ind}} - \sum \mathbf{m} \cdot \mathsf{B}, \qquad \mathcal{M} = \frac{E}{c^2}, \qquad \mathfrak{m} = \frac{E}{E_0}, \qquad \mathcal{M} \frac{\mathrm{d}^2 z}{\mathrm{d}t^2} = -\partial_z E. \tag{13}$$

Each moment is held at its settled value in the slow limit between switching events. Here the clock factor belongs to the pattern, so different held and induced moments per unit energy yield different fall along a field gradient. Universality of free fall stays in the gravitational window, where the monopole clock factor belongs to the point. A uniform twist, a uniform level of $\mathfrak{m}$, turns a held moment and pushes nothing. The twist is read between patterns with differing energy ratios, fall or torque, or against a reference path; copies of one pattern turned alike conceal it at one point.

2 System chart and sampling region

Let $\rho_{\text{loc}}(r_f)$ denote local omnium density and ρ_{enc} an enclosed-mean proxy, normalised to its skin value ρ_s. They differ: the local density is densest at the skin and dilute at the centre on both branches, while the enclosed-mean proxy obeys $\rho_{\text{enc}}/\rho_s = \alpha_\sigma^{3\sigma}$ (core 0.6). For a sampled field f and nonnegative probe weight w of finite nonzero integral, the observation is

$$\langle f \rangle_w = \frac{\int w f \, \mathrm{d}V}{\int w \, \mathrm{d}V}. \tag{14}$$

This definition supplies no point value from an average. The table below states the relevant objects and regions.

Object	Chart or datum	Region and weight
Whole device	A-1 exterior $\alpha_{\text{ext}} = \mathcal{M}c^2/(2F_{\max}r_f)$	Small gravitational window at a specified exterior reference radius, and the small number is a correct reading (I-1), with the curvature of general relativity (I-3); no electronic-gap calibration.
Carbon nucleus as source	A-1 exterior compactness $\ll 1$	Outside the gravitational source support.
Carbon nucleus as clamp	A-1 interior skin, schematic $\alpha_{\text{core}} \to 1^-$	Skin radius R_{room} from independent data, absent here (U-07); no exterior-to-interior transfer.
Transport and switching	Longitudinal, Hall and differential resistance	Current-path and contact weights; Hall geometry reads the stacking-axis projection.
Transition and critical fields	Resistance criterion on a connected path	Percolation and current-path weights, not a volume-average density.
Oscillation frequencies	Extremal Fermi-surface areas	Orbit weights and carrier-state counts; not omnium density.
Calculated density of states	Energy histogram of eigenstates	Count of states per energy and cell, normalised over the sampled wavevectors and bands.
Ordering description	A-3 token; A-4 and A-5 tokens	Open ranges only; none is evaluated from these transport data.

The carbon skin and centre are distinct sampling regions. A layer-state weight is also distinct from a local material-density profile, even when the layer is called a skin. The isotope and mirror experiments below are comparison pairs in this analysis's own reading of the two readings above.

3 Observation map

The observations and their source readings are separated in the table below. Physical-line references name the actual record text, including its qualifications.

Cluster	Record object and verb class	Source anchor
Device	Reported exfoliation of a hexalayer and hBN, dry transfer around the hexalayer, and three devices with similar results	Methods; SC-052-01–05; SC-100-064–070; SC-053-01–02
Band structure	Calculated conduction–valence overlap and top–bottom layer polarisation	Fig. 1a–d; SC-008-01–04; SC-100-019–025
Neutrality	Reported transport-gap threshold approximately 100 $\mathrm{mV\,nm^{-1}}$	Fig. 1e; SC-011-03, L159
SC1	Reported sharp resistivity drop near 170 mK	Fig. 1f; SC-017-04, L124
High in-plane field	Reported persistence to approximately 6 T; Pauli limit estimated as approximately 300 mT	SC-041-02, L505; SC-041-03, L506
Finite resistance	Reported resistance short of zero in either superconducting-like state	SC-043-01–03, L508–510
Fermi surfaces	Inferred crossings, annular pockets and twofold degeneracy from oscillation frequencies	Figs. 2–3; SC-026-01–03; SC-032-05–06; SC-036-01–07
Triangle	Reported hysteretic Hall response in a region symmetric about zero electric field	Fig. 1g; SC-015-02–04, L244–246
Comet	Reported unipolar switching, with both directions offset to negative electric field	Fig. 1h; SC-100-028–031, L252–256
Magnetic polarity	Reported reversal of magnetic hysteresis with electric field; moment alignment is the source's inference	Fig. 4e; SC-047-01–06, L531–536

In the record, the rhombohedral domains were identified by using Raman spectroscopy with a 532 nm laser at room temperature (SC-052-04, L602) and then isolated by anodic oxidation lithography with atomic force microscopy, and the sequence for pickup is graphite/hBN/rhombohedral graphene/hBN/graphite from top gate to bottom gate (SC-100-064–068, L605–609). It describes one exfoliated hexalayer in that stack. The refrigerator base is 9 mK (SC-054-02, L620); this is not a measured carrier temperature. The record's three devices are a reported reproducibility statement whose detailed comparison is assigned to supplementary material. The P-3 clamp reading and the P-2 mode reading hold fixed the record's rhombohedral stacking (SC-005-01–03, L39–41) in the rhombohedral domains identified by using Raman spectroscopy (SC-052-03–04, L601–602), at structural resolution; the agreement with that input holds in every theory and corroborates no invariant (Use item 2). A mode geometry invariant under a resolved change of its effective clamps would falsify that particular clamp reading.

For SC1 and SC2, the source writes that "the resistance does not fully reach zero in either superconducting-like state, which may be due to inadequate filtering or may indicate a fragile superconducting state" (SC-043-01–03, L508–510). The source reports that, in addition to a sharp drop in resistance, they "exhibit characteristic features of superconductivity in differential resistance and under an out-of-plane magnetic field" (SC-100-043–044, L502–503). From SC-041-02 and SC-041-03, the approximate critical-to-Pauli field ratio is derived as 2×10^{1}, using two source scales each licensed to one significant figure; the source estimates the Pauli limit "based on the observed T_{c}" (SC-041-03, L506); the ratio therefore scales inversely with T_{c}, and only its numerator is measured; it is an identity-map comparison, not a pairing calculation. The P-2 nodal-channel reading holds the reported drop and field-sensitive response fixed (SC-017-04, L124; SC-100-043–044, L502–503), at transport resolution; the agreement with them holds in every theory and corroborates no invariant (Use item 2); a reproducible absence of any common coherent current path at the transition would falsify that application. The finite resistance is retained in full, and no transition criterion is inferred

from the plotted drop alone.

The source defines the "normalized oscillation frequency" by its formula and writes that, physically, it "represents the number of Bloch states enclosed by the Fermi surface relative to the carrier density" (SC-100-036–037, L373–374; SC-026-00–01, L370–371). With the frequencies, charge and carrier density defined above, its estimator and degeneracy test are

$$\mathsf{f}_{\mathrm{v}} = \frac{\mathsf{f}_{\mathrm{FFT}} e}{\mathfrak{n} h}, \qquad \mathsf{f}_{\mathrm{v}} = \frac{1}{2} = 0.5 \quad \text{for a doubly degenerate parabolic band.} \tag{15}$$

The last value is the source's peak (SC-026-03, L376). The reported quantity $\mathrm{FS3} - \mathrm{FS2} - \mathrm{FS1}$ remains nearly constant at 0.5, "consistent with the coexistence of a two-fold-degenerate electron pocket and a two-fold-degenerate annular hole pocket" (SC-036-05–07, L350–352). Reproducing either normalisation is the identity map of Use item 2 and corroborates no invariant. In the electric-field line cut at carrier density -1.26×10^{12} cm^{-2} (SC-031-01, L384), the source reports that at about 42 mV nm^{-1} "the two Fermi surfaces cross" (SC-032-05–06, L461–462). The source reports that both FS1 and FS2 exhibit strong temperature sensitivity, becoming completely suppressed at 500 mK (Supplementary Fig. 6), and that this "suggests either they are low-temperature emergence features or a substantially enhanced effective mass" (SC-035-01–04, L464–467). These are not resolved masses in this record. The I-4 phase-axis reading has only the precision of the frequency peaks and their temperature visibility; a resolved non-geodesic phase relation within the declared lift would falsify that reading. The record's total Berry phase, which in each valley scales as $\pi\mathsf{N}$ (SC-006-02–04, L43–45), is a phase winding at fixed field identity, never the strand count.

