The Six Laws of Spatial Displacement Theory

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SPATIAL DISPLACEMENT THEORY — COMPLETE LAWS

James Tyndall Melbourne, Australia March 2026

Nine axioms. Two lemmas. Seventeen theorems. One measured calibration (hydrogen). Built on a single medium with one tick rate.

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Law I — Cosmological Relay Throughput

COSMOLOGICAL RELAY THROUGHPUT Formal Statement and Numerical Verification Spatial Displacement Theory — Law I James Tyndall Melbourne, Australia March 2026 The spation lattice is a globally phase-loaded nearest-neighbour relay medium. Every spation, every Planck tick, simultaneously receives, transits, and retransmits the full isotropic throughput state. Because shell multiplicity exactly cancels inverse-square dilution, the steady-state concurrent relay burden through any interior point is Φ = Nε. One calibration constant (the hydrogen force match).

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1. Physical Foundation The spation lattice is the propagation medium for all electromagnetic radiation. At recombination, the universe entered a radiatively open state in which every spation that had been holding deformation content released it omnidirectionally. The resulting cascade of expanding spherical fronts continues to propagate through the lattice. What we observe as the cosmic microwave background is the spectral residue of this already-arrived convergence. This law establishes the quantitative throughput budget of the medium: how much convergent relay content intersects any spation at any tick.
2. Axioms Axiom R1 — The Lattice Space is a countable set Λ of spation positions forming a regular lattice with nearest-neighbour spacing: ℓP = 1.616255 × 10−35 m (R1) Axiom R2 — The Tick The lattice evolves in discrete time steps of duration: tP = 5.39124 × 10−44 s (R2) At each tick, every spation executes one relay operation. The relay advances one spacing per tick: c · tP = ℓP (R2′) Axiom R3 — Pre-Clearing State Before the Clearing, each spation held deformation content in local thermal equilibrium at the recombination temperature Trec ≈ 3000 K: εheld = a Trec4 · ℓP3 (R3) Axiom R4 — The Clearing At the Clearing, every spation transitioned from non-transmissive to transmissive and released its held content isotropically over 4π steradians: εreleased(xi) = εheld, ∀ xi ∈ Λ (R4) Axiom R5 — Faithful Relay After the Clearing, each spation relays every arriving deformation front to its downstream neighbours without loss, absorption, or scattering. The medium is inviscid: εout(xi, n) = εin(xi, n) (R5)

Axiom R6 – Contact event When a kinematic front is passed to a spation in contact with a particle of matter, the spation relays the front with perfect fidelity but the particle absorbs the content. The absorbed content becomes mass-energy of the vortex. The unabsorbed remainder continues with fidelity. Axiom R7 — Occlusion A particle with a cross-section of σ intercepts fraction: focc = σ / (4πr2) (R6) of any arriving front. The intercepted content is absorbed. The remainder continues with fidelity.

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1. Definitions Definition 1 (Shell at depth d). For target spation x0, the shell at depth d is the set of all spations at graph distance exactly d lattice spacings: Sd(x0) = { xi ∈ Λ : d(x0, xi) = d } (D1) Definition 2 (Shell population). In the continuum limit of a regular 3D lattice: |Sd| = 4π d2 + O(d) (D2) Definition 3 (Elementary relay content). The relay content associated with one occupied shell-stage at the present epoch: ε = uCMB · ℓP3 =

a T04 · ℓP3 (D3) Definition 4 (Causal depth). The number of Planck-scale relay stages between any interior point and the Clearing: N = RCMB / ℓP (D4)

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4. The Shell Cancellation Identity Lemma 1 — Single-Source Contribution Lemma 1. A single source at depth d contributes to the target: δΦi = ε / (4π d2) (L1) Proof. Isotropic release (R4) distributes ε over 4π steradians. Target subtends solid angle 1/d2 at distance d. Fidelity (R5) preserves content in transit. Therefore δΦi = ε/(4π) · 1/d2 · 4π/(4π) = ε/(4πd2). ■ Lemma 2 — Shell Population Lemma 2. |Sd| = 4πd2 + O(d). Proof. Lattice points at graph distance d in 3D occupy a spherical shell of area 4π(dℓP)2. At one point per ℓP2 of surface: |Sd| = 4πd2. Discreteness corrections are O(d), negligible for d ≫ 1. Since N ∼ 1061, the correction vanishes for all relevant shells. ■ Theorem 1 — Shell Cancellation Theorem 1. The total convergence from all sources at depth d is independent of d: Φshell(d) = |Sd| · ε/(4πd2) = ε (T1) Proof. By Lemma 1, each source contributes ε/(4πd2). By Lemma 2, there are 4πd2 sources. Product: 4πd2 × ε/(4πd2) = ε. The d-dependence cancels identically. This is an exact geometric identity in Euclidean 3-space requiring only: isotropic release (R4), faithful relay (R5), and Euclidean shell area (D2). All three are exact. ■ Remark. This identity holds across 61 orders of magnitude: from d = 1 (nearest neighbour) to d = N ≈ 5.9 × 1061 (the Clearing). The cancellation is not approximate. It follows from the geometry.

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5. Convergence Accumulation Theorem 2. The total convergence burden at any interior point is: Φ = N · ε (T2) Proof. Sum Theorem 1 over all shells: Φ = Σd=1N Φshell(d) = Σd=1N ε = Nε Each tick brings one additional shell into the causal domain. Since every shell contributes ε (T1), the total grows linearly with tick count. At the present epoch, N = RCMB/ℓP shells have arrived. ■

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6. Numerical Verification All values computed from CODATA 2018 constants and standard CMB observations. One calibration point (hydrogen). 6.1 Input Constants Symbol | Quantity | Value | Source | | c | Speed of light | 299 792 458 m/s | SI exact | | ℓ_P | Planck length | 1.616255 × 10^{-35} m | CODATA 2018 | | t_P | Planck time | 5.39124 × 10^{-44} s | CODATA 2018 | | a | Radiation constant | 7.5657 × 10^{-16} J/m³/K⁴ | CODATA 2018 | | T_CMB | CMB temperature | 2.725 K | FIRAS/COBE | | H_0 | Hubble parameter | 68 km/s/Mpc | Planck 2018 | | z_rec | Recombination redshift | 1100 | Planck 2018 | | 6.2 Derived Quantities CMB energy density: uCMB = aT04 = 7.566 × 10−16 × 2.7254 = 4.172 × 10−14 J/m3 Distance to Clearing: RCMB = ln(1 + zrec) / σ0 = 9.527 × 1026 m Number of Planck shells: N = RCMB / ℓP = 5.894 × 1061 Elementary relay content: ε = uCMB · ℓP3 = 4.172 × 10−14 × 4.222 × 10−105 = 1.761 × 10−118 J 6.3 Shell Cancellation Verification Shell depth d | Sources 4πd^2 | Dilution 1/(4πd^2) | Shell contribution | | 10^0 | 1.26 × 10^1 | 7.96 × 10^{-2} | 1.761 × 10^{-118} J | | 10^{10} | 1.26 × 10^{21} | 7.96 × 10^{-22} | 1.761 × 10^{-118} J | | 10^{30} | 1.26 × 10^{61} | 7.96 × 10^{-62} | 1.761 × 10^{-118} J | | 10^{61} | 1.26 × 10^{123} | 7.96 × 10^{-124} | 1.761 × 10^{-118} J | | Exact invariance across 61 orders of magnitude. 6.4 Principal Results Quantity | Symbol | Value | | Relay content per shell | ε | 1.761 × 10^{-118} J | | Shells to Clearing | N | 5.894 × 10^{61} | | Throughput per spation | Φ = Nε | 1.038 × 10^{-56} J | | Boundary source cells | S = 4πN^2 | 4.366 × 10^{124} | | The 10^{123} | N^2 | 3.474 × 10^{123} | |

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7. Resolution of the Cosmological Constant Problem QFT estimates the vacuum energy density by summing zero-point modes to the Planck cutoff: uQFT ∼ EP / ℓP3 ∼ 10113 J/m3 The observed dark energy density: uΛ ≈ 5.36 × 10−10 J/m3 The discrepancy uQFT / uΛ ∼ 10122–123 is the cosmological constant problem. SDT resolution: N2 = 3.474 × 10123 is not a failed cancellation. It is the number of boundary-condition source cells on the Clearing. QFT computed the correct total throughput and then had no mechanism to spend it. SDT identifies the mechanism: every Planck cell on the Clearing boundary transmits one unit of relay energy per tick through every spation in the interior. The sum is large because the boundary is far and its surface area is N2. The energy is not stored. It is not vacuum fluctuation. It is transit.

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8. Derivation Status Class: Derived from CMB observables, Planck units, and Euclidean solid-angle geometry. Free parameters: One calibration (hydrogen Coulomb match at the Bohr radius). Shell cancellation theorem: Exact geometric identity. Verified across 61 orders of magnitude. Falsification: If the CMB is not isotropic to

the required precision, or if the lattice spacing is not ℓP, the law fails quantitatively. The shell cancellation itself is unfalsifiable—It follows from the geometry.

Law II — The Release Cascade

THE RELEASE CASCADE Formal Theorem and Proof Spatial Displacement Theory — Law II James Tyndall Melbourne, Australia March 2026 The Clearing was the epoch at which every spation that could not transmit released its held deformation content omnidirectionally. The local convergence state at any interior point is the superposed arrival of expanding spherical fronts from every source at every depth, faithfully relayed through every intermediate spation. The apparent distant CMB surface is the optical reconstruction of causal depth. The pressure is the mechanical primitive.

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1. Physical Foundation Before recombination, the spation lattice was opaque. Photons could not propagate—their mean free path was shorter than any macroscopic scale. Every spation was coupled to its neighbours through matter-radiation interaction: holding deformation content that it could not transmit. At recombination ($z \approx 1100$, $T \approx 3000$ K), the coupling broke. The lattice entered a free-relay state. This was the Clearing—not merely "transparency began" but a universal discharge event in which every previously non-transmissive spation released its held content omnidirectionally. Each released front propagates as an expanding spherical shell at c. Each downstream spation faithfully relays every arriving front. Every spation is therefore both a source of its own released content and a relay of every other spation's released content. The local state at any interior point is the superposition of all arrived fronts.

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2. Axiom Application This theorem builds on Axioms R1–R6 established in Law I. The key axioms are: R3 (Pre-Clearing): Each spation holds εheld = aTrec4·ℓP3, cannot transmit. R4 (Clearing): Every spation releases εheld isotropically over 4π sr. R5 (Fidelity): All fronts relayed without loss. R6 (Occlusion): Matter intercepts fraction $\sigma/(4\pi r^2)$ of any front.

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3. The Release Mechanism 3.1 Each Spation as Source At the Clearing, spation xi releases content ε0 as a spherical shell. At tick n after release: Shell radius: rn = n · ℓP Shell surface area: An = 4π(nℓP)2 Content per unit area: ε0 / (4π n2ℓP2) 3.2 Each Spation as Relay When the expanding shell from source xi reaches spation xj, spation xj relays it onward with fidelity (R5). It adds nothing and removes nothing. But xj is also a source: it released its own ε0 at the Clearing. Every spation has this dual role: source AND relay. 3.3 Fidelity and Inviscidity The relay is faithful. No absorption, no scattering (after the Clearing), no dissipation. The medium is inviscid: it transmits deformation without extracting energy. Exception: When a front encounters matter (a displacement vortex), the vortex occludes the front. The occluded fraction does not pass through. The unoccluded fraction continues. This interruption is the sole mechanism that produces force.

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4. The Superposition Principle 4.1 Cumulative Occupancy The expanding shells do not replace each other. They overlap. At any tick, the target point is simultaneously intersected by: — The front from depth d = 1 (released by the nearest spation, arrived one tick ago) — The front from depth d = 2 (arrived two ticks ago) — The front from depth d = N (from the Clearing boundary, arrived N ticks ago) The point is immersed in N simultaneously overlapping fronts. This is why the burden is Φ = Nε, not merely ε. 4.2 Shell Cancellation in Release-Cascade Terms Group all sources at depth d. Each released ε0 over 4π sr. Fraction arriving at target from one source: $1/(4\pi d^2)$. Number of sources on shell: $4\pi d^2$. Total from shell: Φshell(d) = 4πd2 × ε/(4πd2) = ε (T1′) Independent of d. Every shell contributes the same. The cancellation is exact.

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5. The Observational Reconstruction Our instruments are lenses. They collimate arriving radiation and assign directions. When the CMB arrives from all directions at 2.725 K, our instruments reconstruct this as a spher-

ical surface at z = 1100, radius ~46 Gly. This reconstruction is correct as optics. The photons did travel from that distance. But the mechanical reality is different: the point is immersed in N simultaneously overlapping fronts from N source depths. We see the most distant shell because our instruments reconstruct the highest-contrast arrivals. The key sentence: The CMB is not to be interpreted primarily as a distant stationary blackbody surrounding each point, but as the observable spectral residue of an already-arrived, globally convergent boundary transition whose local mechanical manifestation is isotropic pressure.

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6. Throughput Conservation Every photon not intercepted by matter continues as part of the convergence at all downstream points. Every photon intercepted by matter is absorbed—its content becomes mass-energy of the vortex. The total is conserved: Released content = in-transit content + absorbed content Stars are convergence recyclers. They intercept cosmological convergence (gravitational infall), thermalise it (nuclear processing), and re-release it as a local boundary event (photospheric radiation). The stellar cycle: CMB convergence → infall → nuclear processing → photosphere release

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7. Pressure Domains (Theorem 9) Theorem 9. A luminous body of luminosity L dominates the cosmological convergence inside: rdomain = √(L / (4π FCMB)) (T9) where FCMB = cuCMB/4 = 3.131 × 10−6 W/m². Proof. Set L/(4πr2) = FCMB. Solve for r. ■ Solar pressure domain: r⊙ = √(3.828 × 1026/(4π × 3.131 × 10−6)) ≈ 20,800 AU Beyond ~20,800 AU, the cosmological convergence exceeds the solar convergence. This is the true pressure domain boundary of the solar system—distinct from the heliopause (~120 AU), which is a particle boundary, not a radiative one.

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8. Epoch Scaling (Theorem 8) Theorem 8. The per-shell content at the present epoch relates to the Clearing-epoch content by: ε(now) = ε0 · (1 + zrec)−4 (T8) Proof. Radiation energy density scales as u ∝ T4 ∝ (1+z)4. Between recombination and now: u0/urec = (T0/Trec)4 = (2.725/3000)4 = 6.80 × 10−13 Present: ε = 1.761 × 10−118 J. Clearing: ε0 = 2.588 × 10−106 J. Ratio: 6.80 × 10−13 = (1 + 1100)−4. ■

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9. Derivation Status Item | Status | | Axioms | R1–R6 (6 axioms) | | Lemmas | L1–L2 | | Theorems | T1 (shell cancellation), T2 (accumulation), T8 (epoch), T9 (domain) | | Free parameters | One (hydrogen calibration) | | Measured inputs | T_CMB, T_rec, z_rec, ℓ_P, c, L⊙ | | Shell invariance | Verified across 10^{61} orders | | Solar domain | 20,800 AU (derived) | | The Release Cascade Theorem establishes the origin of the convergent state: a universal discharge event producing cumulative superposition of expanding fronts. The CMB is the spectral residue. The pressure is the mechanical primitive. Every unintercepted photon feeds the next point's convergence. Every intercepted photon feeds matter. Stars recycle convergence as local boundary events.

Law III — Convergent Boundary Pressure

CONVERGENT BOUNDARY PRESSURE Force from Angular Occlusion Spatial Displacement Theory — Law III James Tyndall Melbourne, Australia March 2026 The CMB is not a distant stationary blackbody but the observable spectral residue of an already-arrived, globally convergent boundary transition whose local mechanical manifestation is isotropic pressure. Balanced convergence produces scalar compression without net force. Matter breaks the angular balance by occluding convergence sectors. The resulting pressure deficit is force. Gravitation, electrostatics, and nuclear binding are regimes of the same mechanism.

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1. From Convergence to Force Law I established the throughput budget: Φ = Nε at every interior point. Law II established the origin: the Clearing as universal discharge, producing cumulative superposition of expanding fronts. The present law derives the force that emerges when matter breaks the isotropy of the convergent state. The argument proceeds in three steps: (1) the convergence is angularly uniform in empty space;

(2) matter occludes a fraction of the angular domain; (3) the unoccluded remainder creates a net pressure toward the occlusion.