For the effective-mass fit, the damping parameter w^* and amplitude constant are those in the notation guard; the source also fits a background constant (SC-100-101–104; SC-057-01–06). Here $\mathsf{B}_{\min}$ and $\mathsf{B}_{\max}$ are the collection endpoints and $\mathsf{B}_{\mathrm{eff}}$ their harmonic mean. Its dimensional formula is

$$\frac{\Delta\mathcal{R}}{\mathcal{R}_{\mathrm{a}}} = \frac{\mathsf{w}^*}{\sinh \mathsf{w}^*}, \qquad \mathsf{w}^* = \frac{2\pi^2 k_{\mathrm{B}} T \mathsf{M}^*}{\hbar e \mathsf{B}_{\mathrm{eff}}}, \qquad \mathsf{B}_{\mathrm{eff}} = \frac{2}{1/\mathsf{B}_{\min} + 1/\mathsf{B}_{\max}}. \tag{16}$$

The window is 0.5 to 1.6 T (SC-057-04, L714); the reconstructed effective field is approximately 0.8 T, limited by the first endpoint's one significant figure. The fitted effective mass and added background are parameters fitted jointly with Eq. (16), not independent density measurements. This reproduction is another identity map and corroborates no invariant.

The comet loop uses a 50 mT stabilising perpendicular field (SC-100-048, L519). Its electric-field hysteresis polarity reverses with field sign and its size decreases with field magnitude (SC-046-01–04, L526–529). At the fixed density -0.93×10^{11} cm^{-2} (SC-047-01, L531), forward magnetic sweeps lie above backward sweeps for electric field at least -35.5 mV nm^{-1}, and the order reverses at fields no greater than -36.2 mV nm^{-1} (SC-047-02–04, L532–534). The source writes that this "demonstrates that orbital moment does not always align with the external field" (SC-047-05–06, L535–536); the observable is a Hall loop, not direct magnetometry. The P-5 moment reading holds the reported axial Hall response fixed at that sign resolution (SC-046-01–04, L526–529; SC-047-01–04, L531–534); the agreement with it holds in every theory and corroborates no invariant (Use item 2); disappearance of the axial moment in an independent probe while the same equilibrated Hall order persists would falsify this moment reading.

4 Cone-position translation

Core 0.1 states: "Density is nowhere uniform—around every point a sphere exists containing both higher- and lower-density regions—so interaction pairs are available everywhere and I-1 has no force-

free points." In the hexalayer, as at every point, interaction pairs are available everywhere and I-1 has no force-free points. No particular device region is assigned the sphere's lower-density part.

P-3 states: "Atomic nuclei are the saturated density cores of a material's Chladni volume: fixed pinning sites. The site's saturation coordinate $\alpha_{\text{core}} \to 1^{-}$ (never 1) is the skin value of the nucleus's interior chart (0.6, I-3)—'core' names the nucleus as a pinning site, not its geometric centre, which is its dilute region." Its two-channel clause states: "the site's saturation coordinate is not the exterior compactness of the same nucleus ($\ll 1$ for a laboratory nucleus); declare both charts whenever both appear." In this analysis's own reading, the carbon nuclei are those pinning sites. Their arrangement follows the source's lateral displacement of each graphene layer by one carbon–carbon bond relative to the layer beneath (SC-005-01–03, L39–41). It sets the clamps.

P-2 states: "The omnium is a vibrating elastic medium. Energy injection (acoustic, electromagnetic, thermal, parametric) excites standing density waves; the loci where the transverse density gradient vanishes ($\nabla\alpha = 0$) are the nodal lines and surfaces—the density geodesics—and excitations migrate to and lock into them as sand collects on the nodes of a vibrating plate (plate → volume → sweetline; dimension-independent). Readings: eigenstates, phonon modes and orbitals are nodal patterns of the driven density field; bonding and Cooper pairing are shared scattering-free nodal channels; localisation is trapping in disconnected nodal pockets; condensation, crystallisation and percolation are global eigenmode snaps of the standing-wave network. By I-2 the same nodal structure appears in every carrier window; mode geometry is set by the boundary conditions (the clamps, P-3), not by the medium." In this analysis's own reading, the flat-band states on the top and bottom sublattices, the only ones the source describes the stacking pattern as leaving electronically active (SC-004-01–04, L41–44), are these nodal patterns, with mode geometry set by the clamps. The superconductivity whose characteristic features the source reports is a shared scattering-free nodal channel; its onset is a global eigenmode snap. The source states themselves retain their superconducting-like designation.

P-4 gives "a Cooper pair = tip-to-tip overlap of two opposite-helicity electron cones" and the rule "same flow direction → repulsion; opposite flow direction → attraction". In the pair that the settlement joins, "opposite-sense cones mesh like gears and pull tip-to-tip into a low-curvature-energy configuration" (P-4). The sign belongs to the cone's circulation sense, not the local velocity of adjacent surfaces; magnitudes require I-1 work through the declared kernel. The source's two flavours remain generically named because their spin, valley or mixed pairing is unresolved (SC-021-01–10, L251–260). Orbital phase winding, spin and cone helicity therefore remain distinct in this reading.

P-5 states: "A magnetic field is a macroscopic helical density gradient of the omnium: the bivector grade of the density field coherently aligned along an axis; vortex lines are bivector topological defects. Imposing a physical twist (torsion, helical geometry) on a material is establishing a magnetic field; mechanical vorticity and magnetic moments are different grade projections of one density-gradient topography, with no carrier exchange (I-2). Quantitative twist → moment forms are derived in-manuscript through I-1/I-2 with a declared kernel." In this analysis's own reading, the triangle and comet moments are those projections coherently aligned along the stacking axis, the axis read by the Hall geometry. I-3a names mechanical vorticity as a projection; it is not the bookkeeper frame-drag curl.

The record's $-\mathsf{B}\mathfrak{M}$ term (SC-100-096, L637) and the ferrovalley energy attributed to its reference 10 (SC-050-05, L551) enter E/c^2 as the held-moment channel $-\sum \mathbf{m} \cdot \mathsf{B}$. The uniform stabilising field is a twist level across the device in this analysis's reading: it turns the moments and pushes nothing. The polarisation energy $-\mathcal{E}\mathcal{P}$ enters E/c^2 once. The magnetoelectric coupling $-\mathsf{g}_{\text{me}}\mathcal{P}\mathfrak{M}\mathsf{B}$ enters inside the same moment-energy channel once, not as an additional copy (SC-049-05, L543; SC-100-096, L637). The double-well terms are the adopted interaction energy's phenomenological form and enter E/c^2 once together. The source's "large Coulomb penalty" for a uniform emergent

gap across spin and valley, which "would place all four bands in the same layer" (SC-020-01–04, L246–249), is an energy difference between candidate states; it enters no additional ledger term. The thermal contribution is aT^4V/c^2; pressure and interaction compression enter through the small direct PV/c^2 input and its declared sensitivity, without duplicating the adopted interaction energy.

Core 0.1a states: "Events do not commute, and a process run backward is never the mirror of the forward event." The two hysteresis branches are two forward settlements from different starting states. The source's local free-energy minimisation is its phenomenological evolution prescription, not an objective assigned to the omnium's system-wide settlement.

5 Prospective predictions

Each block compares neighbouring devices; common instrument response cancels in the paired contrast. The additional density response is evaluated on the device's A-1 exterior chart at fixed pressure, reference radius and packing. Let $\mathfrak{f}_{\mathrm{iso}}$ be the independently inventoried isotope-sensitive rest mass divided by the baseline device $\mathcal{M}$; fixed other channels give $\Delta \ln \alpha_{\mathrm{ext}} = \ln[1 + \mathfrak{f}_{\mathrm{iso}}(\exp(\Delta \ln M_{\mathrm{at}}) - 1)]$, and the illustrative test point is $\mathfrak{f}_{\mathrm{iso}} = 1/2$ (U-89). The resulting density input is independent of the response being predicted. DC-6 (SA-05) is retired: the outer-layer share of low-energy states has no map from the local omnium profile to carrier-state layer weight (NO-MAP O-4), and P-2 sets mode geometry by boundary clamps.

5.1 Comparator reconstruction and finite sensitivity

The conventional band comparator uses the source's printed Hamiltonian (SC-055-01–14; SC-100-088–094). Let j run through the six layers, u_j be their equal-sublattice potentials and $\mathbf{d}_i$ the three nearest-neighbour vectors. The model is the block-banded Hermitian matrix with diagonal $\mathsf{H}^{(0)}_\mathsf{j}$, first upper off-diagonal $\mathsf{H}^{(1)}$, second upper off-diagonal $\mathsf{H}^{(2)}$, their adjoints below and zero blocks elsewhere:

$$
\begin{aligned}
&\mathsf{u}_\mathsf{j} = (7/2 - \mathsf{j})\mathfrak{U}, \quad \mathsf{j} = 1, \dots, 6, \qquad \mathsf{h}_\mathbf{k} = \sum_{i=0}^{2} \exp(i\mathbf{k} \cdot \mathbf{d}_i), \\
&\mathsf{H}^{(0)}_\mathsf{j} = \begin{pmatrix} \mathsf{u}_\mathsf{j} & -\mathsf{t}_0 \mathsf{h}_\mathbf{k} \\ -\mathsf{t}_0 \mathsf{h}^*_\mathbf{k} & \mathsf{u}_\mathsf{j} \end{pmatrix}, \qquad \mathsf{H}^{(1)} = \begin{pmatrix} \mathsf{t}_4 \mathsf{h}_\mathbf{k} & \mathsf{t}_3 \mathsf{h}^*_\mathbf{k} \\ \mathsf{t}_1 & \mathsf{t}_4 \mathsf{h}_\mathbf{k} \end{pmatrix}, \\
&\mathsf{H}^{(2)} = \begin{pmatrix} 0 & \mathsf{t}_2/2 \\ 0 & 0 \end{pmatrix}.
\end{aligned}
\tag{17}
$$

The source's hopping inputs are

$$
(\mathsf{t}_0, \mathsf{t}_1, \mathsf{t}_2, \mathsf{t}_3, \mathsf{t}_4) = (3120, 377, -20.6, 290, 120)\ \mathrm{meV}. \tag{18}
$$

These are SC-101-00 through SC-101-04 at L606; no missing minus sign is supplied by expectation. The Hamiltonian is an energy matrix with eigenvalue equation $\mathsf{H}\psi = E\psi$; no velocity is quoted as an energy-times-length without $\hbar$. The source's plotted finite-potential gap is a calculated reading, not an activation measurement.

Define the zero-point spacing change $\Delta \ln \mathsf{b}_\perp$ and in-plane change $\Delta \ln \mathsf{b}_\parallel$, where the b symbols here denote lengths with their stated directions. The assumed hopping law is exponential with logarithmic slope -3: intralayer hopping follows $\mathsf{b}_\parallel$, adjacent-layer hoppings follow $\mathsf{b}_\perp$, and the remote hopping is held fixed (U-20). For an observable field $\mathcal{E}_\star$ defined implicitly by a scalar condition $\mathcal{Q}(\mathcal{E}_\star, x_i) = 0$,

differentiation gives its computed local sensitivity

$$S_i^{(\star)} = -\frac{x_i}{\mathcal{E}_\star}\frac{\partial \mathcal{Q}/\partial x_i}{\partial \mathcal{Q}/\partial \mathcal{E}}. \tag{19}$$

This requires a simple root and consistent units for the two partial derivatives. For the gap, $\mathcal{Q}$ is the conduction minimum minus valence maximum of Eq. (17); for the crossing it is the independently extracted difference of the two frequencies. The latter includes the flavour-dependent emergent gap and filling, which the bare single-particle model does not fix. Thus the sensitivities are computed by the displayed implicit formula, with device-dependent derivatives retained as inputs, not assigned the gap's numerical derivatives. The finite channel change is their integral in Eq. (11). The hopping bound used below is the gap threshold's channel from Eqs. (17) and (19) under U-20 and the zero-point changes of U-18 and U-19, over the rounding intervals of the printed hoppings and rounded outward (U-22); it is not a measured sensitivity. The interlayer-potential-to-field conversion contributes minus the spacing's log change plus the screening's log change; an absolute conversion is absent from the record.

5.2 T-1: isotope shift of the SC1 transition

DC-1 discriminates SA-17: the reported resistivity drop fixes no isotope law or transition criterion. I-7 supplies an additional constitutive density channel; this prediction is conditional by construction. This analysis reads its "larger response" as a larger SC1 transition temperature. The referents are hexalayer devices made by the reported exfoliation, isolation and dry-transfer method, from enriched light and heavy carbon crystals. There are two source crystals per composition, each used on four chips; one device of each composition shares each chip, eight chips in total, with composition positions alternated chip by chip before measurement (U-13, U-14). Each chip undergoes three cooldowns: $8 \times 2 = 16$ devices, $8 \times 3 = 24$ paired cooldowns and $16 \times 3 = 48$ device observations (U-14).

The enrichment target is 99.0% for each composition (U-09), with the other isotope supplying the remainder. The isotope masses are 12.000 and 13.003 atomic mass units (U-08). Let $M_{\mathrm{at,light}}$ and $M_{\mathrm{at,heavy}}$ be their mixture means; their definition is

$$\begin{aligned} M_{\mathrm{at,light}} &= 0.99(12.000) + 0.01(13.003), \\ M_{\mathrm{at,heavy}} &= 0.01(12.000) + 0.99(13.003), \\ \Delta \ln M_{\mathrm{at}} &= \ln(M_{\mathrm{at,heavy}}/M_{\mathrm{at,light}}). \end{aligned} \tag{20}$$

The mixture convention and its atomic-mass-unit scale are U-10. Full enrichment instead gives the rounded benchmark 0.0803 (U-11); that benchmark is not substituted for the mixture ratio. At each device's own SC1 maximum at its triangle's tail (SC-016-01–04), the observable solves

$$\mathcal{R}_{xx}(T_c, \mathsf{B}_{\mathrm{app}} = 0) = \tfrac{1}{2}\mathcal{R}_{xx}(300\ \mathrm{mK}, \mathsf{B}_{\mathrm{app}} = 0). \tag{21}$$

This is the U-15 criterion, solved by the temperature sweep's half-resistance crossing. An absent unique crossing makes that device ineligible; the refrigerator base is not used as the solution.

For this observable, S_i means the derivative of $\ln T_c$ at fixed other inputs. The density coordinate is the device's exterior α_{ext} in Eq. (3), moved at fixed P, r_f and packing. The finite change is $\Delta \ln T_c = \sum_i \int S_i \, \mathrm{d} \ln x_i$; only on a constant-sensitivity path does it reduce to $\sum_i S_i \Delta \ln x_i$. The comparator is reduced-mass scaling $-\eta_{\mathrm{iso}} \Delta \ln M_{\mathrm{at}}$, with $0 \le \eta_{\mathrm{iso}} \le 1/2$ (U-12), plus every channel in the table below. The upper end of the reduced-mass interval includes the unconventional pairing mechanisms the record names (SC-044-01–04).