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2. Angular Uniformity (Theorem 3) Theorem 3. In an empty lattice, the directional convergence density is isotropic: $\phi(n) = \Phi / (4\pi)$, $\forall \hat{n} \in S2$ (T3) Proof. For any direction $\hat{n}$ and solid-angle element $\delta\Omega$, the number of source spations in the cone at depth d is: $|Sd \cap C(n, \delta\Omega)| = d2\delta\Omega$ Each contributes $\varepsilon/(4\pi d^2)$ (Lemma 1). Total from cone at depth d: $d2\delta\Omega \times \varepsilon/(4\pi d2) = \varepsilon\delta\Omega/(4\pi)$ This is independent of d and of the direction $\hat{n}$. Summing over all depths: $\phi(n) = \Sigma d{=}1N\ \varepsilon/(4\pi) = N\varepsilon/(4\pi) = \Phi/(4\pi)$ ■ Corollary 3.1 — Newton's First Law The net vector pressure on any body in an empty lattice is: $F = \oint \phi(n)\hat{n}\, d\Omega = (\Phi/4\pi) \oint \hat{n}\, d\Omega = 0$ (C3.1) since $\oint \hat{n}\, d\Omega = 0$ by symmetry. A body at rest stays at rest. A body in uniform motion stays in uniform motion. In this framework, a consequence of isotropic convergence rather than an independent postulate. ■ Corollary 3.2 — Scalar Compression $P_{conv} = \Phi / (3\ell P3) > 0$ (C3.2) The lattice is everywhere under compression despite zero net force. In this model, nominally empty space is under balanced pressure from all directions. ■

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3. The Occlusion Force (Theorem 4) Theorem 4. Two displacement vortices with occlusion radii R1 and R2 at separation r experience mutual attraction: $F = (\pi/4)\ P_{conv}\ R12R22 / r2$ (T4) Proof. Step 1. Without M1, the convergence at x2 is isotropic: $\phi(n) = \Phi/(4\pi)$ for all $\hat{n}$ (Theorem 3). Step 2. With M1 present at distance r in direction $\hat{n}1$, M1 occludes a solid angle: $\delta\Omega 1 = \pi R12 / r2$ (4.1) Step 3. The pressure deficit at x2 in direction $\hat{n}1$: $\delta P = (\Phi / 4\pi\ell P3) \cdot \delta\Omega 1 = (\Phi / 4\pi\ell P3) \cdot \pi R12/r2$ (4.2) Step 4. This deficit acts on M2's cross-section $\sigma 2 = \pi R22$: $F = \delta P \times \sigma 2 = (\Phi/4\pi\ell P3)(\pi R12/r2)(\pi R22)$ (4.3) $= (\pi/4)(\Phi/\ell P3)\ R12R22/r2 = (\pi/4)\ P_{conv}\ R12R22/r2$ (T4) ■ Corollary 4.1 — Newton's Third Law F12 = F21 by symmetry in R1 ↔ R2. Action equals reaction identically. ■ Corollary 4.2 — The Inverse-Square Law The $1/r^2$ dependence is a geometric consequence of solid-angle occlusion in Euclidean 3-space. It requires no field equation, no force carrier, no mediating particle. It follows from the geometry. ■

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4. Numerical Validation 4.1 Coulomb Force at the Bohr Radius For hydrogen (Z = 1), using the occlusion geometry: Input: Rp = 8.414 × 10−16 m (proton), Re = 2.818 × 10−15 m (classical electron radius), r = a0 = 5.292 × 10−11 m. Occlusion force: Focc = (π/4) Peff Rp2Re2 / a02 = 8.23 × 10−8 N Coulomb force: FC = kee2/a02 = 8.24 × 10−8 N Relative error: 0.12%. Within numerical precision of the input constants. (validated at the hydrogen calibration point — consistency at the anchor, not an independent test) 4.2 He^+ at the Bohr Radius For Z = 2: force scales as Z^2. Focc(He^+) = 4 × 8.23 × 10−8 = 3.29 × 10−7 N. FC(He^+) = 3.30 × 10−7 N. Agreement confirmed.

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5. The Seven-Step Mechanism The complete force mechanism, stated as a sequential chain:
6. A universal transparency event establishes a boundary discontinuity.
7. That discontinuity propagates inward by nearest-neighbour relay.
8. At each successive shell, per-channel distinction weakens.
9. Simultaneously, the number of channels participating in convergence increases.
10. The local point therefore experiences a constant total burden of convergent arrival.
11. Because arrival occurs from the full angular domain, the burden is isotropic.
12. Matter breaks that isotropy by excluding portions of the convergent domain. Force, in this framework, is convergent boundary pressure shaped by displacement geometry.

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6. Three Force Regimes, One Mechanism Regime | Scale | Occlusion | Effective Coupling | | Coulomb | Atomic (pm–nm) | Electron/proton vortex radii | P_eff via R_p, R_e | | Gravitational | Planetary–cosmic | Total displacement volume | P_eff via V_disp | | Nuclear | Femtometre | Direct vortex meshing | P_eff via contact geometry | | The formula F = (π/4) Pconv R12R22/r2 is universal. The regimes differ only in the occlusion radii and the effective pressure coupling at each scale.

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7. Derivation Status Item | Status | | Theorems | T3 (isotropy), T4 (occlusion force) | | Corollaries | C3.1 (Newton I), C3.2 (scalar compression), C4.1 (Newton III), C4.2 (inverse square) | | Free parameters | One (hydrogen calibration) | | Coulomb validation | < 0.12% at Bohr radius | | Z^2 scaling | Confirmed for He^+ | | Dependencies | T1 (shell cancellation), T2 (accumulation) from Laws I–II | |

Law IV — Inertial Mass from Throughput Asymmetry

INERTIAL MASS FROM THROUGHPUT ASYMMETRY F = ma from Convergence Reorganisation Spatial Displacement Theory — Law IV James Tyndall Melbourne, Australia March 2026 A displacement vortex excludes a volume from the isotropic convergent relay. The diverted throughput is the rest energy. When the vortex accelerates, the convergence acquires a dipole anisotropy. The resulting pressure gradient opposes the acceleration. That opposition is inertia. Inertial mass equals gravitational mass because both measure the same exclusion volume.

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1. Physical Foundation Law III established that force arises from angular occlusion of the convergent state. The present law derives the response of matter to that force: the resistance to acceleration, the origin of mass, and the identity of inertial and gravitational mass. The central concept: a displacement vortex excludes a volume Vdisp from the relay lattice. The convergent throughput that would otherwise transit that volume is diverted around the boundary. The diverted throughput constitutes the vortex's rest energy. The resistance to reorganising that diversion pattern under acceleration constitutes its inertial mass.

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2. The Rest Frame A vortex at rest sits in isotropic convergence. The angular throughput distribution (Theorem 3): ϕ(n) = Φ/(4π) uniform from all directions (2.1) The vector sum over all solid angles (Corollary 3.1): Frest = ∮ ϕ(n)ˆn dΩ = 0 (2.2) Zero net force. The vortex persists in its state of motion. This is Newton's first law: a throughput symmetry, Within this framework, a derived result.

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3. Acceleration: The Convergence Dipole When the vortex accelerates at rate a through the lattice, the throughput in the vortex frame acquires a first-order dipole anisotropy. The vortex moves into the relay fronts ahead and away from the fronts behind. To first order in v/c: ϕ′(n) = (Φ/4π)(1 + vˆn/c) (3.1) The leading hemisphere (n ·ˆv > 0) carries enhanced convergence. The trailing hemisphere (n ·ˆv < 0) carries diminished convergence. This is the CMB dipole anisotropy—the same dipole measured by COBE and Planck for the Earth's motion through the convergence rest frame (ΔT/T = v/c ≈ 1.23 × 10−3).

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4. Inertial Resistance (Theorem 5) Theorem 5. A displacement vortex of exclusion volume Vdisp accelerating at a experiences: Fresist = − m a, where m = Φ Vdisp / (3ℓP3c2) (T5) Proof. Step 1. The net momentum flux through the vortex's exclusion surface: p = (Vdisp/ℓP3c)(Φ/4π) ∮ (1 + vˆn/c)ˆn dΩ (5.1) Step 2. Evaluate the integral. The monopole term: ∮ˆn dΩ = 0 (by symmetry) (5.2) The dipole term: ∮ (vˆn)ˆn dΩ = (4π/3) v (standard dipole integral) (5.3) Step 3. Substituting: p = (Vdisp/ℓP3c) · (Φ/4π) · (4π/3) · v/c = Φ Vdisp v / (3ℓP3c2) (5.4) Step 4. The resistive force: F = − dp/dt = − [Φ Vdisp/(3ℓP3c2)] a = − m a (5.5) identifying the inertial mass as: m = Φ Vdisp / (3ℓP3c2) (T5′) This is Newton's second law: force equals mass times acceleration, where mass is the convergence reorganisation cost of the exclusion volume. ■

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5. Mass Equivalence (Theorem 6) Theorem 6. minert = mgrav. Proof. Gravitational mass: the angular convergence deficit a body creates for other bodies (Theorem 4). Determined by occlusion cross-section. Determined by Vdisp. Inertial mass: the convergence reorganisation cost of accelerating (Theorem 5). Determined by the exclusion volume in the convergent field. Determined by Vdisp. Same volume. Same convergence. Same quantity. The shadow a body casts on others is the same displacement that resists being moved. The identity is geometric, not coincidental. ■

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6. The Speed Limit (Theorem 7) Theorem 7. No displacement vortex can exceed velocity c. Proof. From the convergence dipole (3.1), the directional convergence in the trailing direction: $\phi'(-\hat{v}) = (\Phi/4\pi)(1 - v/c)$ (7.1) Physical constraint: convergence density cannot be negative: $\phi'(-\hat{v}) \geq 0 \Rightarrow 1 - v/c \geq 0 \Rightarrow v \leq c$ (7.2) At v = c: the trailing hemisphere carries zero convergence. No relay fronts arrive from behind. The vortex has exhausted the angular budget of the medium. No further acceleration is possible because there is no convergence remaining to reorganise. ■ Corollary 7.1 — Relativistic Mass The full relativistic aberration formula: $\phi'(n) \propto (1 - \beta\cos\theta)-2$ (C7.1) gives the well-known relativistic mass $m(v) = m0/\sqrt{(1 - v2/c2)} = \gamma\, m0$. The Lorentz factor is the angular budget depletion: as the trailing hemisphere empties, the reorganisation cost diverges. ■

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7. Summary Theorem | Statement | Key Equation | | T5 | Inertial resistance | $F = ma$, $m = \Phi V/(3\ell^3c^2)$ | | T6 | Mass equivalence | m_inert = m_grav | | T7 | Speed limit | $v \leq c$ | | C7.1 | Relativistic mass | $m(v) = \gamma m_0$ | | Three theorems and one corollary. Newton's second law, the equivalence principle, the speed limit, and relativistic mass—all from the convergence dipole of a displacement vortex in an isotropic relay lattice. One calibration constant (the hydrogen force match). The mass of a body is the medium's resistance to reorganising the throughput geometry around a displacement.

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8. Derivation Status Item | Status | | Axioms | R1–R6 (from Laws I–II) | | New theorems | T5 (inertia), T6 (equivalence), T7 (speed limit) | | New corollaries | C7.1 (relativistic mass) | | Free parameters | One (hydrogen calibration) | | Measured confirmation | CMB dipole $\Delta T/T = v/c$ (COBE, Planck) | | Dependencies | T2 ($\Phi = N\varepsilon$), T3 (isotropy) | | What remains open | V_disp for proton/electron from lattice topology | |

Law V — The Movement Budget

THE MOVEMENT BUDGET Mathematical Proof Spatial Displacement Theory — Law V James Tyndall Melbourne, Australia March 2026 A displacement vortex in the spation lattice has one velocity resource: the lattice tick rate $c = \ell P / tP$. It is spent on internal circulation (which maintains the vortex topology) and translational motion (which moves it through the lattice). The total is fixed. All of special relativity follows.

Abstract We prove that the constraint vcirc2 + vtrans2 = c2 follows from three axioms about the spation relay lattice: a hard speed bound on deformation propagation (M1), the identification of matter as circulating deformation (M2), and the orthogonality of circulation and translation (M3). From this single equation we derive, without additional postulates: time dilation, length contraction, the rest-energy relation E0 = m0c2, the relativistic energy–momentum relation E2 = (pc)2 + (m0c2)2, the photon limit, gravitational time dilation, and the c-boundary. Eight theorems from three axioms with One calibration constant (the hydrogen force match).

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1. Axioms The following three axioms extend the Release Cascade axiom set (R1–R6) established in Laws I–IV. They concern the internal structure of displacement vortices and the lattice constraints on their motion. Axiom M1 — Relay Speed Bound The maximum rate at which any deformation can propagate between neighbouring spations is one lattice spacing per tick: $|u| \leq \ell P / tP = c$ (M1) for any deformation velocity u. This is a hard bound: a spation cannot hand off deformation to its neighbour faster than one tick. It is the lattice-structural origin of the speed of light. Axiom M2 — Vortex as Circulating Deformation A displacement vortex is a self-sustaining pattern of lattice deformation in which spations undergo cyclic displacement around a closed toroidal path. The circulation velocity at the vortex boundary is: vcirc = ω Rmin (M2) where ω is the angular frequency and Rmin is the minor radius of the torus. The vortex exists if and only if vcirc > 0. If the circulation ceases, the topology is trivial and no displacement structure persists. Axiom M3 — Orthogonal Composition At any point on the vortex boundary, the total lattice deformation velocity has two components: vcirc tangential to the toroidal circulation path, and vtrans along the direction of translational

motion through the lattice. These are orthogonal: vcirc ⊥ vtrans at every boundary point (M3) The total deformation velocity is their vector sum: u = vcirc + vtrans.

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2. The Movement Budget (Theorem 10) Theorem 10. For a displacement vortex translating at velocity v through the lattice: vcirc2 + v2 = c2 (T10) Proof. Step 1. At any point on the vortex boundary, the total deformation velocity is (M3): u = vcirc + vtrans Since vcirc ⊥ vtrans (M3), the magnitude satisfies: | u |2 = vcirc2 + v2 (10.1) Step 2. The relay speed bound (M1) requires | u | ≤ c. Therefore: vcirc2 + v2 ≤ c2 (10.2) Step 3. The vortex must maintain its topology against the background convergent pressure. The isotropic convergence Φ = Nε (Theorem 2) presses inward on the exclusion volume from all directions (Corollary 3.2). The vortex resists collapse through its internal circulation: the centrifugal pressure of the circulating deformation balances the inward convergent pressure. At the vortex boundary, the balance condition requires: Pcentrifugal = Pconvergence (10.3) The centrifugal pressure of circulation at velocity vcirc is Pcf = ρs vcirc2, where ρs is the effective mass density of the lattice. At rest (v = 0), the full budget is available for circulation, giving the marginal stability condition: ρs c2 = Pconvergence (10.4) This defines the stable vortex: it circulates at exactly the speed needed to resist convergent collapse. Slower circulation means collapse. Faster circulation violates M1. Step 4. When translating at velocity v, the budget consumed by translation reduces the maximum available circulation: vcirc,max(v) = √(c2 − v2) (10.5) The convergence pressure is unchanged—it depends on Φ, not on the vortex velocity. The balance condition (10.3) still applies. The vortex must operate at the relay limit to resist collapse. Therefore the inequality (10.2) is saturated: vcirc2 + v2 = c2 (T10) ■
3. Time Dilation (Theorem 11) Theorem 11. The internal tick rate of a vortex moving at velocity v is: dτ / dt = √(1 − v2/c2) = 1/γ (T11) where τ is proper time and t is lattice time. Proof. Define the internal clock as one complete circulation cycle. At rest, the period is T0 = 2πRmin/c, since vcirc,0 = c from T10 with v = 0. At velocity v, circulation drops to vcirc = c/γ (T10). The period becomes: T(v) = 2πRmin / (c/γ) = γ T0 (11.1) The ratio of proper time to coordinate time: dτ/dt = T0/T(v) = 1/γ = √(1 − v2/c2) ■
4. Length Contraction (Theorem 12) Theorem 12. A vortex of rest-frame extent L0 along the direction of motion contracts to: L(v) = L0 / γ = L0 √(1 − v2/c2) (T12) Proof. The vortex topology is sustained by circulating deformation. A stable pattern requires round-trip closure: a disturbance propagating forward and returning must complete the circuit in one period. In the rest frame, this is trivially satisfied. At velocity v, the effective propagation speed toward the leading edge is c − v and toward the trailing edge is c + v (in the lattice frame). The round-trip time for extent L′: Tround = L′ c / (c2 − v2) (12.1) Setting Tround = γ T0 = γ L0 / c (from T11): L′ c / (c2 − v2) = γ L0 / c L′ = γ L0(c2 − v2) / c2 = γ L0 / γ2 = L0 / γ ■
5. Rest Energy (Theorem 13) Theorem 13. The rest energy of a displacement vortex is: E0 = m0 c2 (T13) Proof. At rest, the full movement budget is circulation: vcirc = c (T10). The exclusion volume Vdisp diverts convergent throughput from the relay lattice. The kinetic energy of the circulation at the vortex boundary, integrated over the exclusion volume: E0 = ½ ρeff vcirc2 Vdisp = ½ (2m0/Vdisp) · c2 · Vdisp = m0c2 where ρeff = 2m0/Vdisp is the effective displacement density. The rest energy is the circulation energy. In this framework, E0 = m0c2 follows as an identity. ■
6. Energy–Momentum Relation (Theorem 14) Theorem 14. For a vortex of rest mass m0 at velocity v: E2 = (pc)2 + (m0c2)2 (T14) Proof. Begin with the movement budget (T10): vcirc2 + v2 = c2 (14.1) Multiply both sides by γ2m02c2: γ2m02c2 vcirc2 + γ2m02c2v2 = γ2m02c4 (14.2) Evaluate each term. The circulation term: vcirc = c/γ (from T10), so: γ2m02c2 · c2/γ2 = m02c4 = (m0c2)2 (14.3) The translation term: (γ m0v)2c2 = (pc)2 (14.4) The right-hand side: (γ m0c2)2 = E2 (14.5) Therefore: (m0c2)2 + (pc)2 = E2 This is the Pythagorean theorem applied to the movement budget. The rest energy is the circulation leg. The momentum is the translation leg. The total energy is the hypotenuse. ■
7. The Photon Limit (Theorem 15) Theorem 15. A lattice deformation with zero internal circulation propagates at exactly c and has zero rest mass. Proof. From T10 with vcirc = 0: 0 + v2 = c2, giving v = c. Without circulation there is no centrifugal pressure to resist convergent collapse, hence no stable exclusion volume: Vdisp = 0. From T13: m0 = 0. From T14 with m0 = 0: E = pc. Light carries no topology — it is the relay itself. ■
8. Gravitational Time Dilation (Theorem 16) Theorem 16. A vortex at rest at radius r in a convergence field with characteristic velocity v(r) = (c/k)√(R/r) has internal tick rate: dτ/dt = √(1 − zR/r) (T16) where z = 1/k2 is the gravitational compactness. Proof. A stationary vortex at radius r is immersed in a convergence field with characteristic velocity v(r) from the SDT velocity law. Although the vortex is not translating, it must

resist the convergence pressure gradient at that position. The budget fraction consumed by this resistance is v(r)2/c2 = R/(k2r) = zR/r. The remaining circulation budget: vcirc2 = c2(1 − zR/r) (16.1) By Theorem 11, the internal tick rate is vcirc/c: dτ/dt = √(1 − zR/r) Verification. For Earth's surface: z⊕ = GM⊕/(R⊕c2) = 6.95 × 10−9. A surface clock runs slow by Δτ/τ ≈ 3.5 × 10−10, consistent with GPS gravitational corrections. ■

9. The c-Boundary (Theorem 17) Theorem 17. At radius Rc = zR = R/k2 from a central mass, the orbital velocity equals c and the movement budget is fully consumed. No displacement vortex can exist at or below Rc. Proof. From the velocity law at r = Rc: v(Rc) = (c/k)√(R/(R/k2)) = (c/k) · k = c (17.1) From T10: vcirc2 = c2 − c2 = 0. Zero circulation means no vortex topology. Matter cannot exist at this radius. For hydrogen: Rc = α2a0 = re = 2.818 × 10−15 m (the classical electron radius). For the Sun: Rc = 1.477 km. ■

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10. Dependency Structure The eight theorems form a strict deductive chain from three axioms: Theorem | Name | Depends On | Key Result | | T10 | Movement Budget | M1, M2, M3 | v^2_circ + $v^2 = c^2$ | | T11 | Time Dilation | T10 | dτ/dt = 1/γ | | T12 | Length Contraction | T10, T11 | L = L_0/γ | | T13 | Rest Energy | T10, T5 | $E_0 = m_0c^2$ | | T14 | Energy–Momentum | T10, T13 | $E^2 = (pc)^2 + (m_0c^2)^2$ | | T15 | Photon Limit | T10, T14 | v_circ = 0 → v = c, m = 0 | | T16 | Gravitational Dilation | T10, velocity law | dτ/dt = √(1 − zR/r) | | T17 | c-Boundary | T10, velocity law | v(R_c) = c, matter excluded | | Three axioms. Eight theorems. One calibration constant (the hydrogen force match). The entire framework of special relativity and its gravitational extension emerge from one constraint: the lattice processes one tick, the vortex spends it on existing and on moving, and the total is fixed.

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11. Correspondence with Standard Results Standard Result | SDT Derivation | Theorem | | Time dilation dτ/dt = 1/γ | Circulation period lengthens at velocity v | T11 | | Length contraction L = L_0/γ | Circulation reach shrinks along motion | T12 | | E = mc^2 | Rest energy = circulation energy | T13 | | $E^2 = (pc)^2 + (m_0c^2)^2$ | Pythagorean budget in energy units | T14 | | Photon: v = c, m = 0, E = pc | No circulation → full translation | T15 | | Gravitational time dilation | Convergence field consumes budget | T16 | | Schwarzschild radius | c-boundary: full budget consumption | T17 | | Light speed invariance | Budget identity: 0 + $c^2 = c^2$ | T15 | | Massive particles: v < c | v_circ > 0 required for existence | T10 | | γ → ∞ as v → c | Circulation collapse + hemisphere evacuation | T10, T5 | |
12. Position in the SDT Law Sequence Law | Name | Content | Theorems | | I | Cosmological Relay Throughput | Baseline lattice occupancy Φ = Nε | — | | II | Release Cascade | Clearing as universal discharge | T1–T2 | | III | Convergent Boundary Pressure | Force from angular occlusion | T3–T4 | | IV | Inertial Mass | F = ma from convergence dipole | T5–T7 | | V | Movement Budget (this law) | v^2_circ + $v^2 = c^2$ | T10–T17 | | Total across all six laws: 9 axioms (R1–R6, M1–M3), 2 lemmas, 18 theorems, and their corollaries. One calibration constant (the hydrogen force match). Built on a single medium with one tick rate.

Law VI — Vortex Topology Quantisation

VORTEX TOPOLOGY QUANTISATION The Mass Spectrum from Convergent Pressure Spatial Displacement Theory — Law VI James Tyndall Melbourne, Australia March 2026 Four conditions—toroidal closure, circulation quantisation, the movement budget, and marginal stability—determine the allowed masses of displacement vortices. The fundamental scale M_0 ≈ 1 TeV emerges from the convergent pressure of the medium combined with ħ and c. This is within a factor ∼4 of the electroweak vev (246 GeV) — an order-of-magnitude alignment, not a derivation. All known particles are high-winding topologies below this ceiling.

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1. The Four Quantisation Conditions A displacement vortex is a self-sustaining toroidal circulation in the spation lattice. It has major radius R (distance from torus centre to tube centre), minor radius a (tube cross-section), and two independent circulations: poloidal (vp, around the tube) and toroidal (vt, around the major axis). A flow line executes p poloidal turns per q toroidal turns, tracing a (p,q) torus knot. Four conditions

determine the stable configurations. Condition I — Toroidal Closure The flow must close on itself. This requires p and q to be coprime positive integers: gcd(p, q) = 1 (I) If gcd > 1, the flow traces multiple disjoint loops rather than a single closed knot. Condition II — Circulation Quantisation The circulation around any closed path is quantised in units of h/m: a · vp = ħ/(mp) (II.a) R · vt = ħ/(mq) (II.b) These are the fundamental (n = 1) modes. The quantisation arises from the requirement that the deformation pattern be single-valued after one complete circuit. Condition III — Movement Budget From Theorem 10 (Law V), the total deformation velocity at the vortex boundary equals c: vp2 + vt2 = c2 (III) Condition IV — Marginal Stability From the proven marginal stability (§6 of the Gap Resolution), the centrifugal pressure balances the convergent pressure: ρeffc2 = Pconv/3 (IV) where ρeff = 2m/V and V = 2π2Ra2 is the torus volume.

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2. Parametric Solution Parametrise the velocity partition: vp = c cosθ, vt = c sinθ (2.1) which satisfies (III) identically. Define the Compton wavelength λC = ħ/(mc). Then from (II): a = λC/(p cosθ) (2.2) R = λC/(q sinθ) (2.3) The aspect ratio: η = R/a = (p/q) cotθ (2.4)

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3. Derivation of the Mass Formula

   Canon-consistency note (2026-07-03): this winding-number mass treatment is INCOMPATIBLE with the canonical Law VI trefoil spectrum (electron = W=1 unknot; LAW_OF_VORTEX_TOPOLOGY_QUANTISATION.md) — e.g. it assigns the electron $\sim 10^{25}$ winding units. Treat this section as an exploratory alternative, not canon, until reconciled.

Theorem (Vortex Mass). A stable (p,q) torus-knot vortex in the convergent relay lattice has mass: m(p,q) = M0 / (p2q)1/4 (T18) where the fundamental mass scale is: M0 = [π2ħ3Pconv√3 / (2c5)]1/4 (T18′) Proof. Step 1. Substitute the parametric solution into (IV). The torus volume: V = 2π2Ra2 = 2π2λC3/(q sinθ · p2cos2θ) (3.1) Step 2. The effective density: ρeff = 2m/V = mp2q cos2θ sinθ / (π2λC3) (3.2) Step 3. Apply (IV): ρeffc2 = Pconv/3: m p2q cos2θ sinθ · c2 / (π2λC3) = Pconv/3 (3.3) Step 4. Using λC = ħ/(mc), substitute λC3 = ħ3/(m3c3): m4c5p2q cos2θ sinθ / (π2ħ3) = Pconv/3 (3.4) Step 5. Solve for m: m4 = π2ħ3Pconv / (3c5p2q cos2θ sinθ) (3.5) Step 6. Minimise m (energy minimum) by maximising g(θ) = cos2θ sinθ: g′(θ) = cosθ(1 − 3sin2θ) = 0 (3.6) sin2θ* = 1/3, cos2θ* = 2/3 (3.7) g(θ*) = (2/3)(1/√3) = 2/(3√3) (3.8) Step 7. Substitute g(θ*) into (3.5): m4 = π2ħ3Pconv√3 / (2c5p2q) (3.9) m(p,q) = [π2ħ3Pconv√3/(2c5)]1/4 / (p2q)1/4 = M0/(p2q)1/4 ■

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4. The Fundamental Mass Scale Numerical evaluation: M0 = [π2 × (1.055 × 10−34)3 × 2.459 × 1048 × √3 / (2 × (2.998 × 108)5)]1/4 (4.1) M0 = 1.786 × 10−24 kg (4.2) M0c2 = 1002 GeV ≈ 1 TeV (4.3) This is the electroweak scale. The fundamental vortex mass, determined entirely by the cosmological convergence pressure Pconv and the lattice constants ħ and c, sits at the energy scale where electroweak symmetry breaking occurs in the Standard Model. For comparison: the Higgs vacuum expectation value is 246 GeV, the top quark mass is 173 GeV, the Higgs boson mass is 125 GeV. M0 ≈ 1002 GeV is the ceiling of this regime. 4.1 The Stable Budget Angle At the energy minimum, the velocity partition is: vp/c = √(2/3) = 0.8165 (poloidal) (4.4) vt/c = 1/√3 = 0.5774 (toroidal) (4.5) vp/vt = √2 (4.6) The poloidal circulation carries twice the kinetic energy of the toroidal (since KE ∝ v^2, the ratio is 2:1). The stable vortex rotates faster around its tube than around its axis.

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5. The Mass Hierarchy 5.1 Spectrum Structure The mass formula m = M0/(p2q)1/4 means: Higher winding numbers → lighter particle. The (1,1) vortex at ∼1 TeV is the heaviest stable topology. Every other particle is lighter because it has more topological winding. The mass hierarchy is a winding hierarchy. 5.2 Low-Winding Spectrum (p,q) | p^2q | m (GeV) | Notes | | (1,1) | 1 | 1002 | Fundamental mode — TeV ceiling | | (1,2) | 2 | 843 | | | (1,3) | 3 | 761 | | | (2,1) = (1,4) | 4 | 709 | Degenerate pair | | (1,5) | 5 | 670 | | | (1,6) | 6 | 640 | | | (3,1) | 9 | 578 | | | (2,3) | 12 | 538 | | | (4,1) | 16 | 501 | | | (5,1) | 25 | 448 | | | (6,1) | 36 | 409 | | | (7,1) | 49 | 379 | | | 5.3 Known Particles in the Spectrum Particle | m (GeV) | p^2q needed | Regime | | top quark | 173.1 | 1.12×10^3 | Low winding | | Higgs boson | 125.1 | 4.12×10^3 | Low winding | | Z boson | 91.2 | 1.46×10^4 | Moderate winding | | W boson | 80.4 | 2.41×10^4 | Moderate winding | | tau | 1.777 | 1.01×10^{11} | High winding | | proton | 0.938 | 1.30×10^{12} | High winding | | pion± | 0.140 | 2.66×10^{15} | Very high winding |

| muon | 0.106 | 8.09×10^{15} | Very high winding | | electron | 0.000511 | 1.48×10^{25} | Extreme winding | | The particle mass spectrum spans 25 orders of magnitude in topological complexity (p^2q). The electron, the lightest charged particle, has the most elaborate topology: $\sim 10^{25}$ winding units. The top quark, the heaviest known fermion, is among the simplest: $\sim 10^3$ winding units.

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6. Physical Interpretation 6.1 The TeV Ceiling No stable vortex can have mass exceeding M0 ≈ 1 TeV, because the (1,1) mode is the minimum-winding topology. Any attempt to compress more energy into a single circulation pattern either increases the winding (reducing mass) or exceeds the pressure balance (causing collapse). This explains why particle physics encounters no stable fundamental particles above the TeV scale. 6.2 Complexity Means Lightness In the SDT vortex picture, the electron is the most topologically complex stable particle. Its $\sim 10^{25}$ winding units distribute the circulation energy over an enormously long path, reducing the energy density per unit volume and therefore the mass. The proton, with $\sim 10^{12}$ windings, is simpler and heavier. The top quark, with $\sim 10^3$ windings, is simpler still and heaviest of all. This is contrary to the intuition that heavier means more complex. In a convergent pressure medium, heaviness means compactness—fewer turns, shorter path, higher energy density. Lightness means elaborateness—more turns, longer path, lower energy density. 6.3 The Mass Ratio The proton-electron mass ratio is: mp/me = [(p^2q)e/(p^2q)p]1/4 = 1836.15 (6.1) (the electron's (p^2q) value is back-computed from 1836.15^4 — this displays the definition, it does not derive the ratio; see §7 "Status: OBSERVED. Not derived.") Therefore: (p^2q)e/(p^2q)p = 1836.154 = 1.137 × 1013 (6.2) The electron has 10^{13} times more topological complexity than the proton. The enormous charge-to-mass ratio of the electron (compared to the proton) reflects this: both carry one quantum of charge, but the electron distributes its circulation over vastly more turns.

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7. Sensitivity to Cosmological Parameters The mass scale depends on Pconv as the fourth root: M0 ∝ Pconv1/4 ∝ (RCMB/ℓP)1/4 ∝ H0−1/4 (7.1) The Hubble tension (H0 = 67–73 km/s/Mpc) maps to: H_0 (km/s/Mpc) | M_0 (GeV) | Notes | | 67.0 | 1006 | Planck CMB measurement | | 68.0 | 1002 | Reference value used here | | 70.0 | 995 | Intermediate | | 73.0 | 984 | SH0ES distance ladder | | M0 ranges from 984 to 1006 GeV across the Hubble tension. All values are firmly in the TeV regime. The electroweak connection is robust against the H0 uncertainty.

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8. Geometric Properties At the stable budget angle, the torus radii are: a = λC√(3/2) / p (8.1) R = λC√3 / q (8.2) η = R/a = (p/q)√2 (8.3) (p,q) | m (GeV) | λ_C (m) | a (m) | R (m) | η = R/a | | (1,1) | 1002 | 1.97×10^{-19} | 2.41×10^{-19} | 3.41×10^{-19} | 1.414 | | (2,1) | 709 | 2.79×10^{-19} | 1.71×10^{-19} | 4.82×10^{-19} | 2.828 | | (1,2) | 843 | 2.34×10^{-19} | 2.87×10^{-19} | 2.03×10^{-19} | 0.707 | | (3,1) | 578 | 3.41×10^{-19} | 1.39×10^{-19} | 5.91×10^{-19} | 4.243 | | All radii are at the 10^{-19} m scale for low-winding vortices—comfortably above the Planck length (10^{-35} m) and below the nuclear scale (10^{-15} m). The vortex is a mesoscopic structure spanning $\sim 10^{16}$ spations across.

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9. Summary and Derivation Status Item | Status | | Mass formula m(p,q) = M_0/(p^2q)^{1/4} | DERIVED from four quantisation conditions | | Budget angle θ* = arcsin(1/√3) | DERIVED from energy minimisation | | Velocity ratio v_p/v_t = √2 | DERIVED from θ* | | $M_0 \approx 1002$ GeV | COMPUTED from P_conv, ħ, c | | TeV ceiling on particle masses | PREDICTED (fundamental mode limit) | | Mass hierarchy = winding hierarchy | PREDICTED (higher winding = lighter) | | Electroweak scale from cosmology | PREDICTED ($M_0 \approx 1$ TeV) | | Specific (p,q) for proton | OPEN (needs stability selection) | | Specific (p,q) for electron | OPEN (needs stability selection) | | Neutron-proton splitting | OPEN (needs internal electron) | | The vortex topology quantisation derives a discrete mass spectrum from the convergent pressure of the medium. The fundamental scale M0 ≈ 1 TeV emerges from Pconv, ħ, and c with One calibration (hydrogen Coulomb match). The electroweak scale—the energy frontier of particle physics—is a proposed consequence of the cosmological relay throughput law. Every known particle sits below this ceiling as a high-winding topology in the same medium under the same pressure. Position in the SDT law sequence: Law VI. Extends Laws I–V by quantising the displacement topologies that Laws III–V treat as given. The mass formula completes the chain: cosmological boundary

condition → convergent pressure → stable vortex mass → force law → movement budget → the classical force and relativity framework.

Supplementary — Gap Resolution

SDT GAP RESOLUTION Exclusion Volumes, Transfer Function, Marginal Stability, Charge Quantisation, and Helium Binding Spatial Displacement Theory — Law Supplementary James Tyndall Melbourne, Australia March 2026 Every identified open problem in the six-law framework is addressed. V_disp is computed for both particles. The geometric transfer function is expressed in closed form. The marginal stability of T10 is proven as a stable equilibrium. The electron-electron occlusion problem is resolved through charge quantisation. Helium binding is computed from nuclear occlusion geometry (the computation imports the full two-electron QM Hamiltonian and Hylleraas/Pekeris variational results — a rival-machinery import, disclosed at §5; not an SDT-native derivation). Two problems remain genuinely open: R_p from lattice topology and quantisation of stable vortex topologies.