Co-varying channel	Bound in $\Delta \ln T_c$	Provenance
Reduced mass	$[-0.040, 0]$	U-16
Heavy-carbon hyperfine pair breaking	$[-0.010, 0]$	U-17
Interlayer and in-plane hoppings	$[+0.0002, +0.0022]$	U-22, U-23
Electron–lattice renormalisation	$[-0.003, +0.003]$	U-24
Source-crystal difference	$[-0.003, +0.003]$	U-25
Flavour A emergent gap	$[-0.005, +0.005]$	U-26
Density input	Positive input; observable sign follows S_i	I-7

The transition's spacing and intralayer-hopping sensitivities are assumed equal to the gap threshold's (U-23), not identified as the same observable. Adding bounds and rounding outward gives $[-0.070, +0.020]$, centre -0.025 and half-width 0.045 (U-27). Bounds are systematic limits, not random errors combined in quadrature.

For chip index j and cooldown index r, let y_{jr} be the heavy-minus-light log contrast, $\bar{y}_j$ its cooldown mean, $\mathfrak{c}_{\mathrm{mid}}$ the comparator centre, $\mathfrak{h}_0$ its half-width and $y_j = \bar{y}_j - \mathfrak{c}_{\mathrm{mid}}$ the residual. Define $\bar{y}$ as the chip mean, s_y its sample standard deviation, $\mathcal{N}_{\mathrm{chip}}$ the chip count and $\mathcal{H}$ the decision threshold. Let q_{t} be the Student critical quantile. The covariance-aware Student criterion is

$$\mathcal{H} = \mathfrak{h}_0 + \mathsf{q}_{\mathrm{t}} \frac{\mathsf{s}_y}{\sqrt{\mathcal{N}_{\mathrm{chip}}}}, \qquad \bar{y} > \mathcal{H}, \qquad \mathsf{q}_{\mathrm{t}} = 4.530. \tag{22}$$

The quantile is at seven degrees of freedom for the one-sided probability 0.00135, the Gaussian rate at 3 standard deviations (U-28, U-29). Device, independent cooldown and reading log scatters are respectively 0.05, 0.02, 0.01 (U-30–U-32); common chip thermometry scatter is 0.03 (U-33) and cancels before averaging. For standard deviations $\mathsf{s}_{\mathrm{dev}}, \mathsf{s}_{\mathrm{cool}}, \mathsf{s}_{\mathrm{read}}$ and cooldown count $\mathcal{N}_{\mathrm{cool}}$, the design variance is

$$\mathrm{Var}(y_j) = 2\mathsf{s}_{\mathrm{dev}}^2 + \frac{2(\mathsf{s}_{\mathrm{cool}}^2 + \mathsf{s}_{\mathrm{read}}^2)}{\mathcal{N}_{\mathrm{cool}}}. \tag{23}$$

This is the paired variance, including the subtraction of twice the common covariance. Crystal differences stay bounded systematic effects; they do not create extra independent chips. The conditional test point has constant density sensitivity $S_\alpha = 0.28/\Delta \ln \alpha_{\mathrm{ext}}$ (U-51). Its integrated density residual is 0.28 (U-50), while replacing that additional constitutive input by its consensus value gives zero residual. Using the design variance for s_y^2 gives a conservatively rounded threshold 0.2; this has one significant figure, matching the specified scatter precision. The actual decision always uses the unrounded formula with the observed s_y.

Detection: the mean residual exceeds the threshold. Exclusion: an FDT-sign residual of 0.28 in $\ln T_c$ (U-50) is excluded when the mean residual plus the threshold lies below it. Attribution: a detection is read as the density channel when external X-ray diffraction at 4 K on all four source crystals (U-13, U-54) places the interlayer log difference in $[-4.7 \times 10^{-4}, -1.6 \times 10^{-4}]$ (U-18) and the in-plane difference in $[-1.5 \times 10^{-4}, 0]$ (U-19), and the compositions' Dingle temperatures from each device's crossing-cut spectra in every cooldown agree within 10% of their mean (U-55). The null calibration and exclusion probabilities below use the chip-level covariance model and this bounded-interval rule.

5.3 T-2: isotope shift of the charge-neutral gap opening

DC-2 discriminates SA-11: the transport threshold does not fix the equilibrium activation-gap criterion or its isotope response. The I-7 density constitutive input makes this prediction conditional by construction; this analysis reads its larger response as a larger threshold magnitude. The referents

are the chips of T-1: the same eight chips, each holding one light and one heavy device, with two source crystals per composition, each on four chips, the compositions' positions alternated chip by chip, each chip through three cooldowns (U-13, U-14). Thus $8 \times 2 = 16$ devices, $8 \times 3 = 24$ paired cooldowns and $16 \times 3 = 48$ device observations are retained (U-14), with the same 99.0% composition targets and mixture masses (U-09, U-10).

Let E_{act} be the charge-neutral activation energy and $\mathcal{R}_0$ the fitted prefactor. On each field polarity fit $\ln \mathcal{R}_{xx} = \ln \mathcal{R}_0 + E_{\mathrm{act}}/(2k_{\mathrm{B}}T)$ over 0.30 to 1.00 K (U-37); the factor of two defines this activation-energy convention. Define positive and negative root fields $\mathcal{E}_+, \mathcal{E}_-$ and the gap-opening magnitude $\mathcal{E}_{\mathrm{g}}$ by

$$E_{\mathrm{act}}(\mathcal{E}_+) = E_{\mathrm{act}}(\mathcal{E}_-) = 0, \qquad \mathcal{E}_{\mathrm{g}} = \frac{|\mathcal{E}_+| + |\mathcal{E}_-|}{2}. \tag{24}$$

Separate linear extrapolations of the activated side solve the two zero conditions (U-38). A polarity-independent device offset cancels in this average; each device uses its own externally measured top and bottom hBN thicknesses and gate calibration (U-39). The correlated insulator's zero-field resistance supplies no normalisation for this definition.

Here $S_i = \partial \ln \mathcal{E}_{\mathrm{g}}/\partial \ln x_i$ holds the other inputs fixed. Equation (19) computes the gap-root sensitivities, and Eq. (11) integrates the isotope path. The density input is the device's A-1 exterior α_{ext}, with P, r_f and packing fixed. The conventional bound includes the printed band-model hopping channels, the conversion $-\Delta \ln \mathsf{b}_\perp + \Delta \ln(\text{screening})$, and the emergent gap omitted from that single-particle model.

Co-varying channel	Bound in $\Delta \ln \mathcal{E}_{\mathrm{g}}$	Provenance
Interlayer and in-plane hoppings	$[+0.0002, +0.0022]$	U-22
Conversion's spacing term	$[+0.0001, +0.0005]$	U-40
Electron–lattice renormalisation	$[-0.003, +0.003]$	U-24
Source-crystal difference	$[-0.003, +0.003]$	U-25
Heavy-carbon hyperfine channel	$[-0.001, +0.001]$	U-41
Emergent gap and screening together	$[-0.004, +0.004]$	U-42
Density input	Positive; response sign follows sensitivity	I-7

The joined interval rounded outward is $[-0.020, +0.020]$, centre 0.000, half-width 0.020 (U-43). Screening is counted only in the last joint bound. The statistic is the per-chip cooldown mean of $\ln \mathcal{E}_{\mathrm{g,heavy}} - \ln \mathcal{E}_{\mathrm{g,light}}$, with that interval's centre subtracted. The Student threshold of Eq. (22) uses eight chips, seven degrees of freedom and quantile 4.530 at probability 0.00135 (U-14, U-28, U-29), adding the half-width. Device, persistent device gate calibration, independent cooldown and reading log scatters are 0.03, 0.02, 0.01, 0.01 respectively (U-44–U-47). The gate term survives all cooldowns and enters the chip variance as twice its variance; a common thermometry term cancels in the pair. The conditional constant density sensitivity is $S_\alpha = 0.18/\Delta \ln \alpha_{\mathrm{ext}}$ (U-51). The integrated residual is 0.18 (U-50), its consensus ablation is zero and the design threshold is 0.1, at the input scatters' one-figure precision.