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1. Throughput Budget (Review) From Law I (Cosmological Relay Throughput), the steady-state convergence burden at any interior point is Φ = Nε, where N is the causal depth and ε is the elementary relay content. We collect the numerical values here for use throughout this document. 1.1 Input Constants Symbol | Quantity | Value | | c | Speed of light | 299 792 458 m/s | | ℓ_P | Planck length | 1.616255×10^{-35} m | | t_P | Planck time | 5.39124×10^{-44} s | | a | Radiation constant | 7.5657×10^{-16} J/m^3/K^4 | | T_0 | Present CMB temperature | 2.725 K | | z_rec | Recombination redshift | 1100 | | H_0 | Hubble parameter | 2.204×10^{-18} s^{-1} | | α | Fine structure constant | 7.2974×10^{-3} | | m_e | Electron mass | 9.1094×10^{-31} kg | | m_p | Proton mass | 1.6726×10^{-27} kg | | R_p | Proton boundary radius | 8.414×10^{-16} m | | r_e | Classical electron radius | 2.8179×10^{-15} m | | a_0 | Bohr radius | 5.2918×10^{-11} m | | k_e | Coulomb constant | 8.9876×10^{9} N·m^2/C^2 | | e | Elementary charge | 1.6022×10^{-19} C | | R_He | He-4 charge radius | 1.6755×10^{-15} m | | 1.2 Derived Throughput Quantities CMB energy density: uCMB = aT04 = 4.172 × 10−14 J/m3 (1.1) Causal depth to Clearing: N = RCMB/ℓP = 5.894 × 1061 (1.2) Elementary relay content: ε = uCMBℓP3 = 1.761 × 10−118 J (1.3) Convergence burden: Φ = Nε = 1.038 × 10−56 J (1.4) Convergence pressure (Planck scale): Pconv = Φ/ℓP3 = N · uCMB = 2.459 × 1048 Pa (1.5)

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2. Exclusion Volumes (V_disp) 2.1 Derivation from the Mass Equation Theorem 5 (Law IV) establishes inertial mass as: m = Φ Vdisp / (3ℓP3c2) (T5) Solving for the exclusion volume: Vdisp = 3mℓP3c2 / Φ (2.1) Every quantity on the right is measured. Vdisp is therefore computable for any particle of known mass. 2.2 The Electron Theorem (Electron Exclusion Volume). The electron displaces: Vdisp(e) = 3meℓP3c2/Φ = 9.988 × 10−62 m3 (2.2) Proof. Direct substitution: Vdisp(e) = 3 × 9.109 × 10−31 × (1.616 × 10−35)3 × (2.998 × 108)2 / (1.038 × 10−56) = 3 × 9.109 × 10−31 × 4.222 × 10−105 × 8.988 × 1016 / (1.038 × 10−56) = 9.988 × 10−62 m3 The characteristic exclusion radius (modelling the exclusion as a sphere): Rexcl(e) = (3Vdisp/(4π))1/3 = 2.878 × 10−21 m (2.3) ■ 2.3 The Proton Theorem (Proton Exclusion Volume). The proton displaces: Vdisp(p) = 3mpℓP3c2/Φ = 1.834 × 10−58 m3 (2.4) Rexcl(p) = 3.525 × 10−20 m (2.5) Proof. Identical procedure with m = mp. The mass ratio is preserved exactly: Vdisp(p)/Vdisp(e) = mp/me = 1836.15 (2.6) by construction, since Vdisp ∝ m in (2.1). ■ 2.4 Three Radii for Each Particle Every displacement vortex has three distinct characteristic radii, each corresponding to a different physical scale: Radius | Electron | Proton | Physical Meaning | | R_excl (exclusion) | 2.878×10^{-21} m | 3.525×10^{-20} m | Volume of displaced spation | | R_wake (charge) | r_e = 2.818×10^{-15} m | R_p = 8.414×10^{-16} m | Extent of pressure wake | | R_quantum (λ_C) | 3.862×10^{-13} m | 1.321×10^{-15} m | Quantum coherence scale | | Key ratios: Rwake(e) / Rexcl(e) = re/Rexcl(e) = 9.79 × 105 (2.7) Rwake(p) / Rexcl(p) = Rp/Rexcl(p) = 2.39 × 104 (2.8) λC/re = 1/α = 137.036 (2.9) The exclusion radius is the actual volume of spation displaced by the vortex topology. The pressure wake radius is the electromagnetic reach—the scale at which the vortex's displacement perturbs the convergent field. The wake extends ∼104–105 times beyond the physical displacement. This ratio is the amplification factor of the vortex's pressure perturbation over its physical size.

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3. The Geometric Transfer Function 3.1 Definition The hydrogen calibration (Law III, Theorem 4) equates the Coulomb force to the occlusion force at the Bohr radius: kee2 = (π/4) Peff Rp2 re2 (3.1) This defines the effective pressure at the atomic scale: Peff = 4kee2/(π Rp2re2) = 5.225 × 1031 Pa (3.2) (NOTE: LAW_OF_RADIATIVE_PRESSURE_ORIGIN.md quotes P_eff ≈ 1.65×10^{31} Pa for the same quantity — a factor ~π cross-canon inconsistency, unresolved; flagged 2026-07-03.) The transfer function is the ratio of this effective pressure to the Planck-scale convergence pressure: f ≡ Peff/Pconv = 2.125 × 10−17 (3.3) 3.2 Closed-Form Expression Theorem (Transfer Function). The geometric transfer function is: f = 4αħc / (π Rp2re2 · N · uCMB) (3.4) Proof. From (3.2) and (1.5): f = Peff/Pconv = [4kee2/(π Rp2re2)] / [N uCMB] Using kee2 = αħc (exact identity from the definition of the fine structure constant): f = 4αħc / (π Rp2re2N uCMB) Substituting re = αħ/(mec) and uCMB = aT04: f = 4me2c3 / (πα Rp2ħ N a T04) (3.5) ■ Remark. Equation (3.5) mixes atomic constants (α, ħ, me, Rp) with cosmological ones (N, T0). This is the essential feature: the transfer function IS the bridge between atomic and cosmological scales. It cannot be simplified further without deriving Rp from the lattice topology. 3.3 Derivation Status The transfer function f = 2.125 × 10−17 is computed (a definite number) and expressed (closed-form in measured constants). It is not derived from first principles because it contains Rp, the proton charge radius, as a measured input. Deriving Rp from the vortex topology of the proton would complete the chain. This is the single remaining theoretical gap.

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4. The Electron-Electron Occlusion Problem 4.1 The Naive Problem The occlusion force law (T4) is: F = (π/4) Peff R12R22/r2 (T4) For a proton-electron pair at separation r, using R1 = Rp and R2 = re: Fpe = (π/4) Peff Rp2re2/r2 = kee2/r2 □ (4.1) This is exact by the hydrogen calibration (3.1). Now consider an electron-electron pair: Fee(naive) = (π/4) Peff re4/r2 = (re/Rp)2 × kee2/r2 = 11.22 × kee2/r2 (4.2) The naive occlusion model overpredicts electron-electron repulsion by a factor of $(re/Rp)^2$ = 11.22. 4.2 Resolution: Charge as a Quantised Displacement Theorem (Charge Quantisation). The electromagnetic force between any two unit charges is: F = kee2/r2 = (π/4) Peff Rcharge4/r2 (4.3) where the charge interaction radius is: Rcharge = √(Rp · re) = 1.540 × 10−15 m (4.4) Proof. Step 1. The hydrogen calibration (3.1) establishes: kee2 = (π/4) Peff Rp2re2 (4.5) Step 2. This equation is not a product of two independent occlusion cross-sections. It is a single coupling constant kee2 expressed in terms of a product Rp2re2 whose value is fixed: Rp2re2 = 4kee2/(π Peff) = 5.621 × 10−60 m4 (4.6) Step 3. Define the geometric mean as the charge interaction radius: Rcharge ≡ (Rp2re2)1/4 = (Rpre)1/2 = 1.540 × 10−15 m (4.7) Step 4. Then for any pair of unit charges: F = (π/4) PeffRcharge4/r2 = (π/4) Peff(Rpre)2/r2 = kee2/r2 (4.8) regardless of which particles carry the charge. Proton-proton, electron-electron, proton-electron: all give kee2/r2 when using Rcharge. ■ 4.3 Physical Interpretation The elementary charge e is a quantised displacement in the spation medium. One quantum of displacement creates one quantum of occlusion. The occlusion depends on the charge quantum, not on the vortex topology. The proton and electron have vastly different topologies (different Vdisp, different Rwake), but they carry the same charge quantum e and therefore create the same coupling strength kee2 in their electromagnetic interaction. The individual wake radii Rp and re determine particle-specific properties: mass (through Vdisp), magnetic moment (through circulation geometry), Compton wavelength (through ħ/mc). But the charge-charge coupling is universal because the charge quantum is universal.

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5. Helium Binding from Nuclear Occlusion Geometry 5.1 The Alpha Particle The helium-4 nucleus (alpha particle) is a closed mesh of 2 protons and 2 neutrons with all circulations cancelled (spin-0). Its measured charge radius: RHe = 1.6755 × 10−15 m (5.1) If each proton contributes one charge radius to the nuclear occlusion: 2Rp = 2 × 8.414 × 10−16 = 1.683 × 10−15 m (5.2) Agreement: 0.43%. The alpha's charge radius is 2Rp to sub-percent precision. Each proton contributes one Rp to the total nuclear occlusion cross-section, consistent with the c-boundary scaling Rc = Z × re. 5.2 Nuclear-Electron Force Theorem. The nuclear occlusion force on an electron at distance r from the alpha centre is: FHe-e(r) = (π/4) Peff(2Rp)2re2/r2 = 4 kee2/r2 = ke(Ze)2/r2 (5.3) Proof. The nuclear occlusion radius is ZRp = 2Rp for Z = 2. Substituting into T4: F = (π/4) Peff(2Rp)2re2/r2 = 4 × (π/4) PeffRp2re2/r2 = 4 kee2/r2 using the hydrogen calibration (3.1). This is Coulomb's law with Z = 2. No new parameters. ■ 5.3 Electron-Electron Force From Section 4, the e-e force at separation r12 is: Fee(r12) = kee2/r122 (5.4) This is standard Coulomb. Same charge quantum, same coupling strength. 5.4 Total Hamiltonian The helium Hamiltonian in the SDT framework is: H = T1 + T2 + VHe-1 + VHe-2 + V12 (5.5) where: Ti = pi2/(2me) (5.6) VHe-i = −ke(Ze)2/ri = −4kee2/ri (5.7) V12 = +kee2/r12 (5.8) This is identical to the standard non-relativistic helium Hamiltonian. The forces are the

same because the SDT occlusion law reproduces Coulomb exactly. The nuclear geometry (alpha with Z = 2) enters through the Z-scaling of the occlusion cross-section. 5.5 Binding Energy Computation Method 1: First-order perturbation. E(0) = 2 × (−Z2Ry) = 2 × (−4 × 13.606) = −108.846 eV (5.9) E(1) = (5/8)Z × 2Ry = +34.014 eV (5.10) Epert = −108.846 + 34.014 = −74.831 eV (5.11) Measured: −79.005 eV. Error: 5.28%. Method 2: Variational (Hylleraas 1-parameter). Minimise E(Zeff) with respect to Zeff: E(Zeff) = [2Zeff2 − 4Z Zeff + (5/4)Zeff] Ry (5.12) dE/dZeff = 0 ⇒ Zeff = Z − 5/16 = 27/16 = 1.6875 (5.13) Evar = −77.489 eV (5.14) Measured: −79.005 eV. Error: 1.92%. Method 3: Hylleraas 6-parameter (literature). E = −79.0037 eV Error: 0.0016% (5.15) Method 4: Exact non-relativistic (Pekeris 1959). E = −79.0052 eV Error: 0.00025% (5.16) 5.6 Interpretation The SDT force law reproduces Coulomb exactly. Therefore the helium binding energy is identical to the standard quantum-mechanical result at every level of approximation. This is not a new prediction. It is confirmation that the occlusion mechanism, with the nuclear geometry setting Z through Rnuc = ZRp and the charge quantum setting the coupling through Rcharge = √(Rpre), reproduces known physics without additional parameters. The 1.9% error in the 1-parameter variational is not an SDT error. It is the standard variational approximation error, which converges to the exact value with better trial functions. The mechanism is correct. The number is the same.

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6. Marginal Stability of the Movement Budget 6.1 The Question Theorem 10 (Law V) asserts vcirc2 + v2 = c2 with equality. The question: why not vcirc2 + v2 < c2 (sub-limit operation)? 6.2 Proof of Marginal Stability Theorem (Marginal Stability). A displacement vortex in the convergent relay lattice operates at the relay limit: vcirc2 + v2 = c2 (equality, not inequality) (6.1) Proof. Step 1 (Inward pressure). The convergence pressure acts on the exclusion volume from all directions (Corollary 3.2): Pconv = Φ/(3ℓP3) = 2.459 × 1048/3 = 8.197 × 1047 Pa (6.2) This pressure is fixed by the cosmological boundary condition. It does not depend on the vortex. Step 2 (Outward resistance). The vortex resists collapse through centrifugal pressure from its internal circulation: Pcf = ρeff vcirc2 = (m/Vdisp) vcirc2 (6.3) Step 3 (Balance). Structural stability requires: Pcf = Pconv/3 (6.4) (the factor 1/3 is the angular average of the dipole projection for a spherical exclusion). Step 4 (Verification). Substituting the electron's values: ρeff(e) = me/Vdisp(e) = 9.120 × 1030 kg/m3 (6.5) Pcf(e) = ρeffc2 = 8.197 × 1047 Pa (6.6) Pconv/3 = 8.197 × 1047 Pa (6.7) Pcf/Pconv = 1/3 exactly (6.8) Step 5 (Stability analysis). Suppose vcirc < c/γ (below the balance point). Then Pcf < Pconv/3. The convergence pressure exceeds the centrifugal resistance. The vortex contracts. Contraction reduces Vdisp while preserving mass, so ρeff increases. The angular frequency ω = vcirc/Rmin increases as Rmin decreases. This increases Pcf, restoring the balance. Step 6 (Upper bound). Suppose vcirc > c/γ. Then the total deformation velocity |u| = √(vcirc2 + v2) > c, violating M1 (relay speed bound). This is physically impossible: a spation cannot relay faster than one spacing per tick. Step 7 (Conclusion). The vortex is bounded from above by M1 and pushed toward the bound from below by convergent pressure. The only stable operating point is: vcirc = c/γ ⇒ vcirc2 + v2 = c2 This is a stable equilibrium, not an assertion. ■ 6.3 The 1/3 Identity Corollary. Pcf = Pconv/3 is an algebraic identity. Proof. From the mass definition (T5): m = Φ Vdisp/(3ℓP3c2) Therefore: ρeffc2 = (m/Vdisp)c2 = Φ/(3ℓP3) = Pconv/3 The factor 1/3 is not approximate. It is the relationship between the mass definition and the pressure balance. The mass equation (T5) already encodes the marginal stability condition. ■

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7. The Proton-Electron Mass Ratio The mass ratio mp/me = 1836.15 has a geometric near-coincidence: (3/2)3/2 × 103 = 1837.12 (7.1) mp/me = 1836.15 (7.2) Error: 0.053% (7.3) In SDT terms: mp/me = Vdisp(p)/Vdisp(e). The exclusion volume ratio is 1836.15 exactly (by construction). The question is whether this ratio has a geometric origin in the topology of the two vortices. The (3/2)3/2 factor arises in Keplerian orbital mechanics: the ratio of volumes swept by orbits with semi-major axes in ratio 3:2 scales as (3/2)3/2. The factor 103 may correspond to the number of stable modes or the winding number of the proton's toroidal circulation. Status: OBSERVED (0.053% agreement). Not derived. The derivation requires the full vortex topology computation.

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8. Complete Gap Status Gap | Status | Section | | V_disp for electron | COMPUTED: 9.99×10^{-62} m^3 | §2 | | V_disp for proton | COMPUTED: 1.83×10^{-58} m^3 | §2 | | Transfer function | COMPUTED: $f = 2.13 \times 10^{-17}$ | §3 | | — expressed in constants | YES (Eq. 3.5) | §3.2 | | — derived from first principles | NO (needs R_p) | §3.3

| | Electron-electron problem | RESOLVED: charge quantisation | §4 | | — R_charge | $\sqrt{R_p r_e} = 1.54 \times 10^{-15}$ m | §4.2 | | Helium binding energy | COMPUTED: matches QM exactly | §5 | | — alpha geometry | R_He = 2R_p to 0.43% | §5.1 | | — 1-parameter variational | −77.49 eV (1.92% error) | §5.5 | | — converges to exact | −79.005 eV (Pekeris) | §5.5 | | Marginal stability (T10) | PROVEN: stable equilibrium | §6 | | — P_cf = P_conv/3 | EXACT algebraic identity | §6.3 | | Proton-electron mass ratio | 0.053% from $(3/2)^{3/2}\times10^3$ | §7 | | — derived | NO | §7 | | Vortex topology quantisation | OPEN | — | | R_p from lattice topology | OPEN | — | |

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9. Summary Of the six identified gaps in the six-law framework, four are now fully resolved and one is partially resolved: Resolved: Vdisp for both particles (computable from the mass equation). The electron-electron occlusion problem (resolved by charge quantisation). The marginal stability of T10 (proven as a stable equilibrium between convergent pressure and the relay bound). Helium binding energy (computed from nuclear occlusion geometry, identical to QM) (the computation imports the full two-electron QM Hamiltonian and Hylleraas/Pekeris variational results — a rival-machinery import, disclosed at §5; not an SDT-native derivation). Partially resolved: The transfer function (computed and expressed, but not derived from first principles due to Rp dependence). Genuinely open: Rp from lattice topology and quantisation of stable vortex topologies. Both require simulation of toroidal displacement patterns in an inviscid medium under convergent pressure. These are computational problems with well-defined inputs, not conceptual gaps. The six-law framework now has: 9 axioms, 2 lemmas, 18 theorems, their corollaries, and the complete gap resolution presented in this document. Minimal free parameters beyond the hydrogen calibration (which fixes Peff). Two open problems, both computational. Built on a single medium with one tick rate.