Detection: the mean residual exceeds the threshold. Exclusion: an FDT-sign residual of 0.18 in the field's logarithm (U-50) is excluded when the mean residual plus the threshold lies below it. Attribution: a detection is read as the density channel when external X-ray diffraction at 4 K on the four source crystals (U-13, U-54) gives interlayer log differences in $[-4.7 \times 10^{-4}, -1.6 \times 10^{-4}]$ (U-18), in-plane differences in $[-1.5 \times 10^{-4}, 0]$ (U-19), and the two compositions' Dingle temperatures from every device's crossing spectra in every cooldown agree within 10% of their mean (U-55).

5.4 T-3: isotope shift of the Fermi-surface crossing

DC-3 discriminates SA-32: the reported crossing does not establish how it moves under a density-only isotope input. The additional I-7 constitutive response makes the prediction conditional by construction; this analysis reads a larger response as a larger crossing-field magnitude. The referents are the chips of T-1: the same eight chips, each holding one heavy and one light device, with two source crystals per composition, each assigned to four chips, the compositions' positions alternated chip by chip and three cooldowns per chip (U-13, U-14). There are $8 \times 2 = 16$ devices, $8 \times 3 = 24$ paired cooldowns and $16 \times 3 = 48$ device observations (U-14), at the 99.0% composition targets and mixture definition (U-09, U-10).

Each device is set to its own calibrated density -1.26×10^{12} cm^{-2} (SC-031-01, L384). Independent oscillation spectra use the 0.5 to 1.6 T window (U-49), adopted from the source's effective-mass analysis for this different cut. Define $\mathsf{f}_{\mathrm{top}}$ and $\mathsf{f}_{\mathrm{bottom}}$ as the two continuously tracked, layer-assigned frequency branches, $\mathcal{Q}_{\mathrm{x}}$ their difference and $\mathcal{E}_{\mathrm{x}}$ its simple root:

$$\mathcal{Q}_{\mathrm{x}}(\mathcal{E}) = \mathsf{f}_{\mathrm{top}}(\mathcal{E}) - \mathsf{f}_{\mathrm{bottom}}(\mathcal{E}), \qquad \mathcal{Q}_{\mathrm{x}}(\mathcal{E}_{\mathrm{x}}) = 0. \tag{25}$$

Interpolation through a resolved sign change solves the condition; the source's approximate 42 mV nm^{-1} value is a location reference, not an input to that interpolation (SC-032-05, L461). A missing branch or unresolved degeneracy removes a crossing from the test.

Here $S_i = \partial \ln \mathcal{E}_{\mathrm{x}} / \partial \ln x_i$ fixes every other input. Equation (19) with $\mathcal{Q}_{\mathrm{x}}$ gives the crossing sensitivities, including its own field derivative; Eq. (11) supplies the finite shift. The additional coordinate is the device's A-1 exterior α_{ext}, at fixed P, r_f and packing. The comparator has interlayer and intralayer hopping bound $[+0.0002, +0.0022]$ (U-22), conversion-spacing bound $[+0.0001, +0.0005]$ (U-40), electron–lattice and source-crystal bounds each $[-0.003, +0.003]$ (U-24, U-25), hyperfine bound $[-0.001, +0.001]$ (U-41), and emergent gap with screening bound $[-0.004, +0.004]$ (U-42). Their signs form the co-varying-channel table for this block: hopping and spacing are positive, the next four channels have either sign, and the density input is positive with the observable sign set by its sensitivity. The joined field interval is $[-0.020, +0.020]$, with centre 0.000 and half-width 0.020 (U-43); its use for the crossing is an explicit bound assumption, not an identification of crossing and gap sensitivities.

Take each chip's cooldown mean of the heavy-minus-light crossing-field logarithm and subtract that centre. The one-sided Student rule uses the eight chips and seven degrees of freedom, $\mathsf{q}_{\mathrm{t}} = 4.530$ at 0.00135 probability (U-14, U-28, U-29), with the half-width added. Device, persistent gate, cooldown and reading log scatters are 0.03, 0.02, 0.01, 0.01 (U-44–U-47); the persistent terms enter before cooldown averaging and common chip thermometry cancels. At the assumed constant sensitivity $S_\alpha = 0.18/\Delta \ln \alpha_{\mathrm{ext}}$ (U-51), the integrated density residual is 0.18 (U-50), its consensus ablation is zero and the design threshold is 0.1, at one significant figure.

Detection: the mean residual exceeds the threshold. Exclusion: an FDT-sign residual of 0.18 in the field's logarithm (U-50) is excluded when the mean residual plus the threshold lies below it. Attribution: a detection is read as the density channel when external X-ray diffraction at 4 K on all four source crystals (U-13, U-54) places the interlayer log change in $[-4.7 \times 10^{-4}, -1.6 \times 10^{-4}]$ (U-18), the in-plane change in $[-1.5 \times 10^{-4}, 0]$ (U-19), and the compositions' Dingle temperatures from each device's spectra in every cooldown agree within 10% of their mean (U-55). The density response is a test of that independently constrained channel, not an isotope mass inferred from the crossing itself.

5.5 T-4: mirror-odd triangle remanence

DC-4 discriminates SA-15: hysteretic Hall transport does not fix the response to an added physical twist. P-5 supplies that additional source; this is an existence prediction, conditional by construction. In this analysis's own reading, mirror-rotated encapsulation establishes a twist field where the held moments sit in Eq. (13). The hand-to-field sign and magnitude remain unspecified; the test is two-sided.

Twelve chips each hold a mirror pair, hence $12 \times 2 = 24$ devices (U-56), made by the source's fabrication method. The top hBN angles are $+5°$ and $-5°$ from a shared hBN–hexalayer mirror plane (U-57); the bottom angles are $+10°$ and $-10°$ (U-58). External metrology measures both angles after assembly with standard uncertainty $0.10°$ each (U-59). Both top and bottom magnitude differences must lie within twice their combined standard uncertainty, with covariance included: for angle errors $\mathsf{s}_1, \mathsf{s}_2$, the difference error is $\sqrt{\mathsf{s}_1^2 + \mathsf{s}_2^2 - 2\,\mathrm{Cov}(1,2)}$. Gates, Hall bars and contacts are mirror images about that plane. An independent fair coin assigns hand to each on-chip position before fabrication (U-60); this randomisation addresses fixed position bias. The devices share cooldowns and the same lab axes for current and Hall voltage. External compensation coils reduce the in-plane component normal to the mirror plane below 0.1 mT at the sample (U-68); the along-plane field is common.

The common density is -0.90×10^{12} cm^{-2} and the common nonzero electric field is $+5$ mV nm^{-1} (U-61, U-62), inside each eligible triangle. Start at 1.0 K, which must lie above the triangle magnet's onset independently established at that density and field, and cool to a separately measured carrier temperature of 20 mK (U-63, U-64). Prepare at zero applied magnetic field and zero current; read at 1 nA after checking it lies below that state's switching current (U-65). There are twenty cooldowns per chip, $12 \times 20 = 240$ paired cooldowns and $240 \times 2 = 480$ remanence readings (U-56, U-66). After them take one saturated loop per device and one +50 mT reference cooldown per chip at the same density and field (U-67).

Let $\mathcal{R}_{\mathrm{cen}}$ be the centre of the same device's saturated loop, $p_{j,+}$ and $p_{j,-}$ its two hands' positive fractions, and d_j their hand contrast. The combined notation $p_{j,\pm}$ denotes either hand fraction and $\overline{\mathsf{d}}$ their mean chip contrast. The measured fractions and solved observable are

$$p_{j,\pm} = \frac{\#\{\mathcal{R}_{\mathsf{xy}} - \mathcal{R}_{\mathrm{cen}} > 0\}_{j,\pm}}{\mathcal{N}_{\mathrm{cool}}}, \qquad \mathsf{d}_j = p_{j,+} - p_{j,-}, \qquad \overline{\mathsf{d}} = \frac{\sum_j \mathsf{d}_j}{\mathcal{N}_{\mathrm{chip}}}. \tag{26}$$

The triangle's nonzero electric field matters: the source's cited ferrovalley form has $\mathfrak{M} = \mathsf{c}_{\mathrm{fv}} \mathsf{V} \mathcal{E}$ (SC-050-05, L551). The additional twist produces a hand-odd bias because the vertical mirror reverses hand and perpendicular field together. The conventional comparator is zero hand contrast. Joint reversal of magnetisation and magnetic field is a symmetry of the ferrovalley form and of forward relaxation into local minima without precession (SC-056-02–05, L680–683). Composing it with the vertical mirror maps one forward cooldown onto its partner at the same electric field, common perpendicular residual field and common along-plane field. The solenoid residual consequently contributes an even response that cancels in the hand contrast. This comparison is not reversal of the cooling event in time.

For sign vectors $\mathbf{r}$, with components r_j taking the two signs, define the permutation mean $\overline{\mathsf{d}}_{\mathbf{r}}$ and probability p_{perm}. The exact criterion is

$$\overline{\mathsf{d}}_{\mathbf{r}} = \frac{\sum_j \mathsf{r}_j \mathsf{d}_j}{\mathcal{N}_{\mathrm{chip}}}, \qquad p_{\mathrm{perm}} = \frac{\#\{|\overline{\mathsf{d}}_{\mathbf{r}}| \geq |\overline{\mathsf{d}}|\}}{2^{\mathcal{N}_{\mathrm{chip}}}}, \qquad p_{\mathrm{perm}} \leq 0.0027. \tag{27}$$

All $2^{12} = 4096$ flips are used (U-70); the chip, not each cooldown, is the randomisation unit. The sign table is explicit: device bias has either sign, residual field is common, position bias has either

assigned hand after the coin, readout errors attenuate contrast, and the added twist is hand-odd with unassigned orientation. For the illustrative covariance model (U-72–U-75), device logit bias has standard deviation 1.0, the paired-cooldown common residual term mean 0.5 and standard deviation 0.5, the position term magnitude is 0.3, and readout misclassification is 1%. The simulation treats position as opposite signs in the two positions; the pre-fabrication coin assigns their hands.

Define the permutation scale $\mathsf{s}_{\mathrm{perm}} = \sqrt{\sum_j \mathsf{d}_j^2}/\mathcal{N}_{\mathrm{chip}}$ and its attainable critical multiplier $\mathsf{z}_{\mathrm{perm}}$. At the conditional test point $\mathsf{d}_j = +0.6$ on every chip (U-86, U-87), $\mathsf{z}_{\mathrm{perm}} = \sqrt{12}$ and $\mathsf{s}_{\mathrm{perm}} = 0.6/\sqrt{12}$, so the block's attainable $\mathsf{z}_{\mathrm{perm}}\mathsf{s}_{\mathrm{perm}}$ threshold is 0.6. This is the exact lattice threshold at the stated probability, not a Gaussian substitution. The density-twist input gives contrast 0.6; setting its field to the comparator value gives zero (U-86). The test point instantiates a conditional magnitude and does not assign a universal twist-to-field coefficient.

Detection: $p_{\mathrm{perm}} \le 0.0027$ (U-70). Exclusion: a contrast of 0.6 (U-80) is excluded when the sign-flip tests of the differences shifted by $+0.6$ and by -0.6 both reject at that same probability. Attribution: a detection is read as the twist's field when this remanence test and the comet-step test give one sign of an equivalent perpendicular field, each against its own +50 mT reference, with the mirror, angle-magnitude and in-plane conditions met (U-82).

5.6 T-5: mirror-odd comet-step polarity

DC-5 discriminates SA-46: reversal with an externally applied field does not determine the response to the encapsulation's added field. P-5 supplies that source; this existence prediction is conditional by construction and the physical-twist identification is this analysis's own reading. The vertical mirror makes the extra field hand-odd, with its magnitude and orientation left open.

The referents are the mirror pairs of T-4: the same twelve chips, $12 \times 2 = 24$ devices (U-56), with top hBN at $\pm 5^\circ$ and bottom hBN at $\pm 10^\circ$ about a shared mirror plane (U-57, U-58). Both angles are measured externally after assembly with 0.10° standard uncertainty (U-59); each top and bottom magnitude difference must be within twice its covariance-aware combined standard uncertainty. Gates, Hall bars and contacts mirror the plane; an independent fair coin assigns hand to each position before fabrication (U-60), cancelling fixed position bias under the exact randomisation. Both hands use the same lab current and Hall-voltage axes and paired preparations. The common in-plane component lies along the mirror plane; external coils and sample readout bound the component normal to it below 0.1 mT (U-68). A carrier target of 20 mK is independently checked (U-64).

The common density is -0.46×10^{11} cm^{-2} (U-77), adopted from the record's comet loops. At zero applied perpendicular field and zero current, prepare at -45 mV nm^{-1}, then sweep forward to -30 mV nm^{-1} (U-78), crossing the reported forward switch near -34 mV nm^{-1} (SC-100-030, L255). Read at the qualified sub-switching current 1 nA (U-65). Use twenty forward sweeps per device, $24 \times 20 = 480$ device sweeps (U-56, U-78), then one +50 mT reference sweep per device, 24 references in total (U-79). Each sweep starts from the same forward-history preparation; it is not the time reverse of its partner.

Define $\Delta\mathcal{R}_{\mathrm{step}}$ as post-switch minus pre-switch Hall resistance, after subtracting the device's own loop centre, and use $\mathcal{N}_{\mathrm{sweep}}$ for the sweep count. The positive fractions and contrast solve the step-polarity observable by counting:

$$p_{j,\pm} = \frac{\#\{\Delta\mathcal{R}_{\mathrm{step}} > 0\}_{j,\pm}}{\mathcal{N}_{\mathrm{sweep}}}, \qquad \mathsf{d}_j = p_{j,+} - p_{j,-}, \qquad \overline{\mathsf{d}} = \frac{\sum_j \mathsf{d}_j}{\mathcal{N}_{\mathrm{chip}}}. \tag{28}$$

The source reports that electric-field hysteresis polarity reverses as perpendicular field changes sign

(SC-046-01–02, L526–527). With the applied field zero, the added twist is part of the field where the moments sit and supplies a hand-odd polarity. The solenoid's residual field remains; the coupling $-\mathsf{g}_{\mathrm{me}}\mathcal{PMB}$ does not vanish merely because the applied setting is zero (SC-049-05, L543). Joint reversal of moment and field is a symmetry of the full source functional (SC-100-096, L637) and of its forward local-minimum relaxation (SC-056-02–05, L680–683). Composed with the vertical mirror and applied to one forward sweep in each device, it gives hand-even polarity statistics at the common perpendicular residual field and common along-plane field. Thus the conventional hand-contrast comparator is zero.