Supplementary — Traction, Wake, and Toroidal Framework

SDT Traction, Wake, and Toroidal Error-Correction Framework Mathematical synthesis of the boundary-contact mechanism, wake-conditioned propagation, and modal fault tolerance discussed in the current reasoning chain. Working thesis. Matter is not an occupant of space but a persistent exclusion of spations. The central problem is therefore a traction problem: how a pressured, perfectly transmitting medium can be continuously deflected at the boundary of matter and exploited into stable self-maintenance. The toroidal architecture is reintroduced here as a candidate modal machine for converting convergent influx into spin, axial directionality, error correction, and wake-conditioned interaction. | | 1. Core Variables and Meanings Symbol | Meaning | | ℓ_P | Spation-scale relay spacing (substrate grain / floor unit in current formulation) | | t_P | One relay tick | | c = ℓ_P / t_P | Native neighbour-to-neighbour relay rate | | Φ = Nε | Convergent throughput burden at a point | | P_conv | Local convergent pressure associated with Φ | | σ_occ | Effective occlusion cross-section of a structure | | V_disp | Excluded / displaced spation volume associated with a structure | | v_t | Translational component of a structure or boundary | | v_T | Toroidal circulation mode | | v_P | Poloidal cross-coupling mode | | v_C | Contrarotational stabilizing mode | | $\mathcal{W}$ | Wake state written into the surrounding spation medium | | $\mathcal{A}$ | Axial influence field | | 2. Boundary Contact as the Primitive Event The primitive operation is not force between separated bodies but contact-level redirection at the exclusion boundary. At every boundary event, convergent influx reaches matter, cannot co-occupy the excluded region, and must therefore be deflected, redistributed, or translated into another mode. incoming convergent contact → boundary deflection → redirected motion → renewed exclusion In this language, persistence requires a local recurrence rule. A viable matter topology must transform each new boundary contact into a new cycle of self-maintenance rather than a one-off expenditure. 3. Traction Law For a perfectly tractional and perfectly faithful medium, the contact event cannot simply vanish. The medium must either reclose, transmit, or be routed into another degree of freedom. The minimal traction statement is: boundary work = exclusion maintenance + modal redistribution + residual transmission A stable structure therefore requires not merely pressure balance but a mechanism that reuses contact work. This is the operative meaning of traction in SDT. 4. Wake-Conditioned Medium The wake is proposed as a resolvable engine. Persistent exclusion writes an influence field into the surrounding spation medium. At lowest order this field is axial; under sustained operation it becomes helical or otherwise structured. event → axial influence field $\mathcal{A}$ → structured wake $\mathcal{W}$ The wake has two jobs: it preconditions the next boundary event and it creates a local anisotropic pressure gradient. This makes future motion easier along some routes than others, providing continuity, inertia, and directional memory. 5. Light Through a Wake-Conditioned Medium Light remains neighbour-to-neighbour energetic transmission. It does not need to drag the wake. It traverses a medium whose local handoff geometry has already been conditioned by the wake. straight relay: $\mathcal{W} = 0 \Rightarrow \Delta\theta = 0$ smooth wake field: $\nabla\mathcal{W} \neq 0 \Rightarrow$ refraction-like angular bias rough wake field: $\delta\mathcal{W}$ large $\Rightarrow$ scattering / diffusion A clean mathematical target is therefore a local angular deflection law $\Delta\theta = F(\lambda, \mathcal{W}, \nabla P, \hat{n})$ where λ is wavelength, $\mathcal{W}$ the local wake state, ∇P the local pressure gradient, and $\hat{n}$ the propagation direction. This reframes refraction and scattering as geometry problems on a preconditioned medium, in principle solvable before experiment. 6. Magnetic Flux as Organized Spation Flow Within this picture, magnetic flux is not an abstract field but an organized flow-state of the spation matrix. Magnetic-family objects couple strongly to such organized flow; non-magnetic-family objects do not. magnetic behaviour = topology-dependent coupling to organized spation flow This gives a cleaner interpretation of accelerator magnets, magnetospheres, induction, and alignment phenomena: the apparatus sculpts rivers of space, and only compatible topologies entrain cleanly. 7. Why the Toroidal Architecture Reappears The torus is not introduced as a decorative shape but as a candidate error-correcting exploit. It can convert blocked radial influx into circumferential spin while leaving a comparatively clean central axial corridor. deflected outer throughput → circumferential spin central low-resistance channel → axial bias / directionality This directly supports the deflection=spin argument: spin is generated from redirected contact work, while directionality is carried by the comparatively unopposed axial pass-through. 8. The Three Mechanical Modes The relevant modes are not generic 'three velocities' but three real mechanical flow modes operating relative to one another: Mode | Role | Failure if Missing | | Toroidal | Closure, recirculation, persistence of exclusion | One-pass expenditure; no identity storage | | Poloidal | Cross-coupling between inner and outer layers | Dead ring; no depth exchange | | Contrarotational | Balance, anti-twist stabilization, error absorption | Twist accumulation, seam stress, collapse | | The load-bearing claim is that turbulence or defective deflection in any one mode can be translated through the other two. This is proposed as an error-correction mechanism. 9. Minimal Modal Budget The previously developed movement budget can be recast in modal form. A provisional expression is: $v\_t^2 + v\_T^2 + v\_P^2 + v\_C^2 \leq c^2$ This does not yet assert the exact composition law, but it does express the requirement that the boundary machine partition a finite relay/update ceiling across all active channels. The stable architecture is the one that uses this budget while maintaining exclusion under convergent load. 10. Nested Wakes: Stars, Planets, and Magnetospheres The wake is not merely particle-scale. A rotating star writes a system-scale axial and helical conditioning field into the medium. Planetary wakes are then nested perturbations inside the stellar wake, rather than independent competing universes. This reframes several observations: • stellar rotation as persistent conversion of deformity into angular maintenance • orbital coherence as motion inside a preconditioned wake rather than in neutral emptiness • ring planarity as a traction-equilibrium sheet rather than mere debris geometry • magnetospheres as visible toroidal stress-redirection structures with hard sunward contact and trailing bleed-off In this setting, the solar/CMB equalisation radius and the planarity of ring systems become not curiosities but tests of a nested wake framework. 11. Failure Modes that a Real SDT Matter Topology Must Survive Failure surface | What must be shown | Why it matters | | Modal decoupling | Modes remain phase-locked or strongly coupled | Otherwise redundancy is fake and error correction fails | | Energy leakage | Translated disturbance is reintegrated, not merely delayed | Otherwise the structure only postpones collapse | | Axial channel instability | Stable aperture window: enough axial throughput for directionality, enough obstruction for spin | Otherwise the machine collapses into pure spin or pure throughflow | | Contrarotational seam stress | Opposed modes stabilize rather than grind destructively | Otherwise the cure becomes the failure | | Single-point deflection stall | No one bad boundary event can stop the entire machine | Core requirement of robustness | | Pressure mismatch | The candidate topology naturally satisfies convergent-pressure balance | Elegant geometry is useless if physically uninhabitable | | Geometry transmission | Internal topology projects into wake/electronic landscape | Without this, chemistry and optics never follow | | Topology selection | Toroidal machine is preferred over rival closures | Otherwise it remains a plausible toy rather than a necessity | | Cross-scale scaling | One mechanism scales from particle to stellar regimes | Otherwise SDT breaks into special cases | | 12. Reframed Research Program The torus should now be treated as a candidate solver of the deeper traction problem, not as an article of faith. The mathematically correct program is: 1. derive the local boundary recurrence rule for contact, deflection, and reclosure 2. derive the angular transmission law for light through wake-conditioned regions 3. derive the modal locking conditions for toroidal, poloidal, and contrarotational flow 4. derive the stable aperture law for the axial corridor 5. derive the topology-to-field transmission operator linking internal topology to external wake and electron architecture 6. search the topology family for the first stable recurrence under convergent load 13. Compressed Statement Matter is a stable strategy for exploiting the continuously transmitted influx at every spation-scale boundary contact. The wake is the real, resolvable engine that writes anisotropic pressure gradients into the surrounding medium. Light propagates through that wake-conditioned medium faster than the wake reorganises it, so optical bending, scattering, and diffusion are consequences of local angular transmission through a structured substrate. The toroidal architecture matters insofar as it provides a fault-tolerant modal machine—toroidal closure, poloidal cross-coupling, and contrarotational stabilization—capable of turning blocked influx into spin, preserving an axial through-channel, and routing local roughness through redundant modes rather than grinding to a halt.

Extended Reference — Convergent Boundary Pressure (Full Form)

LAW OF CONVERGENT BOUNDARY PRESSURE

Formal Full-Form Statement

Law (Convergent Boundary Pressure). The transparency event at recombination established a universal boundary discontinuity in the spation lattice. That discontinuity has propagated inward by nearest-neighbour relay, shell by shell, at c, and has already arrived at every interior point. The CMB is not a distant surface illuminating the interior. It is the observational residue of an already-arrived, globally convergent boundary transition whose local mechanical manifestation is isotropic scalar compression.

At every point in the lattice, the convergence state is maintained by the continuous relay arrival from the full 4π angular domain. Per-channel energetic distinction weakens with relay depth. Convergent shell multiplicity increases with relay depth. These two effects cancel exactly, preserving an invariant local convergence burden at every interior point.

Let the elementary convergence content per shell-stage be

$$\varepsilon = u_0 \, \ell_P^3$$

where u_0 is the scalar compression-energy density at the operative boundary condition.

Let the causal depth to the boundary be

$$\mathcal{N} = \frac{R_{\text{boundary}}}{\ell_P}$$

Then the total convergence burden at any interior point is

$$\boxed{\Phi = \mathcal{N} \, \varepsilon}$$

This quantity is interpreted as the locally instantiated, isotropically arrived, scalar compression state of the medium. The pressure is primary. The light we observe is one detectable deformation mode of it.

Force arises only where matter occludes a fraction of the angular convergence domain:

$$\boxed{F = \sigma_{\text{occ}} \times \nabla \Phi_{\text{angular}}}$$

where σ_{occ} is the occlusion cross-section of the body and $\nabla \Phi_{\text{angular}}$ is the directional gradient in convergence created by the occlusion.

The Core Distinction

The conventional interpretation:

> There is a blackbody surface far away. It emits light. That light travels to us. We measure a local radiation field.

The SDT interpretation:

> The transparency event defined a universal boundary transition. That transition has already been handed inward shell by shell. What any point experiences now is not distant emission but arrived convergence. "Distance to the CMB" is a retrospective description of the causal stack, not a present mechanical separation.

The CMB is not 46 billion light-years away pushing on us across empty space. The causal history is deep. The mechanics are local. The arrival is current. The convergence is everywhere. The distance is an inferred causal depth, not an empty gap between source and effect.

Expanded Form

1. The Transparency Event

At recombination ($z \approx 1100, T \approx 3000$ K), the universe transitioned from opaque plasma to transparent neutral gas. This represents a **boundary discontinuity** in the relay properties of the lattice.

Before recombination: the lattice was in a coupled state — matter and radiation exchanged energy at every tick. No clean relay was possible. The medium was opaque because the deformation could not propagate without scattering.

At recombination: the coupling broke. The lattice entered a free-relay state. Deformations (photons) could now propagate without interruption. The boundary of last scattering became the **Clearing** — the surface beyond which the lattice first became capable of sustained relay.

This event did not happen "far away." It happened everywhere, simultaneously (in cosmic time). The Clearing is not a place. It is a transition epoch. What we call "the CMB surface" is our retrospective reconstruction of where that epoch sits in our past light cone.

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2. Shell-by-Shell Arrival

After the transparency event, the free-relay state propagated inward through the lattice. Each Planck tick, one more shell-layer of the boundary discontinuity advanced by ℓ_P.

At any interior point now, the convergence from depth $d = 1$ (nearest shell) arrived one tick ago. The convergence from depth $d = 2$ arrived two ticks ago. The convergence from depth $d = \mathcal{N}$ (the Clearing) arrived $\mathcal{N}$ ticks ago — $\mathcal{N} \times t_P \approx 13.8$ billion years ago.

But all of these have **already arrived**. The point is not waiting for light from the Clearing. The light has been here, continuously replenished by the relay, for the entire history since transparency. The "distance" is the retrospective causal depth of the relay stack, not an ongoing journey.

---

3. The Convergence Invariance Theorem

Theorem. For a universal transparency boundary relayed inward through a nearest-neighbour lattice, the decrease in per-channel energetic distinction with progressive relay depth is exactly offset by the increase in convergent shell multiplicity, such that the total local convergence burden remains invariant across all interior points.

Proof.

At relay depth d (measured in lattice spacings from the interior point):

- The convergent shell has surface area $4\pi d^2$ in lattice units
- Each source cell on the shell contributes convergence content $\varepsilon/(4\pi d^2)$ to the interior point (inverse-square dilution)
- The total contribution from shell d:

$$\Phi_{\text{shell}}(d) = 4\pi d^2 \times \frac{\varepsilon}{4\pi d^2} = \varepsilon$$

This is independent of d. Every shell, from $d = 1$ to $d = \mathcal{N}$, contributes the same convergence load.

The total convergence burden:

$$\Phi = \sum_{d=1}^{\mathcal{N}} \varepsilon = \mathcal{N}\varepsilon$$

This is an exact geometric identity in Euclidean space. It holds at every interior point identically.

Corollaries:

(i) Isotropic convergence from all 4π steradians gives zero net vector force.

(ii) Nonzero scalar compression remains — the point is under pressure from all directions.

(iii) Matter produces force by occluding convergence sectors, breaking the angular balance.

(iv) Motion produces anisotropy by changing the relative arrival state (blueshift ahead, redshift behind).

---

4. Pressure Is Primary, Light Is Secondary

The scalar compression at every point is not "caused by" photons arriving from a distant surface. The compression IS the state of the lattice, established by the convergent arrival of the transparency transition.

Light — the electromagnetic deformation mode of the lattice — is one observable aspect of that compression state. When we point a microwave antenna at the sky and measure 2.725 K, we are detecting the spectral signature of the local convergence state, not intercepting a signal from a remote transmitter.

This distinction matters because:

- The pressure is proposed as the mechanical primitive, independent of detection.
- The pressure is the mechanical primitive. The photon spectrum is the observational derivative.
- "Radiation pressure" is not wrong, but it is downstream. The upstream reality is convergent boundary pressure.

The hierarchy:

Transparency event $\rightarrow$ Convergent relay $\rightarrow$ Local compression state $\rightarrow$ Observable as 2.725 K blackbody

The law is about the compression state, not the blackbody observation.

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5. Force from Occluded Convergence

A displacement vortex (matter) excludes a volume of the lattice from the relay. The convergence that would otherwise pass through that volume is diverted around the boundary. From any exterior point, the vortex blocks a solid angle of the convergence domain:

$$\delta\Omega = \frac{\pi R^2}{r^2}$$

The convergence from that solid angle does not arrive. The convergence from all other angles continues to arrive. The angular sum is no longer isotropic. The net pressure points toward the occlusion — toward the matter.

For two bodies at separation r, each occluding a fraction of the other's convergence domain:

$$F = \frac{\pi}{4} P_{\text{conv}} \frac{R_1^2 R_2^2}{r^2}$$

where P_{conv} is the local convergence pressure, determined by the boundary condition and the relay geometry.

This gives: - Coulomb force at atomic scales (where P_{conv} couples through the vortex occlusion radii R_p, R_e) - Gravitational force at macroscopic scales (where P_{conv} couples through the total displacement volume) - Nuclear binding at femtometre scales (where P_{conv} couples through direct vortex meshing)

The same mechanism is proposed across all regimes.

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6. Inertia from Convergence Anisotropy

A vortex at rest: convergence arrives equally from all angles. No net force. No acceleration. Newton's first law.

A vortex accelerating: in the vortex frame, the convergence is no longer isotropic. The leading face receives enhanced convergence (the relay from ahead is being run into). The trailing face receives diminished convergence (the relay from behind is being left behind).

The dipole anisotropy:

$$\frac{\delta\Phi(\hat{n})}{\Phi} = \frac{\mathbf{v} \cdot \hat{n}}{c}$$

This is exactly the CMB dipole anisotropy measured by COBE and Planck for the Earth's motion through the convergence rest frame. The measurement confirms the mechanism: move through the convergence, and you see more pressure ahead than behind. That pressure difference opposes your acceleration. That opposition is inertia.

Mass is the convergence reorganisation cost of a displacement:

$$m = \frac{\Phi\, V_{\text{disp}}}{\ell_P^3\, c^2}$$

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7. The Equivalence Principle from Convergence Geometry

Gravitational mass: the angular convergence deficit a body creates for other bodies. Determined by occlusion cross-section. Determined by V_{disp}.

Inertial mass: the convergence reorganisation cost of accelerating. Determined by the exclusion volume in the convergent field. Determined by V_{disp}.

Same volume. Same convergence. Same quantity.

$$m_{\text{inert}} = m_{\text{grav}}$$

Not a coincidence. Within this framework, a derived result. A geometric identity: the shadow you cast and the resistance you feel are two measurements of the same displacement in the same convergent field.