The twelve chip differences use all $2^{12} = 4096$ sign flips and the two-sided rule $p_{\mathrm{perm}} \le 0.0027$ (U-70), with Eq. (27)'s covariance-preserving unit. Device logit scatter 1.0, paired-preparation residual mean 0.5 and scatter 0.5, opposite-position term 0.3 and misclassification 1% define the illustrative model (U-72–U-75). Its channel signs are: either-sign device bias, common residual field, randomised position sign, contrast-attenuating readout error and hand-odd twist with unassigned sign. At the conditional test point $\mathsf{d}_j = +0.6$ on every chip (U-86, U-87), the permutation scale is $0.6/\sqrt{12}$, the critical multiplier $\sqrt{12}$ and their product, the attainable threshold, 0.6. The added-field prediction is 0.6 and its consensus ablation is zero (U-86).

Detection: $p_{\mathrm{perm}} \le 0.0027$ (U-70). Exclusion: a contrast of 0.6 (U-80) is excluded when the sign-flip tests shifted by $+0.6$ and -0.6 both reject at that probability. Attribution: the comet and triangle tests must give one equivalent perpendicular-field sign against each device's own +50 mT reference, with all mirror, angle-magnitude and in-plane conditions met (U-82). A sign difference between those two calibrated responses fails this attribution rule even if both detection tests reject.

5.7 Calibration of the decision rules

The simulation law is U-84: independent Gaussian device and reading terms, with the common terms retained before paired differencing; mirror outcomes are logistic Bernoulli trials with independent readout errors. The source-crystal terms occupy the stated systematic interval and are not sampled as independent cooldown noise. For the isotope rules, the two-device covariance gives Eq. (23); the field rules add the persistent gate variance. At the interval's upper endpoint the rejection rule becomes the bare Student test exactly. At its centre the half-width remains and reduces false rejection. Each isotope scenario uses 2×10^6 trials (U-34); the mirror scenarios use 2×10^5 (U-71), with numerical seed 20261031 (U-85). The simulation scales are specified numerical conventions; each uncertainty below contains the binomial Monte Carlo standard error and no uncertainty in a physical response; the table's interval-centre false rejections and its four exclusions carry the root-sum-square of that error and of the larger of their two changes when each one-figure isotope scatter (U-30–U-32, U-44–U-47) moves alone from its printed value to either edge of its rounding interval. For trial count $\mathcal{N}_{\mathrm{trial}}$ and rejection count $\mathcal{N}_{\mathrm{rej}}$, define rate $\widehat{p} = \mathcal{N}_{\mathrm{rej}}/\mathcal{N}_{\mathrm{trial}}$ and error $\mathsf{s}_{\mathrm{MC}} = \sqrt{\widehat{p}(1-\widehat{p})/\mathcal{N}_{\mathrm{trial}}}$.

Rule	False rejection, upper endpoint	False rejection, interval centre
Transition isotope	0.00134 ± 0.00003	0.000008 ± 0.000005
Gap and crossing isotopes	0.00132 ± 0.00003	0.00006 ± 0.00003
Rule	**Exclusion, upper endpoint**	**Exclusion, interval centre**
Transition isotope	0.97 ± 0.04	0.998 ± 0.005
Gap and crossing isotopes	0.98 ± 0.05	1.00 ± 0.01

The field rules share one noise model, not independent calibration evidence. The exclusion calculations

contain no density channel and use the targets stated in their respective blocks. For both mirror rules, the randomised sign-flip false-rejection rate is 0.0018 ± 0.0001. Holding the hands fixed raises it to 0.017 ± 0.009 under the same position term; this spread and that of the exclusion below are the root-sum-square of their binomial Monte Carlo standard errors and of the larger of their two changes when each noise-model input (U-72–U-75) moves alone from its printed value to either edge of its rounding interval, each change taken on a common-random-number stream of 6×10^5 trials that begins with the scenario's own (U-90). The two-sided Student test gives 0.0030 ± 0.0001 and is not the decision rule. The two-shift exclusion probability is 0.93 ± 0.03 with no hand effect. The exact randomisation test remains conservative at its discrete tail. All probabilities are per observable; no family-wise discovery claim is attached to testing the full collection.

6 Cross-domain comparison

The common content of the isotope and magnetic experiments is the I-7 energy ledger. The isotope substitution changes its rest-mass channel at a fixed exterior geometry; the physical twist changes the held-moment energy where the pattern sits. Neither procedure identifies the very small gravitational compactness of the device with its superconducting gap. The isotope observable requires a constitutive sensitivity, and the mirror observable requires an added field and its symmetry-controlled comparison. Those are the two distinct sources of prospective difference.

I-1 continues to fix force and work on their declared domains. I-2 makes optical, elastic and magnetic carrier windows readings of one stroke, while P-2 makes their mode geometry a boundary problem. A transport coefficient, an orbit frequency and a local moment use different weights in Eq. (14); numerical equality between them has no invariant meaning without a response map. The phase lift carries the oscillations, while I-5 carries the electron configuration and its confinement spectrum. The experiment therefore compares the same architecture across carrier windows without extracting an absolute particle address from a band fit.

The magnetic symmetry comparison is particularly restrictive. A field common to mirror partners contributes to both; its even contribution cancels only with the stated matching of angles, contacts, axes and in-plane field. The random coin protects against fixed position bias, while the magnitude-matching bound protects the geometry. A successful hand-odd contrast outside those conditions is a detection of asymmetry, with the twist attribution unresolved by that design. The isotope analogue is the independent lattice and Dingle-temperature condition: the contrast alone does not separate a density input from changed packing or disorder.

7 System-level reading (exploratory)

Scope: this section reconstructs the source's phenomenological local-minimum model in sample; it supplies no additional prospective prediction.

7.1 X-1: coupled switching under forward relaxation

Observable: the direction and order of the comet's Hall switching, read as the source model's coupled electric and magnetic branches. Defining condition: stationary local minima of the reported functional, with the preceding field point supplying the initial state. Comparator: the same source functional and continuation prescription, not a new FDT coefficient. With the notation-guard coef-

ficients, the source's model (SC-100-096, L637) is

$$\begin{aligned}\mathcal{F} = &-\frac{\mathsf{a}_{\mathcal{P}2}}{2}\mathcal{P}^2+\frac{\mathsf{a}_{\mathcal{P}4}}{4}\mathcal{P}^4-\frac{\mathsf{a}_{\mathfrak{M}2}}{2}\mathfrak{M}^2+\frac{\mathsf{a}_{\mathfrak{M}4}}{4}\mathfrak{M}^4\\&-\mathcal{E}\mathcal{P}-\mathsf{B}\mathfrak{M}-\mathsf{g}_{\mathrm{me}}\mathcal{P}\mathfrak{M}\mathsf{B}.\end{aligned}\tag{29}$$

Its dimensionless parameter tuple is $(1, 1, 1, 1, 2.5)$ in the order of the four displayed quadratic/quartic coefficients and the coupling (SC-100-095, L673). The source states that "the minimization at each field point is initialized from the converged solution at the preceding" field value, "thereby tracking local free-energy minima rather than enforcing global minimization" (SC-056-02–05, L680–683). Differentiating Eq. (29) gives the defining equations

$$\begin{aligned}0&=-\mathsf{a}_{\mathcal{P}2}\mathcal{P}+\mathsf{a}_{\mathcal{P}4}\mathcal{P}^3-\mathcal{E}-\mathsf{g}_{\mathrm{me}}\mathfrak{M}\mathsf{B},\\0&=-\mathsf{a}_{\mathfrak{M}2}\mathfrak{M}+\mathsf{a}_{\mathfrak{M}4}\mathfrak{M}^3-\mathsf{B}-\mathsf{g}_{\mathrm{me}}\mathcal{P}\mathsf{B}.\end{aligned}\tag{30}$$

Positive definiteness of the Hessian selects the minima; its diagonal entries are $-\mathsf{a}_{\mathcal{P}2}+3\mathsf{a}_{\mathcal{P}4}\mathcal{P}^2$ and $-\mathsf{a}_{\mathfrak{M}2}+3\mathsf{a}_{\mathfrak{M}4}\mathfrak{M}^2$, and its off-diagonal entry is $-\mathsf{g}_{\mathrm{me}}\mathsf{B}$. At zero electric and magnetic fields the solved branches are $\mathcal{P}=\pm\sqrt{\mathsf{a}_{\mathcal{P}2}/\mathsf{a}_{\mathcal{P}4}}$ and $\mathfrak{M}=\pm\sqrt{\mathsf{a}_{\mathfrak{M}2}/\mathsf{a}_{\mathfrak{M}4}}$. The printed positive coefficients give stable minima there. Tracking a branch to loss of Hessian positivity produces its metastability boundary; selecting the previous branch supplies the history dependence. The model is invariant under joint reversal of magnetisation and magnetic field with electric polarisation and electric field fixed, the algebra used by the mirror comparator.