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8. What the CMB Measurement Actually Tells Us

When FIRAS measured the CMB to be a perfect blackbody at 2.725 K:

- It confirmed the spectral form of the convergence state (thermal equilibrium at the transparency epoch, preserved through relay)
- It confirmed the energy density: $u_0 = aT^4 = 4.172 \times 10^{-14}$ J/m³
- It confirmed the isotropy to 10^{-5} (the convergence is angularly complete)
- It confirmed the dipole at $\Delta T/T \sim 10^{-3}$ (our motion through the convergence frame)

These are not properties of a distant surface. They are properties of the local convergence state. The measurement is local. The causal history is deep. The mechanism is continuous relay. The pressure is here, now, arrived, and isotropic.

Canonical Wording for Paper Use

Law of Convergent Boundary Pressure. The CMB is not to be interpreted primarily as a distant stationary blackbody surrounding each point, but as the observable spectral residue of an already-arrived, globally convergent boundary transition whose local mechanical manifestation is isotropic scalar compression. The transparency event at recombination established a boundary discontinuity that has propagated inward through the spation lattice, shell by shell, at c. At every interior point, the decrease in per-channel energetic distinction with relay depth is exactly offset by the increase in convergent shell multiplicity, preserving an invariant total convergence burden $\Phi = \mathcal{N}\varepsilon$. This burden is not stored energy but the locally instantiated compression state of the medium. Matter produces force by occluding sectors of the angular convergence domain. Motion produces inertia by creating dipole anisotropy in the convergence frame. Force, in this framework, is convergent boundary pressure shaped by displacement geometry.

Compact Theorem Form

Theorem (Convergence Invariance). For a universal transparency boundary relayed inward through a nearest-neighbour lattice at c, the total convergence burden at any interior point is $\Phi = \mathcal{N}\varepsilon$, independent of position, because shell multiplicity exactly compensates per-channel dilution at every depth.

Corollary (Isotropic Compression). Balanced angular convergence produces scalar compression without net vector force.

Corollary (Occlusion Force). Matter breaks the angular balance by excluding convergence sectors, producing net force toward the occlusion.

Corollary (Inertia). Acceleration through the convergence frame creates dipole anisotropy. The resulting pressure gradient opposes the acceleration. Mass is the reorganisation cost of the displacement in the convergent field.

Corollary (Equivalence). Gravitational mass (shadow cast) and inertial mass (reorganisation cost) are the same V_{disp} measured from two frames.

Corollary (Speed Limit). At $v = c$, the trailing convergence hemisphere is evacuated. No further reorganisation is possible.

The Seven-Step Mechanism

1. A universal transparency event establishes a boundary discontinuity.
2. That discontinuity propagates inward by nearest-neighbour relay.
3. At each successive shell, per-channel distinction weakens.
4. Simultaneously, the number of channels participating in convergence increases.
5. The local point therefore experiences a constant total burden of convergent arrival.
6. Because arrival occurs from the full angular domain, the burden is isotropic.
7. Matter breaks that isotropy by excluding portions of the convergent domain.

The Key Sentence

> The CMB is not to be interpreted primarily as a distant stationary blackbody surrounding each point, but as the observable spectral residue of an already-arrived, globally convergent boundary transition whose local mechanical manifestation is isotropic pressure.

The Three SDT Laws in Sequence

Law 1: Cosmological Relay Throughput. The lattice is a globally phase-loaded nearest-neighbour relay medium. Shell cancellation preserves $\Phi = \mathcal{N}\varepsilon$ at every point. The 10^{123} is $\mathcal{N}^2$: the boundary cell count, not a failed vacuum energy cancellation.

Law 2: Convergent Boundary Pressure. The pressure is primary. The CMB spectrum is secondary. The convergence has already arrived. The mechanics are local. Force is occluded convergence. Inertia is convergence anisotropy. Mass is convergence reorganisation cost. Light is one observable mode of the convergent state.

Law 3: Inertial Mass from Throughput Asymmetry. $F = ma$ is the rate of convergence condensation across an exclusion volume. $m_{\text{inert}} = m_{\text{grav}}$ because both are V_{disp}. The speed limit is convergence hemisphere evacuation.

Three laws. One boundary condition. One mechanism. One calibration (hydrogen Coulomb match).

Derivation Status

Class: DERIVED from the transparency boundary condition, Planck lattice geometry, and the Convergence Invariance Theorem.

Measured input: $T_{\text{CMB}} = 2.725$ K (confirming the spectral form of the convergence state, not defining it)

Free parameters: one measured calibration (hydrogen) — see header.

Critical distinction: The pressure is not caused by distant radiation. The pressure is the local state of the medium, established by the already-arrived convergence of the transparency transition. The CMB observation confirms the state; it does not create it.

What this law proposes to reinterpret: - Gravity as spacetime curvature - Inertia as an intrinsic property of mass - The CMB as a passive relic radiation bath - The cosmological constant discrepancy (reinterpreted as boundary cell count) - The equivalence principle as an unexplained coincidence

What this law requires next: - Numerical derivation of G from Φ and lattice geometry - Numerical derivation of V_{disp} for proton and electron - Explicit connection between convergence pressure regimes (Coulomb vs gravitational) - Quantisation of stable vortex topologies from lattice boundary conditions

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Extended Reference — Inertial Mass (Full Form)

LAW OF INERTIAL MASS FROM THROUGHPUT ASYMMETRY

Formal Full-Form Statement

Law (Inertial Mass from Throughput Reorganisation). A displacement vortex at rest in the spation lattice experiences isotropic relay throughput from all 4π steradians and therefore no net vector force. When an external agency accelerates the vortex, the throughput pattern in the vortex frame becomes anisotropic: the leading hemisphere receives compressed throughput and the trailing hemisphere receives rarefied throughput. The net pressure deficit opposing the acceleration is proportional to the rate of throughput reorganisation across the vortex's occlusion cross-section.

Let the displacement vortex have exclusion volume

$$V_{\text{disp}} = \text{volume of spation medium displaced by the vortex topology}$$

Let the local steady-state throughput be

$$\Phi = \mathcal{N}\varepsilon$$

as established by the Cosmological Relay Throughput Law.

Then the rest energy of the vortex is the throughput deficit created by its exclusion volume:

$$\boxed{E_0 = \frac{\Phi}{\ell_P^3}\, V_{\text{disp}} = \frac{\mathcal{N}\varepsilon}{\ell_P^3}\, V_{\text{disp}}}$$

The inertial mass is the throughput reorganisation cost per unit acceleration:

$$\boxed{m = \frac{E_0}{c^2} = \frac{\mathcal{N}\varepsilon\, V_{\text{disp}}}{\ell_P^3\, c^2}}$$

and Newton's second law is the statement that force equals the rate at which the angular throughput pattern must be reorganised:

$$\boxed{F = m\, a = \frac{\mathcal{N}\varepsilon\, V_{\text{disp}}}{\ell_P^3\, c^2}\, a}$$

In this framework, mass is the medium's resistance to reorganising the throughput geometry around a displacement.

Expanded Form

1. Rest Frame: Isotropic Balance

A displacement vortex at rest occludes a solid-angle fraction of the incoming throughput equally from all directions. By the Shell Cancellation Invariant, every shell from $d = 1$ to $d = \mathcal{N}$ contributes identical relay load ε. The total throughput through the vortex's position is $\Phi = \mathcal{N}\varepsilon$, distributed isotropically.

The angular throughput distribution in the rest frame:

$$\left.\frac{d\Phi}{d\Omega}\right|_{\text{rest}} = \frac{\Phi}{4\pi} = \frac{\mathcal{N}\varepsilon}{4\pi}$$

This is uniform. The vector sum of pressure contributions over 4π steradians is zero:

$$\mathbf{F}_{\text{rest}} = \oint_{4\pi} \frac{d\Phi}{d\Omega}\,\hat{n}\,d\Omega = \mathbf{0}$$

Zero net force. The vortex persists in its state of motion. This is Newton's first law stated as a throughput symmetry.

---

2. Acceleration: Broken Isotropy

When the vortex accelerates at rate **a** through the lattice, the throughput in the vortex frame acquires a dipole anisotropy. To first order in v/c:

$$\left.\frac{d\Phi}{d\Omega}\right|_{\text{accel}} = \frac{\Phi}{4\pi}\left(1 + \frac{\mathbf{v}\cdot\hat{n}}{c}\right)$$

The leading hemisphere ($\hat{n}\cdot\hat{v} > 0$) carries enhanced throughput. The trailing hemisphere ($\hat{n}\cdot\hat{v} < 0$) carries diminished throughput.

The vortex, having occlusion cross-section σ_{occ}, intercepts a different throughput flux from the front than from the back. The net momentum transfer per tick is:

$$\delta p = \frac{\sigma_{\text{occ}}}{c}\oint_{4\pi}\frac{d\Phi}{d\Omega}\,\hat{n}\,d\Omega = \frac{\sigma_{\text{occ}}}{c}\,\frac{\Phi}{4\pi}\,\frac{4\pi}{3}\,\frac{\mathbf{v}}{c}$$

The force opposing the change in velocity:

$$\mathbf{F}_{\text{resist}} = -\frac{d(\delta p)}{dt} = -\frac{\sigma_{\text{occ}}\,\Phi}{3\,c^2}\,\mathbf{a}$$

The factor $\sigma_{\text{occ}}/3$ is the angular average of the cross-section over the dipole distribution. For a body of exclusion volume V_{disp} and characteristic radius R:

$$\sigma_{\text{occ}} = \pi R^2, \qquad V_{\text{disp}} = \frac{4}{3}\pi R^3$$

The proportionality between the cross-section and the exclusion volume carries through to the proportionality between the resisting force and the mass.

---

3. Exclusion Volume Axiom

Axiom. Every displacement vortex excludes a definite volume V_{disp} of spation from the relay lattice. The relay throughput that would otherwise transit that volume is instead diverted around the vortex boundary. The diverted throughput constitutes the vortex's rest energy:

$$E_0 = \frac{\Phi}{\ell_P^3}\,V_{\text{disp}}$$

This is the energy cost of maintaining the displacement against the background throughput. The medium would fill the excluded volume if the vortex ceased to circulate. The circulation sustains the exclusion. The exclusion diverts the throughput. The diverted throughput IS the energy.

Corollary. The exclusion volume is determined by the vortex topology, not by the mass. The mass follows from the exclusion volume and the local throughput density:

$$m = \frac{E_0}{c^2} = \frac{\Phi\, V_{\text{disp}}}{\ell_P^3\, c^2}$$

---

4. Mass as Throughput Condensation

During acceleration, the throughput pattern around the vortex is compressed on the leading face and rarefied on the trailing face. The compression increases the effective throughput density at the center of the vortex. The rarefaction decreases it on the opposite side.

The net effect is a **condensation** of throughput at the vortex center, proportional to the velocity and the rate of change of velocity:

$$\delta\rho_\Phi = \frac{\Phi}{\ell_P^3}\, \frac{v}{c}$$

The condensation grows with velocity. The rate at which it grows is:

$$\frac{d(\delta\rho_\Phi)}{dt} = \frac{\Phi}{\ell_P^3\, c}\, a$$

This condensation rate, integrated over the exclusion volume, gives the force required to sustain the acceleration:

$$F = V_{\text{disp}}\, \frac{d(\delta\rho_\Phi)}{dt} = \frac{\Phi\, V_{\text{disp}}}{\ell_P^3\, c}\, \frac{a}{c} = \frac{\Phi\, V_{\text{disp}}}{\ell_P^3\, c^2}\, a = m\, a$$

Newton's second law is therefore the statement that the force required to accelerate a displacement vortex equals the rate of throughput condensation across its exclusion volume.

---

5. Equivalence of Inertial and Gravitational Mass

Gravitational mass is the throughput deficit that the vortex creates for other bodies:

$$m_{\text{grav}} = \frac{\text{total throughput occluded from other bodies}}{c^2}$$

The throughput occluded from a distant observer at distance r is:

$$\Delta\Phi(r) = \frac{\Phi}{4\pi}\, \frac{\sigma_{\text{occ}}}{r^2}$$

But σ_{occ} is determined by V_{disp}, which determines the inertial mass.

Inertial mass is the throughput reorganisation cost:

$$m_{\text{inert}} = \frac{\Phi\, V_{\text{disp}}}{\ell_P^3\, c^2}$$

Both depend on the same quantity: V_{disp}. The exclusion volume that creates the gravitational shadow is the same exclusion volume that resists acceleration. Therefore:

$$\boxed{m_{\text{inert}} = m_{\text{grav}}}$$

This is within this framework, a geometric identity rather than a coincidence. Both are the same occlusion measured from different frames:

- **Gravitational:** static angular deficit in the throughput seen by distant bodies
- **Inertial:** dynamic reorganisation cost of the throughput seen by the vortex itself

One is the shadow cast on others. The other is the shadow's resistance to being moved.

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6. Velocity Dependence and the Relativistic Limit

At velocity v, the throughput anisotropy grows as v/c. But the anisotropy cannot exceed the total throughput — the trailing hemisphere cannot have negative throughput. The physical limit:

$$\left.\frac{d\Phi}{d\Omega}\right|_{\text{trailing}} \geq 0$$

This requires:

$$\frac{v}{c} \leq 1$$

At $v = c$, the trailing hemisphere is completely evacuated of throughput. All relay arrives from the forward hemisphere. The vortex is surfing on the compression wave of its own throughput deficit. No further acceleration is possible because there is no remaining throughput behind the vortex to reorganise.

The effective mass at velocity v:

$$m(v) = m_0\, \frac{1}{\sqrt{1 - v^2/c^2}}$$

This follows as the geometric consequence of the angular throughput distribution becoming increasingly asymmetric as $v \to c$. The reorganisation cost diverges because the available angular budget from the trailing hemisphere approaches zero.

---

7. Deformation and Deflection

When a vortex is deflected — by collision, by another vortex's occlusion field, by any cause — the throughput pattern must rotate. The angular distribution that was compressed on one side must shift to being compressed on a different side.

The rotation of the throughput pattern propagates through the lattice at c. The disturbance reaches distance r after time r/c. Until the reorganisation is complete at a given distance, the throughput at that distance still reflects the old velocity.

The total reorganisation volume that must be updated grows as c^3t^3. The energy cost of the reorganisation is:

$$\delta E = m\,c^2\left(\frac{1}{\sqrt{1-v'^2/c^2}} - \frac{1}{\sqrt{1-v^2/c^2}}\right)$$

where v and v' are the velocities before and after deflection.

For elastic deflection at constant speed ($|v'| = |v|$), $\delta E = 0$: the total asymmetry magnitude is unchanged, only its direction is rotated. The medium reorganises without net energy cost. This is elastic scattering.

For inelastic deflection ($|v'| \neq |v|$), the asymmetry magnitude changes and energy is either absorbed by or released to the medium. This is the basis of heating (kinetic energy → throughput thermalisation) and radiation (throughput reorganisation emitting pressure pulses at c).

---

8. The Uniqueness of Local Throughput

Every point in space has a unique throughput state $\Phi(\mathbf{x})$ because the angular occlusion pattern from all matter in the universe is unique at every position. If a body of mass M sits at distance r, it occludes a fraction:

$$\delta\Phi(\hat{n}) = -\frac{\Phi}{4\pi}\,\frac{\sigma_M}{r^2}$$

from the direction $\hat{n}$ toward M. The sum over all matter in the universe:

$$\Phi(\mathbf{x}) = \frac{\mathcal{N}\varepsilon}{4\pi}\left(4\pi - \sum_i \frac{\sigma_i}{r_i^2}\right)$$

This is always slightly less than the unoccluded value. The deficit is what we call the gravitational potential:

$$\phi(\mathbf{x}) = -\sum_i \frac{G\,M_i}{r_i}$$

where G is the coupling constant relating occlusion cross-section to mass.

The gradient of $\Phi(\mathbf{x})$ is the gravitational field. It points toward regions of greater throughput deficit (more occlusion). Matter falls toward greater deficit because the unoccluded side has more throughput pressing inward than the occluded side.

Canonical Wording for Paper Use

Law of Inertial Mass from Throughput Asymmetry. A displacement vortex in the spation lattice excludes a definite volume V_{disp} from the relay throughput. The diverted throughput constitutes the vortex's rest energy $E_0 = (\Phi/\ell_P^3)\,V_{\text{disp}}$. When the vortex accelerates, the isotropic throughput in its frame acquires a dipole anisotropy proportional to v/c. The net pressure deficit opposing the acceleration equals the rate of throughput condensation across the exclusion volume, yielding $F = ma$ where $m = E_0/c^2$. Inertial mass equals gravitational mass because both measure the same exclusion volume: inertial mass is the reorganisation cost of the angular throughput pattern, gravitational mass is the static angular deficit cast on other bodies. The speed limit c is the velocity at which the trailing hemisphere is fully evacuated of throughput and no further reorganisation is possible.

Compact Theorem Form

Theorem (Inertial Mass). In a synchronous relay lattice with steady-state isotropic throughput $\Phi = \mathcal{N}\varepsilon$, a displacement vortex of exclusion volume V_{disp} has rest energy $E_0 = (\Phi/\ell_P^3)\, V_{\text{disp}}$ and inertial mass $m = E_0/c^2$. The force required to accelerate the vortex at rate a is $F = ma$.

Corollary (Equivalence Principle). Inertial mass and gravitational mass are identical because both are determined by V_{disp}: the exclusion volume that resists throughput reorganisation is the same exclusion volume that creates angular throughput deficit for other bodies.

Corollary (Speed Limit). The maximum velocity is c because at $v = c$ the throughput from the trailing hemisphere is zero and no further angular reorganisation is possible.

Corollary (Relativistic Mass). At velocity v, the effective mass is $m(v) = m_0/\sqrt{1 - v^2/c^2}$ because the throughput anisotropy diverges as the trailing hemisphere empties.

Minimal Full-Form Version

Every displacement vortex excludes a volume V_{disp} of spation from the isotropic relay throughput Φ. The diverted throughput is the rest energy. The mass is E_0/c^2. Acceleration breaks the throughput isotropy: the leading face of the vortex receives enhanced throughput, the trailing face receives diminished throughput. The resulting pressure gradient opposes the acceleration at a rate proportional to the exclusion volume times the throughput density divided by c^2. This is $F = ma$. The same exclusion volume creates the gravitational shadow that other bodies respond to. Therefore inertial mass equals gravitational mass — both are the throughput cost of the same displacement. At $v = c$, the trailing hemisphere carries zero throughput and no further acceleration is possible. Mass, inertia, gravity, and the speed limit are all consequences of angular throughput geometry in a relay lattice.

Derivation Status

Class: DERIVED from the Cosmological Relay Throughput Law plus the geometric consequence of acceleration in an isotropic relay medium.

Assumptions: 1. The Cosmological Relay Throughput Law holds (isotropic throughput $\Phi = \mathcal{N}\varepsilon$) 2. Every displacement vortex excludes a definite volume V_{disp} 3. Acceleration creates a first-order dipole anisotropy in the local throughput frame

Free parameters: one measured calibration (hydrogen) — see header. V_{disp} is a topological property of the vortex, not a fitting parameter. Φ is determined by the Clearing distance and CMB temperature.

Recovers: - Newton's first law (isotropic throughput → zero force at rest) - Newton's second law ($F = ma$ from throughput condensation rate) - Equivalence principle ($m_{\text{inert}} = m_{\text{grav}}$ from same V_{disp}) - Speed limit c (trailing hemisphere evacuation) - Relativistic mass increase (γ factor from angular budget depletion) - Gravitational potential (throughput deficit from angular occlusion sum)

Does not yet derive: - The numerical value of V_{disp} for the proton and electron from first principles - The explicit connection between V_{disp} and the occlusion radii R_p, R_e used in the Coulomb force law - The gravitational coupling constant G from Φ and lattice geometry - The quantisation of V_{disp} (why only certain vortex topologies are stable)

These are the next derivations required.

Extended Reference — Radiative Pressure Origin

LAW OF RADIATIVE PRESSURE ORIGIN

Formal Full-Form Statement

Law (Radiative Pressure Origin / The Light Law). The spation lattice is the propagation medium for electromagnetic radiation. The cosmic microwave background is light — photons released at recombination, propagating through the lattice at c, arriving at every point from every direction. This light is the sole content of the medium's relay state. Every spation, at every Planck tick, carries this light through itself and hands it to the next. There is no separate "throughput" distinct from the light. The light IS the throughput. The deformation of the medium IS the photon. The pressure at any point in space is the radiation pressure of the CMB arriving from 4π steradians, minus whatever matter has occluded.

Let the CMB radiation energy density be

$$u_{\text{CMB}} = aT_{\text{CMB}}^4$$

where $a = 7.5657 \times 10^{-16}$ J/m³/K⁴ is the radiation constant and $T_{\text{CMB}} = 2.725$ K is the measured CMB temperature.

Then the isotropic radiation pressure at every point in empty space is

$$\boxed{P_{\text{rad}} = \frac{u_{\text{CMB}}}{3} = \frac{aT_{\text{CMB}}^4}{3}}$$

and the directional radiation flux per steradian is

$$\boxed{\frac{dP}{d\Omega} = \frac{u_{\text{CMB}}}{4\pi}}$$

Force arises when matter occludes a fraction of this isotropic light field:

$$\boxed{F(r) = \frac{\pi}{4}\,P_{\text{eff}}\,\frac{R_1^2\,R_2^2}{r^2}}$$

where P_{eff} is the effective pressure coupling at the relevant scale, and R_1, R_2 are the occlusion radii of the two bodies.

The framework proposes that force arises from radiation pressure of the CMB, geometrically interrupted by matter.

Expanded Form

1. Identity Axiom: Light Is the Content of the Medium

The spation lattice propagates electromagnetic radiation. In this model, a photon is the lattice deforming — one spation compresses, hands its compression to the next, which hands to the next. Each handoff is one Planck length in one Planck time:

$$c = \frac{\ell_P}{t_P}$$

This is not a derived velocity. It is the tick rate of the lattice. In this picture, light is the medium deforming rather than a separate entity traversing it.

The CMB is the universal population of this process. Photons released at recombination, 13.8 billion years ago, still propagating, arriving now from every direction at every point. They are not relics of a past event. They are the current, ongoing, active state of the medium. The lattice is loaded with this light at every point, from every angle, at every moment.

Therefore:

$$\text{Throughput} \equiv \text{Light} \equiv \text{CMB radiation field}$$

There is no distinction between the medium's state and the light passing through it. The deformation IS the photon. The relay IS the propagation. The throughput IS the radiation.

---

2. Measurement Axiom: The Pressure Is Known

The CMB radiation field has been measured with extraordinary precision:

Quantity	Value	Source
T_{CMB}	2.7255 ± 0.0006 K	FIRAS/COBE (1990), confirmed Planck (2018)
Blackbody fit	< 50 ppm deviation	FIRAS — most perfect blackbody ever measured
Isotropy	$\Delta T/T \sim 10^{-5}$	Planck satellite (2018)
u_{CMB}	4.172×10^{-14} J/m^3	From aT^4
P_{rad}	1.391×10^{-14} Pa	From $u/3$
Photon number density	410.7 photons/cm^3	From $2\zeta(3)/\pi^2 \times (k_B T/\hbar c)^3$

The pressure that fills the universe rests on one of the most precisely measured quantities in physics. The foundation of SDT rests on a measurement, not an assumption.

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3. Shell Cancellation: Why the Light Is Uniform

The CMB arrives from a boundary at distance $R_{\text{CMB}} \approx 9.5 \times 10^{26}$ m. It was emitted from a surface of last scattering that, from any interior point, subtends the full 4π steradians.

Consider concentric shells of light-emitting surface at distance d from an interior point. Each shell:

- Has surface area $4\pi d^2$ (more sources at greater distance)
- Has flux diluted as $1/(4\pi d^2)$ per source (inverse square law)
- Therefore contributes radiation density independent of d:

$$\delta u(d) = 4\pi d^2 \times \frac{\varepsilon_{\text{shell}}}{4\pi d^2} = \varepsilon_{\text{shell}}$$

This exact cancellation — source multiplicity times inverse-square dilution equals constant — is not an approximation. It is Euclidean geometry. It holds at every distance from $d = \ell_P$ to $d = R_{\text{CMB}}$.

The total radiation density is the sum over all $\mathcal{N} = R_{\text{CMB}}/\ell_P$ shells:

$$u_{\text{total}} = \mathcal{N}\,\varepsilon_{\text{shell}}$$

This is why the CMB is isotropic to 10^{-5}: the geometry demands it. Anisotropy can only arise from matter occluding the light between source and observer.

---

4. Occlusion: The Origin of Force

A body of radius R placed in the isotropic light field blocks a solid angle:

$$\Omega_{\text{blocked}} = \frac{\pi R^2}{r^2}$$

from a point at distance r.

The radiation pressure from the blocked directions no longer arrives. The radiation from all other directions continues to arrive. The imbalance:

$$\Delta P = \frac{u_{\text{CMB}}}{4\pi} \times \frac{\pi R^2}{r^2} = \frac{u_{\text{CMB}}\, R^2}{4r^2}$$

For two bodies (mutual occlusion), each blocks light for the other. The force on body 2 from the shadow of body 1:

$$F_{1\to 2} = \Delta P_1 \times \sigma_2 = \frac{u_{\text{CMB}}\, R_1^2}{4r^2} \times \pi R_2^2 = \frac{\pi\, u_{\text{CMB}}}{4} \frac{R_1^2\, R_2^2}{r^2}$$

By symmetry:

$$F_{2\to 1} = \frac{\pi\, u_{\text{CMB}}}{4} \frac{R_1^2\, R_2^2}{r^2} = F_{1\to 2}$$

Newton's third law is satisfied identically. The $1/r^2$ law emerges from solid-angle geometry.

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5. Scale Coupling: Why u_{CMB} Alone Does Not Give Coulomb

The measured CMB energy density $u_{\text{CMB}} = 4.172 \times 10^{-14}$ J/m³ gives a radiation pressure of 1.39×10^{-14} Pa. This is the ambient pressure of empty space. It is real and measurable.

But the Coulomb force between a proton and electron at the Bohr radius requires an effective pressure $P_{\text{eff}} \sim 10^{31}$ Pa — forty-five orders of magnitude larger than the ambient CMB radiation pressure.

The resolution is the shell cancellation theorem applied to the lattice itself. The throughput through a single spation is not u_{CMB} alone. It is:

$$\Phi = \mathcal{N}\, \varepsilon = \frac{R_{\text{CMB}}}{\ell_P} \times u_{\text{CMB}}\, \ell_P^3$$

The factor $\mathcal{N} = R_{\text{CMB}}/\ell_P \approx 5.9 \times 10^{61}$ counts the number of Planck-scale relay stages between any point and the boundary. Each stage carries one shell's worth of CMB light in transit simultaneously. The light at any spation is not one photon passing through — it is $\mathcal{N}$ overlapping relay stages, each carrying ε of CMB energy, all in transit at the same tick.

The effective pressure at the Planck scale is therefore:

$$P_{\text{Planck}} = \frac{\Phi}{\ell_P^3} = \frac{\mathcal{N}\,\varepsilon}{\ell_P^3} = \mathcal{N}\,u_{\text{CMB}}$$

$$P_{\text{Planck}} = 5.9 \times 10^{61} \times 4.172 \times 10^{-14} = 2.46 \times 10^{48}\ \text{Pa}$$

The Coulomb coupling at the nuclear scale then involves the geometric reduction from this Planck-scale pressure to the effective pressure at the occlusion radii R_p and R_e:

$$P_{\text{eff}}(R_p, R_e) = P_{\text{Planck}} \times f(R_p/\ell_P, R_e/\ell_P)$$

where f is the geometric transfer function that accounts for the finite size of the vortices relative to the lattice spacing. The numerical calibration gives $P_{\text{eff}} \approx 1.65 \times 10^{31}$ Pa, which reproduces Coulomb to $< 1\%$.

The point: the enormous effective pressure is not mysterious. It is the accumulated relay burden of 10^{61} shells of CMB light, all in transit through the same lattice point simultaneously.

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6. Inertial Mass Revisited: Resistance to Moving Through Light

A displacement vortex at rest sits in isotropic CMB light. Equal radiation pressure from every direction. No net force.

When the vortex accelerates, it moves through the light field. In the vortex frame, the light ahead is blueshifted (more energetic, higher pressure). The light behind is redshifted (less energetic, lower pressure). This is the CMB dipole anisotropy — the same dipole measured by COBE and Planck for the Earth's motion through the CMB rest frame.

The pressure difference between front and back:

$$\Delta P = \frac{4}{3}\,u_{\text{CMB}}\,\frac{v}{c}$$

integrated over the vortex's exclusion cross-section gives the resistive force:

$$F_{\text{resist}} = \sigma_{\text{occ}} \times \Delta P = \sigma_{\text{occ}} \times \frac{4}{3}\,u_{\text{eff}}\,\frac{v}{c}$$

The rate of change of this resistance with acceleration gives $F = ma$ where:

$$m = \frac{\sigma_{\text{occ}} \times u_{\text{eff}}}{c^2} \times V_{\text{eff}}$$

Mass is the radiation pressure cost of moving a displacement vortex through the CMB light field. Inertia is the CMB pushing back.

This is measurable. The CMB dipole anisotropy ($\Delta T/T = v/c \approx 1.23 \times 10^{-3}$ for the Earth) IS the inertial frame made visible. The rest frame of the universe is the frame in which the CMB is isotropic. Every other frame sees a dipole. That dipole is the light pushing harder from one side than the other. That asymmetry is inertia.

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7. Gravity Revisited: Shadows in the Light

A massive body occludes CMB light from the directions behind it (as seen from any exterior point). The occluded directions contribute less radiation pressure. The unoccluded directions contribute full radiation pressure. The imbalance pushes the exterior point toward the massive body.

This is gravity. In this framework, it is modelled as a radiation pressure deficit in the CMB light field caused by a physical shadow.

The gravitational acceleration at distance r from mass M:

$$g(r) = \frac{F}{m_{\text{test}}} = \frac{\pi\, P_{\text{eff}}\, R_M^2\, R_{\text{test}}^2}{4\, r^2\, m_{\text{test}}}$$

Since m_{test} is itself determined by R_{test} through the same throughput mechanism, the test body's occlusion radius cancels:

$$g(r) \propto \frac{R_M^2}{r^2}$$

This is $g = GM/r^2$ where G is the coupling constant that converts occlusion cross-section (R_M^2) to mass units. G is treated here as a calibration between two descriptions of the same thing — how much light a body blocks (geometric) versus how much it weighs (conventional).

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8. The Four Primitives Restated

Space: The spation lattice. The propagation medium for light. Not empty. Loaded with CMB radiation from every direction at every point.

Matter: Displacement vortices in the lattice. Regions where the medium is topologically deformed, excluding spations from the relay, creating occlusion shadows in the light field.

Movement: The tick. One Planck length per Planck time. Light advancing through the lattice. Deformation handing off to the next spation. $c = \ell_P/t_P$.

Now: The current tick. The universal clock is the lattice itself, clicking forward one handoff at a time. Time is not a dimension. Time is the count of ticks. Everywhere, simultaneously, the lattice advances by one relay step.

In this picture, spacetime is replaced by a discrete lattice. The tick carries light. The light fills the lattice from the Clearing. Matter interrupts the light. The interruption is force. Force moves matter. Movement is the lattice ticking.

Four primitives. One mechanism. The framework aims to derive as much as possible from these primitives.

Canonical Wording for Paper Use

Law of Radiative Pressure Origin. The spation lattice carries light. The cosmic microwave background is that light — photons from recombination, propagating at c, arriving from 4π steradians at every point. The deformation of the lattice IS the photon; the relay IS the propagation. The isotropic CMB radiation field, measured at $T = 2.725$ K with energy density $u_{\text{CMB}} = aT^4$, constitutes the baseline scalar compression of the medium. Matter produces force by occluding a fraction of this isotropic light: the unoccluded directions press harder than the occluded directions, creating a net force toward the shadow. Inertial mass is the radiation pressure cost of accelerating through the light field — the CMB dipole anisotropy experienced by a moving vortex. Gravitational mass is the radiation shadow cast on other bodies. Both are determined by the displacement vortex's exclusion volume. Force is proposed as interrupted light.

Compact Theorem Form

Theorem (Radiative Pressure Origin). In a spation lattice loaded with isotropic CMB radiation at energy density $u_{\text{CMB}} = aT_{\text{CMB}}^4$, a displacement vortex of occlusion cross-section σ experiences zero net force when at rest (isotropy) and a resistive force proportional to $\sigma u_{\text{eff}} v/c^2$ when accelerating (anisotropy). Two vortices at separation r experience mutual attraction $F = (\pi/4)\, P_{\text{eff}}\, R_1^2 R_2^2/r^2$ from mutual occlusion of the isotropic field.

Corollary (Light Identity). The throughput of the relay lattice is electromagnetic radiation. The photon is not carried by the medium; the photon is the medium deforming. $c = \ell_P/t_P$.

Corollary (Measured Foundation). The entire force framework rests on a single measured quantity: $T_{\text{CMB}} = 2.725$ K. One calibration point (hydrogen). No free constants. One temperature.

Corollary (Gravity is a Shadow). Gravitational attraction is the radiation pressure deficit in the CMB light field caused by matter occluding light from specific directions. G is the calibration constant between occlusion cross-section and conventional mass units.

Minimal Full-Form Version

The spation lattice carries light. The CMB is that light — real photons, measured at 2.725 K, arriving from every direction. The lattice is not empty; it is filled with this radiation. A displacement vortex occludes some of the light, creating a directional shadow. From the unoccluded directions, the light keeps pressing. The pressure imbalance is force. Between two bodies, mutual occlusion creates mutual attraction at $1/r^2$. Acceleration through the light field creates a dipole anisotropy — blueshift ahead, redshift behind — whose pressure difference opposes the acceleration. That opposition is inertia. The mass of a body is the radiation pressure cost of its displacement. Inertial mass equals gravitational mass because both measure the same occlusion. The speed limit c is the tick rate of the lattice. Force is proposed to arise from CMB light, geometrically interrupted by matter.

Derivation Status

Class: DERIVED from the measured CMB temperature, Planck units, solid-angle geometry, and the Cosmological Relay Throughput Law.

Measured foundation: $T_{\text{CMB}} = 2.725$ K (FIRAS/COBE/Planck)

Free parameters: one measured calibration (hydrogen) — see header.

Recovers: - Coulomb force ($1/r^2$ from solid-angle occlusion, validated to $< 1\%$) - Gravitational force ($1/r^2$ from same mechanism at different scale) - Newton's first law (isotropic radiation → zero net force) - Newton's second law (CMB dipole pressure → $F = ma$) - Newton's third law (mutual occlusion is symmetric) - Equivalence principle (same exclusion volume → same mass both ways) - Speed of light as limit (lattice tick rate) - Relativistic mass increase (dipole anisotropy diverges at $v \to c$) - CMB dipole as inertial frame marker (measured by COBE/Planck)

Rests on: - One measurement: T_{CMB} - One mechanism: occlusion of isotropic light - One medium: the spation lattice - Four primitives: space, matter, movement, now

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Extended Reference — Release Cascade Theorem (Full Form)

THE RELEASE CASCADE THEOREM

Formal Full-Form Statement

Theorem (Release Cascade). The Clearing was the epoch at which every spation in the lattice transitioned from a coupled, non-transmissive state to a transmissive state. Each spation that had been holding deformation content — unable to relay because the medium was opaque — released that content omnidirectionally upon entering the transmissive state. Each released front propagates as an expanding spherical shell at c. Each spation that receives a front retransmits it with fidelity to its neighbours. Every spation is therefore both a source (of its own released content) and a relay (of every other spation's released content).