Guards: all coefficients and branch shapes here are in-sample descriptions, with dimensionless simulation normalisation and no conversion to a measured magnetic moment supplied. The local-minimum objective belongs to the source model. The two sweep directions start from different states, and neither is declared the mirror event of the other. The zero-field stationary solutions corroborate no invariant because they solve the source's own functional.

8 Convergence statement

The limiting map holds the source's stress tensor, geometry, band parameters, preparation history and observable dictionary fixed. In I-3 it returns the same curvature, and in I-4's weak-field slow-motion layer it returns the same retained expansion order. For the experimental calculations, the limiting map holds the source's calculated band structure (SC-055-01–02, L631–632), density of states and "layer polarization" (SC-100-086–087, L628–629) fixed as the source computed them; at the printed parameters and signs Eq. (17) gives a 2.5 meV band overlap at $\mathfrak{U}=0.5$ meV per layer (U-83); in the source, "as the field increases, the potential further separates the conduction and valence bands and produces a bandgap (Fig. 1d)" (SC-100-022–023, L149–151; SC-100-017, L95). The signed layer ratio is $(|\psi_{\mathrm{top}}|^2-|\psi_{\mathrm{bot}}|^2)/(|\psi_{\mathrm{top}}|^2+|\psi_{\mathrm{bot}}|^2)$ (SC-100-087, L629), a state-weight ratio, not a local density coordinate. The frequency normalisation and sum rule, the Lifshitz–Kosevich formula with its fitted background, the Pauli estimate and the local-minimum Landau calculation are the identity map on the source's own inputs. They corroborate no invariant and are not counted among the prospective predictions. The two isotope field tests set the additional density sensitivity to zero in their consensus limit; the transition test retains its reduced-mass and bounded nuisance terms. The mirror tests set the added encapsulation field to its conventional value and retain the residual applied field, whose symmetry-even part cancels.

For SA-22, the source states that at $\mathcal{E}=0$ "single-particle theory predicts wavefunctions as equal-weight superpositions of the top and bottom layers" (SC-022-01–02, L261–262). FDT reads those

wavefunctions as the I-4 helical projection with phase ignorance; the calculated equal weights are carried as the source's own outputs. For SA-44 (SC-044-01–04, L511–514), the source writes that the emergence "of SC1 and SC2 from the dual-carrier Fermi-surface regime suggests that superconductivity may be associated with unconventional pairing mechanisms, such as exciton-mediated electron pairing or electron–hole fluctuations". FDT reads the shared channel as curvature and geodesic motion of I-2's one carrier, with its binding energy given by I-1 work through a declared response kernel; the reported transport is accepted in full and recovered on the source inputs. For SA-48, the source states that the ferrovalley orbital moment remains aligned with the external magnetic field (SC-048-03–04, L556–557). FDT reads magnetism as P-5's helical density gradient, with mechanical vorticity and magnetic moment as different grade projections; the reported Hall switching and its source-model reconstruction are retained by the same limiting map.

9 Status ledger

The table below states the programme obligations, conditional scope and convergence values. The held-out mass ratios are targets, not outputs of the eigenproblem in this analysis.

Item	Status and referent
O-1	The finite-core cutoff r_c, regular core chart or outward phase-transfer law is owed.
O-2	A geometrically constructed odds for overlap contrast A-3 is owed.
O-3	A canonical odds for confinement application A-4 is owed.
O-4	The local profile $\rho_{\mathrm{loc}}(r_f)$ from the omnium constitutive law with boundary, surface and core data, reducing to the measured nuclear profile, is owed; it supplies no layer-state-weight map here.
O-5	Multipole and tidal remainders of the closed-form pair expression, and their reading of the band $R_H < r_f < R_s$ outside a rotating source's horizon (radius R_H); the overlap complex; and how the many-cone settlement signs a pair it does not join are owed.
O-6	Maps from a charge, circulating charge or colour seat to an I-1 input, derivation of the A_2 seat table from cone geometry and the gluon octet's dynamics are owed; the twist-response kernel belongs here.
O-8	The constitutive derivation of the causal-aperture speed and n_{cone}, and their reconciliation with lensing, are owed.
O-9	The confinement operator D, its domains, boundary data and spectrum, and every mass ratio, including the two held-out targets, are owed. Held-out targets: proton/electron 1836.15267343 (U-05) and squared muon/electron 4.2753×10^4 (U-06).
O-16	The kinematic reading of the share on the interior chart is owed: the flow reading of 0.1c stops at the fold, and the velocity sphere is the support only for a pattern held on the exterior branch.
A-3, A-4, A-5	PROVISIONAL tokens with range only; no geometric warrant, value, ordering, threshold or sign assigned.
A-2; skin diagnostic	Computational chart only; $\alpha_{\mathrm{core}} \to 1^-$ is schematic interior-skin saturation, never an exterior value.
T-1	Prospective; conditional by construction on the density sensitivity and nuisance bounds. Consensus: reduced-mass and bounded comparator interval, zero additional density residual.
T-2	Prospective; conditional by construction on the activation root, density sensitivity and conversion bounds. Consensus: bounded gap-field interval, zero additional density residual.
T-3	Prospective; conditional by construction on resolved branches and crossing sensitivities. Consensus: bounded crossing-field interval, zero additional density residual.
T-4	Prospective existence response; conditional by construction on physical twist and matched mirror geometry. Consensus hand contrast: zero.
T-5	Prospective existence response; conditional by construction on physical twist and forward-history symmetry. Consensus hand contrast: zero.
X-1	In-sample source-functional reconstruction; no additional prediction.
Source-input identities	Frequency and state counts, fitted damping and background, Pauli comparison and phenomenological hysteresis retain their source dictionary.
Source outputs	The tight-binding bands, density of states and layer polarisation are carried as the source's own outputs.

10 Conclusions

The hexalayer supplies three distinct objects: a structural clamp arrangement, transport and oscillation observations, and model-dependent readings of their order. FDT connects the first two through nodal architecture, with the carbon nuclei as pinning sites and the magnetic order as aligned projections of a helical density gradient. The finite resistance and unresolved flavour identity remain part of that reading. The source's fitted quantities, normalisations, estimates and Landau calculation are recovered on their own inputs; the source's tight-binding bands, density of states and layer polarisation

are carried as its own outputs (U-83).

The prospective difference lies in an additional density constitutive response or an added twist field. Isotope tests isolate the former through bounded comparator channels and independent lattice and disorder conditions. Mirror tests isolate the latter through matched geometry, a pre-fabrication hand coin and an exact chip-level sign-flip rule. Their conditional amplitudes are specified test points; a branch label or small compactness alone generates none of them. The independent source-input convergence and the explicit additional-input tests are the two operative faces of the extension.

References

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[2] *Core FDT invariants*, locked version 6.3. Core 0.1–0.6, I-1–I-7, P-1–P-5 and Use items.