The local convergence state at any interior point is the superposed arrival of all released spherical fronts whose causal histories intersect that point. The apparent distant CMB surface is an observational reconstruction of causal depth. The actual mechanical state is local convergent occupancy established by the already-arrived release cascade.

Let the held deformation density at the Clearing be

$$u_{\text{held}} = aT_{\text{rec}}^4$$

where $T_{\text{rec}} \approx 3000$ K is the temperature at recombination.

Let each spation release content

$$\varepsilon_0 = u_{\text{held}}\,\ell_P^3$$

omnidirectionally at the Clearing.

Then the local convergence burden at any interior point, from all released fronts that have arrived, is

$$\boxed{\Phi = \sum_{d=1}^{\mathcal{N}} \varepsilon(d) = \mathcal{N}\,\varepsilon}$$

where $\varepsilon(d)$ is the per-shell contribution at relay depth d, which is invariant by the Shell Cancellation Identity, and ε incorporates the redshift-degraded content at the present epoch.

The convergence is cumulative because the point is not receiving one shell. It is immersed in $\mathcal{N}$ simultaneously overlapping expanding shells, each from a different source depth, each faithfully relayed through every intermediate spation.

The Pre-Clearing State

What Was Being Held

Before the Clearing, the universe was an opaque plasma. Photons could not propagate — their mean free path was shorter than any macroscopic scale. Every emission was immediately reabsorbed. Every spation was coupled to its neighbours through matter-radiation interaction.

In lattice terms: each spation held deformation content that it could not transmit. The relay function was blocked. The content was not static — it was in continuous local exchange with neighbouring spations and with the matter (baryonic plasma) embedded in the lattice. But the exchange was local, reciprocal, and trapped. No sustained directional propagation was possible.

The held content per spation:

$$\varepsilon_{\text{held}} = u_{\text{coupled}}\,\ell_P^3$$

where u_{coupled} is the thermal energy density of the coupled radiation-matter state. At $T_{\text{rec}} \approx 3000$ K:

$$u_{\text{coupled}} = aT_{\text{rec}}^4 = 7.566 \times 10^{-16} \times 3000^4 = 6.13 \times 10^{-2}\ \text{J/m}^3$$

This is 1.47×10^{12} times the present CMB energy density. The content was there. It was held. It could not leave.

The Transition

At recombination, electrons combined with protons to form neutral hydrogen. The scattering cross-section dropped by orders of magnitude. The lattice entered a transmissive state.

This did not happen at one instant across the universe. It happened over a span of $\Delta z \approx 100$ (roughly 100,000 years). But for each local patch of the lattice, the transition was sharp: coupled → transmissive within a few scattering times.

The moment a spation became transmissive, it released its held content. Not in one direction. Omnidirectionally. A spherical shell of deformation expanding outward at c.

Every spation in the universe did this. Not simultaneously in absolute time, but simultaneously in cosmic time — within the recombination epoch.

The Release

3.1 Each Spation as Source

At the Clearing, spation i at position $\mathbf{x}_i$ releases content ε_0 as a spherical shell. At time n ticks after release:

$$\text{Shell radius: } r_n = n\,\ell_P$$

$$\text{Shell surface area: } A_n = 4\pi(n\,\ell_P)^2$$

$$\text{Content per unit area: } \frac{\varepsilon_0}{4\pi(n\,\ell_P)^2}$$

The shell expands. The content spreads over a growing area. The per-unit-area contribution falls as $1/r^2$. This is ordinary inverse-square dilution of a spherical front.

3.2 Each Spation as Relay

When the expanding shell from source i reaches spation j at distance d_{ij}, spation j does not absorb and re-emit. It **relays**: the arriving deformation passes through j and continues outward. Spation j adds nothing and removes nothing. It transmits with fidelity.

But spation j is also a source. It released its own content ε_0 at the Clearing. Its own shell is expanding outward simultaneously.

Therefore spation j is:

- A **source** of its own released shell
- A **relay** of every other spation's released shell that has reached it

Every spation in the lattice has this dual role. The lattice is not a passive conduit with a few sources. Every point is a source AND a relay.

3.3 Fidelity

The relay is faithful. No absorption. No scattering (after the Clearing). No dissipation (inviscid medium). The deformation front passes through each intermediate spation and continues without loss.

This is what "inviscid" means in SDT: the medium transmits deformation without extracting energy from it. The lattice is not a resistive medium. It is a lossless relay network.

Exception: when a front encounters **matter** (a displacement vortex), the vortex occludes the front. The occluded fraction does not pass through. The unoccluded fraction continues. This is the sole mechanism by which the relay is interrupted. This interruption is force.

The Superposition

4.1 Local State as Overlap of All Arrived Shells

A target point $\mathbf{x}$ is intersected by the expanding shell from source $\mathbf{x}_i$ when:

$$|\mathbf{x} - \mathbf{x}_i| = n\,\ell_P$$

where n is the number of ticks since the Clearing.

At the present epoch, $n = \mathcal{N} \approx 5.9 \times 10^{61}$. Therefore the target point has been reached by shells from every source within radius $\mathcal{N}\,\ell_P = R_{\text{CMB}}$.

The number of source spations within this radius: the entire observable lattice.

The local state at $\mathbf{x}$ is the superposition of:

$$\text{All shells from all sources at all depths } d = 1 \text{ to } d = \mathcal{N}$$

4.2 Why the Burden Is Cumulative

The shells do not replace each other. They overlap. At any given tick:

- The shell from the nearest source ($d = 1$) passed through one tick ago and is now at $d = 2$.
- The shell from $d = 2$ passed through two ticks ago and is now at $d = 3$.
- The shell from $d = \mathcal{N}$ (the Clearing boundary) has just arrived.

Each shell is a separate expanding front. They all coexist at the target point simultaneously. The point is not receiving one front at a time. It is immersed in $\mathcal{N}$ simultaneously overlapping fronts, each from a different source depth, each at a different stage of expansion.

This is why the burden is $\Phi = \mathcal{N}\varepsilon$, not just ε.

4.3 The Shell Cancellation in Release-Cascade Terms

Group all sources at depth d into a shell of surface area $4\pi d^2$ (in lattice units). Each source on that shell released content ε_0. By the time its front reaches the target:

- The front has expanded to radius $d\,\ell_P$
- The content is spread over area $4\pi d^2 \ell_P^2$

- The contribution at the target: $\varepsilon_0/(4\pi d^2 \ell_P^2)$ per source

But there are $4\pi d^2$ sources on the shell (one per spation on the shell surface). Total contribution from all sources at depth d:

$$\Phi_{\text{shell}}(d) = 4\pi d^2 \times \frac{\varepsilon_0}{4\pi d^2 \ell_P^2} \times \ell_P^2 = \varepsilon_0$$

Each source releases ε_0 over 4π steradians. At distance d lattice spacings, the solid angle subtended by one target spation is $\ell_P^2/(d\,\ell_P)^2 = 1/d^2$. So the fraction of source i's release arriving at the target:

$$f(d) = \frac{1}{4\pi d^2}$$

Content arriving from one source at depth d:

$$\delta\varepsilon = \varepsilon_0 \times \frac{1}{4\pi d^2}$$

Number of sources at depth d:

$$N_{\text{shell}}(d) = 4\pi d^2$$

Total from shell at depth d:

$$\Phi_{\text{shell}}(d) = N_{\text{shell}} \times \delta\varepsilon = 4\pi d^2 \times \frac{\varepsilon_0}{4\pi d^2} = \varepsilon_0$$

Independent of d. Every shell contributes the same. The cancellation is exact.

Total convergence burden:

$$\Phi = \sum_{d=1}^{\mathcal{N}} \varepsilon_0 = \mathcal{N}\,\varepsilon_0$$

(with ε_0 at the Clearing epoch; the present-epoch value ε accounts for cosmological redshift degradation of the released content.)

The Observational Reconstruction

5.1 Why We See a Distant Shell

Our telescopes and antennae are lenses. They collimate. They assign a direction to arriving radiation and reconstruct a source position along that direction. When the CMB arrives from all directions at 2.725 K, our instruments reconstruct this as a spherical surface at $z = 1100$, radius ~ 46 Gly, emitting blackbody radiation.

This reconstruction is correct **as optics**. The photons we detect did travel from that distance. Their redshift is consistent with that distance. The angular power spectrum matches a surface at that epoch.

But the mechanical reality is different. The point is not illuminated by a distant shell. The point is immersed in the superposed arrival of $\mathcal{N}$ expanding fronts from $\mathcal{N}$ shell depths, all present simultaneously. We see the most distant shell because our instruments reconstruct the highest-contrast arrivals (the ones from the Clearing itself). The intermediate shells have lower contrast because they were released from regions that were already partially transparent.

The Clearing was the highest-contrast release. It dominates the spectrum. But the mechanical state includes the entire relay stack.

5.2 Sunlight as a Local Boundary Event

The Sun's photosphere is a local transparency boundary. Below it: opaque convective plasma, holding deformation content, unable to transmit. Above it: transparent atmosphere, relay-capable.

At the photosphere, the same mechanism operates: held content is released omnidirectionally. Each point on the photosphere is a source. The expanding shells propagate outward. We reconstruct this as "the Sun is shining on us from 1 AU away." The mechanical reality: the solar release fronts have already arrived at our position and we are immersed in their superposed state.

Near the Sun, the solar convergence dominates the CMB convergence. The solar energy flux at distance r:

$$F_\odot(r) = \frac{L_\odot}{4\pi r^2}$$

The CMB energy flux (isotropic):

$$F_{\text{CMB}} = \frac{c\, u_{\text{CMB}}}{4} = \frac{c\, a T_{\text{CMB}}^4}{4}$$

Equalisation distance where $F_\odot = F_{\text{CMB}}$:

$$r_{\text{eq}} = \sqrt{\frac{L_\odot}{4\pi\, F_{\text{CMB}}}} = \sqrt{\frac{3.828 \times 10^{26}}{4\pi \times 3.131 \times 10^{-6}}}$$

$$r_{\text{eq}} = \sqrt{\frac{3.828 \times 10^{26}}{3.942 \times 10^{-5}}} = \sqrt{9.71 \times 10^{30}} \approx 3.12 \times 10^{15}\ \text{m}$$

$$r_{\text{eq}} \approx 20{,}800\ \text{AU}$$

Beyond $~$20,800 AU, the CMB convergence exceeds the solar convergence. The solar pressure domain has a boundary. Beyond it, the cosmological convergence state is the dominant mechanical reality. This distance is derivable and specific, not approximate.

5.3 Every Star Has a Pressure Domain

Every star, every luminous body, is a local boundary event superposed on the cosmological convergence. Each has a domain radius where its released content exceeds the CMB:

$$r_{\text{domain}} = \sqrt{\frac{L}{4\pi\, F_{\text{CMB}}}}$$

Inside the domain: the star's convergence dominates. This is the stellar pressure domain. Outside the domain: the CMB convergence dominates. This is "deep space" in the mechanical sense.

Planetary orbits sit well inside the stellar domain. Interstellar space sits in the CMB domain. Galactic dynamics operate in a superposition of many stellar domains and the CMB background.

Every Unintercepted Photon Feeds the Next Shell

6.1 The Throughput Conservation Principle

A photon released from source i, propagating through the lattice, arrives at each intermediate spation and is relayed onward. If it encounters no matter (no occlusion), it continues indefinitely. It becomes part of the convergence burden at every subsequent point it crosses.

If it **is** intercepted by matter (occluded by a displacement vortex), it is absorbed. Its content is thermalised into the vortex. It no longer contributes to the convergence burden of points beyond the vortex.

Therefore:

> Every photon not intercepted by matter contributes to the convergence state of all downstream points.

This is the throughput conservation principle: the total released content is either in transit (contributing to convergence) or absorbed by matter (contributing to mass-energy of vortices). None is lost. None is created. The total is fixed at the Clearing.

6.2 Matter as a Convergence Sink

A displacement vortex intercepts a fraction of the arriving convergence fronts. The intercepted fraction is proportional to the vortex's occlusion cross-section:

$$f_{\text{intercepted}} = \frac{\sigma_{\text{occ}}}{4\pi r^2}$$

from any one source at distance r.

The intercepted content does not disappear. It becomes part of the vortex's energy budget. When the vortex re-emits (thermal radiation, photon emission), it releases content back into the lattice, creating new expanding shells that join the convergence cascade.

Stars do this at enormous scale: they intercept convergence (absorb gravitational infall → nuclear fuel), thermalise it, and re-emit it as a local boundary event (photosphere radiation). The stellar cycle is:

$$\text{CMB convergence} \to \text{gravitational infall} \to \text{nuclear processing} \to \text{photosphere release} \to \text{new expanding shells}$$

The star is a convergence recycler. It does not create energy. It intercepts cosmological convergence, concentrates it, and re-releases it as a local boundary event at higher temperature.

The Release Cascade Theorem — Compact Form

Theorem (Release Cascade). At the Clearing, every spation released its held deformation content ε_0 as an expanding spherical shell propagating at c. Each subsequent spation relays every arriving front with fidelity. The local convergence state at any interior point is the superposition of all released shells intersecting that point. By the Shell Cancellation Identity, each depth-shell contributes invariant content ε regardless of distance. The total local convergence burden is $\Phi = \mathcal{N}\varepsilon$ where $\mathcal{N}$ is the causal depth to the Clearing in Planck units.

Corollary (Observational Reconstruction). The apparent distant CMB shell is the optical reconstruction of the highest-contrast release layer. The mechanical state includes all $\mathcal{N}$ layers simultaneously.

Corollary (Local Boundary Events). Any opacity-to-transparency transition (stellar photosphere, accretion disk edge, nebular clearing) produces a local release cascade that superposes on the cosmological cascade.

Corollary (Throughput Conservation). Released content is either in transit (convergence) or absorbed by matter (mass-energy). Stars recycle convergence: intercepting, thermalising, and re-releasing at higher temperature.

Corollary (Pressure Domain). Every luminous body has a pressure domain $r_{\text{domain}} = \sqrt{L/(4\pi F_{\text{CMB}})}$ beyond which the cosmological convergence dominates.

The Four SDT Laws in Sequence

Law 1: Cosmological Relay Throughput. The lattice is a phase-loaded nearest-neighbour relay. Shell cancellation preserves $\Phi = \mathcal{N}\varepsilon$ at every point. Establishes the baseline occupancy.

Law 2: The Release Cascade (this theorem). The Clearing was a universal discharge event. Each spation released held content omnidirectionally. The local state is the superposed arrival of $\mathcal{N}$ expanding shells. The CMB observation is the spectral residue. The pressure is the mechanical primitive. Every unintercepted photon feeds the next point's convergence. Every intercepted photon feeds matter. Stars recycle convergence as local boundary events.

Law 3: Convergent Boundary Pressure. Balanced convergence gives scalar compression without net force. Matter breaks the angular balance by occlusion. Force is the pressure deficit. Gravity, Coulomb, and nuclear binding are regimes of the same occlusion mechanism.

Law 4: Inertial Mass from Convergence Asymmetry. Acceleration through the convergence frame creates dipole anisotropy. The pressure gradient opposes the acceleration. Mass is the reorganisation cost. Inertial mass equals gravitational mass because both are the same exclusion volume. The speed limit c is convergence hemisphere evacuation.

Four laws grounded in one discharge event and one lattice mechanism.

Derivation Status

Class: DERIVED from the physics of the opacity-to-transparency transition, Planck lattice geometry, and the Shell Cancellation Identity.

Initial condition: The held deformation density at recombination: $u_{\text{held}} = aT_{\text{rec}}^4$

Propagation rule: Each spation relays all arriving fronts with fidelity at $c = \ell_P/t_P$

Superposition rule: All arriving fronts coexist at the target point simultaneously

Local burden formula: $\Phi = \mathcal{N}\varepsilon$ (Shell Cancellation Identity)

What this fixes: - Why the burden is cumulative (overlapping shells, not replacement) - Why the CMB appears as a distant shell (optical reconstruction of causal depth) - Why sunlight is a boundary event (local release cascade on the cosmological background) - Where the solar pressure domain ends (~20,800 AU, derivable) - Where the energy goes when matter intercepts it (mass-energy of the vortex) - How stars recycle convergence (intercept → thermalise → re-release)

What remains to derive: - The exact held content $\varepsilon_{\text{held}}$ from pre-recombination plasma physics - The redshift degradation function $\varepsilon(d)$ from Clearing-epoch ε_0 to present-epoch ε - The quantitative bridge from Φ to P_{eff} at nuclear and atomic scales - The coupling function $f(R/\ell_P)$ that sets the force law at different occlusion regimes

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The Key Sentence

> The Clearing was the epoch at which every spation that could not transmit, and therefore was holding deformation content, released that content omnidirectionally. The local convergence state at any point

is not the arrival of light from a distant surface, but the superposed occupancy of expanding spherical release fronts from every source at every depth, faithfully relayed through every intermediate spation. What we see through our lenses as a distant shell is the optical reconstruction of the highest-contrast layer in a cascade that fills the entire lattice.